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NAMAMI GANGE

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Ramganga River Basin Management (RBM) Plan

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Responsible
Laura Sustersic

Support to Ganga Rejuvenation (SGR)
B-5/1, Safdarjung Enclave
New Delhi 110029, India
Phone +91 49495353
Fax +91 49495391
Laura.Sustersic@giz.de
www.giz.de/India

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Coordinators/Editors
Martina Burkard, Laura Sustersic, Chhavi Sharda, Dr Sumit Kumar Gautam, Suvajit Dey

Authors
Bogacki Wolfgang (Dr), Burkard Martina, Dey Suvajit, Dhar Sujana (Dr), Dinesh Kumar A (Dr), Funke Markus, Gautam Sumit Kumar (Dr), Gosain Ashwini Kumar (Dr), Heim Ronjon, Hilhorst Bart, Kulkarni Tejas, Lohr Hubert (Dr), Mazumdar Asis (Dr), Richter Sandra (Dr), Sharda Chhavi, Singh Puja (Dr), Sustersic Laura, Thumser Phillip, Völker Jeanette (Dr)

In consultation with

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G Asok Kumar, Nalin Kumar Srivastava, D P Mathuria, Dheeraj Joshi, Himansu Badoni, Rajiv Ranjan Mishra, Birgit Vogel

With contributions and inputs from
CGWB: Chandreyee Dey, Debojyoti Mondal, Dr Fakhre Alam, S K Shrivastava, S K Swaroop, Sanjay G. Bhartariya, Shailendra Kumar Dwivedi, Sujatro Roy Chowdhuri, Vikash Kumar
CWC: Anuj Kumar, Anupam Prasad, Priyanka Gangwar, Sandeep Bisht, Shivam Tripathi
GIZ-SGR/IEWP: Dr Jyoti P. Nale, Merajuddin Ahmad, Vandana Yadav, Dr Vikrant Tyagi
Ministry of Agriculture: Yogesh Kumar Raundal
NMCG: Dr Hema Patel, Alok Srivastava, Dr Sandeep Kumar Behera, Dr Ishaq Ahmad, Peeyush Gupta, Anuj Kushwaha, Anu Chetal, Harish Kumar Mahavar, Dr S P Raghuvanshi, Vivek raj
NWIC: Manohar Singh Rathore
PTB: Pallavi Bishnoi, Swati Gupta
SMCG-UP: Anil Kumar Gupta, Mithilesh Kumar Mishra, Dr Shefali Srivastava
SPMG-UK: Akshay Kumar, Namita Tripathi, Piyush Kumar Singh
UK Irrigation Department: Mahesh Kumar Khare, Mukesh Mohan, Naveen Kumar Singhal, P K Dixit, Rambabu Singh, Rajeev Khanulia
UK Jal Sansthan/ Pey Jal Nigam: D K Bansal, M K Kotiyal,
UK-PCB: D K Joshi, Dildar Ali, Naresh Goswami, S P Singh
UP Water resources Department: Hemant Kumar Gupta, Naresh Tyagi, Puneet Kumar
UP-PCB: Arti, Ashish Tiwari, Arunima Bajpayee, Ashutosh Chauhan, Girish Kumar, P K Agarwal, Preeti, Rohit Singh, Vikas Mishra, Vipin Kandpal
WWF-India: Mohd Alam, Nitin Kaushal

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Contents

List of Figures

List of Tables

List of Maps

List of Annexes and Technical Reports

Seperate documents:

Document 1: *Annexure document of Ramganga RBM Plan (Annexure A1: KWMI 1; Annexure A2: KWMI 2; Annexure A3: KWMI 3; Annexure A4: KWMI 4; Annexure A5: KWMI 5)*

Document 2: *Hydrological Model (SWAT) for Ramganga RBM Plan*

List of abbreviations

AMRUT	Atal Mission for Rejuvenating Urban Transformation
AO	Authority Order - River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016
BCM	Billion Cubic Meters
BIS	Bureau of Indian Standards
BMU	German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety
BMZ	German Federal Ministry of Economic Cooperation and Development
BOD_5	Biological Oxygen Demand
CA	Cluster Analysis
CETP	Common Effluent Treatment Plant
CGWB	Central Ground Water Board
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CWC	Central Water Commission
DG	Director General
DGC	District Ganga Committee
DO	Dissolved Oxygen
DPSIR	Driver – Pressure – Status-Impact-Response
EC	Electrical Conductivity
E-Flows	Environmental Flows
EPA, 1986	Environmental Protection Act, 1986
EU	European Union
EU WFD	European Union Water Framework Directive
GAP	Ganga Action Plan
GIS	Geographical Information System
GIZ	German Development Cooperation
GloFAS	Global Flood Awareness System
GMU	Groundwater Management Unit
GoI	Government of India
GPI	Grossly Polluting industry
HPP	Hydropower Plant
IEWP	India-EU Water Partnership
INR	Indian Rupees
IPCC	Interngovernmental Panel on Climate Channel
KLD	Kilo Liter per Day
KWMI	Key Water Management Issue
LAWA	Bund/Länder-Arbeitsgemeinschaft Wasser
LULC	Land Use Land Cover
MCM	Million Cubic Meters
MLD	Million Liters per Day
MoHUA	Ministry of Housing and Urban Affairs
MoWR,RD&GR	Ministry of Water Resources, River Development and Ganga Rejuvenation
MW	Mega Watt
NAQUIM	National Aquifer Mapping Porgramme

NDMA	National Disaster Management Authority
NGRBA	National Ganga River Basin Management Authority
NIUA	National Institute of Urban Affairs
NMCG	National Mission for Clean Ganga
NRSC	National Remote Sensing Centre
PPM	Parts Per Million
PoM	Programme of Measures
RBM	River Basin Management
RBM Cycle	River Basin Planning and Management Cycle
RBMP	River Basin Management Plan
Rs	Indian Rupees
SBM	Swachh Bharat Mission
SGR II	Support to Ganga Rejuvenation, Phase II
SoE	Stage of groundwater Extraction
STP	Sewage Treatment Plant
SWM	Solid Waste Management
SWMU	Surface Water Management Unit
TC	Technical Cooperation
TDS	Total Dissolved Solid
TEG	Thematic Expert Group
TOC	Total Organic Carbon
UP	Uttar Pradesh
UKPCB	Uttarakhand Pollution Control Board
UPPCB	Uttar Pradesh Pollution Control Board
UK	Uttarakhand
WII	Wildlife Institute of India
WQ	Water Quality
WQI	Water Quality Index
ZBNF	Zero Budget Natural Farming
ZLD	Zero Liquid Discharge

EXECUTIVE SUMMARY

National Mission for Clean Ganga (NMCG) is the implementation agency of Namami Gange Mission and is entrusted with responsibilities towards protection and rejuvenation of River Ganga and its tributaries. One of the responsibilities of NMCG is to make or cause to make the River Basin Management Plan for Ganga Basin and its sub-basins. In this connection, Indo-German Technical Cooperation project, 'Support to Ganga Rejuvenation (SGR)' has been supporting NMCG towards using integrated river basin management approaches considering the experience from Germany and other EU-MS. Since 2015, the SGR project has been implemented by the GIZ on behalf of German Federal Ministry of Economic Cooperation and Development (BMZ). Since 2017, the SGR project is being implemented in conjunction with India EU Water Partnership Action (IEWP) as co-financed by the EU.

Under this Indo-German Technical Cooperation, the Ramganga River Basin Management Plan has been developed by GIZ together with NMCG. The approach for the development of this RBM Plan is based on the RBM Cycle which is built on the implementation philosophy of European Water Framework Directive (EU WFD). The RBM Cycle provides a structured and stepped method to develop RBMPs in cyclic manner. The main steps of RBMP preparation and implementation include defining a clear coordination & governance, basin characterisation, overview of network of monitoring programme, risk assessment of selected key water management issues (KWMIs), development of Programme of Measures (PoM – implementable action plan to mitigate identified risks), review of progress and revising the Plan for next cycle. The first cycle of Ramganga RBMP is for 5 years in accordance with India's other planning cycle. The 5 KWMIs identified for this first cycle of RBMP are 1) Water quality deterioration due to point sources, 2) Water quality deterioration due to non-point sources including agricultural activities, 3) Alteration in groundwater regime impacting on sub-surface flow, 4) Alteration in river hydrology and water quantity, and 5) Flood risk due to encroachment including sandmining.

This document is structured aligning to the RBM Cycle steps. Chapter 1 provides an overview on the adopted approach, institutional arrangements, and coordination structure for the Ramganga RBM Planning. This is followed by the detailed description of the basin well supported by the different figures, tables, and maps (Chapter 2). Chapter 3 offers an account of existing network of surface and groundwater quality and quantity maintained by various agencies. Chapter 4 lists the KWMIs identified for this cycle and the set vision and management objectives for each of the KWMIs. Following to this is Chapter 5 which explains the methodology and results of risk assessments carried out for each of the KWMI using DPSIR (Driver Pressure Status Impact Response) approach. This risk assessment categorises the basin into three categories i.e. a) no risk to fail to achieve the set vision and management objectives, b) possibility at risk to fail to achieve the set vision and management objectives, and c) at risk i.e. the current status of the basin will fail the set vision and management objectives. The risk assessment exercise has been carried out using the combination of observed data, modelling output, validation through ground truthing/field visits, and experts' judgement (wherever needed). The results are well depicted using geo-spatial maps. Based upon the results of the risk assessment process, a detailed implementable action plan (Programme of Measures) is presented in Chapter 6. The PoM are designed with an overall objective that what actions are to be taken to achieve the set vision and management objectives. The PoM are further categorised based on the urgency to implement them (short, mid, and long term). While Chapter 7 offers a brief account of other relevant missions/programmes for synergies and convergence, Chapter 8 provides the way forward for the NMCG to implement the Ramganga RBM Plan, and also summarises what steps are to be taken up by NMCG to institutionalise the entire RBM Process. Finally, all additional information enabling readers to get complete understanding of the Ramganga RBMP is presented in supplementary technical report and annexures.

1 INTRODUCTION

Rivers and their basins with the related groundwater bodies are vital sources for life to thrive. They support all social, economic, and environmental/ecological activities in their basin. Healthy river landscapes provide habitats for many plants and animals and often have high cultural and religious significance specifically in India. Lately with rapid urbanization, industrialization, and intense agriculture activities (specially post Green Revolution), many of the Indian rivers and the related groundwater resources have been exposed to pollution, overexploitation and altered flow regimes, which have adversely impacted related ecosystems and their services. Pollution from urban areas and industries, informal settlements & encroachment, rising irrigation demand in combination with poor water use efficiencies, indiscriminate waste disposal and lack of law enforcement, and unsustainable reservoir operation, all these factors contribute to the degradation of the natural water resources.

Further, the water resource governance in India exhibits complicated nature as it involves diverse stakeholders'/decision makers from central, state, and local governments via several expert agencies and institutions. A complicated governance structure coupled with an inadequate representation of relevant stakeholders in decision-making, lack of a systematic approach, and unclear or overlapping roles and responsibilities generally result in fragmented efforts and poor delivery towards the protection and rejuvenation of rivers.

Adoption of integrated river basin approaches where a river-basin is seen as a complete unit and requires inter-sectoral coordination, cannot be fully comprehended without a thorough understanding of India's historical river basin planning and management trajectory as attempted in various following sections. The following sections will provide a backdrop understanding of the Ramganga River Basin Management Plan (RBMP).

1.1 A chronological overview of River Basin Planning and Management in India

Efforts to manage rivers date back to as early as 1950s with the enactment of River Board Act (1956) in India. Later, the special purpose River Boards/Cooperations were formed in India like Damodar Valley Cooperation, Bhakra Beas Management Board etc. through Indian parliament. All these efforts limit their scope to the integrated reservoir operation for optimum use of water resources, water resource development and inter-state allocation of water resources and energy (in case of hydropower).

Overall, river basins need to be understood as a single entity including - surface and groundwater quantity and quality, ecology, socio-economic activities, land resources, people, and cultural heritage. Therefore, efforts to rejuvenate rivers and rehabilitate degraded watersheds must include integrated planning, good governance, coordination among sectors, joint investment planning as well as cross-sectoral assessments and evaluations.

The aspects related to protection of rivers including its groundwater from pollution, maintaining its good ecological health were, first, considered in Ganga Action Plan (GAP) I in 1987. The river Ganga and its tributaries are a source of livelihood for over 450 million people (Census 2011). The Indian part of the Ganga Basin is spread over 861,404 km^2 and covers a total of 11 states. While the main stem of Ganga passes through five states (Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal), its major 17 tributaries (such as Yamuna, Ramganga, Kosi, Sone, Ghagra and others) flow through additional six states of the country. The river Ganga with a total of 525 billion cubic meters (BCM) of annual discharge contributes to almost one-third of India's surface water resources.

Since GAP I, Indian efforts to clean, protect and rejuvenate river Ganga has undergone significant transformation as can be seen in Ganga Action Plan II, launch of National River Conservation Plan in 1995. The integrated approach for river basin planning and management was only recognized in 2009 through the constitution of National Ganga River Basin Management Authority (NGRBA) in 2009. The National Mission for Clean Ganga (NMCG) was set up in 2011 as an implementing arm of NGRBA to take up the execution of projects then supported by the World Bank.

In 2014, the Government of India (GoI) announced its one of the most ambitious missions Namami Gange Mission to accomplish the objective of effective abatement of pollution, conservation, and rejuvenation of the Ganga by using as an integrated and holistic conservation approach. NMCG continues to be the implementing agency for this integrated and comprehensive Mission, which brought under one umbrella various action plans in existence for different rivers in the Ganga Basin. With an assured funding of Rs 20,000 crores for five years, the mission was structured as a multi-sectoral programme and finally approved by Union Cabinet in 2015.

The milestone towards integrated river basin management was the issuance of River Ganga (Rejuvenation, Protection and Management) Authorities Order in 2016 (AO 2016) through the erstwhile Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD & GR), GoI (now, Ministry of Jal Shakti, MoJS, GoI). The AO (2016) empowers the National Mission for Clean Ganga (NMCG) as an authority and defines the role and responsibilities of major stakeholders, in particular outlining NMCG's mandate and overall responsibilities for the development of River Basin Management Plan for river Ganga and its tributaries.

Forwarding in this direction, NMCG is in the process to adopt integrated river basin approaches where a holistic river basin management plan (RBM plan) is developed by promoting inter-sectoral coordination among all stakeholders including periodic monitoring and adaptations. In this regard, international experience for cleaning and protection of its rivers such as Rhine, Danube, Elbe gathered in Germany and the EU member states, for example, is more and more considered. A coordinated implementation by the national actors together with the concerned basin states could benefit from the experiences gained by adopting the EU Water Framework Directive (EU WFD) and its Common Implementation Strategy as well as other international water-related directives. Simultaneously, adaptation and evolving of the process to the Indian situation is apparent.

1.2 The European Water Framework Directive (WFD)

The EU-Water Framework Directive introduced a new approach towards the management of water resources in more coordinated and uniform manner across Europe, as it requires not only the compliance of polluters with emission targets but also the achievement of ‘‘good status’’ for surface and groundwaters and the integration of economic issues such as the polluter-pays principle and full cost recovery (Richter, Voelker, Borchardt, & Mohaupt, 2013).

A key objective of the EU-WFD is to reach a good status for all waters (surface water and groundwater) as briefed below (European Commission, 2016).

Surface water

- Ecological status: For defining the ecological status, EU WFD introduced chemical and hydrological parameters. As no standards for biological quality in absolute terms can be set which are applicable for all ecosystems, a tolerable diversion from a potential natural state without human impact was introduced. This means that a potentially natural state must be determined first and the current situation is then evaluated against this potentially natural state. Often hydrological models are applied to determine potentially natural states.

- Chemical status: Good chemical status is defined in terms of compliance with quality standards established for chemical substances at the European level. The Directive also provides a mechanism for renewing these standards and establishing new ones employing a prioritization mechanism for hazardous chemicals. This ensures at least a minimum chemical quality, particularly concerning very toxic substances.

Groundwater

- Chemical status: The presumption in relation to groundwater should be that it should not be polluted at all. For this reason, setting chemical quality standards may not be the best approach, as it gives the impression that it is tolerable to pollute groundwater bodies up to the defined threshold. Despite that, a few standards have been defined for particular substances like nitrates, pesticides and biocides. The common approach, however, is to apply a precautionary approach which prohibits direct discharges to groundwater and stipulates the monitoring of groundwater bodies. Monitoring is important to detect changes in the chemical composition which may arise from indirect discharges. In addition, monitoring is required for early detection of pollution trends.
- Quantitative status: Groundwater recharge is used as guiding parameter for groundwater use. Only the portion that is not needed for connected ecosystems like wetlands can be considered. The Directive limits abstraction to that quantity.

One of the innovations of the Directive was that it provided a framework for the integrated management of groundwater and surface water for the first time at the European level.

Coordination of measures and relevant EU Directives

There are several measures taken at the European Union level to deal with specific pollution problems. Key examples of such measures include the Urban Wastewater Treatment Directive, the Nitrates Directive, and the Industrial Emission Directive. The Urban Wastewater Treatment Directive and the Nitrates Directive, together, address the problem of eutrophication as well as health effects such as microbial pollution in bathing water areas and nitrates in drinking water. The Industrial Emissions Directive deals with chemical pollution. The overall aim is to coordinate the application of all directives to meet the objectives established above.

First, the objectives are established for the river basin as outlined in the previous section. Subsequently, an analysis of human impact is conducted to determine how far each water body diverts from the defined objective. The full implementation of all directives is applied to determine whether objectives can be met or not. The procedure stops at this point if all objectives are achieved. If not, each Member State must identify exactly why cannot the objective be achieved and accordingly must design additional measures needed to satisfy all the objectives. These might include stricter controls on polluting emissions from industry and agriculture, or urban wastewater sources. These additional measures should ensure full coordination.

The combined approach

Combined in the sense of this approach is to consider two different perspectives. The perspective of a pollution source and the perspective of the receiving ecosystem. Standards exist which limit cumulative discharge per year from a pollution source like a wastewater treatment system. On the other hand, maximum tolerable hydrological and chemical parameters were defined to ensure that an ecosystem does not degrade over time.

Cumulative impacts are the underlying reason why the ecosystem perspective was introduced. Low but frequent discharges can gradually damage an ecosystem due to repetitive disturbances when no sufficient time for recovery between the impacts is provided. Therefore, a so-called dose-response relationship was developed linking the magnitude of pollution with its frequency and duration of occurrence. For this reason, a consensus was developed that both are needed in practice - a combined approach.

On the source side, the EU-WFD requires all existing technology-driven measures must be implemented as a first step. The framework contains a list of priority substances ranked based on risk for which the most cost-effective set of measures must be implemented first to achieve load reduction of those substances.

On the effects side, it coordinates all the environmental objectives in existing legislation, and provides a new overall objective of good status for all waters and requires that where the measures taken on the source side are not sufficient to achieve these objectives, additional ones are mandatory.

The River Basin Management Plan (RBMP) as planning instrument

All the elements of this analysis must be set out in a plan for the river basin. The plan is a detailed account of how the objectives set for the river basin (i.e., ecological status, quantitative status, chemical status and protected area objectives) are to be achieved within the required timescale. The plan includes all the results of the above analysis: the river basin's characteristics, a review of the impact of human activity on the status of waters in the basin, an estimation of the effect of existing legislation and the remaining "*gaps*" to meeting these objectives; and a set of measures designed to fill these gaps.

One additional component is that an economic analysis of water use within the river basin must be carried out. This is to enable a rational discussion on the cost-effectiveness of the various possible measures. All interested parties must be fully involved in this discussion and in the preparation of the river basin management plan. This leads to the final element of the Directive, the public participation requirements.

The need to conserve adequate supplies of a resource for which demand is continuously increasing is also one of the drivers behind what is arguably one of the Directive's most important innovations - the introduction of pricing. Adequate water pricing acts as an incentive for the sustainable use of water resources and thus helps achieve the environmental objectives under the Directive.

Annex-VII of the Water Framework Directive stipulates that RBMP are to cover the following elements:

- A general description of the characteristics of the river basin district and a summary of significant anthropogenic pressures and their impact on the status of surface water and groundwater bodies (i.e., pressure and impact analyses),
- Mapping of protected areas
- A map of the relevant monitoring networks and the results of the monitoring programme
- The relevant environmental objectives for water bodies (including identification of instances where exemptions have been made)
- A summary of the economic analysis of water use.
- A summary of the Programme of Measures (PoM), including how the mandated objectives are thereby to be achieved,
- A summary of the public information and consultation measures taken, their results, and the changes to the river basin management plan made consequently.

The goal of attaining the objectives must be in accordance with a clearly defined timeline. The river basin management plans and the various programmes of measures (PoM) are updated during successive six-year periods during which implementation status, new evolutions, and projected success – as well as failures– are documented. In the event the mandated environmental objectives were not reached by 2015 and exemptions are needed, reasons for their use had to be provided. Hence, the RBMP comprise a monitoring instrument for the European Commission and other river basin district management stakeholders.

1.3 Indo-German Technical Cooperation for Support to Ganga Rejuvenation

Indo-German Technical Cooperation (TC) on the rejuvenation of the river Ganga started taking shape in the year 2014/2015. Considering the Namami Gange Mission, the Government of India requested German support for the challenging task of building on ongoing cooperation on various aspects of water resource management. In 2015, GIZ was commissioned by the German Federal Ministry of Economic Cooperation and Development (BMZ) to implement Phase 1 of the *Support to Ganga Rejuvenation* project.

As part of the India-EU Strategic Partnership, the European Union (EU) and India established the India-EU Water Partnership (IEWP) in 2015. It was set-up to consolidate the political and strategic framework for a more coherent and effective cooperation between the EU and India on water management issues.

Since November 2020, GIZ is implementing the Indo-German Technical Cooperation Project *Support to Ganga Rejuvenation, Phase II* (SGR II) on behalf of the BMZ in conjunction with the *Development and implementation support to the India-EU Water Partnership, Phase 2 (IEWP Action, Phase 2)*. The main implementation partners from the Indian side are the National Mission for Clean Ganga (NMCG) and the Central Water Commission (CWC). Measures at the regional level target the states of Uttarakhand and Uttar Pradesh as well as the Tapi Basin (Madhya Pradesh, Maharashtra, and Gujarat).

1.4 River Basin Planning and Management Cycle (RBM Cycle)

Further to develop and implement the RBM plan in a structured manner with defined timelines, the River Basin Planning and Management Cycle (RBM Cycle) was developed by GIZ together with the NMCG after reviewing the EU WFD concepts. The RBM Cycle acts as a planning tool that encompasses all aspects of RBM. As exhibited in Figure 1, the RBM Cycle has been adapted to fit in the Indian context. Essentially, RBM Cycle is built on the implementation philosophy and requirements of the EU Water Framework Directive (2000/60/EC., 2020), which has contributed to the development of almost 200 RBM Plans in the European Union (EU) so far.

Figure 1: River Basin Planning and Management Cycle (RBM Cycle)

The first step of the RBM Cycle prompts to work on a clear governance and coordination structure to allocate responsibilities among all stakeholders. The cycle deploys the pragmatic approach to understand the basins, i.e., the existing pressures on water resources and their impacts, and the risk assessment for identified Key Water Management Issues (KWMIs) across the full hydrological drainage area of the basin. Accordingly, the cycle ascertains that the designing/adapting monitoring networks are part of the process while developing programme of measures (PoM) to address the identified problems. The cycle recommends continuous assessment of water quality and quantity (supporting monitoring post implementation of PoM) and reviews the effectiveness of the RBM plans and their subsequent adaptation/ revision. The phase I of the SGR project also implemented modular trainings on the RBM Cycle to the Indian water professionals from national (NMCG, CGWB, CWC, CPCB) and state departments (from UP and UK) to familiarize them with the integrated Cyclic approach of River Basin Planning and Management. Simultaneously, under IEWP Action Phase I, the RBM Cycle approach was deployed to develop RBM Plan for Tapi River Basin together with the Central Water Commission, Central Ground Water Board and the three states of the Tapi Basin. The Tapi RBM Plan includes a ‘Basin Characterization’ of the Tapi river, a comprehensive Risk Assessment for identified Key Water Management Issues (KWMIs) and recommends the Programme of Measures for implementation to achieve the overall objectives.

1.5 Development of the Ramganga RBM Plan using RBM Cycle approach

Taking forward the concept of viewing a river basin as a single unit and the understanding that many of the tributaries are polluted, NMCG expanded its activities to the major tributaries of river Ganga. One of such major tributary of river Ganga is rain-fed perennial river Ramganga.

About Ramganga River

Ramganga is the first major tributary of river Ganga which meets the Ganga at Kannauj, Uttar Pradesh. Along its course of 596 km, the river originates in the lower Himalaya in Uttarakhand and passes through Uttarakhand and major towns of western Uttar Pradesh. Several small tributaries such as Khoh, Gangan, Aril, Kosi, Gaula, Dhela, Bhela, and Garra also meet the main stem of Ramganga at different locations, mostly after the city of Moradabad. The Ramganga Basin has a catchment area of approximately 30,000 km^2, with a population of 24 million people (2020). According to Uttar Pradesh Pollution Control Board's (UPPCB) Ramganga restoration plan, a total of 445,000 m^3 per day of wastewater from 121 major industries and several cities is discharged into the Ramganga, making the 375 km stretch from Moradabad to Kannauj critically polluted. The river also houses one major hydro-power dam at Kalagarh being an integral part of various economic activities in the basin. Ramganga's annual discharge amounts to 17 billion m^3, which forms 3.1% of the annual flow of the Ganga.

Given the importance of the Ramganga river towards the protection of river Ganga, the NMCG has also been implementing several projects in the Ramganga Basin such as interception/diversion of nallahs, and construction of Sewage Treatment Plants (STPs) in Ramnagar, Kashipur, Moradabad and Bareilly.

Building on the work of Phase 1 of the SGR Project, it was decided together with the NMCG to develop a River Basin Management Plan for the Ramganga Basin. The development of the Ramganga RBM Plan also follows the RBM Cycle approach. The first step is the characterization of the Ramganga River basin, which includes the identification of 5 Key Water Management Issues (KWMIs) and a pressure/impact analysis and a risk assessment for each identified KWMI. Based on this, a Programme of Measures (PoM) will be developed for the Ramganga Basin, suggesting a set of management options and measures for implementation to achieve the set RBM targets and to improve the overall water management situation in the Ramganga Basin.

1.6 Implementation timeline of the Ramganga RBM Plan

Below Table captures the timeline of the development of Ramganga RBM Plan. It is a Cyclic approach or RBM Planning which needs to be repeated after a defined period. Aligning with India's other planning activities, the RBM Cycle for Ramganga RBM is agreed to be repeated **after every five years**. The progress during first cycle (2022-2027) will include the implementation of Programme of Measures (PoM), their continuous monitoring & evaluation, generation of new knowledge and mid-term risk assessment and Pressure Impact analysis of already selected Key Water Management Issues (KWMIs) to assess improvement and impacts, and of new KWMIs as would emerge in first five years. Below Table 1 presents an account of timelines for Ramganga RBM Planning.

Table 1: The timeline of Ramganga RBM Planning

Timelines	Steps / Milestones
December 2021	Ramganga River Basin, a sub-basin of the Ganga, was selected and agreed for the development of RBM Plan
May 2022	• Stakeholder consultations at national and state levels were implemented to identify and agree KWMIs to be taken up in first RBMP Cycle • Workshop with stakeholders on data availability and agreement of the method of data acquisition was completed
June 2022	The static data / information on Ramganga Basin was received
August 2022	• Ramganga River Basin Management Committee was constituted. • Vision and Management Objectives for each of the identified KWMI were agreed with stakeholders through a consultative process
October 2022	First meeting of Ramganga RBM Committee was held, and the Vison and Management Objectives were approved
November 2022	Joint field mission to Ramganga Basin was implemented by international experts and all stakeholders to carryout ground truthing
January 2023	A background document on Ramganga Basin Characteristics and Key Drivers and Pressures on each of KWMI was submitted to all stakeholders
March-April 2023	The methodologies to carry out Pressure – Impact Analysis and Risk Assessment for each of the KWMI was agreed with stakeholders through a consultative process
July – August 2023	The first results of risk assessment exercise were shared and discussed with basin stakeholders to solicit feedback
September 2023	• Joint consultation with basin stakeholders was held to finalise the risk assessment results, to introduce concept of PoM, and agreeing on the next steps. • 2nd meeting of Ramganga RBM Committee was held to present and seek agreement on the revised results, PoM Concept and next steps • Detailed draft PoM were shared with all basin stakeholders to solicit feedback and inputs
October 2023	• 3rd meeting of Ramganga RBM Committee to seek approval on Ramganga RBM Plan, and • Stakeholders meet to consult and agree on the Ramganga RBM Plan implementation strategy
January 2024	Implementation of PoM to be initiated

1.7 Institutional Arrangement and Coordination level of Ramganga RBM Plan

Institutional Arrangement

NMCG, as per the AO (2016) is the nodal responsible authority for the protection and rejuvenation of river Ganga including its tributary Ramganga. Para 38 and 39 of the AO (2016) clearly state that NMCG is responsible to coordinate all activities regarding rejuvenation and protection of Ganga (and its tributaries), and to make or cause to make the RBM Plans (cost, timelines, and responsibilities) and execution of the projects. NMCG is thus responsible to coordinate all activities related to rejuvenation in the Ramganga Basin (sub-basin of Ganga). As per this AO, NMCG also has the power to approve / sanction projects up to INR 1000 Crore. NMCG reports to the National Ganga Council – chaired by Hon'ble Prime Minister of India.

Furthermore, AO (2016) also mandates the formation of District Ganga Committees (DGCs) in each district in Ganga Basin and their role and responsibilities are also aligned with the NMCG's role. Linking this, Ramganga Basin is spread to a total of 20 districts where DGCs are already existing to coordinate activities pertaining to development of District Ganga Plan and their implementation. State Mission for Clean Ganga (SMCG in both Ramganga states – UP and UK) are also responsible for protection and management of river Ganga and its tributaries.

Thus, it is clear that in Ramganga Basin, a three-tier institutional arrangement (national, state and district level) is well established and fully functional.

In addition to the NMCG, SMCGs and DGCs, there are several national and state level departments and parastatal bodies which, through their respective mandates and roles, contribute towards the RBM activities. Below Figure 2 present an overview of the existing institutional arrangement in Ganga (including Ramganga) Basin:

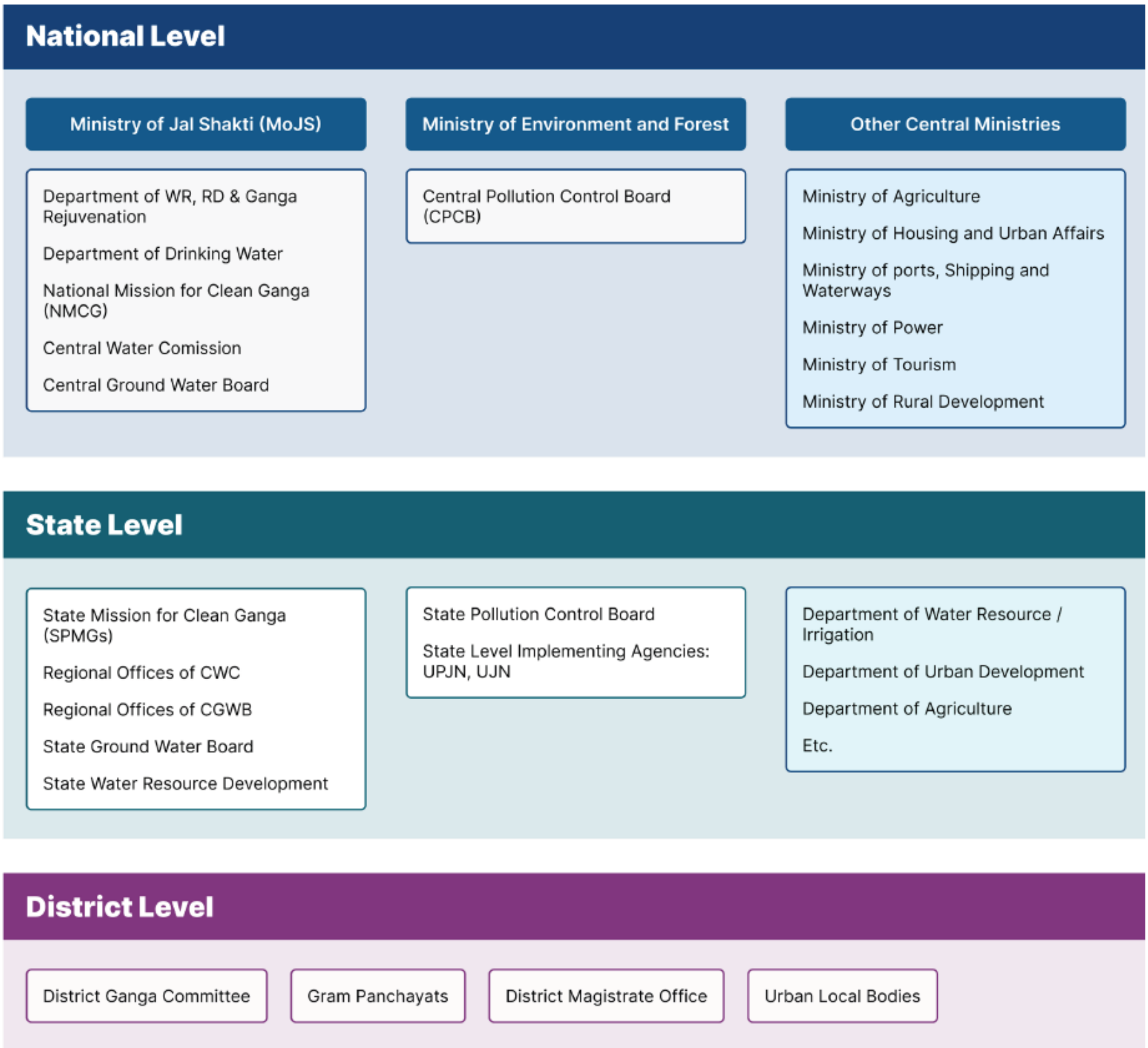


Figure 2: The institutional arrangement in Ganga (including Ramganga) River Basin

Stakeholders for the development of Ramganga RBM Plan

The approach for the development of Ramganga RBM plan was a stakeholder-led consultative process where all available knowledge, experience and expert judgement contributed at every step. Below Table 2 provides an overview of the stakeholder involved in Ramganga RBM Plan development:

Table 2: Stakeholders involved in Ramganga RBM Planning

National stakeholders	Uttar Pradesh state level stakeholders	Uttarakhand state level stakeholders
• NMCG • Central Water Commission (CWC) and their regional offices in Ramganga Basin • Central Ground Water Board (CGWB) and their regional offices in Ramganga Basin • Central Pollution Control Board (CPCB) • Ministry of Agriculture	• SMCG • Jal Nigam • Pollution Control Board • UP Department of Environment, Forests and Climate Change • Urban Local Bodies Directorate • State Missions for SBM • State Mission for AMRUT • State Department of Groundwater • State Department of Water Resources • DGCs in Shahjahanpur, Moradabad and Bareilly	• SPMG • Jal Sansthan • Pey Jal Nigam • Pollution Control Board • Department of Environment and Forests • Department of Urban Development • State Department of Water Resources • DGC in Udham Singh Nagar

Additionally, organizations including WWF-India, Wildlife Institute of India (WII), National Institute of Urban Affairs (NIUA), c-Ganga were also part of the entire process.

Ramganga River Basin Management Committee

A 14 members' Ramganga RBM Committee was constituted by the DG-NMCG with the members representing all levels of planning, coordination and implementation i.e. national, state and district. The role of the committee is to oversee and review the progress of Development of RBM Plan and facilitate coordination among all stakeholders.

2 BASIN CHARACTERISTICS OF THE RAMGANGA RIVER BASIN

This chapter introduces and elaborates on the status of the Ramganga River Basin. The natural baseline includes information on precipitation, flood, drought events, climate, and climate change across the Ramganga River Basin. Subsequent sections elaborate the status of surface waters, groundwater, water infrastructure within the basin. The information presented here serves as the baseline for the pressure-impact analysis and to further carry out the pressure-impact analysis. The salient features of the Ramganga Basin are summarized in the following Table 3.

Table 3: The Salient Features of Ramganga Basin

Feature	Description
Basin Area	30,759 km^2
Sub-Basins or Ramganga	40 Sub-basins with an area ranging from 362 km^2 to 1465 km^2
Link to Ganga	The left tributary of Ganga joins at Kannauj
Tributaries of Ramganga	Khoh, the Gangan, the Aril, the Kosi, Phika, Dhela, Bhela, Gaula and the Deoha (Garra)
Towns and Districts of Ramganga Basin	93 Towns across 20 districts in Uttarakhand and Uttar Pradesh
Major cities in the Ramganga Basin	Bijnor, Moradabad, Rampur, Bareilly, Kannauj, Kashipur, Haldwani-Kathgodam, Ramnagar, Shahjahanpur, Rudrapur
Ecological importance	Rich in flora and fauna including the presence of animals like tigers, elephants, leopards, marsh crocodile, gharial, turtles, golden Mahseer and many other fish and bird species.
Water resource infrastructure	11 dams, 10 barrages, 2 weirs, 1 hydro-powerhouse
NMCG's major activities	I/D of nallas at Kosi River, Ramnagar (55 km) + 8.5 MLD STP Operational Moradabad: 58 MLD STP + 264 km Sewerline + 118 km I/D works Bareilly: 63 MLD STP Kashipur: 10 MLD STP In addition to the above, NMCG is also working in other Ganga towns like Bijnor, Rampur, and Kannauj which have part of their areas in the Ramganga River Basin

2.1 Natural Baseline and Land Use

The 596 km long Ramganga River originates from the lower Himalayas in Garhwal district of Uttarakhand state. The total drainage area of the Ramganga River Basin is 31,843 km^2. Ramganga River Basin is a sub-basin of Ganga River Basin covering 24 million[1] human population from the states of Uttar Pradesh & Uttarakhand. The upper basin also houses a national park - Jim Corbett National Park- a protected and prime Tiger conservation site. At Kalagarh in Bijnor district of Uttar Pradesh, a major hydro-power dam (Kalagarh dam) has been constructed on the river for the purpose of irrigation and hydroelectric production. Almost all tributaries of Ramganga join the main stem of Ramganga on its left

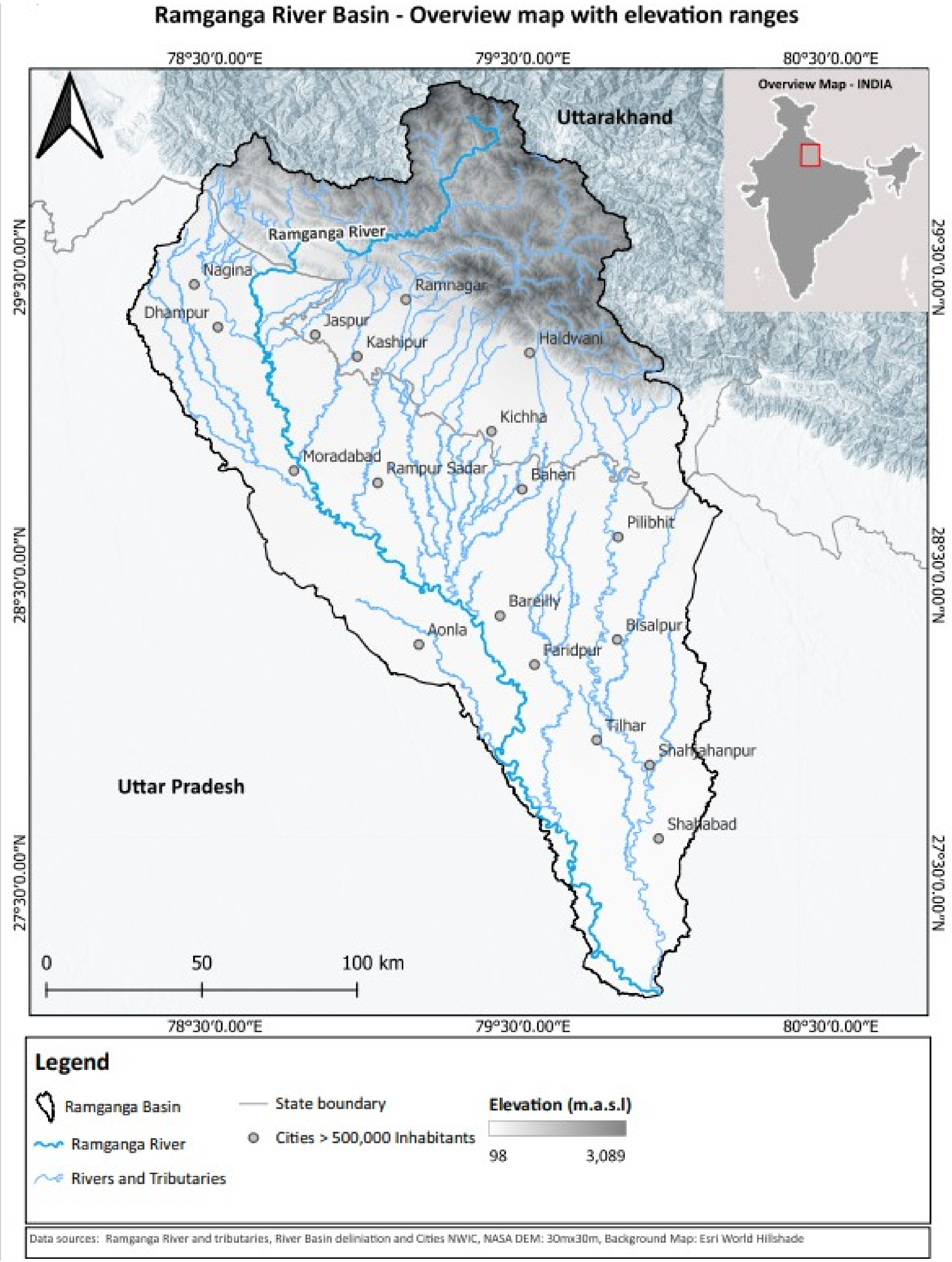
[1] Extrapolated based on Census 2011 data and averaged decadal growth rate

bank. Map 1 shows the Ramganga mainstream and its tributaries stretching over two states of Uttarakhand (approx. 36% of the entire basin) and Uttar Pradesh (approx. 64% of the entire basin). Within this map, only cities with a population larger than 500,000 inhabitants are marked. The Map also shows that most of the cities are located in the lowlands in the southern part of the catchment. It is clearly indicated that the population both in number and density is higher in southern parts of the catchments, which are also the area where cropland is the main type of land use Map 2. A notable spread of land-use is cropland with almost 60% of the total area in the catchment. Other notable uses are forests (approx. 30%) mainly in upper part of Basin in Uttarakhand, built-up (approx. 3%), bare/sparse vegetation (approx. 3%) and Grassland (approx. 3%). Below Table 4 lists the area wise major land use in Ramganga Basin

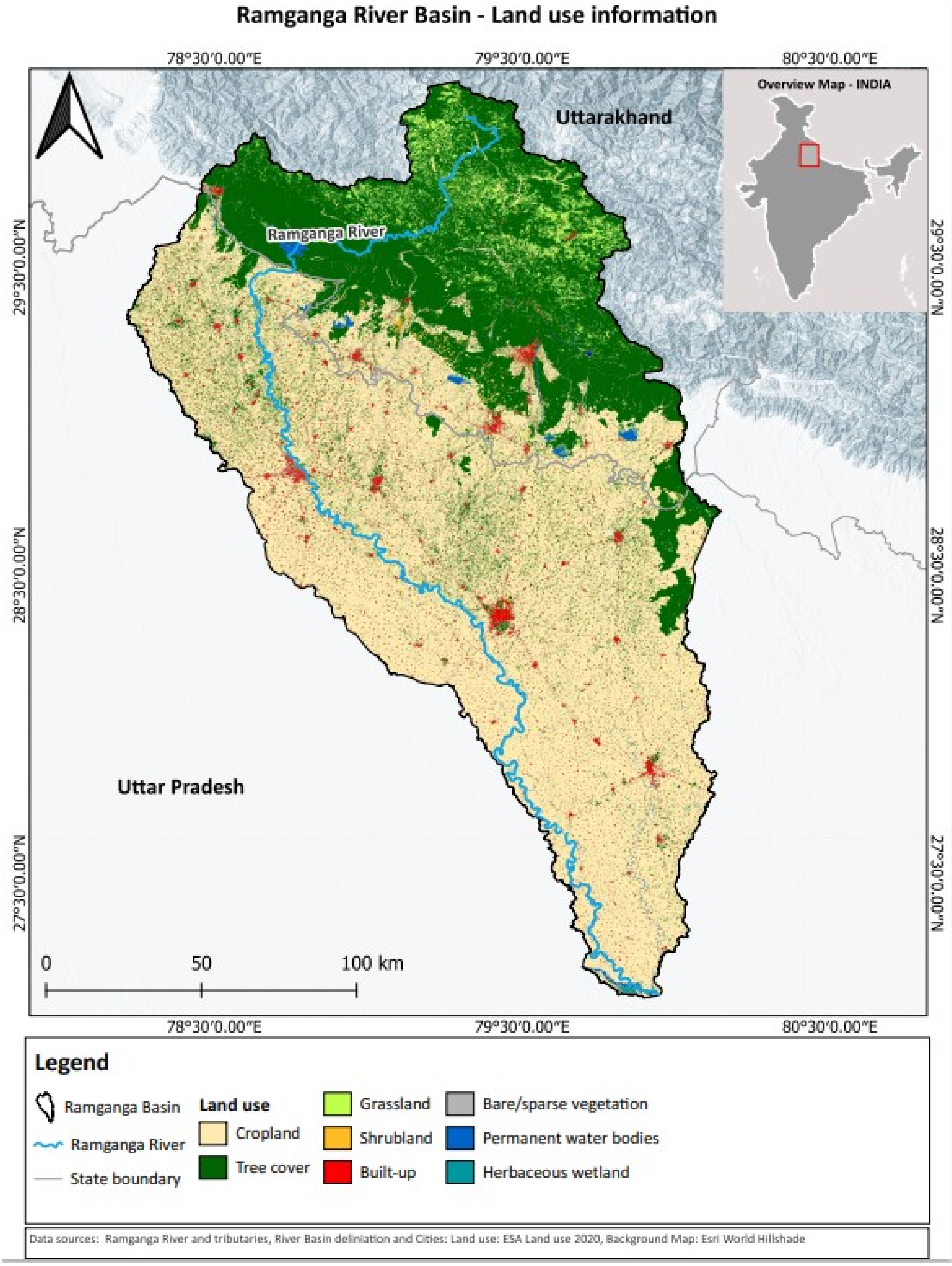
Table 4: Major Land Use along with area in Ramganga Basin (Source: NRSC, 2017/18)

S N	Land use	Area, sq. km	% of Basin Area
1	Built Up	957.8	3.1
2	Kharif Crop	4895.4	15.9
3	Rabi Crop	1699.2	5.5
4	Zaid Crop	51.0	0.2
5	Double / Triple Crop	6980.6	22.7
6	Current Fallow	2507.8	8.2
7	Plantation	935.4	3.0
8	Evergreen Forest	1670.6	5.4
9	Deciduous Forest	4526.8	14.7
10	Degraded / Scrub Forest	1085.5	3.5
11	Grassland	230.1	0.7
12	Wasteland	4027.6	13.1
13	Waterbodies Max	714.1	2.3
14	Waterbodies Min	477.6	1.6
	Total Area	**30759.30**	

There exists a strong gradient in water demand within the Ramganga River Basin. Increase in water demand can be seen from north to south, with population and agricultural activities are mainly concentrated in the southern lowlands of the catchment.



Map 1: Overview of the Ramganga River Basin, elevation and its tributaries



Map 2: Land Use and Land Cover (LULC) in Ramganaga River Basin

2.2 Hydrological Baseline

The Ramganga catchment can be divided into 40 Sub-basins with an area ranging from 362 km^2 to 1465 km^2. The hydrology of Ramganga is strongly characterized by monsoon season, as the river is only fed by rain. The natural flow regime of Ramganga river and its tributaries is regulated through 11 dams, 10 barrages and 2 weirs. The main purpose of these infrastructural buildings is irrigation, while some are additionally also used for drinking water supply and flood protection (especially in the northeastern part). Only Kalagarh dam is also used for power generation. Kalagarh dam with a height of 128 m and length of 630 meter is an earth and rockfill dam with installed hydropower capacity of 198 MW. The total capacity of reservoir is 2400 MCM. The diversion of water for irrigation purpose is through 142 cumec to lower Ganga Canal via a feeder and 14 cumec to direct irrigation systems via Pheeka Doab and Ramganga Main Canal. Whilst the irrigation and flood protection benefits are mainly for the State of Uttar Pradesh, and is managed by the UP Irrigation and Water Resources Department (UPI&WRD), the hydropower generation benefit is meant for the State of Uttarakhand, which is managed by Uttarakhand Jal Vidyut Nigam Limited (UJVNL).

Map 3 illustrates the major regulating infrastructure within the Ramganga Basin. The Map shows that Ramganga, especially northern parts (Uttarakhand), is strongly characterized by water resources management infrastructure, including diversions from one sub-catchment to another. The worth mentioning such hydraulic structures include Afzalgarh weir (73.3 MCM), Hareoli (1600 MCM), Kho Barrage (91.6 MCM), Kosi Barrage (180 MCM), Dhela (115 MCM), Kichha and Nagla (52.82 MCM), Bareilly (725 MCM) and Phika Barrage (75 MCM).

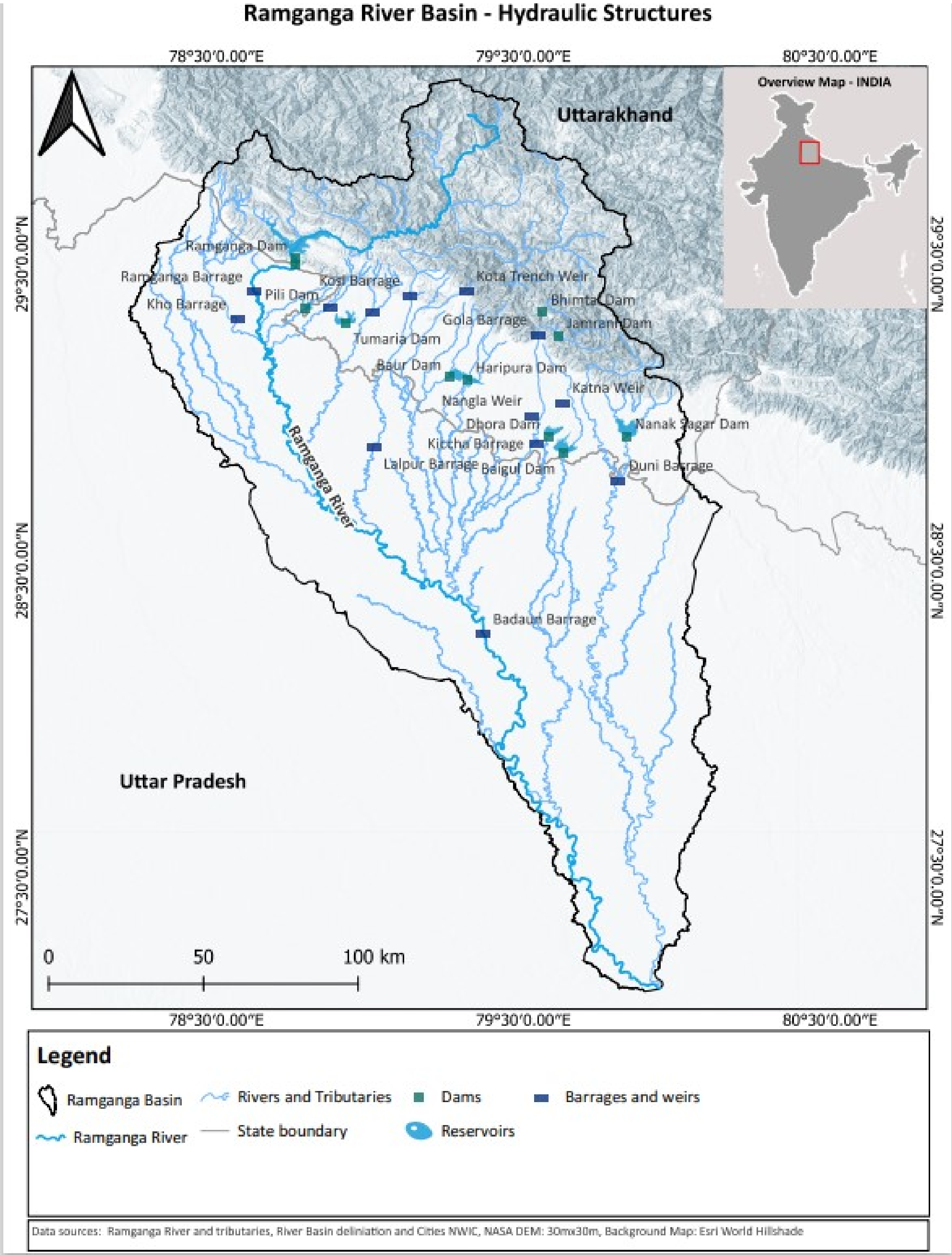
Ramganga Basin sess a significant and well-planned inter-basin transfer to support intense agriculture practices in the Basin and in Lower Ganga Canal. Such transfer of waters also, at times, help in regulating water flows and subsequently the flood events. These abstractions (primarily irrigation) may lead to reduced discharges in downstream areas, impacting the required flows to maintain the ecological entity and health of the river eco-system.

Ranging from a minimum of 150 meters to a maximum of 420 kilometers in length, the Ramganga River Basin encompasses a total of 797 tributaries within its watershed. However, only 18 tributaries exhibit a length more than 100 km as listed in the below Table 5.

Table 5: Main tributaries of Ramganga

Tributaries' Name	Length (in Km)
Deoha/Garra	421
Bahgul (Baigul)	298
Kosi	277
Gangan	239
Bhakra	172
Aril	171
Khanaut	161
Gaula/Kiccha/Gola	160
Ban Nala	153
Dhora	128
Khoh	125
Deoranian	118
Dhela	114
Sukheta Nala	112
Karula Nala	111
Absara	106
Nandhaur	104
Nakatia	103

Further, the Ramganga River Basin contains more than 2,500 water bodies scattered across the entire basin. However only 162 waterbodies extent more than the 1 sq.km area. These water bodies serve not only environmental purposes but also play a crucial role in supporting local communities, providing water for agriculture, and promoting economic growth through environmental tourism. For instance, water bodies such as Nainital, Bhimtal, Sattal, and Naukuchiya Tal are a few of the major tourist attractions. Moreover, Water bodies like, Nanak Sagar, Tumaria, Baigul, Haripur, and Gadgadia serve as hotspots for promoting biodiversity and enhancing the environmental value of the entire Ramganga Basin.

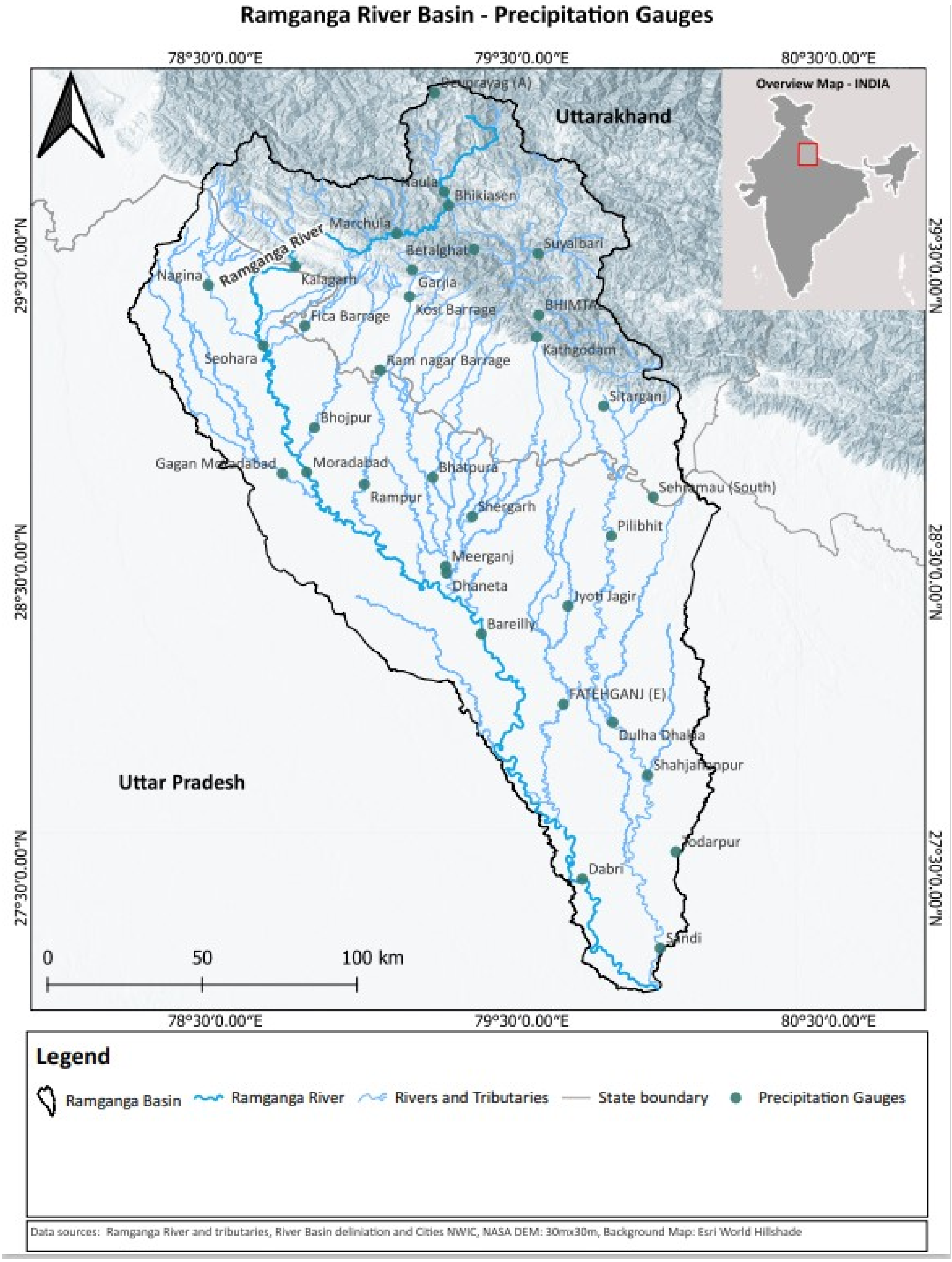


Map 3: Major Hydraulic Structure in Ramganga River Basin

2.2.1 Precipitation

The Ramganga Basin features a high precipitation gradient from north to south or high to low altitude (Figure 3). While the mean annual precipitation is around 2,000 mm in some Himalayan regions in Uttarakhand, the lowlands in Uttar Pradesh, which are almost fully used for agricultural activities, have around 1,000mm. The northern Himalayan regions are the main water source for Ramganga and therefore of great importance for water resources and in particular water use like irrigation projects in the whole basin.

There are in total 34 precipitation gauges distributed within the area of the Ramganga Basin, providing precipitation data on daily basis (see Map 4). The precipitation gauges are mostly located at the same positions as the discharge gauges. Gridded precipitation data is available for India derived from 1901 to 2021. Furthermore, Figure 4 highlights the average monthly rainfall and temperature trends in the Ramganga Basin.



Map 4: Precipitation Gauges in the Ramganga River Basin

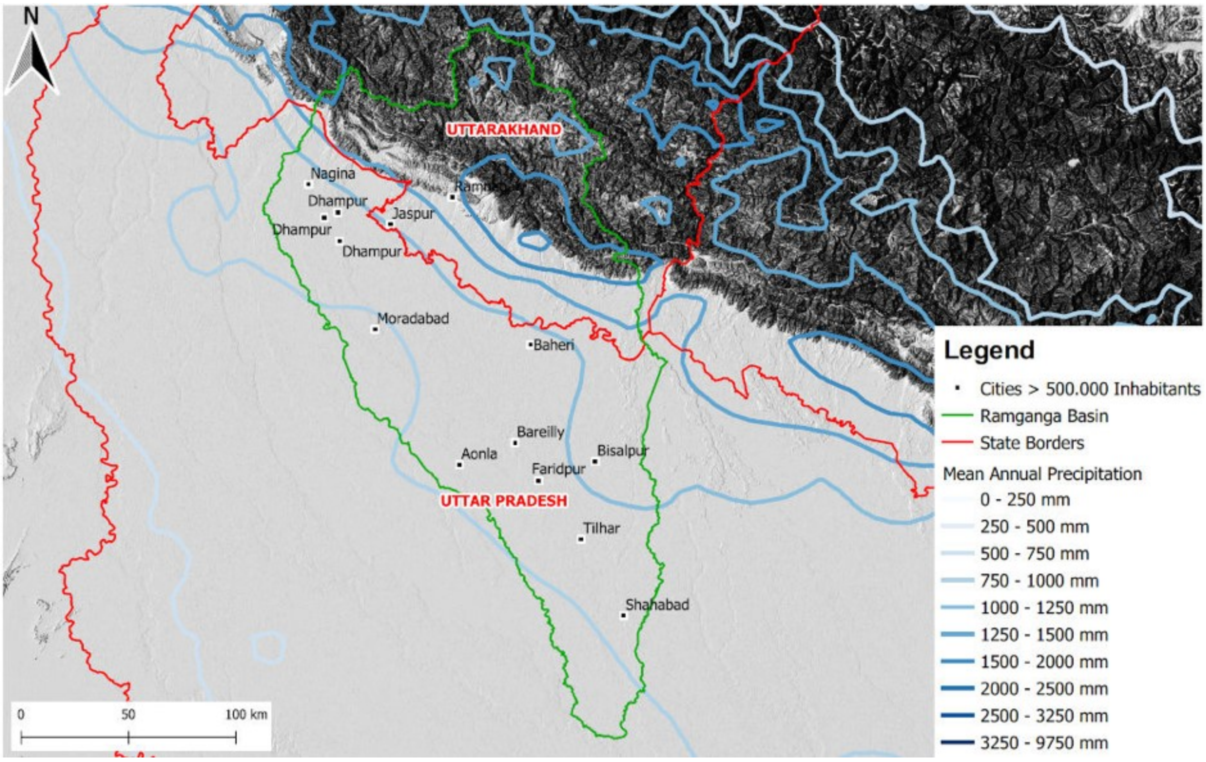


Figure 3: Mean Annual Precipitation in the Ramganga River Basin

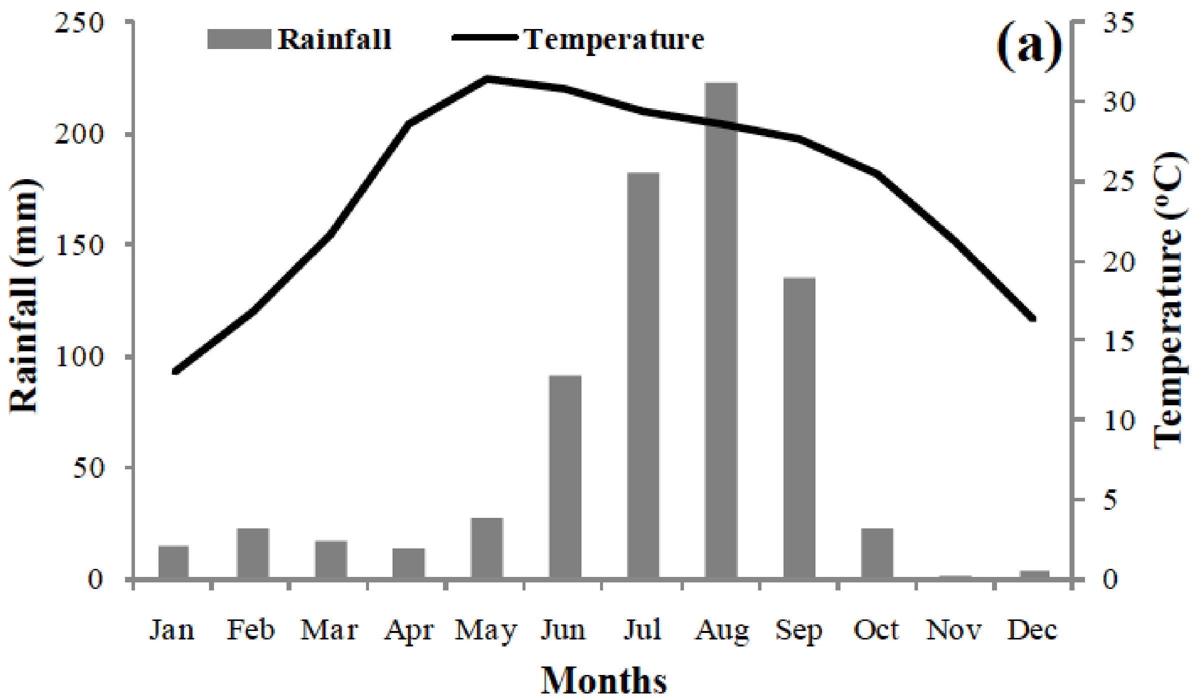


Figure 4: Trend of average monthly rainfall and temperature in the Ramganga Basin (Khan & Tian, 2018)

2.2.2 Evaporation

Global Land Evaporation Amsterdam Model (GLEAM – version 3) data (Martens et al. 2017; Miralles et al. 2011) has been used for getting an overview of actual evaporation information within the Ramganga River Basin. GLEAM, a global dataset with a time series of 42 years (1980 – 2021) is prepared with a combination of observed, reanalysis and satellite-based data and was used because temperature data for the Ramganga Basin - as input for calculating evaporation - was found to be implausible in the Himalaya region and therefore not considered. The original spatial resolution of model data is 0.25°[2]. The evaporation value ranges from 30 – 90mm in the basin (Figure 5). Evaporation values are higher in the Himalayan region (upper catchment area) where most of the freshwater reserves are located. These high values could be due to the direct impact of solar radiation in this region compared to the lower portion of the catchment which has comparatively lower elevation. This higher evaporation value in conjunction with the recent climatic changes in the region might lead to low future water availability for this basin.

[2] In the figure, the resampled data (i.e., finer resolution – 2.5°) has been plotted for a finer image.

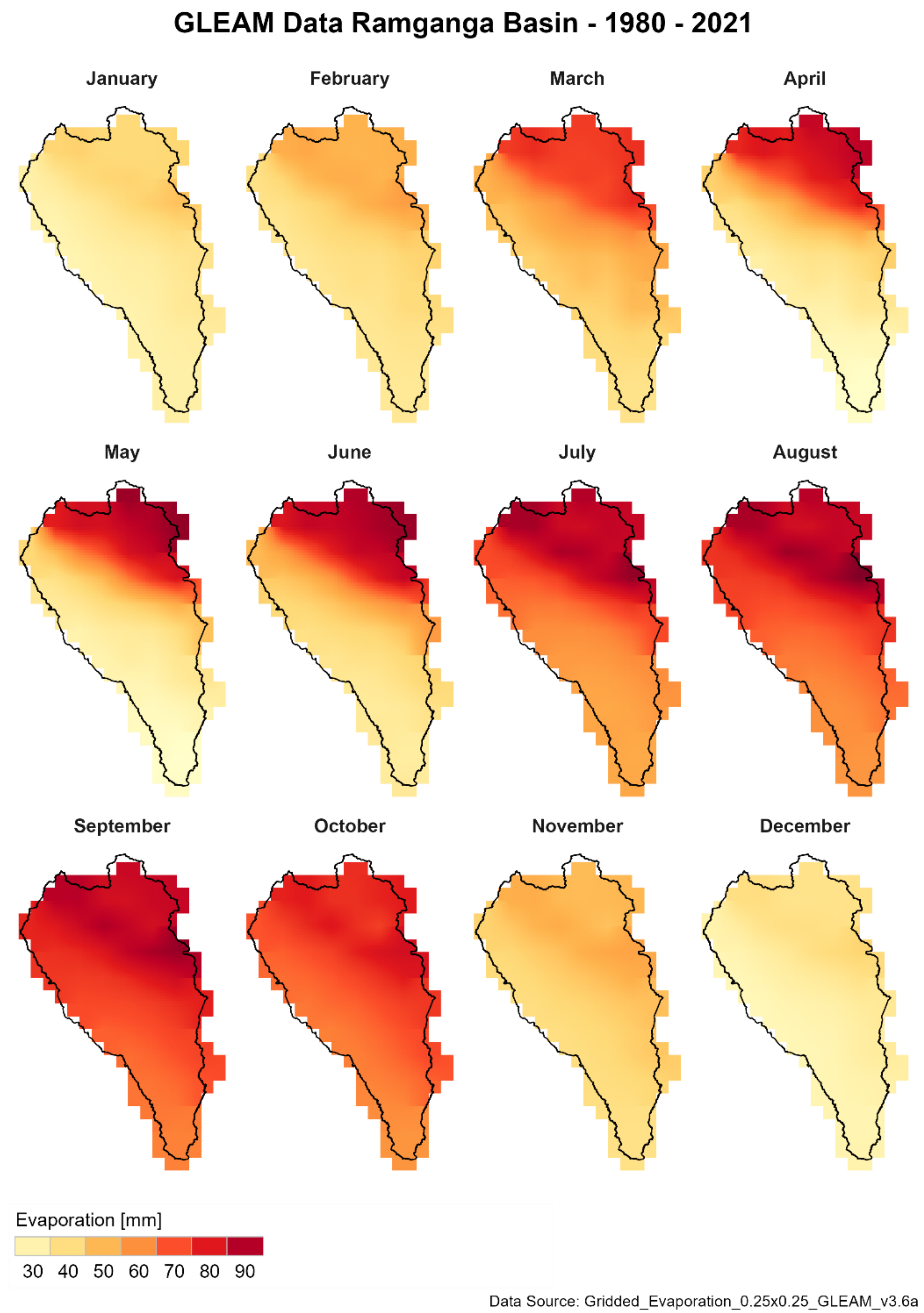


Figure 5: Evaporation in Ramganga River Basin based on GLEAM data (1980 – 2021)

2.2.3 Climate and climate change

The climate of Ramganga Basin is sub-tropical, and monsoonal. Winters (October to February) are cool and dry with occasional fogs and light showers, summers (March to early June) are hot and dry, and the monsoon season (middle June to September) is warm and humid, with frequent heavy rainfall. Diverse climate conditions are observed because of the large variation in the altitude of the catchment area. The lower valley of the basin is usually hot.

Table 6 shows maximum minimum long-term rainfall data and rainfall changes in the selected 5 districts of the Ramganga Basin. From the table, it can be seen that:

- **The annual precipitation is reducing** from the upper catchment in the mountains of Uttarakhand to the lower catchment in the plains of Uttar Pradesh;
- The rainfall data of five districts depicts that the **rainfall has declined** in four districts;
- The decline is **very sharp in two of the districts**, viz., Bareilly and Nainital;
- Additionally, **the annual fluctuation in rainfall is very high** for all the districts.

Table 6: Maximum, minimum and mean annual rainfall and long-term change in (spatial) rainfall of the districts for rainfall data: 1901 to 2021

S N	District	State	Maximum annual rainfall	Minimum annual rainfall	Mean Annual rainfall	Long-term Change in rainfall (mm/year)
1	Almora	Uttarakhand	2,050	671	1,352	No change
2	Nainital	Uttarakhand	2,364	666	1,521	-3.34 mm/year
3	Udham Singh Nagar	Uttarakhand	2,374	693	1,442	-1.32 mm/year
4	Bareilly	Uttar Pradesh	1,994	451	1,024	-3.18mm/year
5	Moradabad	Uttar Pradesh	1,591	293	969	-1.32mm/year
6	Hardoi	Uttar Pradesh	1,681	415	889	-1.15mm/year

Source: analysis based on India-WRIS data

Gridded temperature data is available for India between 1901-2021 for minimum and maximum temperature but has certain limitations in the Himalaya region. It shows unexpected high temperatures in the higher elevation zones (around 15°C) which is why the temperatures in the northern part of the Ramganga River Basin are not considered reliable.

A study on the Ramganga Basin concluded that there is a decrease in annual rainfall at 19 mm year per year. A similar trend was also observed for seasonal rainfall. But there was a significant increase in rainfall during the period of 2001–2008 at a rate of 11 mm year per year. Decreasing trend in monsoon season rainfall was also greater than non-monsoon season rainfall (Surinaidu, et al., 2016) . Such inconsistent pattern in rainfall trends apparently affects the water supply for various socio-economic activities and could lead to conflicts in water allocation in future, if not addressed.

2.2.4 Stream flows

The magnitude of precipitation, its pattern of occurrence, the climatic conditions, land cover and soil types are considered the key attributes influencing the occurrence of runoff and stream flows.

The observed stream-flows at selected monitoring stations (Moradabad, Bareilly and Dabri) on Ramganga river in Uttar Pradesh were analysed and the 75% and 90% dependable mean monthly discharges are presented in Figure 6 to Figure 8, respectively (Source: SWARA, 2020). The river has the highest

(75% dependable) discharge during the month of September at both Moradabad and Bareilly locations, followed by August. The wide difference in the values of 75% dependable and 90% dependable yields, especially during July and August show the high variability in the mean monthly discharges of these months between years.

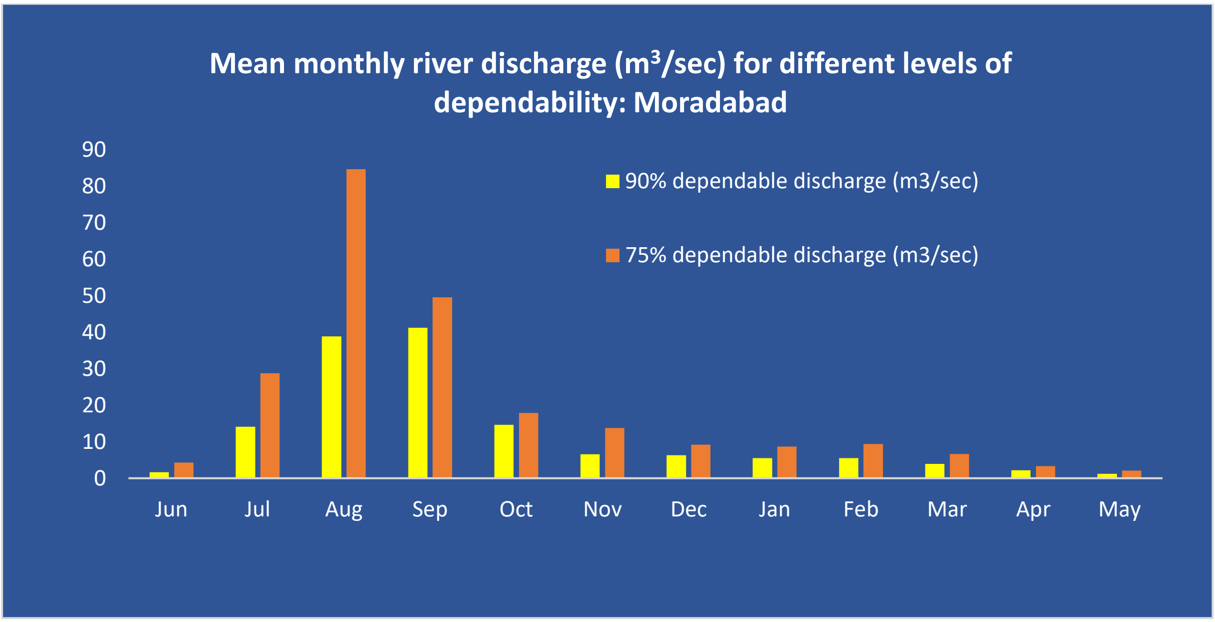


Figure 6: Mean monthly river discharge at different levels of dependability: Moradabad

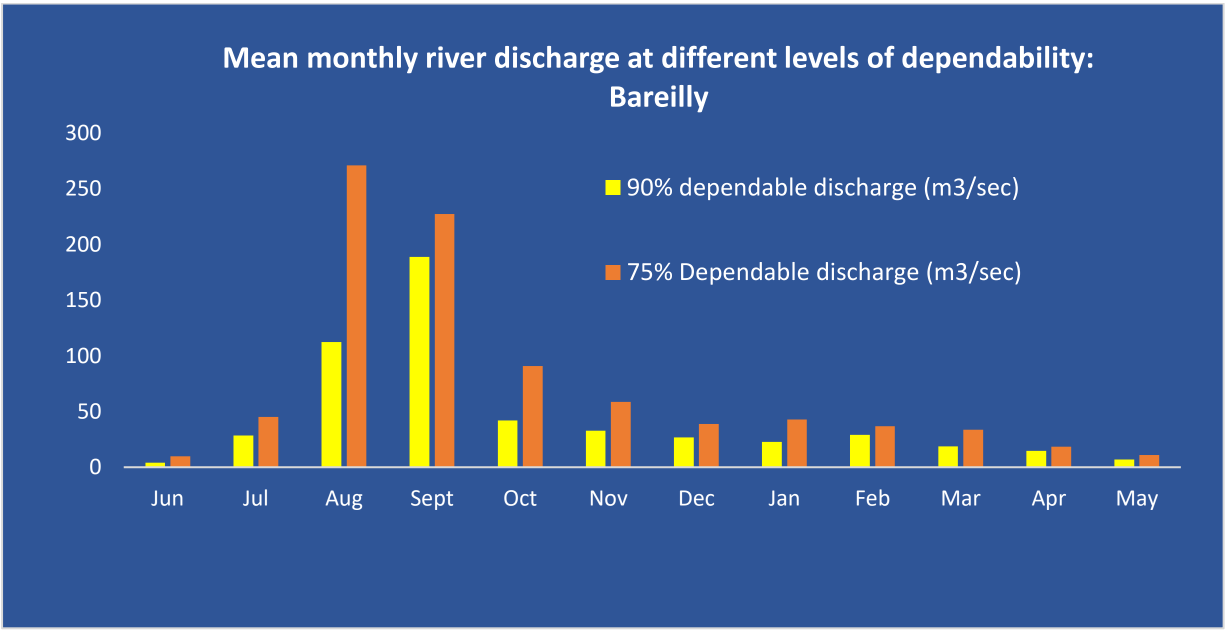


Figure 7: Mean monthly river discharge at different levels of dependability: Bareilly

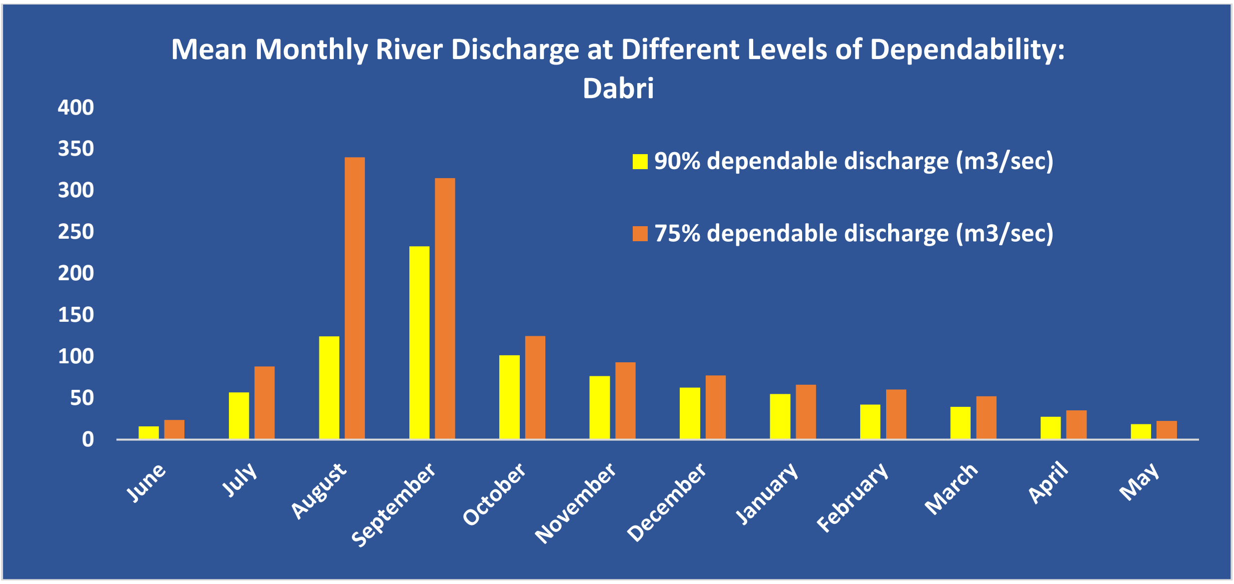


Figure 8: Mean monthly river discharge at different levels of dependability: Dabri

The analysis of mean monthly discharge observed in three different locations, viz.., Moradabad, Bareilly and Dabri for the period of 1978 to 2010 shows a peak value of around 250m3/sec at Marchula in 2010, 425 m3/sec in July 1985 at Moradabad, around 1180 m3/sec in July 1988 at Bareilly and a little above 2200 m3/sec in 1988 at Dabri (source: based on SWAT Output).

The flow dependability curves generated for the virgin runoff of different catchments of Ramganga indicate the sharp variation in the annual flows between years (WWF, 2015). The ratio of the regulated flow to the natural flow is very low in some locations on the river for all the four flow seasons and was however found to be increasing from dry year to wet year (WWF, 2015). The ratio of the regulated flow to the natural flow was more than one in some other locations in certain seasons, implying that the regulated flow in certain parts of the year was more than the natural flows.

2.2.5 Flood and Drought Events

Floods during September 2010 created havoc in the districts of Rāmgangā Basin in Uttar Pradesh, with the city of Moradabad and its outskirts worst hit, as well as villages in close vicinity of the river flood-plain. The floods of 2010 were a combination of extraordinarily heavy rainfall in the upper catchment and heavy discharge off the gates of Kalagarh dam. The CWC's Katghar site of Moradabad recorded its highest ever flow level, with flows reaching 6,400 cumecs (September 21, 2010), with a water-column depth of close to seven meters. Several parts of the Moradabad city were under water and boats were called in for rescue. The floods led to substantial loss of property. However, the impact of the 2010 floods resulted in the Standard Operating Procedures for the operation of Kalagarh dam being revised, which is expected to significantly reduce the likelihood of the recurrence of such an event.

The flood problem in Ramganga Basin is mainly caused by river Ramganga and its tributary Kho, Kosi, Baigul, and Garra/Deoha. The flooding from Ramganga and Kho is mainly caused in Bijnor, Moradabad, Bareilly and Shahjahanpur. Due to flatter slope of the river in lower reaches, some areas are also flooded in Dataganj and Jalalpur areas due to drainage congestion.

Drought

The recurrence period of highly deficient rainfall in in West UP (Ramganga Basin is located here) is estimated to be 10 years In India, the declaration of a meteorological drought depends upon a lot of factors including climatic conditions, its thresholds, bureaucratic processes and functioning, and political scenarios. Each district is declared as "drought affected" by District authorities after careful analysis of these factors. Source: SWARA, 2020

2.3 Water infrastructure

2.3.1 Irrigation projects

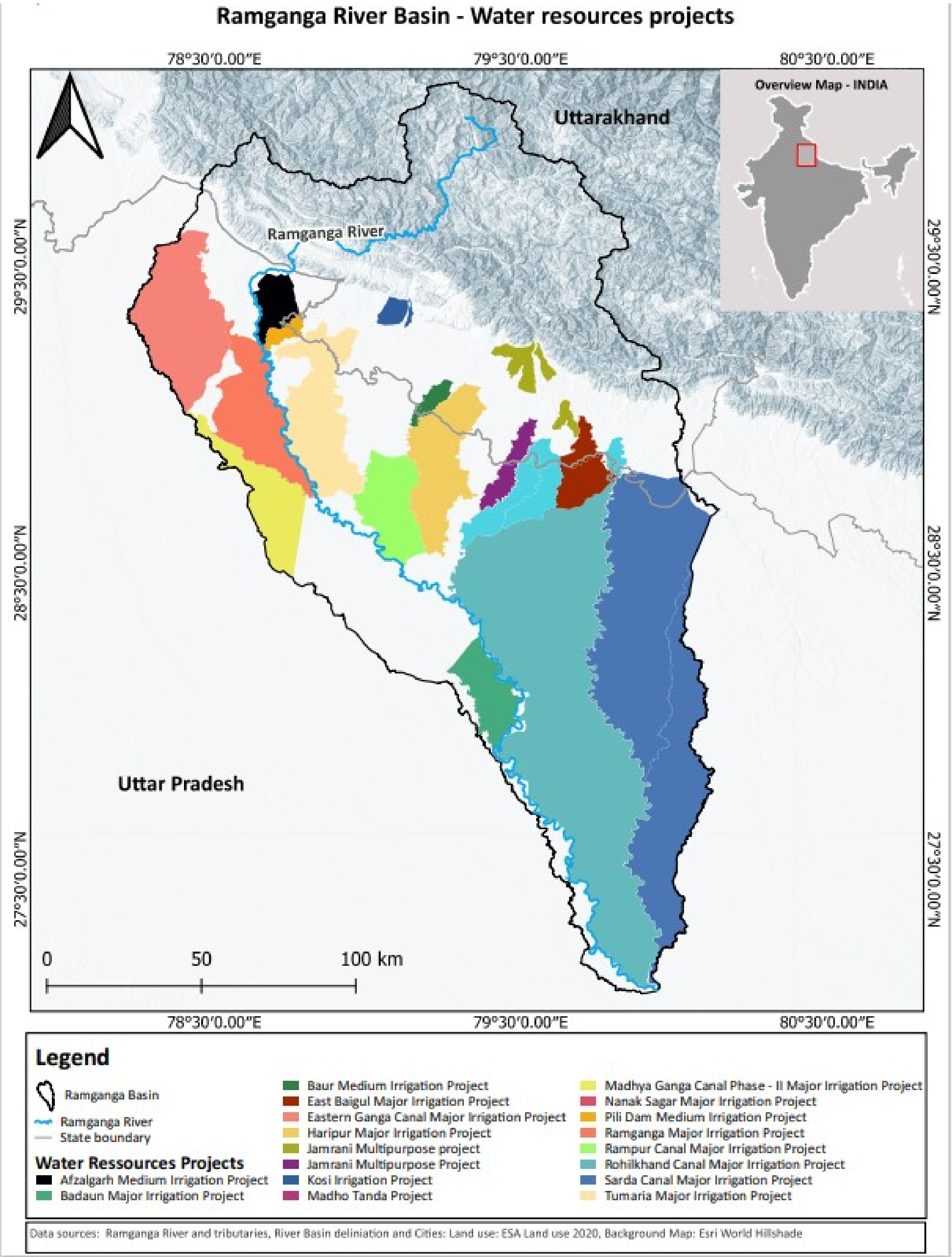
Currently, 15 water resources project command areas are completed, while an additional 3 are ongoing (Map 5). While water availability is mostly given for the northern part of Ramganga Basin, the command areas are mostly located in the south. This requires coordinated water resources management both for surface and ground water.

