केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

In Diu District, UT of DNH Daman and Diu

पश्चिम मध्य क्षेत्र, गुजरात

West Central Region, Gujarat

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास एवम् गंगा संरक्षण विभाग
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GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT
AND
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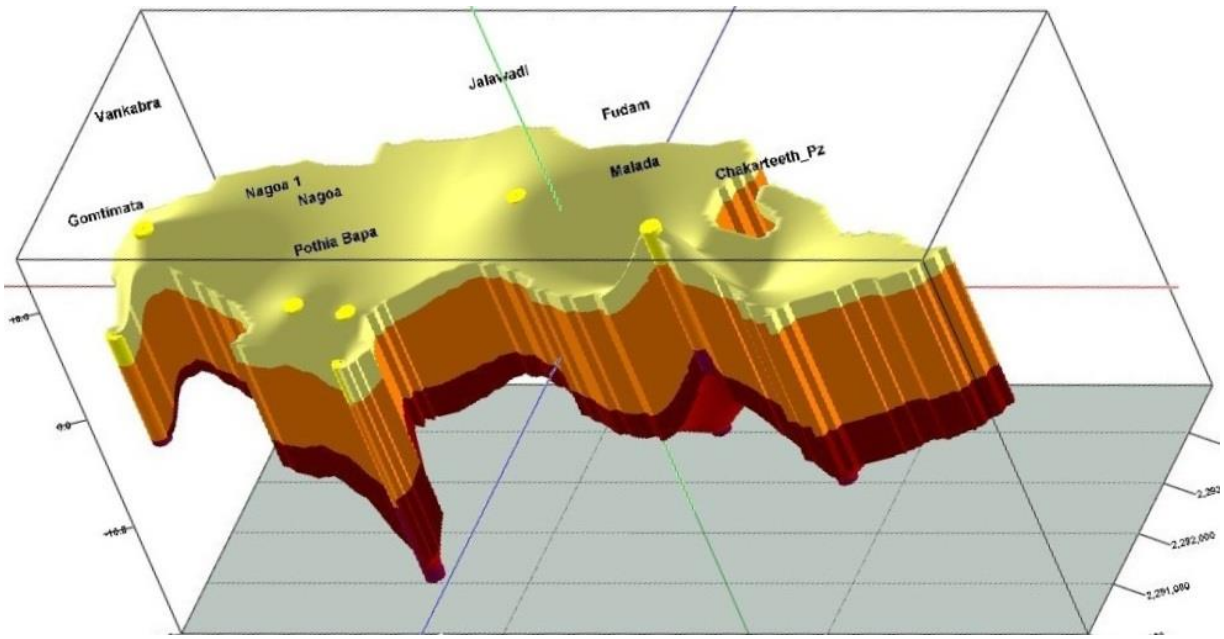
AQUIFER MAPPING AND MANAGEMENT PLAN OF DIU DISTRICT, UT OF DNH, DAMAN AND DIU



CENTRAL GROUND WATER BOARD
WEST CENTRAL REGION
GUJARAT
JULY-2022

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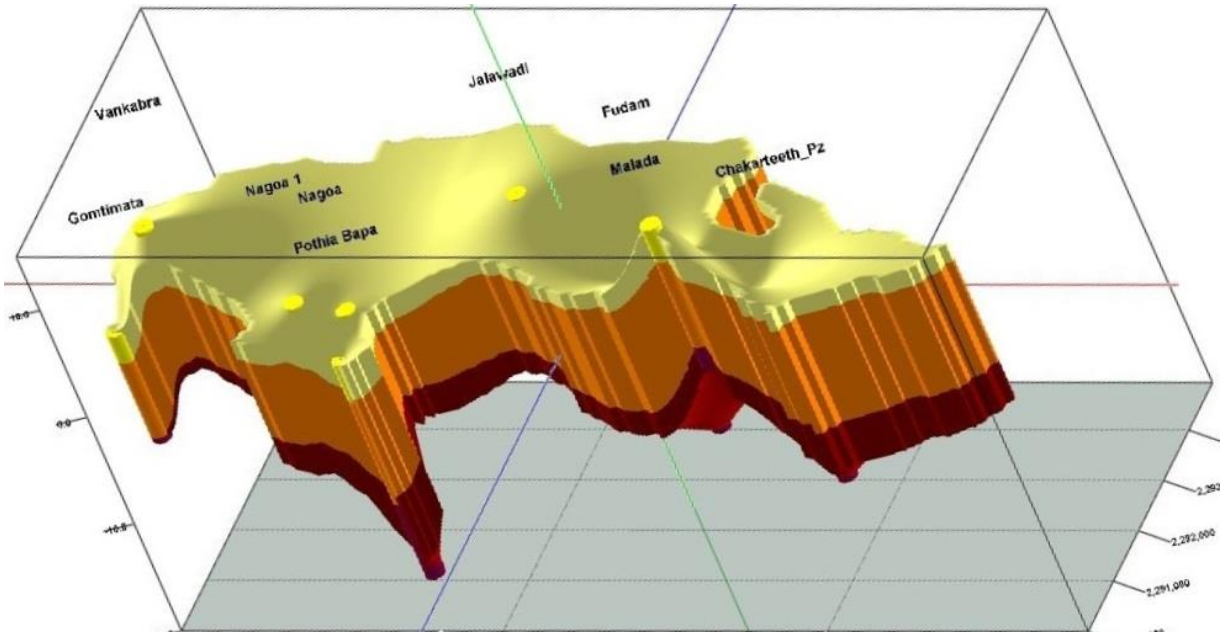

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Senior Technical Assistant (HG)

CENTRAL GROUND WATER BOARD
WEST CENTRAL REGION
GUJARAT
JULY-2022

Report on
AQUIFER MAPPING AND MANAGEMENT PLAN of UT OF DIU

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1. INTRODUCTION

Diu district is an island on southern portion of Gujarat Peninsula. It is joined with Una Taluka of Gujarat State by two bridges over a sea creek. Diu district is situated on western coast of India at a distance of about 700 km from UT head quarter Daman.

UT of Diu is a completely isolated island from mainland Gujarat by an east-west extending marshy low land which remains covered by the tidal waters of the Arabian Sea. Diu is situated between North latitudes 20°41'53.66"N & 20°44'47.89"N and East longitudes 70°52'31.02"E & 71°0'51.25"E and falls in Survey of India Toposheet No. 41 L/14. It covers an area of 40 sq. km with 19.2 km length and width varying from 1 to 2.5 km. The UT of Diu is bounded on the east; west and north side by Gir Somnath district, whereas Southern boundary is the Arabian Sea with its partly rocky and partly sandy shore (Fig. 1).

