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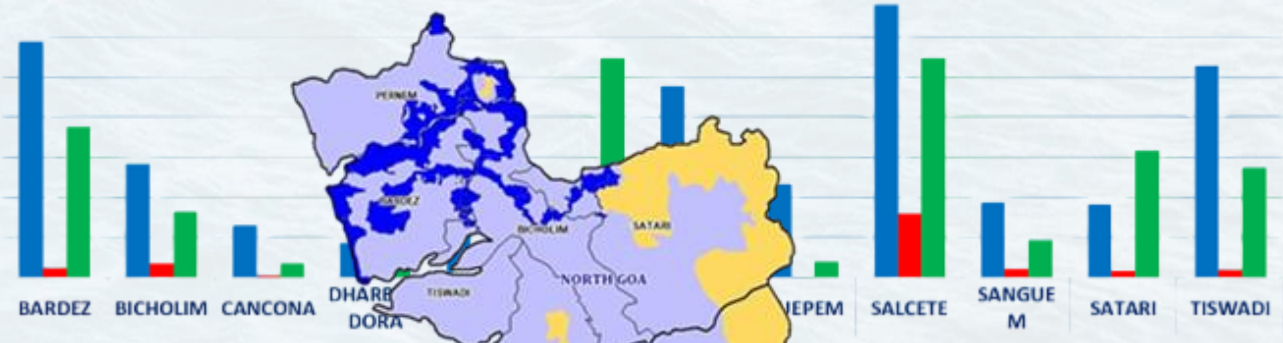
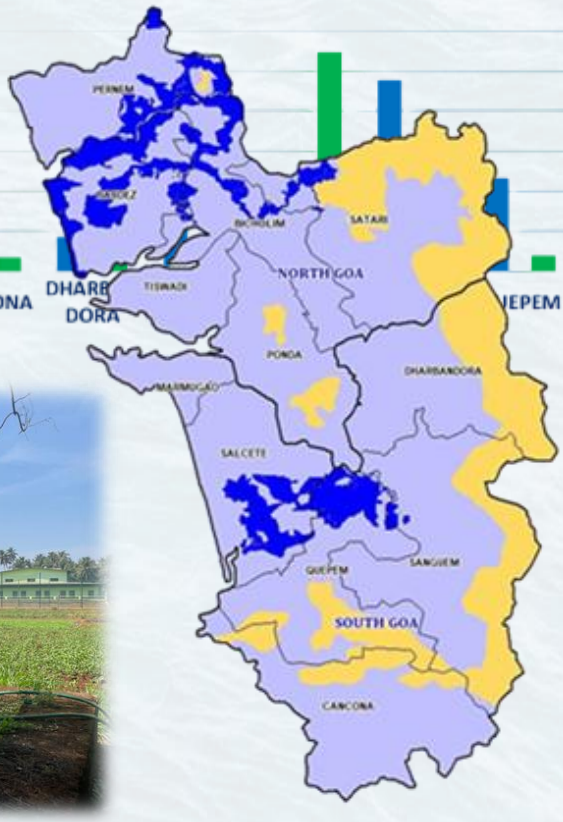
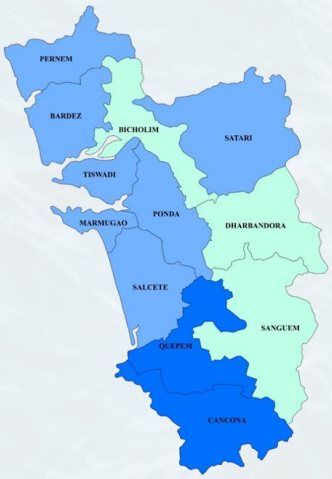
DYNAMIC GROUNDWATER RESOURCES OF GOA - 2024

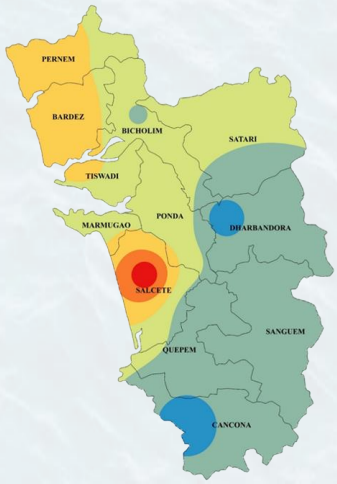






Water Resource Department
Government of Goa
&
Central Ground Water Board
South Western Region
Department of Water Resources,
River Development &
Ganga Rejuvenation
Ministry of Jal Shakti
Government of India

MARCH 2025



DYNAMIC GROUND WATER RESOURCES OF GOA, 2024

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

BENGALURU
MARCH, 2025

FOREWORD OF THE CHAIRMAN, SLC

I consider it my privilege to write this foreword for the Report on Ground Water Resources of Goa – 2024. Groundwater is a critical natural resource that holds immense ecological and economic significance. It serves as the backbone of sustainable development, supporting life, livelihoods, and the integrity of ecosystems. However, challenges such as over-extraction and misuse pose a serious threat to its long-term sustainability.

Goa is blessed with abundant rainfall and a rich reserve of water resources, enjoying a unique position among Indian states. Yet, paradoxically, certain regions experience water scarcity during the lean period, highlighting the need for an integrated and sustainable approach to water management. Traditionally, the focus in Goa has been on harnessing surface water resources. However, with rising demands across domestic, industrial, and agricultural sectors, groundwater has emerged as an essential alternative particularly in remote and underserved areas where piped water supply remains a challenge.

The periodic assessment of groundwater resources is an essential exercise to ensure its sustainable utilization. The Ground Water Resource Assessment (GWRA) – 2024 has been conducted jointly by the Water Resources Department, Government of Goa, and the Central Ground Water Board, South Western Region, Bangalore, following the Ground Water Estimation Methodology 2015. This study, is based on administrative units of taluk, provides a comprehensive evaluation of Goa's groundwater resources.

As per GWRA-2024, the annual extractable groundwater resources in Goa amount to 30,796.71 ham, with a total extraction of 7,055.76 ham, leading to a groundwater extraction stage of 22.91%. These findings reaffirm that while Goa currently enjoys a sustainable groundwater scenario, however careful planning and conservation efforts must continue to ensure long-term water security and sustainability.

I am confident that this report will be of immense value to State Government agencies in groundwater planning and management, as well as to educational institutions, research organizations, local stakeholders, and end users. It provides critical insights that will aid in informed decision-making for groundwater conservation and development.

I take this opportunity to commend the dedicated efforts of the officers of the Central Ground Water Board and the Water Resources Department for compiling this invaluable report in time. Their commitment to sustainable water management is truly commendable, and I trust this report will serve as a guiding document for future policies and an initiative to groundwater conservation and management.

Sri S.S. Gill, IAS
Secretary, Water Resources, Govt. of Goa,
Place: Alto – Porvorim – Goa

MESSAGE OF THE CHIEF ENGINEER, WRD, GOA

Water has always been the foundation of human civilization, with ancient cities and towns flourishing along riverbanks. In Goa, groundwater remains one of the state's most valuable natural resources providing drinking water to both rural and urban communities, supporting agriculture and industries, sustaining river flows, and preserving wetland ecosystems.

Recognizing the importance of sustainable groundwater management, the Water Resources Department (WRD), Government of Goa, in collaboration with the Central Ground Water Board (CGWB), Government of India has been consistently striving to improve the accuracy of groundwater estimation over the past few years. With increasing reliance on groundwater, due to surface water shortage and fluctuations in supply, the Goa Ground Water Regulation Act, 2002, was enacted to regulate groundwater extraction. Presently, all commercial establishments in Goa are monitored through computerized metering and billing systems.

In the latest Ground Water Resource Assessment (GWRA) of 2024 conducted as per the Ground Water Estimation Methodology (GEC) 2015, Goa's annual extractable groundwater resources are estimated at 30,796.71 ham, with a total extraction of 7,055.76 ham, resulting in a groundwater extraction stage of 22.91% under Safe category. Unlike many other states, Goa exhibits a higher proportion of groundwater usage for domestic purposes (56.3%), reflecting its predominant non-agrarian economy.

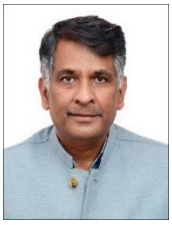
Despite relying on secondary data, the WRD has made significant efforts to enhance estimation accuracy by improving data collection on bore wells, cropping patterns, water conservation structures, surface water sources and also using the available rainfall and water level data from digital water level recorder drilled under Hydrology Project in the state,

This report will serve as an essential reference for policymakers, administrators, industries, and water resource professionals in planning and managing Goa's water sector. I sincerely hope it will help to shape future groundwater strategies, ensuring long-term sustainability and socio-economic progress for the state.

Sri P.B. Badami
Chief Engineer (WRD)
Govt. of Goa
Place: Alto – Porvorim – Goa

MESSAGE OF THE CONCERNED MEMBER, CGWB, CHQ, FARIDABAD

PREFACE BY THE REGIONAL DIRECTOR, CGWB, SWR, BENGALURU



Central Ground Water Board, under Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, Government of India is the National Apex Organization for Scientific and Sustainable development and management of Ground Water Resources. CGWB in association with the respective State Ground Water Departments/UTs has been periodically assessing ground water resources of all the States and Union Territories of the country over the last three decades based on the norms recommended by the Government of India. The precise and reliable estimation of ground water is necessary for its optimal and sustainable development of the precious resource.

It is necessary to acknowledge the hydrogeological characteristics of groundwater and its integral link to land, vegetation and surface water resources and perceive it as a 'resource' rather than a 'source'. Acknowledging the ubiquity of groundwater usage and its importance to all sections of society, it is necessary to recognize it as a common pool resource and adopt an aquifer-based approach to its management.

Here a fruitful attempt has been made by Central Ground Water Board, Bangalore and Water Resources Department, Goa to assess the dynamic ground water resources of the State of Goa for 2024 as per the groundwater estimation committee methodology-2015 on administrative unit basis. At the outset, the basic data needed for the assessment viz; geographical area, forest area, rainfall, details of canal and command area, net irrigated area, irrigation well census, data on WCS, tanks and ponds and groundwater level data, etc. were provided by WRD, Goa. For the three basic parameters viz., water level, specific yield and unit draft, the CGWB data has been used. The support provided by Shri P.B. Badami, Chief Engineer (WR), and his entire team of WRD, involved in GWRA 2024 Goa is duly acknowledged in GWRA-2024. The present report is outcome of the untiring efforts made by Smt. Sangita P. Bhattacharjee, Scientist-D, Shri Rahul R. Shende, Sc-D, Dr.Suchetana Biswas,Sc-C, Smt Caroline Louis, Scientist C and Shri Sushant S. Navarat, AHG of SWR, CGWB, Bangalore and State Unit Office, Belagavi and it is highly appreciable.

The ground water assessment of Goa State for 2024 will be very much useful to the planners, policy makers and other stake holders for effective and proper management of precious ground water resources. I hope that the people of Goa State get benefitted due to the resource estimation as it is the main input for deciding many ground water related Central Government aided schemes and projects.

N. Jyothi Kumar
Regional Director

PRINCIPAL CONTRIBUTIONS BY

Water Resources Department **Government of Goa,** **Alto – Porvorim – Goa**	**Central Ground Water Board** **South Western Region and State Unit Office** **Bengaluru and Belagavi**
Shri Pramod B. Badami, Chief Engineer	Shri N. Jyothi Kumar, Regional Director
Shri S.B. Ghantkar, Superintending Engineer	Smt. Sangita P. Bhattacharjee, Scientist-D
Shri Ankush Gaonkar, Superintending Engineer	Shri Rahul R. Shende, Scientist-D
Shri. Shailesh Pokle, Executive Engineer	Dr. Suchetana Biswas, Sc-C
Shri Milind Gavde, Executive Engineer	Smt Caroline Louis, Scientist C
Shri Gipson Miranda, Executive Engineer	Shri Sushant S. Navarat, AHG
Shri. Shailesh Naik, Executive Engineer	
Shri Mohan Raikar, Executive Engineer	

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3. Annual Ground Water Extraction: 0.07 billion cubic meters (bcm)

4. Stage of Ground Water Extraction: 22.91 %

CATEGORIZATION OF ASSESSMENT UNITS

(Blocks/ Mandals/ Taluks)

Sl. No	Category	Number of Assessment Units		Recharge worthy Area		Annual Extractable Ground Water Resource	
		Number	%	in lakh sq. km	%	(in bcm)	%
1	Safe	12	100	2209.59	59.68	0.31	80
2	Semi Critical	0	0	0	0	0	0
3	Critical	0	0	0	0	0	0
4	Over-Exploited	0	0	0	0	0	0
5	Saline	0	0	0	0	0	0
	TOTAL	**12**	**100**	**2209.59**	**59.68**	**0.31**	**80**

EXECUTIVE SUMMARY

The hydrogeological conditions in Goa indicate that groundwater exists under unconfined to semi-confined conditions in laterites, beach sands, and fractured crystalline rocks. The primary sources of groundwater recharge are rainfall infiltration and water conservation structures, ensuring that groundwater remains suitable for domestic, agricultural, and industrial use.

The Central Ground Water Board (CGWB), in collaboration with the Water Resources Department (WRD) of Goa, conducted a groundwater resource assessment for 2024 using the GEC 2015 methodology. The key findings reveal that the total annual groundwater recharge stands at 0.38 bcm, with 0.31 bcm classified as extractable. The annual groundwater extraction is 0.07 bcm, resulting in a stage of extraction of 22.91%. Notably, all 12 taluks in Goa have been categorized as 'Safe.'

A comparative analysis between GWRA 2023 and GWRA 2024 highlights a slight decrease in total groundwater recharge from 0.40 bcm to 0.38 bcm and a decline in extractable resources from 0.32 bcm to 0.31 bcm. Meanwhile, groundwater extraction has increased marginally due to rising domestic, industrial, and irrigation demands, leading to a rise in the stage of groundwater extraction from 21.37% to 22.91%.

Policy recommendations emphasize the need for continuous groundwater monitoring, particularly in high-extraction zones, to ensure long-term sustainability. Integrating surface water sources with groundwater management can help mitigate dependency on groundwater resources. Additionally, coastal regions require special attention to prevent salinity intrusion, as outlined in the NAQUIM 2.0 program. These insights serve as a critical guide for policymakers and stakeholders in ensuring the sustainable management of Goa's groundwater resources.

CHAPTER 1

INTRODUCTION

Goa state having a total geographical area of 3702 sq.km and is administratively divided into 2 districts and 12 taluks (Fig.-1). Ground water resources of the state of Goa have been assessed on administrative unit (Taluk) wise, based on Groundwater Estimation Committee (GEC) 2015 Methodology. The assessment was done using the Ground Water database as on March 2023 validated by Water Resources Department (WRD), Govt. of Goa and Central Ground Water Board (CGWB), SWR, Bengaluru using INGRES software developed by Vassar Labs. GEC 2015 methodology recognizes that it has considerable scope for refinements and improvements, which can be achieved in a phased manner, as per the guidance of the R&D advisory committee on Groundwater Estimation.

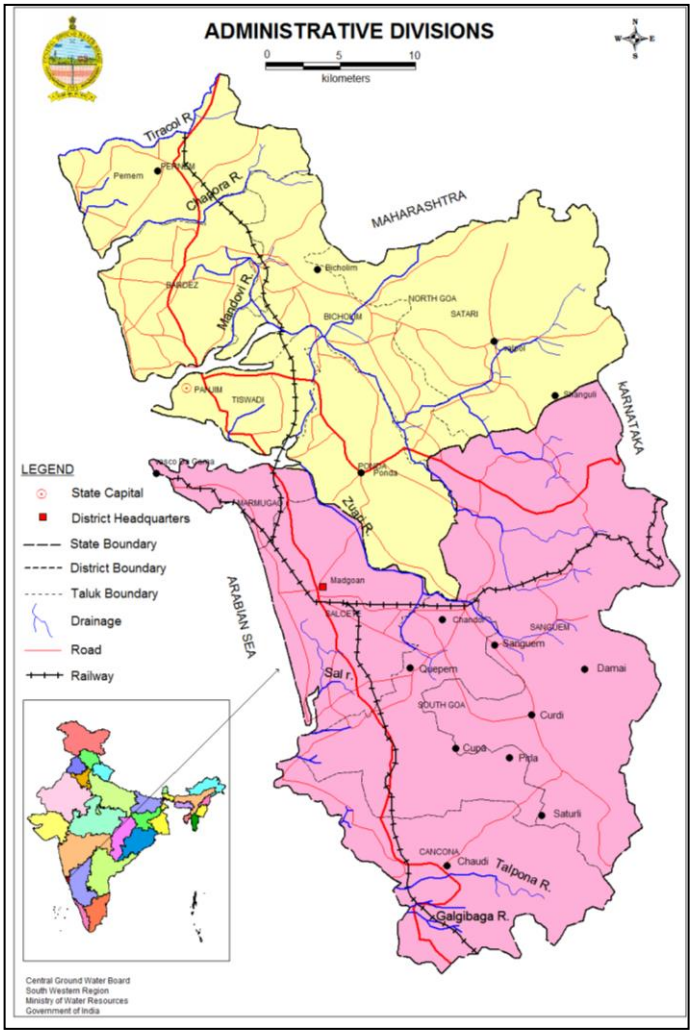

Fig.-1: Index Map

Background

In the State of Goa, groundwater has emerged as an important source to meet the water requirements of various sectors especially domestic, tourism, and industrial sectors. Demands for groundwater resources are ever increasing and competition amongst users has intensified. The sustainable development of groundwater requires precise quantitative assessment based on

reasonably valid scientific principles. The occurrence, movement and storage of groundwater are quite complex, being governed by several factors like meteorology, geomorphology, geology, hydrogeology, and above all the human activities. All these factors make the precise assessment of groundwater very difficult and there is no direct technique available for precise assessment. Hence, the methods applied for groundwater resource estimation are all indirect. There are several techniques and methodologies in vogue for estimation of groundwater resources. Quantification of groundwater resources is often critical and no single comprehensive technique is yet identified which is capable of estimating accurate groundwater potential. Since groundwater is a dynamic and replenishable resource, its proper and economic development on a sustainable basis, requires its realistic assessment. The estimation must be seen as an interactive procedure. Initial estimation is revised and refined by comparing these results with the results obtained by adopting alternative methods and third-party studies.

The Ministry of Jal Shakti, Deptartment of Water Resources, River Development & Ganga Rejuvenation, Govt. of India desires to reassess the Ground Water Resources for the entire country once in every year and hence the current re-estimation of resources as on March 2024 has been taken up in view of the changes that are observed in the ground water scenario. The data provided by the state agencies have been used in the present ground water assessment. During 2020 assessment, a software named INDIA – Groundwater Resource Estimation System "INGRES" has been introduced for assessing the ground water resources of India and the same is used for current assessment. The data collected were compiled as per format in INGRES and was uploaded in the software and the results generated were validated with the manual calculations for few sample assessment units to ensure the error-free functioning of software.

Constitution of State Level Committee

A State Level Committee for Ground Water Resources Assessment (GWRA) was constituted under the chairmanship of Secretary, Water Resources, Govt. of Goa vide U.O. No. 4/9/CE-CPO/WRD/2023-24/31dated 13/04/2023(Annexure I) with Regional Director, Central Ground Water Board, Bangalore being the Member Secretary. The composition of the Committee is as follows:

Secretary, Water Resources	Chairman
Chief Engineer, Water Resource Department	Member
Chief Engineer, (Water Supply & Sanitation Dept.) PHE	Member
Director, Department of Agriculture	Member
Director, Department of Industries	Member
Director, Department of Planning, Statistics & Evaluation	Member
General Manager, NABARD	Member
Superintending Engineer, CPO, WRD	Member
Superintending Engineer, Circle I, WRD	Member
Senior Hydrogeologist, WRD	Member
Regional Director, Central Ground Water Board, Bangalore	Member Secretary

As per the protocol, a GWRA cell comprising of the officers of the CGWB and WRD was also formed for resource evaluation. The members of the group had several meetings and discussions for data authentication, monitoring the progress and address the constraints in resource evaluation. Various departments were requested to provide data required for the purpose.

Brief Outline of the Proceedings of the Committee

The first meeting of the State level Committee (SLC) for Ground Water Resources Assessment - 2024 of Goa State was held on 29.04.2024 at 11.00 hrs in Conference Hall, Sinchai-Bhavan Water Resource Department, Alto-Porvorim, Goa. Shri. Jyothi Kumar, Regional Director, CGWB, SWR, Bangalore & Member Secretary welcomed the members and discussed the methodology for assessments. Shri. Subhash Chandra, Secretary (WRD, Govt. of Goa), Chairman of the committee praised the decision to assess ground water annually and inquired about estimation methods, acknowledging the use of In-GRES software.