2.3.2 Water abstraction and recharge

According to the basin planning report prepared by SWARA, (2020), the estimated virgin runoff contribution from Uttar Pradesh to the Ramganga Basin, having a drainage area of 20,416 sq. km, is around 4,151.6 MCM per annum SWARA, 2020 at 75% dependability, and the contribution from Uttarakhand is 3,469.3 MCM. Therefore, the total surface water availability in virgin conditions is 7,621 MCM. The runoff contribution from Uttarakhand part of the Basin in proportion to the drainage area is higher, owing to the higher precipitation received in the catchments there.

The Ramganga Basin imports water for irrigation from Ganga Basin through eastern Ganga canal and Madhya Ganga canal and the Sarda Basin through the Sarda canal system and Sarda-Deoha-Baigul Canal system. It exports water to Ganga River through Ramganga feeder at a rate of 5,000 cusec (142 m^3/s). In addition, there is also import and export of water from the Uttarakhand part of Ramganga Basin.

The estimates from the stream flow records available for Dabri station (in Uttar Pradesh) shows an annual stream flow of 3,42 MCM only, which shows the combined effect of the large number of water storage and diversion systems that are located upstream, and the surface water import into the Basin for irrigation. The observed stream flows include the return flows from the irrigation schemes that serve the areas on the right-hand side of the river.



Map 5: Water Resources Project Command Areas of Ramganga River Basin

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Below Table 7 lists the details of major water resources projects in Ramganga Basin. The details of Kalagarh dam are already provided in the above sections.

Table 7: Diversion Storage in Ramganga River Basin

S N	Name and Location	Diversion /Storage	Discharge (m^{3}/s)/ storage (MCM)	Purpose	Year of commissioning
1	Afzalgarh weir barrage	Diversion	Irrigation with 200 cumec to Pheeka Canal	Irrigation	NA
2	Jamrani Multipurpose Dam near Kathgodam	Storage	144 MCM live storage	30 MW hydropower 0.15 Million Ha Irrigation Drinking water supply	Under construction
3	Budaun Irrigation project in Bareilly	Diversion	56 m^{3}/s	0.032 million Ha irrigation (Khariff)	Under construction
4	Kosi Barrage at Ramnagar on Kosi River	Diversion	48.8 MCM in Bank Storage	Irrigation	1966-69
5	Rampur Barrage on Kosi 3 km d/s Lalpur weir	diversion	178 MCM	400 cusec Kosi canal capacity increased to 600 cusec	2014-19
6	Kosi Barrage at Almora	Diversion	NA	Drinking water supply to Almora City	1972-2012
7	Tumaria Reservoir, Kashipur Dhela/Bhela/ Kosi	Storage	151 MCM live Storage	Irrigation cca 48563 happa 25000 ha	1970
8	Gola Barrage at Kathgodam, Nainital	Diversion	NA	Drinking Water to Haldwani and Irrigation for Bhabhar field	NA
9	East Baigul Reservoir on Baigul/Sukhi in US Nagar	Storage	86 MCM (Original) 65 MCM (Present)	Medium Irrigation Project UBC – 13564 ha, Bara-3041 ha	1968
10	Pilli Dam, Bijnor Pilli/ Bareilly/Dhara	Storage	55.30 MCM 41.21 MCM utilisable	Medium Irrigation Project CCA 7357 ha, Potential 4044 ha	1968
11	Baur Dam on Kichcha, US Nagar	Storage	3056 Mcuft	Irrigation in 6680 ha	1967
12	Haripura Dam on Bhakra/ West Baigul, US Nagar	Storage	1000 Mcuft	Irrigation cca 11000 ha	1975
13	Nanak Sagar Dam on Deoha river, US Nagar	Storage	116. 521 MCM (Gross) 111.601 MCM (Utilisable)	Medium Irrigation Project 37646 ha	1960-62

14	Dhora on Dhora river, US Nagar	Storage	44.95 MCM (Gross), 44.20 MCM Utilisable	Irrigation in 14000 ha.	1960-61
15	Sarda Sagar on Sarda River in Pilibhit	Storage	406.092 MCM (Gross), 329.876 MCM Utilisable	Irrigation in CCA 16.22 lakh ha in 49% area i.e. 8.04 lakh ha	1954-55/1928

2.4 Geology and Aquifers

The geology of the Ramganga Basin consists of a variety of lithologies, such as the inner lesser Himalaya with bedrocks belonging to the Damtha and Tejam groups and the Berinag formation (Valdiya K. S, 1983). The upper parts of the basin (Almora, Garhwal, and Nainital) are crystalline defined by a variety of schists, micaceous quartzites, and gneisses. The lower parts below the foothills (Bijnor to Hardoi) are filled by Holocene, Quaternary, and Precambrian age alluvium. The detailed geology of the Ramganga sub-basin has been studied and well explained in (Asthana, et al., 2015). The subsurface lithology in the Ramganga indicated clay with silt and sand on the surface and it is underlaid by sand with gravel and boulders with varying proportions (Surinaidu, et al., 2016).

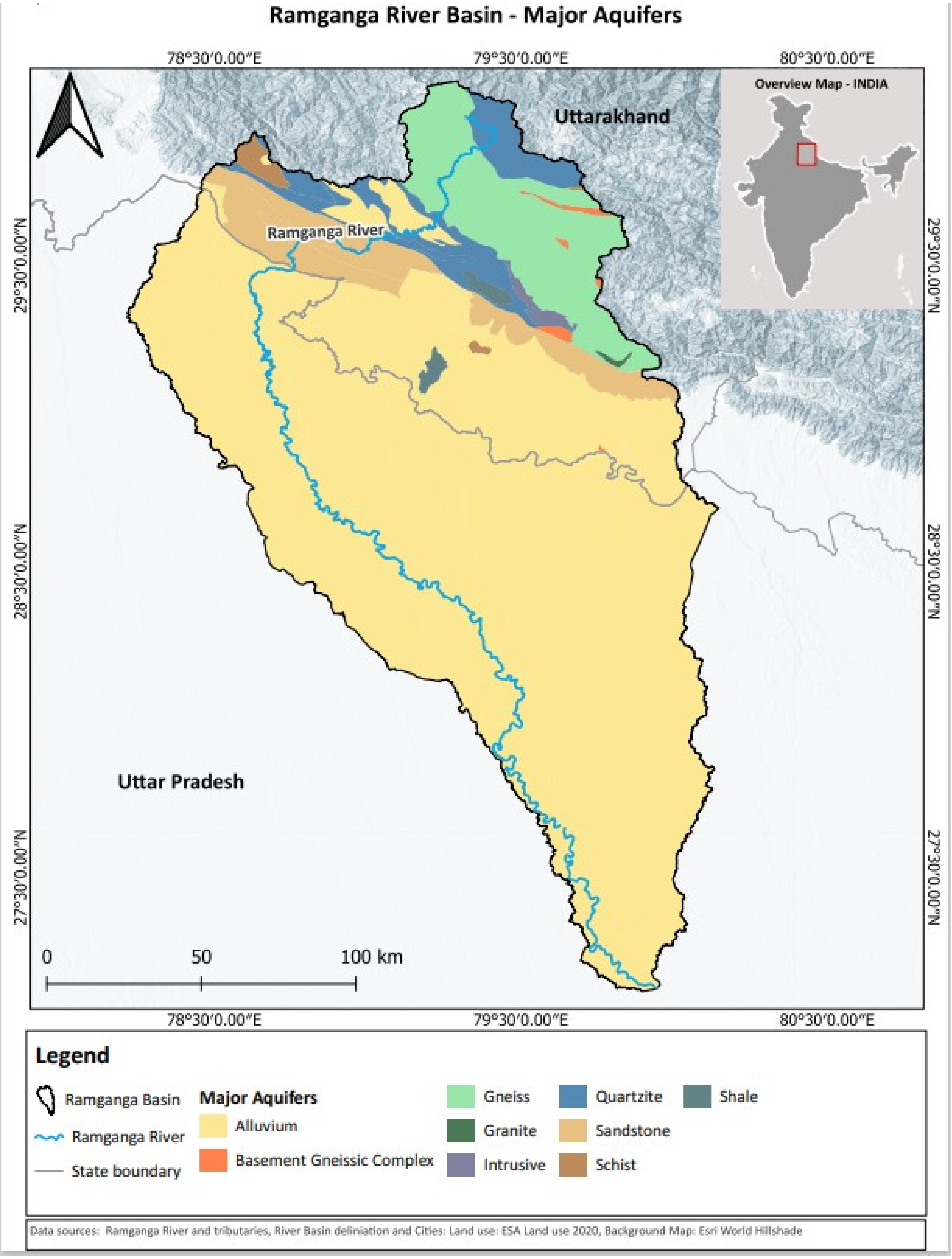
In the Ramganga Basin (Map 6), there are a total of sixteen aquifer types, broadly categorized into two groups: 1. the northern upper part within the Himalayan Mountain Belt (HMB) and 2. the southern lower part of the basin (located in Uttar Pradesh), primarily comprising a large Gangetic alluvial aquifer.

In the northern upper part, the Ramganga Basin primarily extends into the Lesser Himalaya region, enclosed by the Main Boundary Thrust (MBT) to the south and the Main Central Thrust (MCT) to the north, with elevations ranging from 1000 to 3000 meters above sea level. Groundwater availability in hilly areas is limited to small, isolated aquifers with restricted groundwater potential (Central Ground Water Board, 2022). This region is characterized by hard rock aquifers such as Gneiss, Granite, Quartzite, and Schist, which have relatively low permeability. Recharge in these areas occurs primarily through cracks or fissures in the rock. In the Ramganga Basin, most basaltic aquifers are complex, consisting of weathered and unweathered portions, with the latter being confined by impermeable layers. The southern part of the basin is characterized by the Bhabar and Tarai regions, which hold significant potential for groundwater recharge.

In contrast, the southern lower part of the basin (in Uttar Pradesh) consists of younger alluvial deposits (Clay / Silt / Sand / Calcareous concretions) and older alluvial formations (Silt / Sand / Gravel / Lithomargic clay). This area is further divided into two primary groups:

• Aquifer Group-I, the shallow aquifer, occurs in unconfined to semi-confined conditions and is divided into two sections (IA and IB). Aquifer Group IA encompasses the uppermost layer up to 50 meters below ground level (mbgl) and is completely unconfined. Below 50 mbgl, Aquifer Group IB prevails in a semi-confined state (Tahal & INRM, 2020). This aquifer group extends from ground level to depths of 80 – 180 mbgl.

• Aquifer Group-II is separated from Aquifer Group-I by thick, distinctive clay layers and exists in confined conditions. The upper boundary of this confined aquifer ranges from 110 – 180 mbgl, while the lower boundary ranges from 180 – 260 mbgl, with an average thickness of 50 – 60 meters (Tahal & INRM, 2020).



Map 6: Major Aquifers in Ramganga River Basin

The following Table 1Table 8 shows the details about the different aquifer complex and their respective codes.

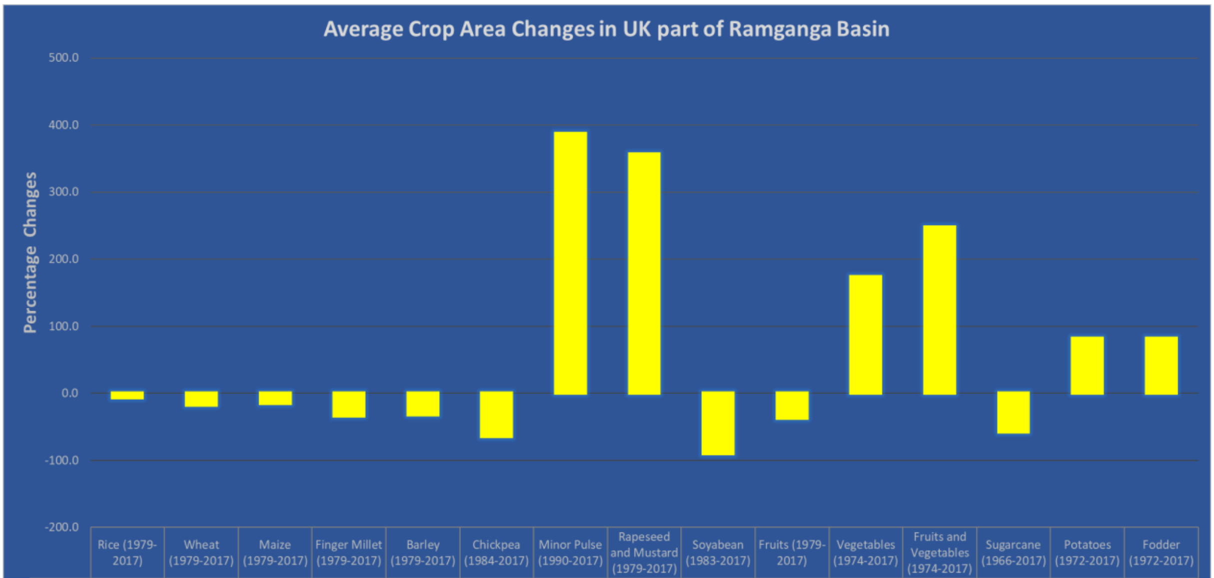
Table 8: Aquifer codes with official colours and aquifer complex - Ramganga River Basin

Aquifer code	Aquifer names	Aquifer Complex	Remarks
BG01	Banded Gneissic Complex	Hard Rock complex	–
IN01	Basic Rocks (Dolerite, Anorthosite, etc.)		
GN01	Undifferentiated metasedimentaries/Undifferentiated metamorphic		
GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite, etc.)		
QZ01	Quartzite (Proterozoic to Cenozoic)		
QZ02	Quartzite (Azoic to Proterozoic)		
SC02	Phyllite		
SC03	Slate		
ST01	Sandstone/Conglomerate	Sandstone/Shale complex	–
ST02	Sandstone with Shale		
SH01	Shale with limestone		
AL01	Younger Alluvium (Clay / Silt / Sand / Calcareous concretions)	Alluvium complex	Alluvium inside Hard Rock complex and lower parts of Uttarakhand
AL02	Pebble / Gravel/ Bazada/ Kandi		
AL03	Older Alluvium (Silt / Sand/ Gravel / Lithomargic clay)		
SC01	Schist		Subsumed small Schist outcrop
SH02	Shale with Sandstone		Subsumed small Shale/Sandstone outcrop
AL01	Younger Alluvium (Clay / Silt / Sand / Calcareous concretions)		–
AL03	Older Alluvium (Silt / Sand/ Gravel / Lithomargic clay)		

2.5 Cropping Pattern

The Ramganga Basin, except hilly areas, witnesses intense agriculture activities with 3 cropping systems. The major crops in the basin include water intensive paddy, wheat and sugarcane.

The Ramganga River Basin in UK has witnessed a significant shift in cropping patterns from the 1970s to the 2010s. Between 1974 and 2017, fruit and vegetable farming in Uttarakhand experienced substantial growth, with a staggering increase of 247%. Similarly, Rapeseed and Mustard cultivation also became increasingly important in Uttarakhand, showing a remarkable growth rate of 357%. From the 1990s onwards, minor pulse crops also demonstrated a steep incline. However, drought-resistant crops like barley and finger millet experienced a notable decline, with a decrease of - 32.3% and -34.7%, respectively, in Uttarakhand's agricultural landscape. Surprisingly, the cultivation shares of paddy and wheat decreased by -6.7% and -17.3%. A similar scenario can be observed in sugarcane cultivation in hilly districts like Nainital. The data indicates that in Uttarakhand, Udham Singh Nagar and Nainital are two of the highest-grossing cultivated areas (Figure 9).



	Rice (1979-2017)	Wheat (1979-2017)	Maize (1979-2017)	Finger Millet (1979-2017)	Barley (1979-2017)	Chickpea (1984-2017)	Minor Pulse (1990-2017)	Rapeseed and Mustard (1979-2017)	Soyabean (1983-2017)	Fruits (1979-2017)	Vegetables (1974-2017)	Fruits and Vegetables (1974-2017)	Sugarcane (1966-2017)	Potatoes (1972-2017)	Fodder (1972-2017)
Average	-6.7	-17.3	-15.2	-33.7	-32.4	-64.2	387.7	356.9	-89.9	-37.1	173.7	247.4	-57.9	82.1	82.1

Figure 9: Changes in crop wise cultivated area in UK part of Ramganga Basin

In Up Part of Ramganga Basin, area under cultivation of rice, paddy and sugarcane continue to grow (77, 93 and 101% respectively) from 1966 – 2017 (Figure 10). As expected, the area under barley, chick-pea, groundnut and sorghum has decreased with same magnitude. Minor pulses witnessed a marginal decrease in the are under cultivation. Interestingly the areas under the cultivation of sesamum, and rapeseed and mustard have increased beyond the comprehension. This could be due to relatively lower area under cultivation. The area under potatoes, fruits and vegetables also continue to grow.

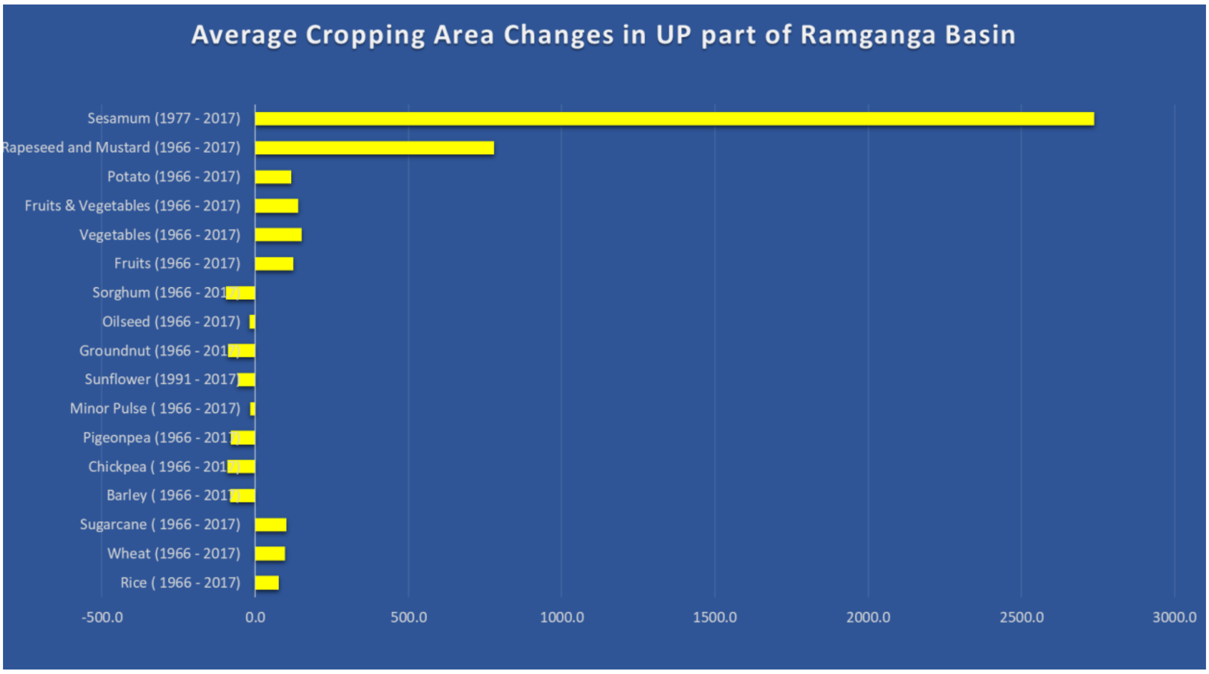


Figure 10: Changes in crop wise cultivated area in UP part of Ramganga River Basin

The analysis of changes in yield of major crops from 1966 simply indicates the imporvement in the production oer ha across all districts. While UK witnessess around 61% and 95% improvement in paddy and wheat, UP records around 300% improvement. Sugarcane records an increased yield of 107% in

UK and 197% in UP. Rapeseed and mustards exhibits extraordinary improvement in yield with 871% in UP and 224% in UK.

2.6 Ecoregions, Biodiversity and Protected Areas

The upper part of the Ramganga Basin is blessed with rich flora and fauna. Life thrives due to availability of adequate freshwater resources and forest areas. Ramganga Basin encompasses a diverse range of habitats, from high-altitude mountains to low-lying plains, making it a hotspot for biodiversity. Additionally, 3.9% of basin area (1190 sq. km) being under different waterbodies contribute to the region's overall ecological diversity.

Ramganga Basin falls under 2 main biogeographical zone, the hilly upper basin falls under the Himalayan biogeographical zone and the lower plain area falls under the Upper Gangetic plains. The Ramganga Basin houses diverse forest types, including tropical moist deciduous forests in the plains, subtropical broadleaf forests in mid-altitudes, and temperate forests in the Himalayan foothills. Alpine meadows, riverine vegetation, bamboo groves, and shrublands further contribute to the basin's varied vegetation.

Protected Areas in Ramganga Basin

The Ramganga Basin is home to several significant protected areas, showcasing the region's commitment to preserving its diverse wildlife and ecosystems. In Uttarakhand part of the basin, the iconic Corbett National Park, established in 1936, spans over 520.82 sq. km and is renowned for its tiger population and diverse flora and fauna. The National Park has 252 tigers within it with other prominent mammal species found in the park including Asian elephants, leopards, sloth bears, Indian pangolins, jackals, and various species of deer such as sambar, chital, and hog deer. The Sonanadi Wildlife Sanctuary, notified in 1987, covers an area of 301.18 square kilometers and acts as a crucial biodiversity protected area in this region. Apart from that, Binsar Wildlife Sanctuary, Nandhaur Wildlife Sanctuary, and Pawalgarh Conservation Reserve, established between 1988 and 2012, collectively contribute to the conservation of various wildlife species in the region. Uttarakhand part of basin also hosts botanical gardens and zoological parks, such as the Government Gardens at the G.B. Pant National Institute of Himalayan Ecology and Environment in Almora, the G.B. Pant Botanical Garden at G.B.P.U. A&T Pantnagar, and the Pt. G.B. Pant High Altitude Zoo in Nainital. The Pilibhit Tiger Reserve, Uttar Pradesh declared in 2014, is a sprawling expanse covering 730.25 square kilometers. This reserve is dedicated to safeguarding the Royal Bengal tiger and other wildlife species that call this region home. Together, these protected areas and conservation initiatives in the Ramganga Basin play a crucial role in preserving the natural heritage and biodiversity of this ecologically significant region.

Aquatic Species

The aquatic fauna of the Ramganga Basin in northern India is diverse and plays a crucial role in the ecosystem of the region. The basin's aquatic ecosystems include rivers, streams, lakes, and wetlands, each supporting a variety of aquatic species.

Phytoplankton and zooplankton

According to GRBMP report (2012), Phytoplankton in Ramganga Basin mainly belongs to four classes i.e. Bacillariophyceae (26 taxa), Chlorophyceae (9 taxa), Myxophyceae (11 taxa), and Xanthophyceae (1 taxa). They, collectively make 92% of the total phytoplankton population. In recent, GIZ-SGR/IEWP E-Flows sampling mission (Dec 2022) to the Ramganga Basin, recorded following five groups of phytoplankton - Cyanophyceae, Chlorophyceae, Desmidiaceae, Bacillariophyceae, and Euglenophyceae.

Although the zooplankton populations are relatively low in the Ramganga River, their population changes from season to season depending on water quality, algal composition, planktonic growth patterns etc. (Srivastava et.al 2019). According to GBRMP, 2012, notable zooplanktons in the Ramganga

River include Protozoa (Arcella, Centropyxis, Diffugia, Volvox, and Vorticella), Rotifera (Asplanchna, Brachionus, Philodina, Pompholix, Polyarthra, and Trichocera), and Crustacea (Bosmina, Ceriodaphnia, Cyclops, Daphnia, Helobdella, and Nauplius). During the joint field mission of CIFRI and GIZ in Ramganga Basin (Dec, 2022) the low zooplankton population was observed. However, most of the zooplankton was noticed near Bareilly site, which contributes 45.16% of total planktonic diversity.

Fishes

The upper Trans-Himalayan region, and the middle stretch of the Ramganga Basin near Moradabad and Bareilly, are the hotspots of the fish community. Some of the key species as reported by WWF-India's E-Flows Assessment report of Ramganga (2018) includes Golden Mahseer (Tor *putitora*), stone roller (Crossocheilus *latius*), boalla (Labeo *dyocheilus*), tor barb (tor *tor*), sucker fish (Garra *mullya*), minnows (Barilius gatensis), sucker head (Garra gotyla), Snow Trout (Schizothorax richardsonii), trout barb (Raiamas bola), dudhnea/khoksa (Barilius vagra/*Barilius barna*), balitora minnows (Psilorhynchus *balitora*), reticulate loach (Botia *lohachata*), mottled loach (Acanthocobitis *botia*). The Golden Mahseer and Snow Trout (Schizothorax *richardsonii*) are categorised as vulnerable species by the IUCN.

During the joint field mission of CIFRI and GIZ in Ramganga Basin a total of 9 orders, 15 families, 30 genera and 38 species of fishes were observed. Cyprinid was the dominant group (39.47%) followed by Bagridae (10.52%), Danionidae (7.89%) and mastacembelidae (7.89%).

Other Aquatic Species

The Ramganga Basin is also a habitat to a diverse range of aquatic species, including gharials, river dolphins, and turtles. Gharial Classified as critically endangered on the IUCN Red List and designated as a Schedule I species under India's Wildlife (Protection) Act of 1972. As of 2007, There were 129 Mugger crocodiles and 42 Gharials documented within the the Ramganga River (WWF, 2018). Turtle can be seen mostly in the midlle stretches. According to GRBMP (2012), six types of Turtle can be noticed in the Ramganga Basin including the Indian flapshell turtle (Lissemys *punctata*), Indian softshell turtle (Nilssonia *gangeticus*), brown roofed turtle (Pangshura *smithii*), Indian tent turtle (Pangshura *tentoria*), spotted pond turtle (Geoclemys *hamiltonii*), and Indian roofed turtle (Pangshura *tecta*). Other than this Dolphins can be noticed in the lower stretch and Otters can be noticed in the higher stretches of the Ramganga Basin.

Mammals and Avaian Species

The snow leopard, musk deer, Himalayan brown bear, Asiatic black bear, and pheasants like Western Tragopan, Himalayan Monal and cheer pheasant are found in the Great Himalaya region and can be seen in Ramganga Basin. Elephants and tigers abound in the Shivaliks and the terai regions. (Malik et.al, 2019) The Jim Corbett Park including Ramganga reservoir is home to over 600 species of birds, including the crested serpent eagle, blossom-headed parakeet, and the critically endangered Bengal florican.

Flora

The Ramganga Basin showcases diverse flora across its landscapes, including tropical moist deciduous forests in the lowlands with teak, sal, and semal trees. At mid-elevations, subtropical broadleaf forests feature oak and rhododendron species. Higher altitudes reveal temperate forests, home to coniferous pines and deodars, alongside broadleaf varieties like oak and maple. Alpine meadows and scrublands thrive at even greater elevations. The river and its tributaries support riverine and wetland vegetation, while bamboo groves dot the region. The basin may also house rare and endemic plant species. Additionally, the availability of medicinal plants adds to its ecological significance, emphasizing the importance of conservation to preserve this rich floral diversity and its potential for traditional medicine practices.

2.7 Demography

The Ramganga River Basin is spread to 20 districts (7 in UK and 13 in UP) with less or more geographic areas covered in Ramganga Basin. Below Table 9 presents an overview of the population and geographical areas of these districts which belong to Ramganga Basin:

Table 9: Population and Area of Districts in Ramganga Basin

State	District	Total population	Total area (sq. km)	Area Under Ramganga Basin (sq.km)	% of Area Coming in Ramganga Basin	Total population live in Ramganga Basin	Total urban population live in Ramganga Basin	Total Rural Population
UK	Almora	6,22,506	3,139	2,506	80	4,97,071	49,707	4,47,364
UK	Bageshwar	2,59,898	2,246	9	0	1,000	35	965
UK	Chamoli	3,91,605	8,030	326	4	15,887	2,415	13,472
UK	Champawat	2,59,648	1,766	60	3	8,786	1,300	7,486
UK	Nainital	9,54,605	4,251	3,753	88	8,42,813	3,27,854	5,14,959
UK	Garhwal	6,87,271	5,230	1,915	37	2,51,691	41,277	2,10,413
UK	Udham Singh Nagar	16,48,902	2,542	2,467	97	16,00,331	5,69,718	10,30,613
UP	Amroha	18,40,221	2,249	270	12	2,20,778	1,40,635	80,142
UP	Bareilly	44,48,359	4,120	3,987	97	43,04,852	27,86,961	15,17,891
UP	Bijnor	36,82,713	4,049	2,605	64	23,69,312	6,65,777	17,03,535
UP	Budaun	36,81,896	4,234	851	20	7,40,090	3,87,363	3,52,727
UP	Farrukhabad	18,85,204	2,181	147	7	1,26,962	98,929	28,033
UP	Hardoi	40,92,845	5,989	1,680	28	11,48,192	1,51,561	9,96,631
UP	Kannauj	16,56,616	2,093	38	2	30,355	25,210	5,145
UP	Kheri	40,21,243	12,805	89	1	28,078	3,229	24,849
UP	Moradabad	47,72,006	3,741	2,186	58	27,87,920	18,68,464	9,19,456
UP	Pilibhit	20,31,007	3,449	2,318	67	13,65,115	11,28,950	2,36,165
UP	Rampur	23,35,819	2,367	2,291	97	22,61,076	0	22,61,076
UP	Sambhal	21,92,933	2,453	288	12	2,57,644	0	2,57,644
UP	Shahjahanpur	30,06,538	4,575	3,052	67	20,05,923	16,09,553	3,96,370
	Total	**4,44,71,835**	**81509.51**	**30839.69**	**42**	**20863876**	**9858939**	**11004937**

Source: Indian Census, 2011

As noticed from the above Table 9, a total of 53% of population lives in rural areas while 47% is based in Urban areas (against the 22% urbanization rate of UP). There are five districts with less than 5% of their areas falling in Ramganga Basin (Bageshwar and Kheri having only 0.38 and 0.7 %). Districts like Almora, Nainital, Rampur, Moradabad, Bijnor, Shajahanpur, Bareilly, Pilibhit and Udham Singh Nagar have more than 50% of their area in Ramganga Basin (both Bareilly and Udham Singh Nagar with 97% of their area). The Ramganga Basin has a total of 134 urban agglomerates (towns) with most of the district headquarters in UP having population of more than 100,000 (AMRUT I towns). As per the Census (2011), only 39% of households in these 134 towns were connected with safe and treated water supply while only a mere 12.4% households had sewer connections. The situation is confidently expected to have improved with the launch and progress of a series of missions i.e. AMRUT-I and II, SBM -Urban and Rural, NMCG, Jal Jivan Mission and other state level schemes.

Main economic activities in the Ramganga Basin are agriculture and industries (as discussed in other sections). Interestingly, the basin has a total of 21,586,370 animals as per the District Agriculture Contingency Plans prepared by respective district administration. Because of this, many of the towns in Basin also exhibit rural nature in some of the wards.

As true for any river in India, Ramganga River and its tributaries enjoy great religious and socio-cultural significance.

2.8 Solid Waste Management

With the advent of Swachh Bharat Mission – Urban, a lot of focus has been given on scientific Municipal Waste Management in Ramganga Basin. As per the updated information on SBM-U portal, the information on municipal waste management is available for 100 towns out of total 134 towns in Ramganga Basin. 90% of the cumulative 1858 wards see 100% door to door collection. Thus, the collected total municipal waste from 100 towns in basin is estimated to be 1975 tons per day. 76% of the collected municipal waste (1516 tons per day) is processed in the basin in a chain of 47 Construction and Demoilition Waste recycling units, 99 Material Recovery Facilities, 98 waste to compost units and 5 waste to energy units. These 100 towns have a total of 14 landfills and 68 dumping sites. Further no dumpsite/landfill has so far conducted any leachate studies to assess any potential groundwater contamination through unscientific dumping. Further in cities like Haldwani, Rudrapur and Moradabad, the waste processing sites are in close proximity of riverbeds, thus potential risk to contaminate surface and groundwater bodies.

Solid and hazard waste generated from major industries in the basin is managed as per the conditions laid in respective Consent to Operate given by Pollution Control Board. Though the PCBs strictly monitor the industrial waste management in registered industries, there exist a large number of household industries in basin (mainly city of Moradabad) whose waste disposal practices are totally unknown. In addition, the city of Moradabad also has a major challenge of legacy wastes - the accurate details on the same could not be traced back.

2.9 Municipal and Industrial Wastewater

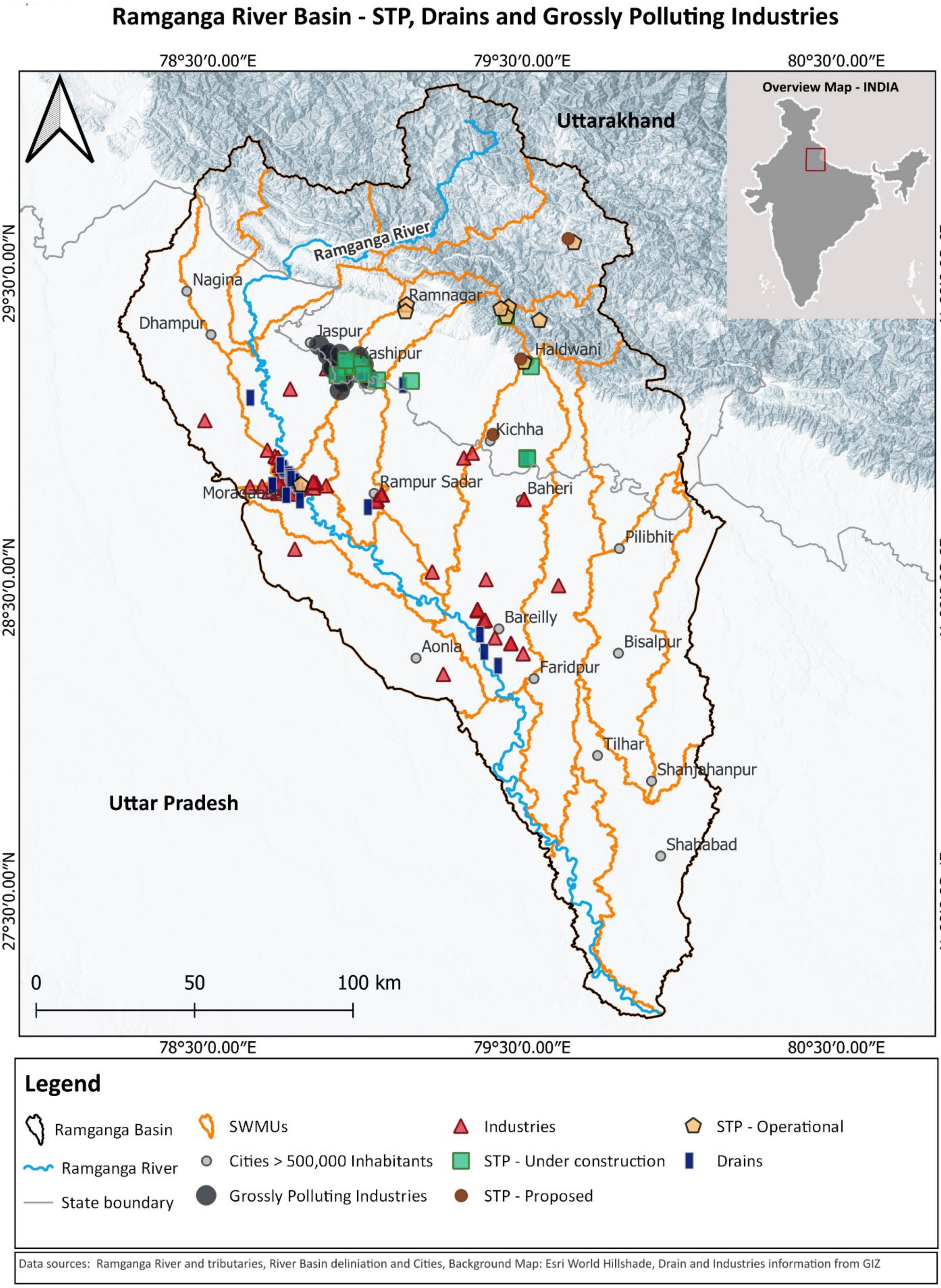
According to UPPCB, around 62.4 MLD treated industrial effluent is emitted into the Ramganga River and its tributaries from UP part of the basin. No detailed statistics are available for domestic sewage. But with a population of approx. 24 million in 2022, and an average per capita emittance of 121 liters per day (Sengupta, 2022), approx. 2,904 MLD domestic wastewater within the whole Ramganga Basin is expected to directly or indirectly emitted into Ramganga and its tributaries. This includes a total emission of 260 tons of BOD_5 per day, with an average daily emittance of 15g per person (Sengupta, 2022). As the 15g from Sengupta (2022) is provided for the rural population, the number might underestimate the total BOD_5 emission within Ramganga Basin given that 47% is urban population. As per the 2011 Census, 81.4% of households have toilet facilities within their premises. This includes 70.9% of households having water closets; 8.8% of households having pit latrines; 1.7% of households having other toilets (connected to open drains, night soil removed by humans, etc., which are unsafe). Out of the

70.9% of households, 12.7% of households have water closets connected to the sewer system and remaining with water closets connected to a septic tank. With the launch of Swachh Bharat Mission-Rural (SBM-R), remaining 18.6% of the households are expected to have had access to toilet facilities [3].

As per the Ministry of Housing and Urban Affairs (MoHUA), 135 litres per capita per day (lpcd) has been suggested as the benchmark for urban water supply (Ministry of Jal Shakti: 02 MAR 2020 5:40 PM by PIB Delhi). In rural areas, the government standard to supply 55 litres per capita per day does not take into account that a large number of rural households' own livestock and need water for their drinking and washing needs. Moreover, in the absence of household-level piped water supply and metering, it is difficult to monitor the quantity of water received by each household. This, in turn, makes it challenging to estimate the per capita needs of rural households. Nevertheless, based on Urban-Rural Population percentage and MoHUA's standards, a preliminary estimate suggests emittance of 1991 MLD sewage in Ramganga Basin.

Domestic human waste includes human excreta, urine and the associated sludge (collectively known as black water), and wastewater generated through bathing and kitchen (collectively known as grey water). In 1950, the average daily output of human waste (i.e. excrement and urine) was estimated to be 3.2 million tonnes; in the year 2000, the estimated daily output increased to 8.5 million tonnes (Sengupta, 2022). Map 7 shows locations of major industries, drains and STPs in Ramganga Basin.

[3] Source: http://cpheeo.gov.in/upload/uploadfiles/files/engineering_chapter1.pdf, opened October 28th, 2022



Map 7: Locations of Industries, STP and major Drains in Ramganga River Basin

2.9.1 Industrial Hotspots in Ramganga Catchment's of Uttar Pradesh

Approximately 24 MLD treated industrial effluent from 121 water-polluting industries is discharged into Ramganga in UP State. The industries are Sugar, Pulp & Paper, Distillery, Textile, Slaughterhouse and Electroplating. These industries have effluent treatment plants and discharge their treated effluent through major drains, where the treated industrial effluent is mixed with the sewage.

Out of these 121 industries, 105 are in Moradabad and Rampur while 16 are situated in the Bareilly area. 4 out of the 105 industries of Moradabad and Rampur (2 distilleries, 1 paper industry and 1 sulfuric acid plant) do not discharge wastewater into any surface water. The rest of the 101 industries of Moradabad and Rampur are discharging treated effluent in drains that reach to the Ramganga River. Sugar and Paper Industries mostly recycle their entire treated effluent or supply it for irrigation use.

Out of 16 industries in the basin area of Bareilly, 2 distilleries do not discharge wastewater into any surface water. The other 14 industries of Bareilly are discharging treated effluent in major and minor drains. Major drains are summarized in Table 10 and

Table 11 while an overview of water-polluting industries located in the Ramganga River Basin of UP is given in Figure 11.

Table 10: Summary of major drains in UP carrying mixed industrial and municipal wastewaters

Drain	Type of Industry discharging into drain							Total Effluent Discharge (MLD)
	Sugar	Pulp & Paper Distillery	Distill-ery	Textile	Slaughterhouse	others	Total	Total
Moradabad								
Karula						02	2	0.01
Katghar Railway Station	0	0	0	0	0	04	4	0.017
Prabhat Nagar	0	0	0	0	0	10	10	0.022
Vivekanand Left						3	3	0.012
Vivekanand Right						4	4	0.024
Chandausi Road drain Left-side						6	6	0.034
Chandausi Road drain Right-side						1	1	0.003
Delhi Road drain Left-side						38	38	0.280
Delhi Road Drain Right-side						2	2	0.010
Rampur			01	-	01	2	04	1.012
Bareilly								
Nakatiya Drain	-	01	-	-	02	-	3	1.6
Deveraniya Drain	-	-	01	-	-	02	3	0.75
Total							**80**	**3.762**

Source: Action Plan for Restoration of Polluted Stretch of River Ramganga from Moradabad to Kannauj, UPPCB, Year 2019-20

Table 11: Summary of minor drains/ Direct discharge into river in UP

District	Type of Industry							Total Effluent Discharge (MLD)
	Sugar	Pulp & Paper Distillery	Distillery	Textile	Slaughter-house	others	Total	Total
Moradabad	4	1	1	1	1	18	26	3.725
Rampur	3	1	0	0	0	1	5	3.428
Bareilly	5	0	1	0	0	4	10	13.052
Total	12	2	2	1	1	23	41	20.205

Source: Action Plan for Restoration of Polluted Stretch of River Ramganga from Moradabad To Kannauj, UPPCB, Year 2019-20

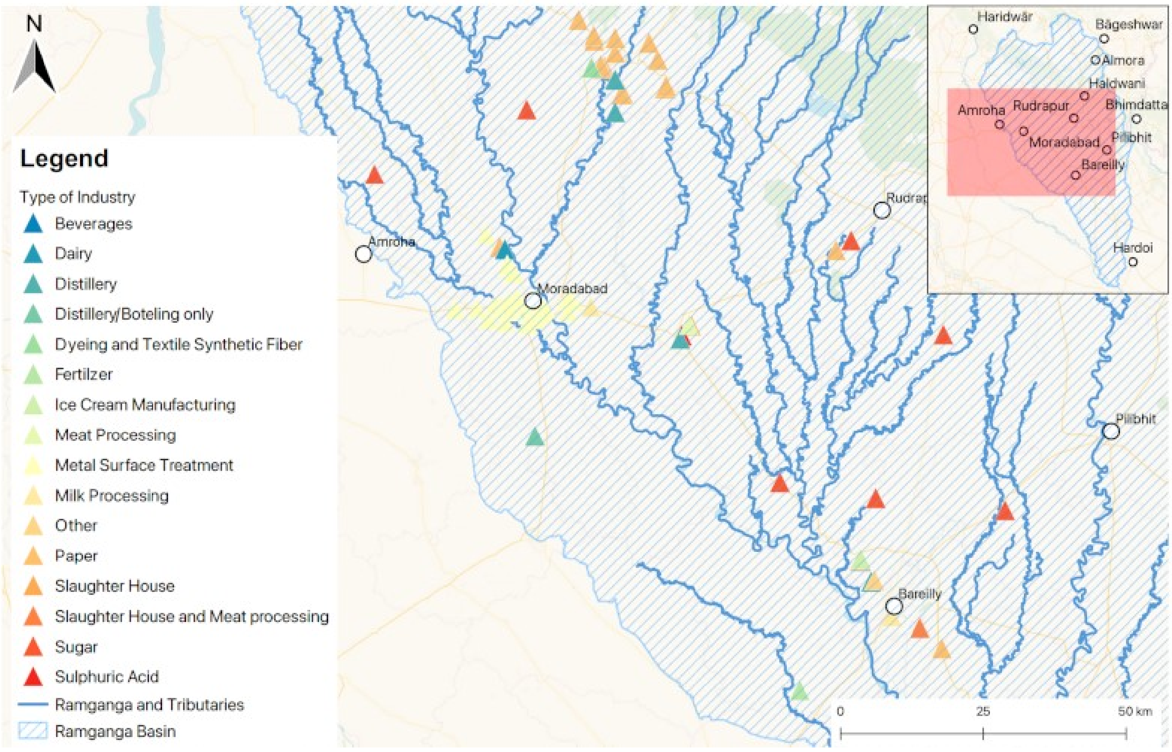


Figure 11: Locations of Major Industries in the Ramganga Basin

2.9.2 Industrial Hotspots in Ramganga Catchment's of Uttarakhand

River Dhela and Kosi are the main tributaries of River Ramganga originating in the headwater area of the Uttarakhand State. The river Bhela is a tributary of river Kosi. All three tributaries of Ramganga receive industrial wastewater. The water quality of the rivers Dhela and Bhela indicates that they are highly affected by industrial pollution as compared to Kosi River.

River Dhela originates from the Ramnagar forest area and passes along the agriculture fields of the Tarai region. Tumaria dam is built on the river Dhela upstream of Kashipur for the diversion of river water for irrigation purposes, resulting most of the time in non-natural discharge conditions in the river. River Dhela also receives wastewater from nearby industrial units which are predominantly pulp and paper industries, located in the Kashipur Industrial area of Udham Singh Nagar District. There are four major drains that contribute industrial wastewater to river Dhela, namely Pachhana Nala, Dandi Nala, Choti Dhela and Lapakna Nala. River Dhela joins river Ramganga upstream of Moradabad in Uttar Pradesh.

As per the data received from the Kashipur Regional office of Uttarakhand Pollution Control Board, there are 12 Grossly Polluting industries (GPIs), mostly Pulp & Paper industries, located along the Dhela riverbanks, which discharge almost 28.6 MLD treated effluent into the river Dhela. All these industrial units have functional ETPs and only treated wastewater is discharged. Most of the time during the dry season the wastewater form the flow in the river. A list of Grossly Polluting industries (GPIs) situated in the Dhela river catchment is summarized in Table 12

Table 12: List of GPIs located in catchment of river Dhela, Kashipur, Uttarakhand

S N	Industry Name	Wastewater Generation, MLD
1	Katyayini Paper Mills Pvt. Ltd.	2.258
2	Naini Papers Limited	4.920
3	Naini Tissues Ltd.	5.020
4	Prolific Papers Pvt. Ltd.	1.005
5	Sidarth Papers Pvt. Ltd (Unit 2) (Formerly Sidarth Papers Ltd)	3.750
6	Siddheshwari Paper Udyog Pvt. Ltd (Formerly Siddheshwari Paper Udyog Ltd.)	2.919
7	Bahl Paper Mills Limited	3.458
8	Sidharth Papers Pvt. Ltd. (Formerly Sidharth Papers Ltd.)	3.800
9	Sahota Papers Limited	2.235
10	Dev rishi papers Pvt. Ltd. (former name Munnaji Paper mill Pvt. Ltd)	0.810
11	M\s Fibremarx Papers Pvt Limited	1.755
12	Vishwanath Paper & Boards Ltd	1.753
	Total	**33.68**

Source: Uttarakhand Pollution Control Board

River Bhela is a small spring-fed River, and receives spill over water from Tumaria dam, agriculture run off and industrial wastewater from industries situated in Ramanagar Road and Bazpur Road of Kashipur industrial area. After flowing through Kashipur Town, river Bhela finally joins the river Kosi near Khabriya Bhur Mustakham village, district Rampur, Uttar Pradesh. Nakti Nala, Pathri Nala and IGL drains are three major drains which contribute industrial wastewater into river Bhela.

There are mainly 6 Grossly Polluting Industries (GPIs) located in Kashipur industrial area in Bhela region. Out of the 6 GPIs, two GPIs are maintaining ZLD (Zero liquid discharge) while the rest of the 4 industries are discharging about 2.57 MLD wastewater directly or indirectly into river Bhela. Apart from these 6 GPIs, there are 40 other water-polluting industries located in the catchment and generating about 3.379 MLD wastewater. Individual industries have installed their own wastewater treatment system (ETP) of appropriate capacity. Details of Grossly Polluting Industries (GPIs) are mentioned in Table 13

Table 13: List of GPIs located in the catchment of river Bhela, Kashipur

S N	Industry Name	Wastewater Generation, MLD	Status of Treatment Plant	Final mode of disposal
1	Banwari Paper Mills Ltd. Ramnagar Road	0.915	Operational captive ETP	Nakti Nala
2	PMV Maltings Pvt. Ltd, Nand Nagar Industrial Estate, Mahuakheragan	0.315	Operational captive ETP	Drain leading to Bhela River
3	Kashi Vishwanath Textile Mill Pvt. Ltd., Ramnagar Road	0.500	Captive ZLD with RO and MEE	ZLD through RO and MEE.
4	Multiwal Duplex Pvt Ltd., Vill-Gangapur Gosain, Kundeshwari Road	0.800	Operational captive ETP	Pathri Nala
5	India Glycol Ltd., (MEG Plant) Bazpur Road, Kashipur	0.540	Operational captive ETP	Drain leading to Bhela River
6	India Glycol Ltd., (Ethanol Plant), Bazpur Road	1.920	Captive ZLD with RO and MEE	ZLD through MEE
A	**Total Wastewater Generation from GPIs**	**2.570**		
B	Others 40 water polluting industries	3.379	Operational captive ETP	-

Source: Uttarakhand Pollution Control Board

The Kosi originates in the middle Himalayas in the Kumaon region of Uttarakhand. Kosi river is one of the few major Himalayan rivers that does not have a glacial source. River Kosi receives approximately 3.879 MLD of treated industrial wastewater from two Pulp & Paper industries located in the stretch between Sultanpur to Patti kalan (Cheema Paper Ltd. And Multiwal Pulp & Paper Mills P Ltd).

2.9.3 Sewage & Urban Pollution Hotspots in Ramganga Basin of Uttar Pradesh (UP)

7 major cities, namely Moradabad, Rampur, Bareilly, Shahjahanpur, Farrukhabad, Hardoi and Kannauj, are located in the Ramganga Basin under UP. Out of these 7 cities, the 3 cities Moradabad, Rampur, and Bareilly have treated and untreated sewage/effluent flows into river Ramganga. In the remaining 4 cities (Shahjahanpur, Farrukhabad, Hardoi, Kannauj), no information is available on drains and their nature.

As per the study conducted by UPPCB and Jal Nigam, Uttar Pradesh, the total sewage discharged into the Ramganga river through 28 major drains is approximately 421.31 MLD. In the polluted stretch of river Ramganga, total sewage and industrial effluent discharge are approximately 445 MLD. The total domestic and industrial discharge flows into river Ramganga through 28 drains as well as through some minor drains directly discharging into the river. 4 out of 28 drains carry an aggregated flow of 8.86 MLD to river Gagan, which flows into the Ramganga downstream of city of Moradabad.

The amount of industrial effluent is based on the summed-up discharge quantity from the industrial units. But actual industrial effluent may be higher than estimated, because of additional discharge from unregistered industries.

2.9.4 Sewage & Urban Pollution Hotspots in Ramganga Basin of Uttarakhand State (UK)

The river Dhela receives wastewater discharge from six major drains namely – Laxmipur minor, Kailash Mandap, Gabiya Nala, Ice Factory Nala, Beljudi Nala and Gularia Nala all from Kashipur town. Further, two municipal drains namely - Jaspur Khurd Nala and Hempur Ismail Nala, discharge sewage into river Bhela.

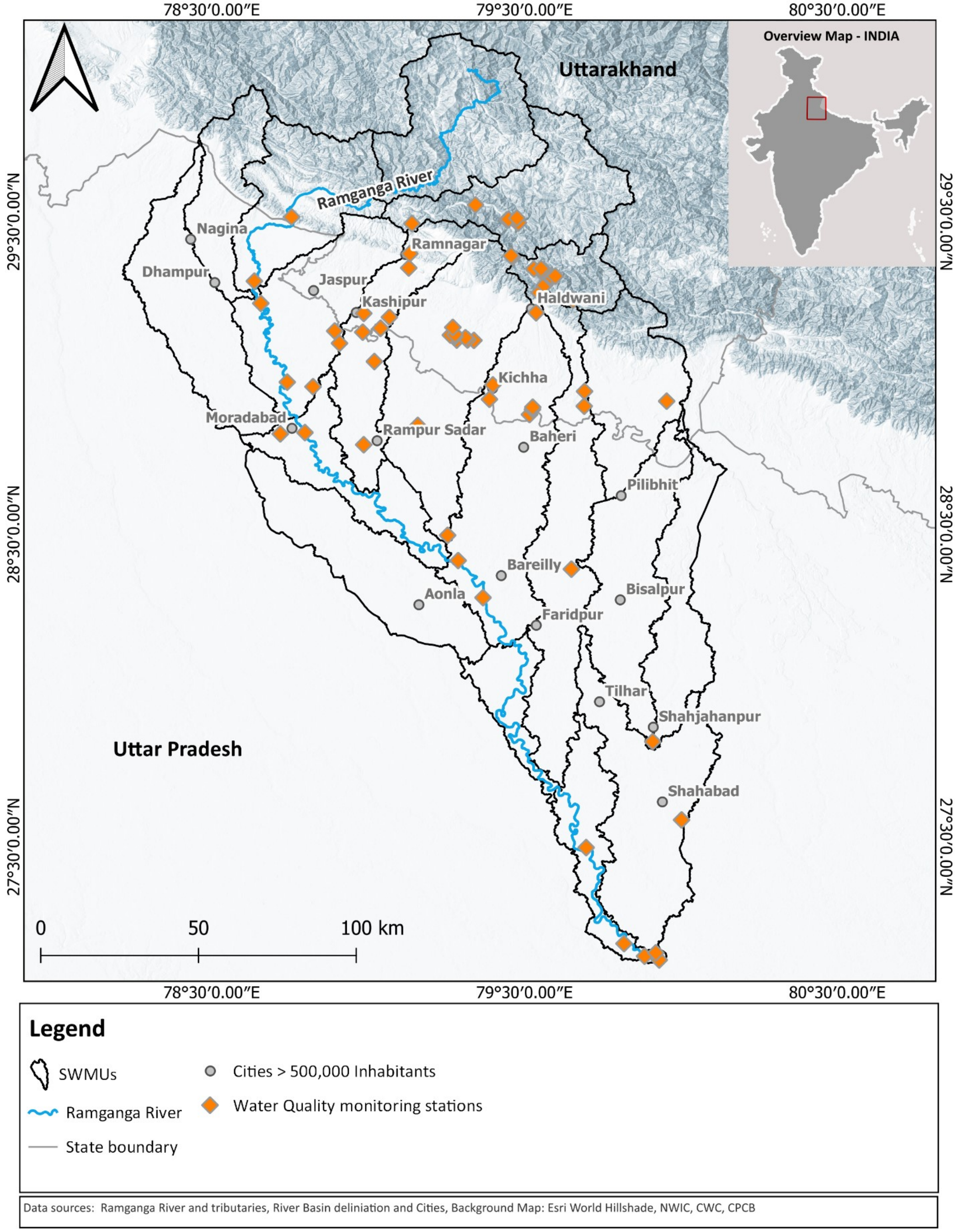
3 Monitoring Network and Programmes

3.1 Surface Water Quality Monitoring

3.1.1 Monitoring Networks and Programmes

There are a total of 76 Water Quality Monitoring Stations across the Ramganga Basin, among which 25 are in located in Uttar Pradesh and 51 are in Uttarakhand. The Uttarakhand Pollution Control Board (UPPCB) has the highest with 39 monitoring stations, followed by CPCB with 23, and CWC with 14 no of stations. The data shows that among the 25 Water Quality Monitoring Stations in Uttar Pradesh, CWC and CPCB have 13 and 12 stations, respectively. In addition to that, there are 25 identified priority drains of the Ramganga River monitored by CPCB in Ramganga Basin. Map 8 shows the list of surface water quality monitoring stations in Ramganga Basin.

Ramganga River Basin - Water Quality Monitoring Stations



Map 8: Surface water monitoring stations in Ramganga River Basin

3.1.2 Surface Water Quality Assessment and Situation

In the context of the aforementioned 76 monitoring stations, a total of 80,897 water quality assessment data points spanning from 1973 to 2022 were accessed through NWIC. Notably, a significant portion of this data, specifically 32,143 entries, was collected between 2012 and 2022. This indicates substantial efforts dedicated to enhancing the monitoring stations during the past decade.

While the Water Quality Assessment encompassed a considerable number of parameters, it is noteworthy that the majority of these parameters primarily pertain to the physical and chemical properties (pH, Temp, DS, Turbidity, DO, BOD, COD) of the water. Information regarding biological parameters is currently limited and warrants further improvement.

Total discharge from all 25 drains amounts to 497.37MLD with a BOD load of 32TPD.[4]The Ramganga River upstream at Kalagarh has a BOD level of 1.9mg/L which changes before the confluence with River Ganga in Kannauj to 5mg/L with a maximum detectable Faecal Coliform level of 15,000/100 ml.[5]

It is noted through various studies and observations that the Ramganga river stretches downstream of Moradabad to Bareilly contains more organic and sulphate content as compared to the river stretch stretches upstream.[6] Table 14Error! Reference source not found. presents the surface water quality data from a quality monitoring study of Ramganga River and its tributaries (Khan, Gani, & Chakrapani, 2015). The study concludes that Nitrates, BOD_5 and COD concentrations in Ramganga and its tributaries are in the same range making both unfit under Class A and B of CPCB's classification of water bodies. The most polluted river stretches are between Moradabad and Farrukhabad, especially in terms of organic load.

Table 14: Average water quality parameters of Ramganga River and its tributaries.

Parameters	Tributaries	Ramganga River
pH	7.7±0.2	7.3±0.45
EC (µS/cm)	437±218	347±163.4
TDS (mg/L)	14.7±4.7	22.2±10.5
Turbidity (NTU)	25.4±3.4	43±3.6
COD	27±12.5	29.4±11.3
BOD5	13.7±6.4	15±6.7
NO_3^- (mg/L)	4.7±0.4	4.7±0.5
Phosphorus (mg/L)	0.29±0.04	0.33±0.2
HCO_3^{-1} (mg/L)	129.6±30.5	116.8±19.5
CL^- (mg/L)	16.6±2.1	8.6±0.9
F^- (mg/L)	0.22±0.1	0.13±0.1
SO_4^{2-} (mg/L)	25.1±2.2	14.3±5.6
Mg^{2+} (mg/L)	11.5±5.6	12.1±7.2
Ca^{2+} (mg/L)	38.4±21.2	47.4±26.2

[4] CPCB, Annual Report 2020-2021
[5] CPCB, Water Quality Data of Rivers under National Water Quality Monitoring Programme (NWMP), 2020
[6] Khan et al, A case study of Ramganga River, Ganga Basin, India, 2015

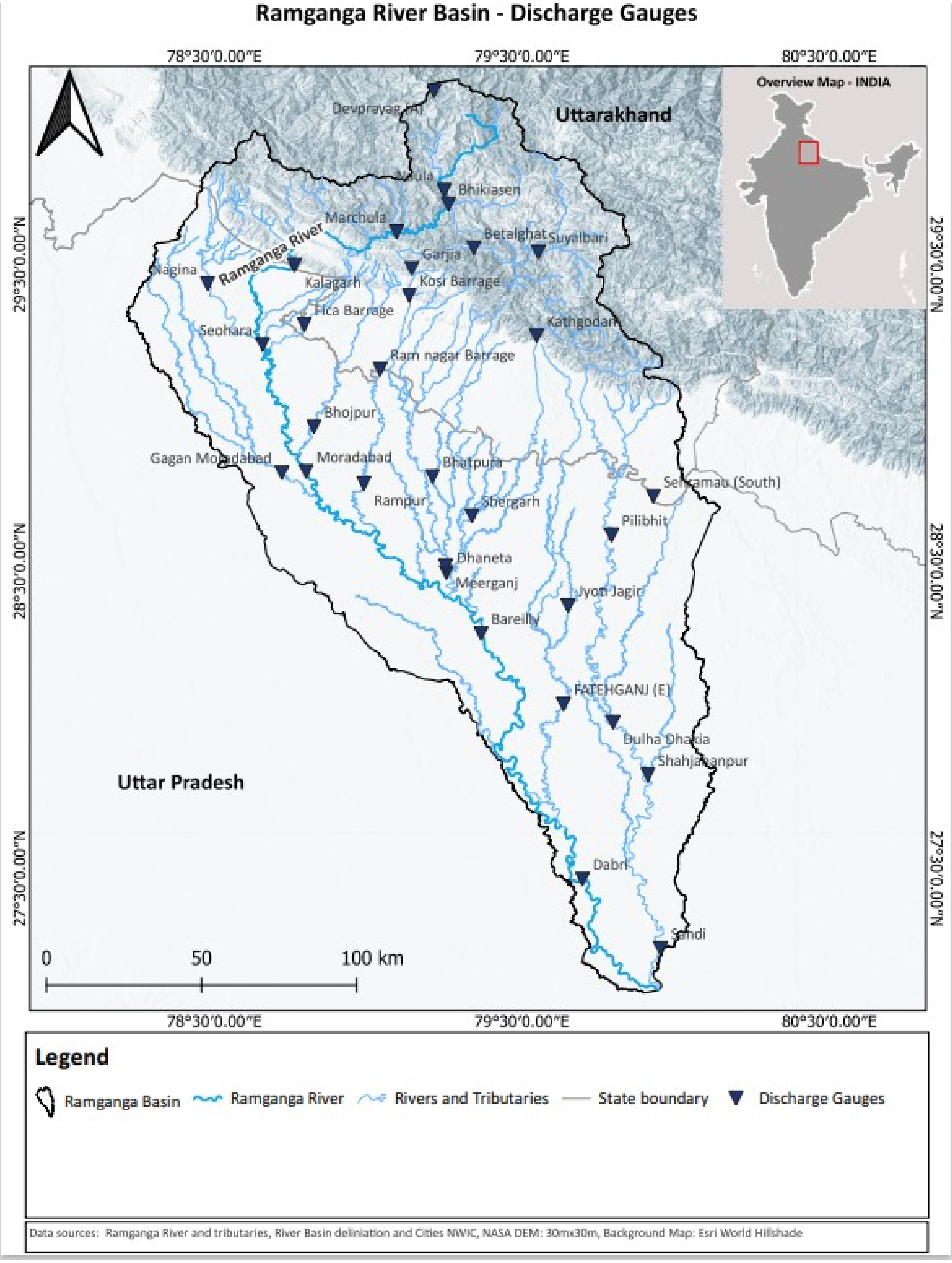
Na^+ (mg/L)	18.5±11.5	23.2±14.1
K^+ (mg/L)	5.6±3.3	5.7±3.2

3.2 Surface Water Quantity Monitoring

3.2.1 Monitoring Networks and Programmes

Hydrological data of surface water is collected through 36 water level gauges maintained by CWC and state Water Resource / Irrigation Department. Since most of the gauges were installed recently, Map 9 relevant datasets for the Ramganga River are only available at 4 gauges.

Ramganga and its tributaries are monitored with a dense network of gauging stations, which enables the monitoring of changes in hydrological regime, both artificial and natural changes.



Map 9: Overview map of water level and discharge gauges in the Ramganga River Basin

3.2.2 Surface Water Quantity Assessment and Situation

The details on surface water quantity assessment are well described in Chapter 2.2

3.3 Challenges in Surface Water Quality Monitoring

Being a classified river, the discharge data of Ramganga Basin is strictly confidential and not accessible through open public domain. There are three agencies (CWC and UP/UK state Water Resources and Irrigation departments) who records the surface water quantity related data. There seems a lack of coordination among all three authorities which results in a not so well-planned network of monitoring stations. As it has been noticed there are certain stretches where multiple stations are available while some stretches of Ramganga and or its tributaries do not have any monitoring stations. There is ample scope to strengthen the coordination and accordingly the network of monitoring stations.

Regarding Surface water quality, a huge number of monitoring stations are set up recently and hence time series information of how water quality has changed over the time is not available. Further, installations of real time monitoring systems will further enrich the timely access to the water quality data. There is also a need to increase the parameters to be monitored in order to have an adequate understanding of the water quality status. This also becomes important in view of the emerging contaminants. Finally, the coordinates of these stations should also be recorded and maintained for geo-spatial analysis.

3.4 Ground Water Quality Monitoring

3.4.1 Monitoring Networks and Programmes

The ground water quality monitoring is meticulously carried out by the block level monitoring stations/ observation wells of CGWB and UP State Groundwater department. Most groundwater monitoring is limited to shallow aquifer. In high altitude gradient locations in Uttarakhand, the groundwater quality is proxied by the sampling and analysis of rainwater/springs.

There are a total of 107 groundwater quality monitoring points in Ramganga Basin – out of which 56 points (11 of CPCB and 41 of CGWB) are in the Uttarakhand part while UP has a total of 51 stations (1 by CPCB and remaining 50 by CGWB). The collected samples are analyzed in the labs of CPCB and CGWB respectively. The major parameters analyzed in groundwater are Electrical Conductivity (EC), Nitrate, pH and presence of selected heavy metals in pre-selected sites. Data series for a total of 42 parameters from 200-2022 was accessed through NWIC.

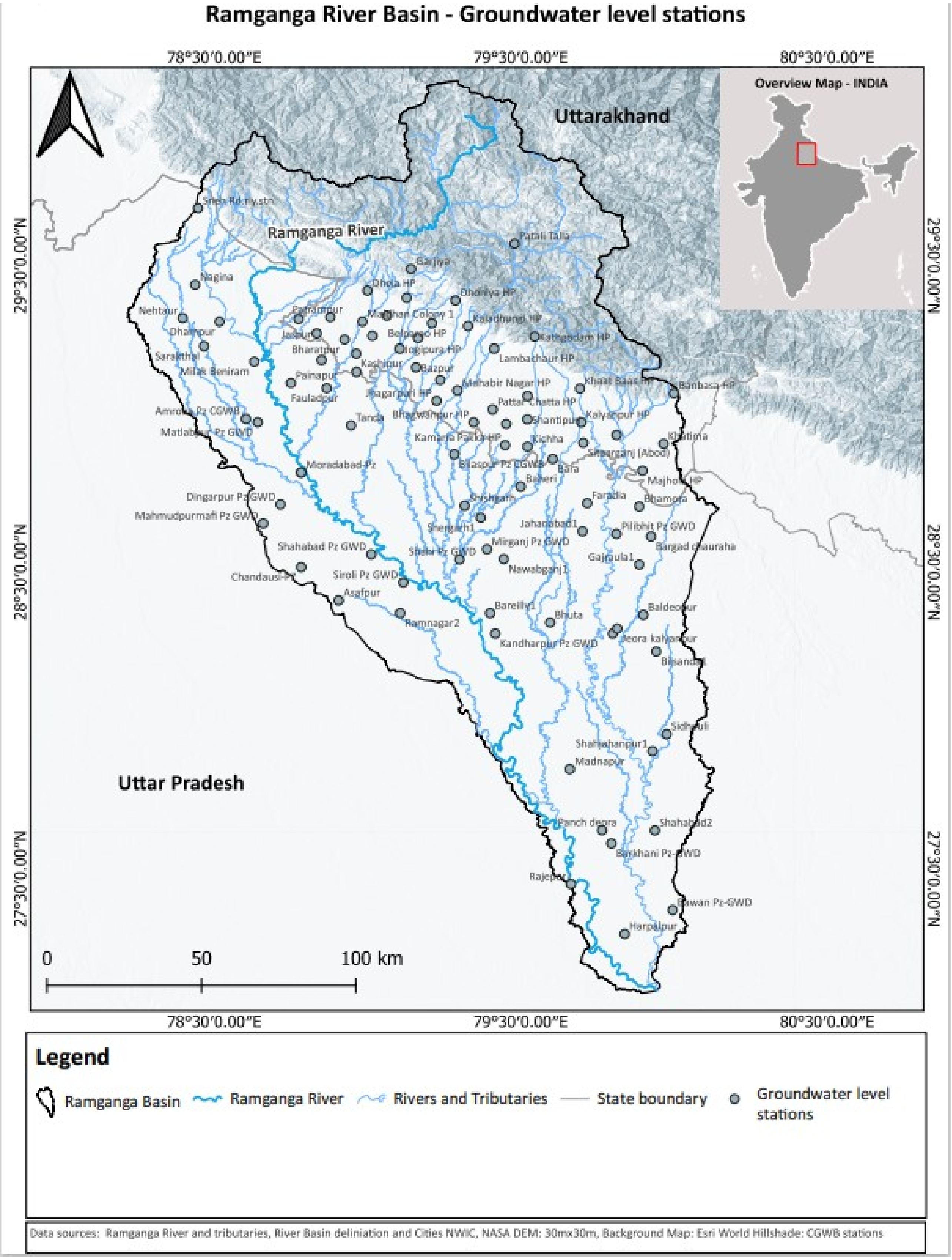
3.4.2 Ground Water Quality Assessment and Situation

There exist 390 observations for last 20 years from 52 stations of CGWB for entire Ramganga Basin. Further, in case of nitrate, only 326 observations are available for last 20 years from 48 stations of CGWB. A quick analysis of these observations reveals that both EC and Nitrate remain well below the permissible standards as set by the authorities (2250 mS/cm for EC and 45 mg/L for nitrate) at most of the stations. The details are presented in chapter on risk assessment.

3.5 Ground Water Quantity Monitoring

3.5.1 Monitoring Networks and Programmes

There are sufficient ground water level monitoring stations within the Ramganga River Basin. These stations are operated by the CGWB. Groundwater levels are surveyed within 947 ground water observation stations – maintained by CGWB and UP State Groundwater Department. Map 10 marks the location of 63 stations providing data with time series longer than 15 years. less than 20 stations provide a time series of 25 years. There are only 17 stations where there is an observation available throughout the length of the time series. On average there are 03 observations available per year.



Map 10:Overview map of Ground Water Level Stations in the Ramganga Basin with time series data

3.5.2 Ground Water Quantity Assessment and Situation

The depth to ground water table ranges from 10 — 70 m. There are 07 stations (i.e., Dhela, Dhoniya, Belaparo, Kaladungi, Kathgodam, Lambachaur, Khaat Baas) within the available time series that show extreme values of depth to ground water table (see Figure 12). It can be assumed that these stations face over abstraction of groundwater resources and hence as a result the groundwater is depleting at these specific locations. A detailed Assessment of the groundwater status in the Ramganga Basin is available from CGWB from 2020 (Map 11) indicating that most of Ramganga Basin classified as safe followed by semi-critical. Only 3 blocks are classified as critical. The groundwater development state is not assessed in the upper part of the Basin (Himalayan region).

Data from the 2020 resource estimation reveals that in the Ramganga River Basin, there are 39 assessment blocks in Uttarakhand and 90 in Uttar Pradesh. Due to its hilly terrain, the majority of Uttarakhand's blocks (30 out of 39) are not assessed. Among the remaining blocks, 7 fall into the safe category, while 2 are classified as semi-critical. These two semi-critical blocks are situated in the southeastern part of Nainital and Western Udham Singh Nagar District.

In contrast, the assessment in Uttar Pradesh is more extensive, as groundwater estimation is relatively easier in the vast alluvial plain. The data indicates that 53 out of 90 blocks (59%) are considered safe, with 26 blocks (28%) falling into the semi-critical category, 6 blocks (7%) in the critical category, and 5 blocks (6%) categorized as over-exploited. Geospatial analysis reveals that, all critical and over-exploited blocks are located in the western and northwestern regions of Uttar Pradesh. Districts such as Moradabad, western Rampur, Budaun, Sambhal, and Bijnor indicate excessive groundwater extraction and a limited scope for aquifer recharge.

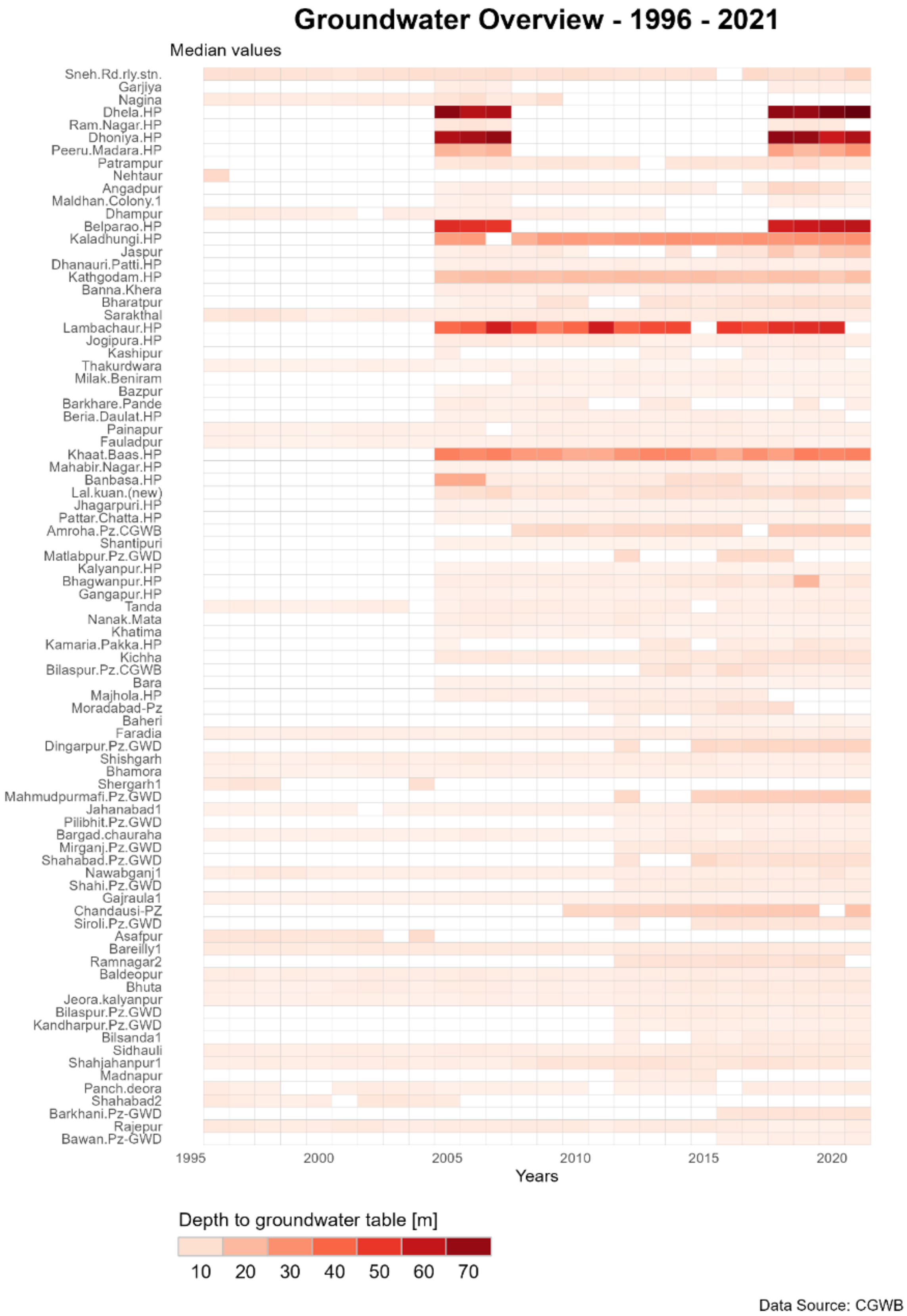
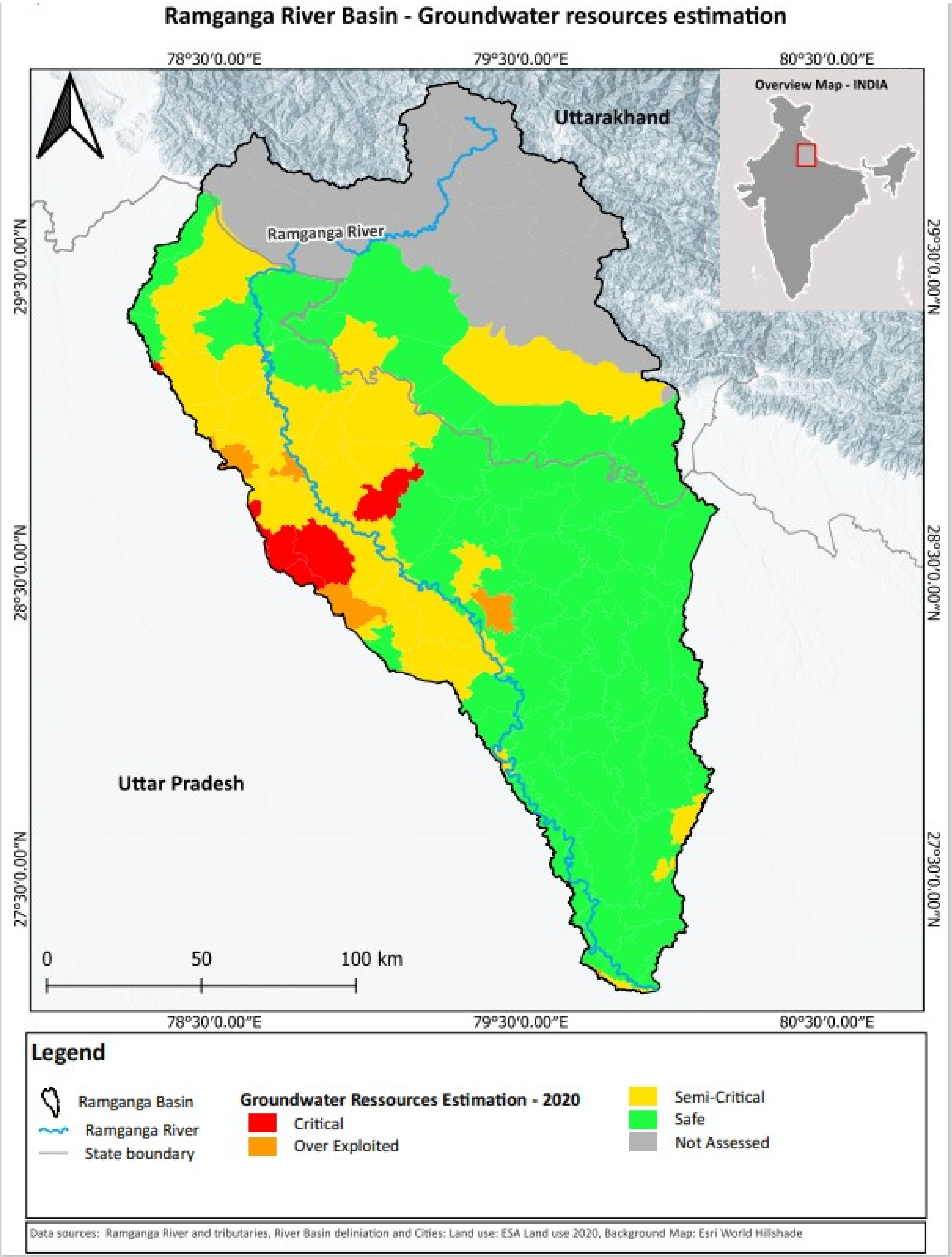


Figure 12: Ground Water Level's yearly median values (1996 -2021) in the Ramganga River Basin



Map 11: Status of Ground Water Resources in the Ramganga Basin (CGWB, 2020)

3.6 Challenges in Ground Water Monitoring

With the launch of NAQUIM, the groundwater monitoring is expected to be strengthened across the Ramganga Basin. The major challenges faced is non-availability of groundwater stage of development information in the hilly areas in Uttarakhand. The same is also true for groundwater quality but which is proxied by the sampling and analysis of rainwater and spring waters. The CGWB has actively been working on updating its Water Resource Estimation Methodology by incorporating the latest knowledge. Deep aquifers are not monitored for their water quality which are major source of domestic water supply in the Ramganga Basin.

4 Key Water Management Issues (KWMIs) in the Ramganga Basin: Drivers, Pressures, Vision and Management Objectives

4.1 Overall Ramganga Basin Vision

A critical step in the RBM Planning process is to set aim and management objectives to be achieved during the implementation of Cyclic RBM Plan. Such agreed aims guide all involved stakeholders towards clearly defined goals.

Overall Ramganga River Basin Aims are the basis of all assessments during the RBM Planning as well as the actions/ PoM. These aims help in aligning the actions and the Programme of Measures (PoM) towards agreed direction for sustainable water resources management in the Ramganga River Basin. For the Ramganga Basin, this will enable the preservation of ecosystems as well as act as a guide towards safe, equitable and gender sensitive access to water resources.

In line with the feedback from stakeholders from the Ramganga Basin during a series of meetings, the two aims as agreed can be summarized as follows:

- Maintain good surface and ground water quality level by reducing pollution from point and non- point sources
- Maintain good surface and ground water quantity by employing efficient water usage techniques

The overall Ramganga Basin Vision*: Protect and enhance the status of all waters and protected areas including water-dependent ecosystems, prevent their deterioration and ensure long-term, sustainable use of water resources.*

4.2 Identified KWMIs and process of identification

Addressing the challenges faced within a river basin requires identification of the Key Water Management Issues (KWMI). The cause of these KWMIs are human usage and other human induced direct or indirect impacts on water resources (surface and groundwater). The KWMI can be considered as human caused negative impacts on water quality and/ or quantity, which can be tackled by managing water resources, policy change and behavior change. These KWMI are identified on 'vital few and not trivial many' principle identified together with authorities and stakeholders during several consultation meetings. These identified KWMI are taken up in the first cycle of Ramganga RBM Plan. Authorities from national level, from the basin states of Uttar Pradesh and Uttarakhand, experts/academia from institutions working in the Ramganga Basin, and representatives from the districts of the Ramganga Basin participated in these consultations.

List of consultations meetings for the identification and confirmation of KWMI

- *2nd May 2022* – NMCG, GIZ and International experts (NMCG office hall)
- *9th May 2022* – NMCG, GIZ, International experts, CWC, CGWB, SMCG UP, UP PCB, UP Forest, UP Ground Water Department, WWF India, UP Agriculture Dept, DGC Shahjahanpur (Lucknow – Hybrid mode)

- *11th May 2022* – NMCG, GIZ, International experts, SPMG UK, UK Irrigation Dept, CGWB Dehradun, CWC, UK Agriculture, UKPCB, UKJVN, UK Urban Development, UK Forest Department, UK Jal Nigam, UK Jal Sansthan, EO Nainital, DGC Pauri Garwal, DGC Rudrapur, WII, Doon University (Dehradun, Hybrid mode)

Table 15 lists the finally agreed five KWMIs for Ramganga River Basin to be taken up in the first RBM Cycle. Other or additional pressures might emerge as relevant during the development of the first RBM Cycle and will be identified as a KWMI for the next Cycle of Planning.

Table 15: Key Water Management Issues as agreed for the first cycle of Ramganga RBMP

KWMI 1	Water quality deterioration due to point sources
KWMI 2	Water quality deterioration due to non-point sources including agricultural activities
KWMI 3	Alteration in groundwater regime impacting on sub-surface flow
KWMI 4	Alteration in river hydrology and water quantity
KWMI 5	Flood risk due to encroachment including sandmining

For addressing these KWMI as part of the Ramganga RBM Plan, the Vision and Management Objectives have been jointly agreed with the national, state and district level stakeholders for each of them. They enable a targeted data collection and meaningful Pressure/Impact Analysis and Risk Assessment. The management objectives follow the Ramganga RBM Cycle timeline for their achievement and are of qualitative and/or of quantitative and measurable nature.

4.3 Visions and management objectives

Vision statements are described first for each KWMI: these build upon the main concerns pertaining to each KWMI and accordingly define the desired state to be achieved by implemented target PoM. The visions for each of the 5 KWMIs for Ramganga RBM Plan have been developed and agreed along with the involved basin stakeholders and finally agreed with Ramganga RBM Committee. The Management Objectives are then identified as a direction for implementable, specific, and targeted steps. Figure 13 shows an example of a vision regarding pollution issues and related critical management objectives.

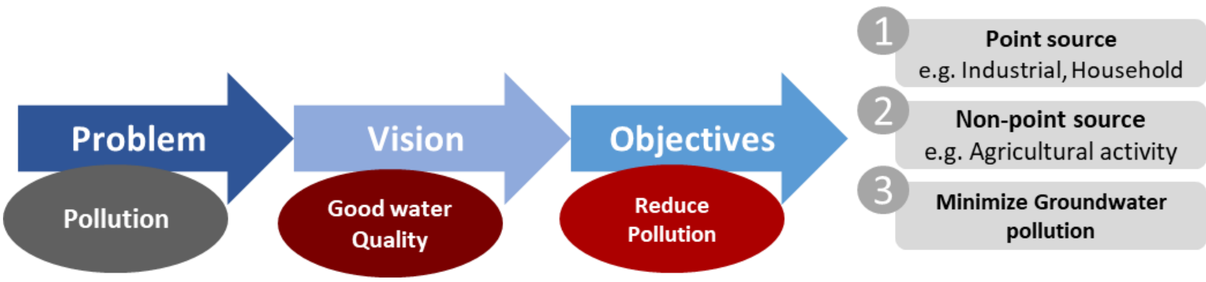


Figure 13: Example of Vision and Management objectives for pollution issues (Source: Ebel Christian)

In other words, the management objectives are the actionable steps to achieve the vision defined for each KWMI. Such major steps include proper data collection and then using this data to perform the necessary pressure and impact analysis. The pressure and impact analyses further lead to development of Program of Measures (PoM) to reduce the pressures (and subsequently the impacts) on water resources. These PoM, when implemented, contribute to achieve the management objectives and accordingly vision set to address each of the identified KWMI. In brief, the overall approach follows DPSIR approach which is further explained in subsequent sections.

The following chapters describe each of the selected KWMIs and summarize how the anthropogenic activities can play a substantial role in triggering these KWMI.

