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

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

KILTAN ISLAND, U.T.OF LAKHDWEEP

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CONSERVE WATER – SAVE LIFE

भारत सरकार
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जल शक्ति मंत्रालय
MINISTRY OF JAL SHAKTI
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DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
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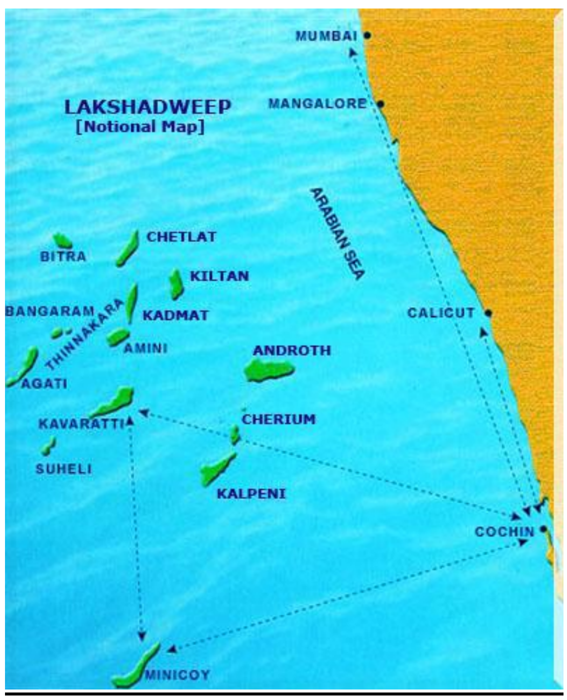
AQUIFER MAPPING AND MANAGEMENT PLAN: KILTAN ISAND UNION TERRITORY OF LAKSHADWEEP



तिरुवनंतपुरम
Thiruvananthapuram
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GOVERNMENT OF INDIA

MINISTRY OF JAL SHAKTI

DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND

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Kiltan Island at a Glance

#	Item	Statistics
1.	**General Information**	
	Latitudes	8^0-12^0N
	Longitudes	73°00′
	Total geographical area (sq. km.)	2.20
	Total land area (sq. km.)	1.76
	Total lagoon area (sq. km.)	3.96
	Population (As per 2011Census)	64473
	Normal Annual Rainfall (mm)	1803
2.	**Geomorphology**	
	Major physiographic Units	Coral Islands –Atoll and Reef
	Major Water Body	Lagoons
3.	**Major Soil type**	Coral Sand
4.	**Major Crop**	Coconut
7.	**Main Geological Formations**	Coral Limestone
8.	**Hydrogeology**	
	Major Water bearing formation Depth to water level (m bgl)	Coral sand and Coral Limestone. 1.60 to 3.70
9.	**Groundwater Quality**	
	Type of water	Alkaline
10	**Dynamic Groundwater Resources (as in March 2017)**	
	Net annual ground water availability	66.30 ha.m
	Annual Ground Water Extraction	15.1 ha.m
	Stage of Ground Water Extraction, %	66.9 %
	Category	Safe
11.	**Groundwater control and regulation**	
	Number of OE & Critical Blocks.	Nil
	Number of blocks notified	Nil
12.	**Major groundwater problems and issues**	Quality deterioration in summer due to thinning of fresh water lens. Anthropological pollution. Saline water up-coning due to pumping.

1.0 Introduction

Oceanic islands have been divided in to small and large Islands depending on the size and their hydrological set up. Large islands have surface drainage systems and their hydrogeology and other features are similar to that of the mainland, whereas the hydrogeological environment of small islands is quite different. It is very difficult to draw a clear line differentiating the small islands from the larger ones by any discrete parameter or size factor. The absence of surface drainage makes the small islands quite distinct from other oceanic islands. These oceanic islands are very small in areal extent and ground water is the only perennial source of freshwater. The Indian peninsula is girdled by about 2500 islands, of which about 1300, including 200 inhabited islands, belong to the neighbouring Maldives. Indian Territory includes more than 600 oceanic islands falling in two major groups viz. the Andaman and Nicobar Islands in the Bay of Bengal and the Lakshadweep group of islands in the Arabian Sea. The sea between the Indian coast and Lakshadweep islands is known as Lakshadweep Sea after these islands.

1.1 Location and extent

The Union Territory of Lakshadweep islands are scattered in the Arabian Sea between north latitude $8^0$00' and $12^0$13'N and east longitude $71^0$00' and $74^0$00'E. The Inhabited islands, Chetlat, Kiltan and Kadamat are closely spaced and are on the northern part of the archipelago, whereas Kalpeni is on the east central part of the group and the Minicoy Island located in the southernmost part of the group and far away from the other islands. The islands Agatti, Kavaratti, Minicoy and Androth are bigger in size compared to others. The Bitra island is the smallest one and the residence of tourist staff. The location of inhabited islands of Lakshadweep including Kiltan is depicted (Fig.1.1).

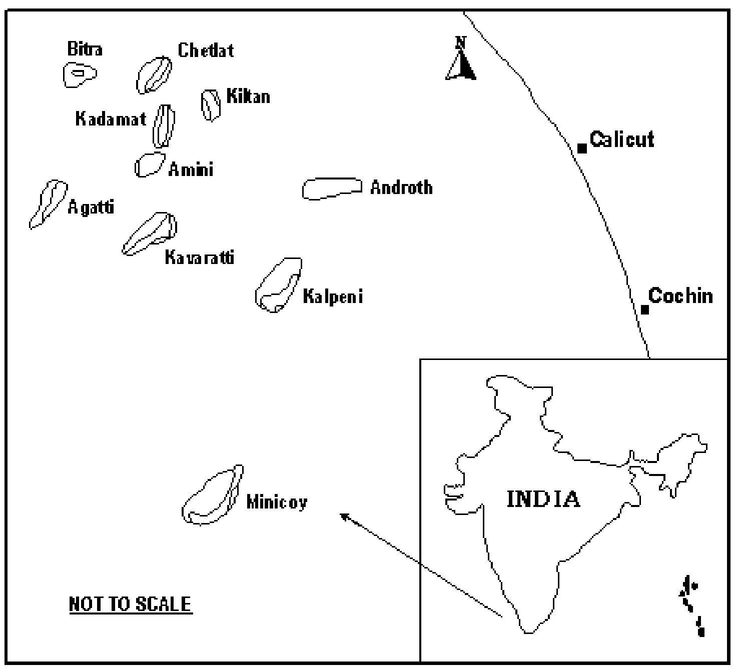


Fig. 1.1: Location of inhabited islands of Lakshadweep including Kiltan

The Lakshadweep group consists of a string of 36 tiny islands of which only ten islands are inhabited. These islands are very tiny, each having an area varying from 0.1 to 4.8 sq. km. The rest comprise seventeen uninhabited islands, four newly formed islets, and five submerged reefs. The total area of these islands is 32 sq.km. Apart from the ten inhabited islands, Bangaram, the only island open to international tourists, is seasonally inhabited. Though the land area is limited, Lakshadweep is one of the country's largest territories considering its lagoon area of about 4200 sq.km, territorial waters of 20000 sq km. and an 'Exclusive Economic Zone' of about 400,000 sq.km (UNI, 2002). The detail of areal extent of Kiltan is compiled (Tables 1.1).

Table 1.1: Area and location aspects of Kiltan Island, UT of LD Islands

#	Area, km^2		Total area, km^2	Location	
	Island	Lagoon		Latitude	Longitude
1	2.20	1.76	3.96	10°29’	73°00’

The entire Lakshadweep group of islands lies on the northern edge of the 2500 km long North-South aligned submarine Lakshadweep-Chagos ridge. The Lakshadweep Sea separates this ridge from the west coast of India. The ridge rises from a depth of 2000-2700 m along the eastern side and 400 m along the western side. The eastern flanks of this ridge appear to be steeper compared to the western portion. It has a number of gaps, the prominent being the nine degree channel. Generally in the islands, the atolls are widest on the southwestern side. The growth of the reef might have been facilitated by the continuous supply of nutrients. Echo-sounding on the reefs of these atolls show that the first break in the profile of the reefs occurs at a depth of about 4-8 m, which extends to about 12 m on the southwest windward reef representing a wave-cut platform of recent origin.

1.2 Administrative set up

The Lakshadweep Islands constitute a uni-district territory with 4 Tehsils (Amini, Andrott, Kavaratti & Minicoy) and 9 Sub-divisions (Agatti, Amini, Andrott, Chetlat (Bitra), Kadamat, Kalpeni, Kavaratti, Kiltan & Minicoy). There are 5 Community Development Blocks namely Amini - (Amini & Kadamat), Andrott - (Andrott & Kalpeni), Kavaratti - (Agatti & Kavaratti), Kiltan - (Bitra, Chetlat & Kiltan) & Minicoy. The Island Councils and Pradesh Councils were originally set up under the Lakshadweep Island Councils Regulation, 1988, and the Lakshadweep (Administration) Regulation, 1988. These have been repealed under Section 88 of Lakshadweep Panchayat Regulation,1994, promulgated by the President of India on 23rd April 1994 consequent on the Constitution (73rd amendment) Act, 1992. The Island Councils came to an end after the expiry of its terms on 5.4.1995. According to the new Panchayat Regulation, there will be a two tier system of Panchayats in Lakshadweep, consisting of Dweep Panchayats and District Panchayat and no intermediary panchayat in this territory. Each of the ten inhabited Islands will have a Dweep Panchayat. The District Panchayat has its Headquarter at Kavaratti.

1.3 Population

According to the Survey of India, the geographical area of Lakshadweep is 32 sq. km, whereas as per revenue records the area is only 28.5 sq km., which represents only the land use area. As per the 2011 census, the total population of LD Islands is 64473, with 33123 males and 31350 females. The density of population is high and stands at 2015 per sq km. The population of the Kiltan as per 2011 census is 3946, with 2012 males and 1934 females. The Kiltan island is having density of population 1524 per sq km.

1.4 Climate

As the Kiltan lying well within the tropics and extending to the equatorial belt, the island has tropical humid, warm and generally pleasant climate. The climate is equable and no distinct and well-marked seasons are experienced. Southwest monsoon period is the chief rainy season which lasts from late May to early October. The mean daily temperature ranges between 22 to 33º C. while the humidity ranges between 72 to 85%.

1.4.1Rainfall

Rainfall distribution, including its quantity and its spatial and temporal variation and evapotranspiration are the major components controlling the availability of freshwater resources. The temporal variation is usually high in the small island whereas the spatial variation is a function of the island’s physiography. The inter-annual variability of rainfall is often high in Kiltan. The island is receiving annual average rainfall of 1600 mm.

