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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

AMINI ISLAND, U.T.OF LAKHDWEEP

केरल क्षेत्र, तिरुवनंतपुरम

Kerala Region, Thiruvananthapuram

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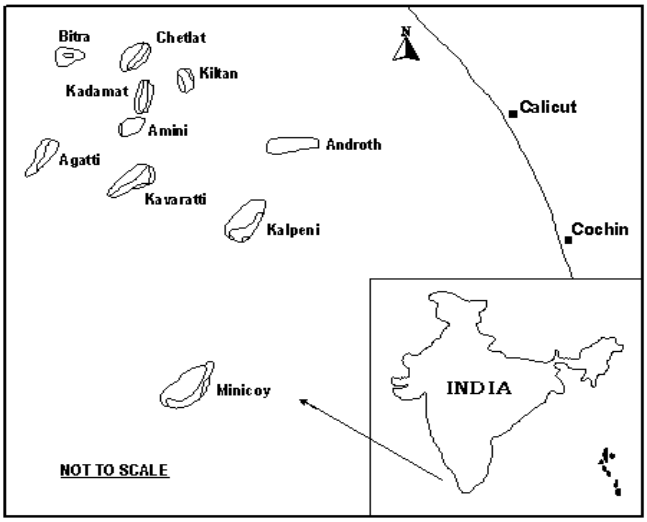
ISLAND WISE AQUIFER MAPS AND MANAGEMENT PLANS AMINI ISLAND, UNION TERRITORY OF LAKSHADWEEP



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AQUIFER MAPS AND MANAGEMENT PLAN OF AMINI ISLANDS, UNION TERRETORY OF LAKSHADWEEP

1.0 SALIENT INFORMATION

1.1 About the Island

Amini is the third smallest island in the Lakshadweep archipelago (Fig.1). It covers an area of 4.1 sq.km of which 2.6 sq.km is island territory and the remaining 1.5 Sq. km is lagoon. Kadamat island is located very close to Amini islands in the northern side. The entire island area lies between 11^0 07' N latitudes and 72^0 44’ E longitudes. Amini has submerged sand banks around the island (Amini-Pitti) which has a lagoonal area of 155.09 sq.km. For administrative control the Lakshadweep Islands make a uni-district territory with 4 Tehsils and Amini is one such Tehsils. Other Tehsils are Androtт, Kavaratti & Minicoy and divided into nine Sub-divisions (Agatti, Amini, Androtт, Chetlat (Bitra), Kadmat, Kalpeni, Kavaratti, Kiltan & Minicoy. It is again divided into Community Development Blocks and for Amini Island Amini and Kadamat islands form one CD block.

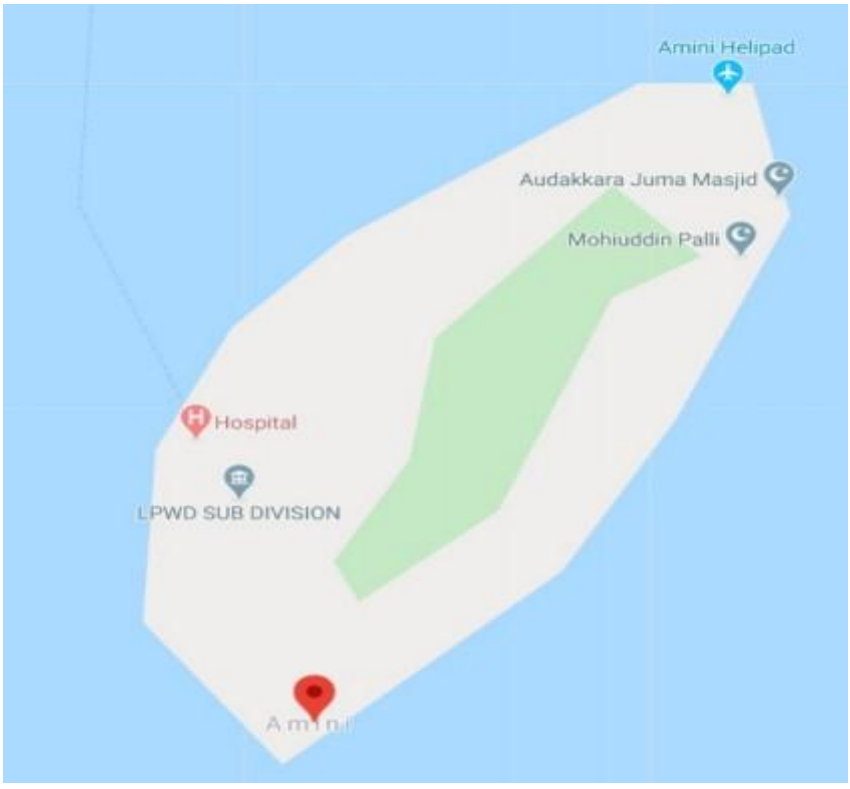


Fig. 1.1: Administrative map of Amini Island

The island is divided into five Cheris or wards of which Keelapallicheri and Melapallicheri lie in the extreme south, Porakkara in the east, Edaniyam in the north and Kodacheri in the west. The most populated areas of the island are Melapallicheri and Edaniyam and most of public institutions are located in these two cheris/wards.

1.2 Population

As per 2011 census, the total population of the island is 7661, and male population is 3829 and female population is 3832. Population density is 2958/ sq.km and males constitute 50% of the population. Amini has an average literacy rate of 71%, higher than the national average of 59.5%, with 55% of the males and 45% of females literate. 15% of the population is under 6 years of age.

1.3 Geomorphology

The islands are flat, rarely rising more than two meters, and consist of fine coral sand and boulders compacted into sandstone. Most atolls have a northeast- southwest orientation with an island on the east, a broad well developed reef on the west and a lagoon in between. The islands are typical atolls, elongated reefs of organic limestone that are partly, intermittently or completely covered by water. They form a ring around a shallow basin of water, the lagoon. The reef varies in width at their surface, reaching a maximum width between lagoon and ocean of over 5 km.

Geomorphologically, the Amini Island has lagoonal beaches, beach ridges, sand dunes and hinterlands. The island is generally flat with localized depressions and sand mounds, which are largely man-made.

1.4 Rainfall

The normal monthly rainfall of Amini Island is given in Table 1.1. Based on 50 years normal rainfall data, the island receives a total of 1504 mm as the normal annual rainfall. Out of this, southwest monsoon contributes the major part of the annual rainfall. The southwest monsoon season from June to September contributes 70.47 % of the annual rainfall. The season is followed by the northeast monsoon season from October to December which contributes about 17.78 % of the annual rainfall and the balance 11.75 % is accounted for January to May months. Minimum and maximum rainfall in the island is 4.3 mm during the month of March and 381mm in the month of June respectively. Monthly average rainfall of Amini island during the period 2005 to 2017 is tabulated in table 1.2 and shown as a histogram in Fig.1.2.

Table 1.1: Normal rainfall in mm (A) Average no. of rainy days (B) days with rain more than 2.5mm

Station	No of Years		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Amini	50	A	20.6	2.0	4.3	25.4	125.2	381	312	217	150	141	85.6	40.9	1504
		B	1.3	0.3	0.3	1.4	5.2	17.3	16.5	12.3	10.2	8.4	5.0	2.2	80.4

Table 1.2: Rain fall data of Amini Island (in mm)

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2005	1.2	11.4	0	35.2	70	156.6	364.2	126.6	236	75.2	106.4	7.2	1190
2006	11	0	19.4	0	458.8	245.2	93	9.2	323.1	58.5	40.2	0	1258.4
2007	8.6	9.2	0	0	206.8	546.8	386.4	282.1	270	260	91	73	2133.9
2008	0	0	54.6	0	49.3	333.3	412.5	178.45	95.1	269.9	22.3	189.6	1605.05
2009	0	0	0	0	56.1	290.3	340.8	286.4	152.8	76.8	150.4	98	1451.6
2010	52	0	0	27.4	101.6	276	299.2	302.8	71.4	241.6	128.2	33.6	1533.8
2011	0	0	0	54.8	68.8	102.2	188.4	176.2	167.8	125	50.8	2.4	936.4
2012	12.4	0	0	25	0	304.6	140.8	306.6	88.8	176.5	10.6	0	1065.3
2013	0	22.2	0	0	76.4	437.3	NA	.NA	.NA	55.8	110.4	0	-
2014	62.5	0	0	0	107.2	129.6	59.6	271.3	74.9	183.4	91.6	99.2	1079.3
2015	0	0	3.8	48.8	81.8	285.4	138.4	147.8	105	133.4	205.6	144.2	1294.2
2016	53	0	0	0	16	263.1	139	55.1	0	45.3	94.8	0	666.3
2017	0	0	0	40	81.6	303.2	113.4	247.6	188.2	68	74	120	1236