4.4 KWMI 1: Water quality deterioration due to pollution from point sources

4.4.1 Problem description

Point source pollution can be attributed to the emissions that are caused by untreated or partially treated wastewater sources (e.g. from sewage and industrial effluent). These point pollution sources are commonly connected to nearby settlements and industries. In the Ramganga River Basin, existing wastewater treatment capacity is insufficient to handle the present situation, especially in the urban areas which are mainly contributing organic and nutrient pollution. Also, in areas not connected with sewerage networks, domestic wastewater (effluent from onsite sanitation system and grey water) is discharged into drains which finally find its way in surface water bodies.

Around 24 million people are living in the Ramganga River Basin (extrapolated based on Census 2011 data and averaged decadal growth rate). This means that there are 24 million people causing organic pollution daily, which is directly discharged into minor or major drains and sewer systems from where, this organic and nutrient pollution is finally transported into rivers. This bulk of generated organic pollution has a negative impact on the oxygen balance of water bodies, which adversely impacts the aquatic life. There is a need to properly monitor the water quality indicators like COD (chemical oxygen demand), BOD_5 (biological oxygen demand) and TOC (total organic carbon) to identify the decay in oxygen levels. It is also crucial to prevent the eutrophication of water which is caused due to overabundance of nutrients (i.e. nitrogen and phosphorous).

In the Ramganga River Basin, there are several different types of industries. The discharge from these industries is one of the contributors to point source pollution. Industrial wastewater needs treatment before discharging it to either surface water or in the public sewer system. But if it remains untreated or even partially treated, this wastewater discharge has severe impact on water quality. It is critically important that there should be only controlled industrial wastewater discharges, otherwise it would cause problems regarding the capacity and thus performance of existing Sewage Treatment Plants (STPs).

Expectedly, the most affected river reaches in the Ramganga Basin can be found downstream of Moradabad and Bareilly.

To summarize, in the Ramganga River Basin there is a need to achieve adequate sewage and industrial wastewater treatment facilities.

4.4.2 Key drivers and related pressures for pollution from point-sources

Population growth is the leading pressure factor behind urbanization and industrialization in the Ramganga River Basin causing a rising number of point pollution sources, especially in cities and around industrial areas. STP capacity was not developed with the same growth rate as population, which results in discharge of partially or fully untreated municipal and industrial wastewater. The rapid urbanization in the Basin also causes to the more quantity of sewage being generated – enabled by access to tapped freshwater. The other impact is the scattered rural towns within the basin, which, in absence of any conventional sewerage treatment, mainly discharge their domestic wastewaters into nearby ponds or drains. Moreover, rising demand of fresh water supply from rural settlements (enabled by Jal Jeevan Mission) will also play its role in worsening the existing wastewater problems. In industrial town of Kashipur, and Moradabad within the Ramganga Basin, there are abundance of household level unregistered industries which also dispose of their wastes either into sewer network or in open stormwater channels. Such mixing of industrial waste with domestic wastewater negatively impacts the performance of STPs.

4.4.3 Vision and management objectives

During stakeholder meetings, a list of visions was elaborated by the participants. Based on their input, the vision for the KWMI 1 is given in the box below.

The vision for the KWMI 1 *Water quality deterioration due to point source pollution* is the holistic planning towards 'close-to-zero' discharge of untreated wastewater (sewage and industrial effluent) water in the Ramganga Basin which enhances pristine water quality from tributaries and surroundings

The key steps toward vision attainment are the implementation of the following agreed management objectives:

- In-depth knowledge of surface water quality and mapping of all hotspots through the implementation of a water quality monitoring system is established for identification of hotspots, drainages or discharges and control of the effectiveness of measures.
- Pinpoint sources of pollution from industries and settlements in the Ramganga Basin are identified through hotspot mapping, and need for action, pre-emptive measures and targeted investments is highlighted.
- Sufficient STP/wastewater treatment capacity in the Ramganga Basin is achieved by installing sufficient capacity, based on the results of hotspot mapping.
- Direct mixing of untreated discharge from industries is prohibited by enforcement of penalties and fines as per the existing rules and legislations.
- Presence of adequate infrastructure for wastewater management for all untreated discharge hotspots in the Ramganga River is ensured through proper consultation while taking all the important stakeholders on board in case of any approval is sought.
- Municipal wastewater from rural communities is effectively managed through the development and implementation of decentralized cost-efficient nature-based solutions. So, it does not contaminate surface or ground water resources.

4.5 KWMI 2: Water quality deterioration due to non-point sources including agricultural activities

4.5.1 Problem description

Intense agricultural activities are pertinent in the context of the Ramganga River Basin, but these activities can also lead to deterioration of water quality. For example, if pesticides and nutrients (e.g. fertilizers) are extensively used, it will lead to polluted surface and groundwater resources in the long term. Pesticides and nutrients in the water are also harmful for human consumption. The use of pesticides in the agricultural activities also results in hormonal imbalance including reproductive problems as well as the disruption of aquatic ecosystem (UNEP, 2016)

Looking at the overall fertilizer emissions, India with 0.29 kg/ha has a comparatively low use, compared to the US with 2.37 kg/ha and the EU with 1.65 kg/ha (FAO, 2019). Yet in the Indian market many hazardous pesticides (e.g. Thiamethoxam, Ziram, etc.) are still available for sale (MoA&FW, 2020, Tapi RBM Plan, 2022). Pesticides, herbicides, fungicides and other hazardous substances used in agriculture may also have a high impact through long term bioaccumulation and bioconcentration even if used in small amounts.

In addition, the indiscriminate disposal of municipal wastes including e-wastes pose additional risks of contamination of soil and subsequent percolation of (leaching) of such hazardous elements into groundwater, and to nearby surface water bodies through surface run off. Ramganga Basin also faces a severe challenge of legacy waste which is still to be inventorised scientifically. Further, dumping of waste in unscientific landfills has a huge potential to contaminate groundwater (shallow aquifer) through the leaching of toxic substances.

4.5.2 Key drivers and related pressures for pollution from non-point sources

Agricultural production is essential for food security. In recent years, with the help of new and fast-growing technologies, India's agriculture has experienced a huge surge in productivity (Patil Anna K, 2011). As agricultural productivity grows without curbing the use of pesticides and fertilizers, the pressure due to non-point source pollution will rise. Additionally, the alluvial soils and high availability of groundwater in middle and lower Ramganga River Basin are ideal for agricultural activities and intensive agriculture with 2-3 crops sown per year is common in this region. As seen in Chapter 2, 58.7% of the land is cultivated in the basin. The major crops grown include water intensive sugarcane, paddy and wheat. As most of the basin still observes traditional methods of irrigations (flood irrigation in case of paddy), the application of fertilizers remains on higher side.

On the other hand, rapid urbanization coupled with the change in lifestyle of people in residing, the amount of municipal solid waste generated is exponentially growing. Though, the efforts towards better solid waste management have seen significant improvement in India in recent years, many of the towns (and especially rural areas) are still struggling to catch up with the growing needs. This is also true for Ramganga Basin. Further, unscientific landfill sites increase the risk of groundwater contamination as the leachates percolate down the alluvial soils of the basin. The indiscriminate disposal of municipal wastes into drains, water bodies, canals and rivers not only contaminate the surface water-bodies but also disrupts the flow and pose a public health risk.

4.5.3 Vision and management objectives

During stakeholder meetings, a list of visions was developed and discussed. The following visions for the KWMI could be identified:

- Good water quality with no or reduced emission of chemicals fertilizers / fertilizers/ pesticides
- Increase in nature-based / organic farming techniques
- Reduction/elimination of uncontrolled dump of solid waste
- Better adaptation of farming practices to climate conditions
- Solid waste management and elimination of garbage dumping in river flood plains;

The vision for KWMI 2 *Water quality deterioration due to non-point sources including agricultural activities* is the *close-to-zero* discharge of pesticides/fertilizers/toxic substances in surface runoff from agricultural fields and other areas of the Ramganga Basin.

The key steps toward vision attainment are the implementation of the following management objectives:

- The available national and state policies on regulation of the use of pesticides, fertilizers and other toxic substances are strictly implemented and supplementary new policies (as needed) are developed and implemented.
- The farmers within the Ramganga Basin are continuously informed and sensitized by arranging awareness campaigns on the harmful use of pesticides/fertilizers/toxic substances for agricultural activities and their possible interaction with surface water.
- It is ensured that only permitted nitrogen effluent discharges shall reach all water bodies as defined in the Indian standards.
- Solid waste disposal sites in the Ramganga Basin are identified through hotspot mapping, to understand the need for action, measures and targeted investments.
- Development of solid waste dumping facilities and landfill sites within flood zones is totally prohibited by devising proper penalties and policies as per local rules and legislations i.e. Solid Waste Management Rules, 2016.
- The citizens in the Ramganga Basin are well-informed and sensitized on the appropriate disposal of municipal solid waste through the implementation of public awareness campaigns
- Sufficient solid waste management capacities are created and implemented, whereas due to critical situations pollution hotspots are tackled at the priority
- Use of new technologies in solid waste management is explored including garbage incineration plants after discussing the feasibility as well as technical, operational, and maintenance aspects of these plants with joint consultation of all the relevant stakeholders.
- Adequate information/data is developed on the leaching from historical solid waste dumping sites located in flood zones.

4.6 KWMI 3: Alteration in Groundwater regime impacting on sub-surface flow

4.6.1 Problem description

In view of deteriorating quality of surface water sources, groundwater resources are considered important to meet the demand for domestic / drinking water purpose in developing countries like India.

Thus, sustainable groundwater management is of significance for both drinking water purposes as well as catering the needs for irrigated agriculture in the Ramganga River Basin. Unregulated supplies and overexploitation of groundwater resources cause groundwater imbalances, which calls for the monitoring of groundwater abstraction as well as monitoring water tables of groundwater to inform efficient management of groundwater resources.

4.6.2 Key drivers and related pressures

Ramganga Basin especially upper part observes very high groundwater-surface water interaction, due to this groundwater quality and quantity directly affects the availability of water resources in the entire basin. The risk of the leaching of contaminants from unscientific landfills within the basin is of concern as the resulting groundwater contamination may severely affect the protected source of drinking water. This also becomes critical since almost all rural areas and smaller towns in Ramganga Basin rely on groundwater to meet their drinking/potable water demand.

Related pressures that have an impact on groundwater are listed below:

- Unregulated and indiscriminate groundwater abstraction for agricultural activities including irrigation is the major pressure on groundwater resources. Drinking water supply and abstraction for industrial production follow but to a minor extend compared to agricultural use.
- Groundwater abstraction through unregulated use of solar pumps might also add a groundwater depletion issue since the limiting factor cost for pumping is bypassed.
- Use of chemicals that infiltrate into the groundwater lead to a reduction of groundwater quality.
- Rehabilitation of groundwater bodies causes high costs and is a lengthy and difficult process due to the slow renewing rate of groundwater.
- Potential of leaching of toxic substances from unscientific waste dumping sites into groundwater

4.6.3 Vision and management objectives

During stakeholder meetings, the following vision was formulated.

The vision is to keep up a sustainable and good groundwater quality and quantity for various purposes by considering the impacts of climate variability. It is in line with the vision to restore the already deteriorated groundwater regime to good quality levels.

The key steps toward vision attainment are the implementation of the following management objectives:

- The groundwater sources for drinking water supply are set to be free from contamination and fully protected. This is regularly monitored by improved groundwater level and quality monitoring system.
- Groundwater extraction is documented by registering all the extractions from the basin.
- Regulations in terms of Groundwater pollution through seepage/leaching of pollutants from solid waste dumping/ management facilities, landfill sites and industries are in place and give regulatory authorities the mandate to enforce the regulations.

- Outreach activities for groundwater user communities to encourage groundwater recharge/ managed aquifer recharge (MAR) and conjunctive use of surface water and groundwater are effectively implemented.
- Adequate information on groundwater for long-term forecasting (for allocation purposes) is generated by deploying a complete basin-wide groundwater modelling database inventory.
- Demand-side management interventions in areas, affected by droughts or where groundwater is already over-abstracted or close to it, are promoted.
- Industries and farmers in the Ramganga Basin are kept well informed and sensitized on the pre-emptive measures taken for keeping groundwater safe and clean

4.7 KWMI 4: Alteration in River Hydrology and Water Quantity

4.7.1 Problem description

Table 16 shows a prediction of the rural and urban population growth in the Ramganga Basin for decadal time horizons up to 2045. As can be seen in the table, population growth will be a serious driver and put increased pressure on the water resources of the Basin. Taking 2015 as a baseline not only is the total population of the Basin is expected to increase by about 30% between 2025 and 2045, the proportion of urban population, with their proportionately greater demand on water resources, is expected to increase even more quickly at 35% over the same period.

Table 16: Projected decadal population growth in Ramganga Basin (baseline 2015)

Year	Projected population at time horizon (millions)					
	rural pop	*% change*	urban pop	*% change*	Total pop	*%*
2015	14.4	*0*	5.4	*0*	19.79	*0*
2025	16.7	*16*	6.5	*20.4*	21.2	*7.1*
2035	18.8	*31*	7.5	*38.9*	26.4	*33.4*
2045	21.0	*46*	8.4	*55.6*	29.4	*48.6*

Source: SWARA, 2020

Further based on the State Water Agency of the Government (SWARA) of UP[7] study, total irrigation demand is projected to decrease slowly over the next two decades in both Agricultural scenarios modelled (business as usual scenario, and along with crop diversification, implementation of conjunctive use management, equitable distribution of water and micro irrigation in 10% of cropped area).

Adding to the domestic and agriculture water demands, economic development is also expected to increase industrial demand over the next two decades (from 10.1 Mm^3 in 2015 to 24.6 Mm^3 in 2045).

An important element of the Development of the River Basin management plan is to identify adequate environmental flows (e-flows) to maintain river health. The successful application and it is important that any alteration of flows due to other demand as above consider the requirements to maintain the

[7] *The Development of River Basin Assessment and Plans for All Major River Basins in Uttar Pradesh,* State Water Resources Agency, Gov of UP March 2020

ecological health of the Ramganga. E-flow assessments for the Ramganga are currently being developed under the India-EU Water Partnership Action, Phase 2 of GIZ-SGR Project.

4.7.2 Key drivers and related pressures for alterations in river hydrology and water quantity

The key drivers and related pressures for alteration in river hydrology and water quantity in the Ramganga Basin are the increasing demands on the surface water resources caused by the following factors:

- Pressure caused by increased water demands in the urban and rural sectors due to population increases and increased per capita expectations concerning water availability and security of supply.
- Pressure caused by increased water demands of an expanding industrial sector.
- Variability of the climate patterns, including high annual rainfall fluctuations in all districts in the Ramganga Basin, leading to multi-year periodic alteration of the river hydrology impacting on all water user sectors but especially on the agricultural sector.
- Climate change issues impacting negatively on the hydrological regime of the Ramganga Basin imposed on the already existing high variability of climate in the Ramganga Basin

4.7.3 Vision and management objectives

Based on the stakeholder interactions, the following Vision, and Management Objectives relevant to issue of alteration in river hydrology and water quantity are mentioned below:

The vision for river hydrology/water quantity in the Ramganga Basin is to maintain sustainable use of surface waters with a natural flow dynamic ensuring, as a minimum, environmental flows and water security as well as considering the impacts of climate variability and climate change.

Objectives of the RRBM Plan are to be monitored, evolved, and regularly updated and addressed as on objective of the management activities of a proactive Ramganga River Basin Committee.

- Key abstraction sources and hydrological alterations that may cause impacts in the Ramganga Basin are identified
- Hotspots regarding alterations of water quantity specifically regarding inadequate E-Flows and changing demands on the water quantity by all sectors are identified.
- Efforts, actions to maintain the adequate E-Flows based on the Ramganga E-Flows assessment are identified together with all relevant stakeholders
- Pertaining national, and state legislation and rules are strictly enforced to prevent any alteration in river hydrology by illegal water abstraction
- Management protocol to maintain adequate flows for identified vulnerable hotspots (prone to draughts or floods), to be developed and established
- To understand and monitor, the water accounting study of the basin is carried out

4.8 KWMI 5: Flood risk due to encroachment, including sand mining

4.8.1 Problem description

Flood risk

Ganga–Ramganga doab is one of the prolonged flood-affected areas in the middle Ganga plain due to seasonal monsoon which leads to a rise in water levels of the Ganga and the Ramganga rivers (Agnihotri, A.K., Ohri, A., Gaur, S. *et al.*, 2019). Floods are a recurrent phenomenon, which can cause loss of lives and damage to property and infrastructure. Flood-related damages show an increasing trend. The average annual flood damage rose from Rs. 18.05 billion (for previous 53 years) to Rs. 47.45 billion for a 10-year period between 1996- 2005. This can be attributed among others to an increase in population, rapid urbanization with encroachment of flood plains coupled with global warming.

Urban Encroachment

With an average of 1% growth in population per year in 2022 and strong movements towards industrialization, India is facing the challenges associated with rapid urbanization. Cities are growing and expanding their areas. In 2022, a population of approximately 24 million people live in the Ramganga River Basin (based on Census 2011 extrapolated with 1% annual growth), bringing cities and settlements closer to the river system and its flood plains. Increasing population also comes with an increase in mobility, which leads to further encroachment due to infrastructure projects (e.g., bridges, dams, streets, etc.). Urban encroachment on floodplains has exacerbated flood disasters. Settlements are exposed to floods when encroaching flood plains and flood plains lose capacity for flood retention, which set settlements downstream to a higher risk (Wahab, Bolanle & Falola, Olusegun 2016).

Sand Mining

Sand mining is directly related to construction activities, which makes it a high-value commodity. As a result of increasing and ongoing construction activities the demand for sand is high, where it is mostly consumed for construction materials, for example concrete (Koehnken and Rintoul, 2018). Globally, sand demand has been increasing in recent years (Padmalal & Maya, 2014), it is also a likely scenario that India will take charge as the highest sand consumer (Koehnken and Rintoul, 2018), given its projected population growth and one of the fast-growing economies in the region (United Nations, Department of Economic and Social Affairs, Population Division, 2015). In 2017, sand demand for India was around 700 million and its annual increase rate is around 6 - 7% (GOIMOM, 2018). As far as Ramganga River Basin is concerned, there is a huge potential of sand mining, as this basin lies in Uttar Pradesh and Uttarakhand states. Uttar Pradesh is one of the highest sand consumption states in India, with a quantum of sand consumption of around 101 million tons in year 2017. The combined total sand consumption for both states (i.e., Uttar Pradesh and Uttarakhand states) is estimated to 108 million tons. Moreover, sand mining in and around the Ramganga River Basin disturbs the hydro-morphological balance of river reaches in terms of erosion and sedimentation and causes bed and bank erosion. Sand mining also poses a threat to villages and fields situated close to the riverbanks. Therefore, it is required to assess the quantity of sand mining within the Ramganga Basin as well as curtailing unregulated sand mining practices within the basin.

4.8.2 Key drivers and related pressures

An increase in the intensity and duration of precipitation in combination with more exposure of settlements to flood prone areas are the drivers for flood problems. The focus is on riverine floods, flash floods are not considered. Floodplains degrade because of encroachment, disconnection of floodplains and wetlands. Engineered flood protection measures in conjunction with levees, dikes, retention basins, channel straightening reduce the flood retention capacity of river systems and impact on hydromorphology and ecosystem health of rivers and riparian zones (EEA, 2020). Therefore, flood mitigation measures are a complex topic.

Pressures on floodplains are closely linked to hydro-morphological pressures, land use and pollution. Flood protection structures play a key role in this context.

Both flood protection infrastructures and drainage affect floodplains and the connectivity of rivers to floodplains, as they cause changes to the land area surrounding water bodies. This can have major implications for the integrity of both riparian and aquatic ecosystems (Junk et al., 1989, Junk and Wantzen, 2004). In a natural system, lateral connectivity between rivers and their floodplains allows the exchange of water, sediment, biota as well as nutrients. The loss of lateral connectivity leads to the loss of key habitats and as a result the decline of species and biodiversity both on the floodplain itself and in the aquatic environment. Further, physical processes are disturbed related to the natural water retention capacity of floodplains as well as sediment dynamics. Artificial bank protections that serve flood protection (embankments, levees or dikes) affect the morphology and dynamics of the river channel by restricting the channel width and the sediment supply from the riverbanks. Bank reinforcement and levee construction can lead to bed incision because of the possible higher flow velocities. Bed incision also reduces the connectivity between the river and its floodplain (lateral connectivity). The reduction of this lateral connectivity damages the functioning of the riparian zone and reduces productivity, nutrient exchange, and dispersal of biota more widely across the floodplain. As far as land drainage is concerned, natural channels have been straightened and deepened for surface drainage ditches with significant effects on channel morphology, instream habitats for aquatic organisms, floodplain and riparian connectivity, sediment dynamics, and nutrient cycling (Blann et al, 2009). The regular maintenance of drainage ditches and rivers (via dredging and weed cutting) seems required but can also lead to physical disturbances and morphological changes in water bodies (Vartia et al., 2018).

4.8.3 Vision and management objectives

Based on the stakeholder inputs, the visions for the issue of flood risk due to encroachment and sand-mining is as below:

To mitigate flood disasters by conserving the functions of the flood retention areas and the preservation/restoration of ecologically intact river system.

The key steps toward vision attainment are the implementation of the following management objectives:

- Interactive flood inundation maps are developed and readily available for Ramganga River and Tributaries as an early warning system and to be a basis to assess encroachments.
- Urban encroachment as identified through the flood inundation mapping is prevented by implementing state policies as per defined rules and regulations.
- The citizens in the basin are kept well-informed and sensitized on the implications of urban encroachment of the floodplain zone and the importance of floodplains and lateral connectivity of rivers.
- Nature-based solution is prioritized and implemented for flood mitigation
- Flood prevention through strengthening reservoir operations, implementation of flood buffer zoning and forecasting as per defined dynamic operational rules, is achieved.

- The maximum volume of sustainable sand mining is assessed by using Hydro morphological models
- The monitoring mechanism of sand mining is improved and strengthened to assess the over-all extraction and accordingly administer the relevant acts, and if needed re-structure approval

5 PRESSURE-IMPACT ANALYSIS AND RISK ASSESSMENT - OVERALL APPROACH

A Pressure-Impact Analysis is linked to risk assessment for all Ramganga KWMIs to access the probability of surface waters and ground waters (or critical portions) failing to meet the overall vision and management objectives. The overall risk-assessment approach for the Ramganga River Basin requires an understanding of the DPSIR approach (Driver, Pressures, State, Impact and Response).

DPSIR is a causal framework of understanding interactions and linkages between society and environment to assist the identification of human pressures and risk of possible impacts on waters through technical judgement.

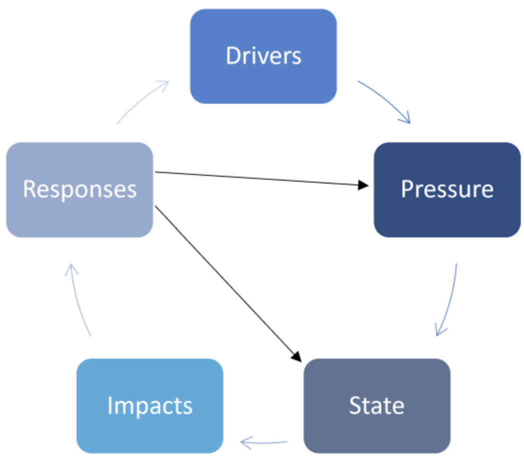
5.1 Background of Pressure/Impact Analysis and Risk Assessment

The pressure/impact analysis and risk assessment as laid down in the EU Water Framework Directive includes the following key elements (EU WFD, 2003):

- Identifying driving forces for the changes in the river basin
- Identifying the significant pressures or stresses caused due to the changes
- Evaluating the current state of the river basin
- Assessing the impacts (biological, economic, and social effects of the environmental change)
- Evaluating the likelihood of failing to meet the objectives.

The outcome of the risk assessment is critical in terms of providing a thorough overview of the present situation in a river basin and possible future damaging impacts on water bodies within that river basin. It is also important to perform the risk assessment beforehand, so that monitoring measures taken for the improvement of water quality or quantity becomes cost-effective.

Table 17: The components of the analytical DPSIR approach

SCEMATIC OF DPSIR APPROACH	
DRIVER	An anthropogenic activity that may cause or may trigger to cause a negative effect on water quality and/or quantity (e.g. agriculture, industry, water supply, infrastructure development). Note: climate change can be a DRIVER even though not anthropogenic.

PRESSURE	The pressure on water resources that are the direct result of the **DRIVER**, which can be classified into three types: (a) excessive use, (b) changes in land cover/use and (c) emissions (pollution).
STATE	The condition of the water quality and/or quantity resulting from both natural and anthropogenic factors/pressures (i.e. physical, chemical and biological characteristics)
IMPACT	The effect of a **PRESSURE** on water quality and/or quantity (e.g. lower population health, crops destroyed, ecosystem modified, aquatic life cannot thrive, flood)
RESPONSE	Actions/measures taken to address an undesired, negative IMPACT which can affect any part of the chain between DRIVERS and IMPACTS (e.g. restricting abstraction, limiting point source discharges, developing best practice guidance for agriculture)

In the Ramganga RBM Plan also, the DPSIR approach is applied. The outcome and findings of a pressure/impact analysis and risk assessment are demonstrated in the form of figures, tables, and thematic maps. The risk assessment is also cross validated against the available information, so that a proper evaluation of the risk of failing objectives is done as highlighted in Figure 14.

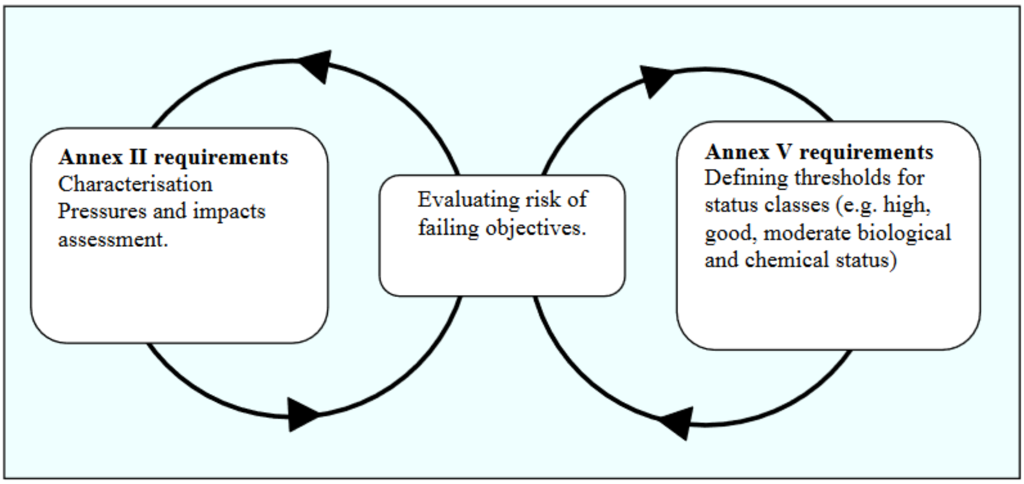


Figure 14: Iterative evaluation of the risk of failing objectives (EU WFD, 2003)

5.2 Pressure/Impact Analysis as part of the Ramganga RBM Plan

In general, the methodology from Tapi RBM Plan has been followed and further improved as per the need of Ramganga River Basin for risk assessment. Key steps for pressure impact analysis are listed as follows:

1. The first step focuses on the identification of drivers and possible pressures that will have negative impacts on achieving the overall set objectives for good surface and groundwater status of the Ramganga River Basin.
2. The second step focuses on certain criteria and threshold limits to assess the possible negative impacts generated by pressures identified in the first step. Step 2 is linked and based on the outcome of the first step. In the case of Ramganga River Basin an objective is considered at risk of failing if it exceeds a defined threshold limit.

The three risk categories (i.e., 'at risk', 'possibly at risk' or 'not at risk') are defined against which results are evaluated and displayed with specific color coding. (See Table 18).

Table 18: Three categories to assess possible risk of failure of the overall Ramganga River Basin Vision and objectives (Source: Tapi RBM Plan)

Risk Category	Surface waters	Criteria/Threshold
1	At risk to fail the aims/objectives	Criteria/thresholds are exceeded
2	Possibly at risk to fail the im/objectives	Unclear if criteria/threshold are ex-ceeded or not; insufficient data
3	Not at risk to fail the aim/objectives	Criteria/threshold are not exceeded

As part of this Ramganga RBM Plan, the outcome of the risk assessment is presented in the form of graphs, figures, tables, and maps.

5.2.1 Identification of Drivers and potential pressures

The focus on identification of drivers with each KWMI and related potential pressures that may impact the overall vision and management objectives of surface water and ground water was identified for the Ramganga River Basin based on consultations with stakeholders, expert judgement, and field visit. In the beginning of the Ramganga River Basin Risk assessment the entire basin was delineated into Surface water Management Units (SWMU) and Groundwater Management Units (GMU). These are practical units on which the future surface water and groundwater management will be carried out and for this purpose, the risk assessment results are presented according to these delineated SWMU and GMU respectively. Example: The risk assessment of the KWMI related to alterations in the groundwater quantity and quality in the Ramganga Basin is based on Groundwater Management Units (GMUs).

Delineation of Surface Water Management Unit (SWMU)

SWMUs are based on homogenous river stretches (i.e., complete river systems) representing hydrological sub-catchments within the Ramganga Basin. The delineation of the SWMUs has been established based on the Hydrological Response Units (HRUs) of the Soil and Water Assessment Tool (SWAT) model. The following steps were carried out for the delineation of the SWMUs.

1. Initially, more than 5,000 HRUs were delineated using the SWAT model. These HRUs are smallest spatial unit that is represented by similar physical characteristics that respond to precipitation and weather events in a similar way.
2. These HRUs were further analysed and combined into 711 hydrological drainage sub-catchments.
3. Finally, these 711 sub-catchments were aggregated by different tributaries while ensuring the continuity of flow within the basin. This delineation approach resulted in a total of 18 SWMUs within the Ramganga Basin.

Table 19 provides information about the area and the population of the SWMUs. Each SWMU has a proper name and code referring to the major contributing rivers or tributaries. In the present SWMU arrangement, the Ramganga River is divided into seven (7) different SWMUs, the rivers Garra and Kosi account for three (3) and two (2) SWMUs, respectively. The area of the SWMUs ranges from 600 to more than 3,000 km². SWMU No. 17, which is also the largest in terms of population, with a total count of more than 4.0 million people[8]. Map 12 shows the SWMUs of Ramganga Basin.

Table 19: SWMUs names, covered area, and total population

SWMUs	SWMU code	Name	Area [km²]	Ramganga Basin Population-2011	Ramganga Basin Population-2022[9]	Population Percentage
1	RG06-001	Ramganga06	614.2	357,266	396,565	1.6%
2	KHOR-002	Khor	1,017.6	569,404	632,038	2.6%
3	KO01-003	Kosi01	1,712.6	351,227	389,862	1.6%
4	RG-02-004	Ramganga02	1,685.6	343,666	381,469	1.6%
5	RG-01-005	Ramganga01	2,016.5	353,509	392,395	1.6%
6	RG-07-006	Ramganga07	925.9	588,362	653,082	2.7%
7	GA03-007	Garra03	2,261.1	1,630,524	1,809,882	7.5%
8	GANGAN-008	Gangan	1,734.3	1,587,098	1,761,679	7.3%
9	RG-03-009	Ramganga03	1,807.9	1,437,498	1,595,623	6.6%
10	KO02-010	Kosi02	1,435.3	1,315,873	1,460,619	6.1%
11	RG-04-011	Ramganga04	1,172.0	2,076,142	2,304,518	9.6%
12	GAN-BHA-012	Ganga Bhakra	2,546.6	1,484,939	1,648,282	6.9%
13	ARIL-013	Aril	1,817.1	1,693,332	1,879,599	7.8%
14	BAIGUL-014	Baigul	2,182.6	1,376,685	1,528,120	6.4%
15	GA01-015	Garra01	1,533.6	562,427	624,294	2.6%
16	KHANAUT-016	Khanaut	1,211.3	606,522	673,239	2.8%
17	RG05-017	Ramganga05	3,310.6	3,656,046	4,058,211	16.9%
18	GA02-018	Garra02	1,854.1	1,672,817	1,856,827	7.7%
	TOTAL		**30,838.9**	**21,663,337**	**24,046,304**	**100%**

[8] Population count is based on the census of year 2011 and then extrapolated to year 2022 with approx. 1% annual growth https://data.worldbank.org/country/IN
[9] Population count is based on the census of year 2011 and then extrapolated to year 2022 with approx. 1% annual growth https://data.worldbank.org/country/IN

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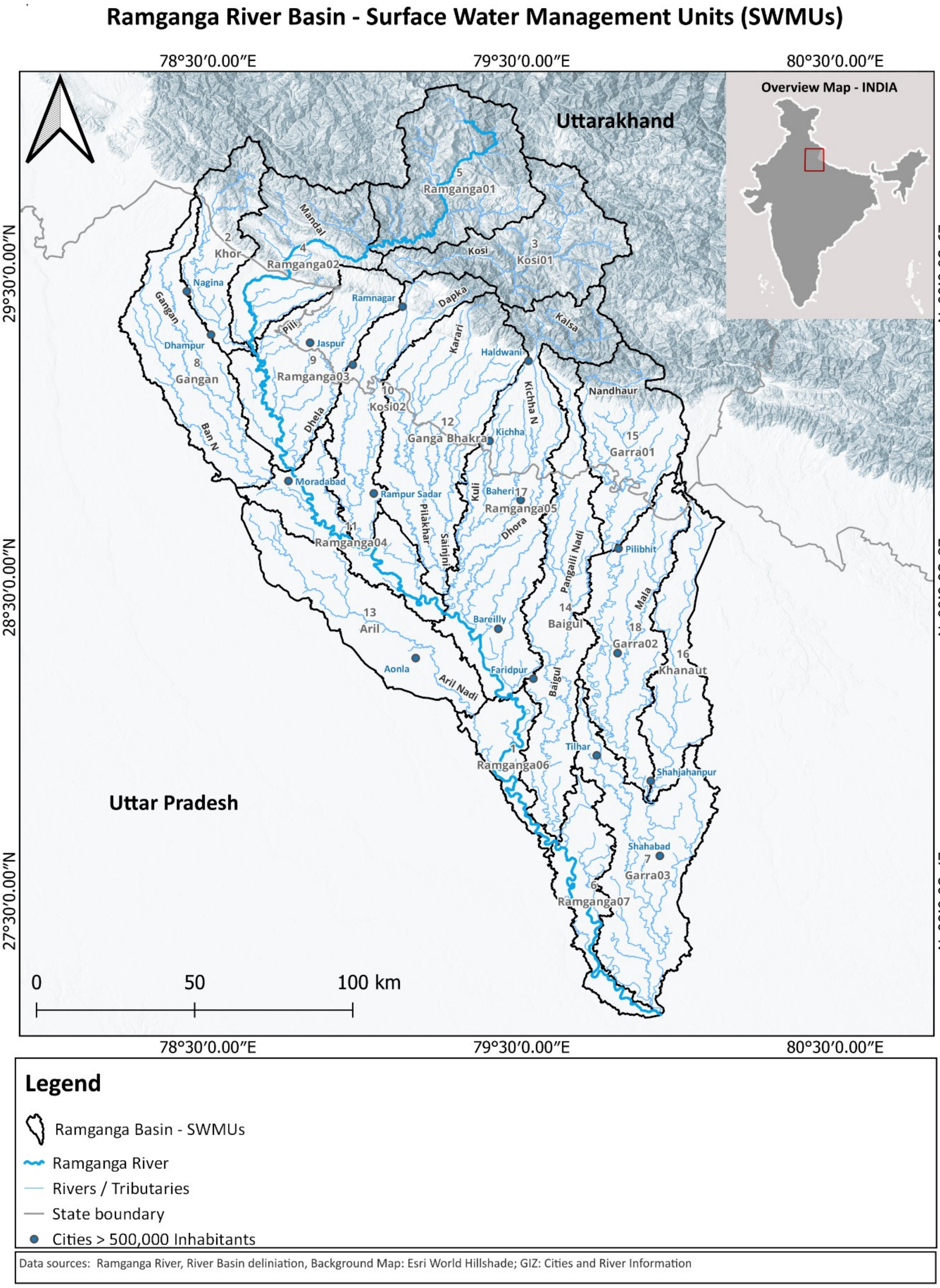


Map 12: Ramganga Basin with Surface Water Management Units (SWMUs)

Delineation Groundwater Management Unit (GMU)

It is important to mention that for the risk assessment most of the needed data, as well as related information, is already available at block/taluka scale. It was agreed that the same approach as adopted in Tapi RBM Plan shall be applied to the risk assessment in the risk assessment related to ground water for Ramganga Basin. While a delineation of GMUs related to different aquifer complexes is reasonable in the mountainous northern parts of the Ramganga Basin, the southern part is formed by a vast alluvial aquifer system of more than 20,000 km^2. For an appropriate risk assessment and management, smaller sub-units are needed.

The following major points were considered for finalizing the GMUs, especially in the alluvial plain, where sub-divisions are defined by groups of talukas having similar characteristics:

1. Initially, more than 5,000 HRUs were delineated using the SWAT model. These HRUs were further analysed and combined into 711 hydrological drainage sub-catchments.
2. The state of groundwater exploitation (using the groundwater resources estimates map of the year 2020).
3. The intensity of high agricultural land use [% of area].
4. k-means clustered post-monsoon depth to groundwater level [mbgl].

Finally, 20 GMUs have been finalized after incorporating feedback from the Central Groundwater Board (CGWB) experts. These GMUs are located in 20 districts and the 20 GMUs are covering 129 entire and partial blocks. The GMU naming system is explained as follows:

A generalized nomenclature for assigning a suitable code to all GMUs within the Ramganga Basin has been developed. The GMU naming system mainly identifies the river basin, the state and the number of clubbed talukas. The first two digits indicate the main River (The river length of greater than 40 km passing through a GMU was considered as the dominant riverine system within the GMU), the second 2-digits indicate the State, then third 2-digits show the Number of clubbed blocks and the last 2-digits are sequential numbers.

Here is an example of GMU code: RG_UP_03_20

River: Ramganga (RG)
State: Uttar Pradesh (UP)
Number of clubbed Blocks: 03, AND **Sequential number**: 20

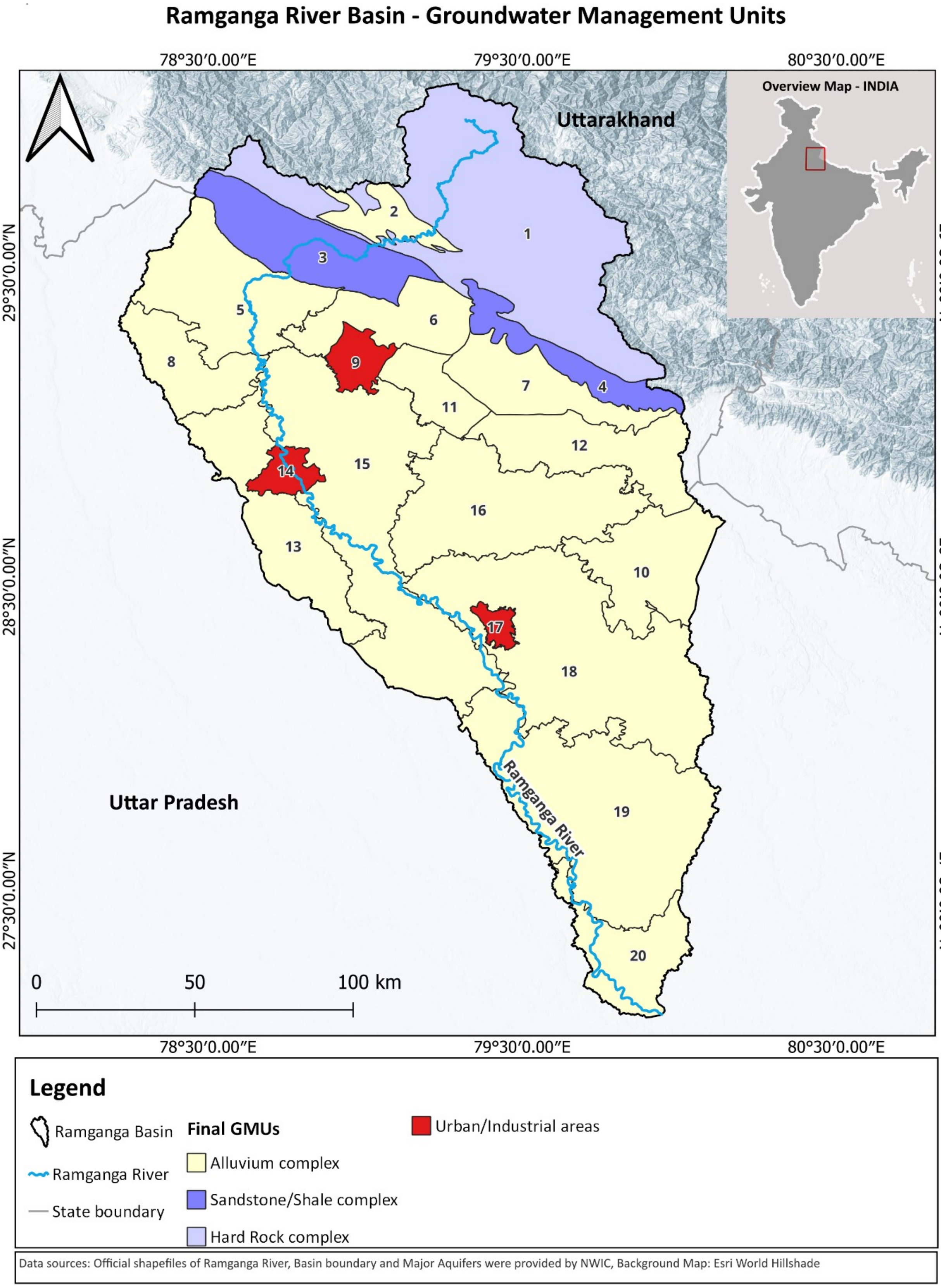
Below Table 20 summarises the salient features of GMUs.

Table 20: GMUs name, covered area, and population.

GMU No.	GMU code	State	Major Districts	Aquifer complex	Population 2022[10]	Area [km²]	Population density [persons/km²]
1	RG_UK_14_01	UK	Almora, Pauri Garhwal, Chamoli	Hard Rock	919,857	4,574	201
2	RG_UK_03_02	UK	Almora, Pauri Garhwal	Hard Rock	60,763	418	145
3	RG_UK_05_04	UK	Nainital, Pauri Garhwal	Sandstone /Shale	109, 706	1,342	82
4	RG_UK_04_04	UK	Nainital, Champawat	Sandstone /Shale	72,144	645	112
5	RG_UP_05_05	UP	Bijnor, Udham Singh Nagar	Alluvium	1,380,823	1,705	810
6	KS_UK_02_06	UK	Nainital	Alluvium	368,696	946	390
7	BK_UK_01_07	UK	Nainital, Udham Singh Nagar	Alluvium	466,119	971	480
8	GG_UP_05_08	UP	Bijnor	Alluvium	1,036,991	891	1,164
9	DH_UK_01_09	UK	Udham Singh nagar	Urban/Industrial	342,923	306	1,121
10	DH_UP_01_10	UP	Pilibhit	Alluvium	916,415	1,273	720
11	BA_UK_02_11	UK	Nainital, Udham Singh Nagar	Alluvium	384,785	541	711
12	DE_UP_03_12	UP	Udham Singh Nagar	Alluvium	884,825	1,292	685
13	GG_UP_08_13	UP	Amroha, Moradabad, Sambhal	Alluvium	1,760,440	1,577	1,116
14	RG_UP_01_14	UP	Moradabad	Urban/Industrial	1,248,958	249	5,016
15	RG_UP_11_15	UP	Moradabad, Rampur, Budaun, Bareilly	Alluvium	4,111,079	3,676	1,118
16	BG_UP_06_16	UP	Bareilly, Rampur, Pilibhit	Alluvium	1,866,308	2,248	830
17	DE_UP_01_17	UP	Bareilly	Urban/Industrial	1,212,927	131	9,259

[10] Population count is based on the census of year 2011, which is extrapolated to year 2022 with approx. 1% annual growth https://data.worldbank.org/country/IN

18	DE_UP_16_18	UP	Shahjahanpur, Bareilly, Pilibhit,	Alluvium	3,257,107	3,641	895
19	RG_UP_07_19	UP	Shahjahanpur, Hardoi, Budaun, Farrukhabad, Kheri	Alluvium	2,946,631	3,427	860
20	RG_UP_03_20	UP	Hardoi, Farrukhabad, Kannauj	Alluvium	698,807	986	709



Map 13: Ramganga Basin with Groundwater Management Units (GMUs)

Reference thresholds and rationale of the risk assessment

The risk if a SWMU or related river reaches are "at risk", "possibly at risk" or "not at risk" to fail the overall Ramganga RBM Vision and management objectives regarding water quality has been assessed using the water quality index (WQI). WQI is one of the most effective tools to monitor surface as well as groundwater pollution and can be efficiently used in the implementation of water quality upgrading programs (Alam and Pathak, 2010). The main objective of having a WQI is to convert complex multi-layered water quality data into simple information that is not only understandable but also commonly useable. A Water Quality Index (WQI) has already been defined by Central Pollution Control Board (CPCB) - the same WQI criteria have been applied in quantifying the WQI for the Ramganga River Basin Management Plan. According to the WQI criteria, there are six classes (see Table 21). The following list represents each class and its designated best use:

- Class A represents drinking Water Quality without conventional treatment but after disinfection.
- Class B is sufficient for outdoor bathing.
- Class C is relevant for drinking water sources but after conventional treatment and disinfection.
- Class D represents the threshold for the propagation of wildlife and fisheries.
- Class E represents irrigation, industrial cooling, and controlled waste disposal.

Class A is the highest class, meaning good water quality and all classes below class C are represented as 'Worse than C' which means poor water quality.

Table 21: Water Quality Index thresholds values (WQI; CPCB)

Water Quality Index Designated Best use	Water class	Total Coliforms Organism (MPN/100 ml)	Bio-chemical Oxygen Demand 5 days 20°C (mg/l)	pH		Dissolved Oxygen (mg/l)	Free Ammonia (mg N/l)	Electrical Conductivity at 25°C (micro mhos/cm)	Sodium absorption Ratio	Boron (mg/l)
		Equal or less than		Limits		No less than	Equal or less than			
Drinking water without conventional treatment but after disinfection	A	50	2.0	6.5	8.5	6				
Outdoor bathing (organized)	B	500	3.0	6.5	8.5	5				
Drinking water source after conventional treatment and disinfection	C	5000	3.0	6.0	9.0	4				
Propagation of wildlife and fisheries	D			6.5	8.5	4	1.2			
Irrigation, industrial cooling, controlled waste disposal	E			6.0	8.5			2250	26	2.0
	F	Not falling in any of above limit								

Source: adapted from https://cpcb.nic.in/water-quality-criteria/

The risk if a GMU or related blocks can be "at risk", "possibly at risk" or "not at risk" to fail the overall Ramganga RBM Vision and management objectives regarding groundwater quality follows water quality index and for quantity has been assessed using the latest ground water resource estimation report published by Central Groundwater Board.

Additionally, the general standards for discharge of environmental pollutants (effluents and wastewater) as per the Schedule VI of the Environment (Protection) Rules, 1986 has been considered and adhered to while defining the risk assessment thresholds.

5.3 Risk assessment for KWMI 1: Water quality deterioration due to point sources of pollution

Water quality deterioration has become a global health hazard due to the rapid increase in population as well as urbanization and industrialization. The exponential increase in population and large-scale rural migration has put a lot of pressure on surface water quality by increasing domestic effluents. Moreover, rapid industrialization and haphazard expansion of urban centers have resulted in the generation of an ample volume of industrial effluents (Srivastava et al., 2011; Singh, 2018).

Ramganga is a perennial river and a tributary of the very important and holy Ganga River. The water quality of the Ramganga River is deteriorating day-by-day and it is not suitable for direct human consumption. It has become a health hazard for the people living not only on the banks of the river, but also for people using the river waters directly or indirectly. The total stretch of the Ramganga River can be divided into three sections; (a) The upstream area; a fertile region, (b) The mild region; full of sand, and (c) The downstream region; mostly alluvial land and fertile (Srivastava et al., 2011).

The first Key Water Management Issue (KWMI 1) identified within the Ramganga Basin under the RBM Plan is related to water quality deterioration due to point sources (e.g., Pollution Source Units), resulting from anthropogenic activities and other pollution sources. The following sections highlight the step-by-step methodology, criteria adopted, datasets, documentary sources, limitation, and challenges for risk assessment for this KWMI.

Data Source

The data used in the risk assessment consist of SWAT model outputs and observed data. The SWAT model results consist of two water quality parameters (i.e., Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO)). Both are globally well-established indicators for pollution from point sources. Furthermore, observed water quality data of Total Coliforms Organism (TC-MPN), BOD, DO, Chemical Oxygen Demand (COD), Electrical Conductivity (EC), Sodium absorption ratio (Na%), and Boron (B) have been collected at some of the sampling sites within the Ramganga Basin by CWC, CPCB, UKPCB, and UPPCB (see Annex A1).

The list of data and their sources are summarized as follows:

- Biological Oxygen Demand (BOD) and Dissolve Oxygen (DO) are taken from the SWAT model output. Even though SWAT model provides the output data for last four decades, only the most actual data should be used to assess the current situation within the Ramganga River Basin. Therefore, the data from the last 10 years have been selected for this analysis. Deviating from other methods in this RBM Plan, the selected period is from 2011 to 2020, as data for 2021 and 2022 (which is the reference period in this RBM plan) were not available.

- Observed data of monitoring stations consist of total Coliforms Organism (Tcol-MPN), BOD, DO, Chemical Oxygen Demand (COD), Electrical Conductivity (EC), Sodium absorption ratio (NA%), and Boron (B). There are significant data gaps in the observations (see Annex A1).

5.3.1 Risk assessment approach, criteria, and thresholds

A point pollution risk assessment for a specific region indicates the magnitude or level of risk of a deterioration of surface water quality. The present assessment analyses the risk of a possible deterioration of surface water quality within the defined Surface Water Management Units (SWMUs) due to point pollution.

The risk assessment for the KWMI-1 considers the following two major risk categories:

- Water Quality evaluation based on water quality parameters (i.e., DO and BOD)
- Water quality indices based on SWAT output and validated against observed values.

The risk assessment criteria for assessing the surface water quality deterioration due to point source pollution (i.e., SWAT-based DO and BOD concentrations) within the Ramganga Basin are based on European standards[11], which were adapted to the Indian context by expert judgement.

Two different threshold values for the Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) have been selected (Table 22).

Dissolved Oxygen (DO)

Dissolved Oxygen is one of the key parameters in water quality assessment. To maintain different forms of aquatic life, the presence of DO is essential. Oxygen balance can be interpreted as the effect of wastewater discharged in a water body (Srivastava et al., 2011). In the context of Ramganga River Basin for the surface water quality assessment, a rather comprehensive DO evaluation approach has been adopted.

The frequency-duration-concentration approach: Concentrations of DO are classified based on the duration and frequency of its occurrence. This accounts for the time sensitivity of concentrations. For example, a short but low DO concentration (not lethal) can be tolerated by an aquatic system if there is enough time for recovery until the next low DO concentration occurs. Thresholds of what is tolerable and can be sustained by the aquatic ecosystem can be fixed based on the number of occurrences and duration of events per year. The thresholds reflect the ecosystem's capacity to recover. This method accounts for cumulative effects when unfavourable concentrations occur more often and is referred to as dose concept.

DO in the risk assessment of Ramganga Basin was classified by a statistical analysis of the DO time series, where events, the most frequent occurring class was selected, which means:

[11] DO: DWA - German association for water management M102-3 (2021) and BWK - Association of Engineers for Water Management, Waste Management and Land Improvement M3-3 (2021)
BOD: Oberflächengewässerverordnung – OgewV, Surface Water Ordinance (2016) and Ordinance on requirements for the discharge of wastewater into bodies of water (Wastewater Ordinance - AbwV) (1997)

- The maximum number of occurring class in the time series, where the DO concentration is more than four times in a year i.e., equal to or below 5 mg/l for consecutive three days in a row, is classified as 'At Risk'.
- The maximum number of occurring class in the time series, where the DO concentration is above 5 mg/l and below 8 mg/l for at least four times in a year for consecutive three days in a row, is classified as 'Possibly at risk'.
- The maximum number of occurring class in the time series, where the DO concentration is above 8 mg/l for more than four times in a year for consecutive three days in a row, is classified as 'No Risk'.

If for a specific reach above classifications are not fulfilled (i.e., Not Applicable), then, in this case, the median value of DO concentration (i.e., years 2011 – 2020) has been taken for that specific reach.

The analysis distinguishes the impact of DO on the ecosystem. For example, even long ongoing peak events for BOD do not necessarily lead to more harmful effects as long as DO stays high due to sufficient flow. The determination of thresholds takes lethal effects and recovery into account. If DO drops below a certain threshold, aquatic life comes to an ultimate end, almost regardless of the duration of the dropdown. Heavy damage to the ecosystem brings subsequently risk to human health (i.e., processes of decomposition may lead to the occurrence of toxic substances in the water which might be harmful to humans). The threshold values are generally accepted values for risk categorization of DO in terms of threshold to higher aquatic life-forms (vertebrates), such as many fish species[12]. The selection of classes is schematically displayed in Figure 15.

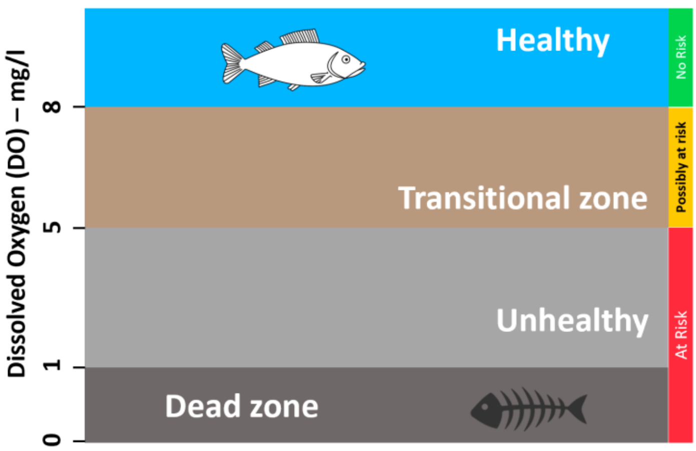


Figure 15: Effect of DO concentration on vertebrate's health and adoption to the Risk Classes

The dataset (i.e., SWAT results) used for this analysis is from the year 2011 to 2020. The method is explained below.

- DO data from the SWAT have been converted into mg/l using the discharge data, which were also provided by the SWAT model. The conversion has been done because the original output

[12] Food and Agriculture Organization of the United Nations (FAO). Fisheries Technical Paper. No. 86. Dissolved oxygen requirements of fresh-water, 1970.

of DO from the SWAT model is in kilograms (kg). This process has been adopted for all the 711 delineated reaches within the Ramganga Basin.

- DO concentrations have been classified based on the principle of frequency of occurrence as described above.
- For the classification of DO all SWAT DO timeseries for all reaches were scanned and evaluated according to the thresholds above
- The final Risk Assessment for Dissolved Oxygen (DO) was conducted by a statistical analysis of the DO time series as described above. The values of DO concentration (i.e., years 2011 – 2020) has been taken for each specific reach.
- Finally, the classification of the DO concentration for all 711 reaches has been done, then the results are transferred as shapefile to the GIS for better visualization.

Biological Oxygen Demand (BOD)

To assess organic pollution, BOD determination is the most relevant single test. BOD concentrations are an indication of the entry of organic waste into the river system. High values provide a hint about the presence of organic pollution (Srivastava et al., 2011). The BOD dataset (i.e., SWAT results) used for this analysis is from the year 2011 to 2020. The following steps have been taken to classify the BOD values:

- BOD concentrations have been classified based on the 90th percentile because it accounts for the constantly high BOD freight throughout the year, which still can be considered a substantial risk, as BOD could be the main cause for critical drops in DO concentration.
- Three different classifications for the BOD concentrations have been defined as follows:
  - If the 90th percentile BOD for a river reach is above 30 mg/l, this reach is considered to be 'At risk'.
  - If the 90th percentile BOD for a river reach is above 3 mg/l but less than or equal to 10 mg/l, this reach is classified as 'Possibly at risk'. (*The 3 mg/l threshold has been selected, considering the bathing criteria for WQI)*
  - If the 90th percentile BOD for a river reach is less than or equal to 6 mg/l, this reach is classified as 'No risk'.

The selected risk criteria for KWMI 1 risk assessment can be found in Table 22. The thresholds were selected by experts and the stakeholders via a consultation process and finalised during a meeting in Nainital dated September 6th, 2023.

Table 22: Risk Criteria for the Dissolved Oxygen and Biological Oxygen Demand

Water Quality Parameters	Risk criterion, point pollution sources in reaches		
	At risk	Possibly at risk	No risk
Dissolve Oxygen (DO) - (mg/l)	≤ 5	> 5 – ≤ 8	> 8
Biological Oxygen Demand (BOD) - (mg/l)	> 10	≥ 3 – ≤ 10	< 3

Note: BOD criteria are adapted are per bathing class norms. Severely polluted river stretches are classified as at risk with BOD greater than 10 mg/l.

Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD) is the amount of oxygen required for a sample to oxidize its organic and inorganic matter. This parameter test is quite reasonable in finding out the pollution concentration of industrial waste and sewage (Srivastava et al., 2011).

It is important to mention that pollution generated by wastewater should not be automatically associated with discharges into drains or river reaches. There are several steps in between and before the water finally finds its way to the river reach. The final situation will depend on the management of different fractions like containment, transport, treatment, and disposal. Additionally, percolation into surface waters, accumulation in soils, and self-degradation in the rivers reduce the actual load in surface waters (Tapi RBM plan, 2020). The COD risk classification has been taken from the Tapi RBM Plan, as this criterion has been defined while considering the Indian context as per the expert judgments (see Table 23).

Table 23: Risk Criteria for the Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) concentrations	Risk criterion, point pollution sources in SWMU		
	At risk	Possibly at risk	No risk
Accumulated COD load after treatment (urban + industrial) (mg/l)	≥ 45	≥ 30 – < 45	< 30

Source: adapted from Tapi RBM plan, 2020

As per this COD risk criteria, a river reach can be classified as 'At risk' if the COD load is greater than or equal to 45 mg/l and if the load is less than 30 mg/l then the river reach will be classified as 'No risk'. It is important to mention that only observed COD data for only three stations (i.e., Moradabad, Bareilly and Dabri) are available. The SWAT model does not provide information on COD concentration within the river reach.

5.3.2 Results from the Risk Assessment and possible impacts on water resources

The risk assessment for the KWMI-1, water quality deterioration due to point sources, works with multilayered criteria. Dissolved Oxygen (DO) is one of these layers. As indicated earlier, the risk assessment has been carried out individually for each of the 711 river reaches (Annexure A1 presents the result for each of 711 sub-basins' WQI).

Risk assessment for point-sources of pollution - Results based on Dissolved Oxygen (DO)
Overall, in terms of river reaches, approximately 39 % of the Ramganga River Basin is classified as 'At risk' where the DO is found to be less than 5 mg/l. In contrast, 25 % is classified as 'Possibly at risk' and the remaining 36 % as 'No risk' where the modelled DO concentration is found to be above 8 mg/l.

The maximum risk percentage is taken as threshold criteria to assign the risk classification for each SWMU. For example, out of 18, there are 8 SWMUs classified as 'At risk' and the same number are classified as at ‘No risk’. Only 2 SWMUs are classified as ‘possibly at risk’. In the case of only the main Ramganga river, 47.3 % is classified as ‘At risk’, 37.3 % as ‘Possibly at risk’ and only 15.4 % as at ‘No risk’.

Table 24 and Figure 16 shows the Percentage (%) of Ramganga Basin in different risk classes for DO. DO Risk assessment map of Ramganga Basin is given in Annexure A2.

Further, the second layer in the risk assessment for the KWMI-1 is the Biological Oxygen Demand (BOD). The reach-wise BOD results have been compiled that indicates, a major chunk of the river is either at ‘No risk’ or classified as ‘At risk’. The river stretch between Moradabad to Bareilly is mainly classified as ‘At risk’. It means that the 90-percentile value of BOD transport between this reach is above 10 mg/l. In case of BOD, most of the river reaches within the Ramganga Basin are classified as ‘No risk’, meaning the 90-percentile BOD is found to be less than 3 mg/l, which leads to some doubts about SWAT output data quality. The results for each river reach are also aggregated for the SWMU (Table 25). Figure 17 show the percentage (%) of Ramganga Basin in different risk classes for BOD. BOD Risk assessment map of Ramganga Basin is given in Annexure A1.

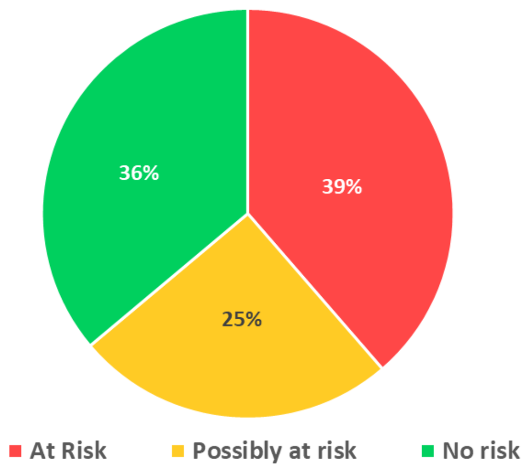
Results for Biological Oxygen Demand (BOD)
Overall, in terms of river reaches, approximately 45 % of the Ramganga River Basin is classified as ‘No risk’ where the 90-percentile BOD is found to be less than 3 mg/l. In contrast, 38 % is classified as ‘At risk’ and the remaining 17 % is classified as ‘Possibly at risk’ where the modelled BOD concentration is found to be between 3 to 10 mg/l.

The reach-wise combined (i.e., DO and BOD) results have been compiled and if any of the overlapping river reach of BOD is at ‘No risk’ and DO reach is ‘At risk’ then the combined result will show that reach as ‘At risk’. Map 14 depicts the risk assessment results combining DO and BOD risk assessment. While Table 26 lists the kilometer stretch in different risk category in Ramganga Basin, Figure 18shows the percentage (%) of Ramganga Basin in different risk classes for combined DO and BOD.

Combined results (BOD and DO)
Overall, accordingly, the combined results of DO and BOD show 44 % of the Ramganga river reaches are classified as ‘At Risk’ that means, in these river reaches DO is less than or equal to 5 mg/l and BOD is greater than 10 mg/l. There are some reaches where the Ramganga River is classified as ‘No risk’ or ‘Possibly at risk’. For example, 24 % of reaches are classified as ‘Possibly at risk’ (i.e., DO = **> 5 – ≤ 8 mg/l and BOD =** ≥ 3 – ≤ 10 mg/l**)**, and the remaining 32 % are classified as at ‘No risk’ (i.e., DO > 8 mg/l and BOD = < 3 mg/l).

Table 24: Dissolve Oxygen – Risk assessment of surface water pollution – river reaches in kilometres

SWMUs	River reach at risk (km)				Percentage of SWMUs at risk - Dissolve Oxygen (DO) (%)				Risk Classes (DO)
	At Risk	Possibly at risk	No risk	No Data	At Risk	Possibly at risk	No risk	No Data	
1	43	62	80	0	23.4	33.5	43.1	0.0	No risk
2	132	23	118	0	48.3	8.4	43.3	0.0	At Risk
3	136	104	84	0	41.9	32.2	26.0	0.0	At Risk
4	83	93	184	0	23.2	25.8	51.0	0.0	No risk
5	134	177	58	0	36.3	47.9	15.8	0.0	Possibly at risk
6	84	85	84	0	33.1	33.6	33.3	0.0	Possibly at risk
7	140	131	399	0	20.9	19.6	59.5	0.0	No risk
8	230	125	190	0	42.3	22.9	34.8	0.0	At Risk
9	246	180	113	0	45.7	33.3	21.0	0.0	At Risk
10	201	81	125	4	48.9	19.7	30.4	1.1	At Risk
11	290	25	19	0	86.7	7.4	5.8	0.0	At Risk
12	491	252	140	8	55.1	28.2	15.7	0.9	At Risk
13	101	106	169	0	26.9	28.2	44.9	0.0	No risk
14	187	210	287	0	27.3	30.8	41.9	0.0	No risk
15	129	118	231	0	27.1	24.7	48.3	0.0	No risk
16	89	74	137	0	29.5	24.8	45.7	0.0	No risk
17	642	235	260	11	55.9	20.5	22.6	1.0	At Risk
18	142	73	421	0	22.4	11.5	66.2	0.0	No risk
	Total				Average				
Ramganga Basin	3,502	2,154	3,100	24	38.6	25.2	36.1	0.2	

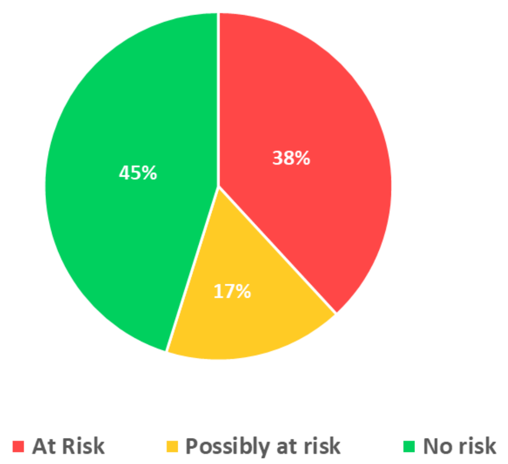


Note: This pie-chart represents the average percentage of river lengths classified with different risk classes within the Ramganga Basin.

Figure 16: Dissolve Oxygen – Risk assessment of surface water pollution – Ramganga Basin

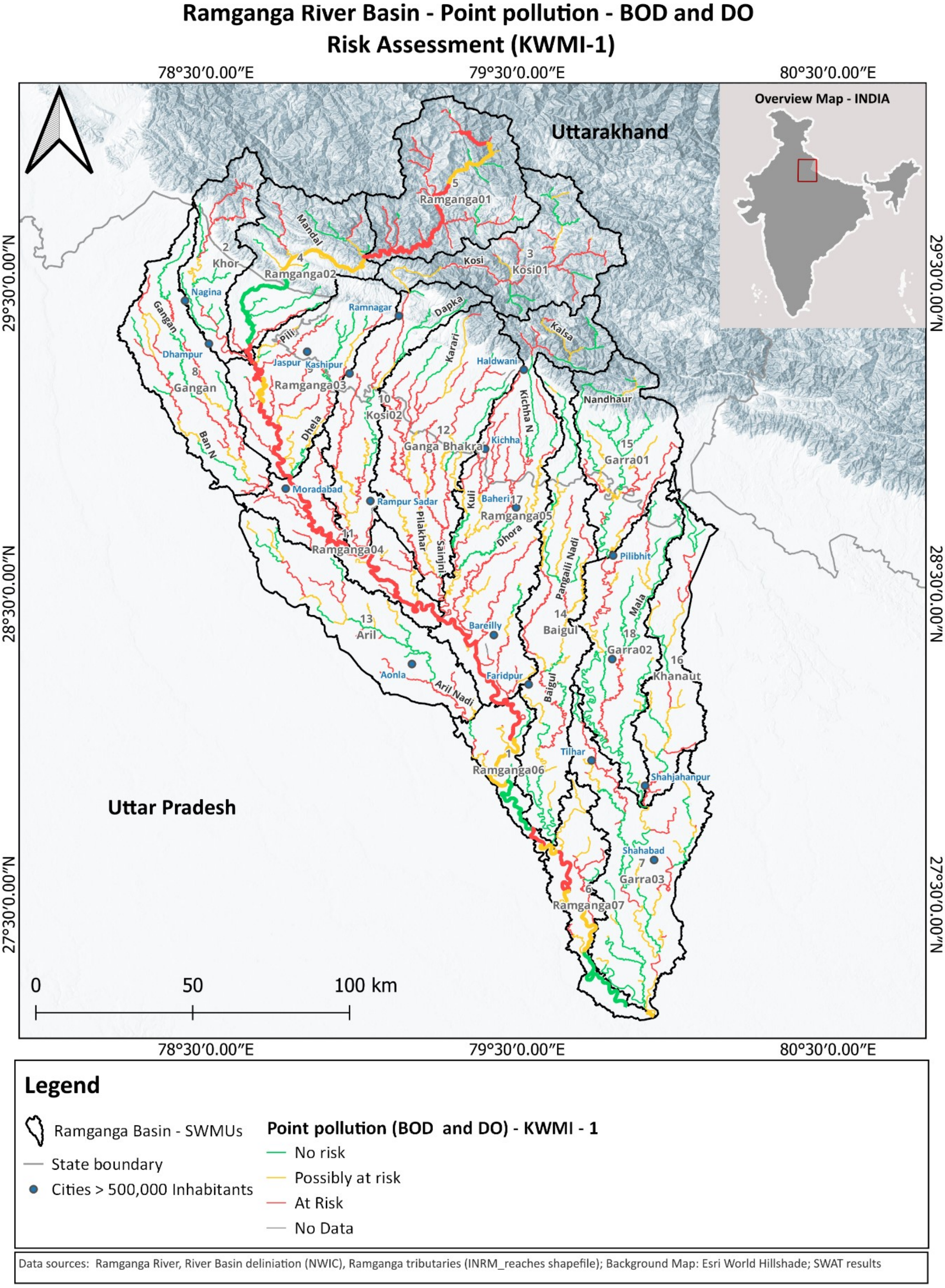
Table 25: Biological Oxygen Demand – Risk assessment of surface water pollution – river reaches in kilometres

SWMUs	River reach at risk (km)				Percentage of SWMUs at risk – Biological Oxygen Demand (BOD) (%)				Risk Classes (BOD)
	At Risk	Possibly at risk	No risk	No Data	At Risk	Possibly at risk	No risk	No Data	
1	46	48	92	0	24.8	25.8	49.4	0.0	No risk
2	132	0	141	0	48.3	0.0	51.7	0.0	No risk
3	157	74	93	0	48.3	22.9	28.8	0.0	At Risk
4	96	11	253	0	26.7	3.1	70.2	0.0	No risk
5	218	40	111	0	59.2	10.8	30.0	0.0	At Risk
6	65	77	111	0	25.5	30.6	43.8	0.0	No risk
7	148	80	442	0	22.1	11.9	65.9	0.0	No risk
8	208	58	278	0	38.3	10.7	51.0	0.0	No risk
9	228	139	172	0	42.3	25.8	31.9	0.0	At Risk
10	184	59	165	4	44.6	14.3	40.0	1.1	At Risk
11	278	31	25	0	83.2	9.4	7.4	0.0	At Risk
12	425	161	296	8	47.7	18.1	33.2	0.9	At Risk
13	124	80	174	0	32.8	21.2	46.1	0.0	No risk
14	153	158	372	0	22.4	23.1	54.4	0.0	No risk
15	86	137	255	0	18.0	28.7	53.4	0.0	No risk
16	82	69	149	0	27.4	22.9	49.7	0.0	No risk
17	625	105	407	11	54.4	9.2	35.4	1.0	At Risk
18	122	77	438	0	19.1	12.1	68.8	0.0	No risk
	Total				Average				
Ramganga Basin	3,377	1.405	3,973	24	38.1	16.7	45.1	0.2	



Note: This pie-chart represents the average percentage of river lengths classified with different risk classes within the Ramganga Basin.

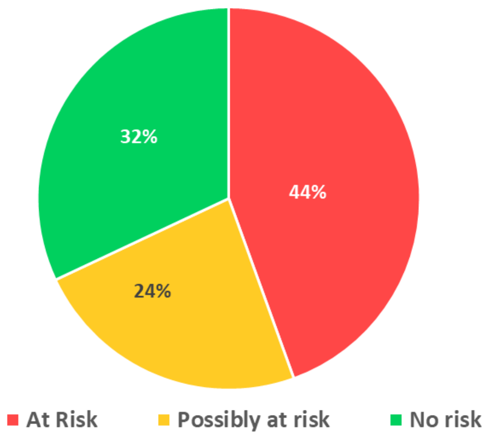
Figure 17: Biological Oxygen Demand – Risk assessment of surface water pollution – Ramganga Basin



Map 14: Reach-wise combined DO and BOD risk assessment – Ramganga River Basin

Table 26: Combined results (BOD and DO) – Risk assessment of surface water pollution – river reaches in kilometres

SWMUs	River reach at risk (km)				Percentage of SWMUs at risk – (BOD+DO) (%)				Risk Classes (BOD+DO)
	At Risk	Possibly at risk	No risk	No Data	At Risk	Possibly at risk	No risk	No Data	
1	46	75	65	0	24.8	40.3	34.8	0.0	Possibly at risk
2	132	23	118	0	48.3	8.4	43.3	0.0	At Risk
3	180	68	77	0	55.5	20.9	23.7	0.0	At Risk
4	96	80	184	0	26.7	22.3	51.0	0.0	No Risk
5	281	33	55	0	76.1	9.0	14.9	0.0	At Risk
6	91	115	47	0	35.9	45.6	18.5	0.0	Possibly at risk
7	148	174	349	0	22.1	25.9	52.0	0.0	No Risk
8	251	104	190	0	46.0	19.1	34.8	0.0	At Risk
9	303	125	111	0	56.2	23.2	20.6	0.0	At Risk
10	216	85	107	4	52.3	20.6	26.1	1.1	At Risk
11	297	37	0	0	88.9	11.1	0.0	0.0	At Risk
12	513	230	140	8	57.6	25.8	15.7	0.9	At Risk
13	142	92	144	0	37.6	24.3	38.1	0.0	No Risk
14	189	243	252	0	27.6	35.6	36.8	0.0	No Risk
15	129	127	221	0	27.1	26.6	46.3	0.0	No Risk
16	98	97	106	0	32.5	32.3	35.2	0.0	No Risk
17	668	243	226	11	58.2	21.2	19.7	1.0	At Risk
18	165	69	403	0	25.9	10.8	63.3	0.0	No Risk
	Total				Average				
Ramganga Basin	3,943	2,020	2,793	24	44.4	23.5	31.9	0.2	

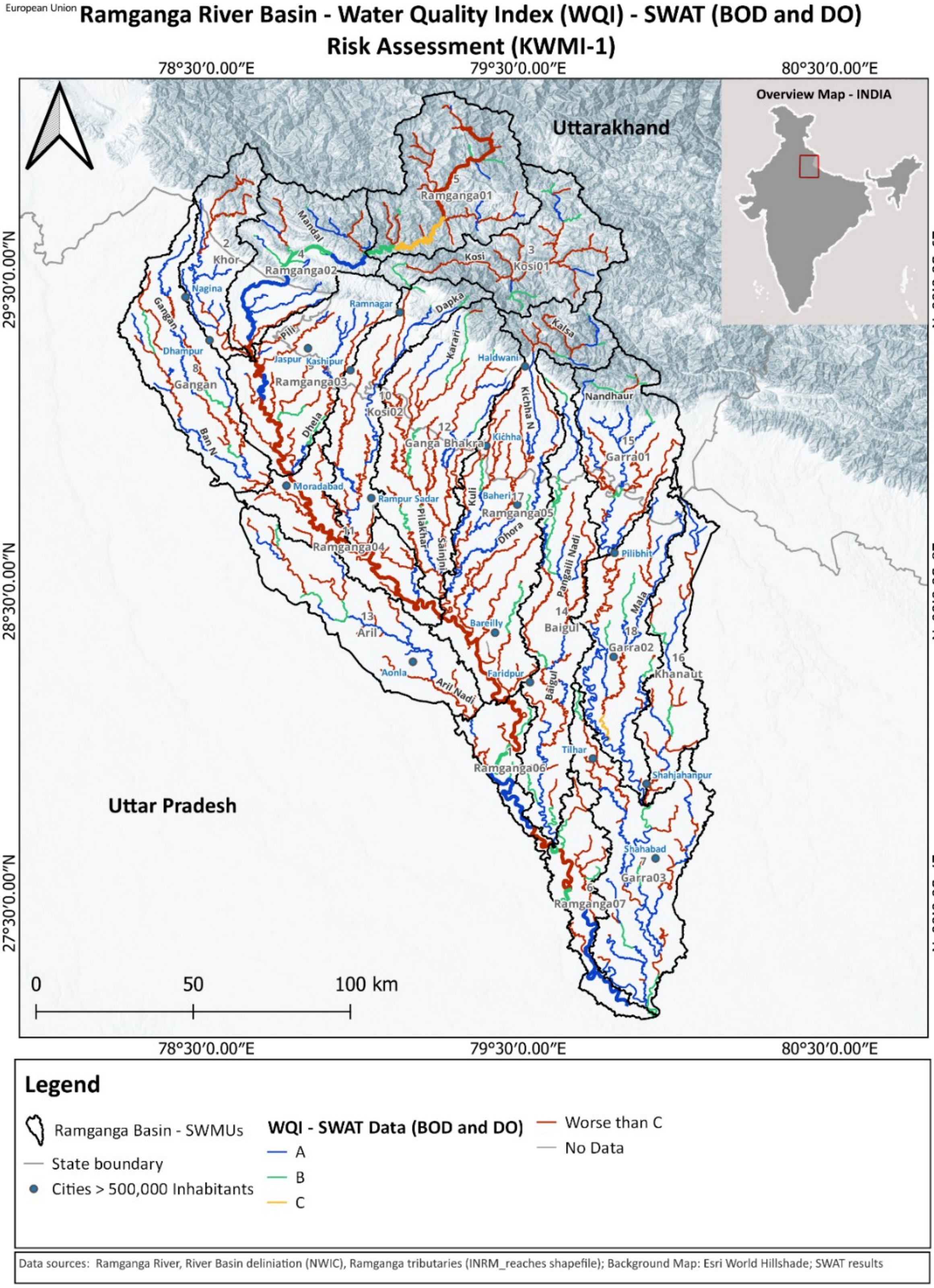


Note: This pie-chart represents the average percentage of river lengths classified with different risk classes within the Ramganga Basin.

Figure 18: Combined results (BOD and DO) – Risk assessment KWMI-1 – Ramganga Basin

A Water Quality Index (WQI) evaluation based on SWAT data (i.e., only DO and BOD) has been done (see Map 15). For the RBMP Risk Assessment, the purpose of assigning WQI to each reach within the Ramganga Basin is to have a broader idea about the WQI on the basin level. It is important to mention that the thresholds in WQI for BOD and DO (see Table 21**Error! Reference source not found.**) are different compared to the risk thresholds (see Table 22). It implies that it is not directly comparable with risk assessment results for each SWMU.

According to these WQI results, more than 50 % of the reaches have been classified with a WQI of 'worse than C', meaning the water is not safe (Figure 19). About 10 % of the reaches are categorized with a WQI of B. Only about 34 % of the river reaches are classified with a WQI of A (see Table 27 and Map 15). It means that the water from these reaches can be used after passing through the disinfection process. As these results are based only on BOD and DO values, it is recommended to interpret these reach-wise WQI results with due caution and keeping in account the local conditions as well as expert knowledge should be taken into consideration. In the case of only the Ramganga River (i.e., thick line on the map) the WQI percentages per reach are as follows, A = 22.7 %, B = 19.1 %, C = 3.8 %, and Worse than C = 54.3 %. It is also critically important to mention that some of the WQI results are not plausible. For example, the river reaches in the SWMU number 3, 4 and even 5 are located at a very high elevation but most of these reaches are classified with a WQI of 'worse than C' which also point towards the presence of a high degree of uncertainties in the input data and its final interpretation shall be done with due caution. A detailed WQI evaluation for each of the 711 sub-catchments (SWAT output) has been provided in Annex A1.

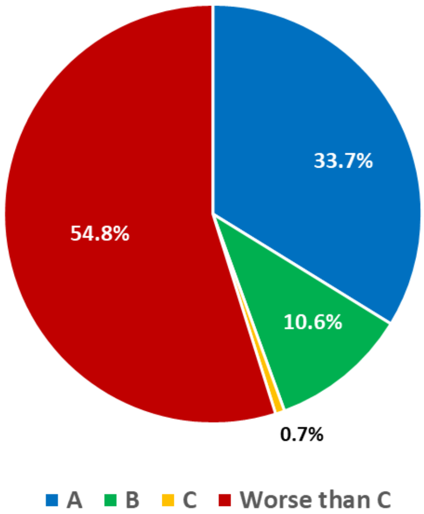


Map 15: Reach-wise Water Quality Index (SWAT-based DO and BOD) – Ramganga River Basin

Table 27: Aggregated WQI per SWMU based on DO and BOD (SWAT data) – Ramganga River Basin

SWMUs	River reach with WQI (km)					Percentage river reach with WQI (%)					WQI[13]
	A	B	C	Worse than C	No Data	A	B	C	Worse than C	No Data	
1	52.1	39.4		93.7		28.1	21.3	0.0	50.6	0.0	Worse than C
2	141.0	0.3		131.9		51.6	0.1	0.0	48.3	0.0	A
3	33.6	59.6		230.7		10.4	18.4	0.0	71.2	0.0	Worse than C
4	206.1	46.9		107.4		57.2	13.0	0.0	29.8	0.0	A
5	36.3	37.2	37.3	258.0		9.8	10.1	10.1	70.0	0.0	Worse than C
6	62.9	48.0		142.1		24.9	19.0	0.0	56.2	0.0	Worse than C
7	366.5	75.9		228.4		54.6	11.3	0.0	34.1	0.0	A
8	228.1	49.6		266.8		41.9	9.1	0.0	49.0	0.0	Worse than C
9	127.0	44.8		367.5		23.6	8.3	0.0	68.1	0.0	Worse than C
10	151.8	13.1		242.9	4.4	36.8	3.2	0.0	58.9	1.1	Worse than C
11	24.9			309.4		7.4	0.0	0.0	92.6	0.0	Worse than C
12	183.7	112.5		586.6	8.1	20.6	12.6	0.0	65.8	0.9	Worse than C
13	133.8	39.9		203.3		35.5	10.6	0.0	53.9	0.0	Worse than C
14	240.7	131.4		311.5		35.2	19.2	0.0	45.6	0.0	Worse than C
15	209.0	45.9		222.8		43.8	9.6	0.0	46.6	0.0	Worse than C
16	115.3	34.0		150.9		38.4	11.3	0.0	50.3	0.0	Worse than C
17	330.9	75.8		730.0	11.3	28.8	6.6	0.0	63.6	1.0	Worse than C
18	371.2	49.6	17.2	198.5		58.3	7.8	2.7	31.2	0.0	A
	Total					Average					
Ramganga Basin	3,015	904	55	4,782	24	33.7	10.6	0.7	54.8	0.2	

[13] Total WQI per SWMU is based on the maximum percentage of WQI within the SWMU. Results are based on DO and BOD values only and thus have high degree of uncertainty and are rudimentary in nature. Finally, WQI for a SWMU can only be assigned by verified water quality samples collected in the field. These results would have been more valuable if all WQI parameters were available through the SWAT model.

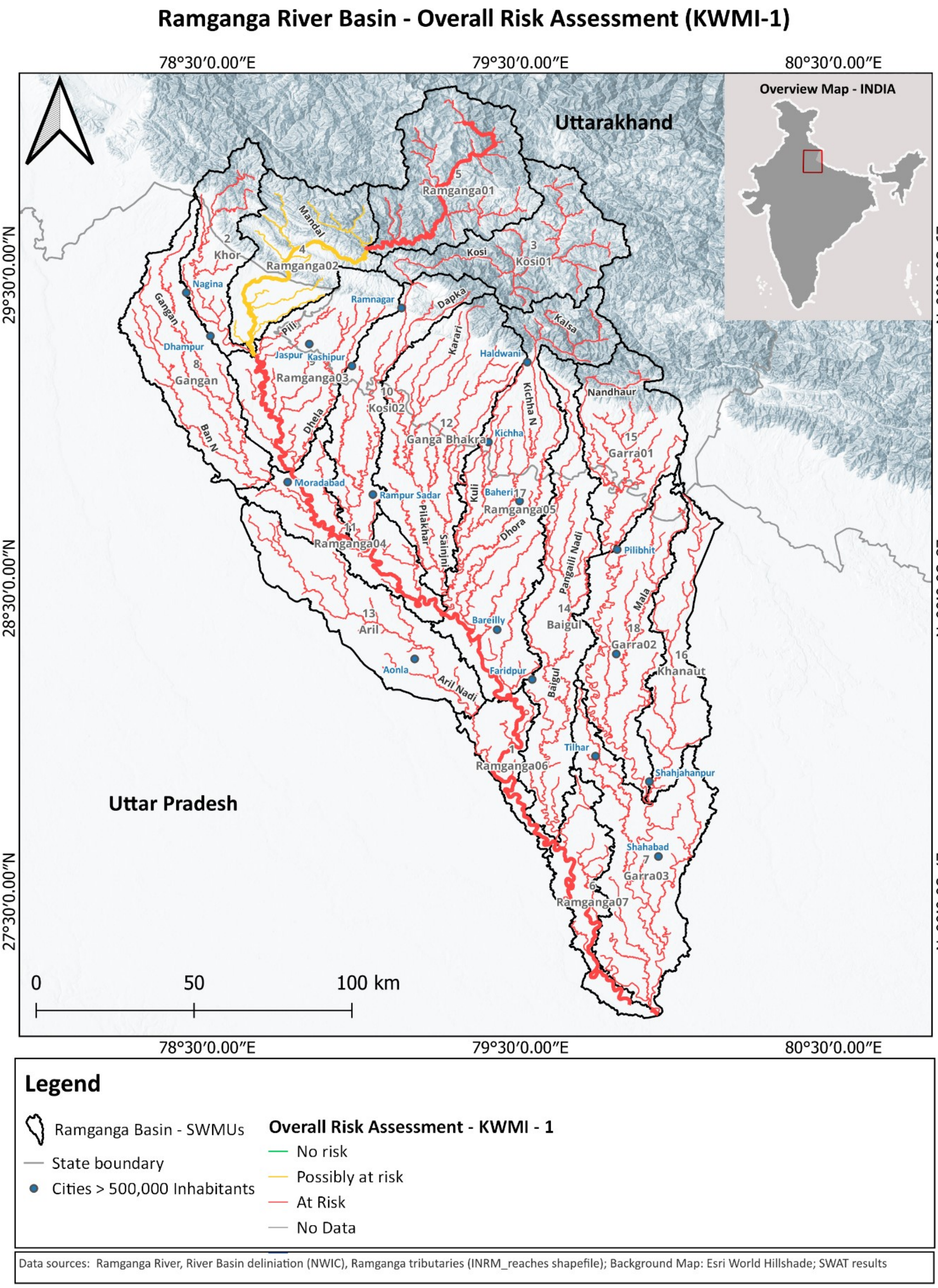


Note: This pie-chart represents the average percentage of river lengths classified with different WQI classes within the Ramganga Basin.