1.4.2 Humidity

The Humidity is high throughout the year and is generally higher in the morning hours compared to the evening hours. It is lower during January to April when it is between 70 and 76% in the morning hours and 66 to 69% in the evening hours. It is higher during June to August when it ranges from 85 to 87% in the morning hours and 83 to 86% in the evening hours.

1.4.3 Temperature

April and May months are the hottest with the mean minimum and minimum temperatures of 25 ^{O}C. and 35 ^{O}C respectively. December and January are the coldest months with the mean minimum and maximum temperatures of 24 ^{O}C and 31.1^{O}C respectively.

1.4.4 Evapotranspiration (ET)

The ET has a vital role on the hydrological cycle of tropical small islands. This is very high and most of the months except in high rainfall season it exceed the rainfall making the water surplus on the negative side.

1.4.5 Special weather phenomena

A few cyclonic depressions and storms, which form in the south Arabian Sea during April and May, affect the weather over the Island. During the post monsoon months of October to December also, a few of such systems originating in the Bay of Bengal and travelling westwards emerge into the south Arabian sea, and occasionally affect the island of Kiltan. In association with these, strong winds and heavy rains are common. The cyclonic storms are believed to be responsible for the deposition of coral debris around the islands forming coral beach and the lagoons.

1.5 Soils

Most of the islands of Lakshadweep have a soil layer overlying coral limestone. The soils are mainly derived from coral limestone and include coral sands, lagoonal sands and mud. The rate of infiltration, the thickness and the moisture contents at both field capacity and wilting point affect the ground water resources of the island.

1.6 Vegetation

The vegetation in Lakshadweep Islands can be classified as either shallow rooted or deep rooted. The shallow rooted vegetation which includes grasses, crops and shrubs obtain their moisture requirements from the soil moisture zone. The deep rooted vegetation consists of those trees whose roots can, where conditions are favourable, penetrate below the soil moisture zone and through the unsaturated zone to the water table. Coconut trees are a typical example of deep rooted vegetation in the islands of Lakshadweep. In relatively shallow areas, coconut trees typically have some roots within the soil moisture zone and some which penetrate to the water table and are referred as phreatophytes and is common on coral atolls where the depth to the water table is typically 2 to 3 m. bgl.

1.7 Previous studies

Various island hydrogeological studies have been carried out by CGWB and are summarised below.

- Hydrogeological studies by CGWB in Lakshadweep Islands dates back to 1978, when a reconnaissance investigation on the ground water resources of the LD Islands was carried out.

- In 1987, scientific investigations were taken up by CGWB in Kavaratti Island to study the feasibility of water supply schemes as per directions of the Hon'ble High Court of Kerala. Based on detailed studies, it was suggested that extraction of large quantities of ground water from point sources was not feasible in view of the risk of up coning of saline water.
- All the inhabited islands except Bitra (0.1 sq.km) have been studied by CGWB through systematic hydrogeological surveys and subsequently by micro level studies.
- Ground water exploration was carried out at five locations in Kavaratti Island down to the depth of 30 m below ground level through construction of zone wells tapping different aquifer zones at each site.
- CGWB has taken up implementation of three demonstrative rainwater harvesting schemes in Kavaratti Island through the LPWD under the Central Sector Scheme to popularize cost-effective techniques for water harvesting suitable for island conditions.
- As part of the IEC activities of the Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India, U.T Level Painting Competitions on Water Conservation for school students are being organized in U.T of Lakshadweep since 2012.
- Detailed mapping of aquifers of nine islands of the U.T of Lakshadweep is being taken up as part of the National Aquifer Mapping Programme of the Board during the XII Plan. This activity envisages delineation and characterization of aquifer zones and formulation of strategies for sustainable development of ground water for the islands.
- A U.T level workshop on Water Management for Sustainable Development was held at Kavaratti under the 'Hamara Jal, Hamara Jeevan' campaign of Government of India during January 2015.
- A number of reports have been published on various aspects of ground water resources in Lakshadweep Islands based on the studies, as listed below:

- Anon (1978): A preliminary note on the ground water resources of Union Territory of Lakshadweep Islands - Minicoy and Amini divi. CGWB, KR, Thiruvananthapuram.
- Anon (1994): Hydrogeological and Hydrochemical studies in Kavaratti Island, UT of LD Islands. CGWB, KR, Thiruvananthapuram.
- Anon (1994): Ground water Resources and Management in the Union Territory of Lakshadweep (Kavaratti, Agatti and Amini Islands. CGWB, KR, Thiruvananthapuram.
- Anon (1995): Ground water Resources and Management in the Union Territory of Lakshadweep (Androth and Minicoy Islands). CGWB, KR, Thiruvananthapuram.
- Anon (1997): Ground water Resources and Management in the Union Territory of Lakshadweep. CGWB, KR, Thiruvananthapuram.
- Anon (2001): Ground water exploration in the Union Territory of Lakshadweep. CGWB, KR, Thiruvananthapuram.
- Anon (2001): Basic data report of exploratory wells drilled in Kavaratti Island of Lakshadweep. CGWB, KR, Thiruvananthapuram
- Anon (2004): Impact of ground water development and tidal influence on freshwater lens of Kavaratti Island –FSP 1997-98. CGWB, KR, Thiruvananthapuram.
- Anon (2004): Hydrogeological Atlas of Lakshadweep Islands. CGWB, KR, Thiruvananthapuram.
- Anon (2011): Report on the Dynamic Ground Water Resources in Lakshadweep Islands, U.T of Lakshadweep as in March 2009. CGWB, KR, Thiruvananthapuram.
- Anon (2014): Report on the Dynamic Ground Water Resources in Lakshadweep Islands, U.T of Lakshadweep as in March 2011.CGWB, KR, Thiruvananthapuram.
- Anon (2017): Groundwater Resources Of Lakshadweep Islands (March 2017). CGWB, KR, Thiruvananthapuram.
- Balakrishnan, K (2018): Ground Water Information Booklet Lakshadweep Islands Union Territory of Lakshadweep, 2019. CGWB, KR, Thiruvananthapuram.
- Balakrishnan, K (2019): Ground Water Information Booklet Lakshadweep Islands Union Territory of Lakshadweep, 2019. CGWB, KR, Thiruvananthapuram.
- Balakrishnan, K, Sreenath, G, Anil Chand, A D (2019): Aquifer Mapping and Management Plan: Union Territory of Lakshadweep. CGWB, KR, Thiruvananthapuram.

2.0 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 Kiltan Island is flat, rarely rising more than two meters, and consists 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. The island is of coral origin and Kiltan is typical atoll and is 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 Kiltan island is 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 island. The elongated reefs of this organic limestone that are partly, intermittently or completely covered by water. Geomorphologically, the island has 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.

3.0 Geological setting

There is no conclusive theory on formation of the coral atoll of Kiltan. The most accepted theory is the Subsidence Theory of origin of coral islands proposed by 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 conditions which favoured the growth of coral island of Kiltan include

- Area situated between 30º North and South of Equator,
- Water is clear and salty,
- Tropical conditions of the area,
- Favourable temperature of more than 23 to 25ºC.

The island is 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.

4.0 Spatial pattern of groundwater table

Groundwater levels were measured in the open dug wells. The measurements taken during February 2017 were used for the spatial interpolation studies by contouring the water level at 2 m intervals.

4.1 Spatial pattern of groundwater salinity

The ground water in the island is generally alkaline with a few exceptions. The Electrical Conductivity (EC) ranges from 500 to 15,000 µS /cm at 25 °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 are the main polluting agents with sewerage and other biological wastes contributing most. The electric conductivity of groundwater samples was indicative of the presence of brackish water throughout the island, with values higher than standards for safe drinking water. The iso-conductivity contours clearly pointed to a decrease in salinity towards the center of the island .However this map manifested major difference from what would be expected in a Ghyben-Herzberg model. For example the northeast area showed a large inward saltwater intrusion and in the southern part there was a marked anomaly relative to depth to water level. In these sectors no correlation was evident between depth to water level and salinity of water.

5.0 Hydrogeological framework

The Kiltan island is made up of coral reefs and materials derived from them, generally enclosing a lagoon. Hard coral limestone is exposed along the beaches of island during low tides and also in well sections. Hard pebbles of coral limestone along with coral sand are generally seen. 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 coral sands and the coral limestone form the principal aquifer in Kiltan. Ground water, existing under phreatic conditions at a depth of 2 – 3 m.bgl, is seen as a thin lens floating over and in hydraulic continuity with the sea water. Large diameter wells are the most common and traditional ground water abstraction structures. In almost all the wells, hard coral limestone is exposed near the bottom. The sand below this hard layer has caved in most of the wells.

5.1 Freshwater lens

The freshwater lens in the island is formed due to the radial movement of the freshwater towards the coast, in a dynamic system in hydraulic continuity with seawater. There is a transition zone through which the salinity increases with depth as suggested by the line XY in Fig. 5.1 (Barker, 1984). The dispersion as well as the fluctuation causes continuous mixing of water of different salinities, creating the transition zone. The width of the transition zone depends on the geology, which controls the branching nature of the flow paths, resulting in dispersion and the fluctuation in water levels due to tides and in response to recharge and discharge. The higher the fluctuation, the thicker is the transition zone.

