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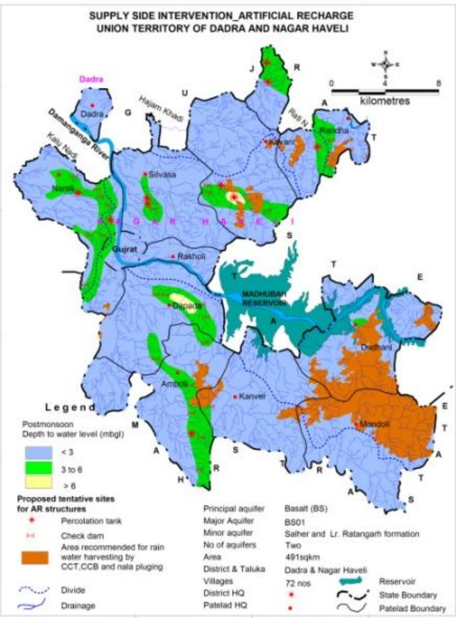
PART -I

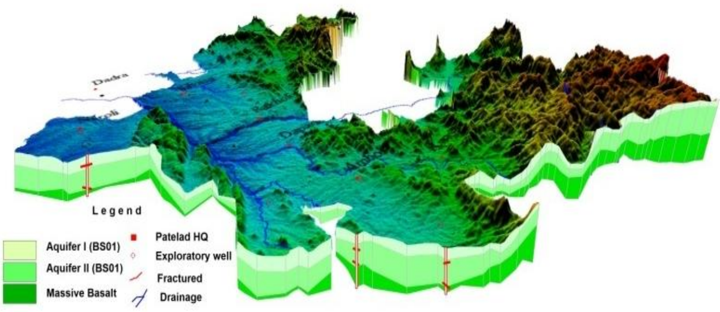
भारत सरकार
Government of India
जल संसाधन, नदी विकास एवं गंगा संरक्षण मंत्रालय
Ministry of Water Resources, River Development & Ganga Rejuvenation
केन्द्रीय भूमिजल बोर्ड
CENTRAL GROUND WATER BOARD

जल बचत जल संचय

Aquifer Maps and Ground Water Management Plan

जलभृत नक्शे तथा भूजल प्रबंधन योजना पर संक्षिप्त रिपोर्ट





Union Territory of DADRA & NAGAR HAVELI

संघ राज्य क्षेत्र दादरा एवं नगर हवेली

मध्य क्षेत्र, नागपुर/ Central Region, Nagpur

फेब्रुवरी / February 2017

PART-I

AQUIFER MAPS AND GROUND WATER MANAGEMENT PLANS, UNION TERRITORY OF DADRA & NAGAR HAVELI

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AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN FOR U.T. OF DADRA & NAGAR HAVELI

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AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN FOR U.T. OF DADRA & NAGAR HAVELI

1 INTRODUCTION

In XII five year plan, National Aquifer Mapping (NAQUIM) had been taken up by CGWB to carry out detailed hydrogeological investigation on toposheet scale of 1:50,000. The NAQUIM has been prioritised to study Over-exploited, Critical and Semi-Critical talukas as well as the other stress areas recommended by the State Govt. Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers.

The vagaries of rainfall, inherent heterogeneity & unsustainable nature of hard rock aquifers, over exploitation of once copious alluvial aquifers, lack of regulation mechanism has a detrimental effect on ground water scenario of the Country in last decade or so. Thus, prompting the paradigm shift from "**traditional groundwater development concept**" to "**modern groundwater management concept**".

Varied and diverse hydrogeological settings demand precise and comprehensive mapping of aquifers down to the optimum possible depth at appropriate scale to arrive at the robust and implementable ground water management plans. The proposed management plans will provide the **"Road Map"** for ensuring sustainable management and equitable distribution of ground water resources, thereby primarily improving drinking water security and irrigation coverage. Thus the crux of NAQUIM is not merely mapping, but reaching the goal-that of ground water management through community participation. The aquifer maps and management plans will be shared with the Administration of UT of Dadra & Nagar Haveli (UT of DNH) for its effective implementation.

1.1 Objective and Scope

Aquifer mapping itself is an improved form of groundwater management – recharge, conservation, harvesting and protocols of managing groundwater. These protocols will be the real derivatives of the aquifer mapping exercise and will find a place in the output i.e, the aquifer map and management plan. The activities under NAQUIM are aimed at:

- identifying the aquifer geometry,
- aquifer characteristics and their yield potential
- quality of water occurring at various depths,
- aquifer wise assessment of ground water resources
- preparation of aquifer maps and
- Formulate ground water management plan.

This clear demarcation of aquifers and their potential will help the agencies involved in water supply in ascertaining, how much volume of water is under their control. The robust and implementable ground water management plan will provide a **"Road Map"** to systematically manage the ground water resources for equitable distribution across the spectrum.

UT of Dadra & Nagar haveli being spread over a small area of 491 sq.km. have been entirely covered during the Annual Action Plan of 2015-16.

1.2 Approach and Methodology

The ongoing activities of NAQUIM include toposheet wise micro-level hydrogeological data acquisition supported by geophysical and hydro-chemical investigations supplemented with ground water exploration down to the depths of 200 / 300 meters.

Considering the objectives of the NAQUIM, the data on various components was segregated, collected and brought on GIS platform by geo-referencing the available information for its utilisation for preparation of various thematic maps. The approach and methodology followed for Aquifer mapping is as given below:

Compilation of existing data (Central & State Govt.)

↓

Generation of different thematic layers

↓

Identification of Primary Aquifer

↓

Identification of data gaps

↓

Data generation (water level, exploration, geophysical, hydrochemical, hydrogeological etc.)

↓

Robust Aquifer Maps with 3D disposition

↓

Preparation of Aquifer Management Plan

1.3 Study area

Keeping in view the current demand and supply and futuristic requirement of water, Central Ground Water Board has taken up the National Aquifer Mapping Programme (NAQUIM) in India during XII five year plan (2012-17). Entire UT of DNH having area of 491 sq. km. was selected for NAQUIM activities during the year 2015-16. The index map of the study area is presented in **Fig.1.1.** Administratively, the UT of DNH is comprising of one Municipal Council, 5 Census Towns and 65 villages forms a single District and single Taluka Union territory. All the villages have been divided into 11 Patelads for revenue purpose.

