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DYNAMIC GROUND WATER RESOURCES OF LAKSHADWEEP ISLANDS (March 2020)

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MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
GOVERNMENT OF INDIA
KERALA REGION

तिरुवनंतपुरम/THIRUVANATHAPURAM

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FOREWORD

Ground Water, being a replenishable and finite resource, realistic assessment of this resource is very much essential for planning and sustainable development in tiny islands of Lakshadweep. The Union Territory of Lakshadweep is an archipelago located in west coast of India; possess a delicate ecosystem with limited fresh water resources. Albeit the island is blessed with average rainfall of 1640 mm for an average 80-90 days a year, complete absence of surface water bodies make ground water an important commodity. In densely populated tiny island, fresh ground water occur as lenses in hydraulic continuity with sea water and the occurrence of fresh water lens depends on size and shape of islands, in addition to rainfall pattern and ground water extraction. The high demand for ground water exerts a stress on this limited resource which is exacerbated by pollution, sea water intrusion due to over-pumping and natural events such as storm surges. Further elevation of the island is very small, which limits the scope for artificial recharge since the aquifer is limited with no additional storage space.

Traditionally, ground water is developed mainly through dug wells in all the islands. Majority of the wells are fitted with small capacity electric pumps. The drinking water demand is supplemented by the supply from desalinization plants in four islands. But apart from the domestic extraction, evapotranspiration loss from trees plays an important part in the consumption of this limited resource. As the fresh water lens is under tidal influence, the size and thickness of the lens varies diurnally and quality shows a wide seasonal variation. Considering the extreme fragile nature of the ground water resources and increasing demand to satisfy the requirements of increasing population especially during summer when quality deteriorates., it is imperative to ensure prevention of contamination, optimum utilization and also long term sustainability.

Realistic assessment of ground water resource availability, status of its utilization and balance available for development are basic pre-requisites for building a sound ground water management strategy. It is heartening to note that the Central Ground Water Board, Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India jointly with the Ground Water Department, Government of Kerala has assessed the ground water resources of the UT as on March 2020 as per the Ground Water Resource Estimation methodology 2015. This effort deserves appreciation as it will help Lakshadweep Administration to identify and prioritize necessary management interventions and initiatives including regulation measures to ensure long-term sustainability of ground water resources in the Island and to ensure its water security for the future generations.

I take the opportunity to congratulate the Central Ground Water Board, Kerala Region, Thiruvananthapuram for the collection, compilation and analysis of voluminous data on various aspects of ground water resources and for bringing out this compilation in such a comprehensive fashion. I hope this document will be of immense use to administrators, planners and other stakeholders to have a better understanding of the ground water scenario of the UT for planning and implementing various projects and schemes to ensure their long-term sustainability.

DISTRICT COLLECTOR
UT OF LAKSHADWEEP
KAVARATTI-682555

S. Asker Ali, IAS
District Collector, UT of Lakshadweep

Kavaratti
16.12.2021

GOVERNMENT OF INDIA
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PREFACE

Islands are unique in many ways, having their characteristic physical, demographic and economic features. Shortage of natural resources and vulnerability to natural disasters often result in serious hydrological and water resource management problems in such islands. Many of the islands are densely populated, which results in considerable stress on their limited water resources. Pollution from various sources poses a serious threat to the available fresh water resources in many islands. Sea-water intrusion due to over-pumping of ground water from fragile aquifers often leads to the depletion and deterioration of their ground water resources. Small islands are highly vulnerable to natural disasters such as cyclones, earthquakes, volcanic eruptions, storm surges to floods and droughts. The threat of sea level rise due to the impact of climate change has added another dimension to the problems faced by the islands in recent years.

The Lakshadweep Islands lie 200 to 300 Km off the coast of Kerala in the Arabian Sea with a total geographical area of 32 km^2. They consist of twelve atolls, three reefs and five submerged banks, with a total of about 36 islands and islets, out of which only 10 islands are inhabited. The islands are densely populated with the population density of the order of about 1985 persons per square kilometer. In the absence of surface water resources, ground water constitutes the only source of water to cater to the drinking and domestic requirements of the populace of the islands. Ground water occurs under phreatic condition and is in hydraulic continuity with sea water. The fresh ground water floats over the sea water with lens shape and thickness of fresh water lens controlled by the elevation of the water table. The size and thickness of lens is also controlled by the topography. The hydrogeological systems of the small islands are more complicated by the tidal fluctuations and climatological vagaries. Increasing development of ground water resources to cater to the needs of a rapidly growing population has been putting a severe stress on the limited ground water resources available. In view of the extremely fragile nature of the ground water resources in the islands, there is need for utmost caution in their development and management to ensure their long-term sustainability.

