भारत सरकार
Government of India
जल शक्ति मंत्रालय
Ministry of Jal Shakti,
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
Department of Water Resources, River Development and Ganga Rejuvenation

केन्द्रीय भूमि जल बोर्ड

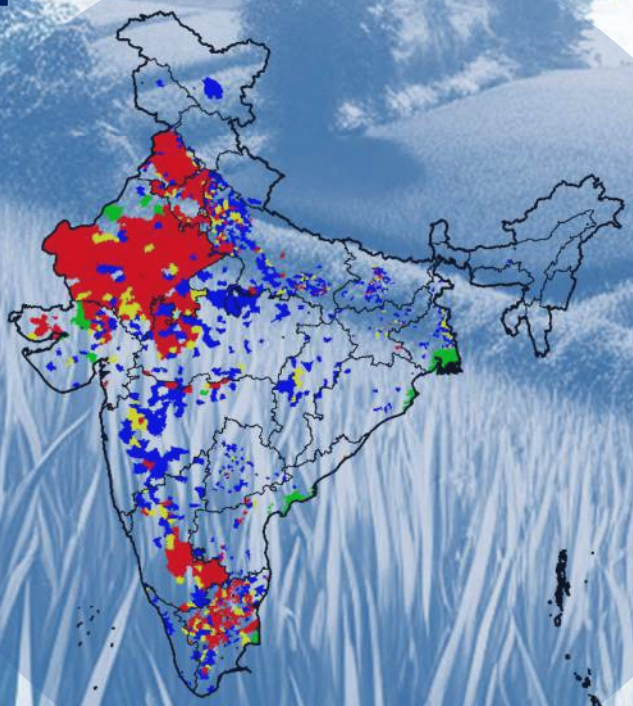
Central Ground Water Board

,

National Compilation on

Dynamic Ground Water Resources of India

2024



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Faridabad
2024

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National Compilation on

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024

Central Ground Water Board
Department of Water Resources,
River Development & Ganga Rejuvenation
Ministry of Jal Shakti
Government of India

Faridabad
December, 2024

ISBN 978-81-984761-7-3

सी आर पाटील
C R Paatil

सत्यमेव जयते

जल शक्ति मंत्री
भारत सरकार
Minister of Jal Shakti
Government of India

MESSAGE

Groundwater is the lifeline of India's water security, playing a pivotal role in sustaining agriculture, ensuring access to drinking water, and supporting livelihoods across the nation. Effective and responsible management of groundwater is essential to secure the nation's food and water needs for generations to come. The Ministry of Jal Shakti has spearheaded transformative initiatives such as the **Jal Shakti Abhiyan- Jan Bhagidari se Jal Suraksha**, and **Atal Bhujal Yojana** to prioritize groundwater management and inspire collective action in safeguarding this invaluable resource.

Groundwater resources vary significantly across states, necessitating a region-specific approach for sustainable management. Regular assessments of groundwater resources provide the scientific foundation for informed planning and effective implementation of groundwater-based schemes. The **National Compilation on Dynamic Ground Water Resources of India, 2024**, meticulously prepared by the Central Ground Water Board in collaboration with State Governments and Union Territories, serves as a comprehensive and actionable guide for stakeholders across the country.

I am confident that this report will empower states and stakeholders with the data and insights required to adopt an integrated and sustainable approach to groundwater management on a national scale. Let us work together to ensure the judicious use and conservation of this critical resource, securing a water-resilient future for India.

I congratulate the Central Ground Water Board, the Ministry of Jal Shakti, and all State Governments and Union Territories for their dedication and collaborative efforts in completing this significant task. Together, let us reaffirm our commitment to protecting and managing India's groundwater resources with care, foresight, and responsibility.

C R PAATIL

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V. SOMANNA

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जल शक्ति एवं रेलवे मंत्रालय
भारत सरकार
Minister of State
Jal Shakti and Railways
Government of India

Message

Groundwater plays a crucial role in fulfilling the irrigation, domestic, and industrial needs of the nation. Its ease of access and lower supply costs compared to other water sources has led to over-extraction of this precious resource in certain parts of the country. Around 70% of India is characterized by hard rock formations and with substantial variations in climate and rainfall in the Peninsular India and North western states, water availability is becoming increasingly critical. Considering our heavy dependence on ground water and the high costs associated with alternative sources, judicious development of this precious resource coupled with effective management practices across India is the need of the hour. The proactive initiatives undertaken by both the Central and State Governments have played a key role in stabilizing groundwater resources over the years.

In our commitment to assessing groundwater resources annually, the Ministry of Jal Shakti and the Central Ground Water Board (CGWB), has made significant strides with the web-based application IN-GRESS (India Groundwater Estimation System). This collaborative effort with all State Governments and Union Territories has culminated in the **National Compilation of Dynamic Ground Water Resources of India 2024**. This report will be a useful document for policymakers, stakeholders, and the general public, and can facilitate holistic groundwater management and its judicious use.

I extend my congratulations to the entire CGWB team and the State government departments for their dedicated efforts in timely completion of the assessment and bringing this national compilation which can be a guiding text for sustainable ground water management in the country.

(V. Somanna)
Minister of State

27th December, 2024
New Delhi

डॉ. राज भूषण चौधरी
Dr. Raj Bhushan Choudhary

सत्यमेव जयते

जल शक्ति राज्य मंत्री
भारत सरकार
नई दिल्ली-110001
MINISTER OF STATE FOR JAL SHAKTI
GOVERNMENT OF INDIA
NEW DELHI - 110001

Message

Groundwater is a cornerstone of India's agricultural productivity and economic growth, supporting livelihoods and ensuring water security for millions. The Central Ground Water Board (CGWB), in collaboration with State Governments and Union Territories, undertakes an annual nationwide groundwater resource assessment to provide a clear understanding of this vital resource. This assessment details the annual groundwater recharge, extractable resources, and potential for future development, offering invaluable insights for effective planning and decision-making.

The National Compilation on Dynamic Ground Water Resources of India, 2024 serves as a critical resource for planners, policymakers, and administrators at all levels. It not only guides the judicious development, management, and regulation of groundwater but also provides the general public and stakeholders with an updated perspective on the country's groundwater scenario. This data-driven approach is essential for evaluating the impact of various interventions initiated by both Central and State Governments towards achieving sustainable groundwater management.

I urge all stakeholders—State Governments, planners, policymakers, and civil society—to leverage the insights from this compilation for safeguarding our groundwater resources. Let us work collectively to ensure that this precious resource is preserved and managed wisely for the benefit of current and future generations.

I congratulate the Central Ground Water Board, along with all State Governments and Union Territories, for their collaborative efforts and commitment in bringing out this significant report in a timely manner. Your dedication is a step towards a water-secure and sustainable future for India.

Raj Bhushan Choudhary
(Dr. Raj Bhushan Choudhary)

New Delhi

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देवश्री मुखर्जी
Debashree Mukherjee
सचिव
SECRETARY

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION

MESSAGE

Groundwater is a vital resource that supports India's drinking, agricultural, and industrial water needs. Despite covering an area of 3.3 million square kilometers and being home to 16% of the global population, India has only 4% of the world's freshwater resources. This limited availability, combined with uneven distribution, overexploitation in some regions and changing climate scenario, highlights the need for sustainable groundwater management.

Effective groundwater management begins with a clear understanding of its availability, usage, and challenges. Every year, the Central Ground Water Board (CGWB), in collaboration with State Groundwater Departments, undertakes a systematic assessment of the country's groundwater resources. The **'National Compilation on Dynamic Ground Water Resources of India, 2024'** consolidates these findings, offering a comprehensive overview of the state-wise groundwater scenario. This report provides a strong scientific foundation for crafting effective policies, management strategies, and regulatory measures.

I commend the CGWB and State/UT Ground Water Departments for their hard work in preparing this valuable report. I am confident it will serve as a key resource for stakeholders across the country, helping us collectively ensure the sustainable use and management of India's groundwater resources.

(Debashree Mukherjee)

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सुबोध यादव
SUBODH YADAV
अपर सचिव
ADDITIONAL SECRETARY

सत्यमेव जयते
आज़ादी का अमृत महोत्सव

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION

Message

Groundwater is a vital component of India's water resources, providing drinking water for millions, supporting agricultural productivity, and sustaining industrial growth. It is integral to maintaining ecological balance and ensuring socio-economic development. Considering the important role in ensuring food and water security, its regular assessment becomes vital for sustainable management and development.

Recognizing the need for a sustainable approach to groundwater management, the Central Ground Water Board (CGWB), in collaboration with the States and Union Territories, has carried out the 'Dynamic Ground Water Resource Assessment – 2024'. This comprehensive assessment provides an up-to-date understanding of groundwater resources across different regions of India, helping policymakers, planners, and water resource managers make informed decisions. It also incorporates scientific advancements, improved methodologies, and updated data, reflecting the dynamic nature of groundwater resources, which are influenced by factors such as rainfall variability, land use changes, and groundwater extraction patterns.

The 2024 assessment stands as a testament to our commitment to developing a holistic groundwater management strategy, balancing development needs with the long-term sustainability of this precious resource. It is heartening to know that 'Safe' assessment units have further improved from the previous assessment in 2023, while 'over-exploited assessment units have declined, indicating an overall improvement in groundwater management.

The cooperation and dedication of State and UT agencies have been instrumental in completing this assessment, and I extend my sincere appreciation to all stakeholders involved. The insights derived from this report will serve as a valuable resource for formulating region-specific groundwater management strategies, ensuring that India's groundwater resources are utilized judiciously, equitably, and sustainably. I am confident that this document will contribute to the broader objective of water security, supporting the nation's progress towards a resilient and water-sufficient future.

(Subodh Yadav)
Additional Secretary

December, 2024
New Delhi.

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डॉ. सुनील कुमार अम्बष्ट
अध्यक्ष
Dr. Sunil Kumar Ambast
Chairman

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन,
नदी विकास और गंगा संरक्षण विभाग
केन्द्रीय भूमि जल बोर्ड
Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development & Ganga Rejuvention
Central Ground Water Board

FOREWORD

Groundwater is a vital resource that sustains agriculture, households and industries nationwide. To ensure the sustainability of this critical resource, planning and implementation of proper management strategies and regulatory measures is the need of the hour. It is rightly said that "we can only manage what we can measure," highlighting the importance of proper monitoring and assessment in groundwater management.

The annual dynamic groundwater resources of the country are being assessed using 'Ground Water Estimation Methodology - 2015' (GEC-2015) through "India Groundwater Resource Estimation System" (IN-GRES), a GIS based web platform for all States and Union Territories. This report on Dynamic Groundwater Resource Assessment of 2024 (GWRA-2024) is a collaborative effort of both the State/UT Ground Water departments and the Central Ground Water Board. The annual assessment is providing a clear understanding of groundwater dynamics, its recharge, extraction and serves as the foundation for planning and implementation of strategies for sustainable management of groundwater resources across the Country.

I commend the dedicated efforts of CGWB, CHQ for their pivotal role in compiling this National report, CGWB's Regional, State Unit offices and all the State Ground Water Nodal Departments in conducting the assessment. I also appreciate the valuable contributions of the Central Level Expert Group (CLEG) and State Level Committees (SLCs) for their guidance in timely completion of the assessment and National Compilation. I believe that, this comprehensive report will serve as an important document for planners, decision-makers and stakeholders in securing the groundwater resources for Viksit Bharat.

Jai Hind.

Faridabad
December, 2024

(Dr. Sunil Kumar Ambast)
Chairman, CGWB &
Chairman of the CLEG

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टी. एस. अनीता श्याम
सदस्य (दक्षिण)
T. S. Anitha Shyam
Member (South)

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग
केंद्रीय भूमि जल बोर्ड
Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development and Ganga Rejuvenation
Central Ground Water Board

PREFACE

Groundwater plays an important role in the Nation's economic growth and forms a vital component of our ecological system. India's agricultural productivity, industrial output, and domestic water supply are heavily reliant on groundwater. However, rising water demands have led to excessive groundwater extraction in many parts of India, exceeding the annual replenishment leading to decline in groundwater level. A thorough assessment of this hidden resources is essential for developing strategies for management and regulatory measures. Since 2022, it has been decided to carry out the estimation of the Dynamic Groundwater Resources of the nation every year to provide the planners, decision makers and all stakeholders with reliable data/information for taking timely measures for sustainable management of groundwater resources.

The assessment of dynamic groundwater resources of the Country is based on the Groundwater Estimation Methodology of 2015 (GEC-2015), which comprehensively factors in all relevant parameters contributing to groundwater recharge and extraction. The Dynamic Groundwater Resource Assessment of 2024 (GWRA-2024) for all States and Union Territories is a collaborative effort involving both the respective State/UT Ground Water Departments and the Central Ground Water Board, utilizing the INDIA-Ground Water Resource Estimation System (IN-GRES) Software.

I extend my heartfelt appreciation to the dedicated officers of CGWB, CHQ, for their significant role in compiling the national-level data. My gratitude also goes to the officers of CGWB and State Ground Water Nodal Departments for their relentless efforts in conducting assessments for their respective States and Union Territories according to the planned schedule.

The valuable contributions of the CLEG and SLC members in refining the National Report are also acknowledged. I hope this national compilation will serve as a important document for planners, decision-makers, and all concerned stakeholders in prioritizing actions necessary to ensure the sustainability of groundwater resources in the country.

(T. S. Anitha Shyam)
Member (South) &
Member Secretary (CLEG)

Faridabad
December 2024

Dynamic Ground Water Resources Estimation of India-2024

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2.	Annual Extractable Ground Water Resources	: 406.19bcm
3.	Annual Ground Water Extraction	: 245.64bcm
4.	Stage of Ground Water Extraction	: 60.47%

CATEGORIZATION OF ASSESSMENT UNITS

(Blocks/ Mandals/ Taluks etc.)

Sl.No	Category	Number of Assessment Units		Recharge worthy Area		Annual Extractable Ground Water Resource	
		Number	%	in lakh sq. km	%	(in bcm)	%
1	Safe	4951	73.39	16.51	66.57	301.17	74.14
2	Semi Critical	711	10.54	2.82	11.40	45.76	11.27
3	Critical	206	3.05	0.88	3.55	13.23	3.26
4	Over-Exploited	751	11.13	4.20	16.93	46.02	11.33
5	Saline	127	1.88	0.38	1.55	NA	NA
	TOTAL	**6746**		**24.80**		**406.19**	

EXECUTIVE SUMMARY

Ground Water Resource Assessment is carried out at periodical intervals jointly by State Ground Water Departments and Central Ground Water Board under the guidance of the respective State Level Committee on Ground Water Assessment at State Levels and under the overall supervision of the Central Level Expert Group (CLEG). Such joint exercises have been taken up earlier in 1980, 1995, 2004, 2009, 2011, 2013, 2017, 2020, 2022, and 2023. From the year 2022, the exercise is being carried out annually.

The assessment involves computation of dynamic ground water resources or Annual Extractable Ground Water Resource, Total Current Annual Ground Water Extraction (utilization) and the percentage of utilization with respect to annual extractable resources (stage of Ground Water Extraction). The assessment units (Talukas/blocks/mandals) are categorized based on Stage of Ground Water Extraction, which are then validated with long-term water level trends. The assessment prior to that of year 2017 were carried out following Ground Water Estimation Committee (GEC) 97 Methodology, whereas from2017 onwards assessment are based on norms and guidelines of the GEC 2015 Methodology.

The main source of replenishable ground water resources is recharge from rainfall, which contributes to nearly 61 % of the total annual ground water recharge.

Over 75% of the annual rainfall is received in the four rainy months for June to September only thereby leading to large variations on temporal scale. Rainfall is the main source of ground water recharge in the country. However, distribution of rainfall has a wide variation both in space and time. The areas on Western Ghats, Sub-Himalayan areas in North East and Meghalaya Hills receive heavy rainfall over 250 cm annually, whereas the areas of Northern parts of Kashmir and Western Rajasthan receive rainfall less than 40 cm. A major part of the country including Northern, Central and Eastern parts receives annual normal rainfall between 75 and 150 cm. In general, rainfall decreases westwards in the northern part of the country, whereas it decreases eastwards and then increases toward the coast in Peninsular India.

Type of rock formations and their storage and transmission characteristics have a significant influence on ground water recharge. Porous formations such as the alluvial formations in the Indo-Ganga-Brahmaputra basin generally have high specific yields and are good repositories of ground water. Ground water occurrence in the fissured formations occupying nearly two-thirds of the geographical area of the country, on the other hand,is mostly limited to the weathered, jointed and fractured portions of the rocks.

In the present assessment, the total annual groundwater recharge in the country has been assessed as 446.90bcm. Keeping an allocation for natural discharge, the annual extractable ground water resource has been assessed as 406.19bcm. The annual groundwater extraction (as in 2024) is 245.64bcm. The average stage of groundwater extraction for the country as a whole works out to be about 60.47 %. Out of the total 6746 assessment units (Blocks/ Mandals/ Talukas) in the country, 751 units in various States/ UTs (11.13%) have been categorized as ‘Over-exploited’ indicating ground water extraction exceeding the annual replenished ground water recharge. In, 206 (3.05 %) assessment units, the stage of groundwater extraction is between 90-100% and have been categorized as ‘Critical’. There are 711

(10.54 %) "Semi-critical'' units, where the stage of ground water extraction is between 70 % and 90 % and 4951 (73.39 %) 'Safe' units, where the stage of Ground water extraction is less than 70 %. Apart from these, there are 127(1.88%) assessment units, which have been categorized as 'Saline' as major part of the ground water in phreatic aquifers in these units is brackish or saline. The percentage of Over-exploited and Critical administrative units are more than 25% of the total units in the State/UT of Delhi, Haryana, Punjab, Rajasthan, Tamil Nadu, Dadra & Nagar Haveli, and Daman & Diu . Similarly, out of 2480.22 thousand sq km recharge worthy area of the country, 419.93 thousand sq km (16.93%) are under 'Over-Exploited', 88.16 thousand sq km (3.55 %) are under 'Critical', 282.77 thousand sq km (11.40%) are under 'Semi-Critical', 1651.03 thousand sq km (66.57 %) are under 'Safe' and 38.31 thousand sq km (1.55%) are under 'Saline' category assessment units. Out of 406.19bcm of Total Annual Extractable Resources of the country, 45.02bcm (11.33%) are under 'Over-Exploited', 13.23bcm (3.26%) are under 'Critical', 45.76bcm (11.27%) are under 'Semi-Critical', 301.17bcm (74.14%) are under 'Safe' category assessment units.

In comparison to 2023 assessment, the total number of assessment units in the country has increased from 6553 to 6746 with major contribution (in increase) from the State of Jammu Kashmir and Sikkim, where assessment for the year 2024 has been done with Block as the assessment unit in place of District. Similarly there has been minor increase in the number of assessment units for Telangana, Karnataka, Maharashtra, Andhra Pradesh, and Meghalaya due to modifications in the existing administrative units.

In comparison to Dynamic Ground Water Resource Assessment 2023,the total annual ground water recharge has decreased marginally from 449.08bcm to 446.90bcm, The change is attributed mainly to change in recharge from 'Other Sources' specially reduction in return flow from irrigation. Accordingly, the annual extractable ground water resources has also decreased marginally from 407.21 to 406.19bcm. The ground water extraction has marginally increased from 241.34 bcm to 245.64bcm. The overall stage of groundwater extraction has marginally increased from 59.21 % to 60.47 %.

The over-exploited assessment units are mostly concentrated in :(i) the north western part of the country including parts of Punjab, Haryana, Delhi and Western Uttar Pradesh where even though the replenishable resources are abundant, there have been indiscriminate withdrawals of ground water leading to over-exploitation; (ii) the western part of the country, particularly in parts of Rajasthan and Gujarat, where due to arid climate, groundwater recharge itself is limited, leading to stress on the resource and (iii) the southern part of peninsular India including parts of Karnataka, Tamil Nadu Telangana and Andhra Pradesh, where due to inherent characteristics of crystalline aquifers, the ground water availability is low. In some areas of the country, good continuous rainfall and management practices like ground water augmentation and conservation measures taken up under Central and State Government initiatives have resulted in improvement in ground water situation.

CHAPTER 1

INTRODUCTION

Water is a fundamental resource essential for life, and groundwater has increasingly become a crucial natural resource meeting the freshwater needs of various sectors in India. However, the sustainable development and efficient management of this limited resource pose significant challenges. Groundwater is the backbone of India's agriculture and drinking water security, contributing nearly 62% to irrigation, 85% to rural water supply, and 50% to urban water supply. Although groundwater is replenished annually, its availability is uneven across different locations and times. The groundwater in the zone of water level fluctuation is primarily recharged annually, with rainfall being the main contributor.

The National Water Policy of 2012 emphasizes periodic, scientifically-based assessments of groundwater resources, including evaluating trends in water availability due to factors such as climate change during water resource planning. To meet growing water demands, the policy advocates for direct rainfall use, desalination, and minimizing unnecessary evapotranspiration to augment usable water resources. Additionally, the policy prioritizes safe water for drinking and sanitation, followed by other domestic needs (including animals), food security, subsistence agriculture, and minimum ecosystem needs. Any remaining water should be allocated to promote conservation and efficient use. Therefore, sustainable groundwater utilization requires a realistic and scientifically sound quantitative assessment of its availability.

1.1 PREVIOUS ASSESSMENTS

The assessment of water resources in India began in 1901 with the First Irrigation Commission estimating surface water resources at 144 million hectare-meters (M.ham). In 1949, Dr. A.N. Khosla estimated the total average annual runoff, including both surface and groundwater, as 167 M.ham. Various committees and task forces have since assessed groundwater resources in response to development needs. The National Commission on Agriculture in 1976 estimated total groundwater resources at 67 M.ham, with 26 M.ham available for irrigation.

The first systematic groundwater assessment methodology was developed in 1979 by the Ground Water Over-Exploitation Committee, estimating the gross recharge at 47 M.ham and net recharge at 32 M.ham. In 1982, the Ground Water Estimation Committee (GEC) was formed, and its recommendations led to the GEC 1984 methodology for assessing dynamic groundwater resources. In 1995, India's total replenishable groundwater was assessed at 432 billion cubic meters (bcm), with 361 bcm available for irrigation and a groundwater development level of 32%.

In 1995, a new committee reviewed and revised the methodology, resulting in GEC 1997. To address challenges in hard rock terrains, further revisions were made in 2001. Dynamic groundwater resources were assessed using GEC 1997 methodology for base years 2004, 2009, 2011, and 2013. Comprehensive revisions led to the GEC 2015 methodology, which has been used for assessments since 2017 (2017, 2020, 2022 & 2023). In response to the rapidly changing patterns of groundwater extraction, the formulation of management strategies, and the need for regulatory interventions to address short-

term fluctuations in groundwater resources, the Ministry of Jal Shakti has proposed the annual estimation of groundwater resources for the country, starting from the year 2022 onwards.

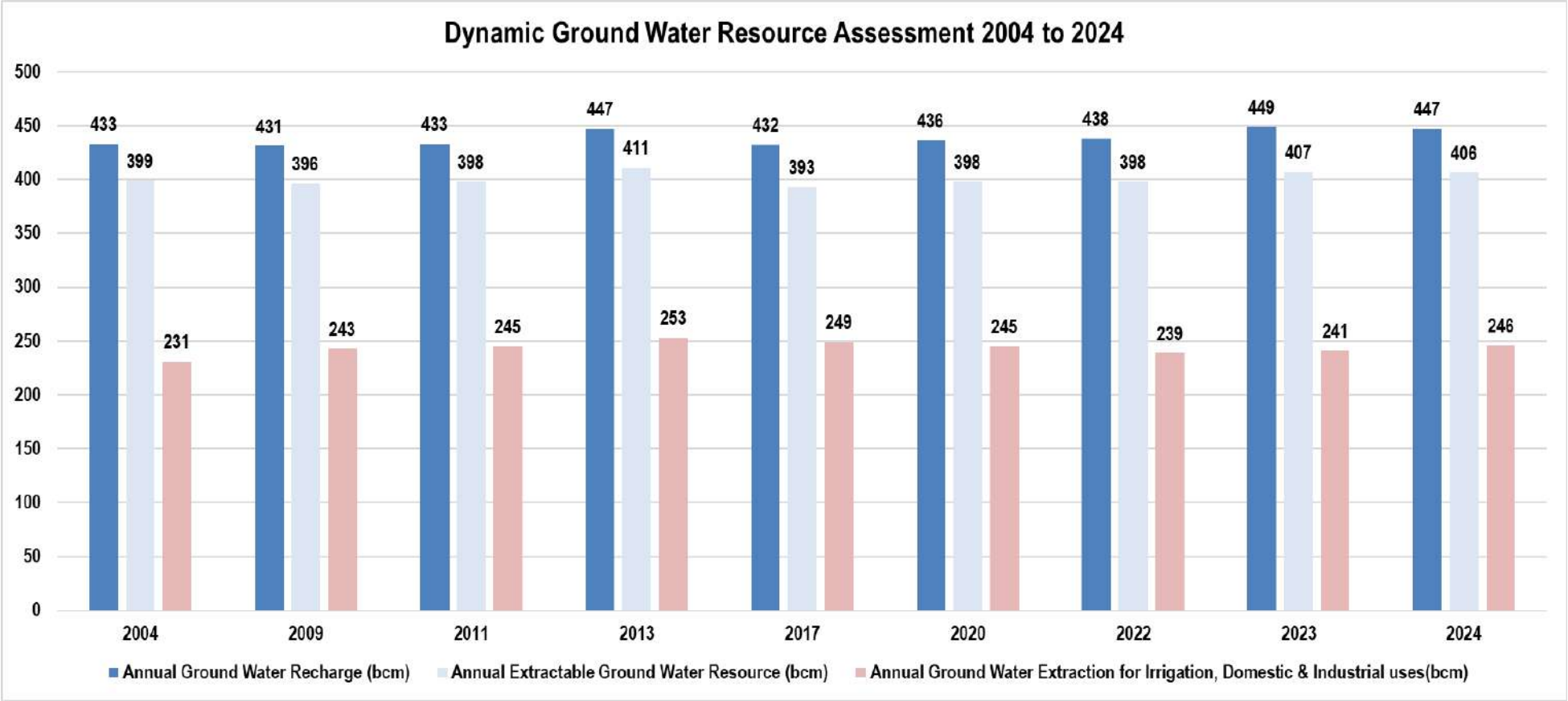
In the present assessment, the total annual groundwater recharge in the country has been assessed as 446.90 bcm. Keeping an allocation for natural discharge, the annual extractable ground water resource has been assessed as 406.19 bcm. The annual groundwater extraction (as in 2024) is 245.64 bcm. The average stage of groundwater extraction for the country as a whole works out to be about 60.47 %. Out of the total **6746** assessment units (Blocks/ Mandals/ Talukas) in the country, **751 units** in various States/ UTs (11.13 %) have been categorized as **'Over-exploited'** indicating ground water extraction exceeding the annually replenishable ground water recharge. In **206** (3.05 %) assessment units the stage of groundwater extraction is between 90-100% and have been categorized as '**Critical**'. There are **711** (10.54 %) "**Semi-critical''** units, where the stage of ground water extraction is between 70 % and 90 % and **4951** (73.39 %) **'Safe'**units, where the stage of Ground water extraction is less than 70 %. Apart from these, there are **127**(1.88%) assessment units, which have been categorised as **'Saline'** as major part of the ground water in phreatic aquifers in these units is brackish or saline. Salient details of status of ground water resources and categorization of assessment units in 2004, 2009, 2011, 2013, 2017, 2020.2022, 2023 and 2024 are shown in ***Table-1.1*** and ***Table-1.2*** respectively.

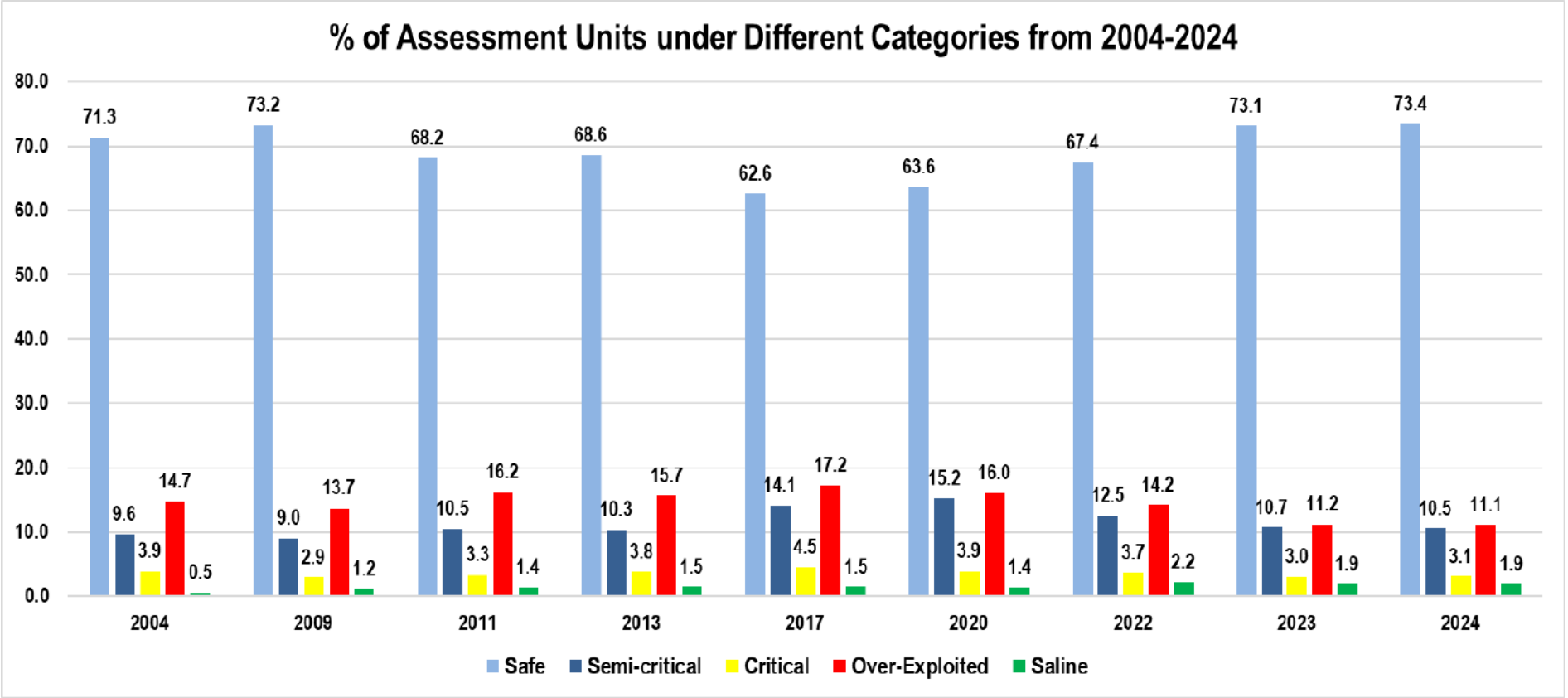
Table-1.1: Ground water Resources assessment 2004 to 2024

S. No.	Ground Water Resources Assessment	2004	2009	2011	2013	2017	2020	2022	2023	2024
1	Annual Ground Water Recharge (bcm)	433	431	433	447	432	436	438	449	446.90
2	Annual Extractable Ground Water Resource (bcm)	399	396	398	411	393	398	398	407	406.19
3	Annual Ground Water Extraction for Irrigation, Domestic & Industrial uses(bcm)	231	243	245	253	249	245	239	241	245.64
4	Stage of Ground Water Extraction (%)	58 %	61 %	62 %	62 %	63 %	62 %	60%	59%	60.47%

Table-1.2: Categorization of assessment units from 2004 to 2024

		2004		2009		2011		2013		2017		2020		2022		2023		2024	
S. No.	Categorization of Assessment Units	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1	Total Assessed units	**5723**		**5842**		**6607**		**6584**		**6881**		**6965**		**7089**		**6553**		**6746**	
2	Safe	4078	71.3	4277	73.2	4503	68.2	4519	68.6	4310	62.6	4427	63.6	4780	67.4	4793	73.1	4951	73.39
3	Semi-critical	550	9.6	523	9	697	10.5	681	10.3	972	14.1	1057	15.2	885	12.5	698	10.7	711	10.54
4	Critical	226	3.9	169	2.9	217	3.3	253	3.8	313	4.5	270	3.9	260	3.7	199	3	206	3.05
5	Over-Exploited	839	14.7	802	13.7	1071	16.2	1034	15.7	1186	17.2	1114	16	1006	14.2	736	11.2	751	11.13
6	Saline	30	0.5	71	1.2	92	1.4	96	1.5	100	1.5	97	1.4	158	2.2	127	1.9	127	1.88


Dynamic Ground Water Resource Assessment 2004 to 2024
500
450
400
350
300
250
200
150
100
50
0
433
399
231
431
396
243
433
398
245
447
411
253
432
393
249
436
398
245
438
398
239
449
407
241
447
406
246
2004
2009
2011
2013
2017
2020
2022
2023
2024
Annual Ground Water Recharge (bcm)
Annual Extractable Ground Water Resource (bcm)
Annual Ground Water Extraction for Irrigation, Domestic & Industrial uses(bcm)


% of Assessment Units under Different Categories from 2004-2024
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
71.3
9.6
3.9
14.7
0.5
73.2
9.0
2.9
13.7
1.2
68.2
10.5
3.3
16.2
1.4
68.6
10.3
3.8
15.7
1.5
62.6
14.1
4.5
17.2
1.5
63.6
15.2
3.9
16.0
1.4
67.4
12.5
3.7
14.2
2.2
73.1
10.7
3.0
11.2
1.9
73.4
10.5
3.1
11.1
1.9
2004
2009
2011
2013
2017
2020
2022
2023
2024
Safe
Semi-critical
Critical
Over-Exploited
Saline

1.2 GROUND WATER ASSESSMENT AND MANAGEMENT INITIATIVES

The findings from groundwater resource assessments are used by planners and stakeholders for managing and optimizing groundwater use. The Government of India has planned and implemented several measures based on these assessments,

1. CGWB has taken up National Aquifer Mapping & Management Programme (NAQUIM), for mapping of major aquifers, their characterization and formulation of Aquifer Management Plans to ensure sustainability of the resources, prioritising Over-exploited, Critical and Semi-critical assessment units. CGWB has also initiated NAQUIM 2.0 under which mapping is being taken up at even finer scale in identified priority areas to address groundwater management issues in challenging areas.
2. The Ministry of Jal Shakti has issued a Model Bill to States/UTs for groundwater regulation and initiated the National Aquifer Mapping & Management Programme (NAQUIM) to map and manage major aquifers, focusing on over-exploited areas.
3. CGWB has taken up high resolution mapping of the aquifers through the state-of-the-art heli-borne geophysical surveys prioritizing the water stressed Over Exploited, Critical and Semi Critical areas. So far, nearly 1.0 lakh sq km area has been covered under this survey in arid parts of NW India. The results of the Heliborne Survey are being used for preparing village/ panchayat level aquifer maps and suitable management interventions.
4. Atal Bhujal Yojana (ATAL JAL) with focus on community participation and demand side interventions for sustainable ground water management in identified water stressed areas has been taken up by DoWR RD &GR. This scheme is expected to contribute significantly towards the water and food security of the participating States. The scheme was launched by the Hon'ble Prime Minister on 25.12.2019 and is being implemented from 1.04.2020 for a period of 5 years. The scheme is being taken up in 8220 water stressed Gram Panchayats of 229 administrative blocks/ Talukas in 80 districts of seven states, viz. Haryana, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh spread over Northern, Central and Southern Parts of the Country.
5. Master Plan for Artificial Recharge to Groundwater- 2020 has been prepared by CGWB in consultation with States/UTs which is a macro level plan indicating various structures for the different terrain conditions of the country including estimated cost. The Master Plan envisages construction of about 1.42 crore Rainwater harvesting and artificial recharge structures in the Country to harness 185 Billion Cubic Metre (BCM) of monsoon rainfall.
6. Several State Governments are implementing watershed development programmes, in which, ground water conservation forms an integral part. Water conservation measures are also taken up as a part of the MGNREGA.
7. Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) Ground Water Component is implemented by the Ministry of Jal Shakti, Government of India, to create irrigation potential through groundwater in Safe assessment units where there is sufficient scope for further future ground water development.
8. Jal Shakti Abhiyan-I (JSA-I) launched in 2019 across 1592 blocks in 256 water-stressed districts, focused on water conservation, rainwater harvesting, and resource management through

targeted interventions. Expanded in 2021 as "Catch the Rain," it covered all districts nationwide, continuing through 2022 and 2023.

The assessment results form the foundation for planning, implementing management schemes, projects, and regulating groundwater resources for various State Governments.

1.3 RE-ASSESSMENT OF GROUND WATER RESOURCES, 2024

Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, constituted a permanent Central Level Expert Group (CLEG) for over-all supervision of the re-assessment of ground water resources in the entire country as in 2024. The terms of reference of the committee include supervision of assessment of annual replenishable ground water resources and the status of utilization for reference year 2023 onwards. A copy of the Government Resolution is in **Appendix A**.

Groundwater resources assessment for reference year 2024 at the State/U.T levels have been carried out jointly by State Ground Water Departments and Central Ground Water Board under the supervision of State Level Committees (**Appendix B**), with technical guidance from Central Level Expert Group. The assessment carried out was approved by the respective State Level Committee (**Appendix D**). Based on the assessments provided by the respective State Level Committees and joint assessment made in the aforesaid States, the *National Compilation of Dynamic Ground Water Resources of India, 2024* has been compiled. The National compilation report provides summary and analysis of ground water resources in different States. The report was reviewed and deliberated upon during the meeting of CLEG held on 08.09.2024 and was approved as mentioned in **Appendix E.**

CHAPTER 2

GROUND WATER RESOURCE ESTIMATION METHODOLOGY

Ground water resource as in 2024 have been estimated following the guidelines mentioned in the GEC 2015 methodology using appropriate assumptions depending on data availability. The principal attributes of GEC 2015 methodology are given below:

It is also important to add that as it is advisable to restrict the groundwater development as far as possible to annual replenishable resources, the categorization also considers the relation between the annual replenishment and groundwater development. An area devoid of ground water potential may not be considered for development and may remain safe whereas an area with good groundwater potential may be developed and may become over exploited over a period. Thus, water augmentation efforts can be successful in such areas, where the groundwater potential is high and there is scope for augmentation.

2.1. GROUND WATER ASSESSMENT OF UNCONFINED AQUIFER

Though the assessment of ground water resources includes assessment of dynamic and in-storage resources, the development planning should mainly focus on dynamic resource as it gets replenished on an annual basis. Changes in static or in-storage resources normally reflect long-term impacts of ground water mining. Such resources may not be replenishable annually and may be allowed to be extracted only during exigencies with proper planning for augmentation in the succeeding excess rainfall years.

2.1.1. Assessment of Annually Replenishable or Dynamic Ground Water Resources

The methodology for ground water resources estimation is based on the principle of water balance as given below –

$$\boldsymbol{Inflow - Outflow = Change\ in\ Storage(of\ an\ aquifer)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Equation (1) can be further elaborated as –

$$\Delta S = R_{RF} + R_{STR} + R_C + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \ldots\ldots\ldots (2)$$

Where,

- ΔS - Change is storage
- R_{RF} - Rainfall recharge
- R_{STR} - Recharge from stream channels
- R_C - Recharge from canals
- R_{SWI} - Recharge from surface water irrigation
- R_{GWI} - Recharge from ground water irrigation
- R_{TP} - Recharge from Tanks & Ponds
- R_{WCS} - Recharge from water conservation structures
- VF - Vertical flow across the aquifer system

LF - Lateral flow along the aquifer system (through flow)
GE - Ground Water Extraction
T - Transpiration
E - Evaporation
B - Base flow

Due to lack of data for all the components in most of the assessment units, at present the water budget has been assessed based on major components only, taking into consideration certain reasonable assumptions. The estimation has been carried out using lumped parameter estimation approach keeping in mind that data from many more sources if available may be used for refining the assessment.

2.1.1.1. Rainfall Recharge

Ground water recharge has been estimated on ground water level fluctuation and specific yield approach since this method considers the response of ground water levels to ground water input and output components. In units or subareas where adequate data on ground water level fluctuations are not available, ground water recharge is estimated using rainfall infiltration factor method only. The rainfall recharge during non-monsoon season has been estimated using rainfall infiltration factor method only.

2.1.1.1.1. Ground Water Level Fluctuation Method

The ground water level fluctuation method is used for assessment of rainfall recharge in the monsoon season. The ground water balance equation in non-command areas is given by

$$\Delta \boldsymbol{S} = \boldsymbol{R_{RF}} + \boldsymbol{R_{STR}} + \boldsymbol{R_{SWI}} + \boldsymbol{R_{GWI}} + \boldsymbol{R_{TP}} + \boldsymbol{R_{WCS}} \pm \boldsymbol{VF} \pm \boldsymbol{LF} - \boldsymbol{GE} - \boldsymbol{T} - \boldsymbol{E} - \boldsymbol{B} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\boldsymbol{3})$$

Where,

ΔS - Change is storage
R_{RF} - Rainfall recharge
R_{STR} - Recharge from stream channels
R_{SWI} - Recharge from surface water irrigation
R_{GWI} - Recharge from ground water irrigation
R_{TP} - Recharge from Tanks& Ponds
R_{WCS} - Recharge from water conservation structures
VF - Vertical flow across the aquifer system
LF - Lateral flow along the aquifer system (through flow)
GE - Ground water extraction
T - Transpiration
E - Evaporation
B - Base flow

Whereas the water balance equation in command area have another term i.e., Recharge due to canals (R_C) and the equation is as follows:

$$\Delta S = R_{RF} + R_{STR} + R_C + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \ldots\ldots\ldots\ldots (4)$$

The change in storage has been estimated using the following equation:

$$\Delta S = \Delta h \times A \times S_Y \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where,

ΔS - Change is storage
Δh - rise in water level in the monsoon season
A - Area for computation of recharge
S_Y - Specific Yield

Substituting the expression in equation (5) for storage increase ΔS in terms of water level fluctuation and specific yield, the equations (3) & (4) becomes (6) & (7) for non-command and command sub-units,

$$R_{RF} = \Delta h \times A \times S_Y - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \ldots\ldots\ldots\ldots\ldots (6)$$

$$R_{RF} = \Delta h \times A \times S_Y - R_{STR} - R_C - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \ldots\ldots\ldots (7)$$

Where base flow/ recharge to/from streams have not been estimated, the same is assumed to be zero. The rainfall recharge obtained by using equation (6) and (7) provides the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate has been normalized for the normal monsoon season rainfall as per the procedure indicated below.

Normalization of Rainfall Recharge

Let R_i be the rainfall recharge and r_i be the associated rainfall. The subscript "i" takes values 1 to N where N is the number of years for which data is available. This should be at least 5. The rainfall recharge, R_i is obtained as per equation (6) & equation (7) depending on the sub-unit for which the normalization is being done.

After the pairs of data on R_i and r_i have been obtained as described above, a normalisation procedure is carried out for obtaining the rainfall recharge corresponding to the normal monsoon season rainfall. Let r(normal) be the normal monsoon season rainfall obtained as the average of recent 30 to 50 years of monsoon season rainfall. Two methods are possible for the normalisation procedure. The first method is based on a linear relationship between recharge and rainfall of the form

$$R = ar \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where,

R = Rainfall recharge during monsoon season
r = Monsoon season rainfall

a = a constant

The computational procedure is followed in the first method is as given below:

$$\boldsymbol{R_{RF}(normal)} = \frac{\sum_{i=1}^{N}\left[R_i \frac{r(normal)}{r_i}\right]}{N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where,

R_{RF}(normal) - Normalized Rainfall Recharge in the monsoon season

R_i- Rainfall Recharge in the monsoon season for the i^{th}year

r(normal) - Normal monsoon season rainfall

r_i- Rainfall in the monsoon season for the i^{th} year

N - No. of years for which data is available

The second method is also based on a linear relation between recharge and rainfall. However, this linear relationship is of the form,

$$R_{RF}(normal) = a \times r(normal) + b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Where,

R_{RF}(normal) - Normalized Rainfall Recharge in the monsoon season

r(normal) - Normal monsoon season rainfall

a and b - Constants.

The two constants ‘a’ and ‘b’ in the above equation are obtained through a linear regression analysis. The computational procedure has been followed in the second method is as given below:

$$a = \frac{NS_4 - S_1S_2}{NS_3 - S_1^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

$$b = \frac{S_2 - aS_1}{N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Where,

$$S_1 = \sum_{i=1}^{N} r_i \ , \quad S_2 = \sum_{i=1}^{N} R_i \ , \quad S_3 = \sum_{i=1}^{N} r_i^2 \ , \quad S_4 = \sum_{i=1}^{N} R_i r_i$$

2.1.1.1.2. Rainfall Infiltration Factor Method

The rainfall recharge estimation based on Water level fluctuation method reflects actual field conditions since it takes into account the response of ground water level. However the ground water extraction estimation included in the computation of rainfall recharge using water level fluctuation approach is often subject to uncertainties. Therefore, the rainfall recharge obtained from water level fluctuation approach has been compared with that estimated using rainfall infiltration factor method. Recharge from rainfall is estimated by using the following relationship –

$$R_{RF} = RFIF \times A \times \frac{(R-a)}{1000} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

Where,

R_{RF} - Rainfall recharge in ham
A - Area in hectares
RFIF - Rainfall Infiltration Factor
R- Rainfall in mm
a - Minimum threshold value above which rainfall induces ground water recharge in mm

The threshold limit of minimum and maximum rainfall event which can induce recharge to the aquifer is considered while estimating ground water recharge using rainfall infiltration factor method. The minimum threshold limit is in accordance with the relation shown in equation (13) and the maximum threshold limit is based on the premise that after a certain limit, the rate of storm rain is too high to contribute to infiltration and they will only contribute to surface runoff. Thus, 10% of Normal annual rainfall has been taken as minimum rainfall threshold and 3000 mm as maximum rainfall limit. While computing the rainfall recharge, 10% of the normal annual rainfall has been deducted from the monsoon rainfall and balance rainfall is considered for computation of rainfall recharge. The same recharge factor is used for both monsoon and non-monsoon rainfall, with the condition that the recharge due to non-monsoon rainfall is taken as zero, if the normal rainfall during the non-monsoon season is less than 10% of normal annual rainfall. In using the method based on the specified norms, recharge due to both monsoon and non-monsoon rainfall has been estimated for normal rainfall, based on recent 30 to 50 years of data.

2.1.1.1.3. Percent Deviation

After computing the rainfall recharge for normal monsoon season rainfall using the ground water level fluctuation method and rainfall infiltration factor method these two estimates is compared with each other. A term, Percent Deviation (PD) which is the difference between the two expressed as a percentage of the later is computed as

$$PD = \frac{R_{RF}(normal, wtfm) - R_{RF}(normal, rifm)}{R_{RF}(normal, rifm)} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Where,

R_{RF} (normal, wlfm) = Rainfall recharge for normal monsoon season rainfall estimated by the ground water level fluctuation method

R_{RF} (normal, rifm) = Rainfall recharge for normal monsoon season rainfall estimated by the rainfall infiltration factor method

The rainfall recharge for normal monsoon season rainfall is finally adopted as per the criteria given below:

- If PD is greater than or equal to -20%, and less than or equal to +20%, R_{RF} (normal) is taken as the value estimated by the ground water level fluctuation method.
- If PD is less than -20%, R_{RF} (normal) is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.

- If PD is greater than +20%, R_{RF} (normal) is taken as equal to 1.2 times the value estimated by the rainfall infiltration factor method.

2.1.1.2. Recharge from Other Sources

Recharge from other sources constitutes recharges from canals, surface water irrigation, ground water irrigation, tanks & ponds and water conservation structures in command areas where as in non-command areas it constitutes the recharge due to surface water irrigation, ground water irrigation, tanks & ponds and water conservation structures. The methods of estimation of recharge from different sources are used in the assessment as follows.

Sl. No.	Source	Estimation Formula	Parameters
1	Recharge from Canals	$R_C = WA \times SF \times Days$	R_C = Recharge from Canals WA = Wetted Area SF = Seepage Factor Days = Number of Canal Running Days
2	Recharge from Surface Water Irrigation	$R_{SWI} = AD \times Days \times RFF$	R_{SWI} = Recharge due to applied surface water irrigation AD = Average Discharge Days = Number of days water is discharged to the Fields RFF = Return Flow Factor
3	Recharge from Ground Water Irrigation	$R_{GWI} = GE_{IRR} \times RFF$	R_{GWI} = Recharge due to applied ground water irrigation GE_{IRR} = Ground Water Extraction for Irrigation RFF = Return Flow Factor
4	Recharge due to Tanks & Ponds	$R_{TP} = AWSA \times N \times RF$	R_{TP} = Recharge due to Tanks & Ponds AWSA = Average Water Spread Area N = Number of days Water is available in the Tank/Pond RF = Recharge Factor
5	Recharge due to Water Conservation Structures	$R_{WCS} = GS \times RF$	RWCS = Recharge due to Water Conservation Structures GS = Gross Storage = Storage Capacity multiplied by number of fillings. RF = Recharge Factor

2.1.1.3. Evaporation and Transpiration

Evaporation is estimated for the aquifer in the assessment unit if water levels in the aquifer are within the capillary zone. For areas with water levels within 1.0mbgl, evaporation is estimated using the evaporation

rates available for other adjoining areas. If depth to water level is more than 1.0mbgl, the evaporation losses from the aquifer is taken as zero.

Transpiration through vegetation has been estimated if water levels in the aquifer are within the maximum root zone of the local vegetation. If water levels are within 3.5mbgl, transpiration is estimated using the transpiration rates available for other areas. If it is greater than3.5m bgl, the transpiration has been taken as zero.

2.1.1.4. Recharge During Monsoon Season

The sum of normalized monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into & out of the sub unit and stream inflows & outflows during monsoon season is the total recharge/ accumulation during monsoon season for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

2.1.1.5. Recharge During Non-Monsoon Season

The rainfall recharge during non-monsoon season is estimated using rainfall infiltration factor Method only when the non-monsoon season rainfall is more than 10% of normal annual rainfall. The sum of non-monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into & out of the sub unit and stream inflows & outflows during non-monsoon season is the total recharge/ accumulation during non-monsoon season for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

2.1.1.6. Total Annual Ground Water Recharge

The sum of the recharge/ accumulations during monsoon and non-monsoon seasons is the total annual ground water recharge/ accumulations for the sub unit. Similarly, this is computed for all the sub units available in the assessment unit.

2.1.1.7. Annual Extractable Ground Water Resource (EGR)

The Annual Extractable Ground Water Resource (EGR) is computed by deducting the Total Annual Natural Discharge from Total Annual Ground Water Recharge.