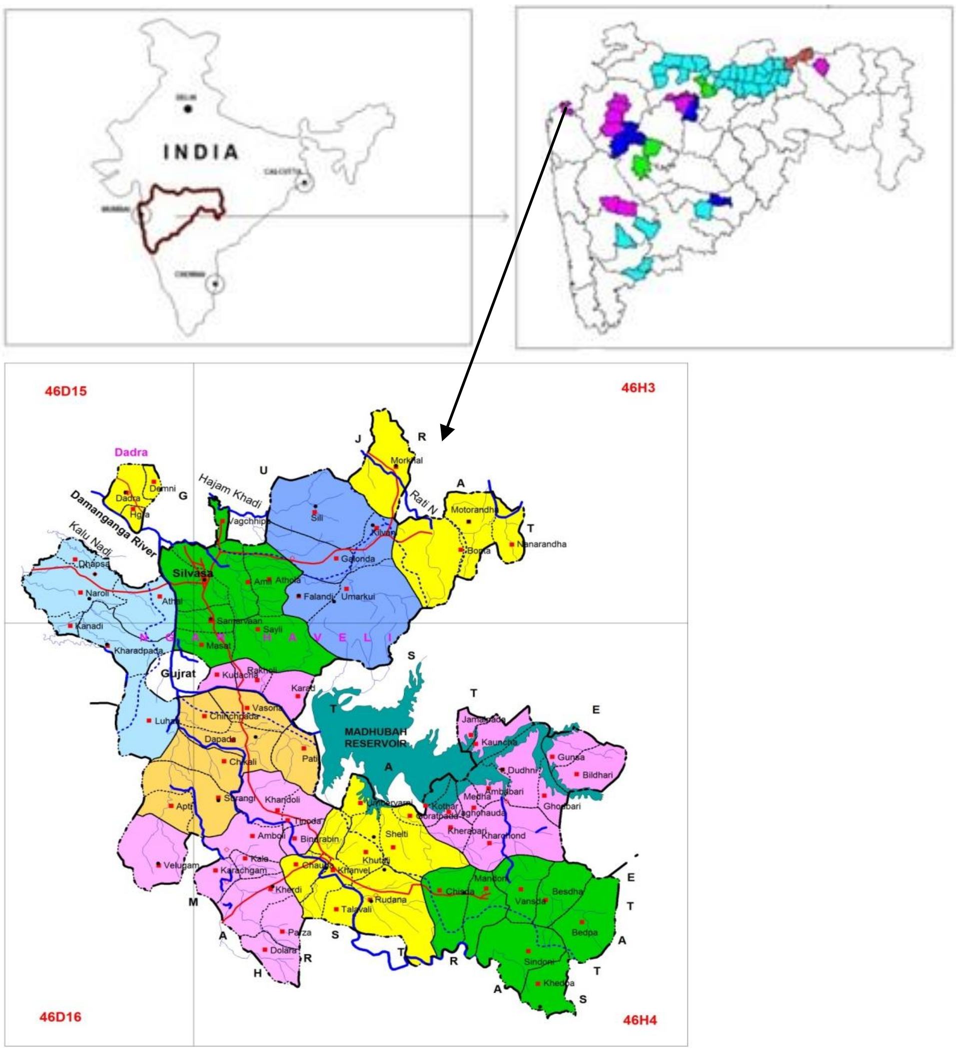


Fig. 1.1: Index map, Union Territory of Dadra and Nagar Haveli (DNH)

1.4 Data Adequacy and Data Gap Analysis:

The available data of the Exploratory wells drilled by Central Ground Water Board, Central Region, Nagpur, Geophysical Survey carried out in the area, Ground water monitoring stations and ground water quality stations monitored by Central Ground Water Board were compiled and analysed for adequacy of the same for the aquifer mapping studies. The locations of existing exploratory wells and ground water monitoring wells which are also used as ground water quality sampling locations are shown in **Fig. 1.2**. In addition to these the data on geophysical investigations done by NGRI was also utilised for data adequacy and data gap analysis. Due to absence of State Ground Water Dept. in UT of DNH, the desired primary data was not available. However, the ancillary data such as ground water abstraction structures, irrigation facilities, rainfall etc., have been collected from the Administration of UT of DNH. The data adequacy and data gap analysis was carried out for each of the quadrant of falling in the study area mainly in respect of following primary and essential data requirements:

- Exploratory Wells

- Geophysical Surveys
- Ground Water Monitoring and
- Ground Water Quality

After taking into consideration, the available data of Ground Water Exploration, Geophysical survey, Ground Water Monitoring and Ground Water Quality, the data adequacy is compiled and the summarised details of required, existing and data gap of Exploratory wells, Ground Water monitoring and Ground water quality stations is given below.

Table – 1.1: Data Adequacy and Data Gap Analysis

EXPLORATORY DATA			GEOPHYSICAL DATA			GWMONITORING DATA			GW QUALITY DATA		
Req.	Exist.	Gap	Req	Exist.	Gap	Req.	Exist.	Gap	Req.	Exist.	Gap
5	13	2	22	0	22	16	26	7	16	26	7

