DYNAMIC GROUND WATER RESOURCES OF UT OF LAKSHADWEEP, 2024

Central Ground Water Board

Department of Water Resources,

River Development & Ganga Rejuvenation

Ministry of Jal Shakti

Government of India

Thiruvananthapuram

January, 2025

Dr. R. Giri Sankar, IAS
District Collector

सत्यमेव जयते

UNION TERRITORY OF
LAKSHADWEEP
SECRETARIAT, KAVARATTI - 682555
Tel: 04896 262235
Email: lk-coll@nic.in

Dated: 07/04/2025

Groundwater is a vital component of the freshwater resources available in the Union Territory of Lakshadweep for providing drinking water for thousands and supporting agricultural productivity. It is integral in maintaining ecological balance and ensuring socio-economic development. Considering the important role in ensuring water and food security, its regular assessment becomes crucial for sustainable management and development.

Effective ground water management begins with a clear understanding of its availability, usage and challenges. Every year, Central Ground Water Board (CGWB), Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti, Government of India along with the Public Works Department, UT of Lakshadweep undertakes systematic assessment of the state's ground water resources. The report on Dynamic Ground Water Resources of UT of Lakshadweep, 2024 consolidates these findings, offering a comprehensive overview of the block wise ground water scenario. This report provides a strong scientific foundation for crafting effective policies, management strategies and regulatory measures.

The efforts of CGWB and the Lakshadweep Administration in preparing this valuable report is commendable. The resource assessment particulars provided in this report will serve as a valuable aid for formulating region-specific groundwater management strategies, ensuring that the groundwater resources of the Islands are utilized judiciously, equitably, and sustainably. I am confident that this document will contribute to the broader objective of water security towards a resilient and water sufficient future.

[Dr. R. Giri Sankar, IAS]

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

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

MESSAGE

The report entitled "Dynamic Ground Water Resources of the Union Territory of Lakshadweep, 2024" has been prepared by the Central Ground Water Board (CGWB), Kerala Region office for the year 2024. As the Member of Central Ground Water Board concerned with overseeing the activities of Kerala Region, and also being Member Secretary of the Central Level Expert Group (CLEG) which oversees the preparation of the national report on Ground Water Resources of India, I am immensely pleased to observe the intensive and rigorous scientific efforts made for compiling the report. The report shall aid in the sustainable management of groundwater resources in the ecologically unique and hydrogeologically challenging Lakshadweep Islands.

The Union Territory of Lakshadweep, an archipelago of coral atolls in the Arabian Sea, relies heavily on its fragile groundwater reserves, which exist as thin freshwater lenses atop saline water. This report, prepared as per the revised GEC-2015 methodology and leveraging the advanced IN-GRES platform, provides a comprehensive assessment of the dynamic groundwater resources of 2024. With a total annual groundwater recharge of 1,380.26 hectare-meters (ham) and an extractable resource of 570.48 ham, the islands exhibit a stage of groundwater extraction of 61.32%, reflecting a largely sustainable utilization pattern. Notably, four of the five assessed blocks—Amini, Androth, Kiltan, and Minicoy—are categorized as 'Safe,' while Kavaratti, with an extraction rate of 74.03%, falls under the 'Semi-Critical' category, signaling the need for targeted interventions.

This assessment underscores the critical interplay between rainfall recharge, evapotranspiration, and human demand in shaping the groundwater scenario of Lakshadweep. The availability of 211.13 ham for future use offers a promising buffer, yet it also highlights the importance of proactive measures such as rainwater harvesting—evidenced by over 4,451 structures with a capacity of 40.5 million liters—and ongoing aquifer mapping initiatives like NAQUIM 2.0. These efforts are vital to preserving the delicate hydrogeological balance of the islands amidst challenges posed by climate variability, tidal influences, and population pressures.

I commend the team at CGWB, Kerala Region, for their dedication and precision in delivering this report, which serves as a cornerstone for informed policymaking and sustainable water resource management. My gratitude extends to the UT-level committee and all stakeholders who have contributed to this endeavor. It is my earnest hope that the insights herein will guide administrators, planners, and the island communities toward a future where water security and environmental integrity coexist harmoniously in Lakshadweep.

Faridabad
March, 2025

(T. S. Anitha Shyam)
Member (South)

Bhujal Bhawan, NH-IV, Faridabad – 121001 (Haryana)
Tele. : 0129-2477204 Email : msouth-cgwb@gov.in Website : cgwb.gov.in

भारत सर्कार
GOVERNMENT OF INDIA
जल संसाधन, नदी विकास एवं गंगा जीर्णोद्धार मंत्रालय
MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION
केंद्रीय भूमिजल बोर्ड, केरल क्षेत्र
CENTRAL GROUND WATER BOARD, KERALA REGION

Phone: 0471-2442191/2442175
Fax: 0471-2442191/2555026
E-mail:rdkr-cgwb@nic.in

Thiruvananthapuram
Kerala – 695 004
13.02.2025

PREFACE

As the Regional Director of the Central Ground Water Board (CGWB), Kerala Region, Thiruvananthapuram, it is my privilege to present the 2024 assessment of the dynamic groundwater resources of the Union Territory of Lakshadweep. This report, meticulously prepared by our dedicated team, underscores CGWB's commitment to advancing scientific understanding and sustainable management of groundwater in one of India's most unique and fragile hydrogeological settings—the coral atolls of Lakshadweep.

Situated in the Arabian Sea, Lakshadweep's small islands face distinct challenges in securing freshwater due to their limited landmass, high permeability of coral sands, and vulnerability to tidal influences and climate variability. This assessment, conducted as of March 2024, employs the revised GEC-2015 methodology and the cutting-edge India-Groundwater Resource Estimation System (IN-GRES), ensuring precision in evaluating the dynamic groundwater resources. The findings reveal a total annual groundwater recharge of 1,380.26 hectare meters (ham), with an extractable resource of 570.48 ham, of which 349.79 ham is currently utilized, resulting in a stage of groundwater extraction of 61.32%. Notably, four of the five assessed blocks remain in the "Safe" category, while Kavaratti, with a higher extraction rate of 74.03%, is classified as "Semi-Critical," signaling the need for targeted interventions.

This report builds on previous assessments, integrating updated data on rainfall, evapotranspiration, and extraction patterns, alongside management initiatives like rainwater harvesting and aquifer mapping under NAQUIM 2.0. It reflects the collaborative efforts of the UT-level committee, chaired by the District Collector, and our field professionals, whose insights have been instrumental in validating these results.

As we navigate the complexities of groundwater management in Lakshadweep, this document serves as a vital tool for policymakers, administrators, and communities. It highlights the sustainability of current practices while emphasizing the importance of continued monitoring, demand-side management, and infrastructure enhancements to safeguard the delicate freshwater lenses that sustain life on these islands. I extend my gratitude to the team at CGWB Kerala Region and all stakeholders for their unwavering dedication to this endeavor, ensuring water security for Lakshadweep's 74,326 inhabitants amidst growing environmental challenges.

13/2/25
Mini Chandran
Head of Office

DYNAMIC GROUNDWATER RESOURCES OF LAKSHADWEEP ISLANDS, 2024

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXURES

DYNAMIC GROUND WATER RESOURCES OF UT OF LAKSHADWEEP, 2024

AT A GLANCE

1.	**Total Annual Ground Water Recharge**	**: 1,122.57 ham (0.0112 bcm)**
2.	**Annual Extractable Ground Water Resources**	**: 570.48 ham (0.0057 bcm)**
3.	**Annual Ground Water Extraction**	**: 349.79 ham (0.0035 bcm)**
4.	**Stage of Ground Water Extraction**	**: 61.32 %**

CATEGORIZATION OF ASSESSMENT UNITS

(Blocks/ Mandals/ Taluks)

Sl. No.	Category	Number of Assessment Units		Recharge worthy Area		Annual Extractable Ground Water Resource	
		Number	%	in sq. km	%	(in bcm)	%
1	Safe	4	80	19.87	75.81	0.0014	76.13
2	Semi Critical	1	20	6.34	24.19	0.0043	23.87
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	5	100	26.21	100	0.0057	100

EXECUTIVE SUMMARY

This report, prepared by the Central Ground Water Board (CGWB), Kerala Region, under the Ministry of Jal Shakti, Government of India, assesses the dynamic groundwater resources of the Union Territory of Lakshadweep as of March 2024. The evaluation follows the revised GEC-2015 methodology, incorporating aquifer-specific parameters and a web-based application (IN-GRES) for enhanced accuracy.

Key findings and highlights are summarized below:

1. Rainfall and Geographical Area: Lakshadweep received a uniform rainfall of 1805.54 mm across all blocks. The total geographical area assessed is 2621 hectares, with recharge-worthy areas varying across blocks. For instance, Amini has 571 hectares, while Androth has 712 hectares.

2. Groundwater Recharge: The annual groundwater recharge across Lakshadweep is 1380.26 ham (hectare meters), with entire contributions from rainfall recharge. Kiltan has the lowest recharge (140.60 ham), while Androth has the highest (374.95 ham).

3. Extractable Groundwater Resources: The total annual extractable groundwater resource is 570.48 ham, with extraction for all uses amounting to 349.79 ham. This indicates that 61.32% of the available groundwater is being extracted, which is a moderate level of utilization.

4. Groundwater Extraction and Future Availability: The stage of groundwater extraction varies across blocks, with Kavaratti having the highest extraction (100.8 ha m) and Kiltan the lowest (36.13 ha m). The net annual groundwater availability for future use is 211.13 ham.

5. Domestic Allocation and Environmental Flows: The allocation of groundwater for domestic use by the projected year 2025 is 359.34 ham. Environmental flows are maintained at 552.09 ham, ensuring ecological sustainability.

6. Ground water Availability: The total groundwater availability is 570.48 ham, all of which is fresh water.

Key Takeaways:

1) Lakshadweep's groundwater resources are primarily recharged by rainfall and evapotranspiration.
2) Groundwater extraction is within sustainable limits.
3) The region has sufficient groundwater reserves for future use, with 211.13 ham available after current extraction.
4) Environmental flows are adequately maintained, ensuring the health of ecosystems dependent on groundwater.

This data underscores the importance of sustainable groundwater management in Lakshadweep to balance human needs and environmental conservation.

Key Findings

1. Groundwater Recharge and Extraction:

   1. Total Annual Recharge: 1,380.26 hectare-meters (ham), primarily from monsoon rainfall (70% of annual precipitation).

   2. Annual Extractable Resource: 570.48 ham, after accounting for evapotranspiration (257.69 ham), outflow to sea (276.05 ham), and buffer reserves (276.05 ham).

3. Current Extraction: 349.79 ham, predominantly for domestic use (97% of total demand).

2. Stage of Groundwater Extraction (SOGWE):
    1. Overall SOGWE: 61.32%, categorizing most islands as "Safe" (extraction ≤70%).
    2. Kavaratti block is classified as "Semi-Critical" (SOGWE: 74.03%) due to higher extraction rates.

3. Comparison with 2023 Estimates:
    1. Minimal changes in recharge metrics, but Amini island shifted from "Semi-Critical" to "Safe" due to a newly commissioned desalination plant.
    2. Evapotranspiration rates were refined based on recent studies (30 liters/day/tree).

4. Hydrogeological Context:
    1. Groundwater occurs as thin freshwater lenses floating over seawater, influenced by tidal fluctuations and high permeability of coral sands.
    2. Challenges include limited storage capacity, saline intrusion risks, and dependency on monsoon recharge.

Management Initiatives

1. Rainwater Harvesting: Over 4,451 structures with a total capacity of 40.5 million liters mitigate freshwater scarcity.
2. Aquifer Mapping: Ongoing NAQUIM 2.0 studies in Amini and Minicoy address quality issues.
3. Policy Measures: The UT-level committee oversees sustainable resource management, aligning with the National Water Policy.

Recommendations

1. Prioritize demand-side management in Kavaratti to prevent over-extraction.
2. Expand rainwater harvesting and desalination infrastructure to reduce groundwater dependence.
3. Strengthen long-term water-level monitoring to validate extraction trends.

Conclusion

Lakshadweep’s groundwater resources remain largely sustainable, with 211.13 ham available for future development. Continued scientific assessment, community engagement, and adaptive policies are critical to ensuring water security for the islands’ 74,326 inhabitants.

