केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

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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

MINICOY ISLAND, U.T.OF LAKHDWEEP

केरल क्षेत्र, तिरुवनंतपुरम

Kerala Region, Thiruvananthapuram

भारत सरकार / GOVERNMENT OF INDIA
जल शक्ति मंत्रालय / MINISTRY OF JAL SHAKTI
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AND GANGA REJUVENATION
केंद्रीय भूजल बोर्ड / **CENTRAL GROUND WATER BOARD**
केरल क्षेत्र / **KERALA REGION**

REPORT ON ISLAND WISE AQUIFER MAP AND MANAGEMENT PLAN OF MINICOY ISLAND, U.T. OF LAKSHADWEEP

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September 2020

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AQUIFER MAP AND MANAGEMENT PLANS FOR MINICOY ISLAND

1.0 Salient information

1.1 About Minicoy Island

Minicoy Island, the southernmost and second-largest inhabited island, is a 10.66 km long and 0.94 km wide island in the Union Territory of Lakshadweep, India. It is the only major island that is located south of the nine-degree channel. Geographically, it is located at the latitude of 08°16' N and longitude of 73°03' E. It is a crescent-shaped island with an area of 4.80 sq.km, elongated in the N-S direction and has a vast lagoon on its western side that covers an area is 30.60 km^2 (Fig. 1). Minicoy is located 400 km west off the coast of Trivandrum. The atoll contains two islands. The main island is located on the eastern and southeastern side of the lagoon, along the reef fringe. It measures about 10 km from its northern end to its southernmost point and it is about 1 km wide in its southern half, while the northern half is a narrow sandpit, often less than 100 m wide. Administratively, Minicoy island is divided into eleven villages.

Physiographically, the island is devoid of any major topographic features. Its western side is fringed by a narrow reef and coral rock. The interior of the lagoon is sandy and of moderate depth, rarely reaching 4 m. It has some coral patches. The island is made of coral reefs and materials derived from them, which are 100 million years old. The hard-coral limestone is exposed all along the beach during low tides and in the well sections. Hard pebbles of coral limestone along with coral sand are generally seen. A soil layer exists and this overlies the coral limestone. The soils are mainly derived from coral limestone and include coral sands, lagoonal sands, and mud. Most parts of the island are covered by a layer of soil that is highly permeable and allows rainfall to readily infiltrate; with the result, surface run-off does not occur except in local areas of compacted soils. There are no streams or major surface water bodies. At Minicoy, a pond is being formed at the southern edge, but a bund has been constructed and this has created an artificial brackish water pond. The coral sands and the coral limestone form the principal aquifers. The sand below this hard layer has caved in most of the wells.