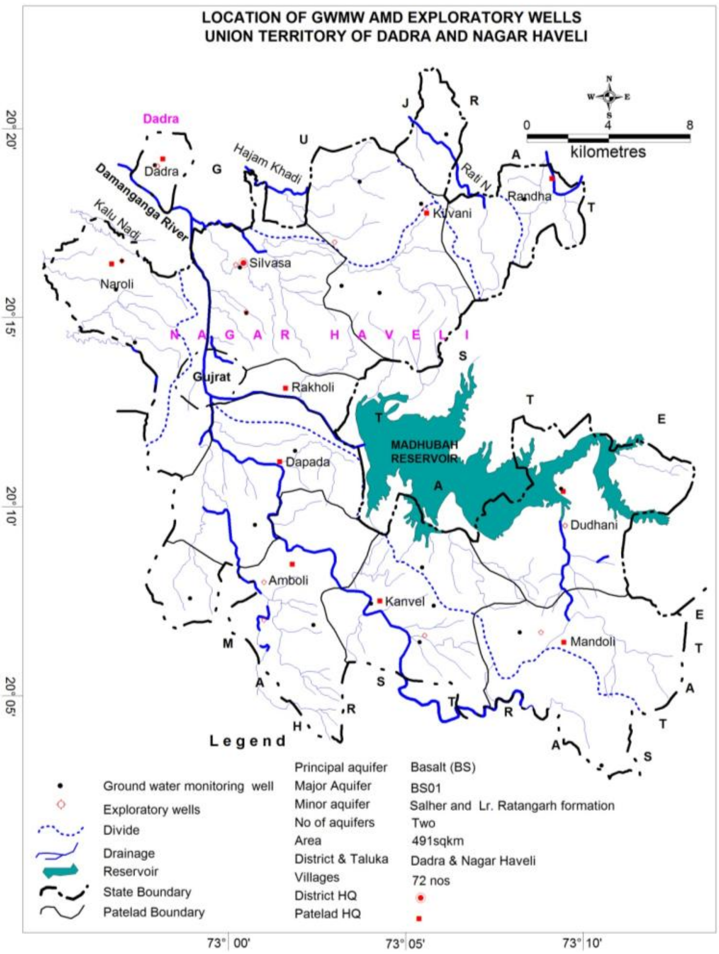


Fig 1.2: Locations of Existing Exploratory Wells and Ground Water Monitoring Wells.

1.5 Data Gap Identification

The data adequacy as discussed above indicates that the existing data is not sufficient for preparation of aquifer maps, hence data gap has been identified for Exploratory Wells, Geophysical Survey (VES), Ground Water Monitoring Wells and Ground Water Quality. Based on the data gap identification, the data generation activity was planned and completed in 2015-16.

1.6 Climate and Rainfall

Agriculture in the area depends mainly on the rainfall from south-west monsoon. The area experiences the sub-tropical to tropical temperate monsoon climate. The summers are hot and become more humid in their later part with temperatures reaching as high as 39° in the month of May. The monsoon starts in the month of June and extends until September. The rainfall is brought by South West monsoon winds. Winters are between maritime temperate and semi-tropical with temperatures ranging from 14° to 30°. The average wind speed recorded is 7.4 km/h.

The annual rainfall data for the period 2004 to 2013 is presented in Table-1.2. The perusal of data indicates that the minimum rainfall of 1574.28 mm was received in the year 2012, whereas maximum rainfall of 3036.60 mm was received in the year 2013. The average annual rainfall for the decade was found to be 2459.54 mm. Average Annual Rainfall in UT of Dadra & Nagar Haveli shown in **Fig.1.3**. The figure indicates that the rainfall is increasing from east to west and is maximum (>2500 mm) in the western part.

Table 1.2: Annual Rainfall Data - 2004-2013 (mm)

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average
Rainfall	2399.50	2725.66	2626.30	2612.60	2385.00	2006.00	2547.10	2682.40	1574.28	3036.60	**2459.54**

(Source: Socio Economic Development of Dadra & Nagar Haveli, 2012-13)

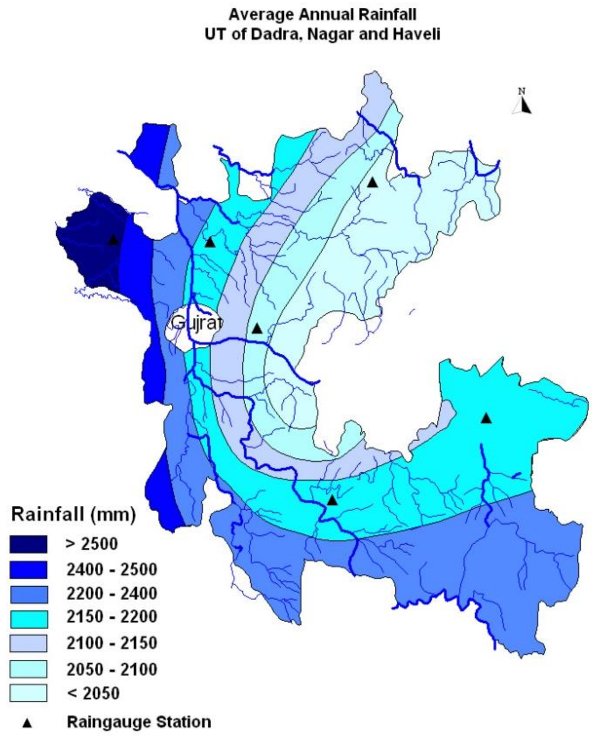


Fig.1.3: Average Annual Rainfall

The analysis of long term rainfall data pertaining to the period 1966-2013 has also been carried out (**Annexure-I**) and the probability of occurrence of normal annual rainfall over the UT of DNH has been studied. It was observed that the distribution of rainfall is more or less uniform over the area. The rains usually start in the second week of June and last till the end of September. The intensity of rainfall is the highest in July. It is observed that the

- The chances of receiving normal annual rainfall are around 42%.

- The coefficient of variation of annual rainfall from normal is around 28%.
- The percentage probability of receiving excess rainfall (i.e. 25% or more in excess of the normal) is around 15% i.e. once in 6 to 7 years.
- The probability of occurrence of moderate drought is around 14%, i.e. one drought in every 7 years.
- The long term trend of rainfall is rising @ 4.73 mm/year.

1.7 Physiography

The UT of DNH has hilly terrain especially towards the North-East and East where it is surrounded by ranges of Sahyadri Mountains (Western Ghats). The terrain is intersected by the River Daman Ganga and its three tributaries. The river rises in the Ghat 64 km.'s from the western coast and discharges itself in the Arabian Sea at the port of Daman.

1.8 Geomorphology

Geomorphologically, the UT of DNH forms part of Deccan Plateau. The UT of DNH is divided into three units i.e., Residual Plateaus, Denudational Slopes and Valley Plains as evident from **Fig. 1.4** and their description is as follows.