In the water level fluctuation method, a significant portion of base flow is already accounted for by taking the post monsoon water level one month after the end of rainfall. The base flow in the remaining non-monsoon period is likely to be small, especially in hard rock areas. In the assessment units, where river stage data are not available and neither the detailed data for quantitative assessment of the natural discharge are available, allocation of unaccountable natural discharges to 5% or 10% of annual recharge is considered. If the rainfall recharge is assessed using water level fluctuation method this has been taken 5% of the annual recharge and if it is assessed using rainfall infiltration factor method, 10% of the annual recharge is considered. The balance is account for Annual Extractable Ground Water Resources (EGR).

2.1.1.8. Estimation of Ground Water Extraction

Ground water draft or extraction is assessed as follows.

$$GE_{ALL} = GE_{IRR} + GE_{DOM} + GE_{IND} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

Where,

GE_{ALL} = Ground water extraction for all uses
GE_{IRR} = Ground water extraction for irrigation
GE_{DOM} = Ground water extraction for domestic uses
GE_{IND} = Ground water extraction for industrial uses

2.1.1.8.1. Ground Water Extraction for Irrigation (GE_{IRR})

The methods for estimation of ground water extraction are as follows.

Unit Draft Method: – In this method, season-wise unit draft of each type of well in an assessment unit is estimated. The unit draft of different types (eg. Dug well, Dug cum bore well, shallow tube well, deep tube well, bore well etc.) is multiplied with the number of wells of that particular type to obtain season-wise ground water extraction by that particular structure.

Crop Water Requirement Method: – For each crop, the season-wise net irrigation water requirement is determined. This is then multiplied with the area irrigated by ground water abstraction structures. The database on crop area is obtained from Revenue records in Tehsil office, Agriculture Census and also by using Remote Sensing techniques.

Power Consumption Method: –Ground water extraction for unit power consumption (electric) is determined. Extraction per unit power consumption is then multiplied with number of units of power consumed for agricultural pump sets to obtain total ground water extraction for irrigation.

2.1.1.8.2. Ground Water Extraction for Domestic Use (GE_{DOM})

There are several methods for estimation of extraction for domestic use(GEDOM). Some of the commonly adopted methods are described here.

Unit Draft Method: – In this method, unit draft of each type of well is multiplied by the number of wells used for domestic purpose to obtain the domestic ground water extraction.

Consumptive Use Method: – In this method, population is multiplied with per capita consumption usually expressed in litre per capita per day (lpcd). It can be expressed using following equation.

$$GE_{DOM} = Population \times Consumptive\ Requirement \times L_g \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

Where,

L_g = Fractional Load on Ground Water for Domestic Water Supply.

The Load on Ground water can be obtained from the Information based on Civic water supply agencies in urban areas.

2.1.1.8.3. Ground Water Extraction for Industrial Use (GE_{IND})

The commonly adopted methods for estimating the extraction for industrial use are as below:

Unit Draft Method: - In this method, unit draft of each type of well is multiplied by the number of wells used for industrial purpose to obtain the industrial ground water extraction.

Consumptive Use Pattern Method: – In this method, water consumption of different industrial units is determined. Numbers of Industrial units which are dependent on ground water are multiplied with unit water consumption to obtain ground water extraction for industrial use.

$$GE_{IND} = Number\ of\ Industrial\ Units \times Unit\ Water\ Consumption \times L_g \ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

Where,

L_g = Fractional load on ground water for industrial water supply.

The load on ground water for industrial water supply can be obtained from water supply agencies in the Industrial belt.

Ground water extraction obtained from different methods need to be compared and based on field checks, the seemingly best value may be adopted. At times, ground water extraction obtained by different methods may vary widely. In such cases, the value matching the field situation should be considered. The storage depletion during a season, where other recharges are negligible can be taken as ground water extraction during that particular period.

2.1.1.9. Stage of Ground Water Extraction

The stage of ground water extraction is defined by,

$$Stage\ of\ GW\ Extraction = \frac{Existing\ Gross\ GW\ Extraction\ for\ all\ Uses}{Annual\ Extractable\ GW\ Resources} \times 100 \ldots\ldots\ldots\ldots\ldots (18)$$

The existing gross ground water extraction for all uses refers to the total of existing gross ground water extraction for irrigation and all other purposes. The stage of ground water extraction should be obtained separately for command areas, non-command areas and poor ground water quality areas.

2.1.1.10. Validation of Stage of Ground Water Extraction

The assessment based on the stage of ground water extraction has inherent uncertainties. In view of this, it is desirable to validate the 'Stage of Ground Water Extraction' with long term trend of ground water levels.

Long term Water Level trends are prepared for a minimum period of 10 years for both pre-monsoon and post-monsoon period. If the ground water resource assessment and the trend of long term water levels contradict each other, this anomalous situation requires a review of the ground water resource computation, as well as the reliability of water level data. The mismatch conditions are enumerated below.

SOGWE	Ground Water Level Trend	Remarks
≤ 70%	Significant decline in trend in both pre-monsoon and post-monsoon	Not acceptable and needs reassessment
> 100%	No significant decline in both pre-monsoon and post-monsoon long term trend	Not acceptable and needs reassessment

2.1.1.11. Categorisation of Assessment Unit

2.1.1.11.1. Categorisation of Assessment Unit Based on Quantity

The categorisation based on status of ground water quantity is defined by Stage of Ground Water Extraction as given below:

Stage of Ground Water Extraction	Category
≤ 70%	Safe
> 70% and ≤90%	Semi-critical
> 90% and ≤100%	Critical
> 100%	Over Exploited

2.1.1.11.2. Categorisation of Assessment Unit Based on Quality

As it is not possible to categorize the assessment units in terms of the extent of quality hazard, based on the available water quality monitoring mechanism and database on ground water quality, the Committee recommends that each assessment unit, in addition to the Quantity based categorization (safe, semi-critical, critical and over-exploited) should bear a quality hazard identifier. If any of the three quality hazards in terms of Arsenic, Fluoride and Salinity are encountered in the assessment sub unit in mappable units, the assessment sub unit has been tagged with the particular Quality hazard.

2.1.1.12. Allocation of Ground Water Resource for Utilisation

The Annual Extractable Ground Water Resources are to be apportioned between domestic, industrial and irrigation uses. Among these, as per the National Water Policy, requirement for domestic water supply is to be accorded priority. This requirement based on population has been projected to the year 2025, per capita requirement of water for domestic use, and relative load on ground water for urban and rural water supply. In situations where adequate data is not available to make this estimate, the following empirical relation has been utilized.

$$\boldsymbol{Alloc = 22 \times N \times L_g mm\ per\ year} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\,\boldsymbol{(19)}$$

Where,

Alloc = Allocation for domestic water requirement

N = population density in the unit in thousands per sq. km.

L_g= fractional load on ground water for domestic water supply (≤ 1.0)

2.1.1.13. Net Annual Ground Water Availability for Future Use

The water available for future use is obtained by deducting the allocation for domestic use and current extraction for Irrigation and Industrial uses from the Annual Extractable Ground Water Recharge. The resulting ground water potential is termed as the net annual ground water availability for future use. The

Net annual ground water availability for future use is calculated separately for non-command areas and command areas. As per the recommendations of the R&D Advisory committee, the ground water available for future use can never be negative. If it becomes negative, the future allocation of Domestic needs can be reduced to current extraction for domestic use. Even then if it is still negative, then the ground water available for future uses has been projected as zero.

2.1.1.14. Additional Potential Resources under Specific Conditions

2.1.1.14.1. Potential Resource Due to Spring Discharge

Spring discharge occurs at the places where ground water level cuts the surface topography. The spring discharge is equal to the ground water recharge minus the outflow through evaporation and evapotranspiration and vertical and lateral sub-surface flow. Thus, Spring Discharge is a form of 'Annual Extractable Ground Water Recharge'. It is a renewable resource, though has not been used for Categorisation. Spring discharge measurement has been carried out by volumetric measurement of discharge of the springs. Spring discharges multiplied with time in days of each season will give the quantum of spring resources available during that season.

$$\boldsymbol{Potential\ ground\ water\ resource\ due\ to\ springs} = \boldsymbol{Q \times No.of days} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{20})$$

Where,

Q = Spring Discharge

No of days = No of days spring yields.

2.1.1.14.2. Potential Resource in Waterlogged and Shallow Water Table Areas

In the area where the ground water level is less than 5m below ground level or in waterlogged areas, the resources up to 5m below ground level are potential and would be available for development in addition to the annual recharge in the area. The computation of potential resource to ground water reservoir in shallow water table areas has been done by adopting the following equation:

$$\boldsymbol{Potential\ groundwater\ resource\ in\ shallow\ water\ table\ areas} = (\mathbf{5} - \boldsymbol{D}) \times \boldsymbol{A} \times \boldsymbol{S_Y} \ldots\ldots\ldots\ldots (\mathbf{21})$$

Where,

D = Depth to water table below ground surface in pre-monsoon period in shallow aquifers.

A = Area of shallow water table zone.

S_Y = Specific Yield

2.1.1.14.3. Potential Resource in Flood Prone Areas

Ground water recharge from a flood plain is mainly the function of the following parameters-

- Areal extent of flood plain
- Retention period of flood
- Type of sub-soil strata and silt charge in the river water which gets deposited and controls seepage

Since collection of data on all these factors is time taking and difficult, in the meantime, the potential resource from flood plain may be estimated on the same norms as for ponds, tanks and lakes. This has been calculated over the water spread area and only for the retention period using the following formula.

$$\boldsymbol{Potential\ groundwater\ resource\ in\ Flood\ Prone\ Areas} = \mathbf{1.4} \times \boldsymbol{N} \times \frac{\boldsymbol{A}}{\mathbf{1000}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{22})$$

Where,

N = No. of Days Water is Retained in the Area

A = Flood Prone Area

2.1.1.15. Apportioning of Ground Water Assessment from Watershed to Development Unit

Where the assessment unit is a watershed, there is a need to convert the ground water assessment in terms of an administrative unit such as block/ taluka/ mandal. This has been done as follows.

A block may comprise of one or more watersheds, in part or full. First, the ground water assessment in the subareas, command, non-command and poor ground water quality areas of the watershed has been converted into depth unit (mm), by dividing the annual recharge by the respective area. The contribution of this subarea of the watershed to the block, is now calculated by multiplying this depth with the area in the block occupied by this sub-area.

The total ground water resource of the block has been presented separately for each type of sub-area, namely for command areas, non-command areas and poor ground water quality areas, as in the case of the individual watersheds.

2.2. GROUND WATER ASSESSMENT IN URBAN AREAS

The Assessment of Ground Water Resources in urban areas is similar to that of rural areas. Because of the availability of draft data and slightly different infiltration process and recharge due to other sources, the following few points are to be considered.

- Even though the data on existing ground water abstraction structures are available, accuracy is somewhat doubtful and individuals cannot even enumerate the well census in urban areas. Hence the difference of the actual demand and the supply by surface water sources as the withdrawal from the ground water resources has been considered for the assessment.

- The urban areas are sometimes concrete jungles and rainfall infiltration is not equal to that of rural areas unless and until special measures are taken in the construction of roads and pavements. Hence, 30% of the rainfall infiltration factor has been taken into consideration for urban areas as an adhoc arrangement till field studies in these areas are done and documented field studies are available.

- Because of the water supply schemes, there are many pipelines available in the urban areas and the seepages from these channels or pipes are huge in some areas. Hence this component has been included in the other resources and the recharge has also been considered. The percent

losses have been collected from the individual water supply agencies, 50% of which has been considered as recharge to the ground water system.

- In the urban areas in India, normally, there is no separate channels either open or sub surface for the drainage and flash floods. These channels also recharge to some extent the ground water reservoir. As on today, there is no documented field study to assess the recharge. The seepages from the sewerages, which normally contaminate the ground water resources with nitrate also contribute to the quantity of resources and hence same percent as in the case of water supply pipes has been taken as norm for the recharge on the quantity of sewerage when there is sub surface drainage system. If estimated flash flood data is available, the same percent has been used on the quantum of flash floods to estimate the recharge from the flash floods.

- Urban areas with population more than 10 lakhs, has been considered as urban assessment unit while assessing the dynamic ground water resources.

2.3. GROUND WATER ASSESSMENT IN WATER LEVEL DEPLETION ZONES

There are areas where ground water level shows a decline even in the monsoon season. The reasons for this may be any one of the following: (a) There is a genuine depletion in the ground water regime, with ground water extraction and natural ground water discharge in the monsoon season (outflow from the region and base flow) exceeding the recharge. (b) There may be an error in water level data due to inadequacy of observation wells.

If it is concluded that the water level data is erroneous, recharge assessment has been made based on rainfall infiltration factor method. If, on the other hand, water level data is assessed as reliable, the ground water level fluctuation method has been applied for recharge estimation. As ΔS in equation 3& 4 is negative, the estimated recharge will be less than the gross ground water extraction in the monsoon season. It must be noted that this recharge is the gross recharge minus the natural discharges in the monsoon season. The immediate conclusion from such an assessment in water depletion zones is that the area falls under the over-exploited category which requires micro level study.

2.4. NORMS HAS BEEN USED IN THE ASSESSMENT

2.4.1. Specific Yield

Recently under Aquifer Mapping Project, Central Ground Water Board has classified all the aquifers into 14 Principal Aquifers which in turn were divided into 42 Major Aquifers. Hence, it is required to assign Specific Yield values to all these aquifer units. The values recommended in the ***Table-2.1*** has been followed in the present assessments, unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values

Table-2.1: Norms Recommended for Specific Yield

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	10	8	12
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	16	12	20
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	6	4	8
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	16	12	20
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay)	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	16	12	20
7	Alluvium	AL07	Glacial Deposits	Quaternary	16	12	20
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	2.5	2	3
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
11	Basalt	BS02	Ultra Basic - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	3	1	5
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	3	1	5
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	3	1	5
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	3	1	5
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	3	1	5

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	3	1	5
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	1.5	1	2
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	1.5	1	2
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	1.5	1	2
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	1.5	1	2
25	Limestone	LS01	Miliolitic Limestone	Quarternary	2	1	3
26	Limestone	LS01	KarstifiedMiliolitic Limestone	Quarternary	10	5	15
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	2	1	3
28	Limestone	LS02	Karstified Limestone / Dolomite	Upper Palaeozoic to Cenozoic	10	5	15
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	2	1	3
30	Limestone	LS03	Karstified Limestone/Dolomite	Proterozoic	10	5	15
31	Limestone	LS04	Limestone with Shale	Proterozoic	2	1	3
32	Limestone	LS04	Karstified Limestone with Shale	Proterozoic	10	5	15
33	Limestone	LS05	Marble	Azoic to Proterozoic	2	1	3
34	Limestone	LS05	Karstified Marble	Azoic to Proterozoic	10	5	15
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered , Jointed	Mesozoic to Cenozoic	1.5	1	2
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite	Mesozoic to Cenozoic	0.35	0.2	0.5

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
			etc.)-Massive or Poorly Fractured				
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	3	2	4
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	0.35	0.2	0.5
41	Schist	SC02	Phyllite	Azoic to Proterozoic	1.5	1	2
42	Schist	SC03	Slate	Azoic to Proterozoic	1.5	1	2
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	1.5	1	2
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.3	0.2	0.4
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	3	2	4
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	1.5	1	2
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	0.3	0.2	0.4
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	1.5	1	2
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
53	Gneiss	GN01	Undifferentiated metasedimentaries/	Azoic to Proterozoic	1.5	1	2

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
			Undifferentiated metamorphic - Weathered, Jointed				
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	3	2	4
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	1.5	1	2
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
61	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
62	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5

2.4.2. Rainfall Infiltration Factor

The values mentioned in ***Table-2.2*** has been used in the present assessment. The recommended Rainfall Infiltration Factor values has been used for assessment, unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values.

Table-2.2: Norms Recommended for Rainfall Infiltration Factor

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	22	20	24
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	22	20	24
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	22	20	24
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	22	20	24
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) -East Coast	Quaternary	16	14	18
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) - West Coast	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	22	20	24
7	Alluvium	AL07	Glacial Deposits	Quaternary	22	20	24
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	7	6	8
9	Basalt	BS01	Basic Rocks (Basalt) - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered	Mesozoic to Cenozoic	7	6	8
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
11	Basalt	BS02	Ultra Basic - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
11	Basalt	BS02	Ultra Basic - Weathered	Mesozoic to Cenozoic	7	6	8
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	12	10	14
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	12	10	14
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	12	10	14

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	12	10	14
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	6	5	7
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	6	5	7
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	4	3	5
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	4	3	5
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	4	3	5
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	4	3	5
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	4	3	5
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	4	3	5
25	Limestone	LS01	Miliolitic Limestone	Quarternary	6	5	7
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	6	5	7
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	6	5	7
31	Limestone	LS04	Limestone with Shale	Proterozoic	6	5	7
33	Limestone	LS05	Marble	Azoic to Proterozoic	6	5	7
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered , Jointed	Mesozoic to Cenozoic	7	5	9
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	2	1	3
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	11	10	12

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	7	5	9
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
41	Schist	SC02	Phyllite	Azoic to Proterozoic	4	3	5
42	Schist	SC03	Slate	Azoic to Proterozoic	4	3	5
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	6	5	7
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	6	5	7
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	5	4	6
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	2	1	3
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	7	5	9
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	2	1	3
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	7	5	9
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	2	1	3
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	7	5	9
54	Gneiss	GN01	Undifferentiated metasedimentaries/	Azoic to Proterozoic	2	1	3

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
			Undifferentiated metamorphic - Massive, Poorly Fractured				
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	11	10	12
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	7	5	9
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	2	1	3
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
61	Intrusive	IN02	Ulrta Basics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
62	Intrusive	IN02	Ulrta Basics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3

2.4.3. Norms for Canal Recharge

The Norms suggested in ***Table-2.3*** has been used for estimating the recharge from Canals, where sufficient data based on field studies are not available.

.Table-2.3: Norms Recommended for Recharge due to Canals

Formation	Canal Seepage factor ham/day/million square meters of wetted area		
	Recommended	Minimum	Maximum
Unlined canals in normal soils with some clay content along with sand	17.5	15	20
Unlined canals in sandy soil with some silt content	27.5	25	30
Lined canals in normal soils with some clay content along with sand	3.5	3	4
Lined canals in sandy soil with some silt content	5.5	5	6

All canals in hard rock area	3.5	3	4

2.4.4. Norms for Recharge Due to Irrigation

The Recommended Norms are presented in ***Table-2.4***.

Table-2.4: Norms Recommended for Recharge from Irrigation

DTW m bgl	Ground Water		Surface Water	
	Paddy	Non-paddy	Paddy	Non-paddy
≤ 10	45.0	25.0	50.0	30.0
11	43.3	23.7	48.3	28.7
12	40.4	22.1	45.1	26.8
13	37.7	20.6	42.1	25.0
14	35.2	19.2	39.3	23.3
15	32.9	17.9	36.7	21.7
16	30.7	16.7	34.3	20.3
17	28.7	15.6	32.0	18.9
18	26.8	14.6	29.9	17.6
19	25.0	13.6	27.9	16.4
20	23.3	12.7	26.0	15.3
21	21.7	11.9	24.3	14.3
22	20.3	11.1	22.7	13.3
23	18.9	10.4	21.2	12.4
24	17.6	9.7	19.8	11.6
≥ 25	20.0	5.0	25.0	10.0

2.4.5. Norms for Recharge due to Tanks & Ponds

As the data on the field studies for computing recharge from Tanks & Ponds are very limited, for Seepage from Tanks & Ponds has been used as 1.4 mm / day in the present assessment.

2.4.6. Norms for Recharge due to Water Conservation Structures

The data on the field studies for computing recharge from Water Conservation Structures are very limited, hence, the norm recommended by GEC-2015 for the seepage from Water Conservation Structures is 40% of gross storage during a year which means 20% during monsoon season and 20% during non-monsoon Season is adopted.

2.4.7. Unit Draft

The methodology recommends to use well census method for computing the ground water draft. The norm used for computing ground water draft is the unit draft. The unit draft can be computed by field studies. This method involves selecting representative abstraction structure and calculating the discharge from that particular type of structure and collecting the information on how many hours of pumping is

being done in various seasons and number of such days during each season. The Unit Draft during a particular season is computed using the following equation:

$$\boldsymbol{Unit\ Draft = Discharge\ in\ m^3/hr \times No.of\ pumping\ hours\ in\ a\ day \times No.of\ days} \ldots\ldots\ldots (\mathbf{29})$$

But the procedure that is being followed for computing unit draft does not have any normalization procedure. Normally, if the year in which one collects the draft data in the field is an excess rainfall year, the abstraction from ground water will be less. Similarly, if the year of the computation of unit draft is a drought year the unit draft will be high. Hence, there is a requirement to devise a methodology that can be used for the normalization of unit draft figures. The following are the two simple techniques, which are followed for normalization of Unit Draft. Areas where, unit draft values for one rainfall cycle are available for at least 10 years second method shown in equation 31 is followed or else the first method shown in equation 30 has been used.

$$\boldsymbol{Normalised\ Unit\ Draft = \frac{Unit\ Draft \times Rainfall\ for\ the\ year}{Normal\ Rainfall}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{30})$$

$$\boldsymbol{Normalised\ Unit\ Draft = \frac{\sum_{i=1}^{n} Unit\ Draft_i}{Number\ of\ Years}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{31})$$

2.5. INDIA -GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES)

"INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES) is a Software/Web-based Application developed by CGWB in collaboration with IIT-Hyderabad. It provides common and standardized platform for Ground Water Resource Estimation for the entire country and its pan-India operationalization (Central and State Governments). The system takes 'Data Input' through Excel as well as Forms, compute various ground water components (recharge, extraction etc.) and classify assessment units into appropriate categories (safe, semi-critical, critical and over-exploited). The Software uses GEC 2015 Methodology for estimation and calculation of Groundwater resources. It allows for unique and homogeneous representation of groundwater fluxes as well as categories for all the assessment units (AU) of the country.

URL of IN-GRES →http://ingres.iith.ac.in

The detailed description about IN-GRES Software is given in **Appendix-C**.

CHAPTER 3

RAINFALL OF INDIA

Rainfall is the main source of ground water recharge in the country. However, distribution of rainfall has a wide variation both in space and time. Rain gauge stations are established and maintained by different departments and Undertakings of Central and State governments and also by private parties as per their specific data requirements. Though the period of seasons varies from place to place, for climatological purposes especially for rainfall, a year is divided into 4 seasons: Winter (January and February), Pre monsoon (March to May), South West Monsoon (June to September) and Post Monsoon (October to December). Most part of India receives rainfall mainly during SW Monsoon season.

The rainfall has direct impact on ground water regime. Groundwater table is usually deeper during pre-monsoon and before the onset of the monsoon and it becomes shallow during monsoon and shortly before the cessation of monsoons. The extraction of groundwater is not extensive for irrigation during the monsoons and in subsequent month after the monsoon, as sufficient moisture remains in the root zone from the monsoon rainfall. After the end of monsoon, as the ground water extraction increases, the groundwater table begins to decline, displaying two distinct phases. The first phase, after the end of the monsoon, there is a rapid decline represented as a relatively steeper slope in the hydrograph and continued to be declined until the preceding monsoon begins in the subsequent year. Based on these dynamics, the ground water assessed in a groundwater year (June to May) comprises both monsoon season, spans from the beginning of the monsoon to one month after its cessation and non-monsoon season, the remaining period of the groundwater year. It is pertinent to mention that, the assessment of ground water resources for monsoon period in a ground water year include both monsoon months plus one subsequent calendar month after monsoon.

The normal rainfall distribution across States and Union territories showcases a broad spectrum, reflecting the country's diverse climatic conditions. The minimum normal rainfall is observed in Ladakh, with just 50.9 mm, while Meghalaya, known for its heavy precipitation, records the highest at 3751.6 mm. On average, the country’s average normal rainfall is 1537.77 mm, though the distribution is uneven. The median normal rainfall stands at 1255.95 mm, meaning that half of the states and UTs experience rainfall below the normal, indicating that a significant portion of the country has received lesser rainfall than the national average. The standard deviation is 854.99 mm, reflects the variability in rainfall, with some regions, particularly in the northeast, receiving abundant rainfall, while others, like the arid areas of Rajasthan and Ladakh, receive far less.

The annual rainfall in 2023 varied significantly across Indian States/UTs. Goa received the highest rainfall (3642.3 mm), followed by Andaman & Nicobar Islands (3510.9 mm) and Meghalaya (3022.6 mm). Ladakh experienced the lowest rainfall (84.1 mm), though this was 65.2% above its normal rainfall. The Comparison of annual rainfall of 2023 to the normal rainfall reveals that, 20 states/UTs experienced below-normal rainfall (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, West Bengal, Jharkhand, Bihar, Uttar Pradesh, Jammu & Kashmir, Odisha, Maharashtra, Chhattisgarh, Andhra Pradesh, Puducherry, Karnataka, Kerala, and Lakshadweep), 16 with above-normal precipitation (Sikkim, Uttarakhand, Haryana, Chandigarh, Delhi, Punjab, Himachal Pradesh, Ladakh, Rajasthan, Madhya Pradesh, Gujarat, Dadra & Nagar Haveli and Daman & Diu, Goa, Andaman & Nicobar Islands, Telangana, and Tamil Nadu).

The most significant negative deviations were observed in Manipur (-50.8%), Mizoram (-30.5%), and Kerala (-23.8%). However, some States/UTs experienced substantially higher than normal rainfall. Ladakh received the highest positive deviation (65.2%), followed by Chandigarh (52.3%) and Rajasthan

(29.8%). The rainfall pattern for the groundwater assessment year 2023-24 also reveals a similar trend to that of the calendar year 2023. Goa received the highest total rainfall (3734.3 mm), followed by the Andaman & Nicobar Islands (3551.2 mm) and Meghalaya (2959.0 mm). Ladakh experienced the lowest total rainfall (94.9 mm). The northeastern states, along with Goa and the Andaman & Nicobar Islands, received significantly higher rainfall compared to most other states. In contrast, northwestern states like Rajasthan, Haryana, and Delhi received considerably less rainfall during the groundwater assessment year 2023-24.

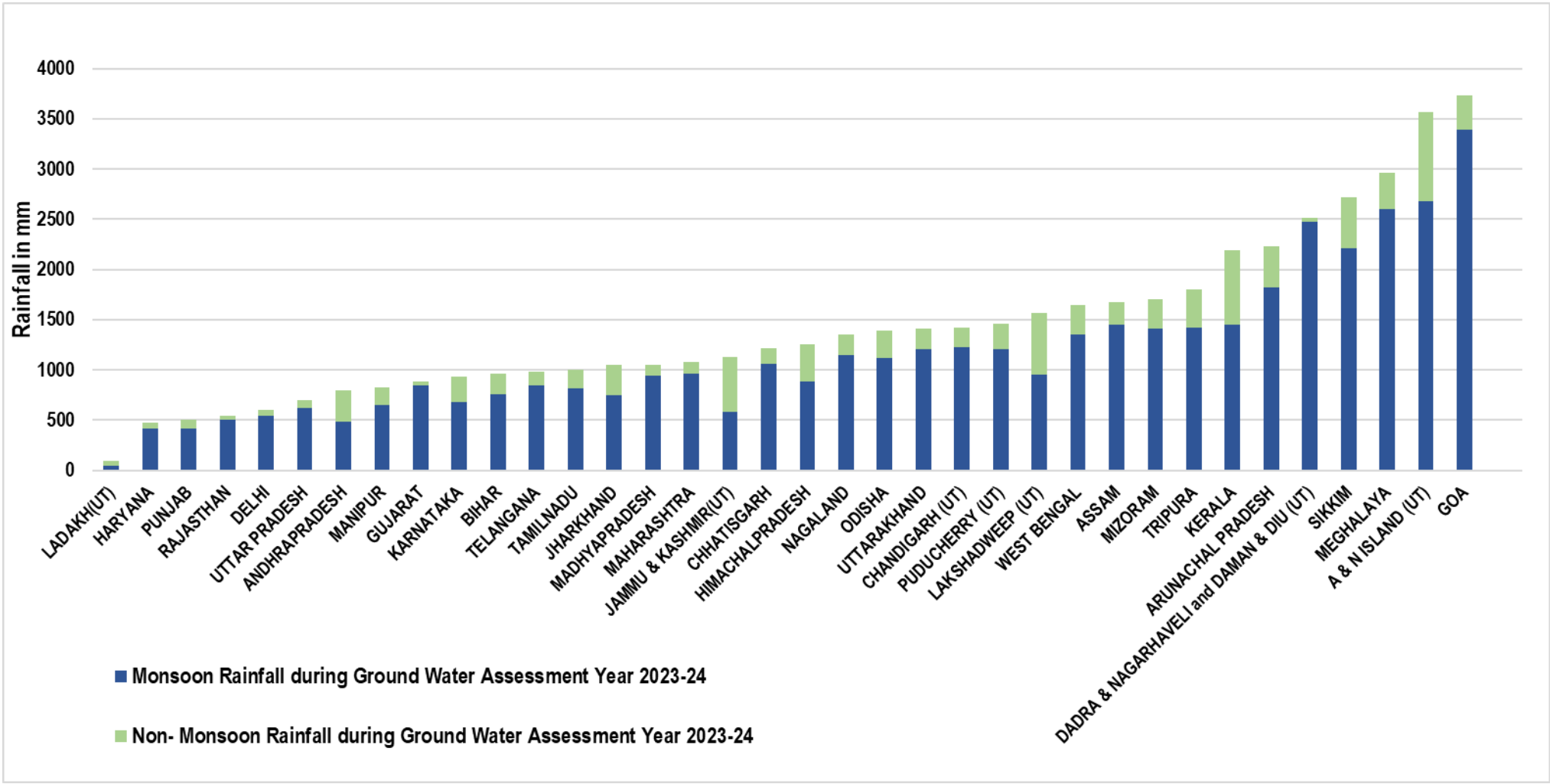


Fig. 3.1.: State/UT-wise Annual, Monsoon and Non-Monsoon Rainfall for Ground Water Assessment Year 2023-24

Table. 3.1.: State/UT-wise Rainfall Statistics

S. No	STATES	State -wise Monthly Rainfall (mm) -Year 2023												State -wise Monthly Rainfall (mm) -Year 2024					Normal Rainfall (mm)	Rainfall during Calendar Year 2023 (mm)	Rainfall during Ground Water Assessment Year 2023-24 (mm)	Monsoon Rainfall during Ground Water Assessment Year 2023-24 (mm)	Non-Monsoon Rainfall during Ground Water Assessment Year 2023-24 (mm)
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY					
1	ARUNACHAL PRADESH	10.9	99	114	110.6	222	382.8	492	438.1	179	167.3	14	19.9	9.3	92.6	107.7	263	225.8	2807.0	2249.5	2235.3	1824.5	410.8
2	ASSAM	0.5	26	88.7	108.5	138	455.4	281.4	316.8	152.4	114.5	17.3	17.2	1.2	28	47.7	120.1	253.7	2220.8	1716.8	1678.4	1452.5	225.9
3	MEGHALAYA	0.1	7.4	133	81.1	172.5	892.4	598.6	581.5	277.4	237.9	15.3	25	1.2	22.3	53.8	41.9	575.1	3751.6	3022.6	2959.0	2603.5	355.5
4	NAGALAND	0.3	2.1	45	62.2	118.6	231.1	298.5	300.3	134	64.4	25.7	32.1	0.7	46.6	42.7	159.7	172.5	1557.3	1314.3	1356.9	1144.7	212.2
5	MANIPUR	0	0.8	36.1	37.6	48.4	176.3	114.1	164.2	108.5	43.4	39	30.3	0	27.8	36.2	64.2	299.7	1623.0	798.7	825.8	649.1	176.7
6	MIZORAM	0	0	56.8	109.4	136.4	288.8	266.4	377.8	236.8	113.1	58.9	69.9	2.2	21.7	18.2	64.5	317.9	2465.0	1714.3	1699.6	1415.6	284.0
7	TRIPURA	0	0	72.5	94.3	97	356.8	271.9	386.3	217.6	92.2	117.4	44.3	0.3	46.9	76.1	70.3	362.4	2289.5	1750.3	1801.1	1423.9	377.2
8	SIKKIM	0.7	99	196	200.9	258.2	514.2	506.5	536.3	195.3	276.9	18.2	8.4	22.8	65	116.3	166.5	156.9	2570.1	2811.0	2719.0	2211.4	507.6
9	WEST BENGAL	0.1	1.7	62.7	41.1	108.5	271.7	282.1	356.8	293.6	167.9	4.7	38.9	11	14.4	54.6	7.4	187.4	1773.1	1629.8	1645.3	1353.8	291.5
10	JHARKHAND	0	0	34.5	26.2	35.3	106.5	167.5	228.3	249	135.2	3.1	36.5	8.2	25.5	34.4	2.9	48.3	1220.7	1022.1	1045.4	751.3	294.1
11	BIHAR	0.2	0	19.7	14.8	40.1	85	178.2	306.5	190.9	94.6	0.1	8.1	1	13.1	31.2	0.7	52.3	1164.4	938.2	961.7	760.6	201.1
12	UTTAR PRADESH	8.1	0	24.9	11.9	37.3	77.6	221.7	198.8	123.4	26.5	3.3	5.9	2.5	17.4	15.7	1.7	3.5	844.1	739.4	698.0	621.5	76.5
13	UTTARAKHAND	30.6	6.6	63.5	64	98.4	150.5	547.1	353.9	151.8	20	2.2	4.4	0.1	49.2	70.3	6.2	51	1477.4	1493.0	1406.7	1203.3	203.4
14	HARYANA	11.6	0	41.8	14.6	52.4	81.1	236.9	58.5	43.6	9.9	4.8	2.8	0	15.2	16.6	4	5	521.8	558.0	478.4	420.1	58.3
15	CHANDIGARH (UT)	27.7	0	65.7	36.3	106.5	142.9	760.7	270.7	52.8	23.4	18.3	32.4	0	57.2	36.5	25.2	0	1009.7	1537.4	1420.1	1227.1	193.0
16	DELHI	18.3	0	52.8	11.8	85.1	133.5	230.5	86.9	91.2	4.5	8.7	0.3	0	23.6	5.1	11.9	1	660.0	723.6	597.2	542.1	55.1
17	PUNJAB	15.1	0.1	56.6	26	45	65.8	231.3	54.9	64.4	24.8	12	3.3	1.2	15.4	22.1	8.6	2.5	565.4	599.3	506.3	416.4	89.9
18	HIMACHALPRADESH	86.8	30	66.7	103.5	118.2	120.7	447.5	246.4	67.1	27.2	11.7	5.7	7	102.9	138.3	66	16.9	1245.0	1331.0	1257.4	881.7	375.7

S. No	STATES	State -wise Monthly Rainfall (mm) -Year 2023												State -wise Monthly Rainfall (mm) -Year 2024					Normal Rainfall (mm)	Rainfall during Calendar Year 2023 (mm)	Rainfall during Ground Water Assessment Year 2023-24 (mm)	Monsoon Rainfall during Ground Water Assessment Year 2023-24 (mm)	Non-Monsoon Rainfall during Ground Water Assessment Year 2023-24 (mm)
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY					
19	JAMMU & KASHMIR(UT)	135	41	80.3	129.1	100.5	110.7	261.1	131	78.5	79.7	38.6	12.6	8.7	108.4	127.9	147.1	25.5	1232.4	1198.0	1129.8	581.3	548.5
20	LADAKH(UT)	9.9	12	1.1	10.6	3.8	4.7	40	0.2	0.3	1.4	0.1	0	0	30.4	10.9	6.5	0.4	50.9	84.1	94.9	45.2	49.7
21	RAJASTHAN	13	0	18.6	14.5	62.3	156.9	228.4	30.9	83.4	8.6	9.9	4.8	0.4	5	2.7	3.8	4.3	486.5	631.3	539.1	499.6	39.5
22	ODISHA	0.1	0	58.9	63.4	56	163.7	319.7	299.9	332.1	75.4	12.5	31.9	14.3	11.2	50.4	15.1	70.5	1444.7	1413.6	1396.7	1115.4	281.3
23	MADHYAPRADESH	5.5	0	22.1	23.1	33.6	149.2	311.7	201.8	284.2	8	20.4	17.9	7.8	11	11.7	17	11.2	1040.4	1077.5	1051.9	946.9	105.0
24	GUJARAT	1.6	0	13.9	6.4	17.8	229.2	423.2	20.9	168.4	1.8	23	1.1	0.5	0	3.4	2.8	6.3	747.6	907.3	880.6	841.7	38.9
25	DADRA & NAGARHAVELI and DAMAN & DIU (UT)	0	0	0.9	1	31.2	445.5	1518.7	174.4	337.8	14.3	24.5	0	0	0	0	0.1	0	2278.4	2548.3	2515.3	2476.4	38.9
26	GOA	0	0	0.9	0	24.3	653.1	1846.5	297.3	598.6	127.1	94.5	0	4.3	0	0.3	29.8	82.8	3279.6	3642.3	3734.3	3395.5	338.8
27	MAHARASHTRA	0.3	0	9.5	30.3	24.1	113.5	491.9	114.8	244.9	19.7	34.1	6.1	1.6	2.5	4.8	20.9	21.6	1124.9	1089.2	1076.4	965.1	111.3
28	CHHATISGARH	0.1	0	35.3	40.6	33.9	167	331.8	240.5	320.9	29.4	4.9	28.1	4.5	6.4	29	16.8	36.4	1266.9	1232.5	1215.7	1060.2	155.5
29	A & N ISLAND (UT)	27.4	24	11.2	15.7	134.4	494.5	492.5	477.1	1064.7	280	349.8	139.8	112.4	2.7	1.4	1.9	319	2838.2	3510.9	3551.2	2678.9	886.1
30	ANDHRAPRADESH	0.9	0	49.7	28.7	90.7	62.1	172.1	72.2	179.5	16.1	73.4	132.7	1.9	0.1	4.4	3.1	81.3	914.8	878.1	798.9	485.9	313.0
31	TELANGANA	0.4	0	42.9	48	67.7	65.2	481.3	79.9	220.4	6.6	19.2	27	0.1	1.1	5.3	9	67.4	938.8	1058.6	982.5	846.8	135.7
32	TAMILNADU	5.1	16	34.3	45.5	122.9	53.4	64.9	87.4	148.3	98.6	231.8	127.6	50	2.1	1.2	8.6	132.4	919.8	1035.3	1006.3	812.0	194.3
33	PUDUCHERRY (UT)	6.2	42	26.2	51.3	76.1	100.9	126.6	89.9	145.1	58.6	567.7	113.5	182.5	0.5	0.4	0.9	74.2	1423.3	1404.0	1460.8	1202.3	258.5
34	KARNATAKA	0.7	0	8.6	30.3	86.4	93.9	373.5	55.9	155.5	44.3	58.9	6.2	8.5	0	0.7	20.1	118.7	1131.6	914.2	936.2	678.8	257.4
35	KERALA	12.8	2.4	31.6	76.5	128.9	259.4	591.6	60	415.4	310.5	240.1	74.3	59	0.6	11.6	41.9	446.9	2890.9	2203.5	2193.3	1455.3	738.0

S. No	STATES	State -wise Monthly Rainfall (mm) -Year 2023												State -wise Monthly Rainfall (mm) -Year 2024					Normal Rainfall (mm)	Rainfall during Calendar Year 2023 (mm)	Rainfall during Ground Water Assessment Year 2023-24 (mm)	Monsoon Rainfall during Ground Water Assessment Year 2023-24 (mm)	Non-Monsoon Rainfall during Ground Water Assessment Year 2023-24 (mm)
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY					
36	LAKSHADWEEP (UT)	33.4	1	3.4	16	80.9	226.9	291.9	85.4	268.5	135.4	174.7	138.4	156.8	0	7.9	5	344.3	1584.0	1455.9	1571.8	953.6	618.2

CHAPTER 4

HYDROGEOLOGICAL SETUP OF INDIA

India is occupied by a variety of hard and fissured formations, including crystalline, trappean basalt and consolidated sedimentaries (including carbonate rocks), with patches of semi- consolidated sediments in narrow intra-cratonic basins. Apart from this, the northern part of the country and south of Himalayan terrain is occupied by alluvial formation stretching from Rajasthan in the west to Brahmaputra valley in the east. Rugged topography, compact and fissured nature of the rock formations combine to give rise to discontinuous aquifers, with moderate to poor yield potentials. The near surface weathered mantle coupled with deeper fractures form an important aquifer in case of hard rocks. In hard rock terrains, deep weathered pediments, lowlands, valley fills and abandoned river channels, generally have adequate thickness of porous material, to act as repositories of groundwater.

4.1 AQUIFER SYSTEMS OF INDIA

Various rock formations with different hydrogeological characteristics act as distinct aquifer systems of varying dimensions. The aquifer systems of India can be broadly categorized into 14 Principal Groups. A brief description of the Principal Aquifer Systems (***Fig- 4.1***), as identified by CGWB (CGWB 2012) is given below.

4.1.1 Alluvial Aquifers

The Quaternary sediments comprising Recent Alluvium, Older Alluvium, Aeolian Alluvium (Silt/ Sand) and Coastal Alluvium of Bay of Bengal are by and large important unconsolidated formations constituting major alluvial aquifers. These sediments are essentially composed of clays, silts, sands, pebbles, Kankar etc. These are by far the most significant ground water reservoirs for large scale and extensive development. The hydrogeological environment and ground water regime in the Indo-Ganga-Brahmaputra basin indicates the existence of potential aquifers having enormous fresh ground water reserves. Bestowed with high incidence of rainfall and covered by a thick pile of porous sediments, these ground water reservoirs get replenished every year and are being used heavily. In these areas, in addition to the Annual Replenishable Ground Water Resources available in the zone of Water Level Fluctuation (Dynamic Ground Water Resource), there exists a huge ground water reserve in the deeper part below the zone of fluctuation as well as in the deeper confined aquifers. The coastal aquifers show wide variation in water quality, both laterally and vertically, thus imposing quality constraints for groundwater development.

4.1.2 Laterite

Laterites are formed from the leaching (chemical weathering) of parent sedimentary rocks (sandstones, clays, limestones); metamorphic rocks (schists, gneisses, migmatites) and igneous rocks (granites, basalts, gabbros, peridotites). It is rich in iron and aluminium, formed in hot and wet tropical areas. Laterites are the most widespread and extensively developed aquifer especially in the peninsular states of India. Laterite forms potential aquifers along valleys and topographic lows where the thickness of the saturated zone is more and can sustain large diameter open wells for domestic and irrigation use.

4.1.3 Sandstone, Shale Aquifers

The sandstone and shale aquifers generally belong to the group of rocks ranging in age from Carboniferous to Mio-Pliocene. The terrestrial freshwater deposits belonging to Gondwana System and the Tertiary deposits along the west and east coast of the peninsular region are included under this category. The Gondwana sandstones form highly potential aquifers, locally. Elsewhere, they have moderate potential and in places they yield meager supplies. The Gondwanas, Lathis, Tipams, Cuddalore sandstones and their equivalents are the most extensive productive aquifers in this category.

4.1.4 Limestone Aquifers

The consolidated sedimentary rocks include carbonate rocks such as limestones, dolomite and marble. Among the carbonate rocks, limestones occupy the largest area. In the carbonate rocks, the principal water bearing zones are the fractures and solution cavities. Consolidated sedimentary rocks of Cuddapah and Vindhyan subgroups and their equivalents consist of limestones/dolomites apart from other major litho-units such as conglomerates, sandstones, shales, slates and quartzites.

4.1.5 Basalt Aquifers

Basalt is a basic volcanic rock which forms alternate layers of compact and vesicular beds of lava flows as seen in the Deccan trap area. The ground water occurrence in basalts is controlled by nature and extent of weathering, presence of vesicles and lava tubes, thickness of flows, number of flows and the nature of inter-trappean layers. Basaltic aquifers have usually medium to low permeability. Ground water occurrence in the Deccan Traps is controlled by the contrasting water bearing properties of different flow units, thus, resulting in multiple aquifer system, at places. The water bearing zones are the weathered and fractured zones.

4.1.6 Crystalline Aquifers

The crystalline hard rock aquifers such as granite, gneisses and high-grade metamorphic rocks such as charnockites and khondalites constitute good repository of ground water. Most of the results of groundwater exploration projects have proven that hard rocks neither receive nor transmit water, unless they are weathered and/or fractured. The aquifers are the weathered zone or the fracture system. The fracture system includes fractures, joints, bedding planes, and solution holes. These openings do not have an even distribution and are rather localized. The weathered zone is underlain by semi-weathered rock, fractured rock followed by bedrock. The depth of the bed rock varies from 30-100 m.

In hard rock terrains, ground water occurs under phreatic condition in the mantle of weathered rock, overlying the hard rock, while within the fissures, fractures, cracks, joints within the hard rock, ground water is mostly under semi-confined or in the confined state. Compared to the volume of water stored under semi-confined condition within the body of the hardrock, the storage in the overlying phreatic aquifer is often much greater. In such cases, the network of fissures and fractures serves as a permeable conduit feeding this water to the well. Ground water flow rarely occurs across the topographical water divides and each basin or sub-basin can be treated as a separate hydrogeological unit for planning the development of ground water resources.

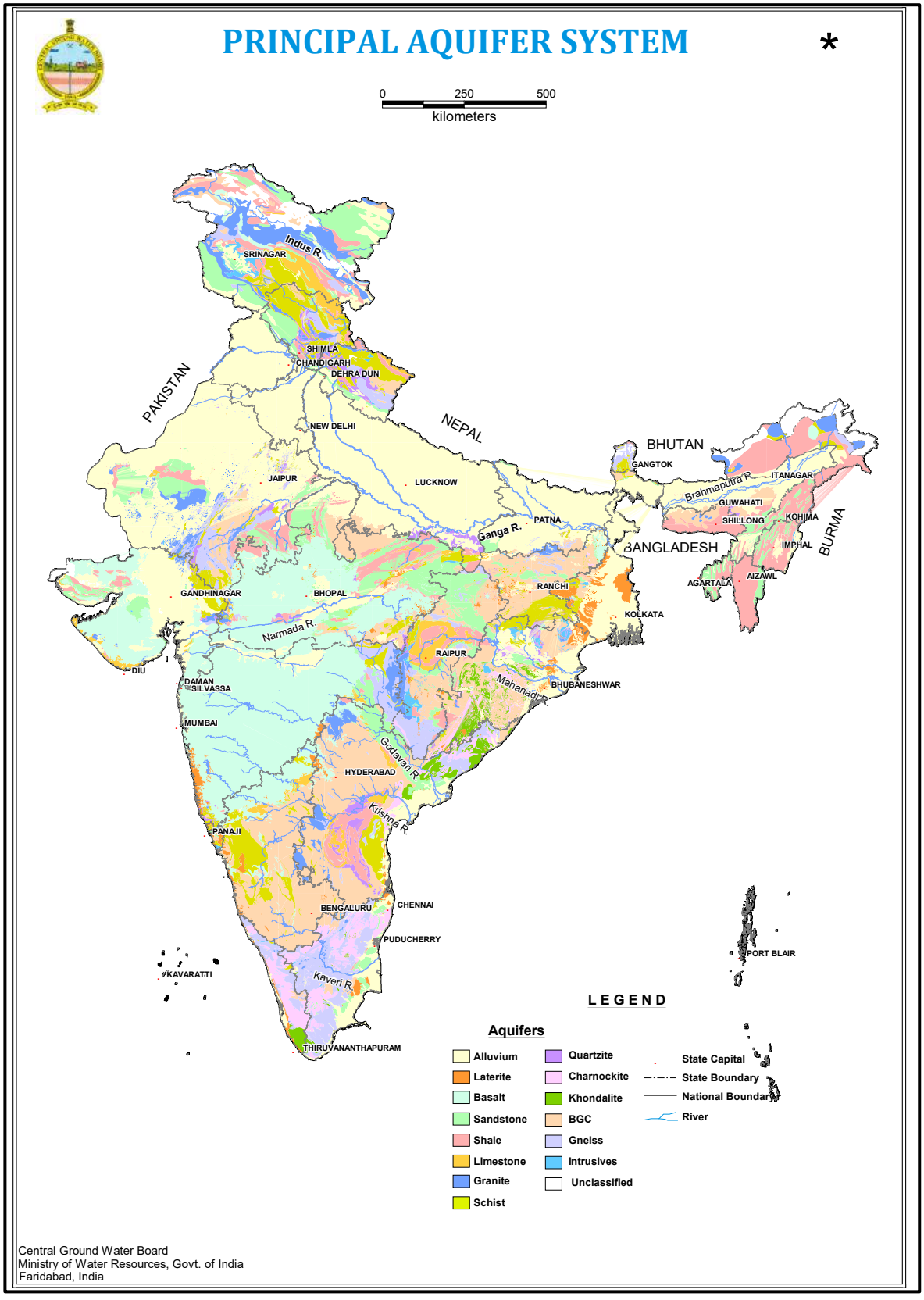


Fig-4.1: Principal Aquifer Systems of India

CHAPTER-5

GROUND WATER LEVEL SCENARIO IN THE COUNTRY

Groundwater level is one of the basic data elements, which reflects the groundwater regime in an area. Central Ground Water Board (CGWB) monitors groundwater levels four times a year during January, April/ May, August and November through a network of fixed observation wells spreading throughout the country. The periodicity of groundwater level monitoring by the State Governments varies from State to State. The primary objective of monitoring the groundwater level is to record the response of groundwater regime to the natural and anthropogenic stresses on recharge and discharge components which are governed by geology, climate, physiography, land use pattern and hydrologic characteristics. Natural conditions affecting the regime include climatic parameters like rainfall, evapotranspiration etc. Anthropogenic influences include pumpage from the aquifer, recharge due to irrigation systems and other practices like waste disposal etc. Water level data generated and archived by CGWB along with data from State Government departments have been used for assessment of groundwater resources. An outline of groundwater scenario during the period of assessment is given below.