Shri Pramod B. Badami, Chief Engineer, WRD, Goa welcomed all the members and informed that Ground Water Resources Assessment should reflect the improvement in resources due to various recharge and water conservation works taken up by the State Govt. He stressed that although the resource assessment is an estimation based on norms, it should reflect the actual groundwater situation prevalent in the state. He requested the committee members to expedite the data collection process. Sri D.Y. Salelkar, ACE, WRD emphasized the importance of monitoring groundwater levels, quality, and usage patterns to inform policy decisions and conservation efforts. Proper assessment can help prevent over-extraction, contamination, and can support the long-term availability of clean water for various needs in Goa.

Smt. Sangita P. Bhattacharjee, Scientist-D & OIC, CGWB, SUO, Belagavi delivered a presentation on the "Dynamic Groundwater Resources of Goa-2023," highlighting current groundwater availability, utilization patterns, challenges such as over-extraction and contamination, and sustainable practices with recharge plans. She outlined the methodology (GEC-2015) and focus areas for the upcoming Ground Water Resource Assessment – 2024 emphasizing data collection, stakeholder involvement, and policy recommendations. The presentation underscored the importance of sustainable groundwater management to ensure long-term water security in Goa. Groundwater assessment is vital for sustainable water resource management, ensuring that the region's water needs are met without depleting this essential resource.

The 2nd meeting of the State Level Committee (SLC) for Ground Water Resources Assessment (GWRA) 2024 for Goa was held online on September 24, 2024. Chaired by Shri Pramod B. Badami, Chief Engineer of the Water Resource Department (WRD), the meeting aimed to review and approve the findings of GWRA 2024. Members of the SLC and officers from the Groundwater Cell participated.

Shri Rahul R. Shende, Scientist-D welcomed the attendees, acknowledged the efforts of involved departments, and outlined the resource estimation activities.

Smt. Sangita P. Bhattacharjee, Scientist-D presented findings of GWRA 2024, which assessed groundwater resources at the taluk level. Rainfall recharge was identified as the primary source of groundwater replenishment, and the overall groundwater extraction stage for Goa was 22.91%, placing all 12 Taluks in the "Safe" category. Domestic extraction accounted for the highest usage followed by irrigation and industrial use.

Shri Pramod B. Badami, Chief Engineer, emphasized the need to reduce groundwater extraction for domestic purposes by enhancing surface water supplies. He highlighted the ongoing efforts under NAQUIM 2.0 to address coastal salinity intrusion in North Goa.

Suggestions to include Goa's Forest Department and Department of Mines in the SLC for future assessments were accepted for implementation in 2025.

The meeting concluded with acknowledgment of contributions by various departments and appreciation of efforts that ensured timely completion of GWRA 2024. After thorough discussions, the SLC members unanimously approved the GWRA 2024 of Goa.

The minutes of the meeting are attached as Annexure-III.

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 –

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

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

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

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:

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

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

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

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

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

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:

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

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,

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

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:

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

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

Where,

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

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 –

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

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

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

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.

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

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.

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

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,

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

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. Categorization of Assessment Unit

2.1.1.11.1. Categorization of Assessment Unit Based on Quantity

The categorization 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. Categorization 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 Utilization

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.

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

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 Categorization. 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.

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

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.

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

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

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/Litho margic 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	3	1	5

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
				Palaeozoic to Cenozoic			
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
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	10	5	15

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
				Proterozoic			
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 etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	0.35	0.2	0.5
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

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
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*** have 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/Litho margic 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/Conglomera te	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
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic	12	10	14

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
				to Cenozoic			
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
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly	Proterozoic to Cenozoic	2	1	3

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
			Fractured				
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/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	11	10	12

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
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.

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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.

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

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

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

2.6 PROCEDURE FOLLOWED IN THE PRESENT ASSESSMENT 2024

2.6.1 Data Source& Base Year of Data

For assessment, data from multiple agencies involved in water sector is required like Water Resources Dept. (WRD), Minor Irrigation Dept., Agriculture Dept., Industries Dept., Statistics Dept. etc. The data compilation and validation in itself a huge task. The various data inputs required and used for the assessment are discussed below.

The rainfall and water levels data for the past 5 years from 2019 to 2023 has been considered in the computations. Based on this database the sub-unit wise average pre-monsoon and post-monsoon groundwater levels and fluctuations are calculated and used in the assessment. The canal, tanks, ponds and water conservation structures data of the year 2023-24 was utilized. The 2011 census data with annual growth rate have been used in the computations for estimation of ground water extraction for domestic purpose based on consumptive method.

2.6.1.1 Area

In Goa State, taluks are being used as a unit of assessment in the State irrespective of the Methodology. The areas of the taluk have been computed from shape files and revenue dept. data. The command areas of the Irrigation Project as per the command area map of NWIC, GoI and Water Resources Department, Govt. of Goa have been used in this assessment. No poor-quality areas were considered in the current assessment. This data base was used for sub-dividing the assessment unit into command and non-command area. There are 12 assessment units in the State. Out of these 12 taluks, parts of Pernem, Bardez, Bicholim and Satari taluks in North Goa district and parts of Salcete, Quepem and Sanguem taluks in South Goa district come under both Command and Non—command units. However, no taluks are considered under poor-quality area.

Out of the total area (370198 ha) of the state, the non-worthy area (hilly area – 149239 ha) is deducted and only the recharge worthy area (220959 ha) is considered for this assessment. The recharge worthy area is further sub-divided into command (28715 ha) and non-command areas (192244 ha) and their percentages for the State are 13% &87% respectively.(Fig.2.1, 2.2)

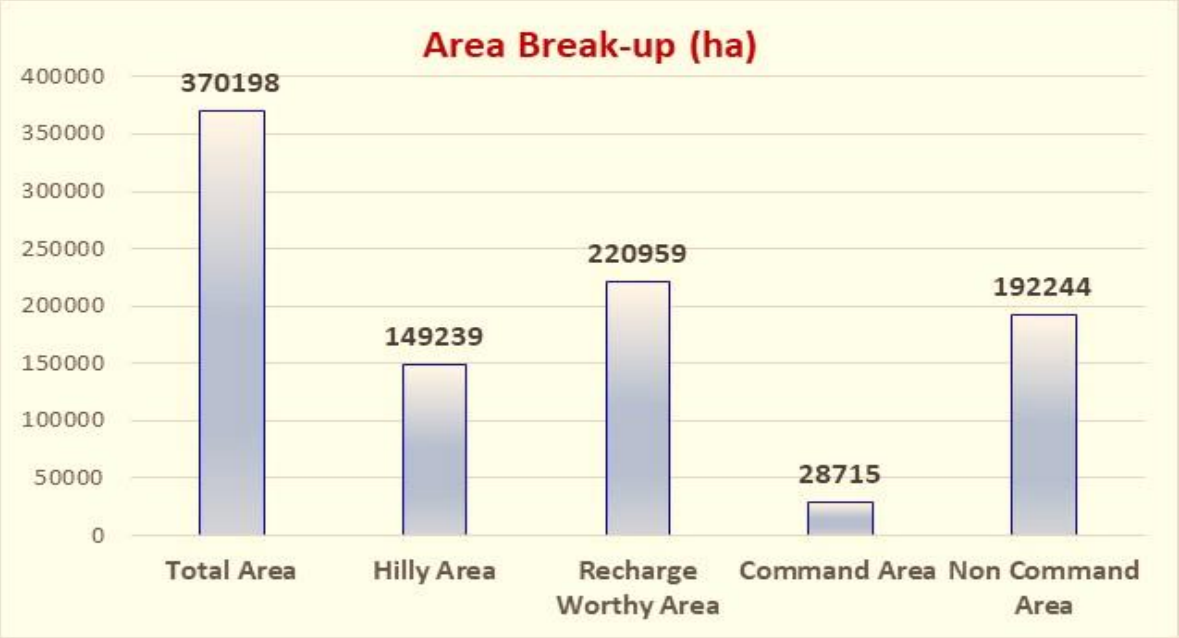


Fig.-2.1: Areas under different categories

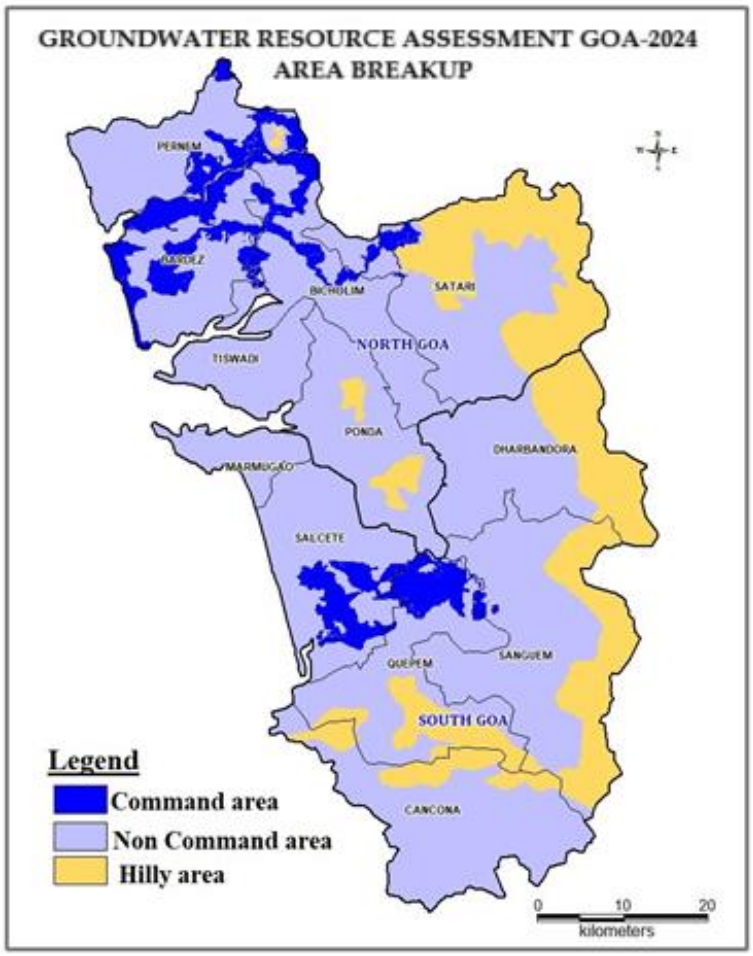


Fig.-2.2: Area Break-up Map

2.6.1.2 Well Census

For estimation of ground water extraction for Irrigation purpose, the minor irrigation well census data as well as the data from district administration provided by WRD was considered. Both the irrigation dugwells and borewells have been considered for the draft purpose.

For estimation of ground water extraction for domestic purpose, consumptive method based on population (2011) was used.

For estimation of ground water extraction for industrial purpose, the data on number of wells being used by industries and their annual requirement was considered to arrive at unit draft. This data was acquired from WRD as they are the nodal dept. for ground water regulation in the State.

2.6.1.3 Canals, Tanks & Ponds

The data base related to canals, command area, number of rotations, and volume of water released into the canals etc have been collected at taluk/circle level from the Water Resources Dept. The taluk level data on tanks and ponds was also provided by WRD. The data is as of the year 2023-2024.

2.6.1.4 Water Conservation Structures

The data base related to WCS was at taluk level was also provided by WRD. The data is as of the year 2023-2024.

2.6.1.5 Cropping Pattern

The taluk wise crop data and irrigated agriculture data, as on 2023-2024 season, collected from district offices of the State Agriculture Department by WRD have been used for the computations of irrigation return flow.

2.6.1.6 Rainfall

The rainfall data has been sourced from WRD, Goa. The normal as well as yearly actual monsoon and non-monsoon rainfall measured at various stations within the assessment unit upto 2023 has been used.

2.6.1.7 Ground Water Levels

The CGWB is monitoring the groundwater levels in the State on quarterly basis i.e., in January, March, May and November. There are about 83 dug wells of CGWB and 54 dug wells of WRD, Goa. The water level data of May 2023 and November 2023 were considered for the assessment purpose.

2.6.1.8 Population

The 2011 census data has been used in the computations for estimation of ground water extraction for domestic purpose based on consumptive method.

2.6.2 Various Norms Used

2.6.2.1 Assessment area

Out of the total geographical area, the hilly area (slope > 20%), hill tops and rocky waste land were identified and subtracted and the remaining area is considered as recharge worthy or assessment area.

2.6.2.2 Specific Yield

The specific yield values recommended as per prescribed norms of GEC-2015 methodology were taken.

2.6.2.3 Rainfall infiltration factor

In all the watersheds, the coefficients for RIF are as per the recommended values of GEC-2015 methodology norms.

2.6.2.4 Recharge due to canal seepage

The prescribed norms of GEC-2015 methodology i.e., 3.5 Ham per day/million sq. m wetted area for all canals in hard rock have been considered.

2.6.2.5 Recharge from Tanks and Ponds

The prescribed norms of GEC-2015 methodology i.e., Average water spread area (60% of total water spread area) * No. of days * 0.00144 meters per day per Ha, has been considered.

2.6.2.6 Recharge from water conservation structure

The recharge considered due to water conservation structures was considered as 50% instead of 40% (per norms) of the gross storage capacity of the water conservation structure. The number of fillings considered are ranging from 1 or 6 depending on the local conditions.

2.6.2.7 Unit Draft or Extraction

The unit draft computed for different abstraction structures representing typical geological formations has been used for the estimation. The unit draft for irrigation dug well fitted with electric pump was considered as 0.27 ham/annum. For irrigation bore wells (with electric pump), the unit draft considered was 0.54 ham/ annum. For irrigation Dug cum bore wells, the unit draft considered was 0.45 ham/ annum. The unit draft considered for the various types of abstraction structures is given below in Table – 2.5.

Table-2.5: GW abstraction structure wise unit draft values for Irrigation draft

STRUCTURE	UNIT DRAFT (HAM/ANNUM)
DUG WELL	0.27
BORE WELL	0.54
DUG CUM BOREWELLS	0.45

For Industrial dug wells (with electric pump), the unit draft considered ranges from 0.05 to 0.97 ham/ annum, whereas for Industrial bore wells, the unit draft considered ranges from 0.14 to 1.62 ham/annum and is given below in Table – 5.

Table-2.6: GW abstraction structure wise unit draft values for Industrial draft

STRUCTURE	UNIT DRAFT (HAM/ANNUM)
DUG WELL	0. 05 – 0.97
BORE WELL	0. 14 – 1.62

2.6.2.8 Return flow from irrigation

The prescribed norms of GEC-2015 methodology have been adopted for estimation of recharge due to return flow from surface water and ground water irrigation.

2.6.2.9 Stage of Ground water Extraction and Categorization

The norms of GEC-2015 methodologyhave been used for the computation of the Stage of Ground water Extraction and Categorization.

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

CHAPTER 3

RAINFALL

Rain occurs during the monsoon period from June to September. Over 90 percent of annual rainfall occurs during monsoon period. The balance of 10 percent occurs during the pre-monsoon period from March to May and post monsoon period from October to December. However the rainy period extends from May to November.

The analysis of Rainfall data for the period of 1971 to 2020 from 12 stations over the Goa state indicates that the monsoon rainfall is in the order of 3460 mm (90 % of annual rainfall), 218.1 mm (6%) during post monsoon period of October to December and 102.5(4%) are from January to May months. The overall annual rainfall over the Goa state based on 30 years rainfall data is of 3483.3mm. The minimum rainfall of 2611.7mm is recorded at Marmugao station falls in South Goa district and maximum of 5090 mm is in Sanguem station also from South Goa. The annual normal rainfall in North Goa ranges from 2766.9 mm at Panaji along the west coast and highest at Valpoi in the east (Ghats section) indicating rainfall increases from west to east. Average rainfall in North Goa is 3400.1mm. Similarly in South Goa it ranged 2611.7 mm at Marmugao in west coast and maximum at Sanguem in the east again ghat section indicating that the rainfall increases from west to east. The overall annual normal rainfall in south Goa is 3733.13 mm.

The months of June (840.7 mm) and July (1246.9 mm) are the wettest months with around 2187.6 mm (62.80% of annual normal rainfall) rainfall in two months. Rainfall during the months of January and February is negligible. Valpoi in the north Goa and Sanguem in the south Goa, both in the interior hilly areas, are wettest places in the state. Isohyetal Map of Goa state for the period 1970 to 2000 has been presented in **Plate 3** Normal monthly rainfall in respect of 12 stations of Goa state is presented in **Table 2**.

1. Normal Rainfall of the State/ UT

The normal annual rainfall for the Goa state is 3370mm.

2. District Wise Normal Rainfall of the State/UT

The normal annual rainfall in North Goa district is 3389.74 mm and for South Goa district it is 3212.55 mm. The normal rainfalls for the Goa state is 3352.2 mm.

3. Rainfall during the Calendar Year 2023 for the State/UT and District Wise

Sl.No	District / Block	Assessment Unit Taluk name	*Year	Monsoon	Non-Monsoon	Total rainfall
				Actual (mm)	Actual (mm)	Actual (mm)
1	GOA NORTH	PERNEM	2023-2024	3124.5	195	3319.5
2	GOA NORTH	SATARI	2023-2024	3619.5	380.5	4000
3	GOA NORTH	TISWADI	2023-2024	3363.5	423	3786.5
4	GOA NORTH	BICHOLIM	2023-2024	3472	250.5	3722.5
5	GOA NORTH	BARDEZ	2023-2024	3363.5	423	3786.5
	DISTRICT TOTAL			**3388.6**	**334.4**	**3723**
1	SOUTH GOA	MARMUGAO	2023-2024	2917.5	373.5	3291
2	SOUTH GOA	SALCETE	2023-2024	3431.5	140.5	3572
3	SOUTH GOA	DHARBANDORA	2023-2024	3339	254.5	3593.5
4	SOUTH GOA	CANCONA	2023-2024	2888.5	102	2990.5
5	SOUTH GOA	QUEPEM	2023-2024	3496	505.5	4001.5
6	SOUTH GOA	SANGUEM	2023-2024	3475	417	3892
7	SOUTH GOA	PONDA	2023-2024	3342.5	333.5	3676
	DISTRICT TOTAL			**3270**	**303.79**	**3573.79**

CHAPTER 4

Hydrogeological Setup of Goa State

4.1 Geomorphology:

Geomorphologically, Goa state is divided into four morphological units namely, the 1. Coastal plains with dominant marine land forms on the west, followed successively towards the east by the 2. Vast stretch plain, 3. Low dissected denudational hills and table land and 4. Deeply dissected high Western Ghats with denudational hills occurring all along the eastern part of Goa rising to a maximum of 832 meters above mean sea level (m amsl). The fluvial landforms are limited in aerial extent.

Goa state forms part of coastal tract of the west coast of India. The principal perennial rivers are Terekhol, Chapora, Mandovi, Zuari and Galjibagh, whereas Baga, Sal, Saleri and Talpona are ephemeral rivers. Kumbharjua canal is an important feature of natural drainage of Goa and it links Mandovi River with Zuari River about 20 km east of the coast and it provides natural link connecting two major rivers of Goa.

4.2 Soils:

Soils of the state can be grouped into 5 classes whose aerial distribution and brief descriptions are as under: -

1. Lateritic Soils

These are highly porous and permeable and constitute 2150 km2 of the state area. These are slightly acidic with low pH values, low in organic matter, Ca and P.

2. Alluvial Soils

They are reddish brown to yellowish coarse grained and confined to narrow valleys of rivers and are well drained. These soils are acidic with low pH and organic content. These occupy an area of 80 km2 in the state.

3. Hilly Area Soil

These soils occupy an area of 705km^2. Theyare rich in humus content and retain good soil moistures. However, the thickness of the same is very limited.