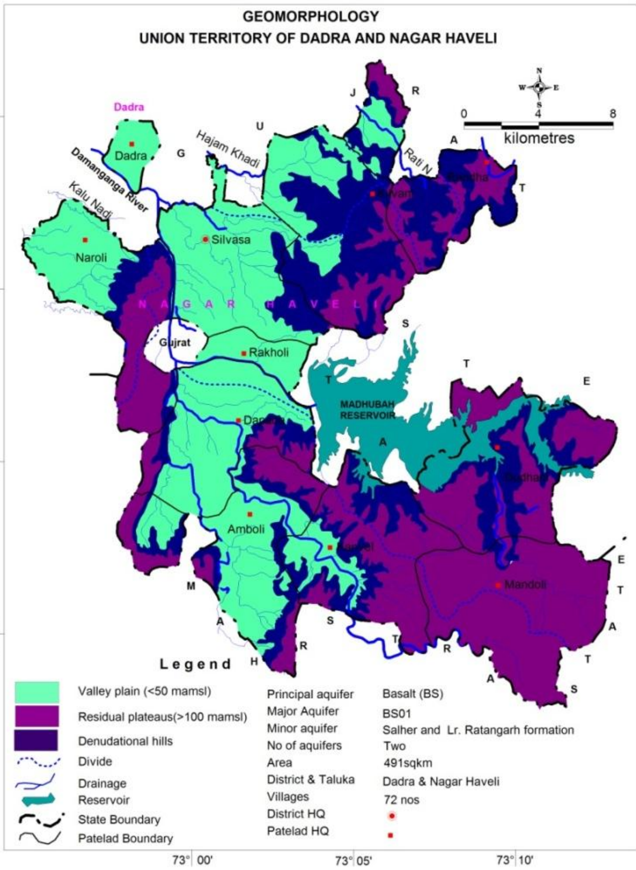


Fig.1.4: Geomorphology

1.8.1 Residual Plateau's

These are flat-topped crests surrounded by steep scarps. These residual plateaus occur in the western fringe, the south-eastern part and in the isolated patches in the north eastern part of the Territory covering an area of about 183 sq.km. The elevation in this category ranges between 100-

300 m amsl the elevation more than 200 m amsl is seen in north eastern and south-eastern part of the Territory.

1.8.2 Denudational Hills

These form the scarp zone between plateaus and plains occupying an area of about 124 sq.km., and comprises of moderate to steep slopes. The major area under this category lies almost in the eastern part in north south alignment in dissected form ranging roughly between 50 and 100 m above MSL.

1.8.3 Valley Plains

The valley plains occupying an area of 184 sq.km. and forms the flat topography with gentle slope of SE-NW forming the Damanganga River and its tributaries and it ranges in elevation below 50 m above m amsl. It comprises of weathered rock fragments and soils. The rock fragments are various sizes and mixed with soils.

1.9 Land Use, Agriculture, Irrigation and Cropping Pattern

Forest and agriculture are the prominent land use aspects in UT of DNH and forms 41.46% and 44.62% of total area respectively followed by the industrial and built-up structures. Eastern part of Dadra & Nagar Haveli has thick forest cover, whereas the major agricultural activity is restricted in the central part corresponding with the valley part. The spatial distribution of land use is presented in **Fig. 1.5**.

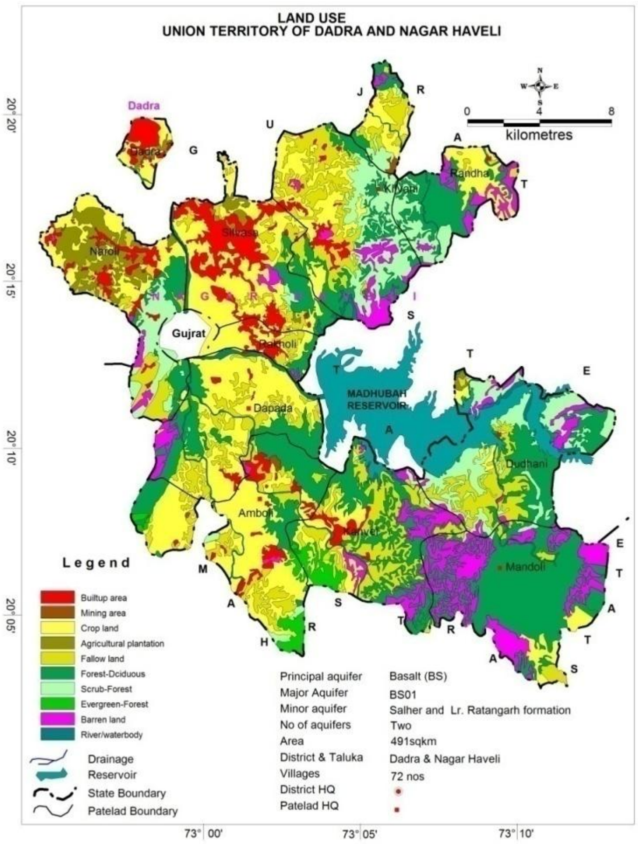


Fig.1.5: Land Use

The agricultural distribution of crops does follows traditional pattern as paddy is the most dominant single crop in the UT of DNH with an area of 98 sq.km., cereals like Ragi, Wheat, Jowar, Maize and Small Millets etc., being grown in 123 sq.km, whereas pulses like tur, gram, udid, moong, val etc., covering 37.50 sq.km., the cash crop sugarcane is also cultivated in small area of 4.10 sq.km.

Table- 1.2: Taluka wise Land Use, Agriculture and Irrigation (fig. in sq.km)

Cultivable/ Agricultural	Forest	Settlement	Agricultural Land Break up			GW irrigated	SW irrigated
			Paddy	Cereals	Pulses		
202.12	203.21	31.33	98	123	37.50	6.63	79.13

The surface water based irrigation caters to the major area i.e., 79.13 sq.km. (39% of cultivable area), out of which 67.64 sq.km is due to Damanganga major irrigation project whereas minor irrigation schemes are able to irrigate 11.49 sq.km. area. The ground water development is the area is low and the same is also reflected in the irrigated area which is about 6.63 sq.km (3% of cultivable area).