Realistic assessment of the ground water resource is a prerequisite for formulation of strategies for its judicious and scientific management. The ground water resource and balance available are normally being computed based on the 'Ground Water Estimation Methodology 2015', which is designed basically for the computation of the ground water resource on mainland aquifers and does not have any norms for the ground water resource computation of tiny oceanic islands where the ground water occurs as a floating lens. 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 the computation. The assessment of ground water resources of the Lakshadweep Islands was carried out earlier in 2017.

The details of re-assessment of ground water resources of the island as in March 2020, computed as per the directions of the Government of India are presented in this report. All efforts have been made to compute the resources as realistically as possible. It is hoped that this report will help the planners, administrators and other stakeholders in formulating plans for scientific management of ground water in the islands to ensure their optimum utilization and long-term sustainability.

I sincerely appreciate the assistance and cooperation extended by Smt. Rani V. R., Scientist C Central Ground Water Board, Kerala Region, Trivandrum in the computation of this report. Thanks are also due to all the organizations which have provided valuable data on various aspects of ground water in the islands.

(Dr.A. Subburaj)
RegionalDirector

DYNAMIC GROUNDWATER RESOURCES OF LAKSHADWEEP ISLANDS (March 2020)

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DYNAMIC GROUNDWATER RESOURCES OF LAKSHADWEEP ISLANDS (March 2020)

1.0 INTRODUCTION

Being a replenishable and finite resource, realistic assessment of groundwater is a pre-requisite for its proper and economic development on a sustainable basis. The National Water Policy of Indiaalso stresses the need for periodic assessment of ground water resources of India on scientific basis. The estimation of the dynamic ground water resources of the country has gained increasing importance over the years. The first attempt to estimate the groundwater resources of the country on a scientific basis dates 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 normsare used for estimation of dynamic ground water resources of the countryconsidering 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 previous assessment of dynamic ground water resources of Lakshadweep Islands was carried out during 2017. Subsequently, in accordance with the policy of Government of India to carry out estimation of dynamic ground water resources once in three years, the current re-estimation of resources as in March 2020 has been taken up.To improve the GEC assessment a new 'INDIA-GEC Software/Web Based Application namely, Automation of Estimation of Dynamic Ground Water Resources using GEC-2015' was used in the current assessment (developed by CGWB in collaboration with by IIT-Hyderabad).India GEC system allows dataa input through Excel as well as through inbuilt- forms, compute various ground water components (recharge, draft, flux, etc.), classify assessment unit into appropriate categories, 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.

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 2020 was undertaken with focus on assessment units categorized as "Over-exploited" and "Critical". The present ground water scenario in these assessment units were reviewed with the help of field data and enquiries with the field hydrogeologists/local residents and units where the ground truth did not match with the categorization were identified. 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 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 UT of Lakshadweep" by CGWB, which envisages implementation of Rain Water Harvesting structures to optimize the utilization of ground water resources of these islands. 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.

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. For the first time, the entire computation for assessment has been automated and is being done in GIS environment.

As per the direction from Central Head quarter of Central Ground Water Board, ground water Resources estimation has to be carried out as per the methodology GEC-2015 as on March 2020. In this regard the committee was again re-constituted (in accordance with the request from the Regional Director, CGWB)vide F. No.118/02/2008-S4/1813 Dt. 03.09.2020 (Annexure II). The members of the committee are as enlisted:

Collector	Chairman
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

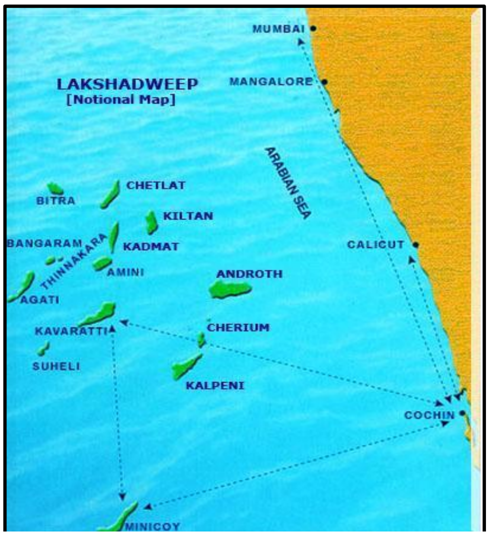
The meeting of the committee to review the methodology and work plan was finalized during first UT Level Meeting on 24.11.2020 (Annexure III). The assessment of the dynamic and static resources of UT of Lakshadweep as on March 2020 was approved by the committee on 30.03.2021 and the Chairman directed Regional Director, CGWB to share the report/presentation with all members. Copy of the minutes of the meeting of 2ndUTL Meeting is presented in AnnexureIV.

1.2General Features

The Union Territory of Lakshadweep is an archipelago off the western coast of peninsular India in the Arabian Sea located about 200 to 300 km off the coast of Kerala. This group of islands, spread over a distance of 300 km, consists of 36 coral atoll islands (with low elevation of 3-5 m above mean sea level with an area of 32 km^2) and a number of sunken banks, open reef and sand banks between latitudes 8^0 and 14^0 N and longitudes 74^0 41' and 74^0 10' E. Ten of these islands are inhabited, Kavaratti, Agati, Minicoy, and Aminibeing the major population centres. The capital is Kavaratti located on KavarattiIsland.

These islands are typically a chain of low coral islands surrounding a shallow lagoon, consisting of deposits of recent sediments on top of older coral limestone. In general lagoons are on the western (windward) side and relatively steep slopes predominate along the eastern margins except for AndrothIsland, which extends east-west. Only one-fourth(28 Km^2) of the total area of the islands is inhabited with a total population of about 64473 (2011 census). The basic details regarding the islands are summarized below. The location of the islands is shown in **Plate-I.**

Figure 1.1: Location Map of Lakshadweep Islands.



The island wise area, population details and decadal growth in population are given in **Tables 1.1 and 1.2**respectively.

1.	Geographical Location			
		Latitudes	:	8^0 – 12^0 N
		Longitudes	:	71^o – 74^0 E
2.	Total no. of islands		:	36
3.	Total no. of inhabited islands		:	10
4.	Total geographical area		:	32 Sq.km
5.	Total land use area		:	26.32 Sq.km
6.	Total lagoon area		:	4200 Sq. km
7.	Territorial water		:	20,000 Sq.km
8.	Exclusive economic zone		:	4,00,000 Sq.km
9.	Total population		:	64,473(2011 census)

Table 1.1: Island wise area and population (2011 census)

Island	Land use area sq.km	Male	Female	Population	Population per sq.km
Agatti	2.71	3894	3672	7566	2791.9
Amini	2.59	3829	3832	7661	2957.9
Androth	4.84	5500	591	11191	2312.2
Bitra	0.10	154	117	271	2710.0
Chetlat	1.04	1172	1175	2347	2256.7
Kadmat	3.12	2690	2714	5404	1732.1

Kalpeni	2.28	2324	2095	4419	1938.2
Kavaratti	3.63	6182	5039	11221	3091.2
Kiltan	1.63	2012	1934	3946	2420.9
Minicoy	4.37	5366	5081	10447	2390.6
Total	**26.31**	**33123**	**31350**	**64473**	**2450.5**

Table 1.2: Decennial Population Growth Rate (2001-2011)

Island	**Population census**		**Decennial growth rate (%)**
	2001	**2011**	
Agatti	7009	7566	7.95
Amini	7353	7661	4.19
Androth	10727	11191	4.33
Chetlat	2291	2347	2.44
Kadmat	5334	5404	1.31
Kalpeni	4321	4419	2.27
Kavaratti	10119	11221	10.89
Kiltan	3669	3946	7.55
Minicoy	9495	10447	10.05

2.0 HYDROGEOLOGICAL FRAMEWORK

2.1 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 33^0C while the humidity ranges between 72 to 85%.

