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GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES
GROUNDWATER INFORMATION BOOKLET
Nicobar District, A&N ISLANDS

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&

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Nicobar District at a Glance

Sl. NO	Items	Statistics
1	**GENERAL INFORMATION**	
	i) Geographical area(Sq.Km.)	1841
	ii) Administrative Divisions (as on 31.03.2013)	
	• No. of Zilla Parishad	Nil
	• No. of Panchayat samiti	1
	• No. of Subdivisions	3
	• No. of Blocks/Tehsils	3
	• No. of Municipalities	Nil
	• No. of Gram panchayats	3
	• No. of revenue villages	7
	• No. of census villages	192
	• Inhabited villages	171
	• Un-inhabited villages	21
	• Urban area	Nil
	• Rural area(Sq.Km.)	1841
	• Total number of islands in the district	13
	• Number of inhabited islands	13
	• Biggest inhabited island	Great Nicobar Island-1045 Sq.Km.
	• Smallest inhabited island	Pillow-Millo island- 1.3 Sq.Km
	• Southern most island	Great Nicobar
	• Northern most Island	Car Nicobar
	• Highest Peak	Mount Thullier-642m
	• Average length(Km)	259
	• Average width(Km)	58
	iii) Population(as per 2011 census with population density per sq. km.)	36819(Male-20705,Female-16114),Population density-20
	iv) Actual annual rainfall(in mm) in 2012	3076.6 in Car Nicobar & 2980.4 in Nancowry
2	**GEOMORPHOLOGY**	
	Major physiographic units	1. Low to moderately high steep hills 2. Intermontane narrow valleys. 3. Gently sloping narrow to moderately wide coastal plain (0.02-0.8 km) Overall altitude of the islands varies from sea level to 642m.

Sl.No	Items	Statistics
3	**MAJOR DRAINAGE**	Galathea river, Alexandria river,Amrit Kaur all in Great Nicobar
4	**LAND USE**	
	a. Forest area(in Sq. Km)	1542.07
	b. Reporting area for land utilization(in Sq. Km)	1577.95
	c. Area available for cultivation(in Sq. Km)	1544.75
	d. Not available for cultivation (in Sq. Km)	16.71
	e. Other uncultivated land excluding fallow Land(in Sq. Km)	4.44
	f. Current fallow (in Sq. Km)	4.73
	g. Fallow lands other than current fallows (in Sq. Km)	7.32
	h. Net area sown(in Sq. Km)	2.68
	i. Area sown more than once(in Sq. Km)	1.10
	j. Area submerged after tsunami (in Sq. Km)	26.94
5	**MAJOR SOIL TYPES**	Entisols, Inceptisols and alfisols
6	**AREA UNDER PRINCIPAL CROPS(as in 2012)**	Coconut, arecanut,root crops etc.
7	**IRRIGATION BY DIFFERENT SOURCES (Areas in Sq.Km.) & No. of structures as on 2012)**	
	Dugwells 125 Nos.	1.25 Sq.Km
	Borewells Nil	Nil
	Check Dams 1 No.	.05 Sq.Km
	Ponds/Tanks 35 Nos	0.21 Sq.Km
	Actual area(Sq.Km.) irrigated by Ground water	1.25 Sq.Km
	Actual area(Sq.Km.) irrigated by Surface water	0.26 Sq.Km
	Total irrigated area(Sq.Km.)	1.51 Sq.Km
	Number of Groundwater monitoring wells of CGWB (as on 31.03.2013)	Nil
	Dug wells	Nil
	Piezometers	Nil
8	**PREDOMINANT GEOLOGICAL FORMATIONS**	Marine Sedimentary formations(Mithakhari & Flysch) comprising Fine grained sandstone, siltsone,shale,conglomerate;Ignoeo-us ophiolite suite comprising Acid- & Intermediate lava,Pillow basalt,Ultramafic

		rocks; chalk,mudstone,coralline and foraminiferal limestone,Nicobar Marl of Nicobar Group
9	**HYDROGEOLOGY**	
	Major water bearing formation	Ground water in Marine sedimentary formation occurs under unconfined condition in weathered residuum. Preponderance of clayey mineral renders groundwater development possibility very low. Yield of dugwell (5-6m dia,6m depth) in Marine sedimentary group varies from 4000-5000 litres/day. Ground water in Ophiolites occurs under unconfined to semi-confined condition in weathered residuum while in fractured hard rock in deeper horizon in confined condition. Yield of dugwell (5-6m dia,6m depth) in Marine sedimentary group varies from 40,000-50000 litres/day.The formation is yet to be explored for development in the district. In Coralline limestone in Nicobar group yield of dugwell (5-6m dia,6m depth) varies from 1,00,000-1,50,000 litres/day or even high. Springs are profuse in all the geological formations. However, springs are sustainable in ophiolite formation and in the limestones of Nicobar group.
	Premonsoon depth to water level during 2012	Not available as hydrograph stations are absent.
	Premonsoon depth to water level during 2012	Not available as hydrograph stations are absent.
	Long term water level trend in 10 years(2002-2012) in m/yr	Not available as hydrograph stations are absent.
10	**GROUND WATER EXPLORATION BY CGWB(as on 31.3.2013)**	
	No. of wells drilled	9
	Depth range	27.36 m-101 m
	Discharge	Negligible- 0.5 m^3/hr
	Storativity(S)	-
	Transmissivity(T)	-
11	**GROUNDWATER QUALITY**	
	Presence of Chemical constituents more	Iron in pockets and brackishness in dugwells

	than the permissible limit	close to the coastal tracts
	Type of water	Ca-Mg-HCo_3-Na- HCo_3
12	**DYNAMIC GROUNDWATER RESOURCES(2008-09)**	
	Net Groundwater availability	10421.11 Hectare metre
	Existing groundwater draft for drinking purposes	144.20 Hectare metre
	Stage of Groundwater development	1.56%
13	**AWARENESS AND TRAINING ACTIVITY**	
	Mass awareness programme organized (numbers)	Nil
	Water management training programme organized (numbers)	Nil
14	**EFFORTS OF ARTIFICIAL RECHARGE AND RAINWATER HARVESTING**	
	Projects completed under technical guidance of CGWB and funded by MOWR(Nos. and amount spent)	Nil
15	**GROUND WATER CONTROL AND REGULATION**	
	No. of overexploited blocks	Nil
	No. of Critical blocks	Nil
	No. of blocks notified	Nil
16	**Major Groundwater related problems and issues**	High iron in groundwater in some pockets. Water scarcity in the islands especially in Chowra island. Optimum rainwater harvesting in the islands through needful structures. Qualitative problems (salinity) in the coastal stretches in the post-tsunami. Post-tsunami changes on quantity and Quality of groundwater resources. Intensive groundwater surveillance and monitoring system in the islands to adjudge sea water ingress.

NICOBAR DISTRICT

1.0 INTRODUCTION:

1.1 Location and Administrative details: Nicobar district is the southern most district of the Union Territory of A&N islands and it is separated from South Andaman district by 10^0 channel in Indian ocean. The district of Nicobar is comprising three Subdivisions ,three blocks/ Tehsils and a panchayat samiti. Car Nicobar is the district Headquarters of Nicobar district. There are jetties in all the inhabited islands. However, large ships can touch at Car Nicobar,Nancowry and Great Nicobar(Camp Bell bay) islands. Inter island as also mainland, i.e. Chennai bound ships run both by the A&N Administration and Shipping Corporation of India, ply at regular interval through all the inhabited as also the above major islands. There is regular Pawan Hans Helicopter service of A&N Admn. to all the inhabited islands and there is daily helicopter service to Car Nicobar. Dominant population of the district is tribal barring the non-tribal population which is constituted mainly by the Govt. servants. However, a considerable nontribal population is also formed by the businessman, contractors and their work force. The islands in Nicobar barring the Great Nicobar island is not open for the tourist and one has to acquire special entry pass showing specific reasons other than tourism from Andaman & Nicobar Administration to enter into the tribal islands.