5.1 Groundwater Level Scenario (2023)

Groundwater level data of pre-monsoon 2023 for the country reveals that the general depth to water level of the country ranges from 2 to 10 m bgl. Very shallow water level of less than 2 m bgl is observed in scattered patches in about 6.5% of monitored wells in almost all States/UTs except Chandigarh, Nagaland and Dadra and Nagar Haveli and Daman and Diu. The groundwater level in the range of 2 to 5 m bgl (in 32% of wells) is prominently seen in Assam, Uttar Pradesh, Bihar, Coastal parts of Odisha, few pockets in Andhra Pradesh, Gujarat, Kerala, Tamil Nadu, Telangana and Maharashtra. About 39% of the wells across the country indicate water levels in the range of 5 to 10 m bgl which is significantly observed in almost all states. In major parts of north-western and western states, especially in the states of Delhi, Haryana, Punjab and Rajasthan, depth to water level is generally deeper and ranges from about 20 to more than 40 m bgl. (Fig 5.1)

The groundwater level data for post-monsoon 2023 indicates that depth to water level ranges from 0 to 5 m bgl as observed at about 60% of the monitoring stations. Very shallow water level of less than 2 m bgl is observed in scattered patterns, particularly in the states of Assam, Odisha, Maharashtra, West Bengal, and Tripura. Approximately 42% of wells have groundwater levels ranging from 2 to 5 m bgl, which is significantly observed throughout the entire country except Chandigarh, Delhi, Haryana, Punjab and Rajasthan. In parts of north-western and western states, especially in the states/UTs of Chandigarh, Delhi, Haryana, Punjab and Rajasthan, depth to water level is generally deeper and ranges from about 10m bgl to more than 40 m bgl. The peninsular part of country recorded a water level in the range of 2 to 10 m bgl. (Fig 5.2)

5.1.0 Fluctuation of Groundwater Level:

Comparison of Pre-monsoon 2023 to Pre-monsoon 2022

A comparison of depth to water level of Pre-monsoon 2023 with Pre-monsoon 2022 (Fig. 5.3) indicates that 40.27% of the total analyzed wells tapping phreatic aquifers show rises in water level whereas 58.12% wells show decline in water level. 1.6% wells show no change. Rise and fall in water level are

primarily in the 0 to 2 m range. The declining groundwater level is prominently observed in the parts of states of Andaman and Nicobar Islands, Assam, Bihar, Chandigarh, Chhattisgarh, Delhi, Goa, Jharkhand, Karnataka, Kerala, Nagaland, Odisha, Puducherry, Punjab, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, West Bengal. The rising groundwater level is observed in the parts of states of Andhra Pradesh, Arunachal Pradesh, Daman and Diu, Dadra and Nagar Haveli, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Meghalaya, Rajasthan, Telangana.

Comparison of November 2023 to November 2022

A comparison of the depth to water level in November 2023 with November 2022 (Fig. 5.4) reveals that 38.01% of the total analyzed wells tapping phreatic aquifers showed a rise in water level, while 61.12% of wells showed a decline in water level. Only 0.88% of wells showed no change. The rise and decline in water levels were mainly in the range of 0 to 2 meters. The rise in water level was notably observed in the scattered areas of states/UTs of Andaman and Nicobar Islands, Chandigarh, Delhi, Goa, Himachal Pradesh, Jammu and Kashmir, Kerala, and West Bengal. Groundwater levels have decreased in various areas of all states in a scattered pattern, with more significant decreases observed in states such as Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Jharkhand, Karnataka, Maharashtra, Madhya Pradesh, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Tripura and Uttar Pradesh.

Comparison of Pre-Monsoon 2023 with decadal mean of Pre-Monsoon (2013 to 2022)

The comparison of the decadal water level fluctuations with the mean of pre-monsoon (2013 to 2022) and pre-monsoon 2023 (Fig. 5.5) shows that 56.11% of the analyzed wells have experienced a rise in water levels, while 43.56% have shown a decline. Only 0.33% of the wells have shown no change. The rise and decline in water levels are primarily in the 0-to-2-meter range. The rise in water levels is prominently seen in the parts of states/UTs of Andhra Pradesh, Assam, Chandigarh, Delhi, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Puducherry, Rajasthan, Tamil Nadu, Telangana, and The Dadra and Nagar Haveli and Daman and Diu. Similarly, states where a decline in water levels is prominently observed include significant parts of Andaman and Nicobar Islands, Arunachal Pradesh, Bihar, Chhattisgarh, Goa, Haryana, Jammu and Kashmir, Jharkhand, Punjab, Tripura, Uttar Pradesh, Uttarakhand, and West Bengal.

Comparison of Post-Monsoon 2023 with decadal mean of Post-Monsoon (2013 to 2022)

A comparison of decadal water level fluctuation with mean of post-monsoon (2013 to 2022) and post-monsoon 2023 (Fig. 5.6) indicates that 48.43% of the analysed wells show rise in water level whereas 51.22% wells show decline in water level. Only 0.36% of the wells have shown no change. Rise and decline in water level are primarily in the 0 to 2 m range. Rise in water level is prominently seen in the states/UTs of Andaman And Nicobar Islands, Chandigarh, Chhattisgarh, Delhi, Gujarat, Himachal Pradesh, Jammu and Kashmir, Kerala, Madhya Pradesh, Odisha, Puducherry, Tamil Nadu, Telangana, The Dadra And Nagar Haveli And Daman And Diu, Uttar Pradesh, Uttarakhand and West Bengal. Similarly, states where a decline in water levels is observed include significant parts of Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Goa, Haryana, Jharkhand, Karnataka, Maharashtra, Meghalaya, Punjab, Rajasthan and Tripura.

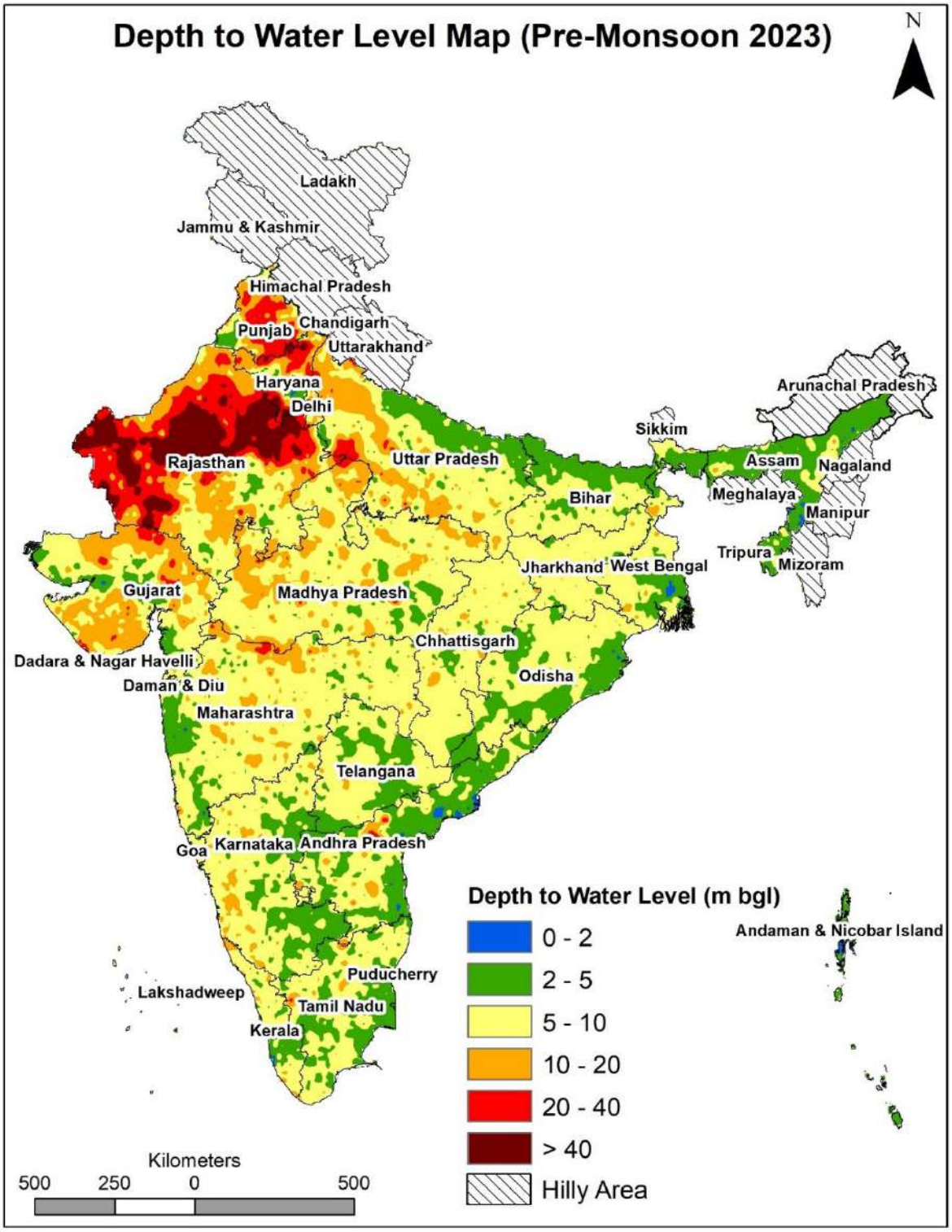


Fig-5.1: Pre-monsoon Depth to Water Level Map (2023)

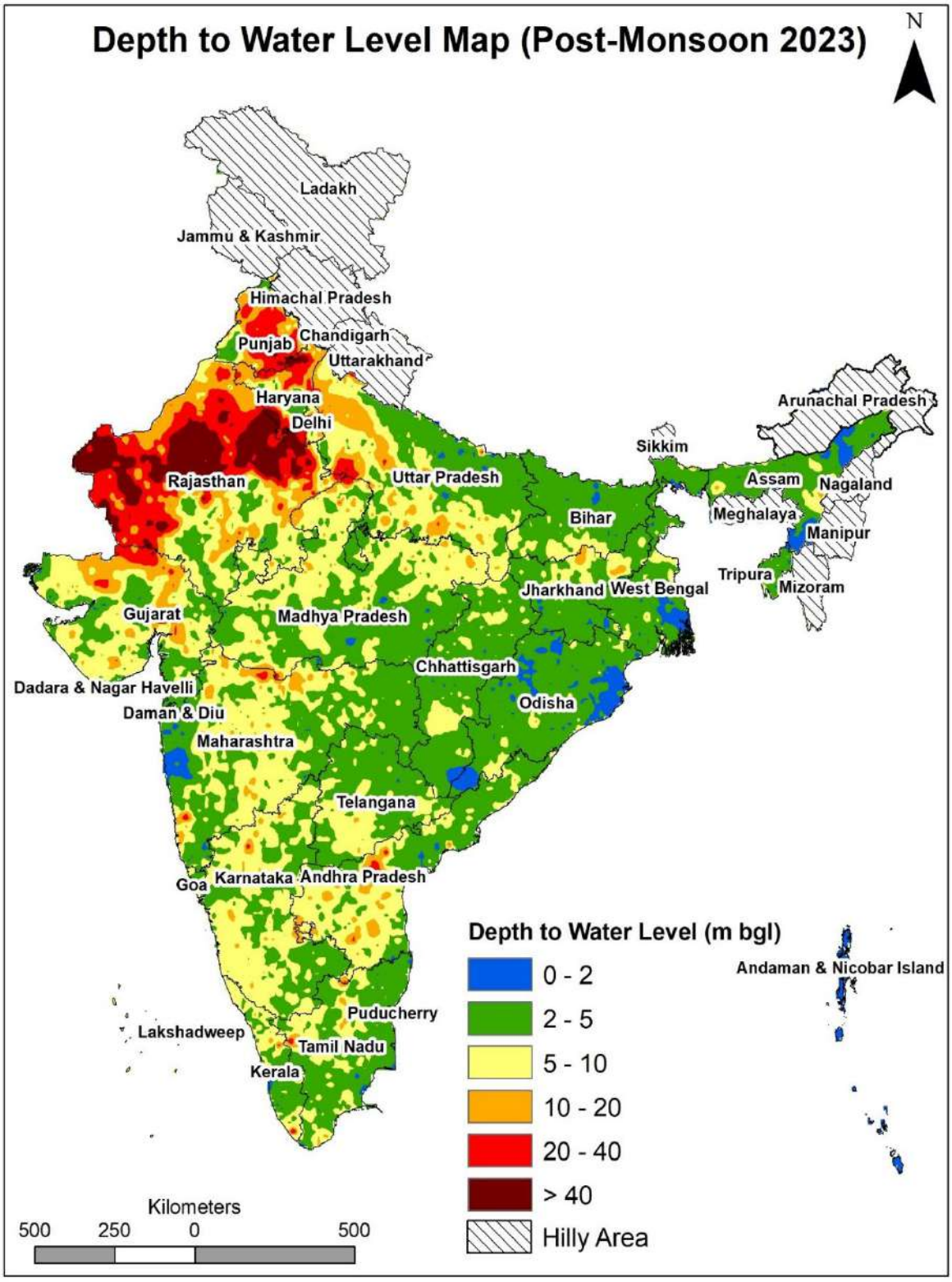


Fig-5.2: Post-monsoon Depth to Water Level Map (2023)

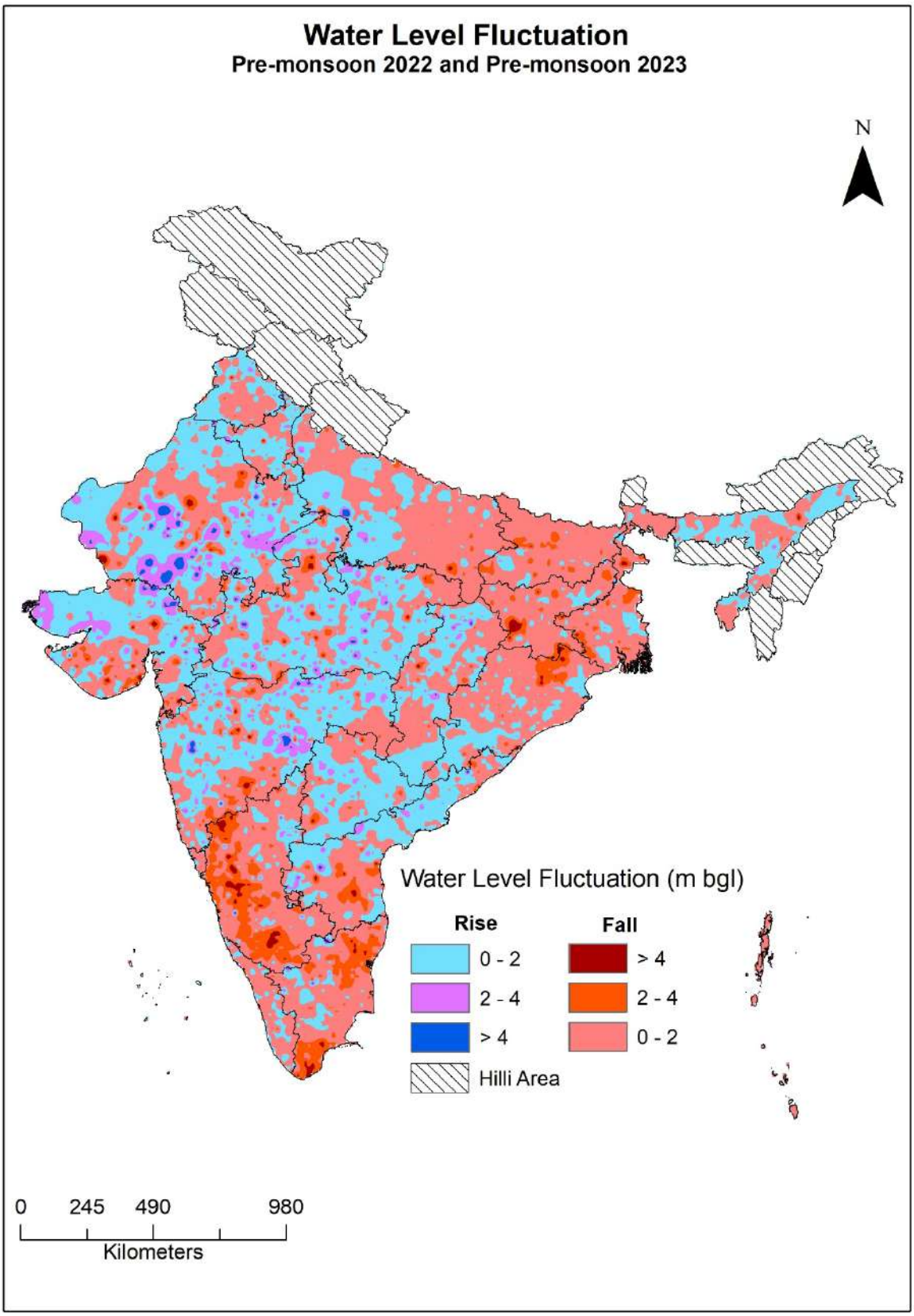


Fig-5.3: Groundwater Level Fluctuation: Pre-monsoon 2022 compared to Pre-monsoon 2023

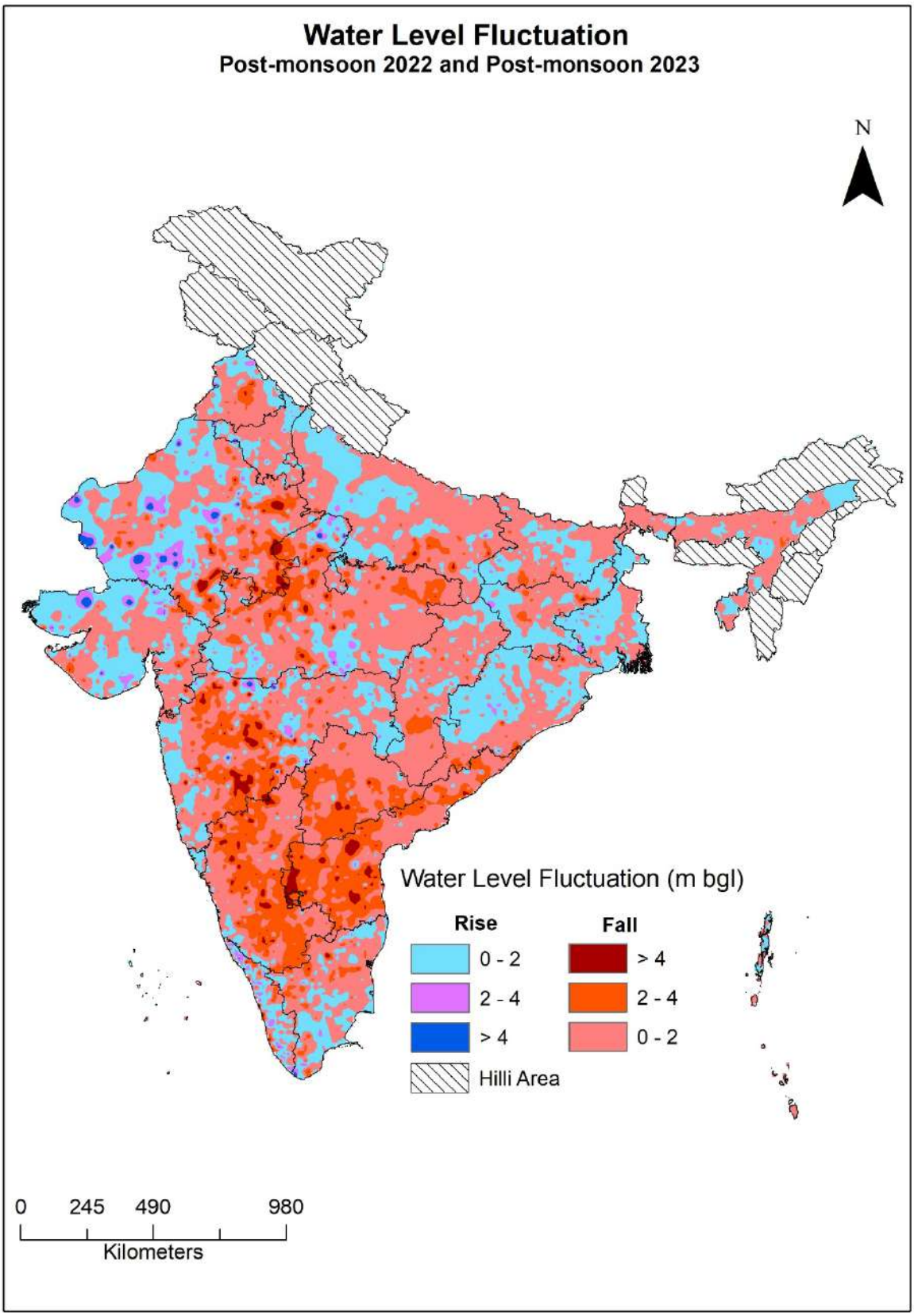


Fig-5.4: Groundwater Level Fluctuation: November 2022 compared to November 2023

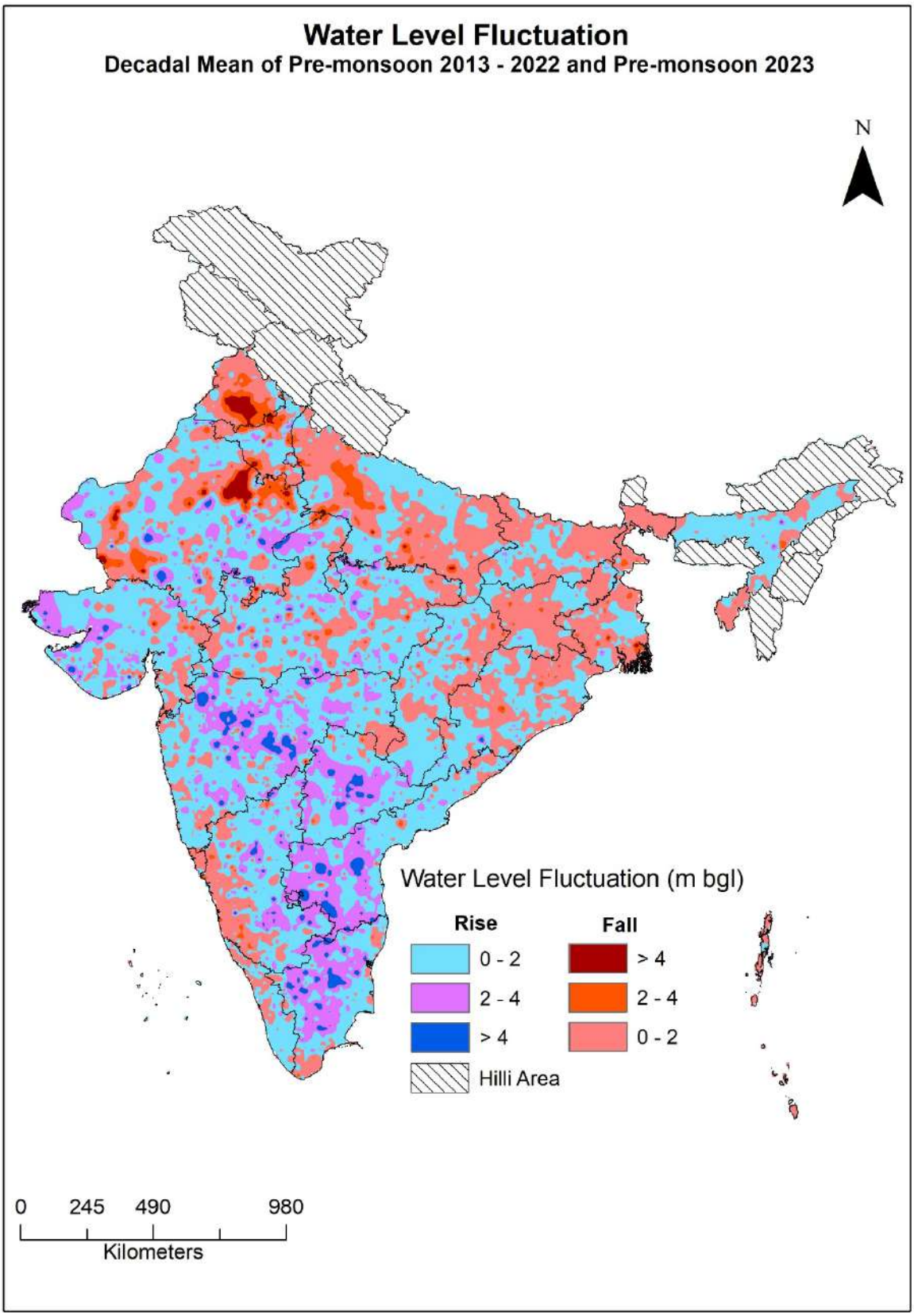


Fig-5.5: Decadal water level fluctuation with mean Pre-Monsoon (2013 to 2022) and Pre-Monsoon 2023

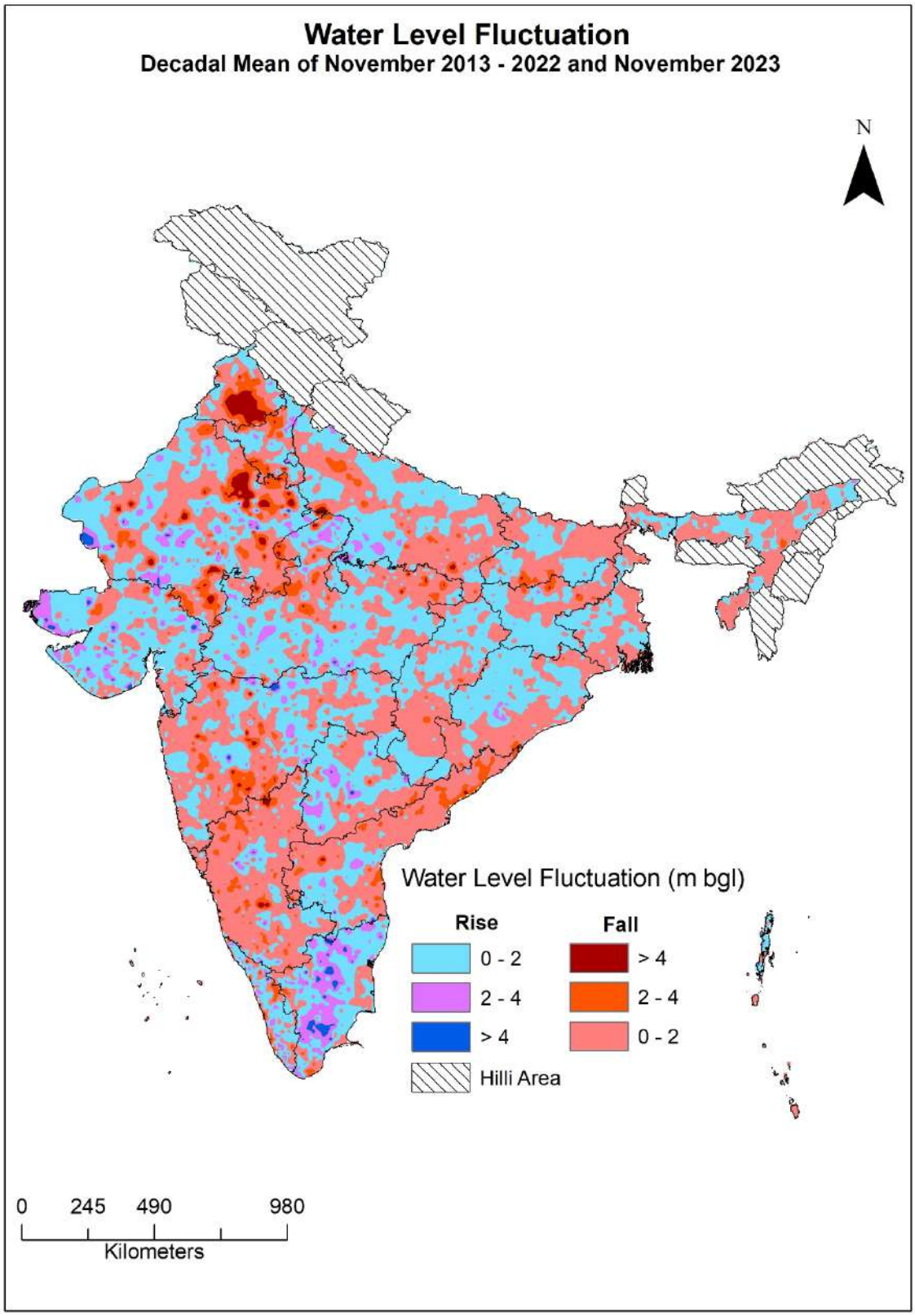


Fig-5.6: Decadal water level fluctuation with mean Post-Monsoon (2013 to 2022) and Post-Monsoon 2023

CHAPTER 6

GROUND WATER RESOURCES OF INDIA

The Dynamic ground water resources (as in 2024) of the entire country have been assessed jointly by CGWB and State Ground Water Departments under the supervision of the State level Committees. The dynamic ground water resources are also known as Annual Ground Water Recharge, since it gets recharged every year from rainfall and other secondary sources such as applied irrigation water, surface water bodies, water conservation structures, etc. Methodology adopted for the assessment has been outlined in Chapter-2 of this report. This section provides a summary of the Ground water Resources Assessment 2024 (GWRA-2024) made for the country.

6.1. DYNAMIC GROUND WATER RESOURCES

As per the 2024 assessment of Dynamic Ground Water Resources, the Total Annual Ground Water Recharge for the entire country has been assessed as 446.90 billion cubic meter (bcm) and the Annual Extractable Ground Water Resources for the entire country is 406.19 bcm with total natural discharges at 41.05 bcm.

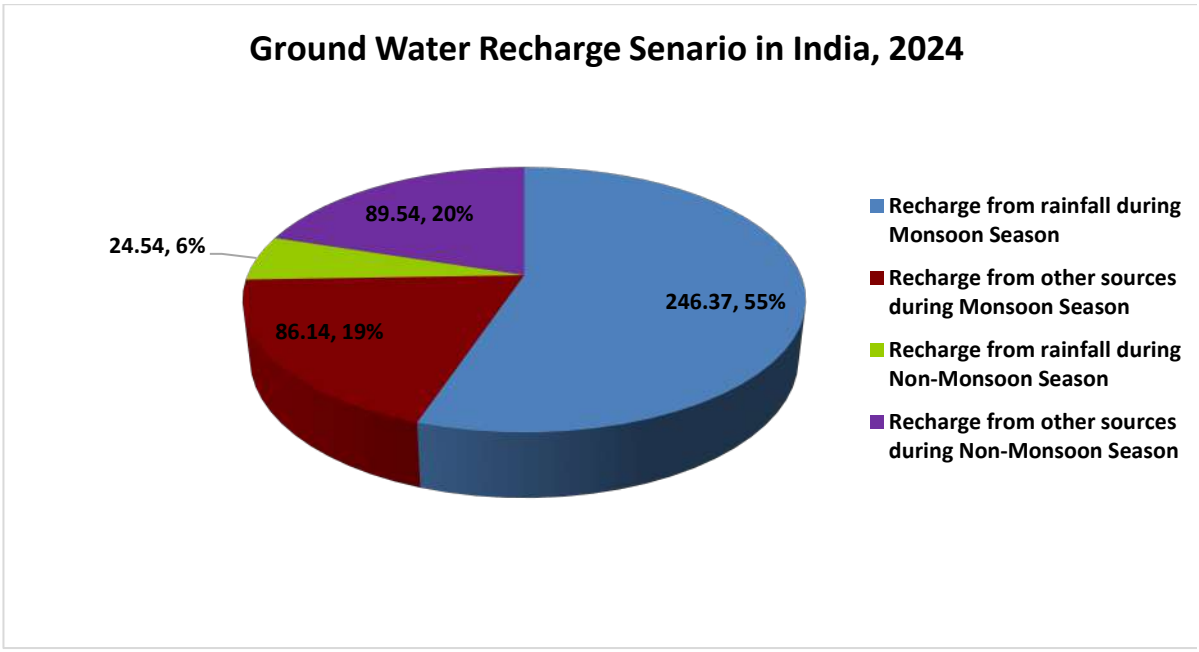
Rainfall recharge during monsoon and non-monsoon period is the major contributor of total annual groundwater recharge of the country, which is 270.91 bcm or 61 % of the total recharge (Monsoon season: 55%, Non-monsoon season: 6%) and the remaining 39% (Monsoon season: 19%, Non-monsoon season: 20%) or 175.68 bcm is from 'Other sources' viz. canal seepage, return flow from irrigation, recharge from tanks, ponds and water conservation structures taken together. (***Fig-6.1***). In addition, 0.31 bcm is contributed by lateral flows in Punjab state to the annual ground water recharge. The contribution in annual ground water recharge from rainfall during monsoon season is more than 70% in the states/UT of Assam, Goa, Gujarat, Jharkhand, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Rajasthan, Daman & Diu, and Lakshadweep (***Fig- 6.2***). The overall contribution of rainfall (both monsoon & non-monsoon) recharge to country's total annual ground water recharge is 60% and the share of recharge from 'Other sources' viz. canal seepage, return flow from irrigation, recharge from tanks, ponds and water conservation structures taken together is 40%.

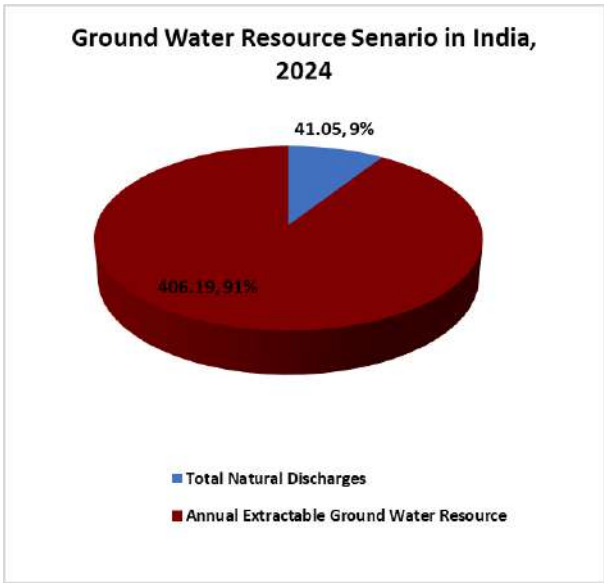
State-wise Ground Water Resources of India (as in 2024) are given in **Annexure-I** and the district-wise figures for each State are given in **Annexure-II**. The over-all scenario of ground water resource and extraction in the country is given in ***Fig-6.1, 6.2, 6.3, 6.4 & 6.5.***

In order to compare the unit recharge of different assessment units, the volumetric estimates of annual ground water recharge had been converted to depth units (m) by dividing the annual ground water recharge (ha.m) by the area of the respective assessment units (hectare). Spatial variation in annual ground water recharge (m) is shown in **Fig-6.3.** The annual ground water recharge is significantly high in the Indus-Ganga-Brahmaputra alluvial belt in the North, East and North East India covering the states of Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal and valley areas of North Eastern States, where rainfall is plenty and thick piles of unconsolidated alluvial formations are conducive for recharge. Annual Ground Water Recharge in these regions are more than 0.20 m. The coastal alluvial belt particularly Eastern Coast also has relatively high annual extractable ground water resource, in the range > 0.20 m. In western India, particularly Rajasthan and parts of northern Gujarat that have arid climate, the annual ground water recharge is scanty, mostly below 0.075 m. Similarly, in major parts of the southern peninsula

covered with hard rock terrains and parts of Central India, the annual ground water recharge mostly ranges from 0.075 - 0.20 m. This is primarily because of comparatively low infiltration and storage capacity of the rock formations prevailing in the region.

Annual Ground Water Recharge (m)	States/UTs
>0.2 m	Arunachal Pradesh, Assam, Bihar, Chandigarh, Dadra and Nagar Haveli and Daman and Diu, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Uttar Pradesh, Uttarakhand, West Bengal, Puducherry, and Andaman and Nicobar (17 Nos)
>0.1 and ≤0.2 m	Andhra Pradesh, Chhattisgarh, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nagaland, Odisha, Sikkim, Tamil Nadu, Telangana, Tripura. (13 Nos)
>0.075 and ≤0.1 m	Karnataka, Jharkhand, Ladakh, and Lakshadweep (4 Nos).
≤0.075 m	Mizoram and Rajasthan (2 Nos)





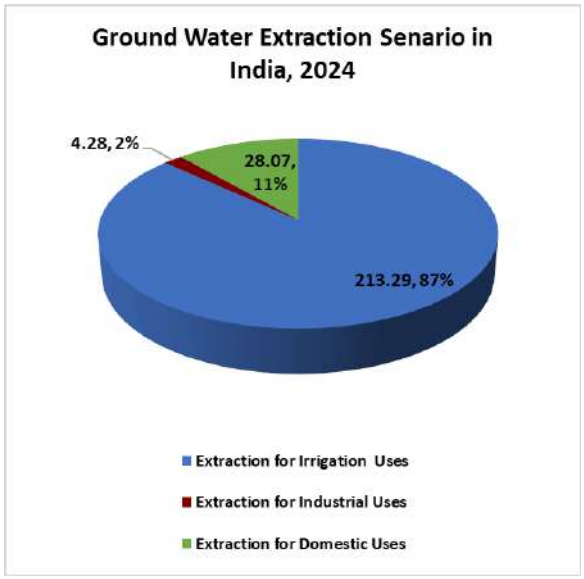


Fig-6.1: Ground Water Resources and Extraction Scenario in India, 2024

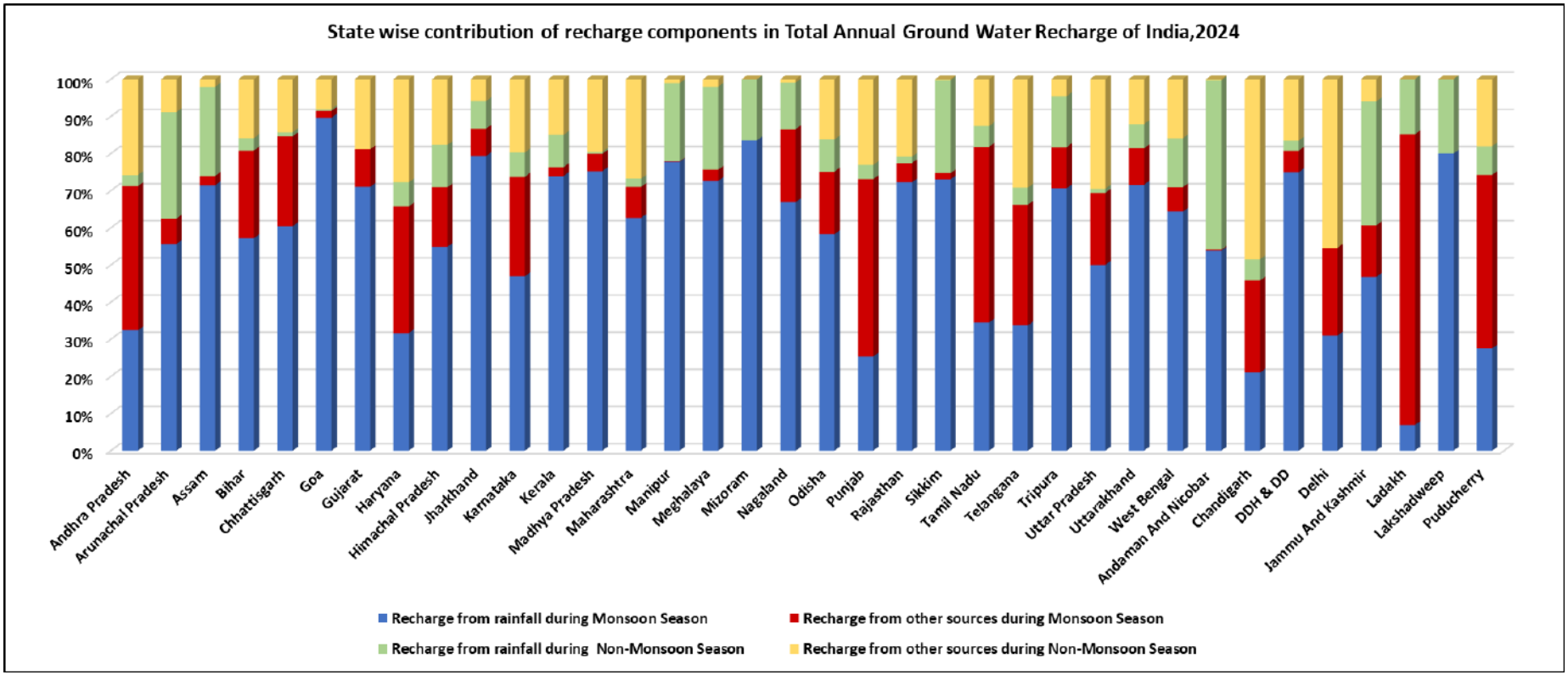


Fig-6.2: State wise contribution of recharge components in Total Annual Ground Water Recharge of India, 2024

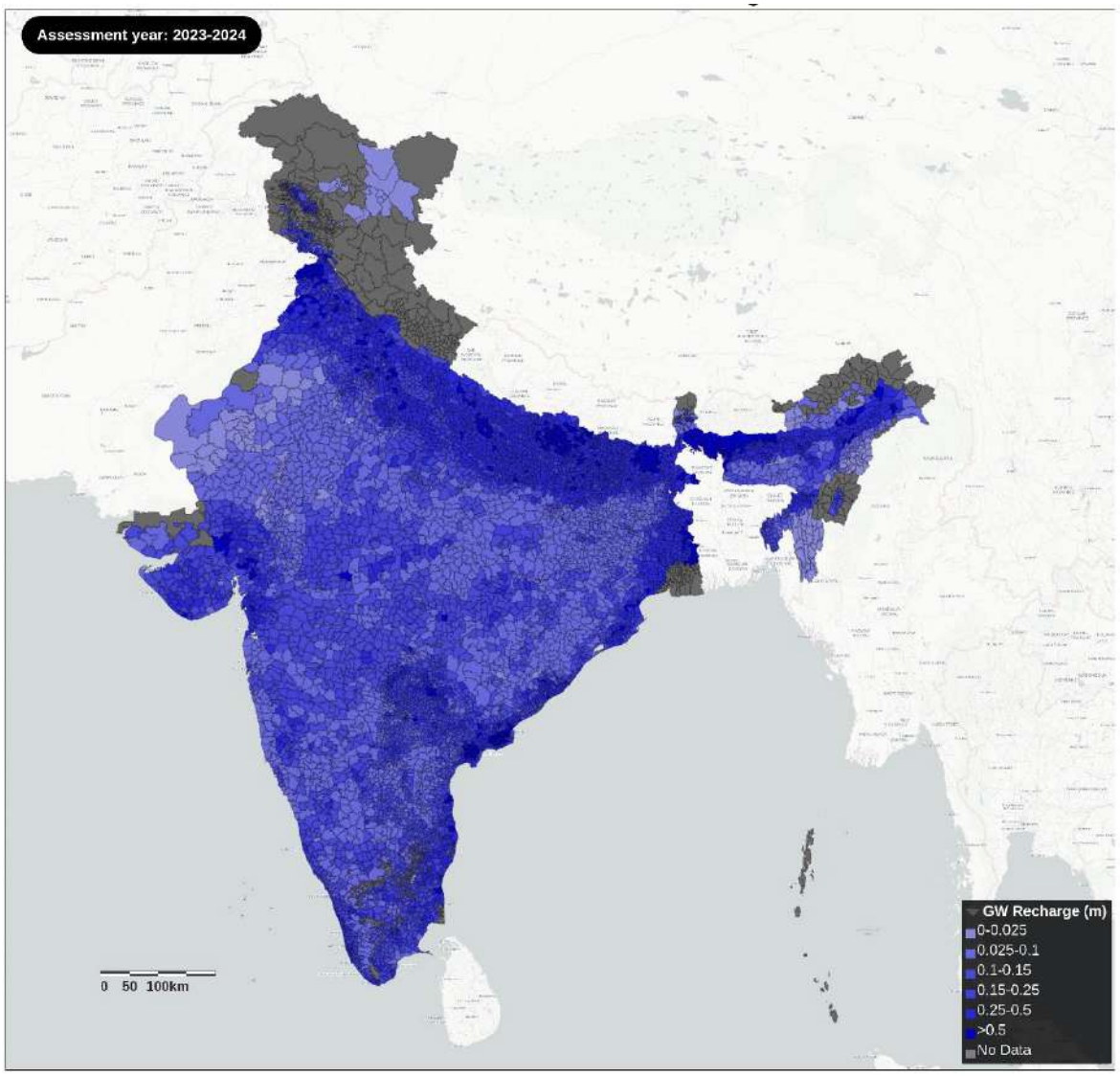


Fig. 6.3: Spatial variation in annual ground water recharge (in m), 2024

6.2. GROUND WATER EXTRACTION

The assessment of ground water extraction is carried out considering the Minor Irrigation Census data and sample surveys carried out by the State Ground Water Departments. The Total Annual Ground Water Extraction of the entire country for the year 2024 has been estimated as 245.64 bcm. The agriculture sector is the largest consumer of groundwater resources, accounting for 87% of the total annual groundwater extraction, which amounts to 213.29 bcm. The domestic use accounts for 11% (28.07 bcm), while industrial use represents 2% (4.28 bcm) of total annual groundwater extraction of the Country. In the states/UTs of, Arunachal Pradesh, Delhi, Goa, Kerala, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Andaman and Nicobar, Chandigarh, Jammu and Kashmir, Ladakh, Lakshadweep the ground water extraction for domestic uses is more than 40 % **(*Fig-6.4*).**

6.3. STAGE OF GROUND WATER EXTRACTION

The overall stage of groundwater extraction in the country is 60.47 %. The State/UT wise distribution of Stage of Groundwater Extraction is as follows:

1. **Stage of Groundwater Extraction > 100%:** Punjab, Rajasthan, Dadra and Nagar Haveli and Daman and Diu, Haryana, and Delhi.
2. **Stage of Groundwater Extraction > 90% to 100%:** Nil
3. **Stage of Groundwater Extraction > 70% to 90%:** Tamil Nadu, Uttar Pradesh, Puducherry and Chandigarh.
4. **Stage of Groundwater Extraction < 70%:** Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Sikkim, Telangana, Tripura, Uttarakhand, West Bengal, Andaman and Nicobar, Jammu and Kashmir, Ladakh, Lakshadweep.

6.4. CATEGORIZATION OF ASSESSMENT UNITS

In the present assessment, the total annual groundwater recharge in the country has been assessed as 446.90 bcm. Keeping an allocation for natural discharge, the annual extractable ground water resource has been assessed as 406.19 bcm. The annual groundwater extraction (as in 2024) is 245.64 bcm. The average stage of groundwater extraction for the country as a whole works out to be about 60.47 %. Out of the total 6746 assessment units (Blocks/ Mandals/ Talukas) in the country, 751 units in various States/ UTs (11.13%) have been categorized as 'Over-exploited' indicating ground water extraction exceeding the annual replenished ground water recharge. In, 206 (3.05 %) assessment units the stage of groundwater extraction is between 90-100% and have been categorized as 'Critical'. There are 711 (10.54 %) "Semi-critical'' units, where the stage of ground water extraction is between 70 % and 90 % and 4951 (73.39 %) 'Safe' units, where the stage of Ground water extraction is less than 70 %. Apart from these, there are 127(1.88%) assessment units, which have been categorized as 'Saline' as major part of the ground water in phreatic aquifers in these units is brackish or saline. The State-wise and District-wise numbers of assessment units under different categories are given in **Annexure III (A) and Annexure III (B)** respectively. The percentage of Over-exploited and Critical administrative units more than 25% of the total units are in Delhi, Haryana, Punjab, Rajasthan, Tamil Nadu, Dadra & Nagar Haveli, Daman & Diu (***Fig-6.5***). The State-wise name of the assessment units under Over-exploited, Critical and Semi-critical categories and Quality problems in assessment units are given in **Annexure IV (A) and Annexure IV (B)** respectively. Similarly, out of 2480.22 thousand sq km recharge worthy area of the country, 419.93

thousand sq km (16.93%) are under 'Over-Exploited', 88.16 thousand sq km (3.55 %) are under 'Critical', 282.77 thousand sq km (11.40%) are under 'Semi-Critical', 1651.03 thousand sq km (66.57 %) are under 'Safe' and 38.31 thousand sq km (1.55%) are under 'Saline' category assessment units. State-wise and District-wise details are given in **Annexure III (E) and Annexure III (F)** respectively. Out of 406.19 bcm of Total Annual Extractable Resources of the country, 46.02 bcm (11.33%) are under 'Over-Exploited', 13.23 bcm (3.26%) are under 'Critical', 45.76 bcm (11.27%) are under 'Semi-Critical', 301.17 bcm (74.14%) are under 'Safe' category assessment units. State/UT-wise and District-wise details are given in **Annexure III (C) and Annexure III (D)** respectively.