The normal rainfall in Lakshadweep islands is in the range of 1505 (Amini) to 1640 (Minicoy). Annual rainfall decreases from South to North. Southwest monsoon extending from June to October with 80-90 rainy days is the main rainy season. Winds are light to moderate during October to March. The normal rainfall and average number of rainy days (days with rain of 2.5 mm or more) at Minicoy and Amini Islands are given in **Table.2.1.**

Table 2.1: Normal Rainfall and Average Number of Rainy Days (days with rain of 2.5 mm or more) in Minicoy and Amini Islands.

Station	**No: of Years (Data)**		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Minicoy	50	a	43.2	22.3	20.8	51.3	179.6	309.1	238.3	209.3	158.2	179.1	143.3	85.9	1640.4
		b	2.6	1.3	1.4	2.9	8.7	17.4	13.9	12.4	10.1	10.6	8.1	4.7	94.1
Amini	50	a	20.6	2	4.3	25.4	125.2	380.7	311.9	217.2	149.6	141.1	85.6	40.9	1504.5
		b	1.3	0.3	0.3	1.4	5.2	17.3	16.5	12.3	10.2	8.4	5	2.2	80.4

2.2 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.

2.3 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 CheriyaPanniyam, 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,reachinga 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.

2.4Geology 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.

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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.

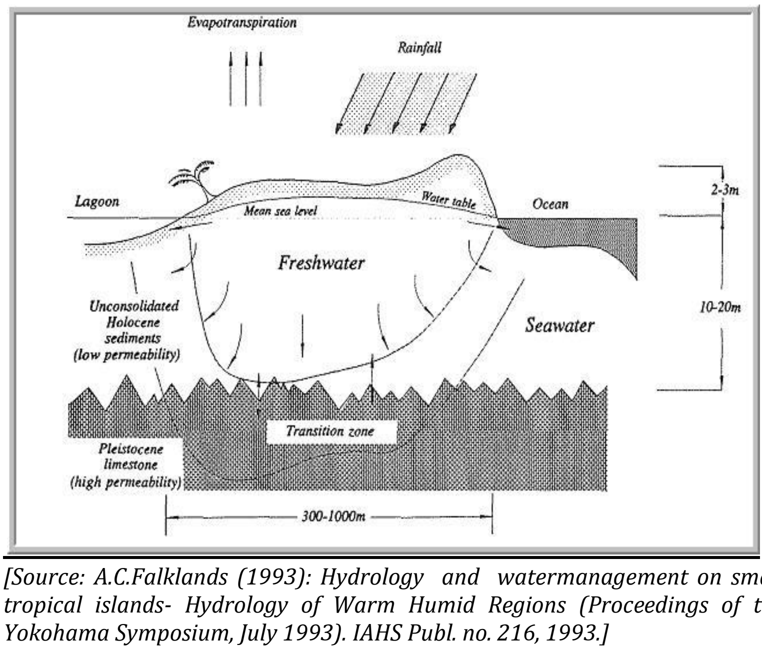
The islands are composed mainly of coral reefs and material derived from them. The litho-units identified include calcareous sand of the beach facies, strand line facies, dune facies and anthropogenically modified varieties identified on the basis of base morphometric units, grain size and other physical 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 consists 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 consists 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.

2.5 Ground Water Conditions

Coral atolls of Lakshadweep islands consists 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 existdue 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 occur 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). Permeabilities greater than 1000 m/day occur in solution cavities within the limestone. These extremely high permeabilities allow 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.5.1). 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 5.1: 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, inspite 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 centimetres 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.

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 2.1 to 4.5 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 1.6 to 7.5 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.

2.6 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 centres. 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.

3.0 GROUNDWATER RESOURCE ESTIMATION METHODOLOGY (GEC - 2015) –A BRIEF DESCRIPTION

Groundwaterresources 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 data base 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.

In the U.T. Lakshadweep each islands are 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.

3.1 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 waterbalance 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.

3.1.1 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

$$R = (h \times Sy \times A) + GE \quad \text{……………………… Eqn.3}$$

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 are 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.

3.1.2 Non-Monsoon season

During non-Monsoon season, rainfall recharge is computed by using Rainfall Infiltration Factor (RIF) methodonly 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.

3.2 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.

3.3 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.