NA- Data not available

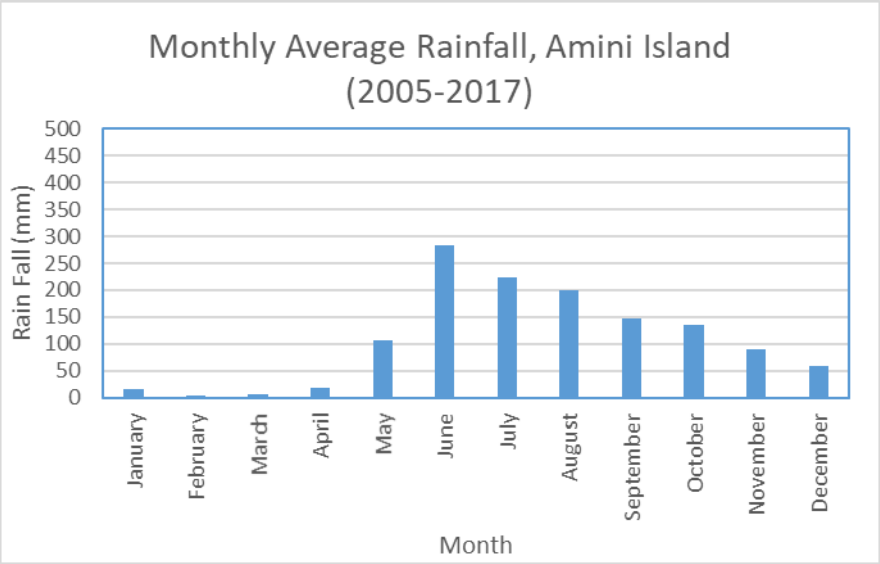


Fig. 1.2: Monthly rainfall in mm in Amini Island

1.5 Groundwater resources availability & Extraction

The groundwater resource availability in Amini island is restricted to the top few meters of the phreatic aquifers, composed of coral sands and coral limestone. The coral sands and the coral limestone form the principal aquifer in the island. Groundwater which is existing under phreatic conditions at a depth of 2 – 3 m below ground level is seen as a thin lens floating over and in hydraulic continuity with the sea water. Large diameter wells are the most common and area acting as traditional groundwater 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.

Freshwater lens: The freshwater lens in the islands is formed due to the radial movement of the freshwater towards the coast which is in hydraulic continuity with seawater. 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 (Table 1.3). 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. Islands with aspect ratio greater than 0.5 are found to have stable fresh water lens, under identical geomorphological settings.

Table 1.3: Details of aspect ratio of Amini Island

Island -Amini	**Particulars**
Area (sq.km)	2.59
Max. length (km)	2.89
Max. Width (km)	1.25
Aspect ratio=A/(L/B)	1.1
Shape	Oblong
Trend of longer axis	NE-SW

Groundwater extraction in the Island, by and large, is for domestic uses of the populace. As per GEC-2017 resource calculation, the domestic extraction accounts for 28.7Ha.m in Amini islands and balance resource available for extraction is 6.8 Ha.m and stage of groundwater extraction is 89.9 indicating a semi- critical category and the statistics is given in table1.4.

Table.1.4: Groundwater Resource Assessment (GEC 2017) of Amini Island

Island	Population (Projected as on 2017)	Area (Ha)	Normal Monsoon Rainfall (m)	Rainfall Infiltration	Total Resource (Water Surplus) (Ha.m)) [2*3*4]	ET loss from Trees for 6 non-monsoon	Water loss due to outflow to sea (20% of 2)	Buffer zone for reserve during delayed or lesser	Balance available resource (Ha.m)	Domestic Extraction @100 lpcd [1*100*365]	Gross Annual GW Extraction (Ha.m)	Groundwater balance available	Stage of groundwater extraction	Category
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Amini	**7854**	**259**	**1.355**	**30**	**105.3**	**27.8**	**21.1**	**21.1**	**35.4**	**28.7**	**28.7**	**6.8**	**80.9**	**Semi-Critical**

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 groundwater extraction.

1.6 Existing and future water demands (for phreatic aquifer)

The existing draft for various needs are listed below

Existing gross GW draft for domestic use	: 0.287MCM
Existing gross draft for all uses	: 0.287 MCM
GW availability for future development	: 0.068 MCM

By considering the quantum of water utilized from the total resource stage of development has been derived as 80.9% and categorised as semi-critical category.

1.7 Water level behaviour

Amini is located on the north-central part of the Lakshadweep archipelago. It is elliptical in shape and is oriented in a roughly NE-SW direction. Amini Island is quite unique by having a lagoon all around it unlike most of the other islands with a fringing reef on the eastern periphery and a lagoon on their west. Fig.1.3 showing locations of the key wells, depth to water table (pre-monsoon 2016) and hydrograph of the island is given in figures 1.4 and 1.5 respectively. The freshwater availability in this island is limited to south western and north eastern parts, while it is brackish in the central part. The depth to water varies from 0.97 to 6.37 m. and depth of wells range from 1.92 to 7.0 m. The comparatively deeper wells are seen north western part of the island where hard coral lime stone is exposed. There are 1050 domestic dug wells with a density of about 420 wells/ sq km.

The long term trend of water level as per weekly data is presented in figue-1.5. The figure shows that there is no much variation in water level with rainfall and variation is mainly due to tidal influence.

The depth to water level is influenced by the tides. The water level fluctuation in the island is significantly controlled by tides when compared to the groundwater recharge and draft. The diurnal fluctuation of water level due to tides is in the range of negligible to 80 cm.

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 groundwater recharge is not so significant when compared to tidal fluctuations.