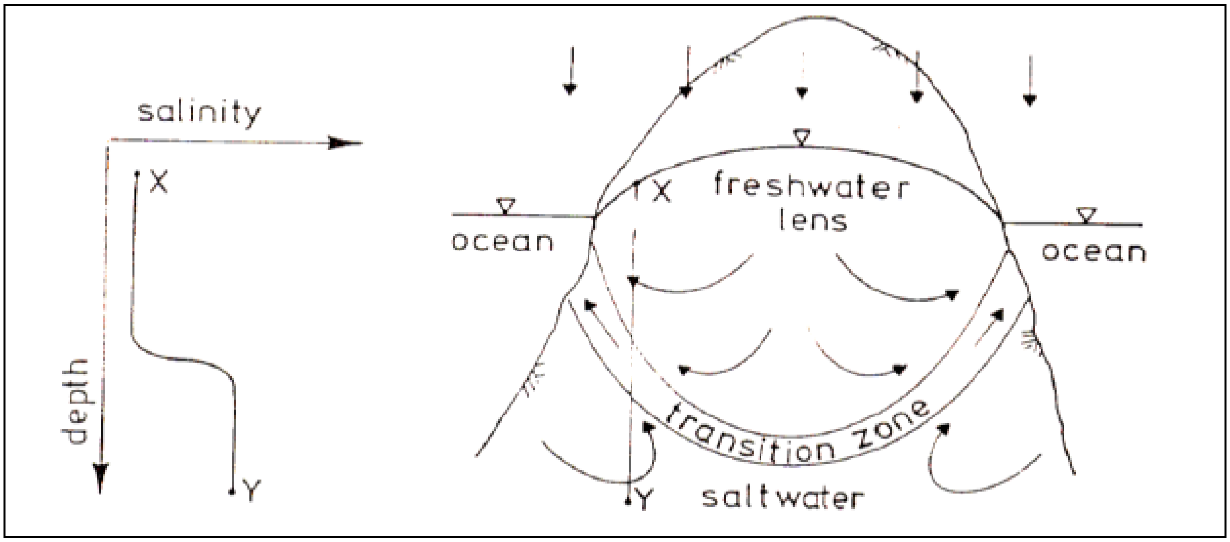


Fig. 5.1: Freshwater lens in Oceanic Islands- Schematic Diagram (Barker, 1984)

The occurrence of freshwater lens over saline water in island conditions was studied by Badon W Ghyben, 1888 in Netherlands and by Mike Herzberg, 1901, in the islands of North Sea off the German coast (Ghassemi. et al. 1990). Both these workers established the relation between the freshwater head above mean sea level (hf) and the depth to freshwater - saltwater interface (hs) to form a freshwater lens floating over saline water as shown in Fig. 5.2 (Ghyben-Herzberg (GH) Rule). In the simplified form of the GH approximation, the ratio of thickness of freshwater lens below and above mean sea level can be presented as

$$h = \frac{\sigma f}{\sigma s - \sigma f}$$

where, h = thickness of the freshwater lens below msl to that above msl, ϱs = density of seawater (normally 1.025) and ϱf = density of freshwater (normally 1.000) and is simplied as h = 40, which means that each meter thickness of freshwater lens above mean sea level is supported by a 40 m thick lens below mean sea level. However, studies in small islands indicate that the ratio of thickness of freshwater above and below msl is highly variable. In the Cayman Islands it is 1: 20 while it is 1: 30 in Tarawa and 1: 20 in Christmas Island (Falkland, 1984).

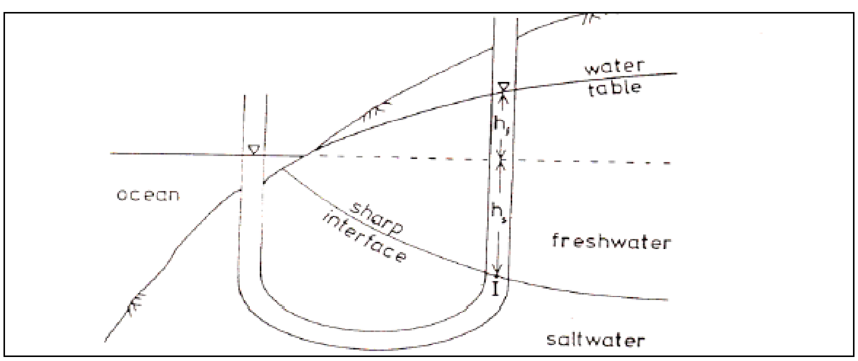


Fig. 5.2: Ghyben-Herzberg approximation for oceanic islands

The basic assumptions for the applicability of Ghyben-Herzberg relation are water table lie above msl and water table slope downward towards the ocean. In order to identify the role of the shape of the island in deciding the freshwater lens, the aspect ratio of the islands is made use of. Since the shape of the islands does not conform to any geometric form, the aspect ratio is computed taking into consideration the length, breadth and area of the island (Najeeb, 2003). The island area is divided by ratio of its length to breadth to get the aspect ratio. This ratio has been used to study the stability of the freshwater lens in these islands and the salient features are given in Table 5.1. Island with aspect ratio greater than 0.5 are found to have stable fresh water lens, under identical geomorphological settings. As the aspect ratio is below 0.50 (0.39), the fresh water lens is found to be unstable in Kiltan.

Table 5.1: Salient Features of Kiltan Island

#	Item	Detail
1	Area	2.20
2	Maximum length, km	3.36
3	Maximum width, km	0.60
4	Aspect ratio, A/(L/B)	0.39
5	Shape	Elongated
6	Trend of longer axis	N-S

5.2 Tidal influence

As the ground water is in hydraulic continuity with seawater, it is highly influenced by the diurnal tidal fluctuations of the sea. The magnitude of the tidal fluctuation is dependent on several factors amongst which the permeability of the aquifer material, the proximity of the site to the sea and the magnitude of tidal variation in the sea play significant roles. There is a time lag between tidal fluctuation in the sea and in the ground water levels, which is also dependent on the above factors.

5.3 Ground water scenario

In Kiltan island, fresh water floats over marine water in hydraulic continuity with it (Fig. 5.3).

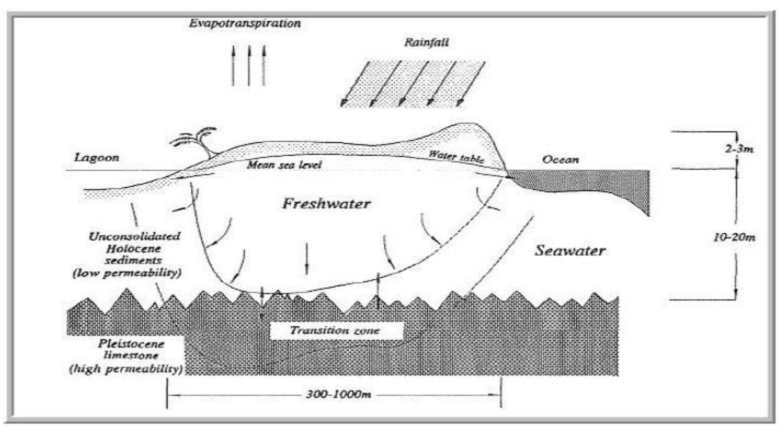


Fig. 5.3: Freshwater lens in small Islands (Exaggerated vertical scale)
(Falklands, 1993)

The calcareous sands overlying this island are highly porous and infiltrate bulk of the rainfall received. The infiltrating rainfall displaces the saline water to a freshwater lens due to density difference and the hydraulic continuity of ground water with seawater. There is no rejected recharge of ground water even during heavy rainfall. About 18 to 51 percent of the annual rainfall gets recharged into the ground water depending on the intensity, frequency and distribution of rainfall. However, the rise in water level due to recharge gets adjusted within the lens as per the Ghyben-Herzberg approximation and hence appreciable increment in the water level is not observed. Rainfall received in the Kiltan is fully recharged and adjusted in the fresh water lens, as a result of which significant rise in water levels are not discernible in the wells even after the monsoon rains.

The organic tiny carbonate coral atoll of Kiltan consists of a layer of Recent (Holocene/Anthropocene) 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 results in alternate periods of emergence and submergence of the atoll. During periods of emergence, solution and erosion of the reef platform can occur, while further deposition of coral limestone can 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). Permeability greater than 1000 m/day occur 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.

In Kiltan has freshwater lens which is saline to brackish. There exists a high magnitude of temporal and spatial variations in thickness, shape as well as the ground water quality of these lenses. The exact geometry of these lenses, chemical quality, behaviour under various stresses and their potential are of great significance for planning and effective management of the freshwater resources in the island. Ground water is developed by dug/open wells, shallow filter point wells and step wells. The depth to water level in the islands vary from few centimetres to about 5 m. bgl and the depth of the wells vary from less than a metre to about 6 m. The water levels in the entire island are highly influenced by tides.

The Lakshadweep Public Works department had established Observation Wells in the entire Island for periodic quality monitoring and for the weekly monitoring of water levels of the dug wells. For the hydrogeological studies select wells from LPWD observation wells and other dug wells and filter point wells were studied. The well inventory details are compiled (Appendix-I), well location details and Depth to the water level map, hydrogeology as in Fig.5.4, 5.5 & 5.6. Kiltan is located about 50 km to the northeast of Kadamat Island and is an elongated island oriented in a roughly N-S direction. The island covers a small lagoon on its west. Almost the entire island has freshwater lens except along the southern tip, where the ground water is brackish. There are about 685 wells with a density of about 421 wells/ sq km. The depth to water level in the island ranges from1.60 to 3.70 m and the depths of wells range from 2.10 to 4.30 mbgl. The maps showing locations of the key wells, depth to water table (pre-monsoon 2016) and hydrogeology of the island is given in figures 5.5, 5.5 and 5. 27 respectively.