3.4 Annual Ground Water Extraction

Annual groundwater extraction has been calculated for Irrigation, Domestic and Industrial uses. The gross groundwater extractionwould 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.

3.5 Stage of Ground Water Extraction, SOGWE

The stage of Groundwater extraction has been computed as given below

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

3.6Validation 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 longterm trend	Not acceptable and needs reassessment

3.7 Categorization of Assessment Units

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

(a) Categorization of Assessment Unit Based on Quantity

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

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

(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.

4.0 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 makes 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.

4.1 Unit of Computation

The unit of computation is taken as island. 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 andthickness) 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 upto 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.

4.2 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:

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

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 thelens 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:

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

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

The average annual rainfall (2010-20) in Lakshadweep islands is 1643.12 mm (Minicoy), 1421.34mm (Agatti) and 1530.51 mm (Amini). 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 June to September. 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. For six months from May to October, the Normal Monsoon Rainfall (NMR) is taken as 1273.6mm for Minicoy and other islands the NMR value of Amini is adopted, which is 1325.7mm. For remaining period, the Normal Non- Monsoon Rainfall (NNMR) is taken as 366.8mm for Minicoy and other islands the NMR value of Amini is adopted, which is 178.3mm.

A rainfall infiltration factor of 0.40 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 0.004 mm/day from each island. The number of ET days has been restricted to non-monsoon period of 180 days for computation.

4.3 Annual ExtractableGround 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.

4.4 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 details of the ground water abstraction structures are given in **Table 4.1**. Considering the supply of water from desalinization plants in each island, the per capita consumption was computed for each island separately and it varies from 87 to 95 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.

Table 4.1: Details of Wells, Ponds, Hand pumps and Rain Water Harvesting Tanks

Islands	Well		Ponds		RWHT*	
	In use	Not in use	In use	Not in use	In use	Not in use
Agatti	2188	0	37	167	721	0
Androth	2059	0	496	0	300	0
Amini	1231	103	52	7	450	0
Bitra	0	0	10	0	110	0
Chetlat	647	15	31	0	362	0
Kadmat	1609	26	39	99	381	0
Kalpeni	1162	0	267	99	475	0
Kavaratti	1660	21	76	42	739	0
Kiltan	1009	103	16	7	362	0
Minicoy	1628	0	16	48	655	0
Total	8108	303	842	321	4555	0

**Rain Water Harvesting Tanks*

(Source: Department of Public Works, Lakshadweep)

4.5 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 usesand
A is the Annual Extractable Groundwater Resource

4.6 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.

5.0 COMPUTATION OF GROUNDWATER RESOURCES INLAKSHADWEEP ISLANDS.

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. The computational details and island wise recharge figures are given in **Annexure I**.

As per the computation, the total annual rainfall recharge in the islands amount to 1324.48Ha.m, ranging from 51.54Ha.m in Chetlat Island to 242.22Ha.m in Minicoy Island. Evapotranspiration from coconut trees during 6 non-monsoon months amounts to 295.06ha.m, whereas the water loss due to outflow into sea is of the order of 264.9Ha.m. 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 available for development ranges from 18.61Ha.m (Chetlat) to 89.47Ha.m (Androth), amounting to a total of 499Ha.m for the group of Islands as a whole.

Ground water extraction in the Islands, by and large, is for domestic uses of the populace. The extraction component ranges from 8.86Ha.m in Chetlat islands to 56.19Ha.m in Kavaratti Island, amounting to a total of 292.02Ha.m.

The annual extractable ground water resources available in the Islands range from 8.17Ha.m (Chetlat) to 35.42(Kadmat), adding up to a total of161.83Ha.m for the group of Islands as a whole. The stage of ground water extraction for the group of islands is of the order of 57.47 % and ranges from 35.6% (Kadmath) to 83.1% (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, Aminiand Kavaratti Islands have been categorized as 'Semi-Critical' and the remaining islands have been categorized as 'Safe'.

5.1Comparison with Earlier Estimates

A comparison with the earlier estimate of 2017 indicatesanincrease in the rainfall recharge component in all the islands which can be attributed to the marginal increase in rainfall infiltration factor from 30 to 40% and computation of non-monsoon recharge component was included in the present resource estimation that was excluded in the previous estimation. Similarly there isanincrease in the extraction component in all the islands which can be attributed to the marginal increase in population.As the Annual extractable resource has been improved from previous assessment by 28%, which has resulted in improved annual extractable ground water resources and consequently, lower stage of ground water extraction in all the islands.