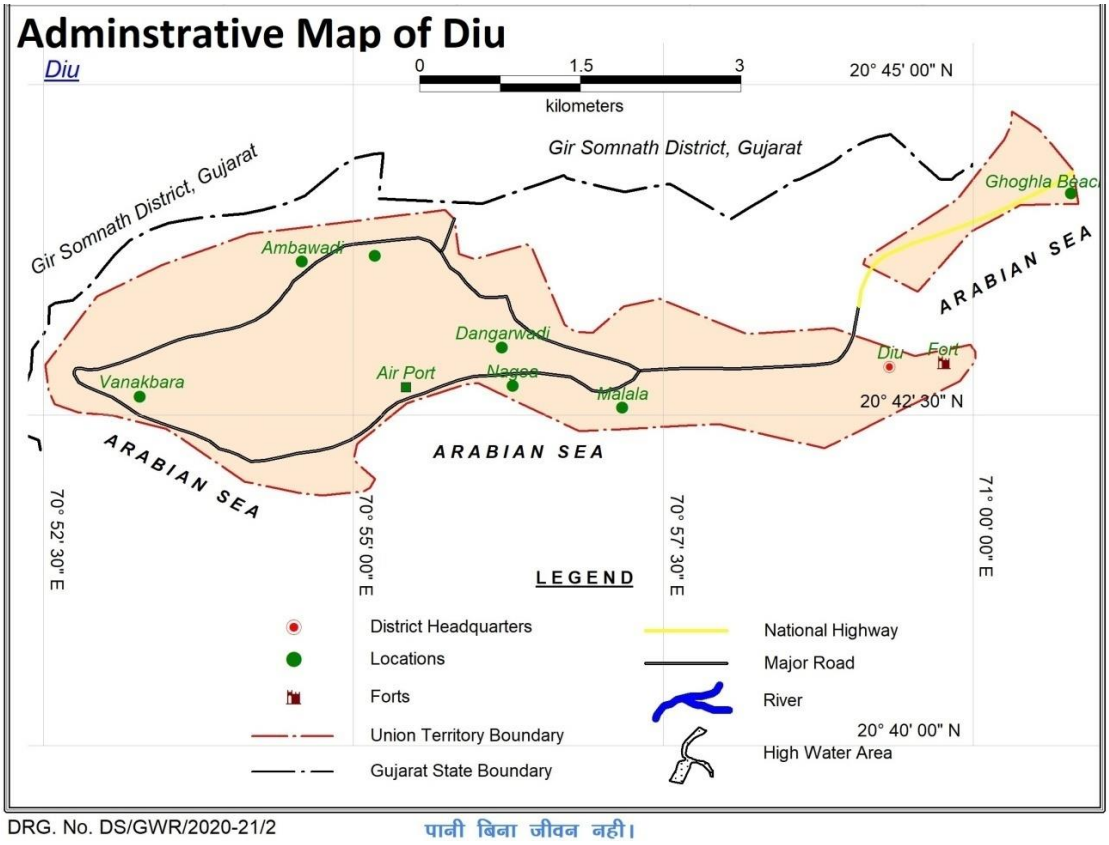

Figure 1- Administrative Map of Diu

TABLE 1- GENERAL INFORMATION

General Information		
Sr No	Parameters	Diu
1	Area (KM)	40
2	Population (Census-2011)	52074
3	Population Density (Per KM)	1302
4	Villages (Nos.)	4
5	Industrial Unit (Nos.)	19
6	Total Agricultural Land (Ha)	597
7	Cultivable Land (Ha)	543
8	Main Crop	Bajra

1.1 DEMOGRAPHY

The total population of the Diu district as per 2011 census is 52,074, which include 25642 male and 26432 female. The sex ratio is about 1110 Women per 1000 men. The rural population is 28083 and urban population is 23991.

Population(Census) growth for Diu		
Census	**Population**	**%±**
1951	49,000	—
1961	37,000	−24.5%
1971	63,000	70.30%
1981	79,000	25.40%
1991	102,000	29.10%
2001	158,204	54.90%
2011	243,247	53.78%

1.2 GEOMORPHOLOGY AND SOIL TYPE

There is a central high land made up of sand dune and sloping in all the direction and the reduced level comes to around 2 m agl along the coast.

Up to almost a kilometre from the coast, the soils are saline and alkaline with higher percentage of silt. These are formed due to degeneration of coastal soils by salinity ingress. These soils slowly grade into yellowish brown calcareous soils which contain admixture of medium to coarse grained material comprising Miliolite shell pieces. They range in thickness from 0.3 to 1 m. in low lying areas, accumulation of organic material coupled with intense weathering, have given rise to black cotton soil covers varying from few cm to nearly a metre in thickness. The blown sand deposits, on the central high land, are essentially weathered products of the friable Miliolitic limestone and are thus highly calcareous.

1.3 RAINFALL:

The rainfall occurs during the southwest monsoon, starting from June and extending up to September. The rainfall is inconsistent, with average annual rainfall 598.60mm in 34 rainy days. The long term average annual rainfall is 664.04 mm. Long term monthly means of annual rainfall distribution shows that over 90 % of the rainfall occur occurs from mid June to mid-September due to southwest monsoon and associated intense low-pressure system. The rainfall characteristics have a strong impact on the groundwater level and quality.

Table 2- RAINFALL (MM) IN UT OF DIU

Rainfall (mm)	
Year	Diu
2012-13	635
2013-14	919
2014-15	1072
2015-16	642
2016-17	1031
2017-18	939
2018-19	950
2019-20	1100
2020-21	1136

1.4 CLIMATIC CONDTION

Diu being an island enjoys a maritime climate, with the constant sea breezes affecting its temperature. With a plain topography, the weather remains dry, though pleasant throughout the year. During summers, the climate in Diu ranges between a maximum of 36°C and a minimum of 20°C. However, during winters, it comes down to a maximum of 26°C and the minimum temperature remains about 20°C.

The relative humidity in the nearby Veraval as per IMD varies between 55.5% January and 87.5% during August. The wind velocity in the Veraval varies from about 205 km/d during November to about 561 km/d during July.

The potential Evapo-transpiration, calculated using Penman's Method varies between 3.7 mm/d during August and 6.0 mm/d during April. The nearest station is situated in Veraval district Junagadh (20°54' N: 70 22' E- Altitude 8.0 m amsl) and its detail is given table-4 and shown in Fig. 3.

Table 3- Climatological data for IMD station Veraval

Month	Max Temp (°C)	Mini Temp (°C)	Humidity (%)	Wind Spd. Kmpd	Sunshine (Hours)	Solar Rad. (MJ/m2/d)	Eto (mm/ month)
January	28.8	14	55.5	242.4	9.7	18.5	4.8
February	29.7	15.1	63.5	258.3	10.3	21.3	5.2
March	31.5	18.5	70	291.9	9.9	23	5.8
April	32	21.8	76	318.4	10.5	25.4	6
May	31.8	25.5	81	337.9	10.3	25.5	5.8
June	31.6	27.1	83.5	447.6	7.4	21	5.1
July	30.1	26.1	87	560.8	4	15.8	3.9
August	29.2	25.3	87.5	465.2	4.3	16	3.7
September	30.3	24.4	83.5	311.3	6.2	18	4.2
October	33.3	22	73.5	226.4	9.4	20.8	5.2
November	33.1	19.1	61.5	205.2	9.7	18.9	5
December	30.4	15.9	56.5	217.6	9.5	17.5	4.6
Average	31	21.2	73.3	323.6	8.4	20.1	4.9

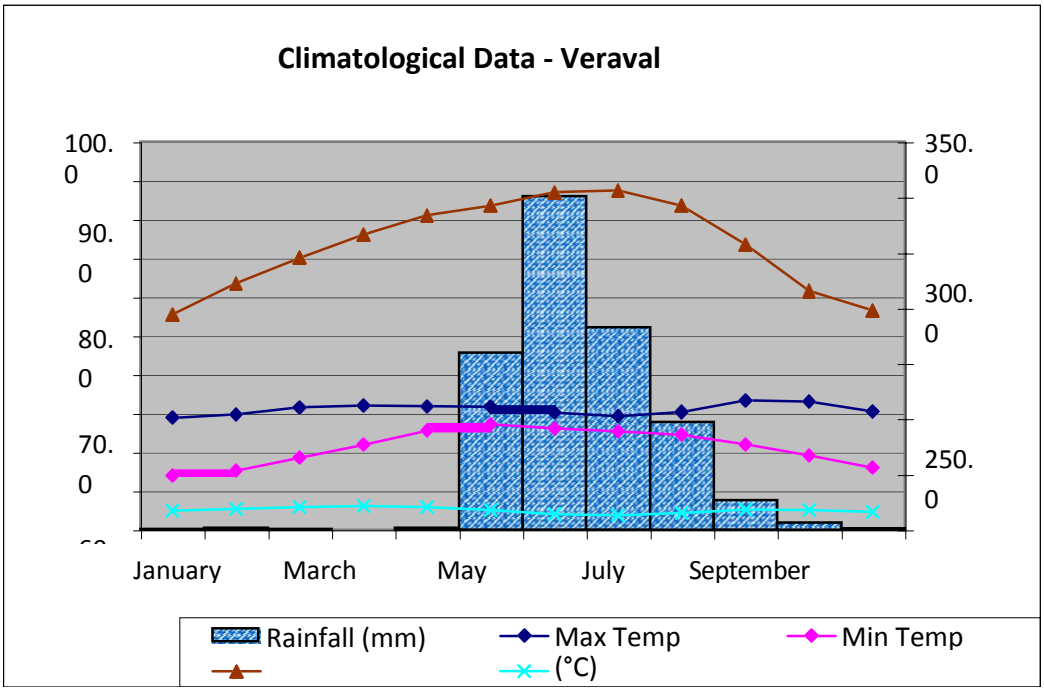

Figure 2- Pictorial Representation of Climatological Data

2. GEOLOGY

The area comprises Miliolite limestone of Pleistocene to Recent age and of about 50 m thick. It is a highly porous limestone which is friable except for the one or two layers near the ground surface, where the calcification of the limestone due to calcium carbonate solution has given rise to hard and compact crust. The Miliolite limestone is of high grade with very little contents of magnesium and insoluble. Solution activity has resulted in formation of caverns of varying dimensions. This karstic activity is more predominant in the zone of water level fluctuation and near the lower contact with the underlying clay formations. The limestones exhibits strike which is roughly parallel to sea and the dips are undulating like typical sand-dune deposits.