4. Saline Soils

Saline soils occupy flood plains of Zuari and Mandovi rivers in Tiswadi, Ponda and Bardez taluks and also occur in Cancona, Pernem taluks. These Soils are deep, poorly drained and less permeable. Saline soils are saline, high in pH and contain humus and organic matter and occupy an area of 430 km^2 in the state

5. Marshy Soils

Marshy soils occur in low lying water logged and tidal affected areas confined to patches in Salcete, Canacona and Marmugao taluks. These soils occupy an area of 119 km^2 in the state

4.3 Geology

Goa state is dominantly covered by the formations of the Goa group belonging to Dharwad Super Group of Archaean to Proterozoic age, except for a narrow strip along the north eastern corner occupied by Deccan Trap of Upper Cretaceous to Lower Eocene age. The Goa group is consisting of green schist facies of the metamorphic rocks and is divided in to Barcem, Sanvordem, Bicholim and Vageri formations in the ascending order of super position. The Goa groups of rocks have been intruded by granite gneiss, feldspathic gneiss, hornblende gneiss and porphyritic granite, followed by

basic intrusive. During the Sub-Recent and Recent times, the rocks have been subjected to lateritisation of varying thickness. Coastal alluvium occurring along the coastal planes consists of fine to coarse sands with intercalations of sandy loam, silt and clay. The general geological succession of Goa is as follows.

Table- 1: Geological Succession of Goa State

AGE	GROUP	FORMATION	ROCK TYPE
Quaternary		Alluvium	Beach Sand
Cenozoic			Laterites
Upper Cretaceous to Eocene	Deccan Trap		Basalt
Lower Proterozoic	Closepet Granite		Granite
		Peridotite, Gabbro, Norite	Pyroxenite, Periditite, Serpentinite, Gabbro
Archaean to Lower Proterozoic	Goa Group	Vageri Formation	Carbonate-quartz-chlorite schist with Greywacke
		Bicholim Formation	Dolomitic limestone
			Quartz- Sericite schist
			Banded iron formation
			Chert and quartzite
			Quartz-chlorite-biotite schist with layers of chert, iron oxide, carbonate, metabasalt and meta gabbro
		Sanvordem Formation	Greywacke with conglomerate
			Quartzite
		Barcem Formation	Quartz-chlorite schist
			Meta-acid volcanics
			Metabasalt
			Ortho-quartzite
Archaean	Peninsular Gneissic complex		Granite Gneiss, Migmatites and Granites

The Goa group of rocks is disposed in a general NW-SE direction throughout the territory except in south western part where they have WNW-ESE trend. The rock types indicate three cycles of folding. The straight coastal line suggests the major fault along the west coast. Associated with this fault a number of weak planes have developed. Along these weak planes Terekhol, Chapora, Mandovi and Zuari rivers flow to meet the Arabian Sea. Western Ghats which extends in NS to NNW-SSE direction represent a prominent fault zone. Even though the rock types of Goa group have suffered considerable faulting, all the faults are not exposed on surface owing to the extensive cover of laterite. During the sub- recent to recent times, the rocks have been subjected to lateritisation resulting in cover of laterite of varying thickness.

4.4 Ground Water Conditions:

Ground water bearing formations in Goa state are alluvium, laterite, granite and granite gneiss, meta-volcanics and sedimentaries. The major aquifer system in Goa is presented in Fig.-4.

1. Alluvium

The thickness of the coastal alluvium varies from 5 m to 22 m. Fine to coarse sands with intercalations of sandy loam, silt and clay occurring at depth range of 1.42 to 8.0 meters below ground level (mbgl) is tapped by dug wells. Depth to water levels in these formations varies from 1.4 to 5.85 m bgl. Specific capacity ranges between 72 and 297.85 m3/day/m. Exploratory tube wells constructed in alluvium vary in depth from 15.5 to 22 m. The thickness of sand and gravel bed varies from 3 to 3.5 m occurring at depth range of 10 and 20 mbgl. The recorded discharges are between 1.88 and 3 liters per second (lps). The specific capacities vary between 27.1 and 200.78 m^3/day/m and transmissivity varies from 25.44 to 177.5 m^2/day.

2. Laterites

The laterites are the important water bearing formations in the state. Laterites are of two type's viz. as in-situ in plateau areas or of detrital origin generally occupying valley portions. Besides inherent porosity the laterites are highly jointed and fractured which control their water bearing capacity. The topographic settings of laterites control its ground water potential. The thickness of laterites extends up to 40 m. Irrigation dug wells tapping laterite range in depth from 2.85 m 20.38 m and depth to water level varies from 1.3 to 19.0 mbgl. Ground water occurs under phreatic condition. Specific capacities vary from 1.73 to 3205 m^3/day/m. Promising areas for groundwater development are located near Malpem and Tuem in Pernem taluk, Advalpal and Mayem in Bicholim taluk, Kirlapal in Sanguem taluk and Arlem in Salcete taluk.

3. Granites and Granite Gneisses

Ground water occurs under unconfined, semi-confined and confined conditions in the weathered and fractured zones of granite and granitic gneiss. Depth to water level in these formations in open wells varies from 3.8 to 6.25 mbgl and specific capacities between 14.4 and 77.3 m3/day/m. Exploratory boreholes drilled in granite and granite gneiss are in the depth range of 70.7 to 124m bgl with discharges ranging from 0.77 to 8.8 lps. Specific capacities in exploratory wells vary from 2.27 to 43 m^3/day/m and transmissivity from 0.87 to 34.6 m^2/day.

4. Meta-volcanics

The aquifer characteristics of the meta-volcanics and meta-sedimentaries vary widely. Irrigation dug wells are tapping the weathered zones up to 9.25 mbgl. The diameter of dug wells vary from 2.2 to 6.1 m and depth to water varied from 1.48 to 6.26 mbgl. Specific capacity varies from 10.6 to 228.7m^3/day/m. Exploratory wells and deposit wells drilled in this formation range in depth from 37.2 to 200.75 m and recorded discharges ranging from 0.18 to 25 lps. Productive zones were encountered down to 119 mbgl. The specific capacities of the boreholes tested varied from 0.46 to 988.47 m^3/day/m and transmissivity values from 0.25 to 346.1 m^2/day. Studies have indicated that boreholes drilled in meta-volcanics and meta-sedimentaries with thick lateritic cover in the plateau areas and close to lineaments have yields ranging between 2 to 5 lps. Artesian wells with free flow of 2.8 lps with head of 4.61 m agl was encountered within the meta-greywacke at depths of 38.2 and 65 m bgl at Honda in Satari taluk and free flow of 0.2 lps with head of 0.6 m bgl in quartzite within phyllite was encountered at 67.70 and 112-113.5 mbgl depths at Virnoda in Pernem taluk.

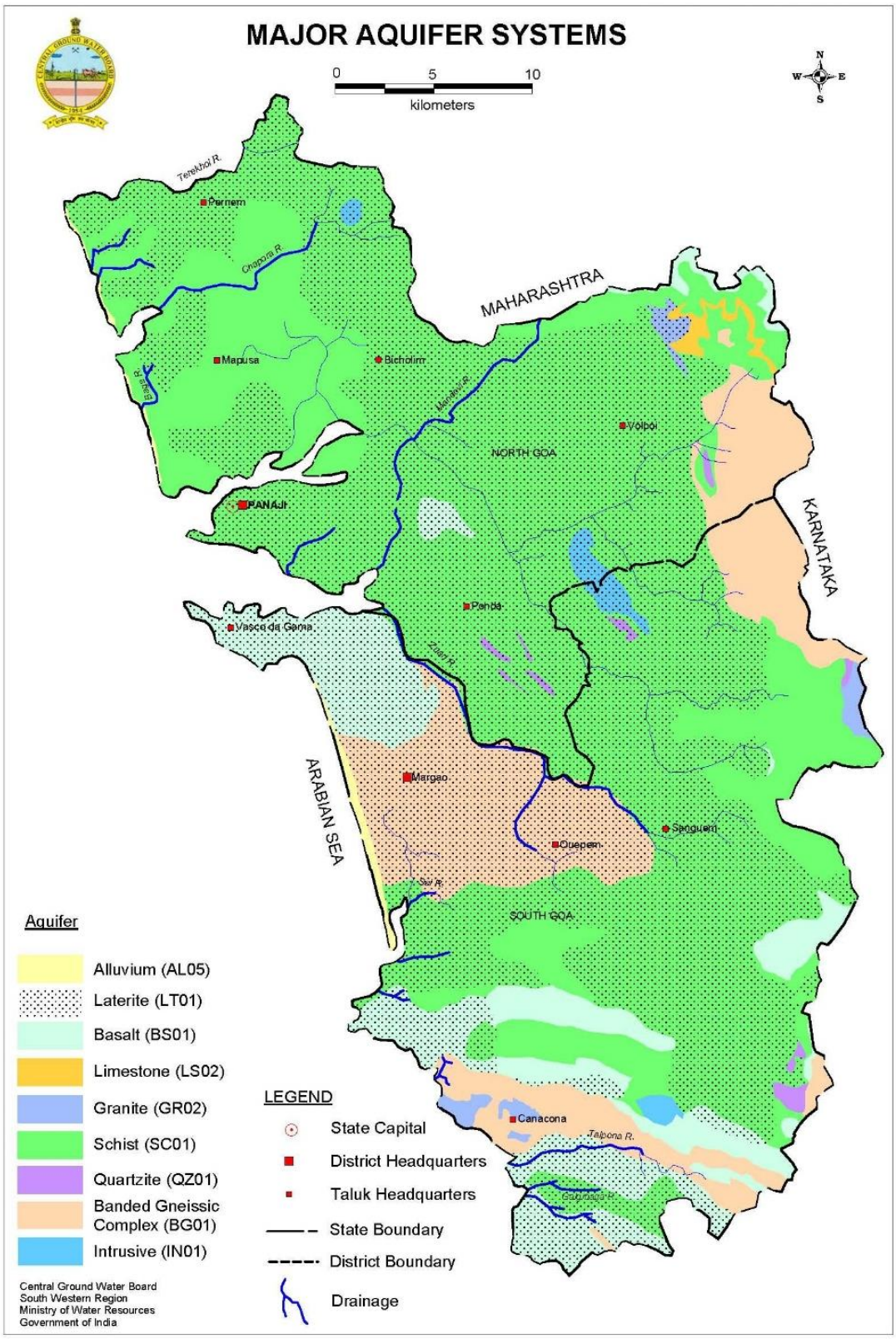


Fig.-4: Major Aquifer System Map

CHAPTER-5

GROUND WATER LEVEL SCENARIO IN GOASTATE

Ground Water Level Scenario

CGWB is monitoring83 dug wells under National Hydrograph Network Monitoring Stations in the state of Goa and Water Resources Dept., Govt. of Goa is monitoring 54 dug wells in the state. (Fig 5.1)Data from these stations were used for assessing the pre-monsoon and post monsoon water levels, fluctuation and decadal trends. The water levels data of May 2023& November 2023 is utilized for the assessment purpose.

Pre-monsoon Depth to Water Level (May 2023)

A perusal of the water level data reveals that the depth to water level ranged from 2.20 m bgl (Salcele taluk) to 14.90 m bgl (Sanguem taluk). The salient feature of the analysis is that the depth to water level over major part of the State lies within 10 m bgl in 86.4 % of wells analyzed, while 13.6 % of wells show depth to water level more than 10 m bgl. Depth to water level of less than 2 m bgl has been recorded in 0% of wells analyzed. Depth to water level in the range of 2 to 5 m bgl has been recorded in 47% of wells analyzed and noted in all the taluks except Tiswadi. Depth to water level in the range of 5 to 10 m bgl has been recorded in 39.4% of wells analyzed and noted in all the taluks except Mormugao taluk. Depth to water level in the range of 10 to 20 m bgl has been observed in 13.6% of wells analyzed and noted as isolated Tiswadi, Sattari, Sanguem, Salcete and Bardez taluks. (Fig.-5.2)

Post Monsoon Depth to Water Level (November 2023)

A perusal of the water level data reveals that the depth to water level ranged from 1.22m bgl (Salcete taluk) to 12.93m bgl (Bardez taluk). The salient feature of the analysis is that the depth to water level over major part of the State lies within 10 m bgl in 92% of wells analyzed, while 8% of wells show depth to water level more than 10 m bgl. Depth to water level of less than 2 m bgl has been recorded in 8% of wells analyzed and noted in Tiswadi, Salcete, Pernem, Canacona and Bardez taluks. Depth to water level in the range of 2 to 5 m bgl has been recorded in 45% of wells analyzed and noted in all the taluks. Depth to water level in the range of 5 to 10 m bgl has been recorded in 39% of wells analyzed and noted in all the taluks except Bicholim,Mormugao and Quepem taluks. Depth to water level in the range of 10 to 20 m bgl has been observed in 8% of wells analyzed and noted as isolated Bardez and Sanguem taluks(Fig.-5.3).

5.1 Fluctuation of Groundwater Level:

Comparison of Pre-monsoon 2023 to Pre-monsoon 2022

The statement showing the distribution of ground water monitoring wells falling in different ranges of fluctuation is presented in table 5.1. A comparison of ground water level between May 2022 and May 2023 shows that a fall in the water level is recorded in 34% of wells analyzed, while 66% recorded rise i.e majority of the state is showing rising water level. The fluctuation in water level has been plotted in Fig5.4.

- A perusal of the plate shows that a general fall in the range of 0 – 2 m is noticed in major part of the area, and further breakup given below.

- Rise in the water level in the range of 0-2 m has been observed in 66% of wells analyzed and observed in parts of all taluks.
- The fall in water level in the range of 0-2 m has been observed in 34% of wells analyzed and noted in parts of all the taluks except Bicholim, Tiswadi and Quepem taluk.

The Dharbhandora, Satari, Salcete, Canacona and Quepem taluks shows fall in water level compared to the previous year's same season while all other taluks showed rise. When the recharge exceeds discharge there will be a rise in the ground water storage. The rise in water level during May 2023 compared to May 2022 may be due to an increase in rainfall and/or due to changes in groundwater draft for various uses.

Comparison of November 2023 to November 2022

The statement showing the distribution of ground water monitoring wells which is rising and falling in different ranges of annual fluctuation in Shallow aquifer is presented in table 5.2. A comparison of water level shows that a rise in the water level is recorded in 86% of wells analyzed, while 14% recorded fall i.e majority of the state is showing rising water level. The Annual fluctuation in water level of Shallow aquifer has been plotted in Fig5.5. A perusal of the plate shows that a general rise in the range of 0 – 2 m is noticed in major part of the area, and further breakup given below.

- Rise in the water level in the range of 0-2 m has been observed in 69% of wells analyzed and observed in all taluks.
- Rise in the water level in the range of 2-4 m has been observed in 10% of wells analyzed in Bardez, Pernem, Satari and Sanguem taluks.
- Rise in water level more than 4 m has been observed in 7% of wells analyzed and noted in Ponda, Satari, Canacona and Sanguem taluks.
- The Fall in water level in the range of 0-2 m has been observed in 12% of wells analyzed and noted in Pernem, Canacona and Sanguem taluks.
- The fall in water level more than 4 m has been observed in 2% of wells analyzed and noted in Bardez taluk.

Major part of the state shows rise with in 2 m during post monsoon season compared to previous years post monsoon. Fall is noted as isolated pockets spread over the whole state. When the recharge exceeds discharge there will be a rise in the ground water storage and vice versa. The rise in water level may be due to an increase in rainfall and/or due to changes in irrigation practices.

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

The statement showing the distribution of ground water monitoring wells falling in different ranges of fluctuation is presented in Table 5.3. The fluctuation in water level has been plotted in Fig5.6. A comparison of water level shows that a fall in the water level is recorded in 71% of wells analyzed, while 29% recorded rise i.e majority of the state is showing falling water level. Salient features of the comparison of water levels are given below.

- Rise in the water level in the range of 0-2 m has been observed in 29% of wells analyzed, noted in parts of all taluks except Bicholim and Tiswadi taluk.

- The fall in water level in the range of 0-2 m has been observed in 62% of wells analyzed and noted in parts of all taluks.
- The fall in water level in the range of 2-4 m is observed in 6% of wells analyzed and noted in parts of Tiswadi, Bicholim, Ponda and Sanguem taluk.
- The fall in water level in the range of more than 4 m is observed in 3% of wells analyzed and noted in parts of Bicholim and Pernem taluk.

Fall in water level is observed all over the state while rise is noticed in southern part and in some isolated pockets. The decline in water level may be due to an increase in draft for different purposes or less recharge to ground water.

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

The statement showing the distribution of ground water monitoring wells which is rising and falling in different ranges of decadal fluctuation in Shallow aquifer is presented in Table 5.4. The Decadal fluctuation of water level of Shallow aquifer has been plotted in Fig5.7. A comparison of water level shows that a fall in the water level is recorded in 77% of wells analyzed, while 23% recorded rise i.e majority of the state is showing falling water level. Salient features of the comparison of water levels are given below.

- Rise in the water level in the range of 0-2 m has been observed in 22% of wells analyzed, noted in all taluks except Quepem and Marmugoa taluks.
- Rise in water level in the range of 2-4 m has been observed in 1% of wells analyzed and noted in Satari taluk.
- The fall in water level in the range of 0-2 m has been observed in 73% of wells analyzed and noted in all taluks.
- The fall in water level in the range of 2-4 m has been observed in 2% of wells analyzed and noted in Bardez and Sanguem taluks.
- The fall in water level of more than 4 m is observed in 2% of wells analyzed and noted in Bardez and Pernem taluks.

Fall in water level is observed all over the state while rise is noticed in isolated pockets. The decline in water level may be due to an increase in draft for different purposes or less recharge to ground water.

TABLE 5.1: TALUK WISE – WATER LEVEL FLUCTUATION AND FREQUENCY DISTRIBUTION FOR DIFFERENT RANGES OF SHALLOW AQUIFER (MAY 2022-MAY 2023)

S.No	Taluk Name	No. of Wells analyzed	Rise_Range of Fluctuation (m)						Fall_Range of Fluctuation (m)					
			0-2		2-4		>4		0-2		2-4		>4	
			No of wells	%	No of wells	%	No of wells	%	No of wells	%	No of wells	%	No of wells	%
1	Bardez	11	8	73	0	0	0	0	3	27	0	0	0	0
2	Bicholim	2	2	100	0	0	0	0	0	0	0	0	0	0
3	Pernem	6	5	84	0	0	0	0	1	16	0	0	0	0
4	Ponda	3	2	67	0	0	0	0	1	33	0	0	0	0
5	Sattari	6	2	33	0	0	0	0	4	67	0	0	0	0
6	Tiswadi	1	1	100	0	0	0	0	0	0	0	0	0	0
7	Canacona	7	4	57	0	0	0	0	3	43	0	0	0	0
8	Quepem	1	1	100	0	0	0	0	0	0	0	0	0	0
9	Salcete	4	2	50	0	0	0	0	2	50	0	0	**0**	**0**
10	Sangeum	12	8	67	0	0	0	0	4	33	0	0	0	0
	Total	**53**	**35**	**66**	**0**	**0**	**0**	**0**	**18**	**34**	**0**	**0**	**0**	**0**

TABLE 5.2: TALUK WISE – WATER LEVEL FLUCTUATION AND FREQUENCY DISTRIBUTION FOR DIFFERENT RANGES OF SHALLOW AQUIFER (NOV 2022-NOV 2023)

S.No	Taluk Name	No. of Wells analyzed	Rise_Range of Fluctuation (m)						Fall_Range of Fluctuation (m)						Rise	Fall
			0-2		2-4		>4		0-2		2-4		>4			
			No of wells	%	No of wells	%	No of wells	%	No of wells	%	No of wells	%	No of wells	%		
1	**Bardez**	10	7	70	2	20	0	0	0	0	0	0	1	10	9	1
2	**Bicholim**	2	2	100	0	0	0	0	0	0	0	0	0	0	2	0
3	**Pernem**	5	3	60	1	20	0	0	1	20	0	0	0	0	4	1
4	**Ponda**	3	2	67	0	0	1	33	0	0	0	0	0	0	3	0
5	**Satari**	9	6	67	2	22	1	11	0	0	0	0	0	0	9	0
6	**Tiswadi**	2	2	100	0	0	0	0	0	0	0	0	0	0	2	0
7	**Canacona**	5	3	60	0	0	1	20	1	20	0	0	0	0	4	1
8	**Quepem**	2	2	100	0	0	0	0	0	0	0	0	0	0	2	0
9	**Salcete**	6	6	100	0	0	0	0	0	0	0	0	0	0	6	0
10	**Sanguem**	14	7	50	1	7	1	7	5	36	0	0	0	0	9	5
	Total	**58**	**40**	**69**	**6**	**10**	**4**	**7**	**7**	**12**	**0**	**0**	**1**	**2**	**50**	**8**

TABLE 5.3 TALUK WISE – WATER LEVEL FLUCTUATION AND FREQUENCY DISTRIBUTION FOR DIFFERENT RANGES FROM DECADAL MEAN MAY (2013-2022) TO MAY 2023 OF SHALLOW AQUIFER