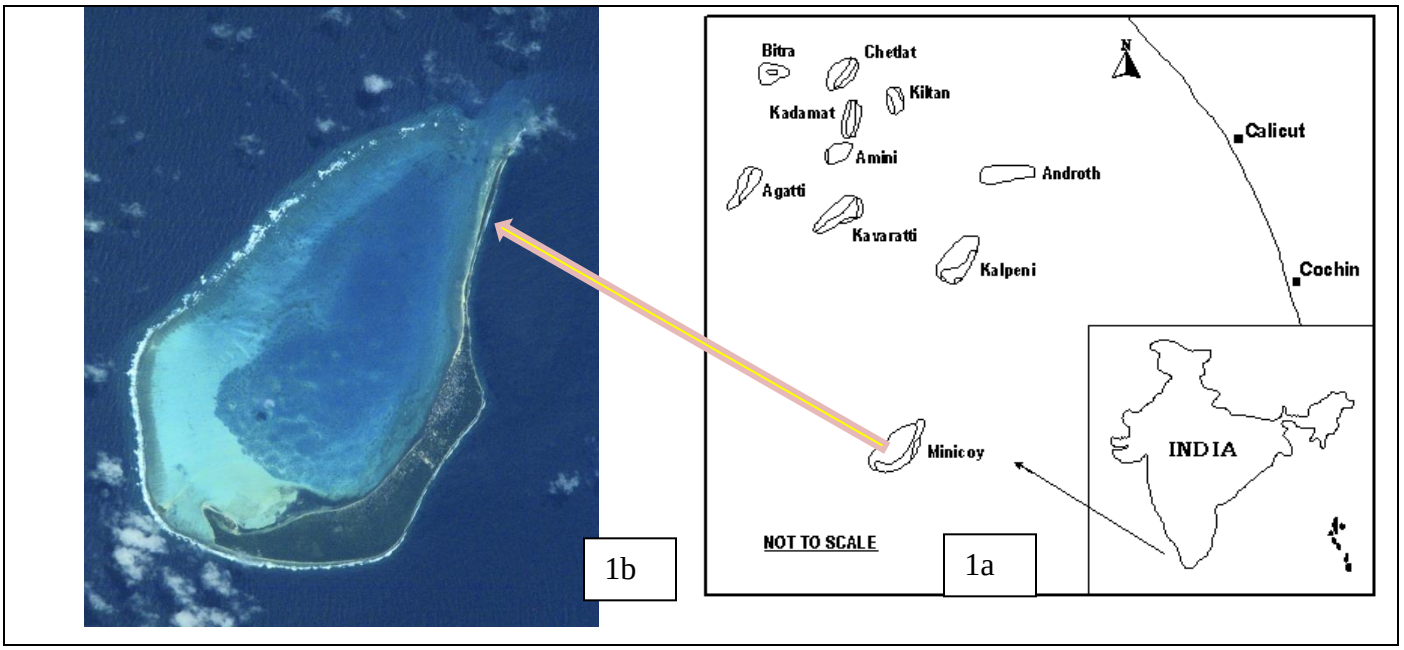

Fig. 1a: Location map of Minicoy Island. Inset: Outline map of India
Fig .1b: Satellite Imagery of Minicoy Island Administrative map

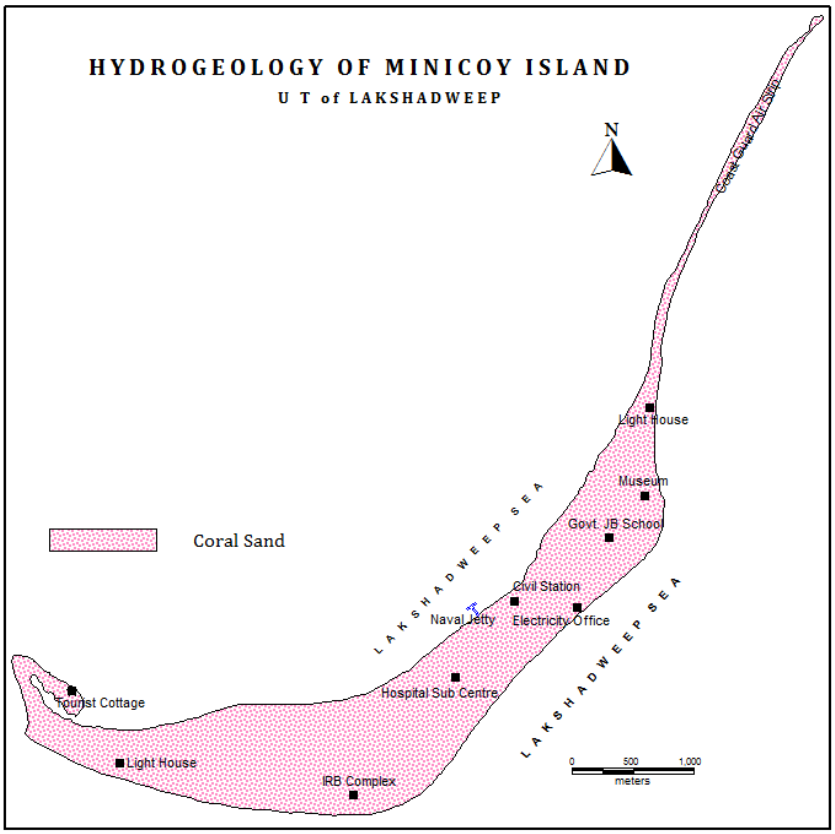

Fig. 2: Hydrogeology map of Minicoy Island

1.2 Population

As per census 2011, the population of the island is 10477. The male population is 5366 and the female population is 5081. The population density of the village is 2176 persons/sq.km. The majority of the population on the island depends on coconut and fish for their livelihood.

1.3 Rainfall

The island experiences a tropical humid, warm, and generally pleasant climate as it is lying within the tropics. The climate is equable and no distinct and well-marked seasons are experienced. The normal rainfall distribution and the number of rainy days in Minicoy Island are given in Table 1. Monthly average rainfall (2005-2017) in Minicoy Island is given in Fig. 3. Southwest monsoon period is the chief rainy season which lasts from late May to early October. The mean daily temperature ranges from 25 to 33° C, while the humidity ranges between 67 to 80%. Evapotranspiration is very high and most of the months, except in the high rainfall season, it exceeds the rainfall making the water surplus on the negative side.