Miliolite limestones are underlain by Gaj formations of Miocene age. The Gaj formations comprise upper yellowish white clays underlain by interbedded marls, calcareous sandstones and grits, impure limestones and clays. The Gaj formation is found to be extending down to the explored depths of 200m. The base of Gaj Formation rests over the Deccan Trap Basalt.

The generalized geological succession in the area is given below in Table No- 6.

Table 4- STRATIGRAPHIC SEQUENCE OF DIU DISTRICT

Age	Formation	Lithology	Max. thickness/ Remarks
Recent to Pleistocene	Coastal Alluvium & Miliolite limestone	Sand, clays, Miliolite-limestone	40-50 m
Miocene (Tertiary)	Gaj beds	Clay, Marl, calc. sandstone, lime stone etc.	Not Exposed, +200 m
Upper Cretaceous to Eocene	Deccan Trap	Basaltic lava	Not exposed

3. HYDROGEOLOGY

Ground water occurs under water table condition in the Miliolite limestone. The depth to water table varies from 12 m bgl in the central high land to 3 m bgl in the area up to 1 km inland from the high tide water line. Close to salt pans or sea, the water levels are almost same as high water line levels. This suggests that the central high land is the main ground water recharge area and sub-surface flow of ground water is from the central high land to the coastal area. The seasonal fluctuation in the water table level is 2 to 5 m in the central high land but along the coastal strip, the seasonal water level fluctuations are insignificant. The yields of wells are very high (50 m^3 to 240 m^3/ day) and drawdown ranging from 0.5 to 1.25 m.

In Guj formation the ground water occurs in inter-bedded calcareous sandstones, grits and arenaceous limestones in depth. Ground water is observed in some places in confining condition with piezometric levels varying from 1.5 m to 3.0 m bgl. The quality of the water is saline in the Gaj formations, which is inherent as the deposition of Gaj formation was in marine condition. The intercalated marls and clay formations, which restrict the circulation of ground water, cause further deterioration in quality.

Pumping tests in two Dugwells (Large Diameter wells) were carried out by A.Ahmed (1980).

The results of the short duration pumping test conducted at Sarwari, near airfield and Phophrona village revealed the specific capacities of the dugwells were (as determined by Slitcher's formula) 566.39 lpm/m and 31 lpm/m respectively. The rates of infiltration were 322.8 lpm and 40.92 lpm respectively (After Ahmed, 1980). The major Aquifer system of Diu District is represented in below Figure No.3

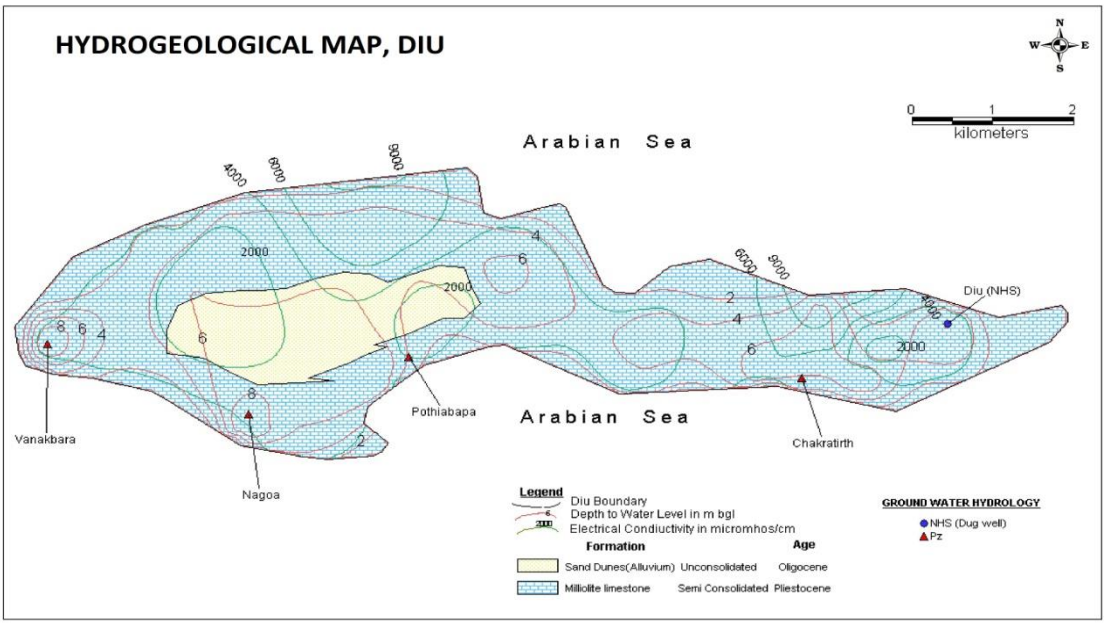

Figure 3- Major Aquifer system of DIU

3.1 AQUIFER PARAMETERS:

Aquifer parameters are available from ground water exploration carried out in the alluvium formation of the district as well as from the pumping tests carried out on wells in Miliolite Limestone.

Table 5 AQUIFER CHARACTERISTICS

Aquifer Characteristics and Disposition									
Stratigraphy	Aquifer	Lithological character	Depth of occurrence	Thickness	Water Level	TDS	Discharge	Transmissivity	Nature of Aquifer
			Aquifer (mbgl)	Range (m)	Range (m)	Mg/l	lps	m2/day	
Pleistocene	Miliolite Limestone	Sand, clays, Miliolite-limestone	0.5-20	0 to 15	3 to 9	800 to 2000	0.58 to 1.5		Phreatic

3.2 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING:

In order to establish the three-dimensional disposition of aquifer system in the area, the existing data along with established key wells of CGWB were used to prepare a hydro geological cross section, and 3D Model. The data has been analyzed using Rockworks 16 software and is presented below in the Hydro-geological cross sections A-A' to B-B' and Solid Model of the district showing the depiction of phreatic aquifer up to 20m. Map showing section lines are presented in Fig. 4. The stratigraphic sections depicting Phreatic Miliolite formations are placed at Figs 5 & 6. 3D Solid Model Diagram of Diu district is depicted in Fig. 7, respectively.

3.3 CONCEPTUALIZATION OF AQUIFER SYSTEM IN 2D AND 3D MAP:

Based on existing data along with established key wells and local ground water survey, two hydro-geological sections have been prepared along section lines shown in below figure 4 to understand the subsurface disposition of aquifer system. Also 3-D Aquifer disposition map and Fence diagram is prepared to know the aquifer geometry in the district.