1.10 Hydrology and Drainage

The UT of Dadra and Nagar Haveli lies in the middle of the undulating watershed of the Daman Ganga River, which flows through Nagar Haveli and later forms the short southern border of Dadra. The towns of Dadra and Silvassa lie on the north bank of the river. The Western Ghats range rises to the east, and the foothills of the range occupy the eastern portion of the UT. While the UT is landlocked, the Arabian Sea is just to its west, and can be reached via the state of Gujarat. The major river of the area is Damanganga which flows in SE- NW direction. The major tributaries of Damanganga are Dudhninadi, Sakartondnadi, Dongarkhadinadi, Pipriya and Ratinadi. The drainage and hydrology map of the UT of DNH is shown in **Fig. 1.6**.

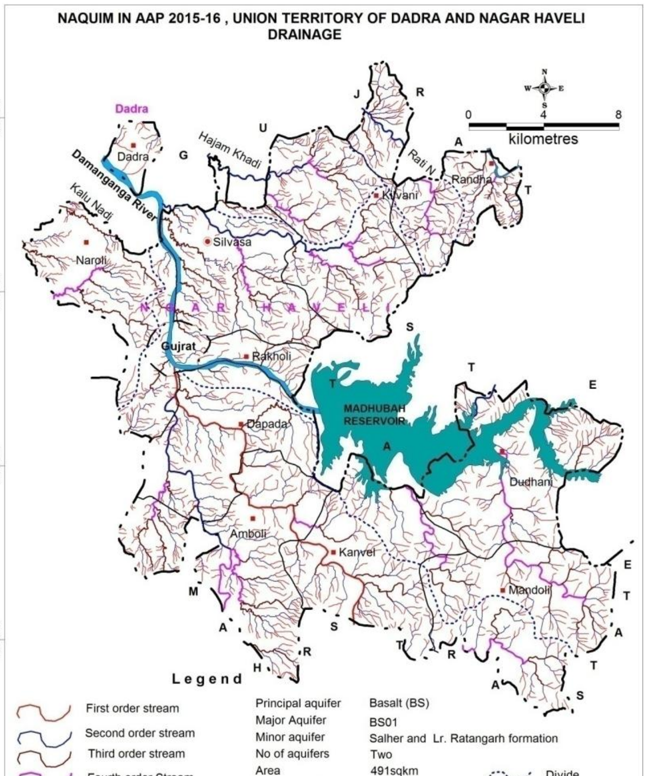


Fig.1.6: Hydrology and Drainage

The Damanganga major irrigation project on the Damanganga river near Madhuban village (close to Silvassa) which has a catchment area of 1813 sq.km.'s and it caters to the irrigation and drinking water requirements of UT of DNH and also that of UT of Daman and the State of Gujarat. The culturable command area of the project is 51138 ha, out of which 41303 Ha falls in Gujarat, 6764 Ha falls in UT of Dadra & Nagar Haveli, whereas 3071 Ha falls in UT of Daman. It also provides water supply to UT of DNH for domestic purpose to the tune of 12.75 MGD.

1.11 Prevailing Water Conservation and Recharge Practices

The UT of DNH is blessed with high rainfall in the range of 2000 to 2500 mm, hence the need for water conservation and artificial recharge is not felt much by the people as well as the DNH administration. However as per the data available, check dams are the most preferred water conservation structures in the UT of DNH. At present, the DNH administration has constructed about 43 check dams spread across the UT and their locations are provided in **Fig. 1.7**.

2 DATA COLLECTION AND GENERATION

Due to absence of State Ground Water Dept. in UT of DNH, the desired primary data such as water levels, quality and lithological inputs were not available. However, the ancillary data such as numbers of ground water abstraction structures, irrigation facilities, rainfall etc., have been collected from the Administration of UT of DNH and compiled.

2.1 Data Collection and Compilation

The data collection and compilation for various components was carried out as given below.

- Hydrogeological Data – Current and historical water levels along with water level trend data of 9 monitoring wells representing Aquifer-I of CGWB. The water levels of 15 exploratory wells representing Aquifer-II were also collected and compiled.
- Hydrochemical Data - Ground water quality data of 9 monitoring wells of CGWB representing shallow aquifer and data of 13 exploratory wells representing deeper aquifer.
- Exploratory Drilling – Ground water exploration data of 13 exploratory wells of CGWB.
- Geophysical Data – The weathered zone resistivity and weathered zone thickness maps of NGRI.
- Hydrology Data – Data on various irrigation projects, their utilisation status, number of ground water abstraction structures and area irrigated from PWD, Div-III (Irrigation).
- Hydrometeorological Data - Long term rainfall data for each of the taluka from Dept. of Planning.
- Water Conservation Structures – Numbers, type and storage potential of water conservation structures prevailing in the area from Dept. of Planning.
- Cropping Pattern Data – Data on prevailing cropping pattern from Agriculture Dept.

2.2 Data Generation

After taking into consideration, the data available with CGWB on Ground Water Exploration, Geophysical survey, Ground Water Monitoring Wells (GWMW) and Ground Water Quality, the data adequacy was compiled and it indicated that exploratory drilling is required at 2 locations, ground water monitoring wells are required at 7 locations for water level and water quality sampling. Further, CGWB has not done any geophysical survey in the UT of DNH, hence VES were required at 22 locations. These 22 VES are proposed through outsourcing and the same will be conducted after approval of proposal by CHQ. The requirement, availability and gap of major data inputs i.e., exploratory wells, geophysical data, GWMW and ground water quality data are detailed in the **Table 2.1**. Based on Data Gap Analysis, all the necessary data was generated except VES as discussed below.

Table – 2.1: Data Adequacy and Data Gap Analysis

EXPLORATORY DATA			GEOPHYSICAL DATA			GWMONITORING DATA			GW QUALITY DATA		
Req.	Exist.	Gap	Req	Exist.	Gap	Req.	Exist.	Gap	Req.	Exist.	Gap
5	13	2	22	0	22	23	16	7	23	16	7

2.2.1 Ground Water Exploration

As seen from **Table-2.1**, exploratory drilling was required at 2 locations i.e., Mandoni and Kilvani. The drilling at these two sites was done down to 200 m depth by deploying DTH/LMP-87/77 and 11 m bgl to assess the lithological disposition of shallow aquifer (Aquifer-I) and deeper aquifer (Aquifer-II). The deep aquifers are encountered in depth of 38.0-41.10, 146.00-148.00, however their yield was negligible, whereas the water level was recorded in only well i.e., Mandoni (43.6 mbgl). The locations of exploratory wells are shown in **Fig. 2.1**. The details of exploratory and observation wells are given in **Annexure-II.**

2.2.2 Ground Water Monitoring Wells

As observed from Table-2.1, GWMW's were required at 7 locations and correspondingly 8 key observation wells (KOW) were established in addition to the existing GWMW to assess the ground water scenario of shallow aquifer (Aquifer-I) of the area. The depth of these dug well varies from 5.0-20.00 mbgl. The pre monsoon depth to water level in these wells varies from 0.30 (Kherdi Kathepada) to 5.40 mbgl (Rakholi). The post monsoon depth to water level (Nov. 2015) in the dug well varies from 1.60 (Chinsda) to 5.20 mbgl (Rakholi). In general field EC of dug well zone was in the range of 182-1643 µmhos/cm. The locations of KOW's are shown in **Fig. 2.1**.