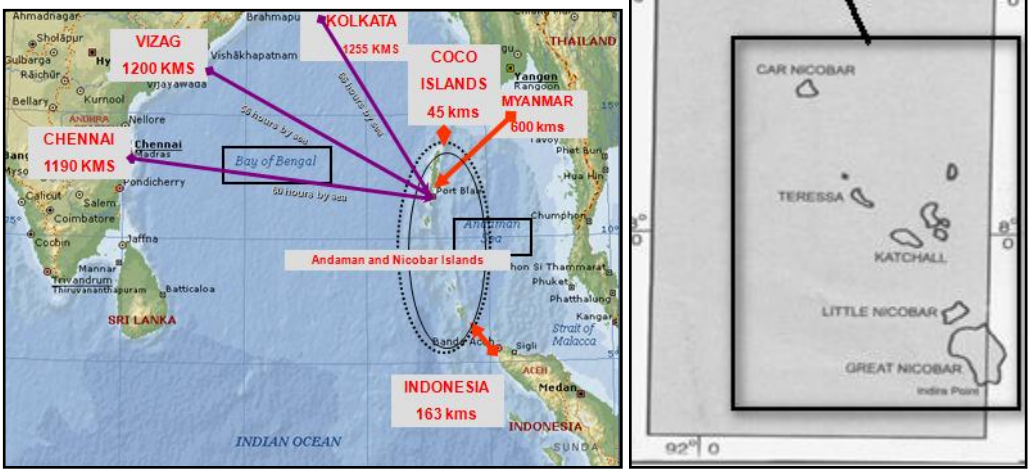


Fig- 1.1 Location and Administrative Map of Nicobar District

1.2 Population: As per 2011 census population of Nicobar district is 36819 where Male was 20705 and Female-16114 with Population density of 20 per Sq. Km.

1.3 Land use: Forest covers a major part of the district.The low lying lands, mostly under utilisation for settlement and agriculture, were submerged under sea water due to the subsidence of many parts of South Andaman island after the mega earthquake(M=9.3) on 26.12.2004. The landuse of South Andaman district is enumerated below(Table-1.3.1)

Table- 1.3.1 Land use in South Andaman District

Item	Land use (as in 2012)
Total Geographical Area(in Sq. Km)	1841.00
Forest area(in Sq. Km)	1542.07
Reporting area for land utilization(in Sq. Km)	1577.95
Area available for cultivation(in Sq. Km)	1544.75
Not available for cultivation (in Sq. Km)	16.71
Other uncultivated land excluding fallow Land(in Sq. Km)	4.44
Current fallow (in Sq. Km)	4.73
Fallow lands other than current fallows (in Sq. Km)	7.32
Net area sown(in Sq. Km)	2.68
Area sown more than once(in Sq. Km)	1.10
Area submerged after tsunami (in Sq. Km)	26.94

Source: Dept. of Economics and Statistics,A&N Admn.

1.4 Works carried out by CGWB: Because of the absence of any groundwater surveys and investigation department in A&N Administration, all the ground water surveys and exploration in the islands of Nicobar district are undertaken from time to time by CGWB and the erstwhile groundwater wing of Geological Survey of India . Systematic hydro-geological surveys and geophysical surveys coupled with groundwater exploration were taken up in Great Nicobar under the leadership of Shri I.Banerjee,Sr.Hydrogeologist,Eastern Region which continued from 1984 to 1990. The studies on artificial recharge and conservation of rainwater and groundwater was initiated in 2001 by Sh. Shri A.Kar, Scientist-D of CGWB, E.Region, and Kolkata. Since then upto 2007 extensive studies on artificial recharge and rainwater harvesting in the district was continued. In 2002, a special groundwater studies were carried out by Shri A.Kar,Scientist-D in Car Nicobar island in connection with the construction of Mus Break Water. Following a request from District Administration of Nicobar(Dy. Commissioner,Nicobar) a special study for a pilot project on rainwater harvesting and artificial recharge was conducted by CGWB(Kar,2004) in water scarce Chowra Island. The recommendation was put forward based upon the detailed study. The implementation work was initiated by the district administration which was abandoned due to the tsunami devastation and temporary evacuation of the islanders. CGWB still want to

implement the plan through APWD. Besides, CGWB (Kar, 2003&2005) has put forward the plan for optimum harvesting of surplus run-off, soil conservation through check dams in streams, construction of ponds, dug wells and bore wells for augmentation of irrigated agriculture both in the Pre and Post tsunami. CGWB (Kar & Adhikari, 2005) has carried out impact assessment study of tsunami and earthquake on groundwater resources in Nicobar district. In this connection CGWB has undertaken extensive surveys in the Post tsunami in all the inhabited islands in Nicobar district while Geophysical surveys were also undertaken in Car Nicobar Island. Currently APWD,A&N Administration is preparing the Master Plan of Water Resources of A&N Islands under the technical guidance of CGWB.

1.5 Groundwater Basin: There is no typical river occur which drains as also receives the entire run-off occur in the district as happens in mainland. More over the islands are discrete and separated by sea .However the major streams in the various islands fall in the district are described in the following chapter.

CLIMATE AND RAINFALL

2.1 Climate The islands in Nicobar district enjoy tropical humid climate because of their location in the equatorial zone surrounded by the Andaman Sea. Winter is virtually absent and the islands have only two season's viz. rainy Season and summer Season. The mean relative humidity of the islands is 79%.The mean maximum temperature is 30.2^{o}C and means minimum temperature is 23.8°C. The relative humidity varies from 79% to 89% and wind speed varies from 7 km/hr to 10km/hr. The maximum and minimum temperatures in the islands fluctuate between 27 to 33^{0}c and 21 to 25^{0}c. Daily evaporation rate in the island is fairly high which cumulatively ranges from 1500-1800 mm. per annum. The geographical localization is responsible for high average evaporation rate to the tune of 1500-1800mm per annum. Climatic aberration is highly influential in matters of the availability of surface water and ground water in the islands. In few years in the past decade i.e. in 2002 and 2007 the water supply scenario in Nicobar Group was highly affected .

2.2. Rainfall : The district of Nicobar (Fig-1.1) receives on an average 3000 mm of rainfall per annum The rainfall is received in the district through South - West and North - East monsoons spans for the period from May to December. Average annual rainfall in these Islands is about 3000 mm while the normal annual rainfall of the islands as calculated at Port Blair is 3180 mm. The meteorological parameters of the islands are interpreted from the records of lone IMD station situated at Port Blair. Rain gauze stations were established in the Police radio offices of Car Nicobar,Nancowry and Kondul islands in Southern Group. However, the rain gauzing in Kondul island was terminated after the tsunami devastation in 2004.

3.0 GEOMORPHOLOGY AND SOIL

3.1 Geomorphology : Geomorphology of various islands in the district is highly varied. At places small to moderately high hills flanked by narrow coast could be seen as in case of Great Nicobar,Liitle Nicobar,Kamorta, Katchal ,Teressa,Bampooka,Nancowry ,Tillonchang islands where as small low lying to flat islands like Kondul,Pillow millow,Chowra etc. are also available in the district . Irrespective of the size of the islands, luxuriant coral growth occur encircling the islands. Rugged topography, steep slope, low infiltration capacity and close proximity of hill to sea disallow creation of potential groundwater reservoirs in many of the islands except the Coralline(atoll) Islands like Car Nicobar which are endowed by bonanza of groundwater resources due to highly porous and permeable limestone underlying the island. Although the island of Chowra is water scarce, although underlain by porous shell limestone. Typical geomorphologic setup of the island is responsible for absence of fresh ground water lens developed in the island.

3.2 **Drainage:** Nicobar district is endowed with stupendous rainfall. Facilitated by the flow from perennial springs as also the base flow and rainfall, perennial flow throughout the year could be observed in the streams .In Great Nicobar,Kamorta, Nancowry,Trinket, Tillonchong,Teressa, Bampooka, Katchal, Little Nicobar ,Pilllo millo,Kondul etc. drainage density is high, while in Car Nicobar,Chowra Islands drainage system is either absent or poor . However, potential springs are developed in Carnicobar because of cavernous condition in Limestone. At places copious emanation from springs also give rise to potential drainage in Car Nicobar. Because of relatively less areal extent and paucity of catchments in the islands of Nicobar, river systems are almost absent barring the Galathea,Amrit Kaur,Alexandria rivers in Great Nicobar . However, a few perennial streams such as Magar Nala IN Great Nicobar and numerous other streams in other islands drain the Nicobar district. All the *nalas* meet the sea in Bays through creeks. The general drainage pattern of the islands varies from dendritic to sub-dendritic. Land subsidence in the Post-tsunami have greatly influenced the tidal ingress along the streams of Nicobar District.