S.No	Taluk Name	No of wells analyzed	Rise_Range of Fluctuation (m)						Fall_Range of Fluctuation (m)						Rise	Fall
			0-2		2-4		>4		0-2		2-4		>4			
			No of wells	%	No of wells	%	No of wells	%	No of wells	%	No of wells	%	No of wells	%		
1	Bardez	12	2	17	0	0	0	0	10	83	0	0	0	0	2	10
2	Bicholim	3	0	0	0	0	0	0	1	33.33	1	33.33	1	33.33	0	3
3	Pernem	6	4	66	0	0	0	0	2	34	0	0	1	17	4	2
4	Ponda	4	1	25	0	0	0	0	2	50	1	25	0	0	1	3
5	Sattari	9	1	11	0	0	0	0	8	89	0	0	0	0	1	8
6	Tiswadi	3	0	0	0	0	0	0	2	67	1	33	0	0	0	3
7	Canacona	8	6	67	0	0	0	0	2	33	0	0	0	0	6	2
8	Quepem	2	1	50	0	0	0	0	1	50	0	0	0	0	1	1
9	Salcete	5	1	20	0	0	0	0	4	80	0	0	0	0	1	4
10	Sangeum	12	3	23	0	0	0	0	8	69	1	8	0	0	3	10
	Total	**65**	**19**	**29**	**0**	**0**	**0**	**0**	**40**	**62**	**4**	**6**	**2**	**3**	**19**	**46**

TABLE 5.4: TALUK WISE – DECADAL WATER LEVEL FLUCTUATION AND FREQUENCY DISTRIBUTION FOR DIFFERENT RANGES FROM MEAN NOV (2013-2022) TO NOV 2023 OF SHALLOW AQUIFER

S.No	Taluk Name	No. of Wells analyzed	Rise_Range of Fluctuation (m)						Fall_Range of Fluctuation (m)						Rise	Fall
			0-2		2-4		>4		0-2		2-4		>4			
			No of wells	%	No of wells	%	No of wells	%	No of wells	%	No of wells	%	No of wells	%		
1	**Bardez**	12	3	25	0	0	0	0	7	59	1	8	1	8	3	9
2	**Bicholim**	7	2	28	0	0	0	0	5	72	0	0	0	0	2	5
3	**Pernem**	9	2	22	0	0	0	0	6	67	0	0	1	11	2	7
4	**Ponda**	5	2	40	0	0	0	0	3	60	0	0	0	0	2	3
5	**Satari**	9	3	33	1	11	0	0	5	56	0	0	0	0	4	5
6	**Tiswadi**	4	1	25	0	0	0	0	3	75	0	0	0	0	1	3
7	**Canacona**	9	2	22	0	0	0	0	7	78	0	0	0	0	2	7
8	**Quepem**	3	0	0	0	0	0	0	3	100	0	0	0	0	0	3
9	**Salcete**	8	1	13	0	0	0	0	7	87	0	0	0	0	1	7
10	**Sanguem**	14	2	14	0	0	0	0	11	79	1	7	0	0	2	12
11	**Marmugoa**	1	0	0	0	0	0	0	1	100	0	0	0	0	0	1
	Total	**81**	**18**	**22**	**1**	**1**	**0**	**0**	**58**	**73**	**2**	**2**	**2**	**2**	**19**	**62**

Fig 5.1: Groundwater Level monitoring locations of CGWB and WRD, Goa (Dugwells)

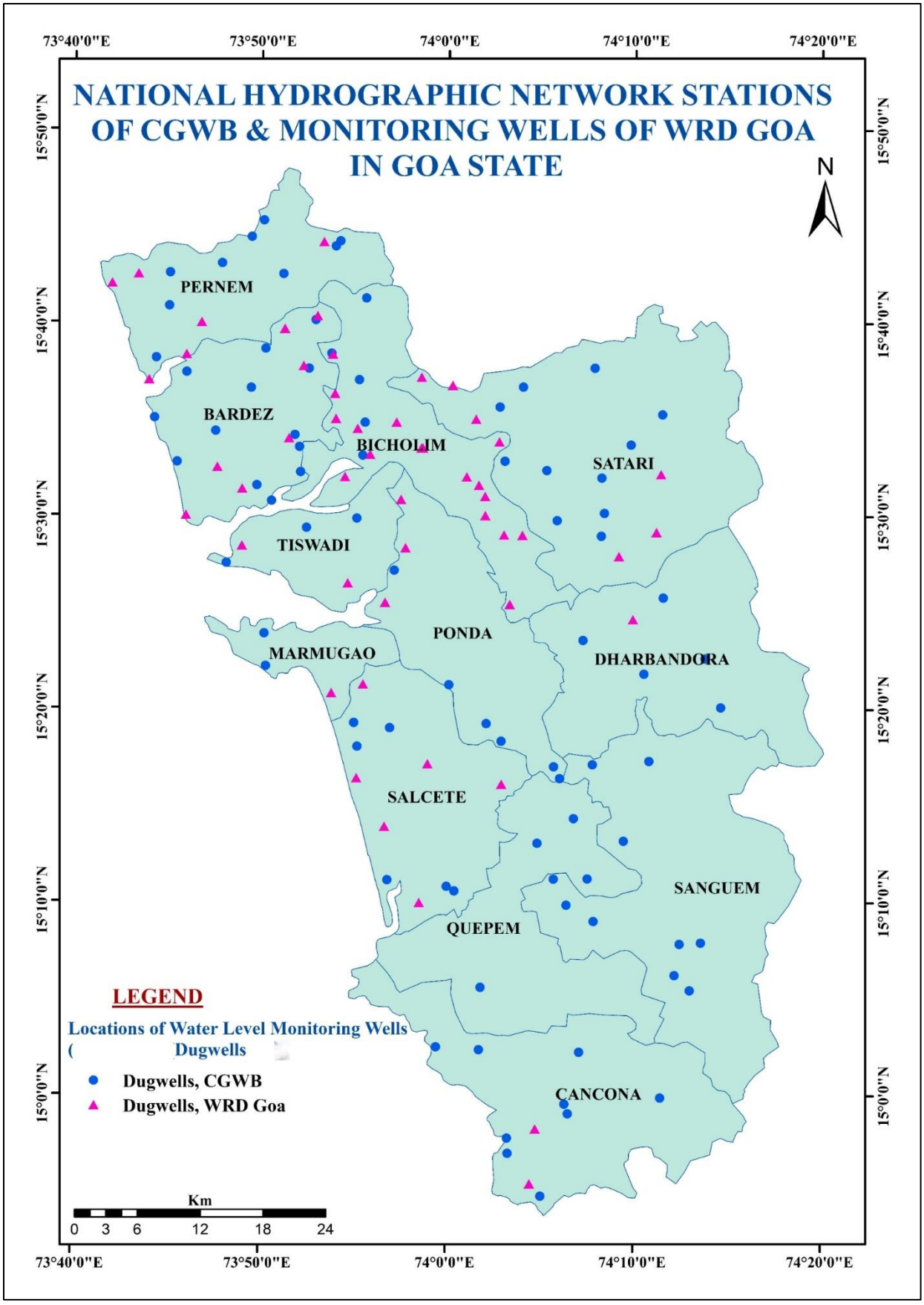


Fig 5.2: Depth to water level map of Goa State (May 2023)

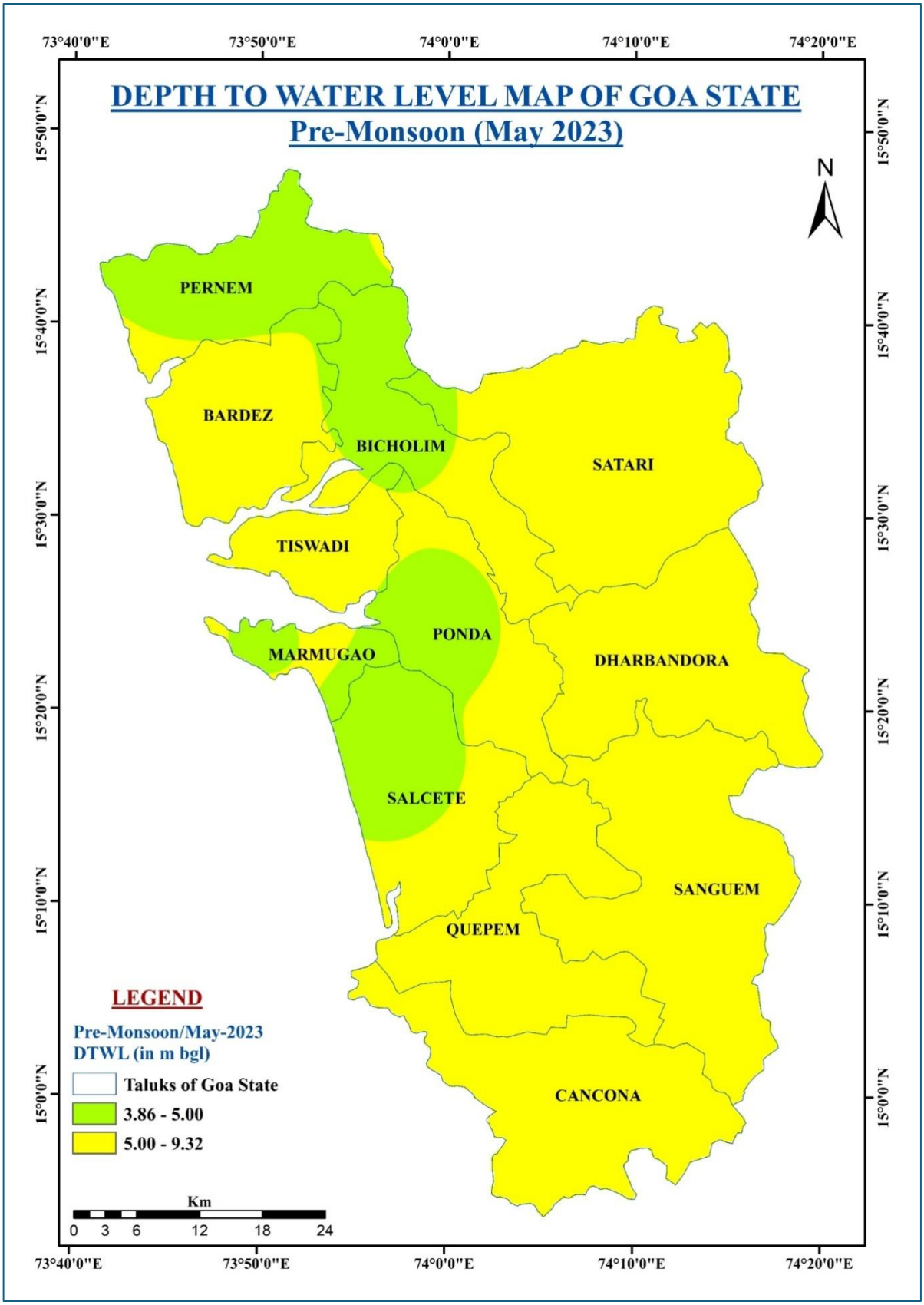


Fig 5.3:Depth to water level map of Goa State (November 2023)

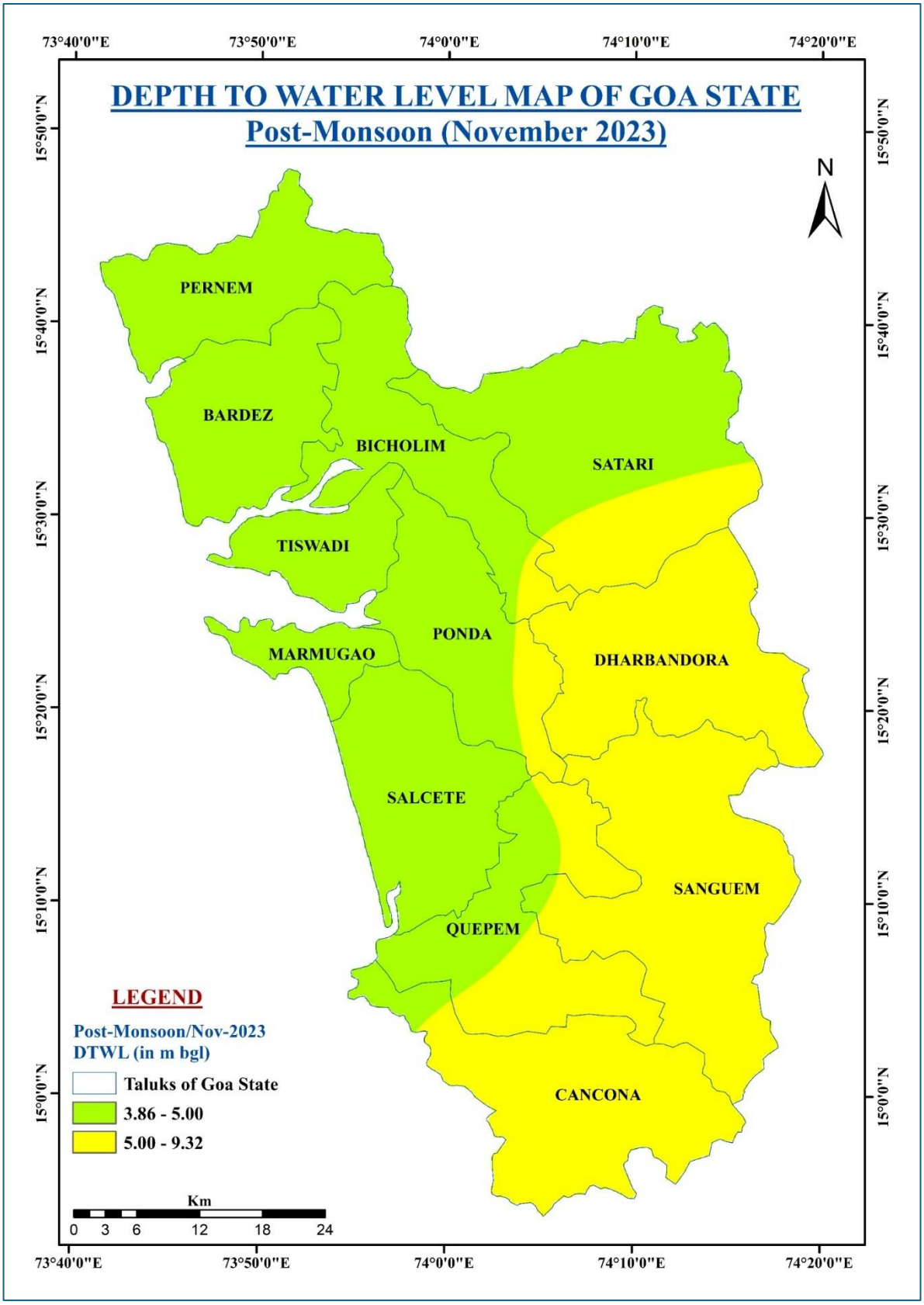


Fig 5.4: Groundwater Level Fluctuation: Pre-monsoon 2022 compared to Pre-monsoon 2023 (May 2022 - May 2023)

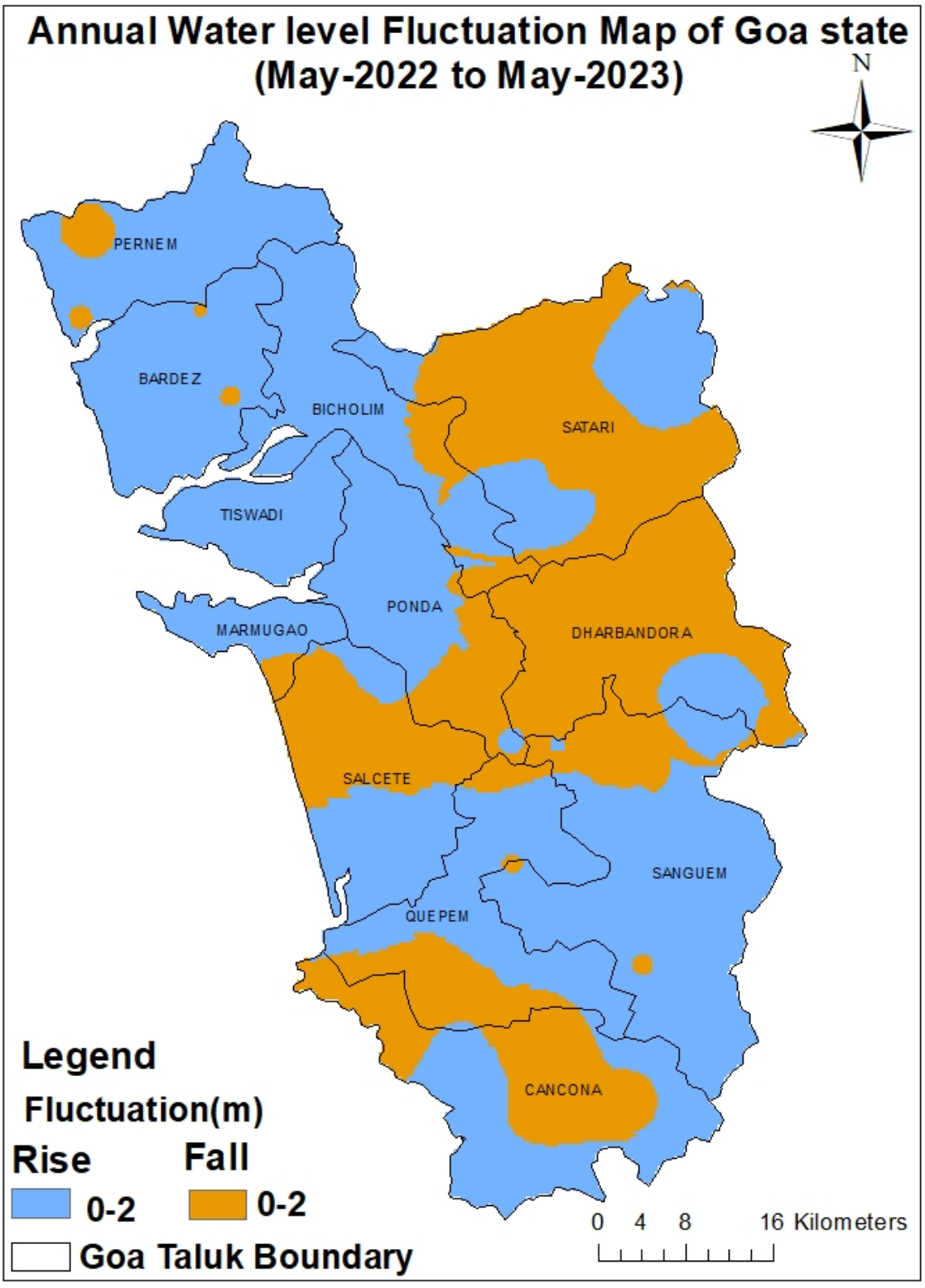


Fig 5.5: Groundwater Level Fluctuation: Post-monsoon 2022 compared to Post-monsoon 2023 (November 2022 to November 2023)