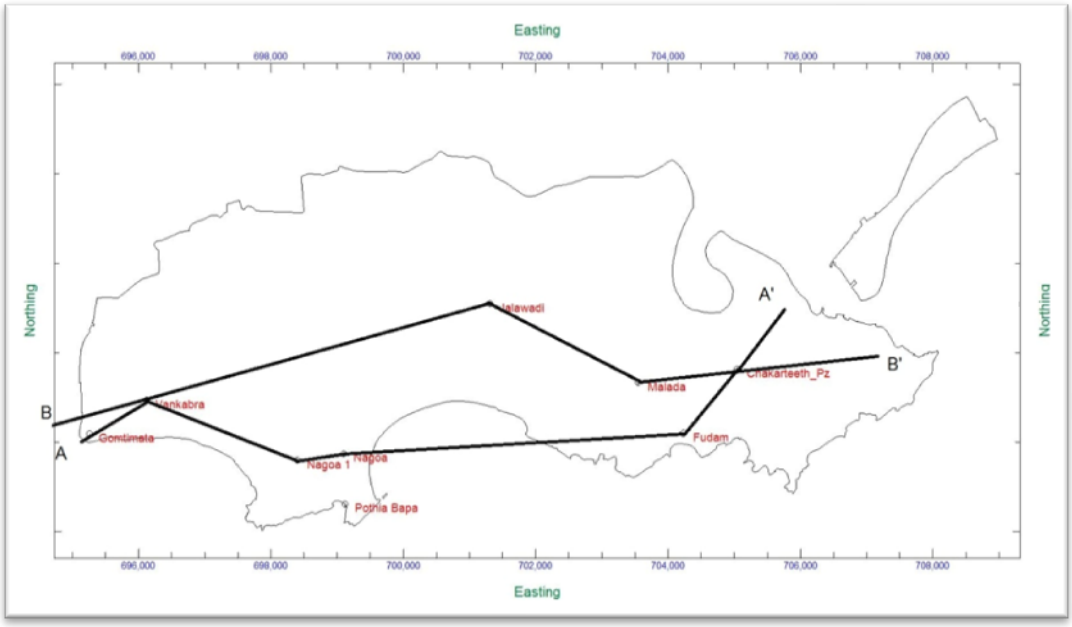

Figure 4 CROSS-SECTION LINES

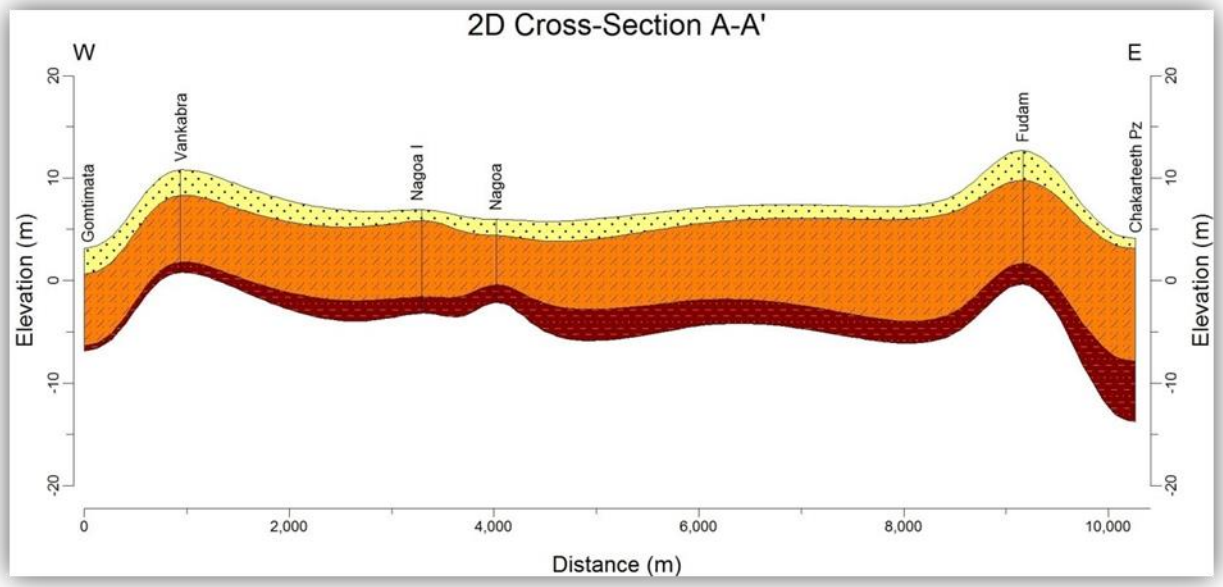

Figure 5- 2D AQUIFER CROSS-SECTION (A-A')

Cross-Section is drawn roughly W-E direction and start from Gomtimata to Charakteerth passing through Vankabra, Nagoa and Fudam. Top sandy horizons is underlain by Milliolite limestone followed by Guj formation composed by calcareous limestone, shale, sandstone.

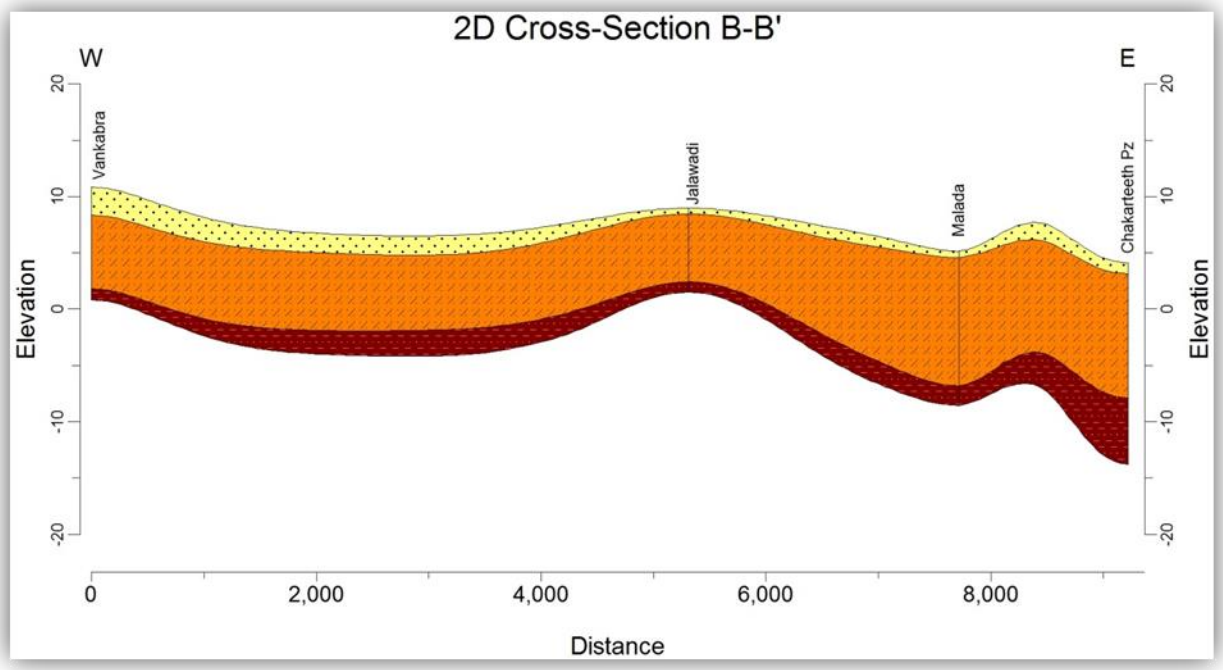

Figure 6- 2D AQUIFER CROSS-SECTION (B-B')

Cross-Section is drawn roughly W-E direction and start from Vankabra to Charakteerth passing through Jalawadi and Malada. Formations along this section disposed as same as in the previous section with varying thickness of layers.