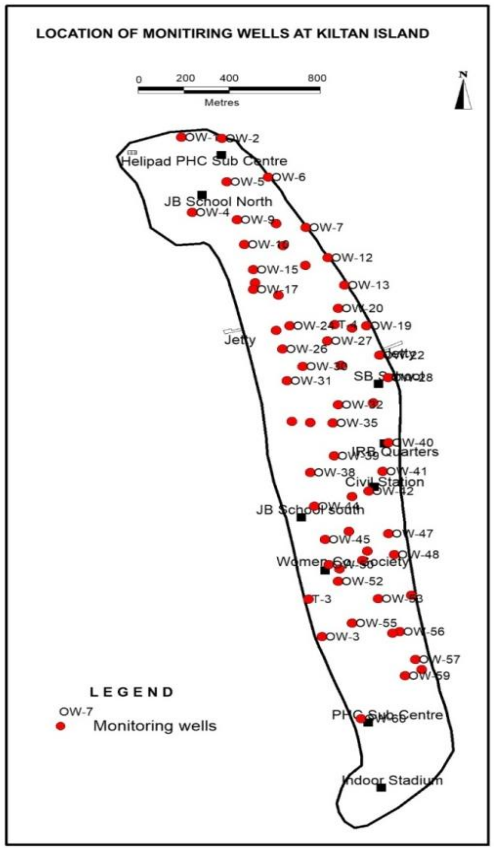


Fig. 5.4: Key well locations in Kiltan Island

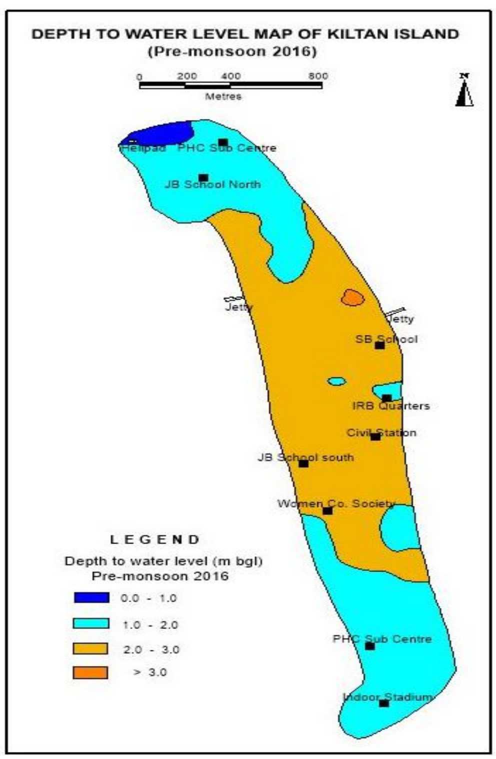


Fig. 5.5: Depth to the water level map, Kiltan Island

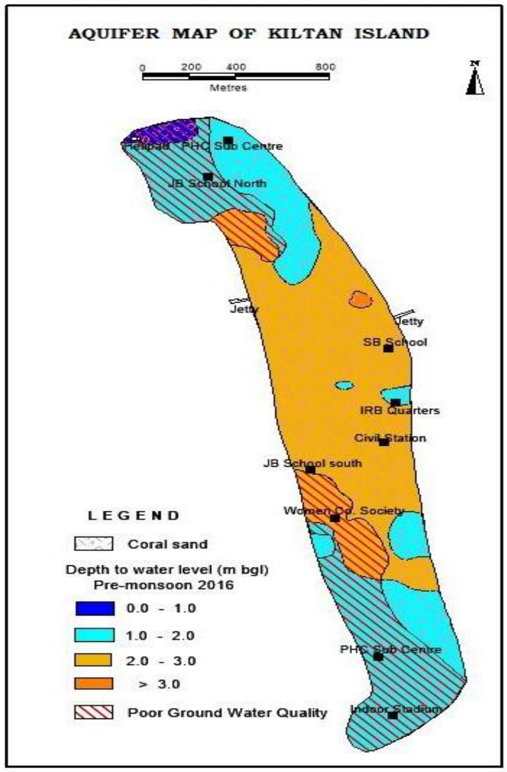


Fig. 5.6: Aquifer map of Kiltan Islands

6.0 Quality of Ground Water

Ground water in Kiltan Island is generally alkaline with few exceptions. The electrical conductivity ranges from 500 to 15,000 µS/cm at 25^{o}C. The Ranges of pH, EC and concentrations of important chemical constituents in ground water in the island are shown in Table. 6.1. The LPWD is maintaining chemical lab in all the islands and are monitoring the periodic chemical quality of the Observation Wells. The chemical data from this lab are utilised for the study.

Table 6.1: Hydrochemistry of select ground water samples collected from open wells in Kiltan

#	No of Samples	pH	EC (µS/cm)	Total Hardness(mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)
2010 Pre-Monsoon							
1	4	7.66-8.30	494-881	234-300	57-74	22-29	20-100
2010 Post-Monsoon							
1	4	7.84-8.01	437-817	195-300	50-82	12-34	21-71

The major ions in the fresh water lens are within the permissible limits and fluoride varies from 0.12 to 1.52 mg/l. Lateral, vertical and temporal changes in quality of ground water are observed. The fresh water lens is generally alkaline with pH ranging from 7.22 to 7.55. The dissolution of CaCO3 during rainwater infiltration leads to high pH of ground water. However, samples from the pumping wells immediately after pumping are found to be slightly acidic. This is because of the precipitation of $CaCO_3$ from water due to instability of equilibrium between Calcium and bicarbonate ions. $CaCO_3$ precipitate is quite often seen at the bottom of such pumping wells. The decrease of pressure that accompanies pumping from a certain depth below water level is likely to cause a decrease of dissolved CO_2 and to render the water more saturated with calcite than it originally was (Mandal, S and Shiftan, Z.L, 1981). The overall reaction describing $CaCO_3$ dissolution and precipitation is given below:

$CaCO_3 + H_2O + CO_2 = Ca^{++} + 2HCO_3^-$. Higher concentrations of the dissolved solids are generally seen along the periphery of the island and also close to pumping centres.

6.1 Variations in ground water quality

The ground water quality variations in the Island could be lateral, vertical and temporal. The quality is also highly variable and reversible. It is observed that the quality improves with rainfall. Other factors affecting the quality are tides, ground water recharge and draft. There is a vertical variation in the quality due to the zone of the interface and underlying sea water. It is also seen that any perforation like drilling affects the quality. This acts as a conduit for up-coning of seawater.

Quality of ground water in the islands varies with time too. Wells from which water is drawn by bucket and rope retain more or less the same quality over a long period, whereas quality deterioration is observed around pumping centres. A trend towards sea water composition is observed with increasing electrical conductivity in and around pumping centres. Similarly, brackish water is seen along topographic lows and in areas where coarse pebbles and corals are seen.

6.2 Ground water quality characteristics in Kiltan

In general, the quality of ground water in the freshwater lens is good and within the permissible limits for drinking purpose as per BIS in about 90 % of dug wells in the island. The water is almost neutral to slightly alkaline with the pH in the range of 7.2–7.55. The EC ranges from 480 to 4370 µS/cm at 25^o C. The chloride is in the range of 40 to 400 mg/l. Fluoride and nitrate values range from 0.3- 1.2 mg/l and 0.2-68 mg/l. The spatial variations in EC are depicted in Fig. 6.2.

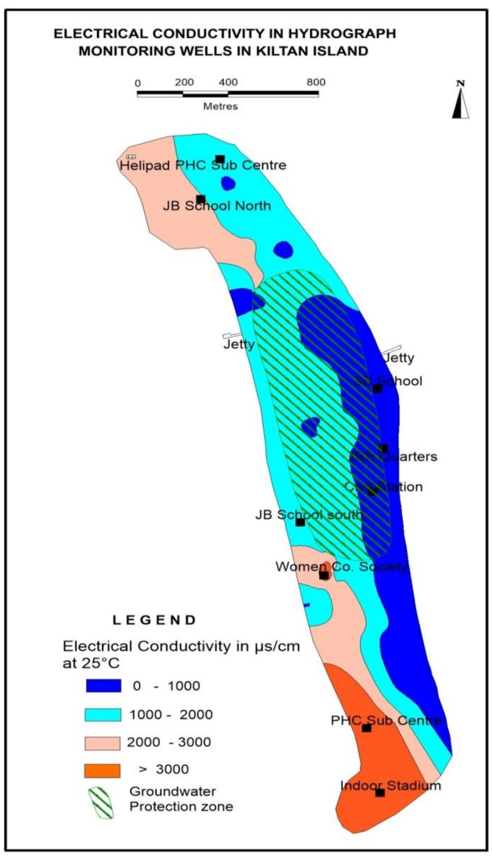


Fig. 6.2: Spatial variation of EC in Kiltan island

6.3 Factors affecting ground water quality

In Kiltan island, ground water flow is mostly vertical with fluctuations due to diurnal tidal effects, recharge and draft. Horizontal flow of ground water is relatively insignificant as the freshwater lens contracts and expands in response to draft and recharge. The tidal effect on the fresh water lens, shallow ground water conditions, pollution from unscientific sewerage disposal, use of detergents for washing, presence of soak pits/ septic tanks and other kinds of human interference with the eco-system are causes of concern as far as the quality of ground water in the island is concerned. Various factors affecting the quality of water in the tiny coral aquifer system in Kiltan are discussed.

6.3.1 Tidal influence

As the ground water is in hydraulic continuity with seawater, its quality is influenced by the diurnal tidal fluctuations of the sea. There is a marked variation in water quality with time in Kiltan. Quality variation is observed with tidal fluctuation and some of the wells located in areas where the freshwater lens is very thin and are brackish during low tides yield freshwater during high tides. It is established that the quality variation due to tides is not very significant. However, it is seen that best quality of water available is during high tide and more specifically, during the rising limb of high tide.

6.3.2 Effect of ground water over draft

The freshwater-salt water interface in Kiltan is in a delicate equilibrium and any undue stress on this equilibrium by over draft results in the up-coning of the saline water from beneath. Thus the movement of saline front is not horizontal as in the case of inland aquifers. Heavy withdrawal of ground water from a point source induces up-coning of saline water and the quality deterioration due to pumping is evident even on limited pumping.

6.3.3 Effect of ground water recharge

Studies in Lakshadweep Islands revealed that there is no rejected recharge of ground water even during heavy rainfall. About 18 to 51 percent of the annual rainfall gets recharged into the ground water depending on the intensity, frequency and distribution of rainfall. The Ghyben-Herzberg (GH) equation (Todd 1959) indicate that the depth to interface between fresh and salt water is about forty times the thickness of freshwater above mean sea level in small islands in ideal situations. This indicates that only a fraction of the freshwater lens is available above mean sea level and the rest is below. Consequently, whenever there is a recharge into the ground water in Kiltan, a major part of the recharged water gets readjusted below mean sea level by expansion of the lens. Hence, there will not be any significant rise in water level, and only a small fraction of the recharge will be above mean sea level. Many times this fractional increment will be less than the negative influence created by the tides, which is difficult to decipher by regular hydrograph analysis. The effect of rainfall is evident in improvement in the quality of freshwater lens, which is very well elucidated from various studies.

6.3.4 Aspect ratio of Islands

The shape and size of the islands have a role in the water quality as well the stability of freshwater lens. Hence, the aspect ratio of the island was worked out to study the behaviour and stability of the freshwater lens, as mentioned in one of the previous sections. The aspect ratios of the islands were studied with reference to the stability of the freshwater lens. It is postulated based on the studies that in islands where the aspect ratio is more than one, the fresh lens is stable and the changes in quality due to draft and recharge is not remarkable. In islands where the aspect ratio is less than 0.5, the freshwater lens is highly vulnerable to changes in draft and recharge.