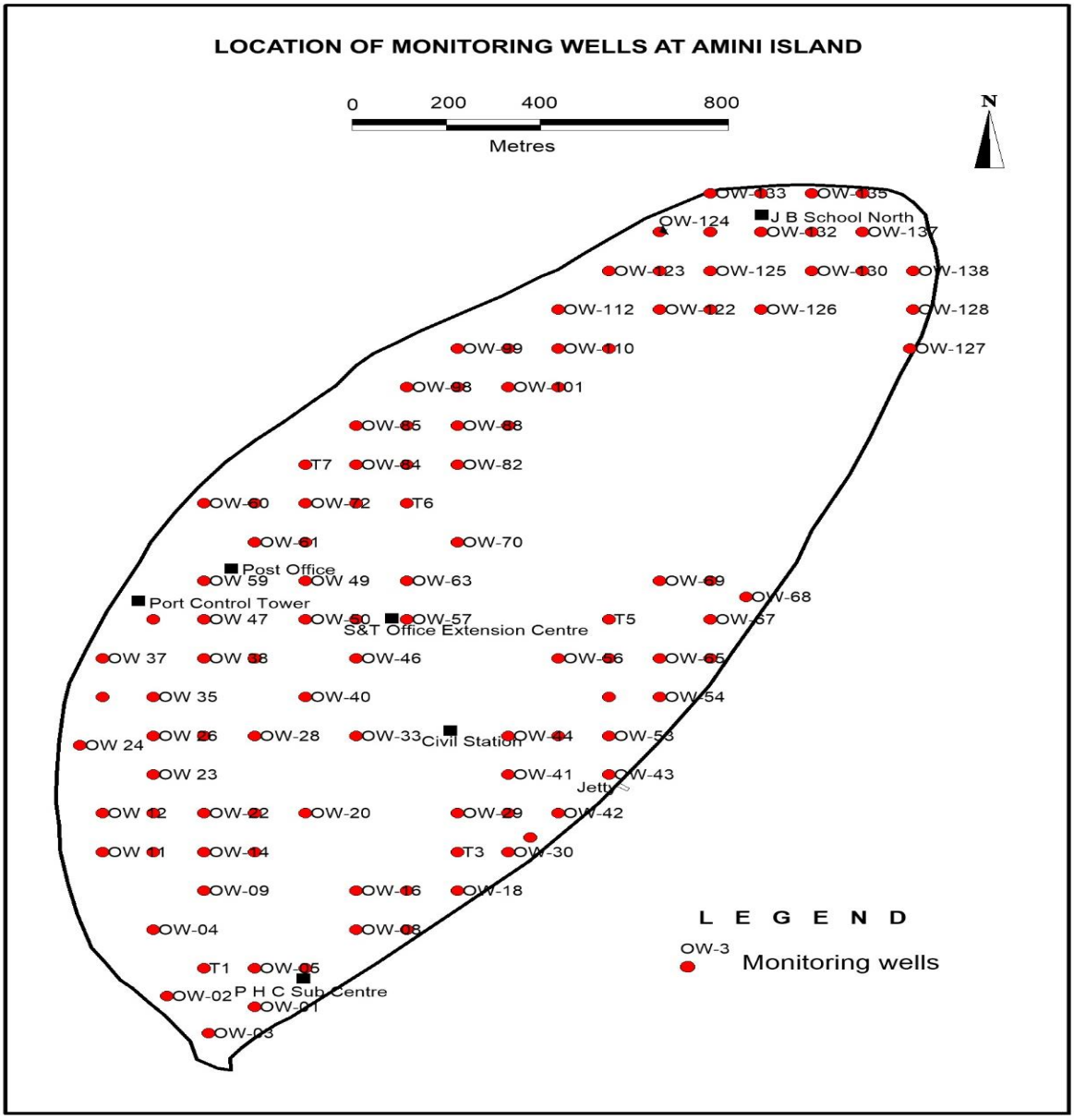


Fig. 1.3: Key well locations in Amini island

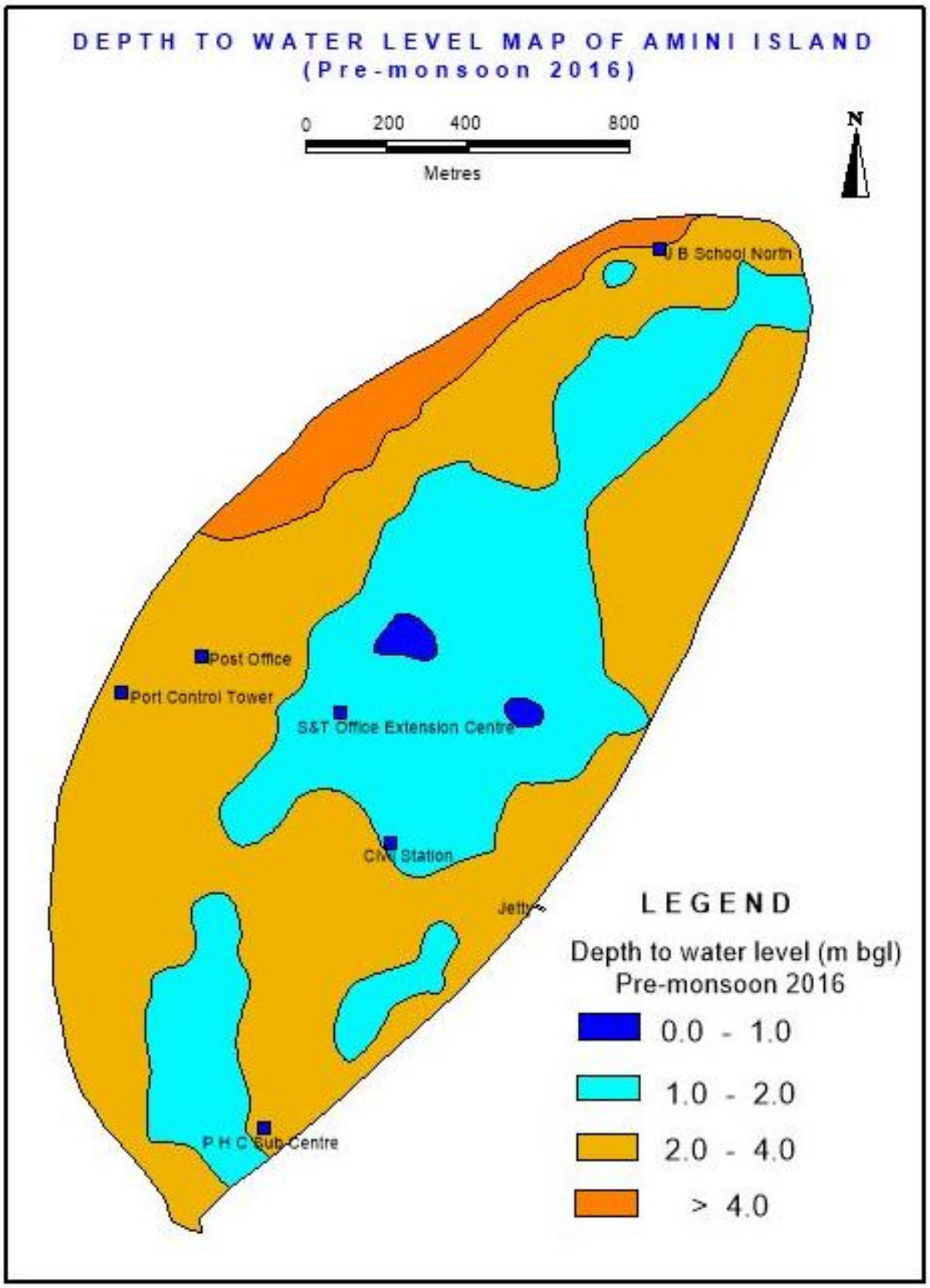


Fig. 1.4: Depth to water level map of Amini island

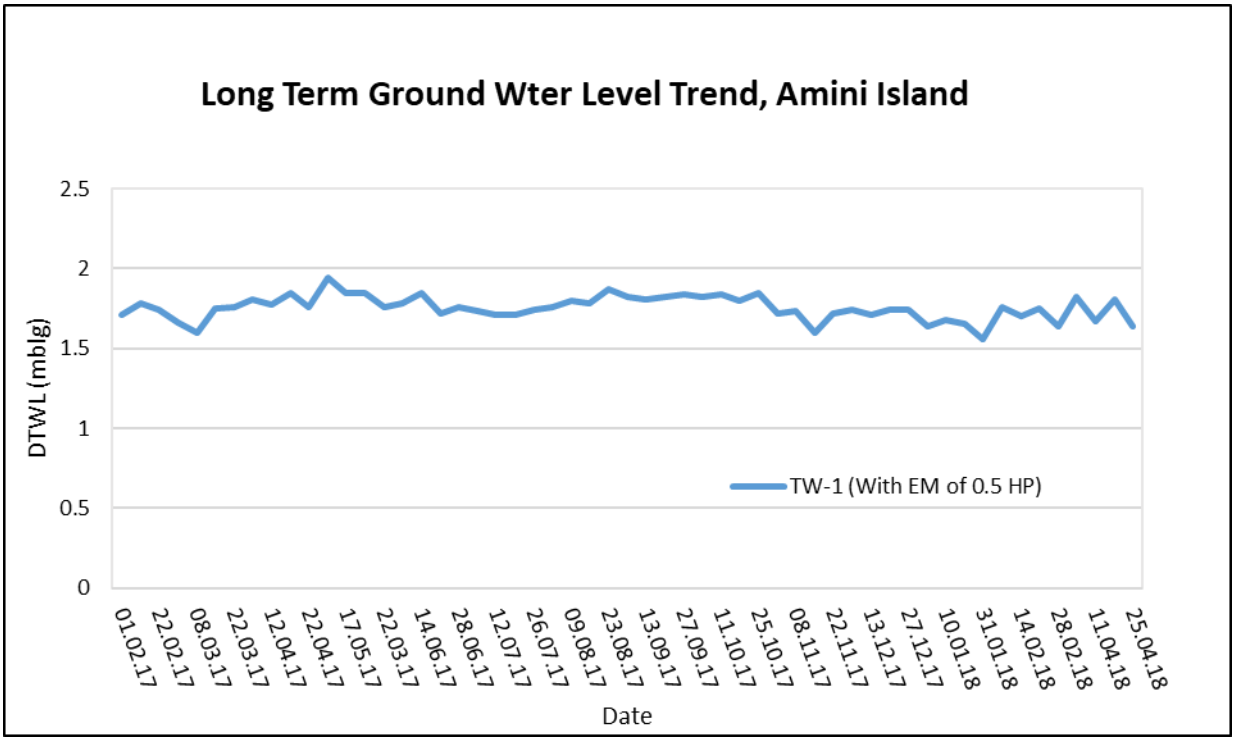


Fig. 1.5: Long term trend of Groundwater level in Observation wells at Amini island

2.0 AQUIFER DISPOSITION

Like other islands in Lakshadweep archipelago, Amini 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 islands 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.