The state wise summary of assessment units improved or deteriorated from 2023 to 2024 assessment and detailed comparison of categorization of assessment units from 2023 and 2024 are given in **Annexure V (A) and Annexure V (B)** respectively**.**

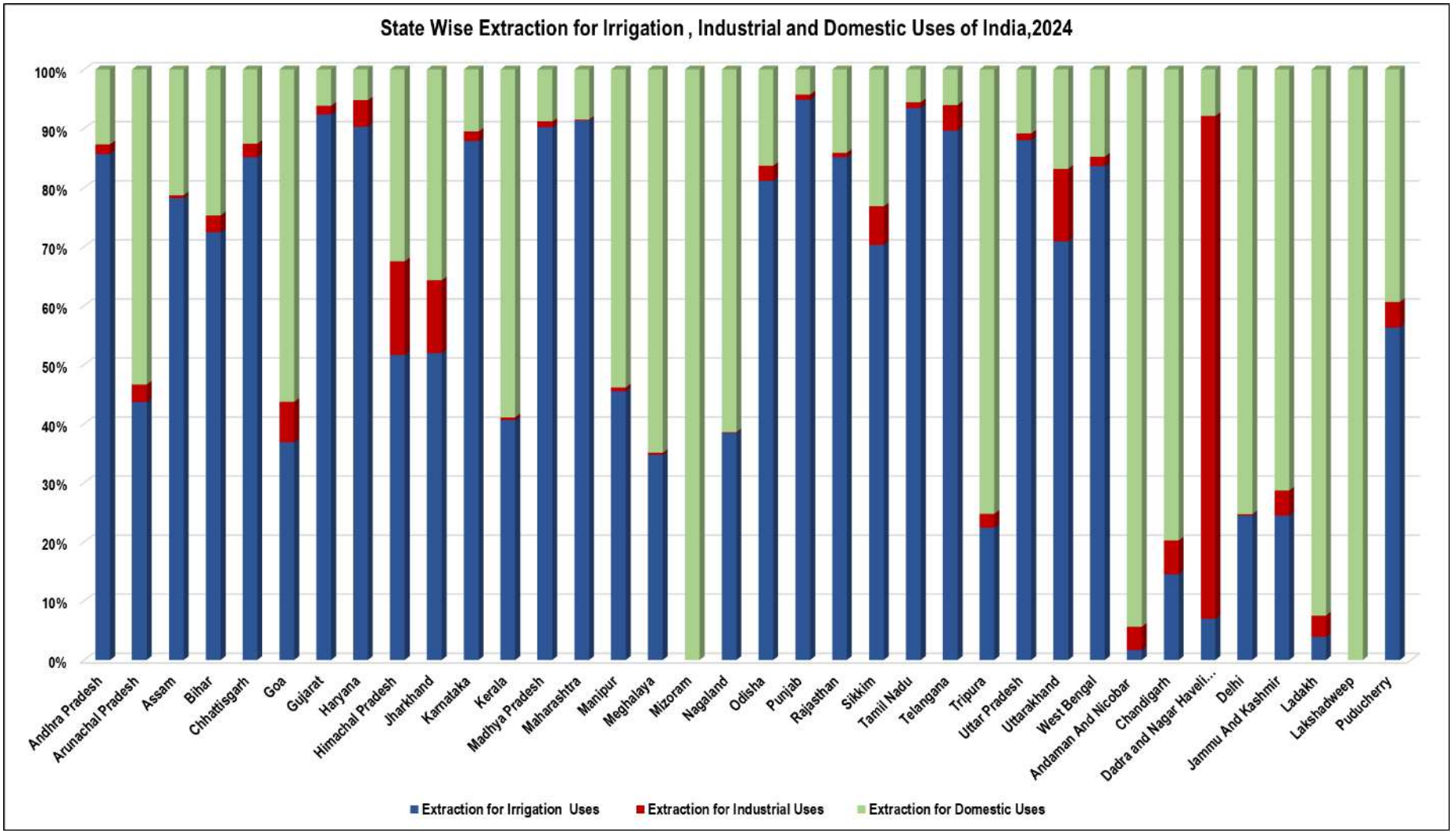
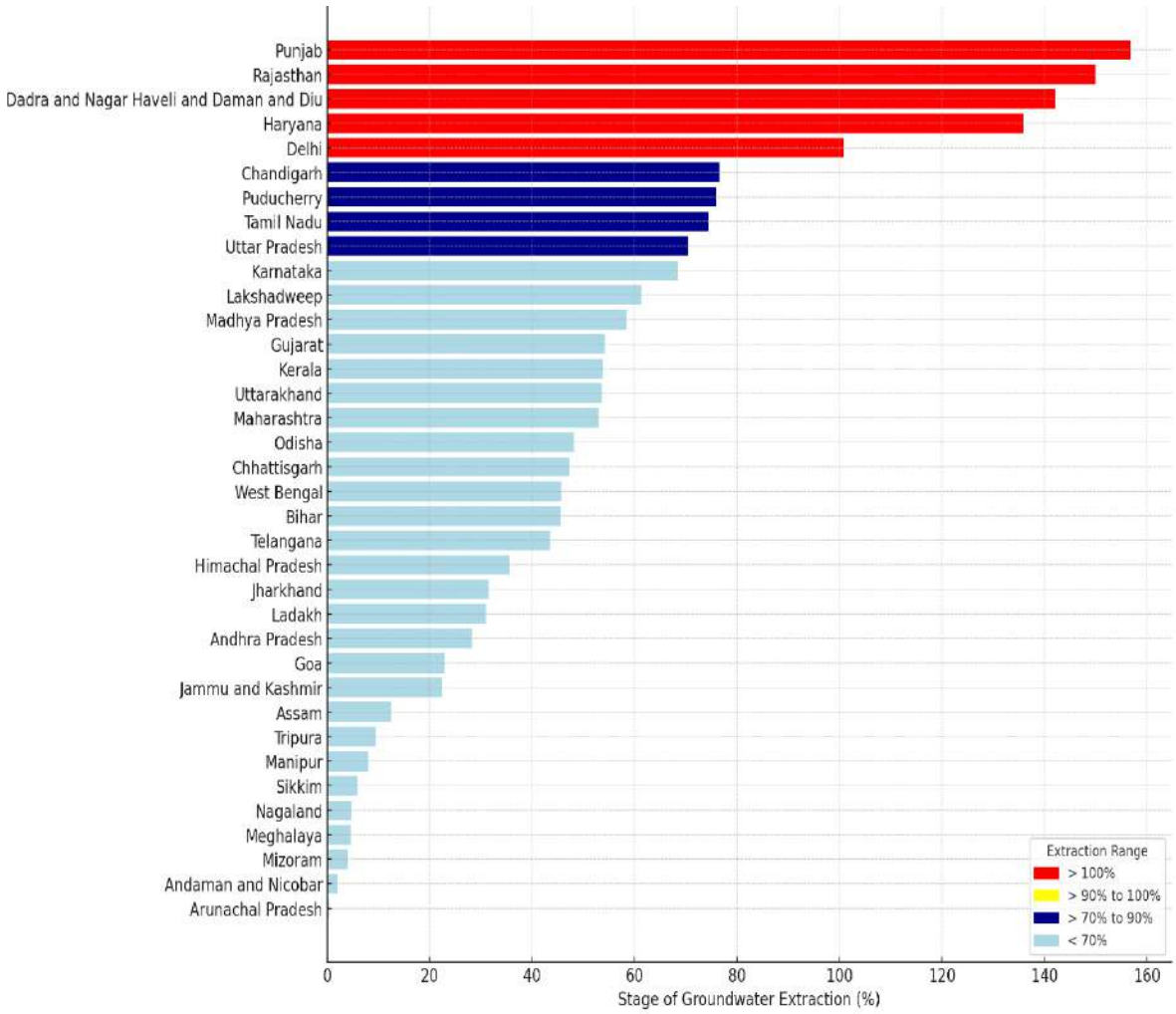


Fig-6.4: State wise % of Groundwater extraction for Irrigation vs. Industrial and Domestic Purposes


Punjab
Rajasthan
Dadra and Nagar Haveli and Daman and Diu
Haryana
Delhi
Chandigarh
Puducherry
Tamil Nadu
Uttar Pradesh
Karnataka
Lakshadweep
Madhya Pradesh
Gujarat
Kerala
Uttarakhand
Maharashtra
Odisha
Chhattisgarh
West Bengal
Bihar
Telangana
Himachal Pradesh
Jharkhand
Ladakh
Andhra Pradesh
Goa
Jammu and Kashmir
Assam
Tripura
Manipur
Sikkim
Nagaland
Meghalaya
Mizoram
Andaman and Nicobar
Arunachal Pradesh
Extraction Range
> 100%
> 90% to 100%
> 70% to 90%
< 70%
0
20
40
60
80
100
120
140
160
Stage of Groundwater Extraction (%)

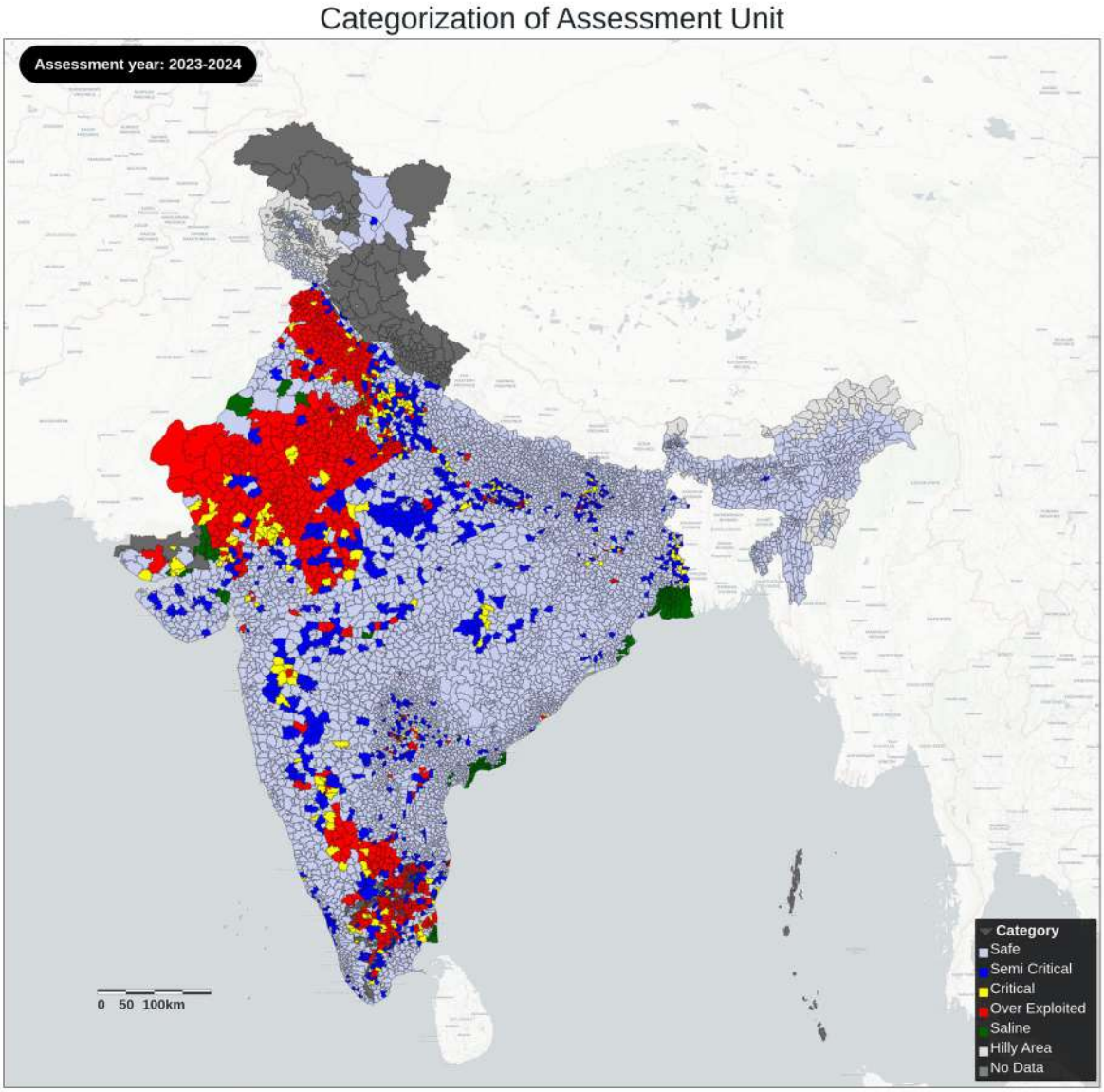


Fig-6.5: Categorization of Assessment Units

6.5. INTEGRATION OF GROUND WATER AND SURFACE WATER DATA WITH A VIEW TO FACILITATE PLANNING FOR CONJUNCTIVE USE OF WATER RESOURCES

Assessment of ground water resources is based on the principle of water balance using the equation 'Inflow – Outflow = Change in Storage (of an aquifer)'. Major inflow components include recharge due to rainfall and recharge from other sources. Major outflow component is ground water extraction for domestic, irrigation and industrial uses. Vertical flow across the aquifer system, lateral flow along the aquifer system (through flow), transpiration, evaporation and base flow are other important components.

The area of each assessment unit (block/taluk/mandal/tehsil etc.) is divided into command area and non-command area for the purpose of assessment. If an assessment unit is having more than 100 ha area under major and medium irrigation projects then that much area will be considered as command area. For the command area, along with other data/information pertaining to ground water resource assessment, data/information related to canal flows is collected from the relevant agencies for assessing the recharge from canal seepage. Similarly, data related to irrigation water applied in the assessment area from surface and ground water sources in different seasons are estimated for assessing the return flow from irrigation (return flow factor depends upon depth to water level, paddy/non-paddy crops etc.). Recharge from water bodies/tanks/lakes are assessed in the area based on average water spread area and recharge factor. Recharge from water conservation structures in the area are assessed based on the storage capacity, number fillings and recharge factor. All these data/information are collected/compiled for assessment of ground water resource of the assessment units. Based the ground water resources assessed and surface water sources availability, integrated water resource management plan and planning for conjunctive management of surface and ground water can be devised at block/assessment level by the planners. This data/information collected/compiled for assessment will be very useful for local administrators for managing water resources in a holistic and sustainable manner.

CHAPTER 7

STATE WISE GROUND WATER RESOURCE SCENARIO

The ground water conditions, its availability and utilization scenario and categorization of assessment units in different states are given in Annexure I, II, III & IV. State wise summaries are given below.

7.1 ANDHRA PRADESH

The State is divided into 679 assessment units (Mandals) as the State is predominantly covered by hard rocks. The Ground water resources of these watersheds were estimated separately for Command, Non-Command and Poor ground Water Quality areas for the reference year 2024. The state is underlain by diverse rock types of different geological ages from Pre-Cambrian to Recent. As much as 80% of the State is underlain by hard rock formations like Archaeans, Pre- Cambrians, Cuddapahs, Kurnools and Deccan traps. The remaining 20% is underlain by soft rocks including Gondwanas, Rajahmundry sandstone and Recent Alluvium.

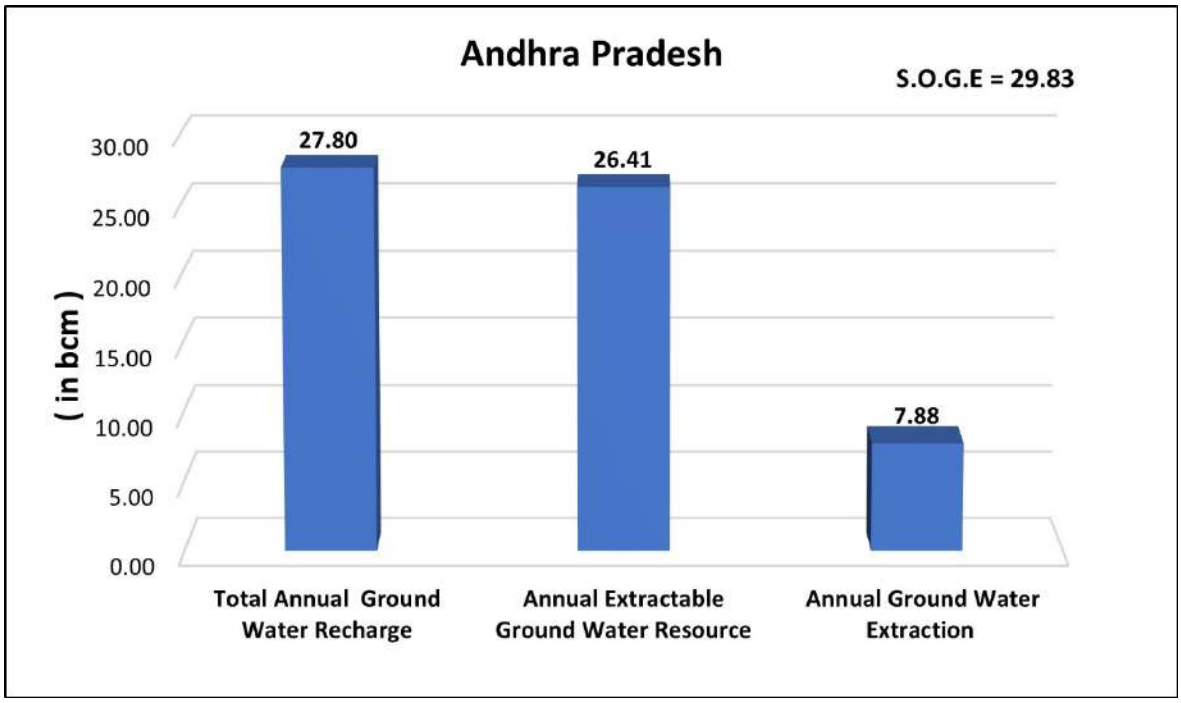
Ground Water Resources have been assessed on a watershed basis and allocated to mandals. The total annual groundwater recharge for the state is estimated at 27.8 bcm, with an annual extractable resource of 26.41 bcm. The current annual groundwater extraction for all uses is 7.88 bcm, and the stage of groundwater extraction is 29.83%. In 2023, the Ground Water Resource Assessment units (mandal) covered 667 units, but this increased to 679 units in 2024, reflecting a difference of 12 mandals. These additional mandals include 1 in Ananthapuram Urban, 1 in Kurnool Urban, 1 in Guntur Urban, 3 in NTR (Vijayawada) Urban, and 6 in Visakhapatnam Urban.

Out of 679 assessment units (mandals), 09 (1.32%) units have been categorized, as ‘Over-exploited’, 02 units (0.29%) as ‘Critical’, 38 units (5.59%) as ‘Semi-Critical’, 591 units (87.03 %) as ‘Safe’ and 39 units categorized as ‘Saline’ (5.74%).

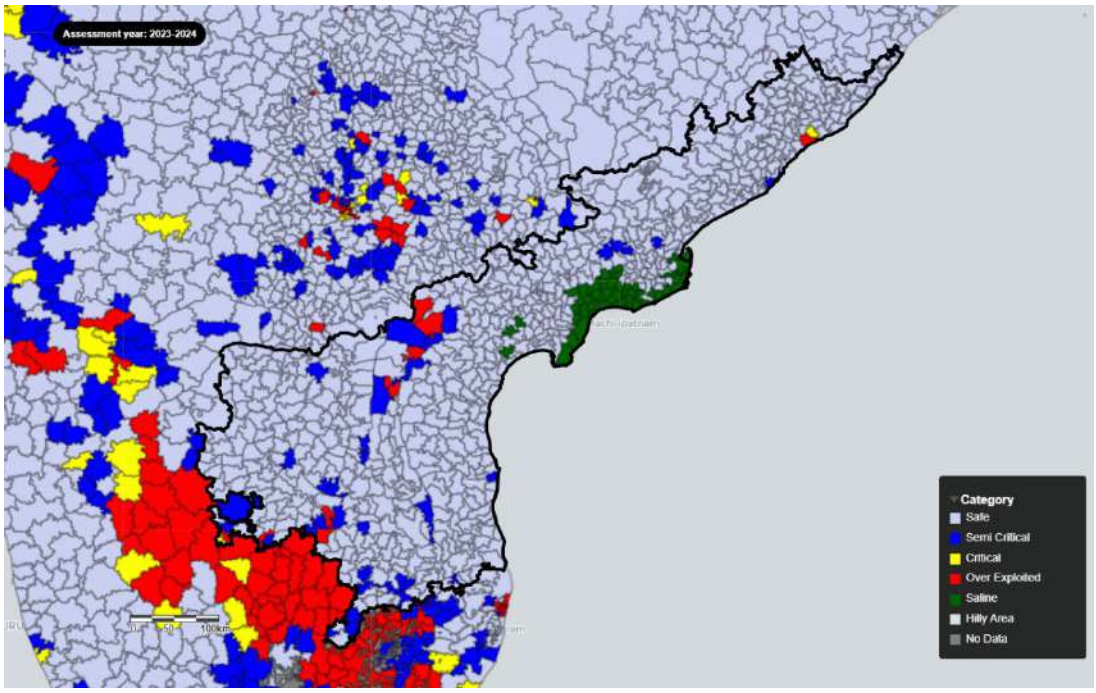
Similarly, out of 140378.61 sq km recharge worthy area of the State, 2278.23 sq km (1.62 %) area are under ‘Over-Exploited’, 236.68sq km (0.17 %) under ‘Critical’, 7947.83 sq km (5.66 %) under ‘Semi-critical’, 123819.54 sq km (88.2 %) under ‘Safe’ category of assessment units. 6096.33 sq km (4.34%) area is under ‘Saline’ category of assessment units.

Out of total 26411.44 mcm annual extractable ground water resources of the State, 261.89 mcm (0.99%) are under ‘Over-exploited’, 66.12 mcm (0.25 %) under ‘Critical’, 897.37 mcm (3.4 %) under ‘Semi-critical’ and 25056.01 mcm (94.87 %) are under ‘Safe’ categories of assessment units.

As compared to the 2023 assessment, the total Annual Ground Water Recharge for the state shows a negligible difference, decreasing slightly from 27.83 bcm to 27.80 bcm.



Dynamic Ground water Recourses Scenario 2024-AndhraPradesh



Categorization Map of GWRA 2024 –Andhra Pradesh

7.2 ARUNACHAL PRADESH

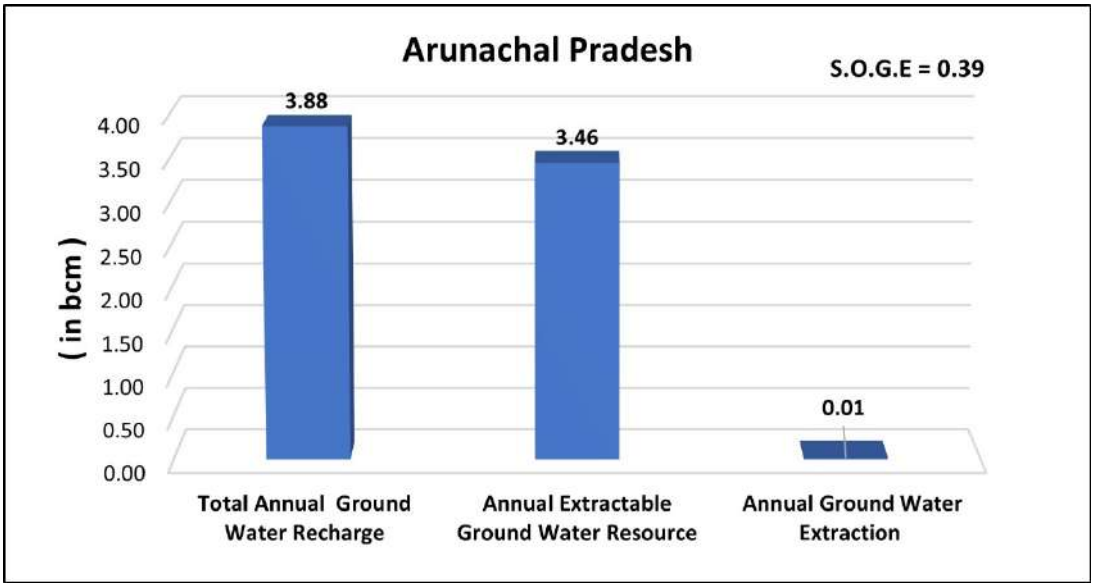
The state of Arunachal Pradesh is underlain by diverse rock types of different geological ages from Pre-Cambrian to Recent. Major part of the state is covered with consolidated crystalline rocks and meta-sediments of Precambrian and Palaeozoic age, while Tertiary sediments consisting of semi-consolidated argillaceous assemblage, represented by the Disang, Barail, Tipam, Siwalik and Dihing groups of rock, occupy periphery areas bordering Assam and behave as run-off and in select patches functions as infiltration zone. In consolidated formations, ground water potential appears to be limited. Semi-consolidated Tertiary formations are likely to give moderate or poor yield and expected to be controlled by aquifer geometry and structural features. Ground water in both consolidated and semi-consolidated formations also manifests as springs and in all geological formation springs occur as both seasonal and perennial in nature.

Unconsolidated Quaternary sediments comprising the terrace deposits of Pleistocene (Bhabar zone) and also the terrace and alluvial fan deposits of Holocene age prevail in the fringe valley areas and as thin carpet in isolated structural valley sand with considerable thickness in open and wide valleys joining Brahmaputra Alluvial plains. The unconsolidated alluvial sediments in the valley areas act as good repositories for ground water development. Valleys adjoining Assam are most promising where good thickness of granular zones is distributed. Discharge of the deep tube wells, tapping mostly unconsolidated Quaternary sediments & at places Upper Tertiary formations, varies from 1.4m³/hr to 54m³/hr, while transmissivity ranges from 1 to 661m²/day. Storativity ranges from $0.35x10^{-3}$ to $6.65x10^{-3}$

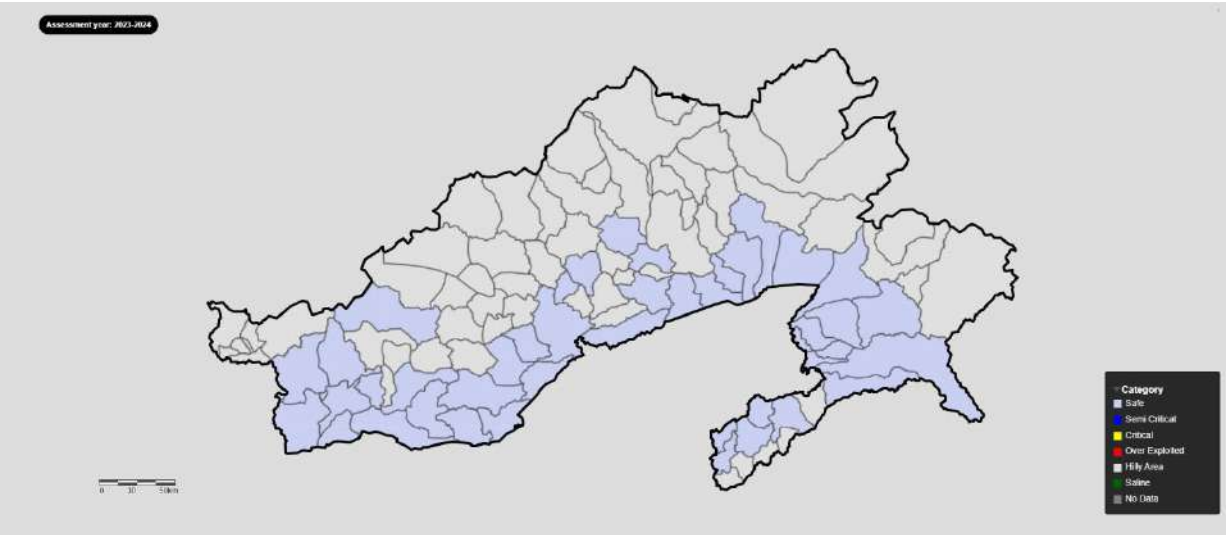
The ground water resource estimation of the state has been done block-wise by considering 42 nos. of groundwater recharge worthy blocks as assessment unit. The Total Annual Groundwater Recharge of the State has been estimated as 3.88 bcm and Annual Extractable Groundwater Resources is 3.46 bcm. The Current Annual Ground Water Extraction for all uses is 0.013 bcm and Stage of Ground Water Extraction is 0.39 %. The Total Annual Ground Water Recharge has decreased from 4.65 bcm to 3.88 bcm. There is minor change in the current annual ground water extraction. All the 42 assessment units have been categorized as ‘Safe’. There is no saline area in the state.

Similarly, out of 5721.38 sq km recharge worthy area of the State, 5721.38 sq km (100 %) under ‘Safe’ categories of assessment units. Out of total 3455.95 mcm annual extractable ground water resources of the State, 3455.95 mcm (100 %) are under ‘Safe’ categories of assessment units.

As compared to 2023 assessment, the Total Annual Ground Water Recharge for the State has decreased from 4.65 bcm in 2023 to 3.88 bcm in 2024, Annual Extractable Ground Water Resources decreased from 4.16 bcm in 2023 to 3.46 bcm in 2024 and Total Ground Water Extraction decreased from 0.02 bcm in 2023 to 0.013 bcm in 2024. The Stage of Ground Water Extraction decreased from 0.42 % to 0.39 %.



Dynamic Ground water Recourses Scenario 2024–Arunachal Pradesh



Categorization Map of GWRA 2024 – Arunachal Pradesh

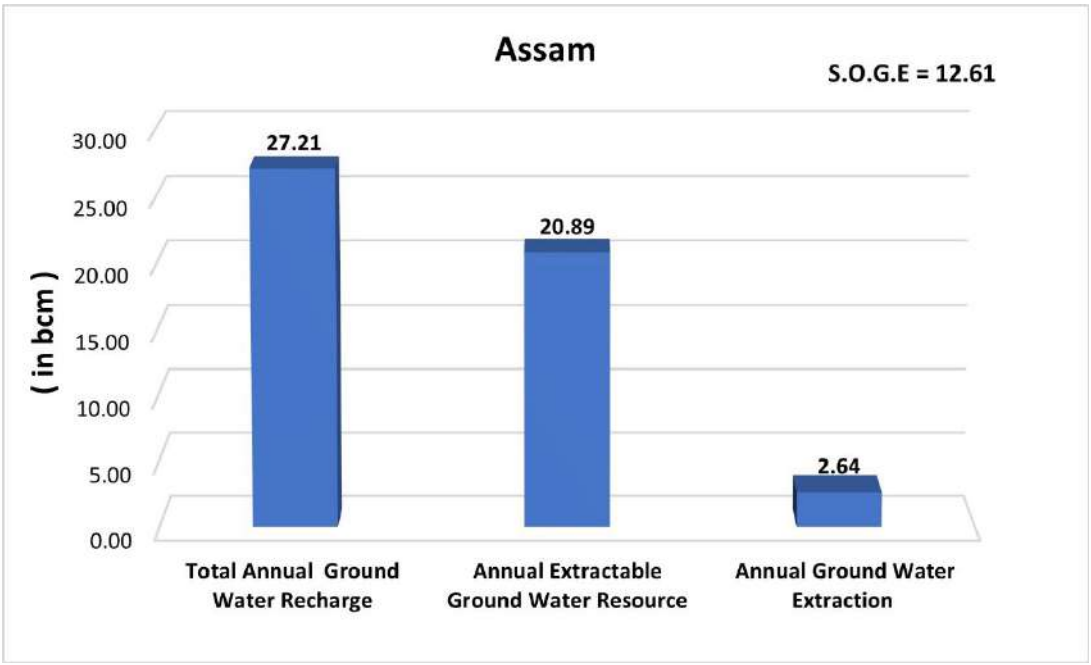
7.3 ASSAM

The State is underlain mainly by unconsolidated Quaternary formation in Brahmaputra valley and potential aquifers lie at shallow as well as deeper zone. The semi-consolidated Tertiary formations are found to occur in the southern part of Karbi Anglong, Cachar, Karimganj and Hailakandi districts and in Upper Assam covering southern fringe of Dibrugarh, Tinsukia, Sibsagar, Jorhat, Golaghat districts. The consolidated Precambrian rocks occur mainly in N.C. Hills, Karbi-Anglong, Kamrup, Goalpara, Dhubri, and Nagaon.

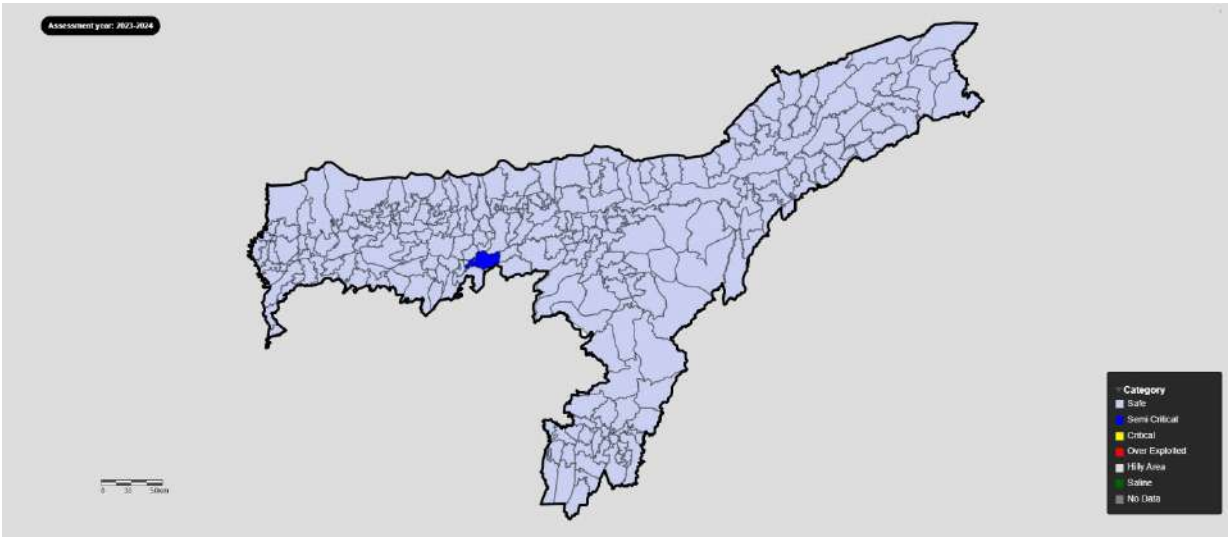
Groundwater resources have been estimated for this year on a block-wise basis for the state. The Total Annual Groundwater Recharge of the State has been estimated as 27.21 bcm and Annual Extractable Groundwater Resources is 20.89 bcm. The Current Annual Ground Water Extraction for all uses is 2.64 bcm and Stage of Ground Water Extraction is 12.61%. Out of 245 assessment units, 244 have been categorized as 'Safe' and one assessment unit of Guwahati is in 'Semi Critical' condition. There is no saline area in the state

Similarly, out of 68817.93 sq km recharge worthy area of the State, 200.42 sq km (0.29 %) under 'Semi-critical', 68617.51 sq km (99.71 %) under 'Safe' categories of assessment units. Out of total 20891.31 mcm annual extractable ground water resources of the State, 41.47 mcm (0.2 %) under 'Semi-critical' and 20849.84 mcm (99.8 %) are under 'Safe' categories of assessment units.

As compared to 2023 assessment, the Total Annual Ground Water Recharge for the State has decreased from 27.26 bcm in 2023 to 27.21bcm in 2024, Annual Extractable Ground Water Resources decreased from 20.93 bcm in 2023 to 20.89 bcm in 2024 and Total Ground Water Extraction increased from 2.63 bcm in 2023 to 2.64 bcm in 2024. Stage of Ground Water Extraction increased from 12.54 % to 12.61 %.



Dynamic Ground water Recourses Scenario 2024– Assam



Categorization Map of GWRA 2024 – Assam

7.4 BIHAR

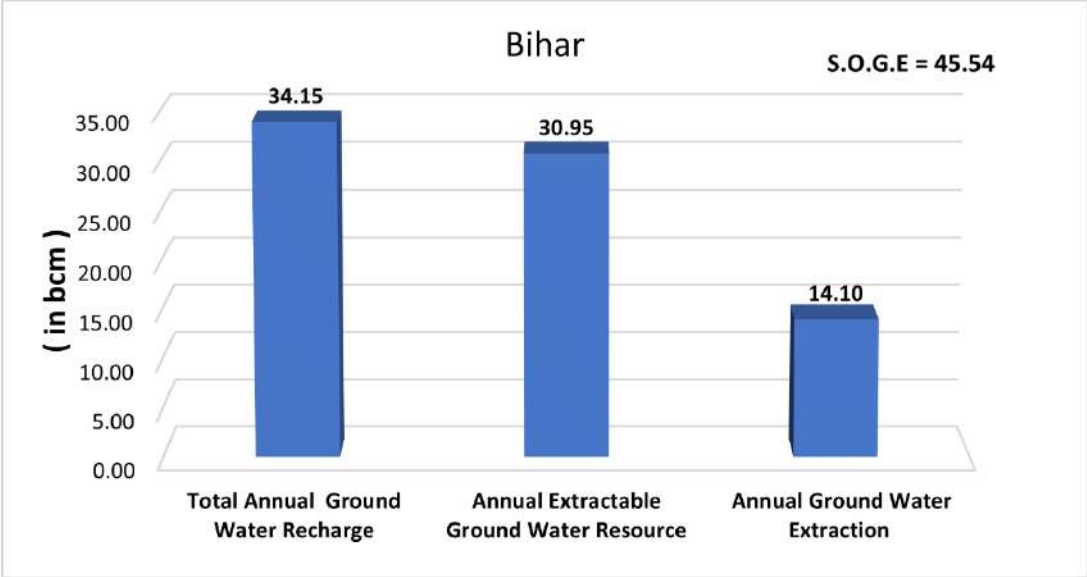
The State is covered with Gangetic alluvium in more than 89 % of its geographical area. The consolidated formations occupy fringes in the southern parts of the state. Dug wells and shallow tube wells tapping the phreatic zone are the common ground water abstraction structures. The assessment of dynamic ground water resources has been carried out in 535 Assessment Units (534 blocks + Patna Urban) of the State.

The Total Annual Ground Water Recharge has been worked out as 34.15 bcm with the Annual Extractable Ground Water Resources as 30.95 bcm. The Current Annual Ground Water Extraction for all uses has been estimated as 14.10 bcm and the Stage of Ground Water Extraction of the State is 45.54 %.

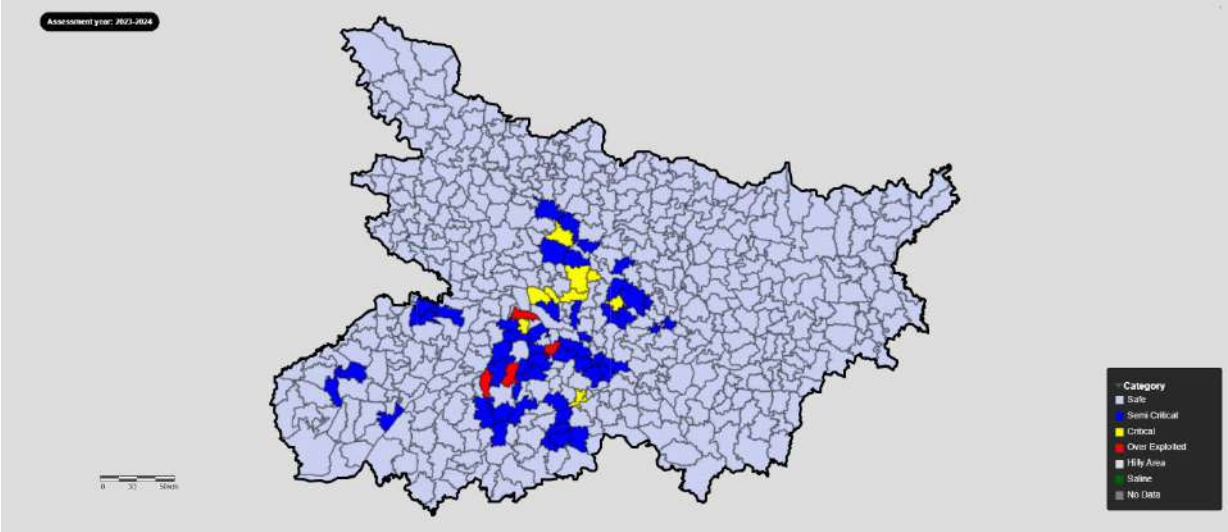
Out of the total 535 assessment units (534 blocks plus Patna Urban), 4 units (0.75%) are categorized as 'Over-exploited,' 9 units (1.68%) as 'Critical,' 49 units (9.16%) as 'Semi-Critical,' and 473 units (88.41%) as 'Safe.' There are no 'Saline' blocks in the state

Similarly, out of 90,348.7 sq. km recharge worthy area of the State, 440.99 sq km (0.49 %) area are under 'Over-Exploited', 900.68 sq. km (1 %) under 'Critical', 6,818.28 sq. km (7.55 %) under 'Semi-critical', 82,188.75 sq. km (90.97 %) under 'Safe' categories of assessment units. Out of total 30,954.51 mcm annual extractable ground water resources of the State, 120.9mcm (0.39 %) are under 'Over-exploited', 314.09 mcm (1.01 %) under 'Critical', 1,995.4 mcm (6.45 %) under 'Semi-critical' and 28,524.13mcm (92.15 %) are under 'Safe' categories of assessment units.

As compared to 2023 assessment, the Total Annual Ground Water Recharge and Annual Extractable Ground Water Resources for the State have increased from 33.96 to 34.15 bcm and 30.72 to 30.95 bcm respectively. The Annual Ground Water Extraction has increased from 13.75 to 14.10 bcm. Stage of Ground Water Extraction marginally increased from 44.76 % to 45.54 %. This year, the dynamic resources of the State have been estimated separately for canal command and non-command areas. Slight variations in recharge, both from canal sources and rainfall has been observed. The revival and renovation of tanks and water bodies as part of the Jal Jeevan Hariyali Mission, initiated by the Government of Bihar, resulted in a marginal increase in recharge from surface water sources and surface water irrigation.



Dynamic Ground water Recourses Scenario 2024– Bihar



Categorization Map of GWRA 2024 –Bihar

7.5 CHHATTISGARH

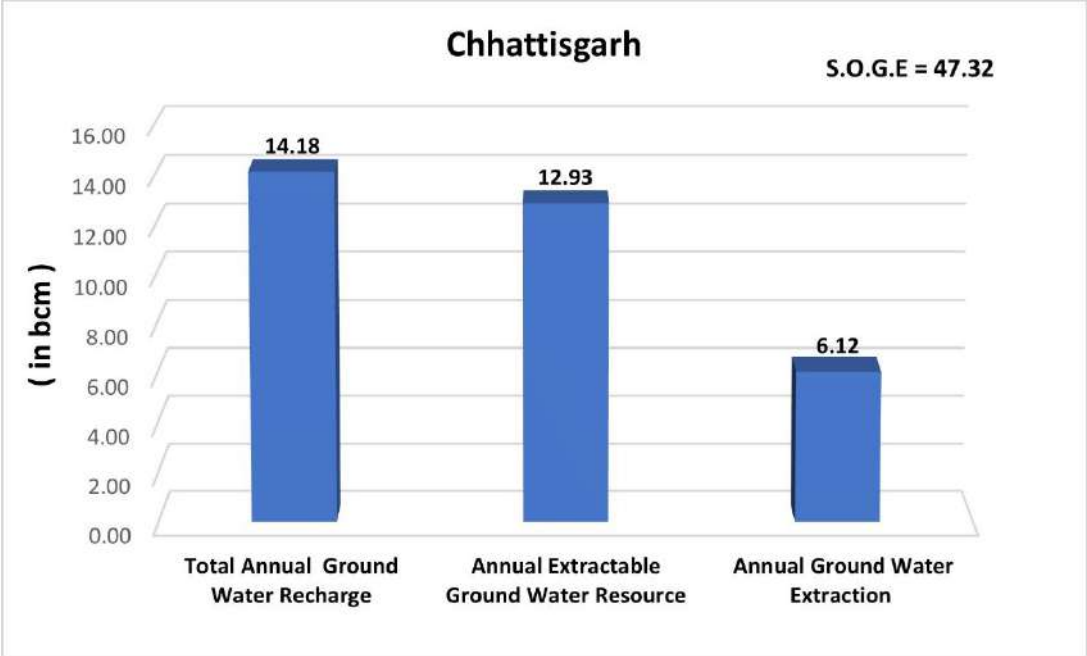
The State is underlain by diverse rock types of different geological ages from Pre-Cambrian to Recent. 87% area of the State is underlain by hard rock and the ground water in these areas is being tapped mostly by dug wells constructed in the weathered zone and bore wells tapping the deeper aquifers. The yield of open (dug) wells varies from 1 to 2 lps and the yield of the bore wells ranges from < 1 to 5 lps. About 13 % area of the State is occupied by Semi-consolidated sedimentary rocks where Dug wells & tube wells have yield range of 1 to 10 lps.

The assessment of ground water resources has been carried out block-wise. The Total Annual Ground Water Recharge of the State has been assessed as 14.18 bcm and Annual Extractable Ground Water Resource is 12.93 bcm. The Total Current Annual Ground Water Extraction is 6.12 bcm and Stage of Ground Water Extraction is 47.32 %.

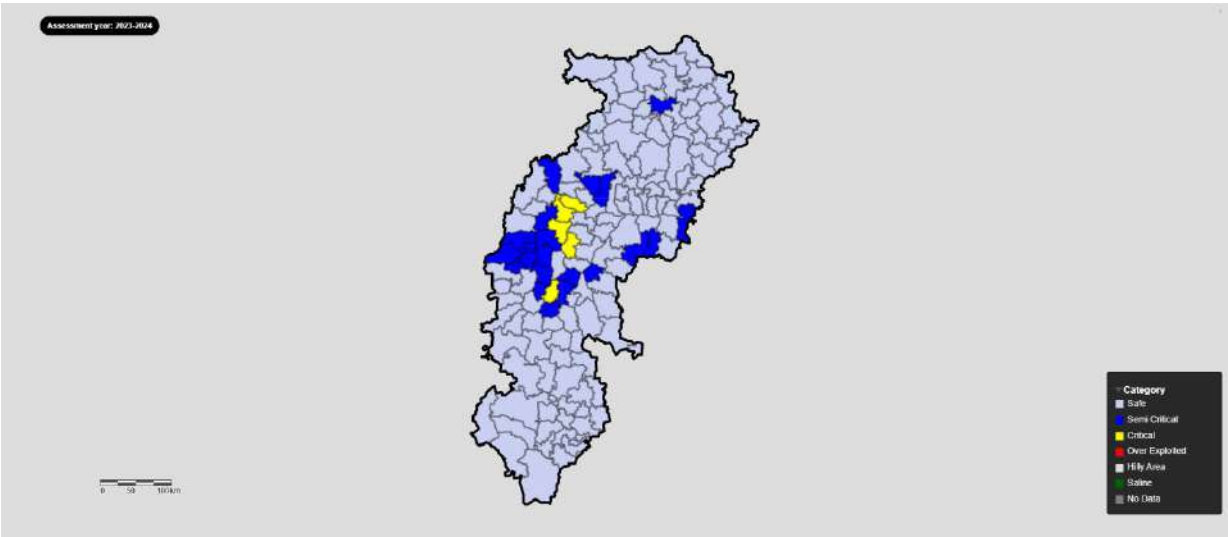
Out of 146 assessment units (blocks), 5 units (3.42 %) as 'Critical', 21 units (14.38 %) have been categorized as 'Semi-critical' and 120 units (82.19 %) as 'Safe' categories of assessment units. There are no 'Over-exploited' and 'Saline' categories of assessment units. Out of 106078.71 sq km recharge worthy area of the State, 3119.06 sq km (2.94 %) area are under 'Critical', 14090.19 sq km (13.28 %) under 'Semi- critical', 88869.46 sq km (83.78 %) under 'Safe' categories of assessment units. Out of total 12927.34 mcm annual extractable ground water resources of the State, 464.40 mcm (3.56 %) under 'Critical', 2334.88 mcm (18.06 %) under 'Semi-critical' and 10132.06 mcm (78.38 %) are under 'Safe' categories of assessment units.

In Chhattisgarh, the ground water development concentrates in the central part of the state (Chhattisgarh basin) more as compared to the other parts of the State. Therefore, most of the 'Semi- critical' and 'Critical' blocks are falling in the central part of the State.

As compared to the 2023 assessment, there is an increase in ground water extraction from 5.75 to 6.12 bcm. The stage of ground water extraction has changed from 47.17 % to 47.32 %. The increase in the number of irrigation wells resulted in the increase of total extraction. The increase in return flow thus generated by the increase in ground water irrigation area is the reason for the increase in ground water recharge.



Dynamic Ground water Recourses Scenario 2024–Chhattisgarh



Categorization Map of GWRA 2024 – Chhattisgarh

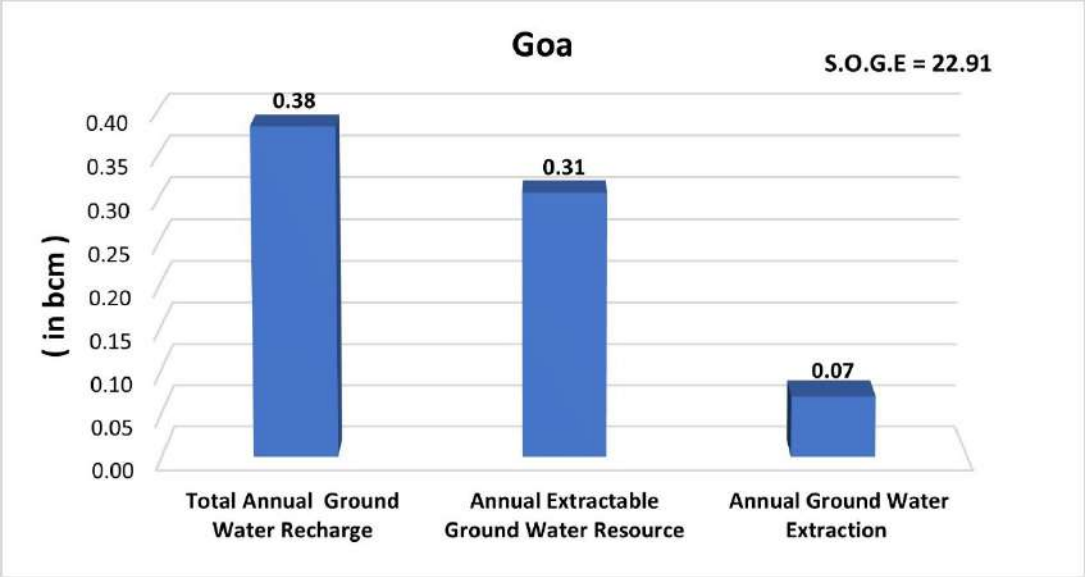
7.6 GOA

Major part of Goa State is covered by consolidated formations of Dharwar Super Group. Ground water occurs under unconfined to semi-confined conditions in beach sands, laterites, weathered and fractured crystalline rocks. The development of ground water from phreatic zone is mostly through dug wells and shallow bore wells.

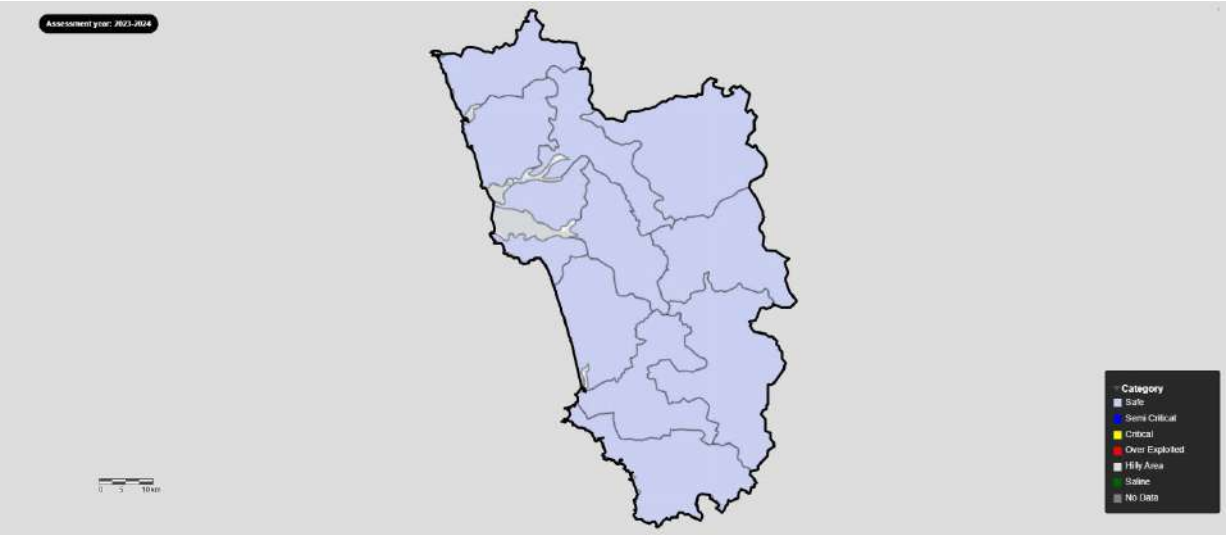
The Ground Water Resources have been assessed taluk-wise. Total Annual Ground Water Recharge has been assessed as 0.38 bcm and Annual Extractable Ground Water Resources as 0.31 bcm. The Annual Ground Water Extraction is 0.07 bcm and Stage of Ground Water Extraction is 22.91 %. All 12 taluks in the State have been categorized as ‘Safe’.

Likewise, within the State's 2209.59 sq km of recharge-worthy areas, the entire expanse falls within the 'Safe' category of assessment units. Out of the State's total annual extractable groundwater resources of 307 mcm, the entirety 100%, falls within the 'Safe' category of assessment units.