CHAPTER 1

1. INTRODUCTION

Since groundwater is a limited and replenishable resource, a realistic evaluation of it is necessary for its appropriate and sustained economic growth. A periodic, scientific evaluation of India's groundwater resources is another important aspect of the country's National Water Policy. Through time, the evaluation of the nation's dynamic ground water resources has become more and more significant. The first attempt to estimate the groundwater resources of the country on a scientific basis date back to the year 1979, when the 'Ground Water Over-Exploitation Committee' was constituted by Agriculture Refinance and Development Corporation (ARDC) of Reserve Bank of India for the purpose. The ground water resources of India were assessed based on the norms recommended by the above Committee. Subsequently, with the objective of refining the assessment methodology, the "Groundwater Estimation Committee (GEC)" headed by the Chairman, Central Ground Water Board (CGWB), came into existence. Based on the information gathered during the studies carried out by CGWB, the Committee formulated the detailed methodology for estimation of groundwater resources in 1984 (GEC' 84). The methodology was reviewed in 1997 in the light of feedback from different agencies and information gathered from a modified methodology was formulated in 1997(GEC'97) for computation of groundwater resources. This methodology has since undergone minor modifications and the modified GEC-1997 norms are used for estimation of dynamic ground water resources of the country considering 2004, 2009, 2011 and 2013 as base years. The methodology underwent comprehensive revisions again in 2015 and a revised methodology, namely GEC- 2015 methodology has been prescribed for ground water assessment. This methodology is being followed for assessment carried out from 2017 onwards.

The exercise of resource estimation commenced with the collection, collation, compilation and validation of relevant data from various sources. A critical evaluation of the results of the ground water resource assessment taken up during 2024 was undertaken with focus on assessment units categorized under OCS category (Over exploited, Critical and Semi-critical). The estimation of dynamic ground water resources was undertaken using methodology appropriate for the prevailing hydrogeological conditions of the islands and dynamic ground water resources were computed for all the inhabited islands. The results were validated in consultation with field professionals of CGWB.

1. 1 Previous Assessments

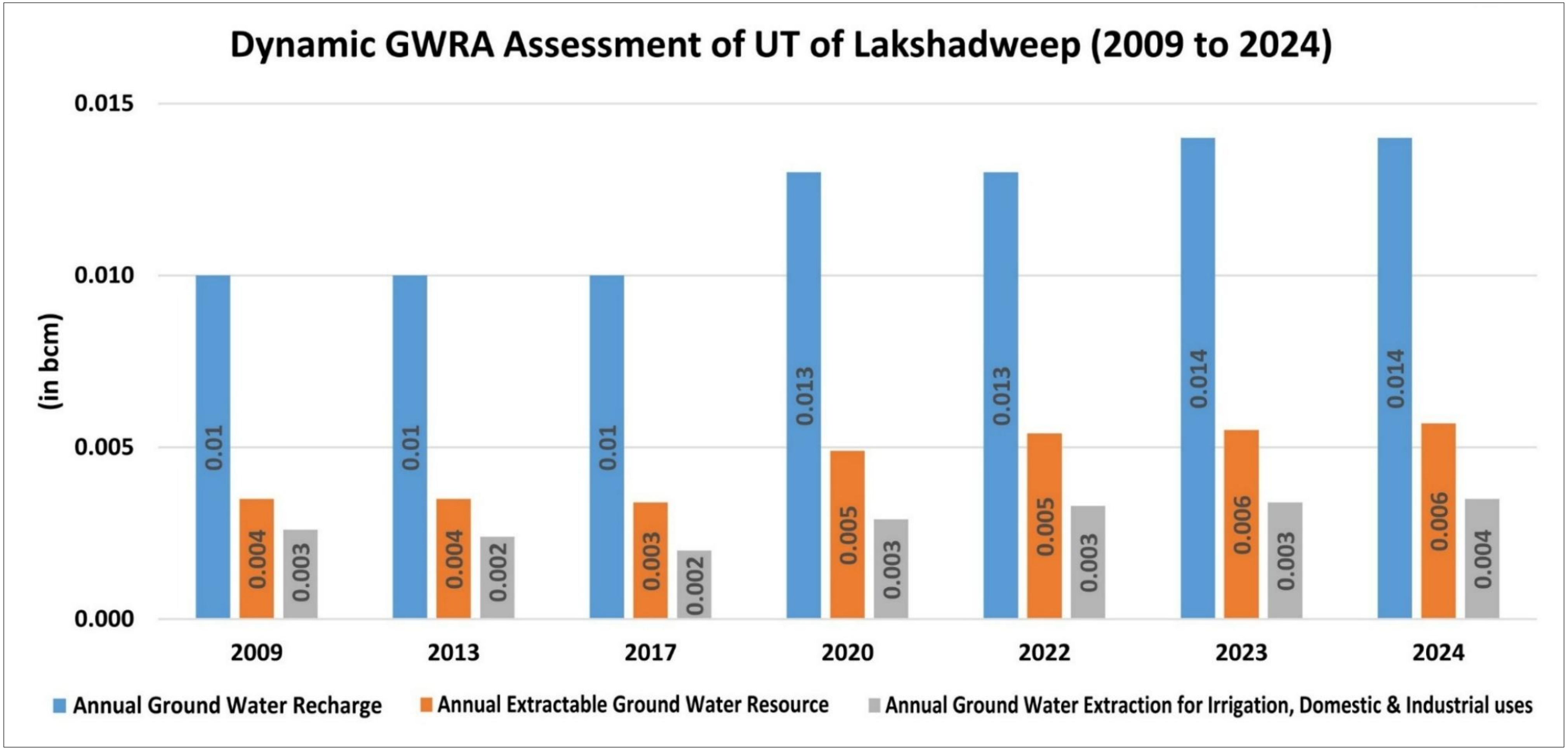
The first attempt to estimate the groundwater resources of the island on a scientific basis was carried out in 2004 based on GEC -1997 methodology. This GEC-1997 methodology was modified subsequently, and GEC-2015 norms were issued. The later assessments were done during 2013, 2017. 2020, 2022, 2023, and 2024. In 2020, for the first time, the entire computation for assessment has been automated and is being done using web-based application IN-GRES (https://ingres.iith.ac.in/).The previous assessment of dynamic ground water resources of Lakshadweep Islands was carried out during 2023. In accordance with the policy of Government of India, the estimation of dynamic ground water resources is being carried out every year. The current re-estimation of resources is as on March 2024. To improve the GEC assessment a Web Based Application namely INDIA- Groundwater Resource Estimation System (IN-GRES) for estimation of Dynamic Ground Water Resources using GEC-2015 methodology was used in the current assessment (developed by CGWB in collaboration with by IIT-Hyderabad and Vassar lab). IN-GRES allows data input through Excel as well as through inbuilt- forms, compute various ground water components (recharge, draft, flux, etc.), classify assessment unit into appropriate categories and develop visibility dashboards for each of the components. System allows user to view the data in both MIS as well as GIS view. User can also download the reports in required formats.term fluctuations in groundwater resources, the Ministry of Jal Shakti has proposed the annual estimation of groundwater resources for the country, starting from the year 2022 onwards.

Table 1:1 Ground water Resources assessment 2009 to 2024

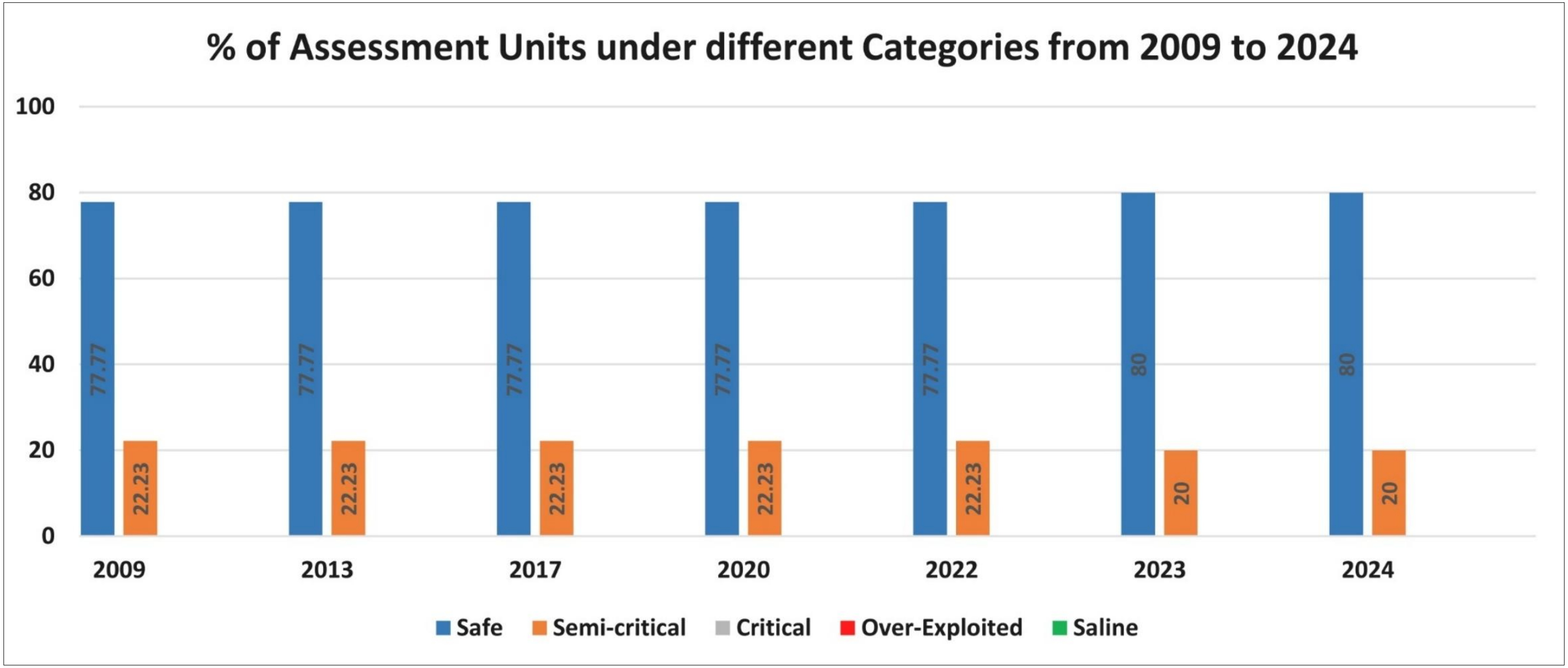
S. No.	Ground Water Resources Assessment	2009	2013	2017	2020	2022	2023	2024
1	Annual Ground Water Recharge (bcm)	0.01	0.01	0.01	0.013	0.013	0.014	0.014
2	Annual Extractable Ground Water Resource (bcm)	0.0035	0.0035	0.0034	0.0049	0.0054	0.0055	0.0057
3	Annual Ground Water Extraction for Irrigation, Domestic & Industrial uses(bcm)	0.0026	0.0024	0.002	0.0029	0.0033	0.0034	0.0035
4	Stage of Ground Water Extraction (%)	73.97%	68 %	65.70%	57.40%	61.78%	61.72%	61.32%

Table 1:2 Categorization of assessment units from 2009 to 2024

		2009		2013		2017		2020		2022		2023		2024	
S. No.	**Categorization of Assessment Units**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
1	Total Assessed units	**9**		**9**		**9**		**9**		**9**		**5**		**5**	
2	Safe	7	77.77	7	77.77	7	77.77	7	77.77	7	77.77	4	80	4	80
3	Semi-critical	2	22.23	2	22.23	2	22.23	2	22.23	2	22.23	1	20	1	20
4	Critical	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Over-Exploited	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Saline	0	0	0	0	0	0	0	0	0	0	0	0	0	0



Dynamic GWRA Assessment of UT of Lakshadweep (2009 to 2024)
(in bcm)
0.015
0.010
0.005
0.000
0.01
0.004
0.003
0.01
0.004
0.002
0.01
0.003
0.002
0.013
0.005
0.003
0.013
0.005
0.003
0.014
0.006
0.003
0.014
0.006
0.004
2009
2013
2017
2020
2022
2023
2024
Annual Ground Water Recharge
Annual Extractable Ground Water Resource
Annual Ground Water Extraction for Irrigation, Domestic & Industrial uses


% of Assessment Units under different Categories from 2009 to 2024
100
80
60
40
20
0
77.77
22.23
77.77
22.23
77.77
22.23
77.77
22.23
77.77
22.23
80
20
80
20
2009
2013
2017
2020
2022
2023
2024
Safe
Semi-critical
Critical
Over-Exploited
Saline