3.3 Springs: The characteristic geological and geomorphologic conditions of the islands have facilitated the origin of numerous springs in all the three major geological formations (i.e. Marine sedimentary group of rocks, volcanic and other igneous rocks and coralline limestone). The rural water supply in the entire district except Car Nicobar and coastal stretches of the islands of Nicobar (Water supply in Car Nicobar is done from the wells) is maintained either directly from the springs or spring or spring fed

perennial streams. These springs are, in general, formed in high altitudes because of good fracturing in the rocks . For this they also may be termed as fracture springs. However, the springs are highly yielding and sustainable in, igneous rocks and limestone as seen in Teressa, Bampooka,Tilonchang,Munak village of Kamorta underlain by igneous rocks and in Car Nicobar island ,underlain by coralline limestone.

3.4 Soils: Soils in Nicobar district is mainly derived from igneous and sedimentary rocks like sandstone,limestone, coral and shell sand ,mud stone silt stone and shale and the igneous rock comprising Pillow lava, gabbro,peridotite,dunite etc.. They are mostly representing alluvial soil,sandy soil,valley soil and hilly soil. These type of soils are mostly deep to very deep,moderately to poorly drained,clay to clay loam.The soils in the islands like Car Nicobar,Chowra and the coastal tracts of all the islands underlain by coralline sand and limestone are extremely well drained with high permeability ,sandy,loamy sand,sandy loam in texture. Most of the alluvial soil is found in valley and is used for paddy crop in Kharif season and vegetables,pulses and oilseeds in Rabi season. Most of the plantation crops like coconut,arecanut are mostly cultivated in the coastal plain and hilly land where slope gradient is less than 10%. Valley lands are relatively fertile due to the enrichment of organic matter comes from the hill slope. In the coralline islands and tracts due to coarse soil texture there is no chances of water logging during rainy season. As regards the soils of Great Nicobar are concerned,they are derived from sedimentary rocks comprising Shale,mudstone,siltstone and sandstone and represent deep to very deep loamy sand to clay in texture and possess 1-3% slope utilities for paddy cultivation. The coarse texture of the soil is facilitating growth of coconut,arecanut and various types of fruites like guava,sapota,mango and spices.Vegetation of Great Nicobar is having wide variation with that of the other islands of A&N Islands.

4.0 **AGRICULTURE AND IRRIGATION:**

4.1 Agriculture: Agriculture is the mainstay of people in the district although the islands are not self dependent in matters of production of food grains. For this reason, the needful commodities are imported from the mainland while green vegetables are brought mainly from South Andaman district esp. Little Andaman(Hutbay). However,vegetables are grown in Great Nicobar island. In all the tribal islands of Nicobar district the population is not interested for growing vegetables for business purposes. They mostly grow coconut, areca nut and tuber crops(tapioca).Tsunami and earthquake made a colossal impact on agriculture. Ministry of Agriculture, Govt. of India had taken up Rajiv Gandhi Rehabilitation project for agriculture(RGRPA) for helping the affected people and rejuvenation of their agricultural practice. Agriculture is mostly rainfed. However, irrigation facilities are created tapping groundwater and surface water sources in Great Nicobar island and many irrigation sources especially dugwell were constructed in all the affected islands under RGRPA. This has improved the production of vegetables as also other crops in good quantity.Islandwise cropping pattern is presented in the following table (Table-4.1).

Table- 4.1 Island wise cropping pattern in Nicobar District

Sl. No	Island	Crops Grown
1	Car Nicobar	Coconut, Areca nut, Fruits, Tuber crops, Vegetables
2	Chowra	Coconut, Tuber crops
3	Teressa	Coconut, Areca nut, Cashew, Fruits, Tuber crops
4	Bompuka	Coconut, Tuber crops
5	Katchal	Paddy,Red oil Plam, vegetables,coconut, Areca nut,Spices
6	Kamorta	Coconut, Areca nut, Cashewnut,banana
7	Nancowry	Coconut, Areca nut, Fruits, Tuber crops
8	Trinket	Coconut
9	Little Nicobar	Coconut, Areca nut, colocasia,Diascoria
10	Pillomilo	Coconut, Colocasia
11	K ondul	Diascoria
12	Great Nicobar	Paddy,vegetables,Coconut, Areca nut, Fruits

Source: Dept. of Economics and Statistics,A&N Admn.

4.2 Irrigation: In want of irrigation facility, the agriculture in the district was mainly rainfed. However, based upon the recommendation of CGWB(Kar,2003;Kar,2006) rainwater harvesting through ponds and wells was encouraged by the A&N Admn. and the practice was further accelerated in the Post tsunami under the Rajiv Gandhi Rehabilitation project for agriculture. However, there has been a significant impact of boxing day (i.e. 26.12.2004) mega earthquake(M=9.3) on water resources in general and groundwater resources in particular. The impact was varied in sedimentary and igneous formations and it affected qualitatively and quantitatively the water resources. Many of the effects are obliterated while some are permanent and still continuing.The impact of tsunami and earthquake on water resources is enumerated in the following chapters.

5.0 GROUNDWATER SCENARIO

5.1 Geology: The Islands in the Nicobar district(Fig- 5.2.3.1) are composed mainly of thick Eocene sediments deposited on Pre-Tertiary sandstone, silt stone and shale with intrusions of basic and ultrabasic igneous rocks(Ophiolites).The Tertiary Group is overlain successively by the Nicobar Group and the Quaternary Holocene Group, intervening with unconformity. Marine inorganic sedimentary group of rocks comprising shale, sandstone, grit and conglomerate(Mithakhari Groups),mudstone and siltstone and organic sedimentaries like Coralline atolls and limestone belonging to Nicobar Group and extrusive ad intrusive igneous rocks (volcanics and ultramafics) of Ophiolite suite occupy the entire geographical area of the district . Amongst these, the Sedimentary Mithakhari and Nicobar Group is most pervasive and occupy nearly 80% of the entire area of the islands while the Igneous group covers nearly 5% and the rest 15% goes to the coralline and limestone formations .All these rock formations are brought under tectonism because of their alignment in a tectonically active zone, evident from the occurrence of shallow and deep focus earthquakes in the islands. The last earthquake and devastation by tsunami were also the effect of tectonic setting of this archipelago in a

converging plate margin. Because of tectonism, the igneous and Sedimentary groups of rocks are highly fractured and fissured. The fracturing in hard rocks form conduits for movement of ground water in the deeper horizon. The geology of the islands is highly varied and even changes within a small distance**.** The generalized geological succession is given in **Table. 5.1**.

Table 5.1 Generalized Geological Succession of Andaman & Nicobar Islands

Age	Group	Formation
Recent to sub-Recent	Quaternary Holocene Group	Beach sands, Mangrove clay, Alluvium, Coral rags and Shell limestone, loosely consolidated pebble beds
----------	**Unconformity**	----------
Pleistocene to Late Pliocene	Nicobar Group	Abbeville Shell limestone, Nicobar Marl ; Sandstone, Claystone, etc.
Miocene	Archipelago Group (Upper)	White claystone, Melville Limestone
----------	**Unconformity**	----------
Oligocene to Paleocene	Andaman Flysh , Mithakhari Group	Thinly bedded alternations of Sandstones and siltstones, grit, conglomerate, Limestones, black Shales with olistoliths.
----------	**Unconformity**	----------
Late Cretaceous	Ophiolite Group	Dyke swarms, acidic suite,Pillow lava with radiolarian chert and ultramafic suite.

5.2 Hydro geological framework of the islands of Nicobar District

5.2.1 **Car Nicobar Island :** Car Nicobar is the District(Fig-5.2.1) Head quarters of Nicobar District and the first island after crossing the Ten degree channel and it is bounded within the $9^0 7' 30'' N$ to$9^0 15' 30'' N$ latitude and $92^0 43' E$ to$92^0 53' E$ longitude and occupies al geographical area of 126.91 sq.km . The elevation of Car Nicobar Island above MSL varies from 3 to more than 45 metres. Because of higher infiltration drainage system is not properly developed in the Island.Two major drainage channels are developed in the higher reaches which are debouching near passa beach and Kimios. Like other islands in Andaman and Nicobar archipelago,the Car Nicobar island enjoys tropical humid climate.

5.2.1.1 Geological setup: The island is underlain by lower Pleistocene to Middle upper Miocene Abbeville (shell & Coralline) limestone and Nicobar Marl belonging to Nicobar group and Holocene to Pleistocene (Recent to sub Recent) coral rags and coralline sands. A thorough traverse was taken all along the island to check up the Geological formations during the source finding work. The study revealed that the Central part of the Island especially covering the higher elevated areas are underlain by calcareous marl type of formations whose potentiality to yield ground water is relatively less. Same type of

Geological formations are available in the northern part especially in elevated areas which ultimately merges with the Central marl formations. Encircling this Marl formation highly porous Shell-coralline limestones are available even at higher elevations. Nearby the coast sand deposits are observed which are developed by attrition facilitated by wind and sea waves.