As compared to 2023 assessment, the Total Annual Ground Water Recharge decreased from 0.396 bcm to 0.38 bcm and Annual Extractable Ground Water Resources decreased from 0.317 bcm to 0.31 bcm. The Annual Ground Water Extraction has also marginally increased from 0.068 bcm to 0.071 bcm, due to increase in domestic, industrial and irrigation draft. The Stage of Ground Water Extraction has marginally increased from 21.37 % to 22.91 %.



Dynamic Ground water Recourses Scenario 2024– Goa



Categorization Map of GWRA 2024 – Goa

7.7 GUJARAT

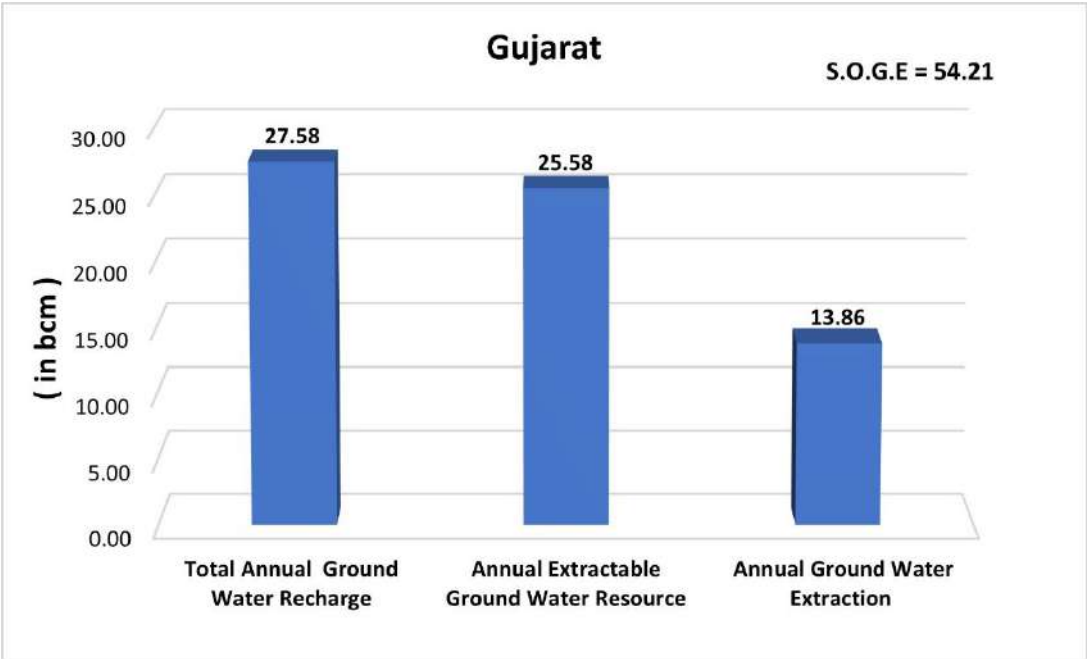
The State is underlain by diverse rock types of different geological ages from Pre-Cambrian to Recent. As much as 60% of the State is underlain by hard rock and rest by soft rock/alluvium formations. In hard rock areas, the ground water is tapped mostly through dug wells constructed in the weathered zone. Dug cum bore wells and deep bore wells are common for irrigation. In alluvium/ soft rock areas, deep tube wells are common for both irrigation and domestic usage. The yield of open (dug) wells varies from 2 to 10 m^3/day, whereas that of tube wells ranges from less than 10 to 100 m3/day.

The assessment of groundwater resources has been carried out Taluka-wise. Total Annual Ground Water Recharge of the State has been assessed as 27.58 bcm and Annual Extractable Ground Water Resources as 25.58 bcm. The Annual Ground Water Extraction has been assessed as 13.86 bcm and Stage of Ground Water Extraction as 54.21 %.

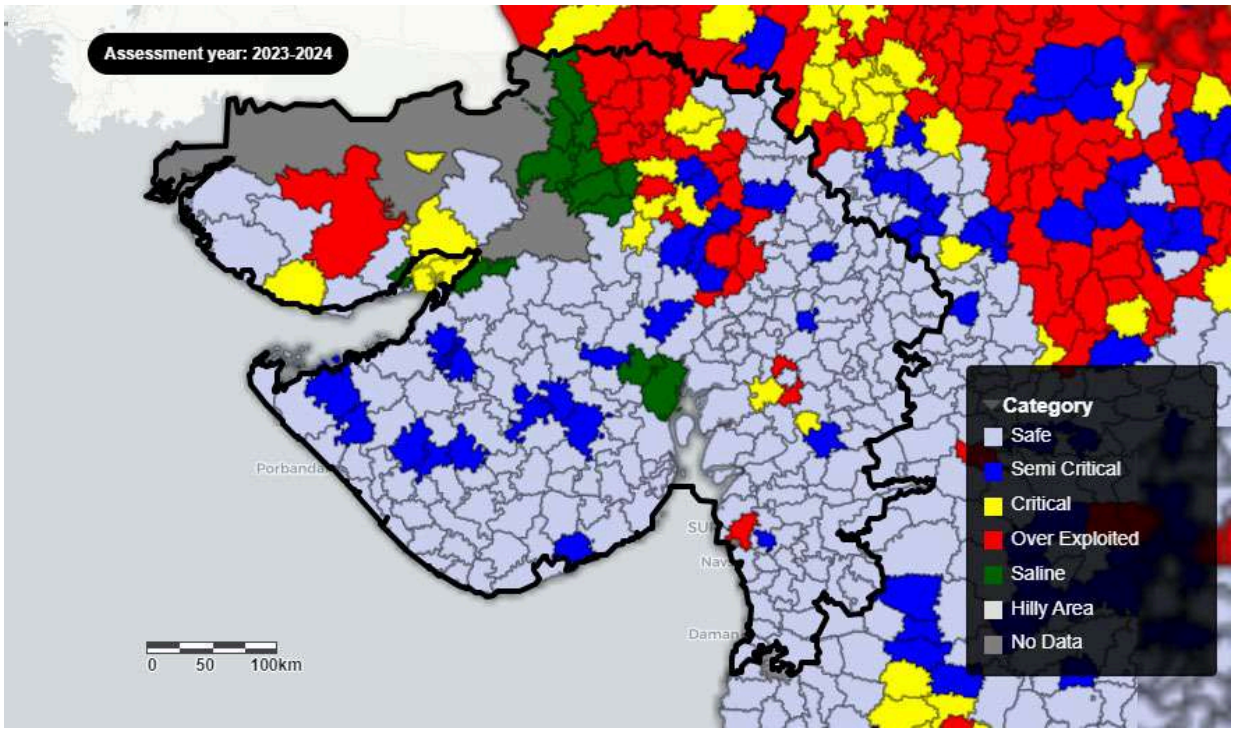
Out of 252 assessment units, 22 units (8.73 %) have been categorized as 'Over- exploited', 10 units (3.97 %) as 'Critical', 24 units (9.52 %) as 'Semi-critical', 184 units (73 %) as 'Safe' and there are 12 units (4.76 %) as 'Saline' categories of assessment units.

Similarly out of 162778.15 sq km recharge worthy area of the State, 16271.58 sq km (10.0 %) area are under 'Over-Exploited', 7712.28 sq km (4.7 %) under 'Critical', 14572.01 sq km (9.0 %) under 'Semi-critical', 115335.48 sq km (70.9 %) under 'Safe' and 8886.8 sq km (5.5 %) area under 'Saline' categories of assessment units. Out of total 25578.51 mcm annual extractable ground water resources of the State, 2207.4 mcm (8.6 %) are under 'Over-exploited', 860.67 mcm (3.4 %) under 'Critical', 2389.22 mcm (9.3 %) under 'Semi-critical' and 20121.22 mcm (78.7 %) are under 'Safe' categories of assessment units.

As compared to 2023 assessment, Total Annual Ground Water Recharge has increased from 27.35 bcm to 27.58 bcm and Annual Extractable Ground Water Resource has increased from 25.41 to 25.58 bcm. The Annual Ground Water Extraction has marginally increased from 13.13 to 13.86 bcm. As compared to 2023 assessment, increase in Annual Ground Water Recharge is because of increase in the recharge by rainfall whereas the Annual Ground Water Extraction is increased marginally. Hence, the Stage of Ground Water Extraction has increased from 51.68 % to 54.21 %.



Dynamic Ground water Recourses Scenario 2024– Gujarat



Categorization Map of GWRA 2024 – Gujarat

7.8 HARYANA

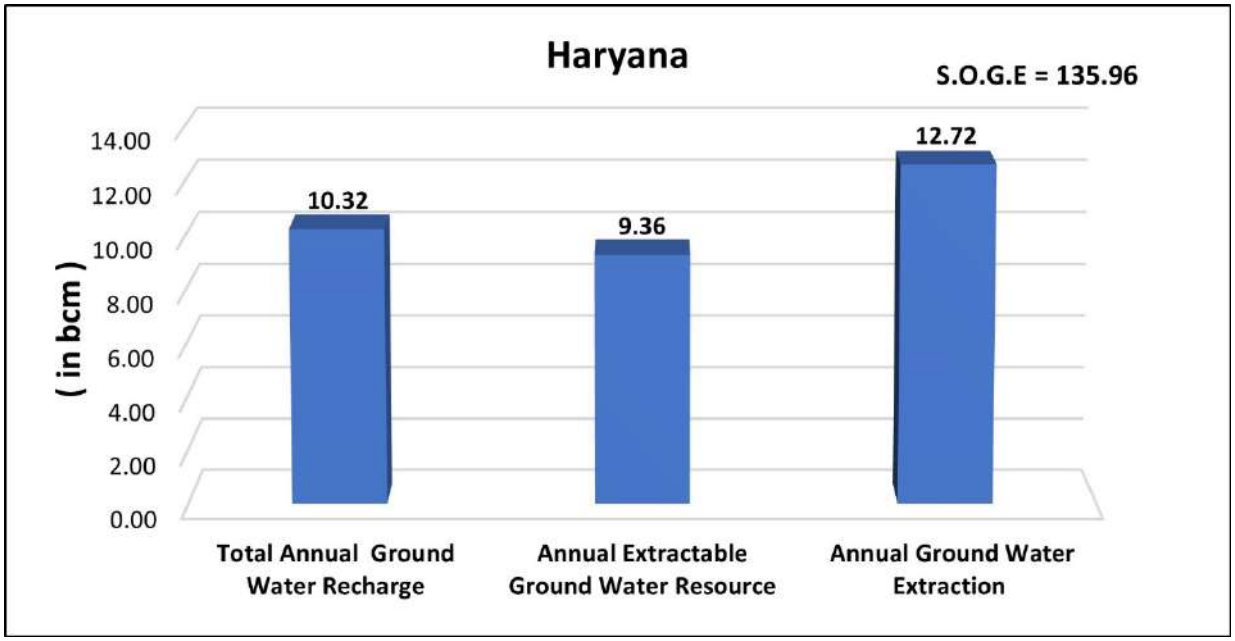
Haryana State is mainly occupied by the alluvial deposits, which cover around 98 % of the State while hardrock covers around 2 %. Alluvial deposits are of older and newer types and consist chiefly of clay, silt and fine to medium sand. Other deposits are piedmont deposits, which are confined to a narrow zone, about 2 to 4 km wide, between Siwalik Hills and Alluvial Plains. Sand-dunes are found in the districts of Bhiwani, Mahendragarh, Hissar and Sirsa. Coarse sand, gravels and boulders are found to occur in piedmont areas and in the adjacent alluvial tracts. The hard rock formations belong to the formation of Delhi systems of Pre- Cambrian age and occupy the southern part of the state, while Shivalik system of Tertiary age are occupying the northern most part of the state.

Total Annual Ground Water Recharge of the State has been assessed as 10.32 bcm and Annual Extractable Ground Water Resource is 9.36 bcm. The Total Current Annual Ground Water extraction is 12.72 bcm and Stage of Ground Water extraction is 135.96 %.

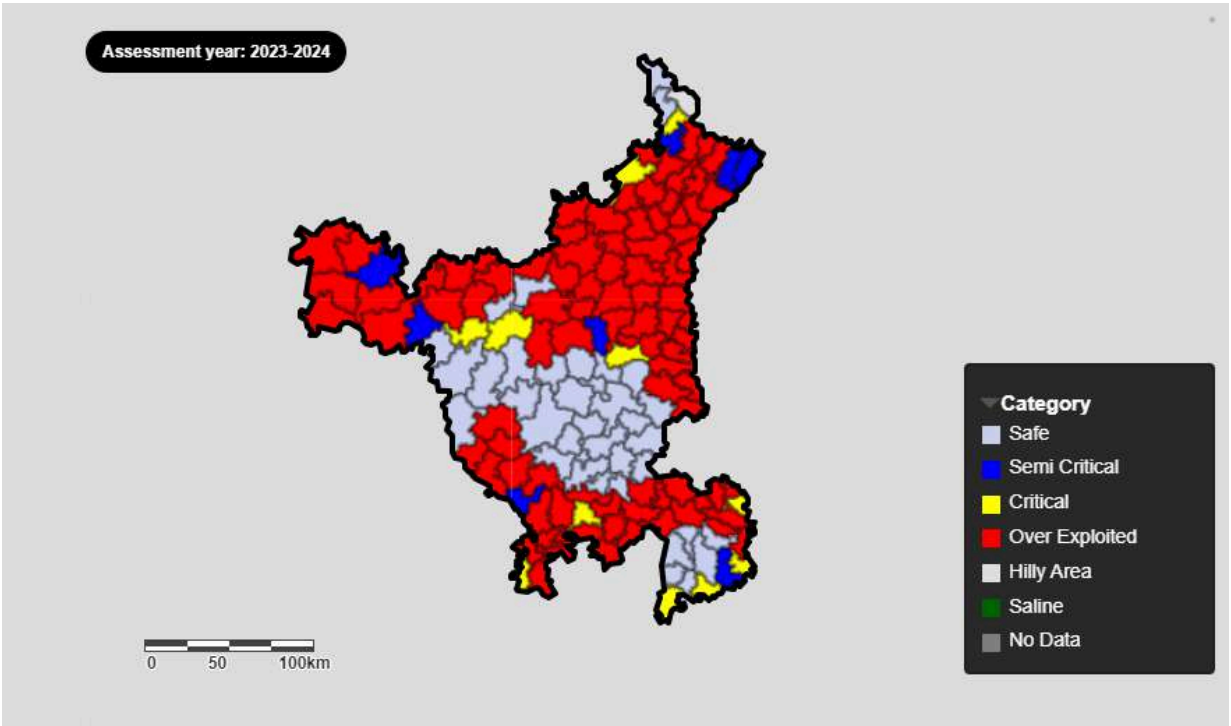
Out of total 143 assessment units (blocks/Urban), 88 units (61.54 %) have been categorized as 'Over-exploited', 11 units (7.69 %) as 'Critical', 08 units (5.59 %) as 'Semi Critical' and 36 units (25.17 %) as 'Safe' categories of assessment units.

Similarly, out of 43205.82 sq. km recharge worthy area of the State, 26131.63 sq. km (60.50 %) area are under 'Over-Exploited', 2675.04 sq. km (6.20%) under 'Critical', 2129.80 sq. km (4.9%) under 'Semi-critical', 12269.36 sq. km (28%) under 'Safe' categories of assessment units. Out of total 9358.58 mcm annual extractable ground water resources of the State, 6104.07 mcm (65.22 %) are under 'Over-exploited', 547.44 mcm (5.85 %) under 'Critical', 568.22 mcm (6.07 %) under 'Semi-critical' and 2138.84 mcm (22.85 %) are under 'Safe' categories of assessment units.

As compared to 2023 assessment, the Total Annual Ground Water Recharge have increased from 9.55 to 10.31 bcm in 2024, Annual Extractable Resources have increased from 8.69 to 9.36 bcm and the Annual Ground Water Extraction have increased from 11.80 to 12.72 bcm. The Stage of Ground Water Extraction has increased marginally from 135.74 to 135.96 %.



Dynamic Ground water Recourses Scenario 2024– Haryana



Categorization Map of GWRA 2024 – Haryana

7.9 HIMACHAL PRADESH

The diverse physiographic, climatic, topographic and geologic conditions have given rise to diversified groundwater situation in different parts of the state. The rock formations ranging in age from Archean to Recent occupy the State and control the occurrence and movement of ground water depending upon aquifer composition, structure and deposition. Hilly and mountainous parts with steep slopes mainly constitute the run off areas and have low ground water potential. In valley and low-lying areas, unconsolidated / semi-consolidated formations form potential aquifers.

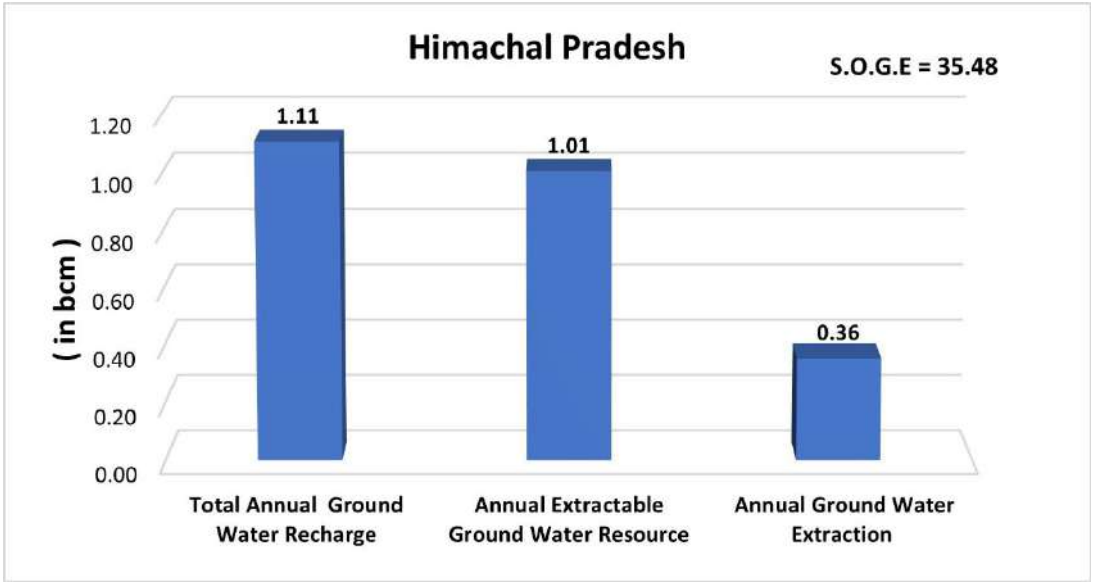
In consolidated formations the water availability is restricted to weathered mantle, joints/fractures, weak planes, bedding planes and limestone caverns. The limestone associated with phyllite and quartzite forms potential aquifers. In granites, potentiality of the aquifer is highly dependable on the fracture intensity. In granitic aquifers the discharge ranges between 1-3 lps. Groundwater in hard rock areas is either developed though bore wells or natural springs are tapped for both drinking and irrigation purposes.

In the unconsolidated formations the occurrence and movement of ground water is highly dependent on lithology particularly the presence of clay content. The unconsolidated formations are confined to valley areas, having good yield prospects that can sustain moderate to high-capacity deep tube wells. The yield of the tube wells depends on the thickness of the total granular zones available within the aquifers tapped which ranges from 5-40 lps in different valleys. The Ground water resources have been assessed valley-wise.

Total Annual Ground Water Recharge of the State has been assessed as 1.11 bcm and Annual Extractable Groundwater Resources is 1.01 bcm. The Current Annual Ground Water Extraction for all uses is 0.36 bcm and Stage of Ground Water Extraction is 35.48 %. Out of the 10 assessment units, all the ten assessment units have been categorized as ‘Safe’ and there is no saline assessment unit in the State.

Similarly, out of 3468 sq. km recharge worthy area of the State, 100 % under ‘Safe’ categories of assessment units. Out of total 1010.3732 mcm annual extractable ground water resources of the State, 1010.3732 mcm (100 %) are under ‘Safe’ categories of assessment units.

As compared to 2023 assessment, the Total Annual Ground Water Recharge slightly increases from 1.11 to 1.113 bcm and Annual Extractable Ground Water resources remain same from 1.01 to 1.01 bcm. However, there is increase in Ground Water Extraction from 0.3546 to 0.3585 of the State. The Stage of Ground Water Extraction has increases from 34.95 % to 35.48.



Dynamic Ground water Recourses Scenario 2024– Himachal Pradesh

Categorization Map of GWRA 2024 – Himachal Pradesh

7.10 JHARKHAND

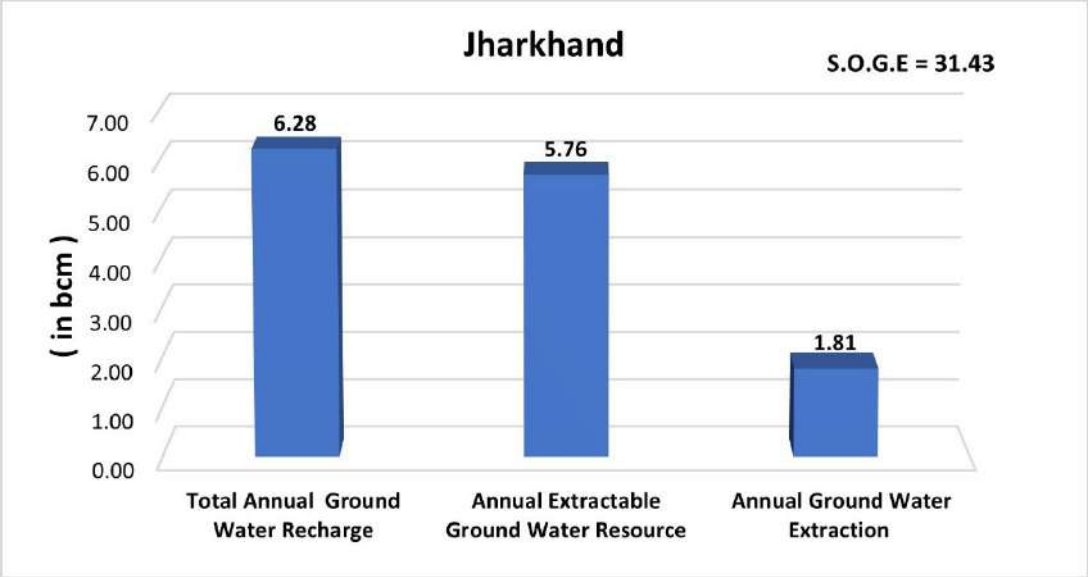
The State is underlain by diverse rock types of different geological ages ranging from Archaean to Recent. The major rock types are igneous and metamorphic rocks covering nearly 85 percent of the geographical area of the state. The weathered zone ranging between 10-30 m acts as a good repository of ground water. However, the secondary porosities in the form of fracture zones below the weathered zones also form potential aquifers. The yield of the exploratory wells ranges from negligible upto 151 m^3/hr. In Gondwana Super group, bore well discharge ranges between 7 to 15 m^3/hr and in Tertiary formations, yield ranges from 18 to 78 m^3/hr. The Younger Alluvium deposits are confined to patches. The depth of dug wells in general ranges between 10 to 15m bgl. The yield of the dugwells ranges from 0.5 to 0.75 m^3/hr. The dug wells tapping the weathered zone have an average yield of 0.5 to 1.2 m^3/hr.

Ground Water Resource of the State has been assessed block-wise and identified urban area. The Total Annual Ground Water Recharge of the State has been assessed as 6.28 bcm and Annual Extractable Ground Water Resources is 5.76 bcm. The Annual Ground Water Extraction is 1.81 bcm and Stage of Extraction is 31.43 %.

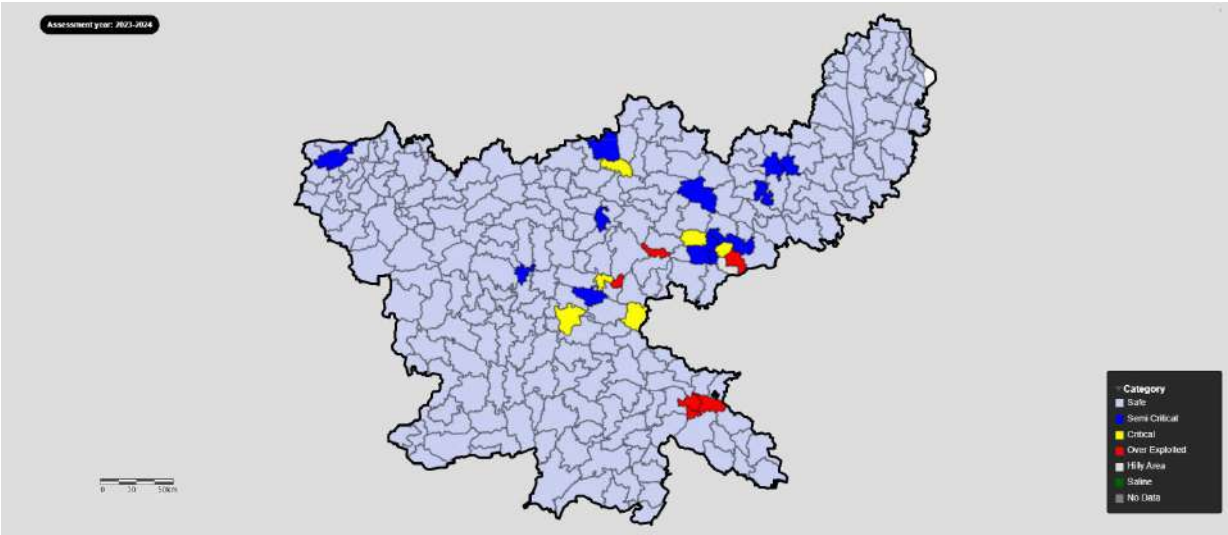
Out of 263 assessment units (blocks-259, Urban area-04), 5 units (1.90 %) have been categorized as 'Over-exploited', 6 units (2.28 %) as 'Critical', 12 units (4.56 %) as 'Semi-critical' and rest 240 units (91.25 %) are under 'Safe' category and there is no saline assessment unit in the State.

Similarly, out of 60646.73 sq km recharge worthy area of the State, 463.92 sq km (0.76 %) area are under 'Over-Exploited', 1068.48 sq km (1.76 %) under 'Critical', 2396.09 sq km (3.95 %) under 'Semi-critical' and 56718.24 sq km (93.52 %) under 'Safe' categories of assessment units. Out of total 5757.56 mcm annual extractable ground water resources of the State, 63.13mcm (1.1%) are under 'Over-exploited', 132.32mcm (2.3%) under 'Critical', 259.77mcm (4.51%) under 'Semi-critical' and 5302.35mcm (92.09%) are under 'Safe' categories of assessment units.

As compared to 2023 assessment, Total Annual Ground Water Recharge and Annual Extractable Ground Water Resources have increased from 6.25 to 6.28 bcm and 5.73 to 5.76 bcm respectively. The Annual Ground Water Extraction for the State has increased from 1.79 to 1.81 bcm and the Stage of Ground Water Extraction has increased from 31.38 % to 31.43%.



Dynamic Ground water Recourses Scenario 2024-Jharkhamd



Categorization Map of GWRA 2024 –Jharkhand

7.11 KARNATAKA

Karnataka State is underlain by rock types ranging in age from Archaean to Recent. Major portion of the State is covered by Peninsular Gneisses, Granites and Dharwar Schists of Archaean age. Substantial area in the northern part of Karnataka is underlain by basalts, which form a continuation of the Deccan Traps occurring in Maharashtra. The sedimentary formations comprising Bhima and Kaladgis occupy a small area in the northern districts. The recent alluvium is restricted to a narrow belt in the coastal area and along stream courses.

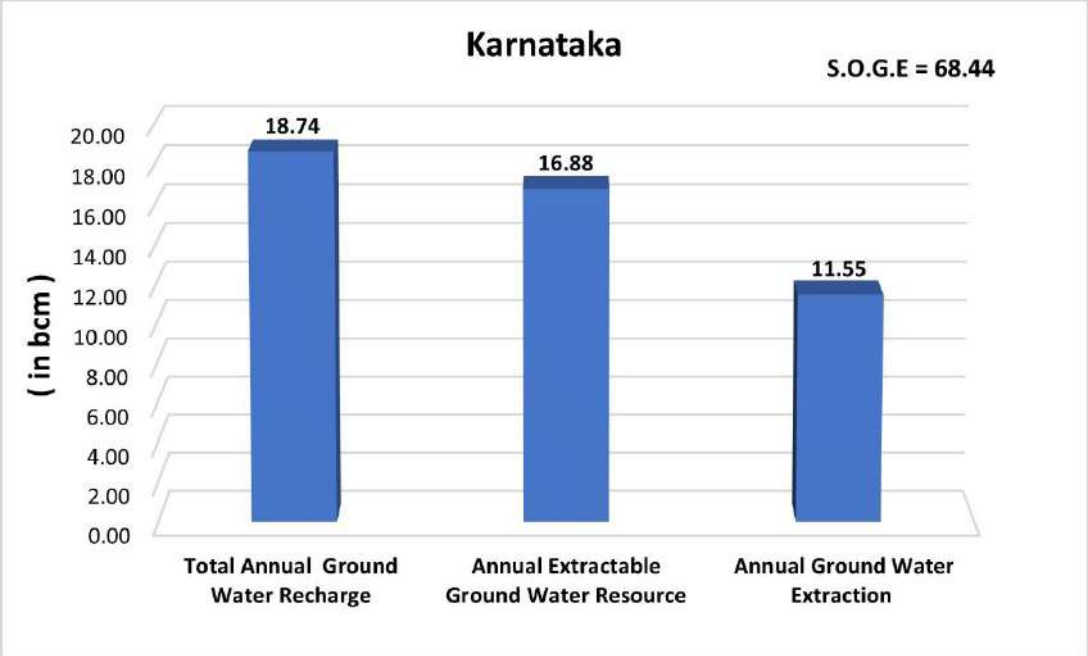
The aquifer systems are classified into nine major groups depending upon their characteristics and are Banded Gneissic Complex (BGC), Basalt, Schists, Granites, Charnockites, Limestones, Laterites, Sandstones and Alluvium.

Ground Water Resource of the State has been assessed taluk-wise The Annual Ground Water Recharge has been assessed as 18.74 bcm and the Annual Extractable Ground Water resource is 16.88 bcm. The present Annual Ground Water Extraction is 11.55 bcm and the Stage of Ground Water Extraction is 68.44%.

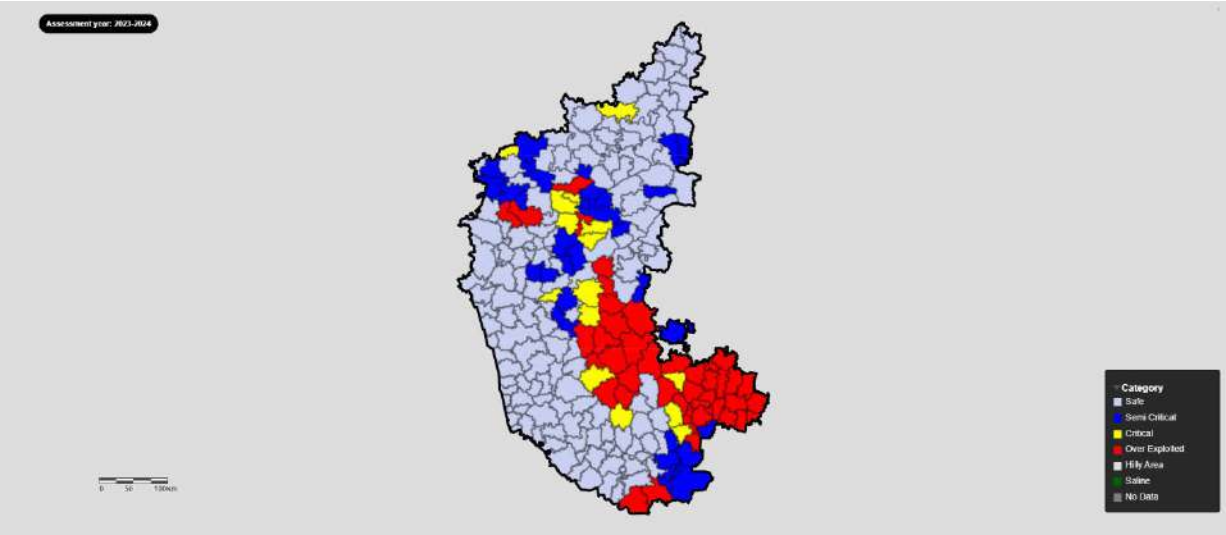
Out of the 237 assessment units (taluks), 45 units (18.99 %) have been categorized as 'Over exploited', 15 units (6.33 %) as 'Critical', and 33 units (13.92 %) as 'Semi critical' and 144 units (60.76 %) have been categorized as 'Safe'. There is no taluk under "Saline" category.

Similarly, out of 170730.92 sq km recharge worthy area of the State, 35255.08 sq km (20.7%) area are under 'Over-Exploited', 12357.11 sq km (7.2 %) under 'Critical', 23383.92sq km (13.7 %) under 'Semi-critical' and 99734.80sq km (58.4%) under 'Safe' categories of assessment units. Out of total 16881.47 mcm annual extractable ground water resources of the State, 2717.68 mcm (16.1 %) are under 'Over-exploited', 1021.41 mcm (6.05%) under 'Critical', 2358.89 mcm (13.97%) under 'Semi-critical' and 10783.48 mcm (63.88%) are under 'Safe' categories of assessment units.

As compared to 2023 assessment, there is decrease in Annual Ground Water Recharge from 18.93 bcm to 18.74 bcm and Annual Extractable Ground Water Resources from 17.08 bcm to 16.88 bcm. There is marginal increase in the Current Annual Ground Water Extraction for all uses from 11.32 to 11.55 bcm during this period. Hence overall, the Stage of Ground Water Extraction has increased from 66.26 % in 2023 to 68.44 % in 2024.



Dynamic Ground water Recourses Scenario 2024– Karnataka



Categorization Map of GWRA 2024– Karnataka

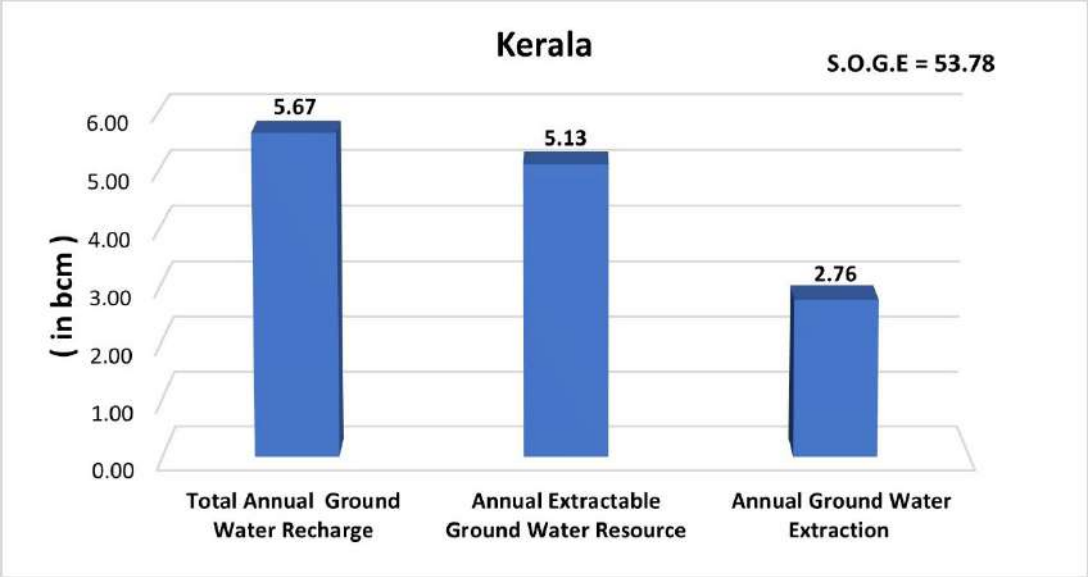
7.12 KERALA

The State of Kerala is underlain by diverse rock types of different geological ages from Pre- Cambrian to Recent. Nearly, 88% of the State is underlain by crystalline rocks of Archaean age comprising Schistose formations, Charnockites, Khondalites and Gneisses. All these formations are intruded by dykes of younger age. The sedimentary formations of Tertiary age occurring along the western parts of the State comprise four distinct beds viz. Alleppey, Vaikom, Quilon and Warkali. The crystalline and the Tertiary formations are lateritized along the midland area. Yields of open (dug) wells in these areas vary from 0.02 to 0.12 lps, whereas that of bore wells ranges from less than 1 to 35 lps. About 12% of the State is underlain by Semi-consolidated and unconsolidated sedimentary formations where dug wells and filter points have yields of 0.02 to 0.4 lps, whereas deep tube wells have yields in the range of 1 to 57 lps. Laterites, which cover most of the geological formations in the major part of the state also forms an important aquifer in the state with dug wells having yields in the range of 0.005 to 0.069 lps.

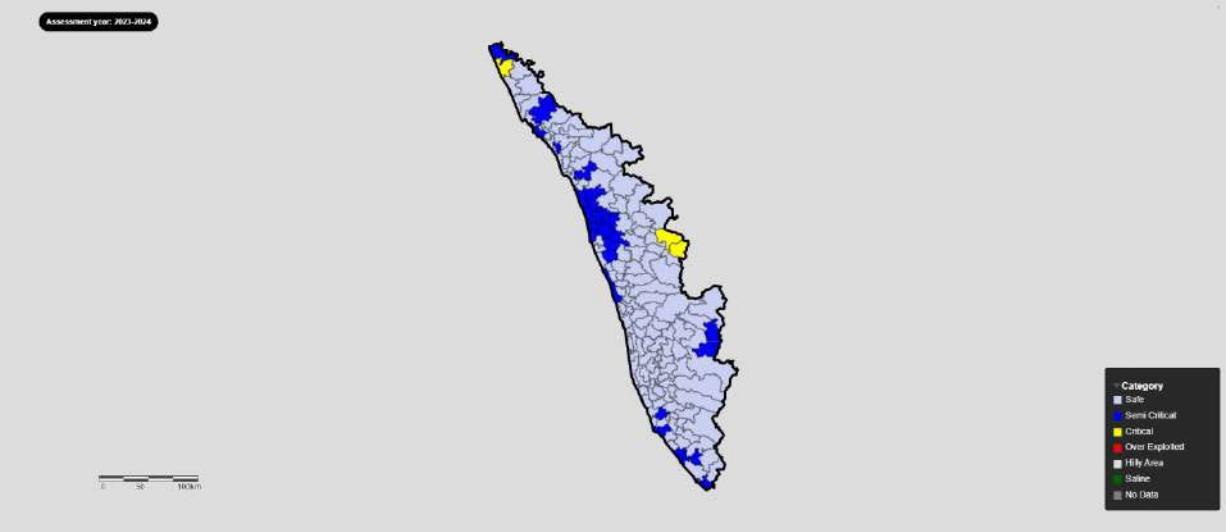
The ground water resources for the state have been assessed block-wise. Total Annual Ground Water Recharge has been estimated as 5.67 bcm and Annual Extractable Ground Water Resource is 5.13 bcm. The Annual Ground Water Extraction is 2.76 bcm and Stage of Ground Water Extraction is 53.78 %.

Out of total 152 assessment units (blocks), 3 units (1.97 %) have been categorized as 'Critical', 29 units (19.08 %) as 'Semi-Critical' and 120 units (78.95 %) as 'Safe' categories of assessment units. There is no 'Over- exploited' and 'Saline' assessment unit in the State. Similarly, out of 27047.53 sq km recharge worthy area of the State, 777.38 sq km (2.87 %) area are under 'Critical', 4109.06 sq km (15.19 %) under 'Semi-critical' and 22161.1 sq km (81.93 %) area are under 'Safe' categories of assessment units. Out of total 5129.67 mcm annual extractable ground water resources of the State, 136.86 mcm (2.67%) are under 'Critical', 752.74 mcm (14.67%) under 'Semi-critical' and 4240.06 mcm (82.66%) are under 'Safe' categories of assessment units.

As compared to 2023 assessment, Total Annual Ground Water Recharge of the State has increased from 5.53 to 5.67 bcm and Annual Extractable Ground Water Resources from 5.01 to 5.13bcm. The annual ground water extraction has increased from 2.73 to 2.76 bcm, and the Stage of Ground Water Extraction has decreased from 54.55 % to 53.78 %.



Dynamic Ground water Recourses Scenario 2024– Kerala



Categorization Map of GWRA 2024 – Kerala

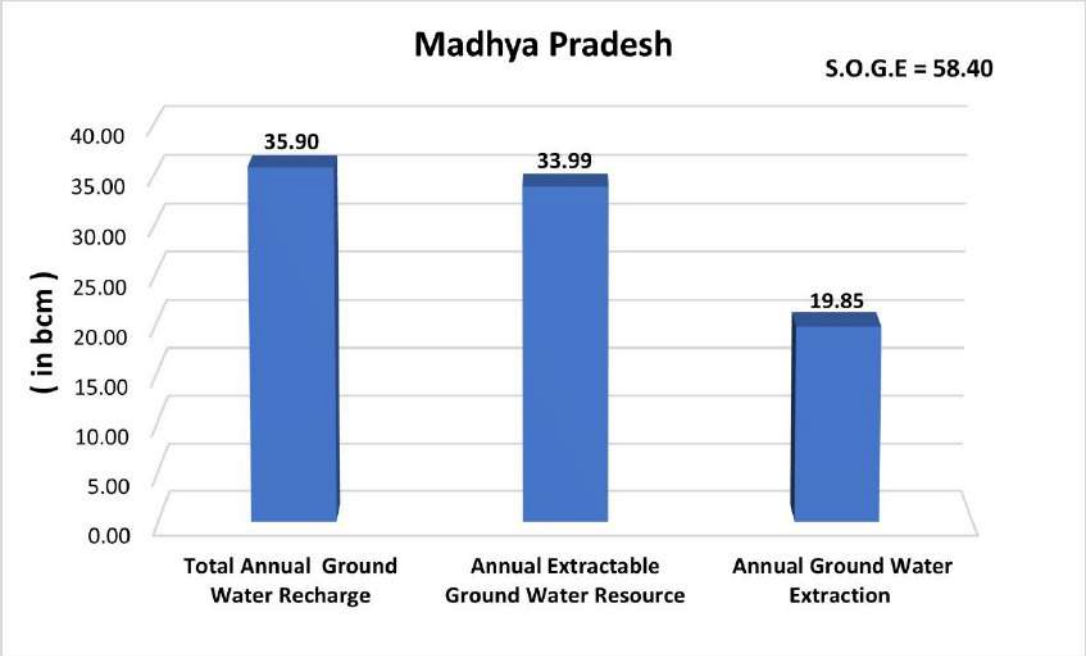
7.13 MADHYA PRADESH

The State of Madhya Pradesh has varied hydrogeological characteristics due to which ground water potential differs from place to place. The State is underlain by various Geological formations ranging in age from the Archaean to the Recent. Hard rock areas cover more than 80% of total land area of the State. These hard-rock areas show wide variations and complexities in nature and composition of rocks, geological structures, geomorphological set up and hydro meteorological conditions. The crystalline rocks of Archaean age like granite, gneiss, granulites, schist, quartzite and granitoids occupy about 15% of geographical area of the State. The basaltic rocks of Deccan lava flows are the predominant formations and occupy nearly 45% of total geographical area. The consolidated sedimentary rocks of Vindhyan Super Group and Mahakoshal (Cuddapah) Super Group of Proterozoic age occupy about 19% of total geographical area and the semi consolidated (Gondwana Formation) occupies about 7%. Recent unconsolidated alluvial sediments occupy about 14% of total geographical area.

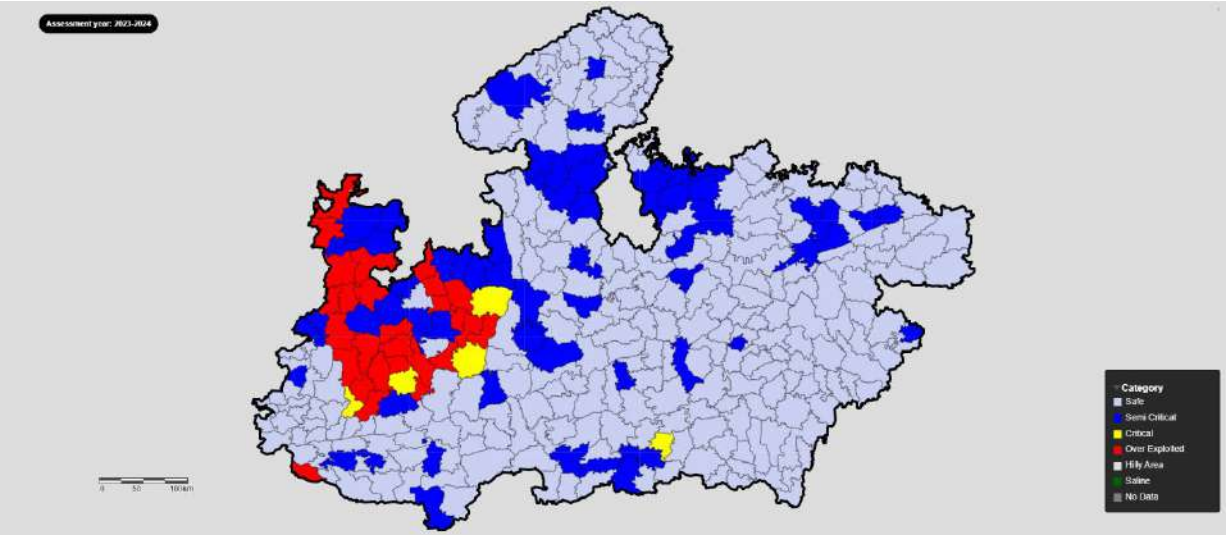
Total Annual Ground Water Recharge of the State has been assessed as 35.90 bcm and Annual Extractable Ground Water Resources is 33.99 bcm. The Annual Ground Water Extraction is 19.85 bcm and Stage of Ground Water Extraction is 58.40 %.

Out of 317 assessment units (313 blocks and 4 urban areas), 26 units (8.2 %) has been categorized as ‘Over Exploited’, 5 units (1.58 %) as ‘Critical’, 61 units (19.24 %) as ‘Semi-Critical’ and 225 units (70.98 %) as ‘Safe’ categories of assessment units and there are no saline assessment unit. Similarly, out of 269333.27 sq km recharge worthy area of the State, 22554.86 sq km (8.37%) area is under ‘Over-Exploited’, 4249.07 sq km (1.58 %) under ‘Critical’, 52998.18 sq km (19.68 %) under ‘Semi-critical’ and 189531.16 sq km (70.37 %) under ‘Safe’ categories of assessment units. Out of total 33989.73 mcm annual extractable ground water resources of the State, 3533.45 mcm (10.40 %) are under ‘Over-exploited’, 554.63 mcm (1.63 %) under ‘Critical’, 6464.26 mcm (19.02 %) under ‘Semi-critical’ and 23437.40 mcm (68.95 %) are under ‘Safe’ categories of assessment units.

In the 2024 assessment, a shift in groundwater dynamics compared to the 2023 evaluation has been observed. Notably, both groundwater recharge and extraction have increased. Total Annual Ground Water Recharge of the State has increased from 35.47 bcm to 35.90 bcm and Annual Extractable Ground Water Resources from 32.85 to 33.99 bcm. The Annual Ground Water Extraction has increased from 19.3 to 19.85 bcm and the Stage of Ground Water Extraction has decreased from 58.75 % to 58.40 %.



Dynamic Ground water Recourses Scenario 2024– Madhya Pradesh



Categorization Map of GWRA 2024 – Madhya Pradesh

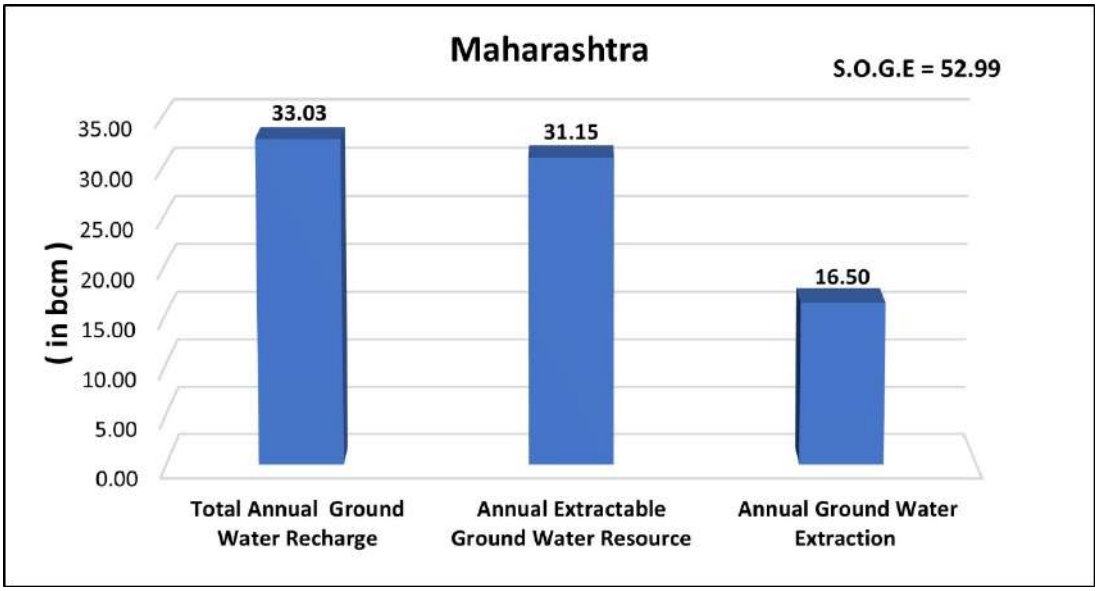
7.14 MAHARASTRA

The State is underlain by diverse rock types of different geological ages from Pre-Cambrian to Recent. The state is mostly covered by Deccan Traps. The other geological formations, older and younger than Deccan Traps, occur in the northeast and as isolated patches in the Sindhudurg and Ratnagiri districts. Large part of the State is underlain by Basaltic hard rocks where dug wells are predominant. They mostly tap the weathered zone and fractures/joints. The yield of dug wells varies from 3 to 5 lps. A small part of the State is occupied by Semi- consolidated sedimentary rocks where tube wells have a yield of 5 to 45 lps. The central part of Maharashtra which is a drought prone area, receives very less rainfall i.e., from 400 to 700 mm, but the geology is favourable for the ground water recharge. Hence, in this area the dependency on groundwater is very high. Two-third of irrigation wells are from this area only. This primarily includes parts from Dhule, Nashik, Jalgaon, Ahmednagar, Pune, Satara, Sangli, Solapur, Osmanabad, Beed and Aurangabad districts.