1. 2 Ground Water Assessment and Management Initiatives

The inferences drawn from the ground water resources assessment is utilized as an input to the planners and stakeholders for taking appropriate management measures for optimal utilization and sustainable development of the ground water resources. Several measures, primarily based on the findings of the resource assessment, have been taken up by the Government of India to conserve as well as for optimum utilization of ground water resources of Lakshadweep. Initiatives in this regard includes constitution of Ground Water Authority for U.T. of Lakshadweep in 2019 for regulation of ground water development and compilation of a conceptual document titled “Master Plan for Artificial Recharge to Ground water in U.T. of Lakshadweep” by CGWB, which envisages implementation of Rain Water Harvesting structures to optimize the utilization of ground water resources of these islands. Besides, CGWB has taken up National Aquifer Mapping & Management Programme (NAQUIM), for mapping of major aquifers, their characterization and formulation of Aquifer Management Plans to ensure sustainability of the resources during 2014-17 and the additional data generated has been incorporated into the computations wherever required before finalizing the results. As part of NAQUIM 2.0, during the AAP 2023- 24, microlevel studies have been taken up in Amini and Minicoy islands of the UT to address the quality issues rampant along the island stretches. The Central Ground Water Board (CGWB), Kerala Region has implemented several initiatives for groundwater assessment and management in the th UT of Lakshadweep Islands, addressing the unique hydrogeological challenges of these coral atolls. Here's an organized overview:

1.2.1. Groundwater Assessment Initiatives

1.2.1.1. Hydrogeological Studies

a) Aquifer Mapping (NAQUIM): Under the National Aquifer Mapping Program, CGWB has mapped the islands' freshwater lenses, which are thin layers of freshwater overlying saline water. Studies focus on understanding aquifer geometry, recharge zones, and safe extraction limits.

b) Dynamic Freshwater Lenses: CGWB assesses the sustainability of these lenses, which are highly vulnerable to over-extraction and seawater intrusion. Reports highlight the limited thickness (often <10 m) and seasonal variability of freshwater reserves.

1.2.1.2. Monitoring Networks

a) Observation Wells: The Laksadweep Public Works department (LPWD) maintains a network of monitoring stations to track groundwater levels and quality under the technical supervision of CGWB. Data is used to detect salinity ingress and seasonal fluctuations.

b) Water Quality Testing: Regular testing for parameters like chloride, TDS, and nitrate ensures compliance with potable standards is being done by the LPWD under the consultation with CGWB. Salinization due to over-pumping and tidal influence is a key concern.

c) Recently the CGWB Kerala Region has taken path braking initiative for implementing our own DWLR enabled real time ground water monitoring network in the islands (both quality and quantity) through outsourcing mode. The initial steps for the mission were planned with the island administration in the quarterly dialogue platforms with CWC and U T level agencies.

1.2.2. Groundwater Management Initiatives

1.2.2.1. Rainwater Harvesting (RWH)

a) Promotion of RWH Systems: CGWB advocates rooftop rainwater harvesting as the primary freshwater source, reducing dependence on groundwater. Public buildings and residential areas are prioritized.

b) Storage Infrastructure: Recommendations include constructing rainwater storage tanks

1.2.2.2. Demand Management.

a) Tourism Regulations: CGWB advises the Lakshadweep Administration to enforce water-use guidelines for resorts and tourists, a major stressor on resources.

1.2.2.3. Policy and Regulation

a) Groundwater Extraction Controls: CGWB recommends strict licensing for bore wells and pumps to prevent over-exploitation.

b) Legal Framework: To update groundwater regulation in the Union Territory of Lakshadweep in line with the Central Ground Water Authority's (CGWA) new guidelines, the existing framework—established under the Lakshadweep Groundwater Legislation—should incorporate key provisions such as mandatory No Objection Certificates (NOCs) for withdrawals, installation of IoT-based monitoring systems, and payment of groundwater abstraction/restoration charges..

1.2.2.4. Community Engagement

a) Awareness Campaigns: Workshops and educational programs train locals in water conservation and RWH maintenance.

b) Collaboration with Local Authorities: CGWB partners with the Lakshadweep Administration to integrate groundwater management into development plans.

c) The Jal Shakti Abhiyan guide community-led sustainable management, though implementation in remote islands remains challenging

1.2.3. Challenges & Future Focus

a) Geographic Constraints: Small land area and dispersed islands complicate infrastructure deployment.

b) Climate Change: Rising seas and erratic monsoons necessitate adaptive strategies like decentralized RWH and desalination hybrids.

c) Data Gaps: Enhanced real-time monitoring and IoT-based systems are needed for dynamic aquifer management.

Key Reports & Resources

a) CGWB's "hydrogeological information booklet" provide detailed Lakshadweep-specific recommendations.

b) NAQUIM reports outline aquifer characteristics and recharge potential for each inhabited island.

By combining scientific assessment, community participation, and adaptive policies, CGWB aims to secure Lakshadweep's fragile groundwater resources amidst growing climatic and anthropogenic pressures.

1. 3 Re-Assessment of Ground Water Resources, 2024

As per the direction from Central Head Quarter of Central Ground Water Board, ground water Resources estimation as per the methodology GEC-2015 as on 2024 has to be carried out. In this regard a permanent U.T level committee was re-constituted (in accordance with the request from the Regional Director, CGWB) vide F. No.118/03/2022-S4/330 Dt. 22.02.2022 (Annexure II). The members of the committee are as enlisted:

District Collector, UTL	Chairman
Conservator of Forest	Member
Superintending Engineer, LPWD	Member
Director (Agriculture)	Member
Director (Industries)	Member

Director (Planning, Statistics & Taxation)	Member
Director (Science & Technology)	Member
Regional Director, CGWB, Kerala Region	Member Secretary

The meeting of the committee to review the methodology and work plan was finalized during first UT Level Meeting on 17.05.2024 (Annexure III). The assessment of the dynamic resources of UT of Lakshadweep, 2024 was approved by the committee on 23.09.2024. Copy of the minutes of the meeting of 2nd UT Level Meeting is presented in Annexure IV.

CHAPTER 2

2. GROUND WATER RESOURCE ESTIMATION METHODOLOGY

A groundwater resource of the entire country was assessed during 1995 as per the recommendations of Groundwater Estimation Committee- 1984 (GEC'84). The GEC'84 methodology was subsequently modified in the light of enhanced database and new findings of experimental studies in the field of hydrogeology. In view of the limitations of ground water assessment in hard rock terrain, another Committee on Ground Water Estimation Methodology in Hard Rock Terrain was formed in 2001 to review the existing methodology for resource estimation in such formations. The Committee made certain suggestions on the criteria for categorization of blocks to be adopted for the entire country irrespective of the terrain conditions. Based on GEC 1997, the dynamic ground water resources of India have been estimated for the entire country considering 2004, 2009, 2011 and 2013 as base years. The methodology underwent comprehensive revisions again in 2015 and a revised methodology, namely GEC 2015 methodology has been prescribed for ground water assessment. This methodology is being followed for assessment carried out from 2017 onwards. A brief description of the salient aspects of the methodology is furnished below.

The methodology recommends aquifer wise ground water resource assessment of both the Groundwater resources components, i.e., Replenishable ground water resources or Dynamic Ground Water Resources and In-storage Resources or Static Resources. GEC 2015 recommends estimation of Dynamic Ground Water Resources and In-storage Resources or Static Resources for both unconfined and confined aquifer. Wherever the aquifer geometry has not been firmly established for the unconfined aquifer, the in-storage ground water resources have to be assessed in the alluvial areas down to the depth of bed rock or 300 m, whichever is less. In case of hard rock aquifers, the depth of assessment would be limited to 100 m. In case of confined aquifers, the dynamic as well as in-storage resources are to be estimated only if it is known that groundwater extraction is being done from this aquifer. If it is firmly established that there is no ground water extraction from this confined aquifer, then only in-storage resources of that aquifer has to be estimated. Until aquifer geometry is established on appropriate scale, the existing practice of using watershed in hard rock areas and blocks/mandals/ firkas in soft rock areas may be continued.

The revised methodology GEC – 2015 recommends aquifer wise ground water resource assessment. An essential requirement for this is to demarcate lateral as well as vertical extent and disposition of different aquifers. A watershed with well-defined hydrological boundaries is an appropriate unit for ground water resource estimation if the principal aquifer is other than alluvium. Ground water resources worked out on watershed as a unit may be apportioned and presented on administrative units (block/ taluka/ mandal/ firka). This would facilitate local administration in planning of ground water management programmes.

Till 2022 in the U.T. Lakshadweep each island was taken as separate assessment units and dynamic ground water resources were computed as per the prevailing hydrogeological conditions of the islands. The rainfall infiltration method is used for computation of dynamic ground water resources of the islands. As fresh water is floating over saline water in the islands, in-storage resource and resource of confined aquifer has no significance being saline zone.

2. 1 Assessment of Annually Replenishable or Dynamic Ground Water Resources

The assessment of ground water includes assessment of dynamic and in-storage ground water resources. As fresh water is floating over saline water in the islands, in-storage resource and resource of confined aquifer has no significance being saline zone.

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

Inflow – Outflow = Change in Storage (of an aquifer) ……………………. Eqn. 1

Equation 1 can be further elaborated as -

$$\Delta S = R_{RF}+R_{STR}+R_{C}+R_{SWI}+R_{GWI}+R_{TP}+R_{WCS} \pm VF \pm LF - GE - T - E - B \quad \text{……………………. Eq.2}$$

Where,

ΔS - Change in 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

It is preferred that all the components of water balance equation should be estimated in an assessment unit. Due to lack of data for all the components in most of the assessment units, it is proposed that at present the water budget may be restricted to the major components only, taking into consideration certain reasonable assumptions. The estimation is to be 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 Rainfall Recharge

It is recommended that ground water recharge should be 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 as specified above, ground water recharge may be estimated using rainfall infiltration factor method only. The rainfall recharge during non-monsoon season may be estimated using rainfall infiltration factor method only.

(a) Ground Water Level Fluctuation Method

The ground water level fluctuation method is to be used for assessment of rainfall recharge in the monsoon season. A couple of important observations in the context of water level measurement must be followed. It is important to bear in mind that while estimating the quantum of ground water extraction, the depth from which ground water is being extracted should be considered. One should consider only the draft from the same aquifer for which the resource is being estimated.

The resources assessment during monsoon season is estimated as the sum total of the change in storage and gross extraction. The change in storage is computed by multiplying water level fluctuations between pre and post monsoon periods with the area of assessment and specific yield of the formation. Monsoon recharge can be expressed as

R= (h x Sy x A) + GE……………………. Eqn.3

Where,

h = rise in water level in the monsoon season,

A = area for computation of recharge

Sy = specific yield and

GE= gross groundwater extraction

The rainfall recharge during monsoon season computed by Water Level Fluctuation (WLF) method is compared with recharge figures from Rainfall Infiltration Factor (RIF) method. In case the difference between the two sets of data is more than 20% then RIF figure is considered, otherwise monsoon recharge from WLF is adopted. While adopting the rainfall recharge figures, weightage is to be given to WLF method over ad hoc norms method of RIF. Hence, wherever the difference between RIF and WLF is more than 20%, data have to be scrutinized and corrected accordingly.

(b) Rainfall Infiltration Factor Method

The rainfall recharge estimation based on Water level fluctuation method reflects actual field conditions since it considers 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, it is recommended to compare the rainfall recharge obtained from water level fluctuation approach with that estimated using rainfall infiltration factor method. Recharge from rainfall is estimated by using the following relationship –

Rrf = RFIF * A* (R – a)/1000……………………. Eqn.4

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 to be considered while estimating ground water recharge using rainfall infiltration factor method. It is suggested that 10% of Normal annual rainfall may be taken as minimum rainfall threshold and 3000 mm as maximum rainfall limit. While computing the rainfall recharge, 10% of the normal annual rainfall is to be deducted from the monsoon rainfall and balance rainfall would be considered for computation of rainfall recharge. The same recharge factor may be used for both monsoon and non-monsoon rainfall, with the condition that the recharge due to non-monsoon rainfall may be 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 may be estimated for normal rainfall, based on recent 30 to 50 years of data.

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 have to be compared with each other. A term, Percent Deviation (PD) which is the difference between the two expressed as a percentage of the later is computed as

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

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%, RRF (normal) is taken as the value estimated by the ground water level fluctuation method.
- If PD is less than -20%, RRF (normal) is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.
- If PD is greater than +20%, RRF (normal) is taken as equal to 1.2 times the value estimated by the rainfall infiltration factor method.