Figure 19: WQI results based on SWAT output (DO and BOD) – Ramganga River Basin

The final step is related to the overall summarized risk assessment in addition to consideration of the outcome from the KWMI-2 (i.e., non-point pollution risk assessment). **Error! Reference source not found.** shows the results from all previous steps (i.e., multi-layered criteria plus additional land use information) for the point source pollution risk assessment. These summarized results are based on Dissolved Oxygen, Biological Oxygen Demand and Water Quality Index results from the KWMI-1, as well as land use risk assessment results from the KWMI-2. If the results for a specific SWMU do not match, a conservative approach is taken to use the worst classification for that SWMU. In the final overall result of the risk assessment, 17 SWMUs are classified as ‘At risk’, 1 as ‘Possibly at risk’, and there is no SWMU which is classified as ‘No risk’.

Summarized risk assessment results – Point source pollution
To interpret this outcome in the context of river water quality, a map was created, highlighting the assignment of different risk classes based on point source pollution results (i.e., KWMI-1) for all tributaries in the Ramganga river basin including the main Ramganga River (see Map 16). In the case of Ramganga River (i.e., thick line in the map), 86% is ‘At Risk’ and 14 % is ‘Possibly at Risk’. Overall, for the complete basin with all tributaries, 96 % is ‘At Risk’ and 4 % is ‘Possibly at Risk’.



Map 16: Overall risk assessment results for KWMI-1 – Ramganga Basin

Challenges and data gaps relevant to KWMI 1

According to the findings in the Ramganga Basin, most of the surface water quality monitoring stations have a WQI of 'C' or 'Worse than C' (Annexure A1 lists the WQI based on both SWAT outputs and observed values). Also, it is important to note that there are many data gaps and this analysis of WQI is based on available datasets. If a water quality parameter value is not available for a station, it will not be considered for the Risk Assessment. These results may change in the future, depending on how the water quality management will be carried out for these monitoring stations.

The available WQI information is not optimal, and it is not as detailed as in the case of observed water quality data, where the data for more water quality parameters were available. But for the RBMP Risk Assessment, the purpose of assigning WQI to each reach within the Ramganga Basin is to have a broader idea about the WQI on the basin level.

Due to a lack of information about other WQI parameters, only the DO and BOD concentrations are used to assign a WQI to each reach within the Ramganga Basin. Of course, in the future when all WQI parameters are available from the SWAT model then the results can be revised. This surface water quality criterion can be improved by incorporating expert judgment and feedback from relevant stakeholders.

5.3.3 Limitation for risk assessment for KWMI 1: Challenges and Limitations

The SWAT model was used to have spatio-temporal data related to the overall hydrology of the basin including the risk posed by point sources of pollution (BOD and DO). On the other hand, the data on surface water quality was collected from the monitoring stations (Pollution control board data) on the Ramganga River that doesn't completely provide homogeneous information of the river system. To understand the linkages of water quality with hydrology and environment of each river reach and SWMUs use of a model or a robust monitoring system for water quality is needed.

Considering this, there is a need to create homogeneous information on the surface water quality parameters for better confidence level during the mid-term risk assessment of KWMI 1.

5.4 Risk Assessment for KWMI 2: Water quality deterioration due to non-point sources including agricultural activities

The second Key Water Management Issue (KWMI 2) identified within the Ramganga Basin is the risk posed by water quality deterioration due to non-point sources (i.e., area-based pollution) resulting from agricultural activities and other diffuse pollution sources. For the area-based pollution sources land-use, fertilizer and pesticides usage is considered as main indicators.

Data sources

The observed information used in this pressure impact analysis include land use, district-wise fertilizer, and pesticide usage. Furthermore, literature-based values of Mismanaged Plastic Waste (MMPW) were added to the risk assessment matrix. It is important to note that SWAT results related to 'organic Nitrogen and Phosphorus transported within the river reach' were also considered as a separate parameter of the risk assessment. Expert judgment from the concerned stakeholders is also an important factor for risk assessment results validation and finalisation.

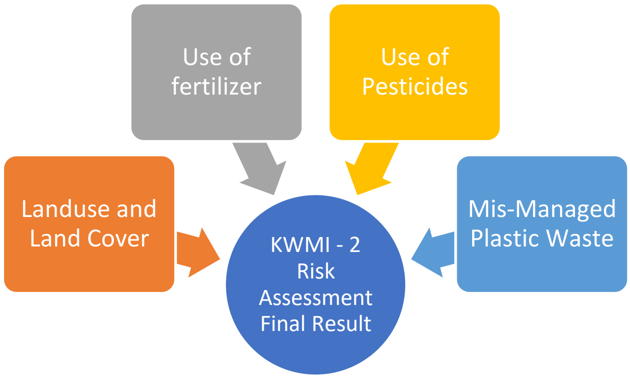


Figure 20: Factors for pressure-impact analysis related to non-point sources of pollution

Land use is a factor considered in the area-based pollution risk assessment. Agricultural activities for example have effects on water quality, due to the extent of soil-disturbing nature of those activities, and associated impacts from sediment, fertilisers, pesticides, and herbicides. The land uses that are exposed to such practices on regular basis offer potential risk to contribute to the failure of the vision and management objectives of the KWMI 2. The official land use[14] information has been used for the categorization of different risk classes.

Further, in this context the fertilizer use possess the risk to cause non-point pollution within the Ramganga Basin. District-wise fertilizer usage information for the Ramganga Basin is available for the years 2014 and 2015. The complete dataset can be found in Annex A2. This data has been used for further risk assessment. Further, the Nitrogen, Phosphorus and Potassium (NPK) fertilizer data is collected from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The fertilizer use data for Uttar Pradesh is available for the year 2014, whereas for the state of Uttarakhand, it is only available for the year 2015. The district-wise data for the Gross Cultivated Area (GCA) has been collected from the district contingency plan, prepared by the Department of Agriculture and Farmers Welfare (2008-09).

Data talks: Use of fertiliser-NPK in Ramganga Basin Sates

The NPK usage in the districts of Uttar Pradesh is significantly higher than in the Uttarakhand districts. In Uttar Pradesh, Nitrogen usage is in the range of approximately 110 – 181 (kg/ha), Phosphorus 32 – 53 (kg/ha), and Potassium 07 – 11 (kg/ha). In contrast, in the districts of Uttarakhand, the normal range for Nitrogen application is 02 – 14 (kg/ha) (some values as high as 144.5 (kg/ha) and 495.4 (kg/ha) in the districts of Nainital and Udham Singh Nagar). In the case of Phosphorus, application rates are in the range of 0.5 – 51 (kg/ha) and potassium in the range of 0.1 – 17 (kg/ha).

Also, district-wise pesticide use information for the Ramganga Basin is available for the years 2019-20, 2020-21, and 2021-22. The complete dataset can be found in Annex A2. This data has been used for the risk assessment related to pesticide usage.

[14] National Water Informatics Centre (NWIC) land use data

Insecticide data has been collated from the Agricultural Departments of Uttar Pradesh & Uttarakhand. Gross Cultivated Area (GCA) information is based on data of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), 2017 & Agriculture Contingency Plan for District 2008-09. Where ICRISAT data was unavailable at this source (namely, Amroha, Kannauj, US Nagar, Bageshwar, Champahat) then it was collected from the District Contingency Plan 2008-09 and for the Sambhal district the data was collected from UP agricultural department. It is important to mention that Uttarakhand data contains chemical insecticides only, while Uttar Pradesh data contains both chemical and biological pesticide use information.

Data Talks: Use of pesticides in the Ramganga Basin States

There is no characteristic trend observed. The average aerosol used in Uttar Pradesh is around 254.4 kg per thousand hectares compared to 97.0 kg per thousand hectares in UK. The use of fungicide in Uttarakhand (172.4 kg/000, ha) is higher compared to UP where it stands at 77.7 kg per thousand hectares. Weed and mouse controls are also used in both states. In UP average district-wise weed control use is around 137.4 kg per thousand hectares in comparison to UK where its usage is less than half of that amount (i.e., 56.4 kg/1000, ha). The average district-wise use of mouse control products is 3.4 and 4.9 kg per thousand hectares in both states, UK and UP respectively. The bio-pesticide use information is only available for UP, where the district-wise average use is 155.5 kg per thousand hectares of GCA. To see the spatial distribution of pesticide use, all available pesticide data has been mapped at district level.

Additionally, pollution from plastic debris is considered as one of the pressures that originates from land-based sources and is transported through rivers, finally ending up in the marine environment and damaging aquatic life. The Ramganga river is thus a pathway for plastic transport which will finally upset marine life. Keeping this in mind, mismanaged plastic waste has been considered as an additional factor for area-based pollution.

Pressure of Nitrogen and Phosphorus transport caused by Intensive agricultural activities in conjunction with population growth and urbanization have resulted in surface water quality deterioration by mobilizing nitrogen and phosphorus loads to the rivers (Wu and Chen, 2009). These nitrogen and phosphorus loads can be simulated using the SWAT model, which has the capacity to model nutrient balances in agriculture dominated watersheds. The outputs in the form of organic nitrogen (OrgN) and phosphorus (OrgP) loads for the Ramganga Basin modelling have been used as an input for developing the criteria for the area-based pollution risk assessment.

5.4.1 Risk assessment approach, criteria and possible impacts

Overall, for the risk assessment approach includes assessment of all factors contributing the key issue related to non-point sources of pollution. For this purpose of assessment is done using the following category of datasets:

- District-wise pesticide Data
- District wise fertiliser data - Risk due to Nitrogen and Phosphorus transport
- Mismanaged Plastic Waste data (MPW)
- Land-use data

Criteria and possible impacts

Non-point sources of pollution based on most exposed land-use type

Following the approach established earlier in one Indian river basin i.e. during development of Tapi RBM Plan, three (03) clubbed land use risk classes have been defined (see Table 28). These classes are identified based on their potential to generate non-point source pollution. Land use risk categories 1 (high risk) and 2 (possibly at risk) can be associated with the generation of area-based (diffuse) pollution depending on the intensity of fertilizers used in agriculture and the extent of urban and industrial activity. The third land use risk category consists of forest area and water bodies.

Table 28: Clubbed land use categories explanation and risk classification

Risk class	Risk categories for land use	Clubbed land use categories - explanation
1	At risk	**Built-up Area + Double Cropped Area + Perennial Crops** This land use class 1 poses the highest potential of diffuse (non-point) and point source pollution. The land use category 'built up area' includes urban, semi-urban, and rural areas as well as industrial and commercial establishments. The areas with double-cropped agriculture and perennial crops are supposed to be subject to intensive fertilizer and pesticide usage.
2	Possibly at risk	**Other Agriculture Area** This land use class 2 comprises all other agricultural activities (except double crops and perennial crops) and poses moderate potential for diffuse (non-point) and point source pollution.
3	No risk	**Forest Area, Water Bodies, Wasteland** This land use class 3 covers all other land use categories which are assumed to cause no risk of failing to meet the Ramganga RBM targets for surface water quality.

Classification and determination of threshold for land-use included:

- Categorization of land use using the GIS Tools (i.e., re-classified) into three risk classes as per available land use grid code information (see Annex A2).
- Overlay of land use categorised data with the SWMUs shapefile to calculate the overlapping risk area within each SWMU.
- Finally, using the defined clubbed land use risk assessment criteria (see Table 29) all areas and subsequently SWMUs were classified into different risk classes. Since no uniformly defined criteria for land use risk assessment is available, this risk criterion has been adopted from the Tapi RBM Plan 2020.
- A certain territory (and subsequently a SWMU) will be considered 'At risk' if the percentage of its clubbed area with land uses corresponding to risk category 1 is greater than or equal to 50% or if the percentage of its area corresponding to risk category 2 is greater than or equal to 75%.

Table 29: Risk assessment criteria to classify SWMUs based on risk of non-point sources of pollutions based on land use

Land uses and risk classification	Percentage of land use		
	At risk	Possibly at risk	No risk
Risk class 1: Built-up Area + Double Cropped Area + Perennial Crops	≥ 50%	≥ 20% – < 50%	< 20%
Risk class 2: Other Agriculture Area	≥ 75%	≥ 40% – < 75%	< 40%

Extensive use of fertilizer as a pressure for issue of non-point sources of pollution

The extensive use of fertilizers as part of the agricultural practise potentially lead to the deterioration of the surface water quality as the excess will be carried out along with the agricultural run-offs into various water resources.

A reasonable fertilizer use risk criteria was defined. Indian fertilizer use information has been collected from the website of CEIC: Global Economic Data, Indicators, Charts & Forecasts[15] for this purpose. From the yearly NPK fertilizer consumption for India for the last 12 years (2010-21), the average value was found to be around 131 kg/ha (combined value of all nutrients-NPK). Based on this information a fertilizer use risk class has been defined (see Table 30). Moreover, global and regional fertilizer consumption for the year 2020 based on World Bank data[16] were also compared. It seems that fertilizer consumption in India is higher (209.41 kg/ha) than in other South Asian countries (197.3 kg/ha) and the rest of the world (146.4 kg/ha).

This pressure factor for KWMI 2 is accounted for during the risk assessment for KWMI 2 using the following approach:

- In a second step district-wise fertilizer usage data were aggregated to SWMU-based fertilizer usage. District-wise NPK usage were overlayed with the SWMUs shapefile and SWMU-wise consumption for each nutrient component (N, P and K) was analysed. The data for each nutrient (N, P, and K) is separately available in Annex A2.
- Further, the summation of all NPK values for each SWMU was done and total consumption was calculated (Map 18).
- Finally, the total NPK consumption was categorized according to the risk criteria defined in Table 31.

Table 30: Historic fertilizer consumption India

Year	Fertilizer (NPK) consumption (kg/ha. a)
2010	135.3
2011	146.3
2012	130.8
2013	131.4
2014	118.5
2015	127.5
2016	130.7
2017	124.4
2018	127.6
2019	132.1
2020	127.8
2021	137.2
Average	130.8

[15]CEIC data Source: ceicdata.com/en/india/chemical-fertilizers-nitrogen-phosphate-and-potash-npk-consumption-per-hectare-by-regions/chemical-fertilizers-npk-consumption-per-hectare-all-india

[16] World bank data Source: https://data.worldbank.org/indicator/AG.CON.FERT.ZS?end=2020&start=2020&view=map

Table 31: Fertilizer usage risk classification

Risk class	At risk	Possibly at risk	No risk
Fertilizer (NPK) usage (kg/ha. a)	> 200	>130 – ≤ 200	≤ 130

Use of Pesticides as a pressure for issue for non-point sources of pollution

Reasonable use of pesticides is a key agricultural input that can help to protect seeds and safeguard agricultural outputs (crops) from unwanted plant diseases, pests, and insects (FAO, 2022). However, excessive use of pesticides not only is harmful for consumption and to human health but also has negative impacts on the environment. Excessive use of pesticides can also cause a reduction in crop yield.

On a global scale pesticide use is concentrated in certain world regions. For example, more than half of the globally used pesticides are utilized in Asia. India is in the 12th position in the ranking of global pesticide use and at the 3rd position in Asia according to Nayak and Solanki (2021). The Indian states Maharashtra and Uttar Pradesh account for 41% of India's pesticide consumption. It is worth mentioning that India applies fewer pesticides per hectare of cropland area than the global average. However, uncontrolled, and random pesticide usage can lead to the presence of pesticide residues in both natural and physical environments, ultimately impacting water quality. In contrast, bio-pesticides can be a suitable alternative to chemical pesticides (Nayak and Solanki, 2021).

A report published recently by the Food and Agriculture Organization of the United Nations (FAO) shows the United States of America at the top of the list of the largest users of pesticides with 408,000 tonnes in the year 2020, followed by Brazil and China. In this report India ranked 9th with a total pesticide use of 61,000 tonnes in the year 2020.

As per the global pesticide use per cropland area, India lies in the lowest pesticide per area usage band with the range of 0 – 1 kg/ha of pesticides used per cropland area. Moreover, the pesticide used in both Uttar Pradesh (UP) and Uttarakhand (UK) within the Ramganga Basin boundary has no fixed pattern. Annex A2 lists all different pesticide use information within the Ramganga Basin at district level. Map 19 represents, the total SWMU-wise pesticide use (i.e., the sum of all the available pesticides).

Excessive use of pesticide negatively impacts the surface water quality and is therefore, one of the factors considered during the risk assessment of the key issue related to non-point sources of pollution in the Ramganga Basin. The first step involved defining a reasonable pesticide use risk criteria based on which the risk assessment can be performed.

To define these criteria two datasets were considered:

- Literature-based (Indira Devi et al. 2017) information about the state-wise (i.e., UP and UK) pesticide consumption for 2012 – 2013 (Table 32).
- Historic pesticide usage indicators for India per hectare of cropland (years 1990 – 2020), based on recent FAO, 2022 statistics (see Annex A2).

Table 32: State-wise pesticides consumption

States	Pesticides consumption – kg/ha of GCA
Uttar Pradesh	0.545
Uttarakhand	0.304
Average	**0.4245**

As per the available information, state-wise average pesticide consumption is about 0.42 kg/ha of GCA. In comparison, India's average pesticide (i.e., chemical pesticides) consumption is around 0.30 kg/ha, which is well below the global average of 1.58 kg/ha (years: 1990 – 2020)[17]. Against this backdrop, a reasonable value of 0.50 kg/ha has been selected as a threshold for the pesticide use risk assessment in the Ramganga Basin. Table 33 represents the complete criteria for the risk assessment. If pesticide usage exceeds the value of 0.50 kg/ha, then it is classified as 'Possibly at risk', whereas a pesticide use of > 0.65 kg/ha comes under the 'At risk' category (see Table 14). It should be noted that these threshold values are not related to any one specific type of pesticide but to total pesticide usage.

Table 33: Pesticide usage risk classification limits

Risk class	At risk	Possibly at risk	No risk
Pesticides usage (kg/ha)	> 0.65	> 0.50 – ≤ 0.65	≤ 0.50

Further, the assessment approach for the pesticide usage that followed is summarised below:

- The aggregation and conversion of district-wise pesticide usage to SWMU-based pesticide usage was done. GIS tools were used to first intersect the district-wise pesticide usage with the SWMUs shapefile and then for each pesticide parameter SWMU-wise consumption was calculated.
- Summing up of all pesticide use values for each SWMU was done by using GIS Tools.
- Finally, the total pesticide consumption was categorized according to the defined criteria.

Pressure of plastic debris/waste as non-point source of pollution

The risk assessment for Mismanaged Plastic Waste (MMPW) in the Ramganga Basin is based on the findings of Schmidt et al. (2018), who have compiled data on plastic debris in the water column across a wide range of rivers of different sizes. The results show that plastic debris loads including microplastic (particles < 5 mm) and macroplastic (particles > 5 mm) are directly related to the mismanagement of plastic waste (MMPW) in river catchments. This correlation is non-linear in large rivers with population-rich catchments which deliver a disproportionately high fraction of MMPW into the sea. It is noteworthy that 88 – 95% of the global plastic load into the sea is carried by the top 10-ranked rivers (Schmidt et al., 2018). However, due to the lack of data a high uncertainty regarding the estimated plastic loads exists and, hence, the results for a specific river catchment must be considered with caution.

The global dataset of the ten top ranked rivers in a study by Schmidt et al. (2018) also includes the Ganga (as Ganges). The MMPW generation per capita for the Ganga River (0.013 kg d^{-1}) has been used as a base value for estimating the yearly plastic load in the Ramganga Basin (Annex A2).

The MMPW load for the Ramganga river basin has been estimated using the following approach:

- For each SWMU of the Ramganga Basin population of the year 2022 has been calculated. This is done by using the value (0.013 kg d^{-1}) for Ganga as mentioned above. This gives an estimated load of 4.75 kg yr^{-1}. For the sake of simplification, the estimated load of each SWMU has been converted to thousand tons/yr.
- The average value for the Ramganga Basin is about 6 thousand ton/yr which is considered as a threshold value for the risk assessment. If the value of MMPW generation for a SWMU is above the average (i.e., > 6 thousand tons per year) then this SWMU is classified as 'at risk',

[17] Source: https://www.fao.org/3/cc0918en/cc0918en.pdf; https://www.fao.org/faostat/en/#data/EP

and the SWMUs with values equal to or less than 3 thousand ton/yr are classified as at 'no Risk' (see Table 34)

Table 34: Risk classification for Mismanaged Plastic Waste

Mismanaged Plastic Waste	Risk classes		
	At risk	Possibly at risk	No risk
MMPW - [thousand tonnes / yr]	> 6.0	> 3.0 – ≤ 6.0	≤ 3.0

Pressure of Nitrogen and Phosphorus (Nutrient) transport

Agricultural activities in conjunction with population growth and urbanization have resulted in surface water quality deterioration by mobilizing nitrogen and phosphorus loads to the rivers (Wu and Chen, 2009) along with the agricultural run-off/ percolation. The concentration of organic Nitrogen (N) and Phosphorus (P) fractions added into the nearby water resources varies based on scenarios or conditions (Green and van Griensven, 2008). It is also well-established that different flow components may have varied contributions of mineral or organic nitrogen and phosphorus.

The risk assessment criterion for assessing the surface water quality deterioration due to non-point source pollution (i.e., SWAT-based organic N and P loads) within the Ramganga Basin are based on the results of the report 'Calculation of Emissions into Rivers in Germany using the MONERIS18 Model'19 (See Table 35) (Fuchs et al. 2010). Separate threshold values for nitrogen and phosphorus have been selected. In case, the nitrogen load is greater than 25 kg/ha. a then the SWMU is classified as 'at risk'. Values less than or equal to 5 kg/ha. a are classified as at 'no risk'. For the phosphorus loads the thresholds are relatively low. A SWMU is classified as 'at risk' of failing the objectives of the Ramganga RBM plan if the phosphorus load is greater than 0.2 kg/ha. a, and it will be considered as 'possibly at risk' if phosphorus loads are greater than 0.02 but less than or equal to 0.20 kg/ha. a. This is a preliminary criterion which can be revised by incorporating expert judgment and feedback from relevant stakeholders.

Table 35: Risk classification for Nitrogen and Phosphorus transport within a river reach

Nutrients (kg / ha. a)	Risk classes		
	At risk	Possibly at risk	No risk
Nitrogen (N)	> 25	> 5 – ≤ 25	≤ 5
Phosphorus (P)	> 0.2	> 0.02 – ≤ 0.20	≤ 0.02

5.4.2 Results from the Risk Assessment and possible impacts on water resources

The risk assessment for the KWMI 2 works with multi-layered criteria. Land use is one of these layers. Table 36 (column 5) and Map 17 represent all results related to land use risk class 1.

Non-point sources of pollution based on most exposed land-use type
In the case of land use risk class 1, out of 18 SWMUs, there are 4 SWMUs categorized as 'No risk', only 1 SWMU is classified as 'Possibly at risk' and the remaining 13 SWMUs are categorized as 'At risk'. For the land use risk class 2 all SWMUs are classified as 'No risk'.

[18] MONERIS: Modelling Nutrient Emissions in River Systems

[19] Report: https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4018.pdf

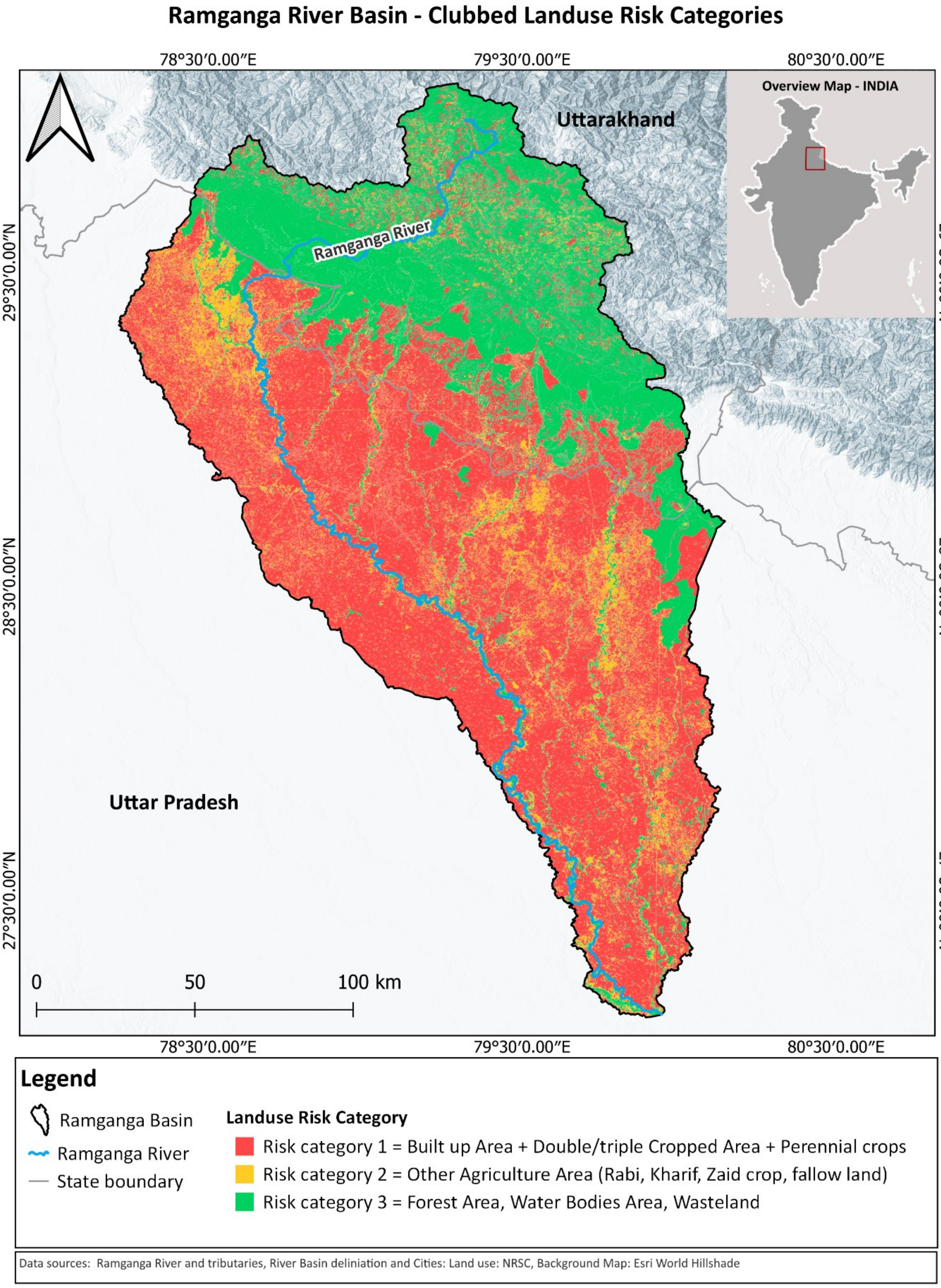
The combined results based on land use category in risk classes 1 and 2 can be found in Table 36 (last column). These results are obtained by overlaying the results of both risk classes 1 and 2. The final classification has been carried out based on the risk class which has a greater contribution towards the non-point (area-based) pollution (i.e., risk class 1).

As an additional calculation, percentage of agricultural land, built-up area and other land uses for each of the SWMUs can be found in Annex A2. The major land use in most of the SWMUs is agriculture. Nonetheless, for some of the SWMUs located in the Himalayan region, the agricultural area is small compared to other land uses. The SWMUs where agricultural activities are present to a lesser extent will bear less risk compared to the areas where agriculture is the major activity.

Table 36: Results of land use-based risk classification

SWMUs	Area percentages (%)			Risk assessment results		
	Risk class 1	Risk class 2	Risk class 3	Risk class 1	Risk class 2	Combined risk
1	71.8	14.7	13.5	At risk	No risk	At risk
2	19.9	28.1	52.0	No risk	No risk	No risk
3	8.8	10.7	80.5	No risk	No risk	No risk
4	17.2	12.1	70.7	No risk	No risk	No risk
5	15.9	13.7	70.4	No risk	No risk	No risk
6	68.2	18.2	13.6	At risk	No risk	At risk
7	76.2	17.2	6.5	At risk	No risk	At risk
8	70.8	26.6	2.6	At risk	No risk	At risk
9	56.8	15.7	27.4	At risk	No risk	At risk
10	59.6	10.8	29.6	At risk	No risk	At risk
11	79.5	15.8	4.7	At risk	No risk	At risk
12	66.9	9.4	23.7	At risk	No risk	At risk
13	89.5	9.9	0.6	At risk	No risk	At risk
14	71.6	16.5	11.9	At risk	No risk	At risk
15	41.2	7.9	50.8	Possibly at risk	No risk	Possibly at risk
16	60.9	13.8	25.3	At risk	No risk	At risk
17	55.4	17.6	27.0	At risk	No risk	At risk
18	55.0	27.5	17.5	At risk	No risk	At risk

Note: The colors for the SWMUs in **Error! Reference source not found.** are assigned based on the risk criteria percentages mentioned in **Error! Reference source not found.**. If an SWMU is classified as 'No risk (green color)' it does not mean that it belongs to risk priority class 3. Only the risk classes 1 and 2 have been assessed in this risk assessment. Class 3 poses no potential risk of non-point source pollution.



Map 17: Clubbed land use risk categories for the Ramganga Basin

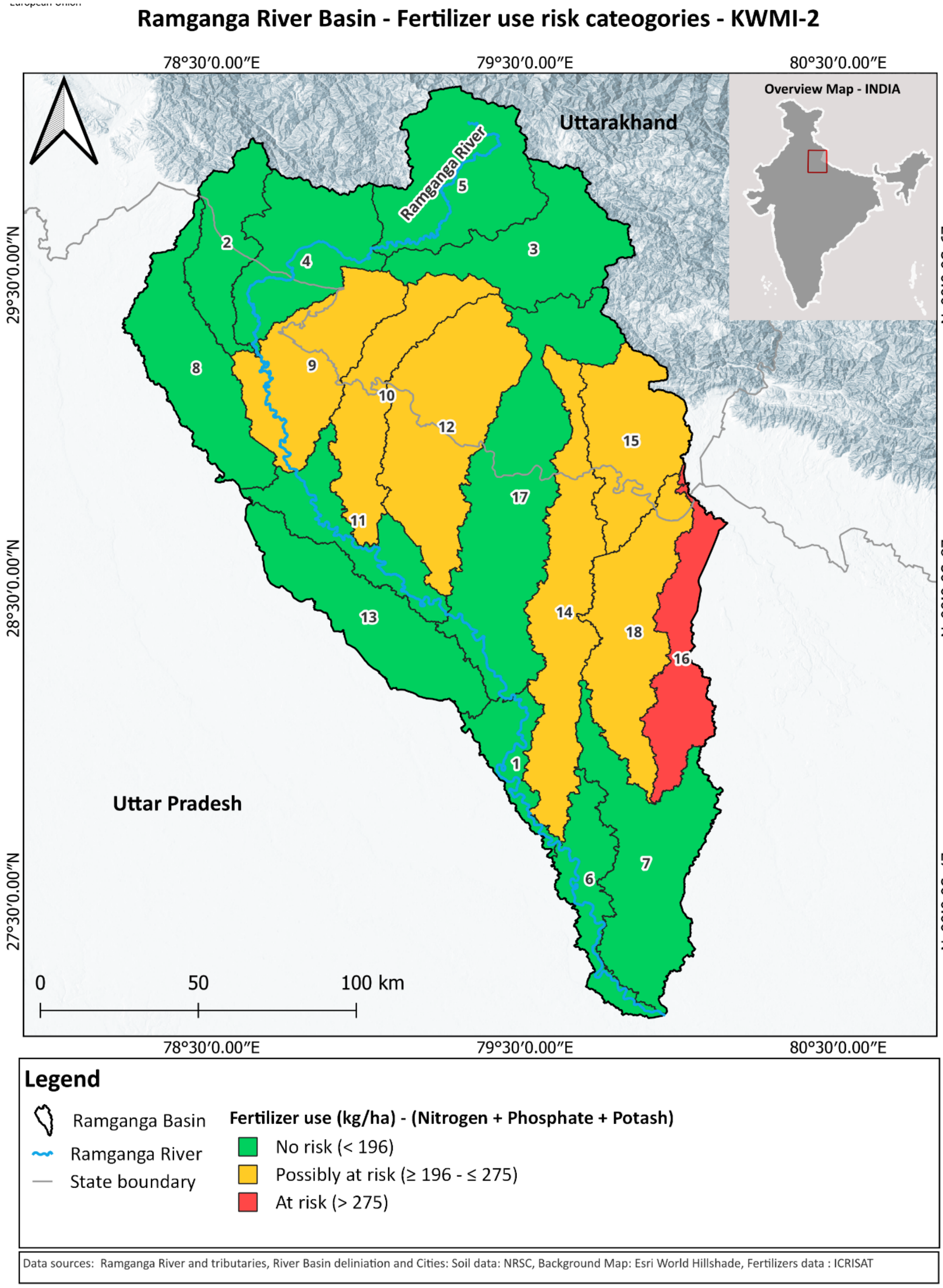
Results based on use of fertilizer

Fertilizer use
Overall, out of 18 SWMUs in the Ramganga Basin 11 SWMUs are classified as 'No risk' and 6 SWMUs are classified as 'possibly at risk' and only 1 SWMU is classified as 'At risk'. To summarize, 4% of the Ramganga Basin area and 3% of the Ramganga population will be at risk, whereas 37% of the Ramganga Basin area and 36% of the population will possibly be at risk. The remaining 59% of the basin area and 61% of the population fall into the 'No risk' category.

When translating these results into percentage of area and population affected with non-point sources of pollution such arising from use of fertilizer, then 4% of the Ramganga Basin area and 3% of the Ramganga population will be at risk, whereas 37% of the Ramganga Basin area and 36% of the population will possibly be at risk. The remaining 59% of the basin area and 61% of the population fall into the 'No risk' category (Table 37).

Table 37: Results of the fertilizer use risk assessment for each SWMU

SWMUs	Nitrogen (N)	Phosphorus (P)	Potassium (K)	$N+P_2O_5+K_2O$ (kg/ha)	Consumption level	Fertilizer use risk
	Fertilizer use (kg/ha)					
1	127.8	36.9	7.5	172.2	Below average	No risk
2	93.1	26.9	5.4	125.4	Below average	No risk
3	50.8	8.3	2.6	61.8	Below average	No risk
4	110.2	25.4	6	141.6	Below average	No risk
5	31.9	5.5	1.6	39	Below average	No risk
6	120.6	34.9	7.2	162.6	Below average	No risk
7	134.9	38.9	7.9	181.8	Below average	No risk
8	109.6	31.8	6.5	147.9	Below average	No risk
9	190.1	32.6	8.4	231.2	Above average	Possibly at risk
10	223.4	36.7	9.7	269.8	Above average	Possibly at risk
11	123.9	35.8	7.3	167.1	Below average	No risk
12	223.9	36.8	9.7	270.4	Above average	Possibly at risk
13	122.7	35.4	7.3	165.4	Below average	No risk
14	206.3	37.3	9.4	253	Above average	Possibly at risk
15	196	28.6	8.1	232.8	Above average	Possibly at risk
16	253.5	42.4	10.8	306.7	Above average	At risk
17	147.6	26.6	6.8	181	Below average	No risk
18	221.8	41	9.9	272.7	Above average	Possibly at risk



Map 18: Fertilizer use risk assessment per SWMU in the Ramganga Basin

As mentioned in the previous sections, pesticide use risk assessment results are categorized into three categories i.e., No risk, possibly at risk, and at risk. These risk classes have been assigned after assessing the pesticide consumption level. If in an SWMU (area-averaged value), the pesticide consumption level is below 0.50 kg/ha then it is classified as 'No risk' whereas if the consumption level is above 0.50 kg/ha then it is either classified as 'possibly at risk' or 'at risk' depending upon the difference of pesticide consumption range. Results presented in Table 38 and Map 19 are subject to change in case any other suitable criteria are applied. Overall, out of 18 SWMUs in the Ramganga Basin 5 SWMUs are classified as at 'No risk' and 5 SWMUs are classified as 'possibly at risk'. Whereas the remaining 8 SWMUs are classified as 'At risk'.

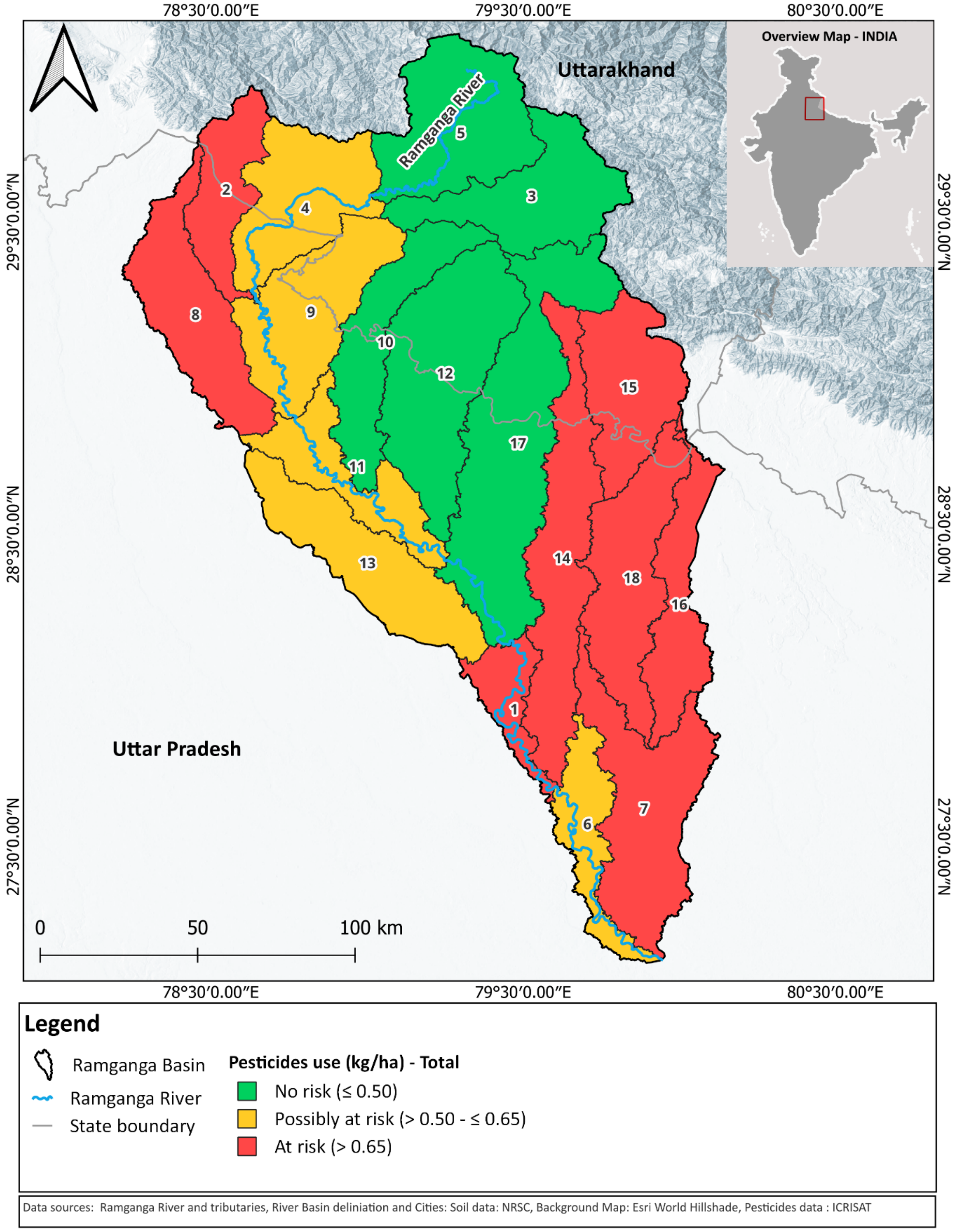
Result of risk assessment based on the use of pesticides
Overall, out of 18 SWMUs in the Ramganga Basin 5 SWMUs are classified as at 'No risk' and 5 SWMUs are classified as 'possibly at risk'. Whereas the remaining 8 SWMUs are classified as 'At risk'. To summarize, 40% of the area and 39% of the Ramganga population will be at risk, whereas 24% of the area and 28% of the population will possibly be at risk. The remaining 36% of the area and 33% of the Ramganga population are categorized under the 'No risk' category.

If these results are translated in terms of the percentage of the Ramganga Basin area and population affected due to the negative effect of pesticide consumption, then 40% of the area and 39% of the Ramganga population will be at risk, whereas 24% of the area and 28% of the population will be possibly at risk. The remaining 36% of the area and 33% of the Ramganga population are categorized under the 'No risk' category. A major portion of these SWMUs that are classified as 'At risk' is located within the lower part of the Ramganga Basin (i.e., in Uttar Pradesh).

Table 38: Results of pesticide use – risk assessment for each SWMU

SWMUs	Aerosol	Insecticides	Fungicides	Weed control	Mouse control	Biopesticide	Total	Pesticide use risk
	(kg/ha)							
1	0.23	0.04	0.06	0.14	0.01	0.19	0.66	At risk
2	0.31	0.13	0.20	0.07	0.01	0.07	0.78	At risk
3	0.08	0.08	0.10	0.03	0.00	0.00	0.29	No risk
4	0.22	0.10	0.14	0.06	0.01	0.05	0.57	Possibly at risk
5	0.10	0.12	0.17	0.03	0.00	0.00	0.43	No risk
6	0.22	0.07	0.07	0.12	0.00	0.17	0.65	Possibly at risk
7	0.22	0.05	0.06	0.14	0.01	0.20	0.67	At risk
8	0.26	0.09	0.14	0.09	0.01	0.08	0.66	At risk
9	0.18	0.08	0.12	0.09	0.00	0.04	0.51	Possibly at risk
10	0.15	0.05	0.07	0.09	0.00	0.04	0.41	No risk
11	0.22	0.05	0.08	0.09	0.00	0.13	0.56	Possibly at risk
12	0.18	0.05	0.08	0.10	0.00	0.08	0.49	No risk
13	0.20	0.05	0.07	0.10	0.00	0.13	0.56	Possibly at risk
14	0.21	0.07	0.09	0.18	0.01	0.12	0.68	At risk
15	0.17	0.11	0.14	0.18	0.00	0.05	0.66	At risk
16	0.26	0.10	0.11	0.25	0.01	0.13	0.85	At risk
17	0.15	0.07	0.10	0.10	0.00	0.07	0.49	No risk
18	0.26	0.08	0.11	0.22	0.01	0.15	0.82	At risk

Ramganga River Basin - Pesticides use risk cateogories - KWMI-2



Map 19 : Pesticide use risk assessment per SWMU in the Ramganga Basin

The results for MMPW have been summarized in Table 39 .It shows that 10 out of 18 SWMUs, which is more than 50%, are classified as 'At risk'.

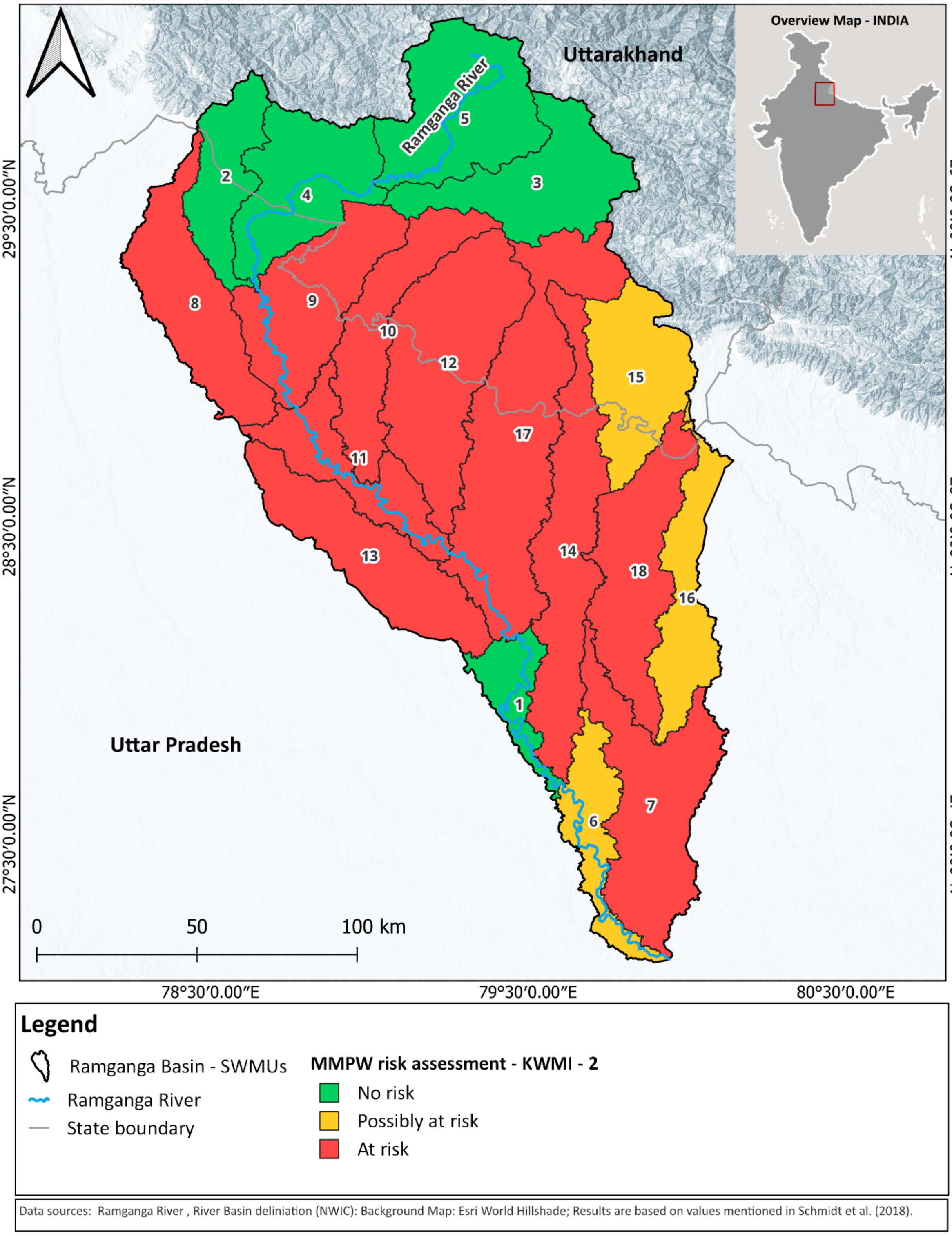
Results of risk assessment based on the factor: Mismanaged Plastic Waste
Overall, 10 out of 18 SWMUs are classified as 'At risk'. Only 3 SWMUs are classified as 'Possibly at risk' and 5 SWMUs are classified as at 'No risk'.

It is important to mention that these results are directly proportional to the population of SWMU. That means the greater the population of a SWMU, the higher the MMPW generation rate will be and, subsequently, the SWMU is likelier to be classified as 'At risk' of failing to achieve the objectives of Ramganga RBM Plan. Following the results presented in Table 39, a risk assessment map for MMPW generation in the Ramganga Basin has been prepared which provides a spatial overview of risk classification for different SWMUs (see Map 20).

Table 39: Risk assessment results for the Mismanaged Plastic Waste (MMPW)

SWMUs	Ramganga Basin Population-2022	MMPW [thousand, tons / yr]	Average Level	Risk
1	396,565	1.9	Below	No risk
2	632,038	3.0	Below	No risk
3	389,862	1.9	Below	No risk
4	381,469	1.8	Below	No risk
5	392,395	1.9	Below	No risk
6	653,082	3.1	Below	Possibly at risk
7	1,809,882	8.6	Above	At risk
8	1,761,679	8.4	Above	At risk
9	1,595,623	7.6	Above	At risk
10	1,460,619	6.9	Above	At risk
11	2,304,518	10.9	Above	At risk
12	1,648,282	7.8	Above	At risk
13	1,879,599	8.9	Above	At risk
14	1,528,120	7.3	Above	At risk
15	624,294	3.0	Below	Possibly at risk
16	673,239	3.2	Below	Possibly at risk
17	4,058,211	19.3	Above	At risk
18	1,856,827	8.8	Above	At risk
Total	**24,046,304**	**114.2**		

Ramganga River Basin - Mismanaged Plastic Waste (MMPW) - Risk Assessment



Map 20: Mismanaged Plastic Waste risk assessment per SWMU in the Ramganga Basin

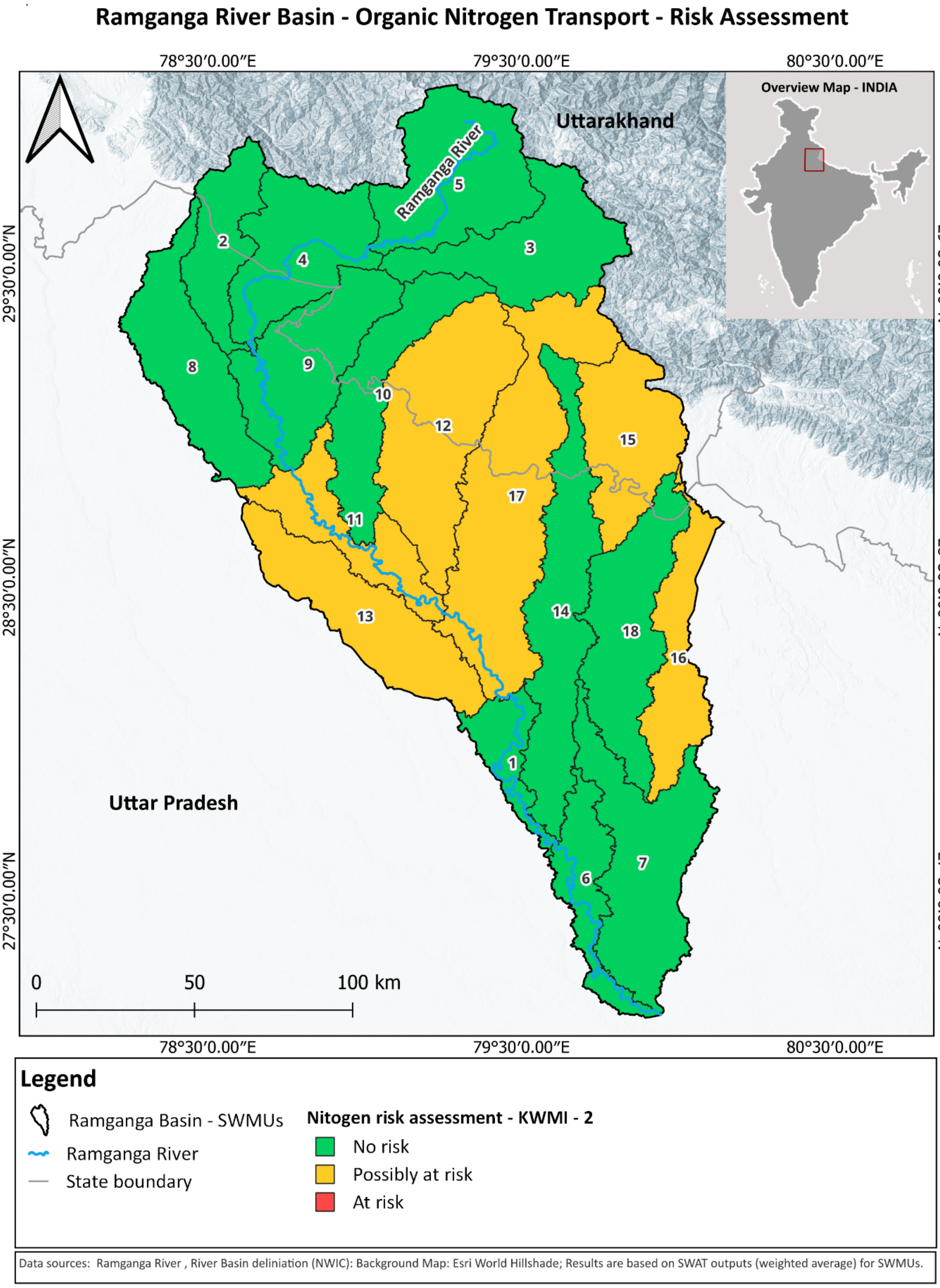
Nitrogen and Phosphorus (Nutrients) transfer as non-point sources of pollution - SWAT results
In the case of organic nitrogen (N) only 6 SWMUs are classified as ‘Possibly at risk’, the remaining 12 SWMUs are classified as at ‘No risk’. Interestingly, none of the SWMUs is classified as ‘At risk’. The results for organic phosphorus (P) indicate that 15 SWMUs are at ‘high risk’ and only 3 SWMUs are classified as ‘Possibly at risk’.

It is important to note that no SWMU is classified as at ‘No risk’ (see Table 40). Consequently, the risk of failing to meet the Ramganga RBM objective is higher considering the organic phosphorus criterion. Results for the two nutrients (i.e., nitrogen and phosphorus) have also been mapped in Map 21 (Nitrogen) and Map 22 (Phosphorus). The results for organic N and P are relatively inconsistent for the different SWMUs. For example, a SWMU is classified as at ‘No risk’ for ‘organic N’ and at the same time it is classified as ‘at risk’ for transporting higher ‘organic P’ loads. Surprisingly, these results from the SWAT model show that there are higher phosphorus loads in the Himalayan region (i.e., SWMUs 3, 4 and 5). In this context, it is important to analyse and interpret these modelled nutrients results with caution considering these differences. These results cannot be directly compared with the observed data. Hence, the results based on observed data will be used for further definition of PoMs.

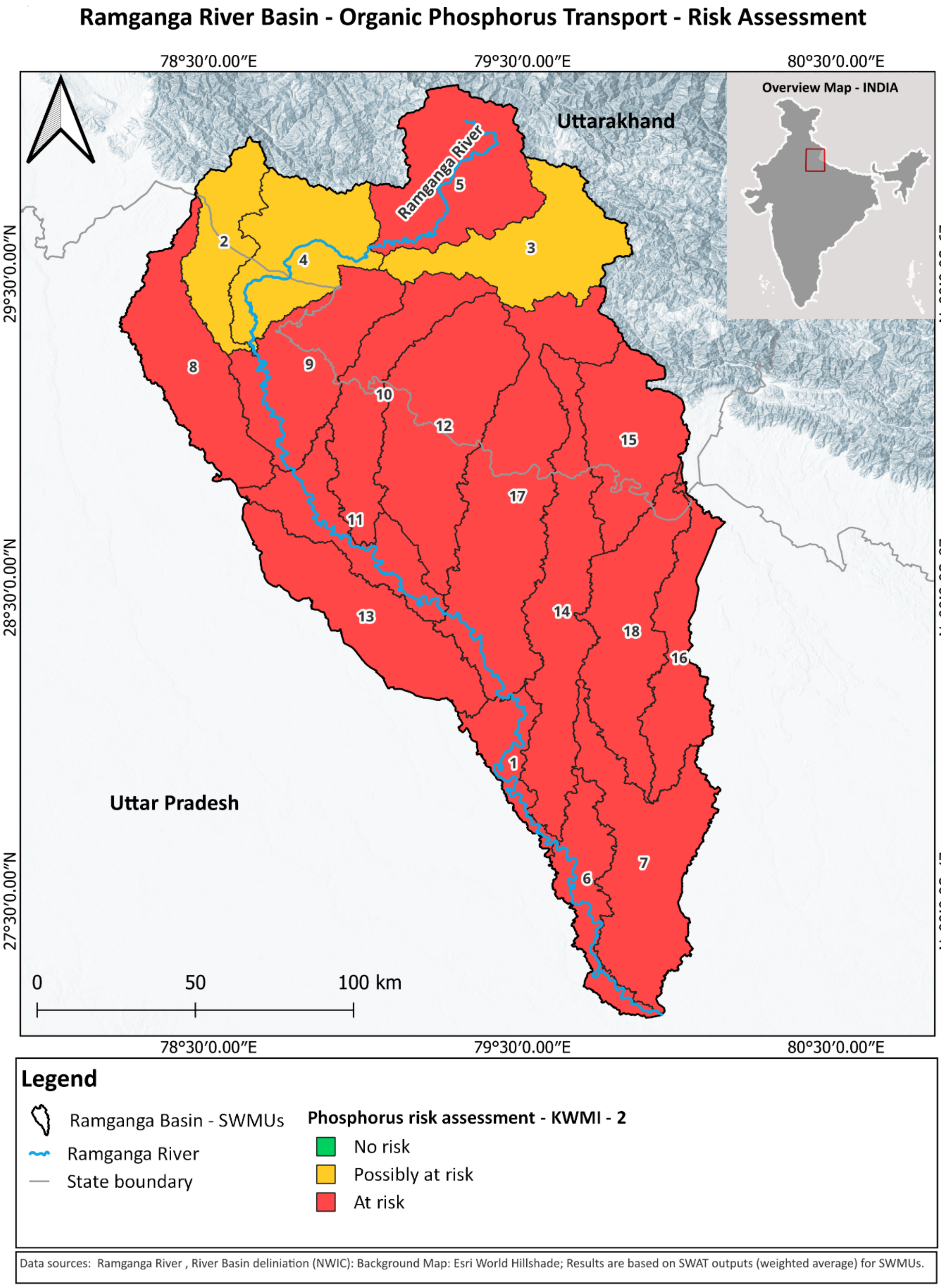
Table 40: Risk assessment for nutrients transport – SWAT data (year: 2011 – 2020)

SWMUs	Organic N	Organic P	Risk Assessment	
	(kg/ha. a)		Organic N	Organic P
1	3.66	0.40	No risk	At risk
2	0.66	0.12	No risk	Possibly at risk
3	0.96	0.13	No risk	Possibly at risk
4	0.28	0.05	No risk	Possibly at risk
5	1.67	0.25	No risk	At risk
6	2.82	0.32	No risk	At risk
7	3.51	0.39	No risk	At risk
8	2.45	0.41	No risk	At risk
9	3.28	0.52	No risk	At risk
10	4.75	0.63	No risk	At risk
11	7.39	0.84	Possibly at risk	At risk
12	10.69	1.38	Possibly at risk	At risk
13	8.18	0.92	Possibly at risk	At risk
14	4.86	0.57	No risk	At risk
15	7.15	0.84	Possibly at risk	At risk
16	6.07	0.70	Possibly at risk	At risk
17	6.58	0.79	Possibly at risk	At risk
18	4.36	0.50	No risk	At risk

***Note**: These results are based on only the SWAT data.



Map 21: Organic nitrogen transport risk assessment per SWMU in the Ramganga Basin



Map 22: Organic phosphorus transport risk assessment per SWMU in the Ramganga Basin

Finally, the combined result for the risk assessment related to non-point sources of pollution is presented in Table 41. The Table shows the result from all previous steps (multi-layered criteria) of the non-point source (i.e., area-based) pollution risk assessment. These summarized results are based on land use risk classes 1 and 2, fertilizer use, pesticide use and mismanaged plastic waste generation within the Ramganga Basin. If there is a discrepancy of results for the same SWMU then, using a conservative approach, the worst classification is considered for this SWMU. In the combined result of the risk assessment 15 SWMUs are classified as ‘At risk’, 1 SWMU as ‘Possibly at risk’, and the remaining 2 SWMUs are classified as at ‘No risk’.

Combined Risk Assessment results for issues related to non-point sources of pollution in Ramganga Basin
In the combined result of the risk assessment out of 18 SWMUs, 15 SWMUs are classified as ‘At risk’, 1 SWMU as ‘Possibly at risk’, and the remaining 2 SWMUs are classified as at ‘No risk’. In general, it can be concluded that area-based pollution needs to be rectified in the Ramganga Basin as most of the basin is classified as ‘At risk’. The results show that it is critically important to have efficient management strategies in place to protect this river which is polluted by nutrients due to discharges of different types of wastewaters including domestic sewage, mismanaged plastic waste and agricultural run-off.

Table 41: Results of non-point source pollution – risk assessment for each SWMU

SWMUs	Land use Risk class - 1	Land use Risk class - 2	Fertilizer use risk	Pesticide use risk	MMPW risk	Final risk
1	At risk	No risk	No risk	At risk	No risk	At risk
2	No risk	No risk	No risk	At risk	No risk	At risk
3	No risk	No risk	No risk	No risk	No risk	No risk
4	No risk	No risk	No risk	Possibly at risk	No risk	Possibly at risk
5	No risk	No risk	No risk	No risk	No risk	No risk
6	At risk	No risk	No risk	Possibly at risk	Possibly at risk	At risk
7	At risk	No risk	No risk	At risk	At risk	At risk
8	At risk	No risk	No risk	At risk	At risk	At risk
9	At risk	No risk	Possibly at risk	Possibly at risk	At risk	At risk
10	At risk	No risk	Possibly at risk	No risk	At risk	At risk
11	At risk	No risk	No risk	Possibly at risk	At risk	At risk
12	At risk	No risk	Possibly at risk	No risk	At risk	At risk
13	At risk	No risk	No risk	Possibly at risk	At risk	At risk
14	At risk	No risk	Possibly at risk	At risk	At risk	At risk

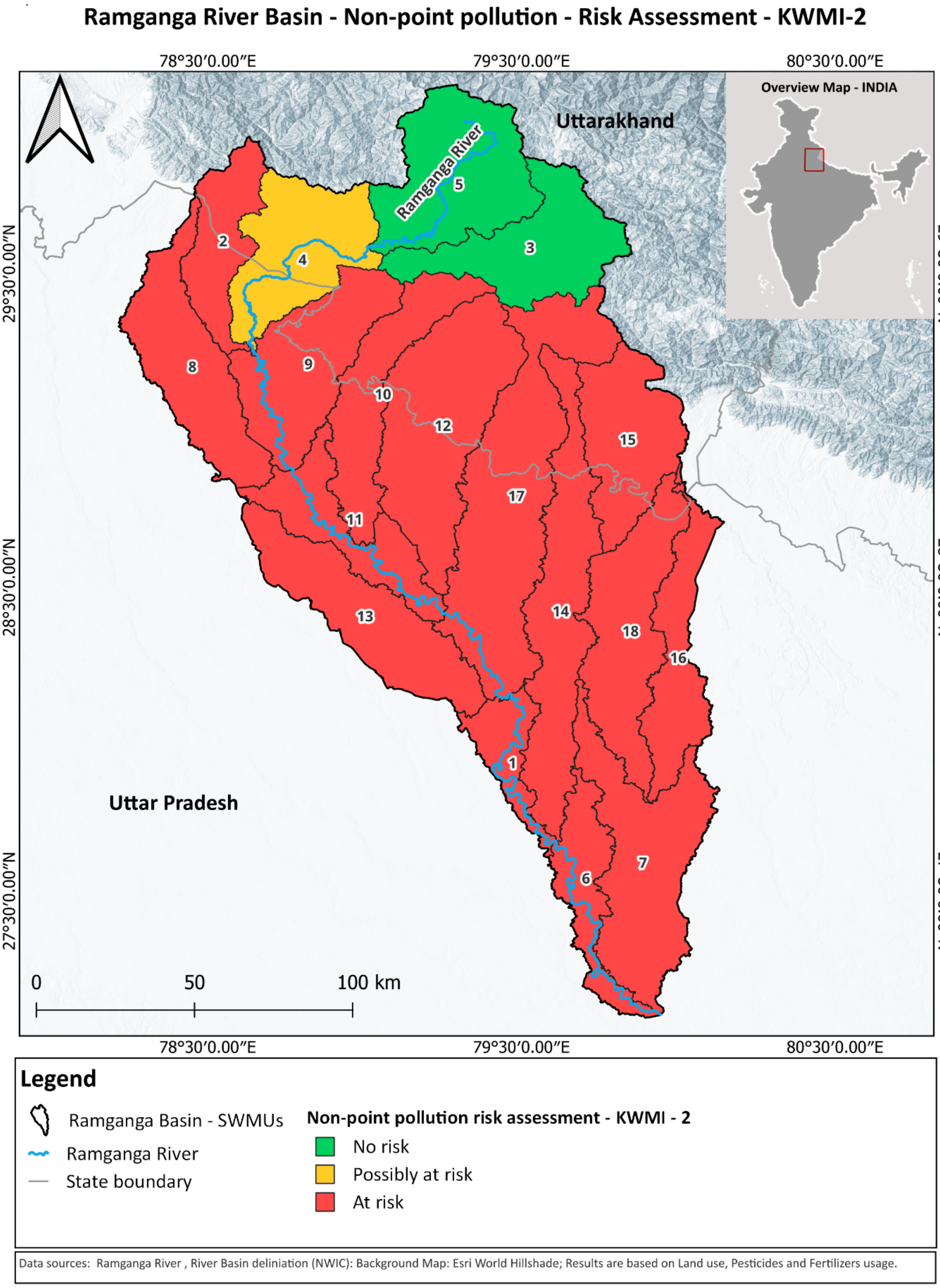
SWMUs	Land use Risk class - 1	Land use Risk class - 2	Fertilizer use risk	Pesticide use risk	MMPW risk	Final risk
15	Possibly at risk	No risk	Possibly at risk	At risk	Possibly at risk	At risk
16	At risk	No risk	At risk	At risk	Possibly at risk	At risk
17	At risk	No risk	No risk	No risk	At risk	At risk
18	At risk	No risk	Possibly at risk	At risk	At risk	At risk

Note: These results are based on only the observed data.

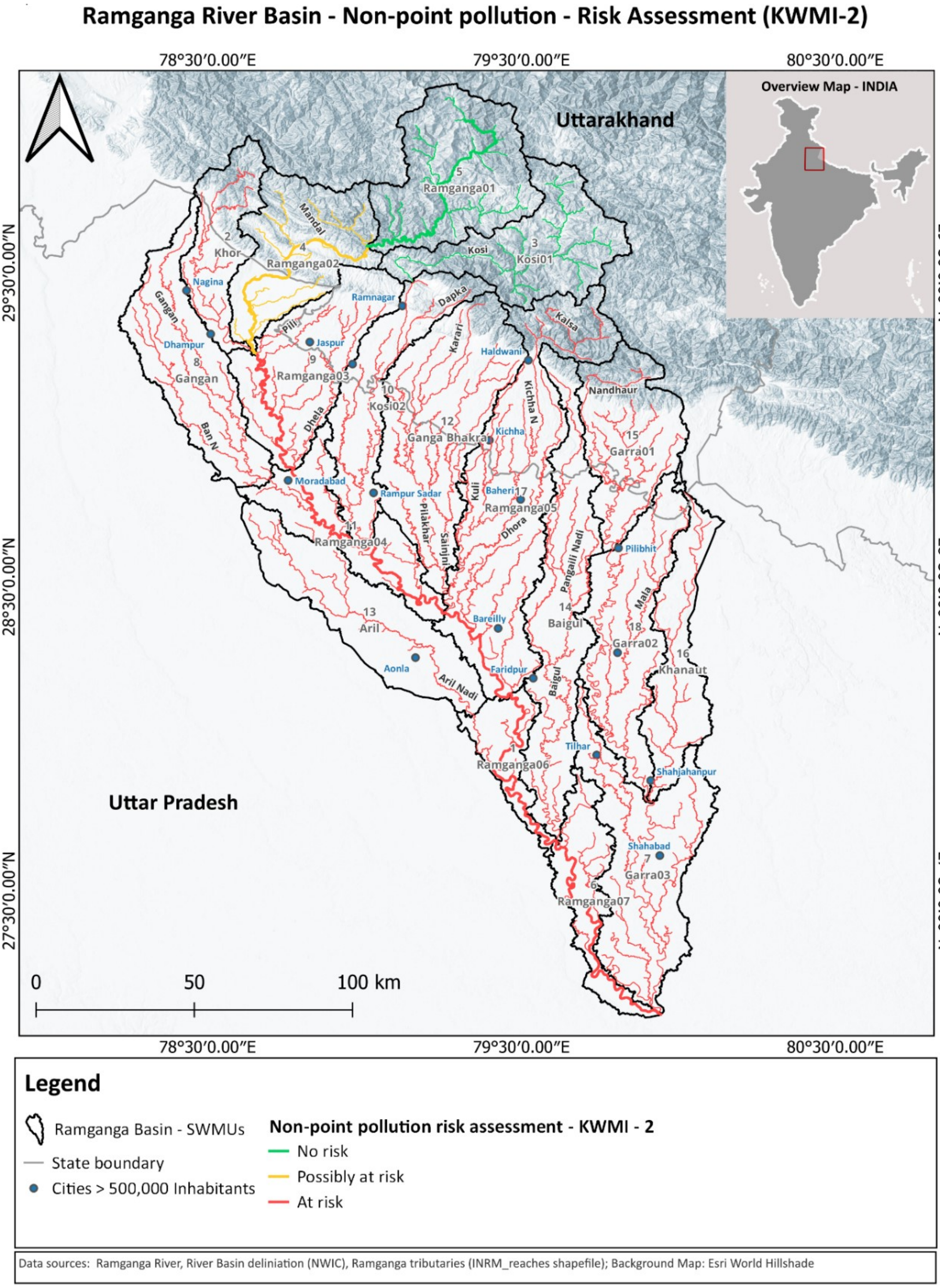
Map 23 presents the combined classification based on all multi-layered risk assessment criteria. These results can also be used as an additional criterion for the groundwater quality risk assessment. To interpret this outcome in the context of river water quality, a map highlighting the assignment of different risk classes based on non-point source pollution results (i.e., KWMI-2) for all tributaries in the Ramganga river basin including the main Ramganga River has been prepared (see Map 24).

After a thorough discussion and consultation with all the relevant stakeholders a final agreed risk class has been assigned to each of the delineated Surface Water Management Unit (SWMU) (see Step 3 of Table 42 and Table 43). The final synthesis has been prepared and a confidence class[20] has been assigned to each of the SWMU (see Step 4 of Table 42 and Table 43).

[20] Confidence level: It is representing the confidence level of the risk assessment results for each of the SWMU. If the results are mixed (e.g., At risk, possibly at risk or no risk), then it is termed 'low'. If all the risk assessment results are leading towards one outcome, then the confidence level is set as 'high'. If the risk assessment results for a SWMU are in between then the confidence level is set to 'medium'.



Map 23: Overall area-based pollution (Land use + Fertilizers + Pesticides) - SWMUs



Map 24: Overall area-based pollution (Land use + Fertilizers + Pesticides) - River reaches

Table 42: Water quality risk assessment due to non-point pollution sources – Observed data

SWMU No.	**Step -1:** Existing Pressures				**Step 2a:** Land use classes			**Step 2b:** Observed and literature-based data						**Step 3:** Expert Judgement[21]	**Step 4:** Final Synthesis		
			Pollution Sources													Significant pressures	
	Non-Point	Others[23]	No. pressure types	Pollution Source Units[24]	LU risk class – 1 [%]	LU risk class – 2 [%]	Interim Risk -1	Monitoring Sites[22]	Fertilizers use risk	Pesticides use risk	MMPW risk	Interim Risk - 2	Pressure / indicator causing risk		Final Risk Assessment	Non-point source[25]	Confidence level
1	X	-	1	-	71.8	14.7	At risk	-	No risk	At risk	No risk	At risk	P	Agreed risk assessment results	At risk	P	Medium
2	X	-	1	-	19.9	28.1	No risk	-	No risk	At risk	No risk	At risk	P		At risk	P	High
3	-	X	1	1	8.8	10.7	No risk	8	No risk	No risk	No risk	No risk	-		No risk		High
4	X	-	1	-	17.2	12.1	No risk	3	No risk	Possibly at risk	No risk	Possibly at risk	P		Possibly at risk	P	High
5	-	-	-	-	15.9	13.7	No risk	-	No risk	No risk	No risk	No risk	-		No risk		High
6	X	-	1	-	68.2	18.2	At risk	4	No risk	Possibly at risk	Possibly at risk	At risk	P		At risk	P, MMPW	Low
7	X	-	1	-	76.2	17.2	At risk	2	No risk	At risk	At risk	At risk	P		At risk	P, MMPW	High
8	X	X	2	2	70.8	26.6	At risk	-	No risk	At risk	At risk	At risk	P		At risk	P, MMPW	High
9	X	X	2	39	56.8	15.7	At risk	4	Possibly at risk	Possibly at risk	At risk	At risk	F, P		At risk	F, P, MMPW	Medium
10	X	X	2	22	59.6	10.8	At risk	9	Possibly at risk	No risk	At risk	At risk	F		At risk	F, MMPW	Low
11	X	X	2	89	79.5	15.8	At risk	2	No risk	Possibly at risk	At risk	At risk	P		At risk	P, MMPW	Low
12	X	X	2	8	66.9	9.4	At risk	13	Possibly at risk	No risk	At risk	At risk	F		At risk	F, MMPW	Low
13	X	X	2	2	89.5	9.9	At risk	-	No risk	Possibly at risk	At risk	At risk	P		At risk	P, MMPW	Low
14	X	X	2	1	71.6	16.5	At risk	3	Possibly at risk	At risk	At risk	At risk	F, P		At risk	F, P, MMPW	High
15	X	-	1	-	41.2	7.9	Possibly at risk	1	Possibly at risk	At risk	Possibly at risk	At risk	F, P		At risk	F, P, MMPW	High
16	X	-	1	-	60.9	13.8	At risk	1	At risk	At risk	Possibly at risk	At risk	F, P		At risk	F, P, MMPW	High
17	X	X	2	27	55.4	17.6	At risk	26	No risk	No risk	At risk	At risk	-		At risk	MMPW	Medium
18	X	-	1	-	55.0	27.5	At risk	-	Possibly at risk	At risk	At risk	At risk	F, P		At risk	F, P, MMPW	High

[21] Risk assessment results have been updated with the expert judgement. Final risk assessment results are mutually agreed with all the relevant stakeholders after a thorough consultation.

[22] See Annex-III, Map of water quality stations in the Ramganga basin.

[23] Consists of all point-pollution sources including major drains, STPs and polluting industries like metal, meat, sugar, fertilizer, and paper industries.

[24] Represents the sum of all point-sources of pollution including industries, drains and STPs (operational and under construction) – See Annex-III.

[25] P = Pesticides, F = Fertilizer, MMWP = Mismanaged Plastic Waste

Table 43: Water quality risk assessment due to non-point pollution sources – SWAT output

SWMU No.	**Step -1:** Existing Pressures				**Step 2a:** Land use classes			**Step 2b:** SWAT output					**Step 3:** Expert Judgement[26]	**Step 4:** Final Synthesis		
	Pollution Sources				LU risk class – 1 [%]	LU risk class – 2 [%]	Interim Risk -1	Monitoring Sites[27]	Organic Nitrogen risk	Organic Phosphorus risk	Interim Risk - 2	Pressures /indicators causing risk		Final Risk Assessment	Significant pressures	Confidence classes
	Non-Point	Others[28]	No. pressure types	Pollution Source Units[29]											Non-point source[30]	
1	X	-	1	-	71.8	14.7	At risk	-	No risk	At risk	At risk	F, P	Agreed risk assessment results	At risk	F, P	High
2	X	-	1	-	19.9	28.1	No risk	-	No risk	Possibly at risk	Possibly at risk	P		Possibly at risk	P	Medium
3	-	X	1	1	8.8	10.7	No risk	8	No risk	Possibly at risk	Possibly at risk	-		Possibly at risk	-	Medium
4	X	-	1	-	17.2	12.1	No risk	3	No risk	Possibly at risk	Possibly at risk	F, P		Possibly at risk	F, P	Medium
5	-	-	-	-	15.9	13.7	No risk	-	No risk	At risk	At risk	-		At risk	-	Medium
6	X	-	1	-	68.2	18.2	At risk	4	No risk	At risk	At risk	F, P		At risk	F, P, MMWP	High
7	X	-	1	-	76.2	17.2	At risk	2	No risk	At risk	At risk	F, P		At risk	F, P, MMWP	High
8	X	X	2	2	70.8	26.6	At risk	-	No risk	At risk	At risk	F, P		At risk	F, P, MMWP	High
9	X	X	2	39	56.8	15.7	At risk	4	No risk	At risk	At risk	F, P		At risk	F, P, MMWP	High
10	X	X	2	22	59.6	10.8	At risk	9	No risk	At risk	At risk	F		At risk	F, MMWP	High
11	X	X	2	89	79.5	15.8	At risk	2	Possibly at risk	At risk	At risk	F, P		At risk	F, P, MMWP	High
12	X	X	2	8	66.9	9.4	At risk	13	Possibly at risk	At risk	At risk	F		At risk	F, MMWP	High
13	X	X	2	2	89.5	9.9	At risk	-	Possibly at risk	At risk	At risk	F, P		At risk	F, P, MMWP	High
14	X	X	2	1	71.6	16.5	At risk	3	No risk	At risk	At risk	F, P		At risk	F, P, MMWP	Low
15	X	-	1	-	41.2	7.9	Possibly at risk	1	Possibly at risk	At risk	At risk	F, P		At risk	F, P, MMWP	Medium
16	X	-	1	-	60.9	13.8	At risk	1	Possibly at risk	At risk	At risk	F, P		At risk	F, P, MMWP	High
17	X	X	2	27	55.4	17.6	At risk	26	Possibly at risk	At risk	At risk	F		At risk	F, MMWP	High
18	X	-	1	-	55.0	27.5	At risk	-	No risk	At risk	At risk	F, P		At risk	F, P, MMWP	High

[26] Risk assessment results have been updated with the expert judgement. Final risk assessment results are mutually agreed with all the relevant stakeholders after a thorough consultation.
[27] See Annex-III, Map of water quality stations in the Ramganga basin.
[28] Consists of all point-pollution sources including major drains, STPs and polluting industries like metal, meat, sugar, fertilizer, and paper industries.
[29] Represents the sum of all point-sources of pollution including industries, drains and STPs (operational and under construction) – See Annex-III.
[30] P = Pesticides, F = Fertilizer, MMWP = Mismanaged Plastic Waste

5.4.3 Challenges and data gaps

It must be mentioned that data is available only for two years and two different states. For a more reliable fertilizer use risk assessment longer time-series are required. This data constraint can be addressed in the next phase of the project by collecting more field-oriented and site-specific information about NPK fertilizer usage in the Ramganga Basin.

Present pesticide related data is only available for three years and two different states (i.e., UP and UK). It would be useful to have longer data time series for a more credible pesticide use risk assessment. This data constraint can be addressed in the next phase of the project by collecting more field-oriented and site-specific information for different pesticide usage within the Ramganga Basin. This improved information will positively contribute to the credibility of the risk assessment results.

Also, within the Ramganga Basin there is very little observed information available regarding the area-based pollution. For example, observed fertilizer data was only available for two years and for pesticide data it was available for merely three years.

Mismanaged Plastic Waste (MMPW) is an important factor in causing area-based pollution. In the present report, risk assessment related to MMPW has been done on empirical grounds as consistent data relevant to MMWP was not available during the course of risk assessment.

It is emphasized that a systematic inventory of fertilizer usage, pesticide usage as well as MMWP should be created not only to cover the gaps in existing information but also to improve the risk assessment results for the future. One of the crucial challenges is to deal with the uncertainties in the risk assessment results which mostly occurred due to bridging data gaps with possible assumptions. This situation could be improved in the future by ensuring good quality of input data.

5.5 KWMI 3 Alteration in groundwater regime impacting on sub-surface flow

Alteration in groundwater resources (both quantity and quality) is an important aspect to understand the status of river basin like Ramganga Basin where the surface and groundwater interaction is very high. Also, intense agricultural activities have dual impacts on the groundwater i.e. impacts on the groundwater quality due to use of nutrients and extraction of groundwater for irrigation purposes. Almost all towns and rural areas in the Ramganga Basin rely on groundwater resources to meet their potable/drinking water demand. Given the alluvial nature of the majority of aquifer, groundwater's health is an important parameter for this cycle of Ramganga RBM Plan.

Data Source

The risk assessment related to the alterations of groundwater consists of two parts. The first part is related to the risk assessment of groundwater quantity. The second part is related to groundwater quality. The dataset used in carrying out groundwater quantity and quality risk assessment is provided by CGWB.

- The groundwater quantity data consists of groundwater observations and resource/extraction assessments. These observations are carried out only for the unconfined alluvial aquifer. All information pertaining to SoE was provided by CGWB. The base year selected for risk assessment is 2022.
- SWAT model data has been used as proxy where CGWB data is not available (i.e., Hard rock and Sandstone /Shale complex).
- Observed data related to groundwater quality parameters such as Nitrate (NO_3) and Electrical Conductivity (EC) have been used in the groundwater quality risk assessment. These parameters are regularly monitored by the CGWB's network of monitoring Programme. The average data for 2011-2022 has been used for the groundwater quality risk assessment.

The following section highlights the data aggregation steps for both CGWB and SWAT model datasets.

CGWB Dataset (GMUs Number 5 – 20)

The groundwater resources/extraction assessments (i.e., groundwater extraction and recharge) are based on block level. In total the data covered 15 major districts and 96 blocks within the Ramganga Basin. However, to use this data for all GMUs, aggregation is necessary. The following steps describe the data aggregation process.

4. First, percentage coverage of each block within a GMU has been calculated. As the data is based on block level it is necessary to calculate the coverage.
5. Second, the groundwater data (i.e., recharge and extraction) from these 96 blocks were aggregated to respective GMUs for risk assessment.
6. CGWB data has been used for the GMUs number 5 – 20 (i.e., Alluvium complex).

SWAT Model Dataset (GMUs Number 1 – 4)

The delineation of GMUs based on the SWAT model output and major aquifers of Ramganga Basin is already described earlier in the chapter. This is to be highlighted that further SWAT data has been only used for the GMUs number 1 – 4 (i.e., Hard rock and Shale /Sandstone complex).

5.5.1 Risk assessment approach, criteria and thresholds

The risk assessment of KWMI 3 has two parts i.e. groundwater quantity and groundwater quality. The risk assessment approach including criteria and thresholds are presented below:

5.5.1.1 Groundwater quantity assessment methodology

The following 4-step risk assessment approach was adapted for the groundwater quality risk assessment in the Ramganga Basin.

- **Step 1**: Consideration of existing pressures (i.e., extraction[31]) and identification of the aquifer complex for each GMU within the Ramganga Basin.
- **Step 2**: Consideration of the percentage of the Stage of groundwater Extraction (SoE) for examining the groundwater exploitation level. If SoE > 100% then also consideration of the post-monsoonal groundwater level trends as an additional criterion.
- **Step 3**: Incorporation of stakeholders' feedback and expert judgment related to the conceptual understanding of the GMUs and field observations.
- **Step 4**: Final synthesis with the final risk assignment, including all related significant pressures and the confidence level of the risk assessment result.

Criteria and threshold for groundwater quantity assessment

The **S**tage **o**f groundwater **E**xtraction (SoE) in percentage is an important parameter to check the exploitation level of groundwater resources. The SoE is the percentage between the existing gross groundwater extraction for all uses and the annual Extractable Groundwater Resource (EGR). A comprehensive set of criteria for the groundwater quantity risk assessment has been developed by the CGWB which has also been used in this Ramganga RBM Plan (see Table 44). According to these criteria, there are three resource classes (A, B, and C) in addition to three exploitation levels (i.e., Safe, Alert, and Over Exploited) based on mm of resource and SoE [%].

Table 44: Groundwater quantity risk assessment matrix – Ramganga River Basin

Classes	Resource (mm)	Stage of groundwater Extraction - SoE (%)		SoE (%) > 100 %			
		SoE (%): < 70%	SoE (%): 70% – 100%	Class and exploitation level	At least 10-years post-monsoon decreasing trend (cm/yr)		
					< 10	10 – 20	> 20
Class A	>200	Class A - Safe	Class A - Alert	Class A - Over Exploited	Low Risk	Medium Risk	High Risk
Class B	100 – 200	Class B - Safe	Class B - Alert	Class B - Over Exploited	Medium Risk	High Risk	High Risk
Class C	< 100	Class C - Safe	Class C - Alert	Class C - Over Exploited	High Risk	High Risk	High Risk

The following table shows the risk class and colors assigned to each risk class.

Risk colors	Risk classes
Green	Not At risk
Blue	Low risk
Yellow	Medium Risk
Red	High Risk

As shown in Table 44, if SoE is less than 100%, only the groundwater resource class and level of exploitation are considered. However, if the SoE [%] is greater than 100%, the three overexploited resource

[31] No other pressures have been identified within the Ramganga basin.

classes (A, B, and C) will further be subdivided into three categories, based on the post-monsoon decreasing trend (i.e., minimum 10-year trend). The post-monsoon trend is further subdivided into three categories (i.e., groundwater level decreasing trend) with less than 10 cm/yr, 10 –20 cm/yr and greater than 20 cm/yr. These risk levels or classes are used as a decisive factor in whether a GMU is within the overall Ramganga RBM Plan objectives. Finally, for the groundwater quantity risk assessment in the Ramganga Basin, the following four risk classes have been identified:

- Not at risk
- Low risk
- Medium Risk
- High Risk

Calculation of the Stage of Groundwater Extraction (SoE)

The stage of groundwater extraction in the Ramganga Basin has been calculated using groundwater extraction and recharge data. As indicated earlier section, groundwater resources assessment data for the year 2020 has been provided by CGWB. In the following equations, groundwater recharge is referred to as Extractable Groundwater Resource (EGR), which is calculated by deducting the Total Annual Natural Discharge from Total Annual Groundwater Recharge.

Extractable Groundwater Resource Estimation

$$SoE\ [\%] = \frac{Existing\ gross\ GW\ extraction}{Annual\ extractable\ GW\ resources\ (EGR)} \times 100 \qquad \text{(Eq.1)}$$

$$EGR = Total\ Annual\ GW\ recharge - Total\ Annual\ discharge \qquad \text{(Eq.2)}$$

For example, SoE = 200% means that the annual extraction is double than the annual extractable groundwater resources. Similarly, SoE = 50%, means the annual extraction is half of the annual extractable groundwater resources.

The following points summarized the SoE calculation for the Ramganga Basin:

- Annual groundwater extraction and recharge on the block level has been intersected with the GMUs and percentage area coverage for each block within the GMU has been calculated.
- The recharge and extraction for each GMU has been aggregated by multiplying the percentage area coverage of each block with the observed recharge and extraction.
- Finally, to calculate the groundwater resources as defined in Table 44, groundwater extraction and recharge has been converted to mm using area of each of the GMUs.