Groundwater exists under phreatic conditions at a depth of 2–3 m below ground level, which is seen as a thin lens floating over and in hydraulic continuity with the sea water (Fig.2.1). Hard coral limestone is exposed near the bottom of this phreatic aquifer. The sand below this hard layer has caved in most of the wells.

Coral atolls generally consist of a layer of recent (Holocene) sediments, comprising mainly coral sands and fragments or coral, on top of older limestone (Fig.2.2). The occurrence of groundwater lenses within this upper coral sand is due to its moderate permeability (Typically 5 to 10 m/day) compared with higher permeability of the older limestone (typically 50 to 100 m/day). Permeabilities greater than 1000 m/day occur in solution cavities within the

limestone. These extremely high permeabilities allow almost unrestricted mixing of freshwater and sea water which is less likely to occur in the upper sediments.

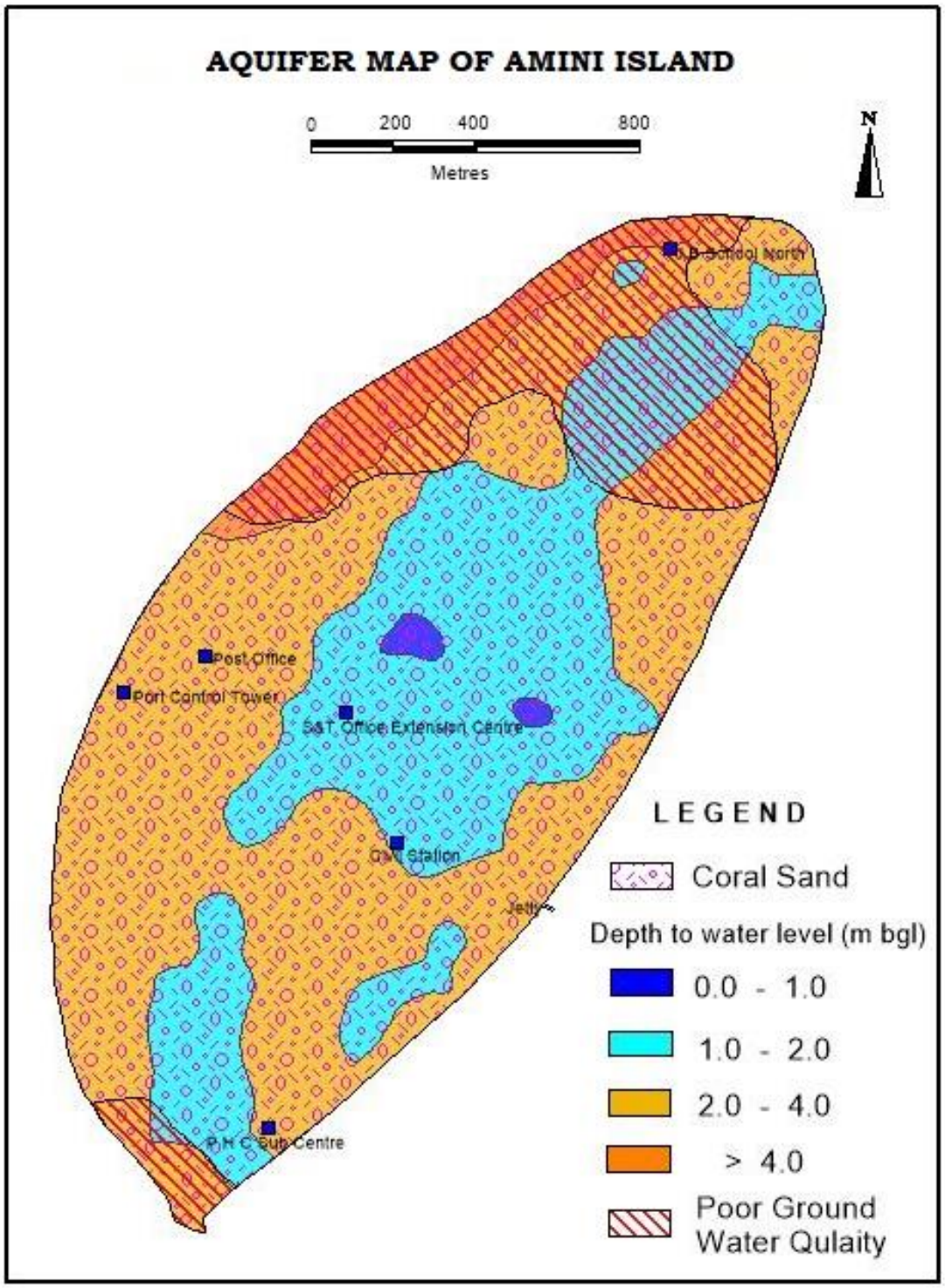


Fig. 2.1: Aquifer map of Amini island

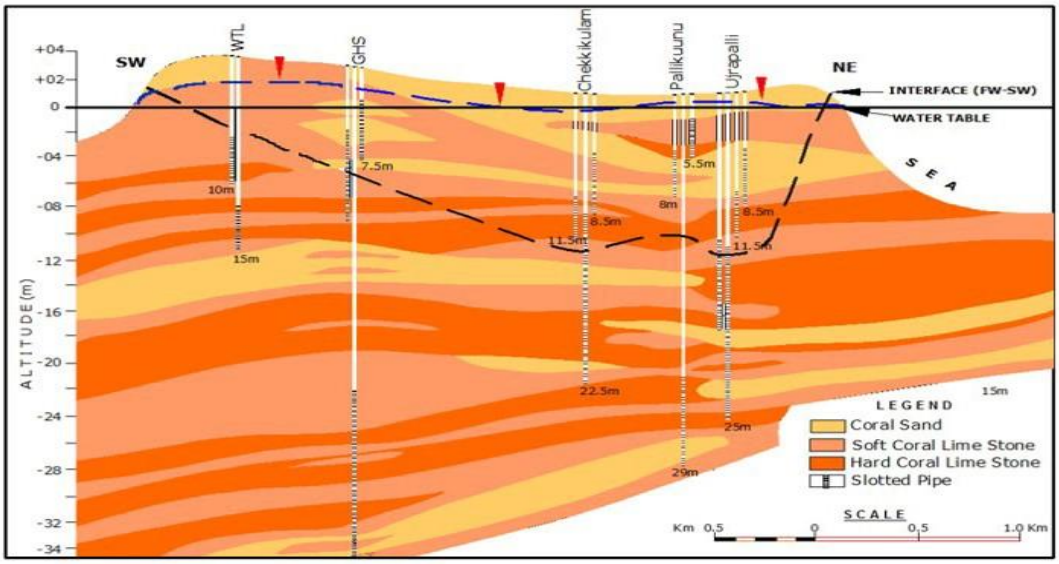


Fig. 2.2: Conceptual Hydrogeological cross section of island

(Note: Subsurface disposition of sediments is only available for Kavaratti island and the same is shown as standard cross section which is common in all islands).

2.1. Geophysical investigations in Amini Island

In Amini island one Wenner profile has been carried out from western coast end to a length of 250 m to know the groundwater condition. A total of 16 Nos VES has been carried out in the island. The surface geophysical survey was conducted by using an ABEM Terrameter from ABEM Instrument's AB, Sweeden. Profiling has been carried out by using Wenner configuration with inter electrode spacing (a) is 5 m and VES survey done with maximum AB spacing of 90 m by using Wenner configuration. The Location maps of Wenner Profiling line and Vertical Electrical Soundings carried out in Amini Island is compiled in Fig. 2.3.