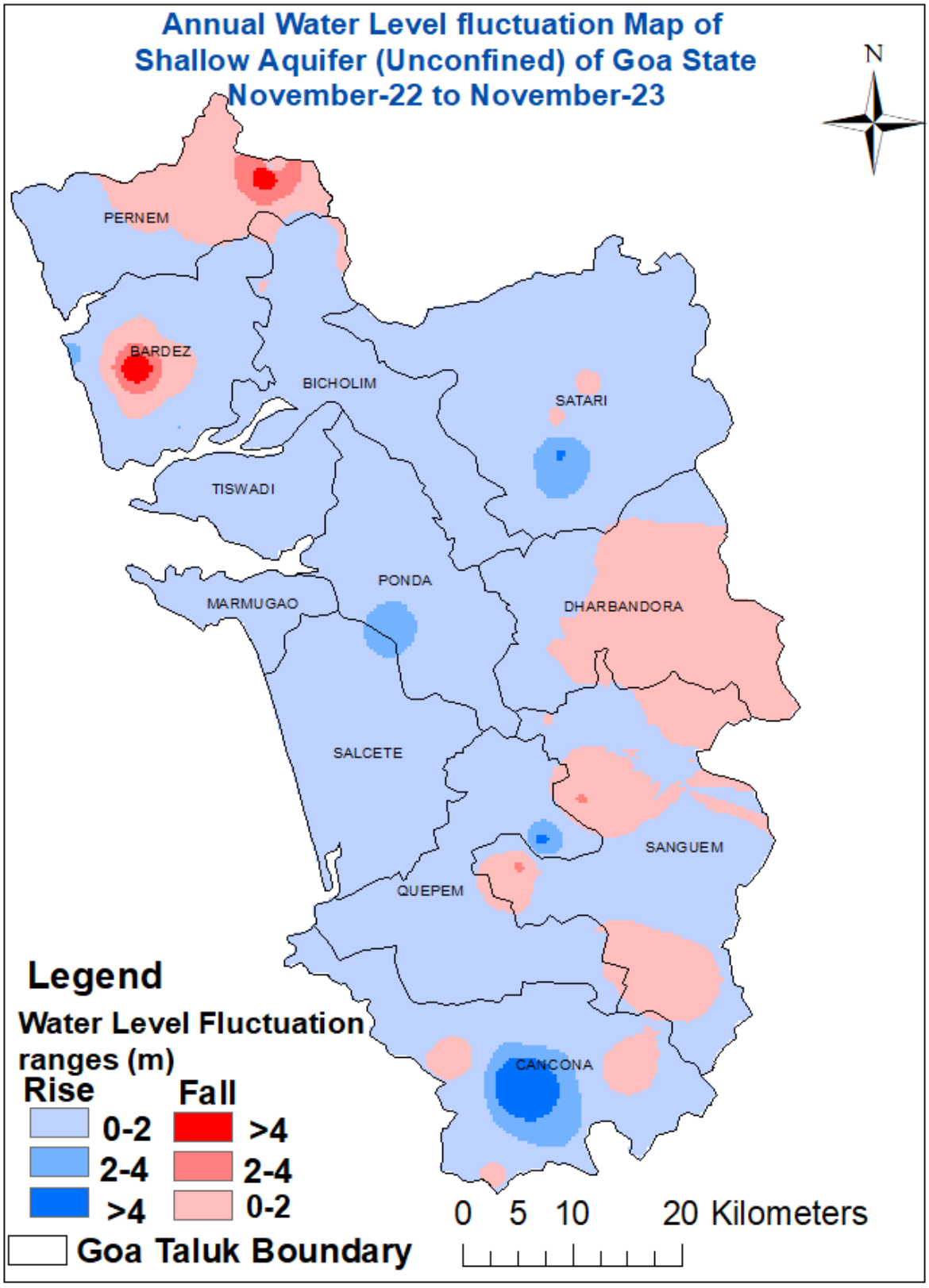


Fig 5.6: Decadal Water Level Fluctuation Map-Shallow Aquifer (May 2013- 2022 to May 2023)

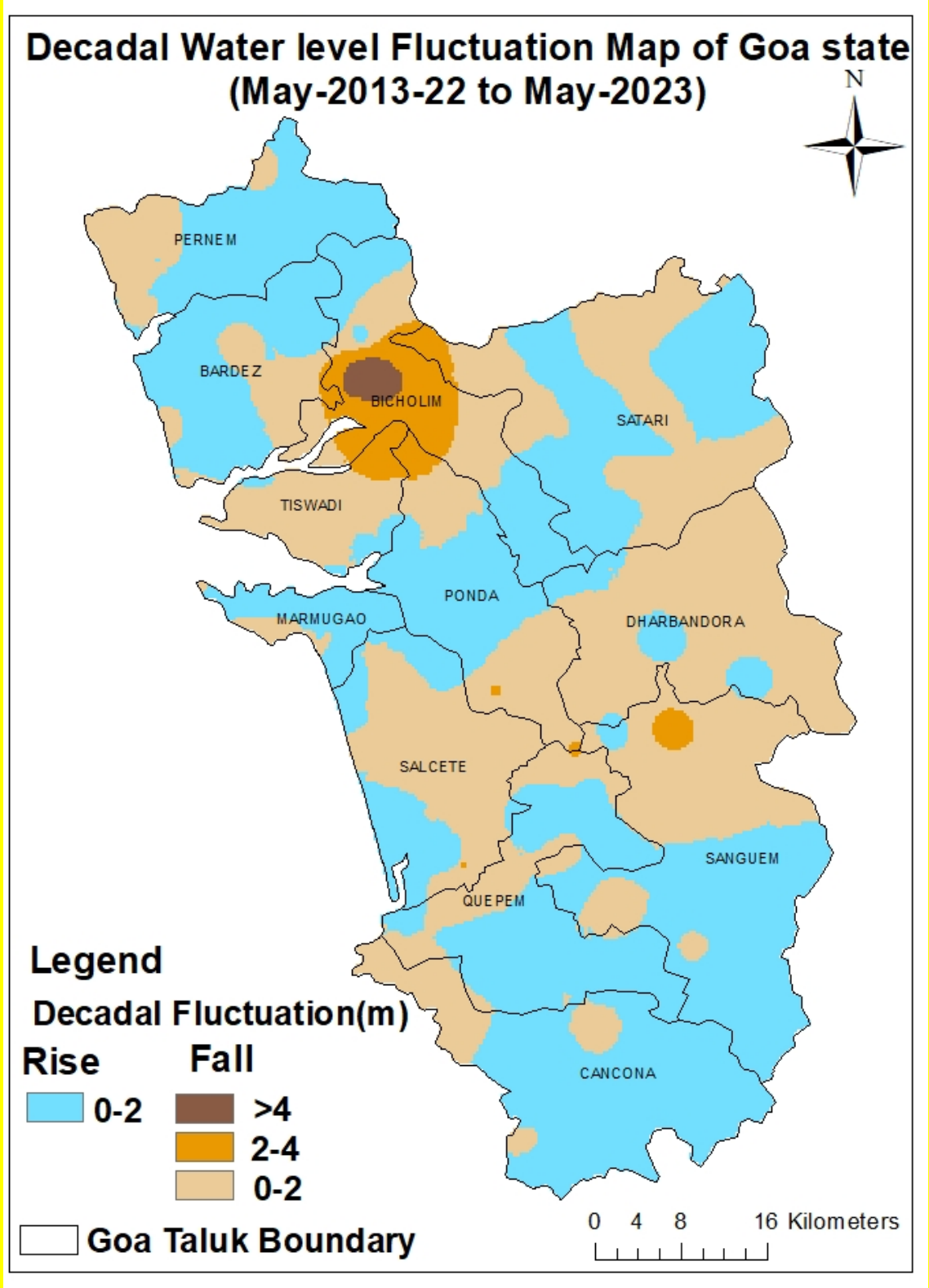
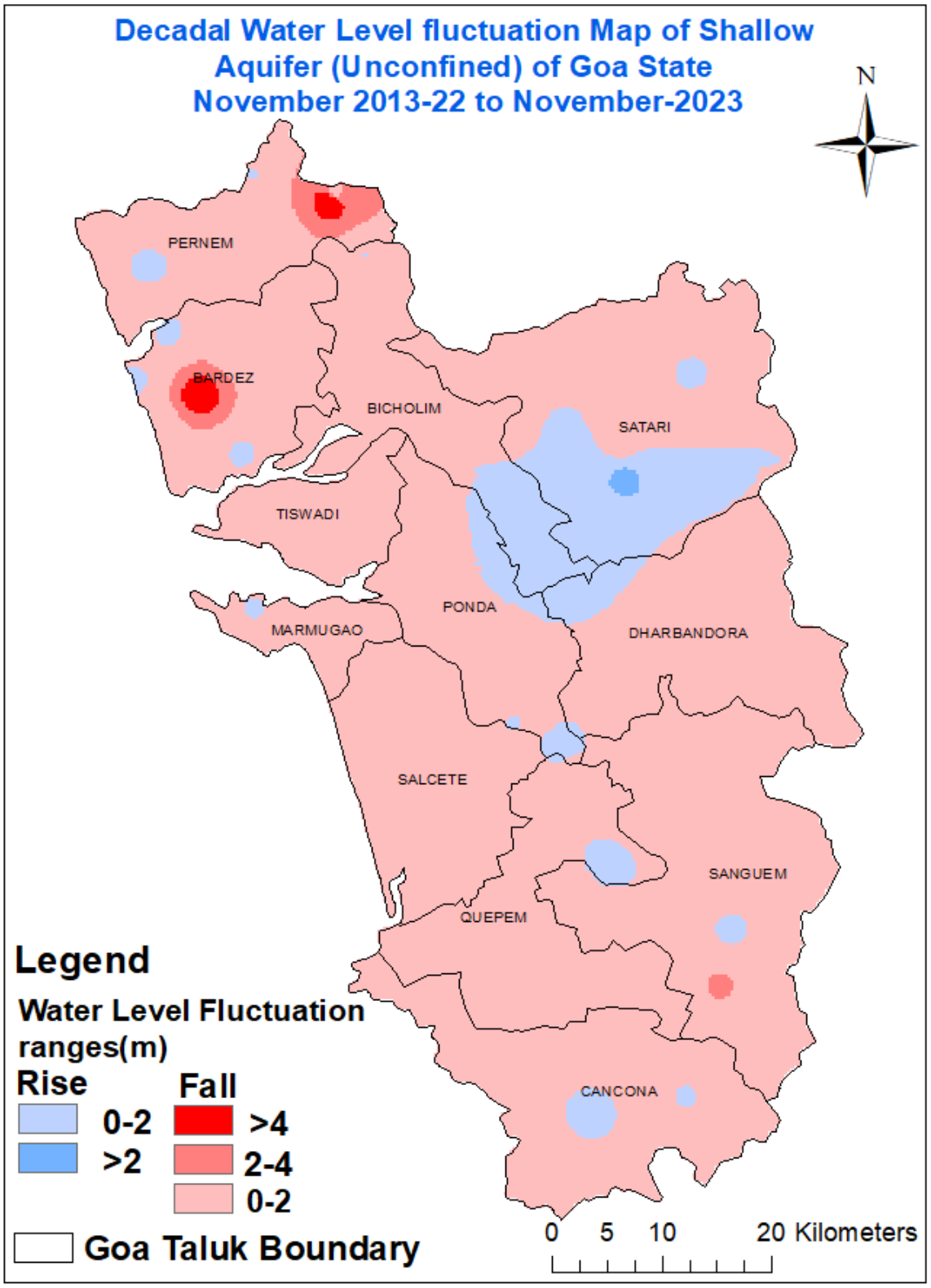


Fig 5.7: Decadal Water Level Fluctuation Map-Shallow Aquifer (November 2013- 2022 to November 2023)



CHAPTER 6

GROUND WATER RESOURCES OF THE STATE/UT

6.1.ANNUAL GROUND WATER RECHARGE

Recharge to ground water from different sources was computed based on the GEC 2015 methodology. As per assessment it was observed that the total recharge from all sources is 38495.88 ham and the recharge due to rainfall is the major contributor with 34665.56ham, followed by recharge due to return flow from surface water irrigation and recharge due to water conservation structures @ 1215.72 ham and 1079.4 ham. The recharge due to seepage from canals, return flow from ground water irrigation and tanks & ponds and is pegged at 746.35 ham, 585.19 ham and 203.66 ham respectively as shown in Fig.-6.1.

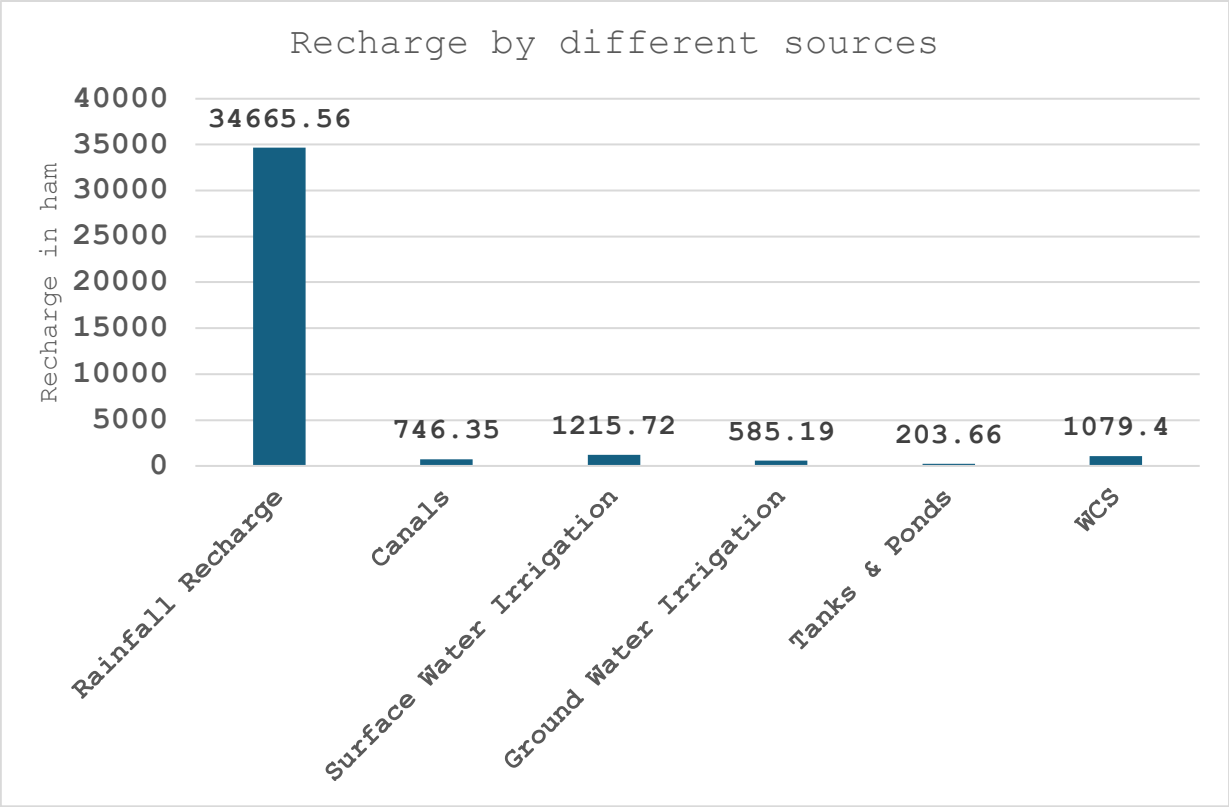


Fig.-6.1: Recharge by Different Sources

The taluk wise recharge is also presented in Fig.-6.2 and it indicates that maximum recharge is taking place in Salcete taluk (5538.09 ham) and minimum recharge is taking place in Dharbondara taluk (1630 ham). In all the districts, rainfall recharge is the major contributor. The assessment unit wise ground water resources 2024 (recharge component) is presented in Annexure-VA.

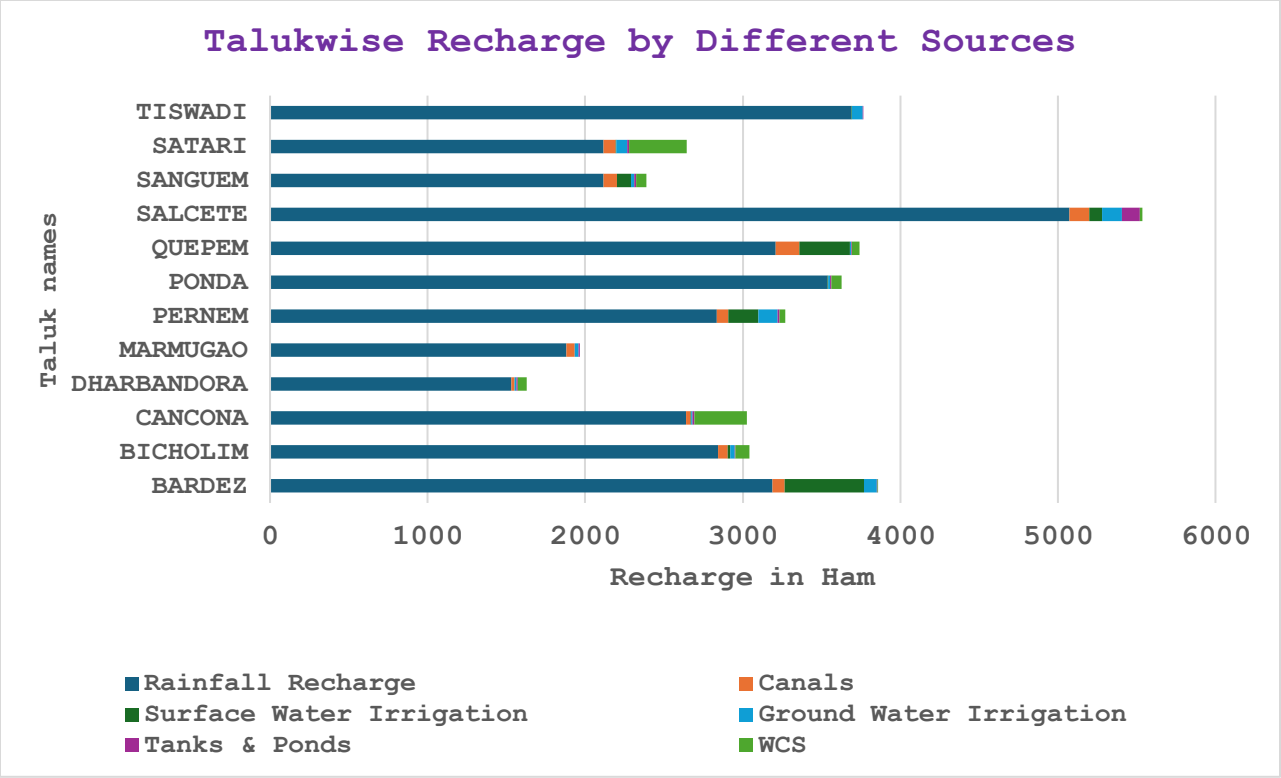


Fig.-6.2: Taluk Wise Recharge by Different Sources

6.2.ANNUAL EXTRACTABLE GROUND WATER RESOURCES

The entire quantum of ground water recharge cannot be considered for extraction since ecological commitments need to be fulfilled, before the extractable resources are defined. To cater to the ecological requirements, some percentage of ground water recharge is subtracted from annual ground water recharge based on the GEC 2015 guidelines. If the rainfall recharge is assessed using water level fluctuation method this will be 5% of the annual recharge and if it is assessed using rainfall infiltration factor method, it will be 10% of the annual recharge. The balance accounts for Annual Extractable Ground Water Resources (EGR). As per assessment data, the annual extractable ground water resources for the State are 30796.61 ham and it ranges from 1304.05ham at Dharbandora taluk to 4430.37 ham in Salcete taluk.

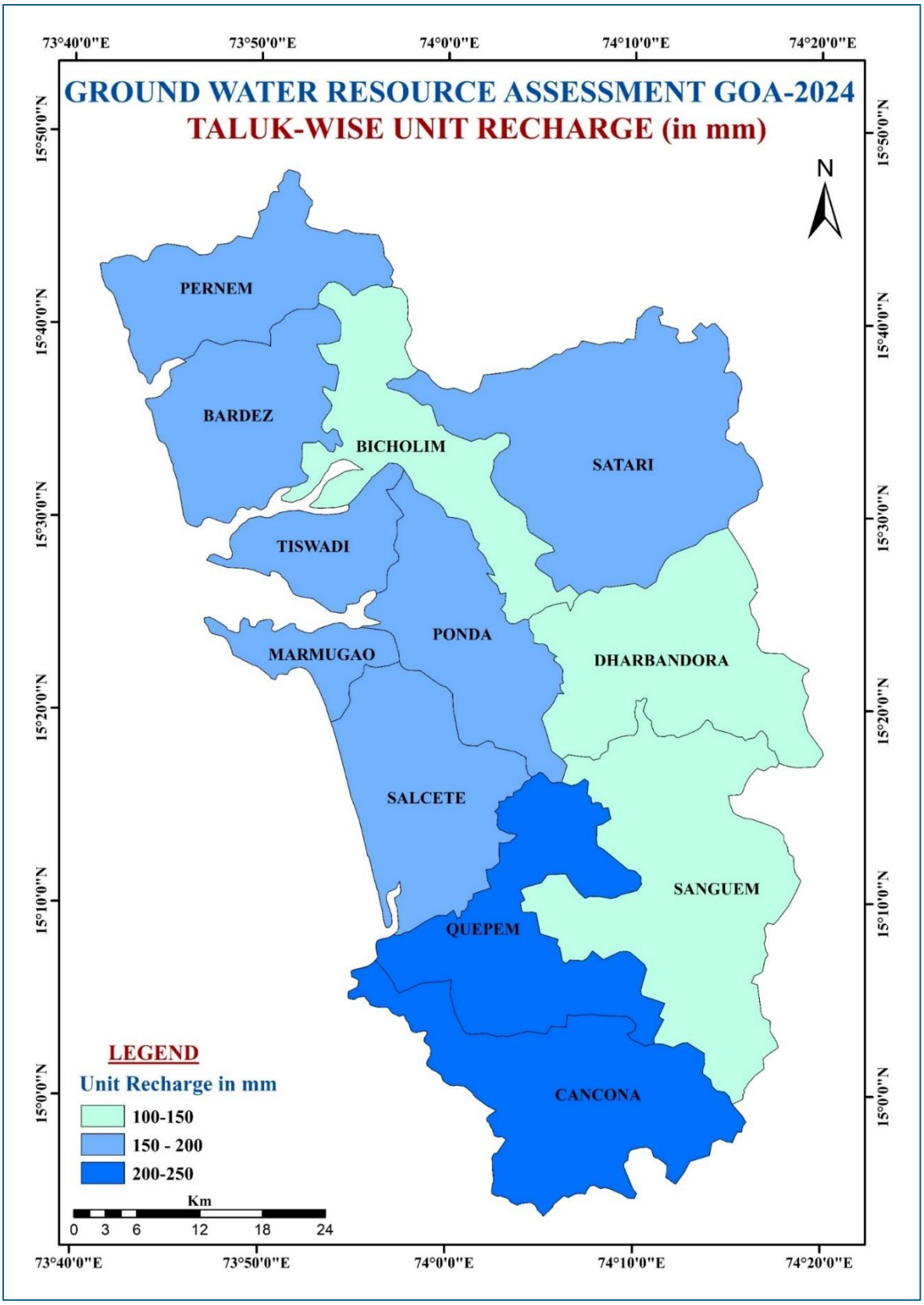


Plate 6.3:Taluk wise unit recharge in Goa

6.3.ANUAL TOTAL GROUND WATER EXTRACTION

The ground water extraction for various uses viz., irrigation, domestic and industrial has also been assessed as shown in **Fig.-6.4** and it indicates that major extraction about 56.3% is for domestic @ 3973.05 ham, whereas 36.87% is for irrigation @ 2602 ham and 6.83% for industrial purpose @ 481 ham. The assessment unit wise ground water resources 2024 is presented in ***Annexure-VI***.