Aggregated results of extraction and recharge for all GMUs are summarized in Annex A3. In the alluvial part of the Ramganga Basin, the average annual recharge for the year 2020[32] is about 275 mm. The minimum and maximum annual recharge values within the alluvium part of the Ramganga Basin at GMU level are in the range from 79 mm (i.e., GMU number 7) to 361 mm (i.e., GMU number 11) respectively.

Calculation of the post-monsoon groundwater level trends

[32] These results are based on CGWB data (i.e., GMU 5 to 20). SWAT model results are only used for hard rock and sandstone complex i.e., GMU 1 to 4.

The post-monsoonal groundwater level trends have been calculated using observed data from more than 80 stations located within the Ramganga River Basin. These stations are operated by CGWB. The following steps summarize the calculation of the post-monsoon groundwater level trends:

- First, groundwater level data have been plotted and the trend slope for each station has been calculated using a linear trend line (units are finally converted to cm/yr).
- Secondly, observations (i.e., the groundwater level trends) have been averaged per GMU, based on the location of the groundwater level monitoring station within the Ramganga Basin.

It should be noted that CGWB groundwater monitoring stations are mainly located in the shallow aquifer, while a portion of groundwater extraction is also taken from the deeper confined aquifer. Nevertheless, groundwater levels of these monitoring stations are taken as an indicator of the overall level trend in the aquifer system.

5.5.1.2 Groundwater quality assessment methodology

The Ramganga River Basin has a substantial number of groundwater quality monitoring stations. However, there are still some GMUs that are not covered by the monitoring network. For groundwater quality risk assessment (as agreed with CGWB), only two water quality parameters, i.e., Nitrate (NO_3) and Electrical Conductivity (EC), are considered. In addition, for the pressure impact analysis land use information has been used as a representative indicator of potential anthropogenic pressures. A 4-step approach has been applied for the groundwater quality risk assessment in the Ramganga Basin.

- Step 1: Consideration of point and non-point pollution sources within the Ramganga Basin
- Step 2: Consideration of potential anthropogenic pollution sources, by using clubbed land use information in addition to groundwater quality monitoring data (i.e., NO_3 and EC).
- Step 3: Incorporation of stakeholders' feedback and expert judgment related to the conceptual understanding of the GMUs and field observations.
- Step 4: Synthesis with the final risk assignment, including all related significant pressures and the confidence level of the risk assessment result.

In step 1, point and diffuse pollution sources, including the use of pesticides and fertilizers, have been considered for GMUs. The risk assessment for the second Key Water Management Issue (i.e., KWMI-2: Diffuse pollution sources including agricultural activities) deals with the use of pesticides and fertilizer for agricultural activities and their possible impacts on water quality.

In the second step, land use data were classified based on their potential of posing a risk of not achieving the RBM targets for groundwater quality. The details of clubbing of land use data are already presented in section 5.4 of this chapter (under KWMI 2). A GMU will be considered at 'High risk' if the percentage of its clubbed area with land uses corresponding to risk category 1 is greater than 50% or if the percentage of its area corresponding to risk category 2 is greater than or equal to 75% (see Table 45).

Table 45: Percentages of clubbed land use and risk assessment classification

Interim risk result - Step 2a		Risk criterion (percentage % of the total GMU area)			
Priority land use classes	Land use categories included	No risk	Low risk	Moderate risk	High risk
1	Built-up Area + Double Cropped Area + Perennial crops	≤ 10	> 10 – ≤ 25	> 25 – ≤ 50	> 50
2	Other Agriculture Area	≤ 25	> 25 – ≤ 50	> 50 – ≤ 75	> 75
3	Forest Area, Water Bodies Area, Wasteland				

Source: adapted from the Tapi RBM plan, 2020

Criteria and threshold for groundwater quality assessment

The groundwater quality parameters have certain thresholds, and the second layer of groundwater quality risk consists of evaluating the observations of the two water quality parameters NO_3 and EC against their thresholds, as defined by the national standards by BIS. The threshold value for NO_3 is 45 mg/l whereas EC has a threshold limit of 2250 µS/cm. The first risk assessment methodology for evaluating these two water quality parameters is rather simple. If a percentage of monitoring sites (i.e., observation) within a GMU exceeds the threshold limit by their mean (in the period i.e., 2000 - 2018), the respective GMU will be assigned a risk class accordingly (see Table 46). For example, a GMU will be considered at 'High risk' if 50% of monitoring sites (i.e., observations of either EC or NO_3) exceed the threshold value as defined in Table 46. Similarly, if in a GMU the percentage of monitoring sites exceeding their defined thresholds is less than or equal to 30%, the GMU will be considered at 'No risk'. It means these GMUs will have satisfactory status in achieving the objectives of having good groundwater quality for the Ramganga Basin.

Table 46: Risk assessment criteria based on Nitrate and Electrical conductivity thresholds

Interim risk result - Step 2b	No risk	Moderate risk	High risk
Percentage of monitoring sites exceeding the threshold value by their annual mean value	≤ 30%	> 30% – ≤ 50	≥ 50

Threshold values according to standard BIS 10500:2012 (*BIS - Bureau of Indian Standard)*

NO_3	45 mg/l	drinking water criterion
EC	2250 µS/cm	agriculture criterion

Thiessen polygons analysis

The above approach of 'counting' sites in a GMU has its limitations, as some of the GMUs are represented by only one groundwater quality monitoring station. Therefore, a Thiessen polygon analysis for both NO_3 as well as EC values has been carried out with the intention to improve the existing results. The baseline methodology is the same that if High risk sample points have equal to or greater than 50% Thiessen polygon area within the GMU then the GMU is classified as at 'High Risk'. Similarly, if the 'No risk' water quality observation points (i.e., NO_3 and EC) have less than or equal to 30% area of the Theissen polygon within the GMU then the GMU is classified as at 'No risk'. The output Theissen polygon maps for both EC as well as NO_3 can be found in Annex A3.

5.5.2 Groundwater quantity: Results from the Risk Assessment and possible impact

The groundwater quantity risk assessment has two layered criteria. The first layer is the Stage of groundwater Extraction (SoE). The second layer is the groundwater level trend. Groundwater level trends become decisive once the percentage of SoE exceeds 100%.

Following the risk assessment criteria defined in Table 46, the GMUs are categorized into four different risk classes (i.e., Not At risk, low risk, medium risk and high risk). Two GMUs are classified as at 'Medium Risk', only 1 GMU (i.e., GMU number 14 – Moradabad) is classified as at 'High Risk' and there is no GMU classified as at 'Low Risk' (see Table 47) The remaining 17 GMUs are classified as 'Not At Risk'. In other words, 85% of the GMUs are not at risk, while 15% of the remaining GMUs are at different levels of risk (see Figure 21). If these results are translated into GMU area at risk, then approximately 96% of the area is classified as 'Not At Risk' whereas only 4% of the GMU area is classified either at High or Medium level of risk.

Table 47: Groundwater quantity risk assessment results – Ramganga River Basin

Groundwater quantity risk classes	Number of GMUs
Not At Risk	17
Low Risk	0
Medium Risk	2
High Risk	1

A map of groundwater quantity risk assessment with different risk classes has been prepared for a spatial outlook of the risk assessment (see Map 25). The complete results of the risk assessment related to groundwater quantity have been summarized in the risk assessment matrix (see Table 48)

The highest value of the stage of groundwater extraction, which is more than 200% (it means more than 2 times more abstraction than recharge), has been calculated for GMU number 17 (i.e., built-up industrial complex – Bareilly urban area). Moradabad block (i.e., GMU 14) has the second highest value of SoE with more than 100%. The overall post-monsoon decreasing trend in GMU number 14 is around 40 cm/yr which puts it in a 'High Risk' class. This is the only GMU within the Ramganga Basin which has been classified as at 'High Risk'. As indicated earlier, only 2 GMU has been classified as at 'Medium Risk'. These are GMU number 7 located in Nainital region covering Haldwani block and GMU number 17 covering Bareilly block (i.e., urban/industrial complex). In contrast, all other GMUs are classified as 'Not At Risk'. The SoE (%) of these GMUs are well below 100% even though groundwater level decreasing trend is of more than 30 cm/yr and 20 cm/yr in GMU number 13 and 19 respectively. As far as the resource class and warning level is concerned most of the GMUs are falling in the Safe category. There are only two GMUs (i.e., GMU 14 and GMU 17) which are categorized as 'Over Exploited' with more than 100% of SoE values. GMU Number 7 ,8, 13, 15 and 20 are categorized with different resource classes but with a warning level of 'Alert'.

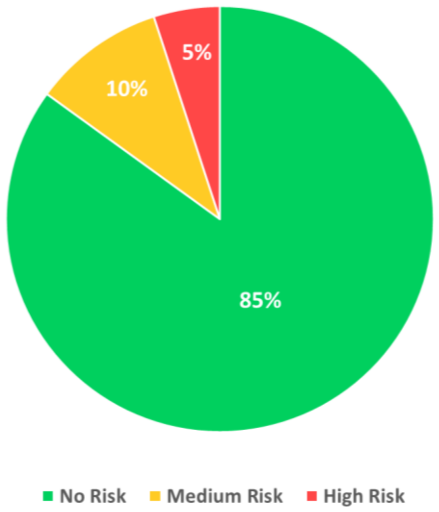
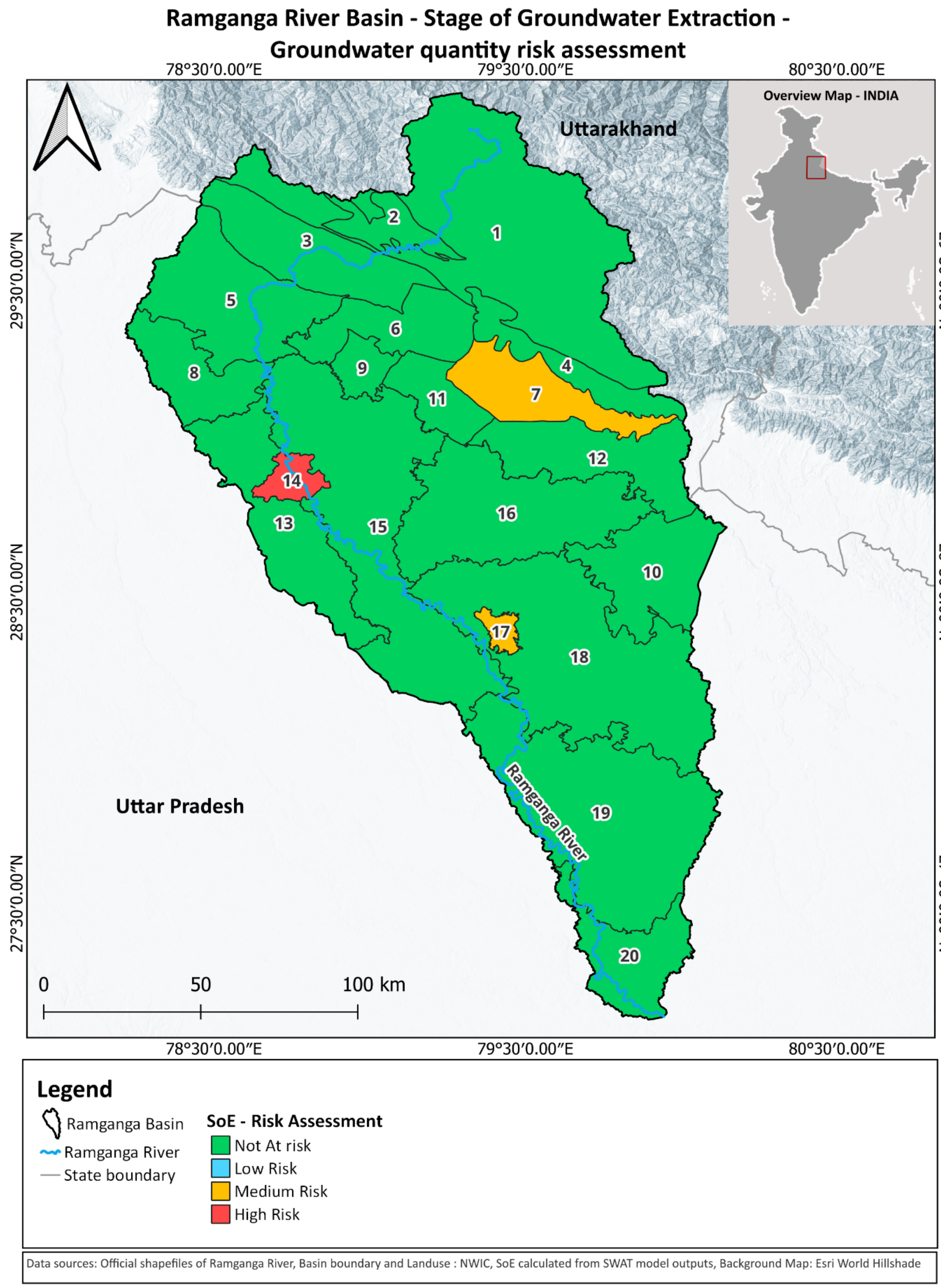


Figure 21: Final groundwater quantity risk classes percentages - Ramganga River Basin

While in most of the GMUs at least 1 monitoring station can be found, there are only 2 GMUs (numbers 2 and 3) where no monitoring station is available. In total, 9 GMUs have 5 or more than 5 monitoring stations. The final risk assessment and synthesis after a through discussion with all the relevant stake-holders and incorporating the expert judgements (see Step 3 of Table 48), can be found in Table 48 (see step 4).

A confidence level for the risk assessment for each of the GMU has been assessed. As results for the GMU number 1 to 4 are based on SWAT model output, the risk assessment classification for these GMUs are given 'low' confidence. GMU number 6, 7, 13 and 19 have been assigned as 'Medium' confi-dence class because these are place in the 'Not At Risk' class according to their SoE, but the post-mon-soonal decreasing trend is more than 20 cm/yr. GMU number 17 where the SoE is more than 200% but the post-monsoonal trend is less than 5 cm/yr is also given a 'Medium' confidence, as both facts are contradicting. The remaining GMUs risk assessment results are assessed to be at 'High' confidence level.

Groundwater Quantity
Overall, 17 GMUs have been classified as 'Not At Risk'. Two GMUs are classified as at 'Medium Risk', only 1 GMU (i.e., GMU number 14 – Moradabad) is classified as at 'High Risk' and there is no GMU classified as at 'Low Risk'. In terms of GMU area 96% of the area is classified as 'Not At Risk' whereas only 4% of the GMU area is classified either at High or Medium level of risk.



Map 25: Groundwater quantity risk assessment – Stage of Groundwater Extraction

Table 48: Groundwater quantity risk assessment matrix - Ramganga River Basin

GMU No.	**Step - 1:** Existing Pressures		**Step - 2a:** Exploitation	**Step - 2b:** Observed data / Level trends		Interim Risk	**Step 3:** Expert Judgement[33]	**Step 4:** Final Synthesis		
	Extraction	Aquifer complex[34]	Stage of groundwater Extraction (SoE) [%] – CGWB (Year: 2020)[35]	Monitoring sites[36]	Trend [cm/yr] Post-Monsoon			Final Risk Assessment	Significant pressures (Abstractions)	Confidence level
1	–	Hard Rock	0.1	1	0	Not At Risk	Agreed risk assessment results	Not At Risk	–	Low
2	–	Hard Rock	0.0	0	–	Not At Risk		Not At Risk	–	Low
3	X	Sandstone /Shale	23.4	0	–	Not At Risk		Not At Risk	Irrigation, Domestic	Low
4	–	Sandstone /Shale	0.0	1	70.1	Not At Risk		Not At Risk	–	Low
5	X	Alluvium	67.6	3	-10.1	Not At Risk		Not At Risk	Irrigation, Domestic	High
6	X	Alluvium	57.2	12	-21.9	Not At Risk		Not At Risk	Irrigation	Medium
7	X	Alluvium	84.2	4	-24.1	Medium Risk		Medium Risk	Irrigation, Domestic	Medium
8	X	Alluvium	75.9	3	4.7	Not At Risk		Not At Risk	Irrigation	High
9	X	Urban/Industrial	70.1	4	-14.2	Not At Risk		Not At Risk	Irrigation, Industrial	High
10	X	Alluvium	59.5	6	-4.0	Not At Risk		Not At Risk	Irrigation	High
11	X	Alluvium	48.6	5	0.6	Not At Risk		Not At Risk	Irrigation	High
12	X	Alluvium	51.6	12	-8.0	Not At Risk		Not At Risk	Irrigation	High
13	X	Alluvium	89.1	6	-31.1	Not At Risk		Not At Risk	Irrigation	Medium
14	X	Urban/Industrial	125.4	2	-39.6	High Risk		High Risk	Irrigation, Domestic	High

[33] Risk assessment results have been updated with the expert judgement. Final risk assessment results are mutually agreed with all the relevant stakeholders after a thorough consultation.
[34] Only the upper, unconfined part of the alluvial aquifer complex is considered.
[35] Further details can be found in Annex-I (see Figure A2 and Table A3). SoE for GMU No. 1 – 4 is calculated from SWAT model results.
[36] A map for groundwater level monitoring sites can be seen in Annex-I (see Figure A3).

15	X	Alluvium	78.7	7	-8.4	Not At Risk		Not At Risk	Irrigation, Domestic	High
16	X	Alluvium	62.1	5	23.2	Not At Risk		Not At Risk	Irrigation, Domestic	High
17	X	Urban/Industrial	244.3	1	-4.8	Medium Risk		Medium Risk	Irrigation, Domestic	Medium[37]
18	X	Alluvium	61.4	9	-5.8	Not At Risk		Not At Risk	Irrigation	High
19	X	Alluvium	61.6	5	-21.3	Not At Risk		Not At Risk	Irrigation	Medium
20	X	Alluvium	58.9	3	0.3	Not At Risk		Not At Risk	Irrigation	High

[37] The confidence level is medium because SoE is very high, and trend is based on one monitoring site only.

5.5.3 Groundwater quality: Results from the Risk Assessment and possible impacts:

The groundwater quality risk assessment for a GMU also has two layered criteria. The first layer is the clubbed land use priority risk class, and the second layer is related to the water quality parameters NO_3 and EC. All results have been summarized in the groundwater quality risk evaluation matrix (see).

In the Ramganga Basin at GMU level both point, and non-point pollution pressures are present. For example, the GMU number 9, 14, and 15 which are based on blocks like Kashipur, Moradabad and nearby region can be treated as deteriorating groundwater quality hot spots. It is because there is a presence of substantial pollution pressures (i.e., point and diffuse sources). To identify in detail, the location and number of existing point-pollution sources on a GMU level, a detailed point-pollution sources map has been prepared (see Chapter 2). This map is an outcome of the first Key Water Management Issue (i.e., KWMI-1: Water quality deterioration due to point pollution sources). But this result can not only be used to identify potential hotspots, where groundwater quality is deteriorating but also might help devise a comprehensive target-oriented Program of Measures (PoM) for abating the pollution and improving the groundwater quality within the Ramganga Basin.

There are different sub-levels of risk assessment including interim risk – 1, interim risk – 2 and final risk assessment. The GMUs are categorized into four different risk classes (i.e., Not at risk, low risk, medium risk, and high risk). In the case of interim risk – 1, almost all the Uttar Pradesh region (in the Ramganga Basin) seems to be at a high-risk level (i.e., clubbed land use priority risk class 1 has more percentage within a GMU compared to other risk classes). Twelve (12) GMUs (i.e., GMU number 8 to 20 except GMU number 10) are composed of more than 50% area of priority risk class 1 which puts them in the 'high risk' category. In contrast, for the risk priority class 2, only two (2) GMUs (i.e., GMU numbers 5 and 8) are classified as at 'low risk' and the remaining 18 GMUs are classified as at 'No risk' (see Annex A3). The results of the interim risk assessment based on the land use risk priority class can be seen in Map 26. The results of the interim risk – 2 are like the interim risk – 1 and in short are heavily influenced by the land use risk assessment. In the final risk assessment results, which is also representing the summarised results of both previous steps as well as it also includes the expert judgement and thorough stakeholders' consultation. In the final risk assessment due weightage has been given to the groundwater quality monitoring sites (i.e., monitoring NO_3 and EC) as well as land use as per the following criteria.

- If there are at least 2 groundwater quality monitoring stations within the GMU, then NO_3 (Thiessen polygon method) has a priority in assigning the risk class.
- If there are less than 2 groundwater quality monitoring stations within the GMU, then priority has been given to land use classes.

Interestingly, for EC all GMUs are classified as at 'No Risk'. It means all GMUs are within safe limits of the defined EC thresholds. In the case of NO_3, results have been interpreted based on the Thiessen polygon method. Finally, 3 GMUs are classified as at 'Moderate Risk' (GMU number 5, 8 and 15), and 6 GMUs including the urban blocks like GMU number 14 – Moradabad block and GMU number 17 – Bareilly block are classified as at 'High Risk'. There is no GMU which is classified as at 'Low Risk' (see

Table 49 and Figure 22). The remaining 11 GMUs are classified as at 'No risk' of failing the objectives of the Ramganga RBM Plan. Overall, 55% of the GMUs are classified as at 'No risk', whereas 15% are classified as at ‘Moderate risk’. The remaining 30% of the GMUs are at ‘High risk’. In terms of area 28% of Ramganga Basin is at ‘High risk’ of poor groundwater quality whereas, 20% area is at ‘Moderate Risk’ and remaining 52% area is classified as at ‘No Risk’.

Table 49: Groundwater quality risk assessment results based on clubbed land use

Groundwater quality risk classes	Number of GMUs
No Risk	11
Low Risk	0
Moderate Risk	3
High Risk	6

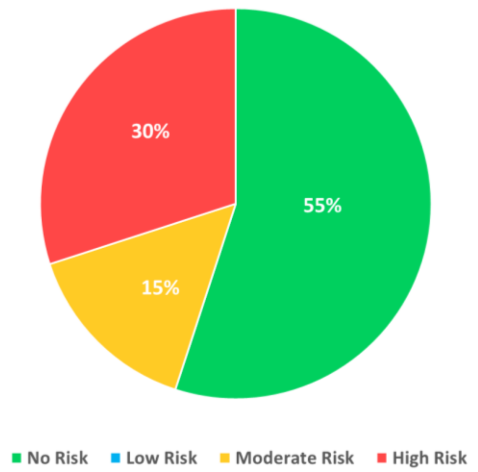
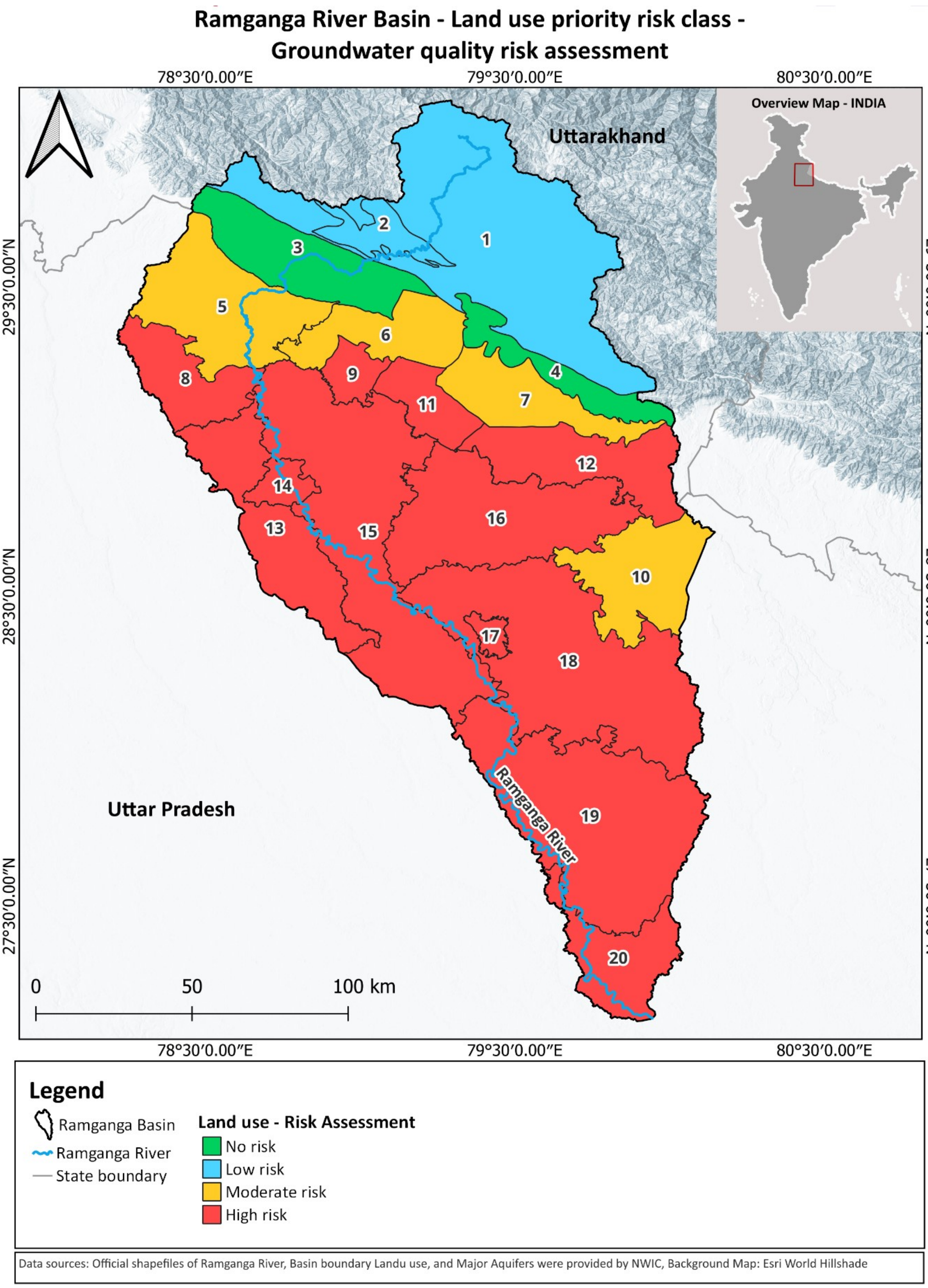


Figure 22: Final groundwater quality risk classes percentages - Ramganga River Basin

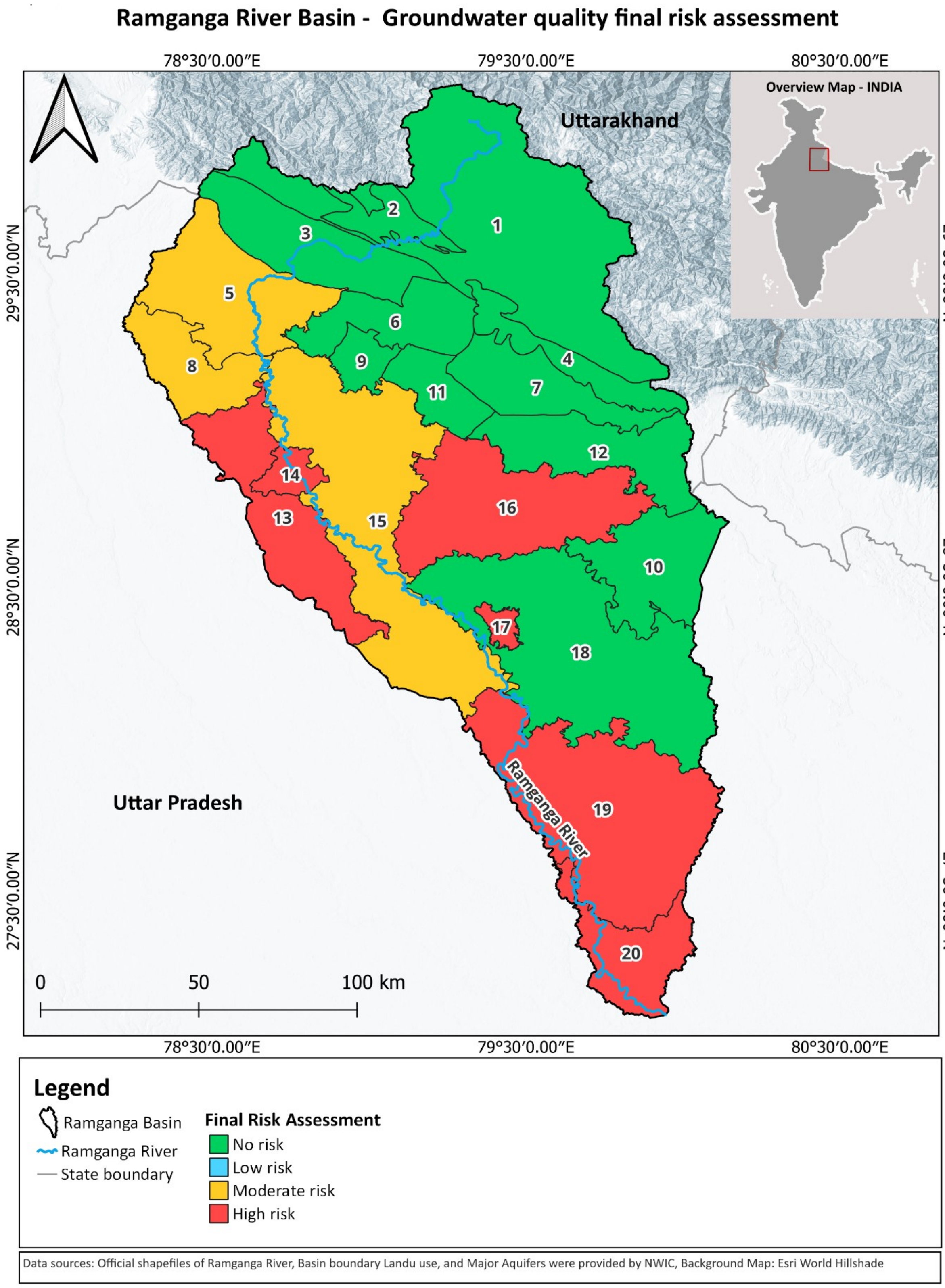
The evaluation matrix (see Table 50) also summarizes the results related to both methods adopted for NO_3 risk assessment. One benefit of Theissen polygon method is that it can extrapolate the no data areas as well. But due to uncertainties related to this method the results should be interpreted with caution.

In the final synthesis (Step 4 of Table 50) a confidence level for the risk assessment for each of the GMU has been assessed. The results for the GMU number 2, 3 and 17 have been assigned ‘Low’ level of confidence because these results are representing the extrapolated values for no data areas. GMU number 8, 13, 15, 16, 19 and 20 have been assigned as ‘Medium’ confidence class because these GMUs are presenting contradictory results based on either NO_3 evaluation (Theissen polygon) or land use priority risk class-1. The remaining GMUs risk assessment results are assessed to be at ‘High’ confidence level.

Groundwater Quality
Overall, out of 20 GMUs, 11 GMUs are classified as ‘No risk’, 3 GMUs are classified as at ‘Moderate Risk’ and remaining 6 GMUs including urban blocks like GMU number 14 (Moradabad block) and GMU number 17 (Bareilly block) are classified as at ‘High Risk’. There is no GMU which is classified as at ‘Low Risk’. In the Ramganga Basin 28 % area is at ‘High risk’ of poor groundwater quality whereas, 20% area is at ‘Moderate Risk’ and remaining 50% area is classified as at ‘No Risk’ (Map 27).



Map 26: Groundwater quality risk assessment based on clubbed land use classes



Map 27: Final groundwater quality risk assessment results

Table 50: Groundwater quality risk assessment matrix - Ramganga River Basin

GMU No.	**Step - 1**: Existing Pressures			**Step - 2a**: Land use classes			**Step - 2b**: Data Observed							Interim Risk-2	Pressures/ indicators causing risk	**Step - 3**: Expert Judgement	**Step - 4**: Final Synthesis			
	Pollution Sources			Priority class - 1 [%]	Priority class - 2 [%]	Interim Risk - 1	Monitoring[38]		Sites exceeding threshold [%]		Groundwater quality parameters risk assessment						Final Risk Assessment	Significant pressures		Confidence
	Point[39]	Non-point[40]	No. of Pressure types				NO_3	EC	NO_3	EC	NO_3 (observation)	NO_3 (Thiessen polygon)	EC[41]					Point	Non-point	
1	4	F: low, P: low	2	12.4	10.8	Low Risk	5	7	0	0	No Risk	No Risk	No Risk	Low Risk	–	Following experts' suggestion, due weightage was given to groundwater quality observations instead of taking	No Risk	X	–	High
2	0	F: low, P: low	1	12.3	16.5	Low Risk	–	–	–	–	No Data	No Risk	No Data	Low Risk	–		No Risk	–	–	Low
3	0	F: low, P: medium	1	1.6	0.8	No Risk	–	–	–	–	No Data	No Risk	No Data	No Risk	–		No Risk	–	–	Low
4	2	F: medium, P: high	2	2.5	1.4	No Risk	1	1	0	0	No Risk	No Risk	No Risk	No Risk	–		No Risk	X	X	High
5	0	F: low, P: high	1	43.8	36.6	Moderate Risk	3	3	33	0	Moderate Risk	Moderate Risk	No Risk	Moderate Risk	NO_3		Moderate Risk	–	X	High
6	4	F: medium, P: medium	2	33.2	5.6	Moderate Risk	6	8	0	0	No Risk	No Risk	No Risk	Moderate Risk	–		No Risk	X	X	High

38 Map of NO_3 and EC locations can be found in Annex-I (see Figure A9 and Figure A10).
39 Represents the sum of all point-sources of pollution including industries, drains and STPs (operational and under construction) – See Annex-I, Figure A14.
40 F = Fertilizer use and P = Pesticides usage – Results from the KWMI-2 are intersected with all GMUs to obtain respective fertilizer and pesticide usage level.
41 There is no difference in results for EC between 'counting' and Thiessen polygon method.
42 Criteria: If there are less than 2 groundwater quality monitoring stations within the GMU the priority has been given to land use classes, otherwise NO_3 (Thiessen polygon method) has a priority in assigning the risk class.

GMU No.	Step - 1: Existing Pressures			Step - 2a: Land use classes			Step - 2b: Data Observed							Interim Risk-2	Pressures/ indicators causing risk	Step - 3: Expert Judgement	Step - 4: Final Synthesis			
	Pollution Sources			Priority class - 1 [%]	Priority class - 2 [%]	Interim Risk - 1	Monitoring[38]		Sites exceeding threshold [%]		Groundwater quality parameters risk assessment						Final Risk Assessment	Significant pressures		Confidence
	Point[39]	Non-point[40]	No. of Pressure types				NO_3	EC	NO_3	EC	NO_3 (observation)	NO_3 (Thiessen polygon)	EC[41]					Point	Non-point	
7	2	F: medium, P: high	2	32.8	4.9	Moderate Risk	3	3	0	0	No Risk	No Risk	No Risk	Moderate Risk	–		No Risk	X	X	High
8	0	F: low, P: high	1	68.3	30.3	High Risk	2	2	50	0	High Risk	Moderate Risk	No Risk	High Risk	NO_3		Moderate Risk	–	X	Medium
9	34	F: medium, P: medium	2	72.8	13.3	High Risk	3	6	0	0	No Risk	No Risk	No Risk	High Risk	–		No Risk	–	X	High
10	0	F: medium, P: high	1	48.2	21.2	Moderate Risk	3	3	0	0	No Risk	No Risk	No Risk	Moderate Risk	–		No Risk	–	X	High
11	2	F: medium, P: low	2	79.7	10.7	High Risk	5	7	0	0	No Risk	No Risk	No Risk	High Risk	–		No Risk	X	X	High
12	8	F: medium, P: high	2	54.1	10.3	High Risk	11	17	20	0	No Risk	No Risk	No Risk	High Risk	–		No Risk	X	X	High
13	5	F: low, P: medium	2	83.8	15.6	High Risk	1	1	0	0	No Risk	High Risk	No Risk	High Risk	–		High Risk	X	X	Medium
14	98	F: low, P: medium	2	77.7	19.6	High Risk	1	2	100	0	High Risk	High Risk	No Risk	High Risk	NO_3		High Risk	X	X	High
15	13	F: medium, P: medium	2	83.7	11.9	High Risk	2	4	50	25	High Risk	Moderate Risk	No Risk	High Risk	NO_3		Moderate Risk	X	X	Medium
16	4	F: medium, P: medium	2	77.9	18.2	High Risk	1	2	0	0	No Risk	No Risk	No Risk	High Risk	–		High Risk	X	X	Medium
17	8	F: low, P: low	2	76.1	13.4	High Risk	–	–	–	–	No Data	No Risk	No Data	High Risk	–		High Risk	X	–	Low

GMU No.	Step - 1: Existing Pressures			Step - 2a: Land use classes			Step - 2b: Data Observed							Interim Risk-2	Pressures/ indicators causing risk	Step - 3: Expert Judgement	Step - 4: Final Synthesis			
	Pollution Sources			Priority class - 1 [%]	Priority class - 2 [%]	Interim Risk - 1	Monitoring[38]		Sites exceeding threshold [%]		Groundwater quality parameters risk assessment						Final Risk Assessment	Significant pressures		Confidence
	Point[39]	Non-point[40]	No. of Pressure types				NO_3	EC	NO_3	EC	NO_3 (observation)	NO_3 (Thiessen polygon)	EC[41]					Point	Non-point	
18	7	F: medium, P: high	2	70.5	24.0	High Risk	3	4	0	0	No Risk	No Risk	No Risk	High Risk	–		No Risk	X	X	High
19	0	F: low, P: high	1	76.5	16.4	High Risk	1	3	0	0	No Risk	No Risk	No Risk	High Risk	–		High Risk	–	X	Medium
20	0	F: low, P: high	1	68.7	17.0	High Risk	1	1	0	0	No Risk	No Risk	No Risk	High Risk	–		High Risk	–	X	Medium

5.5.4 Challenges and data gaps

Groundwater quantity

The groundwater quantity monitoring network already has good coverage within the Ramganga Basin, but it would be beneficial if groundwater monitoring network can be densified in the future. For example, Kashipur has a rather densified groundwater monitoring network compared to the rest of the urban blocks. This situation needs to be improved in the next cycle of the Ramganga RBM Plan.

The suggestions and recommendations for improving groundwater quantity are as follows:

- It is suggested to establish a well-calibrated/validated model for groundwater recharge estimates, like e.g., the SWAT model, for the Ramganga Basin. In addition to the present, observation-based groundwater resources assessment, it would be helpful to perform groundwater recharge predictions under different climate change scenarios.
- It is recommended to implement more exploration drillings and monitoring wells for the deeper (confined) alluvial aquifers.
- A proper groundwater model for the alluvial aquifer system including deep aquifers would be helpful for groundwater management.

Groundwater quality

The situation related to groundwater quality monitoring stations within the Ramganga Basin is good but not ideal. The following list provides some insight into the groundwater quality monitoring within the Ramganga Basin.

- There are some GMUs where only one station is available with the groundwater quality data (i.e., NO_3 and EC).
- The data challenge is bigger even for the urban GMUs like Moradabad and Bareilly where groundwater data scarcity is really an issue, and it needs to be tackled in the future.
- There is only one station for Moradabad whereas for Bareilly there is none with the water quality data. This data gap has been handled by employing the Thiessen polygon analysis, but it also adds bias to the groundwater quality data of nearby GMUs. More groundwater quality stations are needed at appropriate locations within the Ramganga Basin.
- It would be beneficial to define a few “principle” groundwater quality monitoring sites, where a periodical observation and proper analysis of key quality parameters is guaranteed.

The current scope of groundwater quality monitoring for the Ramganga River Basin is also quite limited and focused on a few core indicators (NO_3 and EC). In the future it is recommended to screen and monitor the impacts of intensive agriculture and most toxic pesticides according to the WHO guidelines. This type of monitoring will enable a validation of the identified risks and allow for setting targeted measures.

5.6 KWMI 4: Alteration in river hydrology and water quantity

The fourth Key Water Management Issue (KWMI 4) identified for the Ramganga Basin is the risk posed by alternation in river hydrology and water quantity. As the Ramganga river provides for water demand for domestic, industrial, agricultural irrigation and hydropower generation, alternating hydraulic regime and associated water quantity in the climate change scenarios pose a pressure for many crucial social, economic, and environmental functions of the Ramganga River System. Example: Flooding or droughts, increase in ground water exploitation and depletion and maintenance of aquatic ecosystem.

The unique hydrological features of the Ramganga Basin are considered during risk assessment of alternating hydrological regime and associated water quantity. Though some of the variables/factors considered in the Tapi are considered for this purpose while those that are not relevant are excluded. For instance, groundwater depletion in Ramganga Basin, given the high rainfall, good recharge, and extensive surface irrigation in the alluvial plains of Uttar Pradesh is not consider as a critical factor for assessing risk associated due to alternating river hydrology. On the other hand, flooding is a concern that is considered in the risk assessment of this key issue related to alteration in river hydrology. Also, flooding is identified to be included. The ecological and socioeconomic impacts of flood hazard also need to be assessed. Unlike in the case of Tapi river basin, in the case of Ramganga river basin, the risks associated with floods along with human-induced flow alterations are therefore, considered.

Data sources

A total of 17 factors are identified broadly to understand the extent and the impact of flow alterations in terms of water scarcity for agricultural irrigation, domestic, economic and livelihood. Additionally, impact of alternations of river hydrology on the quality of water was also considered.

For this data relevant to each of these parameters was collected. The data compiles was related to flow, climate, river ecology, water abstractions and socio-economic profile. Tables provided in Annex A4 gives complete information on the data requirements, collection, and their sources.

Overall, it is to be noted that the flow data of the Ramganga River Basin was used from the outputs of the hydrological simulation study using SWAT. The extent of flow alteration is estimated by taking the ratio of the 'difference between the current annual flows and the mean annual virgin flows these outputs. In addition to the SWAT outputs, the CWC hydrological year-book and data from CGWB was referred to validate data related to climate of the basin, reservoir storage details, critical groundwater blocks. The data was used to estimate aridity, rainfall variability and annual renewal water resources (ARWR). ARWR has a direct impact on the water scarcity for irrigation, domestic uses, and environmental water scarcity in the basin. Higher the ARWR, lower will be the scarcity of water for irrigation and domestic uses and environmental water scarcity. It is estimated by taking the sum of the mean annual runoff and the mean annual groundwater recharge.

The data relating to river ecology included the number of aquatic and riparian species (flora and fauna) that the river provides habitat for (source: based on Sponseller et al., 2013: Thompson & Lake, 2010; Ward & Stanford, 1983; Webster, 2007); and the biological processes (nutrient recycling; breeding of aquatic animals) that the continuous flow of water supports (Barbarossa et al., 2020).

For irrigation water security, expert analysis based on data from various sources, viz., the SWRDs, CGWB, India-WRIS was taken.

Socio-economic profile data, reports of ecological studies available for the Ramganga Basin including published reports were used to estimate proportion of people who are directly dependent on the river water (for the ecological functions and the economic activities that they support) for livelihoods. For this total number of people who are dependent on fishing from the river, navigation and recreational services for their livelihood divided by the total population was used. Similar datasets in addition to the information on population of farmers, cattle rearing communities and fishermen was used to estimate the proportion of people whose source of livelihood was dependent directly on surface and groundwater resources.

Latest census data and statistics from the agriculture department was used to estimate the proportion farm outputs dependent on surface water. This was estimated by taking the ratio of the approx. value of agricultural outputs from surface water irrigated area and the total agricultural outputs in value terms (including that from rain-fed areas).

Further census data was referred for Proportion of population who depend on surface water as primary source of water for domestic use but have alternate sources of potable water. This can be deduced from the data on population having different types of primary and secondary water sources for the respective districts.

State Disaster Management Authority and Census data provides information on the low-lying areas. Proportion of people living in low-lying area who are poor was estimated by taking the ratio of the approximate number of poor people living in low lying area and the total population living in low-lying areas. This forms the basis for this vulnerability assessment. Likewise, the vulnerability of drinking water users to pollution due to floods was considered as a factor. With the assumption that higher the proportion of people living in the shallow groundwater areas dependent on wells for domestic water supply, higher the vulnerability to pollution caused by floods the proportion of people in the shallow groundwater areas of the sub-catchments who are dependent on wells for domestic water supply was estimated. This was estimated by taking the proportion of the geographical area under shallow groundwater (as a fraction) and multiplying by the proportion of HHs or population in the sub-catchment who are dependent on GW for drinking purpose (as a fraction).

The magnitude of the frequency of the flood was taken from the time series data on flood discharge in different years, and the available records of the ecological damages caused by floods. From the flood frequency analysis (using rainfall and catchment parameters), the frequency of occurrence of floods of the designated magnitude was estimated.

Irrigation potential is estimated by taking the ratio of the total volume of water available from various sources for irrigation and the volume of water required to irrigate one ha of land; the total land area requiring irrigation is worked out by considering the total arable land where the potential evapotranspiration (PET) exceeds the effective rainfall and considering the likely future expansion in irrigated area.

5.6.1 Risk assessment approach, criteria, and thresholds

The risk assessment approach for issue related alteration in river hydrology consists of the following steps:

1. The Ramganga Basin was divided into six sub-catchments, defined by distinct drainage lines and boundaries. The boundaries of these six sub-catchments are as defined by and obtained (using- www.hydroSHEDS.org). These six sub-catchments were identified for risk assessment to constitute drainage areas with similar features aggregated within single sub-catchment. These six identified sub-catchments were chosen for risk assessment of alteration in river hydrology and quantity in such a way that they constitute drainage areas that are large enough for computation of the various physical and socio-economic parameters involved in the assessment of hazard, exposure, and vulnerability.

Aril	Bhakra	Garra	Kosi	Upper Ramganga	Lower Ramganga

2. To understand the extent and the impact of flow alterations in each of these sub-catchments in terms of water scarcity for agricultural irrigation, domestic, economic and livelihood, 17 parameters were identified broadly.
3. These parameters were further seen from the lens of and categorised into Hazard, Risk and Vulnerability. There were overall five factors under 'hazard', six under 'exposure' and another six under 'vulnerability'. The definition of these factors and the way in which they are likely to influence the risk through hazard or exposure or vulnerability are highlighted.
4. Further, thresholds for each of these 17 parameters were defined based on the data availability and stakeholder consultation (combined consultation on methodology for Ramganga and Tapi was held).
5. Four risk categories, depending on the value of the risk index were identified. The various risk categories, the value ranges for each category and the colour codes are given below in Table 51. The lowest risk value that any hydrological unit can obtain is 0.035.

Table 51: Risk categories and value range

S No.	Risk Categories	Value Range	Colour Code
1	No Risk	0.035 to 0.20	
2	Low Risk	0.201 to 0.350	
3	Moderate Risk	0.351 to0.650	
4	High Risk	0.651 to 1.0	

Hazard

- Extent of flow alteration, considering the ecological water demand: higher the extent of alteration in river flows, higher will be the magnitude of the hazard.
- Aridity: higher the aridity, higher will be the intensity of water-related hazard due to flow reduction. That said, there is sharp variation in aridity from the hills of Uttarakhand to the plains of Uttar Pradesh.
- Rainfall variability: Higher the year-to-year variation in rainfall, higher is the water-related hazard due to hydrological alterations. It is high in Uttar Pradesh part of the basin.
- Annual renewable water resources: In regions where annual renewable water resources are less, the magnitude of hazard due to hydrological alterations will be less.
- Magnitudes and frequency of Floods: Higher the frequency of floods of certain magnitude that is capable of causing ecological and economic consequences, higher will be the hazard induced by floods. The plains of Uttar Pradesh are prone to flooding.

Exposure

- Impact of flow alteration on the ecological and economic functions: larger the number of ecological and economic functions of the river that the flow regime support, higher will be the ecological and economic impacts of the flow alterations.
- Drought proofing capacity of groundwater: higher the stock of groundwater in the area, lower will be the exposure of the socioeconomic system to water-related hazard resulting from flow reduction. Groundwater stock is substantial in the alluvial belt of UP, and is non-existent in the crystalline formations of Uttarakhand
- Irrigation water scarcity: higher the extent of scarcity of irrigation water in an area, higher would be the exposure of the socioeconomic system water-related hazard resulting from flow alteration
- Drought Proofing Capacity of Reservoirs: Like groundwater, higher the stock of water in reservoirs of the area, lower will be the exposure of the socioeconomic system to water-related hazard resulting from flow reduction. There are several large and medium reservoirs in Uttarakhand, whereas in UP there are only diversion systems
- Proportion of people who are living in low-lying (flood-prone): higher the proportion of people living in low-lying areas, higher will be the impact of flood hazards
- Susceptibility of groundwater to pollution caused by floods: higher the areas where aquifers are shallow, higher the exposure of the drinking water sources based on groundwater in such areas to biological contamination. Such areas are high in the alluvial belt in Uttar Pradesh part of the basin.

Vulnerability

- Proportion of people dependent on river water for ecological functions and economic activities: dependence of a large proportion of the people to river water for ecological functions and economic activities is suggestive of their higher vulnerability to disruptions in ecological functions and economic activities to hazard associated with flow alterations.
- Proportion of people dependent on surface water and groundwater for livelihoods, directly: if a great proportion of people are directly dependent on water (surface water or groundwater) for their livelihoods, it is suggestive of greater vulnerability to the hazards associated with flow alterations

- Proportion of farm outputs that is dependent on surface irrigation: if a great portion of the agricultural production is dependent on surface water, it would increase the vulnerability of the agricultural dependent communities on hazards associated with hydrological alterations.
- Proportion of people who are dependent on surface water as primary source for domestic purpose, but have alternative potable water sources: access to alternate sources of water would reduce the vulnerability of the households to the disruptions in water supply from surface sources due to the hazards associated with hydrological alterations
- Proportion of people living in the shallow groundwater areas who are dependent on wells for domestic water supply. In the shallow groundwater areas (like in alluvial UP part of the basin), if there is a large local population dependent on wells for drinking water supply, their vulnerability to health risks will be high.
- Vulnerability of drinking water users to pollution due to floods: poor people generally have low capacity to adapt. Therefore, higher the proportion of poor people, higher will be the vulnerability

The summary of the risk assessment thresholds agreed for each of the 17 factors defining the hazard, exposure and vulnerability related to alteration in river hydrology and quantity within the Ramganga River Basin is compiled in Table 52.

Table 52: Defining Quantitative Criteria for Assigning Values for Different Influencing Variables

S. No	Risk Assessment Variables	Quantitative criteria for Assessing the Variables		
		(a) Hazards		
	Variables	Highly prone to hazard	Moderately prone	Least prone to hazard
1	Extent of flow alteration	If flow alteration > 90% of mean runoff of monsoon season and > 50% of the non-monsoon (lean season) flows in a semi-arid area, or > 50% of mean runoff of monsoon and > 25% of the mean runoff of lean season in sub- humid area	Flow alteration between 90% and 50% of the runoff of the monsoon season and between 50% & 25% of the runoff of the lean season in semi-arid area, or between 50% and 25% of the mean monsoon runoff and between 25%-10% of the lean season flow in sub-humid area	Flow alteration <50% of the monsoon runoff and < 25% of the lean season runoff in a semi-arid area or < 25% of the monsoon runoff and < 10% of the lean season runoff in sub-humid area
2	Aridity	Arid to Hyper-arid	Semi-arid	Humid-sub- humid
3	Rainfall variability (coefficient of variation, %)	CV more than 40%	CV in the range of 17-40%	CV less than 17%
4	Annual renewable water resources (m^3/capita)	<1000m^3/capita/year	Between 1000 and 1700 m^3/capita/year	1700 m^3/capita/year

S. No	Risk Assessment Variables	Quantitative criteria for Assessing the Variables		
5	Magnitude and frequency of floods: frequency of occurrence of flood of a designated magnitude	Periodicity > once in 10 years	Periodicity between once in 10 years to once in 20 years	Periodicity between once in 20 years and once in 50 years
	(b) Exposure			
	Variables	High exposure	Moderate exposure	Low exposure
1	Impact on Ecology: Extent of impact of flow alterations on the ecological and economic activities that the river supports	Both ecological and economic functions are severely affected	Ecological and economic functions are moderately affected	Economic and ecological functions are not affected
2	Irrigation water scarcity: irrigation potential of the existing sources/ total land area requiring irrigation #	Irrigation potential of existing sources in ha/total arable land in ha < 0.5	Irrigation potential of existing sources/total arable land = 0.5 to 1.0	Irrigation potential of existing sources/total arable land> 1
3	Drought Proofing Capacity of Reservoirs: Provision of buffer storage of water in reservoirs (m3/capita/year)	Provision of buffer storage in a reservoir less than 10 m^3/capita/year	Provision of buffer storage in a reservoir is 11 to 36 m^3/capita/year	Provision of buffer storage in a reservoir is > 36 m^3/capita/year
4	Drought Proofing Capacity of Groundwater: Groundwater stock reduces the exposure of agricultural systems and drinking water supply systems to shocks from droughts (m^3/capita)	Groundwater stock per capita/annum < 200 m^3	Groundwater stock per capita/annum, 200-500 m^3	Groundwater stock per capita > 500 m^3
5	Proportion of people living in low-lying areas	Proportion > 50%	Proportion =50% to 25%	Proportion < 25%
6	Susceptibility of groundwater to pollution caused by floods: Proportion of the area in the sub-basin where the groundwater table is available within 10 m depth	Proportion > 50%	Proportion =50% to 25%	Proportion < 25%
	(c) Vulnerability			
	Variables	High vulnerability	Moderate vulnerability	Low vulnerability
1	Proportion of people dependent on the river (for the ecological functions and economic activities that they support) for livelihoods (%)	Proportion > 25%	Proportion, 25% to 10%	Proportion < 10%
2	Proportion of people whose source of livelihood is dependent on surface water and groundwater,	Proportion >50%	Proportion = 50 % to 20%	Proportion < 20%

S. No	Risk Assessment Variables	Quantitative criteria for Assessing the Variables		
	directly (agricultural communities, cattle rearing communities and fisher folk (%)			
3	Proportion of farm outputs dependent on surface water	Proportion> 30%	Proportion – 30 to 10%	Proportion < 10%
4	Proportion of population who depend on surface water as primary source of water for domestic use, but have alternate sources of potable water	Less than 25% of those dependent on surface-water have alternate source	50-25% of those dependent on surface-water have alternate sources	More than 50% of those dependent on surface water have alternate sources
5	Proportion of people living in low-lying area who are poor	Proportion> 50%	Proportion = 50 to 20%	Proportion < 20%
6	**Vulnerability of drinking water users to pollution due to floods**: higher the proportion of people living in the shallow groundwater areas dependent on wells for domestic water supply, higher the vulnerability to pollution caused by floods	Proportion >50%	Proportion = 50 % to 20%	Proportion < 20%

The final risk will be estimated by using the final hazard, exposure and vulnerability evaluation using all the identified parameters. Say, if the value of hazard for a sub-basin is 0.6, exposure 0.40 and vulnerability 0.40, then the risk will be 0.096 (0.60 X 0.40 X 0.40=0.096).

Risk = H x E x V;

H is the hazard, includes factors that causes the pressures on water resources, human and biodiversity

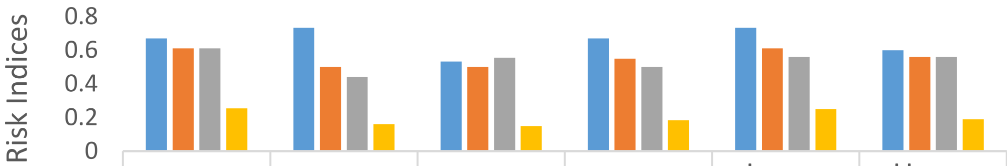
E is the exposure, includes factors that have potential to contribute to the pressures

V is the vulnerability, includes factors that increases the susceptibility of the pressures of alterations due to hydrology and water quantity in the Ramganga Basin.

5.6.2 Results from the Risk Assessment and possible impacts on water resources

The mapping of risk due to hydrological alterations for Ramganga river basin is done by computing the risk index for individual sub-catchment. The variables considered, method of estimation of those variables and data sources from which they were obtained included parameter specific estimations and expert judgement. The approach was agreed with inputs from the basin stakeholders. The estimates of sub-catchment-wise risk assessment for the six sub-basins of Ramganga Basin are presented in Annex A4.

The risk assessment based on the threshold corresponding to each of the parameter for the six catchments Aril, Bhakra, Garra, Kosi, Upper Ramganga and Lower Ramganga was done. Further, a summary of the values of the hazard, exposure and vulnerability values for all the six sub-catchments is presented in Figure 23. The lowest value of risk estimated was 0.148 for Garra, followed by 0.16 for Bhakra and 0.184 for Kosi. The highest value of risk was 0.254 for both lower Ramganga and Aril and both of them fall in the 'low risk' category. Upper Ramganga had a risk value of 0.189. So out of the six sub-catchments, two fall under the low risk category and the remaining four (Garra, Bhakra, Kosi and Upper Ramganga) do not face any risks associated with alterations in surface hydrology.



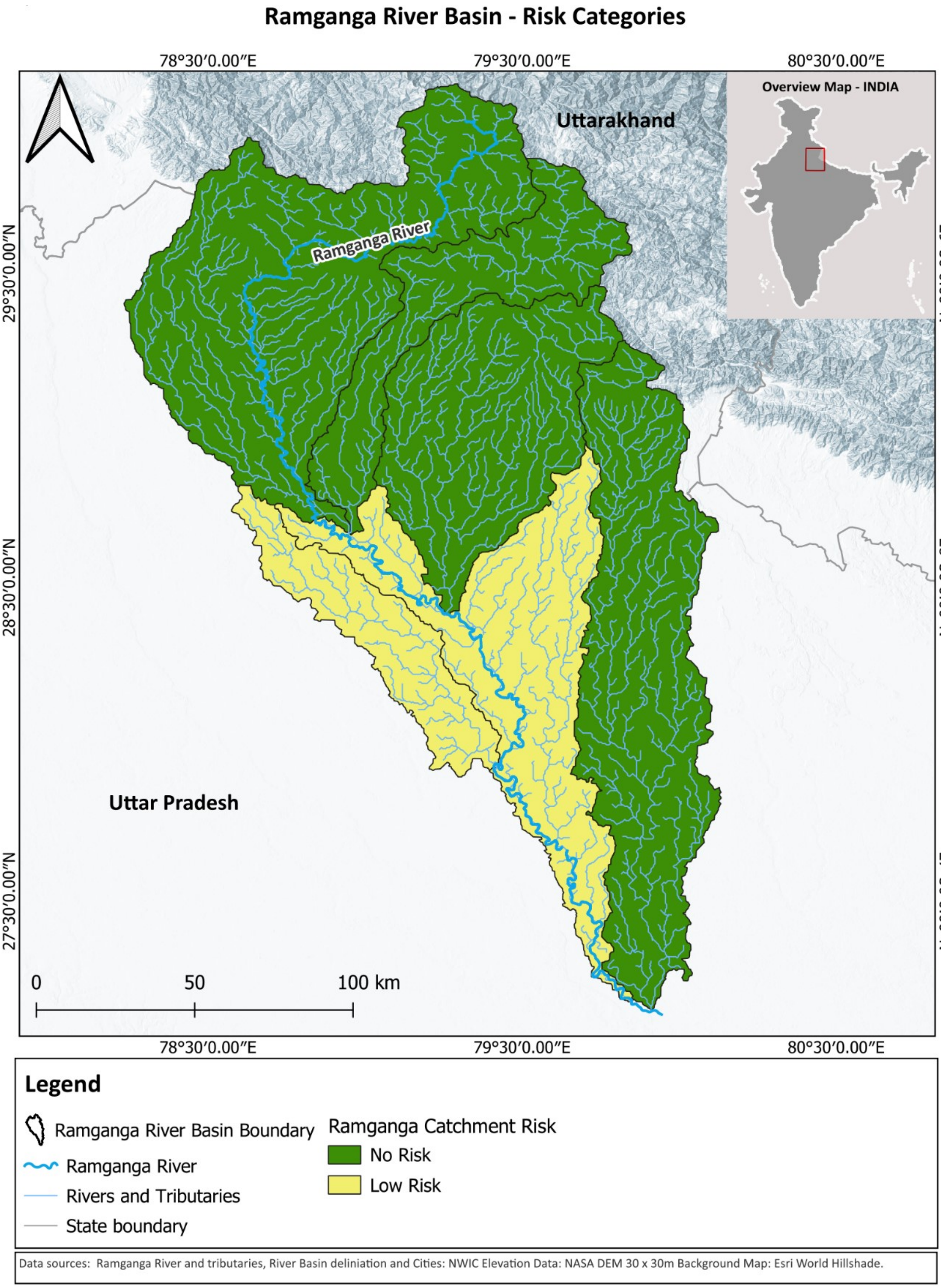
	Aril	Bhakra	Garra	Kosi	Lower Ramganga	Upper Ramganga
Hazard	0.67	0.733	0.533	0.67	0.733	0.6
Exposure	0.611	0.5	0.5	0.55	0.61	0.56
Vulnerability	0.611	0.44	0.556	0.5	0.56	0.56
Total Risk	0.254	0.16	0.148	0.184	0.25	0.189

Figure 23: Hazard, Exposure, Vulnerability, and Total Risk Index values for all catchments in Ramganga River Basin

The lowest risk values are for the three sub-catchments viz., Garra, Bhakra and Kosi. In the case of Garra, the low risk is because of low degree of exposure (0.50). In the case of Bhakra and Kosi, the low risk is because of low vulnerability (0.44 for Bhakra and 0.505 for Kosi). The low values of vulnerability for Garra are because of good drought-proofing capacity of the reservoirs/barrages existing in the sub-catchment; low proportion of people living in low-lying areas; and low irrigation water scarcity owing to plenty of canal water and groundwater available for irrigating the cropland.

In the case of Bhakra, the low vulnerability (0.44) is because of four main factors: 1) proportion of people dependent on river water for ecological and economic activities is low; 2) proportion of people whose livelihood is dependent on water directly is quite low; 3) the proportion of farm outputs dependent on surface water is low; and, 4) proportion of people who are living in low-lying area and who are poor is low. In the case of Kosi also, the reasons are more or less same as that of Bhakra, except that the proportion of farm outputs dependent on surface water is relatively higher in that sub-catchment.

The highest values of risk for Aril and lower Ramganga (0.250) is due to the relatively high hazard (0.73 for lower Ramganga and 0.67 for Aril). The high hazard for lower Ramganga is because of high frequency of occurrence of damaging floods in the sub-catchment; and limited availability of renewable water resources on an annual basis. In the case of Aril, the same factors contribute to the high hazard. Further for both the sub-catchments, exposure is also high (0.61) due to poor drought-proofing capacity of the available reservoirs and high susceptibility of groundwater to pollution caused by floods. Map 28 presents the risk categories of all sub-basins in Ramganga River Basin.



Map 28: Risk assessment result for alteration in river hydrology

5.6.3 Challenges and data gaps

The vision for river hydrology/water quantity in the Ramganga Basin is to maintain sustainable use of surface waters with a natural flow dynamic ensuring, as a minimum, environmental flows and water security as well as considering the impacts of climate variability and climate change. Since only limited datasets are available on climate change variability and adequate E-Flows in the Ramganga Basin and establishing linkages to hydrological regime and ecology requires concerted multi-expert specialized group consultation, a dedicated E-Flows expert group should be formed to advise on establishing these linkages with the risk assessment in the next cycle and further develop such PoM.

5.7 KWMI 5: Flood risk due to encroachment including sandmining

The pressure/impact analysis and the risk assessment for flood due to encroachment and sand mining, consists of two major components:

(i) Flood risk
(ii) Sand mining

Sand is a valuable resource and its transport from the mountains to the sea, the so-called sediment continuum, is a very fragile system in which alterations (such as e.g. sand mining) are directly connected to morphological alterations, ground water, aquatic life and many more. It also acts as a backbone of the construction industry. Due to its overuse in construction almost all Indian states are facing an acute shortage of sand. Annex 5 shows the state-wise demand and supply of sand within India[43]. In Uttar Pradesh demand is around 45 million tons per annum, compared to a supply of 18 million tons per annum. An approximately 60% gap in sand supply thus exists, which results in the need to obtain sand, within or outside the state, ultimately putting pressure on existing infrastructure, river morphology and, subsequently, river hydrology as well as aquatic ecosystems. Ganga (including Ramganga) in UP and Kosi, Gola in Uttarakhand show to be among most affected rivers due to sand mining in Uttar Pradesh and Uttarakhand (Rawat and Thakkar 2020).

Also, sand is inevitably required for construction and glass industries and more, which makes it a high-value commodity. Construction activities and therewith also sand mining and the demand for sand are closely related to population growth and urbanization. Intensive sand mining has several negative impacts on rivers:

- Disturbance of the river sediment balance by changing sediment supply and the transport capacity of the channel. Sand mining has negative impacts on the Ramganga river health which ultimately influences the Ganges.
- Sand mining also has an impact on channel morphology, narrowing the river channel, lowering the riverbed, and causing unnatural erosion of riverbanks and deposition of sediment (Rai et al. 2018).
- Both the sand mining itself and its impacts severely affect aquatic ecosystems.

As seen in Annex 5, the Ramganga Basin has the combined total sand consumption around 108 million tonnes (Uttar Pradesh: 101 million tonnes; Uttarakhand: 7 million tonnes). The main pressures caused by intensive sandmining are as follows:

- Coarsening of riverbeds, instability of channels, lowering of water tables, erosion of riverbanks and deposition of sediment.
- Weakening of hydraulic structures which may lead to structural failure.
- Disruption of the natural balance of sediment flux within a channel.
- Deterioration of aquatic flora and fauna and loss of biodiversity.
- Increase of river pollution load and disruption of species habitats.

Data source

Flood data

A flood risk assessment for a specific area usually comprises an evaluation of the risk of flooding to the community and nearby infrastructure, followed by the identification of mitigation measures. For the

[43] Source: https://www.downtoearth.org.in/coverage/environment/india-can-rely-on-sand-imports-till-the-time-it-is-viable-60892

Ramganga flood risk assessment, primary precipitation and water level data has limited availability and in the present study only online publicly available flood risk datasets have been used.

Further, a publicly available dataset[44] has been used for the flood risk assessment. The resolution of this raster-based data is 30 arc-seconds (i.e., approx. 1x1 km). The data not only shows the inundated area but also indicates the estimated water depths (in meters) for a flood return period of 100-years. The 100-years return period has been selected as this is an internationally well-established hydrological standard, during which an extreme event is expected to have occurred. The data has been prepared using a novel procedure of global flood hazard mapping. The long-term discharge data used in this process is based on the hydrological simulations of the Global Flood Awareness System (GloFAS) (Dottori et al., 2016). A conceptual schematic of the flood hazard mapping methodology adopted to prepare this dataset can be seen in Figure 24.

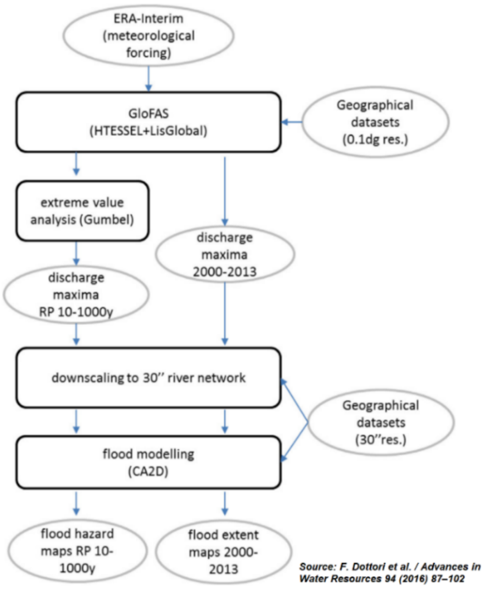


Figure 24 Conceptual schematic of the flood hazard mapping methodology

ERA-Interim (global atmospheric reanalysis from 1979) meteorological forcings with the GloFAS dataset has been used to finally prepare the flood hazard data, which is downscaled to the river network resolution of 1x1 km (Dottori et al., 2016). It is important to mention that this dataset has been tested and evaluation has been carried out at different locations and basins in different regions[45] (see Figure 25). It is encouraging to see that the Ganga Basin (with Ramganga being a part of the Ganga catchment as shown in the Figure 25) is also included as an evaluation basin for testing this dataset. This means that a considerable credibility which may be expected when using this dataset in the flood risk assessment in case of unavailability of any other in-situ information. However, the interpretation of this data in terms of flood risk assessment in the Ramganga River Basin is done with caution after thorough consultation, including expert judgment and feedback from all relevant stakeholders.

[44] Data source: https://data.jrc.ec.europa.eu/dataset/jrc-floods-floodmapgl_rp100y-tif

[45] Figure source: Dottori et al., (2016) Development and evaluation of a framework for global flood hazard mapping

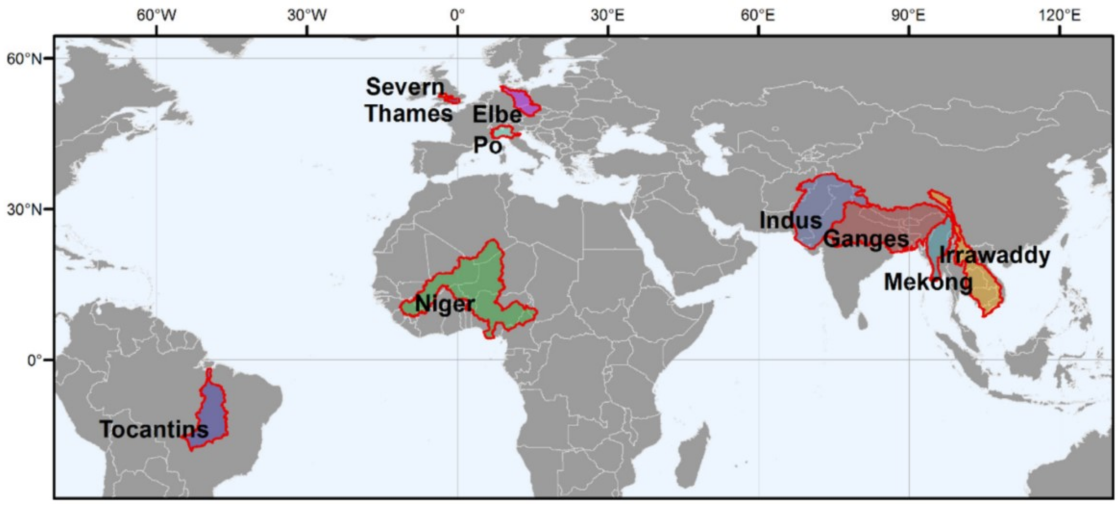


Figure 25 Location of test areas and river basins used for flood hazard map evaluation

Additionally, agricultural land is considered as an important parameter when it comes to flood risk assessment because flood damages to agricultural lands might lead to food security issues. Land use and Land cover[46] information (NRSC) has been for this estimation.

Sand Mining Data

The dataset used in the sand mining risk assessment has directly been downloaded from the website of the Government of Uttar Pradesh, Directorate of Geology and Mining[47] and the Uttarakhand Forest Development Corporation[48] (see Figure 26 and Table 53). It consists of mineral wise lease details (Government of Uttar Pradesh) and minor mineral collection details (Government of Uttarakhand). The Directorate of Geology and Mining website lists five minerals including ordinary sand 1, ordinary sand 2, Morrum, Gittiyan and Riverbed mineral. However, information about only two mineral categories (i.e., ordinary sand 1, and ordinary sand 2) is available for the districts which lie in the Ramganga Basin, which is why only two minerals are considered in the risk assessment. The mineral wise lease data for the districts of Uttar Pradesh is available for 10 years (2017 – 2026). The records also include information about future lease details.

The sand mining risk has been evaluated using the quantum of sand leases (m^3) in different districts of Uttar Pradesh, that lie within the Ramganga Basin. This data has been used to map the district-wise sand lease details (as a proxy to sand mining) to identify the potential hotspots of sand usage (or sand transportation). Similarly, for Uttarakhand, information about sand collection in Ramnagar (River: Kosi, Dabka) and Haldawani (River: Gaula Haldwani) has been considered for the sand mining risk assessment (see Table 53).

As a second approach, the district-wise population data is used to estimate cement consumption, and this cement consumption has been converted into sand consumption, which lends a better approximation towards assessing the risk (or quantifying the results for assessing the risk).

[46] National Remote Sensing Centre (NRSC), 2016 - 2017
[47] Source: http://dgmup.in/minerallist/home/MineralRate
[48] Source: http://www.uafdc.in/minning.html

Sr. No.	District	Sub Mineral Name	Lease Holder's Name	Lease Holder's Mobile No.	Lease Detail				Lease Period	Dispatched Quantity of Minerals(Cubic Mt.)	Lease Sanctioned	Selling Mi
					Gata No.	Village	Area(Acre)	Tehsil			Per Cubic Mt.	Per Cubic Mt.
1	Agra	Ordinary Sand 1	DOLI GARG MS MAHAKALI CONSTRUCTION	63952/1548	1 2	SWAMI	14.99		31/01/2018 - 30/01/2023	4807.00	98.00	315.00
2	Agra	Ordinary Sand 1	Arun Kumar Rishabh Herbal Pvt Ltd	63969/3551	1175 Sa	AKBARA	19.99		23/05/2018 - 22/05/2023	29357.00	70.00	350.00
3	Agra	Ordinary Sand 1	Harvansh lal	9889327154	1034 MI	MADRA	14.99	agra	20/06/2018 - 19/06/2023	33643.00	68.00	245.00
4	Agra	Ordinary Sand 1	Ramgopal Chaudhary	8393832111	63/2	KARMANA	14.99		15/06/2018 - 14/06/2023	26983.00	73.00	245.00
5	Ambedkar Nagar	Ordinary Sand 1	Aditya Singh	8985225665	56 Angh Mi	Majha SALARPUR	5.26	Tanda	09/06/2020 - 01/06/2023	106371.00	161.00	0.00

Figure 26: Mineral wise lease details – Directorate of Geology and Mining – Government of UP

Table 53: Minor mineral collection dataset – Uttarakhand Forest Development Corporation

Division Name	River Name	Volume detail
Ramnagar	Kosi, Dabka	14 lakh Cubic meter
Haridwar	Ganga and its Tributries	21.50 lakh Cubic meter
Dehradun	Yamuna-Song-Naronala-Kotmot	229 Ha
Nandhaur	Nandhaur-Kailash	21 lakh Cubic meter
Tanakpur	Sharda	7.60 lakh Cubic meter
Haldwani	Gaula Haldwani	54 lakh Cubic meter
Kotdwar	Malan	35 Thousand Cubic meter

S.No	River	Target Volume (m3)	Area (ha)
1	Gaula	5400000	1497
2	Ganga	2000000	1380
3	Nandhaur	2100000	468
4	Sharda	1200000	384
5	Kosi	2030000	254
6	Dabka	848000	223
7	Song I	375000	225
	Song II	425000	273
	Song III	300000	270
	Song - Mussoorie	150000	64
8	Jakhan I	325000	195
	Jakhan II	125000	100
9	Swarna	98000	23.75
10	Malan	12500	35
	Total	**15278000 (m3)**	**5333 ha**

Source: http://www.uafdc.in/minning.html

As the risk assessment is done on the district level, it is also important to have information about the population at this level, to gauge the severity of the situation and quantify subsequent impacts. To estimate the population (urban, and rural) within the Ramganga river basin data of the 2011 census extrapolated to the year 2022 have been used. This estimation has been performed using GIS tools, considering all points that lie within the boundaries of the basin.

Table 54 provides district-wise information about urban and rural population in the Ramganga Basin. The overall population (extrapolated to the year 2022) in the basin is more than 24 million (see Table 54). This is a large population figure which ultimately might be affected by the negative impacts of sand mining.

Table 54: District-wise urban and rural population information in the Ramganga Basin

District	State	Town	Village	Total population
Almora	Uttarakhand	69,169	520,206	589,375
Bageshwar	Uttarakhand	–	–	–
Chamoli	Uttarakhand	–	49,119	49,119
Champawat	Uttarakhand	–	1,204	1,204

District	State	Town	Village	Total population
Nainital	Uttarakhand	412,625	557,141	969,766
Pauri Garhwal	Uttarakhand	57,677	163,838	221,515
Udam Singh Nagar	Uttarakhand	651,304	1,131,592	1,782,896
Bareilly	Uttar Pradesh	1,740,761	3,202,777	4,943,538
Bijnor	Uttar Pradesh	551,129	1,866,138	2,417,267
Budaun	Uttar Pradesh	55,325	637,954	693,279
Farrukhabad	Uttar Pradesh	–	122,684	122,684
Hardoi	Uttar Pradesh	138,685	1,056,475	1,195,160
Amroha	Uttar Pradesh	–	239,868	239,868
Kannauj	Uttar Pradesh	–	37,471	37,471
Kheri	Uttar Pradesh	–	68,914	68,914
Moradabad	Uttar Pradesh	1,283,743	2,180,228	3,463,971
Pilibhit	Uttar Pradesh	345,663	1,349,208	1,694,871
Rampur	Uttar Pradesh	653,398	1,938,815	2,592,213
Shahjahanpur	Uttar Pradesh	640,103	2,020,309	2,660,412
Sambhal	Uttar Pradesh	29,436	273,345	302,781
Total Ramganga Basin population			**24,046,304**	

** **Note**: These population figures represent the area lying within the Ramganga Basin. Some districts are fully within the Ramganga Basin boundary, whereas, for some districts there is only minor coverage. It means the population figures in the above table might not represent the actual district population in some districts. To have the consistent basin-wide population figure, we adjusted the basin-wide population. As there were some inconsistencies in the intersection of Ramganga Basin and districts shapefile.*

The sand lease data has been downloaded directly from the ministry's website. It was seen that five different types of minor minerals come under the category 'sand'. However, on the website data is only available for two sand classes, i.e., ordinary sand 01 and ordinary sand 02. For the risk classification a summed-up value of these two sand types (m^3) for all districts (where data is available) has been taken. The mapping of district-wise sand quantum is shown in Annex A5.

In the case of Uttarakhand, only the information (see Table 53) related to the Nainital district has been considered. No information is available for the remaining districts. The information about minor mineral collection for the Nainital district adds up to 6.8 million m^3 (i.e., 68 lakhs), falling thus in the 'High Risk' class.

In Uttar Pradesh, sand lease information is available for 6 districts. The districts of Moradabad and Rampur are classified as 'High Risk' due to the high quantum of sand lease, whereas Budaun and Farrukhabad lie in the 'Moderate Risk' class. As per the information available, Bareilly and Kannauj fall in the 'Low Risk' class.

5.7.1 Risk assessment approach, criteria, and thresholds

Flood risk management consists of different aspects and one of the most critical aspects is the assessment of potential damage to critical infrastructure, including housing infrastructure, in case of flooding. A common method to estimate these flood related damages uses depth-damage curves, which indicate the potential damages at specific water depths per asset or land-use category. Many flood-damage models are available which make use of past flood events and determine flood damage. However, these models cannot be applied to all regions. For example, in the Ramganga RBM Plan, because of data constraints they may lead to unrealistic flood damage assessments.

Furthermore, the methodology of flood damage estimation is not harmonized, which restricts its direct comparison with other available methodologies. To resolve this problem, a globally consistent flood damage database has been developed (EC et al., 2017), which also considers the socio-economic World

Development Indicators (WDI). This database consists of different depth-damage curves which estimate the potential maximum damage that might occur for different land use categories. It is important to mention that depth-damage curves are available for different continents with damage specific values on a country scale.

Figure 27 shows the main schematic of the project, highlighting the workflow for the estimation of the global flood depth-damage functions[49]. These flood damage curves and related datasets can not only be used for flood damage assessments at national scale where data sets are available, but they can also provide some guidance in assessing flood related damages in countries where no other flood damage estimation model is currently available (Huizinga and Szewczyk, 2017).

The following steps have been taken for the categorization of flood risk:

1. GIS based spatial and statistical tools have been used to extract the spatial extent as well as flood water depth from the flood inundation layer on the SWMU scale.
2. Flood depth-damage functions have been analysed to obtain multi-layered risk assessment criteria. Information regarding global flood depth-damage functions is found in the flow-chart provided below in Figure 27.

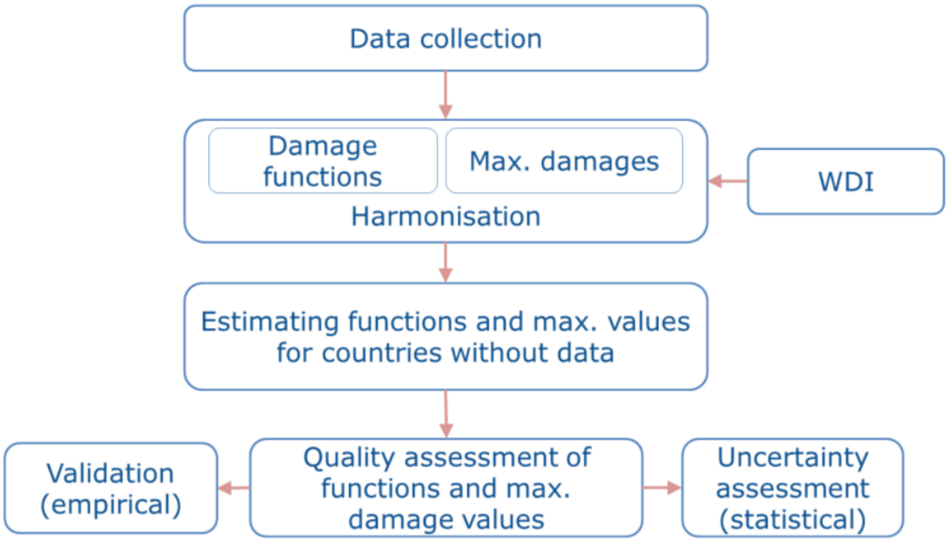


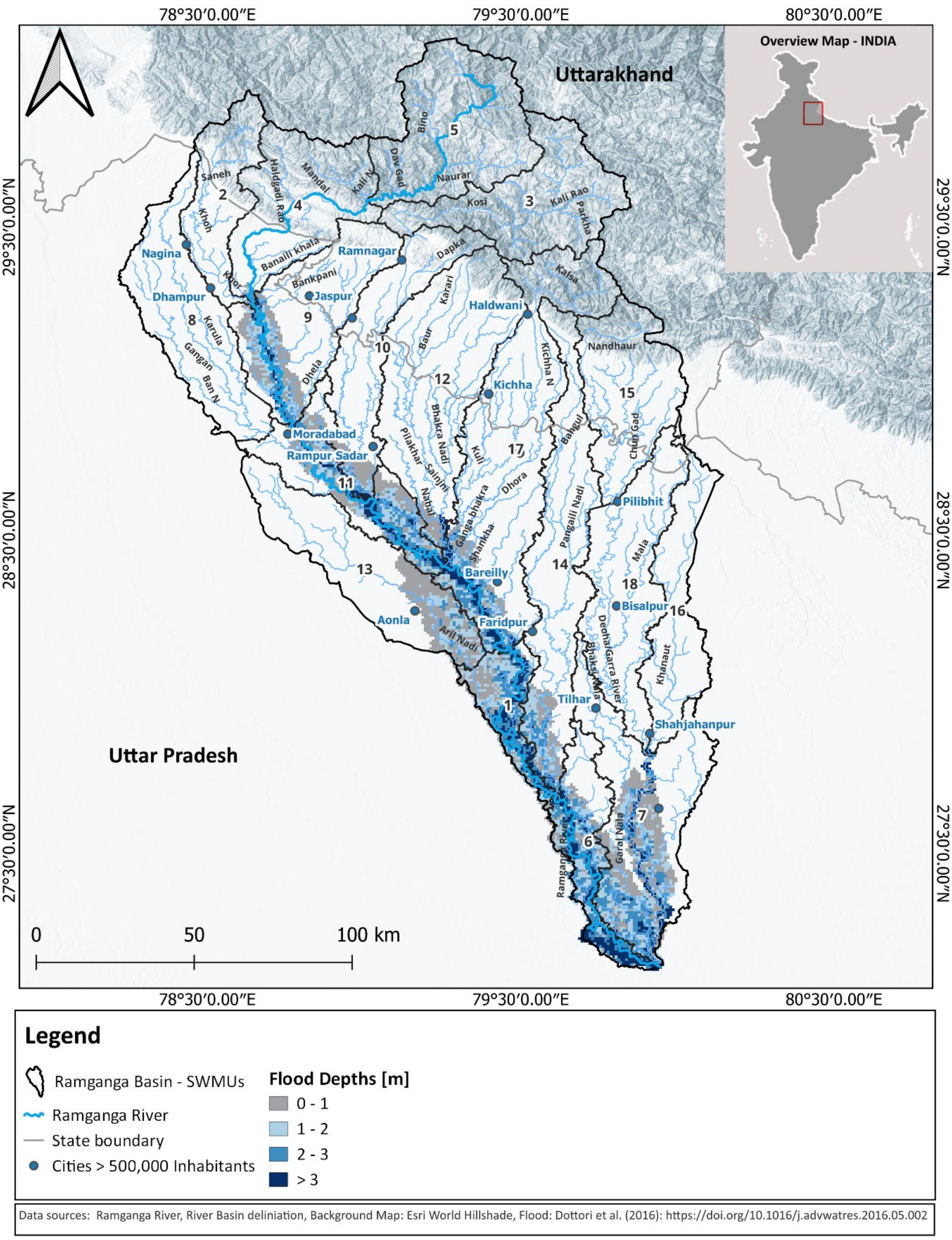
Figure 27: Main schematic of the project to estimate global flood depth-damage functions

Flood water depth

An important parameter for the flood risk evaluation is the flood water depth. With the limited data, estimate of how the flood depth might vary in different SWMUs can still be made. The data has been re-classified into 4 different levels of flooding depth (m) as shown in Map 29. In some SWMUs the estimated flood depth seems to be greater than 2 m which is expected to cause huge damage to people, livestock, agricultural activities, and infrastructure (see Table 55). Flood water depth has been mapped to identify flood prone SWMUs as shown in Annex 5.