6.3.5 Marine aerosols

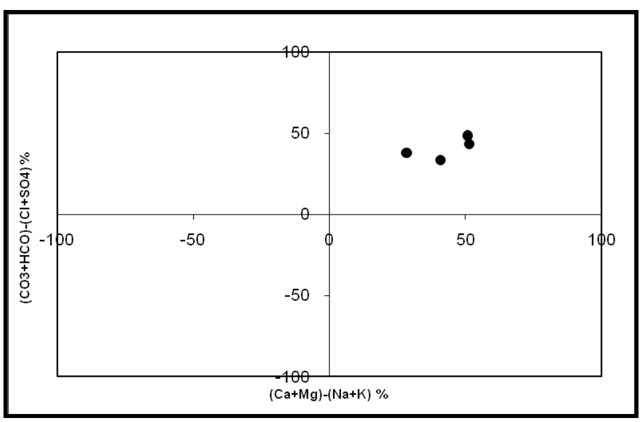
The rainwater quality in Lakshadweep Islands is influenced by the aerosols in the atmosphere. The atmosphere in the coastal parts and islands are enriched in Chloride ions, which gets washed down to the ground during the rains. The first rain, after a long dry spell, will have a higher concentration of Chloride compared to the rains received after continuous rainy days. Similarly, the concentration of chloride is less as we go towards the central part of the island as the thick vegetation obstructs the aerosols.

6.4 Seasonal changes in ground water quality

There is a marked improvement in quality of ground water during monsoon months in a majority of the wells in the Kiltan island. Only in wells located in thick freshwater lens, where the mineralization is very low, the quality variation is not significant which indicates that chemical change is inversely proportional to the lens thickness at any given time. Studies have established that the quality variations in these islands are not irreversible. This is in contrast to mainland situation, where the reversal of quality deterioration is a very slow process. This finding gives a much-needed leverage for the development of the ground water resources in extreme drought situations. It is established from the studies that a water surplus of 20 mm is sufficient to reverse the deteriorating trend in water quality in summer months. Water surplus of above 100 mm give a marked improvement in quality that sustains for the next two to three months with the normal rate of draft. The freshwater lens continuously contracts in the absence of rainfall, due to the effect of water lost due to mixing, draft by vegetation and draft for domestic consumption. The quality variation is higher in the fringe areas of freshwater lens during various seasons as compared to that of the central part of freshwater lens, where the water is fresh all through.

7.0 Hydrochemical facies of water lens

The Chadha, 1999 plots for the Premonsoon (PRM) and post monsoon (PSM) samples of 2010 reveal that all samples are falling under distribution within the field 5 (Fig.7.1 &2). Thus alkaline earths and weak acidic anions exceed both alkali metals and strong acidic anions, (Ca+Mg)+(CO3+HCO3)> (Na +K)+(Cl+SO4). As the samples falling in Field I, the fresh water lens is Ca-HCO3 Type and is of Recharge Type



Field IV Na-HCO3 Type. Base Exchange water	Field I Ca-HCO3 Type. Recharge Type
Field III Na-Cl Type. Sea water Type	Field II Ca-Mg-Cl Type. Reverse Ion exchange Type

Fig. 7.1: Chadha, 1999 plots for the PRM samples

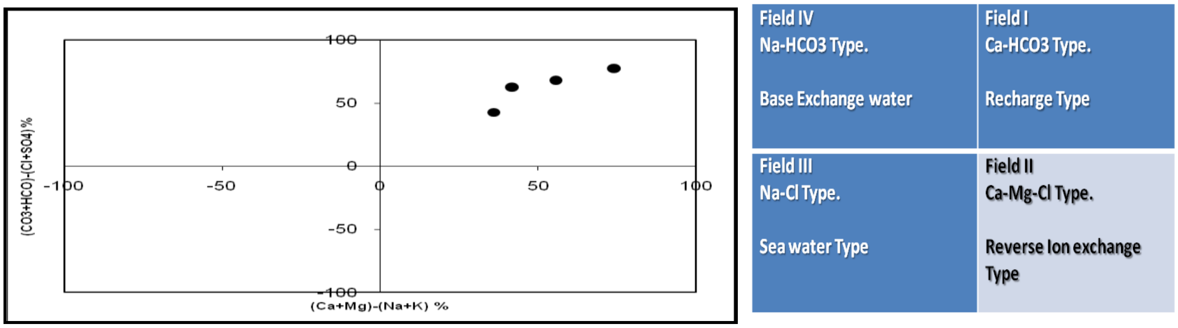


Fig. 7.2: Chadha, 1999 plots for the PSM samples

8.0 Mechanism of formation of fresh water lens

Coral aquifers are devoid of clay minerals and mainly consist of coral sands and shells (CaCO3). Cation exchange of sodium of seawater for calcium of aquifer material and dissolution of CaCO3 are the major chemical reactions in this aquifer system, leaving apart the daily and seasonal mixing of seawater.

$CaCO_3^{+}$ H_2 O + CO_2 = Ca^{++} + $2HCO_3^{-}$ (CaCO3 dissolution)--------- 1

2 Na (water) + Ca – aquifer → 2Na-aquifer + Ca (water) .. …..… 2

Normally, ground water exchange calcium for Sodium in a ground water flow regime. But, in the present situation, there is not much scope for adsorbed sodium in the aquifer material for exchange with calcium ion as there is no adsorbing material like clay in the aquifer system. The high sodium concentrations observed are due to mixing of seawater. The cation exchange process in such mixing zones is reversible in nature, such that the seawater exchanges sodium ion for calcium, with the Ca-Mg-HCO3 type water of the fresh water lens which ultimately evolves to Na-Cl type water.

9.0 Correlation coefficient

The relationship between two variables is the correlation coefficient (r) which shows how one variable predicts the other. Associated with r, the multiple correlations, which are the percentages of variance in the dependent variable, explained collectively by all of the independent variables. A high correlation coefficient (near 1 or -1) means a good relationship between two variables, and a correlation coefficient around zero means no relationship. Positive values of r indicate a positive relationship while negative values indicate an inverse relationship (Table 9.1 &2).

The ANOVA analysis shows significant change in certain chemical composition of groundwater when the groundwater is sampled at different climatic conditions. It can be observed that the concentrations of main ions generally decrease in PSM. This decrease may be due to the high contribution of rainwater in PSM due to dilution and input of more fresh water into the aquifer. From the ANOVA analysis, pH, EC, HCO_3, NO_3, SO_4, Ca, Mg, K and Na show significant variations with respect to PRM and PSM. High positive correlation exists between EC Vs TH, Ca, Na, HCO_3, Cl and NO_3 for PRM and high positive correlation exists between EC Vs TH, Mg, Na, K, Cl, HCO_3, Cl, SO4 and F for PSM in 2010.

Table 9.1: Correlation Matrix for Chemical analysis results of premonsoon, 2010

	pH	EC	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
pH	1												
EC	-0.42	1											
TH	-0.45	0.98	1										
Ca	-0.92	0.72	0.76	1									
Mg	0.80	0.20	0.17	-0.51	1								
Na	-0.64	0.86	0.76	0.77	-0.17	1							
K	-0.46	0.02	-0.14	0.24	-0.57	0.52	1						
CO3	0.81	-0.25	-0.40	-0.79	0.64	-0.21	0.12	1					
HCO3	-0.69	0.81	0.91	0.91	-0.17	0.64	-0.17	-0.75	1				
Cl	-0.44	0.99	0.93	0.71	0.16	0.92	0.16	-0.18	0.75	1			
SO4	0.80	0.01	-0.13	-0.66	0.82	-0.08	-0.05	0.95	-0.53	0.06	1		
NO3	-0.21	0.60	0.41	0.29	0.08	0.83	0.68	0.35	0.13	0.71	0.41	1	
F	0.70	-0.31	-0.18	-0.56	0.63	-0.75	-0.94	0.15	-0.19	-0.43	0.24	-0.73	1

Red Good Correlation (r=>0.6 or -0.60)
Yellow and unhighlighted Poor Correlation

Table 9.2: Correlation Matrix for Chemical analysis results of post monsoon, 2010

	pH	EC	TH	Ca	Mg	Na	K	HCO3	Cl	SO4	NO3	F
pH	1											
EC	0.54	1										
TH	0.13	0.90	1									
Ca	-0.50	0.27	0.59	1								
Mg	0.60	0.88	0.72	-0.13	1							
Na	0.81	0.92	0.67	-0.11	0.92	1						
K	0.06	0.68	0.79	0.83	0.26	0.41	1					
HCO3	0.00	0.84	0.98	0.57	0.72	0.59	0.69	1				
Cl	0.93	0.73	0.39	-0.14	0.62	0.87	0.43	0.24	1			
SO4	0.76	0.86	0.62	-0.25	0.97	0.97	0.23	0.58	0.76	1		
NO3	0.92	0.17	-0.26	-0.76	0.34	0.53	-0.30	-0.37	0.72	0.53	1	
F	0.62	0.72	0.51	-0.39	0.96	0.85	-0.02	0.53	0.53	0.95	0.46	1

Red Good Correlation (r=>0.6 or -0.60)
Yellow and unhighlighted Poor Correlation

10.0 Ground water contamination

Contamination of ground water is a major threat to ground water in the Kiltan island. Human waste, sewerage, biological wastes and fertilizers are the major agents of pollution of ground water. The traditional burial grounds also contribute to ground water contamination to some extent. The chemical analysis data from the Island in 2010 is compiled (Table 11.1).

11.0 Status of Ground Water Resources

The ground water resource availability in Kiltan Island is restricted to the top few meters of the phreatic aquifers, composed of coral sands and coral limestone. The salient details of computation of the dynamic ground water resources of Kiltan Island are described.

11.1 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.

11.2 Ground water recharge

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

The ground water recharge Kiltan Island has been computed for six months from May to October using rainfall Infiltration method. The Normal Monsoon Rainfall (NMR) is taken as 1416.9 mm for Minicoy islands, whereas the NMR of 1325.7 mm, recorded at Amini is taken. In areas with no coconut trees, the recharge to ground water is about 50% of the rainfall and as the coconut tree increases to a full cover, the recharge can reduce to about 30% of the rainfall. A rainfall infiltration factor of 0.30 is adopted for the entire island.

The evapotranspiration (ET) value for coconut tree is taken as 80% of that of shallow rooted vegetation which in turn is assumed to be equal to the PET of a reference crop. The proportions of freshwater lens area covered by deep rooted vegetation can be estimated from ground observations or aerial photographs. For Kiltan island, the proportion is taken as 30%. The PET from the coconut trees has been estimated for a period of 6 non-monsoon moths @ 30 liter/ day/ tree for 180 days.

11.3 Total available ground water resource

About 20% of the total recharge from rainfall in the island is considered lost due to mixing with seawater during tides and another 20% is allocated for reserve for use during periods of delayed or low rainfall. These components, along with the transpiration losses from coconut trees are deducted from the total recharge for getting the total available resource in each island.