5.2.1.1 Hydrogeological setup:

5.2.1.2 Aquifer disposition,characreistic and potential: Hydrogeologically this island formed a bonanza of fresh water resources through higher infiltration in the porous corralline limestone formations. Depth to water level in the coastal areas vary from 2m to 3m during post-monsoon time and 3 m to 4 m during pre-monsoon times. The rainfall infiltration used to occur from the top of the hills through the fissures and fractures in Marl formation and the porous coralline formations and the recharged water was forming a lens of 25 to 30 m thickness below the ground surface and it used to be discharged into the sea in the low lying areas. The study by CGWB in the area revealed that the fresh – sea water front used to remain away from the tidal line and consequently good quality fresh water also was available in the shallow wells along the coast line as also in the wells in the near shore areas constructed by APWD, A&N Administration and MES for water supply in the Civil and Defense areas. Two wells inside IAF campus (constructed by Japanese by explosives) under use by MES was yielding 6 lakh litres or more with a draw down of only 0.2m with out any quality deterioration. These wells are located only 200 m away from the shoreline, similar observations were made from the other pumping wells of APWD. APWD had 9 larger dia dug wells (0.5 to 6 m dia and 4.5 to 10 m depth) for pumping of fresh water for drinking water supply in the pretsunami . Similarly ALHW, Govt. of India had two pumping wells at Mus and Kinmai for their campus use and supply to the ships. The depth to water level at higher elevations at Mus, Kinmai and Perka area used to vary from 7.5 to 9 Mtrs. In various reasons (pre and post-monsoon). However, in low lying areas at higher elevations depth to water lever varies from 2 to 3 m in all seasons and at places good springs (discharge 0.4 to 10 LPS) are also developed.

The earthquake and tsunami had devasted the island significantly.The coasts were damaged along with the destruction and contamination of many wells in the coastal stretch. It is noteworthy in this context that the Nicobari population in the entire Nicobar district had an inherent liking to dwell along the coast. As per the easier availability based on hydrogeologic condition, the wells were also constructed consequently along the coast. sedimentary rocks in valleys and adjacent to Bays, depth of dug wells are restricted to 3.5 to 4 m bgl. A map showing the Geology and Hydrogeology of Nicobar Islands is given in **Fig.5.2.1.**

5.2.2 **Kamorta Island:** This Island (Fig-5.2.2.1) is having geographical area of 188.03 sq.km..Geologically mostly Marine sedimentary group of rocks underlie the islands barring small patches near changua, Al-u-kheak, Ramjau and Munak villages. The coastal tracts underlain by potential coralline formation were mostly devastated during the Tsunami. Potential springs are developed in the

volcanic formation. Although potential stream are also available was formerly the source of water supply in the village .One check dams was constructed to tap the sources .

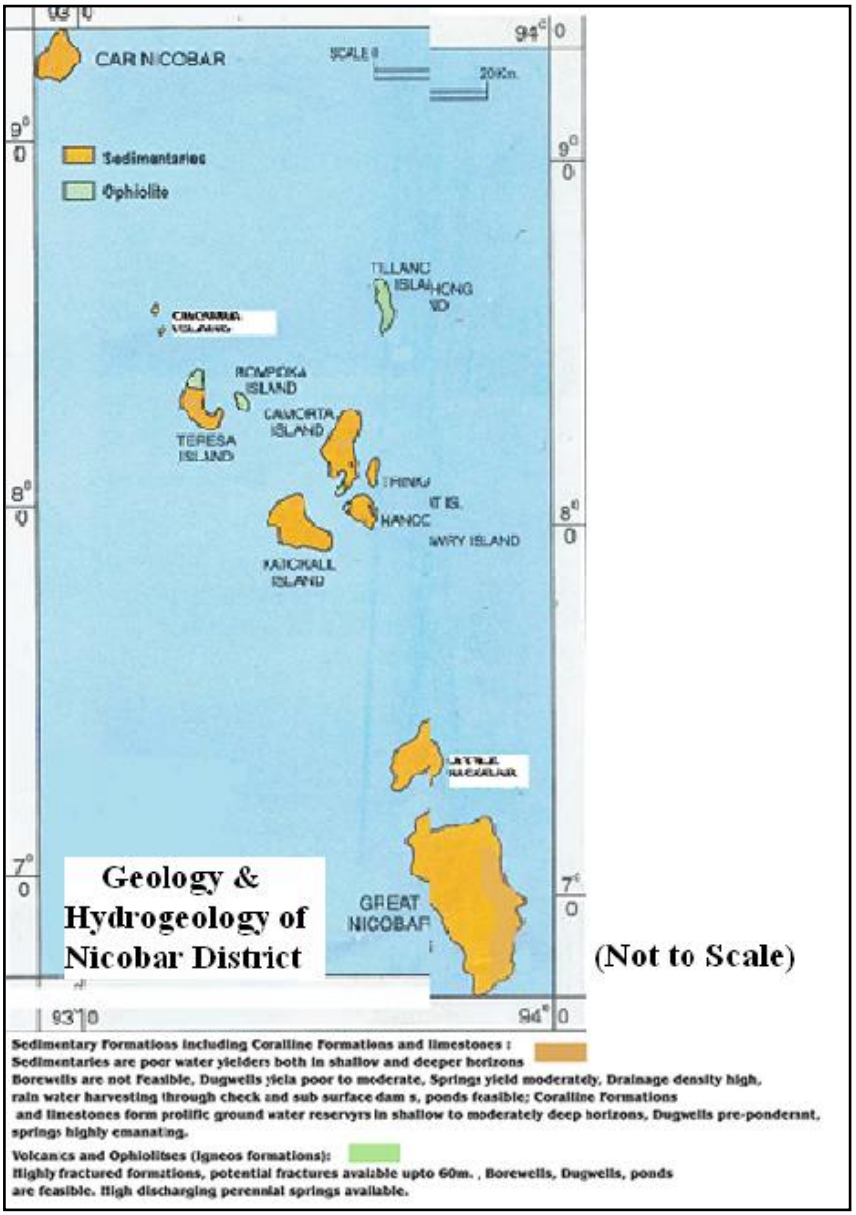
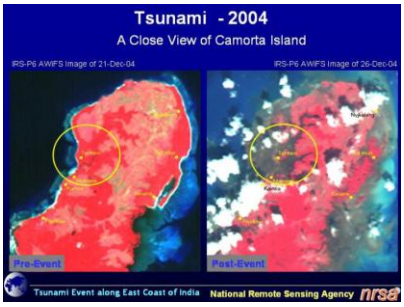


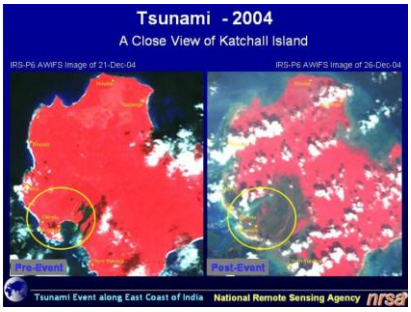
Fig- 5.2.1 Geology and Hydrogeology of Nicobar district

However, after the Tsunami and earthquake the village has been destroyed and the supply pipelines were also partially damaged This stream source may further be tapped for drinking water supply and irrigation. The rest part of the island is covered by Marine sedimentary group of rocks which are generally not potential ground water yielding formation . As per the hydrogeological situation available in the island, wells , check dam and subsurface dams as also ponds would be feasible structures here. Depth of the wells should be restricted to 4.0meters in the foothill areas where the upland meets the

devastated coast and 6 to 8 meter in the upland areas. The following good stream sources were seen in Kamorta island for tapping of fresh water both for drinking as well as agriculture.



1a



1b

Fig- 5.2.2.1 **Satellite image showing loss in land area of (1a)Kamorta Island (1b) Katchal Island after 26.12.04 earthquake & tsunami**

5.2.3 Nancowry Island: Geologically Nancowrie island (Fig-5.2.1) is underlain mostly by marine sedimentaries which occupy the major portion of the inhabited villages barring the southern part of Tapong village where volcanic rocks are cropping out along the stream course. However, akin to other islands the devastated coast is underlain by coral line formation. Consequently the water availability situation in this island was Precious in Pre. Tsunami and equally bad or worse in post Tsunami period . The topography and geological formation disallows formation of potential groundwater reservoir especially in Champin, Hinpova and Hitui villages. The post Tsunami submergence of the well sources further aggravated the fresh water availability situation . While groundwater is scarce simultaneously perennial streams are also available in the area. To improve the water availability situation check dams and well may be constructed here in non perennial streams . In addition roof top rain water harvesting at its conservation in surface and subsurface tanks in case of community use , while more roofs are connected to a subsurface tank.