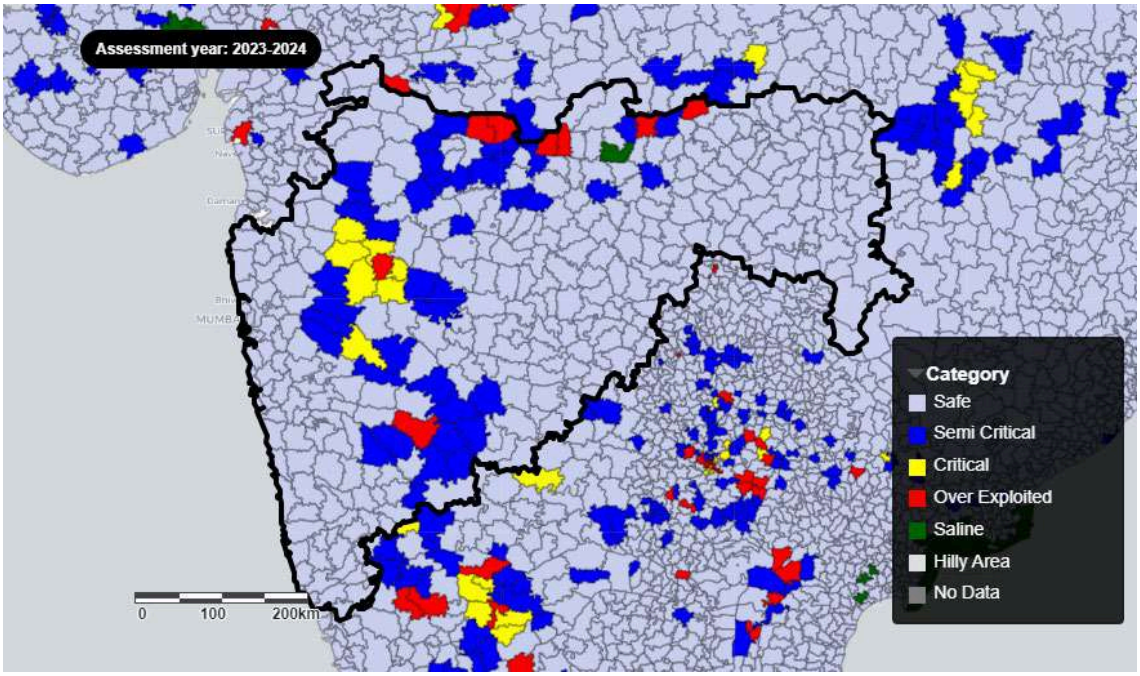
Groundwater resources have been assessed watershed-wise in the State and subsequently apportioned to the taluk level. For the current year, groundwater resource assessment has also been carried out for 6 urban areas, including Nagpur City (District Nagpur), Pune City (District Pune), Mumbai (District Mumbai), Andheri, Kurla, and Borivali (District Mumbai Suburban). This brings the total number of assessment units to 359 (Talukas). The Annual Ground water resources for State has been estimated as 33.03 bcm and Annual Extractable Ground Water Resources is 31.15 bcm. The Annual Ground Water Extraction is 16.50 bcm and Stage of Ground Water Extraction is 52.99%.

Out of 359 assessment units (taluks), 8 units (2.2%) have been categorized as ‘Over-exploited’, 7 units (1.9 %) as ‘Critical’, 41 units (11.4 %) as ‘Semi-critical’ and remaining 302 assessment units (84.1 %) as ‘Safe’ and 1 unit (0.28 %) as ‘Saline’. Similarly, out of 260349.01 sq. km recharge worthy area of the State, 6333.63 sq. km (2.43 %) area is under ‘Over-Exploited’, 7709.543 sq. km (2.96 %) under ‘Critical’, 40751.55 sq. km (15.65 %) under ‘Semi-critical’, 204777.39 sq. km (78.65 %) under ‘Safe’ and 776.89 sq. km (0.30 %) area under ‘Saline’ categories of assessment units. Out of total 31147.44 mcm annual extractable ground water resources of the State, 715.28 mcm (2.30 %) are under ‘Over-exploited’, 902.27 mcm (2.90 %) under ‘Critical’, 4317.33 mcm (13.86 %) under ‘Semi-critical’ and 25212.56 mcm (80.95 %) are under ‘Safe’ categories of assessment units.

As compared to 2023 assessment, the Annual Ground Water Recharge and annual extractable ground water resources in 2024 has increased marginally from 32.76 bcm to 33.03 bcm and 30.95 bcm to 31.15 bcm respectively and Annual Ground Water Extraction has decreased marginally from 16.66 bcm to 16.50 bcm in 2024. The Stage of Ground Water Extraction has also decreased marginally from 53.83% to 52.99%.



Dynamic Ground water Recourses Scenario 2024– Maharashtra



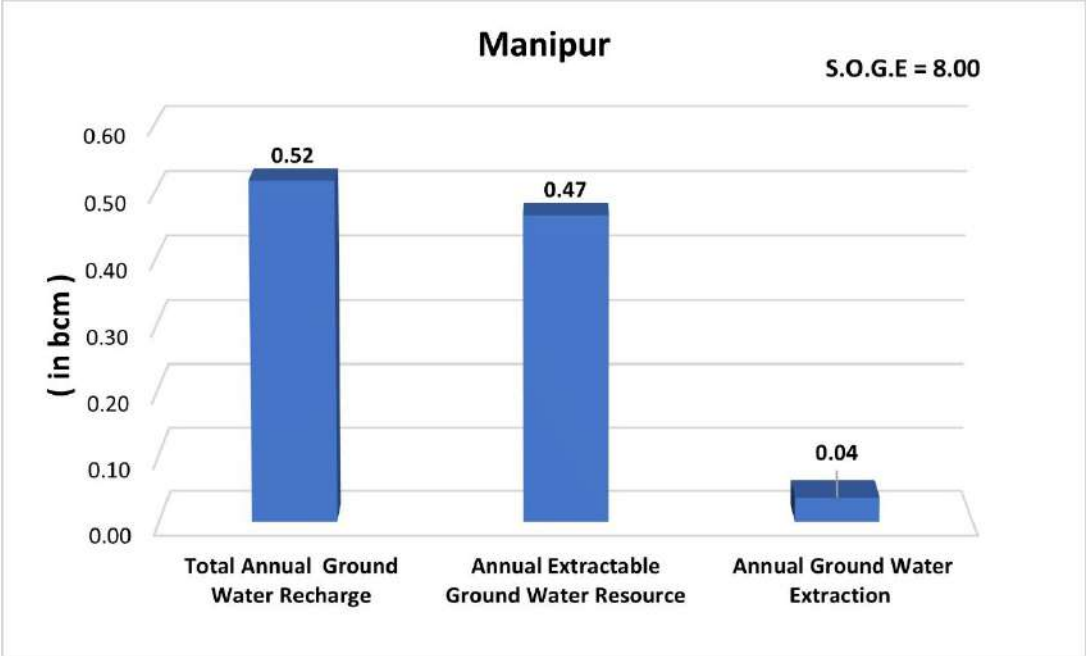
Categorization Map of GWRA 2024– Maharashtra

7.15 MANIPUR

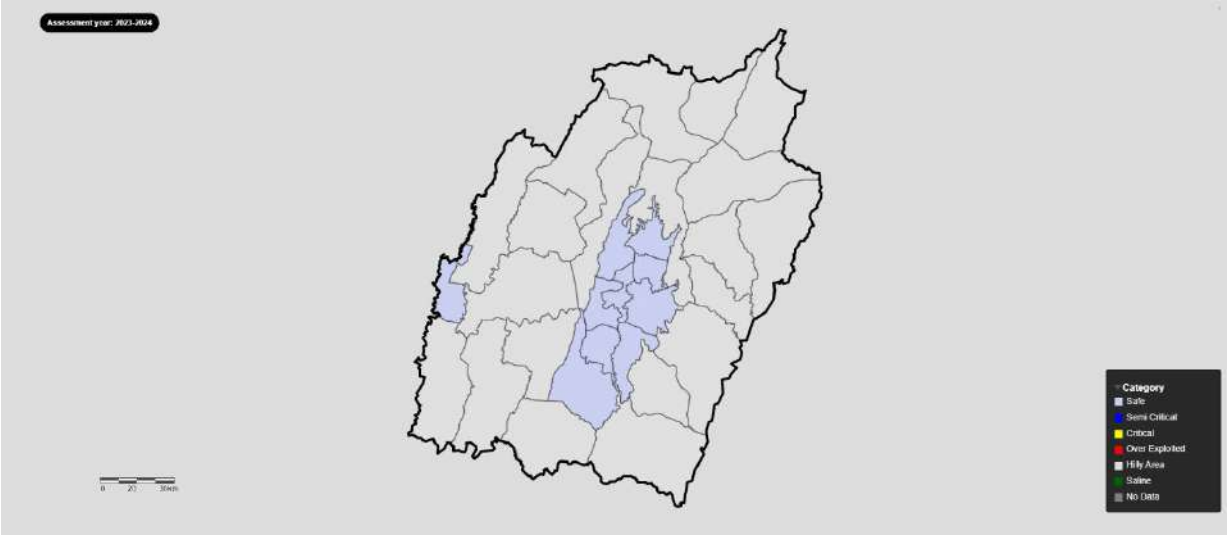
The State of Manipur is occupied by mostly North South parallel hill ranges made up of consolidated and semi-consolidated rocks ranging in age from pre-Mesozoic to Miocene. The consolidated rocks confined to the eastern part of the state along the Myanmar border. The semi-consolidated formations, which cover almost the entire state, comprise shale, siltstone, sandstone, and conglomerate. These formations belong to Disang, Barail, Surma and Tipam group of rocks. In the western and central part of the State, unconsolidated alluvium of quaternary age occurs in the valleys and topographical lows. Ground water is restricted to secondary porosity in joints, fissures, fractures and weathered residuum of consolidated and semi-consolidated rocks and inter-granular pore spaces of alluvial deposits. In the valley, ground water is utilized through tube wells, tapping granular zones with 10 to 20 m thickness, and the yield of the tube well varies from 10 to 30 m3/hr.

The Ground Water Resources of Manipur as in 2024 have been assessed block-wise for the recharge worthy area. Total Annual Ground Water Recharge of the State has been assessed as 0.52 bcm and Annual Extractable Ground Water Resources as 0.47 bcm. The Annual Ground Water Extraction is 0.04 bcm and Stage of Ground Water extraction is 8.00 %. All the assessment units have been categorized as ‘Safe’ and there is no saline area in the state. Out of 9 assessment units 9 units (100 %) as ‘Safe’ categories of assessment units and there is no saline assessment unit.

Similarly, out of 2559 sq. km recharge worthy area of the State, 2559 sq. km (100 %) under ‘Safe’ categories of assessment units. Out of total 466.0754 mcm annual extractable ground water resources of the State, 466.0754 mcm (100 %) are under ‘Safe’ categories of assessment units. The comparison with previous assessment shows there is no major changes in the Ground Water Resources of Manipur.



Dynamic Ground water Recourses Scenario 2024– Manipur



Categorization Map of GWRA 2024 – Manipur

7.16 MEGHALAYA

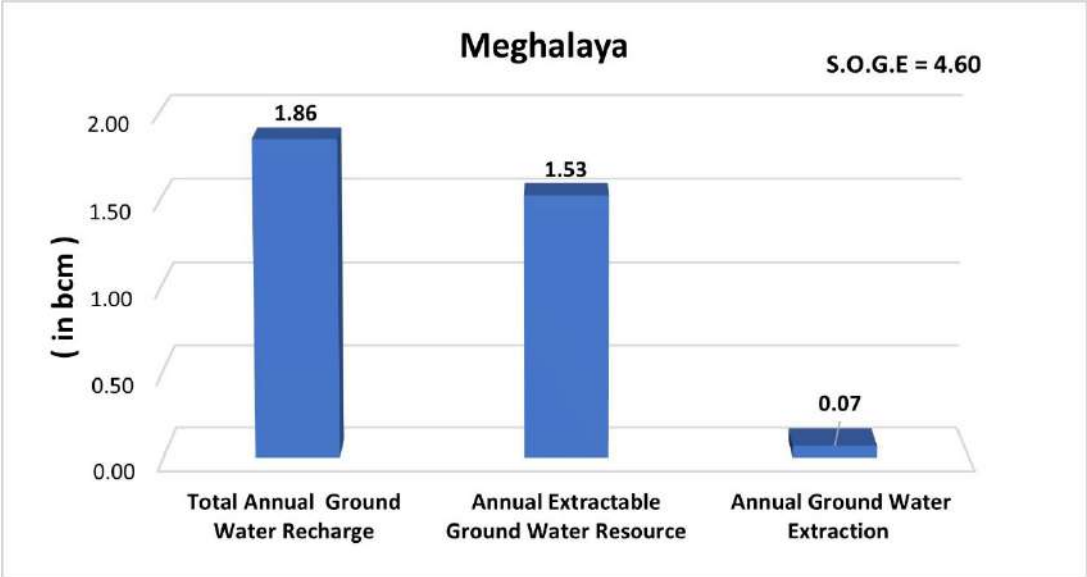
The Meghalaya State is essentially occupied by hard rocks belonging to the Archean gneissic complex with acidic and basic intrusives and Precambrian Shillong Group of rocks. The aquifer system in the state can be divided as two aquifer systems, viz., first aquifer (shallow) and second aquifer (deeper). Shallow or first aquifer consists of weathered residuum where ground water occurs under water table condition and is mainly developed through construction of dug wells. The second aquifer is the deeper aquifer which tapped the fractured zone and is mainly developed through borewells. Based on the study of litholog and analysis of depth of construction of dug wells and bore wells, it is found that the first aquifer occur within depth of 20 to 40 m. Ground water in the second aquifer occurs under semi-confined to confined condition in the fractures upto the maximum explored depth of 280m. The south-western, southern and south-eastern parts of the state is covered by semi- consolidated formations comprising sandstones, shales, conglomerates, limestones etc. belonging to Cretaceous – Tertiary age. The aquifers are formed by rock strata that are granular/porous, fissured/fractured or cavernous. These aquifers are thick and discontinuous in nature. The unconsolidated sediments comprising sand, gravel, silt, clay, etc. are found to occur as thin veneer along rivulets and as valley-fills.

The Ground water resources have been assessed block-wise. The Total Annual Ground Water Recharge of the State has been assessed as 1.86 bcm and Annual Extractable Ground Water Resources as 1.53 bcm. The current Annual Ground Water Extraction is 0.07 bcm and Stage of Ground Water Extraction is 4.60 %. All the 40 assessment units have been categorized as ‘Safe’.

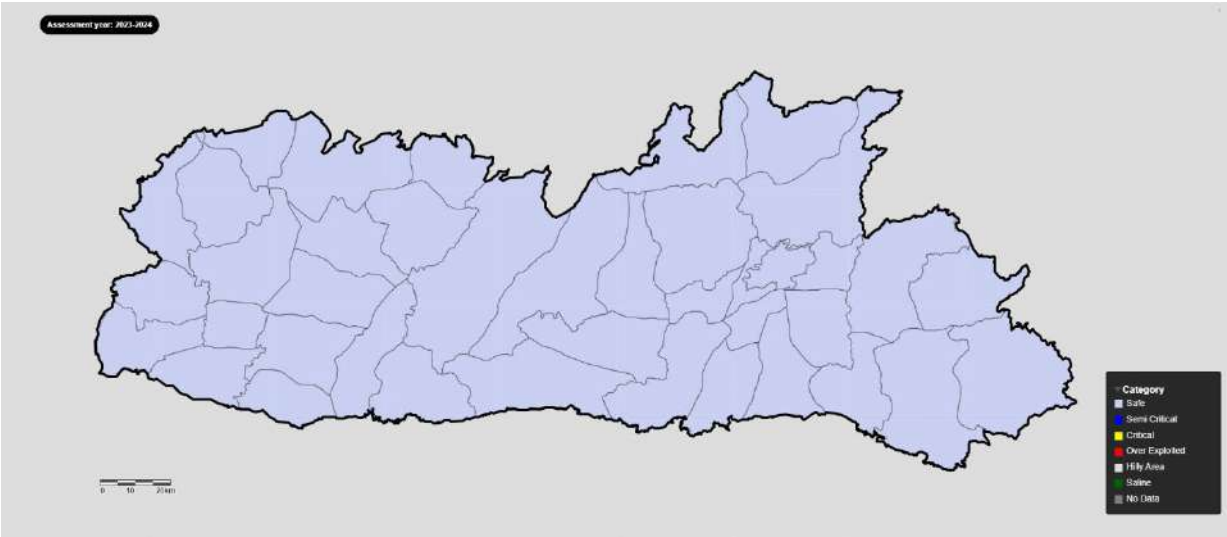
Out of 40 assessment units, all are categorized as ‘Safe’ assessment units and there are no saline assessment unit.

Similarly, out of 8135.45 sq km recharge worthy area of the State, 8135.45 sq km (100 %) under ‘Safe’ categories of assessment units. Out of total 1532.31 mcm annual extractable ground water resources of the State, 1532.31 mcm (100 %) are under ‘Safe’ categories of assessment units.

As compared to 2023 assessment, the Annual Ground Water Recharge has increased from 1.82 to 1.86 bcm during 2024 assessment, Annual Extractable Ground Water Resources has increase from 1.51 to 1.53 bcm. The reasons can be attributed to increase in recharge from rainfall and other sources. The Ground Water Extraction has increased minutely. Therefore, Stage of ground water extraction has slightly increased from 4.58 % to 4.60 %.



Dynamic Ground water Recourses Scenario 2024– Meghalaya



Categorization Map of GWRA 2024 – Meghalaya

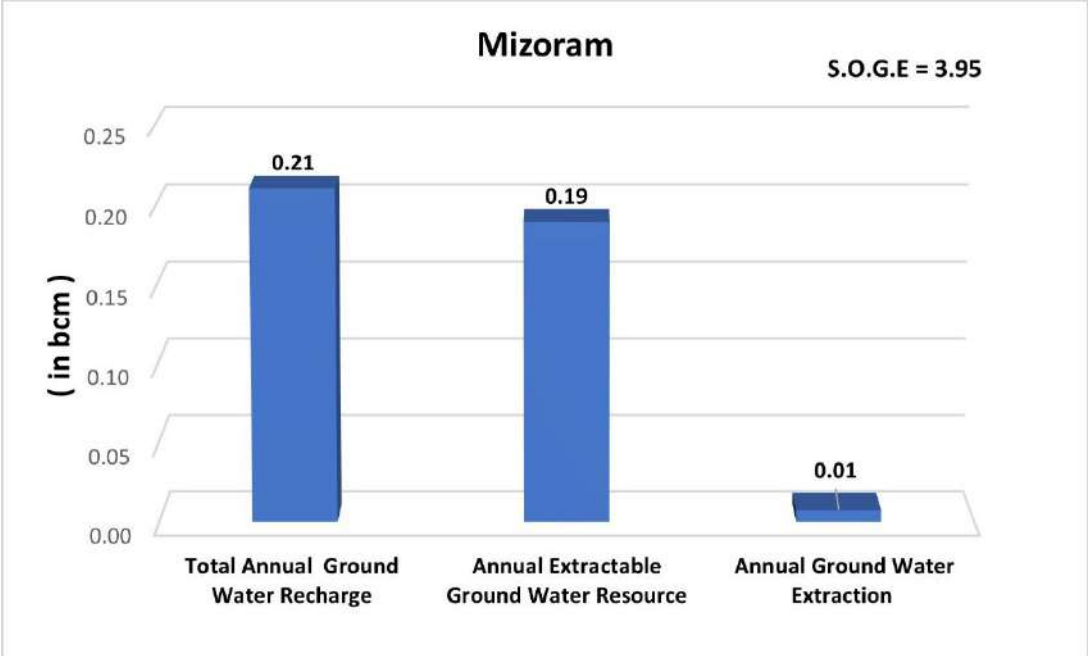
7.17 MIZORAM

The State is occupied mainly by the rocks of the Tertiary formation ranging in age from Oligocene to Miocene to Recent. The Barail formation the lowermost rock units comprising siltstone and bands of soft and hard fine-grained sandstone with strings of carbonaceous material and occur in the north eastern part of the state. The Surma is divided into two formations, Bhuban and Bokabil. The Bhuban is made up of grey sandstone and shale and occupies the major part of the State along the length of the state. The Bokabil, predominantly argillaceous, mostly occurs along the western part of the State. The Tipam sandstone is of semi- consolidated nature comprising medium to coarse grained sandstone with subordinate shale and occurs in limited extent in the north western part of the state. The alluvial deposits comprising silt, clay and sands occur in the valley fill area with very limited thickness. Ground water is restricted only to valley filled areas and secondary porosities of semi-consolidated rocks. These aquifers are the main source for springs. Ground water stored in the hill slopes emanates in the form of springs, which are being used as a source for water supply. In the valley area, the yield potential of tube wells within the depth range of 200 m tapping Tertiary sandstone ranges from 120 to 330 liters per minute (lpm) for drawdown of 13 to 20 m. The transmissivity and Storativity are to the tune of 11 to 46 m^2/day and 4.28 x 10^{-4}respectively.

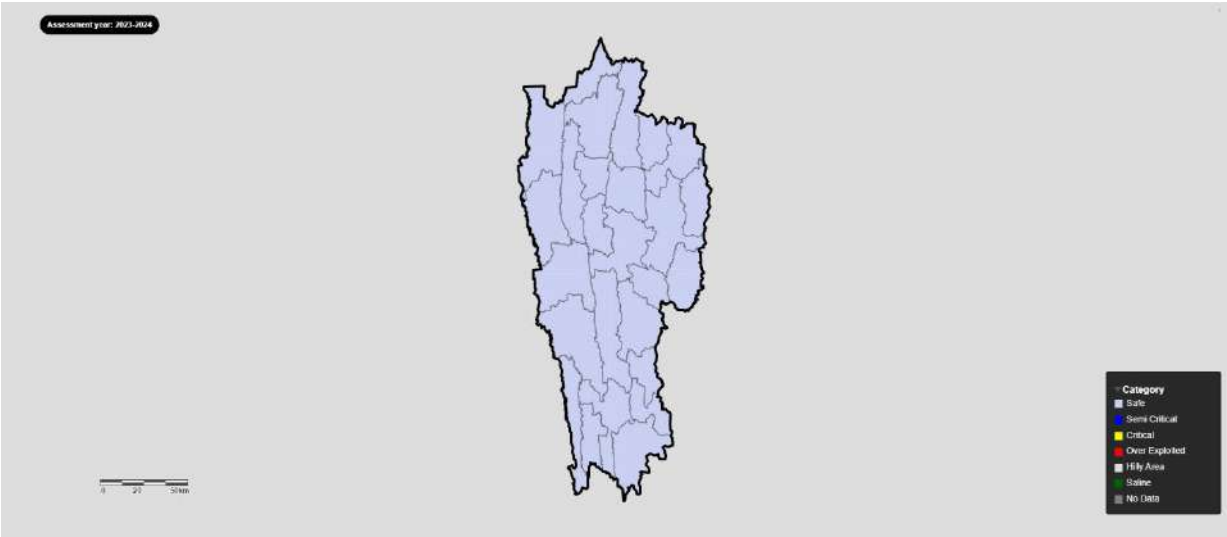
The ground water resources for the state have been assessed block-wise. Total Annual Ground Water Recharge has been assessed as 0.21 bcm and Annual Extractable Ground Water Resource is 0.19 bcm. The Annual Ground Water Extraction is 0.01 bcm and Stage of Ground Water Extraction is 3.95 %. All the 26 assessed blocks have been categorized as ‘Safe’. There are no saline areas in the state.

Similarly, out of 3149.41 sq km recharge worthy area of the State, 100 % of the area under ‘Safe’ categories of assessment units. All the total 190.30 mcm annual extractable ground water resources of the State, are under ‘Safe’ categories of assessment units. The comparison with previous assessment shows there is no major changes in the Ground Water Resources of Mizoram.

As compared to 2023 assessment, there is no major change in Annual Groundwater Recharge, Annual Groundwater Extractable Resources and Groundwater Extraction. Stage of GW Extraction has increased marginally from 3.7 % in 2023 to 3.95 % 2024.



Dynamic Ground water Recourses Scenario 2024– Mizoram



Categorization Map of GWRA 2024 – Mizoram

7.18 NAGALAND

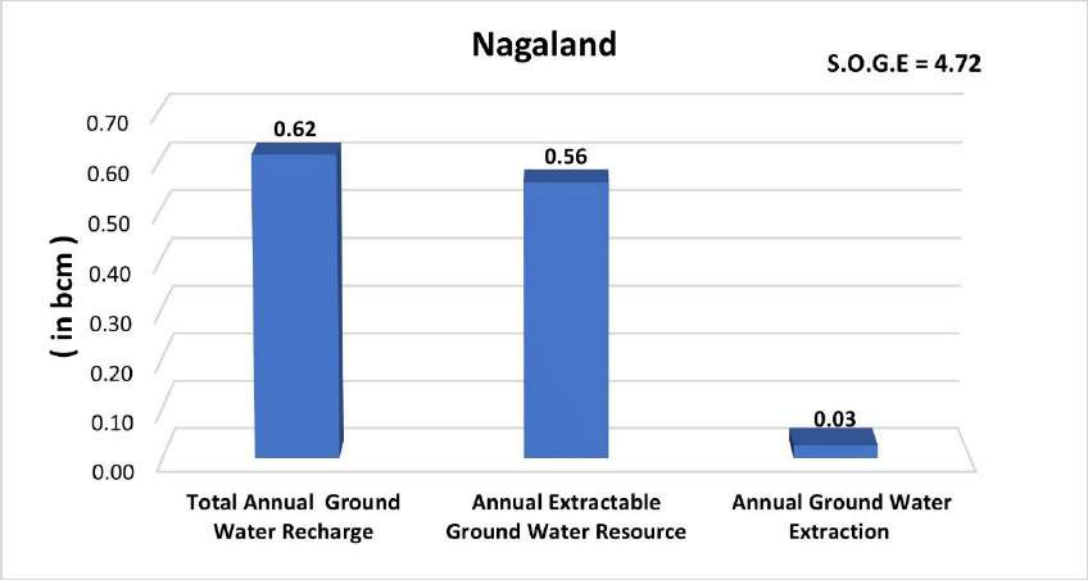
The State is covered by rocks ranging in age from Pre-Cretaceous to Recent. The rock sequences comprise the geosynclinals facies, represented by Disang Group, Barail Group, Surma Group, Tipam Group, Namsang formation and Dihing Group. While the Disang and Surma Group of rocks are mainly argillaceous, the Barail and Tipam groups are Arenacious. The Girujan clay formation overlying the Tipam sandstones is characterized by typical blue, mottled clay and argillaceous sandstone beds. Older rocks occupy southern parts of the State, where as younger rocks are exposed in the northern parts. The unconsolidated alluvial plains, comprising clay, sand pebble, cobble and boulder assemblages, occupy the narrow, intermountain and open valleys in the northern part of the state bordering upper reaches of Brahmaputra flood plains of Assam. The consolidated formations are confined to the south eastern part of the State along the Burma (Myanmar) border.

Ground water development potentiality in valley fill and alluvial deposits are restricted to construction of open wells having depth of 15 to 20 meters and deep tube well down to 100 m depth which yield to the tune of 10 to 45m^3/day with more than 5m drawdown. Water bearing formations pertaining to Tertiary deposits are found to have moderate potentials which can sustain deep tube wells having yield prospects varying from 10 to 20m3/hr. The valleys underlain by Tipam sandstones form good aquifers with yield prospects varying from 30 to 80m^3/hr. In the consolidated formations, ground water abstraction structures can be constructed in structurally weak zones. Ground water emerges as perennial springs which are the main source of water supply for domestic needs in the state.

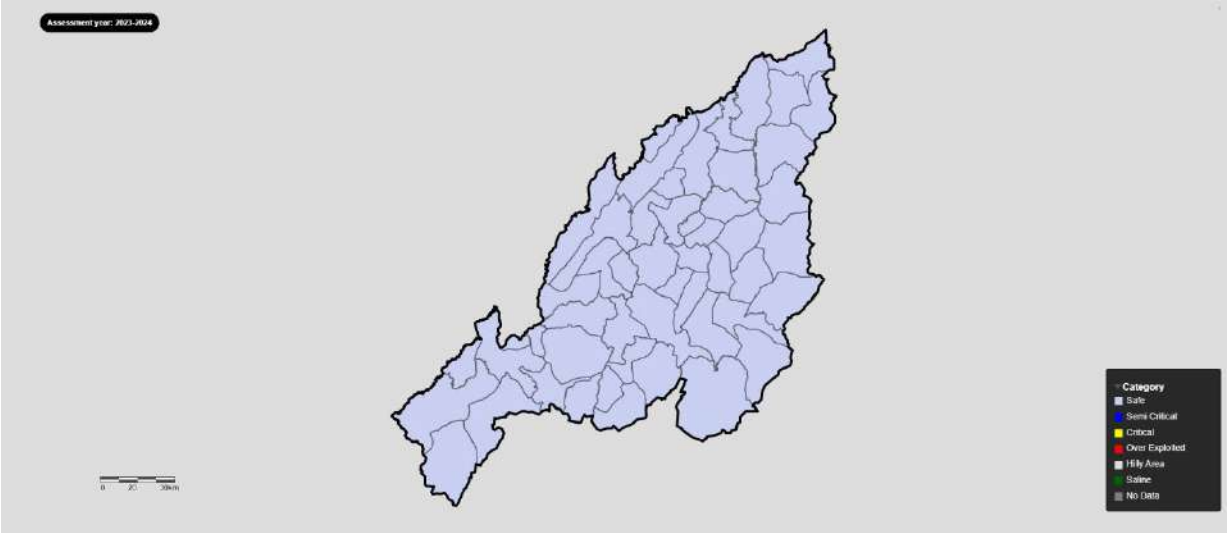
The Ground water resources for the State have been assessed block-wise. The total Annual Ground Water Recharge of the State has been assessed as 0.62 bcm and Annual Extractable Ground Water Resource as 0.56 bcm. Annual Ground Water Extraction is 0.03 bcm and Stage of Ground Water Extraction is 4.72%. All the 52 Assessment Units have been categorized as ‘Safe’. There is no saline area in the State.

Similarly, out of 3855.07 sq km recharge worthy area of the State, 100 % of the area is under ‘Safe’ categories of assessment units. The entire 562.18 mcm Annual Extractable Ground Water resources of the State is under ‘Safe’ categories of assessment units.

As compared to 2023 assessment, Annual Ground Water Recharge of the State has increased from 0.60 bcm to 0.62 bcm. The Annual Extractable Ground Water Resource has increased from 0.54 bcm to 0.56 bcm and total Ground Water Extraction increased from 0.02 bcm to 0.03 bcm in 2024. The Stage of Ground Water Extraction has increased from 3.76 % to 4.72 %. There is no major changes in the Ground Water Resources of Nagaland in comparison with previous assessment.



Dynamic Ground water Recourses Scenario 2024– Nagaland



Categorization Map of GWRA 2024 – Nagaland

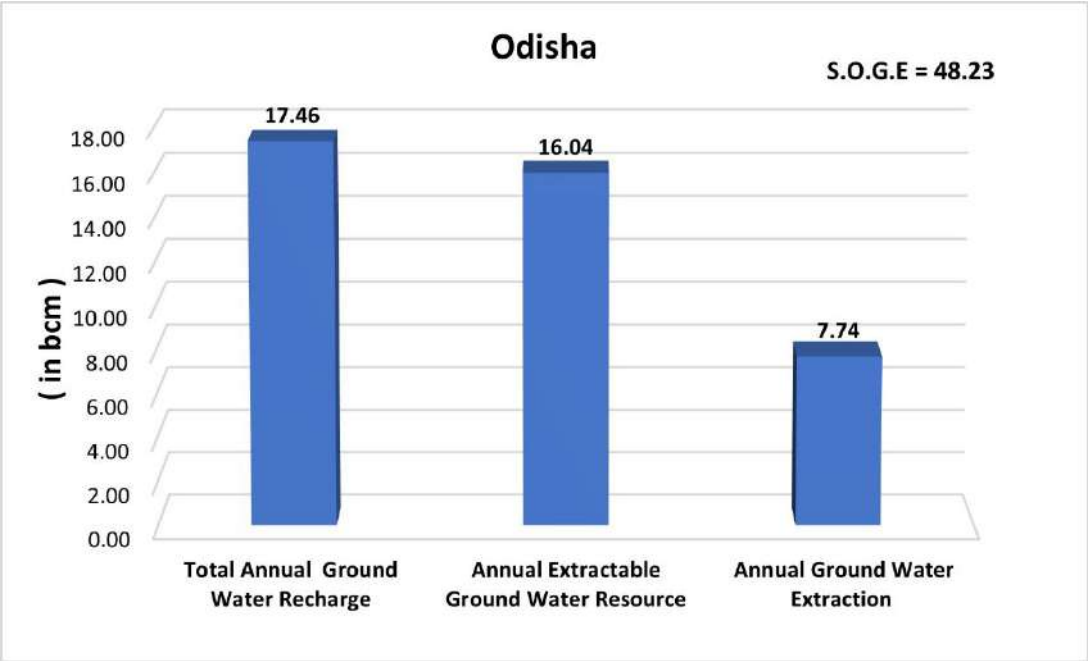
7.19 ODISHA

The State is underlain by diverse rock types, which range in age from Precambrian to Cenozoic era. The Precambrian occupy nearly 80 % of the total geographical area of the State. The Tertiary and the Quaternary Alluvial formations are restricted mainly to the narrow coastal tracts. The Gondwana group of rocks belonging to Paleozoic and Mesozoic era occurs in isolated patches in different parts of the State. These formations occur in Talcher area of Angul district and in river valley area of Sambalpur and Sundargarh districts. Ground water abstraction in the state is mostly done by dug wells constructed in the weathered zone in hard rock areas and in shallow phreatic aquifers in alluvial areas. The yield of open (dug) wells varies from 1 to 5 lps. However, at present, bore wells, shallow to medium deep tube wells, filter point tube wells are also in use for ground water abstraction both for domestic and irrigational purpose. The yield of bore wells varies from 2 to 5 lps in general depending on the occurrence of saturated fractures at depths. The yield from shallow and medium deep tube wells may vary from 6 to 10 lps in general depending on the aquifer disposition.

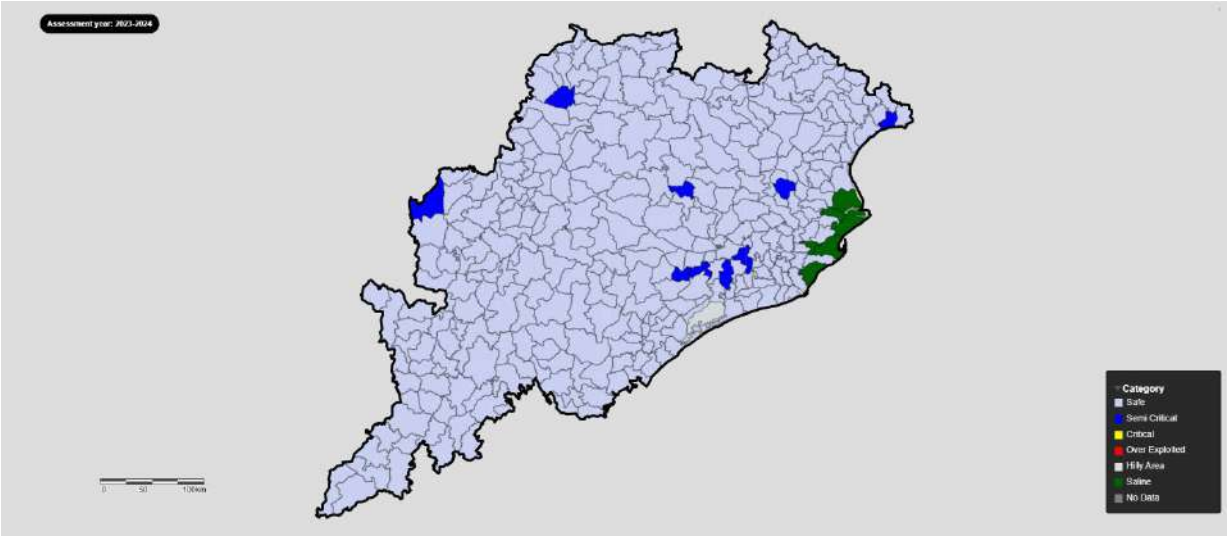
The Ground water resources in the state have been assessed block-wise. Total Annual Ground Water Recharge of the State has been assessed as 17.46 bcm and Annual Extractable Ground Water Resource as 16.04 bcm. The Annual Ground Water Extraction is 7.74 bcm and Stage of Ground Water Extraction is 48.23 %.

Out of the total of 314 assessment units (blocks), 9 units (2.87 %) have been categorized as ‘Semi-critical’, 299 units (95.22 %) as ‘Safe’ and 6 units (1.91 %) as ‘Saline’ categories of assessment units.
Similarly, out of 121593.15 sq km recharge worthy area of the State, 3339.96 sq km (2.75 %) area are under ‘Semi-critical’, 116071.86 sq km (95.46 %) under ‘Safe’ and 2181.33 sq km (1.79 %) area under ‘Saline’ categories of assessment units. Out of total 16041.33 mcm annual extractable ground water resources of the State, 495.09 mcm (3.09 %) are under ‘Semi-critical’ and 15546.23 mcm (96.91 %) are under ‘Safe’ categories of assessment units.

As compared to 2023 assessment, the Annual Ground Water Recharge has increased from 17.35 to 17.46 BCM. Similarly Annual Extractable Ground Water Resource has increased from 15.94 to 16.04 bcm and total annual ground water extraction for all uses has increased from 7.39 to 7.74 bcm. The stage of ground water extraction has increased to 48.23 % in 2024 as compared to 46.33 % in 2023.



Dynamic Ground water Recourses Scenario 2024– Odisha



Categorization Map of GWRA 2024 – Odisha

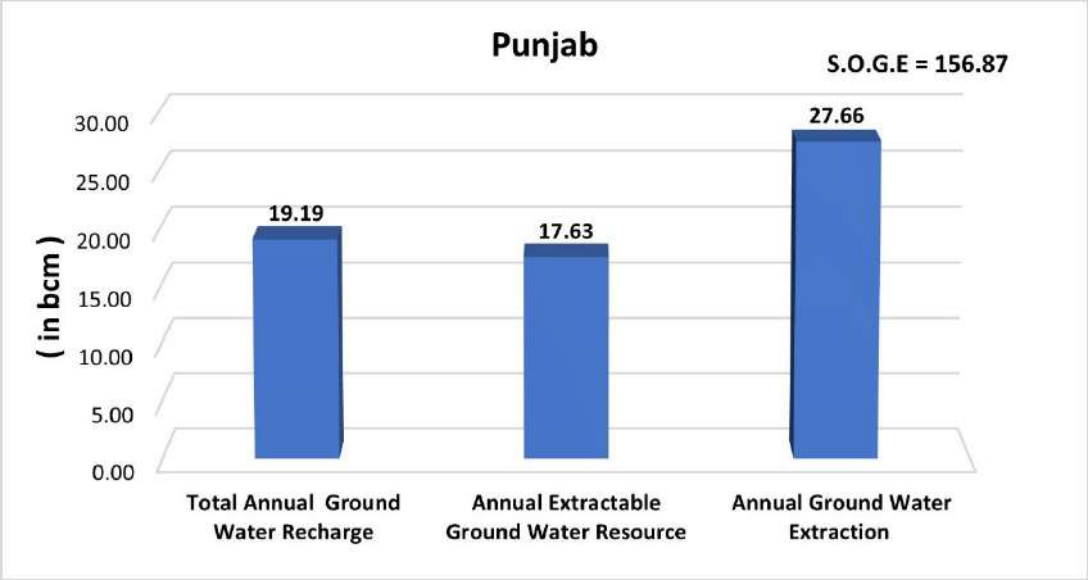
7.20 PUNJAB

Punjab is one of the smallest states of India having 3 perennial rivers namely Sutlej, Beas and Ravi and one non- perennial river Ghaggar. The Punjab State is a flat alluvial plain having a thin belt of mountains along north eastern border and stable sand dunes are seen dotting the landscape in the south western parts. The alluvial deposits in the State comprise sand, silt and clays often mixed with kankar. Sandy zones of varying grade constitute abundant ground water resources & act as a reservoir. The alluvial plain towards the hills is bordered by the piedmont deposits comprising Kandi and Sirowal. Immediately south-west of the hills, Kandi belt is 10 to 15 km wide followed by Sirowal which imperceptibly merges with the alluvial plain. Kandi deposit explored up to 450 m depth show gradation from boulders to clays and at places an admixture of various grades in different proportions. The Sirowal deposit is essentially composed of finer sediments but occasional gravel beds are also encountered in them.

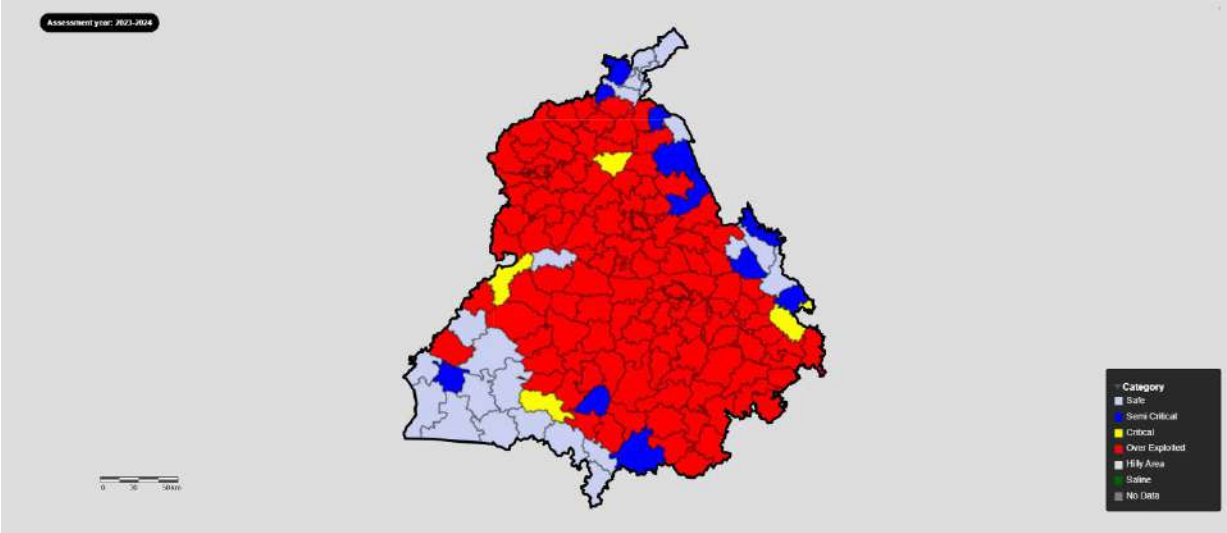
The ground water resources for the state have been assessed block-wise. Total Annual Ground Water Recharge of the State has been assessed as 19.19 bcm and Annual Extractable Ground Water Resource as 17.63 bcm. The Annual Ground Water Extraction is 27.66 bcm and Stage of Ground Water Extraction is 156.87 %.

Out of total 153 assessment units including 3 urban areas taken for study, 115 assessment units (75.16%) i.e. 112 blocks and 3 urban areas have been categorized as 'Over-exploited', 04 blocks (2.61%) as 'Critical', 12 blocks (7.84%) as 'Semi Critical' and 22 blocks (14.38%) as 'Safe'. Similarly, out of 50175.27 sq. km recharge worthy area of the State, 35786.32sq km (71.32 %) area are under 'Over-Exploited', 1597.32 sq. km (3.18%) under 'Critical', 3827.50sq km (7.63%) under 'Semi-critical' and 8964.13sq km (17.87 %) under 'Safe'. Out of total 17633.76 mcm annual extractable ground water resources of the State, 12618.20 mcm (71.56%) are under 'Over-exploited', 720.19 mcm (4.08 %) under 'Critical', 1044.85 mcm (5.93 %) under 'Semi-critical' and 3250.53 mcm (18.43 %) are under 'Safe' categories of assessment units.

As compared to 2023 estimates, the Annual Ground Water Recharge has increased from 18.84 to 19.19bcm and similarly, Annual Extractable Ground Water Resource increased from 16.98 to 17.63bcm and total current annual ground water extraction decreased 27.80 to 27.66bcm. The stage of ground water extraction has decreased from 163.76% to 156.87%.



Dynamic Ground water Recourses Scenario 2024- Punjab



Categorization Map of GWRA 2024 – Punjab

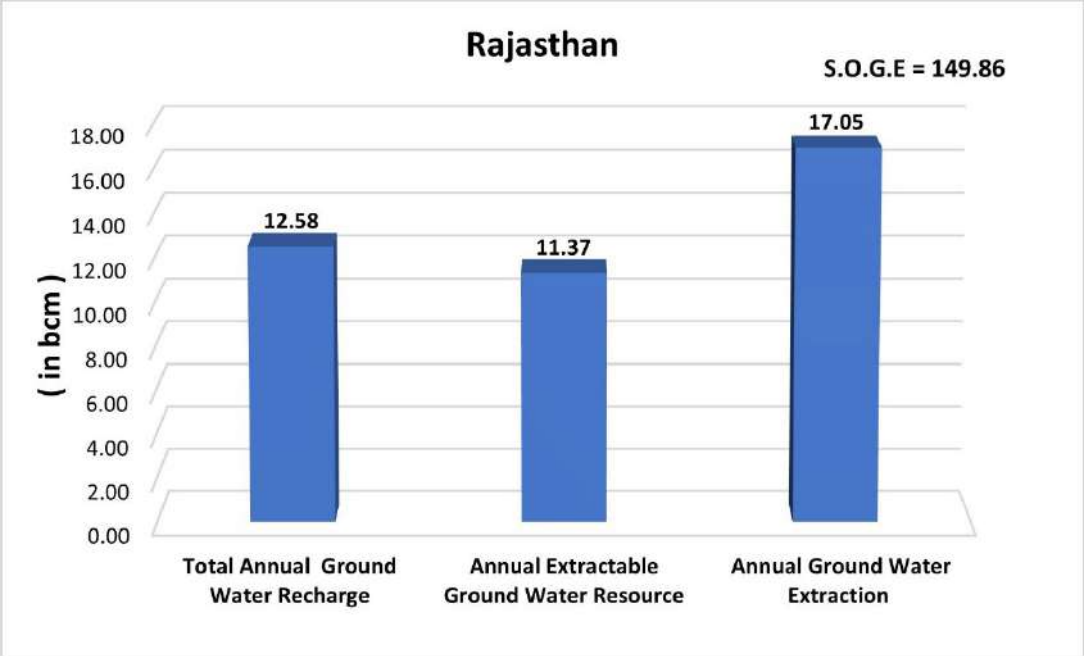
7.21 RAJASTHAN

The State of Rajasthan has diversified geology, ranging from Archean metamorphic to recent alluvial sediments. Based upon geological diversities, geomorphological setup and ground water potentialities, the state of Rajasthan can be divided into three broad hydrogeological units. (i) Unconsolidated formation (ii) Semi-consolidated formation (iii) Consolidated (Fissured formation). Large part of the State is underlain by Quaternary sediments (Thar Desert) consisting of clay, silt, sand and gravel of various grades. Exploratory drilling data reveals that the yield vary from meager to 10 m^3/day, transmissivity ranges between 80 to 300 m^2/day and storage co-efficient vary from 1.1x 10^{-5} to 3.9x 10^{-6} in the state. Ground Water occurs within the weathered residue and in the secondary porosity in Sandstone belonging to the Vindhyan formation. Yield potential is limited due to compact nature of the formation. The limestone is also having low ground water potential. The yields of dug wells vary from 0.25 to 0.75 m^3/day. The yield of the wells drilled in Vindhayan formation has been observed to be 15 m^3/day, tapping fractures between 50-75 m bgl. In consolidated formation (Fissured) the thickness of the weathered zone varies from 5 to 50 m. Ground Water occurs under unconfined condition within the weathered zone. The results of the exploratory drilling carried out by CGWB in hard rock are as indicate presence of productive fractures down to the depth of 100 m and yield varies from 3 to 15 m^3/day, whereas transmissivity varies from 3 to 30 m^2/day.

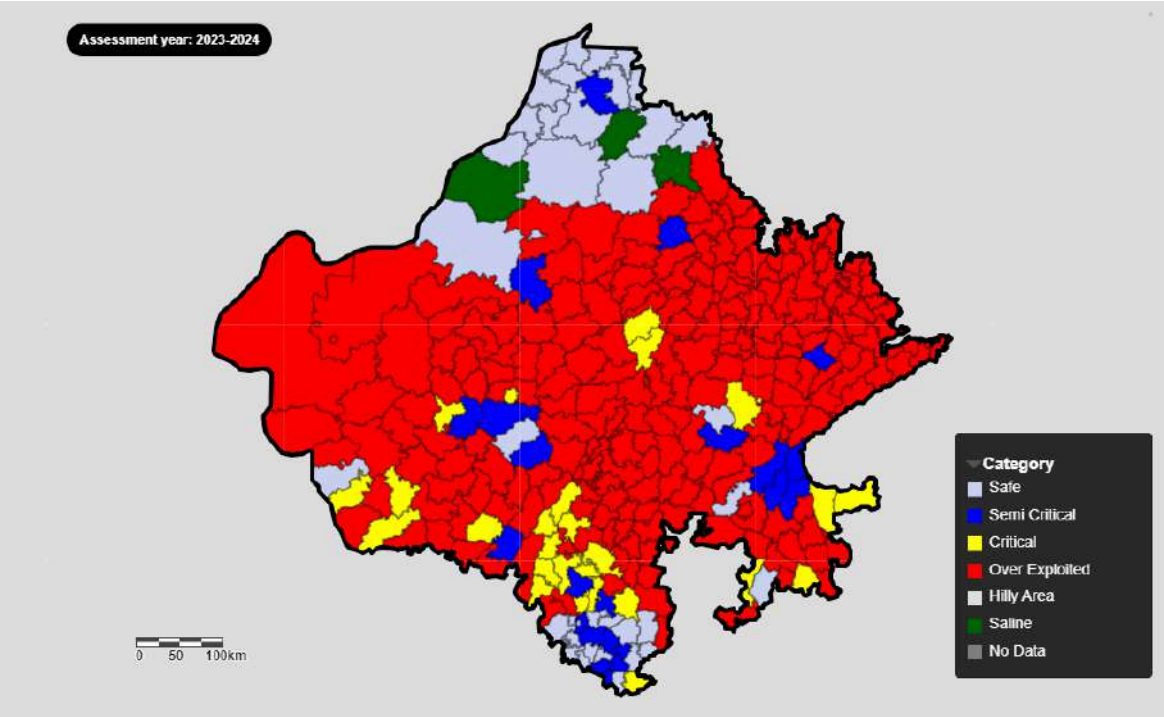
The dynamic ground water resources for the state have been assessed block-wise. Total Annual Ground Water Recharge of the State has been assessed as 12.58 bcm and Annual Extractable Ground Water Resource as 11.37 bcm. The Annual Gross Ground Water Extraction is 17.05 bcm and the Stage of ground water extraction in the state is 149.86%.