11.4 Ground water draft

The major component of ground water draft in Kiltan Island is the extraction through wells for domestic consumption. Almost all households have their own dug well and more than 75% of the wells are fitted with small capacity (normally 0.5 HP) electric pumps. A per capita consumption of 150 lpd has been considered for domestic draft calculation, on the basis of the population as per 2001 census. Irrigation drat is negligible in the islands as almost all the crops are rain-fed.

11.5 Stage of ground water development

The stage of ground water development (SD) has been computed using the following formula
SD = {B/A} x 100; Where, B is the gross ground water draft and A is the total available ground water resource.

11.6 Categorization of island

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 making long-term trend insignificant. However, categorization has been attempted in this estimation purely based on stage of ground water extraction.

11.7 Computation of ground water resources

The dynamic ground water resources have been assessed by computing various components of recharge and draft. Rainfall is the only source of recharge in the Islands, whereas domestic draft, evapotranspiration losses and water loss due to base flow into the sea are the major components of draft. 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 Table 6.1.

Evapotranspiration from coconut trees during 6 non-monsoon months amounts to 282.8 ha.m, whereas the water loss due to subsurface flow into sea is of the order of 210.9 Ha.m. An equal quantum of water is reserved as buffer to cater to late or deficit monsoon years in the islands. The balance ground water resources available for development ranges from 14.10 Ha.m (Chetlat) to 63.70Ha.m (Minicoy), amounting to a total of 360.80Ha.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 8.70Ha.m in Chetlat islands to 41.80 Ha.m in Kavaratti Island, amounting to a total of 238.00 Ha.m.

Balance ground water resources available in the Islands range from 5.40Ha.m (Chetlat) to 25.10 (Minicoy), adding up to a total of 122.90Ha.m for the group of Islands as a whole.

The stage of ground water extraction for the Kiltan Island is of the order of 66.9 %. In the absence of long-term water level data, the islands have been categorized solely based on the stage of extraction. Based on the stage of extraction (66.9%), Kiltan Island has been categorized as 'Safe'.

Table 11.1: Dynamic Ground Water Resources of Kiltan Island (As in March 2017)

#	Annual components of Water Balance	Details
1	Population (Projected as on 2017)	4125
2	Area, Ha	163.0
3	Normal Monsoon Rainfall, m	1.355
4	Rainfall Infiltration Factor, %	30
5	Total Resource (Water Surplus) (Ha.m)) [2*3*4]	66.3
6	ET loss from Trees for 6 non-monsoon months, Ha.m	17.3
7	Water loss due to outflow to sea [20% of (3), Ha.m	13.3
8	Buffer zone for reserve during delayed or lesser monsoon period [20% of (3) , Ha.m	13.3
9	Balance available resource, Ha.m	22.5
10	Domestic Extraction @100 lpcd [1*100*365], Ha.m	15.1
11	Gross Annual GW Extraction, Ha.m	15.1
12	Groundwater balance available [9-11], Ha.m	7.4
13	Stage of ground water extraction [11*100/9], %	66.9
14	Category	Safe

12. Ground water management scenario

12.1. Water Supply

Apart from rain, ground water constitutes the only conventional source of fresh water in Kiltan. Due to the typical geological and hydro geological nature of Kiltan, no single system to provide water supply to the island.

The right approach to solve the problem of drinking water in the island include Use the ground water to the extent available, the exact quantum of extraction without danger of salinity to be determined by a detailed island wise study, wherever the ground water is not adequate to provide water to the entire population, this has to be supplemented by desalination of brackish water through Reverse Osmosis Plants and to optimize the availability of the resource by encouraging rain water harvesting so that at least some of the water which otherwise is wasted could be utilized for part of the year. The water available from the above sources may be distributed through a common network of underground pipes and public stand posts, with the distribution system managed by local Panchayaths. Lakshadweep Administration has prepared water supply scheme for the U.T of Lakshadweep for the extraction of ground water through collector wells, which envisages extraction of ground water through radial perforated pipes of 5 m length located at specified shallow depths. The ground water flows under gravity through these pipes and collect in a collector well. This mechanism of ground water extraction prevents excessive extraction in the following ways: The extraction is not from a point source, but is distributed over a large area. In no case the water below a pre-decided level will be collected since the inflow is only through the perforated pipes. The bottom of the wells is sealed with concrete and as such does not allow seepage of water from the bottom. There are 4 to 6 such collector wells in each island among the LD Islands (http://lakshadweep.nic.in/depts/lpwd/water_supply.htm). These wells are selected at sites where quality of water is good and thickness of sweet water lens is maximum. Water from these collector wells is pumped intermittently to the collection sump. Extraction of water from each well is done for half an hour and then stopped for an interval of 2 ½ hours to allow time for the interface to subside. After chlorination, the water is pumped from the collection sump to the overhead water tanks. The water is supplied through stand-posts on the streets.

12.2 Rainwater Harvesting Systems

Rainwater collection has long been recognized as the most suitable and adoptable method to make up the short falls in ground water availability Kiltan Island. Rainwater is being collected from the roof tops of the buildings in storage tanks of various capacities ranging from 5000 to 10,000 thousand liters and in some cases, up to 50,000 liters. Such tanks are normally attached Government quarters, non-residential buildings and some private houses. The water collected from the roof tops is made to flow to the collection through a filter, designed to remove suspended particles. The water is then chlorinated and distributed to the public. Operation related to the pumping and distribution of water is entrusted with the respective Village (Dweep) Panchayaths in respect of water collected in community rainwater tanks in Hospitals, Schools etc. Community rainwater harvesting systems using public buildings such as hospitals and schools have also been implemented in Kavaratti and Minicoy islands, from which the harvested water, after filtration and chlorination in a centralized unit, is pumped into overhead tanks for distribution along with water collected from other sources such as ground water, desalination plants etc.

12.3. Desalination Plants

As per information available from Lakshadweep Administration, a total of ten brackish water reverse osmosis (R.O) desalination plants have been established in the U.T of Lakshadweep. Desalination plants set up by the National Institute of Ocean Technology (NIOT) under the Ministry of Earth Sciences, GOI, which is based on the temperature differential in the seawater and not on the conventional membrane (RO) technology, are functioning in Kavaratti, Agatti and Minicoy Islands. Each of these plants has the capacity of 1 lakhs litre of desalinated water/day, which is supplied free of cost to the local residents through taps. The variation in ocean water temperature with an increase in depth is used in the Low Temperature Thermal Desalination (LTTD) plants to flash evaporate the warm water at low pressure and condense the resulting vapour with the deep sea cold water.

12.4 Ground water Quality monitoring

There is water Quality Testing Laboratory installed in Kiltan. The Laboratory is regularly monitoring the quality of ground water from select wells. The local Public Health authorities are kept informed of any change in the quality of ground water, especially salinity.

12.5 Ground water regulation

The Lakshadweep Ground Water (Development and Control) Regulation, 2001 was promulgated on August 6, 2001. As per the regulation, a Ground Water Authority is to be constituted in the U.T of Lakshadweep, which will have the powers to control and regulate the extraction and use of water in any form in Kiltan island in Lakshadweep. The Authority, however, is yet to be constituted.

12.6. Ground water management issues

Major constraints in the sustainability of limited ground water resources in the Kiltan Island include absence of surface water resources in the islands putting stress on the limited ground water resources available, deterioration of ground water quality especially during summer months, existing supplies unable to cope with the rapidly increasing demands for drinking and domestic uses and indiscriminate ground water extraction at places, resulting in up-coning of saline water and consequent quality deterioration.

12.7 Management interventions for sustainable development

Requirements to meet the needs of a growing population and the non-availability of alternatives is likely to put the limited ground water resources in Kiltan island under increasing stress in the coming years. Some of the feasible management interventions to ensure long-term sustainability of ground water in the island are:

- Rehabilitation, restoration, renovation and protection of available ponds and wells,
- Large scale implementation of roof top rainwater harvesting schemes through participation of local communities,
- Regulation / control on the indiscriminate extraction of ground water through mechanical devices,
- Regular monitoring of water levels and water quality,
- Encouraging use of water efficient domestic fixtures like taps/ flush tanks to improve water use efficiency and reduce wastage,
- Decentralized garbage / waste treatment systems to prevent further contamination of available fresh water resources.
- Installation of desalination plants in Kiltan to reduce stress on ground water
- Sensitization and capacity building of stakeholders at all levels on the importance of water conservation and ways and means for its judicious management for ensuring long-term sustainability of water resources.

13. Aquifer management plan

In Kiltan Island, groundwater occurs in phreatic condition and is in hydraulic continuity with sea water. The management strategy suitable for aquifer in the continental land is not appropriate for the tiny island of Kiltan. Since surface run off is totally absent and the coral sands are fully receptive of the rainfall received, there is no need for artificial recharge. Management strategy needs to concentrate on limited ground water withdrawal and optimum utilization. The people of island should be educated about the danger of over exploitation of the groundwater resource and about water management practices.

13.1 Major natural challenges for ground water related Issues

The major natural challenges for ground water related Issues in the Kiltan Island are

- Climate Change,
- Sea Level Rise,
- Variation in rainfall (tropical cyclones, Drought),
- Natural groundwater discharge to ocean due to hydraulic continuity between aquifer and Sea water,
- Evapotranspiration loss due to vegetation-Coconut tree roots are touching water table at places, and
- High population density and associated pressure on the limited ground water resources.

13.2 Groundwater pollution by sanitation

The highly porous coral sands and shallow groundwater conditions are susceptible to anthropogenic contamination. Groundwater in Kiltan island. Contamination by pathogens has been recorded in the island. General guidelines of 30 meters separation between domestic septic tanks and water supply wells found to giving inadequate protection from pathogens, especially in highly permeable aquifers like coral sands. The U.T administration has taken steps to ensure installation of scientifically designed septic tank in all newly constructed houses and other buildings.

13.3 Control Measures

13.3.1. Institutional

- Comprehensive island water legislation would help to resolve institutional uncertainties on roles and responsibilities and provide a firm foundation for addressing systematically and consistently the issues involved in water resource management.
- The need for the introduction of a water-pricing regime should be a priority, essential to the operation and maintenance of the water supply system and as a demand side management.

13.3.2 Community

Control measures to prevent sanitation impacts on water supplies and human health on the island may include one or more of the following:

- Creating public awareness on the linkage between sanitation and drinking water quality
- Developing public health regulations on the design and maintenance of sanitation systems
- Establishing a periodic monitoring procedures for pathogens and nitrogen in drinking water supplies, and
- Disinfection of water supply wells or finding alternative water supplies (eg rainwater and desalinized water). The acceptability and effectiveness of the various measures will obviously depend on the involvement of the local community.