Table 1: Normal rainfall distribution of Minicoy island

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	238	209	158.2	179	143	85.9	1640
		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

(A)Normal rainfall in mm (B) Average no. of rainy days (days with rain more than 2.5mm)

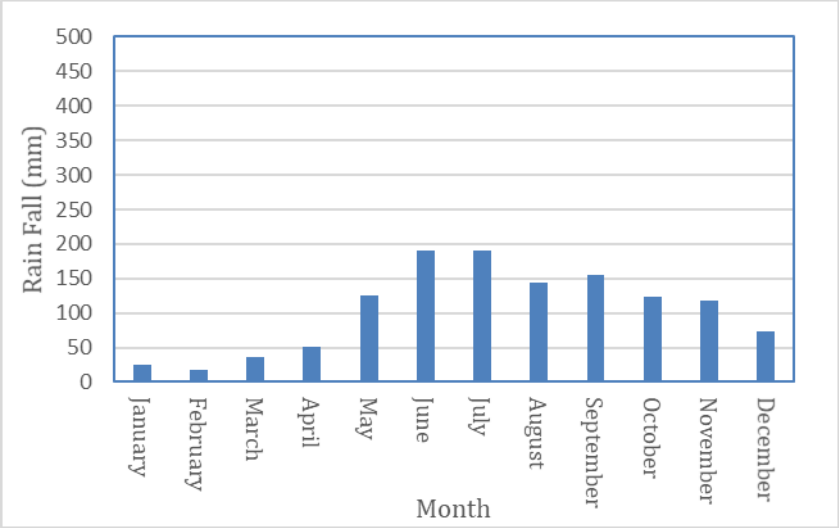

Fig. 3: Average Monthly Rainfall in Minicoy island (2005-2017)

1.4 Agriculture and Irrigation

The vegetation on the island 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 favorable, 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 on this island. In relatively shallow areas, coconut trees typically have some roots within the soil moisture zone and some of which penetrate the water table. Phreatophytes are common on coral atolls where the depth to the water table is typically 2 to 3 m. below ground level.

1.5 Groundwater resources availability & Extraction

The groundwater resource availability in Minicoy Island is restricted to the top few meters of the phreatic aquifers, which is composed of coral sands and coral limestone. Central Ground Water Board (CGWB) periodically assesses the dynamic groundwater resources of the islands, by computing various components of recharge and extraction. Rainfall is the only source of recharge in the Islands, whereas domestic extraction, evapotranspiration losses, and water loss due to outflow into the sea are the major components of the draft. A part of the annual water surplus (20%) is reserved as a buffer zone during delayed or deficit monsoon years. The total annual groundwater recharge (total resource) has been

estimated to be 184.9 ha.m. Groundwater extraction in the Islands, by and large, is for domestic uses of the populace, amounting to a total of 38.6 ha.m.

Groundwater Extraction

The major component of groundwater extraction in Minicoy Island is 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. There are 1645 dug wells used for domestic purposes on the island. For domestic draft calculation, per capita consumption of 150 lpd has been considered for the population as per the 2011 census. Irrigation drat is negligible in the islands as almost all the crops are rain-fed. Thus groundwater extraction in the Island comes to the tune of 38.6 Ha.m.
Apart from domestic extraction, significant groundwater consumption is by the vegetation since coconut trees form the major vegetation, which has a root penetration up to 3m bgl. As the depth to water table in the island is very shallow, the roots of these trees are accessible to groundwater throughout the year. The water extracted by these trees is lost to the atmosphere as evapotranspiration and the total evapotranspiration loss from trees for 6 non-monsoon months comes to the tune of 47.3 ha. m.

1.6 Existing & Future Water demand

As per the computation, the total annual surplus of groundwater in the islands amount to 184.9 ha. m, Evapotranspiration from coconut trees during 6 non-monsoon months amounts to 47.3 ha. m, whereas the water loss due to outflow (diffusion) into the sea is of the order of 37 ha. m. An equal quantum of water is reserved as a buffer to cater to late or deficit monsoon years in the islands. Balance groundwater resources available in the island are 25.01 Ha.m. The stage of groundwater extraction is 60.6%. Based on the stage of extraction, Minicoy Islands has been categorized as 'Safe'. As per census 2011, the decennial population growth rate of the island is 10.03%. Consequently, the demand for freshwater will also escalate. Moreover, another sector that is demanding a huge quantity of water is the construction sector where control of these activities has to be done. In order to meet the escalating demand, groundwater management measures to be taken up.