Wenner profiling has been carried out in Amini Island with the station interval of 5 m and the distance between two adjacent electrodes is 5m. The results of wenner profiling have been shown in below fig. 2.4. From the graph it is clearly indicating that from a distance of 25-60, 85-95, 125-135, 145, 165-200, 215 and 225-250 m in the X axis is showing below 40 ohm.m resistivity which is giving information about the brackish to saline water in that area at 5 m below ground level, other than that the remaining part of the profile line the resistivity value is showing more the 50 ohm.m, which is giving information about the fresh water available in that area at 5 m below ground level.

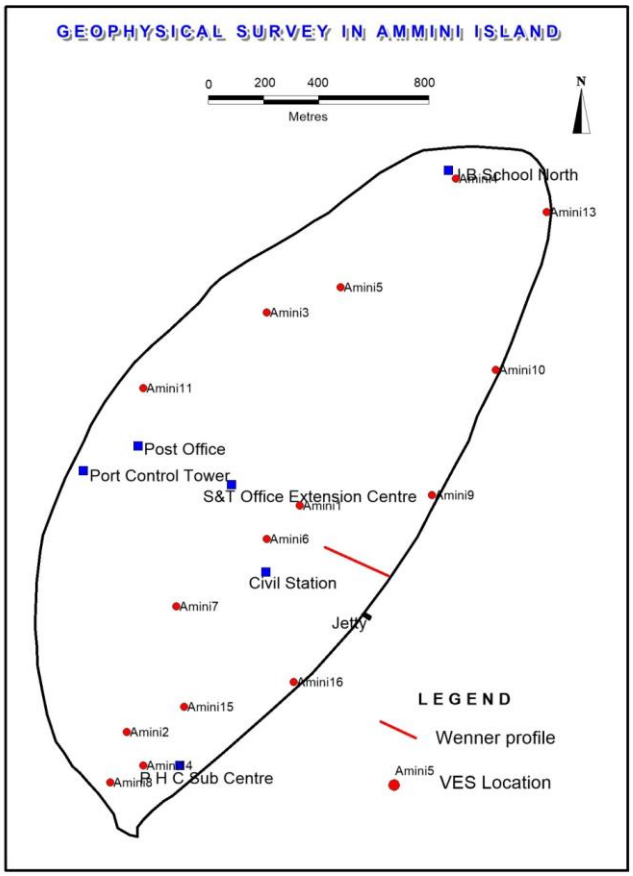


Fig. 2.3: location map of Profiling & VES at Amini Island

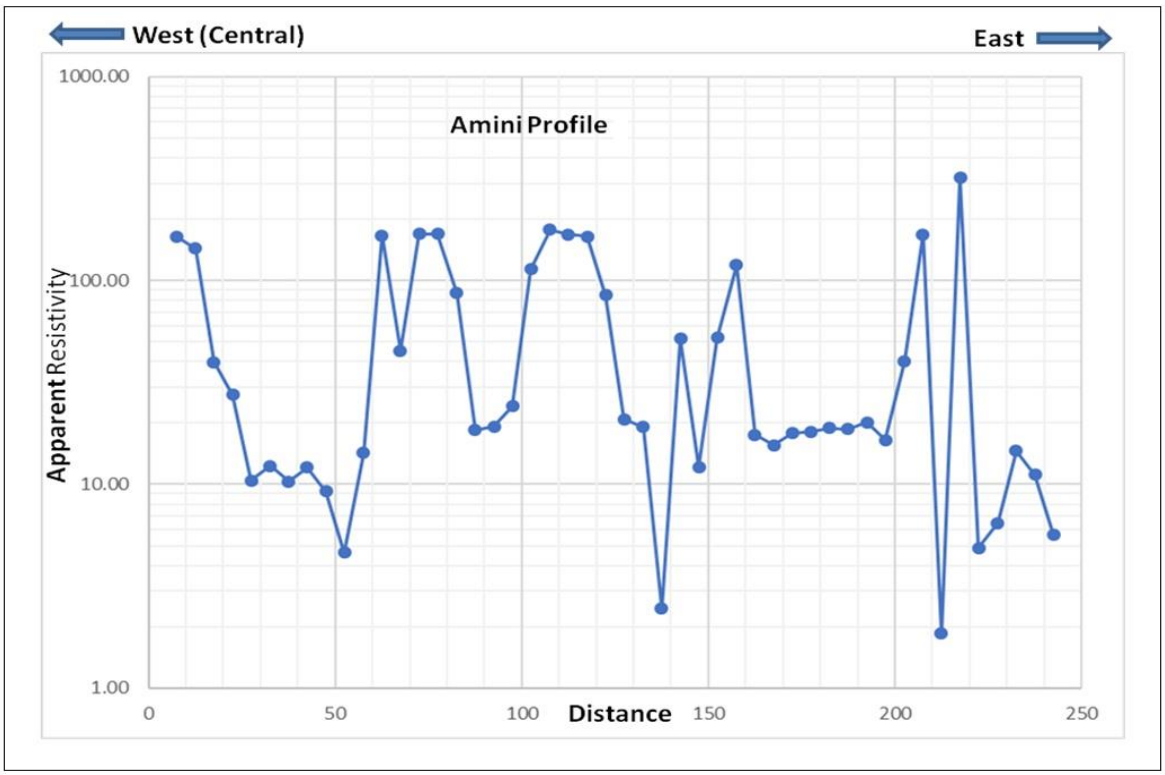


Fig. 2.4: Wenner Profiling in Amini Island

In Amini Island 16 sites has been investigated by conducting 16 VES. The interpreted results have given rise to 3 to 4 layered geoelectric sections. In all 16 VES the last geoelectric layer is showing the decreasing trend due to salinity. The main types of the curve observed in this island are Q and QQ respectively.

The first geoelectric layer resistivity was varying in the range of 20-5483ohm.m, and the thickness of this geoelectric layer is varying in the range of 0.4-3.4 m. The second geoelectric layer resistivity was varying in the range of 4-788 ohm.m, and the thickness of this geoelectric layer is varying in the range of 0.8-8.3 m., at about 1 VES (#13/Amini10) the geoelectric layer was extending in nature. The third geoelectric layer resistivity was varying in the range of 1-122 ohm.m and the thickness of this geoelectric layer is varying in the range of 1.2-3.3 m, at about 11 VES the geoelectric layer was extending in nature. The fourth geoelectric layer resistivity was varying in the range of 3-5ohm.m, at about 5 VES the geoelectric layer was extending in nature. The interpreted results were presented in Table 2.1. By considering the type of VES curves, resistivity, thickness of the geoelectric layers, Amini1, Amini6, Amini7, Amini8, Amini10, Amini14 & Amini 15 sites are represented that those are showing the Resistivity of <=22 ohm.m, up to the depth of 3m below ground level. Some of the examples of field curves at Amini-9 & Amini-13 has been shown in the below Fig. 2.5. The Resistivity of the curves in the entire area is showing that it is decreasing with increasing a-separation between adjacent Electrodes.