2.1.2 Non- Monsoon season

During non-Monsoon season, rainfall recharge is computed by using Rainfall Infiltration Factor (RIF) 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 subunit and stream inflows & outflows during non-monsoon season is the total recharge/ accumulation during non-monsoon season for the subunit. Similarly, this is to be computed for all the subunits available in the assessment unit.

2. 2 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 subunit. Similarly, this is to be computed for all the subunits available in the assessment unit.

2. 3 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.

Annual Extractable Groundwater Recharge = Total Annual Groundwater Recharge - Natural discharge.

2. 4 Annual Ground Water Extraction

Annual groundwater extraction has been calculated for Irrigation, Domestic and Industrial uses. The gross groundwater extraction would include the groundwater extraction from all existing groundwater structures during monsoon as well as during non-monsoon period. While the number of groundwater structures should preferably be based on latest well census, the average unit draft from different types of structures should be based on specific studies or ad-hoc norms given in GEC 2015 report.

2. 5 Stage of Ground Water Extraction, SOGWE

The stage of Groundwater extraction has been computed as given below

$$\text{Stage of Groundwater Extraction (\%)} = \frac{\text{Existing Gross Groundwater Extraction for all uses}}{\text{Annual Extractable Groundwater Resource}} \times 100$$

2. 6 Validation of Stage of Ground Water Extraction

The stage of ground water extraction is validated with long term trend of ground water levels as it has inherent uncertainties. 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%	**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. 7 Categorization of Assessment Units

As emphasised in the National Water Policy, 2012, a convergence of Quantity and Quality of ground water resources is required while assessing the ground water status in an assessment unit. Therefore, it is recommended to separate estimation of resources where water quality is beyond permissible limits for the parameter salinity.

(a) <u>Categorization of Assessment Unit Based on Quantity</u>

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**

(b) 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 may be tagged with the particular Quality hazard.

2. 8 Procedure Followed in the Present Assessment Including Assumptions

The ground water resources and balance available is to be computed based on the Ground water Estimation Methodology 2015 (GEC, 2015). This methodology is designed basically for the computation of the groundwater resource of mainland aquifers and doesn't have any norms for the groundwater resource computation of tiny oceanic islands where the groundwater occurs as a floating lens. The hydrogeological systems of the small islands are more complicated by the tidal fluctuations and climatological vagaries. The size and thickness of the lens is also controlled by the topography. All these facts make the computation of the groundwater resource of small islands a complex exercise.

The water level fluctuation method cannot be applied since the thin floating lens is controlled by the tidal fluctuations and more over there is no seasonal water level fluctuation. Rainfall infiltration method has been considered for computation.

2.8.1. Unit of Computation

The unit of assessment for the evaluation has shifted from island to block from the assessment year 2023. The islands and their corresponding blocks are listed below

Sl No.	Blocks	Islands
1	**Amini**	**Amini & Kadamat**
2.	**Androt**	**Androt & Kalpeni**
3.	**Kavaratti**	**Kavaratti & Agatti**
4.	**Kiltan**	**Kiltan & Chetlat**
5.	**Minicoy**	**Minicoy**

However, all resource calculations have been made island wise and then apportioned to block level.

An island with well-defined hydrogeological boundaries is an appropriate Hydrogeological unit for ground water resource estimation. The geographical area of the island varies from 1.04 sq.km to 4.84 sq.km. There are no surface runoff systems in these islands.

Several techniques are available for estimating the extent and sustainable yield of freshwater lenses on small coral islands. To estimate the sustainable yield of a freshwater lens it is necessary to know the extent (location, width and thickness) and behavior (response to external influences) of the lens, and the rate of recharge to the lens. These parameters provide the information about the storage characteristics of the ground water and the input (from rainfall) to the ground water. There are a number of techniques which can be used to assess the location and size of fresh water lenses.

The preliminary methods are based on the Ghyben - Herzberg ratio (approximately 40:1) by using elevation of water table above mean sea level. Detailed investigations include geophysical methods (mainly electrical resistivity and electromagnetic), combined with a drilling program. Geophysical techniques offer a particularly suitable means of assessing freshwater lens. Drilling of 150 mm diameter holes up to 30 m below ground surface for ground water investigations has been successfully undertaken with rotary rigs in Kavaratti by CGWB during 1999-2000. The salinity profile obtained from the appropriately drilled and constructed bore holes could help in the successful interpretation of geophysical logs by providing independent calibration. Lithological log provides useful information on the depth of upper sediments.

2.8.2. Recharge Computation

Reliable estimates of recharge are required as input to ground water models in order to estimate sustainable yield of ground water resources. Recharge to ground water in a small island condition can occur only through rainfall. The portion of precipitation which eventually recharges the freshwater lens is given by the following water balance model for atoll islands:

$$R = P - I - ET \pm \Delta ST \quad (1)$$

Where:

R = Recharge to the freshwater lens

P = Total Precipitation

I = Intercepted Precipitation

ET = Evapotranspiration (evaporation from the surface, transpiration from the root zone, and extraction from the lens by deep-reaching coconut roots)

ST = Change in storage

A small portion of the total precipitation does not reach the ground surface of the island, as it is intercepted by vegetation and subsequently evaporated. The rainwater which reaches the ground surface, the "effective rainfall", infiltrates the surface and enters the soil zone. A portion of the water is taken up by the roots of plants, another portion may be used to increase the soil moisture if the field capacity of the soil has not yet been reached, and the remainder percolates down to recharge the freshwater lens. The top of the lens is normally only about 2-3 meters below the ground surface, enabling a portion of the coconut roots to extract water directly from the lens. Surface runoff, normally included in a water balance model, is not usually observed on atoll islands except during extremely intense rainfall. Runoff can also occur on islands where a concrete airstrip has been built.

The intercepted rainfall is thought to be approximately 15% of the total rainfall. The above water balance model becomes important when considering time-dependent recharge. For steady-state conditions the change in soil moisture and groundwater storage can be ignored. Several investigators have reduced the above water balance model to the following relationship for long-term conditions:

$$R = P - ET \quad (2),$$

where the terms are the same as in equation (1).

The average monsoonal rainfall (2018-23) in Lakshadweep islands is 1442mm (Agatti), 1505 mm (Amini), 1615 mm (Androth), 1445mm (Kalpeni), 1504 (Kiltan) and 1380 (Minicoy). The maximum temperature is 31.5°C (Minicoy) and 31.9°C (Amini). The minimum temperature is 24.4°C (Minicoy) and 23.7°C (Amini). About 70% of the rainfall is contributed by the southwest monsoon during May to October. During these months rainfall exceeds PET and recharge to ground water takes place as there is no surface runoff due to the highly permeable nature of the top soil (i.e. Coral sand).

In small island conditions, the estimation of recharge based on ground water fluctuation method is not practicable unlike the continental coastal aquifers. The head build up due to rainfall recharge will dissipate within 2-3 days and diurnal fluctuation is nearly same as seasonal fluctuation. Therefore the water table fluctuation method cannot be adopted for assessing the dynamic ground water potential of Lakshadweep islands.

The ground water recharge has been computed using rainfall Infiltration method. The Average Monsoonal Rainfall for six months from May to October, is taken for Agatti, Amini, Androth, Kalpeni and Minicoy islands. Since rainfall data of remaining islands are not available, the Average Monsoonal Rainfall data of Amini is adopted, which is 1505 mm. For remaining period, the Average Non- Monsoon Rainfall (NNMR) is taken.

A rainfall infiltration factor of 0.35 is adopted for the entire islands in the current estimation procedure. As islands are densely covered with coconut trees, evapo-transpiration plays a main role in the extraction of ground water resource from thin fresh water lenses. As s detailed study has not been carried out about the root penetration depth and evapo-transpiration rate from various islands, hence in this computation average root depth is considered as 1.5 m with evapo-transpiration (ET) at a rate of 4 mm/day from each island for capillary rise of 1 m and the average ground water level in the zone is taken as 1.75 m. The number of ET days has been restricted to non-monsoon period of 180 days for computation.

2.8.3. Annual Extractable Ground Water Resource

About 20% of the total recharge is accounted for lost due to mixing with sea water during tides and another 20% is allocated for reserve for use during periods of delayed or lesser rainfall to maintain the buffer zone. These components along with the transpiration loss for the coconut trees are deducted from the total annual ground water recharge for getting the annual extractable ground water resource.

2.8.4. Ground Water Extraction

The major extraction component of these islands is the domestic consumption. Almost all households have their own dug well and more than 75% of the wells are fitted with small capacity electric motor pump (0.5 HP). The per capita requirement of water per day for per person in the island is taken as 140 l. Considering the supply of water from desalinization plants in each island and rainwater harvesting structure, the per capita consumption was computed for each island separately and it varies from 107 to 139 lpd, which has been considered for domestic draft calculation, on the basis of the population of 2011 census. Irrigation draft is negligible in the islands as almost all the crops are rain-fed. The details of the Rain water harvesting structures used for are given in **Table 4.1**.

Table 2:1 Details of Rain Water Harvesting Tanks

Island	No. of structures	Capacity in Litres
Agatti	754	7540000
Amini	483	4322000
Androth	341	2930000
Chetlat	309	2425000
Kadmat	382	3350000
Kalpeni	445	3067000
Kavaratti	720	7675000
Kiltan	362	3120000
Minicoy	655	6129000
Total	**4451**	**40558000**

**Rain Water Harvesting Tanks*

(Source: Department of Public Works, Lakshadweep)

2.8.5. Stage of Ground Water Extraction

The stage of ground water extraction (SOGWE) was computed based on the following formula

$$\textbf{SOGWE} = \{B/A\} \times 100$$

where,
B is the Existing Gross Groundwater Extraction for all uses
A is the Annual Extractable Groundwater Resource

2.8.6. Categorization of Islands

Categorization of islands as per the GEC-2015 methodology is not applicable in island conditions due to the peculiar nature of the hydrogeological regime. The freshwater lens will quickly adjust with the incremental additions or abstractions by virtue of its floating nature thereby masking any long-term trend of fluctuation. However, categorization has been attempted in this estimation purely based on stage of ground water extraction.

2. 9 India - Groundwater Resource Estimation System (IN-GRES)

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

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

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

CHAPTER 3

3. RAINFALL OF UT OF LAKSHADWEEP

The Union Territory of Lakshadweep, an archipelago in the Arabian Sea, experiences a tropical maritime climate characterized by warm temperatures year-round and significant rainfall influenced by monsoons. Here's a detailed overview of its rainfall patterns:

1. Monsoon Influence:
   - Southwest Monsoon (June–September): The primary rainy season, contributing the majority of annual rainfall. The monsoon typically arrives in early June, aligning with the onset over Kerala.
   - Pre-Monsoon Showers (April–May): Isolated thunderstorms and convective rains occur before the monsoon.
   - Post-Monsoon (October–December): Rainfall decreases significantly, though occasional showers may occur due to retreating monsoons or cyclonic activity in the Arabian Sea.

2. Annual Rainfall:
   - Average annual rainfall ranges between 1,500 mm to 1,700 mm, with variability across islands. The heaviest precipitation is usually in June and July.

3. Key Features:
   - Uniform Distribution: As low-lying coral islands, Lakshadweep lacks orographic effects, leading to more evenly distributed showers compared to mainland India.
   - Humidity and Temperature: High humidity (~80%) and steady temperatures (25–32°C) foster a consistent evaporation-precipitation cycle.
   - Cyclonic Activity: Rare but possible during pre- and post-monsoon months, influencing short-term heavy rains.

4. Dry Season:
   - January–March is relatively drier, though sporadic showers may still occur.

5. Climate Variability:
   - Factors like El Niño-Southern Oscillation (ENSO) can alter rainfall patterns, though Lakshadweep is less prone to extreme deviations compared to mainland India.

In summary, Lakshadweep's rainfall is dominated by the Southwest Monsoon, with moderate annual totals and a humid, tropical climate sustaining its delicate ecosystems.