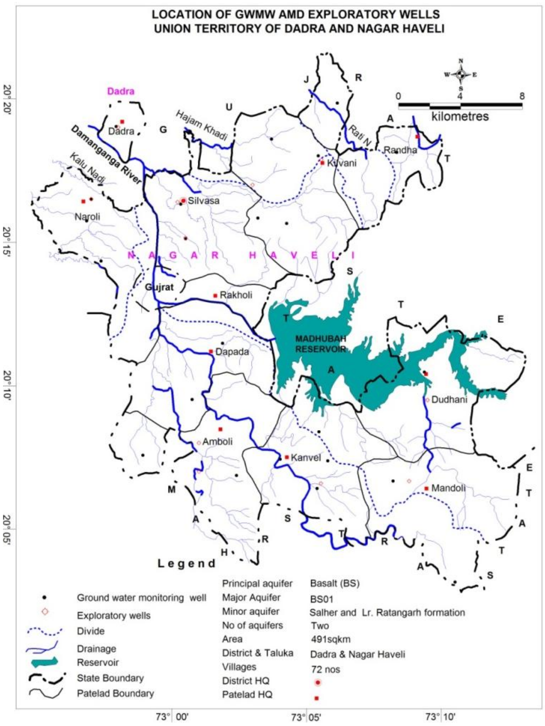


Fig.2.1: Locations of Exploratory Wells and Key Observation Wells

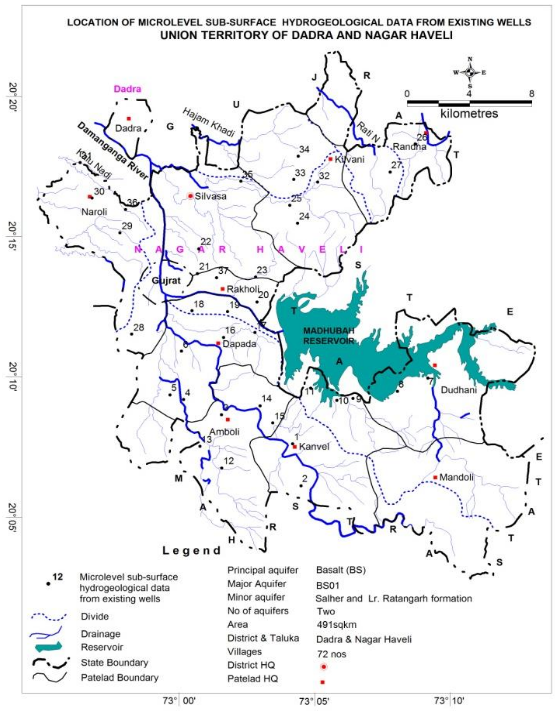


Fig.2.2: Locations of Micro Level Hydrogeological Data Acquisition Wells

2.2.3 Ground Water Quality

As observed from **Table-2.1**, ground water quality stations were required at 7 locations and correspondingly 8 key observation wells (KOW) were established (**Fig. 2.1**) in addition to the existing GWMW to assess the ground water quality of shallow aquifer (Aquifer-I) of area.

2.2.4 Micro Level Hydrogeological Data Acquisition

In addition to the KOW's, micro level hydrogeological data was also required at 36 locations as per data gap analysis for deciphering the sub-surface lithological disposition, water level scenario and other hydrogeological inputs such as weathered thickness etc., of shallow aquifer (Aquifer-I). Thus against the requirement of 36 well, 37 dug wells were inventoried for micro level data acquisition. The details of dugwells inventoried for micro level data acquisition are given in **Annexure-III**. The locations of micro level hydrogeological data acquisition wells are shown in **Fig. 2.2**.

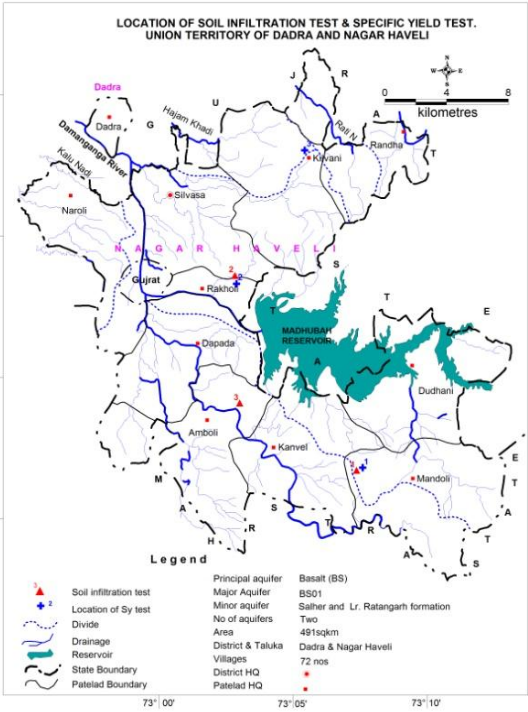


Fig.2.3: Locations of Soil Infiltration Tests and Specific Yield Tests

2.2.5 Soil Infiltration Tests

To estimate the actual rate of infiltration of various soil cover and their impact on recharge to ground water, 3 infiltration tests have been conducted at Saily, Khadoli and Chasda on various soil types (**Fig. 2.3**). The data has been analyzed and the salient features of the infiltration tests are presented in **Table 2.2**, whereas the data is presented in **Annexure-IV** and the plots of soil infiltration tests are presented in **Fig. 2.4**. The duration of the test ranged from 100 to 150 minutes, the depth of water infiltrated varied from 0.30 cm to 0.60 cm and the final infiltration rate in the area ranged from 1.80 cm/hr at Khadoli for the deep black clayey soil type to 3.60 cm/hr at Chasda for sandy loamy soil type.