5.2 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 5.1: Comparison of Major components of Ground Water Resource Estimation 2020 vs 2017

Sl No	Components	2017	2020	Remarks
1.	Rainfall Infiltration Factor (RIF)	30%	40%	
2.	Rainfall Recharge (ham)	1072.8	1324.3	Increase due to component 1 and non-monsoon recharge computed
3.	Evapotranspiration (ham)	282.75	295.26	ET rate of 40l/day/tree
4.	Outflow components – outflow to sea & Buffer Zone (ham)	429.04	529.8	Directly taken as 40% of component 2.
5.	Annual Extractable Ground water Resource (ham)	361.01	499.42	28% increase due to component 1
6.	Ground Water Extraction Domestic (ha.m)	237.98	292.02	22% - increase. Marginal Growth in population.
7.	Stage of Ground Water Extraction (%)	65.68	57.44	Increase in resource availability when compared to outflow components
8.	Categorization	3 - Semi-critical 6 - Safe	2 - Semi-critical 7- Safe	Agatti shows an improvement due to commissioning of desalination plants.

ANNEXURES

Annexure I: Dynamic Ground Water Resources of Lakshadweep Islands (2020)

Sl.No.	Annual components of Water Balance	Name of Island									Total
		Agatti	Amini	Androth	Chetlat	Kadmat	Kalpeni	Kavaratti	Kiltan	Minicoy	
1	Population(Projected as on 2020)	8093	7953	11631	2398	5467	4510	12345	4218	11409	68024
2	Area (Ha)	271.0	259	484	104	312	228	363	163	437	2621
3	Normal Monsoon Rainfall (m)	1.504	1.504	1.504	1.504	1.504	1.504	1.504	1.504	1.6404	1.519
4	Rainfall Infiltration Factor (%)	40	40	40	40	40	40	40	40	40	40
5	Total GW Recharge(Water Surplus) (Ha.m)) [2*3*4*0.01]	134.3	128.3	239.8	51.5	154.6	113.0	179.9	80.8	242.2	1324.5
6	ET loss from Trees for 6 non-monsoon months (Ha.m)	29.4	30.7	54.4	12.3	35.0	25.7	39.3	19.4	49.0	295.3
7	Water loss due to outflow to sea (Ha.m) [20% of (5)]	26.86	25.67	47.97	10.31	30.92	22.60	35.98	16.16	48.45	264.90
8	Buffer zone for reserve during delayed or lesser monsoon period (Ha.m) [20% of (5)]	26.86	25.67	47.97	10.31	30.92	22.60	35.98	16.16	48.44	264.90
9	Balance available resource (Ha.m) [(5)-(6)-(7)-(8)]	51.197	46.33	89.47	18.61	57.78	42.09	68.61	29.03	96.30	499.42
10	Domestic Extraction(Ha.m)	34.6	34.3	50.5	8.9	20.6	17.3	56.2	16.8	53.0	292.0
11	Gross Annual GW Extraction (Ha.m)	34.6	34.3	50.5	8.9	20.6	17.3	56.2	16.8	53.0	292.0
12	Annual Extractable GW Resource (Ha.m) [(9)-(11)]	16.6	12.1	38.9	9.8	37.2	24.8	8.5	12.3	43.3	203.5
13	Stage of ground water extraction (%) [(11)*100/(9)]	67.5	74.0	56.5	47.6	35.6	41.1	83.1	57.7	55.0	57.4
14	Category	**Safe**	**Semi-Critical**	**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

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F.No.118/02/2008-S4 /1813 दिनांक/Dated: 03 .09.2020.

ORDER

Central Ground Water Board (CGWB) Kerala region has requested to reconstitute the committee constituted for the assessment of dynamic ground water resources as on March 2020 for U.T of Lakshadweep.

The Hon'ble Administrator U.T of Lakshadweep is pleased to constitute **Ground Water Re Estimation Committee for U.T of Lakshadweep** to compute the ground water resources as per 2015 methodology for the base year 2019-20 with the following composition.