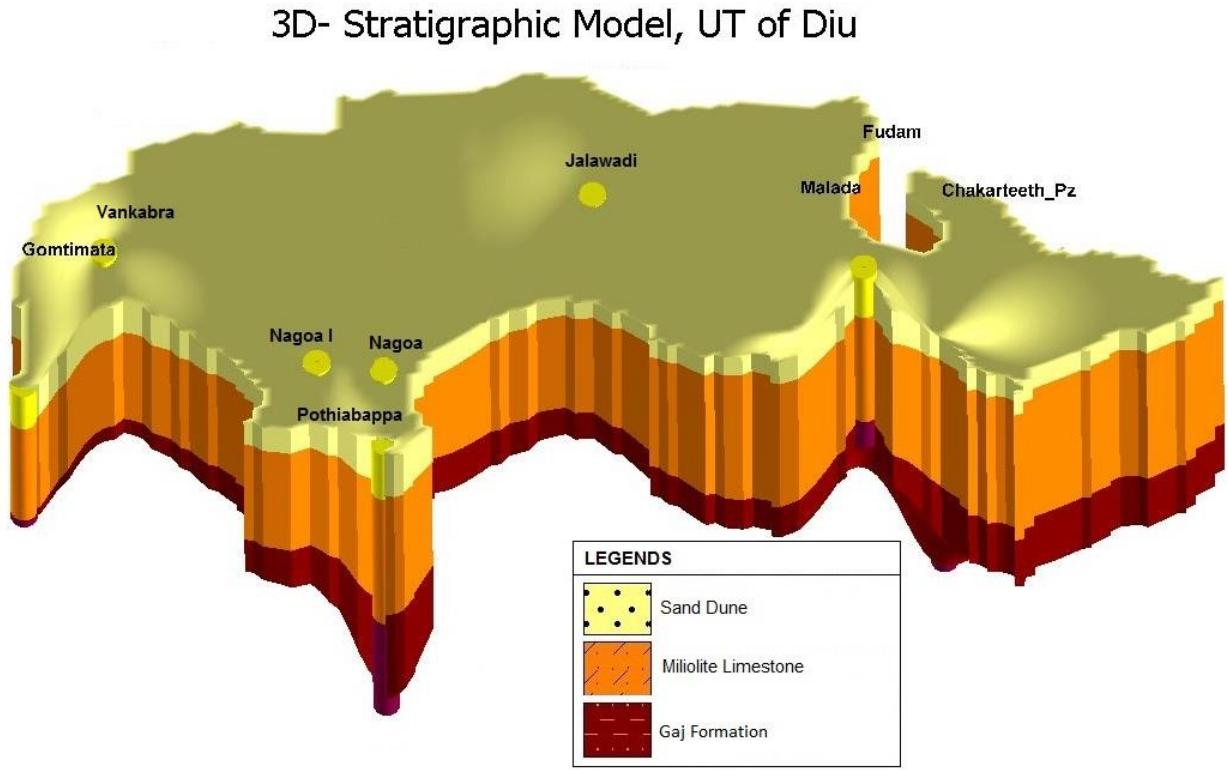

Figure 7- 3D AQUIFER DISPOSITION DIAGRAM

This 3D model is prepared in Rockwork-16 Software. This diagram shows the aquifer geometry in 3 dimensions. Lower boundary of the model demarcated by Guj formations overlain by potential aquifer of Milliolite limestone. Area is covered by sand dunes.

3.4 GROUNDWATER REGIME MONITORING

Central Ground Water Board periodically monitors 06 no. of Ground Water monitoring wells in the Diu district in four times a year i.e. in January, May (Pre-monsoon), August and November (Post-monsoon). Ground water regime monitoring is the basic component of groundwater management and it is carried out in parts of UT of Diu district through National Hydrograph Network Stations (NHNS). These hydrograph stations comprised of dug wells and Piezometers and Observation wells. There are 4 Dug Wells and 2 PZ in Diu District as part of the NHS monitoring. These water level data have been used for preparation of depth to water level maps of the district to understand the behaviour of ground water regime.

3.4.1 Depth to Water Level Pre-Monsoon (May 2021)

Depth to water level is ranges from 3 to 7 m bgl in most of the area of Diu whereas deep water level more than 7 m bgl is shown in small isolated patches located in eastern and western part of Diu. The pre-monsoon depth to water level map is shown in **Fig. 8.**

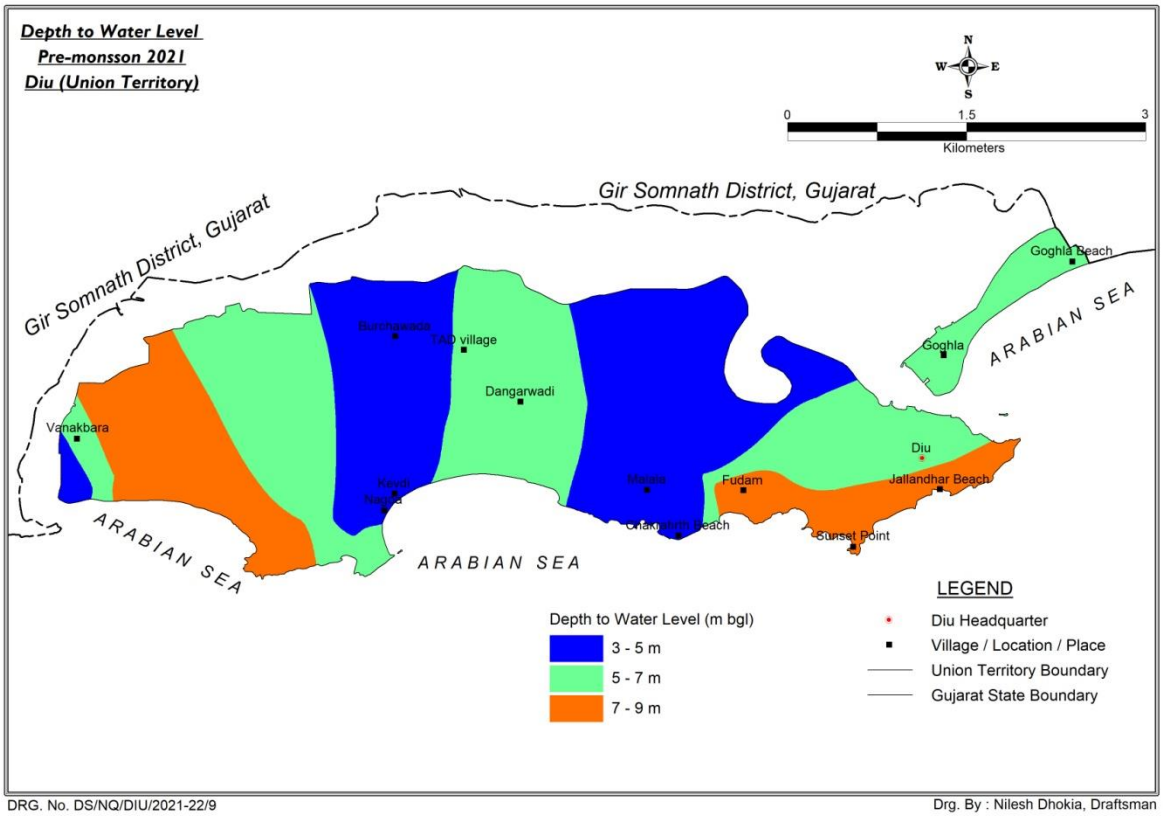

Figure 8- Pre-Monsoon Depth to Water Level Map-2021

3.4.2 Depth to Water Level Post-Monsoon (November 2021)

The depth to water levels in Diu district during November 2021 ranges between 2.0 (Gomtimata village, Diu District) and 9 mbgl (Fudam DW, Diu District). Major part of the area in center, is observed the water level between 2m to 5 m bgl. The post-monsoon depth to water level map is depicted in **Fig. 9.**