1.7 Water level behaviour

Groundwater is extensively developed through dug wells, filter point wells, and traditional step-wells from the thin freshwater lens floating over the seawater. There are 25 observation wells in the island (Fig 4). The depth of dug wells ranges from 1.3 to 3.2 m bgl and the depth to water level ranges from 0.75 – 2.8 m (Fig 5). In this island, freshwater is found in about 85 percent of the area along the north-central part and brackish water in the rest of the area. The contact between the fresh and brackish water in the lens changes during severe summer and monsoon. Thus, the wells located in the peripheral area exhibit maximum fluctuation in groundwater quality; whereas those located in the north-central part do not show much variation in quality over time. The broad brackish southern zone widens further north in extreme summer. The tidal fluctuation is in the range of 0.13 to 0.26 m. In the island, the freshwater lens continues to expand laterally as well as vertically if sufficient rainfall is available. A major part of the recharged water gets readjusted below mean sea level by the expansion of the lens and diffusion. Hence, there will not be any significant rise in water level, and only a small fraction of the recharge will be above the mean sea level. The effect of rainfall is evident in improvement in the quality of the freshwater lens, which is very well elucidated from various studies.

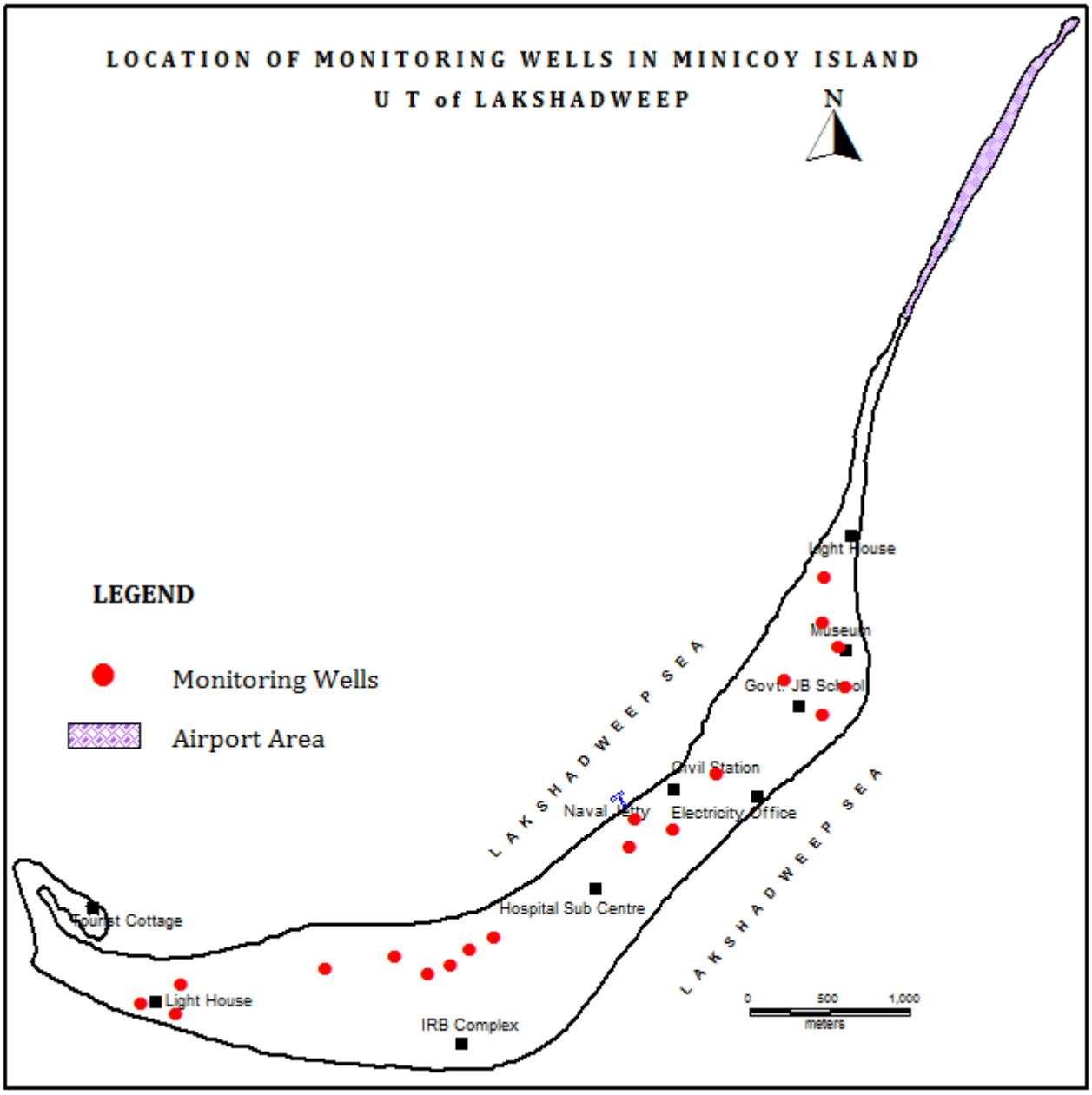

Fig. 4: Location of monitoring wells

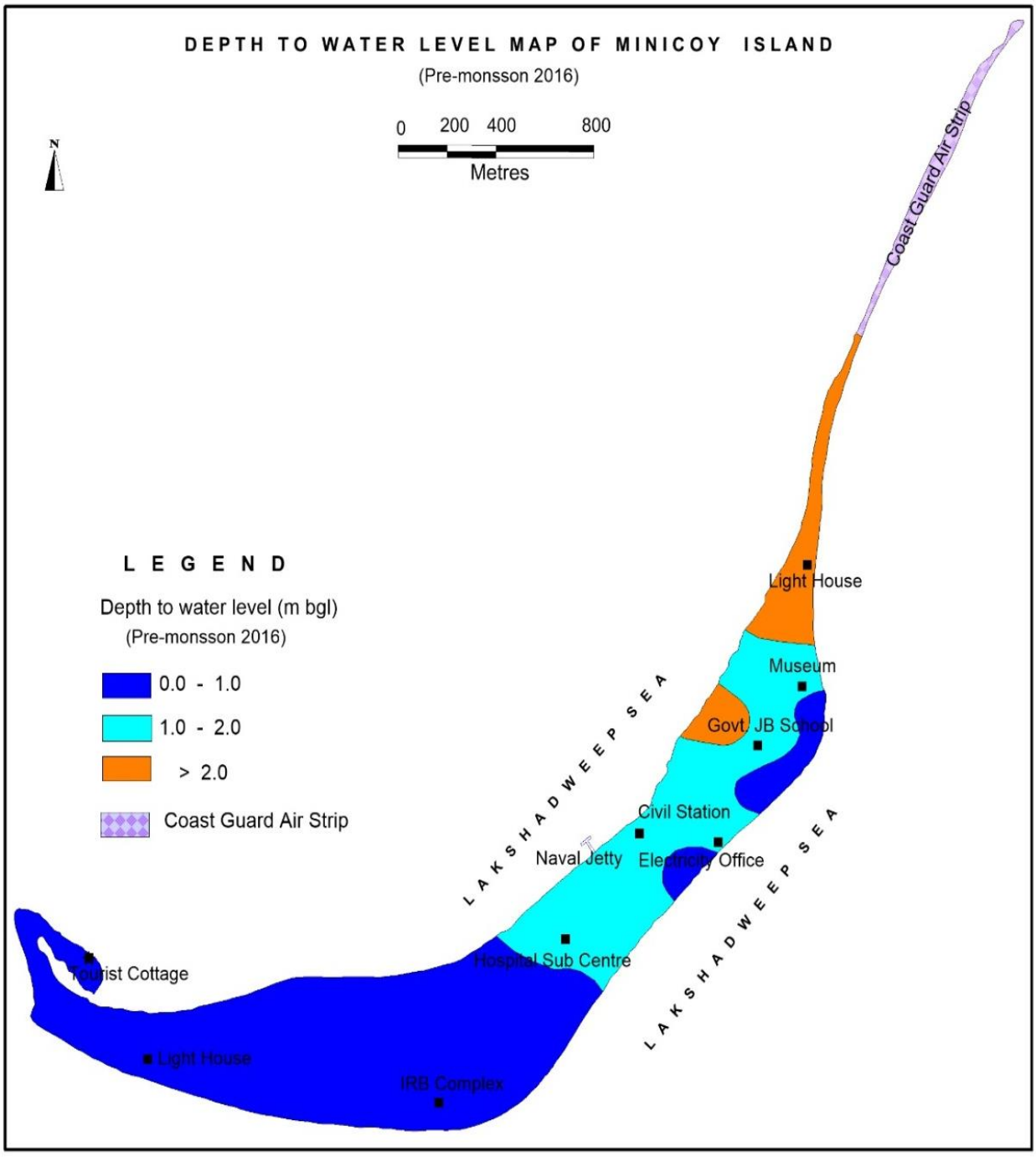

Fig. 5: Depth to water level map

2.0 AQUIFER DISPOSITION

The coral sands and the coral limestone form the principal aquifers. Groundwater occurs under phreatic conditions and is seen as a thin lens floating over the seawater and is in hydraulic continuity with seawater and hence it is influenced by tidal fluctuations. The fresh-seawater interface is theoretically a sharp one but seldom seen in nature where groundwater is developed. This is usually seen as a zone and is termed 'transition zone'. The position and the thickness of the interface mainly depend on the diurnal tidal fluctuation, seasonal water level fluctuation, groundwater recharge and draft, dispersion of the flow pattern, molecular diffusion, and so on. Depending upon the permeability and porosity, the shape and thickness of the freshwater lens also vary. Groundwater is developed by dug / open wells and to a limited extent through shallow filter point wells. The groundwater flow is mostly vertical with fluctuations due to several factors like diurnal tidal effects, recharge, draft, etc. The horizontal flow of groundwater is relatively insignificant as the freshwater lens contracts and expands in response to draft and recharge. The stability of the freshwater lens in the case of islands can be drawn from the aspect ratio, which in turn shows the role of the shape of the islands. In the case of Minicoy Island, the aspect ratio is 0.4 indicating that the freshwater lens is highly prone to tidal fluctuations.

3.0 Groundwater contamination and other issues

The quality of water in the island is good and potable. The quality is within the permissible limit for drinking purposes in 87% of the dug wells in the area. The water is slightly alkaline with pH values ranges from 7.12 to 7.97. The EC values are generally in the range of 340 - 2500 µS/ cm at 25°C and about 85 % of the dug wells have EC less than 3000 µS / cm at 25°c. The salinity is the highest of the southwestern part of the island where it is 12200 µS / cm at 25°C. Chloride content shows vide variation from 89 mg/l to 3834 mg/l. The spatial variations in EC are shown in Fig. 6. Lakshadweep Public Works Department is maintaining a chemical lab in the island and is monitoring the periodic chemical quality of the observation wells (Table 2).

Table 2: Hydrochemistry of groundwater samples, Minicoy Island

#	Name of Island	No of Samples	pH	EC (µS/cm)	TDS (mg/l)	Total Hardness(mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)
1	Minicoy	11	7.12-7.97	340-2500	120-690	32-198	9.7-66	120-380	89-3834

3.1 Chemical quality of groundwater and Contamination

Groundwater occurs as a thin lens floating over the seawater and is in hydraulic continuity with seawater and hence it is influenced by tidal fluctuations. Since a fragile relation exists