Report on Dynamic Ground Water Resources of Ut of Lakshadweep, 2024																							
S. No.	**STATES**	**State -wise Monthly Rainfall (mm) -Year 2023**												**State -wise Monthly Rainfall (mm) -Year 2024**					**Normal Rainfall (mm)**	**Rainfall during Calendar Year 2023 (mm)**	**Rainfall during Ground Water Assessment Year 2023-24 (mm)**	**Monsoon Rainfall during Ground Water Assessment Year 2023-24 (mm)**	**Non-Monsoon Rainfall during Ground Water Assessment Year 2023-24 (mm)**
		JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**					
36	LAKSHADWEEP (UT)	33.4	1	3.4	16	80.9	226.9	291.9	85.4	268.5	135.4	174.7	138.4	156.8	0	7.9	5	344.3	1584	1455.9	1571.8	953.6	618.2

CHAPTER 4

4. HYDROGEOLOGICAL SETUP OF UT OF LAKSHADWEEP

4. 1 Climate and Rainfall

Lying well within the tropics and extending to the equatorial belt, these islands have a tropical humid, warm and generally pleasant climate, becoming more equatorial in the southern islands of the territory. The climate is equable and no distinct and well-marked seasons are experienced. Southwest monsoon period is the main rainy season which lasts from late May to early October. The mean daily temperatures range between 22 to 33^0 C while the humidity ranges between 72 to 85%.

The average Monsoonal rainfall in Lakshadweep islands is in the range of 1380 mm (Minicoy) to 1615 (Androth). Southwest monsoon extending from May to October with 80-90 rainy days is the main rainy season. Winds are light to moderate during October to March. The normal rainfall of Lakshadweep Islands is given in **Table.2.1.**

Table 4:1 Normal Rainfall of Lakshadweep Islands.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
15.4	**9.8**	**10.7**	**35.2**	**157.4**	**330.3**	**294**	**223.2**	**165.6**	**142.3**	**125.3**	**54.2**	**1563.4**

4. 2 Evapotranspiration

Evapotranspiration also is vital part of the hydrological cycle of tropical small islands and can account for the loss of more than half of the rainfall on an annual basis. In fact, evapotranspiration often exceeds the rainfall for individual months or consecutive months during dry season or drought periods. In Lakshadweep islands the variability of evapotranspiration is much lower than that of rainfall. Typical annual values of potential evapotranspiration in the islands are between 1600 mm and 1800 mm.

Vegetation intercepts part of rainfall and causes transpiration to occur. Interception and transpiration tend to decrease recharge and hence, decrease the available groundwater resource. Depending on the depth to water table and type of vegetation, direct transpiration losses from groundwater aquifers can increase. Coconut trees growing on coral atoll islands for example act as phreatophytes which draw water directly from the water table, and can contribute to a reduction in groundwater resource during dry periods.

4. 3 Geomorphology

The Lakshadweep Ridge approximately 800 km long and 170 km wide is a fascinating and conspicuous feature of Arabian Sea. It is inclined southerly (1/715-gradient) with a narrow strip (10 km) near Goa and widens to 170 km west of Cape Comorin, This domain is distinct with scores of islands, banks, and shoals, topographic rises, and mounts, inter mount valleys and sea knolls.

Notable feature of the individual island of the ridge is that the relief of all the islands above MSL is uniformly low (4-5 m). However, height of the submerged banks and shoals varies considerably. Based on the structural features, trends of the individual islands, geophysical anomalies and related faults/ dislocations, Lakshadweep islands are classified into northern, central and southern blocks. All the important islands fall in the central block separated by Bassas de Pedro fracture in the north and a NNE-

SSW trending valley in the south. The northern block is dominated by coral banks and southern by few islands and small banks.

The islands are flat, rarely rising more than two meters, and consist of fine coral sand and boulders compacted into sandstone. Most atolls have a northeast, southwest orientation with an island on the east, a broad well-developed reef on the west and a lagoon in between. All Lakshadweep islands are of coral origin and some of them like Minicoy, Kalpeni, Kadmat, Kiltan and Chetlat are typical atolls. The coral reefs of the islands are mainly atolls except one platform reef of Androth.

The islands on these atolls are invariably situated on the eastern reef margin except Bangaram and Cheriyakara which lie in the centre of the lagoon. On Bitra, the island is on the northern edge of the lagoon. The atolls show various stages of development of the islands, the reefs at Cheriya Panniyam, Perumalpar and Suheli represent the earliest stage while Kalpeni, Kavaratti, Agatti and Kadmat are in intermediate stage and Chetlat and Kiltan are in an advanced or mature stage of development. The development and growth of the islands on eastern reef margin has been controlled by a number of factors. The cyclones from the east have piled up coral debris on the eastern reef while the very high waves generated annually during the southwest monsoon have pounded the reef and broken this into coarse and subsequently to fine sediments which was then transported and deposited on the eastern side behind the coral boulders and pebbles on the eastern reef.

The Lakshadweep islands are of coral origin which developed around volcanic peaks. It seems that they first rose to the surface in the form of shallow oval basins and under the protection of the reef, the eastern rim gradually developing towards the center, forming the islands. The process of development towards the center of the lagoon is still going on in some of the islands. Identical in structure and formation, the islands rise no more than 5 m above MSL and are of varied size. The islands are typical atolls, elongated reefs of organic limestone that are partly, intermittently or completely covered by water. They form a ring around a shallow basin of water, the lagoon. The reef varies in width at their surface, reaching a maximum width between lagoon and ocean of over 5 km.

Geomorphologically, the islands have lagoonal beaches, storm beaches, beach ridges, sand dunes and hinterlands. The islands are generally flat with localized depressions and sand mounds, which are largely man-made.

4. 4 Geology and Structure

There are no conclusive theories about the formation of these coral atolls. The most accepted theory is the one proposed by the English Evolutionist Sir Charles Darwin. He concluded in 1842 that the subsidence of a volcanic island resulted in the formation of a fringing reef and the continual subsidence allowed this to grow upwards.

The islands are of coral origin which developed around volcanic peaks. It seems that they first rose to the surface in the form of shallow oval basins and under the protection of the reef, with the eastern rim gradually developing towards the center, forming the islands. The process of development towards the center of the lagoon is still going on in some of the islands. Identical in structure and formation, the islands rise no more than 5 m above MSL and are of varied size. The islands are typical atolls, elongated reefs of organic limestone that are partly, intermittently or completely covered by water. They form a ring around a shallow basin of water, the lagoon. The reef varies in width at their surface with a maximum width between lagoon and ocean of over 5 km.

Beneath a thin layer of vegetal humus there is fine coral sand extending over the surface of all the islands. Below this is a compact crust of fine conglomerate looking like coarse oolitic limestone with embedded bits and shell, and beneath this crust there is another layer of sand.

The Lakshadweep Group of atolls lie on the prominent N-S Lakshadweep ridge and the alignment appears to be a continuation of the Aravalli strike of Rajasthan. Based on this, many geologists have speculated that the islands are a buried continuation of the Aravalli Mountain chain and that the Deccan Traps have been faulted down in the sea along the West coast of India. A great thickness of traps and associated sediments occur to the west. Based on seismic study (Ermenko and Datta, 1968), it is inferred that the Indian shield (continental crust) extends as far as to the Lakshadweep. The transition zone separating the continental and oceanic crust occurs to the west of the Lakshadweep. Further, using seismic refraction measurements (Francis and Short, 1966), it was postulated that 1.5 km to 2 km thick volcanic rocks lie below the sea floor on the Lakshadweep ridge.

The islands are composed mainly of coral reefs and material derived from them. The litho-units identified include calcareous sand of the beach facies, strand line facies, dune facies and anthropogenically modified varieties identified on the basis of base morphometric units, grain size and other physical characteristics. Coralline grit and gritty conglomerates, coralline limestones and shingles are of submerged reef facies. While the lagoonal beach is made up of fine to medium grade calcareous sand, the berm portions consist of slightly coarser sand and the dune portion, coarse, unsorted sand. The interior parts of the island have anthropogenically reworked calcareous sand. The sand ridge portions consist of assorted sand, which is somewhat compact. The coral limestone, gritty limestone and gritty conglomerates are exposed on the beaches in the form of wave-cut terraces. The sediments of the lagoon consist chiefly of gravel and sand-sized material, composed mainly of various types of dead corals produced by the breaking up of reefs by the waves.

4. 5 Ground Water Conditions

Coral atolls of Lakshadweep islands consist of a layer of recent (Holocene) sediments, comprising mainly coral sands and fragments or coral, on top of older limestone. An unconformity separates these two layers at typical depths of 10m to 20 m below mean sea level. Several deeper unconformities may exist due to fluctuations in sea level which resulted in alternate periods of emergence and submergence of the atoll. During periods of emergence, solution and erosion of the reef platform occur, while further deposition of coral limestone occurs during periods of submergence. The upper sediments are of primary importance from a hydrogeological viewpoint as freshwater lenses occur solely or mainly within this layer. The occurrence of such lenses within this layer is due to its moderate permeability (Typically 5 to 10 m/day) compared with higher permeability of the older limestone (typically 50 to 100 m/day). Permeability greater than 1000 m/day occurs in solution cavities within the limestone. This extremely high permeability allows almost unrestricted mixing of freshwater and sea water which is less likely to occur in the upper sediments. The upper unconformity, therefore, is one of the main controlling features of the depth of freshwater lens.

Ground water occurs under phreatic condition and is in hydraulic continuity with sea water. The fresh ground water floats over the seawater because of the density difference and the nature of the porous medium. The shape and thickness of freshwater lens in these islands depends on the elevation of water table (Fig.2.1). As per the Ghyben - Herzberg relationship, the fresh water - salt-water interface is at a depth of about 40 times the height of water table above the mean sea level. This is possible only in ideal conditions. However, on small islands where the fresh water lens is thin and the tidal range is usually greater than the head above mean sea level. Heads are often of little value in determining the fresh water thickness. Due to the diurnal fluctuations a sharp interface does not exist but rather a transition zone develops between the fresh and salt water. The recharge to the ground water is only through rainfall infiltration.

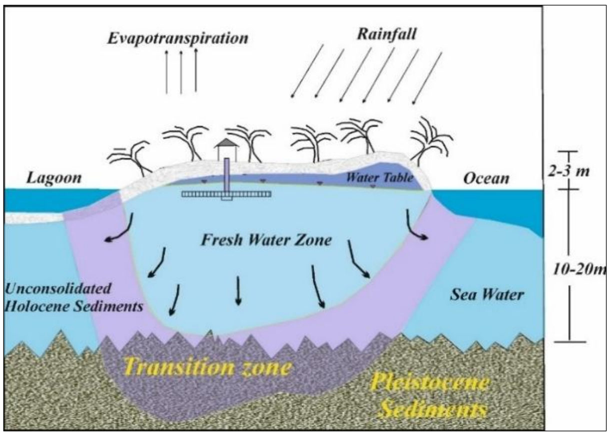


Figure 4:1 Fresh Water Lens in Small Islands (Exaggerated Vertical Scale)

[Source: A.C.Falklands (1993): Hydrology and watermanagement on small tropical islands- Hydrology of Warm Humid Regions (Proceedings of the Yokohama Symposium, July 1993). IAHS Publ. no. 216, 1993.]

Open, manually dug wells are the traditional method used by the islanders to obtain freshwater for their basic needs. As the depth from the surface to the groundwater table is generally just a few meters, and the soil is fairly easy to excavate by hand, open wells or pits, 1m to 2m in diameter, are excavated to depth of 30 to 90 cm below groundwater table. Almost every household is having a dug well which is mainly used for domestic purposes. Some are drawing water for coconut seedlings or for cattle breeding. The islanders have been conserving water by using step wells, ponds or tanks for washing and bathing purposes. But recent trend is to use small capacity centrifugal pumps mostly of 1/2 HP capacity for their domestic needs The Union Territory of Lakshadweep is an archipelago on the western coast of Peninsular India in the Arabian sea spread over a distance of 300 km and comprising of small islands having area between 0.1 and 4.8 sq km. The growing population and raised standard of living has imparted stress on the available fresh water resources. The lack of surface and ground water storage capacity in these islands, in spite of high rainfall, makes freshwater resources a dear commodity. Ground water occurs under phreatic conditions in these islands occurring as a thin lens floating over the seawater and is tapped by open wells. Majority of the wells included under participatory monitoring tap coral sands and in almost all the wells hard coral limestone is exposed near the bottom. The depth to water level in these islands varies from a few centimeters to 5 m below ground level and depth of the wells varies from less than a meter to about 6 m. The depth to water level is highly influenced by the tides.