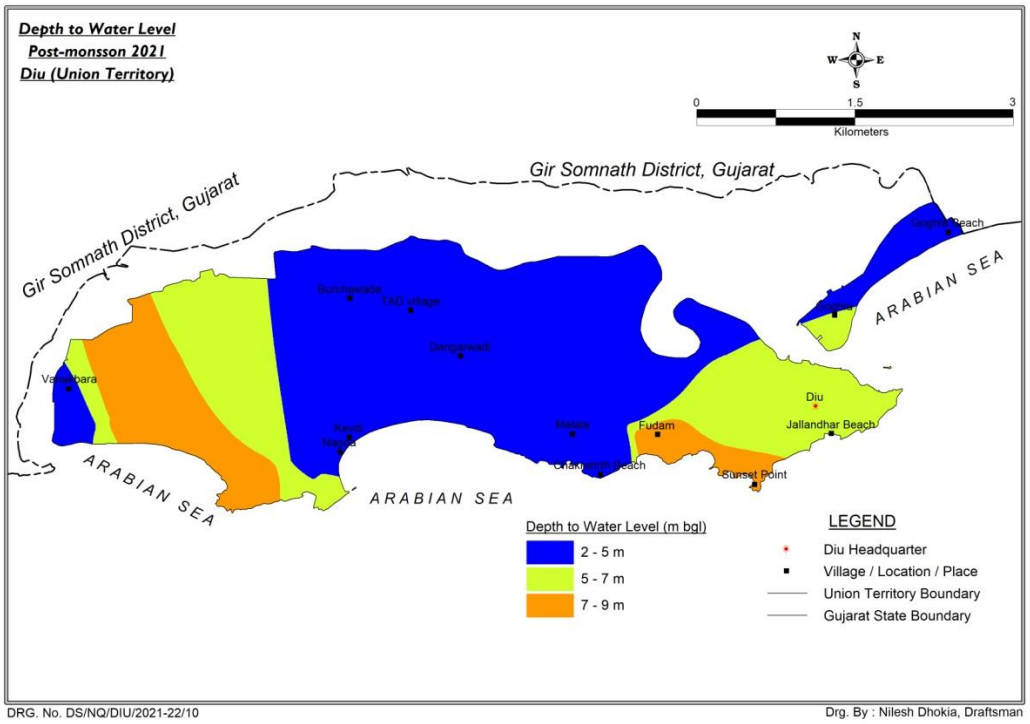

Figure 9- Post-Monsoon Depth to Water Level Map-2019- Diu

3.4.3 Decadal Average (2012-21) depth to water level Pre-monsoon

Decal average DTWL for the period of May 2012 to 2021 is personated in Fig. 6. Maximum part of Diu is occupied by DTWL between 5 and 10 m bgl. Water level >10 m bgl is observed in isolated patches in the north.

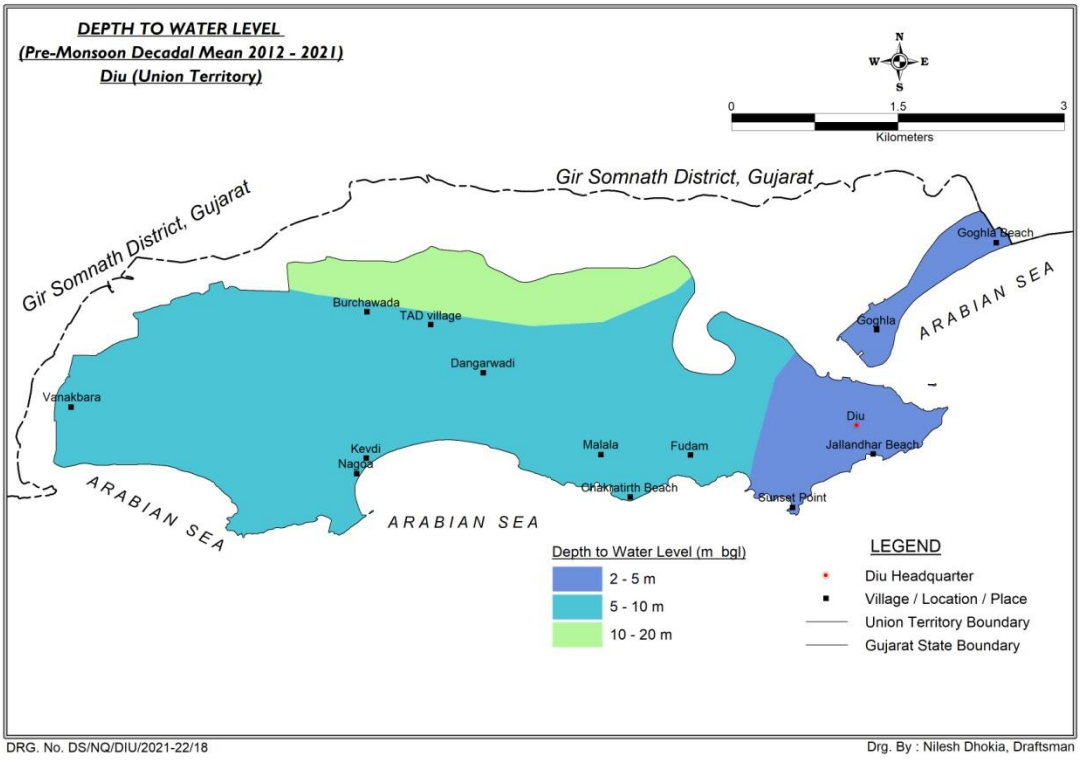

Figure 10- Decadal Pre-Monson Depth to Water Level

3.4.4 Decadal Average (2012-21) depth to water level Post-monsoon

Decadal average for the period of November 2012 to 2021 is shown in Fig. 7. Most of the area is presented the depth to water level 5 to 10 m bgl.

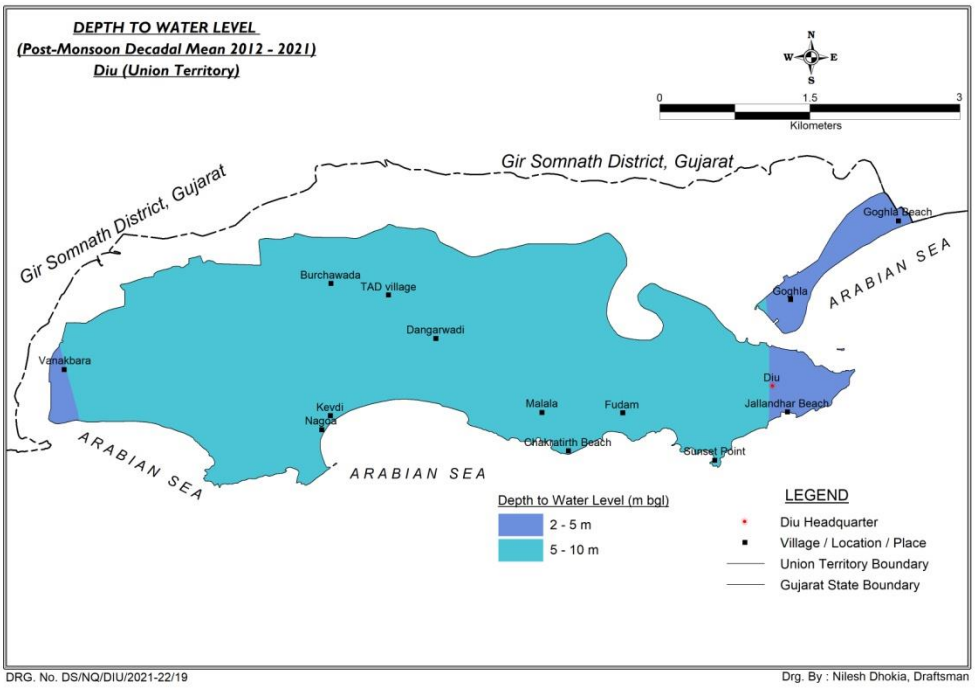

Figure 11- Decadal Post-Monson Depth to Water Level-Diu

3.5 QUALITY:

3.5.1 Total Dissolved Solids (TDS):

Total Dissolved Solids (TDS) in groundwater during pre-monsoon season 2021 ranges between 500 to 2000 mg/l in almost whole part of the area (Fig. 12).