1. Collector - Chairman
2. Superintending Engineer, LPWD - Member
3. Director (Agriculture) - Member
4. Director (Industries) - Member
5. Director (Planning, Statistics & Taxation) - Member
6. Director (Science & Technology) - Member
7. Regional Director, CGWB, Kerala Region - Member

(Vijendra Singh Rawat IAS)
Secretary (Works)

To

The All members of the Committee.

Annexure III: Minutes of First UT Meeting on Re-estimation of Ground Water Resources of Lakshadweep as on March 2020.

MINUTES OF THE FIRST UT LEVEL MEETING ON RE-ESTIMATION OF GROUND WATER RESOURCES OF LAKSHADWEEP AS ON MARCH 2020

The First UT level Meeting on Re-estimation of Ground Water Resources of Lakshadweep was held online on 24.11.2020 under the Chairmanship of Shri. S. Asker Ali, IAS, Collector, UT of Lakshadweep and Chairman of Ground Water Re-Estimation Committee at 15.30 hours. The following Members attended the meeting.

1.	Shri. C. N. Shajahan, Superintending Engineer, LPWD	Member
2.	Dr. A. Subburaj, HOO, CGWB	Member Secretary
3.	Shri. P. Abdul Samad, Director, Planning	Member
4.	Shri. P. Abdul Samad, Director, Industries	Member
5.	Shri. P. Attakoya, Director, Agriculture	Member
6.	Shri. P. Pookoya, Director, Science & Technology	Member
7.	Shri. C. Hidayathulla, Chemist, LPWD	Invitee
8.	Dr. V. S. Joji, Scientist, CGWB	Invitee
9.	Dr. N. Vinayachandran, Scientist, CGWB	Invitee
8.	Smt. Rani V. R., Scientist, CGWB	Invitee

At the outset, the Chairman welcomed the members and stressed the need for periodic re-assessment of ground water resource and also reminded members regarding the time frame to complete the exercise as February 2020. Then Chairman invited Head of Office, CGWB to deliver a presentation on Ground Water Resources of Lakshadweep. Dr. A. Subburaj, HOO, CGWB, Kerala Region briefed the methodology adopted for estimation of ground water resources in an island and appraise the status of ground water resource in different islands as per the last assessment carried out during 2017. The presentation concluded by detailing the data requirements to re-assess the resource and the details are given below.

- Rainfall – Normal Monsoon and Non-monsoon period (Amini, Agatti & Minicoy)
- Monthly Rainfall data with no: of rainy days (>2.5mm) – 2017-19
- No: of Coconut trees in each island
- Evapo-transpiration rate, Average root depth, capillary rise, no: of days for monsoon and non-monsoon
- Census data of dug wells, hand pumps, ponds, tanks and Rain water harvesting in each island as on March 2020 (in-use and not in-use)
- No: of dug wells fitted with pump & its capacity
- Status of implementation of Desalinisation plant in each island
- Status of piped water supply from RWH & Desalinization plant in each island

Presentation was followed by deliberations on Estimation of Resource methodology and Superintending Engineer, LPWD assured the timely submission of required data from the concerned department. Meanwhile, Chairman inquired the status of ground water resource estimation in uninhabited islands of Lakshadweep, especially the 5 islands (Bangaram, Bitra, Thinnakara, Suheli and Cheriyam), which are earmarked for eco-tourism projects by UT administration. Also suggested that detailed resource mapping in these developing islands may help to articulate the management plans to be considered. HOO appraised the limitations in the data availability of those islands and accepted the proposal to take up detailed mapping in 5 uninhabited islands. Chairman opined the need to demarcate the areas where the ground water resource is limited or extraction is more in the case of semi-critical Kavratti, Amini and Agatti Islands. HOO expressed the dearth in data availability of CGWB to demarcate the areas in a micro-level, which can be accomplished if geo-tagged data of existing dug wells are shared with CGWB. Chairman guaranteed the full-hearted involvement of all line departments and reiterated the need for field visit in five islands.

The meeting ended with thanks to the Chair.

This Issued with the approval of Collector U T of Lakshadweep & Chairman of the committee vide dairy No. 2990 dated 27/11/2020.

02/12/2020

Dr. A. Subburaj
HOO, GGWB & Member Secretary

Annexure IV: Minutes of Second UT Meeting on Re-estimation of Ground Water Resources of Lakshadweep as on March 2020.