Table 2.2: Salient Features of Infiltration Tests

S. No.	Village	Date	Soil Type	Duration (min)	Water Level (cm agl)	Final Infiltrated Water Depth (cm)	Final Infiltration Rate (cm/hr)
1.	Chisda	10-03-2016	Sandy loamy black soil	120	20.00	0.60	3.60
2.	Khadoli	11-03-2016	Deep black clayey	150	20.00	0.30	1.80
3.	Saily	13-03-2016	Shallow loamy soil	100	20.00	0.50	3.00

2.2.6 Specific Yield Tests

To estimate the aquifer parameters of shallow aquifer (Aquifer-I) in the area, 3 pumping tests on open dug wells have been conducted and their locations are shown in **Fig. 2.3**. The data has been analyzed by Kumarswamy method, the salient features of pumping tests are given in **Table 2.3**. The discharge of the wells ranged from 140 to 180 lpm for pumping duration of 140 to 180 minutes.

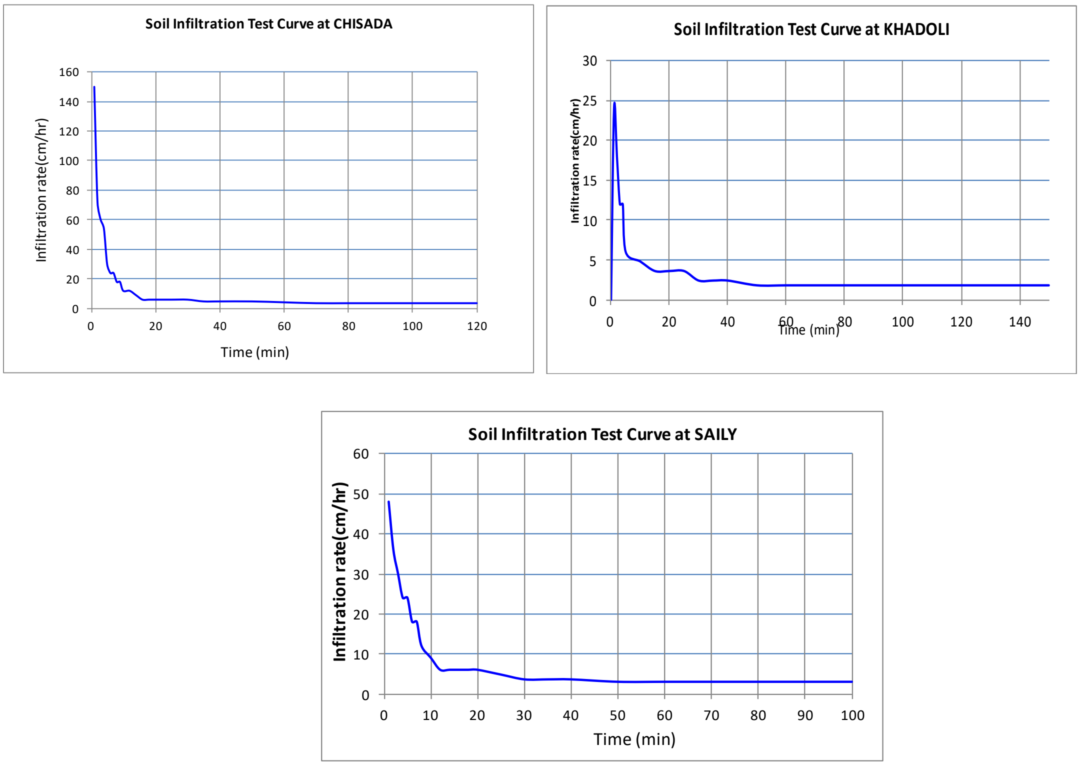


Fig.2.4: Soil Infiltration Plots for Chisda, Khadoli and Saily

The drawdown observed at the end of the pumping ranged from 0.69 to 2.44 m and the residual drawdown for the 1st minute was observed to be ranging from 0.62 to 2.40 m. The aquifer parameter values estimated by Kumarswamy method are observed to be well within the general range of values for weathered and jointed basalt i.e., the transmissivity value was observed from 7.16 to 10.27 m^2/day, whereas the specific yield 1.6% to 2.4%, whereas specific capacity values ranged from 88.11 to 385.51 lpm/m.

Table 2.3: Salient features of pumping tests – shallow aquifer (dug well) using Kumarswamy method

S. No.	Village	Diameter (m)	Depth (mbgl)	SWL (mbgl)	Q (lpm)	Pt (min)	DD (m)	RDD (m)	C (lpm/m)	T m2/day	Sy
1	Chisda	7.5	17	7.73	180	160	1.09	1.06	165.14	10.27	0.018
2	Saily	7.1	14	3.1	266	180	0.69	0.62	385.51	11.76	0.024
3	Kelwani	6.8	15	10.78	215	140	2.44	2.4	88.11	7.16	0.016

Here, SWL – Static Water Level, Q – Discharge, Pt - Pumping duration, D/D – Drawdown, RDD - Residual drawdown, C - Specific Capacity, T – Transmissivity, Sy - Specific Yield

2.2.7 Thematic Layers

The following 5 thematic layers were also generated on GIS platform which supported the primary database and provided precise information to assess the present ground water scenario and also to propose the future management plan.

- Drainage
- Geomorphology
- Soil
- Land Use – Land Cover
- Geology and Structure

The thematic layers such as drainage, geomorphology, soil, land use-land cover have been described in Chapter – I. The geology of the area is presented in **Fig. 2.5**.