The taluk wise ground water extraction for various uses has also been assessed as shown in **Fig.-6.5** and it indicated that ground water extraction for domestic, irrigation and industrial uses is highest in Salcete taluk, whereas it is lowest in Dharbandora taluk.

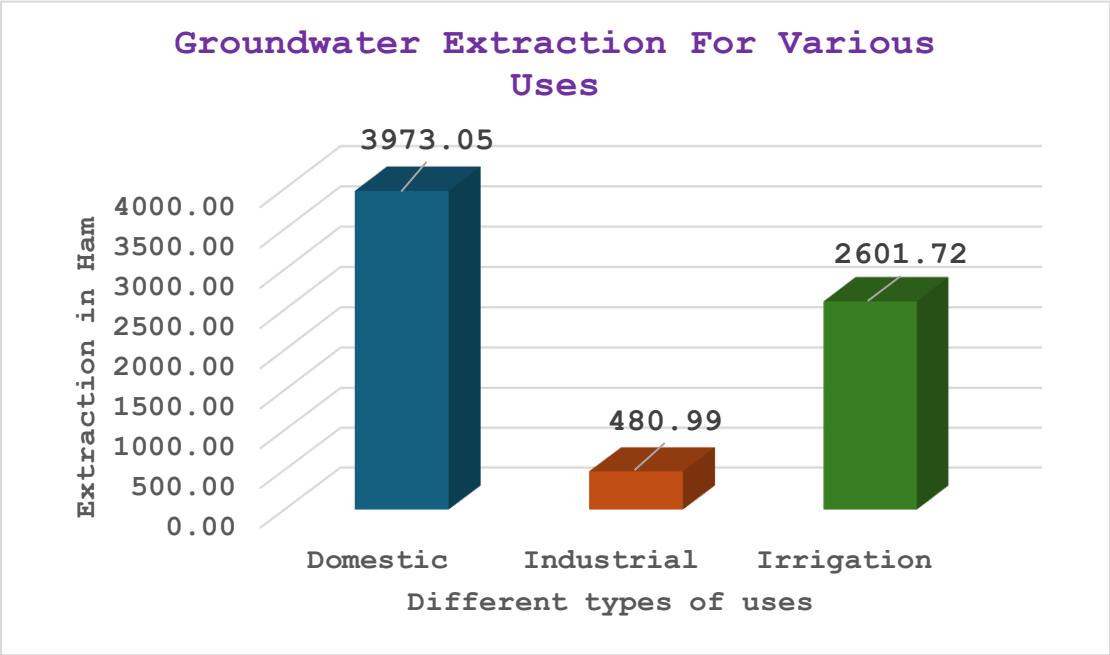
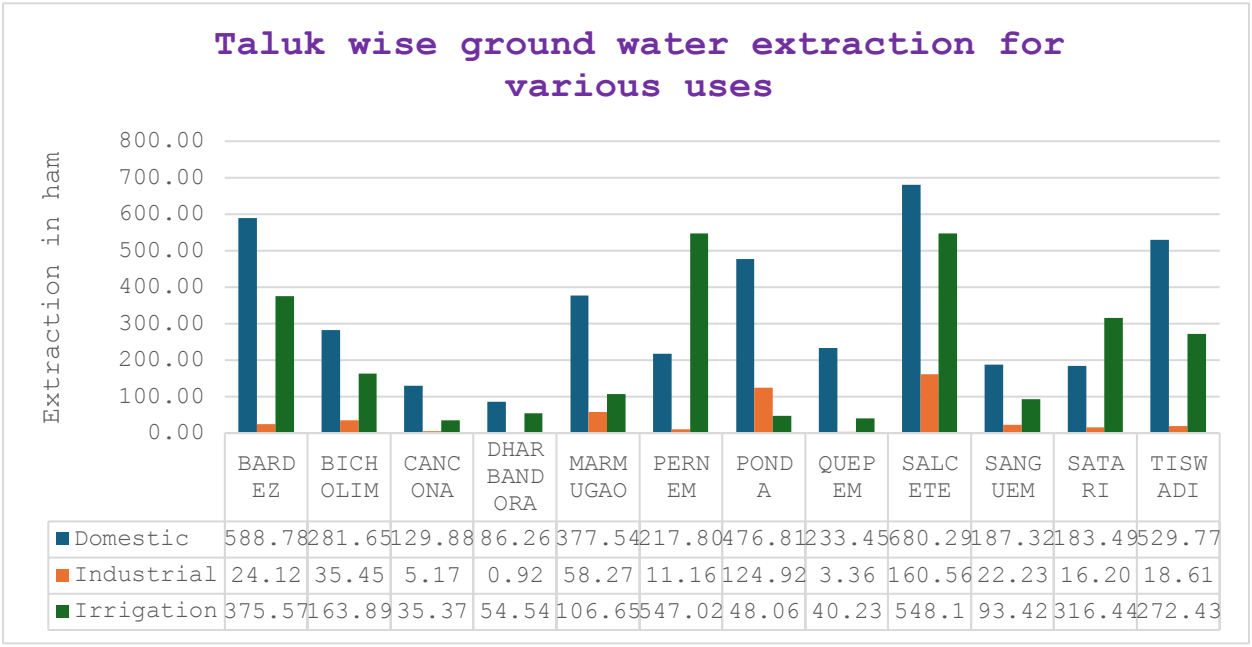


Fig.-6.4: Ground Water Extraction for Various Uses



	BARDEZ	BICHOLIM	CANCONA	DHARBANDORA	MARMUGAO	PERNEM	PONDA	QUEPEM	SALCETE	SANGUEM	SATARI	TISWADI
Domestic	588.78	281.65	129.88	86.26	377.54	217.80	476.81	233.45	680.29	187.32	183.49	529.77
Industrial	24.12	35.45	5.17	0.92	58.27	11.16	124.92	3.36	160.56	22.23	16.20	18.61
Irrigation	375.57	163.89	35.37	54.54	106.65	547.02	48.06	40.23	548.1	93.42	316.44	272.43

Fig.-6.5: Taluk Wise Ground Water Extraction for Various Uses

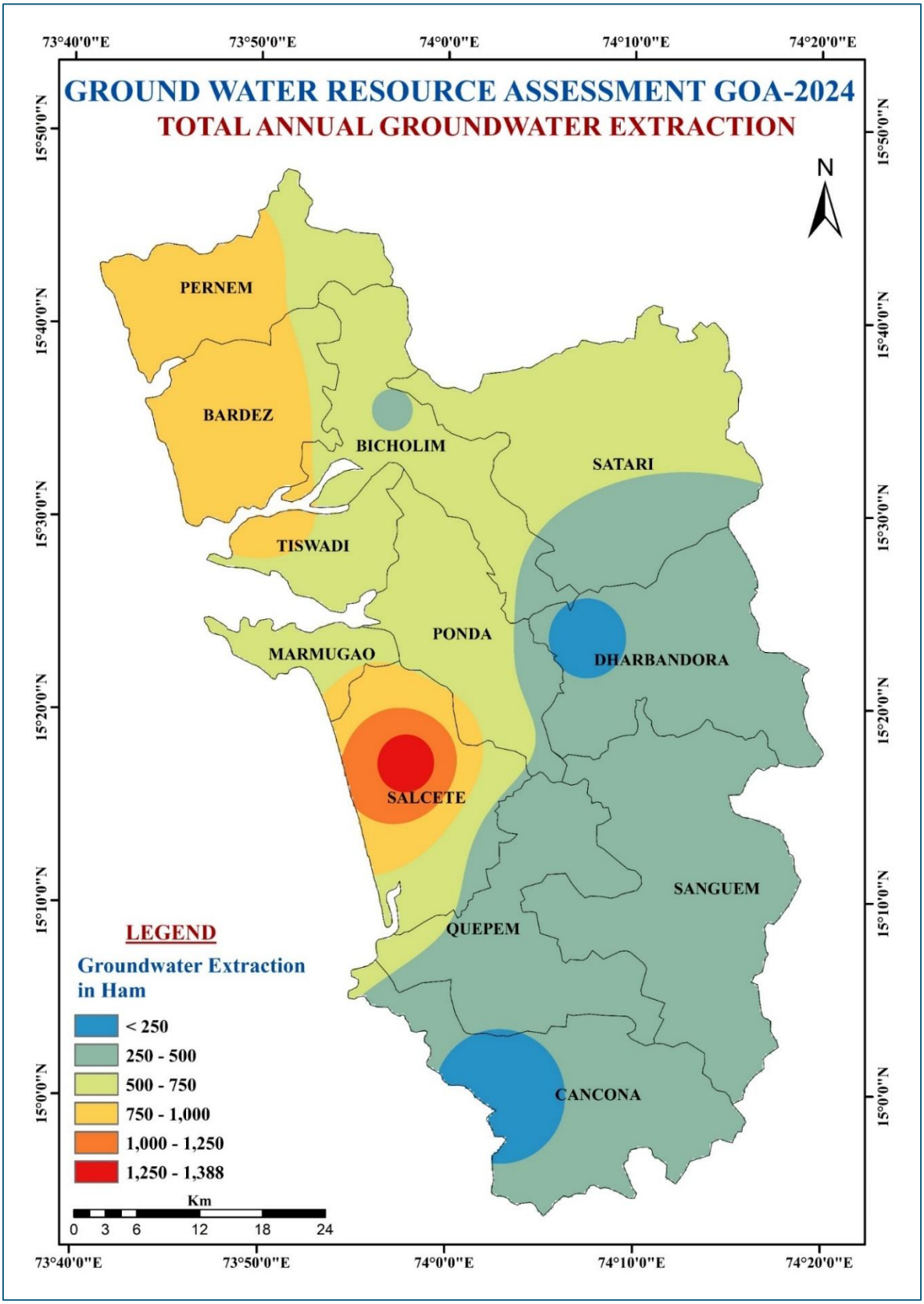


Fig 6.6:Total Annual Ground Water Extraction in Goa

6.4. STAGE OF GROUND WATER EXTRACTION

The total annual ground water recharge was 38495.88 ham and the total extraction was 7055.76ham. The recharge was maximum in Salcete taluk(5538.09 ham) and minimum in Dharbandora taluk(1630.06 ham). The extraction was also maximum in Salcete taluk(1388.94 ham) and minimum in Dharbandora taluk(141.73 ham). The stage of groundwater extraction of the state is 22.91%. The stage of groundwater extraction for North Goa district is 26.63% and that of South Goa district is 18.75%. Mormugao taluk,South Goa district has highest Stage of Extraction at 34.45%.Cancona taluk of South Goa district has the lowest Stage of Extraction at 7.04%.(Fig 6.7, 6.8)

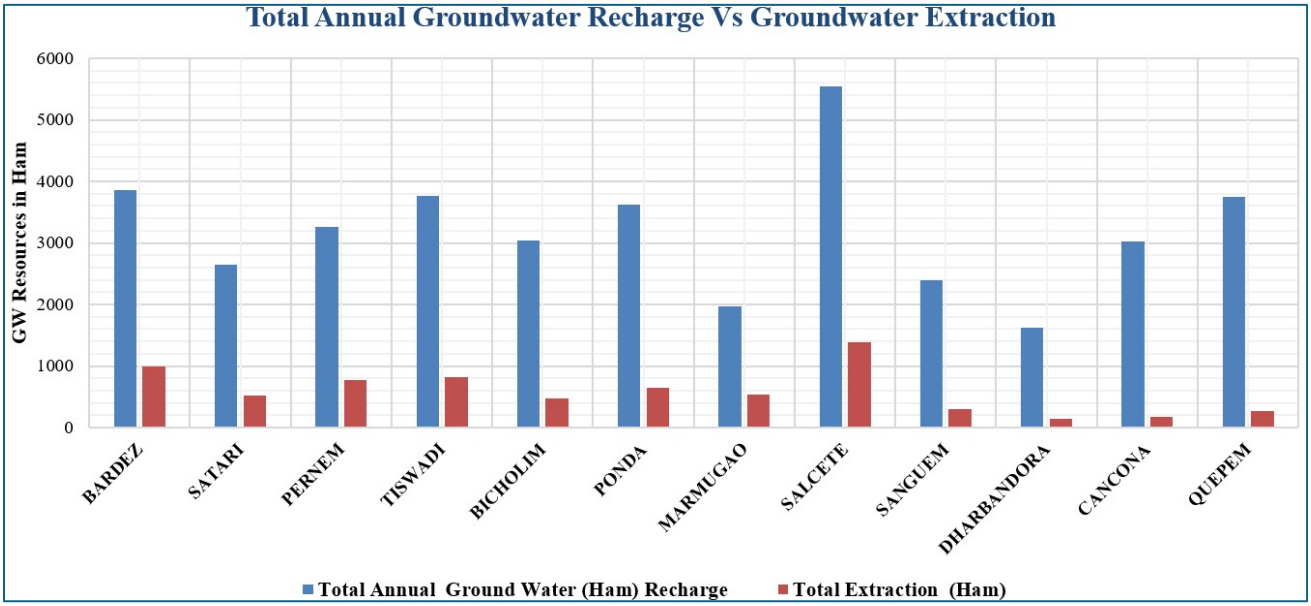


Fig.-6.7: Taluk Wise Total Annual GW Recharge vs Extraction

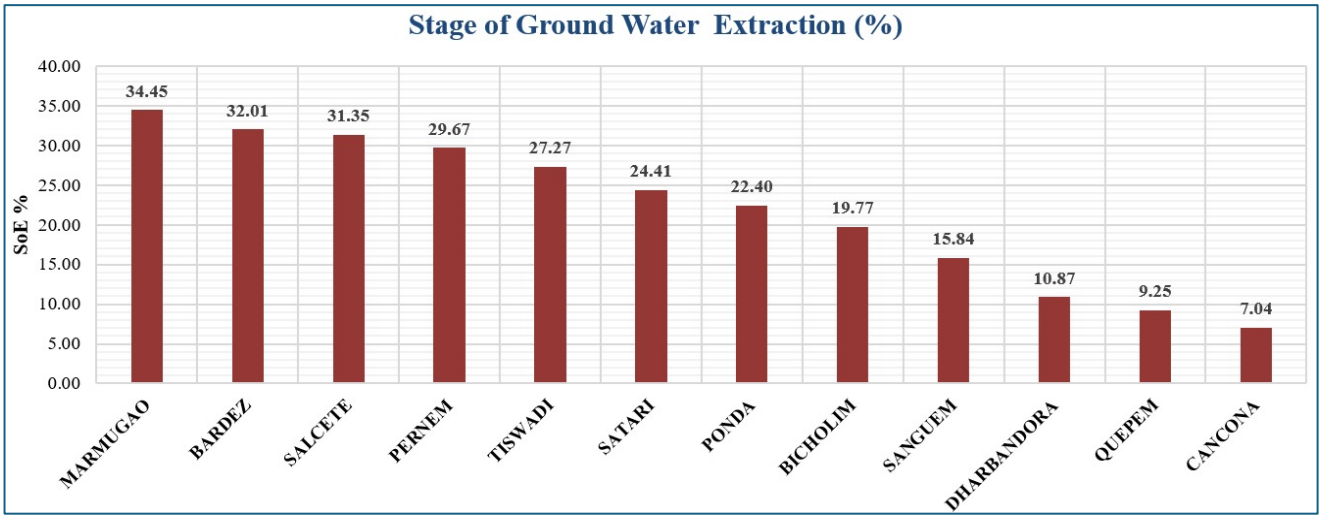
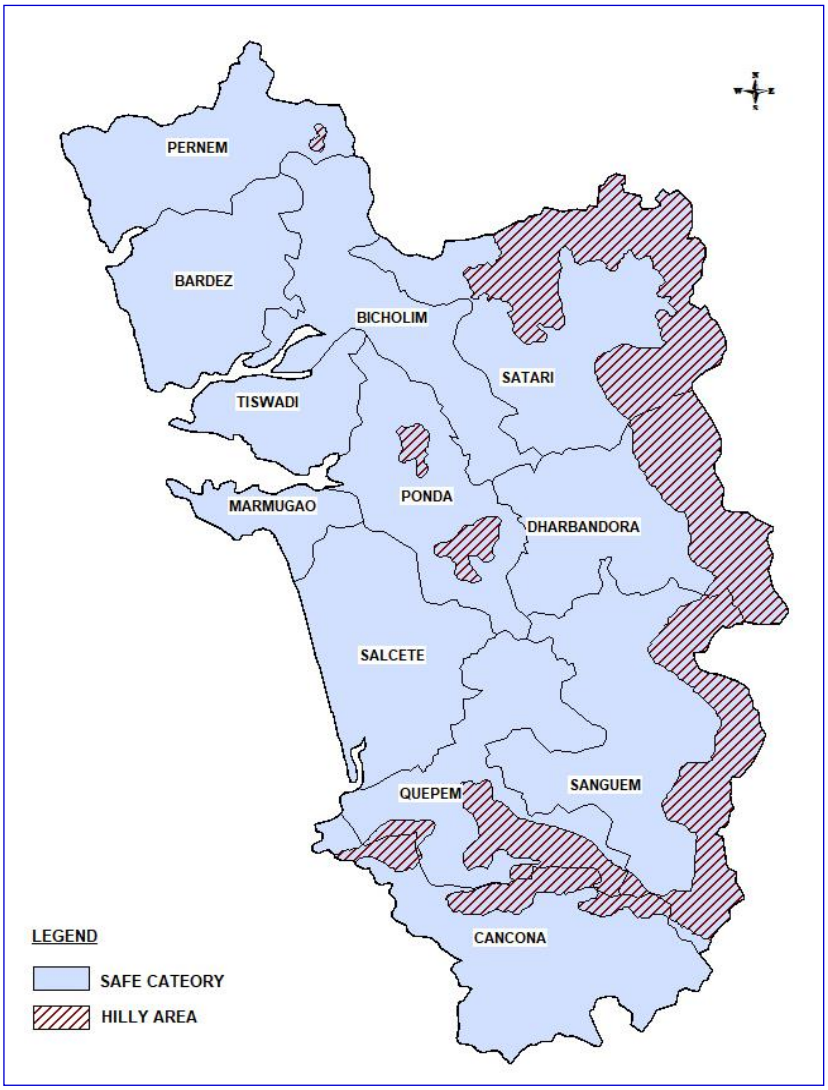


Fig.-6.8: Taluk Wise Stage of Ground Water Extraction in decreasing order

6.5. CATEGORIZATION OF ASSESSMENT UNITS

Fig.6.9: Taluk wise Categorization Map



The categorization of taluks is done as per the norms mentioned in GEC-2015 methodology. Based on these computations, it is observed that all 12 taluks are falling in Safe category. Taluka wise categorization is given in ***Annexure V B***. The categorization of taluks is also shown in **Fig.6.9.**

6.6. COMPARISON WITH PREVIOUS ASSESSMENT

As compared to 2023 assessment, the Total Annual Ground Water Recharge decreased from 0.40 bcm to 0.38 bcm and Annual Extractable Ground Water Resources decreased from 0.32 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 %.