In the year 2024, assessment has been done for 302 units. Out of the 302 assessment units (blocks and urban areas), 214 units (70.86 %) have been categorized as 'Over Exploited', 27 units (8.94 %) as 'Critical', 21 units (6.95 %) as 'Semi-Critical', 37 units (12.25 %) blocks as 'Safe' and 3 units (0.99 %) as 'Saline'. Similarly, out of 317010.74 sq km recharge worthy area of the State, 222797.93 sq km (70.28 %) area are under 'Over-Exploited', 21084.64 sq km (6.65 %) under 'Critical', 17908.38 sq km (5.65 %) under 'Semi-critical', 46283.9 sq km (14.6 %) under 'Safe' and 8935.89 sq km (2.82 %) area under 'Saline' categories of assessment units. Out of total 11374.61 mcm annual extractable ground water resources of the State, 8249.68 mcm (72.53 %) are under 'Over-exploited', 977.91mcm (8.6 %) under 'Critical', 930.04 mcm (8.18%) under 'Semi-critical' and 1216.98mcm (10.7 %) are under 'Safe' categories of assessment units.

As compared to 2023 assessment, the Annual Ground Water Recharge and Annual Extractable Ground Water Resource have increased from 12.45 bcm to 12.58 bcm and from 11.25 bcm to 11.37 bcm respectively. Annual ground water extraction has increases from 16.74 bcm to 17.05 bcm. The stage of ground water extraction has increased marginally from 148.77 % to 149.86%.



Dynamic Ground water Recourses Scenario 2024– Rajasthan



Categorization Map of GWRA 2024 – Rajasthan

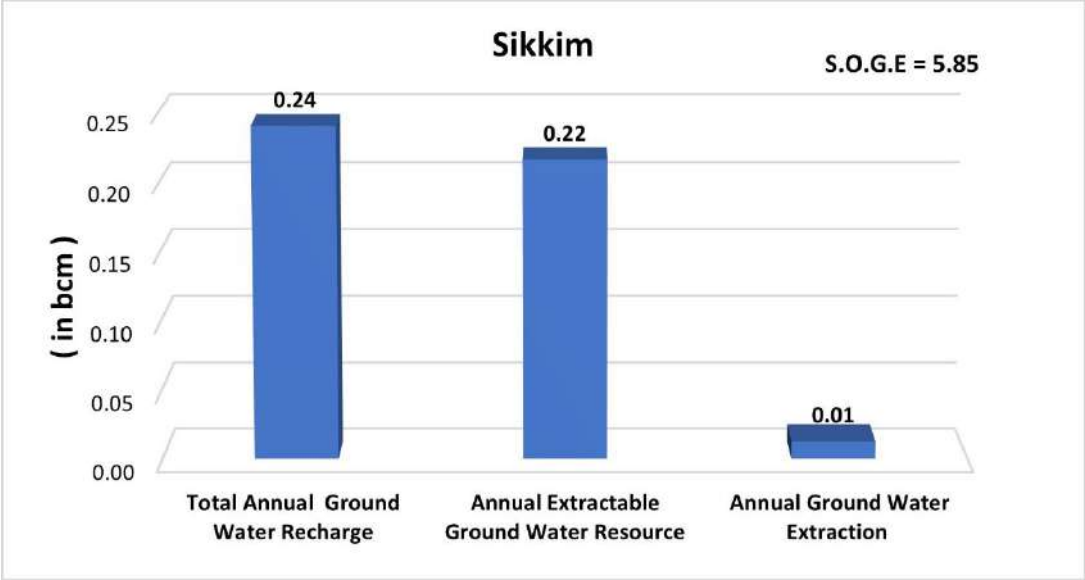
7.22 SIKKIM

Sikkim is a small mountainous State characterized by rugged undulating topography with series of ridges and valleys. The various rock types prevalent in the state are pelitic and carbonate rocks and Gondwanas over a gneissic basement and occasional colluviums and valley fill deposits, as well as alluvial terraces along higher order streams and river courses. The formations reveal an intense tectonic-structurally complex deformational history. Ground water occurs largely in disconnected localized pockets and in deeper fractures zones. Springs are the main source and conduits of water.

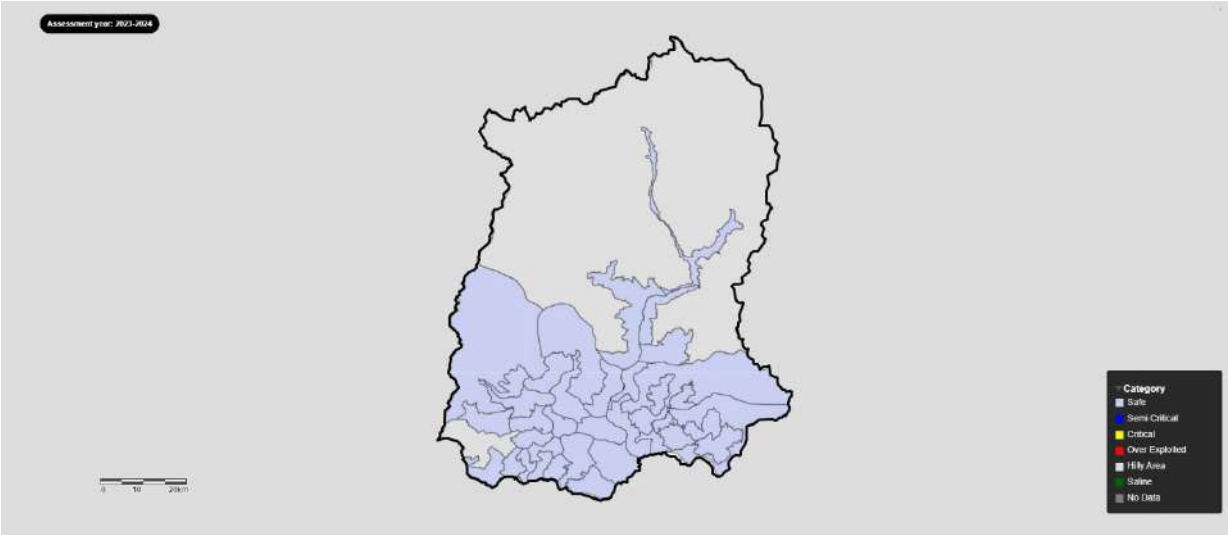
The ground water resource assessment (in 2024) for the State of Sikkim has been carried out as per GEC 2015 guidelines through 'IN-GRES' tool with Blocks as primary assessment units. A total of 38 units has been assessed for Ground Water Resource Assessment 2024. Out of these 38 assessment units, 34 are administrative blocks and rest 4 assessment units are not part of any block. These 4 assessment units represent remaining areas in six district which are mountainous and is not covered by any administrative block. For the sake of completeness of the estimation process, these areas are designated as Rest of the Area of the District and assessed as a unit.

Total Annual Ground Water Recharge has been estimated at 0.24 bcm and Annual Extractable Ground Water Resource has been estimated at 0.22 bcm. Current Annual Ground Water Extraction for all uses has been estimated at 0.01 bcm, which translates into a Stage of Ground Water Extraction at 5.85 %, and as per the present assessment all 38 assessment units/ Blocks are in 'Safe' category.

As compared to 2023 assessment, Total Annual Ground Water Recharge of the State and Annual Extractable Ground Water Resource remained same at 0.24 bcm and 0.22 bcm respectively. The Annual Ground Water Extraction from all sources marginally increased from 0.0121 bcm to 0.0127 bcm. Stage of Ground Water Extraction increased marginally from 5.54 % to 5.85 %.



Dynamic Ground water Recourses Scenario 2024- Sikkim



Categorization Map of GWRA 2024– Sikkim

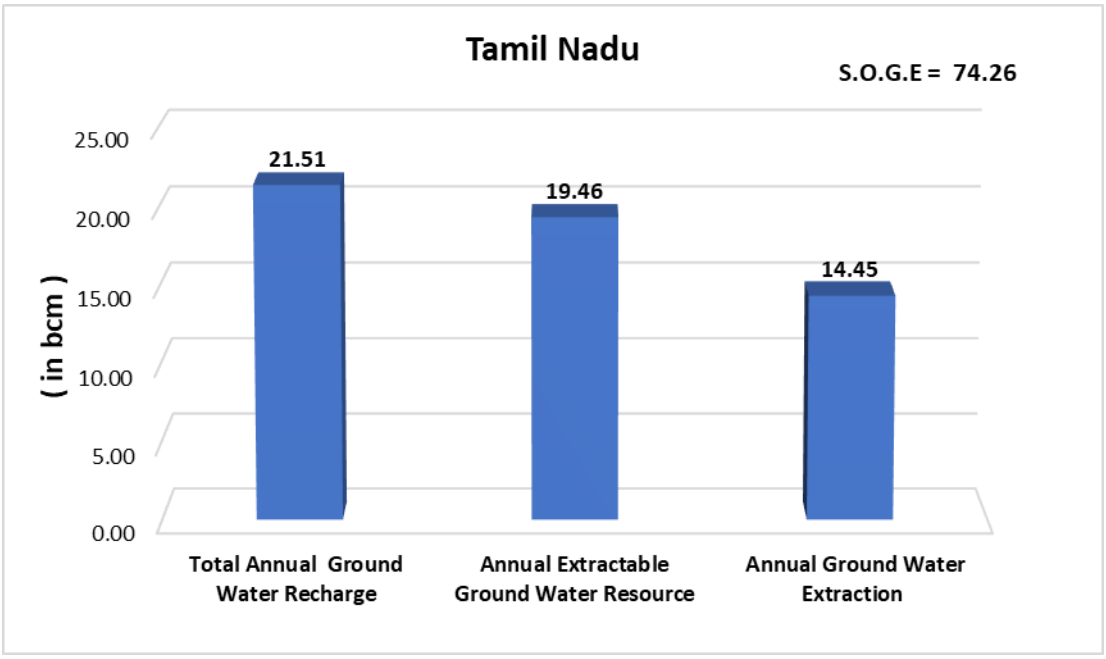
7.23 TAMIL NADU

Tamil Nadu state is underlain by diverse hydrogeological formations. Nearly 73 % of the state is occupied by hard rock's (consolidated), semi-consolidated and unconsolidated formations which are mainly confined to the eastern part including the coastal tract. In the hard rock areas, groundwater is developed through dug wells tapping the weathered zone and dug cum bore wells and bore wells tap the deeper fractures down to a depth of 300 m. In semi consolidated and unconsolidated formation, shallow zones are tapped by filter points and shallow tube wells and deeper zones through deeper tube wells. The yield of open wells vary from 1 to 3 lps, where as in dug wells tapping soft rocks including sedimentary formations, the yield is up to 10 lps. The yield from unconsolidated and semi consolidated formations are in general 10 to 20 lps and also as high as 40 lps are also noticed at select places.

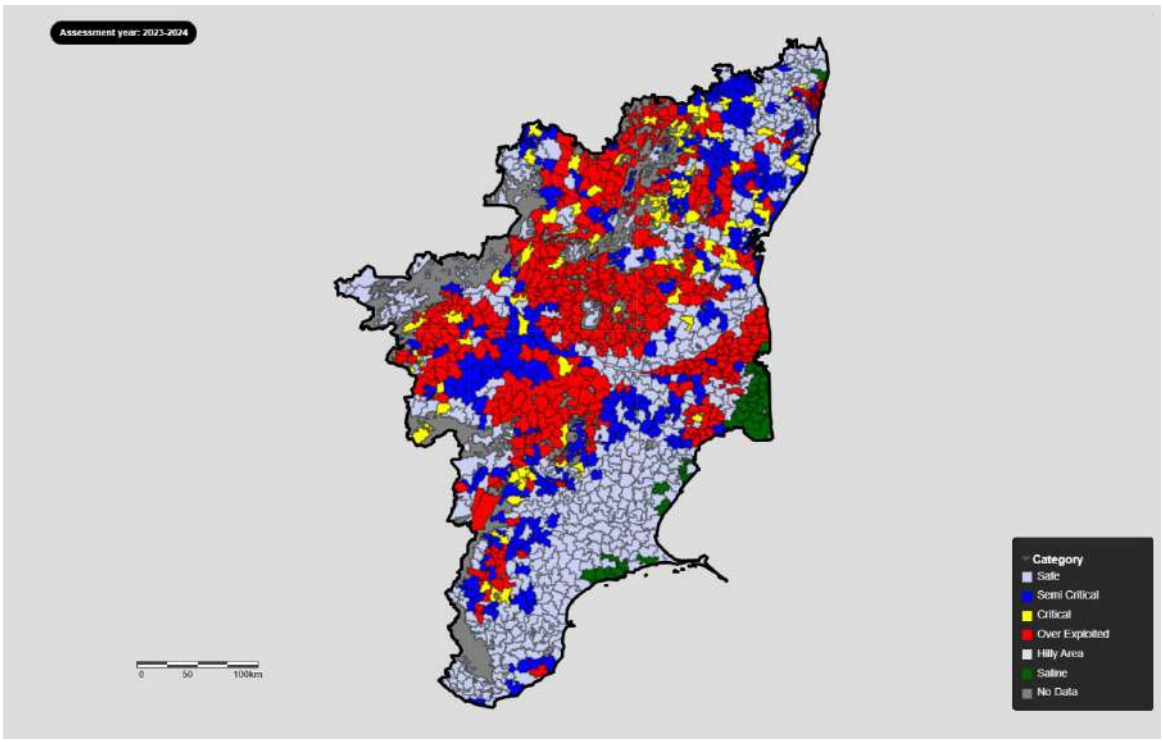
The ground water resources for the State have been assessed Block-wise (Taluka). The Firka (1202 Firka) resources were summed up to taluk level. Total Annual Ground Water Recharge of the State has been assessed as 21.51 bcm and Annual Extractable Ground Water resources as 19.46 bcm. The Annual Ground Water Extraction is 14.45 bcm and Stage of Ground Water Extraction as 74.26 %.

Out of 313 assessment units (taluka), 106 units (33.87 %) have been categorized as 'Over Exploited', 20 units (6.4 %) as 'Critical', 55 units (17.6 %) as 'Semi-Critical', 127 units (40.3 %) as 'Safe' and 5 units (1.60 %) have been categorized as 'Saline'. Similarly, out of 108613.35 sq km recharge worthy area of the State, 33301.69 sq km (30.66 %) area are under 'Over-Exploited', 8540.25 sq km (7.86 %) under 'Critical', 19244.96 sq km (17.72 %) under 'Semi-critical', 45614.89 sq km (42 %) under 'Safe' and 1911.56 sq km (1.76 %) area under 'Saline' categories of assessment units. Out of total 19461.53 mcm annual extractable ground water resources of the State, 5094.25 mcm (26.18 %) are under 'Over-exploited', 1619.24 mcm (8.32 %) under 'Critical', 3550.20 mcm (18.24 %) under 'Semi-critical' and 9197.84 mcm (47.26 %) are under 'Safe' categories of assessment units.

As compared to 2023 assessment, Total Annual Ground Water Recharge has marginally reduced from 21.59 to 21.51 bcm. The Annual Extractable Ground Water Resources has also marginally reduced from 19.51 to 19.46 bcm and the annual ground water extraction has increased marginally from 14.42 to 14.45 bcm. Consequently, there is an increase in the stage of ground water extraction from 73.91 % to 74.26 %.



Dynamic Ground water Recourses Scenario 2024– Tamil Nadu



Categorization Map of GWRA 2024 – Tamil Nadu

7.24 TELENGANA

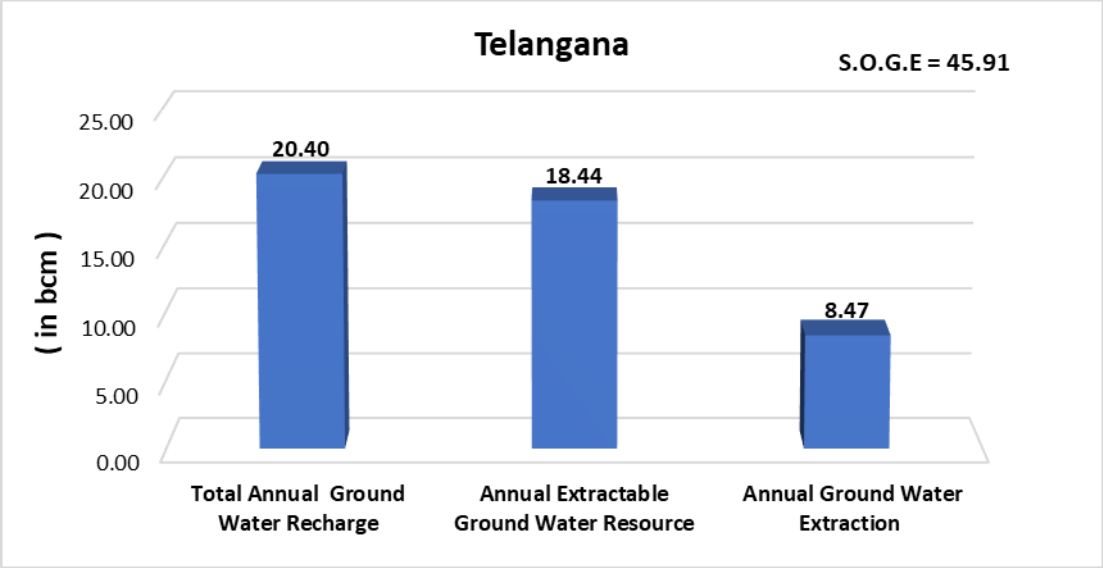
The State of Telangana shares its boundaries with Andhra Pradesh, Chattisgarh, Maharashtra and Karnataka. The state is drained by 2 major rivers, the Godavari and the Krishna which finally debouches into Bay of Bengal after draining though adjacent Andhra Pradesh State. The River Godavari with its tributaries Lower Godavari, Middle Godavari Penganga, Wardha, Pranhita, Manjeera and Maneru, drains through the northern parts of the State. The River Krishna with its tributaries Bhima, Musi, Paleru Munneru and lower Krishna flows through the Southern parts of the State.

Telangana state is characterized by wide range of geological formations from Archaean to Recent age. Nearly 85% of the state is underlain by hardrocks (consolidated formations) belonging to the Peninsular Gneissic Complex, Dharwar and Eastern Ghats of Archaean to Middle Proterozoic age, Pakhal Group of rocks belonging to Middle to Upper Proterozoic age and Deccan Traps. In hardrocks average well yields are around 50 to 125 lpm. The rest of the state is underlain by semi consolidated sedimentary formations encompassing Gondwanas, Tertiary group of formations and Sub-Recent to Recent unconsolidated sediments. Transmissivity of these aquifers varies between 28 and 950m2/day. The unconsolidated formations are represented by inland river alluvium.

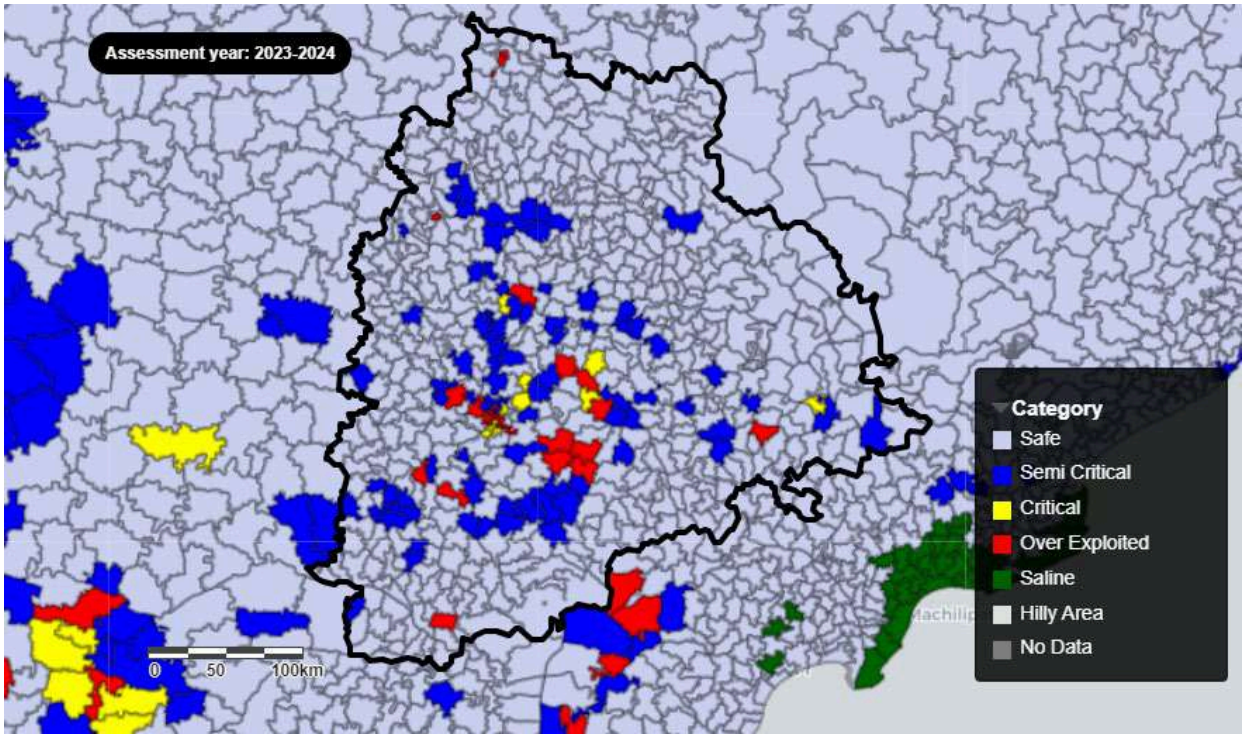
The Ground water resources for the state have been assessed watershed-wise and apportioned to mandal-wise. Total Annual Groundwater recharge of the State has been assessed as 20.40 bcm and Annual extractable Ground Water resource as 18.44 bcm. The Annual Ground Water Extraction is 8.47 bcm and Stage of Ground Water Extraction is 45.91 %.

Out of 620 assessment units (Mandals), 32 units (5.16 %) have been categorized as ‘Over Exploited’, 13 units (2.10 %) as ‘Critical’, 85 units (13.71 %) as ‘Semi-Critical’ and 490 units (79.03 %) as ‘Safe’. There is no ‘Saline’ category of assessment unit in the state. Similarly, out of 105777.24 sq km recharge worthy area of the State, 2830.80 sq km (2.68 %) area are under ‘Over-Exploited’, 875.67 km (0.83 %) under ‘Critical’, 12119.96 sq km (11.46 %) under ‘Semi-critical’, 89950.81 sq km (85.04 %) under ‘Safe’ categories of assessment units. Out of total 18442.87 mcm annual extractable ground water resources of the State, 428.83 mcm (2.33 %) are under ‘Over-exploited’, 120.90 mcm (0.66 %) under ‘Critical’, 1742.45 mcm (9.45%) under ‘Semi-critical’ and 16150.68 mcm (87.57 %) are under ‘Safe’ categories of assessment units.

As compared to 2023 assessment, Total Annual Ground Water Recharge of the State has decreased from 23.14 to 20.40 bcm. This is mainly due to decrease in recharge from ‘Other sources. The Annual Extractable Ground Water Resources has decreased from 20.92 to 18.44 bcm. The Annual Ground Water Extraction increases from 8.09 bcm to 8.47 bcm. The overall Stage of Ground Water Extraction increased from 38.65% to 45.91%.



Dynamic Ground water Recourses Scenario 2024– Telangana



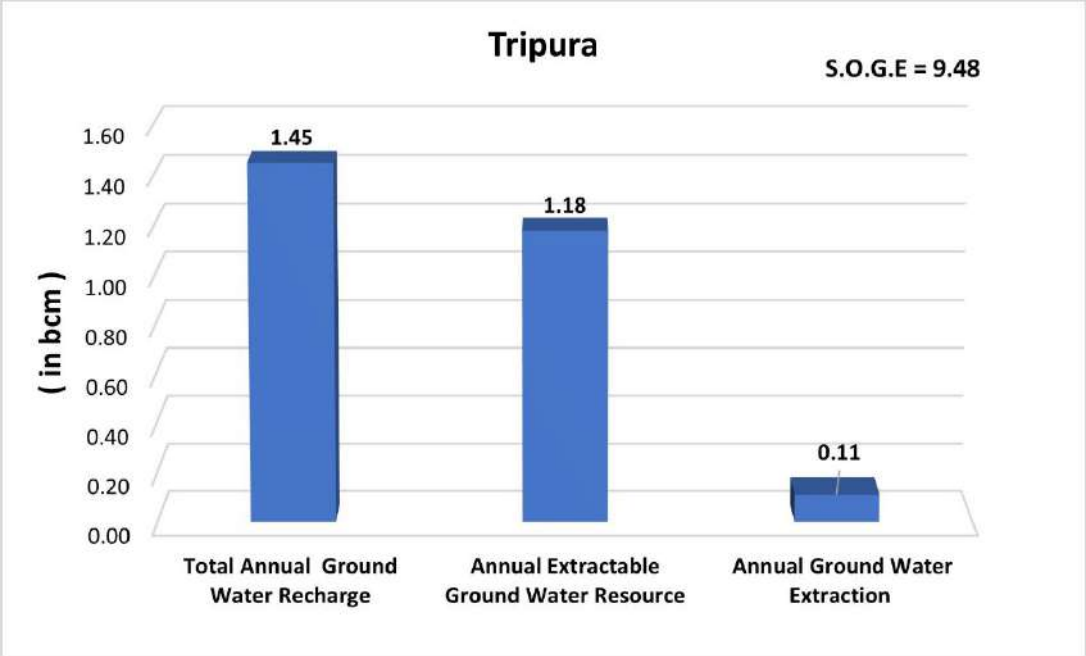
Categorization Map of GWRA 2024 – Telangana

7.25 TRIPURA

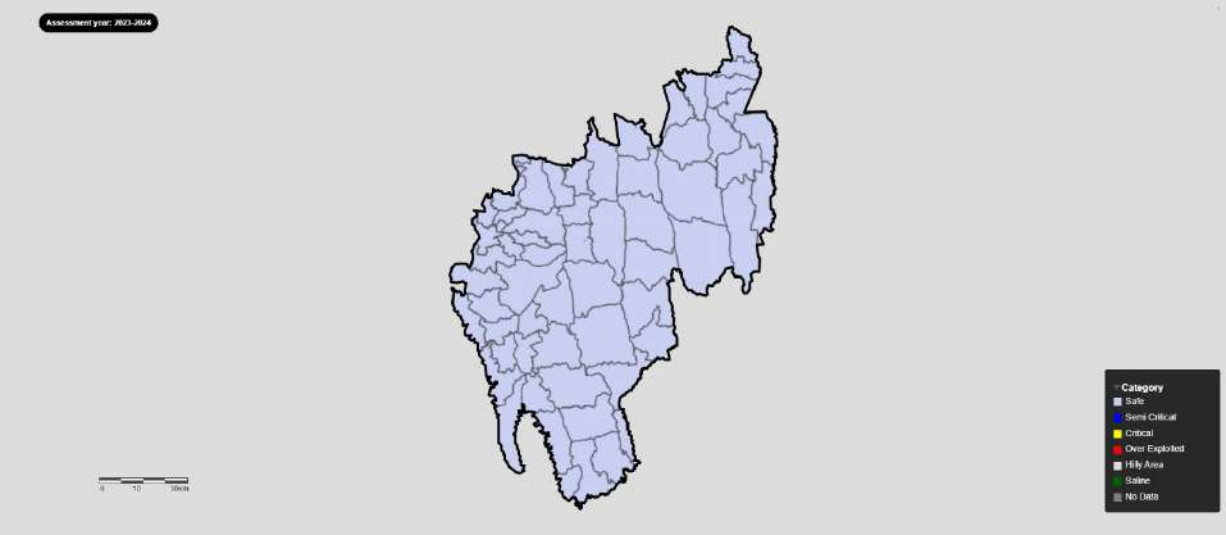
The State of Tripura is occupied by the rocks ranging in age from Upper Tertiary to Quaternary. Mobile trough geosynclinal deposition of Barail group followed by flysch type of Surma &Tipam sediments, overlain by Dupitila formation, is noticed in the State. Most of the longitudinal synclinal valleys of the state are the basins of deposition of recent formation. Recent alluvium occurs along the streams and the flood plains of major rivers.

Ground water occurs under unconfined condition in Dupitila, Recent &Tipam formations. Besides, it also occurs under confined to semi-confined conditions in Tipam formation at considerable depth. Recharge areas for the deeper aquifer lies in the adjacent anticlinal hills. Wherever a good thickness of impermeable clay beds underlie & overlie the saturated granular zones, auto flow artesian conditions have been found in the valleys, which are the discharge area. The artesian flowing conditions occur in patches both at shallow depth and at deeper depth. The auto discharge of the flowing wells in the State ranges from 100 to 6000 lph, the maximum auto discharge from deep tube well to the extent of 54000 lph has been found in Khowai valley near Khowai town, where the piezometric head rose up to 7 m above ground level.

Ground water resources have been assessed block-wise for recharge worthy area. Total Annual Ground Water Recharge of the State has been assessed as 1.45 bcm and Annual Extractable Ground Water Resource as 1.18 bcm. The Annual Ground Water Extraction is 0.11 bcm and Stage of Ground Water Extraction is 9.48 %. All the 59 assessment units have been categorized as ‘Safe’.
The state has Recharge worthy area of 6197.84 Sq. Km and Total Annual Extractable Resource is of 1180.139 mcm is under ‘safe’ categories of assessment units.
As compared to 2023 assessment, there is no significant change in ground water recharge and ground water extraction in the State.



Dynamic Ground water Recourses Scenario 2024– Tripura



Categorization Map of GWRA 2024– Tripura

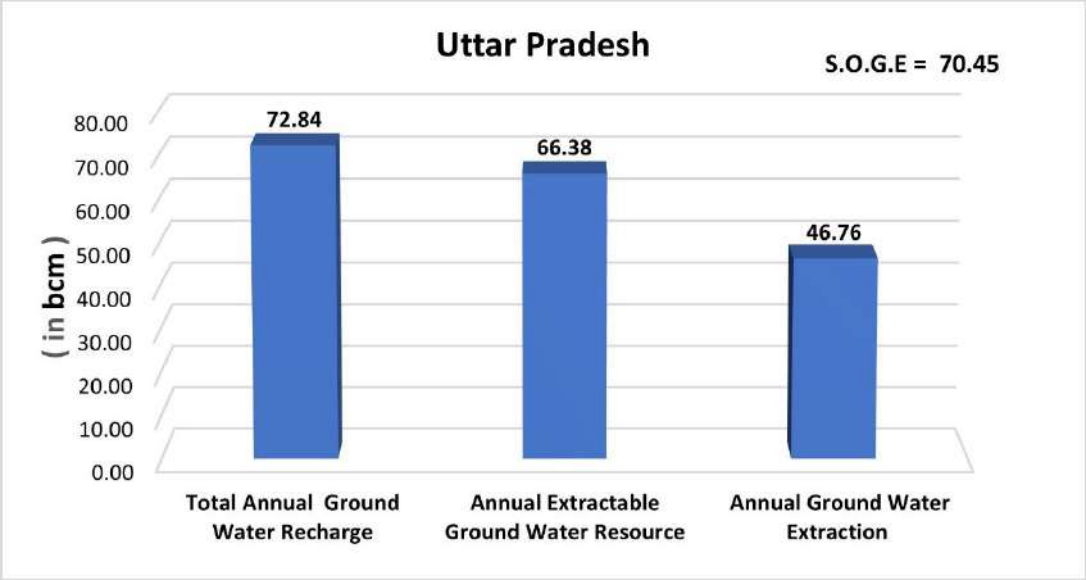
7.26 UTTAR PRADESH

The State of Uttar Pradesh is categorized with five distinct hydrogeological units – Bhabar, Terai, Central Ganga Plains, Marginal Alluvial Plain, Southern Hardrock area. Bhabar is mainly the recharge zone having deeper water levels. Ground water extraction in phreatic aquifer is through hand pumps, dug wells, dug cum bore wells and shallow tube wells. The yield from these wells has been generally found to be in the range of 40 to 60lps. Terai zone lies between Bhabar in the North and Central Ganga Plain in the South. It is characterized by fine grained sediments with occasional pebbles and boulders. The average yield of tube wells constructed in this zone varies from 30 to 60 lps with moderate drawdown. Central Ganga Plain constitutes the most promising ground water repository characterized by multi-layered aquifer systems. The yield of the open wells and hand pumps constructed in the phreatic aquifer vary from 5 to 10 lps. The tube wells in the phreatic aquifer yield between 20 to 28 lps at 6 to 8 m drawdown. Marginal alluvial plain consists of kankar mixed clay-silt beds intercalated with sand and gravel lenses. The aquifer in this area is capable of yielding 15 to 40 lps at moderate drawdown. Southern part mainly occupied by Hard rocks comprising of Granite/ Granitic Gneiss and Marginal Alluvium in Bundelkhand Region and Vindyan Sedimentary formations in Mirzapur and Sonbhadra Districts. The wells tapping these formations generally recorded yield between 2 to 8 lps. The Ground water resources of the State have been assessed block-wise.

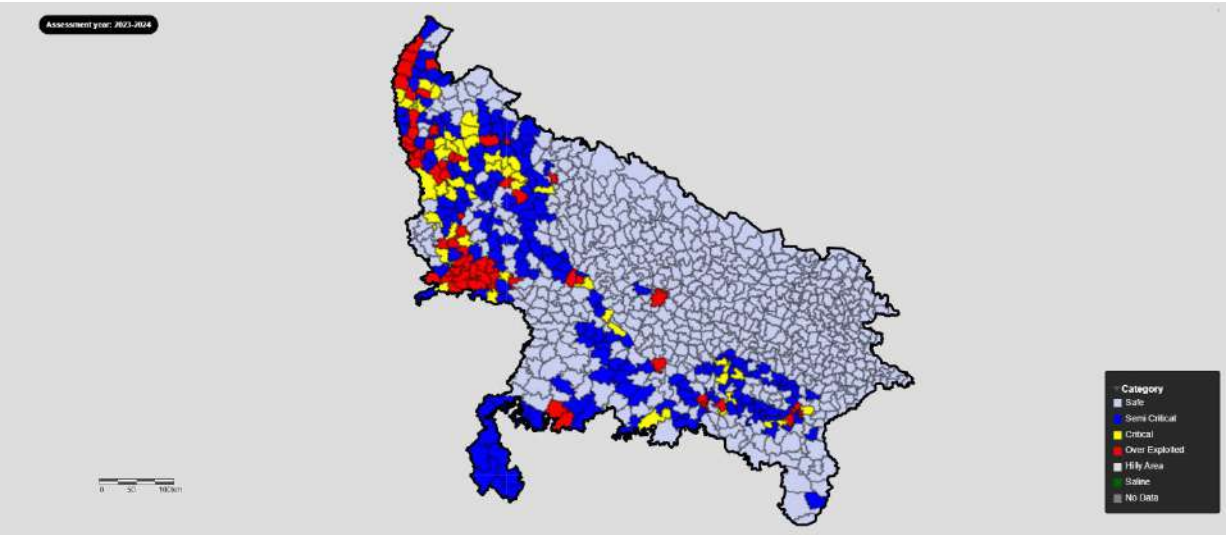
Total Annual Ground Water Recharge of the state has been assessed as 72.84 bcm and Annual Extractable Ground Water Resource as 66.38 bcm. The Annual Ground Water Extraction is 46.76 bcm and average Stage of Ground Water Extraction of the State is 70.45%.

Out of the 836 assessment units consisting of 826 blocks and 10 cities, 59 units (7.06 %) have been categorized as ‘Over- exploited’, 46 units (5.50 %) as ‘Critical’, 165 units (19.74 %) as ‘Semi-critical’ and 566 units (67.7 %) as ‘Safe’. Similarly, out of 229554.18 sq km recharge worthy area of the State, 14287.33 sq km (6.22 %) area are under ‘Over-Exploited’, 12464 sq km (5.43 %) under ‘Critical’, 48296.28 sq km (21.04 %) under ‘Semi-critical’, 154506.56 sq km (67.31 %) under ‘Safe’ categories of assessment units. Out of total 66375.17 mcm annual extractable ground water resources of the State, 3639.61 mcm (5.48 %) are under ‘Over-exploited’, 3520.44 mcm (5.3%) under ‘Critical’, 12109.78 mcm (18.24 %) under ‘Semi-critical’ and 47105.34 mcm (70.97 %) are under ‘Safe’ categories of assessment units.

As compared to 2023 assessment, ground water recharge and ground water extraction figure increased minutely. The stage of ground water extraction has also marginally decreased from 70.76 % to 70.45%.



Dynamic Ground water Recourses Scenario 2024– Uttar Pradesh



Categorization Map of GWRA 2024 – Uttar Pradesh

7.27 UTTARAKHAND

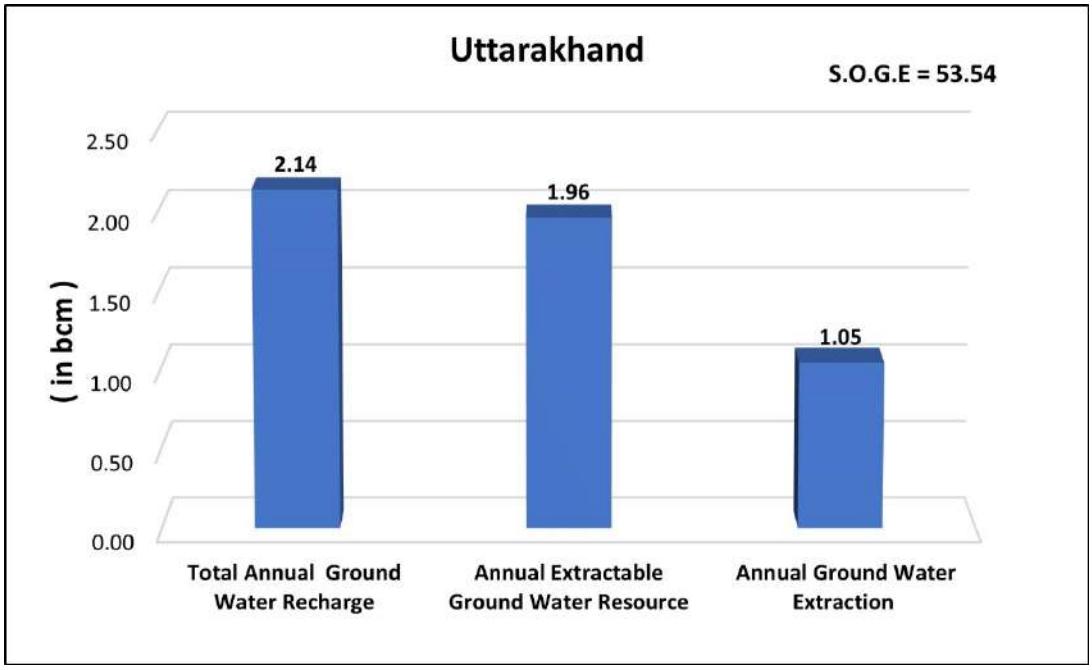
Uttarakhand State, a predominantly hilly state, covers a total geographical area of 53,483 km^2 and is situated between 28°43'20" – 31°28'00" N Latitude and 77°34'06" – 81°01'31" E Longitude. Most of the northern part of the state is covered by high Himalayan peaks and glaciers. The state shares international boundaries with China (Tibet) in the north and Nepal in the East. The assessment of dynamic ground water resources has been carried out in 20 assessment units (blocks) of the state.

Total Annual Ground Water Recharge in the State (2024) has been assessed as 2.14 billion cubic meters (bcm). The Total Annual Extractable Ground Water Resource of the State has been assessed as 1.96 bcm, after keeping a provision for natural discharge. The Annual Ground Water Extraction of the State (2024) is 1.05 bcm, the largest user being irrigation sector. The Stage of ground water extraction for the entire State, which is the percentage of ground water extraction with respect to Annual Extractable Ground Water Recharge, has been computed as 53.54 %.

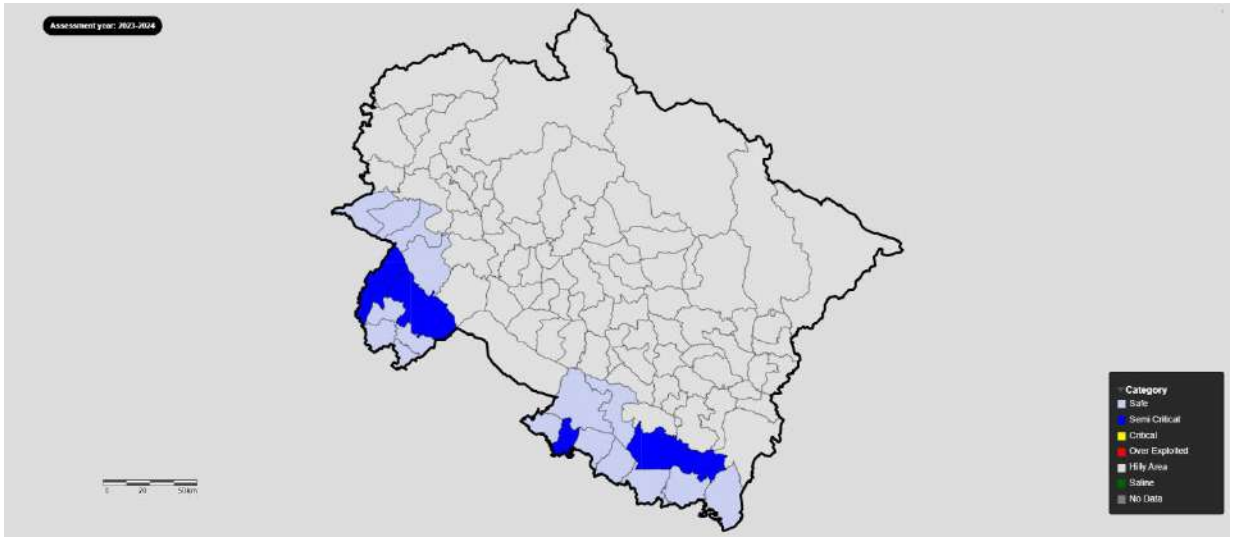
Out of the 20 assessed blocks of Uttarakhand State, 16 blocks have been categorized as Safe (80%), whereas remaining 4 have categorised as Semi Critical (20%). There are no issues related to groundwater quality in the assessment units and hence there is no poor quality or saline block in the State.

Out of 6491.88 sq km recharge worthy area of the State, 5339.7 sq km (82.25 %) fall under Safe and 1152.18 sq km (17.75 %) under Semi Critical category of assessment units. Out of total 1964.073 MCM annual extractable ground water resources of the State, 380.10 MCM (19.35 %) under 'Semi-critical' and 1583.97 MCM (80.65 %) are under 'Safe' categories of assessment units.

As compared to 2023 estimate, there is an increase in Annual Ground Water Recharge, Annual Extractable Ground Water Resources and Annual Ground Water Extraction in 2024. The stage of groundwater extraction has increased from 51.69% to 53.54%.



Dynamic Ground water Recourses Scenario 2024–Uttarakand



Categorization Map of GWRA 2024 –Uttarakand

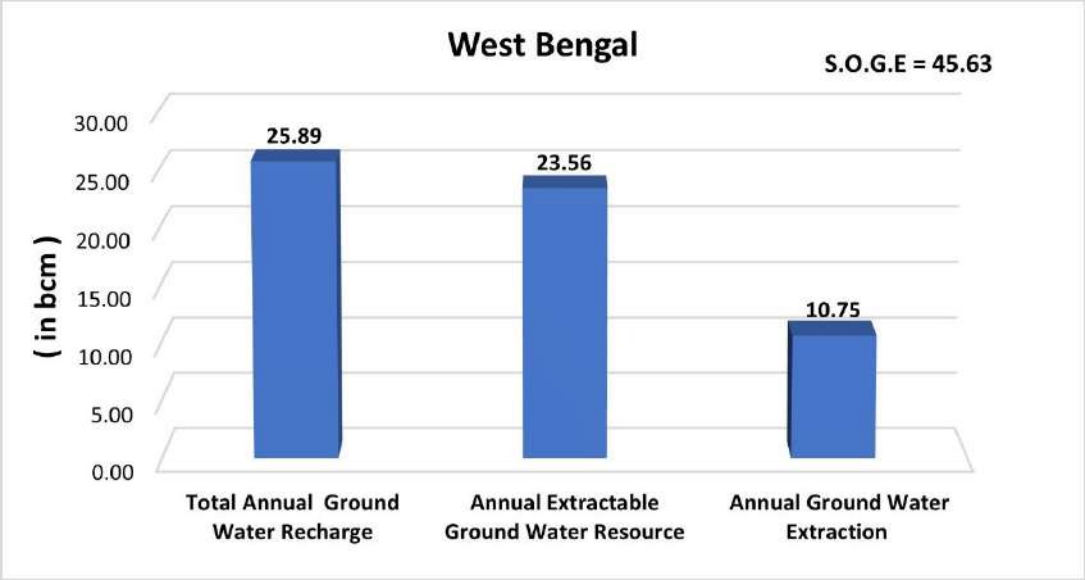
7.28 WEST BENGAL

Nearly two third area of the State is occupied by unconsolidated sediments; the western part of the state is partly occupied by the hard rocks. Phreatic aquifer is generally developed through dug well, dug cum bore well and shallow tube well. Yield potential of these wells varies from 1 to 5 lps.

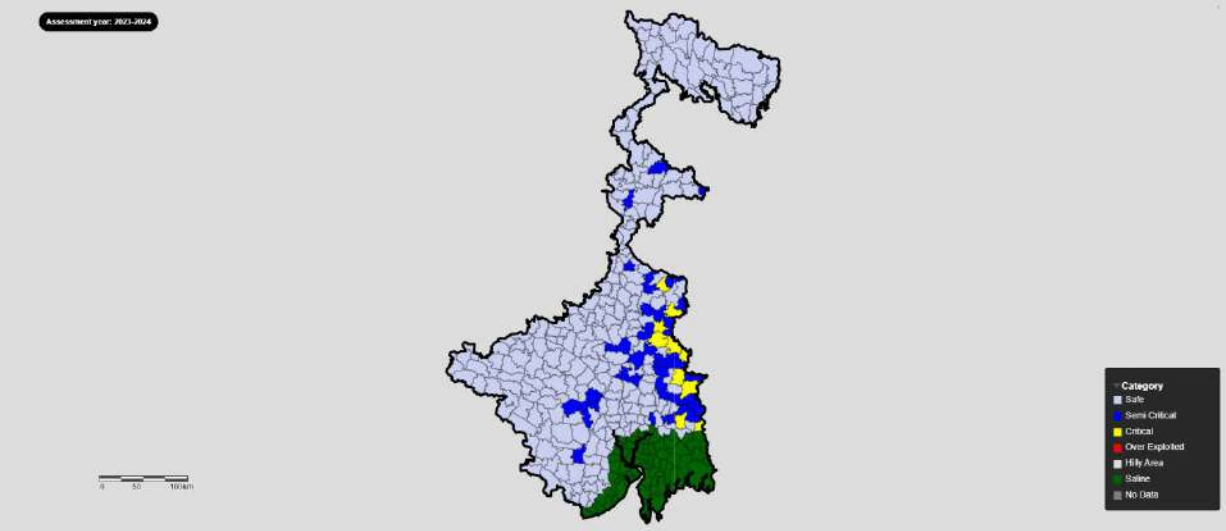
The ground water resource assessment (in 2024) for the State of West Bengal has been carried out as per GEC-2015 guidelines through 'IN-GRES', with blocks as primary assessment units. All 344 blocks of the State of West Bengal and one (01) urban area as Kolkata Municipal Corporation is assessed. Groundwater assessment is carried out for both Dynamic and Static part of the unconfined & confined aquifer. Total Annual Ground Water Recharge has been estimated at 25.89 bcm and Annual Extractable Ground Water Resource has been estimated at 23.56 bcm. Current Annual Ground Water Extraction for all uses has been estimated at 10.75 bcm, which translates into a Stage of Ground Water Extraction at 45.63 %. As per present assessment categorization scheme, out of 345 assessed units, 239 AUs are Safe, 36 AUs are Semi-Critical, 10 AUs are Critical and 60 AUs are of poor groundwater quality. There is no Over-Exploited Blocks in the State.

Similarly, out of 79765.77 sq km recharge worthy area of the State, 2316.07 sq km (2.9 %) under 'Critical', 7099.53 sq km (8.9 %) under 'Semi-critical', 60842.07 sq km (76.28 %) under 'Safe' category of assessment units. 9508.1 sq km (11.92%) area is under 'Saline' category of assessment units. Out of total 23562 mcm annual extractable ground water resources of the State, 1150.97 mcm (4.88 %) under 'Critical', 3007.8 mcm (12.77 %) under 'Semi-critical' and 19403.24 mcm (82.35 %) are under 'Safe' categories of assessment units.

The Annual Ground Water Recharge and Annual Extractable Ground Water Resources have decreased in 2024 in comparison to 2023 assessment and the Stage of Ground Water Extraction is also increased from 44.81% to 45.63%.



Dynamic Ground water Recourses Scenario 2024– West Bengal



Categorization Map of GWRA 2024 – West Bengal

7.29 ANDAMAN AND NICOBAR ISLANDS

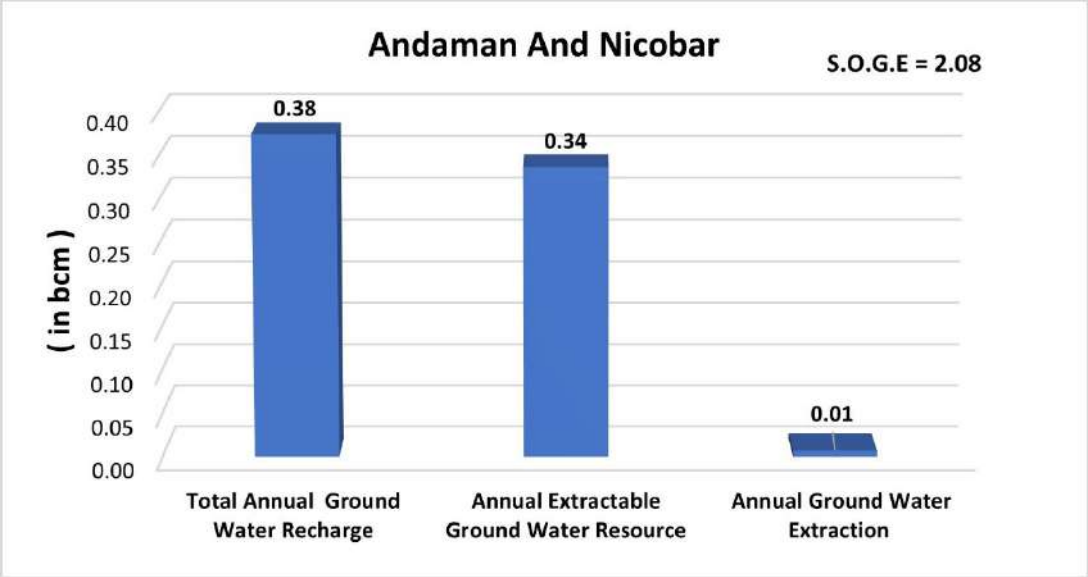
Andaman & Nicobar Islands comprise an arc-shaped chain of islands in the Bay of Bengal and are characterized by rugged topography, steep slope, low infiltration capacity and close proximity of hills to the sea. Marine sedimentary group of rocks comprising shale, sandstone, grit and conglomerate; extrusive and intrusive igneous rocks (volcanics and ultramafics) and limestone occupy the entire geographical area. Amongst these, the Sedimentary Group is most pervasive and occupy nearly 70% of the entire area of the islands while the igneous group covers nearly 15% while the rest of 15% goes to the coralline and limestone formations. All these rock formations have been subjected to many tectonic activities, evident from the occurrence of shallow and deep focus earthquakes in the islands.