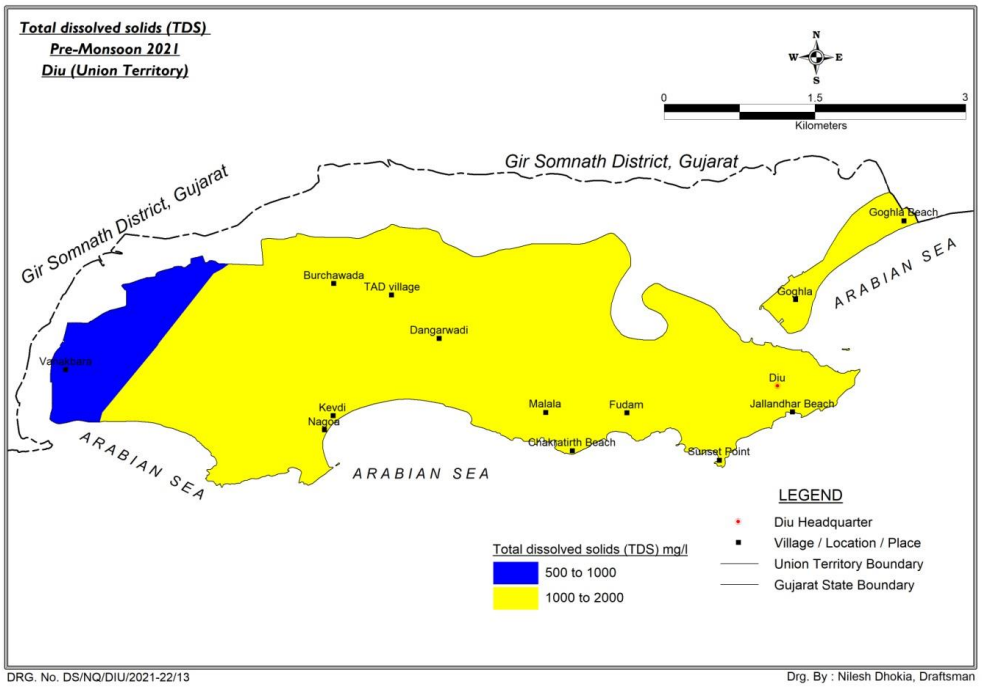

Figure 12-TDS Map

3.5.2 Nitrate:

Nitrate concentration during pre-monsoon season 2021 ranges between 0 to 22 mg/l. It is observed that nitrate concentration of Ground Water in phreatic zone is under permissible limit in the Diu district (Fig. 15).

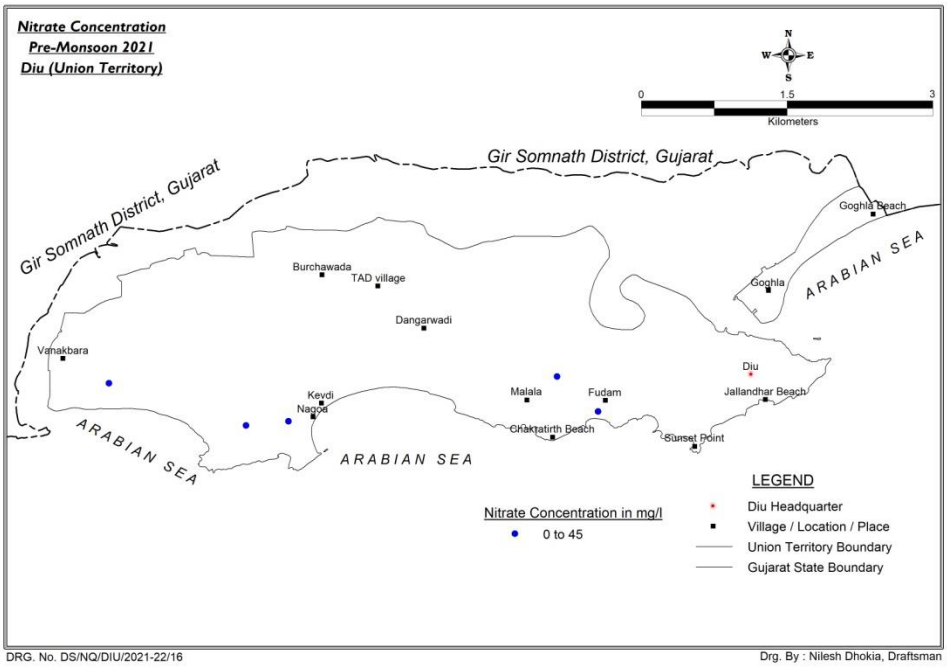

Figure 13- Nitrate Concentration Map

3.5.3 Fluoride:

Fluoride concentration during pre-monsoon season 2021 ranges between 0.3 to 0.47 mg/l. It is observed that fluoride concentration of Ground Water in phreatic zone is under permissible limit in the Diu district (Fig. 16).

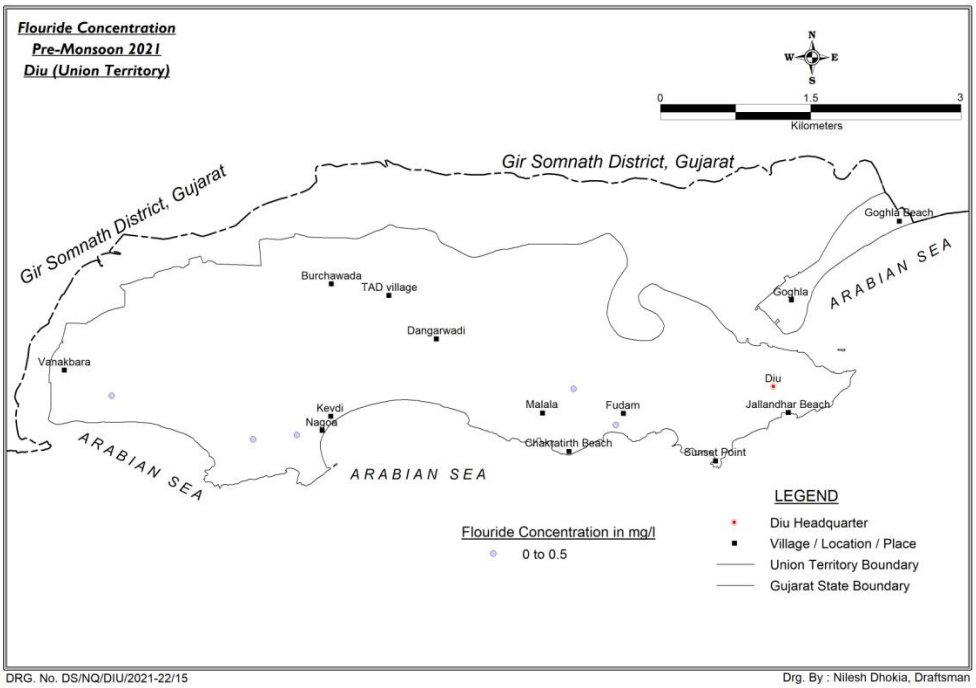

Figure 14- Fluoride Concentration Map

4. Dynamic Ground Water Resources

Central Ground Water Board estimated the ground water resources of Diu district based on GEC-15 methodology in GWRE-2020. Ground water resources are given in Table 6, and graphical representations of the resources on the map are shown in Figure-17.

Table 6- GROUND WATER RESOURCES ESTIMATION AS PER GWRE 2020

UT of Diu										
S. No.	Name	*Total Geographical Area (ha)	Total Annual Ground Water Recharge	Total Natural Discharges	Annual Extractable Ground Water Resource	Current Annual Ground Water Extraction for all uses	Annual GW Allocation for for Domestic Use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)	Safe/SC/Critical/OE/Saline
1	Diu	4000	245.37	12.26	233.11	42.20	175.69	15.22	18.10	Safe

As per the Ground Water Resources estimation 2020, the annual replenishable ground water is 245.37 Ham and the net annual ground water availability comes to be 233.11 Ham. The gross draft for all uses is estimated at 42.2 Ham with irrigation being the main and only sector. The domestic and industrial water requirements are worked at 0 Ham. The overall stage of ground water development for the district is 18.10%. The assessments indicate that the Diu district fall under "Safe" category.