CHAPTER 7

CONCLUSIONS

The groundwater estimation is carried out for 12 taluks of Goa State. As per the protocol the groundwater availability and use has been computed for the taluk wise assessment-units, and the categorization has been done for the Taluk. The State abstract showing details of Dynamic Groundwater Resources 2024 is given in **Table 7**.

As per the assessment, the total rechargeable fresh groundwater resources in the State are computed as 38495.88 ham and the Annual Extractable Ground Water Resource is to the tune of 30796.71ham. The Total Extraction is 7055.76 ham. The Stage of groundwater development for the State, as whole, is 22.91%.

Considering the domestic and industrial requirement the annual ground water allocation for domestic water supply as on March 2025 is 4112.62 ham. Leaving this allocation, the net groundwater availability for future use development is around 23601.4 ham. All the taluks had been categorized as Safe.

Table-7: Ground Water Resources – At a Glance

Description	**GWRA 2023**	**GWRA 2024**
Total No. of Assessment Units in the State	12	12
Rainfall Recharge	35950.82	34665.56
Recharge due to Other Sources	**3673**	**3830.34**
Annual Groundwater Recharge (ham)	39624.42	38495.88
Total Natural Discharges (ham)	7924.86	7699.17
Annual Extractable Ground Water Recharge (ham)	31699.56	30796.71
Groundwater Irrigation Extraction (ham)	2485	2601.72
Groundwater Extraction Domestic (ham)	3818.9	3973.05
Groundwater Extraction Industrial (ham)	472	480.99
Total Annual Extraction (Draft) (ham)	6775	7055.76
Allocation of Ground Water Resource for Domestic Utilization upto 2025 (ham)	4003	4112.62
Net Annual Ground Water Availability for Future Use (ham)	24740	23601.4
Stage of Ground Water Extraction (%)	21.37	22.91
Categorization	Safe	Safe
No. of Over Exploited / Critical / Semi Critical Assessment Units	Nil	Nil

Comparison with Earlier Assessments

Ground Water Recharge

Compared to 2023 there is decrease in annual ground water recharge from 39624.42 ham to 38495.88ham with decrease by 4%; recharge due to other sources has increased from 3673 ham to 3830.34 ham, with the increase of 4.3%; recharge due to return flow from ground water irrigation has increased 558 ham to 585.19 ham with an increase of 4.87%, whereas in case of recharge due to return flow from surface water irrigation has increased from 816 ham to 1215.72 ham with an increase of 49% as depicted in **Fig. 7.1**. The decrease in recharge due to rainfall may be attributed to deficit in rainfall in 2023 which has lead to increase in dependency on groundwater for irrigation. The recharge due to SWI has also increased by 75% due to constant effort made by State Government for surface water irrigation. The number of WCS structures remained the same as during 2022, they were constructed under the various water conservation schemes taken by State Govt., as well as de-silting of structures taken up by State Govt. under various district levels schemes including MGNREGA. The recharge input from Canals, Tanks & Ponds and Water Conservation Structures remained the same, as there is neither change in the number of structures nor in the length of canals.

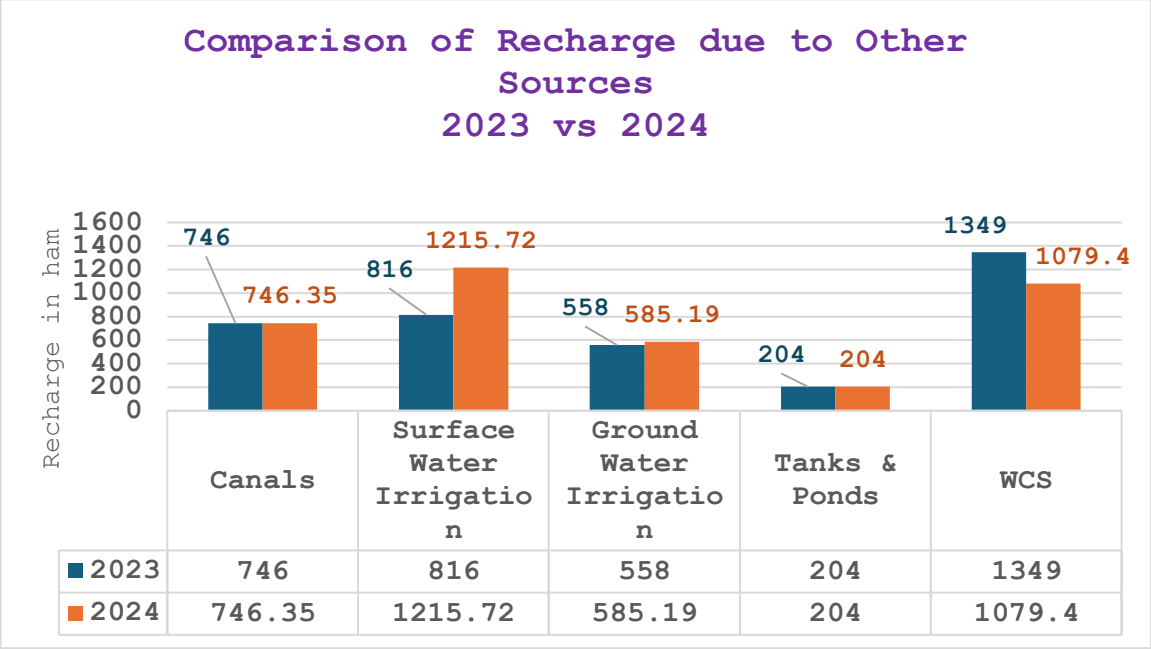


Fig.-7.1: Comparisonof Recharge due to Other Source (2023 and 2024).

The past good rainfall years supported by the development of new surface irrigation systems, and well functioning of water conservation structures, tanks & ponds has replenished the ground water in the non-monsoon period also. The initiatives taken up by the Govt. of Goa and community in developing and maintaining the water conservation structures, tanks & ponds, canal network is being reflected in the increased recharge due to other sources as compared to earlier assessment.

The comparison of historical recharge due to rainfall and other sources has also been carried out for the ground water resource assessments from 2011 to 2024 and is presented in **Fig. 7.2**. It indicates that the recharge due to rainfall has increased continuously from 16315 ham in 2011 to 35951 ham in

2023, with slight decrease in 2024 to 34665.6 ham. Recharge due to other sources has decreased from 7923 ham in 2011 to 3674 ham in 2023, with slight increase in 2024 to 3830.34ham.

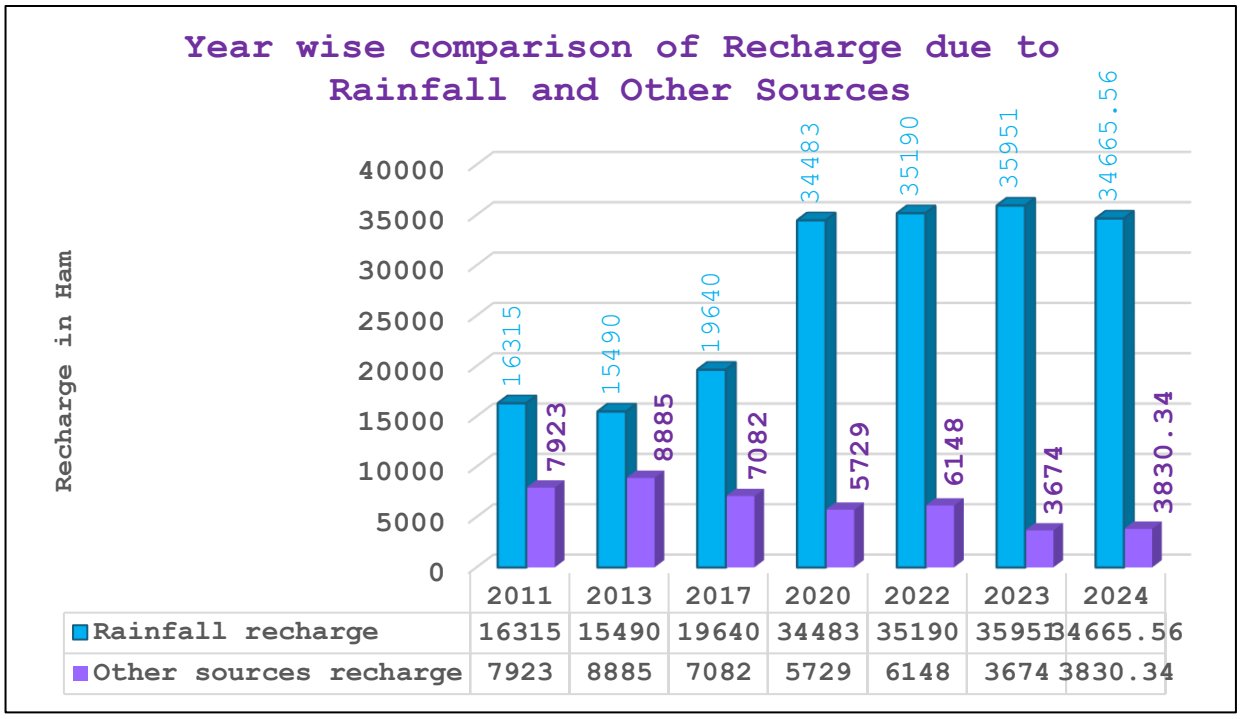


Fig.-7.2: Comparison of Recharge due to Rainfall and Other Sources (2011 to 2024)

Ground Water Extraction / Draft

The importance of ground water resource for domestic, irrigation and other purposes is critical as major share of these is met from ground water sources. A comparison of ground water extraction / draft since 2011 to 2024 presented in **Fig. 7.3** also re-iterates this fact. It indicates that extraction/draft has increased from 4114 ham in 2011 to 7055.76 ham in 2024 an increase of about 71.5% in last 13 years. This is probably due to increase in number of abstraction structures in the last decade or so.

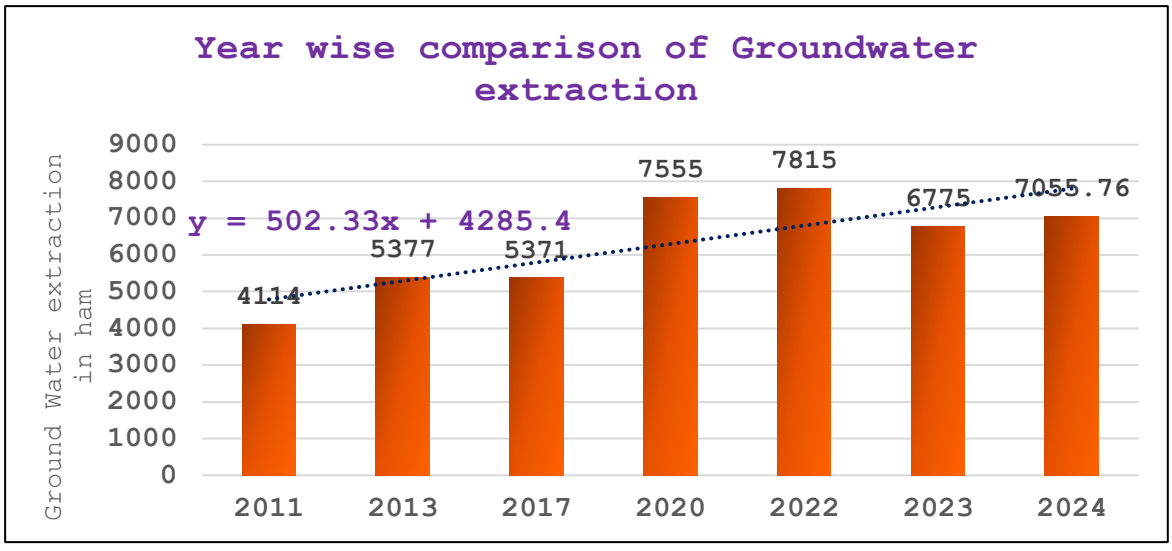


Fig.-7.3: Comparison of Ground Water Extraction (2011 to 2024)

Comparison of Ground Water Resources 2023 and 2024

The comparison of ground water resources for 2023 and 20234is also done and presented in **Table – 8**. It indicates that the rainfall recharge has decreased by 3.5%, whereas recharge due to other sources has increased by 4.3%. The total annual ground water extraction has increased by 1.54%.

Table – 8: Comparison of Ground Water Resource Assessment 2023 with 2024

Description	**GWRA 2023**	**GWRA 2024**	**Increase/ Decrease in %**
Total No. of Assessment Units in the State	12	12	No change
Rainfall Recharge	35950.82	34665.56	-3.5%
Recharge due to Other Sources	**3673**	**3830.34**	**4.3%**
Annual Groundwater Recharge (ham)	39624.42	38495.88	-2.84%
Total Natural Discharges (ham)	7924.86	7699.17	-2.84%
Annual Extractable Ground Water Recharge (ham)	31699.56	30796.71	-2.93%
Groundwater Irrigation Extraction (ham)	2485	2601.72	4.69%
Groundwater Extraction Domestic (ham)	3818.9	3973.05	4.04%
Groundwater Extraction Industrial (ham)	472	480.99	1.9%
Total Annual Extraction (Draft) (ham)	6775	7055.76	4.14%
Allocation of Ground Water Resource for Domestic Utilization upto 2025 (ham)	4003	4112.62	2.74%
Net Annual Ground Water Availability for Future Use (ham)	24740	23601.4	-4.6%
Stage of Ground Water Extraction (%)	21.37	22.91	1.54%
Categorization	Safe	Safe	No change
No. of Over Exploited / Critical / Semi Critical Assessment Units	Nil	Nil	No change

***

Annexure-I

Ground water resources availability, utilization and stage of extraction (as in 2024)

Sl. No	State	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization
1.	**GOA**	**30796.71**	**2601.72**	**480.9862**	**3973.045**	**7055.76**	**4112.62**	**23601.37**	**22.91**	**Safe**

Annexure-II

District-wise ground water resources availability, utilization and stage of extraction (as in 2024)

District	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (Over-Exploited/Critical/Semi-Critical/Safe/Saline)
NORTH GOA	13261.4	1675.35	105.5487	1801.485	3582.4	1864.76	9615.73	26.62511	safe
SOUTH GOA	17535.31	926.37	375.4375	2171.561	3473.36	2247.86	13985.64	18.74506	safe

Annexure-III(A)
Categorization of blocks/ mandals/ taluks in India (as in 2024) for Goa State

CATEGORIZATION OF BLOCKS/ MANDALS/ TALUKS IN INDIA (2024)												
S.No.	State/Union Territories	Total No. of Assessed Units	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
	States		Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%
1	GOA	12	12	100	-	-	-	-	-	-	-	-
	Total	12	12	100	-	-	-	-	-	-	-	-

Annexure III (B)
District Wise Categorization of blocks/ mandals/ taluks for Goa State (as in 2024)

GOA												
S.No	Name of District	Total No. of Assessed Units	Safe		SemiCritical		Critical		OverExploited		Saline	
			No.	%	No.	%	No.	%	No.	%	No.	%
1	GOA NORTH	5	5	100.0	-	-	-	-	-	-	-	-
2	SOUTH GOA	7	7	100.0	-	-	-	-	-	-	-	-
	Total	12	12	100.0	-	-	-	-	-	-	-	-

Annexure III (C)

Annual Extractable Ground Water Resource of Assessment Units under Different Category for the State/UT (as in 2024)

ANNUAL EXTRACTABLE RESOURCE OF ASSESSMENT UNITS UNDER DIFFERENT CATEGORIES IN GOA (2024)										
S.No.	State/Union Territories	Total Annual Extractable Resource of Assessed Units (in mcm)	Safe		Semi-Critical		Critical		Over-Exploited	
			Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%
1	GOA	307.97	307.97	100	-	-	-	-	-	-

Annexure- III (D)

District Wise Annual Extractable Ground Water Resource of Assessment Units under Different Category for the State/UT (as in 2024)

GOA										
S.No	Name of District	Total Annual Extractable Resource of Assessed Units (in Mcm)	Safe		Semi-Critical		Critical		Over-Exploited	
			Annual Extractable Resource (in Mcm)	%	Annual Extractable Resource (in Mcm)	%	Annual Extractable Resource (in Mcm)	%	Annual Extractable Resource (in Mcm)	%
1	GOA NORTH	132.61	132.61	100	-	-	-	-	-	-
2	SOUTH GOA	175.35	175.35	100	-	-	-	-	-	-
	Total	307.97	307.97	100	-	-	-	-	-	-
	Grand Total	307.97	307.97	100	-	-	-	-	-	-

Annexure- III (E)

Recharge Worthy Area of Assessment unit under Different Category for the State/UT (as in 2024)

AREA OF ASSESSMENT UNITS UNDER DIFFERENT CATEGORIES IN GOA (2024)												
S.No.	States/Union Territories	Total Recharge Worthy Area of Assessed Units (in sq.km)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			Recharge Worthy Area (in sq.km)	%	Recharge Worthy Area (in sq.km)	%	Recharge Worthy Area (in sq.km)	%	Recharge Worthy Area (in sq.km)	%	Recharge Worthy Area (in sq.km)	%
1	GOA	3701.98	2209.59	2209.59	100	-	-	-	-	-	-	-
	Total	3701.98	2209.59	2209.59	100	-	-	-	-	-	-	-

Annexure III (F)

District Wise Recharge Worthy Area of Assessment unit under Different Category for the State/UT (as in 2024)

GOA												
S.No	Name of District	Total Recharge Worthy Area of Assessed Units (in sq.km)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%
1	**GOA NORTH**	989.87	989.87	100.0	-	-	-	-	-	-	-	
2	**SOUTH GOA**	1219.72	1219.72	100.0	-	-	-	-	-	-	-	
	Total	2209.59	2209.59	100.0	-	-	-	-	-	-	-	

Annexure IV (A)
Categorization of Over Exploited, Critical and Semi Critical blocks/ mandals/ taluks (as in 2024)

GOA							
S. No	**Name of District**	**S. No**	**Name of Semi-Critical Assessment Units**	**S. No**	**Name of Critical Assessment Units**	**S. No**	**Name of Over-Exploited Assessment Units**

ABSTRACT			
Total No. of Assessed Units	**Number of Semicritical Assessment Units**	**Number of Critical Assessment Units**	**Number of Over Exploited Assessment Units**
12	0	0	0

Annexure IV (B)
Quality problems in Assessment units (as in 2024) : NIL

GOA							
S. No	**Name of District**	**S. No**	**Name of Assessment Units affected by Fluoride**	**S. No**	**Name of Assessment Units affected by Arsenic**	**S. No**	**Name of Assessment Units affected by Salinity**

ABSTRACT			
Total Number of Assessed Units	**Number of Assessment Units affected by Fluoride**	**Number of Assessment Units affected by Arsenic**	**Number of Assessment Units affected by Salinity**
0	0	0	0

Annexure IV (C)
List of Saline Assessment units
NIL

Annexure V (A)
Summary of Assessment units improved or deteriorated from 2023 to 2024 assessment

State-Wise Summary OfAssessmet Units Improved Or Deteriorated From 2024 To 2023 Assessment							
S. No.	**Name of States / Union Territories**	**Total Number of Asssessed Units**	**Number of Assessment Units Improved**	**Number of Assessment Units Deteriorated**	**Number of Assessment Units With No Change**	**Number of Assessment Units Newly formed or Previous Assessment Units Reorganized**	**Remarks**
1	**GOA**	**12**	0	0	12	0	

Annexure V (B)
Comparison of categorization of assessment units (2023 to 2024)

There is no change in categorization.