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GOVERNMENT OF INDIA/
LAKSHADWEEP ADMINISTRATION/ T
(LAKSHADWEEP PUBLIC WORKS DEPARTMENT)/ T
CIRCLE OFFICE/
KAVARATTI — 682555

F.Ho.118/01/2021-S4 (o/ /Dated: \ .04.2021

To,

The Regional Director,
Central Ground Water Board Kerala Region,
Kedaram,
Kesavadasapuram,
Thiruvanenda Puram,
Kerala - 695004

Sub / : approval of Minutes of the Second UT level Meeting - Reg
Ref:- Your mail dated 13/04/2021

Sir/

The Collector and Chairman, Ground water Re-estimation Committee for UT of Lakshadweep vide diary No 494 dated 19/04/2021 approved the draft minutes of the Second UT level meeting held on 30.03.2021 forwarded vide reference cited. This is for information and further action.

Yours faithfully/

C.N. Shajahan
Superintending Engineer

MINUTES OF THE SECOND UT LEVEL MEETING ON RE-ESTIMATION OF GROUND WATER RESOURCES OF LAKSHADWEEP AS ON MARCH 2020

The Second UT level Meeting on Re-estimation of Ground Water Resources of the Lakshadweep was held online on 30.03.2021 under the Chairmanship of Shri. S. Asker Ali, IAS, Collector, UT of Lakshadweep and Chairman of Ground Water Re-Estimation Committee at 12.30 hours. The following Members attended the meeting.

1.	Shri. C. N. Shajahan, Superintending Engineer, LPWD	Member
2.	Dr. A. Subburaj, HOO, CGWB	Member Secretary
3.	Shri. P. Abdul Samad, Director, Planning	Member
4.	Shri. P. Abdul Samad, Director, Industries	Member
5.	Shri. P. Attakoya, Director, Agriculture	Member
6.	Dr. IdresBabu, Director, Science & Technology	Member
7.	Shri. C. Hidayathulla, Chemist, LPWD	Invitee
8.	Dr. N. Vinayachandran, Scientist, CGWB	Invitee
9.	Smt. Rani V. R., Scientist, CGWB	Invitee

At the outset, the Chairman welcomed the members and invitees to the meeting and asked Dr. A. Subburaj, HOO, CGWB, Kerala Region to make the presentation.

- Dr. A. Subburaj briefed the methodology adopted for estimation of ground water resources in an island and informed that the dynamic ground water resources of the Lakshadweep Islands as on March 2020 has been computed for 9 islands based on data collected from various government departments of the Lakshadweep administration as well as the data generated by CGWB during Aquifer Mapping (NAQUIM) studies. It was highlighted that for the first time, the entire computation for assessment has been automated and is being done in GIS environment.
- The committee was informed that the rainfall infiltration factor considered for islands has been revised from 30 to 40% inorder to accommodate the rainfall recharge during non-monsoon season. Ground Water Extraction for domestic uses in the islands have been updated based on projected population, keeping 2011 census as the base year. 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 finalise 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 Lakshadweep islands are of the order of 499 Ha.m and 292 Ha.m respectively.
- The Stage of Ground Water Extraction of UT of Lakshadweep is 58.475%. Based on the estimation of available resources and ground water extraction, two islands – Amini and Kavaratti are categorized as 'Semi-Critical' while the remaining islands are in 'Safe' category.

The final results of the computation were deliberated in detail by the committee. Chairman enquired about the quality of groundwater in capital island, Kavaratti and emphasized the need for more water quality monitoring stations. Chairman also discussed the feasibility of recharge by utilizing desalinated water and concluded that it is economically unviable.

Finally, the assessment of dynamic ground water resources of Ut of Lakshadweep as on 31.03.2020 was approved by the committee.

The meeting ended with thanks to the Chair.

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CONTRIBUTORS' PAGE

1.	Data Collection, Analysis & Compilation of Report	**Smt. Rani V. R.** Senior Hydrogeologist, CGWB, Kerala Region, Trivandrum
2.	Report Scrutiny & Finalization	**Dr. A. Subburaj** Regional Director, CGWB, Kerala Region, Trivandrum
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