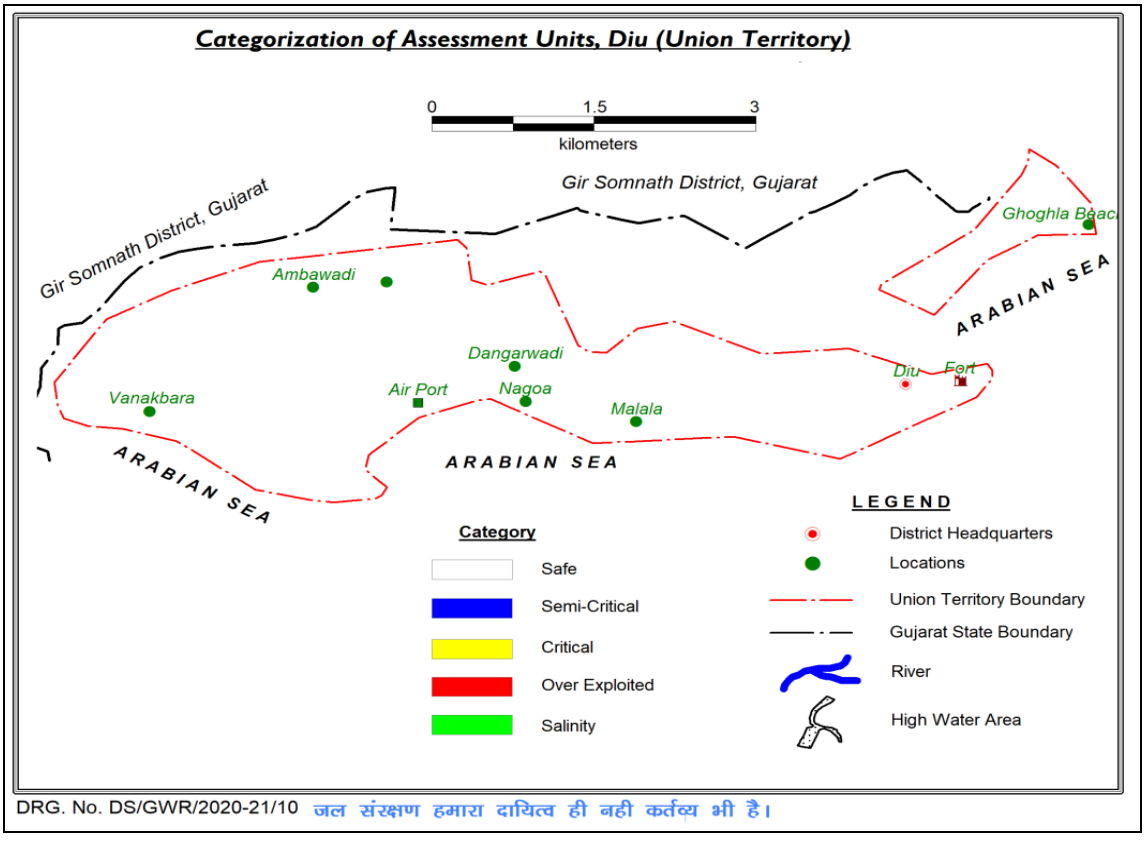

Figure 15- Categorization Map of Diu district as per GWRA-2020

5. GROUND WATER MANAGEMENT PLAN AND SUSTAINABLE DEVELOPMENT:

The management plan has been proposed to manage the ground water resources and to arrest further decline in water levels. The management plan comprises two components namely; supply-side management and demand side management. The supply side managements proposed based on Roof top Rain water harvesting and recharge whereas the demand side management is proposed by use of change in cropping pattern.

5.1 GROUND WATER RELATED ISSUES:

1. **Ground water Quality:** Ground water in phreatic aquifer is Potable and fit for domestic, irrigation and other industrial purposes but below the phreatic depth of 13-15 mbgl the ground water is saline.
2. **Groundwater management plan:** Ground water management plan (Both supply side and Management side) needs to be prepared with an aim to enhance the groundwater usage for creation of additional irrigation potential for the district.
3. **Sea Water Ingression:**

5.2 SUPPLY SIDE MANAGEMENT

Taking into consideration of shallow water level condition and more or less, stable ground water condition and predominately semi urban and urban types habitat system, roof top rain water harvesting is suggested for augmenting the availability of water for supply. The Diu Island gets average monsoon rainfall of 750 to 850 mm by south west monsoon system during mid June to September / October months. As per 2011 census data number of urban household in Diu is 5,249. Estimating 25 % houses are suitable for harvesting and considering 40 sq m area per house, total ~0.47 lakh sq m areas is available for roof top harvesting in Diu. The source water available for harvesting has been taken as 60 % of average annual rainfall of the area, after making allowance for storm rain etc., total source water available for roof top harvesting has been estimated as 0.02 MCM /year. The average cost of making the rooftop harvesting arrangements is @ Rs 10,000 /- per house.

Table 7- Roof top Rainwater Harvesting in Diu

Sl No	District	Urban Population (Census 2011)	Household (Census 2011)	Roof Area considering average 40 sq.m @ 25% of House Hold (sq.m)	Average Rainfall (mm)	Volume of harvestable water (MCM)	Unit Cost (Lakh)	Total Cost (Lakh)
1	Diu	52074	5249	47241	800	0.02	0.01	131.23

5.3 GROUND WATER DEVELOPMENT PLAN

As per GWRE 2020 Diu district are under safe category Ground water stage of development ranges from 18.10 %. In view of the present stage of groundwater development 18.10%, some 10 no. of Dug wells (12-15m depth) are proposed in central upland area and may use in future if drought conditions are prevailed in the area. The extraction structures will result in additional ground water 5 Ham of which will create 10 Ha additional irrigation potential for Diu.

As Diu is an Island So there is no further scope of development as it may cause sea water ingression.

5.4 EXPECTED BENEFITS:

The impact of groundwater management plans on the groundwater system in the Diu after its implementation is evaluated and the outcome shows little improvement in groundwater scenario is as given in the Table 8.

Table 8- PROJECTED STATUS OF GROUNDWATER RESOURCE

Net G.W. Availability (Ham)	Additional Recharge from RTRWH (ham)	Additional Recharge from Return flow of GW Irrigation	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	GW Development after construction of extraction structures (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation & Recharge measures (in %)	Additional Irrigation Potential Created (Ha)
233.11	2.27	0.50	235.88	42.20	5.00	47.20	18.10	20.20	20.01	10

6. Sum Up:

1. A thorough study was carried out based on data gap analysis, data generated in-house; data acquired from State Government departments and GIS maps prepared for various themes. All the available data was brought on GIS platform and an integrated approach was adopted for preparation aquifer maps and aquifer management plans of Diu.
2. Diu district covering an area of 40 sq km. Geologically, The area of Diu Island is underlain by Quaternary formation consisting of Miliolite rocks and stabilised sand dunes. The Miliolite rocks (Lime Stone) form the main aquifer system of the area. The stage of ground water development is 18.10%.
3. The management plan has been proposed to manage the ground water resources and to arrest further decline in water levels. The management plan comprises two components namely supply-side management and demand side management.
4. As a part of Supply side Management, 0.02 MCM rain water is available from rooftop and conserve in subsurface in closed tank as similar structures in Rajasthan in dessert area.
5. Miliolite limestone forms the main fresh water aquifer. Although this cavernous limestone with its high porosity, supports wells with high yields, the limited storage capacity of the groundwater reservoir on account of limited column of fresh water floating over the saline water, does not allow for large scale groundwater exploitation.
6. The cavernous nature of the limestone aquifer with the conduits extending right into the sea, make it highly vulnerable to sea water ingress, Even on the central high lands, heavy pumping may causes up coning of saline water which occurs in all aquifers just below sea level.

7. In order to prevent further deterioration in groundwater water quality along coastal strip, efforts should be made to reduce the groundwater draft and make surface water to the recharge the groundwater.
8. Disposal of industrial waste from the developing industrial estate should be planned carefully to avoid the contamination of groundwater.
9. Rainwater harvesting may be carried out by storing water in underground closed tanks. There is a scope for harnessing of rainwater in central highlands.
10. With the commencement of surface water supply, the groundwater withdrawal would be reduced. These untapped water resources can be utilised in case of draughts.
11. Development of groundwater resources need to be supported by regulation, so that the resources are protected for future generation and also serve as ground water sanctuary in times of distress/drought. IEC activities and capacity building activities needs to be aggressively propagated to establish the institutional framework for participatory ground water management.