49 Source: https://op.europa.eu/en/publication-detail/-/publication/a20ecfa5-200e-11e7-84e2-01aa75ed71a1/language-en

Ramganga River Basin - Flood Inundation Depths



Map 29: Map of flood inundation with water depths within the SWMUs

Table 55: Results of flood risk evaluation parameters

SWMU No.	Flood Depth (cm)	SWMU Flooded Area (km²)	Flooded Agricultural land Area (km²)	Flooded Built-up Area (km²)	Affected Population	Flood Damages [Mio EUR]
1	203	586.1	471.5	31.9	377,792	5,760
2	40	4.1	3	0.15	3,408	4
3	0	0	0	0	0	0
4	90	22.1	19.3	0.2	2,148	63
5	0	0	0	0	0	0
6	269	624.8	483.8	21.6	402,031	6,198
7	145	1,051.5	925.1	47	741,953	11,127
8	0	0	0	0	0	0
9	125	459.7	413.1	17.9	380,434	3,847
10	84	149.3	135.6	5.5	153,107	930
11	168	752.3	658.8	40.1	625,867	7,094
12	91	84.1	74.7	6.2	114,389	379
13	63	462	421.8	35.9	440,817	5,480
14	117	307.4	275.1	18.9	197,355	2,993
15	0	0	0	0	0	0
16	259	3.6	2.3	1.2	1,722	193
17	211	479.2	378.1	38.7	456,512	6,817
18	209	1.8	1.3	0.1	698	5

Flood affected area – SWMU

The next risk evaluation parameter is related to the flood affected area (km^2) in a specific SWMU. As the area of the SWMUs differ, it was decided to consider the area in km^2 rather than a percentage of the total area to avoid underestimation of inundation in large SWMUs. Some SWMUs are not at all affected by flooding (according to the inundation layer used for this analysis). These are categorized as at 'No Risk' whereas if an area greater than 100 km^2 within an SWMU is affected then the SWMU is termed as at risk of failing to meet the Ramganga RBM targets (see Table 55). **Error! Reference source not found.** shows a complete flood risk assessment map for all SWMUs.

Flood affected area – Agricultural land

Agricultural land is considered as a parameter when it comes to flood risk assessment. The estimation on how much an agricultural land will be affected by flooding is done using Land-use and Land-cover data. The results show that there are some SWMUs where the agricultural land will not or only partially be affected (i.e., area < 5 km^2), but in some SWMUs a huge portion of agricultural land will be disturbed due to flooding. Based on the different areas, three agricultural land risk classes are defined. If there is no flooding, the SWMU falls under the class 'No Risk' and if the flooded agricultural area is greater than 50 km^2, the SWMU is classified as 'At Risk'. SWMUs with a flooded agricultural area smaller than 50 km^2 are 'Possibly at risk'. It is important to mention that these values in Table 55 represent only the agricultural land affected by flooding and not the total area within the SWMU. Annex 5 highlights the SWMUs where agricultural land will be affected by flooding.

Flood affected Built-up area

The built-up area potentially affected by flooding is an important parameter when it comes to flood risk analysis, because there will not only be damage to infrastructure but also to people. For the built-up area the risk criteria have been further narrowed down to a flooded area ≤ 10 km^2 ('Possibly at Risk') and > 10 km^2 ('At Risk'). This information helps to identify settlements which are under threat of flooding and take proper measures to avoid damage. Again, it is important to highlight that the values in Table 55 represent the built-up area affected by flooding and not the total area within the SWMU. Annex 5 shows the SWMUs categorized in different risk classes considering the flood risk to built-up areas.

Flood affected population

The population affected by flooding is also included in risk evaluation, because flooding in urban areas will ultimately cause damage to human lives. In this context, it is important to know how many people will be affected by flooding in the Ramganga Basin. Census data of 2011 extrapolated to the year 2022 has been utilized to obtain the exact number of people who might be affected by flooding. SWMUs where no one is affected come under the class 'No Risk', but if population is affected, then the risk category has been assigned depending on the number of people within the flood affected area.

The risk level is 'intermediate' if less than 5000 people are affected by flooding, whereas it is 'high' if it affects more than 5000 people. This criterion may be subject to change depending on the latest census data (see Table 55). Considering the risk of drowning or washout, all areas with a water depth greater than 0.5m are considered to be 'At Risk'. Annex 5 shows the risk classes for all SWMUs where population might be affected by floods.

Flood damages

Flood damage calculations are based on global flood damage functions. Land use and land cover[50] data has been used to estimate the damages to agricultural and built-up areas. A summary of the global flood damage can be found in other section of this chapter (Huizinga and Szewczyk, 2017).

The following steps summarise the flood depth-damage calculations for a 100-year return period flood in the Ramganga Basin.

- First, land use data has been re-sampled as per the resolution of flood depth raster data.
- In a second step, land use and land cover information has been extracted by mask using the flood extents.
- In a third step, the absolute flood damage cost for each flood depth pixel for individual land use classes has been assigned. The damage cost per land use is based on the data of the year 2010 as mentioned in the flood depth-damage functions document (see section 3 for the data source).
- Finally, for each SWMU a pixel wise damage cost within the inundated area has been calculated and aggregated (i.e., summed up).

In the flood risk assessment, three risk classes have been considered: "no Risk", "possibly at risk", "at risk", based on 6 different risk parameters (flood depth, area affected by flood in SWMUs, agricultural land area, built-up area, affected population and potential cost of flood damages). If these parameters are classified as at 'No Risk', then the respective SWMU is not at risk of failing to meet the Ramganga RBM targets for flood risk. In contrast, if any of these parameters are classified as 'Possibly at Risk' or 'At Risk' then the risk level is intermediate to high (see Table 56).

[50] Land Use-Land Cover, National Remote Sensing Centre, 2026-2017

Table 56: Flood risk evaluation classes and defined ranges for different flood affected categories.

Risk classes	Flood depth [cm]	Flood affected area (km²)			Flood Risk	
		SWMUs	Agricultural land	Built-up Area	Affected population	Damages [Mio. EUR]
No Risk	0	0	0	0	0	0
Possibly At Risk	> 0 – ≤ 50	> 0 – ≤ 100	> 0 – ≤ 50	> 0 – ≤ 10	> 0 – ≤ 5000	> 0 – ≤ 5
At Risk	> 50	> 100	> 50	> 10	> 5000	> 5

Sand mining

Sand mining happens on various scales and in many ways. Figure 28 is an aerial image[51] showing a stone crusher unit in the Ramganga riverbed, as an example of a large-scale sand mining activity in the Ramganga Basin. On the other hand, a lot of small-scale sand mining exists (see Figure 29), for example by hand and with oxcarts, which also might add up to large volumes over time. Especially the small-scale mining is difficult to control, resulting in a lack of data regarding the total volume of sand mining.

Figure 28: Aerial image of a stone crusher unit in the Ramganga riverbed

[51] Source: https://sandrp.files.wordpress.com/2020/11/north-india-ppt.pdf

Figure 29: Sand mining with an oxcart in Moradabad (source: Philipp Thumser)

Given the lack of specific official information, the quantum of sand leases and information about minor minerals collection has been used as a proxy to quantify sand usage, providing at least an overview of the potential risks related to sand mining (or substantial use). Presently, two methods have been adopted for estimating sand consumption and performing a risk assessment:

1. Quantum of sand leases converted to sand mining risk (land lease information based)
2. Cement usage as a proxy for sand consumption

The first is related to the dispatched quantity of minerals (m^3) and the second is using the conversion of cement usage to sand usage. Based on this information, a final evaluation has been carried out which considers the results of both methods. Three different risk classes have been used: 'Low Risk', 'Moderate Risk' and 'High Risk'. If the dispatched quantity of sand from a district is greater than 100,000 m^3/year (i.e., 1 lakh m^3/year) then it is classified as 'High Risk', whereas quantities smaller than 50,000 m^3 (i.e., 1 lakh m^3/year) are classified as 'Low Risk'.

The approach for sand mining risk assessment is done at the district level as it is based on the cement consumption at the Tehsil or district level (if available), so an overall district-wise sand usage status within the Ramganga Basin could be mapped. The core idea of this approach is to use cement consumption as a proxy for sand usage gaining some insight into identifying potential hotspots of sand usage. Of course, high cement usage (or cement sales) in one district does not necessarily translate into intensive sand mining, but it could provide information about where to focus.

Note: If sand lease (dispatched quantity) information in a district is unknown (or not available), then it is labelled as 'No Data' (see Table 57).

Similarly, based on the estimated average value of cement consumption the subsequent sand consumption has been classified into three categories considering 0 – 600,000 tonnes as 'Low Risk' and > 100,000 tonnes as 'High Risk'.

Table 57: Defined risk classes and thresholds for the dispatched quantity of minerals lease

Risk classes	Low Risk	Moderate Risk	High Risk	No Data
Dispatched quantity of minerals (m^3)	≤ 50,000	> 50,000 – ≤ 100,000	> 100,000	unknown
Sand consumption (thousand tonnes)	> 0 – ≤ 600	> 600 – ≤ 1000	> 1000	unknown

Quantum of sand lease (proxy of sand mining)

The available land lease data for sand mining was classified into three different risk categories, based on the available values. Expert consultations helped in validation and further inputs. If in a district a certain threshold in the dispatched quantity of sand is achieved, a risk class has been assigned to that district. These risk classes may be subject to change if different threshold limits are selected for defining these risk criteria. It is also important to mention that 'No Data' is available for Bijnor, Hardoi, Kheri, Pilibhit and Shahjahanpur (see Table 58 and Annex 5).

Table 58: Results of district-wise risk assessment - type of minerals (sand) lease

District	Sand-01 (m^3)	Sand-02 (m^3)	Total sand (m^3)	Sand lease Risk Assessment
Almora	–	–	Unknown	No Data
Bageshwar	–	–	Unknown	No Data
Chamoli	–	–	Unknown	No Data
Champawat	–	–	Unknown	No Data
Nainital	–	–	6,800,000*	High Risk
Pauri Garhwal	–	–	Unknown	No Data
Udam Singh Nagar	–	–	Unknown	No Data
Bareilly	–	11,659	11,659	Low Risk
Bijnor	–	-	Unknown	No Data
Budaun	–	97,395	97,395	Moderate Risk
Farrukhabad	–	80,419	80,419	Moderate Risk
Hardoi	–	0	Unknown	No Data
Amroha	–	–	Unknown	No Data
Kannauj	–	22,359	22,359	Low Risk
Kheri	0	0	Unknown	No Data
Moradabad	150,624	65,298	215,922	High Risk
Pilibhit	–	0	Unknown	No Data
Rampur	–	132,222	132,222	High Risk
Shahjahanpur	–	0	Unknown	No Data
Sambhal	–	–	Unknown	No Data

*Note: Total sand (m^3) for the Nainital district is a summed-up value of Ramnagar and Haldwani divisions, which has been taken from Uttarakhand Forest Department website (see Table 53).

Cement consumption (proxy of sand usage)

An empirical approach for estimating sand consumption as a proxy of cement consumption was also used. The per capita cement consumption in India is 195 kg which is significantly less than the global average of 500 kg per capita[52]. In the case of the Ramganga Basin, the same per capita cement consumption value as the Indian average has been used (i.e., 195kg). To convert the cement consumption

[52] Source: Bureau of energy and efficiency (https://beeindia.gov.in/en/cement)

to sand consumption, a cement to sand conversion factor of 2.5 has been used, as estimated in the sand mining framework of 2018[53].

For example, if cement consumption in a district is 10,000 tonnes, the approximate sand consumption should be around 25,000 tonnes. This empirical approach can be termed as 'concrete mix ratio approach' which translates the cement consumption into potential sand quantity needed to prepare the concrete mix. Three major sectors are using cement in India: housing, infrastructure, and commercial & industrial. The housing sector has a dominant share of about 65% of total cement consumption, followed by infrastructure (20%) and commercial & industrial (15%) (Sand mining framework, 2018). This sectoral distribution of cement consumption in India is shown in Figure 30. The map showing cement to sand consumption in Ramganga Basin can be found in Annex 5.

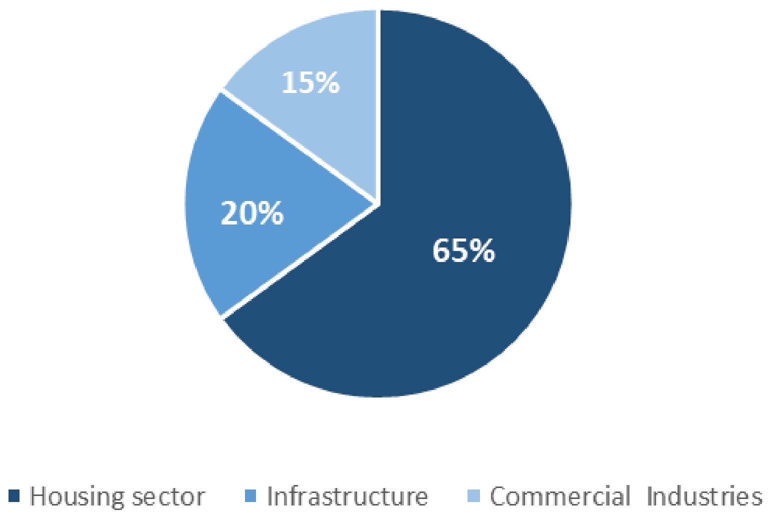


Figure 30: Sectoral cement consumption share in India

Different sectors use different cement and sand mix ratios as per their standard requirements, depending on the strength of concrete required. Table 59 shows the relevant cement to sand mix ratios (Sand mining framework, 2018). The following assumptions for the cement to sand ratio in the different sectors have been made.

Table 59: Sectoral cement to sand ratios

Sector	Ratio of Cement: Sand being used
Housing Sector	1:2
Infrastructure Sector	1:4
Commercial and Industries	1:8
Weighted Average	1:2.5

[53] Source: Sand mining framework INDIA, 2018 https://mines.gov.in/writereaddata/Content/sandminingframework260318.pdf

Further, normalization Factor of district population was considered. Cement consumption at the district level has been calculated by multiplying the district population with a per capita cement consumption of 195 kg (0.195 tonnes).

Conversion of cement consumption to sand consumption
To calculate sand consumption, the estimated district-wise cement consumption (i.e., population x 0.195 tonnes/person) is multiplied with the cement to sand conversion factor of 2.5.

For example: A district ***'X'*** has a total population of 2 million. Then the estimated cement consumption of the district is 0.195 tonnes x 2 million = 0.39 million tonnes. Hence the sand consumption of district ***'X'*** is 0.975 million tonnes (i.e., 0.39 million tonnes x 2.5 conversion factor).

5.7.2 Results from the Risk Assessment and possible impacts on water resources

Flood risk

Table 55 shows the flood damage in million euros (€) based on data of the year 2010. This can be converted to INR (₹) with the relevant conversion rate (1 ₹ = 0.0165 € – conversion value taken from the document EC et al., 2017). **Error! Reference source not found.**Map 30 shows the risk of damage mapped to the SWMUs. The calculation of flood damage has been performed using Geographic Information System (GIS) tools. Due to the pixel size of the generated flood damages raster, some of the pixels do not fully lie within the SWMU boundaries (e.g., SWMU No. 18). In this case, pixel values were manually identified and summed up for this SWMU. This manual identification might also add uncertainties in the final calculations.

The result of the flood risk evaluation has been obtained from the multi-layered criteria that uses parameters of flood depth, agricultural area affected by flood in each SWMU, Agricultural land area, built-up area that is affected by flood, affected population and flood related damages. As shown in Table 60 (flood risk assessment based on selected criteria), according to this analysis, 4 SWMUs are at 'No Risk', 2 are 'Possibly at Risk', and 12 are 'At Risk'. These risk assessment results have been mapped to the different SWMUs as shown in Map 31. These results would change if different limits to the above-mentioned flood risk evaluation parameters were defined.

Table 60: Results of flood risk assessment based on selected criteria

SWMU No.	Flood Depth	SWMUs Area	Agricultural land Area	Built-up Area	Affected Population	Flood Damages	Final Risk
1	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk
2	Possibly At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk
3	No Risk	No Risk	No Risk	No Risk	No Risk	No Risk	No Risk
4	At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk	At Risk	At Risk
5	No Risk	No Risk	No Risk	No Risk	No Risk	No Risk	No Risk
6	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk
7	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk
8	No Risk	No Risk	No Risk	No Risk	No Risk	No Risk	No Risk
9	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk
10	At Risk	At Risk	At Risk	Possibly At Risk	At Risk	At Risk	At Risk
11	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk

12	At Risk	Possibly At Risk	At Risk	Possibly At Risk	At Risk	At Risk	At Risk
13	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk
14	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk
15	No Risk	No Risk	No Risk	No Risk	No Risk	No Risk	No Risk
16	At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk	At Risk	At Risk
17	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk
18	At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk	Possibly At Risk

The final summarized flood risk assessment evaluation matrix can be found in Table 61. A special column of 'constraints' related to the unavailability of data has been added. **Error! Reference source not found.**61 shows four different steps involved in the process of flood risk assessment with multi-layered criteria. Overall, 12 SWMUs are classified as 'At Risk', 2 as 'Possibly at Risk' and 4 as 'No Risk'.

The final step in the risk assessment is the discussion with all concerned stakeholders and the incorporation of expert judgement (see **Error! Reference source not found.**: step 03). Once the assessment results are mutually agreed, then the final synthesis can be prepared (i.e., **Error! Reference source not found.**: step 04).

These risk assessment results have been mapped to the different SWMUs as shown in Map 31. It is important to note that these results would change, if different limits to the above-mentioned flood risk evaluation parameters were defined. In total 67% of the SWMUs will be at high risk of flooding whereas 11 % will possibly be at risk. Only 22% of the SWMUs will be at no risk of flooding (see Figure 31).

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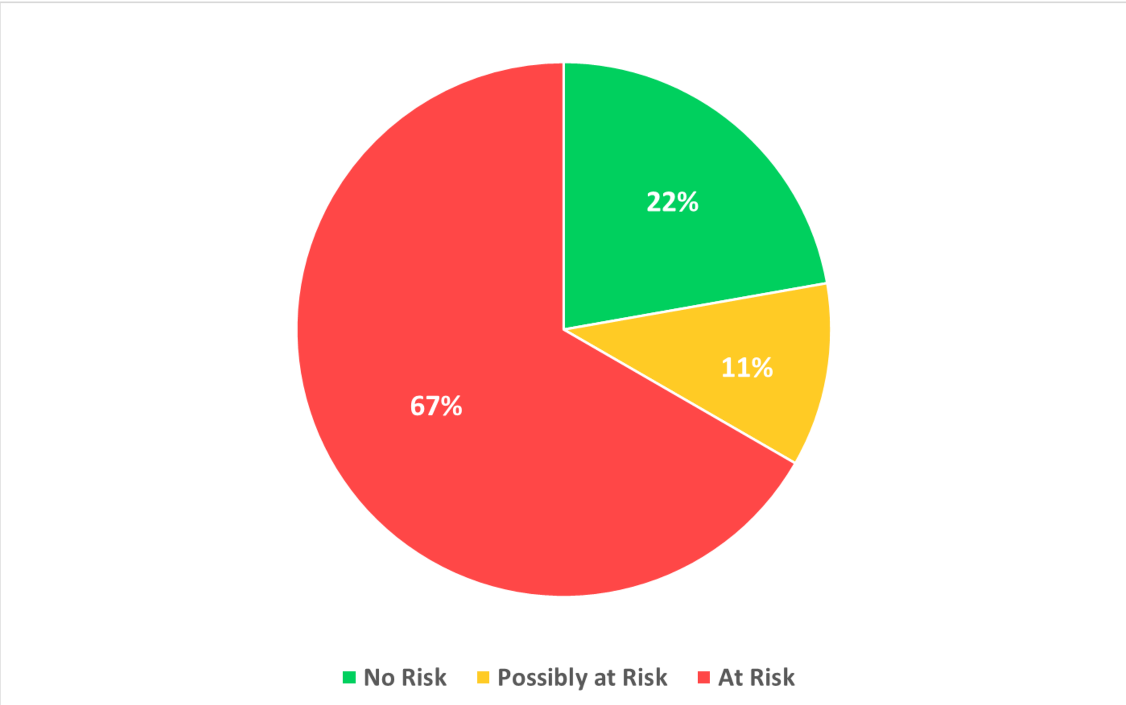


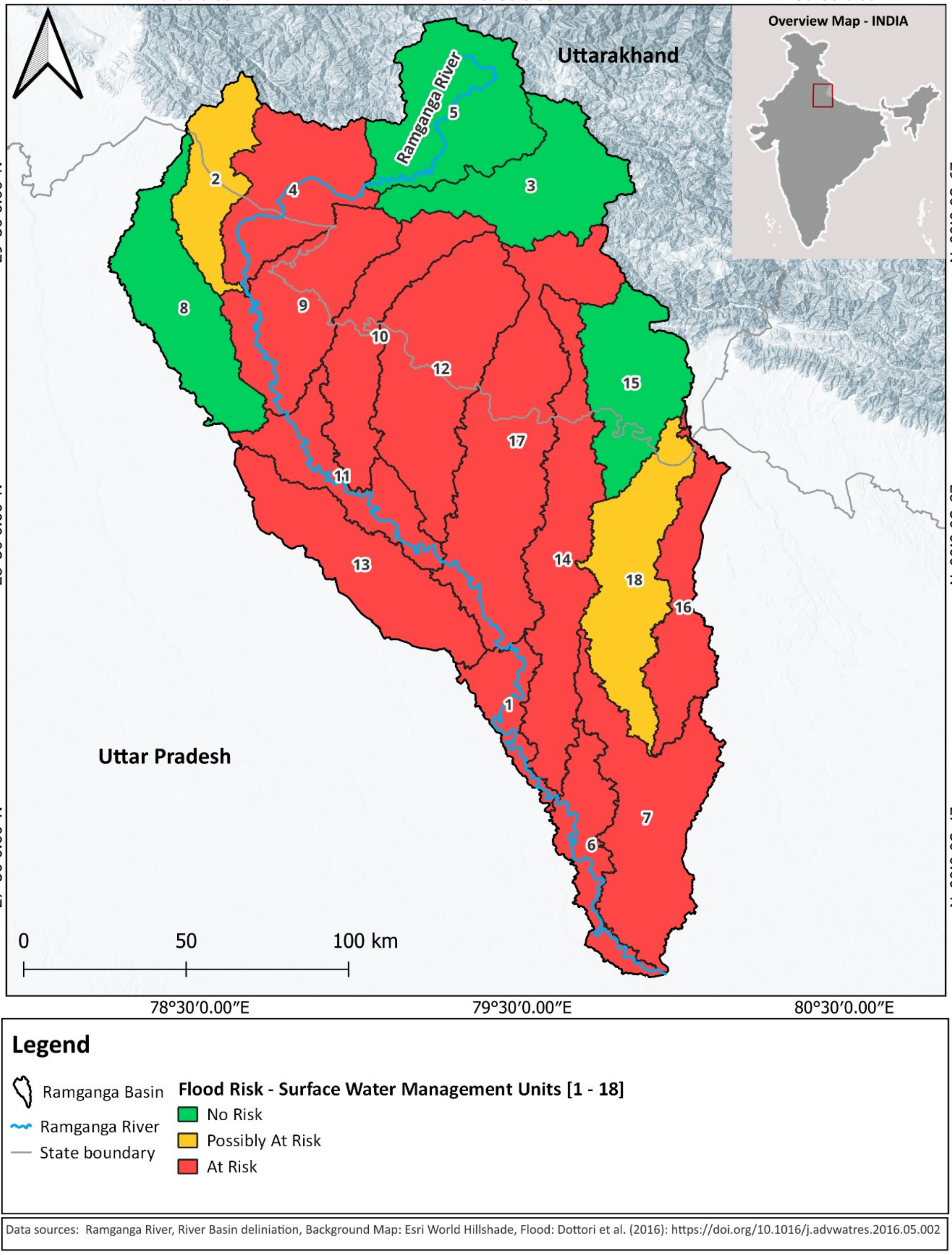
Figure 31: Overall flood risk assessment results of the Ramganga Basin on SWMU scale

Table 61: Flood risk assessment matrix

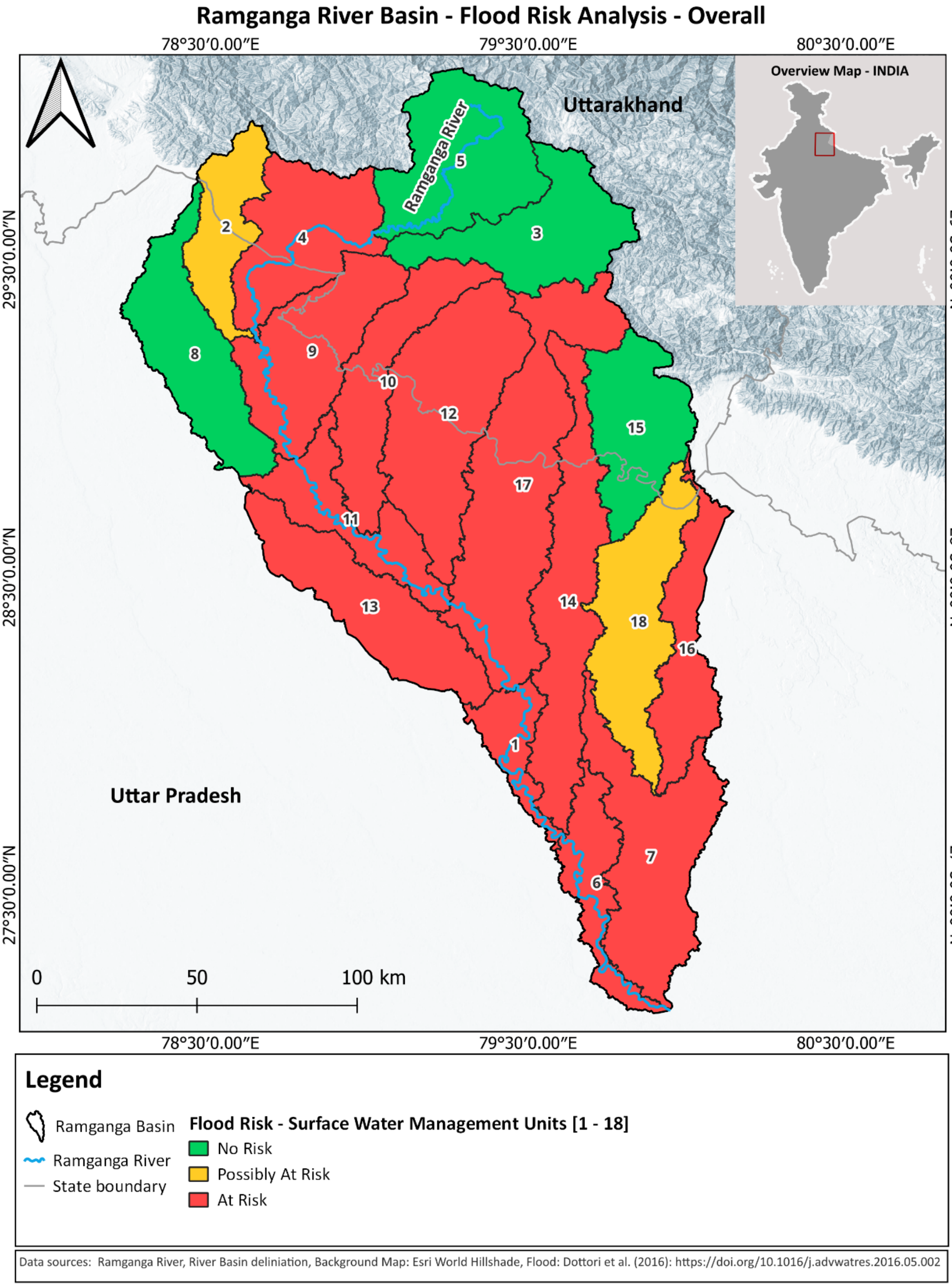
SWMU No.	**Step – 1**: Flood Inundation – Ramganga Basin						**Step – 2a**: Affected Land use type		**Step – 2b**: Flood water levels – Interim Risk Assessment				**Step 3:** Expert Judgement[54]	**Step 4**: Final Synthesis	
	Flooded Area [km^2]	Major land use type [%]			Affected Population[55]	Constraints (if any)	Built-up area /Settlements	Agricultural land	Low	Medium	High	Risk Class		Risk Assessment	Confidence classes
		Agricultural land	Built-up	Others											
1	586.1	81.0	5.5	13.5	377,792	*Unavailability of observed data related to floods*	YES	YES			X	At Risk			
2	4.1	45.1	2.9	52.0	3,408		To some extent	To some extent		X		Possibly At Risk			
3	0	18.9	0.6	80.5	0		NO	NO	X			No Risk			
4	22.1	28.3	0.9	70.8	2,148		To some extent	To some extent			X	At Risk			
5	0	29.2	0.4	70.4	0		NO	NO	X			No Risk			
6	624.8	82.2	4.2	13.6	402,031		YES	YES			X	At Risk			
7	1,051.5	88.1	5.4	6.5	741,953		YES	YES			X	At Risk			
8	0	91.2	6.1	2.7	0		NO	NO	X			No Risk			
9	459.7	68.4	4.2	27.4	380,434		YES	YES			X	At Risk			
10	149.3	65.7	4.7	29.6	153,107		To some extent	YES			X	At Risk			
11	752.3	87.0	8.2	4.8	625,867		YES	YES			X	At Risk			
12	84.1	72.4	4.0	23.6	114,389		To some extent	YES			X	At Risk			
13	462	92.9	6.4	0.7	440,817		YES	YES			X	At Risk			
14	307.4	82.8	5.3	11.9	197,355		YES	YES			X	At Risk			
15	0	45.6	3.5	50.9	0		NO	NO	X			No Risk			
16	3.6	69.5	5.3	25.2	1,722		To some extent	To some extent			X	At Risk			
17	479.2	65.5	7.6	26.9	456,512		YES	YES			X	At Risk			
18	1.8	77.7	4.8	17.5	698		To some extent	To some extent		X		Possibly At Risk			

[54] These are preliminary results which need to be discussed with the stakeholders for their feedback and expert opinion. The final risk class can be assigned to the respective SWMUs after this discussion.
[55] The data is from the Census of 2011, extrapolated to the year 2022, as mentioned in chapter 1.

Ramganga River Basin - Flood damages [million €] based on flood water depth functions



Map 30: Flood risk assessment based on estimated damages using depth-damage functions



Map 31: Final flood risk assessment based on all selected criteria

Sand mining

The results of cement consumption as a proxy to sand usage are also useful to fill the data gaps in the sand lease methodology. Only one district (Bageshwar) has been classified as 'unknown', because there was no intersecting population point within the district lying in the Ramganga Basin. The sand consumption estimation results show that the districts of Bareilly, Rampur, Moradabad, Bijnor, Udam Singh Nagar, Pilibhit and Shahjahanpur fall into the 'moderate to high consumption' category, with more than 800,000 tonnes per year. These values are directly proportional to the district population. Bareilly has the highest population share (20.6%), followed by Moradabad (14.4%) and Shahjahanpur with 11.1%. The estimated cement consumption for all districts within the Ramganga Basin can be found in Table 62. A map of the estimated district-wise cement consumption can be seen in Annex 5.

In total, 12 districts are classified as 'Low Risk' in terms of sand consumption, whereas 5 districts are classified as 'High Risk' and 2 are classified as 'Moderate Risk' (see Table 62). In this methodology 'Nainital' has been classified as ''Low Risk', in contrast to the 'quantum of sand leases' methodology where it has been classified as 'High Risk' (see Table 53). It is important to mention that these district-wise estimations of sand consumption only use population information (i.e., Census 2011 extrapolated to the year 2022) and calculate per district cement consumption using a per capita cement consumption of 0.195 tonnes/yr. The outcome is then converted into sand usage by multiplying with a conversion factor of 2.5. If in the future information about the actual district-wise cement consumption is available, the outcome of this methodology will be more credible. However, this empirical approach is also helpful to identify potential hotspot areas. These risk assessment results will be more useful once the stakeholder feedback together with the expert judgement is added to the final risk assessment.

Table 62: Results of district-wise risk assessment related to cement and sand consumption

Districts	Population 2022[56]	Cement consumption (thousand tonnes/year)	Sand consumption thousand tonnes (conversion factor = 2.5)	Sand consumption Risk Assessment
Almora	589,375	114.9	287.3	Low Risk
Bageshwar	–	–	–	unknown
Chamoli	49,119	9.6	23.9	Low Risk
Champawat	1,204	0.2	0.6	Low Risk
Nainital	969,766	189.1	472.8	Low Risk
Pauri Garhwal	221,515	43.2	108.0	Low Risk
Udam Singh Nagar	1,782,896	347.7	869.2	Moderate Risk
Bareilly	4,943,538	964.0	2410.0	High Risk
Bijnor	2,417,267	471.4	1178.4	High Risk
Budaun	693,279	135.2	338.0	Low Risk
Farrukhabad	122,684	23.9	59.8	Low Risk
Hardoi	1,195,160	233.1	582.6	Low Risk
Amroha	239,868	46.8	116.9	Low Risk
Kannauj	37,471	7.3	18.3	Low Risk
Kheri	68,914	13.4	33.6	Low Risk
Moradabad	3,463,971	675.5	1688.7	High Risk
Pilibhit	1,694,871	330.5	826.2	Moderate Risk
Rampur	2,592,213	505.5	1263.7	High Risk
Shahjahanpur	2,660,412	518.8	1297.0	High Risk
Sambhal	302,781	59.0	147.6	Low Risk
TOTAL	**24,046,304**	**4,689.0**	**11,722.6**	

[56] Population count is based on the census of year 2011 which is extrapolated to year 2022 with approx. 1% annual growth https://data.worldbank.org/country/IN

Sand mining (sand lease) risk assessment evaluation matrix - The summarized sand mining risk assessment results (as a proxy to quantum of sand lease and cement to sand consumption) can be found in Table 63. A special column of 'constraints' referring to the unavailability of observed data has been added.

Table 63, shows four all steps involved in the risk assessment process. The combined results of both methodologies show that overall, 6 districts are classified as at 'High Risk', 4 as at 'Moderate Risk' and 9 as at 'Low Risk', respectively. The district Bageshwar falls in the class 'unknown' (see Figure 32 and Map 32), because there was no intersected population point for this district within the Ramganga Basin boundary.

The next and final step is the discussion with stakeholders and the incorporation of expert judgement (i.e., Table 63: step 03) into the risk assessment. Once the assessment results are mutually agreed, the final risk assessment and confidence classes can be assigned (i.e., Table 63: step 04).

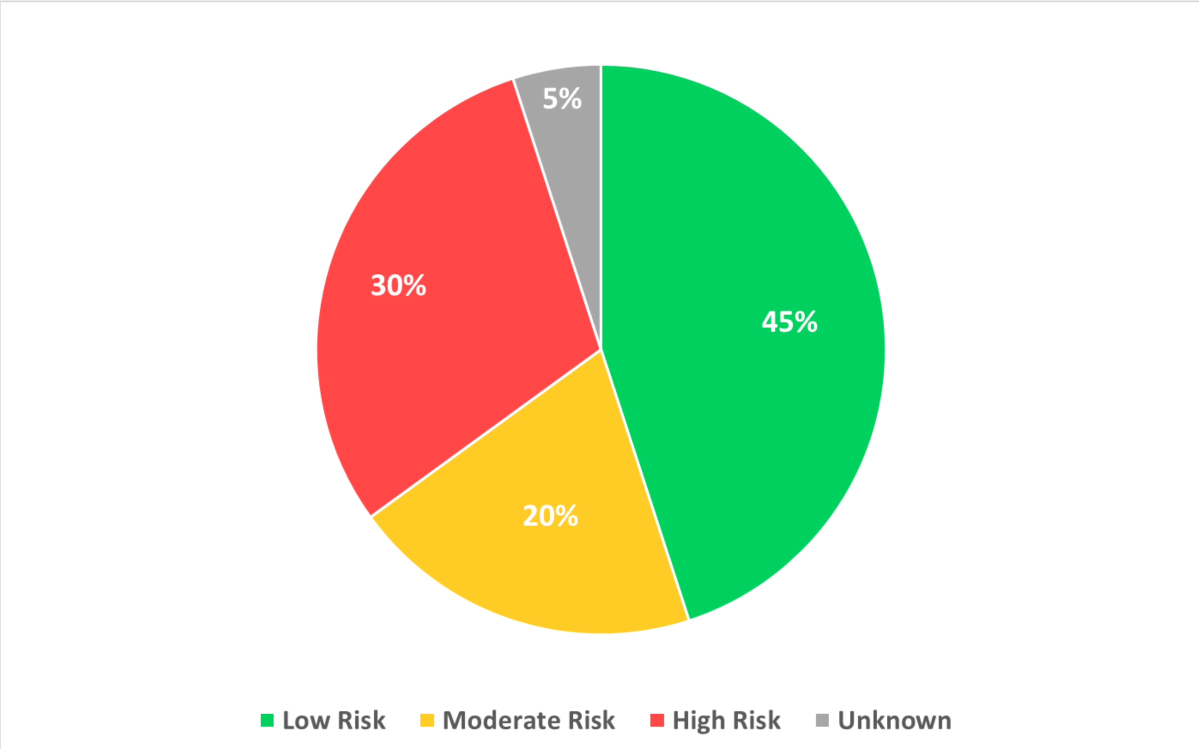


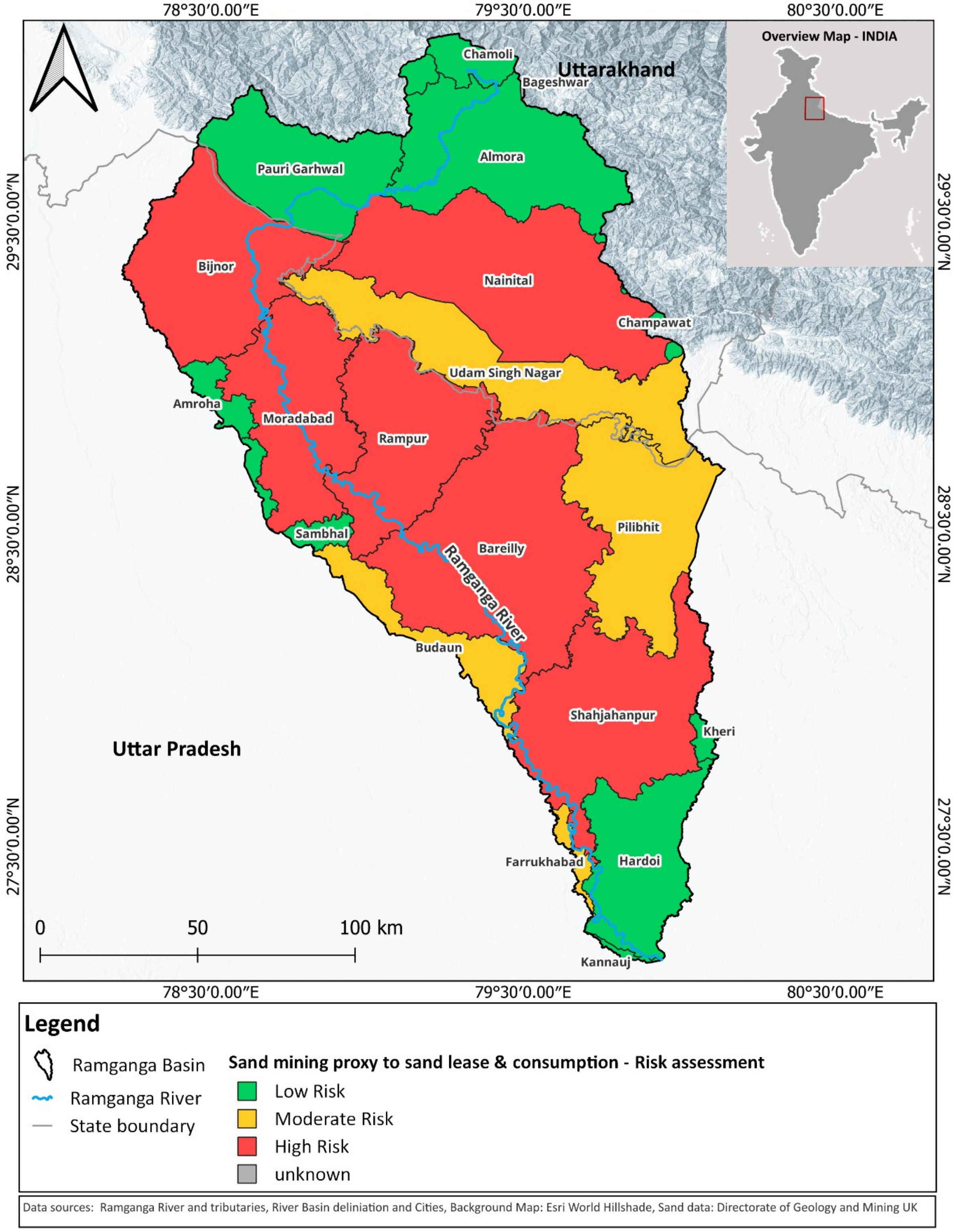
Figure 32 Combined Sand mining final risk assessment results of the Ramganga Basin on District scale

Table 63: Sand lease and sand consumption – Risk Assessment Matrix

Districts	Step - 1: Collected sand mining/ sand lease information and estimated cement consumption as proxy of sand consumption				Step - 2: Quantum of sand lease and sand consumption – combined results (Method 1 and Method 2)					Step - 3: Expert Judgement[57]	Step - 4: Final Synthesis	
	Sand lease details (m³)	Sand consumption (thousand tonnes/yr)	Population-2022[58]	Constraints (if any)	Low	Medium	High	Unknown	Interim-Risk		Risk Assessment	Confidence classes
Almora	Unknown	287.3	589,375	*No official data sheared related to sand mining.*	X				Low Risk			
Bageshwar	Unknown	–	–					X	unknown			
Chamoli	Unknown	23.9	49,119		X				Low Risk			
Champawat	Unknown	0.6	1,204		X				Low Risk			
Nainital	6,800,000[59]	472.8	969,766				X		High Risk			
Pauri Garhwal	Unknown	108.0	221,515		X				Low Risk			
Udam Singh Nagar	Unknown	869.2	1,782,896				X		Moderate Risk			
Bareilly	11,659	2410.0	4,943,538				X		High Risk			
Bijnor	Unknown	1178.4	2,417,267				X		High Risk			
Budaun	97,395	338.0	693,279			X			Moderate Risk			
Farrukhabad	80,419	59.8	122,684			X			Moderate Risk			
Hardoi	Unknown	582.6	1,195,160				X		Low Risk			
Amroha	Unknown	116.9	239,868		X				Low Risk			
Kannauj	22,359	18.3	37,471		X				Low Risk			
Kheri	Unknown	33.6	68,914		X				Low Risk			
Moradabad	215,922	1688.7	3,463,971				X		High Risk			
Pilibhit	Unknown	826.2	1,694,871				X		Moderate Risk			
Rampur	132,222	1263.7	2,592,213				X		High Risk			
Shahjahanpur	Unknown	1297.0	2,660,412				X		High Risk			
Sambhal	Unknown	147.6	302,781		X				Low Risk			

[57] These are preliminary results which need to be discussed with the stakeholders for their feedback and expert opinion. Final risk classes can be assigned to the respective districts after discussion.
[58] These population figures represent the area lying within the Ramganga basin. Some districts are fully within the basin boundaries, whereas for some districts there is only minor coverage, meaning that the population figures in the above table might not represent the actual district population in some districts. This population information is based on the 2011 Census extrapolated to the year 2022.
[59] Total sand (m³) for the Nainital district is a summed-up value of Ramnagar and Haldwani divisions, which has been taken from Uttarakhand Forest Department website (see Table 53).

Ramganga River Basin - Final results of sand mining risk assessment – (Method – 01 & Method – 02)



Map 32: Results of sand mining risk assessment – (Method – 01 & Method – 02)

5.7.3 Challenges and data gaps

Official information was not available within the first cycle of the Ramganga RBM planning for carrying out the risk assessment for sand mining. Given the lack of specific information, alternate approaches were used to provide at least an overview of the potential risks related to sand mining (or substantial use).

5.8 Key Conclusions of the overall Risk Assessment for all five KWMIs

Below Table 64 presents the cumulative results for all KWMI 1, 2 and 5 for Ramganga Basin:

Table 64: Cumulative SWMU wise risk assessment for KWMI 1, 2 and 5

SWMU NO.	KWMI 1				KWMI 2		KWMI 5		Cumulative results
	Result based on SWAT outputs		Result based on observed values		Non Point Source		Flood Risk		
9	Worse than C	2	At Risk	2	At risk	2	At Risk	2	8
10	Worse than C	2	At Risk	2	At risk	2	At Risk	2	8
11	Worse than C	2	At Risk	2	At risk	2	At Risk	2	8
12	Worse than C	2	At Risk	2	At risk	2	At Risk	2	8
17	Worse than C	2	At Risk	2	At risk	2	At Risk	2	8
1	Worse than C	2	Possibly at risk	1	At risk	2	At Risk	2	7
6	Worse than C	2	Possibly at risk	1	At risk	2	At Risk	2	7
5	Worse than C	2	At Risk	2	At risk	2	No Risk	0	6
8	Worse than C	2	At Risk	2	At risk	2	No Risk	0	6
13	Worse than C	2	No Risk	0	At risk	2	At Risk	2	6
14	Worse than C	2	No Risk	0	At risk	2	At Risk	2	6
16	Worse than C	2	No Risk	0	At risk	2	At Risk	2	6
3	Worse than C	2	At Risk	2	Possibly at risk	1	No Risk	0	5
2	A	0	At Risk	2	Possibly at risk	1	Possibly At Risk	1	4
7	A	0	No Risk	0	At risk	2	At Risk	2	4
15	Worse than C	2	No Risk	0	At risk	2	No Risk	0	4
18	A	1	No Risk	0	At risk	2	Possibly At Risk	1	4
4	A	0	No Risk	0	Possibly at risk	1	At Risk	2	3
Scoring criteria: At Risk = 2, Possibly at Risk 1 and No Risk =0									

As seen in Table 64 SWMU No. 9-12, and 17 witness the high-risk categories with respect to the point, non-point sources of pollution and flood/sandmining risks. These SWMUs are spread to the Districts of Moradabad, Rampur, Udham Singh Nagar, Shahjahanpur, and Bareilly. These are the areas where the implementation of PoM should be taken on priority.

Further regarding Groundwater related risks in Ramganga Basin, Table 65 presents the cumulative risks for both groundwater quality and quantity.

Table 65: Cumulative risk for groundwater quality and quantity in Ramganga Basin.

GMU No.	Quantity		Quality		Cumulative Risk
14	High Risk	2	High Risk	2	4
17	Medium Risk	1	High Risk	2	3
13	Not At Risk	0	High Risk	2	2
16	Not At Risk	0	High Risk	2	2
19	Not At Risk	0	High Risk	2	2
20	Not At Risk	0	High Risk	2	2
5	Not At Risk	0	Moderate Risk	1	1
7	Medium Risk	1	No Risk	0	1
8	Not At Risk	0	Moderate Risk	1	1
15	Not At Risk	0	Moderate Risk	1	1
1	Not At Risk	0	No Risk	0	0
2	Not At Risk	0	No Risk	0	0
3	Not At Risk	0	No Risk	0	0
4	Not At Risk	0	No Risk	0	0
6	Not At Risk	0	No Risk	0	0
9	Not At Risk	0	No Risk	0	0
10	Not At Risk	0	No Risk	0	0
11	Not At Risk	0	No Risk	0	0
12	Not At Risk	0	No Risk	0	0
18	Not At Risk	0	No Risk	0	0

As can be noticed that the groundwater related risks are not as severe as shown form surface water related KWMIs. Nevertheless, GMU no 14 (which is Moradabad) needs immediate interventions. It is worth mentioning that while the observed value of nitrate and EC remains well below the risk criteria, 6 GMUs are shown in high-risk categories – that is attributable to the LULC classification (intense agriculture activities). This further needs to be investigated during the course of first cycle of Ramganga RBM.

6 PROGRAMME OF MEASURES TO MITIGATE IMPACTS

After the situation assessment implemented in the Pressure-Impact Analysis (Risk Assessment), the next logical step in the River Basin Management Cycle is to develop a Programme of Measures (POM). The Ramganga POM builds on the detailed analysis presented in the previous chapter. The analysis covered both the natural resources base, the institutional setup, the socio-economic context, and possible funding challenges. The POM will describe a set of interventions to achieve the Vision and Management Objectives—for this management cycle—that have been identified for the respective KWMIs through a consultative process with key stakeholders, and which have been endorsed by the Ramganga River Basin Management Committee.

In view of the scale of the water resources challenges in the Ramganga Basin, it is recognized that not all identified Management Objectives can be achieved in a single management cycle. The POM, therefore, will indicate realistic timelines for each proposed measure. Further, it is acknowledged that some measures that are initiated in this management cycle will be completed in the next one.

Guiding Principles for Developing the Ramganga POM

A set of guiding principles have been adopted for designing the Ramganga POM:

- The measure can be implemented within the existing regulatory framework.
- Measures should be climate sensitive and strive to provide long term co-benefits for climate change adaptations.
- Measures should focus on improving the conditions and livelihood of local people and other immediate stakeholders (in support of the Arth Ganga initiative).
- Measures should have a gender inclusive focus.
- The measure should be effective to reach the stated objective and represent a step towards achieving India's sustainable development goals.
- The measure should be practical and readily implementable, while leading to sustainable and cost-effective solutions.
- The measure should have minimal impact—to no damage—to ecosystems and the environment.
- Decentralized and nature-based solutions will be emphasized.
- The impact of the measure should be measurable.
- The measure should preferably strengthen existing programs (see above).
- The measure should consider the heritage and cultural aspects of a river basin or water body.

6.1 General Overview of Ramganga PoM

6.1.1 Timelines for the Ramganga PoM and Prioritization of Measures

The Ramganga River Basin Management Plan is aligned with the River Basin Management Cycle. The first six-year cycle started in 2023. Implementation of the POM, therefore, will be initiated in late 2023 or early 2024, and this cycle will probably end around 2029.

To achieve the 33 Management Objectives that have been identified for the 5 prioritized KWMIs, over 165 interventions have been outlined in the POM. They range from straightforward measures—which can be implemented in a short time span, by a single implementing agency, and which concern a specific location—to complex measures that cover the entire basin or a large part of it, and which are subject to elaborate implementation and coordination mechanisms.

As discussed above, it is acknowledged that some complex interventions initiated in this cycle will be completed in the next cycle.

To ensure effective implementation of the POM, measures need to be categorized in terms of priority and complexity. To this effect, the POM will indicate for each measure:

- an implementation priority aligned in 3 classes (high / medium / low priority), and
- an estimated implementation timeline.

In principle, the following Table 66 prioritization has been applied within the Ramganga POM:

Table 66: Implementation Priority Class of PoM

Implementation Priority Class	Criteria for Assignment to Implementation Priority Class
1 (High implementation priority)	Measures for river reaches or river-basin management units that have been classified as 'at risk.'
2 (Medium implementation priority)	Measures for river reaches or river-basin management units that have been classified as 'possibly at risk'
3 (Low implementation priority)	Measures for river reaches or river-basin management units that have been classified as 'not at risk'

6.1.2 Types of PoM

Addressing the multi-faceted and wide-ranging issues in the Ramganga Basin will require alignment with ongoing programs, missions, and initiatives at National, State, and District level. It will also build on the existing legal framework at all levels. To this effect, a comprehensive inventory of the existing legal framework and ongoing programs of relevance to the implementation of the Ramganga POM has been presented in Annex A1. It includes programs such as Smart City Mission, AMRUT, Jal Jivan Mission, Mahatma Gandhi National Rural Employment Guarantee Act-MNREGA, and others. The proposed measures in the POM should either strengthen these initiatives or build on them. Further, it is noted that the respective plans observe different scales and geographic boundaries (district, state, basin, sub-basin, urban area). Hence the subsidiarity principle will be explored to avoid duplication of interventions and ensure that measures are implemented as close as possible to the actual beneficiaries.

To reflect the above, the basic structure of the POM holds two categories of measures, which are:

Basic Measures

The PoM includes the existing legal framework, rules and legislations, and policies whose implementation needs to be strengthened. Also, these measures provide a legal standing for the implementation of supplementary PoM. Examples of these basic measures include EPA 1986, Water Act, SWM Rules, 2016, Flood Management Guidelines, AO, 2016, National Framework on SRTW, National Water Policy, National Fecal Sludge and Septage Management Policy, E-Flows Notification, and other UK/UP state level rules, acts and guidelines. The exhaustive list can be seen in Table 67 below.

Table 67: Basic Measures - Relevant National and State level Acts, Rules, Policies and Guidelines

Level (National/State)	Relevant Acts/Rules/Guidelines/Policy/Order/Notification
National	
Acts and Rules	• Water (Prevention and Control of Pollution) Act, 1974 • Environmental (Protection) Act, 1986 and standards for discharge of effluents • Groundwater (Control and Regulation) Act, 1992 • National Disaster Management Act, 2005 • Solid Waste Management Rules, 2016 • The Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008 • The Plastic Waste (Management and Handling) Rules, 2011 • Bio-Medical Waste (Management and Handling) Rules, 1998 • The E- Waste (Management and Handling) Rules, 2011 • The Batteries (Management and Handling) Rules, 2001 • Wildlife Conservation Act, 1972 • Biodiversity Act 2002 • Mahatma National Rural Employment Guarantee Scheme Act 2005 • Dam Safety Act, 2021 • Mines And Minerals (Development and Regulation) Act 1957 • Mineral Concession Rules 1960 • Land Encroachment Act, 1905
Policy	• National Water Policy, 2012 • National Environmental Policy, 2016 • National Urban Sanitation Policy, 2008 • National Fisheries Policy, 2017 • National Policy of Fecal Sludge and Septage Management, 2017 • National Framework on Safe Reuse of Treated Water, 2022 • National Action Plan on Climate Change, 2008 • National Forest Policy, 1988
Guideline	• National Guidelines for Flood Management, 2008 • National Guidelines for the Management of Drought, 2010 • National Guidelines for the Management of Urban Flooding, 2010 • Sustainable Sand Mining Management Guidelines, 2016 • Enforcement & Monitoring Guidelines for Sand Mining, 2020 • River Centric Urban Planning Guidelines, 2021 • CGWA Guidelines to regulate and control ground water extraction in India, 2020
Others	• E-Flows Notification for Ganga, 2018 • River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016 • National Mission on Natural Farming, 2022 • Mission Water Conservation • National Green Tribunal (NGT) Order on Environmental Flows, 2017 • NGT Order on the Polluted River Stretches in India, 2019

Uttar Pradesh	
Acts and Rules	• UP Groundwater Management and Regulation Act, 2019 • UP Groundwater Management and Regulations Rules, 2020 • UP Pond Development, Protection and Conservation Bill, 2017 • UP Revenue Code Rules, 2017 • UP Minor Mineral Concession Rules 1963 • Participatory Irrigation Management Act, 2009 • UP Municipal Corporation Act, 1959 • UP Urban Planning and Development Act. 1973 • UP Municipalities Act, 1916 • UP Building Bylaws as amended in 2018 • UP Mineral (Prevention of illegal mining, illegal transport, and illegal storage) Rule, 2018
Policy	• UP Solid Waste Management Policy, 2022 • UP State Disaster Management Policy, 2019 • UP State Water Policy, 2020 • UP State Action Plan on Climate Change, 2022 • UP State Mineral Policy, 2017 • UP State Forest Policy, 2017
Guidelines/others	• UP State Water and Sanitation Mission, 2021
Uttarakhand	
Acts and Rules	• Uttarakhand Groundwater (Regulation and Control of Development and Management) Act, 2016 • Uttarakhand Plastic and other non-biodegradable garbage (Regulation of Use and Disposal) Act, 2013 • Uttarakhand Flood Plain Zoning Act, 2012 • Uttarakhand Water management and Regulatory Act, 2013 • Uttarakhand Building byelaws and Regulation, 2011 • Uttarakhand Mineral (Prevention of illegal mining, illegal transport, and illegal storage) Rule, 2021 • Uttarakhand Special Provisions for Urban Bodies and Authorities Act, 2018
Policy	• Uttarakhand State Crushers Policy, 2021 • Uttarakhand State Action plan on Climate Change

Supplementary Measures

This set of PoM essentially are designed to support the basic measures and aims at implementation of specified studies, research, capacity building programmes, and technical interventions like creating wastewater management infrastructure, adaptation of monitoring network, implementation of ongoing national and state level missions such as SBM, AMRUT, NMCG. Further, these supplementary measures also encompass institutional strengthening and economic interventions to achieve the vision and management objectives of Ramganga RBMP.

6.2 Measures related to KWMI 1: Water quality deterioration due to point sources.

6.2.1 Reflection of key findings of the KWMI 1 Risk Assessment

Point source pollution is the first issue that needs to be addressed when experiencing a deteriorating quality of surface water bodies. The risk assessment confirms this proposition for the Ramganga Basin. The analysis found out that 17 out of 18 SWMUs 'at risk' and the remaining SWMUs fall in 'possibly at risk'. These results were obtained by combining information on three pollution indicators: 1) non-point source pollution, which is examined under KWMI 2, where 15 SWMU were found 'at risk', 2) the Water Quality Index (WQI) from observed data (all but one SWMUs are classified as C or worse), and 3) DO and BOD loads derived from the SWAT model and from the observed values. For DO, 8 SWMUs were found 'at risk' and two 'possibly at risk'. By contrast, only a seven SWMU was found 'at risk' for BOD.

Further the outputs of the SWAT model made it possible to identify hotspots which warrants immediate attention. These concern specific river reaches where water quality is at risk, and the associated towns, settlements, or industries that probably cause this pollution. It is evident that identifying the exact location of the pollution source is a critical step towards designing and prioritizing measures. While the modeling results are subject to some level of uncertainty and may require additional validation with field data and expert judgement during the course of first cycle of RBMP, the overall picture is clear and the requirements for action are obvious.

The two main causes of point-source pollution are domestic sewage and industrial effluents. In the UP part of the basin, 7 major cities—Moradabad, Rampur, Bareilly, Shahjahanpur, Farrukhabad, Hardoi and Kannauj—are responsible for most untreated and treated sewerage discharges and have thus been identified as hotspots. Only one STP (58 MLD in Moradabad) is operational in the UP part. The industrial hotspots are in Moradabad and Rampur, with 105 out of 121 polluting industries. In Uttarakhand, Kashipur is a key hotspot for industrial effluent with 12 Grossly Polluting Industries (GPI) in the Kashipur industrial area. Another 6 GPI are located in the Bhela region. Kosi also receives approximately 4MLD between Sultanpur and Patti Kalan.

The Risk Assessment used WQ data from multiple sources to extend the coverage of the official monitoring network. This was necessary because several hotspot areas were not covered by the official network. It emphasizes the need to expand and possibly upgrade the official WQ data acquisition system to include, at a minimum, all hotspot areas. In addition, monitoring frequency and WQ parameters may require adjustment to reflect the observed pollution issues.

In view of the context described above, it appears that achieving the Vision for KWMI1 is possible but ambitious for the first cycle of RBMP. This applies specifically to the objective of 'close-to-zero' discharge of untreated wastewater (sewerage and industrial effluent) in the entire Ramganga Basin. This demands a committed focus from all stakeholder groups and government departments to develop a holistic plan to address all pollution sources, also smaller ones. After all, no untreated sewerage or industrial effluent should be permitted to enter any surface water body. Further, improving the quality of the Ramganga waters could also be achieved by enhancing self-purification processes or by hydrological measures that dilute incidental pollution. The rural areas in the basin also provide excellent opportunities for the implementation of Nature Based Solutions for domestic wastewater management. However, improving the Ramganga waters to levels resembling pristine water quality is a realistic long-term objective.

6.2.2 Outline of the POM for each management objective

The set Management Objectives for this first management cycle:

1. **In-depth knowledge of surface water quality and mapping of all hotspots through the implementation of a water quality monitoring system is established for identification of hotspots, drainages or discharges and control of the effectiveness of measures.**

The Risk Assessment revealed an inadequate official WQ monitoring network. It hinders the development of focused action plans and impedes the evaluation of the effectiveness of the initiated and planned measures. Hence WQ monitoring must be expanded either through field monitoring campaigns or by establishing new permanent (online) WQ monitoring stations. The modeling results serve to prioritize areas for network expansion and intensified monitoring. Further, additional information and knowledge is probably available at various agencies, academic institutions, and private entities and should be aggregated into a unified database.

In view of the above, the POM in outline for this management objective involves:

- Conduct a monitoring verification campaign—with a duration of one year—for the hotspots identified in the Risk Assessment.
- Verify modelled data with monitoring results and determine actual hotspots.
- Converge separate WQ monitoring efforts (governmental, academic, private, etc.) and collate the data into a common database in the public domain (such as for example INDIAWRIS and/or NWIC); implement appropriate QAQC of data.
- Identify WQ monitoring gaps (location and parameters) and plan for additional monitoring stations, parameters, and sensors.
- Establish or upgrade (online) monitoring stations and ensure compliance with established monitoring procedures and data QAQC standards.

2. **Pinpoint sources of pollution from industries and settlements in the Ramganga Basin are identified through hotspot mapping, and the need for action, pre-emptive measures and targeted investments is highlighted.**

In terms of volume, industrial effluents are less than domestic effluents. However, industrial effluents pose a serious risk to the aquatic environment due to their specific chemical composition, which typically contain toxic substances. Hence industrial effluents require special attention. Polluting hotspots need to be identified, and a detailed assessment is required of the shortcomings of ongoing measures to mitigate this type of pollution.

The POM in outline for this management objective involves:

- Pollution hotspots are identified by combining data from multiple sources and a targeted monitoring campaign; a list of potential polluters is compiled for these hotspots.
- Third-party survey campaigns—incl. adequacy assessment for the existing CETPs/ETPs—are conducted for identified potential polluters to compare field monitoring results with the documentation provided by these entities.
- In case of non-compliance with the requirements and norms, legal steps are initiated. On the other side incentives are elaborated for overperforming units.
- In case of underperformance of treatment plants, improvement and corrective measures are elaborated.

- DPRs are elaborated for corrective measures while considering future developments and potential additional risks related to effluent WQ.

3. **Sufficient STP/wastewater treatment capacity in the Ramganga Basin is achieved by installing sufficient capacity, based on the results of hotspot mapping.**

There is a substantial gap in the current installed STP capacity to process the existing and anticipated pollution load. Also, many STPs are underutilized, probably because some urban areas are not yet connected to the sewerage network. Further, a considerable number of STPs are not working properly and do not comply with the required effluent standards. A first measure, therefore, would involve improving the operation of these underutilized, non-compliant, and dysfunctional STPs. The Risk Assessment provides adequate information for developing a Plan of Action to this effect. In some areas, the conventional setup of sewerage networks and central STPs are not feasible due to various reasons, and alternative solution approaches must be adopted.

The POM in outline for this management objective involves:

- Identify hotspots and conduct adequacy assessments for sewerage networks and STPs to identify a) areas with inadequate STP capacity, b) inadequate network coverage and untapped drains, and c) underutilized STP capacity.
- The feasibility of upgradation and expanding STP capacity is considered for point 'a' as above.
- Extension of sewerage coverage, and interception and tapping of more open drains, to connect to underutilized STPs for point 'b' as above.
- Extension of sewerage coverage to connect more households and sewage flows to underutilized STPs for point 'c' as above.
- In case of sewage effluents that cannot be collected with sewerage networks in a feasible way, alternative treatment concepts (FSTP, decentral solutions such as bio buffer zones, reed bed filters, biogas, agri-ponic systems, Nature Based Solutions—NBS, etc.) are applied.
- Safe disposal practices for hazardous sludge-waste from STPs are applied; biogas and other reuse concepts are included in the DPRs of new STPs.
- Exploring the options for co-treatment of septage in STPs running undercapacity

4. **Direct mixing of untreated discharge from industries is prohibited by enforcement of penalties and fines as per the existing rules and legislations.**

Discharge of untreated wastewater contaminates unpolluted water sources. This practice is illegal and must be terminated. The POM in outline for this management objective involves:

- Ensure that an adequate legal framework is in place to strictly enforce compliance with existing regulations.
- Ensure that enforcement agencies are sufficiently equipped with monitoring and executive resources.
- Conduct third-party survey campaigns to identify defaulting cases.
- Enforce law on defaulters by issuing directions as powers given to NMCG in Authority Order (2016).
- Potential polluters are obliged to make their WQ monitoring information publicly accessible, according to their consent-to-operate norms.
- Set up a publicly accessible alarm system for suddenly occurring adverse changes in the effluent WQ.

5. **The presence of adequate infrastructure for wastewater management for all untreated discharge hotspots in the Ramganga River is ensured through proper consultation while taking all the important stakeholders on board in case of any approval is sought.**

The implementation of large public infrastructure projects such as STP construction has impacts for the local population and is often delayed due to tedious tendering processes. The planning of these projects, therefore, will require a comprehensive needs assessment and inclusive stakeholder consultation process to consider local issues and concerns. An adequate level of community support should be created by involving stakeholders early on, by creating awareness about the benefits and importance of the projects, by using local capacities, or by other appropriate means. The POM in outline for this management objective involves:

- Identify all key stakeholders and their potential representatives, reach out and create awareness, and assess the needs to address potential conflicts related to the upcoming infrastructure projects or measures.
- For all proposed new projects and measures, initiate public roundtables and hearings to discuss a) the nature and extent of potential problems and opposition, b) potential solutions; reach consensus on a solution, and c) implementation modalities, and subsequent operation and maintenance.
- Identify and involve existing local capacities, and competent resources and manpower, in the planning, construction, and operation of the new infrastructure; also involve local capacities in monitoring the performance of the newly established systems.

6. **Municipal wastewater from rural communities is effectively managed through the development and implementation of decentralized cost-efficient nature-based solutions. So, it does not contaminate surface or ground water resources.**

Centralised solutions are often not cost effective in small rural communities because of the long connection lines between households and the treatment facility. In addition, small-scale conventional treatment systems are difficult to operate and maintain. Decentralized nature-based treatment systems often represent an alternative solution for rural environments with dispersed households. While some approaches, e.g. constructed wetlands have been applied successfully and long-term experiences and design criteria are developed, other new systems still require form R&D. Hence the performance of near-natural or partly ecosystem-based treatment systems—which are currently being piloted—needs to be evaluated, with the objective of developing a standardized system for full-scale application. The POM in outline for this management objective involves:

- Assess point-source pollution from rural communities; identify and prioritize main pollution sources and polluters.
- Identify approved conventional and innovative or promising Nature Based Systems (NBS) solutions.
- Apply conventional and approved NBS solutions to the prioritized polluters.
- Pilot promising NBS innovations in smaller rural polluter communities and evaluate and improve their performance in research programs with academic institutes.
- Set up a guideline for NBS solutions based on the experiences of the conventional and newly piloted NBS solutions.

6.2.3 PoM for KWMI 1

The Table 68 provides implementation details of the PoM as explained above for KWMI 1.

Table 68: Implementation details of PoM for KWMI 1

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	BASIC MEASURES					
1.0.1	Compliance with the CPCB water quality standards per intended use (Environmental (Protection) Act, 1986), after defining the target class per river stretch	1	Basin Level	Total Discharge: 1991 MLD Water Quality Class: C	In 2029: Target class (Bathing class) per river stretch are achieved	National Water Mission, Namami Gange Mission PCB, ULBs, Industrial authorities
1.0.2	Compliance with the wastewater discharge standards, developed by CPCB under the statutory powers of the Water (Prevention and Control of Pollution) Act, 1974	1	STP, ETP, CETP	Industrial effluent Treated: 515 MLD for UP[60],CETP: 2.4 for UP, For STP: 224 MLD capacity for UP, 38MLD capacity for UK[61]	2029 Targeted: ETP and STP comply effluent water quality standards	National Water Mission, Namami Gange Mission PCB, ULBs, Industrial authorities
1.0.3	Compliance with NGT Order 2019 on the CPCB identified polluted river stretches in the Ramganga Basin	1	Urban Local Bodies	UP: along Sherkot and Kannauj UK: Dhella Thakurdwara to Adampur, Kalyani along Pantnagar Kichha Kichha to Pul Bhatta, Koshi along Kashipur	2026: implementation of STPs and connecting drains, interception 2027: Commissioning Target: 80% of generated Wastewater	National Water Mission, Namami Gange AMRUT PCB, Industries, ULBs

[60] Monthly Progress Report of Uttar Pradesh in the NGT matter, June 2023 annexure 4, page 23
[61] Pressure / Impact Analysis and Risk Assessment of Key Water Management Issues (KWMI) 1 – Results table A6

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
				Total Sewage in basin: 1991 MLD Treated: 38 MLD(UK)[61], 224 MLD(UP)[60]		
1.0.4	Implementation of National Framework on Safe Reuse of Treated Water (2019)	1	Urban Local bodies, Panchayat	Reuse of swage: treated water from Shahjahanpur STP (45MLD) to Rosa TPS, treated sewage auctioned to farmers[65]	2027: implementation 2028: commissioning Target: 80% of generated wastewater	National Water Mission, AMRUT ULBs, District authorities, Jal Nigam
	SUPPLEMENTARY MEASURES					
	Technical measures including the application of innovativetechnologies					
1.1.1	Establish or upgrade (online) monitoring stations and ensure compliance with established monitoring procedures and data QAQC standards. (KMO 1.1) • Identification and selection of monitoring parameters and relevant equipment • Procurement of equipment and monitoring infrastructures • Installation of these equipment • Set up Operation and monitoring framework	1	Basin Level and District Level	Implemented: monitoring stations 76[62]	2026 Target: cover the entire basin with an optimal mix of online and offline stations	National Water Mission, Namami Gange Mission PCB
1.1.2	Feasibility of upgradation and extension of STPs is considered for a) (KMO 1.3) • Assess the exact capacity for existing STPs and sewerage	1	District Level, Urban Local	In UK[63], Existing: 29 (38 MLD) Ongoing: 13 (96	2027: Implementation of upgradation and extension of STPs	National Water Mission, Namami Gange

[62]Ramganga POM Stakeholder consultation with NMCG, SMCG (UP), CGWB(NCR) on 04.10.2023
[63] Pressure / Impact Analysis and Risk Assessment of Key Water Management Issues (KWMI) 1 – Results table A6 to A10

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Identify sustainable conventional and innovative technologies of treating wastewater • Select suitable wastewater treatment technology with design, drawing and estimation with benefits • Prepare DPR for the selected STPs		Bodies	MLD) Proposed: 4 (6 MLD) In UP[64], Existing:9 (224MLD), Ongoing: 2(63 MLD), Proposed 1(43 MLD)	Targeted: 100% upgradation of Existing STPs	Mission, AMRUT ULBs, Jal Nigam
1.1.3	Extension of sewerage coverage, and interception and tapping of more open drains, to connect to underutilized STPs for b). (KMO 1.3) • Identify the current situation of sewerage network and open drains • Preparation of design and drawing of additional sewerage network and interception and tapping of drains • open Prepare DPR with estimation • Implementation of additional sewerage and interception networks and open drains with monitoring mechanisms	1	District Level, Urban Local Bodies	Proposed I&D/House Sewer: 20 for UP[64], 30 for UK	2026: implementation of more sewerage, interception, tapping of opening drains Target: increase tapped drains has observed	National Water Mission, Namami Gange Mission, AMRUT Jal Nigam, ULBs
1.1.4	Extension of sewerage coverage to connect more households and sewage flows to underutilized STPs for c) (KMO 1.3) • Identify the current situation of sewerage coverage, households and STPs • Prepare DPR with design, drawing and estimation • Implementation of connecting sewerage and households to underutilized STP with monitoring mechanisms	2	District Level, Urban Local Bodies	Status: % of Utilizing of operated STP: 46% (UK), 36% (UP) 75 MLD under trial run	2026: implementation of connecting sewerage and households	National Water Mission, Namami Gange Mission, AMRUT ULBs, Jal Nigam

[64] Monthly Progress Report of Uttar Pradesh in the NGT matter, June 2023 annexure 1 to 3B, Page 11-22

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
1.1.5	In case of sewage effluents which cannot be collected with sewerage networks in a feasible way alternative treatment concepts (FSTP, decentral solutions e.g., bio buffer zones, reed bed filters, biogas, agriponic systems, NBS, etc.) are applied (KMO 1.3) • Assessment of alternative treatment concepts • Identification of suitable technology with MCDA (multi–Criteria Decision Analysis) • Prepare detailed drawing, design and estimation of selected technology (s) • Implementation of selected treatment facilities with monitoring mechanisms	2	District Level, Urban Local Bodies	NBS is promoted by NMCG, currently in pilot stage, 2 documents on (guidelines for constructed wetland in draft stage) guidelines for small river rejuvenation is available[62]	2024: commence of suitable technology 2026: implementation of alternative treatment technology	National Water Mission, Namami Gange Mission, AMRUT ULBs, Jal Nigam
1.1.6	Identify approved conventional and innovative/promising NBS solutions (KMO 1.6) • Literature review on conventional and innovative/promising NBS • Consultation with experts, stakeholders, local NGOs • Evaluate case studies, regulatory approval, and cost benefit analysis.	2	State level, District Level, Urban Local Bodies	Conventional and approved standards as per CPHHEO technical guidelines	2024: conceptualization of NBS solutions	National Water Mission, Namami Gange Mission, AMRUT ULBs, Jal Nigam
1.1.7	Apply conventional and approved NBS solutions to the major prioritized polluters (KMO 1.6) • Identification of prioritized polluters with pollution assessment • Select appropriate NBS solutions with stakeholders consultation • Feasibility study and regulatory compliance with land allocation • Develop Implementation Plans and monitoring mechanisms	2	State level, District Level, Urban Local Bodies, industrial facilities	Conventional and approved standards as per CPHHEO technical guidelines	2025: implementation of NBS solutions for prioritized polluters 2027: development of monitoring mechanism	National Water Mission, Namami Gange Mission, AMRUT PCB, Pey Jal Nigam, Industries
	Economic measures					

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
1.2.1	Safe disposal practices for hazardous wastes of sludge from STPs are to be applied, biogas and other reuse concepts are to be included in the DPRs of new STPs. (KMO 1.3) • Characterization and assessment of Hazardous sludge • Assessment of safe recovery and reuse concepts • Selection of appropriate safe disposal practices and reuse techniques • Prepare DPR with the proper drawing, design and estimation	1	State level, District Level, Urban Local Bodies, Industrial facilities	Reuse of swage: treated Water from Shahjahanpur STP (45MLD) to Rosa TPS, treated sewage auctioned to farmers[65]	2027: Reusing concepts are adopted in all STPs	National Water Mission, Namami Gange Mission PCB, Jal Nigam, Industries
	Institutional and capacity building measures					
1.3.1	Converge separate WQ monitoring efforts (governmental, academic, private, etc.) and collate the data into a common database in the public domain (such as for example INDIAWRIS); implement appropriate data QA/QC (KMO 1.1) • Identify different sectors (governmental, academic, private, etc.) who conduct WQ monitoring • Set up communication link/media for collecting all relevant WQ information • Upload WQ including GIS location to public domain/website (INDIA-WRIS) • Ensure good visualization mode with the application of GIS tools for better understanding	2	Basin Level and District Level	Implemented: CWC, CPCB data in WRIS	2026 Target: all existing monitoring efforts are accessible through a single platform	National Water Mission, Namami Gange Mission state authority, PCB, CGWB, NMCG
1.3.2	Pilot promising innovative new NBS solutions and evaluate their performance in research programmes with academic institutes in smaller polluter communities (KMO 1.6). • Identify the potential academic institutes • Development of research proposal for piloting the new innovative solutions	2	Basin Level and District Level, industry Facilities	in situ constructed wetlands, concepts for ponds in the rural are in pilot stage[62]	2024: Research project developed 2026: pilot model developed and assessed	Namami Gange Mission, Research programme under DST/ DBT/CSIR

[65] Monthly Progress Report of Uttar Pradesh in the NGT matter, June 2023 Page 10

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Installation of pilot scale model • Evaluate the performance efficiency of the pilot scale model • Showcasing the results with smaller polluter communities with capacity building programme				2027: demonstration of pilot scale model	Central and state research institutes
	Legal, policy and regulatory measures					
1.4.1	In case of entities not complying with the requirements and norms legal steps are initiated (KMO 1.2) • Documentation and Evidence Gathering • Consultation with legal consul and prepare notice for non-compliance • Preparation of temporary, legal measures and enforcement actions	1	District Level, industry Facilities	In UP: Out of 1644, 892 complying, 183 non-compliance show cause notification, 177 closure issue, 357 were temporarily closed, 35 permanently closed	2025: No. of non-complying industries: 0	National Water Mission, Namami Gange Mission PCB, Industrial authorities
1.4.2	Ensure legal framework is in place for enforcement (KMO 1.4) • Legal Review and Gap Analysis • Stakeholder consultation and Amending Legislation • Establishment of regulatory authority • Capacity building and public awareness on enforcement guidelines	1	District Level, industry Facilities	two different surveillance activities: NGT and CPCB third party funded by NMCG, national fishery act, recently being revised[62]	2026: No. of non-complying industries: 0	National Water Mission, Namami Gange Mission NGT, CPCB, Industrial authorities
1.4.3	Ensure enforcement agencies are sufficiently equipped with monitoring and executive resources (KMO 1.4) • Assessment of required resources on enforcement agencies • Budget allocation and recruitment of resources personal	1	District Level, industry Facilities	Enforcement conducted by NGT and CPCB	2026: No. of non-complying industries: 0	National Water Mission, Namami Gange Mission

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Procurement of equipment including technological integration • Capacity building and training for the hired personnel					NGT, CPCB, Industrial authorities
1.4.4	Enforce law on defaulters (KMO 1.4) • Notify and communicate with the defaulters • negotiate with the defaulter to reach a settlement with cooperative approach • Notify and aware about the legal actions, criminal charges and court proceedings • Implement debt collection agencies and establish penalities in case of non-negotiation and obligation for long time	1	District Level, industry Facilities	In UP: Out of 1644, 892 complying, 183 non-compliance show cause notification, 177 closure issue, 357 were temporarily closed, 35 permanently closed	2028: No. of non-complying industries: 0	National Water Mission, Namami Gange Mission NGT, CPCB, Industrial authorities
1.4.5	Potential polluters are obliged to make their WQ monitoring information according to their consent to operate norms publicly accessible (KMO 1.4) • Establish a clear regulatory framework to monitor their water quality • develop a comprehensive water quality monitoring plan with monitoring frequency, sampling methods, and laboratory analysis procedures • Publish the data on a dedicated website or a government portal	1	District Level, industry Facilities	In UP: Out of 1644, 892 complying, 183 non-compliance show cause notification, 177 closure issue, 357 were temporarily closed, 35 permanently closed	2027: 80% All potential polluters make WQ publicly accessible	National Water Mission, Namami Gange Mission PCB, Industrial authorities
1.4.6	Setup a guideline for NBS solutions based on the experiences of the conventional and newly piloted NBS solutions (KMO 1.6) • Review of existing NBS and assessment of Pilot NBS project. • Evaluate the environmental and social impact assessment of both conventional and pilot NBS solutions.	2	District Level, industry Facilities	Conventional and approved standards as per CPHEEO technical guidelines	2028: Draft guideline for implemented NBS solutions prepared and Shared	National Water Mission, Namami Gange Mission PCB, Research Institutes

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Develop a draft of the NBS guidelines based on the collected data, experiences, and best practices • Stakeholders' consultation through workshops for finalizing the guidelines • Develop a strategy for scaling up successful NBS solutions based on the guidelines					
	Studies and assessments for developing and implementing measures					
1.5.1	Third party survey campaign incl. adequacy assessment for the existing ETPs of identified potential polluters is conducted to monitor their effluents and compare the monitoring with the documentation provided by the entities (KMO 1.2) • Select organizations/institutes for third party campaign and adequacy assessment • Develop detailed survey plan, including the specific parameters to be monitored and the sampling locations. • Collect information with sampling and reviewing the documents • Evaluate the adequacy and effectiveness of the ETPs in treating and managing effluents • Prepare a comprehensive report summarizing the survey findings, including any deficiencies, violations, or areas of non-compliance and share with relevant environmental regulatory authorities	1	State level, Industries	two different surveillance activities: NGT and CPCB third party funded by NMCG,	2024-2028: annual inspection of potential polluters and submission of findings	National Water Mission, Namami Gange Mission NGT, CPCB, Research Institutes/expert organizations
1.5.2	Identify gaps of existing monitoring systems (location and parameters) and plan for additional monitoring stations and upgradation (KMO 1.1) • Review the status of existing monitoring stations and WQ parameters	1	Basin Level and District Level	Implemented: Monitoring stations (76)	Target: cover the entire basin with an optimal mix of online and offline stations 2025: Gap assessed	National Water Mission, Namami Gange Mission

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Gap analysis of WQ monitoring stations including geographical, parametric, and technological gaps • Select site for new monitoring stations and placing appropriate monitoring equipment • Prepare comprehensive report with budgetary allocation and monitoring guidelines				2027: improvement of WQ monitoring stations conducted	PCB, NGT
1.5.3	Conduct monitoring verification campaign for one year for the identified hotspots in the (KMO 1.1) • Select organizations/institutes for verification campaign • Develop detailed survey plan, including the specific parameters to be monitored and the sampling locations. • Collect information with sampling and reviewing the documents • Evaluate the information on ETPs in treating and managing effluents • Prepare a comprehensive report summarizing the survey findings, including any deficiencies, violations, or areas of non-compliance and share with relevant environmental regulatory authorities	1	Basin Level and District Level, Industrial facilities	Proposed	2024 Targeted: conducted for all polluting industries in identified hotspots	National Water Mission, Namami Gange Mission PCB, NMCG, NGT, research institutes/organizations
1.5.4	Identify hotspots and conduct adequacy assessment for sewerage and STPs to identify a) lack of sufficient capacity b) lack of sufficient network coverage and untapped drains and c) underutilized STP capacity (KMO 1.3) • Select organizations/institutes for hotspot mapping and adequacy assessment • Prepare GIS map with identification of Hotspots for sewerage • Develop detailed survey plan, including the specific parameters to be monitored and the sampling locations for	1	District Level, Urban Local Bodies	In UK[63], Existing: 29 (38 MLD) Ongoing: 13 (96 MLD) Proposed: 4 (6 MLD) In UP[64], Existing:9 (224MLD), Ongoing: 2(63 MLD), Proposed 1(43 MLD)	2024 Targeted: for All existing STPs, drains	National Water Mission, Namami Gange Mission ULBs, Jal Nigam, research institutes/organizations

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	STPs, drains • Collect information with sampling and evaluate the information on STPs in treating and managing effluents • Prepare a comprehensive report summarizing the survey findings, gaps, and recommendation			% of Utilizing of operated STP: 46% (UK), 36% (UP) 75 MLD under trial run		
1.5.5	In case of underperformance of treatment plants, improvement and corrective measures are elaborated (KMO 1.2) • Select organizations/institutes/agencies for evaluating the treatment performance • Conduct a comprehensive assessment of the treatment plant's performance • Identify the root causes of underperformance with technical observations and stakeholders consultation • Optimize the treatment process based on the data collection and analysis • Develop a proactive operation and maintenance plan	2	District Level, Urban Local Bodies	Status: % of Utilizing of operated STP: 46% (UK), 36% (UP) 75 MLD under trial run	2025 Targeted: for All existing STPs	National Water Mission, Namami Gange Mission, AMRUT ULBs, Jal Nigam, research institutes/organizations
1.5.6	DPRs are elaborated for corrective measures taking into account future development and potential additional risks related to effluent WQ (KMO 1.2) • Make a list of corrective measures with detailed assessment • Select suitable technical measures for future implementation • Include the measures with detailed information (design, drawing, estimation) in DPRs	2	District Level, Urban Local Bodies	Proposed	2026 Targeted: for All existing STPs	National Water Mission, Namami Gange Mission ULBs, Jal Nigam, research institutes/organizations
1.5.7	Assess point source pollution from rural communities and prioritize the polluters (KMO 1.6)	2	District Level, ULBs, Panchayat	Total Population: 24 million	2025: communities on hotspots are identified	National Water Mission, Namami Gange Mission

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Identify relevant stakeholders, including local communities, environmental agencies, health departments, and NGOs • Collect existing information with local point source pollution site and identify the point source pollution in rural areas • Organize field survey to conduct WQ monitoring to identify the pollution load • Prepare a prioritization report, including a list of point sources ranked by pollution level and recommended actions			Rural Population:17.4 million	2026: planning for treating waste water in rural areas is submitted	Pay Jal Nigam, ULBs, Panchayat Officials, research institutes/organizations
	Awareness measures					
1.6.1	Identify all important stakeholders and their potential representatives, reach out and create awareness and assess the needs related to the upcoming activities for adequate infrastructure to address potential conflicts (KMO 1.5) • Identification of all key stakeholders and representatives from communities, govt. agencies, NGOs • Organize stakeholder meetings to assess the needs of the communities and elaborate the upcoming activities and plans for improving and developing infrastructures • Organize awareness programme to showcasing the affects of the pollution and benefits of the new facilities • Collect consent from all stakeholders	1	District Level, ULBs, panchayats	Proposed	2024	National Water Mission, Namami Gange Mission Jal Nigam, ULBs, Panchayat Officials
1.6.2	For all proposed new projects and measures, initiate public roundtables and hearings to discuss a) the nature and extent of potential problems and opposition, b) potential solutions; reach consensus on a solution, and c) implementation modalities, and subsequent operation and maintenance. (KMO 1.5) • Identification of all key stakeholders and representatives from communities, govt. agencies, NGOs • Organize stakeholder meetings to discuss the problems, solutions and planning programme	2	District Level, ULBs, panchayat	Proposed	2024: all stakeholders identified 206: workshops organized	National Water Mission, Namami Gange Mission Jal Nigam, ULBs, Panchayat Officials, NGOs

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mech-anism and nodal agency
	• Organize workshops to elaborate the process involved in implementation, operation and maintenance • Collect consent on the agreed terms and solutions					
	Other measures					
1.7.1	setup a publicly accessible alarm system for suddenly occurring adverse changes in the effluent WQ (KMO 1.4) • Set up parameters of effluent WQ for alarming system • Determine the legal or regulatory requirements that govern the establishment of such an alarm system • Installation of alarm system • Organize awareness programme with local communi-ties for handling the alarm and understanding the ad-verse changes in the effluent WQ	3	District Level, Indus-trial facilities	Proposed	2024 Targeted: for all hotspots industries	National Water Mission, Na-mami Gange Mission PCB, Industrial authorities, NGOs
1.7.2	Identify and involve existing local competent capacities and re-sources/manpower in the planning and monitoring process for the adequate infrastructure (KMO 1.5) • Conduct community needs assessment • Identify and map out local stakeholders for existing lo-cal capacities and manpower • Prioritize local hiring for infrastructure projects to cre-ate job opportunities and stimulate the local economy • Implement a communication strategy to keep the com-munity informed about project updates, timelines, and achievements.	2	District Level, ULBs	Proposed	2024 Targeted: announce-ment of hiring 2025: Recruitment of local capacities	National Water Mission, Na-mami Gange Mission ULBs, Jal Nigam
1.7.3	Pollution hotspots are identified by combining data from multiple sources and a targeted monitoring campaign; a list of potential polluters is compiled for these hotspots. (KMO 1.2)	2	State Level, District Level, ULBs	NGT and CPCPB have compile list of pollution	2027: list of potential polluters have pre-pared	National Water Mission, Na-mami Gange Mission

SN	Measures KWMI 1	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mech-anism and nodal agency
	• Identify the institutes/organizations for collection in-formation and organizing monitoring campaign • Data collection of from different sources Integrate data from different formats and sources into a centralized database • Analyzing the collected data and prepare maps for identified polluters • Collaborate with relevant authorities, industry stake-holders, and environmental experts to develop remedi-ation plans for pollution stretches			stretches		PCB, NGT, ULBs, Jal Nigam, NMCG

6.3 Measures related to KWMI 2: Water quality deterioration due to non-point sources including agricultural activities

6.3.1 Reflection of key findings of the KWMI 2 Risk Assessment

The Risk Assessment for non-point source pollution combined information from a land-use analysis with field data. Because the entire Gangetic plain is either subject to intensive agriculture with double or triple cropping—with high application rates of pesticides and fertilizer—or is highly urbanized, this area is a major source of pollution from agricultural and domestic runoff, with adverse direct impacts on streams, distributaries, and tributaries of Ramganga River.