Annexure VI
Assessment Unit Wise Report (Attribute Table)

Sl. No	State	District	Assessment Unit Name	Assessment Unit Type	Total Area of Assessment Unit (Ha)	Recharge Worthy Area(Ha)	Recharge from Rainfall-Monsoon Season	Recharge from Other Sources-Monsoon Season	Recharge from Rainfall-Non Monsoon Season	Recharge from Other Sources-Non Monsoon Season	Total Annual Ground Water (Ham) Recharge	Total Natural Disharges (Ham)	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (Over-Exploited/ Critical/Semi-Critical/Safe/Saline)
1	GOA	GOA NORTH	BARDEZ	TALUK	26400	23211	3189.4	5.48	0	665.31	3860.19	772.04	3088.15	375.57	24.12	588.78	988.47	609.46	2079	32.01	safe
2	GOA	GOA NORTH	SATARI	TALUK	49510	16580	2116.9	189.78	0	336.22	2642.9	528.58	2114.32	316.44	16.20	183.49	516.13	189.94	1591.74	24.41	safe
3	GOA	GOA NORTH	PERNEM	TALUK	25170	18920	2834.87	25.34	0	408.55	3268.76	653.75	2615.01	547.02	11.16	217.80	775.99	225.44	1831.38	29.67	safe
4	GOA	GOA NORTH	TISWADI	TALUK	21350	19395	3689.54	0.86	0	72.57	3762.97	752.59	3010.38	272.43	18.61	529.77	820.81	548.38	2170.96	27.27	safe
5	GOA	GOA NORTH	BICHOLIM	TALUK	23880	20881	2843.4	46.67	0	151.86	3041.93	608.39	2433.54	163.89	35.45	281.65	481	291.54	1942.65	19.77	safe
		NORTH GOA			**146310**	**98987**	**14674.1**	**268.13**	**0**	**1634.51**	**16576.8**	**3315.35**	**13261.4**	**1675.35**	**105.55**	**1801.48**	**3582.4**	**1864.76**	**9615.73**	**26.63**	safe
6	GOA	SOUTH GOA	PONDA	TALUK	29280	23711	3536.92	5.18	0	83.74	3625.84	725.17	2900.67	48.06	124.92	476.81	649.79	493.56	2234.13	22.40	safe
7	GOA	SOUTH GOA	MARMUGAO	TALUK	10912	10743	1880.36	4.75	0	82.89	1968	393.59	1574.41	106.65	58.27	377.54	542.45	390.81	1018.69	34.45	safe
8	GOA	SOUTH GOA	SALCETE	TALUK	29294	27735	5074.35	126.7	0	337.04	5538.09	1107.62	4430.47	548.1	160.56	680.29	1388.94	704.2	3017.62	31.35	safe
9	GOA	SOUTH GOA	SANGUEM	TALUK	50677.5	16492	2115.42	57.65	0	217.22	2390.29	478.06	1912.23	93.42	22.23	187.32	302.98	193.9	1602.67	15.84	safe
10	GOA	SOUTH GOA	DHARBANDORA	TALUK	36697.2	11942	1532.75	13.29	0	84.02	1630.06	326.01	1304.05	54.54	0.92	86.26	141.73	89.29	1159.29	10.87	safe
11	GOA	SOUTH GOA	CANCONA	TALUK	35202	14016	2641.9	186.68	0	196.49	3025.07	605.02	2420.05	35.37	5.17	129.88	170.43	134.44	2245.06	7.04	safe
12	GOA	SOUTH GOA	QUEPEM	TALUK	31825	17333	3044.35	41.33	165.4	490.7	3741.78	748.35	2993.43	40.23	3.36	233.45	277.04	241.66	2708.18	9.25	safe
		SOUTH GOA			**223888**	**121972**	**19826.1**	**435.58**	**165.4**	**1492.1**	**21919.1**	**4383.82**	**17535.3**	**926.37**	**375.44**	**2171.56**	**3473.36**	**2247.86**	**13985.6**	**18.75**	**safe**
		STATE TOTAL			**370197.7**	**220959**	**34500.16**	**703.71**	**165.4**	**3126.61**	**38495.88**	**7699.17**	**30796.71**	**2601.72**	**480.99**	**3973.05**	**7055.76**	**4112.62**	**23601.37**	**22.90**	SAFE

Annexure VII (A)
Minutes of the 1st Meeting of the SLC

OFFICE OF THE CHIEF ENGINEER
WATER RESOURCES DEPARTMENT,
SINCHAYI BHAVAN,
ALTO – PORVORIM, GOA

No: EO /CE (WRD)/F.9/3 /2024-25/292. Date: 27/08/2024.

REPORT

Sub: Minutes of the 1st State Level Committee for Ground Water Resources Assessment (GWRA) 2024 of Goa State reg.

With reference to above, meeting of the 1st State Level Committee for Ground Water Resources Assessment (GWRA) 2024 of Goa State was held on 29/4/2024 at 11.00 AM in the conference hall of CE(WRD), Sinchayi Bhavan, Porvorim. Draft Minutes of the meeting placed at page 2/c to 5/c.

As per the Order No. 4/9/CE-CPO-WRD/2023-24/31 dated 13/4/2023, Secretary , Water Resources is the Chairman of the State Level Committee for Dynamic Ground Water Resources Assessment (GWRA). Copy placed at 1/c.

In view of the above, Draft Minutes of the Ground Water Resources Assessment Committee meeting are put up for approval of Secretary , Water Resources.

Submitted please.

(Anagha Kulkarni)
Assistant Surveyor of Works

Engineering Officer (WRD)

Chief Engineer, WRD

Secretary (WR)

MINUTES OF THE 1ST STATE LEVEL COMMITTEE FOR GROUND WATER RESOURCES ASSESSMENT (GWRA) – 2024 OF GOA STATE

The meeting of the 1st State level Committee (SLC) for Ground Water Resources Assessment - 2024 of Goa State was held on **29.04.2024** at 11.00 hrs in the Conference Hall near Chief Engineer's room, 2nd Floor, Sinchai Bhavan, Alto-Porvorim, Water Resource Department, Govt. of Goa. State Level committee headed by the Shri. Subhash Chandra IAS, Secretary, Water Resources Department, Porvorim, Goa was constituted by the Government of Goa vide Government Order No. 4/9/CE-CPO-WRD/2023-24/31 (WRD) dated 13.04.2023. The meeting was attended by various committee members or their representatives as per the attached list.

Shri N. Jyothi Kumar, Regional Director, CGWB, SWR, Bangalore & Member Secretary, welcomed the Chairman, Members, and Invitees to the 1st State Level Committee Meeting. He highlighted the NAQUIM 2.0 study undertaken during the AAP-2024-25 at a micro-scale to address groundwater issues, specifically coastal salinity in Bardez & Tiswadi Taluks of North Goa District and highlighted about the Special study on coastal salinity to be taken up for the annual action Plan of 2024-25 and requested for all logistics support from WRD for NOC for site selection for groundwater exploration, complete list of bore wells where NOC where issued by WRD and also permission for isotope sampling from the maintained rain gauge stations . Shri Pramod B. Badami, Chief Engineer, WRD, Goa assured that he will provide all possible cooperation in this regard. He emphasized the importance of Ground Water Resources Assessment (GWRA) in predicting scenarios over smaller time intervals. GWRA is a time-bound process that is reassessed every two years following the GEC-2015 methodology and all data entry needs to be filled in ingress software within the specified time frame.

Shri Pramod B. Badami, Chief Engineer, WRD, Goa welcomed all the members and informed that Ground Water Resources Assessment should reflect the improvement in resources due to various recharge and water conservation works taken up by the State Govt. He stressed that although the resource assessment is an estimation based on norms, it should reflect the actual groundwater situation prevalent in the state. He requested the committee members to expedite the data collection process. Sri D.Y. Salelkar, ACE, WRD emphasized the importance of monitoring groundwater levels, quality, and usage patterns to inform policy decisions and conservation efforts. Proper assessment can help prevent over-extraction, contamination, and can support the long-term availability of clean water for various needs in Goa.

Smt. Sangita P. Bhattacharjee, Scientist-D & OIC, CGWB, SUO, Belagavi delivered a presentation on the "Dynamic Groundwater Resources of Goa-2023," highlighting current groundwater availability, utilization patterns, challenges such as over-extraction and contamination, and sustainable practices with recharge plans. She outlined the methodology (GEC-2015) and focus areas for the upcoming Ground Water Resource Assessment – 2024 emphasizing data collection, stakeholder involvement, and policy recommendations. The presentation underscored the importance of sustainable groundwater management to ensure long-term water security in Goa. Groundwater assessment is vital for sustainable water resource management, ensuring that the region's water needs are met without depleting this essential resource.

Based on the agenda and discussions held during the meeting, following decisions were taken.

1. **Finalisation of assessment units** - Regarding the finalisation of the assessment units, it is decided by the committee to consider the 12 taluks as assessment units, with no change in the shape files of the same, for the Groundwater Resource assessment of 2024.

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2. **Data requirement from various Agencies/Departments** – As per the timelines, the committee was of the opinion that the data compilation was to be completed by 30th April 2024. However, the same is yet to be completed, thus the WRD will direct its field/district level offices to fast track the data collection and compilation from concerned State Govt. Offices by 31St July/2024. Data of Irrigation wells is to be refined and the updated data, which is to be provided from WRD. The concerned State Govt. Departments especially Minor Irrigation, Agriculture, RWS will provide information to WRD officials on priority. On a query of data sharing and dissemination by Smt. Sangita P. Bhattacharjee, Scientist-D & OIC, CGWB, SUO, Belagavi, **he assured to share the rainfall data of the rain gauge stations and also water level of Piezometer and dug wells monitored by WRD under HP II to CGWB at the earliest. (Action: WRD)**

3. **Industrial Data -** Ground water draft data based on the actual number of wells and industries which have been granted NOC by WRD will be considered for resource estimation. The flow-meter data is required for calculation of precise draft. **The WRD will provide the data regarding the same in the desired format. (Action: WRD)**

4. **Timelines to be followed –** The representatives of CGWB & WRD stressed to follow the timelines for GWRA and requested all the line departments to provide the necessary data for the same. They also stressed on the pro-active role to be adopted by WRD and CGWB for its timely completion. It was decided that the data compilation/ collection sheets will be completed by 30.07.2024 by WRD and submitted to CGWB for future computation in INGRES software**. (Action: All members of GWRA of Goa)**

5. **Inclusion of member in the GWRA committee-** During the meeting it was discussed that as Forest department is having lots of data related to resource estimation , it was jointly agreed **to incorporate Forest Department, Government of Goa to include as a member in the committee of GWRA of Goa. (Action: WRD)**

6. **Any other item** – Nil.

The meeting ended with thanks to the Chair proposed by Smt. Veena Achutha, Scientist-D (GP), CGWB, SWR, Bangalore.

(Pramod B. Badami)
Chief Engineer,
Water Resource Department
Goa

Members attending the 1st State Level Committee (SLC) Meeting for Ground Water Resource Assessment (GWRA) for Goa State - 2024
on 29.04.2024 in Conference Hall of WRD, Sinchai Bhavan, Porvorim, Goa

क्र.सं./ Sl. No.	नाम/Name	पदनाम /Designation	विभाग/Department	संपर्क नंबर / Contact No.	ईमेल आईडी/ Email ID	हस्ताक्षर/ Signature
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2	Jyothi Kumar Nalli	Regional Director	CGWB	9717449044	rdswr-cgwb@nic.in	
3	Sangita P B.	Sc-B & OIC (SUO)	CGWB	7760574855	oicbelgaum-cgwb@nic.in	
4	Veena R. Achutha	Sc-B	CGWB	9945197123	Veena.achutha-cgwb@gov.in	
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6	AJAY KUDCHADKER	S.W. (CCPO)	WRD	9850533750	"	
7	Nasreen [illegible]	[illegible]	WRD	98230[illegible]		
8	Sujay Shirodkar	Agriculture Officer (NEW)	Directorate of Agriculture	942331465?	dydirhort-agri.goa@nic.in	
9	Sandeep Fal Dessai	Dy Director Agriculture	Directorate of Agriculture	98[illegible]060	dyagriextn-agri.goa@nic.in	

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क्र.सं./ Sl. No.	नाम/Name	पदनाम /Designation	विभाग/Department	संपर्क नंबर / Contact No.	ईमेल आईडी/ Email ID	हस्ताक्षर/ Signature
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12	Dr. V. KUNHAMBU	Senior Ground Water Consultant	NHP (CPMU) WRD	[illegible]	[illegible]	
3	Pratik Gholap	NHP, WRD Asst. Manager	NABARD	9096054745	panaji@nabard.org	
	M. N. Narasimha Naidu	Sc-B (HP)	CGWB	9705917666	mnnaidu3.kb@karnataka.gov.in	
	Sri. P. B. Badami	CE, WRD, Goa	WRD	942206806?	pramod.badami@gmail.com	

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Sinchai Bhawan, Near Police Station, Alto-Porvorim, Bardez, Goa – 403 521
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No. 4/ 9/CE-CPO-WRD/2023-24/31 Date: -13/04/2023

ORDER

Sub: Constitution of State Level Committee for Assessment of Dynamic Ground Water Resources of Goa

Government is pleased to constitute Permanent State Level Committee for Assessment of Dynamic Ground Water Resources for the state Goa which is being studied jointly by Central Ground Water Board and Water Resources Department Goa.

The committee shall comprise of following members:

1.	Secretary, Water Resources	Chairman
2.	Chief Engineer, Water Resources Department	Member
3.	Chief Engineer, Water supply & sanitation Dept.)PHE	Member
4.	Director, Department of Agriculture	Member
5.	Director, Department of Industries	Member
6.	Director, Department of Planning, Statistics & Evaluation	Member
7.	General Manager NABARD	Member
8.	Superintending Engineer, CPO,WRD	Member
9.	Superintending Engineer, Circle I, WRD	Member
10.	Sr. Hydrogeologist, WRD	Member
11.	Regional Director, CGWB, Bangalore	Member Secretary

The committee may co-opt any other member(s)/ special invitee(s), if necessary and the terms of the reference of the committee will be to review the dynamic ground water resources study reports prepared by CGWB and WRD.

The committee shall meet regularly to guide and suggest the CGWB and WRD for preparation of annual report on Dynamic Ground Water Resources, which will be submitted to the government for its approval.

Expenditure on account of TA/DA to the official members of the committee will be met from the source from which their salaries are drawn and that of non

Annexure VII (B)
Minutes of the2nd Meeting of the SLC

3/c

MINUTES OF THE 2nd STATE LEVEL COMMITTEE FOR GROUND WATER RESOURCES ASSESSMENT – 2024 OF GOA STATE HELD ON 24.09.2024

The 2nd meeting of the State Level Committee (SLC) for Ground Water Resources Assessment - 2024 of Goa State was held in Online mode on 24.09.2024 at 15.00 hrs.

Shri Pramod B. Badami, Chief Engineer, WRD, Member of SLC, chaired the meeting. The meeting was convened to discuss the results and findings of GWRA 2024 and to approve the GWRA 2024. The meeting was attended by various committee members of the State Level Committee (SLC) on Dynamic Groundwater Resources of Goa and officers from Groundwater Cell.

Shri Rahul R. Shende, Scientist-D at CGWB, SWR, Bengaluru, extended a warm welcome to the Chairman, members, and invitees at the State Level Committee Meeting. He provided a concise overview of the various resource estimation activities undertaken by different departments and presented the broader context of these efforts within India. He commended the GWRA Cell, Water Resource Department, and other related departments for their diligent efforts in supplying the necessary data on time for the resource assessment, which made it possible to complete the GWRA 2024 within the stipulated timeline set by the Ministry of Jal Shakti, Government of India.

Smt. Sangita P. Bhattacharjee, Scientist-D and Officer-in-Charge of CGWB, SUO, Belagavi, presented the findings and results of the GWRA 2024. She informed the committee that Goa's water resources were assessed at the Taluka level, further subdivided into Command and Non-command units. Through her presentation, she explained the various recharge components and extraction data utilized for GWRA 2024. She provided detailed insights into the different recharge and draft components estimated along with the Taluka-wise results. According to the assessment, rainfall recharge (34,665.56 Ham) is the primary source of groundwater replenishment followed by recharge from other sources (3,830.32 Ham). On the extraction side, domestic draft is the largest contributor at 3,973.045 Ham, followed by irrigation draft (2,601.72 Ham) and the industrial sector which accounts for 480.986 Ham. The overall stage of extraction for the entire state is calculated at 22.91% and all the 12 taluks falls in Safe Category.

Shri Pramod B. Badami, Chief Engineer of WRD, Goa, commended the efforts of CGWB and WRD in conducting the GWRA 2024 and acknowledged the findings. He emphasized that groundwater extraction has been rising in recent years, as highlighted in the presentation, with domestic extraction accounting for a significant contribution of the total usage compared to other sectors. He stressed the need to focus on reducing the pressure on groundwater extraction for domestic use by enhancing supplementary surface water supply through various initiatives and schemes. He also acknowledged the ongoing efforts under the NAQUIM 2.0 study, which is focused on addressing coastal salinity intrusion in the Bardez and Tiswadi Taluks of North Goa District. This study taken up on request from WRD will be a significant step in understanding the hydro dynamics of the coastal region and contribute in managing and mitigating the groundwater challenges in the region.

Smt. Sangita P. Bhattacharjee, Scientist-D and Officer-in-Charge of CGWB, SUO, Belagavi also informed that there needs to be inclusion of Forest Department, Government of Goa as member in the SLC of Dynamic Groundwater Resources of Goa, which was also deliberated during the first SLC of 2024. In addition to the above, Shri. Rahul R. Shende informed that the Department of Mines, Government of Goa may also be co-opted as member of SLC to incorporate recharge and extraction from mine pits & further refinement of groundwater resource assessment.

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Replying to the above suggestion, Shri Y. Salelkar, ACE, WRD, Goa assured the co-opting of the two departments namely Forest Department and Dept. of Mines and Geology, Government of Goa in SLC on Dynamic Groundwater Resources of Goa for the next assessment of 2025. **(Action: WRD, Goa)**

Smt. Sangita P. Bhattacharjee, Scientist-D and Officer-in-Charge, CGWB, SUO, Belagavi, expressed gratitude to WRD, Goa for their valuable contribution in providing rainfall data as well as water level data of their monitoring well and piezometer drilled under NHP which played a crucial role in the current resource assessment and will continue to support future assessments including the upcoming GWRA of the state.

After detailed discussion and deliberations, she requested the members of SLC to approve the GWRA of 2024 of Goa and all committee members (Annexure I) unanimously **approved GWRA 2024 of Goa**. The salient features of the GWRA 2024 of Goa are presented in Table 1.

Table 1: The brief findings of the approved GWRA 2024 are given below.

DESCRIPTION	GWRA 2024
Total No. of Assessment Units in the State	12
Rainfall Recharge (ham)	34665.56
Recharge due to other sources (ham)	3830.32
Annual Groundwater Recharge (ham)	38495.88
Total Natural Discharges (ham)	7699.17
Annual Extractable Ground Water Resource (ham)	30796.71
Groundwater Extraction – Irrigation (ham)	2601.72
Groundwater Extraction – Domestic (ham)	3973.045
Groundwater Extraction – Industrial (ham)	480.986
Gross Annual Extraction Draft (ham)	7055.76
Allocation of Ground Water Resource for Domestic Utilization up to 2025 (ham)	4112.62
Net Annual Ground Water Availability for Future use (ham)	23601.37
Stage of Ground Water Extraction (%)	22.91
Categorization	Safe
No. of Over Exploited/ Critical/ Semi Critical Assessment Units	Nil

The meeting ended with the vote of thanks to the Chair and to all the esteemed members of the committee which was proposed by Shri. Sushant S. Navarat, Assistant Hydrogeologist, CGWB, SUO Belagavi.

(Pramod B. Badami)
Chief Engineer,
Water Resource Department
Goa

Annexure I

1/c

ATTENDANCE LIST OF MEMBERS IN THE ONLINE 2ND SLC MEETING OF GWRA 2024

1. Shri. Pramod B. Badami, Chief Engineer, WRD, Goa
2. Shri. D. Y. Salelkar, Additional Chief Engineer, WRD, Goa
3. Shri. Ram G. Gauns, SE, WRD Circle I, WRD, Goa
4. Shri. Milind Gawade, EE Div-I, WRD, Goa
5. Shri. Saish Lawande, EE, WRD, Goa
6. Dr. V. Kunhambu, Sr. Groundwater Consultant, WRD, Goa
7. Shri. Raikar, EE Div-VIII, WRD, Goa
8. Director, Department of Industries, Goa
9. Shri. Sujay Shirodkar, Department of Agriculture, Goa
10. Smt. Sangita P. Bhattacharjee, Scientist-D, OIC, CGWB, SUO, Belagavi
11. Shri. Rahul R. Shende, Scientist-D, CGWB, SWR, Bengaluru
12. Ms. Caroline Louis, Scientist-C, CGWB, SWR, Bengaluru
13. Shri. Sushant S. Navarat, Assistant Hydrogeologist