5.2.4 Katchal Island: This island(Fig-5.2.1) is underlain by Marine sedimenaries and coralline formations. The coralline tract was highly devastated and washed out in many areas i.e. near the former jetty area. Kapanga , and Jhoola to west Bay stretch and ponda areas .In the fast Bay area as also near Kapanga, the coastline made of coral line formation are directly under the attack of sea waves and are rapidly being winnowed out. In Katchal possible are the losses of land by transgression of sea during Tsunami have been maximum in the entire A & N islands. However, to continue the agricultural rehabilitation work wells are to be constructed in the devastated coast especially along the foot hill and the depth of the wells are to be restricted to 4m to avoid salinity in the subsurface as occurred at many places along the coast during the devastating earth quake. However, there are number of perennial steams available in the central intact position of the island which may from sustainable sources of drinking water as also irrigation water.

Simultaneously at places (as near Jhoola coast) water harvesting ponds may be constructed.

5.2.5 Chowra Island: The geographical area of island is 8.28 sq, km(Fig-5.2.1). this island was severely devastated after the tsunami and the entire population was rehabilitated to Teresa island. The island is underlain by coralline and foraminiteral limestone. Typical tortoise back topography and low attitude is

the characteristic of the island. The island is the typically water scarce island in the Nicobar District as also entire A&N Islands where exploitable fresh ground water lens does not form. Formerly one R.O plant was installed in the island. This is the only island in A & N Island where age old rainwater harvesting has been in practice. The islanders of this difficult island need to utilize coconut shell to conserve rainwater. In fair seasons. The islanders collect fresh water from the perennial Ponda nallah occurs in the eastern edge of Teresa Island. During 1985-90 four rooftop rainwater harvesting tanks were constructed in the islands (Fig-5.2.5.1). In 2004 roof top rainwater harvesting and recharge studies well carried out solve the drinking water problem. The pilot project was proposed to be constructed near the presently devastated village of Raiheon. Since the Island was devastated by tsunami and islanders were evacuated, the project was dropped. The islanders have returned back subsequently.

Fig- 5.2.5.1 One of the roof top rainwater Harvesting tanks in Chowra island

Fig-5.2.6.1 Mighty spring in Ophiolite in Ponda area,Teressa

5.2.6 TERESSA ISLAND: This island is having a geographical area of 101.26 sq. km(Fig- 5.2.1). Even prior to the Tsunami the connectivity to the island through navigation was not up to the marks while in the aftermath of devastating tsunami and earthquake one could only reach the islands taking the hell of small motor boats after descending from inter islands ships or speed boats . However, inter islands helicopters services are plying to the island once in a week or so. Geologically the islands are underlain by coralline limestone, volcanic pillow lava and Ultramafic of Ophiolite suite, marine sedimentary group of rocks. Ophiolitic formations are cropping out in the north ,north-eastern (in the hilly land north of Bengali village) and south western parts (the upland of Bengali Village)of the island. Consequently these formations are yielding perennial springs at higher altitudes which may be tapped for the drinking water supply and irrigation(Fig-5.2.6.1) .Coralline limestone formations are also very much potential ground water bearing formation generally occur along the coast as also upto 250 meters from coast in a stretch from Bengali to Minuke new settlement area. Good springs are also developed in this formation .The underground spring in such formation near Kalasi village is remarkable. The spring fed stream in Minuke village in the sedimentaries which are reportedly carrying at least nominal flow even during the lean period. However, in the streams nearby the present Allurong camp, good amount of pebbles and gravels are deposited and the streams are also reportedly perennial in nature. Hence the stream close to the village in needed to be tapped through construction of check dams and subsurface dam with a

well to yield sustainable drinking water .the coastal parts of the island was inundated by tsunami and fissures were developed in the coralline formations during the earthquake on 26.12.2004 which had affected the quality of groundwater .Till date in many places, the quality is not improving .however, at places as in kalasi the quality is improved after dewatering. The hydrogcohgical situation which is currently available in Teressa indicate that, in the coastal area, well may be constructed close to the area where the slope from upland breaks and the studies carried out by CGWB revealed that on an average the depth of the well should be restricted to 4.0meters below ground level while in the upland areas wells of 6to 8 meters depth may be constructed . Low duty pumps are recommended for coastal areas where as medium duty pumps (3.5 to 5Hp) may be installed in the upper areas.

5.2.7 Bampooka Island: The island(Fig-5.2.1) is having a geographical area of 13.46 sq, km. It is underlain by the Pillow lava(volcanic) of Ophiolite suite which is flanked by coralline Limestone in the lowlying coastal tracts. Good springs are formed in this volcanic rocks while the coastal coralline formations are sustaining good yielding wells. The entire population was staying in the northern side of the island facing Teressa. After tsunami devastation the islanders were evacuated to Teresa and they also have returned like Chowrans.

5.2.8 Trinket island: Total geographical area of the island 36.26 Sq, km. This is one of the highly devastated islands in Nicobar district. The ground water availability system of the island was good. The island is underlain by sedimentaries (i.e. Mud stone,Silt stone and clay stone of Nicobar Group) while the coastal parts are occupied by coralline formations. Although coralline formations yields good amount of ground water through dug wells, Mud stones-Silt stones are very poor water yielders like Mithkhari Formation. The islanders were evacuated to Kamorta island and they are staying in the permanent shelters in Vikash Nagar village of Kamorta island.

5.2.9 Kondul and Pulomillo Island: These are the tiny islands in the north of Great Nicobar island. Geographical area of islands were 4.66 sq.km. and 1.29 sq, km prior to the tsunami devastation. The islands are underlain by MudStone and Silt Stone formations flanked by coralline formations, which use to facilitate construction of water yielding wells. These islanders were evacuated to Great Nicobar (Campbell Bay) and they were staying in the primary and Intermediate shelters in Rajiv Nagar camp at Campbell bay. After construction of permanent shelters they have returned back to their islands.

5.2.10 Little nicobar island: The geographical area of the island is 159.02 sq, km.. The island is underlain by Clay stones mud stone, siltstone which are surrounded by coralline formations. Akin to other islands, the coralline formations are sustainable source of supplying good amount of ground water. These islanders were evacuated to Great Nicobar (Campbell Bay) and they were staying in the primary and Intermediate shelters in Rajiv Nagar camp at Campbell bay. After construction of permanent shelters they have returned back to their islands.

5.2.11 Great Nicobar Island: Great Nicobar is the island is situated in the southern most end of Indian Subcontinent and occupying a geographical area of 1044.54 Sq.Km. Physiography , high rainfall and geology facilitates formation of highly perennial drainage system which sustains significant flow through out the year. However after the current tsunami and devastating earth quake the area has been hit hard for being very close to the epicenter at Banda Aech in Sumatra. The island is underlain by sandstone,silt stone,shale,conglomerate of Mithakhari Group and does not favour good potential of groundwater both in the shallow and the deeper horizon. Because of this the groundwater exploration carried out in the island was not successful. However, coralline formations are available in the coastal area which sustain good groundwater in wells. However, with the subsidence of land to the tune of 1.8 to 2.5m salinity ingress in subsurface is noticed.