4. 6 Groundwater Quality

The ground water in the islands is generally alkaline with a few exceptions. The Electrical Conductivity (EC) ranges from 500 to 15,000 µS /cm at 25 ^{0}C. Higher concentrations of dissolved solids are generally seen along the periphery of the island and also close to pumping centers. The quality variation is vertical, temporal and also lateral. The quality is highly variable and reversible. It is also observed that the quality improves with rainfall. Other factors affecting the quality are tides, ground water recharge and draft. There is a vertical variation of quality due to the zone of interface and underlying sea water. Perforation created due to drilling or otherwise also affects the quality as it acts as a conduit for flow of sea water.

Wells manually operated retain more or less the same quality of ground water over longer time periods as compared to mechanized wells where, quality deterioration is observed in the form of increasing EC. Brackish water is present along topographic lows and in places where coarse pebbles and corals are present. Another major threat to ground water in the islands is the pollution. The human and livestock wastes, oil spills and fertilizers are the main polluting agents with sewerage and other biological wastes contributing most.

CHAPTER-5

5. GROUND WATER LEVEL SCENARIO IN THE UT OF LAKSHADWEEP

As mentioned earlier, groundwater occurs under phreatic condition in all the islands and is in hydraulic continuity with seawater and hence is influenced by tidal fluctuations. The overall hydrogeological condition of the individual islands is described below.

Agatti: The depth of wells in this island ranges from 2.0 to 4.3 m bgl and the depth to water table ranges from 1.3 to 3.6 m bgl. The fluctuations in water level due to tidal effect in these wells range from 0.15 to 0.25m.

Amini: The depth of wells in this island ranges from 1.5 to 7.2 m bgl and the depth to water table ranges from 1.2 to 3.8 m bgl. The fluctuations in water level due to tidal effect in these wells range from 0.08 to 0.16m. The elevation of water table varies from 0.8 to 1.3 m amsl.

Androth: The depth of wells in this island ranges from 1.9 to 5.2 m bgl and the depth to water table ranges from 1.1 to 3.9 m bgl. The fluctuations in water level due to tidal effect in these wells range from 0.09 to 0.14m.

Chetlat: The depth of wells in this island ranges from 1.7 to 3.9 m bgl and the depth to water table ranges from 1.1 to 3.5 m bgl. The fluctuations in water level due to tidal effect in these wells range from 0.05 to 0.20m.

Kavaratti: The depth of wells in this island ranges from 2.0 to 4.50 m bgl and the depth to water table ranges from 1.75 to 2.50 m bgl. The fluctuations in water level due to tidal effect in these wells range from 0.08 to 0.23m.

Kalpeni: The depth of wells in this island ranges from 1.0 to 3.5 m bgl and the depth to water table ranges from 0.80 to 3.0 m bgl. The fluctuations in water level due to tidal effect in these wells range from 0.01 to 0.21m.

Minicoy: The depth of wells in this island ranges from 1.2 to 3.5 m bgl and the depth to water table ranges from 1.0 to 2.0 m bgl. The fluctuations in water level due to tidal effect in these wells range from 0.13 to 0.26m.

The groundwater scenario in Lakshadweep is unique due to its geographic and geological characteristics as coral atolls. Freshwater availability is limited and highly dependent on rainfall, making groundwater management critical for sustainability.

5. 1 Freshwater Lens System

a) Formation: Rainwater percolates through porous coral sand and accumulates as a thin "freshwater lens" floating above denser saline seawater. This lens is the primary source of groundwater for the islands.
b) Thickness: Typically ranges from 1–5 meters, depending on island size, rainfall, and extraction rates. Larger islands like Kavaratti and Agatti have thicker lenses.
c) Vulnerability: Over-extraction or reduced rainfall can cause the lens to shrink or allow saltwater intrusion, contaminating freshwater reserves.

5. 2 Factors Affecting Groundwater Levels

a) Rainfall Dependency:

   i. Recharge occurs almost entirely during the monsoon season (June–September).
   ii. Annual rainfall (~1,500–1,700 mm) is high, but rapid percolation through porous coral limits retention.

b) Limited Storage Capacity:
   i. Small island size (most islands <5 km²) restricts freshwater storage.

c) Saltwater Intrusion:
   i. Rising sea levels, over-pumping, and tidal surges during cyclones disrupt the freshwater-saline balance.

d) Diurinal variation:
   i. Water tables peak during high tide and decline during the low tide

5. 3 Current Challenges

a) Over-Extraction:
   i. Growing population and tourism have increased demand. Many islands rely on energized pumps, which risk depleting the lens.

b) Pollution:
   i. Contamination from pit toilets, septic tanks, and waste disposal threatens groundwater quality. Coral sand offers minimal natural filtration.

c) Climate Change:
   i. Rising sea levels and erratic monsoons exacerbate saltwater intrusion and reduce recharge efficiency.

5. 4 Management Efforts

a) Rainwater Harvesting:
   i. Mandatory rooftop rainwater harvesting systems (e.g., Kavaratti has over 90% coverage) supplement groundwater use.

b) Desalination Plants:
   i. Diesel-powered desalination units provide safe drinking water but are energy-intensive and costly.

5. 5 Key Observations

a) Islands like Kavaratti and Agatti manage better due to proactive rainwater harvesting, while smaller islands face acute shortages.

b) The Lakshadweep Public works department (LPWD) monitors groundwater quality and salinity levels, reporting increasing stress in recent decades.

CHAPTER 6

6. GROUNDWATER RESOURCES IN THE UT OF LAKSHADWEEP

The dynamic ground water resources have been assessed by computing various components of recharge and extraction. Rainfall is the only source of recharge in the Islands, whereas domestic draft, evapotranspiration losses and water loss due to outflow into the sea are the major components of extraction. A part (20%) of the annual water surplus is reserved as buffer zone for reserve during delayed or deficit monsoon years and another 20% as Water loss due to outflow to ocean. The computational details and recharge figures block wise as well as island wise are given in **Annexure I and Ia**.

As per the computation, the total Groundwater recharge in the islands amount to 1,380.26 ham, ranging from 54.76 ham in Chetlat Island to 254.89 ham in Androth Island. Evapotranspiration from coconut trees during 6 non-monsoon months amounts to 257.69 ham, whereas the water loss due to outflow into sea is of the order of 276.05 ham. An equal quantum of water is reserved as buffer to cater to late or deficit monsoon years in the islands. The annual extractable ground water resources ranges from 23.14 ham (Chetlat) to 114.49 ham (Androth), amounting to a total 570.48 ham for the group of Islands as a whole. The Ground water resource available for future development is 211.13 ham for the whole group of islands, with values ranging from 9.38 ham (Chetlat) to 47.08 ham (Androth).

Ground water extraction in the Islands, by and large, is for domestic uses of the populace. The extraction component ranges from 13.40 ham in Chetlat islands to 65.62 ham in Androth Island, amounting to a total of 349.79 ham.

The stage of ground water extraction for the group of islands is of the order of 61.32 % and ranges from 42.28 % (Kalpeni) to 77.41 % (Kavaratti). In the absence of long-term water level data, the islands have been categorized solely based on the stage of ground water extraction. Based on the Stage of ground water extraction, Kavaratti Island has been categorized as 'Semi-Critical' and the remaining islands have been categorized as 'Safe'.

The Amini Block in Lakshadweep has a total recharge-worthy area of 571 hectares. The block receives an annual rainfall of 1805.54 mm, contributing to a total annual groundwater recharge of 300.70 hectare meters (ham). Of this, 52.92 ham is lost as evapotranspiration, while 120.28 ham is attributed to environmental flows. The extractable groundwater resource in the block is 127.5 ham, with 70.27 ham currently being extracted for all uses. This results in an extraction rate of 55.11%, indicating moderate utilization of groundwater resources.

For future use, 55.31 ham of groundwater is available. Additionally, 72.2 ham has been allocated for domestic use by the projected year 2025. A key insight from this data is that Amini has the lowest extraction rate among all blocks, suggesting sustainable groundwater use. This highlights the importance of maintaining this balance through continued monitoring and conservation efforts to ensure long-term water security.

The Androth Block in Lakshadweep has a total recharge-worthy area of 712 hectares. The block receives an annual rainfall of 1805.54 mm, contributing to a total annual groundwater recharge of 374.95 hectare meters (ham). Of this, 63.07 ham is lost as evapotranspiration, while 149.97 ham, is attributed to environmental flows. The extractable groundwater resource in the block is 161.91 ham, with 85.67 ham currently being extracted for all uses. This results in an extraction rate of 52.91%, indicating moderate utilization of groundwater resources.

For future use, 73.9 ham of groundwater is available. Additionally, 88 ham has been allocated for domestic use by the projected year 2025. A key insight from this data is that Androth has the highest recharge and extractable groundwater resources among all blocks, making it a critical area for water management. This highlights the importance of sustainable management practices to ensure the long-term availability of groundwater resources in the block.

The Kavaratti Block in Lakshadweep has a total recharge-worthy area of 634 hectares. The block receives an annual rainfall of 1805.54 mm, contributing to a total annual groundwater recharge of 333.87. Of this 64.15 lost as evapotranspiration and 133.55 ham is attributed to environmental flows. The extractable groundwater resource in the block is 136.17 ham, with 100.8 ham currently being extracted for all uses. This results in an extraction rate of 74.03%, which is the highest among all blocks, indicating significant pressure on groundwater resources.

For future use, 32.62 ham of groundwater is available. Additionally, 103.55 ham has been allocated for domestic use by the projected year 2025. A key insight from this data is that Kavaratti's high extraction rate (74.03%) calls for immediate attention to ensure sustainable groundwater use. This highlights the need for effective water management strategies, such as promoting conservation measures and monitoring extraction levels, to prevent overexploitation and ensure long-term water security in the block.

The Kiltan Block in Lakshadweep has a total recharge-worthy area of 267 hectares. The block receives an annual rainfall of 1805.54 mm, contributing to a total annual groundwater recharge of 140.6 hectare meters (ham). Of this, 26.14 ham is lost as evapotranspiration, while 56.24 ham, is attributed to environmental flow. The extractable groundwater resource in the block is 58.22 ham, with 36.13 ham currently being extracted for all uses. This results in an extraction rate of 62.06%, indicating moderate to high utilization of groundwater resources.

For future use, 21.1 ham of groundwater is available. Additionally, 37.11 ham has been allocated for domestic use by the projected year 2025. A key insight from this data is that Kiltan has the smallest geographical area and groundwater resources among all blocks, requiring careful management to avoid overexploitation. This highlights the importance of implementing sustainable water management practices, such as efficient water use and conservation measures, to ensure the long-term availability of groundwater in the block.

The Minicoy Block in Lakshadweep has a total recharge-worthy area of 437 hectares. The block receives an annual rainfall of 1805.54 mm, contributing to a total annual groundwater recharge of 230.14 hectare meters (ham). Of this, 51.41 ham is lost as evapotranspiration, while the 92.05 ham is attributed to environmental flows. The extractable groundwater resource in the block is 86.68 ham, with 56.92 ham currently being extracted for all uses. This results in an extraction rate of 65.67%, indicating moderate to high utilization of groundwater resources.

For future use, 28.2 ham of groundwater is available. Additionally, 58.48 ham has been allocated for domestic use by the projected year 2025.

A key insight from this data is that Kiltan block has the smallest geographical area and groundwater resources among all blocks, requiring careful management to avoid overexploitation. This highlights the importance of implementing sustainable water management practices, such as efficient water use and conservation measures, to ensure the long-term availability of groundwater in the block.

6. 1 Summary of Key Findings:

1. Androth block has the highest groundwater recharge (311.88 ham) and extractable resources (161.91 ham), making it a critical block for water management.
2. Kavaratti block has the highest extraction rate (74.03%), indicating potential overuse and the need for conservation measures.
3. Androth blockhas the lowest extraction rate (52.91%), reflecting sustainable groundwater use.
4. Kiltan and Minicoy blocks have moderate extraction rates but limited groundwater resources, requiring careful planning.

This block-wise analysis highlights the importance of tailored groundwater management strategies for each block in Lakshadweep to ensure sustainability and meet future demands.

6. 2 Comparison with Earlier Estimates

A comparison with the earlier estimate of 2023 indicates there is no significant change of the resource metrics with respect to the rainfall recharge and Stage of Ground Water Extraction.

6. 3 Groundwater Recharge in Poor Ground Water Quality Area

Since the area under poor groundwater quality is negligible compared to the total area of the islands, the amount of water recharged in this area is also negligible when compared with the total recharge.