Table 2.1: Interpreted results of VES in Amini Island, U.T of Lakshadweep

#	Village Name.	Ves no.	Interpreted Results.								AB in m.	Remarks
			Resistivity (Ohm.m.)				Thickness (m.)					
			ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	Total(H)		
1	Amini	1	29	9	4	-	0.8	3.3	Ext.	4.1	60	
2		2	3866	788	122	3	0.8	1.9	1.2	4.0	60	
3		3	5483	574	74	4	1.6	1.3	3.3	6.1	60	
4		4	982	250	23	5	1.7	0.8	1.7	4.2	60	
5		5	2075	62	5	-	2.1	1.8	Ext.	3.9	60	
6		6	20	8	3	-	0.9	5.7	Ext.	6.7	60	
7		7	1035	22	5	-	1.5	8.3	Ext.	9.9	60	
8		8	953	10	2	-	1.6	1.5	Ext.	3.1	80	
9		9	1588	94	4	-	1.8	4.8	Ext.	6.6	90	
10		10	1212	4	-	-	2.3		Ext.	2.3	90	

11		11	920	75	4	-	3.4	4.5	Ext.	7.9	90	
12		12	Not Interpretable								90	
13		13	1961	33	2	-	1.5	4.9	Ext.	6.4	90	
14		14	532	13	1	-	1.1	4.9	Ext.	6.0	60	
15		15	146	19	2	-	0.4	3.2	Ext.	3.5	60	
16		16	1354	40	3	-	1.2	2.9	Ext.	4.1	60	

ρ_1 - First layer resistivity in ohm.m h_1 - First layer thickness in m Ext - Extending with dept

An apparent resistivity distribution map for different electrode separations (AB/2) has been prepared with the field data. The maps were prepared with AB/2 distance of 1, 2, 4, 6, 8, 10 and 20 m and are shown in fig. 2.6. Resistivity reduces with increasing current electrode separation. In fig 2.6, the variations in apparent resistivity obtained using half-current electrode separation as 2 m, it was observed that the values were very high at almost all the locations, except locations 1, 6 and 15. The interpreted 1st layer thickness is less than 1 m in these locations and depth to water level is very shallow, less than 1 m bgl at location 6. The result indicates dry coral sand or rock present at the surface and the variations are due to the moisture content of the sand and presence water table in different pockets. The apparent resistivity valve is low where water level is shallow and the formation is sandy and loose soil. The resistance will be more where hard strata are available at the depth even though the water is available. The resistivity reduces considerably when there is seawater mixing which is observed about 8 to 10 meters depth .In the western part of Island since the strata is hard shows more resistance even at 10 meters depth.

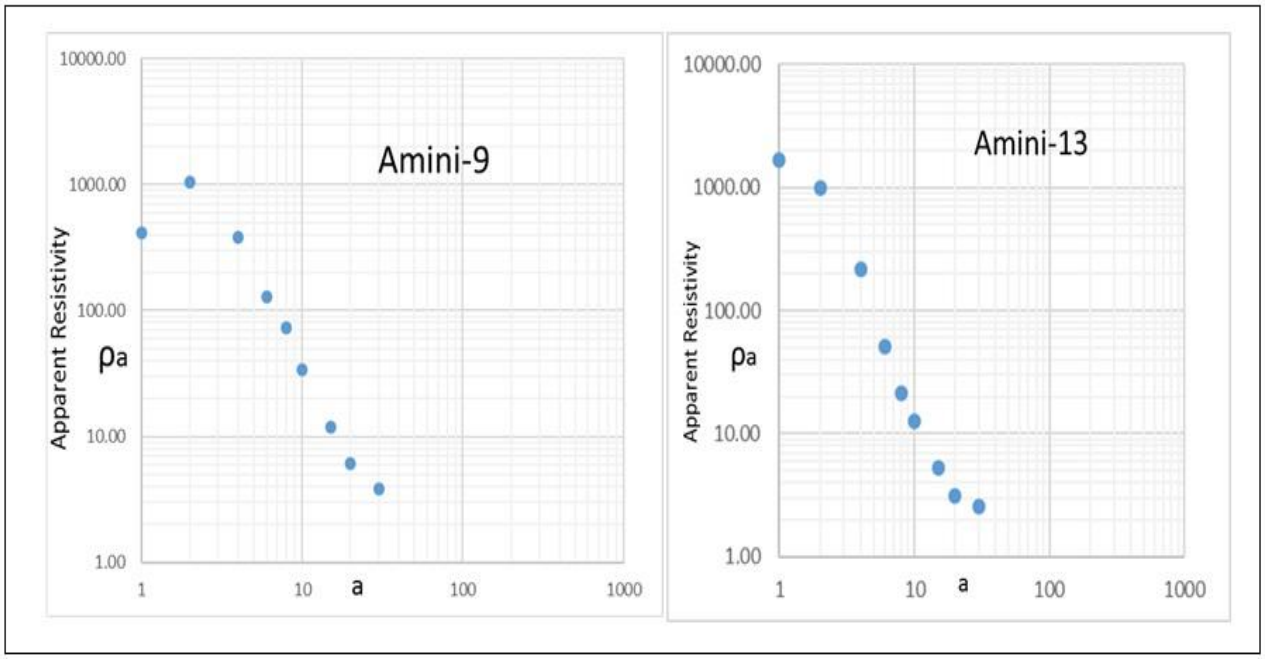
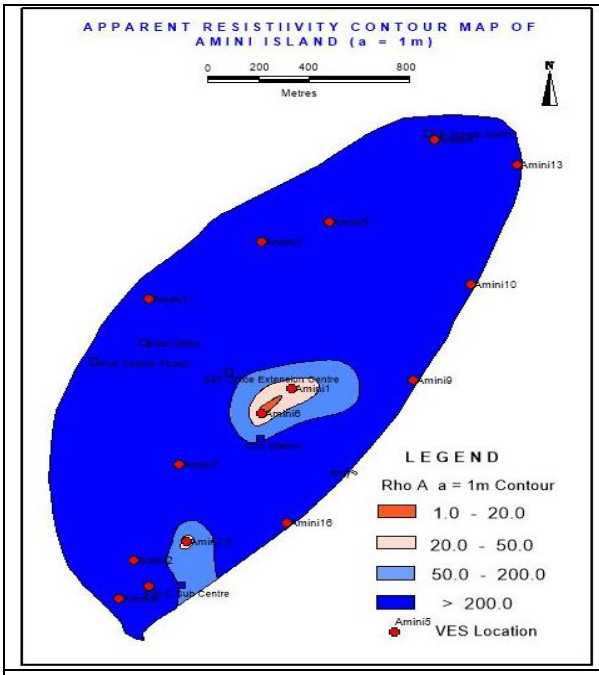
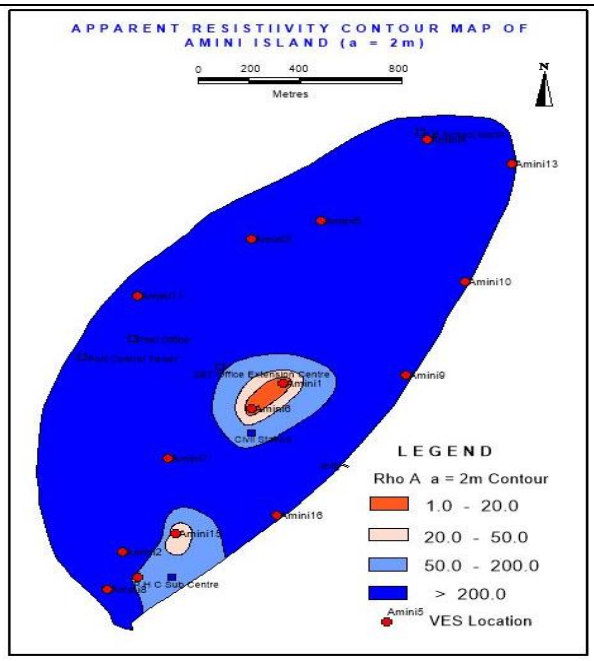


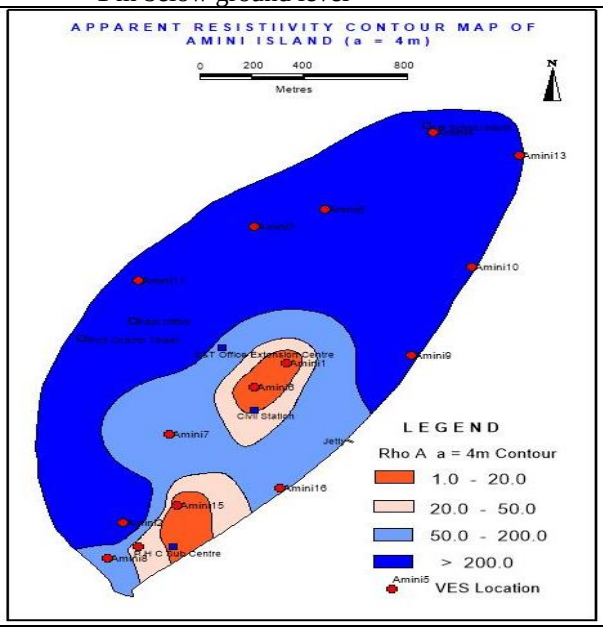
Fig. 2.5: Representation of field curve at Amini-9 & Amini-13