14.0 Conclusions and recommendations

14.1 Conclusions

- Hydrogeological conditions, problems, issues and its manifestations in Kiltan are identical with all Islands.
- The Kiltan Island is lying well within the tropics and extending to the equatorial belt, has a tropical humid, warm climate. The island is flat, rarely rising more than a few meters above mean sea level, and consists of fine coral sand and coral limestone. Kiltan is a typical tiny carbonate is atoll.
- The Kiltan is characterized by the absence of surface drainage and does not have any river or other surface water bodies.
- Ground water exists under phreatic conditions in the island as a thin fresh water lens floating over the saline water in the porous formation and is in hydraulic continuity with the seawater.
- The various abstraction structures in Kiltan are open dug wells, filter point wells and step wells.
- The depth to water level in the island varies from a few centimetres to 5 m.bgl and depth of the wells varies from less than a meter to about 6 m.
- The depth to water level is influenced by the tides. The water level fluctuation in these islands is significantly controlled by tides when compared to the ground water recharge and draft. The diurnal fluctuation of water level due to tides is in the range of negligible to 80 cm.
- The fresh water lens in the Kiltan Island is fragile and the shape of island plays a significant role on its occurrence and stability. As the aspect ratio less than 0.5, the fresh water lens of Kiltan is unstable and will be subjected to sea water mixing.
- The stage of ground water extraction as in March 2017 in the Island is 66.9 % and the Island comes under safe category.

- The water level suddenly rises to fraction of metres immediately after the rainfall and again falls down to the original level within hours. Hence the magnitude of seasonal fluctuation in water level due to ground water recharge is not so significant when compared to tidal fluctuations.
- The Electrical Conductivity of ground water ranges from 480 to 4370µS/cm at 25° C. The quality variation is vertical, temporal and also lateral. Brackish water is present along topographic lows and in places where coarse pebbles and corals are present. Human waste, sewerage and other biological wastes are major sources of ground water contamination in the island. Ground water is limited in quantity and its salinity level increases as a function of time during withdrawal in the dry periods.
- Water supply in the Kiltan Island is through a combination of ground water extracted through collection wells and harvested rainwater. Though the "Lakshadweep Ground Water (Development and Control) Regulation, 2001" was promulgated on August 6, 2001 for control and regulate the extraction and use of water in any form in any of the islands in Lakshadweep through constitution of Lakshadweep Ground Water Authority, the same is yet to be constituted.
- Important constraints in the sustainable development of the limited ground water resources in the Kiltan include the absence of surface water resources in the islands putting stress on the limited ground water resources available, deterioration of ground water quality during summer months, rapidly increasing demands for drinking and domestic uses, indiscriminate ground water extraction at places, resulting in up-coning of saline water and consequent quality deterioration, lack of proper sanitation, resulting in large scale bacterial contamination. Burial places in the Island are potential microbial contaminant sources.

14.2 Recommendations

- As the full requirement of fresh water in the islands cannot be met with from the limited ground water resources, water supply schemes in all islands must resort to a combination of ground water, desalinated water and rainwater harvesting.

- The indiscriminate extraction of ground water through electric pumps from the wells needs to be regulated for protecting the limited water resources from salinization due to up-coning of seawater. The constitution of Lakshadweep Ground Water Authority under the Lakshadweep Ground Water (Development & Control) Regulation, 2001 needs to be expedited to achieve this objective.
- The pumping of water from dug wells directly to multi storied buildings may be stopped. The water may be pumped from dug wells with low capacity pump and collected in ground level storage tanks and from this water may be pumped to multi storied buildings.
- Roof top rainwater harvesting can provide reliable freshwater for the islands during a part of the year. Efforts to popularize rainwater harvesting needs to be accelerated, through incentives wherever necessary, to reduce the increasing stress on the limited ground water resources. Legal provisions to make rainwater harvesting mandatory for all future civil constructions may also be made.
- As the shallow, thin floating lens of groundwater is easily prone to contamination, efforts for proper sewage disposal are to be given top priority.The U.T. Administration has taken steps to ensure installation of scientific septic tank in all newly constructed houses and other buildings. However, the existing soak pit / leach pit toilets need special attention
- Measures for improving water use efficiency through use of water efficient fixtures in homes/buildings should be encouraged.
- Judicious pumping from freshwater lens through radial wells possible in the island, hand drawn wells to be encouraged over energized wells, pumps above 0.25hp should not be allowed and pumping for water supply should be only from radial wells
- Low rate of continuous pumping preferred and should have zero tolerance for Wastage.
- Roof top Rain water harvesting should be mandatory, abandoned wells and pond are to be rejuvenated and protected and wells should not be converted into garbage disposal pit.

15. References

- Falkland, A C (1993): Hydrology and water management in small tropical island-Hydrology of warm Humid Regions (Proceedings of the Yokohama Symposium, .IAHS Publ.no.216.
- Falkland, A C (1993): Hydrology and water management in small tropical island-Hydrology of warm Humid Regions (Proceedings of the Yokohama Symposium, July 1993).IAHS Publ.no.216, 1993.
- Ajayakumar VR, Ramachandran KK (1996): Resistivity survey for describing the freshwater lenses of Agatti Atoll, Lakshadweep, India. Journal of association of Exploration Geophysics
- Barker, J A (1984): Freshwater-salt water relations, Tech. Publ. Series 154, Commonwealth Science Council, London, 2: 124-130.
- Central Ground Water Board (1994): Ground water Resource and Water management in the T.T. of Lakshadweep, Part I. Unpublished Report 1994.
- Central Ground Water Board (2013): Dynamic Ground Water Resource of the U. T. of Lakshadweep. Unpublished Report March, 2013
- Central Ground Water Board (1978): A preliminary note on the ground water resources of Union Territory of Laccadives, Minicoy and Aminidive,
- Central Ground Water Board. (1994): Hydrogeological and Hydrochemical studies in Kavaratti Island, Union Territory of Lakshadweep.
- Central Ground Water Board (1997): Ground water Resources and Management in the Union Territory of Lakshadweep
- Central Ground Water Board (2001): Basic data report of exploratory wells drilled in Kavaratti Island of Lakshadweep. Unpub. Report, p40.
- Central Ground Water Board (2001): Ground water exploration in the Union Territory of Lakshadweep
- Central Ground Water Board (2004): Hydrogeological Atlas of Lakshadweep Islands.
- Central Ground Water Board (2004): Impact of ground water development and tidal influence on freshwater lens of Kavaratti Island –FSP 1997-98.
- CGWB (1995): Ground water Resources and Management in the Union Territory of Lakshadweep (Androth and Minicoy Islands),
- Comte JC, Banton O, Joil JL, Cabioch G (2010): Evaluation of effective groundwater recharge to freshwater lens in small islands by combines modelling of geo-electrical data and water heads, Water Resources research 46: W06601
- Dahlin T, Zhou B (2004): A numerical comparison of 2D resistivity imaging with 10 electrode arrays, geophysical prospecting 52 (5), 379-398.
- Dahlin T, Zhou B (2004): A numerical comparison of 2D resistivity imaging with 10 electrode arrays, eophysical prospecting 52(5), 379-398.
- Ghassemi, F. Jakeman, A.J. and Jacobson, G. (1990): Mathematical modelling of seawater intrusion, Nauru Island, Hydrological Process. 4:269-281.
- Hay, JE. (Ed.) (1991): Proceedings of the Conference on South Pacific Environments, Interactions with Weather and Climate, University of Auckland Press. 237.
- Hem, J.D (1985): Study and Interpretation of the Chemical Characteristics of Natural water. U.S. Geological Survey, Water Supply Paper. 2254, 264 p.
- Jacks G., (1987): Hydrochemistry in Coastal Kerala Project. Un pub. rep. CGWB Trivandrum, 62.
- Jacob V.C., Rajagoplan, K., Thambi, D.S., Najeeb, K.Md., Ramam, K. (1987): Ground water investigation in the Kavaratti island of UT of Lakshadweep. un. pub. rep. CGWB Trivandrum. 114.
- Jean-lambert Join, Oliver Banton, Jean-Christophe Comte, Julie Leze, Frederick Massin and Eric Nicolini (2011): Assessing spatio-temporal pattern of groundwater salinity in small coral islands in the western Indian Ocean Western Indian Ocean Jr. of Marine science Vol., 10, No.1 pp. 1-12, 2011.
- Jean-lambert Join, Oliver Banton, Jean-Christophe Comte, Julie Leze, Frederick Massin and Eric Nicolini (2011): Assessing spatio-temporal pattern of groundwater salinity in small coral islands in the western Indian Ocean Western Indian Ocean Jr. of Marine science Vol., 10, No.1 pp. 1-12, 2011.
- Lloyd JW, Miles JC, Chessman GR Bugg SF (1981): A Ground water resource study of the Pacific Ocean atoll-Tarawa, Gilbert Island. Water Resources Bulletin16:646-653

- Lloyd JW, Miles JC, Chessman GR Bugg SF (1981): A Ground water resource study of the Pacific Ocean atoll-Tarawa, Gilbert Island. Water Resources Bulletin16:646-653
- Lloyd JW., (1985): A review of some of the more important difficulties encountered in small island hydrogeological investigations. Tech. Publ. Series 154, Commonwealth Science Council, London 2: 180-210.
- Mandal, S. and Shiftan, Z.L. (1981): Groundwater Resources. Investigation and development. Academic Press, New York, 269p.
- Najeeb, K.Md. (1994): Ground water resources and management in the UT of Lakshadweep. Part 1. Kavaratti, Agatti & Amini Islands. Un pub. Rep. CGWB Trivandrum, 46.
- Narasimha Prasad N.B. (2011): Geophysical investigation for groundwater exploration in Lakshadweep Islands – A case study J. Ind. Geophysics. Union (October 2011) Vol.15, No.4, pp.221-227
- Narasimha Prasad N.B. (2011): Geophysical investigation for groundwater exploration in Lakshadweep Islands – A case study J. Ind. Geophysics. Union (October 2011) Vol.15, No.4, pp.221-227
- Piper, A.M., (1944): A graphical interpretation of water analysis, Transactions of the American Geophysical Union., 25, 914 -928.
- Stumm ,W. and Morgan,J.J., (1996): Aquatic Chemistry. Wiley Interscience, New York., 349–424.
- Todd, D K (1980): Ground water hydrology, New York: Wiley, 535 p.
- UNESCO (1991): Studies and Reports on Hydrology, Hydrology and Water Resources of Small Islands- A Practical Guide, UNESCO, 49:435
- UNI (2002): Lakshadweep Remains a distant dream for tourists, Vijaya Times. Bangalore, dtd 23.12.02., VI.
- Varma, Ajayakumar R (1997): Studies on ground water resource potential and management of the coral atolls of Lakshadweep, U T of India, Ph.D. thesis Univ. Kerala. Trivandrum, 277.