Table 6:1 Comparison of Major components of Ground Water Resource Estimation 2024 vs 2023

Sl No	Components	2023	2024	Remarks
1.	Rainfall Infiltration Factor (RIF)	35%	35%	
2.	Rainfall Recharge (ham)	1,381.45	1,380.26	No significant change
3.	Evapotranspiration (ham)	282.08	257.69	Based on recent studies, ET rate limited to 30 liter/day/tree
4.	Outflow components – outflow to sea & Buffer Zone (ham)	552.56	552.09	Directly taken as 40% of component 2.
5.	Annual Extractable Ground water Resource (ham)	546.81	570.48	
6.	Ground Water Extraction Domestic (ham)	337.51	349.79	
7.	Stage of Ground Water Extraction (%)	61.72	61.32	No significant change
8.	Categorization	2-semi critical & 7 safe	1- semi critical & 8 safe	Amini island changed from Semi- critical to Safe. New desalination plant commissioned.

CHAPTER 7

7. ISLAND WISE GROUND WATER RESOURCE SCENARIO

The Groundwater Resource Assessment (GWRA) for the Lakshadweep Islands in 2024 provides a detailed analysis of the groundwater availability, extraction, and sustainability across the islands. The assessment is based on various components of the water balance, including population, area, rainfall, infiltration, and extraction.

7. 1 Island-wise Groundwater Resource Assessment

1. Agatti

Agatti Island, with a population of 8,759 in 2023 and a geographical area of 271 hectares, has a total groundwater recharge (water surplus) of 142.71 ham. The annual extractable groundwater resource is 57.11 ham, of which 39.60 ham is utilized for domestic purposes. This leaves 16.43 ham of groundwater available for future development. The stage of groundwater extraction is 69.34%, indicating that the current usage is within sustainable limits. As a result, Agatti is categorized as having a safe groundwater status, ensuring that its water resources are well-managed and sufficient for future needs.

2. Amini

Amini Island, with a population of 8,869 in 2023 and a geographical area of 259 hectares, has a total groundwater recharge (water surplus) of 136.40 ham. The annual extractable groundwater resource is 56.35 ham, of which 38.98 ham is used for domestic purposes. This leaves 16.30 ham of groundwater available for future development. The stage of groundwater extraction is 69.17%, indicating that the current usage is within sustainable limits. As a result, Amini is categorized as having a safe groundwater status, ensuring that its water resources are well-managed and sufficient for future needs

3. Androth

Androth Island, with a population of 12,955 in 2023 and a geographical area of 484 hectares, has a total groundwater recharge (water surplus) of 254.89 ham. The annual extractable groundwater resource is 114.49 ham, of which 65.62 ham is utilized for domestic purposes. This leaves 47.08 ham of groundwater available for future development. The stage of groundwater extraction is 57.32%, indicating that the current usage is well within sustainable limits. As a result, Androth is categorized as having a safe groundwater status, ensuring that its water resources are effectively managed and sufficient to meet future demands.

4. Chetlat

Chetlat, with a population of 2,717 in 2023, spans an area of 104 hectares and has a total groundwater recharge (water surplus) of 54.76 ham. The annual extractable groundwater resource is 23.14 ham, of which 13.40 ham is currently used for domestic extraction. This leaves 9.38 ham of groundwater resource available for future development. With a groundwater extraction stage of 57.91%, Chetlat falls under the "Safe" category, indicating sustainable water resource management.

5. Kadmat

Kadmat, with a population of 6,256 in 2023, covers an area of 312 hectares and has a total groundwater recharge (water surplus) of 164.30 ham. The annual extractable groundwater resource is 71.15 ham, of which 31.29 ham is currently utilized for domestic needs, leaving 39.01 ham available for future development. With a groundwater extraction rate of 43.98%, the region is classified as "Safe", indicating sustainable and well-managed water resource practices.

6. Kalpeni

Kalpeni, with a population of 5,116 in 2023, spans 228 hectares and has a total groundwater recharge (water surplus) of 120.06 ham. The annual extractable groundwater resource is 47.42 ham, of which 20.05 ham is currently used for domestic needs, leaving 26.82 ham available for future development. With a groundwater extraction rate of 42.28%, the region is classified as "Safe", reflecting sustainable water resource management practices

7. Kavaratti

Kavaratti, with a population of 12,991 in 2023, spans 363 hectares and has a total groundwater recharge (water surplus) of 191.16 ham. The annual extractable groundwater resource is 79.06 ham, of which 61.20 ham is currently utilized for domestic needs, leaving 16.19 ham available for future development. With a groundwater extraction rate of 77.41%, the region is classified as "Semi-critical", signaling heightened stress on water resources and the need for cautious management to prevent overexploitation

8. Kiltan

Kiltan, with a population of 4,569 in 2023, spans 163 hectares and has a total groundwater recharge (water surplus) of 85.84 ham. The annual extractable groundwater resource is 35.08 ham, of which 22.73 ham is currently used for domestic needs, leaving 11.72 ham available for future development. With a groundwater extraction rate of 64.79%, the region is categorized as "Safe", indicating that water resources are managed sustainably within replenishable limits.

9. Minicoy

Minicoy, with a population of 12,094 in 2023, spans 437 hectares and has a total groundwater recharge (water surplus) of 230.14 ham. The annual extractable groundwater resource is 86.68

ham, of which 56.92 ham is currently utilized for domestic needs, leaving 28.20 ham available for future development. With a groundwater extraction rate of 65.67%, the island is classified as "Safe", reflecting sustainable management of water resources. Minicoy maintains sufficient groundwater reserves to support future growth while ensuring extraction remains within replenishable limits.

7. 2 Summary

The Lakshadweep Islands, with a total population of 74,326 in 2023 and a combined area of 2,621 hectares, have a total groundwater recharge (water surplus) of 1,380.26 ham. The annual extractable groundwater resource stands at 570.48 ham, of which 349.79 ham is currently utilized for domestic needs, leaving 211.13 ham available for future development. With an overall groundwater extraction rate of 61.32%, the archipelago is categorized as "Safe", reflecting sustainable management of water resources and sufficient reserves to support future growth. However, the semi-critical status of Kavaratti (77.41% extraction) underscores the need for targeted conservation measures to ensure long-term water security across the region.

CHAPTER 8

8. CONCLUSIONS

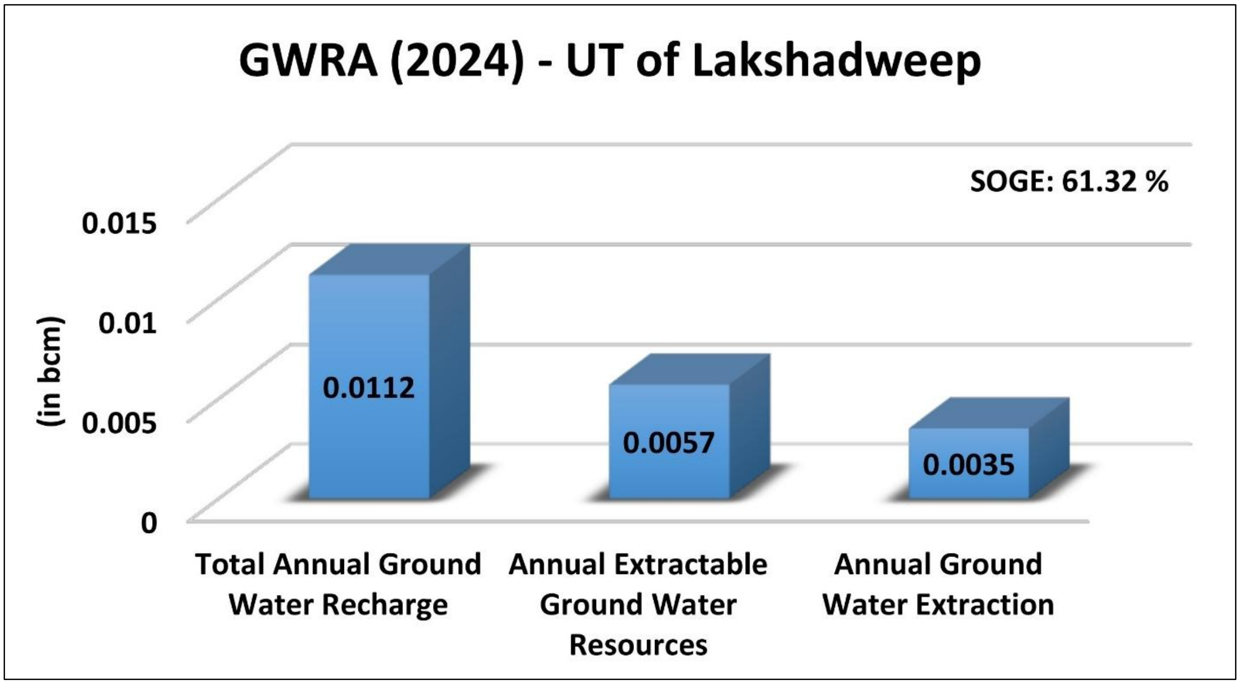
Lakshadweep islands are composed of calcareous sand and materials derived from coral atolls. Alternate layers of loose sand, moderately cemented calc-arenites and well cemented, hard and compact limestone underlie the islands. In these islands, fresh ground water occurs under phreatic conditions as lens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

Lakshadweep is a unidistrict state wherein the dynamic ground water resources have been assessed for individual islands and the output is generated block wise. The total Annual Ground Water Recharge in the UT has been estimated as 0.014 bcm and Annual Extractable Ground Water Resources works out as 0.0057 bcm. The total current Annual Ground Water Extraction has been assessed as 0.0035 bcm and the Stage of Ground Water Extraction as 61.32%. Out of the 5 assessment units, 4 blocks (80%) are categorized as 'Safe' and 1 block (20%) Kavaratti, as 'Semi Critical'.

Similarly, out of 26.21 sq km recharge worthy area, 6.34 sq km (24.19 %) under 'Semi-critical', 19.87 sq km (75.81 %) under 'Safe' category of assessment units. Out of total 5.7 mcm annual extractable ground water resources of the State, 1.36 mcm (23.86 %) under 'Semi-critical' and 4.34 mcm (76.14 %) are under 'Safe' categories of assessment units.

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

The groundwater resources in the Lakshadweep Islands are generally well-managed, with most islands categorized as safe. However, the semi-critical status of Kavaratti indicates areas where more focused conservation efforts are needed. Sustainable management practices, including efficient water use and enhanced recharge techniques, should be prioritized to maintain the health of these vital resources.



Dynamic Ground water Recourses Scenario 2024 – UT of Lakshadweep

9. ANNEXURES

Annexure I: Dynamic Ground Water Resources of Lakshadweep Islands [block wise estimates (2024)]

S.NO	Name of Block	Total Annual Recharge from all sources (ham)	ET loss from Trees for 6 non-monsoon months (ham)	Total Annual Ground Water Recharge	Total Natural Discharge	Annual Extractable Ground Water Resource	Total Extraction	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)	Category
1	AMINI	300.70	52.92	247.78	120.28	127.50	70.27	55.31	55.11	Safe
2	ANDROTH	374.95	63.07	311.88	149.97	161.91	85.67	73.90	52.91	Safe
3	KAVARATTI	333.87	64.15	269.72	133.55	136.17	100.80	32.62	74.03	Semi-critical
4	KILTAN	140.60	26.14	114.46	56.24	58.22	36.13	21.10	62.06	Safe
5	MINICOY	230.14	51.41	178.73	92.05	86.68	56.92	28.20	65.67	Safe
	Total (Ham)	***1,380.26***	***257.69***	***1,122.57***	***552.09***	***570.48***	***349.79***	***211.13***	***61.32***	***Safe***
	Total (BCM)	***0.014***	***0.003***	***0.011***	***0.006***	***0.006***	***0.003***	***0.002***		

Annexure Ia: Dynamic Ground Water Resources of Lakshadweep Islands (2024)