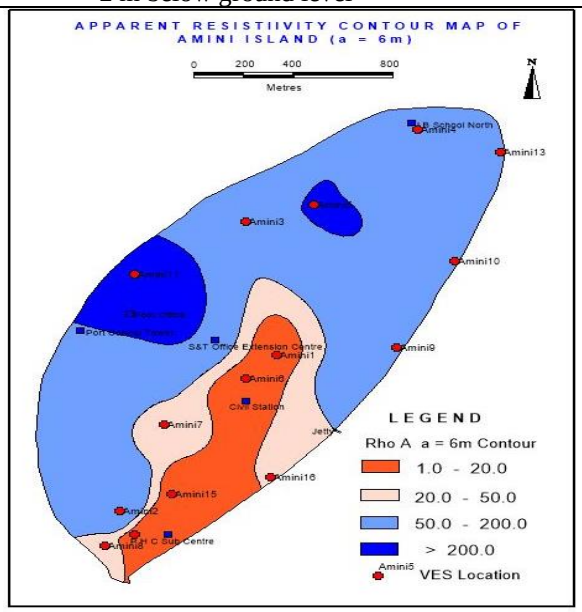
(A) Distribution of apparent resistivity at depth of 1 m below ground level



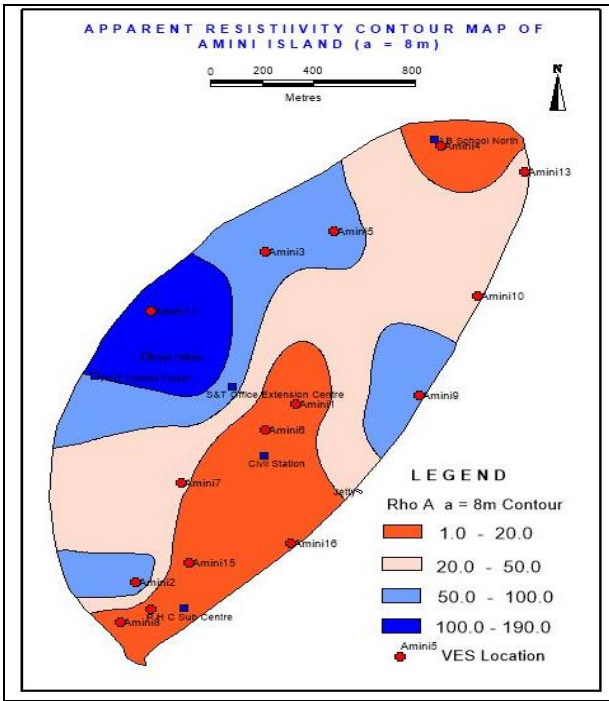
(B) Distribution of apparent resistivity at depth of 2 m below ground level



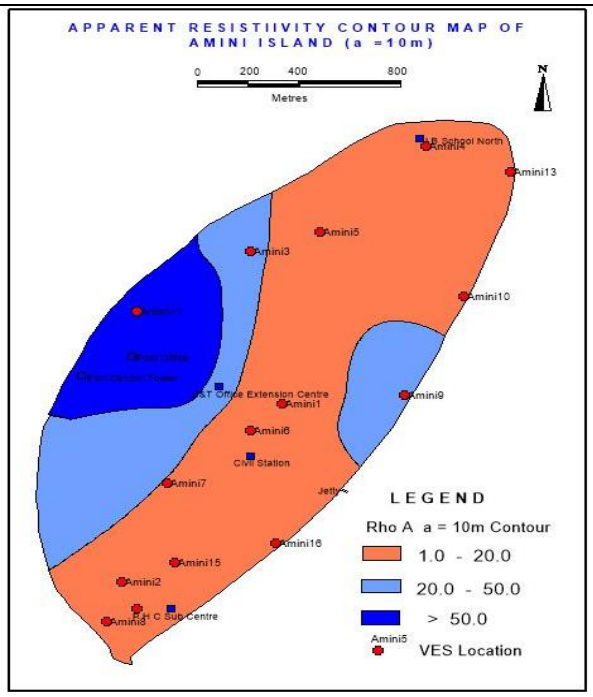
(C) Distribution of apparent resistivity at depth of 4 m below ground level



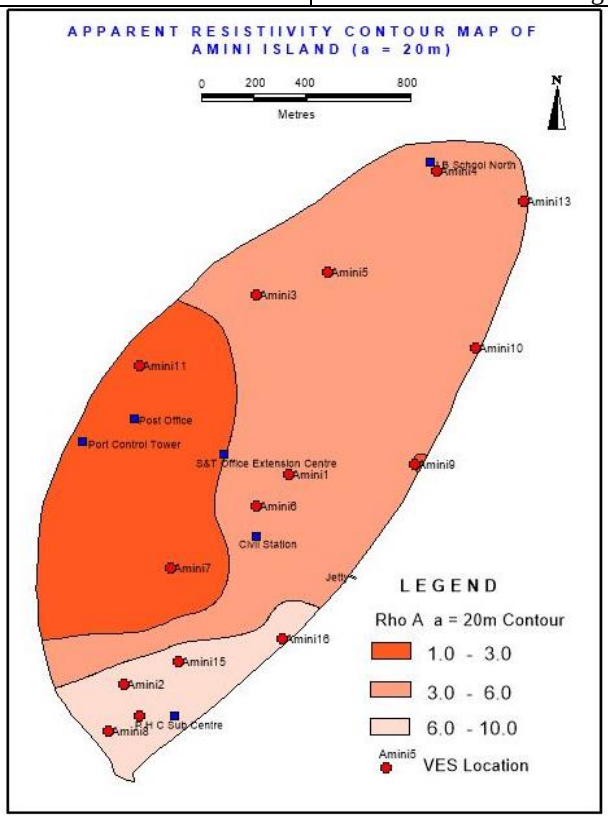
(D) Distribution of apparent resistivity at depth of 6 m below ground level



(E) Distribution of apparent resistivity at depth of 8 m below ground level



(F) Distribution of apparent resistivity at depth of 10m below ground level



(G) Distribution of apparent resistivity at depth of 20 m below ground level

Fig. 2.6: Depth wise distribution of apparent resistivity in Amini islands (A-G)

3.0 GROUNDWATER RESOURCES, EXTRACTION, CONTAMINATION & OTHER ISSUES

3.1 Aquifer wise resource availability and Extraction

Groundwater Resource estimation carried for the year 2017 has brought out the annual extractable groundwater recharge is of 0.287 MCM. Out of which total Groundwater availability is calculated as 0.068 MCM and correspond to 80.9 % of development, hence a less amount of resource is available for further development.

Histogram of total groundwater availability and its utilization from various sectors is given in fig – 3.1.

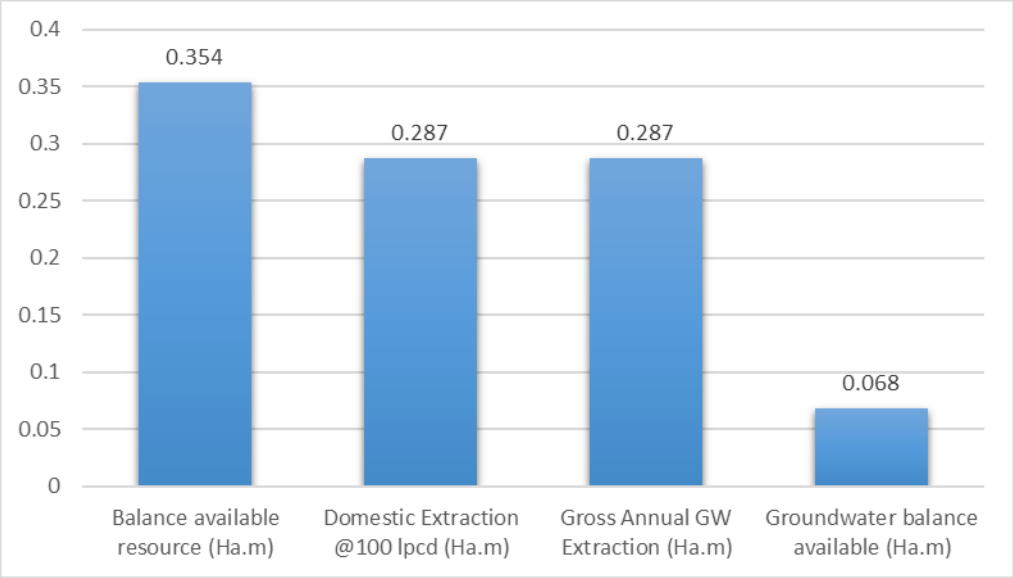


Fig. 3.1: Distribution of Groundwater Resource in Amini Island

3.2 Chemical quality of groundwater and Contamination

Groundwater in Amini islands is generally alkaline. The electrical conductivity ranges from 1180 to 13800 µS/cm at 25^0 C. Ranges of pH, EC and concentrations of important chemical constituents in groundwater in the islands, based on the analytical results of samples collected from select open wells tapping the freshwater lens are shown in Table. 3.1.