Marine sedimentary rocks are developed only through dug wells having meager yield of 0.1 to 0.5 lps. The igneous Ophiolite suite of rocks in the area although restricted in occurrence, are observed to yield moderate to high both in shallow and deeper locales and they are developed by dug wells and bore wells with yield ranging from 1 to 10 lps. Area covered by Coralline Limestone contains appreciable quantity of groundwater with yield ranging from 5 to 25 lps.

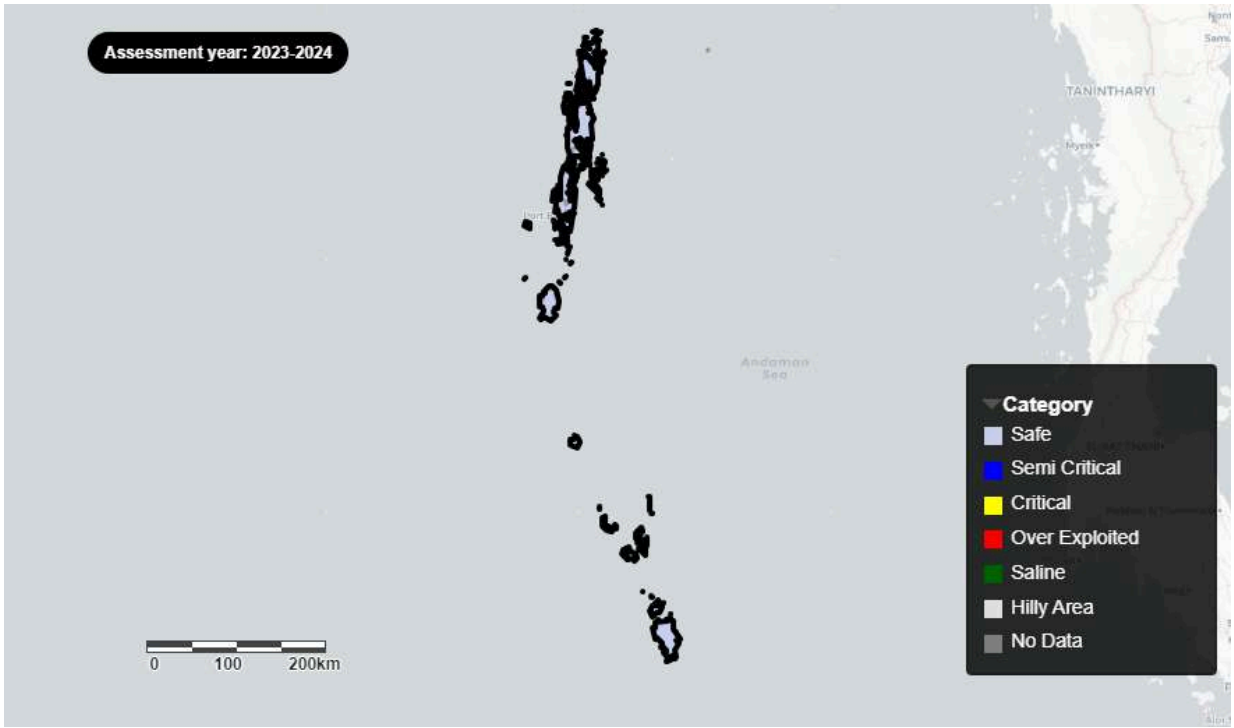
The Ground Water Resources (in 2024), following GEC 2015 guidelines, have been assessed island-wise and further clubbed together block-wise. Total Annual Ground Water Recharge of the A & N Islands is assessed as 0.38 bcm and Annual Extractable Ground Water Resources is assessed as 0.34 bcm. The Annual Ground Water Extraction is 0.01 bcm, which translates to a Stage of Ground Water Extraction of 2.08 %. All the 9 assessment units (Block) are ‘Safe’.

Similarly, out of 1276.39 sq km recharge worthy area of the UT, the entire recharge worthy area is under ‘Safe’ category of assessment units and the total 338.56 mcm annual extractable ground water resources of the UT, is under ‘Safe’ categories of assessment units.

There is a mild increase in Annual Ground Water Recharge by other sources and decline in Annual Ground Water Extraction in North and Middle Andaman. Stage of Ground Water Extraction in 2024 is increased in comparison to 2023.



Dynamic Ground water Recourses Scenario 2024– Andaman and Nicobar



Categorization Map of GWRA 2024 – Andaman and Nicobar

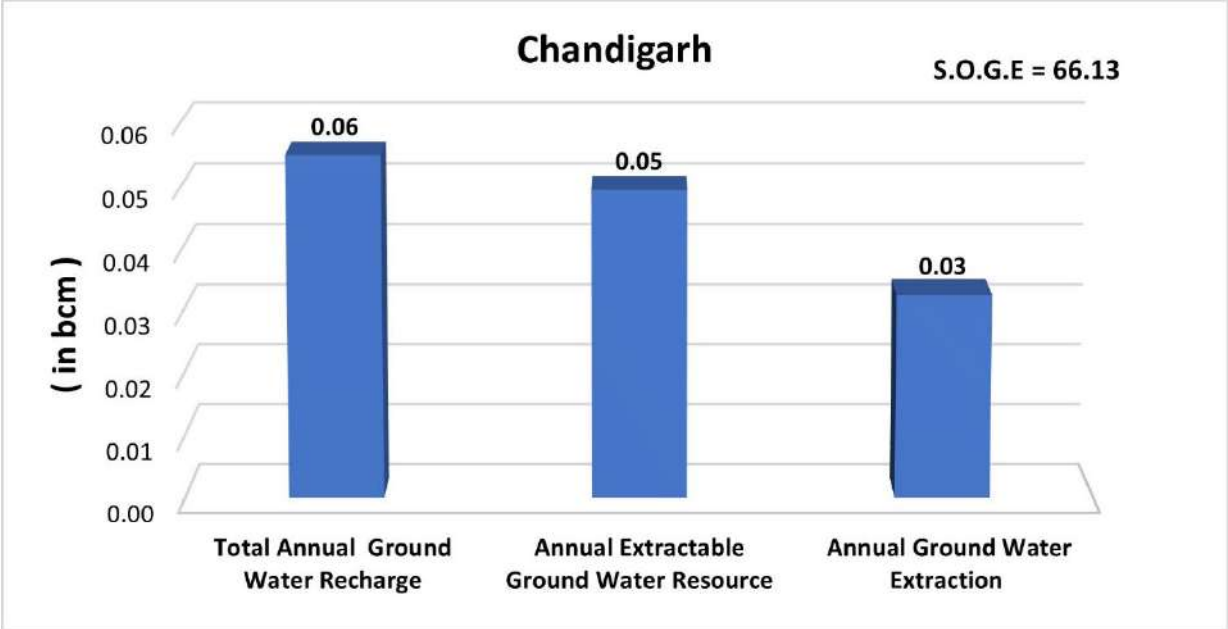
7.30 CHANDIGARH

Chandigarh is underlain by the Quaternary alluvial deposits and comprises layers of fine sand and clay. Coarser sediments occur along the Sukhna Choe and Patialiki Rao, whereas relatively finer sediments underlie the area between these two streams. Fair to good aquifer horizons occur in most part of Chandigarh comprising medium to coarse sand, to a depth of 180 m bgl below which they become finer. Ground water in the area occurs under confined as well as semi-confined conditions. In Manimajra, ground water occurs under unconfined conditions down to about 80 m. In other areas, the semi-confined conditions prevail below 20 to 30 m. The depth of the shallow aquifer system is less than 30 m bgl, whereas the depth of the deeper aquifer system ranges from 40 to 450 m bgl of explored depth. The transmissivity values for the deeper aquifer system ranges between 74 and 590 m^2/day. The transmissivity values of shallow aquifers up to 100 m depth ranges from 70 to 466 m^2/day. Ground water is found to be fresh and suitable for drinking as well as irrigation purposes.

UT of Chandigarh has very small area of 114 sq km and whole UT has been taken as an assessment unit. Total Annual Ground Water Recharge has been assessed as 0.06 bcm and Annual Extractable Ground Water Resources as 0.05 bcm. The UT of Chandigarh has been categorized as 'Safe' with Total Extraction of 0.03 bcm and stage of ground water extraction at 66.13 %.

Out of 114 sq km recharge worthy area of the UT, 100 % of the area is under 'Safe'. The entire 49.62 mcm annual extractable ground water resources of the UT, is under 'Safe' categories of assessment units.

In comparison to 2023 assessment, Total annual recharge has increased marginally from 0.054 bcm to 0.055 bcm owing to increased rainfall recharge. The current ground water extraction has marginally decreased from 0.036 bcm to 0.032 bcm.



Dynamic Ground water Recourses Scenario 2024- Chandigarh

7.31 DADRA AND NAGAR HAVELI AND DAMAN AND DIU

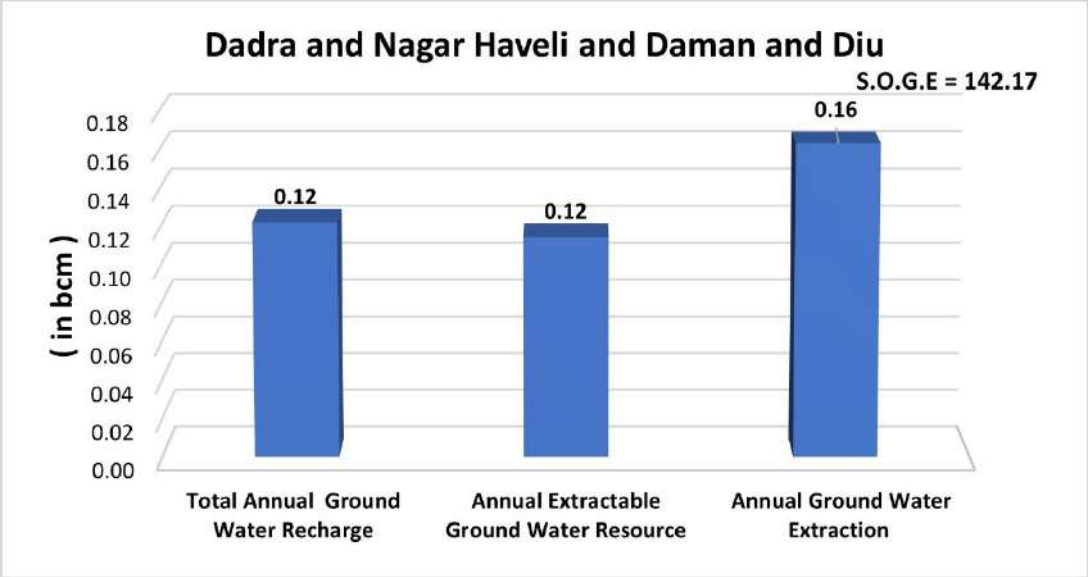
The entire area of UT of Dadra and Nagar Haveli is underlain by hard rock terrain (Deccan basalts). The thickness of vesicular units, ranges from 2 to 8 m. Ground water is developed by means of dug wells and dug cum bore wells. The sustainable yield of dug wells for 3 to 4 hours of pumping is 30 m^3/day. The transmissivity of shallow aquifer ranges from 5.5 to 305 m^2/day.

The entire island area of Diu is about 40 sq. km and is underlain by Alluvium and Milliolite soft rock formation. The Daman has about 72 sq km area out of which 30 % is covered by alluvium and the rest is underlain by Basalt rocks. In UT of Daman & Diu, dug well as well as dug cum bore wells are common for irrigation and domestic use. The yields of open dug wells varies from less than 1 to 5 m^3/day, where as that of Dug cum Bore wells ranges from less than 2 to 10 m^3/day.

The ground water resources have been assessed district-wise. The total Annual Ground Water Recharge has been assessed as 0.12bcm and Annual Extractable Ground water Resources as 0.12 bcm. The total current Annual Ground Water Extraction has been assessed as 0.16bcm and Stage of Ground Water Extraction as 142.17 %. Dadra and Nagar Haveli and Daman and Diu districts have been categorized as 'Over Exploited'.

Out of 526.9 sq km recharge worthy area of the UT, the entire area is under 'Over-Exploited'. Total 115.77 mcm annual extractable ground water resources of the UT, 100% is under 'Over-exploited' categories of assessment units.

There is a minor change in stage of ground water extraction as compared to 2023.



Dynamic Ground water Recourses Scenario 2024– Dadra and Nagar Haveli and Daman and Diu

7.32 DELHI

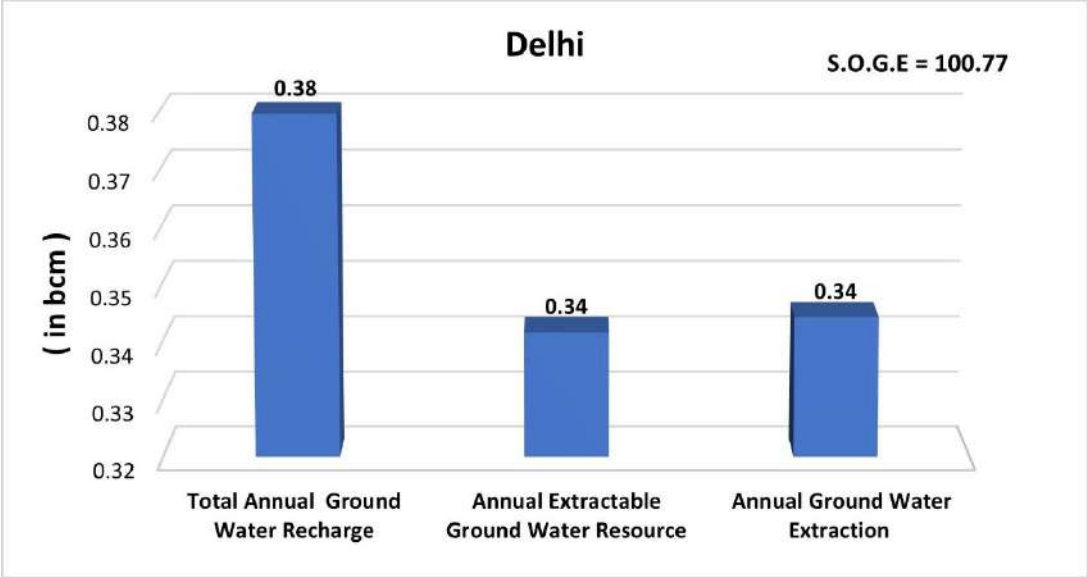
The State is covered by diverse rock types of different geological ages from Pre-Cambrian to Recent. As much as 89% of the State is occupied by alluvium and ground water is being tapped mostly through tube wells. Yields of tube wells vary from 4 to 10 lps in older alluvial deposits and from 25 to 55 lps in newer alluvium. About 11 % of the State is occupied by quartzitic hard rock, where bore wells have yield of 0.6 to 5 lps.

The ground water resources assessment has been carried out tehsil-wise. The Total Annual Ground Water Recharge of the State has been assessed as 0.38 bcm and Annual Extractable Ground Water Resources is 0.34 bcm. The Total Current Annual Ground Water Extraction is 0.34 bcm and Stage of Ground Water Extraction is 100.77%.

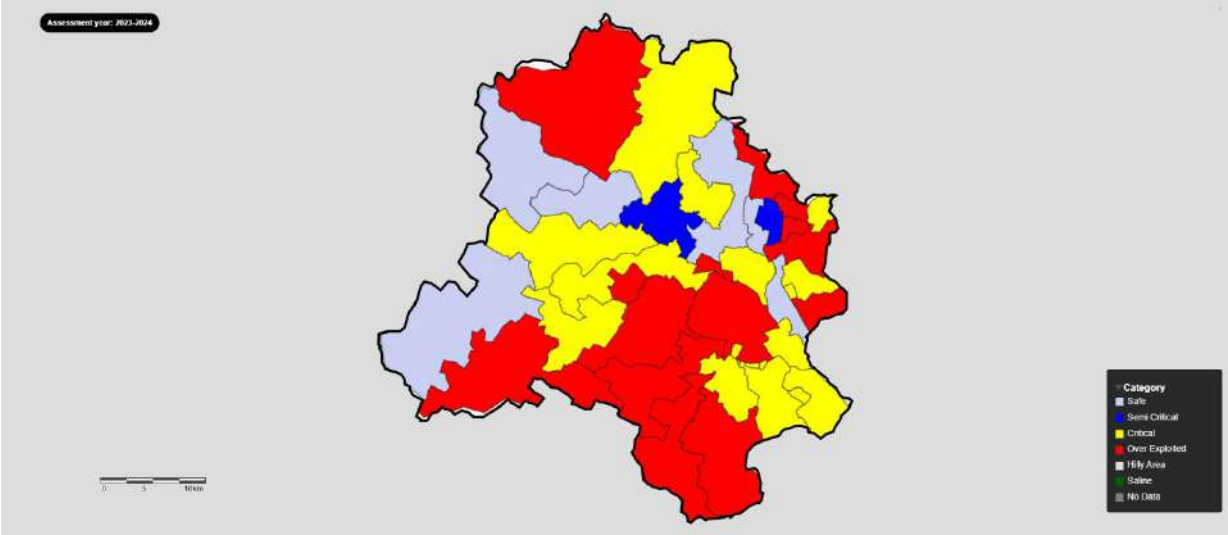
Out of 34 assessment units (tehsils), 14 units (41.18 %) have been categorized as 'Over-exploited', 13 units (38.24 %) as 'Critical', 2 units (5.88 %) as 'Semi-critical', and 5 units (14.71 %) as 'Safe' categories of assessment units.

Similarly, out of 1487.61 sq km recharge worthy area of the State, 634.02 sq km (42.62 %) area are under 'Over-Exploited', 481.41 sq km (32.36 %) under 'Critical', 41.949 sq km (2.82 %) under 'Semi-critical', 330.23 sq km (22.2 %) under 'Safe' categories. Out of total 341.9 mcm annual extractable ground water resources of the State, 129.12 mcm (37.77 %) are under 'Over-exploited', 128.28 mcm (37.52 %) under 'Critical', 12.16 mcm (3.56 %) under 'Semi-critical' and 72.34 mcm (21.158 %) are under 'Safe' categories.

As compared to 2023 assessment, the Total Annual Ground Water Recharge decreased from 381.52 mcm to 379.89 mcm and Annual Extractable Ground Water Resources decreased from 344.49 mcm to 341.90 mcm. There is an increase in the Annual Ground Water Extraction for the state from 341.50 mcm to 344.54 mcm and the Stage of Ground Water Extraction has increased marginally from 99.13 % to 100.77 %.



Dynamic Ground water Recourses Scenario 2024– Delhi



Categorization Map of GWRA 2024 – Delhi

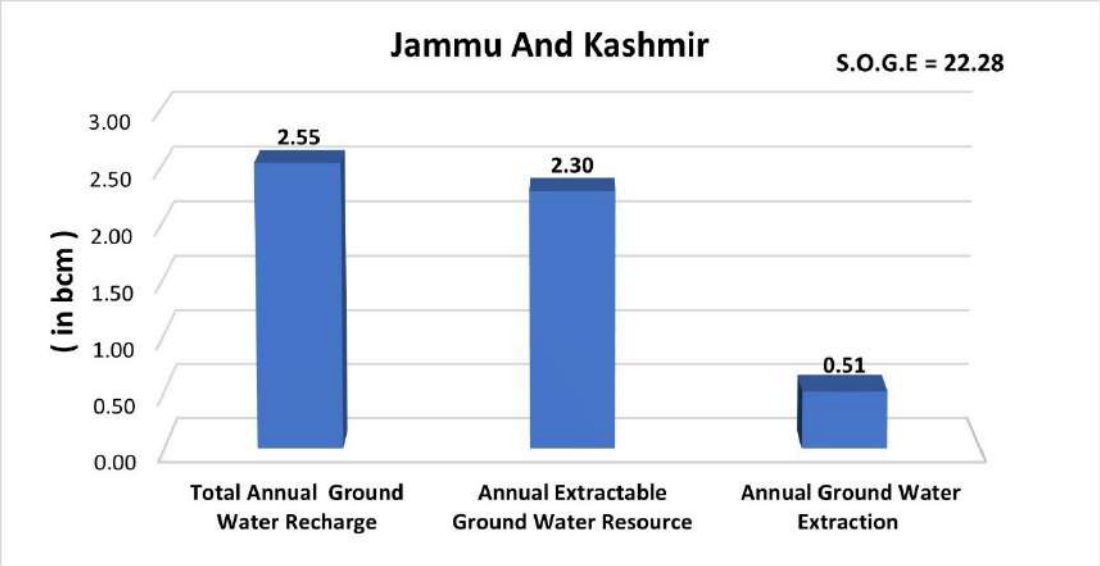
7.33 JAMMU & KASHMIR

Jammu & Kashmir Union Territory consists of two regions, Jammu and Kashmir, each with unique groundwater regimes. In Jammu, groundwater is found in the outer plains and piedmont deposits from Munawar Tawi to the River Ravi, occurring under unconfined conditions. The Kashmir Valley, spanning 5600 sq km, features Karewas with alternating layers of sand, silt, clay, and glacial beds, where groundwater occurs under both confined and unconfined conditions. The Outer Plains of Jammu and Kandi areas near the Siwalik Hills are characterized by semi-consolidated coarse sediments. The Kandi has deep water table conditions, while the adjacent Sirowal area often experiences waterlogging.

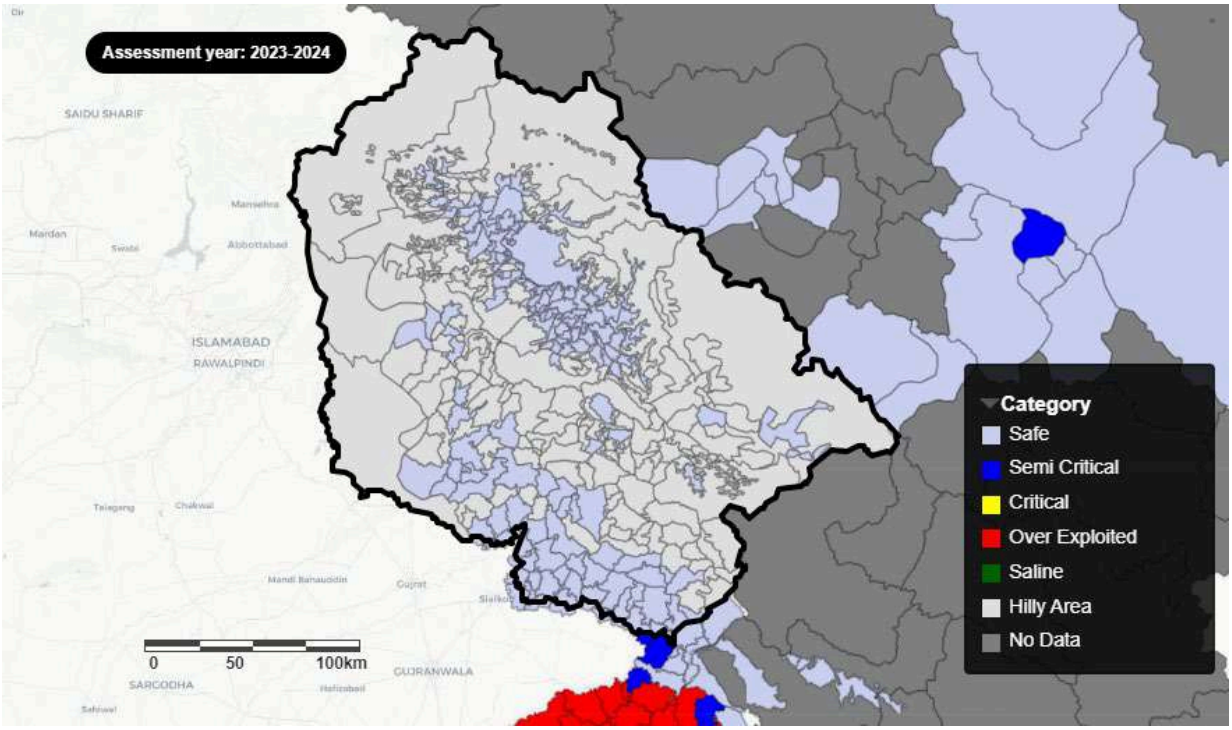
Union Territory is divided into 20 districts which are further sub-divided into 285 development blocks. Most of these development blocks are represented by high mountains and steep slopes. In the present assessment, only 149 assessment units have found ground water recharge worthy and ground water resources have been assessed for these 149 assessment units including the Srinagar urban area (with a population of more than 10 Lakhs). Srinagar Urban Area comprises ground water worthy area of Srinagar district as well as parts of Ganderbal, Baramulla, Budgam, Pulwama and Bandipora districts.

The total Annual Groundwater Recharge of the Union Teriterry has been estimated as 2.55 bcm and Annual Extractable Ground Water Resources is 2.30 bcm. The Total Current Annual Ground Water Extraction is 0.51 bcm and the Stage of Ground Water Extraction is 22.28 %. All 149 assessment units have been categorized as ‘Safe’ including Srinagar Urban Agglomerate.

Similarly, the entire 8571.96 sq km of recharge-worthy area and 2303.3 MCM of annual extractable groundwater resources in the Union Territory fall under the 'Safe' category.



Dynamic Ground water Recourses Scenario 2024– Jammu and Kashmir



Categorization Map of GWRA 2024– Jammu and Kashmir

7.34 LADAKH

Ladakh Union Territory comprises of two districts viz-Leh and Kargil. The Topography of the region is extremely rugged, mountainous and highly inaccessible. The altitude of the area varies from 3000-8000 m amsl. In Leh district, the Indus and Shyok are the main valleys and the Leh plain, more plain, Hanle Plain, Depsang plain and soda plain are some important plains. Leh plain is underlain by morainic deposits consisting of boulders, cobbles, pebbles embedded in an arenaceous matrix and the lake deposits comprising predominantly of clays, sandy- Clays and silt. The sediments are overlain by varved clays and silts of lacustrine origin again succeeded by morainic boulders and cobbles in disintegrated loose sandy matrix and alluvial deposits. Ground water in the valleys occurs in porous formations. This includes moraines and fluvio-glacial deposits of Ladakh.

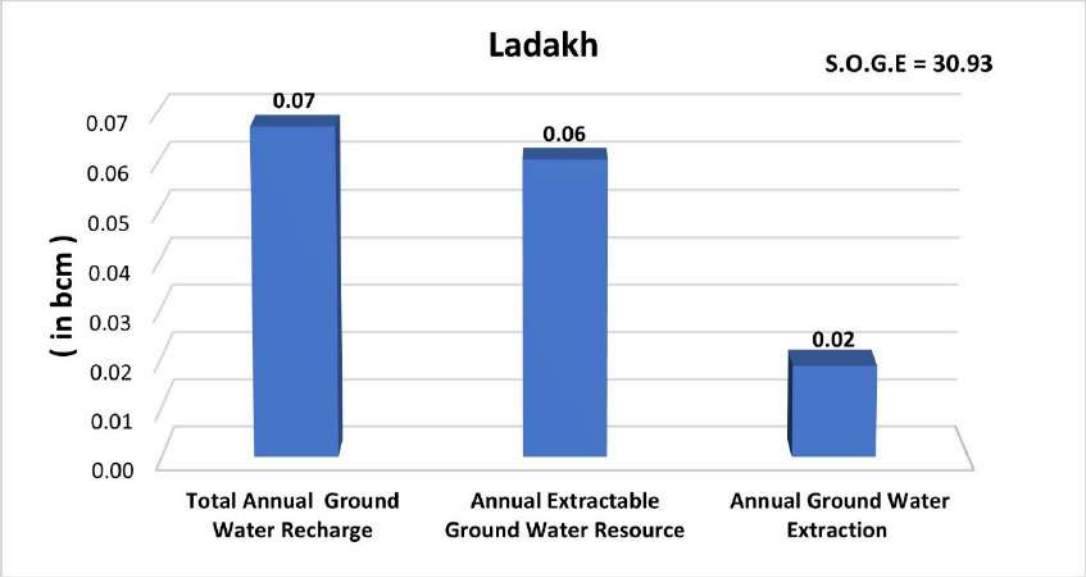
Kargil district comprises of 15 blocks out of which 9 blocks were found ground water recharge worthy areas. Bimbat, Drass, GM Pora, Kargil, Shankoo, Pashkum, Karsha, Zanskar and Shargole blocks are taken as Assessment Units for GWRE 2024.

Similarly, Leh district comprises of 16 blocks out of which 9 blocks were found ground water recharge worthy areas. Diskit, Panamik, Durbuk, Saspol, Nimoo, Leh, Chuchot, Kharu and Thickey are taken as Assessment Units for GWRE 2024. Ground water occurs mainly in the porous formations of morainic deposits comprising of Talus and Scree formations.

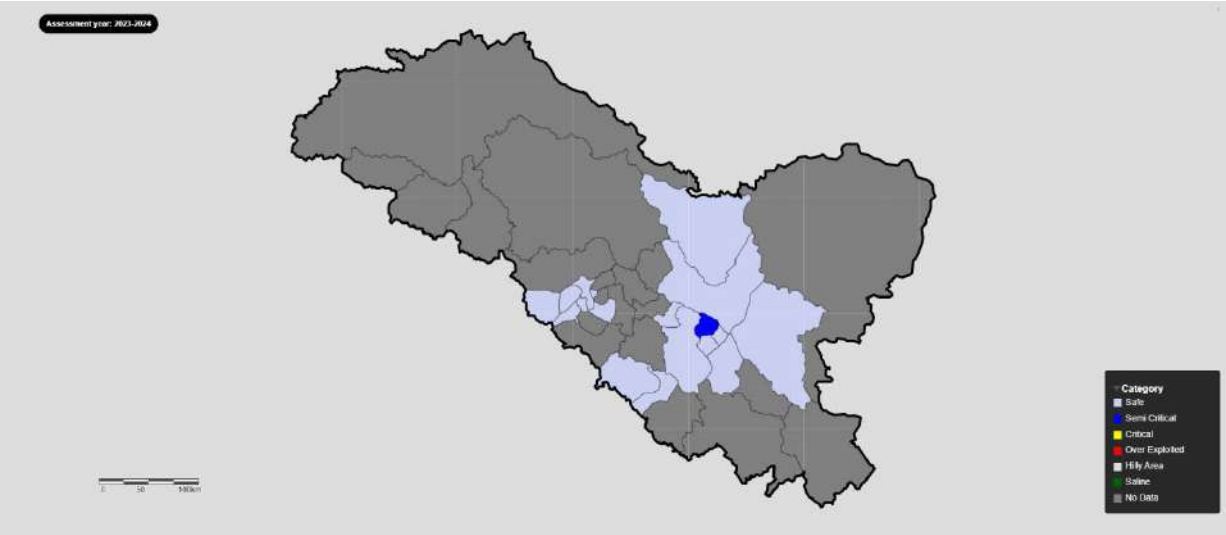
The Ground Water Resources of the Ladakh UT have been assessed on block level in 2 districts. The total recharge of ground water involves several components like rainfall/ snowfall being the major one. The other components are seepage from canal, kuhls and return flow from surface water and ground water irrigation. Total Annual Ground Water Recharge of the UT has been estimated as 0.07 bcm and Annual Extractable Ground Water Resources is 0.06 bcm. The Total Current Annual Ground Water Extraction is 0.02 bcm. The Stage of Ground Water extraction in Ladakh is 30.93 %. Out of the total 18 Assessment Units, 1 AUs (5.56%) of Leh are categorized as ‘Semi Critical’ and remaining 17 AUs (94.44%) are categorized as ‘Safe’.

Out of 963 sq km recharge worthy area of the UT, 90 sq km (9.35 %) under ‘Semi-critical’, 873 sq km (90.65 %) under ‘Safe’ category of assessment units. Out of total 60.68 mcm annual extractable ground water resources of the State, 54.85 mcm (90.39 %) under ‘Safe’ and 5.83 mcm (9.61 %) are under ‘Semi-critical’ categories of assessment units.

As compared to the 2023 assessment, the Total Annual Ground Water Recharge and Annual Extractable Ground Water Resources have decreased marginally from 0.09 bcm to 0.07 bcm and 0.08 bcm to 0.06 bcm respectively. The Annual Ground Water Extraction has decreased from 0.03 bcm to 0.02 bcm. The Stage of Ground Water Extraction has decreased from 37.05 %. to 30.93%.



Dynamic Ground water Recourses Scenario 2024- Ladakh



Categorization Map of GWRA 2024 – Ladakh

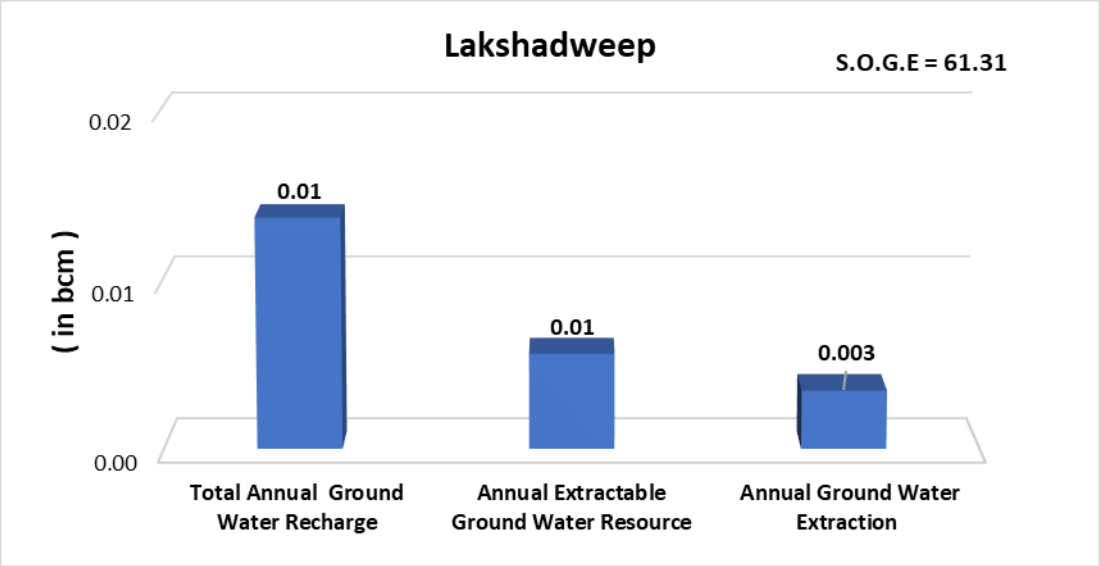
7.35 LAKSHADWEEP

Lakshadweep islands are composed of calcareous sand and materials derived from coral atolls. Alternate layers of loose sand, moderately cemented calc-arenites and well cemented, hard and compact limestone underlie the islands. In these islands, fresh ground water occurs under phreatic conditions as lens floating over the saline water and is in hydraulic continuity with sea water. Water levels in wells are strongly influenced by tides. Dug wells are the common ground water abstraction structures in the islands. The major draft component of these islands is for the domestic consumption. Irrigation draft is negligible in the islands as almost all the crops are rainfed.

Lakshadweep is a unidistrict state wherein the dynamic ground water resources have been assessed for individual islands and the output is generated block wise. The total Annual Ground Water Recharge in the UT has been estimated as 0.014 bcm and Annual Extractable Ground Water Resources works out as 0.005 bcm. The total current Annual Ground Water Extraction has been assessed as 0.003 bcm and the Stage of Ground Water Extraction as 61.32%. Out of the 5 assessment units, 4 blocks (80%) are categorized as ‘Safe’ and 1 block (20%) Kavaratti, as ‘Semi Critical’.

Similarly, out of 26.21 sq km recharge worthy area, 3.63 sq km (13.85 %) under ‘Semi-critical’, 22.58 sq km (86.15 %) under ‘Safe’ category of assessment units. Out of total 5.7 mcm annual extractable ground water resources of the State, 1.39 mcm (24.4 %) under ‘Semi-critical’ and 4.31 mcm (75.6 %) are under ‘Safe’ categories of assessment units.

As compared to the 2023 assessment, there are no significant changes in the Total Annual Ground Water Recharge, Annual Extractable Ground Water Resources, annual ground water extraction and stage of ground water extraction of the UT in 2024.



Dynamic Ground water Recourses Scenario 2024- Lakshadweep

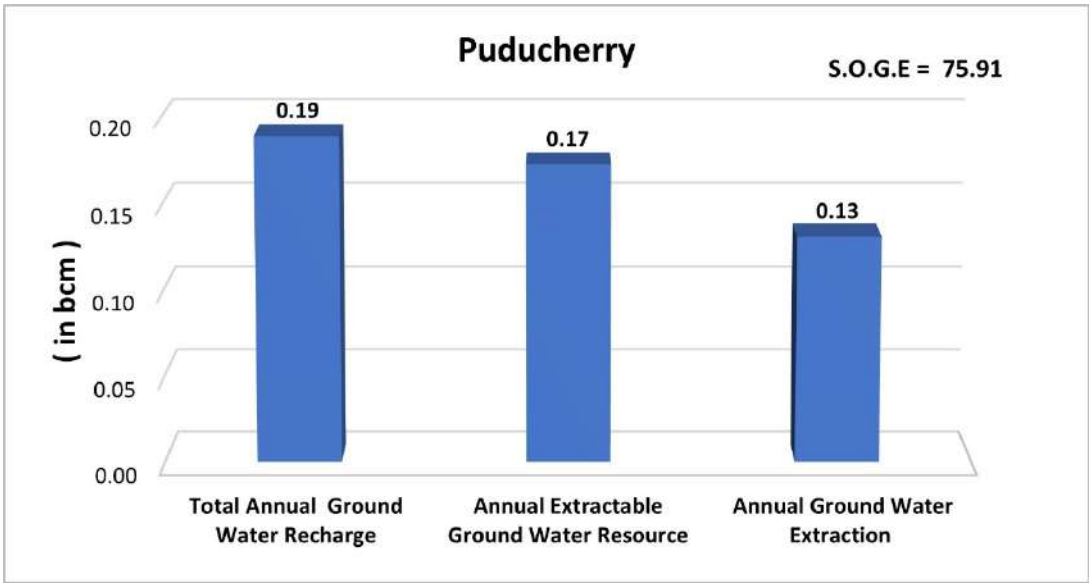
7.36 PUDUCHERRY

The Union Territory of Puducherry is underlain by the semi-consolidated and unconsolidated sedimentary formations, which mainly sustain dug wells, shallow and deep tube wells. The yield of the wells generally varies between 3 to 15 lps. High yielding wells in the range of 10 to 40 lps exists in the Tertiary sandstones.

The Dynamic ground water resources for Union Territory of Puducherry have been assessed Taluk wise i.e Ozhukarai, Villianur, Puducherry, Bahour, Mahe and Yanam taluks comes under Puducherry District and Thirunallar and Karaikal taluks comes under Karaikal District. The Annual Ground Water Recharge of the UT of Puducherry has been assessed as 0.19 bcm, Annual Extractable Ground Water Resources is 0.17 bcm and the Annual Ground Water Extraction is 0.13 bcm. The overall Stage of Ground Water Extraction of Union Territory of Puducherry is 75.91 %. Out of 8 taluks assessed, 3 taluks (37.5%) (Mahe, Karaikal &Thirunallar) fall under 'Safe' category, 3 taluks (37.50%) (Ozhukarai, Villianur & Bahour) have been categorized as 'Semi-Critical', 1 taluk (12.50%) (Puducherry) as 'Over-exploited' and 1 taluk (12.50%) (Yanam) as 'Saline'.

Similarly, out of 483 sq km recharge worthy area of the UT, 41 sq km (8.42 %) area are under 'Over-Exploited', 252 sq km (52.25 %) under 'Semi-critical', 170 sq km (35.20 %) under 'Safe' category of assessment units. 20 sq km (4.14%) area is under 'Saline' category of assessment units. Out of total 173.48 mcm annual extractable ground water resources of the State, 24.07 mcm (13.88 %) are under 'Over-exploited', 108.82 mcm (62.73 %) under 'Semi-critical' and 40.58 mcm (23.39 %) are under 'Safe' categories of assessment units.

As compared to 2023 assessment, there is no significant change in annual ground water recharge, extractable ground water resources & ground water extraction. The Stage of Ground Water Extraction of the UT has increased from 70.27 to 75.91%.



Dynamic Ground water Recourses Scenario 2024– Puducherry

CHAPTER 8

CONCLUSIONS

In the present assessment, the total annual groundwater recharge in the country has been assessed as 447.12 bcm. Keeping an allocation for natural discharge, the annual extractable ground water resource has been assessed as 406.38 bcm. The annual groundwater extraction (as in 2024) is 245.69 bcm. The average stage of groundwater extraction for the country is 60.46 %. Out of the total 6746 assessment units (Blocks/ Mandals/ Talukas) in the country, 750 units in various States/ UTs (11.12%) have been categorized as 'Over-exploited' indicating ground water extraction exceeding the annual replenished ground water recharge. In, 204 (3.02 %) assessment units the stage of groundwater extraction is between 90-100% and have been categorized as 'Critical'. There are 716 (10.61 %) "Semi-critical'' units, where the stage of ground water extraction is between 70 % and 90 % and 4949 (73.36 %) 'Safe' units, where the stage of Ground water extraction is less than 70 %. Apart from these, there are 127(1.88%) assessment units, which have been categorized as 'Saline' as major part of the ground water in phreatic aquifers in these units is brackish or saline. The percentage of Over-exploited and Critical administrative units more than 25% of the total units are in Delhi, Haryana, Punjab, Rajasthan, Tamil Nadu, Dadra & Nagar Haveli, Daman & Diu. Similarly, out of 2480.22 thousand sq km recharge worthy area of the country, 419.94 thousand sq km (16.93%) are under 'Over-Exploited', 87.76 thousand sq km (3.54 %) are under 'Critical', 284.44 thousand sq km (11.47%) are under 'Semi-Critical', 1649.79 thousand sq km (66.52 %) are under 'Safe' and 38.31 thousand sq km (1.55%) are under 'Saline' category assessment units. Out of 406.38 bcm of Total Annual Extractable Resources of the country, 45.99 bcm (11.38%) are under 'Over-Exploited', 13.17 bcm (3.24%) are under 'Critical', 46.05 bcm (11.33%) are under 'Semi-Critical', 301.15 bcm (74.11%) are under 'Safe' category assessment units.

Over-exploitation of ground water resources could be due to various region-specific reasons. Assessment units located in the north-western part of the country (particularly in the states of Punjab, Haryana, Delhi and Uttar Pradesh) have plenty of replenishable ground water resources but because of the over extraction beyond the annual ground water recharge, many of these units have become Over-exploited. Over-exploited units are also common in the western part of the country, particularly in Rajasthan and Gujarat where the prevailing arid climate results in low recharge of ground water and hence stress on these sources. In peninsular India, over-exploited units are wide spread in the states of Karnataka, Tamil Nadu and parts of Andhra Pradesh and Telangana which could be attributed mainly to the low storage and transmission capacities of aquifers of the hard rock terrains, which results in reduced availability of the resource.

In comparison to Dynamic Ground Water Resource Assessment 2023, the total annual ground water recharge has decreased marginally from 449.08 bcm to 447.12 bcm, where major decreases are noticed in the States of Jammu & Kashmir, Telangana and Arunachal Pradesh. The changes are attributed mainly to changes in recharge from 'Other Sources' specially reduction in return flow from irrigation. Accordingly, the annual extractable ground water resources have also decreased marginally from 407.21 to 406.38 bcm. The ground water extraction has marginally increased from 241.34 bcm to 245.69 bcm. The overall stage of groundwater extraction has marginally increased from 59.21 % to 60.46 %.

It is also pertinent to add that as it is advisable to restrict the ground water extraction as far as possible to annual replenishable resources, the categorization also reflects the relation between the annual replenishment and ground water extraction.

GEC-2015 methodology has been developed for prevalent Indian conditions, on the basis of terrain characteristics and data availability. "INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES) is a Software/Web-based Application developed by CGWB in collaboration with IIT-Hyderabad. It provides common and standardized platform for Ground Water Resource Estimation for the entire country and its pan-India operationalization (Central and State Governments). The system takes 'Data Input' through Excel as well as Forms, compute various ground water components (recharge, extraction etc.) and classify assessment units into appropriate categories (safe, semi-critical, critical and over-exploited). The Software uses GEC 2015 Methodology for estimation and calculation of Groundwater resources. It allows for unique and homogeneous representation of groundwater fluxes as well as categories for all the assessment units (AU) of the country.

An analysis of assessment results leads us to the following inferences as the way forward in the assessment of Ground water resources.

8.1 WATER BALANCE STUDIES

Ground water is one of the several components of the Hydrologic Cycle, other important components being rainfall, surface water, soil moisture and evapotranspiration. Holistic water resources management interventions require proper understanding of the interactions between the different components of the hydrosphere. Studies for determining the Base flow and lateral flow components in the Water Balance equation need to be taken up to bring more accuracy to the Ground water Resources Assessment. Initially, the number of such studies can be taken up in areas representing different hydrogeological set up of India (Southern hard rock terrain, Deccan Basaltic terrain, Indo- Gangetic and Brahmaputra alluvial plains, Coastal alluvium, Desert terrain and Himalayan terrain etc.)

8.2 AQUIFER CHARACTERIZATION AND PARAMETER ESTIMATION

One of the key elements that determine the accuracy of ground water resources assessment is the realistic estimation of the recharge and discharge parameters. It is recommended that more experimental studies be taken up for refining the norms of RIF, return flow from irrigation based on soil types and agro-climatic zone, recharge from water conservation and water bodies and more field studies for evaluation of specific yield values as well as its variation with depth.

8.3 CASE STUDIES LINKING ASSESSMENT WITH MANAGEMENT

It is recommended to take up case studies in various assessment units wherein quantitative evaluation of the ground water management interventions and consequent changes in the assessment results could be analysed. Such studies would help bring out the efficacy of various management interventions on the ground water regime.

8.4 TEMPORAL AVAILABILITY OF GROUND WATER RESOURCES

Even though the GEC 2015 methodology advocates season-wise resource assessment, the estimation of recharge during monsoon and non-monsoon seasons may not be sufficient. Temporal variations in groundwater availability, particularly in hard rock terrain are not reflected in present practices. Hence,

the assessment of temporal availability of ground water resources on the basis of available water columns can be attempted by considering the water levels measured frequently using Digital Water Level Recorders (DWLRs).

8.5 CREATION OF DATABASE FOR GROUND WATER RESOURCES ASSESSMENT AND ITS REGULAR UPDATING

GEC 2015 has devised the data structure of all the data elements (like water level, rainfall etc) and norms (like Specific Yield, Rainfall Infiltration Factor etc.) with its name, type of data and its precision. The templates (excel sheets) for data collection/compilation for assessment through IN-GRES using GEC 2015 has also been devised. However, major challenges are lack of dedicated manpower as well as presence of State GW/Nodal Departments (in majority of States) at District level for understanding/analysis of data/information to be collected/compiled from different State Departments (like Agriculture, Irrigation, Water Supply, Industries, Water Conservation etc.). Of particular importance in this regard are data/information related to recharge from water bodies, water conservation/harvesting structures, return flow from applied irrigation and details of ground water extraction structures in use for irrigation, domestic and industrial purpose. These need to be collected/compiled and regularly updated at district/block level so that more realistic assessment of ground water resources could be accomplished.

8.6 AQUIFER-WISE ASSESSMENT WITHIN THE PRESENT ADMINISTRATIVE UNITS (ASSESSMENT UNITS) IN AREAS OTHER THAN HARD ROCK TERRAIN

Areas occupied by unconsolidated sediments (alluvial deposits, aeolian deposits, coastal deposits etc.) usually have flat topography and assessment of ground water resources has been carried out taking administrative units (block/mandal/taluk etc.) as assessment units to facilitate the local administration in planning the ground water management programmes (both supply and demand side). However, if more than one hydrogeological/aquifer units (with distinctive characteristics, sustainability and ground water extraction patterns) exist within these administrative units, and then the assessment units could be further divided into smaller units based on hydrogeological/aquifer characteristics. This will lead to more accurate assessment (aquifer wise) of resources and micro-level/area-specific interventions/management measures could be implemented.

8.7 GROUND WATER ASSESSMENT OF DEEPER AQUIFER SYSTEMS IN INDO-GANGETIC, BRAHMAPUTRA AND COASTAL ALLUVIAL TERRAIN

The dynamic ground water resources mainly comprise ground water resources available within the zone of water table fluctuation which are being regularly replenished every year through rainfall and other sources of recharge. This assessment has been carried out and categorization done based on utilization with respect to annual availability of dynamic ground water resources. However, in Indo- Gangetic, Brahmaputra

and Coastal Alluvial areas multiple aquifer systems exist (on a regional scale) with sustainable and high yield characteristics. For assessment of deeper aquifers, more studies on individual aquifer potential/sustainable yield along with facilities for monitoring of piezometric heads (by establishing piezometers tapping different aquifer zones) have to be carried out. The resources of deeper aquifer systems could be considered for extraction during exigencies as well as for drinking water purpose for nearby regions.

8.8 AQUIFER-STREAM INTERACTIONS

Additional studies on aquifer-stream interactions are required to understand the contribution of ground water to streams and the requirement of environmental flows for sustainability of water resources and surrounding ecosystem.

8.9 GROUND WATER MODELLING AND PREDICTIVE SIMULATION

Besides the assessment of the dynamic ground water resources using norms prescribed in GEC 2015 methodology through automation, the concept of Ground water modelling must be included where predictive simulation can also be done. This would give an idea of the future availability of Ground water resources with respect to the changing climate and extraction patterns.