5.3 Impact of tsunami and Earthquake on groundwater resources in the islands: The mega earthquake (M=9.3) and the killer tsunami on 26.12.04 have made significant impact (Fig-5.3.1) on the fresh water resources especially groundwater of Nicobar islands. The earthquake had developed deep-seated fractures in the earth while the pressure exerted by the propagating tsunami on the aquifer had created several unusual phenomenona whose case studies are not abundant in the literature. Along the fractures free flowing water came to the surface. Along the valleys at places along with sand and mud, new mud volcanoes generated with intermittent emanation of mud slurry slaked with saline water. Pressure fountain was generated at Car Nicobar, just before the arrival of tsunami waves. The entire Nicobar district was subsided which caused natural ingress of seawater(Fig-5.3.2&Fig-5.3.3). The tsunami waves of height varying from 3.5m to 10.5m also contaminated the water resources in the low-lying coastal areas of the affected islands. The tsunami waves devastated the coastal tracts claimed lot of areas which was mostly underlain by Coralline Limestones and had good potential

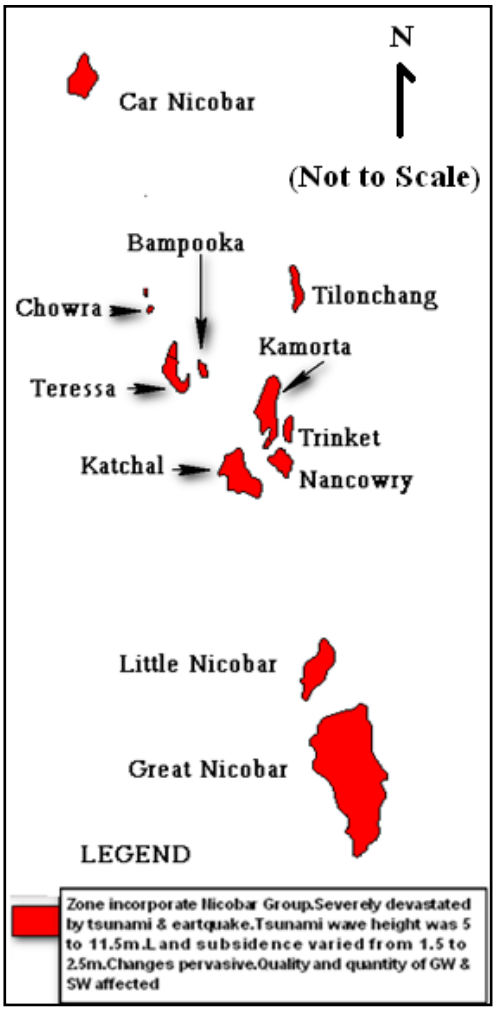


Fig- 5.3.1 Tsunami and Earthquake in Nicobar district

for ground water. Such areas are available in the entire coast lines of Great Nicobar,Little Nicobar,Kondul, Pilo Millo,Teressa,Nancowry,Katchal etc. which are mostly submerged under sea water. Tsunami wave also contaminated the fresh water yielding wells.In many areas along the coastline due to land subsidence the tide has ingressed and the the saline fresh water front and thickness of freshwater lens in the subsurface has been reduced. As for example the main supply

well of APWD at Campbell Bay behind the stadium adjacent to the filter bed which was formerly fresh had become saline after the tsunami as also the supply well of MES near Navy Air Port.Both the wells were completely emptied after the tsunami on 27.12.04 with sludge pump by MES.The result shows that the APWD well was only yielding brackish water with EC 11000 Ms/cm even after pumping while the Navy well revived to fresh (EC-870 Ms/cm).The observation was made by CGWB on 2.1.05. Subsequently the salinity in MES well was increased. Finally the Electrical conductivity of groundwater in the coastal areas were stabilised at higher values(3500-4000 MS/Cm) .The tsunami wave also had destroyed a significant landmass in the coastal tract of few highly affected islands, which is supposed to make a significant reduction in the fresh water volume as conjectured by the study carried out by CGWB (Kar,2008,2010) and also opined by the International Ground water resources assessment centre (IGRAC).The study conducted by CGWB has revealed that the qualitative changes, i.e. the ground water salinity, are not fully obliterated and the brackishness still persist at places. The expected depth wise reduction has warranted very cautious development of ground water and to some extent handicapping the ground water resources development in the Post tsunami. Continuous qualitative monitoring is required to be undertaken for sustainable development of groundwater in these disaster prone and ecologically fragile islands.Besides the qualitative degradation, the colossal earthquake made significant changes in the quantitiavte availability of ground water at various topographic locales.

The following salient observations were noticed

- On 26.12.2004 during the earthquake free flow on the ground surface was observed in Carnicobar
- Cracks were generated in the aquifers which are cropping our in the surface.
- Field studies by various land survey Departments as also the field observations reveal that all the islands in Nicobar district are suffered from land subsidenc evident from permanent saline water ingress.
- The reported range in subsidence vary from 1.8 to 2.5 meter
- The low lying areas in the Nicobar District were devastated by Tsunami waves whose height varied from 3.5 meters to 11.5m. These waves contaminated the ponds, wells and all fresh water bodies along the Coast.

Fig- 5.3.2 Sea water ingress in Teressa

Fig- 5.3.3 Sea water ingress in Great Nicobar

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- After Tsunami at various places in the affected islands, the contaminated wells were pumped out. At many places pumping was done cyclically. Following observations **were** noted.
    - ❖ In many areas during the first phase the wells showed positive result (i.e gradual decrease in salinity). However, after wards it started showing increase in salinity.

- In many places the salinity did not change at all even after evacuation or repeated pumping.
- At places the wells become naturally flushed without pumping.
- At places they are still low brackish.
- From the above observation it may be opined that continuous monitoring should be undertaken for successful construction, proper design and site selection of the water development structures as also the change in sea level due to global sea level rise.

Depending upon the hydrogeological, situation and terrain and aquifer condition the following structures in different Islands are recommended.The various types of structures which are required Nicobar district to conserve recharge and exploitation of ground water and rain water are :

1. Ponds 2. Check dams, 3. Sub surface dams, 4. Recharge shaft, 5. Intake wells 6. Collector wells with infiltration gallery, 7. Lift irrigation points , 8. Roof top rain water harvesting and recharge 9. Dykes along the coast to stop salinity ingress and land reclamation

From the extensive studies carried out by CGWB from 2000-2004(Pre-Tsunami) as also in Post Tsunami in the entire Andaman and Nicobar Islands in general and South Andaman district in particular had been extensively utilised for rain water harvesting, conservation of surplus run-off and other watershed management practices with the structures.

5.4 Vulnerability of the Island with reference to Disaster

Barring the hilly parts of Nicobar district especially in Great Nicobar island , the islands or portion of the islands having relief is within 10m above mean sea level are susceptible to Tsunami devastation. However, land subsidence to the tune of 1.8-2.5m in considerable part of Nicobar district was responsible for a natural sea water ingress. Beside tsunami, Nicobar islands are also vulnerable for earthquake because of its localisation in a highly tectonically active zone(Zone-V). Sea waves generated from cyclonic storm may also invade the islands any time. However, there is no past record of devastating cyclone or sea wave of any kind hitting the island.

5.4.1 Epidemics

Mosquito borne diseases like malaria, filaria , Chikengunia are very common in Nicobar group of Islands. In Chowra filaria is a prevalent disease.Due to the land subsidence, and woozing out of fresh water in the lowlying areas after the tsunami , the malarial fever broke out in Car Nicobar island in the form of epidemics.

5.4.2 Tsunami & Earth Quake

Beside,the devastating Indian Ocean tsunami of 26.12.04, past record reveals that atleast Once in the past tsunami was experienced in the Nicobar district. This was recorded in 1881. This tsunami was also generated due to earthquake having epicentre in the deep sea. Earth quake with intensity below 5.0 in richter scale is a very common phenomena in the district as the islands are situated in the plate collision zone as also falling in Zone-V. Such tremors are harmless . However, severe rocking with tremor above 5.0 is are also recorded.

6.0 Ground Water Exploration:

Central Ground Water Board carried out ground water exploration in Andaman and Nicobar islands from 1985 to 1994 during which 47 exploratory wells had been drilled. Of these, 9 were constructed in Great Nicobar, 3 in Nancowry and 4 were in Katchal. It is concluded from the exploration data that, there is no potential water bearing formation occurs in the subsurface of Great Nicobar,Katchal and Nancowry. All the explorations were unproductive. The quality of water in deeper aquifer deteriorates, probably due to contamination with the saline water . In Kamorta island the discharge wvaries from 0.5 to 1.0 m^3/hr.

7.0 Ground Water Resources: As per the GEC 1997 norm the watershed or administrative unit could not be applied here since the islands are discrete and separated by sea. There are 11 Islands in Nicobar district which are inhabited; hence the ground water resources of these Islands are taken into consideration(Table -7.2). During computation the intermontane valleys and relatively flat topographical areas were considered as recharge areas. The hilly areas having slope more than 20% are deducted from the geographical area available in the inhabited islands. The water level data of all the islands were not available. Hence the rainfall Infiltration method was adopted for resource estimation. Base flow of ground water through streams as also the outflow from springs were also noticed, and the discharges were computed and added to ground water draft. The estimated resources of the A&N Islands as calculated in 2004 and in 2008-09 showed some reduction in the ground water resources in the Post tsunami(2008-09) in comparison to the Pre-tsunami data(2004).