The NPK usage in Uttar Pradesh—averaged over the 20 districts in UP in the Ramganga Basin—is significantly higher than the average for the Ramganga drainage area in Uttarakhand. In UP, fertilizer usage ranges from 110 – 181 (kg/ha) for Nitrogen, 32 – 53 (kg/ha) for Phosphorus, and 7 – 11 (kg/ha) for Potassium. Maximum fertilizer usage in UP was observed in Bijnor (245 kg/ha) and Kheri (209 kg/ha). For Uttarakhand, an even higher fertilizer usage was observed in Udham Singh Nagar (563 kg/ha), while fertilizer application was also very substantial in Nainital (174 kg/ha). This equally applies to phosphorus. In these SWMUs, drainage of nitrogen and phosphorus-rich effluent into water bodies is expected to be exceeding the Indian national standard. It can cause algal blooms as well as oxygen depletion in streams and water bodies, which poses a threat to the rich aquatic life in the Ramganga Basin in a longer timeframe.

The SWAT analysis was based on a 10-year time-series of nutrient loads, which was averaged and then compared with a threshold value. It is noted that the risk of organic phosphorus pollution was found to be higher than the risk associated with nitrogen pollution. Nevertheless, Ramganga Basin Management for now has only considered pollution reduction targets for nitrogen.

Regarding pesticides application, it is observed that aerosol-based pesticides in Uttar Pradesh averaged some 254.4 kg per thousand hectares, compared to 97.0 kg per thousand hectares in Uttarakhand. Contrary, fungicides application in the Ramganga region in UK is higher (172.4 kg per thousand hectares) than in UP (77.7 kg per thousand hectares). The analysis concludes that 8 out of 18 SWMUs belong to the high-risk zone for applying high volumes of pesticides (>0.65 kg/ha) in agricultural fields, which can cause further contamination and degradation of the water quality of the lower Ramganga River Basin. Pesticides and nutrient concentrations (nitrate, phosphate) in surface water is currently not monitored by CPCB. Nevertheless, these data are crucial to understand the effects of non-point source pollution on the health of the environment in the Ramganga River Basin, and to improve agricultural practices and pesticide usage in the large irrigated-agricultural sector.

Though the entire Ramganga Basin witnesses intense agriculture and exhibits high use of pesticides and fertilizers, the nitrate concentrations in groundwater as monitored by the CGWB do not show any significant correlation. Thus, it is with utmost caution that the current surface and groundwater monitoring network needs a robust improvement to validate with reasonable sensitivity the impacts of intense agriculture on the water resources. Nevertheless, the triple cropping pattern and highly urbanized nature of the Ramganga Basin can not be ignored.

Pollution of plastic waste—which is transported through rivers—is detrimental to aquatic life and riverine eco-system. More than 50% of the drainage basin is at risk of plastic waste pollution that exceeds a value of 6 thousand tons per year. This specifically concerns the mid- and lower regions of Ramganga river basin. Mismanaged plastic waste is associated with a lack of awareness and education about the importance of proper waste management practices. It points to the need for efficient waste collection, sorting, recycling, and disposal systems to minimize plastic waste pollution.

While the risks associated with solid waste generation were not yet quantified, it is evident that unplanned urbanization, population growth, inadequate waste management infrastructure, and inadequate public awareness have contributed to widespread solid waste management issues. This further exacerbates pollution and the degradation of water quality of streams in the Ramganga Basin. Hence management of solid waste is essential for sustaining important environmental value and for protecting public health along the Ramganga and its tributaries.

To achieve the key management objectives for KWMI2, a realistic plan of action will comprise focusing on the reduction of uncontrolled application of chemical fertilizer and pesticides. The plan will also involve promoting organic farming/Zero Budget Natural Farming in 'at risk' zones close to water bodies. Further, scientific methods for managing plastic and solid waste in high-risk areas should be adopted in close consultation with key stakeholders.

It was observed that the management objectives for this RBM Cycle for KWMI 2 are fully in line with the analysis presented in the Risk Assessment. While the Vision for KWMI 2 is clear, it is noted that achieving "close-to-zero discharge of pesticides/fertilizers/toxic substances in surface runoff from agricultural fields and other areas of the Ramganga Basin" is ambitious for the first cycle of RBMP. First and foremost, it will require reducing the application of pesticides, fertilizer, and toxic substances to levels that can be "absorbed" by crops on the fields. If the above would prove unattainable, the approach further involves measures such as 1) treating all surface runoff from agricultural fields, 2) reusing agricultural runoff, or 3) hindering it from entering any surface water body and groundwater.

6.3.2 Outline of the POM for each Management Objectives

Management Objectives for this first RBMP include:

1. **The available national and state policies on regulation of the use of pesticides, fertilizers and other toxic substances are strictly implemented and supplementary new policies (as needed) are developed and implemented.**

Important policies in this regard originate from the Federal Ministry of Agriculture, Co-Operation & Farmers Welfare (DAC&FW), which 1) emphasize integrated pest and nutrition management techniques (IPNM), 2) promote biological, cultural, and mechanical methods of pest removal, and 3) advocate need-based, judicious use of pesticides. Specific attention shall be given to the scheme "Strengthening and Modernization of Pest Management Approach in India", which aims to promote IPNM as an environment-friendly broad-ecological approach for managing pest problems. These concepts focus on the optimum usage of pesticides and promotion of organic farming. However, new types of pesticides and other toxic substances are being applied in the agricultural fields, which are not included in the regulation. These contaminants need to be addressed and optimum implementation procedures for application need to be incorporated. When implementing the measures, a focus is to be laid on the high-risk zones identified in the Risk Assessment (SWMUs 1, 2, 7, 8, 14, 15, 16, and 18).

The POM in outline for this management objective involves:

- Assessment of relevant national and state policies on regulation of the use of pesticides, fertilizers and other toxic substances.
- Evaluate the performance of policies and identify policy gap regarding their execution and implementation.
- Revise the legal framework and policies addressing the identified gaps and develop capacities for their application.

- Consult with national and state authorities on efficient implementation of guidelines in district and block level and setup of proper monitoring mechanism.
- Conduct awareness and training campaigns on regulatory policies for enforcing and monitoring entities and agencies on local level.
- Assess, consider, and include local indigenous best-practices for organic farming adopted by similar bodies in the catchment into the new policy documents. The Arth Ganga as being promoted by the NMCG provides ample opportunities to move towards organic farming/Zero Budget Natural Farming (ZBNF)

2. **The farmers within the Ramganga Basin are continuously informed and sensitized by arranging awareness campaigns on the harmful use of pesticides/fertilizers/toxic substances for agricultural activities and their possible interaction with surface water.**

Within the Ramganga River Basin, farmers are key stakeholders for applying pesticides/fertilizers/toxic substances for better crop production. Uncontrolled and unscientific usage of fertilizer and pesticides puts potential threat to the environment and aquatic life as residues of these substances reach the streams/water bodies/rivers through surface and subsurface runoff. Through awareness campaigns, farmers are informed about the risks associated with these chemicals and their interactions with the environment. The block level Krishi Vikas Kendras (KVKs) are nodal agency to run such campaigns at ground. These campaigns disseminate knowledge about eco-friendly farming practices, encourage usage of less toxic chemicals, promote collaboration among stakeholders, and potentially lead to policy changes favoring sustainable agriculture. Ongoing support, monitoring, and evaluation are also essential to track the effectiveness of these campaigns and make any necessary adjustments over time. The implementation of these measures should prioritize the high-risk zones (15 out of 18 SWMUs) in Ramganga River Basin.

The POM in outline for this management objective involves:

- Identify training institutes related to usage of harmful quantities of pesticides/ fertilizers/ toxic substances for agricultural activities.
- Conduct a Training Need Assessment (TNA) on promotion of IPNM and harmful uses of pesticides/fertilizers/toxic substances.
- Develop training modules and IEC materials in local languages, with visual display covering crop specific IPNM practices for local farmers.
- Organize Training of Trainers (TOT) programs for village resource persons/ individual service providers/ irrigation operators on crop wise IPNM strategy.
- Farmers including women farmer groups are sensitized and trained on crop specific IPNM strategy and managing less-toxic pesticides.
- Arrange a series of behavior change communication (BCC), awareness and education events/ campaigns; circulate messages; publish news and articles in cooperation with women water user groups.
- Incentivize the process to promote the use of water soluble, organic fertilizer and bio-pesticides.

Potential for ZBNF in Ramganga Basin Districts

Based on the district agriculture contingency plans of districts in Ramganga Basin, a total of 51.99 million cattle is reared in the basin. Taking an average of 11 Kg excreta/dung produced by each cattle per day and the factors provided for the preparation of Beejamirt and Ghan Jeevamrit, the preliminary estimates indicate that a total of 79,746 Ha of agricultural land (averaged for paddy, wheat, sugarcane, vegetables, and gram cultivation) can be brought under zero budget natural farming across districts of Ramganga Basin. The cost of ZBNF is estimated to be INR 9410 per ha of land. This amount can be very well provided as government assistance under National Mission for Natural Farming.

3. **It is ensured that only permitted nitrogen effluent discharges shall reach all water bodies as defined in the Indian standards.**

Nitrogen effluent typically consists of compounds like ammonia (NH_3) and nitrate (NO_3) that typically arise from various sources such as agriculture (fertilizer runoff), and domestic sewage. These effluents contain nitrogen compounds that can have detrimental effects on water quality and ecosystem health if not properly managed. The Indian standards define permissible limits for nitrogen effluent discharges to protect the water quality and aquatic life in rivers, lakes, and other water bodies. While nitrogen concentrations are elevated as per the Risk Assessment, it has also been observed that phosphorus values are of serious concern and possibly should be included in the overall monitoring and mitigation campaign.

Reducing nitrogen effluent involves implementing a multifaceted approach. Agriculture can optimize fertilizer use and embrace organic farming. Municipalities and Panchayats should focus on implementation of natural buffer zones and cover crops which can mitigate runoff. Wetlands and riparian areas should be protected and restored. Public awareness on IPNM strategy, alternative farming and judicious use of fertilizers can yield comprehensive solutions.

The POM in outline for this management objective involves:

- Identify the concentration of Nitrogen in water as Nitrate, Ammonia, together with Phosphorus in a monitoring campaign, verifying the model information.
- Based on the data, prepare a hotspot map of river stretches and blocks which discharge nitrogen (8 SWMUs).
- Promote IPNM strategy and crop rotation methods in the hotspot regions where optimized use of fertilizer can be demonstrated to farmers through workshops and awareness campaigns.
- Promote sprinkler / drip irrigation methods and multi cropping method for agriculture so that less water can be used, and less fertilizer/pesticide is required so that less contaminated surface and subsurface runoff water enters the streams/rivers.
- Create buffer zones of vegetation between agricultural fields/settlements and water bodies that can help capture and filter nitrogen runoff, and thus preventing it from reaching water bodies.

4. **Solid waste disposal sites in the Ramganga Basin are identified through hotspot mapping, to understand the need for action, measures, and targeted investments.**

Hotspot mapping requires identifying areas with concentrated solid waste accumulation and poor solid waste management practices in the Ramganga River Basin. This process involves collecting data through satellite imagery, ground surveys, and local reports, and the datasets from Swachh Bharat Mission followed by GIS analysis to pinpoint high-priority zones. These solid waste disposal hotspots are then evaluated for severity considering factors like waste volume, type, proximity to water sources, and potential health risks. Subsequently, action plans are developed, including short and long-term strategies for waste collection, disposal, recycling, and community education. Resources need to be allocated to these hotspots to facilitate effective implementation, and collaboration with local communities, governments, and NGOs is emphasized. Continuous monitoring and adaptability of strategies are integrated to ensure sustained progress in waste management, pollution reduction, and overall environmental well-being within the Ramganga Basin.

The POM in outline for this management objective involves:

- Assess status of solid waste disposal sites with literature survey, site survey, and consultation meetings with local authorities.
- Prepare GIS maps based on the assessed information to show hotspot locations for setting up solid waste disposal sites, considering geohydrological, ecological, and socio-economic suitability.
- Prepare action plan for solid waste disposal at suitable sites including short and long-term strategies.
- Conduct feasibility studies and prepare DPRs for setting up sustainable solid waste disposal sites (implementation of the action plan).
- Includes stakeholders meeting from the responsible department such as ULB, and SBM

5. **Development of solid waste dumping facilities and landfill sites within flood zones is totally prohibited by devising proper penalties and policies as per local rules and legislations i.e. Solid Waste Management Rules, 2016.**

Prohibiting the establishment of solid waste dumping facilities and landfill sites within flood zones is essential to ensure sustainable waste management and mitigate disaster risks. Flood zones of Ramganga Basin are prone to natural disaster which may destroy the solid waste management facilities and landfill sites. This involves implementing clear zoning regulations, enforcing penalties for violations, conducting thorough environmental impact assessments, raising public awareness, integrating disaster risk reduction measures, regularly monitoring, and inspecting facilities, updating legislation if needed, coordinating across relevant authorities, and providing capacity-building programs. These actions collectively prevent environmental pollution, health hazards, and vulnerability to natural disasters, fostering a comprehensive approach to waste management aligned with local rules and regulations.

The POM in outline for this management objective involves:

- Develop legal framework, policies, and regulations to include the prohibition of development of solid waste dumping facilities and landfill sites within flood zones.
- Set up the regulatory bodies/local bodies for supervision of the flood zones and capacitated for regulatory actions in case of any violation.
- Inform and create awareness with local planning bodies in charge of developing solid waste dumping sites on flood zone demarcation and legal consequences for defaulting with the prohibition.
- Organize a series of awareness and education campaigns, and behavior change communication with local stakeholders within the flood plain zones motivated to use alternative landfill sites and solid waste management facilities.
- Consequently, enforce laws and regulations on defaulters.

6. **The citizens in the Ramganga Basin are well-informed and sensitized on the appropriate disposal of municipal solid waste through the implementation of public awareness campaigns.**

Public awareness campaigns play a crucial role in promoting responsible waste disposal and encouraging positive behaviors among citizens. When the residents of the Ramganga Basin are well-informed and sensitized about the appropriate disposal of municipal solid waste, there is a high probability of noticeable reduction in pollution leading to cleaner water bodies and air. Additionally, public health has improved due to the decreased spread of diseases associated with improper waste management. The campaigns can also emphasize the importance of preserving natural resources by promoting recycling and responsible waste disposal practices, consequently conserving energy and raw materials. The aesthetic appeal of the region would positively transform as a result of proper waste disposal, contributing to higher property values and increased tourism. Furthermore, the campaigns would also encourage compliance with waste management regulations, ensuring a safer environment and alignment with legal requirements. The collaborative nature of these campaigns, involving governmental bodies, NGOs, businesses, and the community, would indeed strengthen partnerships for effective waste management. The POM in outline for this management objective involves:

- Develop a campaign strategy and content for awareness material.
- Selection of NGOs/Municipalities/ media/ research institutes/organizations for implementing the campaign.
- Organize gender inclusive awareness programs, events, and publications on appropriate disposal of municipal solid waste.

7. **Sufficient solid waste management capacities are created and implemented, whereas due to critical situations pollution hotspots are tackled as the priority.**

Creating and implementing robust capacities for solid waste management is essential to ensure the responsible handling of waste and minimize its adverse effects on the environment and public wellbeing. Promoting waste segregation at its source is not only facilitating the recycling efforts but also encourages proper disposal practices. Integrating comprehensive recycling infrastructure for solid waste materials is the establishment of composting facilities to transform organic waste into valuable compost. Adequate treatment facilities should be in place for hazardous and non-recyclable waste, and the management of sanitary landfills is crucial. The action of effective solid waste management practices with comprehensive strategies for eradicating pollution hotspots requires collaborative efforts among governmental bodies, industries, communities, and environmental organizations.

The POM in outline for this management objective involves:

- Identification of pollution hotspots with GIS mapping, site survey, and consultation meetings with local authorities for setting up a priority list
- Set up regulatory bodies/local bodies to evaluate and implement the effective solid management capacities including collecting systems, waste segregation, recycling infrastructure, composting facilities, waste treatment and landfills.
- Develop monitoring framework/mechanism for implementation solid waste management strategies.

8. **Use of new technologies in solid waste management is explored including garbage incineration plants after discussing the feasibility as well as technical, operational, and maintenance aspects of these plants with joint consultation of all the relevant stakeholders.**

The use of new technologies, such as garbage incineration plants, refused derived fuel, rapid composting, fuel cell technology; bioreactor landfill, etc. can play a significant role in addressing the challenges associated with waste disposal. Different technologies in solid waste management would have different social, environmental, and economic impacts. Therefore, a comprehensive feasibility study should be conducted. This study should be conducted based on the Multi-Criteria Decision Analysis with the evaluating factors such as waste composition, volume, and characteristics, as well as the availability of suitable land, necessary infrastructure and considering the potential environmental impacts, capital investment and operational and maintenance costs of the facility. The outcomes of the study should be demonstrated with the relevant stakeholders for further implementation and adaptation with the local constraints so that appropriate method of implementation, operation, and maintenance can be considered.

The POM in outline for this management objective involves:

- Assess the new technologies on solid waste management with literature review.
- Selection of NGOs/ research institutes/ organizations for organizing feasibility concept, design, implementation, and O& M procedures.
- Conduct a feasibility study of these technologies including the comparison socio-economic, technical, operation and maintenance aspects and select the most effective technology.
- Set up a pilot scale study/model for showcasing the implementation and prepare operation and maintenance guidelines with local considerations.
- Conduct the workshops with all relevant stakeholders to demonstrate the findings of pilot scale application and collect feedback.
- Set up a full-scale application of the adopted technology in the different regions of Ramganga river basin. Prepare the list of potential sellers, cost benefit analysis, after sell service and potential funding

9. **Adequate information/data is developed on the leaching from historical solid waste dumping sites located in flood zones.**

Studying leaching from historical solid waste dumping sites located in flood zones is crucial to understand the potential environmental damage and to formulate appropriate management strategies. This process involves investigating various aspects, such as the composition of waste, hydrological conditions, leaching mechanisms, contaminant transport, and potential risks to human health and ecosystems. Collaboration among experts, robust data collection methods, advanced modeling techniques, and careful risk assessment are essential to developing adequate information and data for effective decision-making and mitigation strategies. Effective leachate management involves installation of collection systems for proper treatment, preventing uncontrolled migration of contaminants. Sufficient information on leachate can be linked with remediation strategies such as capping, liners, and flood-resistant infrastructure, coupled with stakeholder engagement, and contribute to mitigate leaching effects.

The POM in outline for this management objective involves:

- Identify historical/legacy solid waste dumping sites in flood zones.
- Select /collaborate with experts in environmental field and risk assessment to prepare an assessment methodology.
- Collect information on waste characterization, leaching mechanism, and contamination transport.
- Conduct field sampling to collect leachate samples and analyze it to determine the concentrations of various contaminants.
- Prepare Health and Environmental Risk Assessment with computational modeling.
- Set up an adequate database with collected information and used for showcasing through a website for public awareness.

6.3.3 PoM for KWMI 2

Below Table 69 presents the implementation details of PoM for KWMI 2.

Table 69: Implementation details of PoM for KWMI 2

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	BASIC MEASURES					
2.0.1	Implement the Water (Prevention and Control of Pollution) Act, 1974	1	Basin level, State level	As per the Act, the State Pollution Control Boards (SPCBs) have been formed in Ramganga River Basin	2029: end of Ramganga RBM cycle	National Water Mission, Namami Gange Mission PCB, ULBs, Industrial officials
2.0.2	Implementation of the Environmental (Protection) Act, 1986	1	Basin level, State level	Polluted river stretches have been identified by the CPCB in the Ramganga Basin	2029: end of Ramganga RBM cycle	National Water Mission, Namami Gange Mission PCB, District authorities
2.0.3	Implementation of National Water Policy, 2012	1	Basin level, State level	implemented	By the end of the first Ramganga RBM cycle, i.e. 2029, the policy is revised	National Water Mission, Namami Gange Mission PCB, ULBs, District authority, NMCG
2.0.4	Implement the State Water Policy, 2019	1	State level, District level	There is a need for a holistic assessment of the river water	By the end of the first Ramganga RBM cycle, i.e. 2029, the first as-	National Water Mission, Namami Gange Mission PCB, ULBs, District

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
				quality (considering trace metals and pesticide pollution).	sessment is completed	authority, SPMG
2.0.5	Implementation of Solid Waste Management Rules (2016)	1	State level, District level		2028: 80% of basin achieved waste segregation and processing	National Water Mission, Namami Gange Mission, Swachh Bharat Mission ULBs, District authorities
	SUPPLEMENTARY MEASURES					
	Technical measures including the application of innovativetechnologies					
2.1.1	Promote sprinkler / drip irrigation methods and multi cropping method for agriculture so that less water can be used, and less fertilizer/pesticide is required so that less contaminated surface and subsurface runoff water enters the streams/rivers. (KMO 2.3) • Assessment of existing cropping method • Select appropriate method and techniques on sprinkler/drip irrigation method with local and regional adaptation • Organize awareness workshops among the farmers on benefits of sprinkler/drip irrigation uses and benefits	1	State level, District level	Average pesticides usage:0.6 kg/ha Average Fertilizer usage: 188 kg/ha[66]	2027: 20% of farmers are adopted sprinkler /drip irrigation techniques, target pesticides use: (0.3 kg/ha) and fertilize use: 130 kg/ha as per India average	Micro Irrigation Fund, PMKY Agricultural Dept., Irrigation Dept.

[66] Pressure / Impact Analysis and Risk Assessment of Key Water Management Issues (KWMI) 2 –results

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
2.1.2	Create buffer zones of vegetation between agricultural fields/settlements and water bodies that can help capture and filter nitrogen runoff, and thus preventing it from reaching water bodies. (KMO 2.3) • Site assessment of regions for creating buffer zones • Select appropriate vegetation which are well suited to the local climate and soil conditions • Determine the appropriate width for the buffer zone based on local conditions. • Plant a diverse mix of vegetation, including grasses, shrubs, and trees, in the buffer zone. • Organize awareness workshops with landowners, farmers, and the community about the importance of buffer zones and proper land management practices.	1	State level, District level	Organic farming has started, 2km on each side in the tributaries, 1.2 lakh ha is to be planted 0.3 lakh ha have been covered by NMCG, 35crore saplings in July 2023 across the state. State govt. plantation drive[62]	2024: identification of Buffer zones 2027: buffer zones are installed in overall tributaries and stretches	Micro Irrigation Fund, Arth Ganga Agricultural Dept., Irrigation Dept. Horticultural Dept.
2.1.3	Prepare action plan for solid waste disposal at suitable sites including short and long-term strategies. (KMO 2.4) • Evaluate current waste management situation • Review local, state, and national regulations related to solid waste management. • Adopt short term strategies like Waste Reduction and Recycling Programs, improved Collection and Transportation • Explore long-term solutions like waste-to-energy facilities to convert waste into energy, reducing the volume of waste requiring disposal, • Plan and develop new landfill sites with proper engineering, environmental safeguards, and leachate management systems.	1	State level, District level	In UP Existing Pits: 30, composting capacity: 127.78 TPD, Proposed C& D waste processing facilities: 100 TPD[67]	2024: solid waste management assessed 2028: adaptation of long-term solutions in every district	Swachh Bharat Mission ULBs, Municipalities and panchayat authorities, MoHUA, PCB

[67] Monthly Progress Report of Uttar Pradesh in the NGT matter, June 2023 annex 5.1 page 25-28

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Encourage community participation in waste management through community composting, waste sorting, and neighborhood clean-up programs					
2.1.4	Develop monitoring framework/mechanism for implementation solid waste management strategies. (KMO 2.7) • Establish a data collection process to regularly gather information on waste generation, collection, disposal, and recycling • Implement a data management system to organize and store collected data securely • Regularly evaluate performance against established targets on solid waste management strategies. • Utilize GIS technology to map waste generation and disposal patterns for better spatial analysis • Compare your waste management performance with regional or national benchmarks to assess your progress • Continuously review and refine the monitoring framework based on feedback and changing waste management needs	1	Basin Level, State level, District level	Site selection by NMCG	2024: set up monitoring framework 2026: Evaluation of monitoring mechanism 2028: Refinement of monitoring mechanism	Swachh Bharat Mission ULBs, Municipalities and panchayat authorities, MoHUA, PCB
2.1.5	Conduct a feasibility study of these technologies including the comparison socio-economic, technical, operation and maintenance aspects and select the most effective technology (KMO 2.8) • List and research the different waste management technologies available • Gather comprehensive data on each technology, including technical specifications, cost estimates, performance data, and environmental impact assessments and socio-economic aspects	1	Basin Level, State level, District level	Proposed, Sludge reuse for agriculture with IIT Roorkee	2024: Selection of most effective technology	Swachh Bharat Mission ULBs, Research Institutes

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Analyze the operational and maintenance requirements for each technology, including labor, skills, spare parts availability, and downtime • Compare the technologies using the established evaluation criteria and weighting factors and prepare comprehensive assessment of each technology • Develop an implementation of selected technology with the steps, timeline, budget, and resource allocation					
2.1.6	Set up a pilot scale study/model for showcasing the implementation and prepare operation and maintenance guidelines with local considerations (KMO 2.8) • Identify a suitable location for the pilot project, considering factors such as accessibility, proximity to resources, and representation of local conditions • Build and install the pilot project infrastructure and equipment according to the approved design • Implement data collection systems and monitoring tools to collect relevant data during the pilot phase • Develop a comprehensive plan for the operation and maintenance (O&M) of the pilot project with personnel engagement • Organize workshops and capacity building programme with local stakeholders	1	District Level, Panchayat	Proposed	2025: Installation of Pilot model 2026: prepared operation and maintenance guidelines	Swachh Bharat Mission, Research fund under DST, DBT ULBs, Research Institutes
2.1.7	Conduct field sampling to collect leachate samples and analyze it to determine the concentrations of various contaminants. (KMO 2.9) • Develop a sampling plan that outlines the location, frequency, and methods for sample collection	1	District Level	In UP Existing Pits: 30, composting capacity: 127.78 TPD, Proposed C& D waste	2024: preparation of sampling plan 2025: Leachate data prepared	Swachh Bharat Mission, Research fund under DST, DBT

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Identify specific locations within the waste management facility where leachate samples will be collected. • Collect samples with preventive measures and equipment • Prepare laboratory analysis report to understand the characteristics and concentrations			processing facilities: 100 TPD		ULBs, Research Institutes
	ECONOMIC MEASURES					
2.2.1	Incentivize the process to promote the use of water soluble, organic fertilizer and bio-pesticides. (KMO 2.2) • Develop educational programs and materials to inform farmers about the benefits of water-soluble organic fertilizers and bio-pesticides, including their environmental advantages and potential cost savings • Organize training sessions and workshops to educate farmers on the proper use, application methods, and dosages of these eco-friendly agricultural inputs • Provide financial incentives, subsidies, or grants to farmers who transition to these sustainable practices. • Fund research projects and partnerships to develop and improve water-soluble organic fertilizers and bio-pesticides, making them more accessible and effective • Facilitate access to markets for farmers using sustainable practices by connecting them with retailers, restaurants, and consumers interested in organic and eco-friendly products	1	State Level, District Level	30-35K per ha per year is given for 3 years for organic farming horticulture provided by state agricultural department,: trainings, exposure visit pilot on a small area, platforms for selling product are being provided	2024: Prepare framework for incentives and subsidies 2026: Implementation of incentivize process	Swachh Bharat Mission, Research fund under DST, DBT ULBs, Research Institutes, agricultural dept.
2.2.2	Conduct feasibility studies and prepare DPRs for setting up sustainable solid waste disposal sites (implementation of the action plan) (KMO 2.4) • Identify potential site locations based on factors such	1	District Level	In UP Existing Pits: 30, composting capacity: 127.78 TPD, Proposed	2025: waste disposal site selected	Swachh Bharat Mission

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	as proximity to waste sources, accessibility, environmental impact, and regulatory compliance. • Gather relevant data on waste composition, quantity, and characteristics • Assess the technical, social, and environmental feasibility of the waste disposal site, considering aspects like landfill design, leachate management, gas collection, and infrastructure requirements • Develop a preliminary conceptual design, drawing and estimation of solid waste disposal sites			C& D waste processing facilities: 100 TPD[67]		ULBs, Research Institutes, PCB
	INSTITUTIONAL AND CAPACITY BUILDING MEASURES					
2.3.1	Consult with national and state authorities on efficient implementation of guidelines in district and block level and setup of proper monitoring mechanism. (KMO 2.1) • Identify relevant national and state authorities responsible for issuing guidelines • Prepare consortium with the representatives from national and state authorities • Obtain and thoroughly review the guidelines and policies issued by national and state authorities • Establish a standardized system for data collection, reporting, and documentation at the district and block levels. • Set up a monitoring mechanism to track the implementation of guidelines, including regular site visits, audits, and review	1	Basin level, state level, District Level	Forest Research Institute has developed a DPR for all ecological measures	2024: consortium set up 2025: monitoring mechanism established	Micro irrigation fund, PMKY, Arth Ganga Agricultural dept., Irrigation Dept., District authorities, Forest Dept.
2.3.2	Set up the regulatory bodies/local bodies for supervision of the flood zones and capacitated for regulatory actions in case of any violation. (KMO 2.5)	1	Basin level, state level, District Level	demarcation of flood plains: 14446 pillars have been placed	2024: Regulatory body set up 2025: staffs are trained	Micro irrigation fund, PMKY, Arth Ganga

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Establish the regulatory bodies responsible for flood zone management and supervision • Develop or amend existing laws and regulations to provide a legal basis for the creation and operation of flood zone regulatory bodies • Secure the necessary budgetary allocations and resources to fund the operations of the regulatory bodies • Provide training and capacity-building programs for regulatory body staff to enhance their understanding of flood risk management, relevant laws, and enforcement procedures • Define enforcement mechanisms and penalties for violations of flood zone regulations			from Kannauj to Unnao Ministry of housing investigates this implemented with the districts and urban development departments, AE from UPPCB involved, Site select by NMCG		Agricultural dept., Irrigation Dept., District authorities, PCB, ULBs
2.3.3	Set up regulatory bodies/local bodies to evaluate and implement the effective solid management capacities including collecting systems, waste segregation, and recycling infrastructure, composting facilities, waste treatment and landfills. (KMO 2.7) • Establish the regulatory bodies responsible for flood zone management and supervision • Prepare materials and mechanism on evaluating and implementing the solid waste management strategies • Provide training and capacity-building programs for regulatory body staff on effective solid waste management capacities • Set up a system for collecting and analyzing data and incorporate in annual reports on solid waste managements	1	Basin level, state level, District Level	Ministry of housing looks into this implemented with the districts and urban development departments, AE from UPPCB involved, Site select by NMCG	2024: Regulatory body set up 2025: staffs are trained	Swachh Bharat Mission ULBs, District authorities, PCB, MoHUA
	LEGAL, POLICY AND REGULATORY MEASURES					

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
2.4.1	Evaluate the performance of policies and identify policy gap regarding their execution and implementation. (KMO 2.1) • Gather all relevant policy documents, including laws, regulations, and official guidelines and prepare comprehensive database. • Identify and engage key stakeholders, including government agencies, policymakers, experts • Establish clear and measurable performance metrics or indicators that align with the policy objectives • Evaluate the actual outcomes and impacts of the policy for gap identification	1	Basin Level, District Level	Forest Research Institute has developed a DPR for all ecological measures, national fishery act, recently being revised	2025: Policies assessed and gap identified	Micro irrigation fund, PMKY Agricultural dept., Irrigation Dept., District authorities, PCB, Forest Dept.
2.4.2	Revise the legal framework and policies addressing the identified gaps and develop capacities for their application. (KMO 2.1) • Identify specific gaps, shortcomings, or inconsistencies in the existing legal framework and policies through thorough analysis and assessment • Engage key stakeholders, including government agencies, policymakers, experts • Conduct a comprehensive legal and policy analysis to understand the implications of identified gap • Develop drafts of revised policies or new legal instruments to address identified gaps • Conduct public consultations, meetings, capacity building programme to gather input and provide revisions for final documents	1	Basin Level, District Level	Forest Research Institute has developed a DPR for all ecological measures, national fishery act, recently being revised	2025: Policies assessed and gap identified 2026: Draft framework prepared 2027: final document on framework and policies submitted	Micro irrigation fund, PMKY Agricultural dept., Irrigation Dept., District authorities, PCB, Forest Dept.
2.4.3	Develop legal framework, policies, and regulations to include the prohibition of development of solid waste dumping facilities and landfill sites within flood zones. (KMO 2.5)	1	Basin Level, District Level	No legacy dumping sites within 1 km of River	2025: Policies assessed and gap identified	Swachh Bharat Mission

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Assess present policies and legal frameworks • Involve experts and researchers on solid waste dumping facilities and dumping sites • Conduct a comprehensive legal and policy analysis to understand the implications of identified gap • Develop drafts of revised policies or new legal instruments to address identified gaps			Bank[68]	2026: Draft framework prepared 2027: final document on framework and policies submitted	ULBs, District authorities, research organizations
2.4.4	Enforce laws and regulations on defaulters. (KMO2.5) • Notify and communicate with the defaulters • negotiate with the defaulter to reach a settlement with cooperative approach • Notify and aware about the legal actions, criminal charges and court proceedings • Implement debt collection agencies and establish penalties in case of non-negotiation and obligation for long time	2	State Level, District Level	Proposed	2024: No. of non-complying polluters: 0	Namami Gange Mission, Swachh Bharat Mission ULBs, District authorities
	STUDIES AND ASSESSMENTS FOR DEVELOPING AND IMPLEMENTING MEASURES					
2.5.1	Assessment of relevant national and state policies on regulation of the use of pesticides, fertilizers and other toxic substances. (KMO 2.1) • Identify all relevant national and state policies, laws, regulations, and guidelines • Engage stakeholders, including government agencies, agricultural experts, environmental and farmers organizations • Conduct a detailed analysis of the identified policies to	1	State Level, District Level	Implemented: IPNM strategy	2024: existing policies are assessed	Micro irrigation fund, PMKY Agricultural dept., Irrigation Dept., District authorities agriculture research organizations

[68] Monthly Progress Report of Uttar Pradesh in the NGT matter, June 2023, page 5

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	understand their objectives, scope, and legal provisions • Compare national and state policies with international best practices and standards to identify areas where improvements are needed					
2.5.2	Assess, consider, and include local indigenous best-practices for organic farming adopted by similar bodies in the catchment into the new policy documents. (KMO 2.1) • Identify local indigenous communities, farmers, and organizations with knowledge and expertise in organic farming practices in the catchment area • Engage with local indigenous communities and farming groups through meetings, workshops, and consultations • Document traditional indigenous farming practices and techniques, including crop varieties, cultivation methods, pest control, and soil management • Compare indigenous farming practices with modern organic farming techniques and scientific research to identify areas of compatibility and potential improvements • Develop policy provisions that incorporate relevant and proven indigenous farming practices into the new policy documents	1	Basin level, State Level, District Level	Proposed, Organic farming has started in 2023. 2km on each side in the tributaries	2027: Indigenous best practices are adopted in the policy	Micro irrigation fund, PMKY Agricultural dept., Irrigation Dept., District authorities agriculture research organizations
2.5.3	Conduct a Training Need Assessment (TNA) on promotion of IPNM and harmful uses of pesticides/fertilizers/toxic substances. (KMO 2.2) • Identify and involve key stakeholders, including farmers, agricultural extension workers, government officials, researchers, and NGOs	1	Basin level, State Level, District Level	promoting organic farming on 30ha of organic farming, 5km natural and then another 5 organic (voluntarily) in UP	2024: TNA conducted in 50% of basin	Micro irrigation fund, PMKY Agricultural dept., Irrigation Dept., District authorities

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Design questionnaires or assessment tools to gather information from stakeholders • facilitate focus group discussions and interviews to collect data on the existing knowledge, skills, and training needs					agriculture research organizations
2.5.4	Develop training modules and IEC materials in local languages, with visual display covering crop specific IPNM practices for local farmers. (KMO 2.2) • Collaborate with agricultural experts, extension officers, and local farmers to gather insights into effective IPNM practices for crop-specific contexts • Develop comprehensive training modules that cover various aspects of IPNM • Create visually appealing and easy-to-understand IEC materials, such as brochures, posters, info graphics, and videos • Translate the training modules and IEC materials into local languages to ensure accessibility and understanding by the target audience	1	Basin level, State Level, District Level	Ganga Task Force in Kanpur Benares conducts awareness programmes connecting people with the government, (Jan Ganga component connecting with people).	2024: IEC prepared	Micro irrigation fund, PMKY, Ganga prary, NYKS Ganga dut, Ganga Mitra, Ganga vichar munch (GVM) Agricultural dept., Irrigation Dept., District authorities agriculture research organizations
2.5.5	Identify the concentration of Nitrogen in water as Nitrate, Ammonia, together with Phosphorus in a monitoring campaign, verifying the model information. (KMO 2.3) • Select researchers, experts for collect and verifying the information • Conduct water sample collection at the selected monitoring sites • Verify the laboratory results and Integrate into the existing model or database	1	Basin level, State Level, District Level	Monitoring stations: 76	2024: site selected 2025: WQ analyzed 2026: calibration with the model completed	Micro irrigation fund, PMKY Agricultural dept., Irrigation Dept., District authorities, research organizations

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Compare the model predictions or estimates of nitrogen and phosphorus concentrations with the monitoring data to assess the model's accuracy and reliability					
2.5.6	Based on the data, prepare a hotspot map of river stretches and blocks which discharge nitrogen (8 SWMUs) (KMO 2.3) • Determine the criteria for identifying nitrogen discharge hotspots • Use GIS software (e.g., ArcGIS, QGIS) to create the hotspot map. • Analyze the hotspot map to draw meaningful conclusions. Identify the areas with the highest nitrogen discharge and understand the potential environmental impacts • update your hotspot map periodically to monitor changes and the effectiveness of any mitigation measures implemented	1	Basin level, State Level, District Level	Proposed	2025: Hotspots map prepared 2027: hotspot map updated	Namami Gange Mission District authorities, research organizations
2.5.7	Assess status of solid waste disposal sites with literature survey, site survey, and consultation meetings with local authorities. (KMO 2.4) • Select organizations/NGOs for assessment and survey • Reviewing existing reports, studies, and documents related to solid waste disposal in the area. • Collect data on the location, size, capacity, and history of existing solid waste disposal sites. • Conduct on-site visits to the solid waste disposal sites • Engage in discussions with local authorities responsible for waste disposal sites. • provide recommendations for improvements or remediation measures that may be needed to address issues	2	Basin level, State Level, District Level	Solid disposal sites are verified by NMCG, Implemented by MoHUA	2024: Survey conducted on hotspot regions	Namami Gange Mission, Swachh Bharat Mission, Smart City Mission District authorities, research organizations, NGOs, MoHUA, PCB

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	identified during the surveys					
2.5.8	Prepare GIS maps based on the assessed information to show hotspot locations for setting up solid waste disposal sites, considering geohydrological, ecological, and socio-economic suitability. (KMO 2.4) • Gather geohydrological, ecological, and socio-economic. • Use Geographic Information System (GIS) software (e.g., ArcGIS, QGIS) to integrate the collected data and create a comprehensive spatial database • Assign weights to different factors based on their importance and overlays in GIS tools • Set a threshold score above which a location is considered suitable for waste disposal and generate thematic map based on the value	2	Basin level, State Level, District Level	Proposed	2025: Hotspots map prepared	Namami Gange Mission, Swachh Bharat Mission, Smart City Mission District authorities, research organizations, ULBs
2.5.9	Identification of pollution stretches (hotspot) with GIS mapping, site survey, and consultation meetings with local authorities for setting up a priority list (KMO 2.7) • Select research organizations/NGOs for assessment and survey • Assess and collect the present data on solid waste management capacities • Conduct on-site visits to the solid waste disposal sites • Engage in discussions with local authorities responsible for solid waste management in the areas • Use Geographic Information System (GIS) software (e.g., ArcGIS, QGIS) to integrate the collected data and create a comprehensive spatial database	1	Basin level, State Level, District Level	Proposed	2024: site survey conducted 2025: Hotspots map prepared	Swachh Bharat Mission, Smart City Mission District authorities, research organizations, ULBs

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Generate hotspot map based on the collected information and prepare prioritize list based the pressing issues					
2.5.10	Assess the new technologies on solid waste management with literature review. (KMO 2.8) • Gather relevant academic databases, research journals, conference proceedings, government reports • Extract relevant information from the selected literature, including technology descriptions, performance data, case studies, advantages, disadvantages, and environmental impacts • Based on the assessment, make recommendations for the adoption of specific technologies or approaches in solid waste management	2	Basin level, State Level, District Level	Proposed	2024: New technology identified	Swachh Bharat Mission, Smart City Mission District authorities, research organizations, ULBs
2.5.11	Identify historical solid waste dumping sites in flood zones. (KMO 2.9) • collect historical records and documents from local government agencies, environmental organizations, and archives • Conduct field visits to investigate the areas identified through historical records and GIS mapping and tagged the location • Prepare a detailed report with flood risk assessment and risk prioritization.	2	, State Level, District Level	Proposed	2025: all historical solid waste dumping sites identified	Swachh Bharat Mission, Smart City Mission ULBS, district authorities
2.5.12	Prepare Health and Environmental Risk Assessment with computational modeling. (KMO 2.9) • Gather relevant data on environmental contaminants, exposure pathways, and receptor populations with historical data	3	State Level, District Level	Proposed	2024: collection of information and model selection 2025: preparation of management	Swachh Bharat Mission, Research fund under DST, DBT

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Identify and select appropriate computational models for assessing exposure and risk. • estimate the magnitude, frequency, duration, and routes of exposure to environmental contaminants with computational modeling • Conduct sensitivity and uncertainty analyses to assess the robustness of the risk estimates and identify areas of uncertainty in the modeling process • develop risk management strategies with potential risk reduction measures and control options				strategies	ULBs, Research Institutes
2.5.13	Collect information on waste characterization, leaching mechanism, and contamination transport. (KMO 2.9) • Conduct initial literature reviews and desktop research to gather existing information on waste characterization, leaching mechanisms, and contamination transport • Identify and select the specific waste management facility or area where the data collection will take place. • Conduct field sampling to collect representative waste samples • Investigate the leaching mechanisms by conducting laboratory experiments • Develop mathematical models or use existing ones to simulate the transport of contaminants from the waste materials into the surrounding environment	1	State Level, District Level	Proposed	2024: collection of information and model selection 2025: preparation of management strategies	Swachh Bharat Mission, Research fund under DST, DBT ULBs, Research Institutes
	Awareness measures					
2.6.1	Conduct awareness and training campaigns on regulatory policies for enforcing and monitoring entities and agencies on local level. (KMO 2.1)	1	State Level, District Level	Proposed	2026: series of awareness programme organized	Swachh Bharat Mission

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Identify and engage with relevant local government agencies, environmental authorities, and enforcement bodies as key stakeholders. • Create informative and engaging training materials and content that explain the regulatory policies, their importance, and the roles and responsibilities of local entities and agencies. • Develop structured training modules that can be used during awareness and training sessions. • Conduct awareness workshops or seminars for local enforcing and monitoring entities to introduce them to the regulatory policies and their implications.					ULBs, District authorities
2.6.2	Organize Training of Trainers (TOT) programs for village resource persons/ individual service providers/ irrigation operators on crop wise IPNM strategy. (KMO 2.2) • Select NGOs, institutes/organizations • Develop a comprehensive curriculum that covers crop-wise IPNM strategies, including pest management, nutrient management, and sustainable agricultural practices • Identify and select experienced trainers from the community • Create training materials, including presentations, handouts, and reference materials • Organize workshops with the identified trainers	2	State Level, District Level	Ganga Task Force in Kanpur Benares conducts awareness programmes connecting people with the government, , (Jan Ganga component connecting with people).	2024: preparation of training materials 2025: trainers are trained	Swachh Bharat Mission ULBs, District authorities, NGOs
2.6.3	Farmers including women farmer groups are sensitized and trained on crop specific IPNM strategy and managing less-toxic pesticides. (KMO 2.2) • Identify farmers groups prioritized women farmers • Prepare training materials	1	District Level, panchayat	trainings, exposure visit pilot on a small area, platforms for selling produce are being provided	2026: women farmers are aware about IPNM strategy and less pesticides usage	Micro Irrigation Fund, PMKY Agricultural Dept.

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Organize workshops with women farmers • Collected feedback and incorporate in cyclic training sessions					Panchayat authorities
2.6.4	Arrange a series of behavior change communication (BCC), awareness and education events/ campaigns; circulate messages; publish news and articles in cooperation with women water user groups. (KMO 2.2) • Develop a comprehensive campaign plan • Select with women water user groups and other stakeholders • Use interactive and engaging activities to involve the community, such as demonstrations, hands-on training, and role-playing exercises. • Collaborate with local media outlets to publish news articles, op-eds	1	State Level, District Level	Proposed	2026: 20 awareness and education events organized in every block	Micro Irrigation Fund, PMKY District authorities, Panchayat authorities
2.6.5	Promote IPNM strategy and crop rotation methods in the hotspot regions where optimized use of fertilizer can be demonstrated to farmers through workshops and awareness campaigns. (KMO 2.3) • Identify and engage with local farmers, agricultural co-operatives, extension services, and agricultural experts in the region • Develop a comprehensive workshop plan • Organize workshops and training sessions in collaboration with local agricultural organizations and experts • Establish demonstration plots in the hotspot regions to showcase the benefits of IPNM and crop rotation.	1	State Level, District Level	promoting organic farming on 30ha of organic farming, 5km natural and then another 5 organic (voluntarily)[62]	2026:50% of farmers are aware about the IPNM strategy in River Basin	Micro Irrigation Fund, PMKY District authorities, Panchayat authorities
2.6.6	Inform and create awareness with local planning bodies in charge of developing solid waste dumping sites on flood zone demarcation and legal consequences for defaulting with the prohibition. (KMO 2.5) • Identify the local planning bodies, such as municipal councils, waste management authorities, and zoning boards • Develop informative materials, such as brochures,	1	State Level, District Level	proposed	2027:70% of local planning bodies are aware solid waste dumping sites	Swachh Bharat Mission, Smart City Mission ULBs, District authorities

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	pamphlets, fact sheets, and presentations, explaining the risks associated with siting waste disposal facilities in flood-prone areas • Schedule meetings, workshops, or seminars with representatives from local planning bodies responsible for waste management. • Collaborate with planning bodies to identify alternative waste disposal sites that do not fall within flood-prone areas					
2.6.7	Organize a series of awareness and education campaigns, and behavior change communication with local stakeholders within the flood plain zones motivated to use alternative landfill sites and solid waste management facilities. (KMO 2.5) • Activities same as KMO 2.5	2	State Level, District Level	Proposed		Swachh Bharat Mission, Smart City Mission ULBs, District authorities
2.6.8	Develop a campaign strategy and content for awareness material. (KMO 2.6) • Identify the local groups, community members • Develop campaign materials for visualization and showcasing • monitor the performance of campaign with collect feedback • Document the results and outcomes of your campaign	2	State Level, District Level	Proposed	2028: ULBs are more aware about the solid waste management strategies	Swachh Bharat Mission, Smart City Mission ULBs, District authorities
2.6.9	Organize awareness programs, events, and publications on appropriate disposal of municipal solid waste. (KMO 2.6) • Activities same as KMO 2.5	2	State Level, District Level	Proposed		Swachh Bharat Mission, Smart City Mission ULBs, District authorities
2.6.10	Conduct the workshops with all relevant stakeholders to demonstrate the findings of pilot scale application and collect feedback. (KMO 2.8)	2	State Level, District Level	Proposed	2028: local bodies are willing to implement new technology of solid waste	Swachh Bharat Mission, Smart City Mission

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Identify the local stakeholders for pilot scale implementation • Organize series of awareness programme, meetings with stakeholders • Encourage active participation from stakeholders by structuring the workshop to include interactive sessions, group discussions, and Q&A opportunities. • summarizing the findings of the workshop in the synthesis report				management	ULBs, District authorities
2.6.11	Set up an adequate database with collected information and used for showcasing through a website for public awareness.(KMO 2.9) • Gather all relevant information and data • Choose /create a suitable database system for storing and managing your data • Regularly update and maintain the database as new data becomes available or existing information changes • Comply with data privacy regulations and obtain necessary permissions or consents when collecting and displaying sensitive information. • Provide training and support to website administrators and content managers responsible for updating and maintaining the data.	2	Basin Level, State Level, District Level	Proposed	2025: Public website developed 2026: Website launched for public usage	Swachh Bharat Mission, Smart City Mission ULBs, District authorities
	Other measures					
2.7.1	Identify training institutes related to usage of harmful quantities of pesticides/ fertilizers/ toxic substances for agricultural activities. (KMO 2.2) • Identify and select organizations in the specific field on pesticides and toxic substances • evaluate the expertise and qualifications of potential experts from the selected organzations/institutes, considering their educational background, experience, publications, and relevant projects	1	Basin level, state level, District Level	Proposed	2024: organizations/institutes are selected 2025: feasibility concept conducted	PMKY, Micro Irrigation Fund, District authorities, Research organizations, Panchayat

#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Conduct consultations or interviews with potential experts • Prepare agreement on conducting and preparing the assessment and study					
2.7.2	Selection of NGOs/Municipalities/ medias/ research institutes/organizations for implementing the campaign (KMO 2.6) • Same activities for KMO 2.8	2	state level, District Level	Proposed		Swachh Bharat Mission, Smart City Mission ULBs, District authorities, Research organizations
2.7.3	Selection of NGOs/ research institutes/ organizations for organizing feasibility concept, design, implementation, and O& M procedures. (KMO 2.8) • Identify and select organizations in the specific field of design and implementation of solid waste management technology • evaluate the expertise and qualifications of potential experts from the selected organzations/institutes, considering their educational background, experience, publications, and relevant projects • Conduct consultations or interviews with potential experts • Prepare agreement on conducting and preparing the technical concepts and implementation of technology	2	Basin level, state level, District Level	Proposed	2024: organizations/institutes are selected 2025: feasibility concept conducted	Swachh Bharat Mission, Smart City Mission ULBs, District authorities, Research organizations
2.7.4	Select /collaborate with experts in environmental field and risk assessment to prepare an assessment methodology. (KMO 2.9) • Identify and select experts in the specific field of environmental risk assessment	3	Basin level, state level, District Level	Proposed	2025: experts are hired 2026: assessment conducted	Swachh Bharat Mission ULBs, District authorities, Research

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#	Measures KWMI 2	Priority Class	Level (river reaches/subunit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• evaluate the expertise and qualifications of potential experts, considering their educational background, experience, publications, and relevant projects • Conduct consultations or interviews with potential experts • Appoint the experts and researchers					organizations

6.4 Measures related to KWMI 3: Alteration in groundwater regime impacting on sub-surface flow

6.4.1 Reflection of key findings of the KWMI 3 Risk Assessment

Groundwater quantity

The risk assessment confirms the very different nature of the key issues for the two distinct groundwater systems in the Ramganga Basin, which are 1) Upper Basin - the highlands in Uttarakhand, and 2) Lower Basin the Gangetic plains in the lowlands. Although the overall extraction levels in the highlands are considered sustainable (all GMU's in this zone were classified as 'not at risk'), there is limited detailed information about the complex and localized aquifers in this region. For the most part, these aquifers are small and only have limited groundwater potential.

While the risk assessment classified only 1 GMU as 'high risk'—one of which is an urban area—all GMUs in the lower parts of the Ramganga Basin are witnessing a declining trend of the groundwater table. Although this decline is small for most of the affected GMUs, it nevertheless signals that current groundwater exploitation rates in this area are not sustainable in the long run.

In addition, climate change will likely cause more frequent and deeper dry spells, and groundwater can serve as a solution to provide secure water supply—under all drought and water delivery conditions—in this more variable climate. In this setup, the vast groundwater reserves will serve as a buffer to complement surface water when needed. This is specifically valuable in parts of the command area that are vulnerable to occasional water supply deficits. These include, but are not limited to, the zones at the tail-end of the canal systems where groundwater is currently the principal water source. The risk assessment mainly focused on the shallow aquifers in the alluvial zone—which are mostly used for irrigation and industrial water supply.

Groundwater quality

The risk assessment of the quality of groundwater in the Ramganga Basin is primarily based on land use data and observed value of nitrate and electrical conductivity (EC). The land use data highlights potential pollution from built-up areas and agricultural runoff. The analysis results were then complemented and validated by data (NO_3 and EC) from around observations wells obtained from CGWB. It has produced a full coverage of the basin with a high spatial resolution. It also implies that the water quality analysis is limited to the shallow and unconfined aquifers, and that it only considers anthropogenic pollution through infiltration and leaching effects. 6 out of 20 GMUs are at risk in Ramganga Basin while three were at possibly at risk It reflects the livelihood patterns in the basin, where the Gangetic plain is densely populated and intensely cultivated, while the highlands have extensive protected areas and a much lower population density. The analysis results confirm the observations made under KWMI 1 and 2. However, only NO_3 data from observations wells did not support the above conclusion. Despite the direct connection between NO_3 levels and agricultural runoff, septic tank effluent, and industrial wastewater contamination, no GMUs were classified as 'high risk' and 1 GMU was classified as 'moderate risk'. A similar picture emerged when analyzing the EC data. In this case, not a single GMU was found at risk. This incongruity will require further investigation but is probably due to the low density of the groundwater quality monitoring network. It is noted that not all stations measure both parameters. Hence the limited data points are probably not representative for the entire basin, and we maintain that the state of the quality of the shallow aquifer system in the Ramganga Basin is reflected in the analysis results obtained by the land-use approach.

It is also observed that, given the range of chemical substances, anthropogenic pressures, pollution sources, and geological context, there are many more parameters that need to be monitored apart from NO_3 and EC. This specifically includes heavy metals. Thus, it is with utmost caution that the current surface and groundwater monitoring network needs a robust improvement in order to validate with reasonable sensitivity the impacts of intense agriculture on the water resources. Nevertheless, the triple cropping pattern and highly urbanized nature of the Ramganga Basin can not be ignored.

The recharge of the deep aquifers—which are critical for domestic water supply—originates from the upper region of the Ramganga Basin (the foothills, Bhabhar zone), which were classified as 'no risk' or 'low risk'. Thus, the risk assessment suggests that the potential contamination risk of deep groundwater through recharge is minimal. This statement needs to be confirmed by a better understanding of the recharge zones of the deep aquifer system. Further, additional risks regarding the deep aquifers stem from poorly constructed deep wells. In view of the slow rate at which groundwater replenishes naturally—in the deep aquifer in particular—it is vital to prevent contamination. Hence precautionary measures and immediate action are vital in safeguarding groundwater. It emphasizes the need to improve the monitoring network for deep groundwater in the Ramganga Basin.

Vision and Management Objectives

To achieve the vision for KWMI 3, the risk assessment suggests that the current trend—regarding both over-exploitation and pollution—points in the wrong direction and must be reversed. This is feasible but requires a concerted and long-term effort at multiple levels. The management objectives for the current management cycle are all directly supportive of this endeavor.

6.4.2 Outline of the POM for each Management Objectives

Management Objectives for this first RBMP include:

1. **The groundwater sources for drinking water supply are set to be free from contamination and fully protected. This is regularly monitored by improved groundwater level and quality monitoring system.**

The process of remediating polluted groundwater is complex and time-consuming. Hence emphasis is on precautionary and protective steps to minimize contamination of groundwater and by extension of drinking water. The discussions on KWMI 1 and 2 have shown that the shallow aquifers are potentially exposed to contamination through downward infiltration of polluted surface water. By contrast, the deep confined aquifers have been predominantly in pristine condition and of good drinking-water quality. Thus, a straightforward and effective strategy would be to relocate all drinking wells—that supply medium size and larger settlements and towns— to the deep aquifers. This approach should be combined with solid measures to protect the deep aquifers from contamination. It involves enhanced monitoring of the quality of deep groundwater—to identify potential pollution threats early on—in combination with strategic placement of drinking water wells and establishing protection zones around these deep-well fields to prevent vertical contamination. To this effect, land use practices around (deep) wellfields need to be regulated to prevent harmful activities.

In parallel to this, measures need to be implemented to protect the shallow aquifer system from pollution sources (see KWMI 1 & 2), as the interactions between shallow and deeper groundwater are not yet fully understood. In addition, smaller settlements, villages, as well as isolated households, will still obtain their drinking water from the shallow aquifers. A diverse and well-known set of standard measures can be implemented to safeguard the quality of domestic water supply from shallow wells. Concerning the remediation of contaminated groundwater, a promising measure that has not yet been fully explored is Managed Aquifer Recharge (MAR). This topic is discussed further below in this chapter. Thus, the design of the bulk recharge facilities should—apart from augmenting groundwater resources—also aim at purifying contaminated groundwater through dilution, specifically for high-risks areas discussed under KWMI 1 and 2.

Given the paucity of groundwater data at present, the groundwater monitoring network—regarding quality and quantity— needs validation in terms of parameters, frequency, and coverage to effectively represent human impacts within the GMUs, considering the geological context, pollution effects, and user needs. In this context, it is recommended to raise the number of monitoring sites—both for the deep and shallow aquifers—also for reasons of statistical robustness of future modeling efforts.

The POM in outline for this management objective involves:

- In areas where the shallow aquifer's drinking water wells are contaminated, assess the capacity of the deep aquifer to serve as a source of drinking water, addressing both quantity and quality.
- Where suitable, relocate drinking water wells for mid-size and large settlements and towns in areas where the shallow aquifers are overexploited and highly contaminated to the deeper aquifers.
    - Avoid vertical leakage during well installation.
- Assess the status of enforcement of drinking water protection zones around high-yield groundwater sources.
    - Assess and improve land-use regulations and their enforcement within these zones.
    - Assess and improve monitoring practices of compliance and impose penalties for violations.
    - Promote the use of organic farming practices.
- Improve pollution source control (detailed measures are discussed under KWMI 1 and 2).
- Remediation of contaminated sites.
    - Promote groundwater recharge methods such as rainwater harvesting and MAR to reduce solute load in groundwater through dilution.

In addition, implement measures to improve the monitoring of groundwater quality.

- Conduct an inventory of all available monitoring data on groundwater quality in the Ramganga basin; compile data from all related authorities and institutions and assess their quality and comparability.
- To make best use of all available data, the groundwater quality data sets from different monitoring networks should be compiled into a single publicly accessible database and subjected to standard quality control procedures.
- Improve groundwater quality monitoring (infrastructure, frequency, parameters, quality control) for the entire basin based on a needs assessment that screens potentially harmful substances to groundwater resources.
    - Prioritize GMUs where there are less than two GW quality monitoring stations; check where appropriate monitoring wells should be installed or whether analogy conclusions from similar GMUs with monitoring network are admissible.
- Install real-time monitoring sensors at drinking water wells in pollution hotspots.

2. **Groundwater extraction is documented by registering all the extractions from the basin.**

Extraction of groundwater by local users for agricultural and industrial purposes and for local domestic water supply is, in practice, not monitored at present. The inadequacy of this information evidently inhibits the sustainable management of groundwater resources. This topic is also addressed under KWMI 4. A distinction must be made between medium and large users on the one hand, and small users on the other hand. The former should be regulated by means of a permitting system while the latter are much more difficult to regulate because pumps are small and frequently moved. Hence the groundwater registration effort will first focus on the medium and large users, and then progressively include smallholder users. While identifying the abstraction points will be rather straightforward—although it is a large undertaking—determining the exact volume of the groundwater extraction is much more difficult. For large- and medium-volume groundwater users, it will entail installing water meters or other effective measurement devices. This should be combined with a permitting system as discussed under KWMI 4. The inventory of groundwater abstraction will be implemented at district level, but the groundwater registration database needs to be consolidated at river basin level to obtain a comprehensive picture of ongoing groundwater use.

The POM in outline for this management objective involves:

- Identify all medium and large groundwater abstractions through a combination of voluntary registration, field inspections, analysis of remote sensed images, and other relevant information.
- For all large and medium volume abstractions, install water meters.
- Develop or update the registration database for groundwater users at district level, ensure consistency among systems at district level, and develop a mechanism to consolidate this information at basin level.
- Progressively register small groundwater users through awareness campaigns, voluntary registration, field inspections, and the analysis of remote sensed imageries.

3. **Regulations in terms of groundwater pollution through seepage/leaching of pollutants from solid waste dumping/ management facilities, landfill sites and industries are in place and give regulatory authorities the mandate to enforce the regulations.**

The Ramganga Basin is facing a significant challenge regarding solid waste disposal, which is characterized by improper dumping of solid waste and poorly engineered landfills. It frequently leads to contamination of shallow groundwater due to the infiltration of toxins and chemicals. The Swachh Bharat Mission (2014) and the Solid Waste Management Rules (SWM Rules 2016) have been enacted to address the issue of waste handling, disposal, and treatment. However, the risk assessment reports scope for further compliance to the SWM Rules 2016, attributed to institutional and financial challenges such as insufficient resources to acquire new land for landfill sites or to procure necessary SWM technologies. Additionally, shortcomings from legal structures originate from unclear guidelines and limited stakeholder awareness, exacerbated by inadequate regulatory enforcement. The above emphasizes the importance of measures to promote decentralization of waste management, citizen participation, conduct awareness raising campaigns to encourage behavioral shifts among the public, and strengthening and enforcement of existing regulations. The POM in outline for this management objective involves:

- Assess current legal framework on solid waste management and sanitation related to preventing groundwater pollution and its enforcement in the Ramganga Basin; identify gaps for their ineffective enforcement and draft recommendations for their improvement.

- Improve legal framework if needed and/or develop a detailed action plan for its enforcement.
- Establish a clear mandate for regulatory authorities to enforce the regulations.
- Implement a robust monitoring system for groundwater quality around waste management facilities and industries.
- Mandate regular reporting of monitoring data to regulatory authorities for assessment.
- Conduct awareness-raising programs on SWM and capacity building programs on waste treatment technologies including recycling and reusing.

4. **Outreach activities for groundwater user communities to encourage groundwater re-charge/ managed aquifer recharge (MAR) and conjunctive use of surface water and groundwater are effectively implemented.**

In the Ramganga context, managed aquifer recharge at scale can be achieved through interventions such as floodplain restoration, wetland restoration, and village pond restoration. It is noted that these measures directly support several management objectives for KWMI 4 (alterations of the flow regime) and KWMI 5 (flood prevention). Hence their primary function is not groundwater recharge, and the detailed implementation of these measures is discussed under KWMI 4 and 5. Other potential solutions include infiltration wells and infiltration galleries that can be implemented by local communities. However, these interventions have proven difficult to maintain and difficult to implement on a larger scale. While interventions at community level will be pursued—specifically in the mountainous region in Uttarakhand—the most practical and effective approach to achieve bulk groundwater recharge right now is to promote the multi-purpose measures listed above, which are initiated for other objectives. Note that these interventions—such as floodplain restoration—generally have public support in areas with declining groundwater tables.

Conjunctive use of ground and surface water in the tail-end sections, and others, of the gravity-fed irrigation schemes serves to provide water security under all circumstances and is therefore instrumental to achieve agricultural modernization. This is especially important in a changing climate that will probably be characterized by more frequent and more intense drought events. However, it is important that the water authorities can monitor and control the groundwater abstractions to ensure sustainable use. In the large irrigation schemes, therefore, distributed bulk groundwater extraction by the irrigation authorities is preferred to a setup with numerous individual pumps operated by smallholders.

The POM in outline for this management objective involves:

- Support floodplain restoration as needed (see KWMI 5)
- Support wetland restoration as needed (see KWMI 4)
- Support the restoration and establishment of village ponds as needed (see KWMI 4)
- Initiate and support community projects to install infiltration wells and galleries, in cooperation with local organizations, in mountainous areas subject to declining water tables.
- Establish an effective setup for conjunctive use of surface and groundwater that ensures sustainably exploitation of the groundwater resources; this will be scheme specific; implement several pilots.

5. **Adequate information on groundwater for long-term forecasting (for allocation purposes) is generated by deploying a complete basin-wide groundwater modelling database inventory.**

To increase the understanding of the groundwater dynamics and determine sustainable exploitation rates for localized areas within the Ramganga Basin, a Modflow model needs to be developed for the entire alluvial zone—with a high spatial resolution—that interconnects the shallow unconfined aquifers and the deeper confined aquifers. Developing this model will be a multi-year endeavor that will progressively increase the resolution of the model. It will also require accurate data from both the shallow and deep aquifers on groundwater level and withdrawals. The latter has been discussed above. The POM in outline for this management objective involves:

- Develop a Modflow model with a high spatial resolution for the entire alluvial zone in the Ramganga Basin that interconnects the shallow and deep aquifer systems.
- Identify data requirements, both regarding water levels and abstractions.
- Initiate a monitoring exercise for the above data (see measures discussed above in this paragraph)

6. **Demand-side management interventions in areas affected by droughts, or where groundwater is already over-abstracted or close to it, are promoted.**

There is generally ample scope for increasing water productivity and reducing water losses. This specifically applies to the industrial sector. When given proper incentives—such as progressive water tariffs—industrial processes can dramatically reduce their water use. This has been proven worldwide. Groundwater demand management in the agricultural sector is possible but more difficult. A primary focus is on increasing the reliability of water delivery in the large public irrigation schemes. This topic is discussed under KWMI 4. Another strategy entails reducing the acreage of crops with high water consumption such as sugarcane or rice. A side benefit of this approach is that agricultural runoff is reduced since sugarcane requires high quantities of agro-inputs such as fertilizer and pesticides. Nevertheless, sugarcane cultivation is profitable and this strategy—i.e. reducing the acreage of sugarcane cultivation—is adversely affecting the livelihood of farmers and will therefore be controversial.

Demand-side management of domestic water consumption is mostly focused on reducing losses in the water delivery system. However, within the household, strategies to reduce water use are generally not very effective and a less ambitious target for demand management in this sector should therefore be set.

The POM in outline for this management objective involves:

- Design and initiate a basin-wide program to reduce water use in industrial processes; agree on a realistic target with industry stakeholders; an ambitious target can be considered.
- Support the irrigation authorities to improve the reliability of water delivery in the large public irrigation schemes; conjunctively, encourage the irrigation water user associations at community level to reduce untimely and unscheduled (and probably illegal) abstractions from the canal system.
- Support relevant initiatives to reduce the acreage of sugarcane cultivation—specifically in the zone adjacent to the rivers—and shift to less water consuming crops such as wheat.
- Prepare an inventory of water losses in the delivery system for domestic water supply.

7. **Industries and farmers in the Ramganga Basin are kept well informed and sensitized on the preemptive measures taken for keeping groundwater safe and clean.**

Awareness about the importance of the groundwater resources for drinking water and other purposes is key to preventing contamination of the aquifers. In parallel, the public and water users such as industries and farmers need to be sensitized about the existing regulations and enforcement mechanisms towards polluting practices. They also need to be informed about more environmentally friendly and sustainable alternatives. The POM in outline for this management objective involves:

- Develop a comprehensive communication strategy and awareness campaign on water-borne diseases and importance of water quality and waste management to protect groundwater addressing the wider public and all end users, tailored to different stakeholder groups, focusing on their needs and communication preferences.
    - Tailor communication and dissemination activities to different stakeholder groups, focusing on their needs and communication preferences based on a stakeholder assessment (map and categorize stakeholders based on their influence, level of engagement, and potential impact on groundwater)
    - Compile accurate and accessible information about groundwater, its importance, threats to its quality, and pre-emptive measures.
    - Create informative materials such as brochures, pamphlets, videos, and infographics.
- Conduct capacity building programs including trainings, workshops and seminars for industries and farmers to introduce them to groundwater protection concepts such as proper waste management, chemical handling, and sustainable agricultural practices (e.g., organic/permaculture farming, responsible pesticide, and fertilizer use), pollution sources, and potential impacts.
    - Training of trainers.
    - Develop manuals, guidance and brochures on storage, handling, and disposal of pesticide substances.
    - Involve and facilitate knowledge sharing and peer-to-peer learning among industries and farmers who have already adopted groundwater protection measures.
- Offer incentives, awards, or grants to entities that excel in adopting and promoting groundwater-friendly practices.
- Establish partnerships with educational institutions, NGOs, and industry associations to extend the reach and impact of the awareness-campaigns and training programs.

6.4.3 PoM for KWMI 3

Below Table 70 presents the implementation details of PoM for KWMI 3.

Table 70: Implementation details of PoM for KWMI 3

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	BASIC MEASURES					
3.0.1	Enforcement of the implementation of the requirements given in the Water (Prevention and Control of Pollution) Act, 1974	1	National level		By the end of the first Ramganga RBM cycle (2029), E-flows are assessed and implemented.	National Water Mission, Mission PCB, Irrigation Dept.
3.0.2	Compliance with the standards given in Environmental (Protection) Act, 1986	1	National, State, District	standards are not complied with in all cases	Complete compliance by 2028	National Water Mission PCB, ULBs, NMCG
3.0.3	Fully implement the Groundwater (Control and Regulation) Bill, 1992	1	National	National aquifer mapping reports by CGWB include management strategies	To be prepared by the endof the first Ramganga RBM cycle, 2029.	Namami Gange Mission Irrigation dept., CGWB
3.0.4	Implement National Water Policy, 2012	1	National	National aquifer mapping reports by CGWB include management strategies	To be prepared by the endof the first Ramganga RBM cycle, i.e. 2029.	Namami Gange Mission, Atul Bhujal Yojona Irrigation dept., PCBs, ULBs, NMCG
3.0.5	Implementation of Groundwater Regulation Act	1	National	Legal framework in place but need for its enforcement:	To be prepared by the end first Ramganga RBM cycle., 2029	Namami Gange Mission, Atul Bhujal Yojona Irrigation Dept.,

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
				need to improve GW abstraction control and enforce on compliance with domestic sewage disposal and industrial effluents regulations; GW yearbook 2022 under finalization		
	SUPPLEMENTARY MEASURES					
	Technical measures including the application of innovative technologies					
3.1.1	Where suitable (according to 3.1.1), Progressively relocate drinking water wells for mid-size and large settlements and towns to the deeper aquifers in areas where the shallow aquifer is heavily polluted and groundwater is over exploited. (KMO 3.1) • Conduct a comprehensive assessment on the requirement of relocation of existing wells • Conduct a comprehensive hydrogeological assessment to identify suitable deeper aquifers • Identify appropriate locations for the new wells in the deeper aquifers • Install the necessary infrastructure, including pumps, pipelines, and storage facilities, to extract water from the deeper aquifers	1	State level, District Level,	Proposed; depth of wells is reported in the NAQUIM report, GW abstraction data in GW assessment reports by CGWB, prior assessments showed a low potential for the deeper aquifers due to geogenic contamination	2027: Installation of deep water wells in locations which require to be relocated	Atal Bhujal Yojona, Master Plan for Artificial recharge to groundwater in India Pay Jal Nigam, Irrigation Dept., ULBs

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Gradually phase out the use of shallow wells for drinking water to ensure a smooth transition to the deeper aquifers. • Organize meetings and workshops to inform community about the change in water source and promote safe drinking water practices.			(salinity and metals)		
3.1.2	Remediation of contaminated sites (KMO 3.1) • Conduct a thorough site assessment to identify the extent and nature of contamination, including the types of contaminants and their sources • Evaluate the risks posed by the contaminants to human health, ecosystems, and the environment • Create a detailed remediation plan with suitable recharge methods • Promote groundwater recharge methods such as rainwater harvesting and MAR to reduce solute load in groundwater through dilution	1	GMUs under high risk according to the risk assessment: GMU8, GMU9, GMU11, GMU12, GMU13, GMU14, GMU15, GMU16	Proposed	2028: End of Ramganga RBM cycle	Atal Bhujal Yojona, Master Plan for Artificial recharge to groundwater in India Pay Jal Nigam, Irrigation Dept., ULBs, Agricultural Dept.
3.1.3	To make best use of all available data, the groundwater quality data sets from different monitoring networks should be compiled into a single publicly accessible database and subjected to standard quality control procedures. (KMO 3.1) • Identify different sectors (governmental, academic, private, etc.) who conduct GWQ monitoring • Set up communication link/media for collecting all relevant GWQ information • Upload all information in public domain/website (INDIA-WRIS) • Set up the good visualization mode with the application of GIS tools for better understanding	2	Basin Level and District Level	Implemented: CWC, CPCB data in WRIS, CGWB data on saline GW in INGRES	2026	National Water Mission, Namami Gange Mission state authority, PCB, CGWB, NMCG

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#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
3.1.4	Improve groundwater quality monitoring (infrastructure, frequency, parameters, quality control) for the entire basin based on a needs assessment that screens potentially harmful substances to groundwater resources. (KMO 3.1) • Prioritize GMUs where there are less than two GW quality monitoring stations; check where appropriate monitoring wells should be installed or whether analogy conclusions from similar GMUs with monitoring network are admissible. • Identify the parameters that need to be monitored based on the needs assessment and potential risks to groundwater quality. • Develop a monitoring schedule that considers factors such as seasonal variations, land use changes, and potential contaminant sources. Implement a robust data management system to centralize, store, and manage groundwater quality data.	2	GMUs with high risk, large industrial facilities and with less then 3 measurement points: GMU8, GMU9, GMU11, GMU12, GMU13, GMU14, GMU15, GMU16 GMU17 GMU20	Implemented: GW monitoring of shallow aquifers: 153 monitoring stations since 2022 pre-monsoon, additional post-monsoon monitoring in contaminated areas	2026: all existing groundwater monitoring stations have improved facilities	Atal Bhujal Yojona, Namami Gange Mission Pay Jal Nigam, ULBs, CGWB
3.1.5	Install real-time monitoring sensors at drinking water wells in pollution hotspots (KMO 3.1) • Choose appropriate real-time monitoring sensors that can detect a wide range of parameters relevant to water quality • Determine the optimal locations for installing monitoring sensors, prioritizing drinking water wells at high-risk pollution hotspots. • Install the selected sensors at the chosen sites	1	GMUs with high risk, large industrial facilities and with less then 3 measurement points: GMU8, GMU9, GMU11,	proposed	2026: all existing groundwater monitoring stations have real time monitoring sensors	Atal Bhujal Yojona, Namami Gange Mission Pay Jal Nigam, ULBs, CGWB

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Implement a robust data management system capable of collecting, storing, and analyzing real-time data from the monitoring sensors. Continuously monitor water quality parameters in real-time using the installed sensors and Develop a response plan as per results		GMU12, GMU13, GMU14, GMU15, GMU16 GMU17 GMU20			
3.1.6	Implement a robust monitoring system for groundwater quality around waste management facilities and industries. (KMO 3.3) • Identify and map the locations of waste management facilities and industries that have the potential to impact groundwater quality. • Install groundwater monitoring wells at strategic locations, both up gradient and down gradient of waste management facilities and industrial sites • Establish standardized protocols for collecting groundwater samples • Implement continuous monitoring systems where applicable to provide real-time data on groundwater quality.	1	GMUs with high risk, large industrial facilities and with less then 3 measurement points: GMU8, GMU9, GMU11, GMU12, GMU13, GMU14, GMU15, GMU16 GMU17 GMU20 ,	Implemented: GW monitoring of shallow aquifers: 153 monitoring stations since 2022 pre-monsoon, additional post-monsoon monitoring in contaminated areas	2027: implementation of 350 GW monitoring stations measuring all relevant parameters	Atal Bhujal Yojona, Namami Gange Mission Pay Jal Nigam, Irrigation Dept., ULBs, CGWB
3.1.7	Mandate regular reporting of monitoring data to regulatory authorities for assessment. (KMO 3.3) • Development of Regulatory Framework for WQ monitoring data	2	State Level, District Level	Implemented: GW monitoring of shallow aqui-	2027: implementation of monitoring stations: 350	Atal Bhujal Yojona, Namami Gange Mission

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Identify the entities, organizations, or industries that are subject to the reporting mandate. • Establish procedures for data validation and quality control • Develop a system for monitoring compliance with reporting requirements			fers: 153 monitoring stations since 2022 pre-monsoon, additional post-monsoon monitoring in contaminated areas		Pay Jal Nigam, ULBs, CGWB
3.1.8	Establish an effective setup for conjunctive use of surface and groundwater that ensures sustainably exploitation of the groundwater resources; this will be scheme specific; implement several pilots (KMO 3.4) • Conduct a comprehensive baseline assessment of the hydrogeological conditions, surface water availability, and groundwater quality and quantity • Identify suitable pilot sites within the scheme-specific area where conjunctive use can be effectively implemented • Ensure compliance with all relevant local, state, and federal regulations governing water resources management and allocation • Implement MAR techniques such as recharge basins, injection wells, or spreading grounds to enhance groundwater recharge during wet periods	1	Basin Level, State Level, District Level	GW quantity data published by CGWB on INGRES (GIS based platform), GW resources assessment reports on GW quality (from 2022 onwards) and GW quantity on CGWB website; GW yearbook under finalization; master plan for MAR published in 2020; NAQUIM report suggests	2026: MAR techniques are implemented	Atal Bhujal Yojona, Jal Jeevan Mission, Master Plan for Artificial recharge to groundwater in India Pay Jal Nigam, ULBs, CGWB

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
				recharge structures in 36 districts		
3.1.9	Support the irrigation authorities to improve the reliability of water delivery in the large public irrigation schemes; conjunctively, encourage the irrigation water user associations at community level to reduce untimely and unscheduled (and probably illegal) abstractions from the canal system. (KMO 3.6) • Conduct a comprehensive assessment of the current state of the irrigation schemes, including infrastructure, water availability, and the state of canals. • Invest in repairing and upgrading irrigation infrastructure such as canals, dams, and pumping stations. • Provide technical assistance to irrigation authorities in adopting best practices for water management. • Promote the formation and strengthening of irrigation water user associations (IWUAs) at the community level. Provide training to farmers and IWUA members on modern irrigation practices, water-efficient farming techniques, and the importance of adhering to water schedules.	1	Basin Level, District Level	Proposed	2027	Mission Amrit Sarovar, Namami Gange Mission Irrigation Dept., District Authorities
3.1.10	For all large and medium volume abstractions, install water meters (KMO 3.2) • Identify and compile an inventory of all large and medium volume water abstractions within the area of interest • Select appropriate water meters based on the specific needs of each abstraction point	1	GMUs with moderate and high risk according to the risk assessment:	Proposed	2027: all large volume water wells are metered	Jal Jeevan Mission, Namami Gange Mission Pay Jal Nigam, ULBs

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Engage with relevant stakeholders, including water users, local authorities, and water utility providers, to gather input, address concerns, and secure support for the metering initiative • develop a comprehensive installation plan that includes a timeline, budget, and installation team responsible for fitting the meters Install water meters at each large and medium volume abstraction point, ensuring proper placement, calibration, and secure connections		GMU5, GMU13, GMU14, GMU19			
	Economic measures					
3.2.1	Offer incentives, awards, or grants to entities that excel in adopting and promoting groundwater-friendly practices. (KMO 3.7) • Engage with relevant stakeholders, including government agencies, NGOs, industry associations, and community groups • Form a selection committee or panel comprising experts, representatives from relevant organizations, and community members to evaluate and select awardees • Launch a public awareness campaign to inform stakeholders about the incentive program. • Present awards or certificates to the selected entities that have demonstrated excellence in groundwater-friendly practices (e.g. sustainable extraction, protection of well borings from seepage, pollution prevention in GW recharge zones of wells)	2	GMUs under high risk according to the risk assessment: GMU8, GMU9, GMU11, GMU12, GMU13, GMU14, GMU15, GMU16	No incentives are in place; awareness PIP programme promoted water conservation practices to combat water scarcity	2026: incentives, awards and grants are offered in high risk GMUs and have been made use of by stakeholders	Jal Shakti Abhiyan, Atal Bhujal Yojona ULBs, District authorities,
	Institutional and capacity building measures					

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
3.3.1	Initiate and support community projects to install infiltration wells and galleries, in cooperation with local organizations, in mountainous areas subject to declining water tables. (KMO 3.4) • Engage with relevant organizations, NGOs, govt bodies specified on hilly areas • Select site and locations for implementing community projects • Select appropriate methods for installation of infiltration wells and galleries • Organize community meeting for demonstrating the benefits and possible outcomes	2	State Level, District Level	Proposed	2027: 5 hilly regions in Ramganga Basin have installed Infiltration wells and galleries	Atal Bhujal Yojona, jal Jeevan Mission District Authorities, Irrigation dept.
3.3.2	Support relevant initiatives to reduce the acreage of sugarcane cultivation—specifically in the zone adjacent to the rivers—and shift to less water consuming crops such as wheat. (KMO 3.6) • Gather data on the current acreage of sugarcane cultivation, water usage patterns, and crop yields in the target zone with economic and environmental impacts • Collaborate with local farmers, agricultural cooperatives, and sugarcane industry representatives to understand their concerns and motivations. • Introduce financial incentives and subsidies for farmers who shift from sugarcane to wheat or other water-efficient crops. • Provide farmers with training and technical assistance on wheat cultivation techniques	2	State Level, District Level	Proposed	2028: 30% farmers in the Basin practiced less water consuming crops	PMKSY, PMKY Agrictural Dept. District authorities, Agriculture Industries

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Facilitate access to markets for wheat and other alternative crops by connecting farmers with buyers and distributors					
3.3.3	Conduct capacity building programs including trainings, workshops and seminars for industries and farmers to introduce them to groundwater protection concepts such as proper waste management, chemical handling, and sustainable agricultural practices (e.g., organic/permaculture farming, responsible pesticide and fertilizer use), pollution sources, and potential impacts. (KMO 3.7) • Select relevant stakeholders including WUG, Women farmer Groups. • Prepare training materials on waste management, chemical handling, and sustainable agricultural practices • Conduct awareness events and workshops to mobilize the farmers towards sustainable activities	1	GMUs under high risk according to the risk assessment: GMU8, GMU9, GMU11, GMU12, GMU13, GMU14, GMU15, GMU16	Proposed	2027: 40% farmers in the basin aware about the sustainable agricultural practices	PMKY, Clean Ganga Mission Agricultural Dept.,Irrgation Dept.
	Legal, policy and regulatory measures					
3.4.1	Assess current legal framework on solid waste management and sanitation related to preventing groundwater pollution and its enforcement in the Ramganga basin; identify gaps for their enforcement and draft recommendations for their improvement. (KMO 3.3) • Activities on KWMI 2	1	Basin Level, State Level, District Level	See KWMI 2		
3.4.2	Improve legal framework if needed and/or develop a detailed action plan for its enforcement. (KMO 3.3) • Activities on KWMI 2		Basin Level, State Level, District Level	See KWMI 2		
3.4.3	Establish a clear mandate for regulatory authorities to enforce the regulations (KMO 3.3)		Basin Level, State Level,	See KWMI 2		

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Activities on KWMI 2		District Level			
	Studies and assessments for developing and implementing measures					
3.5.1	Prepare an inventory of water losses in the delivery system for domestic water supply (KMO 3.6) • Gather historical data on water supply and distribution from relevant sources, including utility records • Prepare detailed maps and documentation of the entire water distribution system • Install flow meters at key points within the distribution system to measure water flows accurately. • Conduct a comprehensive water audit and deploy leak detection technologies • Propose a set of recommendations and strategies to reduce water losses, including prioritized actions for repairing or replacing infrastructure and improving system management practices	2	District Level, Block Levels	Proposed	2026: 30% of less supply water is wasted	Jal Jeevan Mission, Namami Gange Mission Pay Jal Nigam, ULBs
3.5.2	Assess the status of enforcement of drinking water protection zones around high-yield groundwater sources (KMO 3.1) • Assess and improve land-use regulations and their enforcement within these zones. • Assess and improve monitoring practices of compliance and impose penalties for violations. • Promote the use of organic farming practices.	1	Basin Level, District Level	Proposed	2025: Assessment of all high yield groundwater sources completed	Atal Bhujal Yojona, Master Plan for Artificial recharge to groundwater in India ULBs, District authorities, Irrigation Dept.