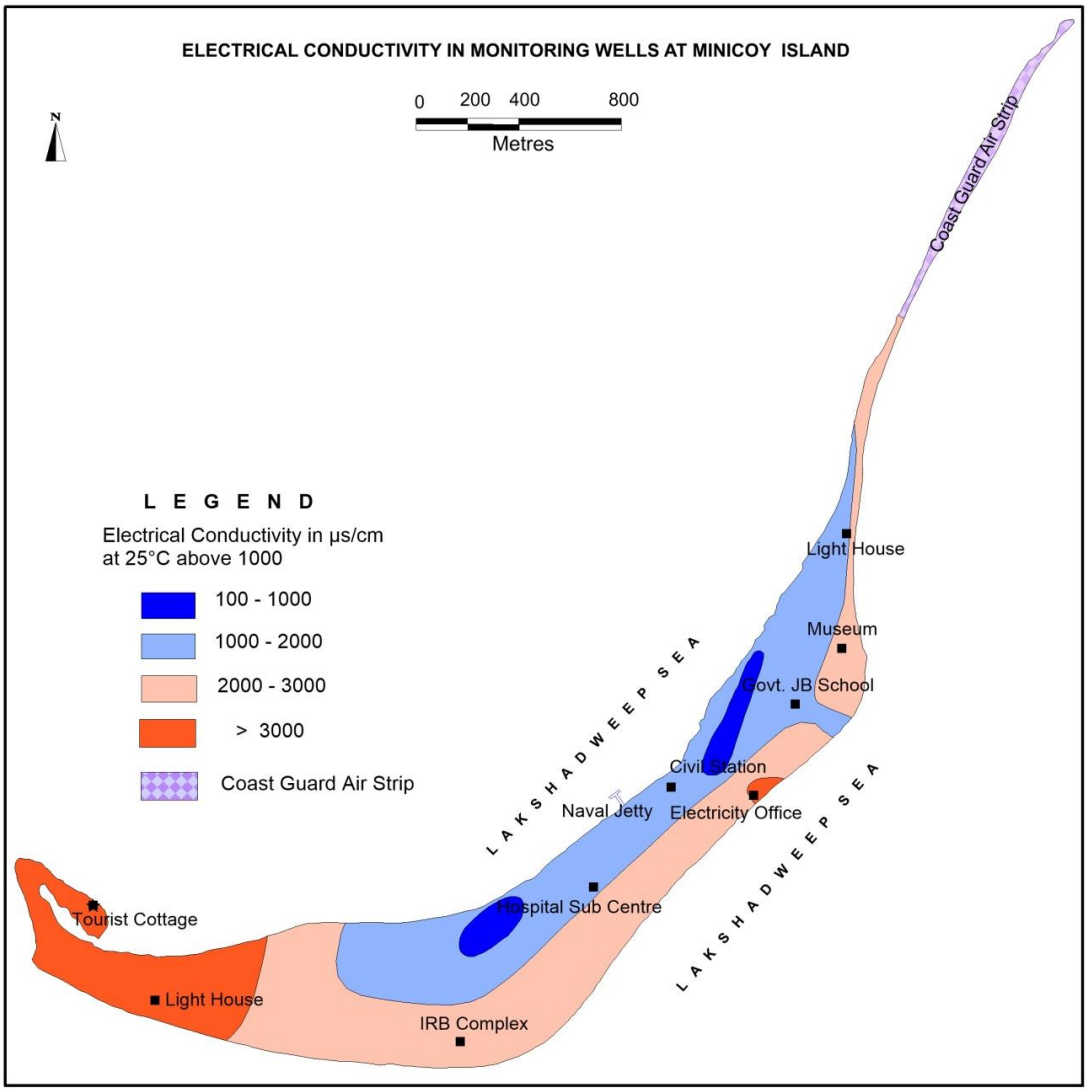

Fig. 6: Distribution of Electrical Conductivity in Minicoy Island

between the freshwater and seawater, the quality variations in the Island are high and reversible. These variations could be lateral, vertical, and temporal. It is observed that the water quality improves with rainfall. Other factors affecting the quality are tides, groundwater recharge, and draft. There is a vertical variation in the quality due to the zone of the interface and underlying seawater. Wells from which water is drawn using bucket and pulley retain more or less the same quality over a long period, whereas quality deterioration is observed around pumping centers. It is also seen that a trend towards seawater composition is observed with increasing electrical conductivity in and around pumping centers. This acts as a conduit for the up-coning of seawater. The quality of groundwater in the islands varies with time too. Similarly, brackish water is seen along topographic lows and in areas where coarse pebbles and corals are seen.

3.2 Seasonal changes in groundwater quality

There is a marked improvement in the quality of groundwater during monsoon months in a majority of the wells on the island. The improvement in groundwater quality in response to a single heavy rainfall continues for succeeding 2-3 months. While the freshwater lens continuously contracts in the absence of rainfall, due to the effect of water loss due to mixing, draft by vegetation, and draft for domestic consumption. The quality variation is higher in the fringe areas of the freshwater lens during various seasons as compared to that of the central part of the freshwater lens, where the water is fresh all through. In contrast to the mainland, the quality deterioration is swiftly reversible.

3.3. Lateral variation in groundwater quality

The detailed studies on variation in chemical quality of groundwater in Minicoy Island could establish that the temporal variation in quality is much more significant and dependent on recharge/draft relations. Generally, in wells fitted with pump sets, the quality of water is inferior to that of neighbouring wells without pump sets, even if the total draft from the non-pumping well is higher.

3.4. Groundwater Issues

The tidal effect on the freshwater lens, shallow groundwater 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 groundwater in this island is concerned. The important factor which affects the groundwater quality in the island is discussed.

(a) **Tidal influence:** As the groundwater is in hydraulic continuity with seawater, its quality is influenced by the diurnal tidal fluctuations of the sea to some extent. This quality variation is very prominent in the peripheral area than the central part. However, it is seen that the best quality of water available is during high tide.

(b) Effect of groundwater overdraft: The majority of the wells on the island is fitted with low capacity pumps. Continuous pumping affects the delicate equilibrium existing between the freshwater-saltwater results in the up-coning of the saline water from beneath and the quality deterioration due to pumping is evident even on limited pumping.

(c) **Marine aerosols:** The atmosphere in the coastal parts and islands are enriched in chloride ions, which gets washed down to the ground during the rains. This can also bring a change in the quality of water.

4.0 Groundwater resource enhancement

Similar to other islands in Lakshadweep archipelago, in Minicoy Island also a delicate ecosystem exists with a very limited freshwater resource. The fresh groundwater resource of this densely populated tiny coral atoll, by and large, occurs as lenses floating in hydraulic continuity with seawater at a shallow depth. Further, the elevation of the island is very small due to which the storage capacity of the aquifer is limited with no additional storage space available for artificial recharge. Moreover, the absence of surface water bodies makes freshwater a prime commodity.