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 report. 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 groundwater are observed. The fresh water lens is generally alkaline with pH ranging from 7.43 to 8.12. The dissolution of $CaCO_3$ during rainwater infiltration leads to high pH of groundwater.

Table 3.1: Hydrochemistry of select groundwater samples collected from open wells in Amini 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)
Amini	140	7.43-8.12	1180-13800	661-7778	200-1370	20-590	10-170	20-3000

It is observed that the 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 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 groundwater in the islands varies with time too. Wells from which water is drawn by hand 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. The spatial variations in EC are depicted in Fig. 3.2

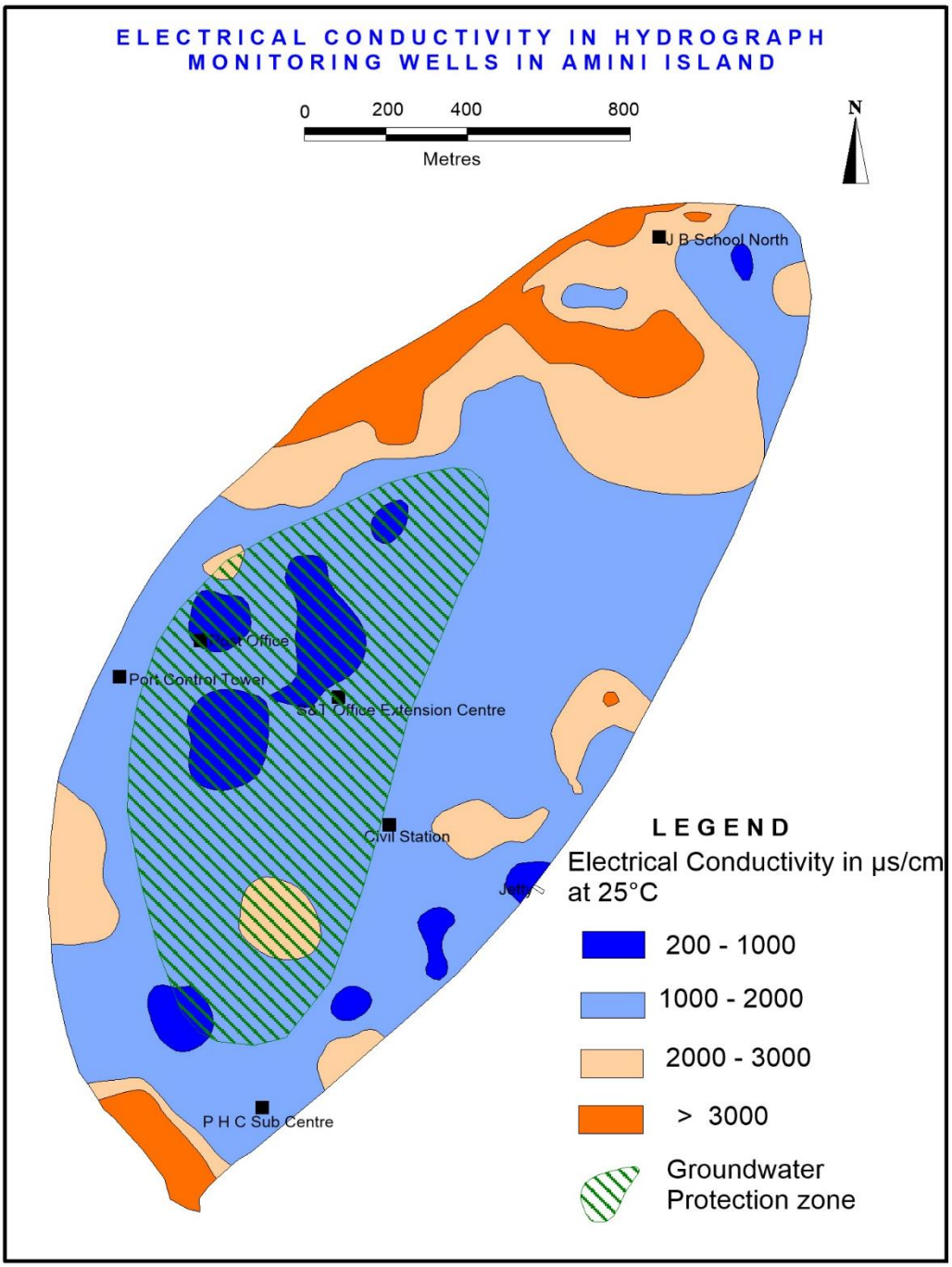


Fig. 3.2: Spatial variations in EC in Amini island
(Source: Report on Aquifer mapping & management plan: UT of Lakshadweep, CGWB, 2019)

Contamination of groundwater is a major threat to groundwater in the Lakshadweep islands. Human waste, sewerage, biological wastes and fertilizers are the major agents of pollution of groundwater. The traditional burial grounds also contribute to groundwater contamination to some extent. Brackish water is present along topographic lows and in places where coarse pebbles and corals are present.

4.0 GROUNDWATER RESOURCE MANAGEMENT

The entire island has limited quantum of groundwater resource and a major part of groundwater is being used by domestic sector. As there is no surface water resources in the island the sustainable development of the groundwater resources is important.

Groundwater is developed by dug/open wells and to a limited extent through shallow filter point wells. The depth to water level in the islands vary from few centimetres to about 5 m. below ground level and the depth of the wells vary from less than a metre to about 6 m. The water levels in all the islands are highly influenced by tides. Stage of Groundwater Development in the island is 80.9 % and about 0.068 MCM of water is available for further development.

Individual and community based Roof top rainwater harvesting system has to be adopted in houses, govt buildings, hospitals, schools etc to fill up the shortfalls in the groundwater availability useful for domestic requirements. There are 15 no govt schools of different types (LP/UP & HS) in the island and can be used for implementing community based roof top rain water harvesting system. Medium sized independent houses can design and accommodate individual rainwater harvesting system depends upon the domestic use. 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 litres.

The over dependency on groundwater system can be further reduced by implementing desalination plants in the island using temperature differential in the seawater i.e. variation in ocean water temperature with an increase in depth.

5.0 DEMAND SIDE INTERVENTIONS

Groundwater is the only conventional source of fresh water in Amini Island, which is being supplemented by rainwater harvesting. Groundwater Resources estimation carried out for Amini Island has brought out status of available recourse. Dug wells are suitable for extraction from shallow unconfined aquifer were the thickness of coral sand is limited.

Island specific extractable groundwater resource against the danger of salinity has to be implemented through micro level schemes. Wherever the groundwater is not adequate to provide water to the entire population, this has to be supplemented by desalination of brackish water through Reverse Osmosis.

5.1 Regulation and control

Optimize utilization of the available resource by encouraging rain water harvesting. At least some of the water which otherwise is wasted could be utilized for part of the year by educating the masses and thereby recognizing the value of water as a scarce resource on Island

Optimum utilization of groundwater should be ensured through regulation of pumping.

5.2 Other Interventions proposed

Installation of desalination plants in the Island is necessary to reduce the stress on groundwater It is necessary to evolve a participatory mechanism wherein the people self-help groups or associations control the overall pumping mechanism with effective support from the local administration by way of technical guidance, incentives.