GWRA Lakshadweep 2024											
Sl. No.	**Annual components of Water Balance**	**Name of Island**									**Total**
		Agatti	**Amini**	**Androth**	**Chetlat**	**Kadmat**	**Kalpeni**	**Kavaratti**	**Kiltan**	**Minicoy**	
1	Population in 2023 (as per JJM website)	8759	8869	12955	2717	6256	5116	12991	4569	12094	74326
2	Area (Ha)	271	259	484	104	312	228	363	163	437	2621
3	Normal Rainfall	1.505	1.505	1.505	1.505	1.505	1.505	1.505	1.505	1.505	
4	Rainfall Infiltration Factor (%)	35	35	35	35	35	35	35	35	35	
5	Total GW Recharge (Water Surplus) (ham)) [(2)*(3)*(4)*0.01]	142.71	136.40	254.89	54.76	164.30	120.06	191.16	85.84	230.14	1380.26
6	ET loss from Trees for 6 non-monsoon months (ham)	28.51	25.49	38.45	9.72	27.43	24.62	35.64	16.42	51.41	257.69
7	Water loss due to outflow to sea (ham) [20% of (5)]	28.54	27.28	50.98	10.95	32.86	24.01	38.23	17.17	46.03	276.05
8	Buffer zone for reserve during delayed or lesser monsoon period (ham) [20% of (5)]	28.54	27.28	50.98	10.95	32.86	24.01	38.23	17.17	46.03	276.05
9	Annual Extractable GW Resource (ham) [(5)-(6)-(7)-(8)]	57.11	56.35	114.49	23.14	71.15	47.42	79.06	35.08	86.68	570.48
10	Annual Domestic extraction (ham)	39.60	38.98	65.62	13.40	31.29	20.05	61.20	22.73	56.92	349.79
11	Gross Annual GW Extraction (ham)	39.60	38.98	65.62	13.40	31.29	20.05	61.20	22.73	56.92	349.79
12	Allocation of Ground Water Resource for Domestic Utilisation for Projected Year 2025 (ham)	40.68	40.05	67.40	13.76	32.15	20.60	62.87	23.35	58.48	359.34
13	GW Resource available for future development (ham) [(9)-(12)]	16.43	16.30	47.08	9.38	39.01	26.82	16.19	11.72	28.20	211.13
14	Stage of ground water extraction in % [(11)/(9)*100]	69.34	69.17	57.32	57.91	43.98	42.28	77.41	64.79	65.67	***61.32***
15	Category	Safe	Safe	Safe	Safe	Safe	Safe	Semi-critical	Safe	Safe	***Safe***

Annexure II: Order regarding Constitution of Ground Water Resource Re-estimation committee for UT of Lakshadweep

सत्यमेव जयते

04896262262(o)
263367(Fax)
Email:selpwd@gmail.com
Email: lk-pwd@nic.in

GOVERNMENT OF INDIA/ भारत सरकार
LAKSHADWEEP ADMINISTRATION/ लक्षद्वीप प्रशासन
(LAKSHADWEEP PUBLIC WORKS DEPARTMENT)/ लक्षद्वीप लोक निर्माण विभाग
CIRCLE OFFICE/ सर्किल कार्यालय
KAVARATTI – 682555

F.No.118/03/2022-S4 /330 **दिनांक/Dated: २२ .02.2022**

ORDER

The Regional Director, CGWB, Kerala region, by enclosing a letter from CGW,CHQ, Ministry of Jal shakthi on the subject of 'Estimation of Ground water resources of Lakshadweep as on March 2022" requested to re constitute UT level committee for the Estimation of Ground water resources of Lakshadweep.

Advisor to the Hon'ble Administrator, **UT of Lakshadweep vide Dairy number 442 dated 14.02.2022** pleased to constitute permanent UT level committee for the Estimation of Ground water resources estimation of Lakshadweep with following composition.

1. District Collector, UTL - Chairman
2. Conservator of Forest - Member
3. Superintending Engineer, LPWD - Member
4. Director(Agriculture) - Member
5. Director (Industries) - Member
6. Director (Planning, Statistics & Taxation) - Member
7. Director (Science & Technology) - Member
8. Regional Director, CGWB, Kerala region - Member Secretary

C.N. Shajahan
Superintending Engineer/ अधीक्षण अभियंता

To,
All members of the committee

Copy to
1. PA to Advisor to the Hon'ble Administrator
2. PA to the Seceratary(Works)

CENTRAL GROUND WATER ... KERALA REGION
358
15/3/22

Annexure III: Minutes of First UT Meeting on Re-estimation of Ground Water Resources of Lakshadweep, 2024

MINUTES OF THE FIRST UT LEVEL MEETING OF PERMANENT COMMITEE ON RE ESTIMATION OF GROUND WATER RESOURCES OF LAKSHADWEEP - 2024

The first UT Level Meeting of Permanent Committee on Re estimation of Groundwater Resources of Lakshadweep was held online on 17.05.2024 under the Chairmanship of Shri Arjun Mohan, IAS, Collector, UT of Lakshadweep and Chairman of Ground Water Re estimation Committee at 15.30 hrs. The following members attended the meeting

1.	Shri Arjun Mohan, IAS	Chairman
2.	Smt Mini Chandran	Member Secretary
3.	Shri C.N Shajahan	Member (SE, LPWD)
2.	Shri N Abdul Raheem	Member (for Conservator of forest)
3.	Shri G Ibrahim	Member (for Director, Agriculture)
4.	Shri Muhsin A.I.	Member (for Director, Science & Technology)
5.	Shri Rakesh Dahiya	Member (Industries)
6.	Smt Saritha S	Invitee (Scientist D, CGWB)
7.	Smt Bindhu J Viju	Invitee (Scientist D, CGWB)
8.	Shri G Sreenath	Invitee (Scientist D, CGWB)

At the outset the Member Secretary welcomed the Chairman and members acknowledging the prompt technical aid provided for the timely completion of the previous Resource Estimation (2024) pertaining to the Lakshadweep islands. Thereafter Shri C.N Shajahan, SE, LPWD addressed the meeting and appreciated the efforts taken by CGWB towards a realistic estimation of the Groundwater Resources of the islands. The Member Secretary was invited to deliver on the salient findings of the Resource Estimation as on March 2023.

Smt Mini Chandran, HOO, CGWB, Kerala Region briefed the methodology adopted for the estimation of groundwater resources and highlighted on the Resource availability and stage of development figured out for each island as per the latest assessment carried out during 2024 . Also informed the Chair on the change in assessment units to five blocks since 2023 in the resource assessment which will incorporate all the nine islands, and will be henceforth assessed annually. During the presentation, the members raised the following technical queries to which explanations are provided below

- **Rainfall infiltration factor taken as 30%**
  The highly porous and permeable coral sands and the underlying soft coral limestone do not allow any surface runoff hence infiltration factor of 30% is adopted after considering other losses

- **Suggestion was made on the resource assessment of Amini and Minicoy islands to be in tandem to the NAQUIM 2.0 studies taken up in 2023-24**
  It was clarified that the assessment of the islands will be done in taqndem to the NAQUIM 2.0 studies

The presentation concluded by briefing on the data requirements for the reassessment of the resources and the details are provided below

- Rainfall – Normal Monsoon and Non-monsoon
- Monthly Rainfall data with no: of rainy days – 2018-23
- No: of Coconut trees in each island
- Status of wells, ponds, tanks and Rain water harvesting in each island during 2023-24 (in-use and not in-use)
- Capacity of pumps
- Status of implementation of Desalinisation plant in each island
- Status of piped water supply from RWH & Desalinisation plant in each island
- The water level data of dug wells monitored for the last 10 years
- Number of coconut trees in each island and the area covered by them in hectares
- Evapotranspiration rate of coconut trees for monsoon and non monsoon period

Presentation was followed by deliberations on the Estimation of Resource Methodology. The data requirements were discussed in detail and finally the Chairman assured the timely submission of the required data from the concerned departments. Members of the Committee were instructed for compliance to this end.

The meeting ended with thanks to the Chair

Signed by
Arjun Mohan
Date: 20-06-2024 18:41:49

Shri Arjun Mohan, IAS
Collector, UT of Lakshadweep
Chairman of Groundwater Re estimation Committee

Annexure IV: Minutes of Second U.T level Meeting on Re-estimation of Ground Water Resources of Lakshadweep, 2024

MINUTES OF THE 2ND MEETING OF THE PERMANENT UT LEVEL COMMITTEE ON RE-ESTIMATION OF GROUND WATER RESOURCES OF LAKSHADWEEP AS ON 2024

The 2nd Meeting of the permanent UT Level committee for the re-estimation of Ground Water Resources of the Lakshadweep was held online on 23.9.2024 under the Chairmanship of Dr Giri Shankar, IAS, District Collector, UT of Lakshadweep and Chairman of the committee at 15.00 hours. The following Members attended the meeting.

1.	Smt Mini Chandran, Scientist D & HOO, CGWB, Kerala Region	Member Secretary
2.	Shri Santosh Kumar Reddy V,IFS, Conservator of Forest, UTL	Member
3.	Shri Rakesh Kumar, DANICS, Director Agriculture, UTL	Member
3.	Shri Rakesh Dahiya, DANICS, Director Industries, UTL	Member
4.	Shri P Abdul Samad, Director (Planning, Statistics & Taxation), UTL	Member
5.	Shri Himanshu Yadav, DANICS, Director Science and Technology	Member
6.	Sh. C. N. Shajahan, Superintending Engineer, LPWD, UTL	Member
7.	Shri Roopesh G Krishnan, Scientist D, CGWB, Kerala Region,	Invitee
8.	Smt Rakhi UR, Scientist D, CGWB, Kerala Region,	Invitee
9.	Smt Saritha S, Scientist D, CGWB, Kerala Region,	Invitee
10.	Sh. G Sreenath, Scientist-D, CGWB, Kerala Region	Invitee
11.	Sh Arun Kumar AV, AHG, CGWB, Kerala Region	Invitee

At the outset, the Chairman welcomed the members and invitees to the meeting and invited Smt. Mini Chandran, Head of Office, CGWB and Member Secretary of the committee to make the presentation on the salient outcomes of the re-estimation of ground water resources of UT of Lakshadweep as on 2024.

- Smt. Mini Chandran briefed the methodology adopted for the estimation of ground water resources in island conditions and informed that the dynamic ground water resources of the Lakshadweep Islands as on 2024 has been computed for 9 islands and projected for the 5 blocks based on the data collected from various government departments of the Lakshadweep administration as well as the data generated by CGWB during Aquifer Mapping (NAQUIM) studies. The Chair was briefed on the change of assessment units during the assessment year- 2023 and that the present assessment would take block as the assessment unit as decided by Central Head Quarters, CGWB and the MIS window of the INGRES portal will be indicating block wise resource computation. However the island wise details will be provided in the GWRA – 2024 report of UT of Lakshadweep.

- The committee was informed that the rainfall infiltration factor method is used for the re-assessment with infiltration factor as 35%. Ground Water Extraction for domestic uses in the islands have been updated based on actual population records available in JJM portal as on 2022. The dependence on groundwater in these islands with desalinization plant has been computed after deducting the water supply from desalinization plants and rainwater harvesting structures provided by LPWD. And in the remaining islands, water supply from rain water harvesting storage tanks has been deducted to finalize the dependence on groundwater.
- The evapo-transpiration rate from each island has been computed based on the value provided by Department of Agriculture, UT Lakshadweep.
- As per the assessment carried out, the Annual Extractable Ground Water Resources and Annual Gross Ground Water Extraction for all uses in the assessment units are of the order of 570.48 Ham and 349.79 Ham respectively.
- The Stage of Ground Water Extraction of UT of Lakshadweep is 61.32 %. Based on the estimation of available resources and ground water extraction, one island –Kavaratti is categorized as 'Semi-Critical' while the remaining islands are in 'Safe' category. Block wise assessment has **Kavaratti** Block under semi critical category with Stage of Extraction at **77.41 %**

The final results of the computation were deliberated in detail by the committee. The Chairman appreciated the efforts of CGWB and other Government departments in the timely completion of the exercise. The member secretary pointed out that the slight lowering in stage of development of some islands are due to the reduction the dependency of domestic population on the ground water resource subsequent to the commissioning of desalination plants in those islands. Finally, the assessment of dynamic ground water resources of UT of Lakshadweep as on 2023 was approved by the committee.

The meeting ended with thanks to the Chair.

Approved for issuance

R. 4 5/11/24.

Dr Giri Shankar, IAS
District Collector
UT of Lakshadweep

10. CONTRIBUTORS' PAGE

1.	Data Collection, Analysis & Compilation of Report	**Sh. G Sreenath** Scientist 'D' CGWB, Kerala Region Thiruvananthapuram **Sh. Arun Kumar A. V.** Scientist 'B' (HG) CGWB, Kerala Region Thiruvananthapuram
2.	Report Scrutiny & Finalization	**Smt. Mini Chandran** HOO, CGWB, Kerala Region, Thiruvananthapuram
3.	Printing & Publication	**Sh. Roopesh G. Krishnan** Scientist 'D' Report Processing Section, CGWB, Kerala Region, Thiruvananthapuram