7.1 Reasons for departure of Groundwater Resources from earlier estimate: The loss in surface area in some of the highly earthquake and tsunami devastated islands have made possible changes in freshwater volume in the islands of Nicobar district(Table-7.1). This has been reflected in the ground water assessment. It's important to note that parts of the Andaman group of islands and the entire Nicobar group of islands were subsided during the plate collision and submerged. Hence net availability of fresh ground water resources have been decreased in comparison to the values obtained in previous ground water resource estimation in the islands in 2004 during Pre-tsunami. Domestic draft includes spring discharge and withdrawal from dugwells.

8.0 Ground Water Quality: The quality of ground water in Nicobar district is fresh barring few parts and it's varying from neutral to alkaline. Chemical analysis data of water samples(dug wells) from Pre-and Post-tsunami surveys and investigations reveal that the groundwater is generally calcium bicarbonate and Sodium bicarbonate type, and the bicarbonate content varies from 85 to 453 ppm greatly predominates over the chloride content varying between 78 to 223 ppm. Detailed studies carried out by CGWB(Kar,2006,Kar et al,2008&2010) indicates that the there has been qualitative deterioration in the ground water quality in parts of the subsided and tsunami devastated islands of Nicobar district.

Table-7.1 : Island wise Damaged Area Due To Tsunami/ Earthquake

Island	Paddy and other field crops (in ha.)			Plantation crops (in ha.)			No. of affected Farmers
	Submerged Area	**Reclaimable area**	**Total Damaged Area**	**Submerged Area**	**Reclaimable area**	**Total Damaged Area**	
Car Nicobar	00	00	00	213.12	756.23	969.35	2378
Kamorta	00	00	00	527.27	110.13	637.40	341
Nancowry	00	00	00	244.02	12.55	256.57	257
Trinket	00	00	00	288.50	40.00	328.50	140
Teressa	00	00	00	342.52	401.44	743.96	268
Chowra	00	00	00	57.80	172.60	230.40	340
Bambooka	00	00	00	20.00	9.55	29.55	15
Katchal	00	00	00	331.25	1297.25	1628.50	317
Great Nicobar	00	00	00	668.86	109.92	778.78	525
Total	**00**	**00**	**00**	**2693.34**	**2909.67**	**5603.01**	**4581**

Source: Rajiv Gandhi Rehabilitaion Project for Agriculture,A&N Admn.,Portblair

Table – 7.2: Groundwater resources estimated in 2008-09

Comparative Criteria	*Resource Assessment 2008-09 (in ham)*
Net annual ground water availability	10421.11 Hectare metre
Ground Water Draft for drinking purposes	144.20 Hectare metre
Stage of Ground Water development	1.56%
Categorization for future ground water development	Safe

The pre tsunami data also revealed the absence of any toxic element present barring presence of high iron in the range of 0.58 to 5.78 ppm which could be seen at places in deeper aquifers as seen in the analytical data of the exploratory wells.

8.1 Qualitative changes in Pre and Post tsunami in Nicobar Group of Islands: Previously it has been repeatedly mentioned that the entire Nicobar Group of islands were severly devatated and subsided during the tsunami and Plate collision on 26.12.04. Considerable loss in rechargeable land resources has resulted in deterioration in the chemical quality as also deline in the freshwater resources. The piper plot of chemical data**(Fig-8.1.1,8.1.2 & 8.1.3)** obtained from the islands have clearly focussed the change in quality of ground water data from Pre to Post tsunami.

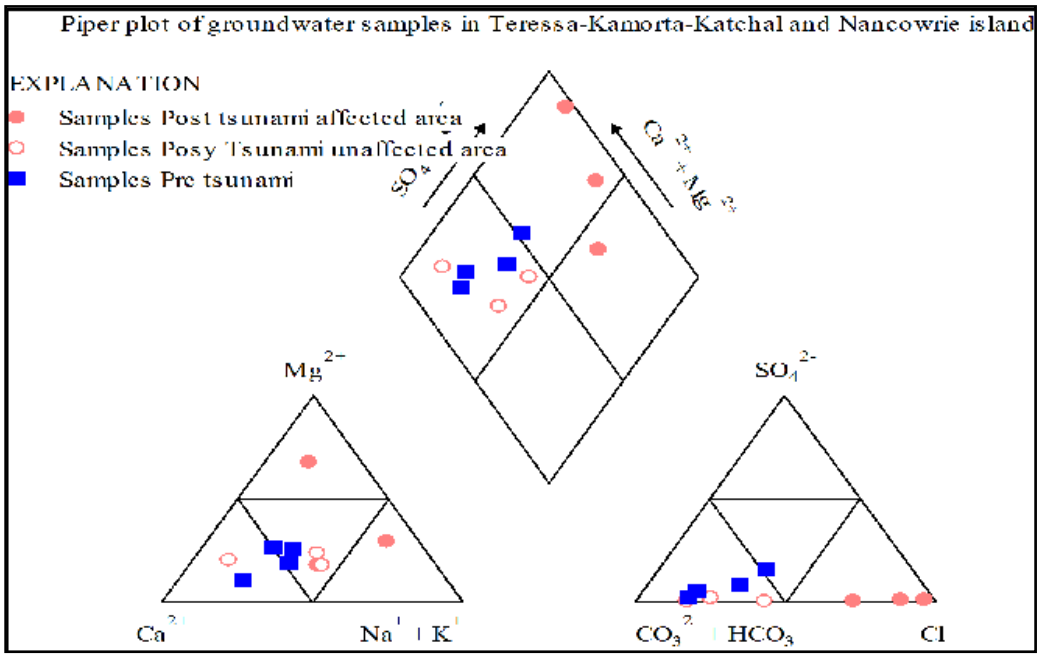

Fig-8.1,1 Piper plot of water samples in Pre & Post tsunami from Teressa-Kamorta-Katchal& Nancowry Island

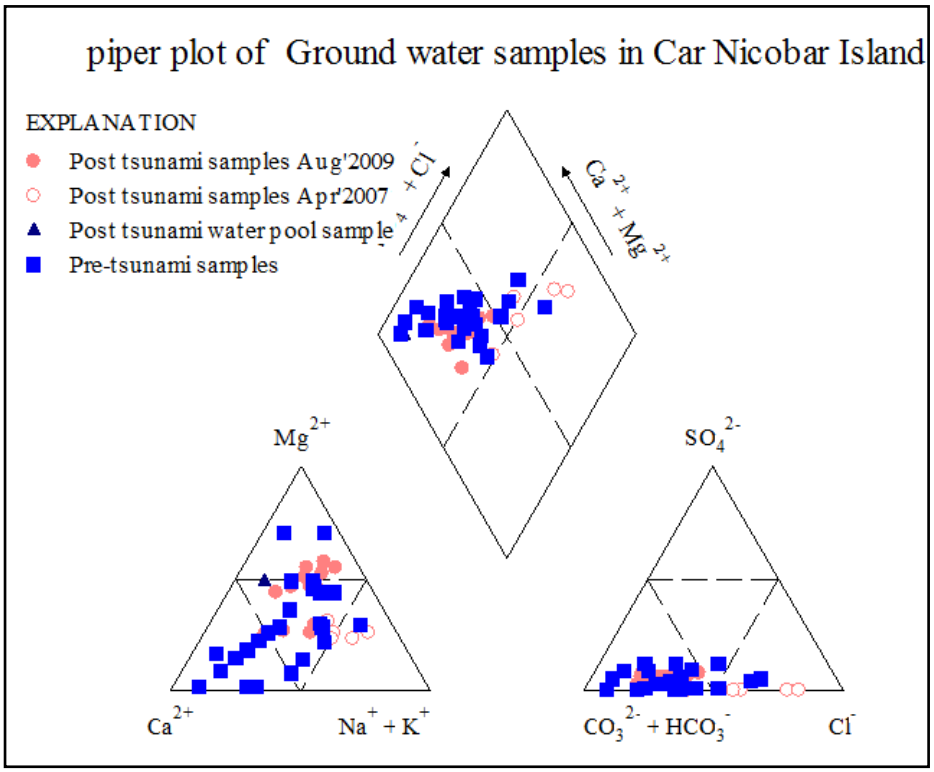

Fig-14.1.1 Piper plot of water samples in Pre & Post tsunami & Post Tsunami from Car Nicobar Is.