Appendix I: Chemical Analysis of Ground Water Samples in Kiltan Island (Pre and Post Monsoon 2010)

#	LOCATION	Well ID	pH	EC	TH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	NO_3	F
	Premonsoon, 2010 April														
1	Kiltan (Community Well near Odipura House)	W1	7.69	876	270	62	28	64	8.7	0	317	114	22	15	0.37
2	Kiltan (Govt. Nursery School)	W2	8.13	522	175	26	27	23	5.9	0	220	50	21	7.3	0.73
3	Kiltan (GSS School, South)	W3	8.25	849	280	42	43	40	2.9	0	329	100	23	9.4	0.89
4	Kiltan (Environment and Forest Office)	W4	8.68	667	200	6	45	35	6.4	24	177	78	27	13	0.73
	Postmonsoon, 2010 November														
1	Kiltan (Community Well near Odipura House)	W1	7.88	670	270	82	16	31	7.7	0	360	50	14	1	0.22
2	Kiltan (Govt. Nursery School)	W2	7.94	817	300	64	34	54	4.9	0	433	57	33	4	0.68
3	Kiltan (GSS School, South)	W3	7.84	437	195	58	12	13	0.6	0	256	21	8.7	2	0.27
4	Kiltan (Environment and Forest Office)	W4	8.01	642	215	50	22	45	2.9	0	256	71	25	10	0.46

Appendix II: Well inventory details in Kiltan, January 2015

	Well ID	**Latitude**	**Longitude**	**Depth, m bgl**	**Dia, m**	**MP, magl**	**DTW, mbgl**	**EC, µS/cm**	**Temp, ºC**	**pH**	**Lining material**	**Lifting device**
1	OW-1	11.5	72	2.17	1.1*1.1	0.78	1.7	1950	28.5	7.5	CSCM	Pump
2	OW-2	11.5	72	3	1.65	0.69	2.4	1210	27.7	7.7	CSCM	Rope & Bucket
3	OW-3	11.49	72.02	2.1	1	0.31	1.6	2800	28.4	7.1	CR	Pump
4	OW-4	11.49	72	3.11	.88*.88	0.61	2.4	2700	28.3	7.2	CSCM	Pump
5	OW-5	11.49	72	2.86	3	0.76	2.3	980	27.9	7.6	CSCM	Pump
6	OW-6	11.49	72	2.66	1.06	0.75	2.07	1100	28.7	7.2	CSCM	Pump
7	OW-7	11.49	72.01	3.16	1.15*1.15	0.65	2.76	1300	28.1	7.2	CSCM	Pump
8	OW-8	11.49	72	2.5	1.3	0.6	1.92	1340	28	7	CSCM	Pump
9	OW-9	11.49	72	2.7	1.2	0.73	2.3	1530	28.2	7.2	CS	Pump
10	OW-10	11.49	72	3.5	1.25	0.55	2.8	2300	28.6	7	CS	Pump
11	OW-11	11.49	72	2.35	1.4	0.51	1.95	880	28.4	7.5	CSCM	Pump
12	OW-12	11.49	72.01	4.2	1.3	0.8	3.7	1250	28.3	7.2	CSCM	Pump
13	OW-13	11.49	72.01	4.17	1.16	0.65	3.6	1270	28.6	7.3	CR	Pump
14	OW-14	11.49	72.01	3.4	1.18	0.9	2.8	1240	28.3	7	CSCM	Rope & Bucket
15	OW-15	11.49	72	3.3	1.32	0.67	2.8	2100	28	7.1	CSCM	Pump
16	OW-16	11.49	72	3.65	1.05	0.7	3	2100	28.2	7.1	CSCM	Rope & Bucket
17	OW-17	11.49	72	3.73	1.18	0.75	2.92	850	27.9	7.4	CSCM	Pump

	Well ID	Latitude	Longitude	Depth, m bgl	Dia, m	MP, magl	DTW, mbgl	EC, µS/cm	Temp, ºC	pH	Lining material	Lifting device
18	OW-18	11.49	72	3.48	1.25	0.6	2.65	1150	28.6	7	CSCM	Pump
19	OW-19	11.49	72.01	3.7	1.1	0.65	3.1	910	28.4	7.2	CSCM	Pump
20	OW-20	11.49	72.01	3.63	1.2	0.65	3	650	28	7.5	CSCM	Pump
21	OW-21	11.49	72	3.48	1.25	0.6	2.25	1150	28.6	7	CSCM	Pump
22	OW-22	11.49	72.01	3.37	1.1	0.72	2.83	770	28.5	7.2	CSCM	Pump
23	OW-23	11.49	72.01	4.3	1.3	0.15	3.77	810	28.2	7.2	CSCM	Pump
24	OW-24	11.49	72	3.45	1.31	0.7	2.8	1110	28.2	7	CS	Pump
25	OW-25	11.49	72	3.77	1	0.8	3.1	1330	28.5	7.1	CSCM	Pump
26	OW-26	11.49	72	3.4	1.2	0.76	2.85	1300	28.7	7	CSCM	Pump
27	OW-27	11.49	72.01	3.88	1.2	0.7	3.2	830	28.6	7.2	CR	Pump
28	OW-28	11.48	72.01	3.43	0.96	0.76	3.1	3	27.6	7.5	CSCM	Nil
29	OW-29	11.49	72.01	0	0	0	0	0	0	0	CSCM	Nil
30	OW-30	11.49	72.01	3.65	1.25	0.65	2.7	1430	28.2	7.2	CSCM	Nil
31	OW-31	11	72	0	0	0	0	0	0	0		
32	OW-32	11.48	72	3.92	1.05	0.85	3.25	1400	28.7	6.9	CR	Nil
33	OW-33	11.48	72.01	3.3	1.05	0.37	2.75	1020	28.1	7.5	CSCM	Rope & Bucket
34	OW-34	11.48	72.01	3.65	1.15	0.75	2.95	770	29	7.3	CSCM	Pump
35	OW-35	11.48	72.01	0	0	0	0	0	0	0		
36	OW-36	11.48	72.01	3.31	1.3	0.68	2.65	1220	28.8	7.1	CS	Pump
37	OW-37	11.48	72.01	3.35	0.9	0.6	2.77	950	28.5	7.3	CS	Pump
38	OW-38	11.48	72	3.5	1.25	0.55	2.99	1120	28.5	7	CS	Pump
39	OW-39	11.48	72.01	3.6	1.12	0.75	2.95	1370	28.9	6.9	CSCM	Pump
40	OW-40	11.48	72.01	3.88	1.15	0.68	3.15	1090	28	7.4	CS	Nil
41	OW-41	11.48	72.01	3.15	1.2	0.63	2.6	840	28.8	7.5	CS	Pump
42	OW-42	11.48	72.01	3.9	1.2	0.6	3.2	750	28.5	7.3	CSCM	Pump
43	OW-43	11.48	72.01	3.53	1.18	0.56	3.2	530	28.3	7.5	CSCM	Pump
44	OW-44	11.48	72.01	3.4	1.05	0.6	3	1430	28.6	6.9	CS	Pump
45	OW-45	11.48	72.01	3.5	1.3	0.65	3.1	1330	28.5	6.9	CSCM	Pump
46	OW-46	11.48	72.01	3.65	1.1*1.1	0.65	3.15	1600	28.8	6.9	CSCM	Pump
47	OW-47	11.48	72.01	3.75	12.*1.2	0.73	2.95	1070	28.4	6.9	CSCM	Pump
48	OW-48	11.48	72.01	3.5	1.55	0.75	2.95	810	27.7	7.4	CSCM	Pump
49	OW-49	11.48	72.01	0	0	0	0	0	0	0		
50	OW-50	11.48	72.01	4	1.25	0.65	3.2	1020	28.1	7	CSCM	Pump
51	OW-51	11.48	72.01	3.85	1.35	0.67	3.15	3500	28.6	6.8	CSCM	Pump
52	OW-52	11.48	72.01	3.8	3.15	0.75	3	1010	28.3	7.4	CSCM	Pump
53	OW-53	11.48	72.01	4.1	1.15	0.75	3.45	2300	28.7	6.9	CSCM	Pump

	Well ID	Latitude	Longitude	Depth, m bgl	Dia, m	MP, magl	DTW, mbgl	EC, µS/cm	Temp, ºC	pH	Lining material	Lifting device
54	OW-54	11.47	72.01	0	0	0	0	0	0	0		
55	OW-55	11.47	72.01	3.08	1.18	0.8	2.45	640	27.9	7.6	CSCM	Rope & Bucket
56	OW-56	11	72	0	0	0	0	0	0	0		
57	OW-57	11	72	0	0	0	0	0	0	0		
58	OW-58	11.47	72.01	3.65	1.29*1.29	0.68	3.1	2400	28.7	6.8	CS	Pump
59	OW-59	11.47	72.01	3.5	1.4	0.62	3.05	1000	28.3	7.4	CSCM	Pump
60	OW-60	11	72	0	0	0	0	0	0	0		
61	OW-61	11.47	72.01	3.26	1.85	0.74	2.61	770	28.6	7.3	CSCM	Pump
62	OW-62	11.47	72.01	3.18	1.18	0.72	2.55	950	28.4	7.5	CSCM	Pump
63	OW-63	11.47	72.01	2.8	1.2	0.7	2.2	760	28.4	7.3	CSCM	Pump
64	OW-64	11.47	72.01	2.9	2.55	0.94	2.42	4100	28.5	7.6	CSCM	Pump
65	T-7	11.47	72.01	3.21	1.3	0.59	2.7	690	26.9	7.5	CSCM	Pump
66	T-6	11.48	72.01	3.85	1.1	0.76	3.05	1080	27.3	7.5	CSCM	Nil
67	T-4	11.49	72.01	3.72	3.1	0.78	3	610	27	8	CSCM	Nil
68	T-3	11.47	72	2.1	0.95	0.55	1.85	990	27.4	7.3	CSCM	Nil