4.1 Aquifer wise space availability for recharge and proposed interventions

There is no scope for artificial recharge to groundwater due to the highly fragile hydrogeological environment existing in Minicoy Island. Moreover, the water level is very shallow with high tidal influence; thus space availability is absent for any kind of intervention.

4.2 Proposal for other interventions

Rooftop rainwater harvesting and storage is the most suitable and cost-effective water conservation measure in the island. The rainfall distribution pattern shows that the average monthly

rainfall is more than 40 mm for eight months a year, from May to December. Further, most of the buildings are tiled roof or RCC roofs and hence ideal for rooftop water harvesting. As the thickness of freshwater lens shrink during summer, the quality of groundwater becomes brackish and this results in water scarcity on the island. This issue can be managed to a good extent by adopting rooftop rainwater harvesting. Minicoy administration has widely recognized the role of rainwater harvesting as the most suitable and adaptable way in supplementing the water supply very long back and it was widely implemented. Government buildings including schools, quarters, and non-residential buildings and some private houses had implemented community rainwater harvesting systems by building tanks of various capacities ranging from $5m^3$ to 10 m^3. At present, rainwater harvesting structures were implemented in 648 buildings, which include the entire government buildings. The harvesting tank capacity is 10 m^3 in 548 buildings and in the remaining 100 buildings the tank capacity is 5 m^3 only. Apart from these the introduction of Low Temperatures Thermal Desalination Plants (LTTD) in Minicoy has reduced the dependency on groundwater for domestic extraction in these islands, which has the capacity of supplying 1 lakh liter desalinated water/day. Considering the rainfall pattern and existing water supply measures prevalent in the Island, the rainwater harvesting systems may be designed to harvest the rainfall received in any two months of the year, except January, February, March, and April to collect and store water enough to meet the requirements of the population for about 100-120 days. Therefore the scope to implement rooftop rainwater harvesting in 1130 buildings exists. Considering the water supply from the desalinization plant the storage capacity of tanks can be restricted to $2.5m^3$.

5.0 Demand side interventions

5.1 Advanced irrigation practices

Due to the limited availability of groundwater, irrigated agriculture is not economically viable on the island and should not be allowed.

5.2 Change in cropping pattern

The only vegetation that exists on the island is coconut trees. The main point to be concerned from groundwater point of view is the high density of these crops and subsequent high evapotranspiration loss. The groundwater resource estimation shows that the evapotranspiration loss through vegetation is more than the domestic draft. Under these circumstances, the best alternative is

to have the optimum density of coconut trees by thinning out the very dense plantation. This will not only save the precious resources but also improve the economy of the islanders by the way of increased returns from these trees.

5.3 Alternate water sources

Desalinisation plant already exists on this island, which has a capacity of 1 lakh liters/day, in addition to rooftop rainwater harvesting structures. Hence no other alternative source is required. With the introduction of the desalinization plant, domestic extraction has been reduced but contradictorily, increased extraction of groundwater for construction purposes, especially in this highly populated island nullifies the decrease of domestic extraction. Proper management of rainwater is sufficient to manage the present crisis during summer.

5.4 Regulation and control

Optimum utilization of groundwater should be ensured through regulation of pumping by the constitution of Ground Water Authority. 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 any of the islands in Lakshadweep. The authority, however, is yet to be constituted.

5.5 Other Interventions proposed

Requirements to meet the needs of the growing population and the non-availability of alternatives are likely to put the limited groundwater resources in this Island under increasing stress in the coming years. Some of the feasible management interventions to ensure the long-term sustainability of groundwater in the islands are:

- Restoration, renovation, and protection of 48 ponds which are not in use in this island.
- In the island, a number of conventional step-wells exist, erstwhile bathing and washing sites. These are the sites of the garbage disposal and the majority is in a very dilapidated condition.

Hence, priority should be given to revive these water conservation structures which in turn will benefit/ contribute to freshwater stability.

- The islanders are complacent with the water scenario in the island and abandoned conventional step wells, which once they used for bathing and washing as a water conservation strategy. Many of these wells were polluted also. These wells should be revived for water conservation Implementation of rooftop rainwater harvesting schemes in 1130 buildings through the participation of local communities. Large scale implementation of harvesting structures has been made but the maintenance should be ensured to reduce the high demand-supply gap during summer.
- Regulation/control of the indiscriminate extraction of groundwater through mechanical devices.
- Regular monitoring of water levels and water quality.
- Decentralized garbage/waste treatment systems to prevent further contamination of available freshwater resources.
- Sensitize the public on over-exploitation of limited resources and create awareness on the importance of water conservation and judicious management for ensuring the long-term sustainability of water resources.