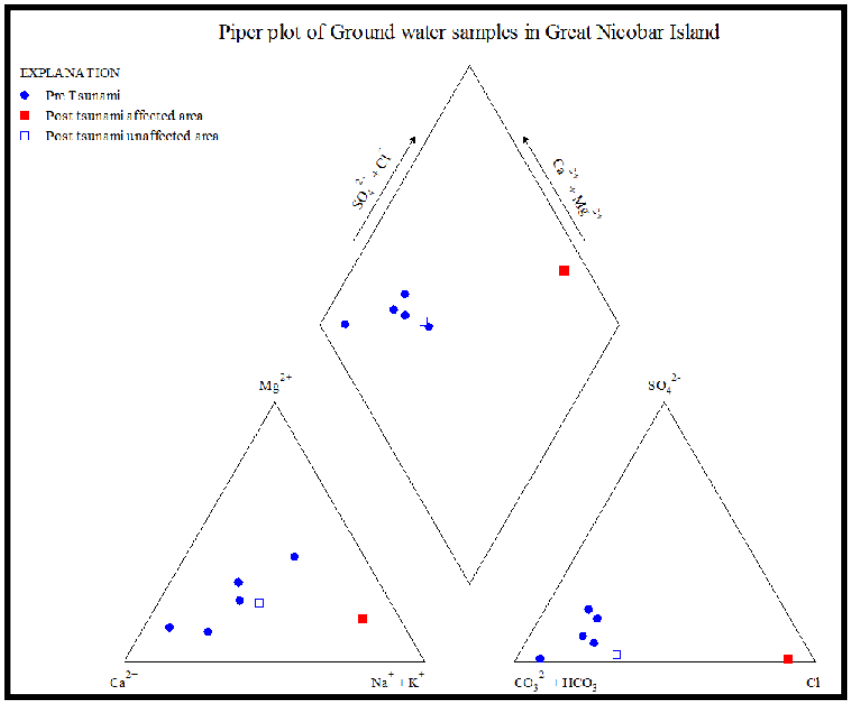

Fig-8.1.3 Piper plot of water samples in Pre& Post Tsunami from Great Nicobar Island

8.2 Water quality behaviour with reference to rainfall

Ground water quality behaviour near by the coast always gets changed during rainy season. Especially in the shallow aquifer the change could be observed soon after the rainfall. In Chowra island where fresh groundwater is unavailable, the quality of groundwater gets changed even to fresh in the low lying areas after rainfall. However, it vanishes with prolonged non-rainy condition.

9.0 GROUND WATER MANAGEMENT STRATEGY

9.1 Major Groundwater related problem

It is already mentioned that the geologic formations in many parts of Nicobar District are highly varied and major parts are occupied by impervious sedimentary rocks (Fig-5.2.1) where ground water development possibility is in the low key. These rocks are unfit for construction of borewells/tubewells. Dugwells are feasible in such formations but yield is restricted. A dug well of 5-6 m diameter and 6m depth can only yield 4000-5000 litres per day. However in select locations especially near the drainage it may discharge in much higher tune. In Teressa,Bompooka,Tillonchang and in parts of Kamorta and Nancowry where igneous rocks are available, in those areas bore wells can be drilled.Chowra island is specifically having problem with fresh water because of various hydrologic and geomorphic reasons. However, Car Nicobar forms a bonanza of groundwater resources where groundwater may be obtained from shallow and porous Coralline limestone Formations through dug wells. During Pre tsunami there was no problem with quality of groundwater , which is slightly deteriorated in the post-tsunami at least in the low lying coastal areas in the west.

9.2 Feasibility of Rainwater and artificial recharge: While the impervious sedimentary formations are unfit for groundwater development, these formations are highly suitable for construction of ponds and check

dams especially in the valleys and topographic lows where it get both ground water through baseflow and act as also as a very good rainwater harvesting structure. Consequently the low-lying areas as opined by CGWB(Kar,2003,2005,2006,2007) can be developed for construction of ponds and check dams. Artificial recharge techniques also could be applied only in small pockets which were advocated by CGWB(Kar,2001,2003).

9.3 Groundwater management problems in the post tsunami

There have been significant changes in groundwater resources of Nicobar islands in the post-tsunami. Both the mega earthquake (M=9.3) and the Killer tsunami on 26.12.04 were responsible for many changes in the availability and quality of groundwater. The tsunami waves of height varying from 3.0 m to 10.5m had contaminated the water resources in the low-lying coastal areas of the affected islands(Fig-10.1a). Subsidence of land in significant portion of the islands and massive destruction of landmass has been caused in few of the highly affected islands. These had caused significant reduction in the fresh water volume as conjectured by the CGWB study as also opined by the International Ground water resources assessment centre (IGRAC). In this regard the models as developed by CGWB, are perfectly matching with the model of IGRAC. Study has revealed that the qualitative changes are not fully obliterated and it still persists at places. The expected depth wise reduction in freshwater has warranted very cautious development of ground water resources in the Nicobar district in the Post tsunami. Consequently with the expected rise in sea level, the coastal aquifers are likely to be stressed further and they are likely to be further endangered.

10. Recommendations

Large scale rainwater harvesting in the watersheds, more and more saline area reclamation and construction of subsurface dams and check dams in the estuarine streams would improve the scenario.

Close qualitative monitoring should be continued for future management of groundwater resources in these disaster prone and ecologically fragile islands.

Owing to the above qualitative deteriorations in the aquifers, problems are being faced for development of ground water resources in the tsunami affected islands. This had significantly jeopardized the rehabilitation measures especially the drinking water supply in the affected islands in the Southern Group (Nicobar District).

a

b

Fig- 10.1 a. Tsunami destroyed and contaminated well inside IAF campus, Carnicobar, b- New dug well under construction at Kakana, Car Nicobar, Water supply was delayed in view of qualitative sustainability

It is to be mentioned that the tribal population in Nicobar Group of Islands used to stay traditionally in the coastal areas, underlain by porous Coralline Limestone Formations, where plenty of ground water was available from dug wells without any quality deterioration in the Pre tsunami. Particularly the depth criteria, maximum availability, and future sustainability are the main concern for them in the changed scenario. Especially in the islands like Car Nicobar and Campbell Bay (Great Nicobar) where ground water availability situation and quality were excellent in the pre-tsunami, there now it's a problem to extract water in abundance from the old sources as before and there was apprehension for the new sources (Fig-10.1 b). This is a clear threat to the environment in matters of future development of ground water in the islands for its optimum development . Now in view of the anticipated sea level rise, the coastal aquifers in the islands appear to be more vulnerable in the forthcoming period. Hence the water user Departments in the islands should go for: -

I. A cautious development in view of the future sustainability.
II. The ground water development surveillance system with quality monitoring for time-to-time detailed assessment should be built up forthwith by the A&N Administration in consultation with CGWB to monitor the situation.
III. To augment the fresh water resources as also to reduce the salinity ingress, large scale rainwater harvesting in the watershed, saline reclamation bunds, tidal bar in the estuarine streems with sub surface dyke would be highly beneficial as observed by the USGS in Atlantic coast (Barlow, 2000), which have been already advocated in the islands (Kar, 2003,2006c).

Soon after disaster at the behest of Govt. of India, the A&N administration had taken up Rajiv Gandhi Rehabilitation Project for Agriculture where ground water development and rainwater harvesting was a very important component. In this regard based upon the the post-tsunami research studies carried out by CGWB (Kar,2006) in liaison with the agriculture dept. ,A&N administration and the post tsunami terrain condition, the modified target of implementation structures were formulated, which are enumerated below and the developmental activities were continued till 2010-11.

From the foregoing discussion it is clear that there has been some qualitative and quantitative changes taken place particularly in the ground water resources in the islands. field observation carried out by the author reveals that with the destruction of coast line by the tsunami, subsidence and progression of tidal line towards coast has caused sea water ingress both in the surface and subsurface . because of this problem it appears that the former thickness of fresh water resources has been reduced, which has caused the changes in quality as being observed in the monitoring wells spread all over the islands. the observations are spectacularly matching with the models and observations made by the International ground water resources management center (IGRAC,2006). For this reason a problem in development of the drinking water supply sources in the islands is being faced by APWD, A&N Administration, especially the depth criteria, availability and future sustainability is the main concern for them in the changed scenario. In the islands like Car Nicobar, Campbell Bay(Great Nicobar) where ground water availability was not at all a problem in the pre-tsunami, there now it's a problem to extract water in abundance as before from the new sources. However, based upon detailed studies and prevailing hydro

geological situation and terrain and aquifer conditions of the islands, the following structures are recommended in the post-tsunami to conserve, recharge and exploitation of ground water and rain water:

1. Ponds 2. Check dams, 3. Sub surface dams/dykes, 4. Recharge shaft/pits/wells , 5. Intake wells 6. Collector wells with infiltration gallery, 7. Lift irrigation points, 8. Roof top rain water harvesting and recharge.