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
3.5.3	Identify all medium and large groundwater abstractions through a combination of voluntary registration, field inspections, analysis of remote sensed images, and other relevant information. (KMO 3.2) • Establish a centralized database to collect, store, and manage information related to groundwater abstractions • Encourage groundwater users, particularly medium and large abstractions, to voluntarily register their wells or boreholes. • Launch awareness campaigns to inform the public about the importance of registering groundwater abstractions and complying with regulations • Conduct field inspections to verify the accuracy of registered information and identify unregistered groundwater users. • Integrate Geographic Information System (GIS) tools to map and analyze groundwater abstractions spatially. • Implement a continuous monitoring system to track groundwater levels and assess the impact of abstraction activities on aquifer sustainability.	1	GMUs with moderate and high risk according to the risk assessment: GMU5, GMU13, GMU14, GMU19	Proposed; data on GW extractions published by CGWB on IN-GRES (associated reports on CGWB website)	2024: High groundwater abstraction is registered 2025: map of high abstraction wells prepared	Atal Bhujal Yojona, Master Plan for Artificial recharge to groundwater in India ULBs, District authorities, Irrigation Dept
3.5.4	Conduct an inventory of all available monitoring data on groundwater quality in the Ramganga basin; compile data from all related authorities and institutions and assess their quality and comparability. (KMO 3.3) • Prepare a multidisciplinary team with expertise in hydrogeology, environmental science, data management	1	Basin Level, State Level	Proposed	2028	Atal Bhujal Yojona, Namami Gange Mission Irrigation Dept., PCB, CGWB, Research organzations

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Identify all relevant authorities, institutions, and organizations that collect groundwater quality data in the Ramganga basin. • Evaluate the quality and reliability of each collected data • Integrate all high-quality and compatible datasets into a centralized database or Geographic Information System (GIS) platform for easy access and analysis • Provide training to relevant authorities and institutions on data collection, management, and quality assurance to improve future data collection efforts					
3.5.5	Develop a Modflow model with a high spatial resolution for the entire alluvial zone in the Ramganga basin that interconnects the shallow and deep aquifer systems. (KMO 3.5) • Select experts on the field of hydro-geologists, geophysicists, modelers • Conduct detailed geological and hydrogeological surveys to understand the subsurface structure and properties. • Perform geophysical surveys to gather subsurface data. • Develop a conceptual model that defines the hydrogeological units, boundary conditions, and recharge/discharge areas with Modflow model • Validate the model's accuracy and predictive capabilities using independent datasets		Basin Level, State Level	Proposed	2027: Predictive Flow and availability of Groundwater of Basin is identified	National Water Mission, Namami Gange Mission state authority, CGWB, Research organizations
3.5.6	Identify data requirements, both regarding water levels and abstractions. (KMO 3.5)	2	Basin Level, State Level	Proposed; data on GW quantity	2026	National Water Mission, Master Plan for

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	• Review existing water regulations and policies to understand mandatory data reporting requirements. • Develop a monitoring network plan that outlines the locations and frequency of data collection points. • Select appropriate methods for collecting water level data, including groundwater monitoring wells, piezometers, and remote sensing technologies. • Establish a data management system to handle the collected information efficiently			and its assessment methodology published on CGWB website and INGRES platform		Aquifer Recharge of India state authority, CGWB, Research organizations
3.5.7	Initiate a monitoring exercise for the above data (KMO 3.5) • Activities mentioned above measures	2	Basin Level State Level			
3.5.8	In areas where the shallow aquifer's drinking water wells are contaminated, assess the capacity of the deep aquifer to serve as a source of drinking water, addressing both quantity and quality. (KMO 3.1) • Analyze water samples from the deep aquifer to assess its chemical and physical properties, looking for potential contaminants and evaluating water quality against regulatory drinking water standards. • Perform pumping tests to determine the aquifer's hydraulic properties, including transmissivity, storativity, and the specific capacity of the well. This helps estimate the aquifer's yield. • Estimate the quantity of water that the deep aquifer can provide sustainably over time, considering		GMUs at high risk according to the risk assessment: GMU8, GMU14, GMU15	Salinity assessments conducted by CGWB see INGRES platform and in the report 'National compilation on dynamic GW resources of India, 2022'		

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	factors like recharge rates, pumping rates, and the potential for overdraft. • Identify potential risks to the deep aquifer, such as pollution sources or over-extraction, and develop contingency plans to mitigate these risks.					
	Awareness measures					
3.6.1	Progressively register small groundwater users through awareness campaigns, voluntary registration, field inspections, and the analysis of remote sensed imageries. (KMO 3.2) • Develop and implement comprehensive awareness campaigns to inform small groundwater users about the importance of registration and responsible water use. • Collaborate with local authorities, community leaders, and grassroots organizations to mobilize support for registration efforts. • Conduct field inspections to verify the information provided during voluntary registration. • Utilize remote sensing technology, such as satellite imagery, to identify unauthorized groundwater abstraction activities and potential unregistered users. • Provide training to community members and local authorities on the importance of sustainable groundwater management and the role of registration.	1	Basin Level	Proposed	2027: 60% of small groundwater users are registered	Atal Bhujal Yonjona, Master Plan for Aquifer Recharge of India Irrigation Dept. ULBs, Panchayats
3.6.2	Develop a comprehensive communication strategy and awareness campaign on water-borne diseases and im-	1	GMUs under high risk according to	Proposed	2028:	State specific action plan for water sector under NWM

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	portance of water quality and waste management to protect groundwater addressing the wider public and all end users, tailored to different stakeholder groups, focusing on their needs and communication preferences. (KMO 3.7) • Tailor communication and dissemination activities to different stakeholder groups, focusing on their needs and communication preferences based on a stakeholder assessment • Select a mix of communication channels to reach a wide audience • Compile accurate and accessible information about groundwater, its importance, threats to its quality, and pre-emptive measures. • Develop engaging and informative content, including videos, infographics, brochures, posters, and educational materials. • Organize community meetings, workshops, and awareness events to directly engage with stakeholders. • Collaborate with local NGOs, community organizations, schools, and health centers to amplify the campaign's reach		the risk assessment: GMU8, GMU9, GMU11, GMU12, GMU13, GMU14, GMU15, GMU16			Irrigation dept., Pay Jal Nigam, NMCG, CGWB
3.6.3	Establish partnerships with educational institutions, NGOs, and industry associations to extend the reach and impact of the awareness-campaigns and training programs (KMO 3.7) • Identify potential educational institutions, NGOs, and industry associations • Initiate contact with potential partners to introduce	2	State Level, District Level	Proposed	2024: Consortium of potential experts formed	Namami Gange Mission, Arth Ganga State Authorities, District Authorities

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
	your initiatives and discuss collaboration opportunities. • Develop clear and formalized MOUs or partnership agreements that outline roles, responsibilities, and expectations of each party. • Clearly define the roles and contributions of each partner in the awareness campaigns and training programs.					
3.6.4	Design and initiate a basin-wide program to reduce water use in industrial processes; agree on a realistic target with industry stakeholders; an ambitious target can be considered (KMO 3.6) • Identify and engage with key industrial stakeholders, including businesses, industry associations, and regulatory agencies, to form a collaborative partnership • Gather data on water consumption, sources, and wastewater discharge from industrial facilities. • Evaluate the feasibility and cost-effectiveness of water-efficient technologies, such as recycling and reuse systems, process optimization, and equipment upgrades • Regularly evaluate the program's performance and seek feedback from industrial stakeholders to make necessary adjustments and improvements	2	Basin Level, State Level	Proposed	2024: Water efficient technologies are designed 2025: industries installed necessary infrastructures	Atal Bhujal Yojona, Namami Gange Mission Pay Jal Nigam, PCB, Industrial authorities
3.6.5	Conduct awareness-raising programs on SWM and capacity building programs on waste treatment technologies including recycling and reusing. • See KWMI 2		Basin Level, State Level, District Level	See KWMI 2		
	Other measures					

#	Measures KWMI 3	Priority Class	Level (river reaches/sub-unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and nodal agency
3.7.1	Develop or update the registration database for groundwater users at district level, ensure consistency among systems at district level, and develop a mechanism to consolidate this information at basin level. (KMO 3.2) • Assess the current state of groundwater user registration systems in each district • Review and validate existing data in district-level databases • Deploy the registration database in each district, ensuring compatibility with existing systems and technologies. • Establish a centralized database or system at the basin level to consolidate district-level data. • Periodically validate and verify the data in the basin-level database to ensure accuracy and completeness.	2	District Level	Proposed	2027	State specific action plan for water sector under NWM Irrigation Dept., District Authorities

6.5 Measures related to KWMI 4: Alteration in river hydrology and water quantity

6.5.1 Reflection of key findings of the KWMI 4 Risk Assessment

The risk assessment evaluated the exposure of the riverine eco-systems and socio-economic production systems in the Ramganga Basin to changes in the hydrologic regime of the river, either due to anthropogenic causes or because of possible climate change. The risk assessment also reviewed more direct water security aspects that affect the people living in the basin, such as flood risk and risks related to inadequate supply of water for domestic consumption. The limitations of the risk assessment are listed in Chapter 5. Also, the environmental flow requirements for many reaches in the comprehensive Ramganga river system are yet to be established. However, important conclusions can be drawn from the risk assessment results, while it also provides a solid basis for designing targeted activities for this management cycle. Further, it is noted that flood risks are covered in detail under KWMI-5.

First and foremost, the risk assessment confirmed that the Ramganga Basin is not water scarce in principle. Rather, the analysis demonstrated that water resources in the Ramganga Basin are quite abundant because of substantial rainfall that ranges—on average—from almost 1000 to more than 2000 mm per year. These humid and sub-humid climatic conditions are combined with considerable groundwater resources in the vast alluvial Gangetic plains immediately adjacent to the Himalayan foothills, where most irrigation areas and large urban concentrations are located. However, rainfall—and by association the hydrologic regime—was found subject to significant temporal variability that causes interannual rainfall volumes to vary substantially. In practice this means that in a dry year—just when more irrigation water is needed—river flows are relatively low. Low flows are even more pronounced because the climate in the basin is subject to a unimodal rainfall regime—that typically lasts from June to September—with consequent low runoff in the months outside the rainy season. Since Ramganga is not glacier-fed, river levels are generally very low in the months just before the start of the monsoon. Substantial water abstractions for irrigation have aggravated this condition. For the Ramganga river system, failure to meet low flow requirements exacerbates well-documented problems related to poor water quality, and adversely impacts on valuable riverine ecosystems.

The above conditions were confirmed by the analysis. The sub-basins Kosi and Bhakra received a score of 3 regarding the risks related to flow alteration—which in effect is focused on low flows—that indicates that this parameter is ‘very prone to hazard’. It is observed that the sub-basins downstream of Kosi and Bhakra—which are Lower Ramganga and Aril—only receive a score of 1, which implies ‘least prone to hazard’. This is plausibly because of return flows from the large upstream irrigation schemes. Nevertheless, the low-flow risks in these sub basins will probably increase in the future because of dramatically higher demand for urban and industrial water supply—which are projected to increase from 9.8 m^3/s to 21.2 m^3/s—most of which will be abstracted from the river. It is noted that we anticipate that domestic water supply in rural areas—which will grow by more than 50% up to 2045—is provided mostly by groundwater and will not substantially burden the surface water system. Consequently, the risk assessment confirms the relevance and agreed-upon focus of the management objectives for KWMI 4 for this management cycle. These objectives emphasize, among others, the need to meet Environmental Flows requirements throughout the Ramganga Basin and make an inventory of existing abstractions.

Realizing the vision for KWMI 4—which includes meeting Environmental Flows requirements and maintaining sustainable use of surface water for diverse productive purposes—should be very well possible in principle. Agriculture will remain by far the largest water consumer in the basin and there are ample options to make better use of irrigation water or groundwater. This would reduce abstractions from the river system. In this context, it is further noted that water demand scenarios for the agricultural sector indicate a gradual decline in the demand for irrigation water.

The priority right now is to determine the Environmental Flows requirements for all key segments of the Ramganga river system. Simultaneously, an inventory is needed of all ongoing water abstractions—both legal and illegal ones. Further, the SWAT model requires further refinement to get a better understanding of the unimpaired (natural) and current flow regime in the basin, and how this may alter for various climate change scenarios. Setting detailed, time-specific, and location specific river flow and abstraction reduction targets for each river segment and irrigation (sub) system will only be possible after the overall knowledge base has been further refined. At that point, options can be reviewed—if needed—for reducing water abstraction.

6.5.2 Outline of the POM for each Management Objectives

Management Objectives for this first RBMP include:

1. **Identify main water abstractions (legal and illegal) that impact on the hydrological regime.**

Water abstractions are regulated by means of a permitting system at river basin and district level. This should concern both surface and groundwater abstractions. For practical reasons, a threshold is defined below which abstractions are exempt from the permitting requirements. The permit database at district level should be linked to the water abstraction database at basin level to obtain a full picture of abstractions at basin level.

Illegal abstractions are twofold in nature. It concerns abstractions that either have no permit or abstractions that do not comply with the permit conditions—both in terms of volume and timing of the water abstraction. Establishing a system that includes all major abstractions and ensures compliance with the permit conditions is key to the effectiveness of integrated water resources management in the Ramganga Basin. This is probably a medium-term undertaking that is best implemented in a stepwise manner. While priority in this management cycle is given to large abstractions, the exercise will also cover medium size abstractions. The POM in outline for this management objective involves:

- Review the existing permitting process and system—for surface and groundwater abstractions—at basin and district level; assess the effectiveness and completeness of the system; assess how compliance is ensured; assess how the permitting database at district level is linked to the basin level.
- Based on above) propose and implement measures to improve the permitting system, procedures, and database, as needed.
- Identify all abstractions without a permit (above a certain threshold) through a combination of field inspections and the analysis of remote sensed images.
- For all large abstractions, verify if actual abstractions comply with the permit conditions; this activity will build on the existing water management infrastructure and procedures—operated for instance by the irrigation department—but may also include establishing dedicated water monitoring equipment for large offtake points.

2. **Existing rules are enforced, and illegal abstractions are stopped.**

Terminating abstractions without a permit should be rather straightforward and employ a process that makes use of the existing administrative and legal framework. However, enforcing compliance for abstractions that have a permit—but are suspected not to meet the permitting conditions—may be more difficult. In some cases, it may require a process to prove that the abstraction does not comply with the terms of the permit. This may involve a case-specific investigation or establishing permanent water monitoring facilities. The POM in outline for this management objective involves:

- Use the existing administrative and legal framework to terminate abstractions (above a certain threshold) that have no permit.
- Prepare an inventory of abstractions that are suspected not to comply with the permit terms; prioritize a reasonable number of cases that will be addressed in this management cycle.
- Develop a process on a case-by-case basis to ensure compliance with permitting conditions; activities may range from sensitization efforts, negotiations, legal action, to acquiring defensible water data that prove beyond reasonable doubt that the current abstraction is in fact illegal.

3. Implement a water accounting study in the basin

A SWAT model was prepared for the Ramganga Basin to support the preparation of the RBM Plan for the current management cycle. This SWAT model will serve as the basis for a detailed water accounting study at sub-basin level or finer. It is likely that this model will require further refinement to be suitable for analysis at the proper scale and with adequate precision. Hence, prior to implementing the water accounting study, the SWAT model will be assessed and improved as needed. The POM in outline for this management objective involves:

- Assess the current SWAT model for the Ramganga Basin and propose measures to refine and improve this model as needed.
- Improve the SWAT model; this may include downscaling climate change models to assess whether environmental flow requirements and water demand projections can be met in a changing climate; it may also include a dedicated data acquisition exercise both concerning water data and environmental data, for instance regarding return flows or current water abstractions; in addition, it may involve refining the coupling of the groundwater and surface water modules.
- Use the SWAT model to implement the water accounting study with the required resolution.

4. Points/hotspots identified that do not meet e-flow requirements and cannot supply adequate water abstractions for diverse water use

The National Water Policy (2012) recognizes the ecological needs of riverine ecosystems. In the Ramganga Basin, critical aquatic and riverine environmental value may be compromised by a combination of over-abstraction for diverse purposes and the prevailing hydrologic regime. The latter is characterized by very low flows in the lean season just prior to the start of the monsoon. The first requirement for hotspot identification is to define the environmental flow requirements (EFA) for critical river reaches. This activity is ongoing in the Ramganga Basin. EFAs are then compared with the current hydrologic conditions, while considering current and projected water abstractions and the possible implications of climate change. The hydrologic conditions for ungauged river reaches are assessed with the SWAT model discussed above. This comprises unimpaired (natural) conditions, current conditions, and future conditions as a function of climate change scenarios and water abstraction projections. The POM in outline for this management objective involves:

- Define EFAs for all critical river reaches; this will probably involve an expansion of the number of sites for which the EFA is currently determined.
- Refine the SWAT model (see above); this activity will involve better information on current and future water abstractions.

- Use the SWAT model and environmental flow targets to identify hotspots where current and future environmental flows are compromised.

5. Potential measures to meet E-Flows requirements are identified, in a joint-process with key stakeholders

Given the relative abundance of water resources in the Ramganga Basin—in combination with the medium to low level of water use efficiency and agricultural water productivity observed in most irrigation schemes—meeting environmental flow targets will not require a fundamental shift in water use patterns at basin scale. Rather, it will probably involve a diverse set of measures at all scales—both technical, institutional, and economic—that are location specific. Many of these measures will focus on increasing the productivity of water used in irrigated agriculture. It is noted that the potential for increasing water productivity is high and that many potential interventions exist that are proven and effective.

However, it is premature to identify and design a suite of location-specific measures before location-specific environmental flow requirements have been defined and, consequently, targets for potential changes in surface water offtake patterns—which may include a reduction of the volume abstracted in some parts of the year, as a function of the hydrological and climatological conditions—have been agreed upon with local stakeholders. Thus, this activity can only commence once the activities under 1), 3), and 4) above have been completed.

Discussions about possible changes in surface water offtake pattern—even if they are small—need to be fully participatory and accompanied by an effective sensitization exercise to inform stakeholders that ample options exist to improve the efficiency of water use, and that their livelihood will not be adversely affected. Designing and implementing the consultation and sensitization mechanisms could be the focus for this specific management objective in the current management cycle. The POM In outline for this management objective involves:

- Determine required changes in surface water offtake pattern; these are location and time specific; this activity is conducted under 1), 3), and 4).
- Design and implement a sensitization exercise for all stakeholders about the ample potential to increase water productivity; this exercise should emphasize that livelihoods will not be adversely affected.
- Per offtake point or (sub) irrigation scheme, prepare an inventory of possible interventions—at all scales, and both of a technical, institutional, and economic nature—to improve water productivity and water use efficiency.
- Design an inclusive and participatory stakeholder consultation exercise to review a potential suite of measures that will achieve the required changes in offtake pattern.

6. Management protocols to meet E-Flows requirements are identified.

Interventions to meet e-flow requirements will be diverse and broad in scope, and probably comprise a combination of technical, institutional, and economic measures. In this regard, management protocols should be part of the comprehensive set of measures identified under 5) above. Thus, in practice, implementation of management objectives 5 and 6 can be combined. Hence management objective 6 has been covered under 5) above.

6.5.3 PoM for KWMI 4

In this section the implementation details of PoM for KWMI 4 is provided in a tabular format.

Table 71: Implementation details of PoM for KWMI 4

#	Measures KWMI 4	Priority Class	Level (river reaches/ subunit level)	Status 2023	Draft Implementation Timeline &Target	Financial Mechanism and Nodal agency
	BASIC MEASURES					
4.0.1	Implementation of National Water Policy (2012) to determine the amount of permitted time and location specific water abstractions.	1	Basin, District	Implemented: SWAT model developed to know virgin flow in each stretch of Ramganga river basin. Calculation of environmental flow and the permitted abstraction on the basis of that is to be evaluated.	2025, Environmental flow and permitted abstraction evaluation shall be done within 2024.	National Hydrology Project SWID, CGWB, District Authorities, WWF
4.0.2	Compliance of Groundwater Regulation Act to envisage registration of industrial and large commercial equipment lifting groundwater.	1	Basin, District		2025 Target.	Atal Bhujal Yojana CGWB, District Authorities, ULBs

#	Measures KWMI 4	Prior-ity Class	Level (river reaches/ subunit level)	Status 2023	Draft Imple-mentation Timeline &Tar-get	Financial Mechanism and Nodal agency
4.0.3	Compliance of National Hydrology Project for acquisition of water related data.	1	Basin, Dis-trict,	Partially imple-mented. Proposal: Imple-mentation of data monitoring required in large off take points, Implementation of groundwater abstraction moni-toring.	2029: end of Ramganga RBM cycle.	National Hydrol-ogy Project
4.0.4	Compliance with the National Green Tribunal (NGT) Order on Environmental Flows (2017) to maintain a minimum of 15% to 20% of the average lean season flow in the river.	1	Basin, Dis-trict	Implemented: SWAT model (provides basic database for en-vironmental flow amount determi-nation) Proposal: Evalua-tion of sustaina-ble amount of ab-straction.	2029: end of Ramganga RBM cycle.	Namami Gange Mission, Smart City Mission PCB, ULBs
4.0.5	Implementation of Micro Irrigation Fund to increase the use of water efficient irrigation system.	1	Basin, Dis-trict, Pan-chayat	micro irrigation technologies de-veloped, dept. of agriculture has programme	2028	Micro Irrigation Fund Agricultural Dept. Irrigation Dept.

#	Measures KWMI 4	Priority Class	Level (river reaches/ subunit level)	Status 2023	Draft Implementation Timeline &Target	Financial Mechanism and Nodal agency
	SUPPLEMENTARY MEASURES					
	TECHNICAL MEASURES INCLUDING THE APPLICATION OF INNOVATIVE TECHNOLOGIES					
4.1.1	Propose and implement measures to improve the permitting system, procedures, and database, as needed. (KMO 4.1) • Checking whether the permitting system is fulfilling sustainability or not. • Checking whether the permitting system is covering all points of abstraction. • Finding how the compliance of permitting system is ensured. • Assessing the linkage between district level and basin level permitting system. • Proposals on the basis of aforementioned points to improve the permitting system.	1	District, Panchayat	For Farming GW no restriction, Tube wells are to be registered free of costs, charges apply for surface water Proposed- Development of current permitting system.	2028: water permit has registered	National Hydrology Project SWID, District Authorities, irrigation dept.
4.1.2	Identify all abstractions without a permit (above a certain threshold) through a combination of field inspections and the analysis of remote sensed images. (KMO 4.1) • Setting up of a field inspection routine. • Developing indicator list to identify an illegal abstraction. • Collection of cloud-free satellite images covering different seasons. • Executing image classification and visual interpretation for identifying illegal water abstractions.	2	District, Panchayat	Proposed: inspection visit per month	2024 for setting up of inspection routine. 2025: remote sensing image analysis.	Namami Gange Mission, SSAP for water sector under NWM SWID, District Authorities, Irrigation Dept.
4.1.3	For all large abstractions, verify if actual abstractions comply with the permit conditions; this activity will build on the exist-	2	State, District	Proposed: Installation of monitoring equipment	2027: installations of water	National Hydrology Project

#	Measures KWMI 4	Priority Class	Level (river reaches/ subunit level)	Status 2023	Draft Implementation Timeline &Target	Financial Mechanism and Nodal agency
	ing water management infrastructure and procedures—operated for instance by the irrigation department—but may also include establishing dedicated water monitoring equipment for large off take points. (KMO 4.1) • Identification of large off-take points. • Determination of parameters to monitor. • Assessing technical expertise for equipment selection. • Installation of equipment.			and compliance of permitting	monitoring equipment.	Irrgation Dept., SWID, Pay Jal Nigam
4.1.4	Refining SWAT model with downscaled climate projections to verify whether the future water availability under climate change scenario is meeting the water demand projections or not and coupling the surface water module of SWAT with dedicated groundwater module for better understanding about surface and groundwater interactions. (KMO 4.3) • Selection of climate model and downscaling with future scenarios. • SWAT model development with future climate projections. • Assessment of future water demand. • Checking whether the SWAT computed water availability is meeting the future water demand or not. • Coupling of SWAT and groundwater flow model (like-MODFLOW).	3	State, District	Implemented-0 Proposed: Evaluation of future projection of climatic variables, future water requirement, development of coupled groundwater and surface water model.	2026	National Hydrology Project, National Water Mission Research Organizations, CGWB

#	Measures KWMI 4	Priority Class	Level (river reaches/ subunit level)	Status 2023	Draft Implementation Timeline &Target	Financial Mechanism and Nodal agency
4.1.5	Use the SWAT model to implement the water accounting study with the required resolution. (KMO 4.3) • Determining the required spatial resolution of water availability. • Analyze the water account in sub basin and HRU scale. • Aggregate the HRUs to the extent of required resolution. • Analyze the water accounts of different scale.	1	State, District	Partially implemented: SWAT model developed. Proposed: Fixation of the resolution in which result is required.	2025	National Water Mission Research Organizations, CGWB
4.1.6	Define EFAs for all critical river reaches; this will probably involve an expansion of the number of sites for which the EFA is currently determined. (KMO 4.4) • Determining the method of environmental flow calculation. • Extract the reach wise result of SWAT to get flow data for every reaches. • Using SWAT results create flow duration curves for each reach. • Determine the environmental flow for each reach using the flow duration curve.	1	State	In UP, E-flow for Kannauj-Unnao maintained as per directions of CWC[69]	2024: determination of EFlows in all river reaches.	Namami Gange, National Hydrology Project Research Organizations, CGWB
4.1.7	Refining SWAT model which shall provide better information about present and future abstractions.(KMO 4.4) • Refining SWAT model by adding the present and future water abstraction amounts of specific locations in SWAT model,	1	State	Implemented:0 Proposed: Figure out the present and possible future abstraction, incorporate it	2026	National Hydrology Project Research Organizations, CGWB

[69] Monthly Progress Report of Uttar Pradesh in the NGT matter, June 2023, Page 10

#	Measures KWMI 4	Priority Class	Level (river reaches/ subunit level)	Status 2023	Draft Implementation Timeline &Target	Financial Mechanism and Nodal agency
	• Incorporate future climatic projections to estimate future water availability. • Coupling of groundwater module (e.g.- MODFLOW) and module like SWAT. • Incorporate future water demand as abstraction and input future climatic projections to predict the future condition more accurately.			with SWAT model.		
4.1.8	Application of SWAT model and Environmental Flow requirements to identify the hotspots of current and future conditions which are not meeting the amount of required flow. (KMO 4.4) • Comparing environmental flow requirement and SWAT flow results for each reach and nodes. • Identifying the points and reaches where flow is less than required environmental flow. • Do the same with SWAT model's result developed using future climatic projections and predicted future water abstraction, • Identify the zones where the flow isn't meeting the environmental flow requirement. • Grade such reaches according to the scarcity severity as very high, high, moderate, low, very low severity classes.	1	State, Basin, District	Implemented-0 Proposed: Evaluation of environmental flow in each reaches.	2025: critical reaches identified	Namami Gange, National Hydrology Project Research Organizations, CGWB, District authorities
	ECONOMIC MEASURES					
	INSTITUTIONAL AND CAPACITY BUILDING MEASURES					

#	Measures KWMI 4	Priority Class	Level (river reaches/ subunit level)	Status 2023	Draft Implementation Timeline &Target	Financial Mechanism and Nodal agency
4.3.1	Develop a process on a case-by-case basis to ensure compliance with permitting conditions; activities may range from sensitization efforts, negotiations, legal action, to acquiring defensible water data that prove beyond reasonable doubt that the current abstraction is in fact illegal. (KMO 4.2) • Create a list of authorities who can intervene into cases of illegal water abstractions. • Providing sufficient dataset to authorities regarding permitted water abstractions. • Case by case report generation of illegal water abstractions. • Case by case planning for intervening properly.	1	District, Panchayat, Urban local bodies	Implementation- 0 Proposed- Development of case-by-case process activities.	2024	National Hydrology Project, National Water Mission ULBs, District authorities
4.3.2	Design an inclusive and participatory stakeholder consultation exercise to review a potential suite of measures that will achieve the required changes in off take pattern. (KMO 4.5 and 4.6) • Formation of Water user organization which includes all stakeholders. • Organize module of campaigns to build up awareness about water use. • Organize programs about the role of over abstraction in water scarcity. • Popularize regulated water abstraction routines while highlighting the bigger profit of society and individuals.	2	District, Panchayat, Urban local bodies	Proposed	2024: WUG formalized 2025: campaigns conducted	State specific action plan for water sector under the NWM District and Panchayat authorities, Training institutes
	LEGAL, POLICY AND REGULATORY MEASURES					

#	Measures KWMI 4	Priority Class	Level (river reaches/ subunit level)	Status 2023	Draft Implementation Timeline &Target	Financial Mechanism and Nodal agency
4.4.1	Use the existing administrative and legal framework to terminate abstractions (above a certain threshold) that have no permit. (KMO 4.2) • Create a special cell in the local authority which shall be responsible to maintain regulated water abstractions. • Create a free grievance informing number for people who can submit an objection against illegal water abstraction. • Maintain proper communication and coordination between water authorities and local administrations to take rapid action. • Develop more awareness among people and authority about the legal bounds of water abstraction,	1	State Level, District Level	No restriction on GW withdrawal Proposed: identification of illegal water abstraction.	2027: all illegal abstractions have accounted	State specific action plan for water sector under NWM District Authorities, SWID
4.4.2	Determine required changes in surface water offtake pattern; these are location and time specific (KMO 4.5 and 4.6) • Planning for cosmetic campaigns and physical visits to reach out the consumers about the water regulations. • Organize awareness programs highlighting “no loss” for livelihoods to popularize changes in offtake patterns. • Put sufficient focus on how an individual is not suffering loss or being compensated adopting the new off take patterns.	1	Basin, District	Total SW abstraction: 2837 MCM[70] Charges for SW abstraction is taken	2024: Listing of required changes. 2026: Regulations of bringing changes in off takes.	National Water Mission SWID, District authorities, IWRD

[70] Development of River Basin Assessment and Plans for All Major River Basins in Uttar Pradesh, Ramganga Basin Plan volume 1, 2020, page 38

#	Measures KWMI 4	Priority Class	Level (river reaches/ subunit level)	Status 2023	Draft Implementation Timeline &Target	Financial Mechanism and Nodal agency
	• At a time, campaign the possible legal actions can be taken against illegal abstractions.					
	STUDIES AND ASSESSMENTS FOR DEVELOPING AND IMPLEMENTING MEASURES					
4.5.1	Review the existing permitting system—for surface and groundwater abstractions—at basin and district level; assess the effectiveness and completeness of the system; assess how compliance is ensured; assess how the permitting database at district level is linked to the basin level. (KMO 4.1) • Assessing whether the water abstraction permitting system covering all sources of abstractions including surface and ground water or not. • Create an assessment report about the permitting abstraction system's role to mitigate water scarcity. • Assess how the compliance of new water abstraction routines can be ensured. Create a report on programs with an objective of compliance. • Assess how the district level regulations are compiled in basin level.	2	State, Basin, District	Total SW abstraction: 2837 MCM[70] Charges for SW abstraction	2024: water abstraction assessment conducted	National Hydrology Project, National Water Mission SWID, CGWB, IWRD
4.5.2	Prepare an inventory of abstractions that are suspected not to comply with the permit terms; prioritize a reasonable number of cases that will be addressed in this management cycle. (KMO 4.2) • Checking each abstraction case and corresponding permit rules. • Make a list of abstractions breaking the permits. • Grade the illegal abstractions according to severity.	1	State, District	Proposed	2024: inventory has prepared	National Hydrology Project District Authorities, ULBs

#	Measures KWMI 4	Priority Class	Level (river reaches/ subunit level)	Status 2023	Draft Implementation Timeline &Target	Financial Mechanism and Nodal agency
4.5.3	Assess the current SWAT model for the Ramganga basin and propose measures to refine and improve this model as needed. (KMO 4.3) • Create a list of refinements can be done to the SWAT model. • Execute a feasibility analysis about data required for each refinement. • Use literatures to create a list of potential measures which can improve the SWAT model performance. • Assess the requirements for improvement measures.	1	State	Implemented-0 Proposed: Data collection for the refinement to be done.	2025	National Hydrology Project Research organizations/ institutes
4.5.4	Per off take point or (sub) irrigation scheme, prepare an inventory of possible interventions—at all scales, and both of a technical, institutional, and economic nature—to improve water productivity and water use efficiency. (KMO 4.5 and 4.6) • Using the inventory of off take points, create brief reports about each. • Create an assessment report on each off take points and rate its productivity and efficiency. • Develop a holistic report on possible actions can be taken to optimize off taking points. • Create a possible list of measures for each off takings to improve water productivity and efficiency.	1	State	Implemented-0 Proposed: Preparation of off take point wise to do list	2026: inventory of interventions has prepared	State specific action plan for water sector under NWM District authorities, NGOs, Research organizations
	Awareness measures					

#	Measures KWMI 4	Prior-ity Class	Level (river reaches/ subunit level)	Status 2023	Draft Imple-mentation Timeline &Tar-get	Financial Mechanism and Nodal agency
4.6.1	Design and implementation of sensitization exercise for all stakeholders about the ample potential to increase water productivity while emphasizing the fact that it shall not impact the livelihoods of the people adversely in anyway. (KMO 4.5) • Conducting workshops to explain the ways of increas-ing water productivity. • Use local administration and dignitaries for convinc-ing "No loss" to the people. • Implement the sensitization workshops with the help of water authority and local administration. • Involve social organizations to sensitize the people.	2	Panchayat, Urban local bodies	stage of GW ab-straction:78%[71]	2024	National Water Mission District authori-ties, NGOs, Re-search organiza-tions
	Other measures					

[71] Development of River Basin Assessment and Plans for All Major River Basins in Uttar Pradesh, Ramganga Basin Plan volume 1, 2020, page IX

6.6 Measures related to KWMI 5: quantity Flood risk due to encroachment including sand mining

6.6.1 Reflection of key findings of the KWMI 5 Risk Assessment

The Risk Assessment confirmed that periodic riverine floods—where the river overflows its banks and inundates the adjacent areas—mainly occur on the Ramganga main stem, as well as on tributaries immediately upstream of their confluence with Ramganga. While minor floods also occur in other parts of the basin, these are, however, mostly localized events that do not require management attention at basin level.

It is noteworthy that the main flood risks are observed downstream of Kalagarh dam. Kalagarh is a multi-purpose reservoir that combines hydropower, and irrigation functions. The live-storage volume of the reservoir is approximately 220 mcm, which is less than 10% of the average annual runoff of the Ramganga. Kalagarh, therefore, cannot capture the accumulated flood wave and does not provide full flood protection for the immediate downstream Ramganga system. Nevertheless, the reservoir attenuates the flood wave on the main Ramganga—the largest contributor to the Ramganga system—and therefore moderates the flood impacts in the downstream river system. This is reflected by the flood hydrograph in the reach from Kalagarh to Moradabad, where peak flood is typically reached after about two days. It provides adequate time for people and livestock to evacuate the area after they receive a flood warning.

Downstream of Moradabad, multiple parallel tributaries originating in the northern foothills join Ramganga. In case of an extreme rain event that covers the entire catchment, these combined tributaries add a large synchronous flood wave to the Ramganga system. Nevertheless, the Risk Assessment demonstrated that while the flood hydrograph in the river downstream of Moradabad is somewhat steeper, it still takes about two days for the flood wave on the Ramganga to reach its peak.

Flooding in the Ramganga, therefore, has major adverse socio-economic consequences and can cover an extensive area but is generally not associated with loss of life, apart from a limited number of isolated and accidental cases.

A realistic objective is to focus on preventing expensive flood damage rather than to prevent all flooding. This approach is reflected in the vision statement for KWMI 5, which corresponds with the "room for the river" approach. This practical approach aims to maintain or reestablish the river's floodplain in areas where this is least harmful—which includes most areas—and only protect important economic assets such as urban areas and critical infrastructure. In this setup, the very productive floodplain can be used for agricultural activities that tolerate occasional inundation—such as cultivation of rice or sugarcane. Hence the floodplain maintains its natural functions such as replenishing groundwater, buffering flood-waves, and supporting rich and diverse environmental value. Floods continue to deposit fertile sediment.

Government responsibility and policy measures for this approach are limited to zoning and prohibiting permanent structures in the floodplain, as well as protecting critical infrastructure and high-value areas.

It is noted that the management objectives for KWMI 5 for this management cycle are fully in line with the above proposition.

6.6.2 Outline of the POM for each Management Objectives

Management Objectives for this first RBMP include:

1. **Interactive flood inundation maps are developed and readily available for Ramganga River and Tributaries as an early warning system and to be a basis to assess encroachments.**

The flood inundation maps will serve as the principal tool to demarcate the floodplain—which is subject to periodic inundation—and the adjacent dry land, which should be protected from flooding. This approach is integral to realizing the vision for KWMI 5, which is based on "conserving the functions of the flood retention area". The flood maps will also serve to assess encroachments.

As the magnitude of future flood events is probably underestimated because of climate change (see paragraph above), a no-regret approach suggests fully maintaining the historic floodplain for flood water retention and related hydraulic functions. This includes areas on the margins of the floodplain that probably only experience infrequent flooding. Demarcating a wider floodplain has the dual advantage of buffering a larger part of the flood wave—thus reducing downstream flood risks—and reducing potential flood damage because the entire zone at risk can no longer be used for permanent settlements or critical infrastructure. It is noted that the productive floodplain can still be used for livestock or crops that tolerate occasional inundation.

Accurate flood inundation maps will be based on a detailed bare-ground and hydrologically correct Digital Elevation Model (DEM) of the riparian zone. Given the low relief in most of this zone, this will probably be based on a LiDAR scan. The resulting DEM—with high vertical and horizontal precision—will then be combined with the SWAT model to develop the inundation maps. Demarcating the floodplain is only partly based on inundation maps. The zoning exercise also requires the consent from local inhabitants to provide legitimacy and prevent future encroachment of the floodplain. Hence local inhabitants need to participate in ground-truthing the inundation maps and check for anomalies. In addition, the demarcation exercise needs to be implemented in a fully transparent and participatory manner.

The POM in outline for this management objective involves:

- Conduct a LiDAR scan to develop a detailed DEM—with high vertical and horizontal precision—of the riparian zone.
- Combine the detailed DEM and the SWAT model to develop inundation maps for a 100-year flood event; given the uncertainties related to climate change, also develop inundation maps for floods with a higher return period.
- In a joint exercise with local inhabitants, ground-truth the flood inundation maps and reach consensus on the demarcation of the floodplain; agree on permissible and non-permissible activities in the floodplain—this can differ per river reach.
- Based on the floodplain demarcation, assess the level of encroachment of the floodplain and the existence of critical infrastructure—that cannot be flooded—in this zone.

2. **Urban encroachment as identified through the flood inundation mapping is prevented by implementing state policies as per defined rules and regulations.**

Encroachment of the riverine zone in urban areas is associated with multiple adverse consequences. It restricts the flow channel during floods and therefore creates a 'chokepoint' that aggravates upstream inundations and consequent flood risks and damage. In addition, urban settlements along the channel—although often illegal and not complying with urban regulations—typically have a high population density and encroach the alluvial zone immediately up to the channel. Hence there is no space for sceptic tanks, drainage systems, or solid waste collection systems, and waste and sewage is dumped directly into the river. The encroachments, therefore, constitute a major source of point-source pollution. Removing and relocating illegal settlements on the riverbank is admittedly a difficult task that requires stakeholder involvement and provision of alternative housing. Hence preventive measures are critical. It will involve a clear physical demarcation of the floodplain, frequent inspections, and strict enforcement of floodplain regulations.

The POM in outline for this management objective involves:

- Sensitize the population living near the floodplain in urban areas regarding the existing regulations; involve community organizations in organizing and implementing the awareness and education campaign.
- Clearly demarcate the floodplain, and protect floodplain boundaries with footpaths, tree lines, or other conspicuous features.
- Floodplain regeneration through constructed wetlands, parks, infiltration ponds, green infrastructure, sustainable urban drainage systems and other flood-resilient developments; conduct frequent inspections of the floodplain areas and ensure strict enforcement of floodplain regulations.
- Identify hotspots and problem areas that require more frequent inspections.

3. **The citizens in the basin are kept well-informed and sensitized on the implications of urban encroachment of the floodplain zone and the importance of floodplains and lateral connectivity of rivers.**

This management objective relates to above management objective no. 2. It emphasizes the importance of public consensus on the role of the floodplain and the community effort that is needed to prevent floodplain encroachment through illegal settlements or activities. The sensitization effort in urban areas is supported by clearly demarcating the floodplain with physical features—such as tree lines or footpaths—and by using the floodplain area for public functions such as parks, small allotments, sport fields, or green spaces. The POM in outline for this management objective is similar to the one discussed under 2) and does not require further elaboration.

4. **Nature-based solution are prioritized and implemented for flood mitigation.**

Nature-based solutions employ natural processes to achieve water-related objectives. In essence it concerns management of vegetation, soils, wetlands, and floodplains with the aim to slow-down the speed at which water flows through the landscape. Most effective is to start at the top of the watershed. Nature-based solutions achieve several key water resources objectives: enhance water availability, improve water quality, and reduce flood and other water-related risks. Additional benefits include carbon sequestration, enhanced environmental value, prevention of soil erosion, and lower ambient temperatures—the latter may be specifically relevant for urban areas in a warming climate. Moreover, nature-based solutions are mostly maintenance free since living processes—when not over-exploited—are regenerative and self-sustained.

To achieve a meaningful attenuation of the flood wave, nature-based solutions need to be employed at catchment scale. This is probably outside the scope of this management cycle. Instead, emphasis will be placed on solutions for the riparian zone in the lower reaches of the Ramganga and its tributaries, where most flood events occur. Measures are concerned with establishing riparian vegetation and reconstruction and maintenance of wetlands.

The POM in outline for this management objective involves:

- Prioritize river reaches that require rehabilitation; encourage tree planting and the establishment of riparian vegetation.
- Delineate and demarcate wetlands.
- Involve NGOs and other community organizations in organizing and implementing an awareness campaign on the value of wetlands, and on their sustainable use.
- Ensure compliance with environmental regulations through appropriate administrative and legal measures, and reverse wetland encroachment and degradation. Monitor wetlands for illegal activities.

5. **Flood prevention through strengthening reservoir operations, implementation of flood buffer zoning and forecasting as per defined dynamic operational rules, is achieved.**

The operation rules of the large Kalagarh reservoir will impact on the propagation of flood waves through the immediate downstream Ramganga river system and can thus assist in mitigating inundation and flood damage. However, it is noted that Kalagarh is a multi-purpose reservoir that supports multiple functions. Achieving secure water supply for irrigation in the large schemes in the Ramganga Basin may have priority over flood prevention. Nevertheless, enhanced operating rules of Kalagarh—specifically when using dynamic rules based on improved forecasts of both inflow and reservoir levels—can contribute to flood management in the downstream riparian zone.

It is noted that the implementation of flood buffers has been discussed under 1), 2), and 4) above. The POM in outline for this management objective involves:

- Develop flood forecasting routines that better predict the inflow into Kalagarh reservoir.
- Develop dynamic operating rules for Kalagarh that optimize the use of the reservoir for hydropower, irrigation, and flood management functions based on real-time data and forecasts. This activity will involve developing an information system and model, such as a Decision Support System.

6. **The maximum volume of sustainable sand mining is assessed by using Hydro-morphological models.**

Excessive riverbed mining is exacerbating natural erosion processes in several reaches of Ramganga and its tributaries. It compromises the structural integrity of hydraulic infrastructure and bridges, erodes farmland immediately adjacent to the river, and has adverse impacts on groundwater levels and riverine ecosystems. Because sandmining is critical to the building industry and represents important economic value, a sustainable level of sandmining must be established.

Sediment dynamics within river channels and floodplains are highly complex and related to the hydrologic regime of the river and the relief and geologic characteristics of the catchment. Different sediment components have different pathways. In addition, hydraulic structures such as dams and weirs alter the flow regime and sediment budget of the river. Specifically, Kalagarh will trap coarse sediment and reduce the overall volume of sediment in the downstream river system. Sediment budgets differ per river reach as a function of load, grain size, slope, hydrologic regime, and hydraulic structures. Consequently, changes in the hydrologic and sedimentation regime of the river because of climate change or catchment management practices will change the dynamic equilibrium that determines the sand replenishment rate and channel stability. Upstream mining activities also impact on the morphology of the downstream river system.

Determining sustainably riverbed mining volumes, therefore, will require a very careful examination of the hydrologic, hydraulic, and morphologic processes. Sustainable mining volumes must be established for each river reach.

The POM in outline for this management objective involves:

- Prepare a setup of a detailed hydro-morphological model and determine data requirements.
- Data collection.
- Calibration and completion of the model.
- Determine sustainable sandmining volumes for each river reach.

7. **The monitoring mechanism of sand mining is improved and strengthened to assess the overall extraction and accordingly administer the relevant acts, and if needed re-structure approval.**

Riverbed mining in the Ramganga Basin is widespread. Some mining activities are legal while others are illegal. Preparing a complete inventory of all sand mining activities and their legal status is a critical step in ensuring that sand mining is within the sand replenishment rate.

The POM in outline for this management objective involves:

- Monitor mining activities and establish the level of compliance with environmental regulations.
- Prepare an inventory of illegal sand mining or other mining activity in the district/basin.
- Ensure compliance by the mining industry with environmental and other regulations through appropriate administrative and legal measures.

6.6.3 PoM for KWMI 5

Below Table 72 presents the implementation details of PoM for KWMI 5.

Table 72: Implementation details of PoM for KWMI 5

Sl No.	Measures KWMI 5	Prior-ity Class	Level (river reaches/sub unit level)	Status 2023	Draft Imple-mentation Timeline & Tar-get	Financial Mechanism and Nodal Agency
	BASIC MEASURES					
5.0.1	**Air Quality Management** (i) control the emissions by a regular preventive maintenance of equipment needs to be carried out on contractual basis; (ii) all transportation vehicles should carry a valid PUC certificate (iii) Plantation needs to be carried out on approach roads and nearby vicinity of Riverbank (iv) regular water sprinkling on road will be carried out to avoid dustiness due to vehicular transportation (v) the speed of the vehicles is maintained within the prescribed limits (vi) trucks are not allowed to be over loaded and should be maintained to the body level; (vii) condition of all trucks needs to be well maintained and (viii) old age trucks are not allowed to be used.	1	State, Basin, District	Proposed	2028: End of RBM cycle	Arth Ganga District Authorities, PCB
5.0.2	**Noise Management** (i) No other equipment except the Transportation vehicles and excavator (as and when required) for loading will be allowed. Noise generated by these equipment's shall be intermittent and does not cause any impact; (ii) all vehicles which create high noise are not allowed; (iii) plantation will be carried out on ap-proach roads and nearby vicinity of River bank, (iv) proper maintenance of vehicles must be ensured; (v) mining activity will be restricted to day time only.	1	State, Basin	Proposed	2028: End of RBM cycle	Arth Ganga District Authori-ties, PCB
5.0.3	**Water Quality Management** (i) No waste water will be generated from the mining activity of minerals as the project only involves scraping of Ordinary Sand from River bed; (ii) Mining will not intersect the Water level; (iii)	1	State, Basin	Proposed	2028: End of RBM cycle	Namami Ga-nage Mission, Arth Ganga

Sl No.	Measures KWMI 5	Prior-ity Class	Level (river reaches/sub unit level)	Status 2023	Draft Imple-mentation Timeline & Tar-get	Financial Mechanism and Nodal Agency
	Mining should be done well above the riverbed water table therefore impact on water regime is not anticipated.					District Authori-ties, PCB
5.0.4	Solid Waste Management (i) No solid waste will be generated from the said mining opera-tions; (ii) Unused material including mineral or spillage (if any) will not be stocked on the banks side in river bed as it will hinder the flow of river in monsoon season.	1	Basin, State, District	Undertaken by MoHUA, PCB		Swachh Bharat Mission, Arth Ganga District Authori-ties, ULBs
5.0 5	Management for Land Use Pattern Including Change of River Course (i) Sand must be collected in a way so that the river flow/course shall not get disturbed (details on that see supplementary measures); (ii) scrapping/dredging of sand shall be started from the center towards the bank periphery in 0.5 meter slice so that the river course does not get affected and a barrier of at least 3 m will be left at both bank side for safety of banks (details on that see supplementary measures); (iii) Unused material includ-ing mineral or spillage (if any) will not be stocked on the banks side as it will hinder the flow of river in monsoon season; (iv) Suitable mitigation measures are needed and to be maintained to avoid water logging.	1	State, Dis-trict, Pan-chayat, Ur-ban local bodies	As Sand Mining Rues, River bed sand mining shall be restricted within the central 3/4th width of the river/rivulet or 7.5 meters (in-ward) from river banks but up to 10% of the width of the River	Effective en-forcement by 2027	Namami Ga-nage Mission, Arth Ganga District Authori-ties, Irrigatin Dept
	SUPPLEMENTARY MEASURES					
	TECHNICAL MEASURES INCLUDING THE APPLICATION OF INNO-VATIVE TECHNOLOGIES					
5.1.1	Conduct a LiDAR scan to develop a detailed DEM—with high ver-tical and horizontal precision—of the riparian zone. (KMO 5.1) • Delineating the area where LiDAR scanning is to be done.	1	National, State	Proposed	2026: DEM with High resolution prepared	Namami Ga-nage Mission,

Sl No.	Measures KWMI 5	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and Nodal Agency
	• Taking aid from technical experts for the necessary requirements of LiDAR scanning. • Developing DEM by interpolating the LiDAR detected altitudes in required zone in GIS interface.					Research institutes/organizations, NIC (National Informatics Centre)
5.1.2	Combine the detailed DEM for SWAT model while considering uncertainties for climate change and determine the 100-year flood event; Create inundation maps of higher return periods also. (KMO 5.1) • Determination of 100-year flood from SWAT flow results incorporated with climate change uncertainties. • Using the detailed DEM and flood model to get inundation map for 100-year flood.	1	Basin Level, State Level	Proposed	2026: Inundation maps are prepared	Namami Ganage Mission, Research institutes/organizations, NIC
5.1.3	Regeneration of floodplain with flood-resilient developments like- green infrastructure, infiltration pond etc.; Conduct frequent visits to ensure strict follow up of floodplain regulations. (KMO 5.2) • Assess current situation of delineated floodplain. • Developing plans for floodplain regeneration. • Fixation of visiting routine of concerned authority for floodplain regulation maintenance.	1	District, Panchayat, Urban local bodies	AMRUT sarovar takes care of all water bodies in urban areas and provides subsidies (1lakh for smaller ponds, 2.68 for bigger)	2028: green infrastructure developed over the floodplain region	Namami Ganage Mission, Arth Ganga, Amrit Sarovar District Authorities, ULBs, Irrigation dept.
5.1.4	Determination of sustainable volume of sand mining for each river reach. (KMO 5.6) • Use the deposition-erosion result of hydro-morphological model. • Evaluate the sustainable amount of sand mining.	1	State Level, District Level	Identified Sand volume: 7.35 million m^3	2027: all sand volume is identified	Namami Ganage Mission, Arth Ganga District Authorities, ULBs, Irrigation dept.

Sl No.	Measures KWMI 5	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and Nodal Agency
	• Conduct field surveys to verify the accuracy of the model predictions and assess the current condition of the riverbed.					
	ECONOMIC MEASURES					
	INSTITUTIONAL AND CAPACITY BUILDING MEASURES					
5.3.1	Conduction of joint exercise with local inhabitants to ground-truth the flood inundation map and demarcation process with consensus and establish agreement on regulations in the floodplain for each river reach. (KMO 5.1) • Identify relevant stakeholders for joint consultation • Provide training and workshops to the local community to explain the concepts of floodplain mapping, inundation modeling, and flood risk management. • Collaboratively identify and demarcate floodplain boundaries using a participatory mapping approach. • Involve local stakeholders in the development of regulations and guidelines for floodplain land use and development.	1	District, Panchayat, Urban local bodies	Flood plain zones of Ramganga have been decided for UP.	2024: stakeholders identified 2025: Training and workshops are conducted	Namami Gange Mission, Arth Ganga District Authorities, ULBs, Irrigation dept.
5.3.2	Involve NGOs and other community organizations in organizing and implementing an awareness campaign on the value of wetlands, and on their sustainable use.(KMO 5.4) • Identify appropriate NGOs/organizations focus on wetland management • Prepare training materials of awareness programme • Identify proper community around wetlands areas • Organize awareness programme for the local community	1	State, District	Proposed	2024: NGOs identified 2025: Training programme organized	Namami Gange Mission, Arth Ganga District Authorities, ULBs, NGOs

Sl No.	Measures KWMI 5	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and Nodal Agency
5.3.3	Development of a decision support system for Kalagarh reservoir based on dynamic operating rules to optimize its multimodal use of hydropower generation, irrigation and flood management based on real-time data and forecasts. (KMO 5.5) • Collect real-time data and Develop a system to integrate data from various sources, including sensors, weather stations, and forecast agencies • Identify stakeholders/institutes for developing hydrological models • Develop a user-friendly interface for stakeholders to access real-time data, forecasts, and optimization recommendations • Evaluate the impact of different scenarios on reservoir operations • Provide training to stakeholders on how to use the DSS effectively	2	Ramganga Basin, Reservoir	Proposed	2025: Decision support system has established for Kalagarh Reservoir	Namami Gange Mission. National Hydrology Project Irrigation Dept. Reservoir authorities
	Legal, Policy and Regulatory measures					
5.4.1	Ensure compliance with environmental regulations through appropriate administrative and legal measures, and reverse wetland encroachment and degradation. Monitor wetlands for illegal activities. (KMO 5.4) • Identify appropriate local authorities and collect information on environmental regulations on wetland encroachment and degradation. • Prepare monitoring frameworks for accounting the illegal activities • Aware the local community on legal actions and regulations on wetland encroachment and degradation.	1	State, District	Proposed	2028: No illegal activities are observed	Namami Ganage Mission, Arth Ganga District Authorities, ULBs, NGOs

Sl No.	Measures KWMI 5	Prior-ity Class	Level (river reaches/sub unit level)	Status 2023	Draft Imple-mentation Timeline & Tar-get	Financial Mechanism and Nodal Agency
	• Prepare legal framework on legislation of administrative and legal measures					
5.4.2	Monitor mining activities and establish the level of compliance with environmental regulations. (KMO 5.7) • Review and familiarize yourself with local, state, and national environmental regulations related to sand mining. • Conduct regular on-site inspections to verify compliance with environmental regulations. • Take appropriate enforcement actions, which may include issuing warnings, fines, or suspending mining operations until compliance is achieved • Periodically review and update environmental regulations based on changing circumstances, technological advancements, and new scientific findings	2	State, District	Monitoring with satellite images, . Mine Mitra doing an artificial intelligence mining monitoring[62]	2028: Sustainable sand mining has achieved	Namami Ganage Mission, Arth Ganga District Authorities, ULBs, NGOs, Environmental dept.
5.4.3	Ensure compliance by the mining industry with environmental and other regulations through appropriate administrative and legal measures. (KMO 5.7) • Identify the need for mining regulations through research and consultation • Establish and maintain comprehensive regulations • Define clear penalties and fines for violations of regulations, and ensure they are enforced consistently. • Engage the public, local communities, and environmental organizations in the regulatory process • Periodically audit mining operations to verify compliance with regulations, including environmental standards.	2	State, District	Environmental clearance is given for the mining activities, gov. agencies are to be trained, Mine and mineral department collects the royalties and surveillance is done by the DM	2028: No illegal activities are observed	Namami Ganage Mission, Arth Ganga District Authorities, ULBs, NGOs, Environmental dept.

Sl No.	Measures KWMI 5	Prior-ity Class	Level (river reaches/sub unit level)	Status 2023	Draft Imple-mentation Timeline & Tar-get	Financial Mechanism and Nodal Agency
	STUDIES AND ASSESSMENTS FOR DEVELOPING AND IMPLE-MENTING MEASURES					
5.5.1	Based on the floodplain demarcation, assess the level of en-croachment of the floodplain and the existence of critical infra-structure. (KMO 5.1) • Identify structures and developments that encroach into the floodplain beyond allowable limits or in viola-tion of regulations. • Compile an inventory of critical infrastructure within the floodplain • Evaluate the collected data to determine the extent of encroachment and the level of flood risk associated with critical infrastructure. • Establish a system for ongoing monitoring of encroach-ments, flood risk, and critical infrastructure vulnerabili-ties.	1	State, Dis-trict	14446 pillars ha-ven placed against 15293 pil-lars for demarca-tion of River Ganga from Kan-nuaj to Unnao. Flood plain zones of Ramganga have been de-cided for UP.	2025: en-croached areas are identified	Namami Ga-nage Mission, Arth Ganga District Authori-ties, ULBs, Irri-gation Dept.
5.5.2	Identify hotspots and problem areas that require more frequent inspections. (KMO 5.2) • Engage with subject experts and collect historic data • Evaluate risks associated with different areas and cate-gorized the information • Prepare GIS map to visualize the hotspots • Prioritize inspections based on the criticality of the re-gions. • Embrace digital tools for data analysis and scheduling	1	District, Ur-ban local bodies	Proposed	2026: Frequent inspections on hotspots areas have conducted	Namami Ga-nage Mission District Authori-ties, ULBs, Irri-gation Dept. Re-search Insti-tutes/organiza-tions
5.5.3	Develop flood forecasting routines that better predict the inflow into Kalagarh reservoir. (KMO 5.5) • Collect historical hydrological data, precipitation rec-ords, river discharge measurements	1	Basin, Res-ervoir level	Proposed	2025: Flood Forecasting models have prepared	Namami Gange Mission. Na-tional Hydrology Project

Sl No.	Measures KWMI 5	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and Nodal Agency
	• Create hydrological models that simulate the behavior of the catchment area, including rainfall-runoff processes and calibrate the model • Utilize remote sensing for better visualization • Develop ensemble models that consider multiple weather forecasts and hydrological model outputs to account for uncertainty and assess its performance • Provide training to forecasters and operational staff responsible for interpreting and using the forecasts.				2026: more accurate predications have observed	Irrigation Dept. Reservoir authorities. Jal Vidyut Nigam
5.5.4	Delineation and demarcation of wetlands. (KMO 5.4) • Combining field surveys, satellite imageries for identifying the wetlands of basin area. • Demarcation of wetlands. • Create detailed wetland maps using GIS software, incorporating data from field surveys and remote sensing.	2	Basin, District	Wetland authority has assessed all wetland health and a management programme is being formalised.	2027: all wetlands in the River basin identified	Namami Ganage Mission, Arth Ganga District Authorities, ULBs, Irrigation dept., Environmental Dept.
5.5.5	Data collection for hydro-morphological model. (KMO 5.6) • Identify data needs for hydro-morphological model • Conduct field surveys to collect primary data about the river system • Use remote sensing technology (e.g., satellite imagery, LiDAR) to gather information on land cover, land use, and topography within the river basin. • Collect soil data, water data, ecological information, flood data, bore hole data for preparing hydrological model	1	State, District	Proposed	2025: data collected for hydro-morphological model	Namami Ganage Mission Research institutes/organizations, NIC (National Informatics Centre)

Sl No.	Measures KWMI 5	Prior-ity Class	Level (river reaches/sub unit level)	Status 2023	Draft Imple-mentation Timeline & Tar-get	Financial Mechanism and Nodal Agency
5.5.6	Calibration and completion of the hydro-morphological model. (KMO 5.6) • Choose an appropriate hydro-morphological model • Identify model parameters that need calibration, such as Manning's roughness coefficients, sediment transport parameters, and channel geometry parameters • Run the model with the initial parameter values and compare the model outputs to observed data. • Conduct sensitivity analyses to assess the impact of variations in model parameters on model predictions.	2	State, District	Proposed	2026: hydro-morphological model prepared	Namami Ganage Mission Research institutes/organizations, NIC (National Informatics Centre)
5.5.7	Preparation of the setup and determination of data requirements for hydro-morphological model. (KMO 5.6) • Clearly articulate the objectives of the hydro-morphological model. • Decide on the modeling approach that best suits your objectives. Common models for hydro-morphological studies include 1D, 2D, or 3D hydraulic models and sediment transport models. • Define the spatial domain for your model, including the river channel, floodplains, and any other relevant features like tributaries or confluences. • Process and preprocess geospatial data to ensure compatibility and consistency. This may involve georeferencing, data interpolation, and data fusion techniques.	2	State, District	Proposed	2026: hydro-morphological model prepared	Namami Ganage Mission Research institutes/organizations, NIC (National Informatics Centre)
5.5.8	Preparation of inventory of illegal sand mining or other illegal mining activity in the district/basin. (KMO 5.7) • Gather information on legal permits and licenses issued for mining activities in the district or basin.	2	Basin, District	Proposed	2026: Inventory of illegal Sand mining has prepared	Namami Ganage Mission, Arth Ganga

Sl No.	Measures KWMI 5	Prior-ity Class	Level (river reaches/sub unit level)	Status 2023	Draft Imple-mentation Timeline & Tar-get	Financial Mechanism and Nodal Agency
	• Investigate the social and economic impact of illegal mining on local communities • Organize all collected data into a comprehensive inventory, including maps, photographs, reports, and testimonies. • Prepare a detailed report summarizing your findings, including the extent and impact of illegal mining in the district or basin.					District Authorities, ULBs, Irrigation dept.
	AWARENESS MEASURES					
5.6.1	Sensitize the population living in floodplains regarding existing regulations; conduct awareness and education campaigns. (KMO 5.2) • Identify the local community and local bodies, such as municipal councils, eoarchment management authorities, and zoning boards • Develop informative materials, such as brochures, pamphlets, fact sheets, and presentations, explaining the risks associated with encroachment in flood-plain regions • Schedule meetings, workshops, or seminars with representatives from local bodies and communities. • Collaborate with planning bodies to identify urban encroachment and to prepare flood inundation map	1	District, Urban local Bodies	CFO and EC is given a member of NMCG to identify the no mining zone, Proposed	2027: Community on flood-plain are more aware on urban encroachment	Namami Ganage Mission, Arth Ganga District Authorities, Research organizations/institutes, NGOs
5.6.2	Prioritize river reaches that require rehabilitation; encourage tree planting and the establishment of riparian vegetation. (KMO 5.4) • Conduct a comprehensive assessment of the river system to identify the areas that require rehabilitation.	2	Basin, State, District	16.4 million of saplings (2022) and 23.3 million saplings have been planted along 14 river	2027: Tree planation has conducted in entire river stretches	Namami Ganage Mission, Arth Ganga

Sl No.	Measures KWMI 5	Priority Class	Level (river reaches/sub unit level)	Status 2023	Draft Implementation Timeline & Target	Financial Mechanism and Nodal Agency
	• Develop a detailed plan for rehabilitating the prioritized river reaches. • Identify suitable tree species that are native to the region and appropriate for the riverbank ecosystem. • Ensure ongoing maintenance of tree plantings and riparian vegetation to ensure their long-term survival and effectiveness.			stretches in UP (2023)[69]		District Authorities, ULBs, Irrigation dept.
	OTHER MEASURES					
5.7.1	Clearly demarcate the floodplain, and protect floodplain boundaries with footpaths, tree lines, or other conspicuous features. (KMO 5.2) • conduct a detailed floodplain mapping and assessment to identify the extent of the floodplain and flood-prone areas • Implement zoning regulations that clearly define the floodplain boundaries and restrict certain types of development within it. • Create well-defined footpaths and recreational trails within the floodplain. • Continuously evaluate the effectiveness of floodplain management measures and adapt strategies based on changing conditions, such as climate variability and development pressures.	1	District, Panchayat, Urban local bodies	14446 pillars haven placed against 15293 pillars for demarcation of River Ganga from Kannuaj to Unnao. Flood plain zones of Ramganga have been decided for UP	2025: demarcation of floodplain has completed 2027: Floodplain boundaries are protected	Namami Ganage Mission, Arth Ganga District Authorities, ULBs, Irrigation Dept., Envirnmental Dept.

7 OPPORTUNITIES FOR SYNERGIES AND CONVERGENCE

As briefly listed in the KWMI specific PoM tables, there are several ongoing missions and programs by National and state governments which provide an excellent opportunity to synergies the efforts and pool resources for effective implementation of PoM for first cycle of Ramganga RBMP. Though the list of such programs/mission is exhaustive, the section below offers an account of key programs with very high potential for synergies.

7.1 National Water Mission (NWM)

The main objective of National Water Mission is conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within states through integrated water resources development and management. NWM has five goals as under:

- Comprehensive water data base in public domain and assessment of the impact of climate change on water resources.
- Promotion of citizen and state actions for water conservation, augmentation and preservation.
- Focused attention to vulnerable areas including over-exploited areas.
- Increasing water use efficiency by 20%, and
- Promotion of basin level integrated water resources management

Budget allocation: Rs 50 crore budget allocated for research and development and implementation of NWM for the period 2023-24

7.2 National Hydrology Project (NHP)

The main objective of NHP is to improve the extent, quality and accessibility of water resources information and to strengthen the capacity of targeted water resources management institutions for integrated water resource management using cutting edge technologies. The project involves modernizing monitoring network, transforming knowledge access, enhancing analytical tools and modernizing institutions. It establishes a nationwide 'Nodal' 'one point' platform for all states to collaborate and share data pertaining to water resources. Significant progress has been made in the fields of WRMS, WRIS, and NWIC has been established. The NHP now focuses on establishment of Real Time Data Acquisition System (RTDAS) on pan India basis.

Budget allocation: Total budget of Rs. 500.0 crores for NHP and Rs.3.95 crore for establishment of National Water informatics Centre (NWIC) for the period of 2023-24.

7.3 Master Plan for Artificial Recharge to Groundwater in India

The revised master plan for artificial recharge to groundwater has been made for the whole country at district/block level. The plan is macro-formulated to work out the feasibility of various structures for the different terrain conditions of the country and respective estimated cost. A total of 11.23 km^2 has been identified for artificial recharge covering all states. The surplus available for recharge after deducting the committed supply has also been estimated for each State.

Budget Allocation: The total cost for implementation of this revised master plan is Rs 1,33,529.69 Cr, with Rs 96,735.45 Cr (72%) for rural areas and Rs 36,794.23 Cr (28%) for urban areas.

7.4 State Specific Action Plan (SSAPs) for Water sector NWM

National Water Mission (NWM) is supporting states and UTs to formulate state specific action plans for water sector. SSAP is a comprehensive policy for promotion of basin level integrated water resource management. It is a multidisciplinary activity requiring active participation of all government departments related to water from supply side, demand side, governance side, technology side and environment and climate change perspective, and also that of non-government agencies and citizens. Thus, the formulation of plans involves convergence and synergy of all stakeholders- Government and Non-government.

Budget Allocation: Uttar Pradesh State Government has approved INR 51 Lakhs for this plan and INR 30 Lakhs has been approved by Uttarakhand State Government.

7.5 Jal Shakti Abhiyan (JSA)

Focuses on saving and conserving rainwater, it involves the states and all stakeholders to create rainwater harvesting structures suitable to climatic conditions and sub-strata. It is aimed to accelerate water harvesting, conservation and bore well recharge activities in 256 water-stressed districts. to promote water conservation and water resource management by focusing on accelerated implementation of five targeted interventions viz. water conservation and rainwater harvesting, renovation of traditional and other water bodies, reuse of water and recharging of structures, watershed development and intensive afforestation. Besides, the special interventions included development of Block Water Conservation Plans and District Water Conservation Plans, Krishi Vigyan Kendra Melas, Urban Wastewater Reuse and 3D contour mapping of all villages. The JSA has already delivered over 3.5 lakh water measures in 256 districts. An estimated 2.64 crore people have already participated in the JSA making it a Jan Andolan.

7.6 Mission Amrit Sarovar

Main objective of this mission is to harvest and conserve water for future generation. This includes conserving water besides serving some other purposes like expediting the infrastructural projects with soil and silt from the ponds, generating employment opportunities, irrigation, augmentation of tourism, fisheries etc. The salient features of the Mission Amrit Sarovar is as follows-

- Every district of the country will construct or rejuvenate at least 75 Amrit Sarovars.
- Every Amrit Sarovar will have a pondage area of at least 1 acre with a water holding capacity of about 10,000 cubic metres.
- Every Amrit Sarovar will be surrounded by trees like Neem, Peepal and Banyan etc.
- Every Amrit Sarovar will be a source of generation of livelihoods by using the water for different purposes like irrigation, fisheries, duckery, cultivation of water chestnut, water tourism and other activities.

Identified synergies with UP State Action Plan on Climate Change

Most water resource management issues as highlighted in UP-SAPCC are cross-cutting and are very relevant to Ramganga RBM Plan and its PoM. A total of INR 64170.13 Crore has been the proposed budget of implementation of Jal Mission under UP SAPCC. The key activities under Jal Mission

- Enhanced monitoring and research to establish water budgets and manage water at micro-watershed level
  - Cover all 551 blocks with hydro met monitoring stations.
  - 4062 piezometers in 4062 wells across UP
  - Water budgets for 59,163 gram panchayats and 3894 urban centre
- Strengthening water sector infrastructure to adapt to climate change
  - Development of guidelines for retrofitting/ building climate resilient water infrastructure (dams, barrages, canals and check dams)
  - Development of course that teaches guidelines for retrofitting/ building climate resilient water infrastructures.
- Enhances water use efficiency across sectors to reduce dependency on surface and groundwater
  - Develop baseline water consumption for water intensive industries (thermal power plants, textile, leather, paper and pulp, sugar and ethanol industries, hotels, beverages industries, dairy and steel miles)
  - A compendium of best practices on water use efficiency across sectors
  - Fixing of water use limits for different industries types and water metering
  - Notification issued to all water intensive industries to re use waste water
- Enhances efforts towards groundwater recharge
- Building resilient towards frequent and unprecedented floods even at non-traditional flooding regions and months
- Proposal to constitute 8 basin authorities for all the 8 rivers flowing through the state.

The financial analysis suggests that out of INR 64170.13 Crore budget, a whooping INR 47301 Crore is already available through different national and state level missions/programmes, and the financial gap is only 26% of the total cost.

In addition to the Jal Mission of UP SAPCC as briefed above, ample opportunities to synergise the efforts are also available under other missions (sustainable agriculture, green UP and disaster management) of UP SAPCC).

7.7 Atal Mission for Rejuvenation and Urban Transformation (AMRUT) – Phase I

While Atal Mission for Rejuvenation and Urban Transformation (AMRUT) phase I focusses on development of basic urban infrastructure in water supply, wastewater management, green area development and stormwater management in the 500 cities (having population more than 100,000). Significant progress has been made under AMRUT -I. There are 15 AMRUT towns in Ramganga Basin which have been benefited from the Mission.

Budget Allocation: Against the total plan size of Rs.77,640 crore of all the SAAPs (State Annual Action Plans), Rs.39,011 crore (50%) has been allocated to water supply, Rs.32,456 crore (42%) to sewerage and septage management, Rs.2,969 crore (4%) storm water drainage projects.

7.8 Swachh Bharat Mission (SBM)

When it comes to solid waste management, Swachh Bharat Mission (SBM) is the major program of GoI which provides exceptional synergy. The SBM 1.0 focused on construction of latrines to achieve Open Defecation Free status and solid waste management. The SBM 2.0 was launched was launched in October 2021 with the mission to make all our cities 'Garbage Free'. SBM-Urban 2.0 focuses on: (i) sludge management, (ii) waste-water treatment, (iii) source segregation of garbage, (iv) reduction in single-use plastics and (v) control of air pollution caused by construction, demolition, and bioremediation of dumpsites. The capacity building/public awareness component of the Mission also provides adequate opportunities to implement several PoM in collaboration.

Budget allocation: SBM (Rural) - Rs. 7192.0 crore and SBM (Urban) – Rs. 5000.0 crore for the year 2023-24

7.9 Namami Gange Mission

Namami Gange Programme is an Integrated Conservation Mission to accomplish the twin objectives of effective abatement of pollution and conservation and rejuvenation of National River Ganga. It is being operated under the MoWR,RD&GR and is implemented by the NMCG, and its state counterpart organizations i.e SMCGs. The Mission is currently in its 2nd Phase which will last until 2026.

Features

- 374 projects on cleaning the main stem of river Ganga and its first order tributaries are taken up along the main stem towns of river Ganga and 15 tributaries. Out of these 374 projects, 210 projects are completed, and the remaining projects are at various stages of completion.
- 49 sewage management projects are under implementation and 98 sewage projects have been completed in 9 states. 28 sewage projects are under tendering and 1 new sewage projects launched in these states. Work is under construction for creating a sewerage capacity of 5175.87 (MLD).
- Projects to develop science - based aquatic species restoration plan for Ganga River along with conservation & restoration of aquatic biodiversity.
- A series of public outreach and community participation activities such as events, workshops, seminars and conferences and numerous IEC activities are organized.
- Regulation and enforcement through regular and surprise inspections of GPIs is carried out for compliance verification against stipulated environmental norms. Action has been taken against 110 non-complying GPIs and are issued closure directions. Online Continuous Effluent Monitoring Stations (OCEMS) connectivity established to CPCB server in 885 out of 1072 GPIs.

Budget Allocation: INR 20,000 crore and INR 22,500 crore for Namami Gange Mission I and II respectively.

7.10 Atal Bhujal Yojana

The goal of Atal Bhujal Yojana (Atal Jal) is to demonstrate community-led sustainable ground water management which has potential for upscaling. The major objective of the scheme is to improve the management of groundwater resources in select water stressed areas in identified states including Uttar Pradesh. The scheme lays emphasis on community participation and demand side interventions for sustainable ground water management in identified water stressed areas in seven States of the country. The scheme also envisages improved source sustainability for Jal Jeevan Mission, positive contribution to the Government's goal of 'doubling farmers income' and inculcating behavioral changes in the community to facilitate optimal water use.

Budget Allocation: The scheme is being taken up in 8353 water stressed Gram Panchayats of 7 states of India. The proposed budget of for facilitating sustainable ground water management is INR 6,000 crore. For the state of Uttar Pradesh, allotted funds is about 729.24 Crores for incentives and institutional strengthening & capacity building.

7.11 Micro Irrigation Fund (MIF)

The main objective of the MIF (Micro Irrigation Fund) is to help and support the state government to prepare and organise resources for Micro Irrigation expansion by setting special and innovative technologies like drip & sprinkler irrigation. It includes providing special subsidies on micro irrigation setups beyond the provision available under Pradhan Mantri Krishi Sinchayee Yojana to encourage farmers to install micro irrigation system. Under MIF, Central Government provides subsidy @55% of the indicative unit cost to small and marginal farmers and @45% to other farmer for encouraging them to install Drip and Sprinkler system. It intends to cover 69.55 million hectare area under micro irrigation. The capacity building/.training part is being handled by the Indian Council of Agriculture Research through KVKs.

Budget Allocation: INR.5,000 crore for setting up MIF (Micro Irrigation Fund)

7.12 Mahatma Gandhi National Rural Employment Guarantee Scheme (MNRGES)

The Mahatma Gandhi National Rural Employment Guarantee Act, 2005 (MGNREGA) is intended to provide at least 100 days of guaranteed wage employment in a financial year to every rural household whose adult members volunteer to do unskilled manual work. Another aim of MGNREGA is to create durable assets (such as roads, canals, ponds, wells). Employment is to be provided within 5 km of an applicant's residence, and minimum wages are to be paid. If work is not provided within 15 days of applying, applicants are entitled to an unemployment allowance. Thus, employment under MGNREGA is a legal entitlement. MGNREGA is to be implemented mainly by gram panchayats (GPs). Labour-intensive tasks like creating infrastructure for water harvesting, drought relief and flood control are preferred. As a sub-component of MNREGS, Mission Water conservation is also being implemented with activities including flood management, groundwater recharge and conservation.

Budget Allocation: The financial allocation under MNRGES for financial year 2021-22, was INR 73,000 crore at Budget Estimate stage to Rs. 98,000 crore at Revised Estimate stage.

7.13 Smart City Mission

Smart Cities Mission is an urban renewal and retrofitting programme launched on 2015 to develop smart cities and make them citizen friendly and sustainable and to address problems orientate to the population growth in cities which connects to infrastructure management and service delivery challenges. The objective of the smart city initiative is to promote sustainable and inclusive cities that provide core infrastructure to give a decent quality of life, a clean and sustainable environment through application of some smart solutions such as data-driven traffic management, intelligent lighting systems, etc. The core infrastructure elements in a Smart City relevant to Ramganga RBMP include:

- Adequate water supply
- Sanitation including solid waste management
- Affordable housing, especially for the poor
- Good governance, especially e-governance and citizen participation
- Sustainable environment

The Mission covers 100 cities including 4 from Ramganga Basin (Moradabad, Rampur, Bareilly and Shahjahanpur) and is being implemented by the MoHUA jointly with state and union territory (UT) governments. Initially, its duration is of 5 years (FY2015-16 to FY2019-20) but the Ministry has extended the timeline to June 2023 due to the Covid pandemic.

7.14 Jal Jeevan Mission (JJM)

Though the Jal Jeevan mission mainly focuses on providing safe water to every household through functional tap, one of the major components of the Mission is to protect sources from any contamination and depletion to ensure sustainable water supply to all. Activities under the source sustainability components encompasses like groundwater recharges, desilting of irrigation dams, rejuvenation of water bodies and afforestation. Also, the JJM-R converges well with MNREGA (rural minimum employment guaranty scheme), Compensatory Afforestation fund Management and Planning Authority (CAMPA), *Atal Bhujal Yojana* for the source sustainability. JJM-R also required *Gram Panchayats* (GPs – Village Council) to develop water safety plan and water budgets detailing the available sources including rainfall. The Mission also has another important component on greywater management which can very well be integrated with PoM of Ramganga Basin.

7.15 Khet Talab Yojana

With the funding support from Rashtriya Krishi Vikas Yojana, UP Government is implementing Khet talab Yojana to promote the collection of rainwater to store safely for groundwater recharge and use for irrigation. 50% Grant in term of subsidy (DBT) is given to the construction of pond. For a small pond (22*20*3 m), Rs 1,05000 and for medium size pond (35*30*3 m), Rs 2,28400 are the current rates.

7.16 Flood Management and Border Area Programme

The GoI supports the State Governments on works related to flood control, anti-erosion, drainage development, restoration of damaged flood management works by providing technical guidance and financial assistance through Flood Management & Border Area Programme (FMBAP). Under River Management and Border Areas (RMBA) component of the programme, 100% central assistance is provided for hydrological observations and flood forecasting, and pre-construction activities for water resources projects on common border rivers, and activities of Ganga Flood Control Commission (GFCC). 427 projects have been completed under the FMP component of the scheme. Benefitting 4.99 mha.

7.17 National Mission of Natural Farming

GoI has launched National Mission on Natural Farming to encourage farmers to opt for chemical free farming by adopting the natural farming. The objective is to induce behavioral change in farmers to shift from chemical based inputs to cow based locally produced input through awareness, training, handholding, and capacity building of farmers. The provision of Rs 459.00 crores for 2023-24 has been considered.

8 IMMEDIATE STEPS AND WAY FORWARD

8.1 Immediate steps

Towards the implementation level of Ramganga RBM Plan, following steps are seen as vital and to be taken up immediately:

- The first step towards implementation could be a ***clear allocation of responsibilities*** among stakeholders (National/SMCG/District/ULB) as defined in the PoM. This shall also include a clear understanding and agreement among all stakeholders on the financial arrangement (exploring convergence opportunity) and timelines. For the long-term PoM, a high-level strategy needs to be agreed with senior leadership of the institutional involved. If deemed appropriate, an implementation plan with milestones may also be requested from these institutions.
- Regarding the issues pertaining to ***legacy waste*** (hazardous electronic wastes), there is a need to carry out a geo-spatial scientific study on the identification of sites, estimation of quantum of waste and understand impacts of legacy waste on water resources. This can be immediately initiate by the UP-PCB in close coordination with the SMCG-UP, District and Municipal Administration of Moradabad. NMCG may issue a directive in this direction.
- One of the important and immediate steps is to ***strengthen the existing network of monitoring programme*** (for both surface and groundwater) i.e. increasing number of monitoring stations, frequency of sampling and parameters. The introduction of new relevant parameters such as emerging contaminants needs to be deliberated. Intense agriculture activities in the basin and associated use of pesticides and fertilisers could not be correlated with the nitrate concentrations as reported in groundwater. Surface water quality does not capture nutrients concentration. There could be a dedicated time bound studies to assess the traces of nutrients and pesticides in surface and groundwater. The All India Network Project on Pesticide Residues (AINP-PR) under Central Ministry of Agriculture and Farmers Welfare can be entrusted with this responsibility. The First step towards this could be the formation of a dedicated TEG having members from NMCG, CPCB, UK/UP -PCB, CGWB and CWC.
- ***Constructed wetlands*** are man-made structures imitating a natural wetland to treat water. They can be continuously flooded, intermittently flooded or even non-flooded systems. Constructed Wetlands require a rather constant inflow of wastewater, appropriate plant selection, enough size, slope and maintenance. They are cheaper compared to engineered wastewater treatment plants. Experiences do exist in tropical environments. If pilot areas/sites are identified, this could be launched quickly since construction does not require a long planning process and implementation can happen fast.
- Another important step is to start streamlining the process to ***acquire data related to sand-mining*** in Ramganga Basin. The state departments of mining and geology and environment could be requested to provide an inventory of sandmining permits along with geo-coordinates. This can further be used to generate geo-spatial tool for regular monitoring.
- As NMCG has already been working to develop DEM maps using Lidar, the same can be extended to develop ***flood inundation maps*** for selected locations (under high risk as per Chapter 5) in Ramganga Basin.
- The on-ground implementation of ***National Framework for Safe Reuse of Treated Water*** shall be deliberated with the basin states. This, if successful implemented, has huge potential to

divert the treated water from entering the water bodies. The co-benefit of SRTW will be the additional revenues for municipal governance which can be further used to implement other PoM.

8.2 Way Forward

This first cyclic Ramganga RBM Plan provides a unique opportunity for NMCG to take a leap towards adopting integrated and cyclic approach for River Basin Planning and Management for the development of RBMPs for other sub-basins of Ganga Basin. The availability of four District Ganga Plans developed using the same RBM Cycle approach further is set to be upscaled in all districts in Ganga Basin. In view of this, following are the recommended steps to proceed in this direction;

- As the work towards RBMPs at basin, sub-basin and district level will amplify, a dedicated **RBM Unit** will be required to be set up at the NMCG in first step and gradually at SMCG level also. The RBM Unit will be responsible for coordinating with the relevant stakeholders for the work related to planning, development, and implementation of RBMPs. RBM Unit will be directly reporting to the DG. To start this, 4-5 experts from NMCG can be identified to be the members of RBM Unit.
- As seen in the Ramganga RBM Plan, there is a good scope to further strengthen the network of monitoring programme and create knowledge on the certain data gaps. Also as proposed in the PoM that certain research studies are to be conducted in first cycle of Ramganga RBMP, it will warrant the formation of expert groups on specific themes (**Thematic Expert Group – TEGs**). The process of formation of TEGs including identification of topics, the experts in relevant department/organisations at national and state level, and their ToR and scope of work shall be initiated by the RBM-Unit. TEGs thus constituted, will also contribute towards the development of RBMPs for other sub-basins. To start with this, following TEGs are proposed to be formed:
    - Water Quality Monitoring and Assessment TEG
    - E-Flows Assessment and Monitoring TEG
    - Flood Plain Protection and Flood Management TEG

Below Figure 33 depicts the proposed coordination mechanism during the implementation of Ramganga RBMP.

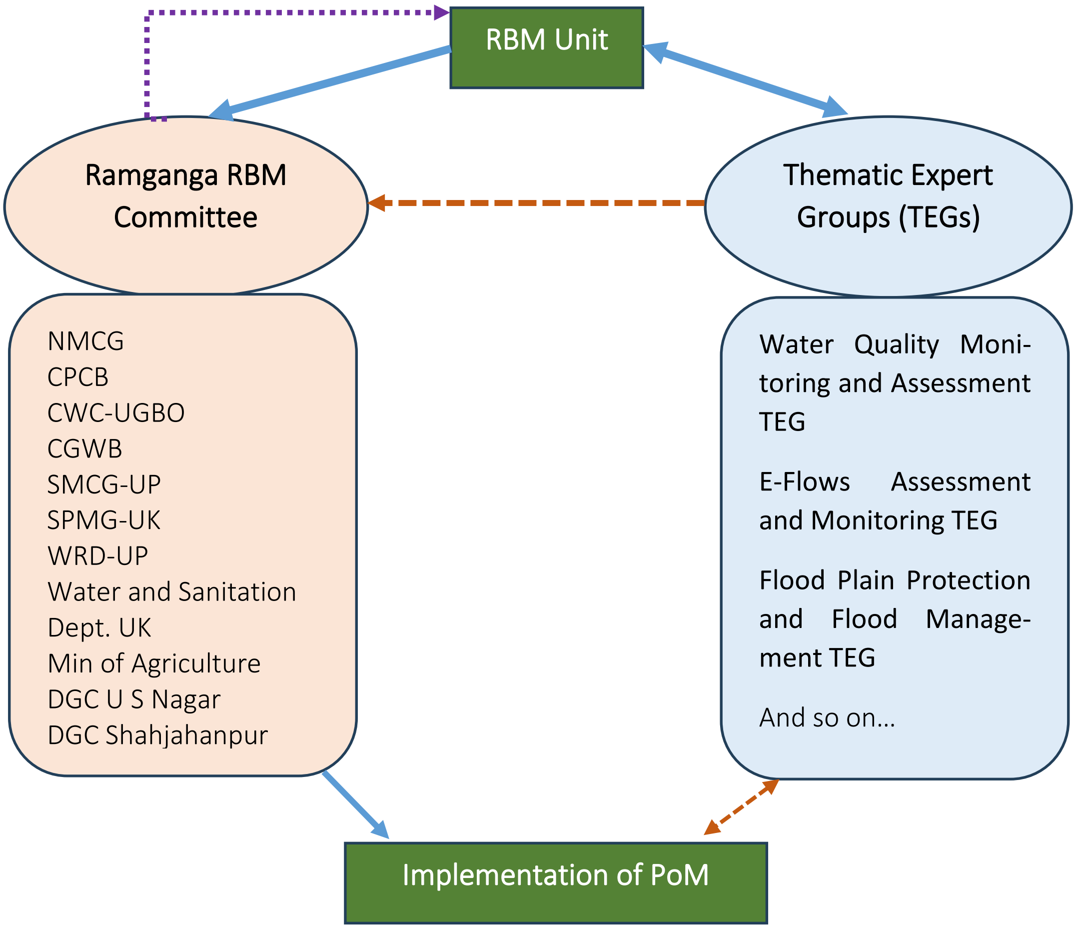

Figure 33: Institutional set-up for the Implementation of PoM

- An effective ***Monitoring and Evaluation*** mechanism including the scheduling of Ramganga RBM Committee meetings must be institutionalised to oversee the progress and take necessary actions as and when required.

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