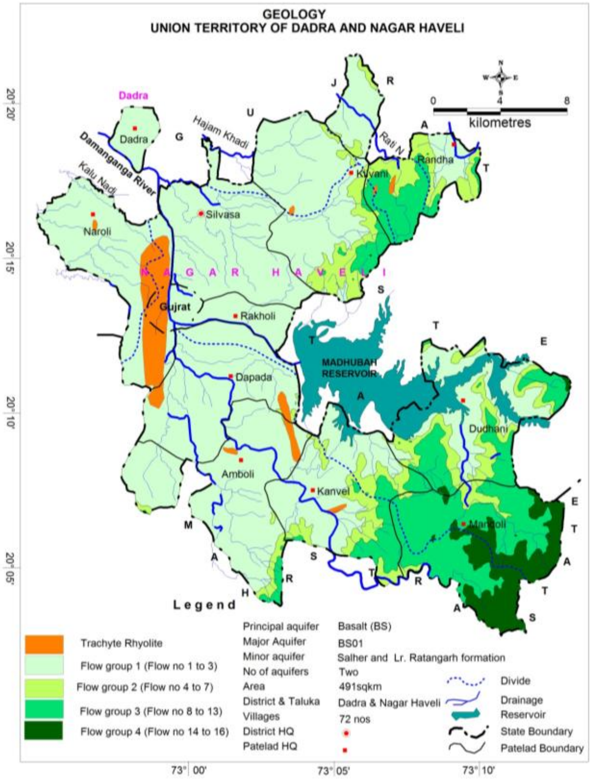


Fig.2.5: Geology

The area exposes a thick succession of basaltic lava flows of cretaceous to Eocene age. The flows have been intruded by a number of basic and intermediate dykes. A major Trachyte-Rhyolite acidic complex in the western part of the area is quite conspicuous. The flows are intruded by dykes of dolerite and basalt. The intrusions have north-south trends and are quite closely spaced. The area is occupied by 16 basaltic flows within 390m thick lava pile between elevation of 40 m and 435 m amsl. Nine out of 16 basaltic lava flows are of 'aa' type and seven are compound pahoehoe in nature.

3 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The data collected and generated on various parameters viz., water levels, water quality, exploration, aquifer parameters, geophysical, hydrology, hydrometeorology, irrigation, thematic layers was interpreted and integrated. Based on this the various aquifer characteristic maps on hydrogeology, aquifer wise water level scenario both current and long term scenarios, aquifer wise ground water quality, 2-D and 3-D sub surface disposition of aquifers by drawing fence and lithological sections, aquifer wise yield potential, aquifer wise resources, aquifer maps were generated and as discussed in details.

3.1 Hydrogeology

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The principal aquifer in the area is Basalt, where the occurrence and movement of ground water primarily depends on the degree of interconnection of secondary pores/voids developed by fracturing and weathering. The hydrogeological map of area is prepared and presented in Fig.3.1.

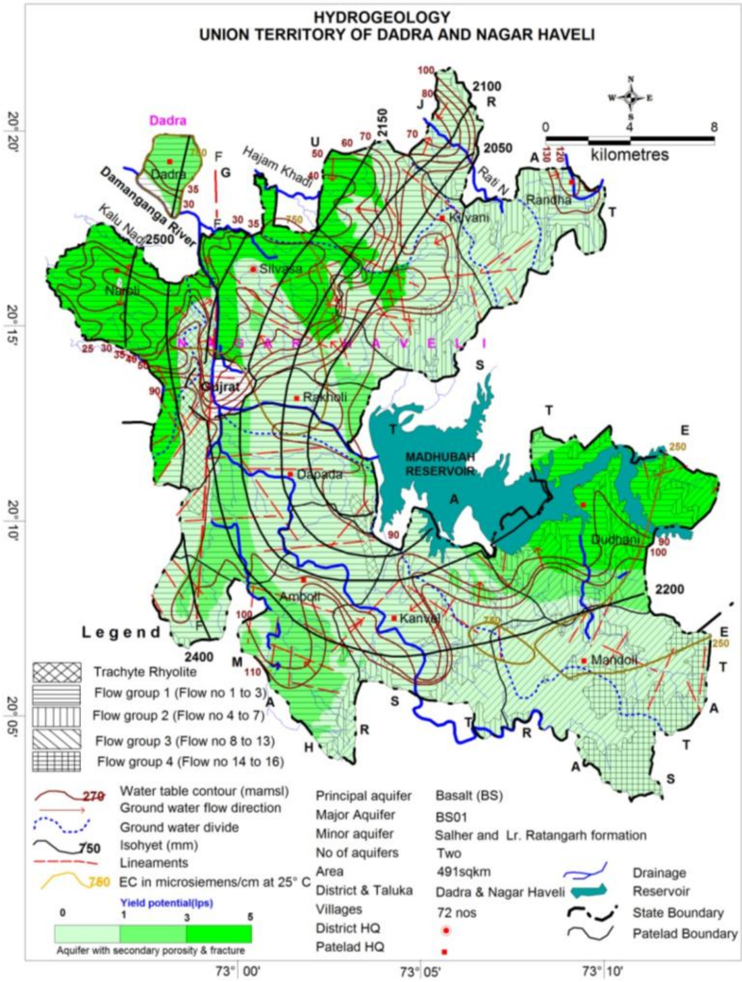


Fig. 3.1: Hydrogeology

The basaltic lava flows are massive and fine grained with negligible primary porosity and transmissivity. The area occurs in the vicinity of western coast, which have witnessed many tectonic disturbances. These have caused development of joints and fractures in the basaltic strata. Also weathered zones of about 10-20 m thickness have developed in plains and depressions. Thus the weathered, jointed and fractured zones of vesicular and massive units of a flow constitute the main water bearing horizons. However, these zones are not continuous and uniformly developed laterally or vertically and this factor plays an important role in the success and failure of wells in the area.

Ground water occurs in unconfined state in shallow aquifer tapped by dugwells of 10 to 30 m depth, water levels are ranging from 1.20 – 15.00 m bgl and yield varies from 10 to 100 m^3/day. The deeper aquifer is also present and it ranges from 30-90 m bgl, whereas the water level ranges from 8 to 55 m bgl. The ground water development is mostly through dugwells rather than borewells.

Limited yields of upto 1 lps are observed in a horse shoe shaped patch occurring along north, central and southern parts, whereas moderate yields of 1 to 3 lps are being observed in limited areas in western parts and high yields of 3 to 5 lps are present in north western and south eastern parts of the UT of DNH.

3.1.1 Water Level Scenario – Aquifer-I (Shallow Aquifer)

The present depth to water level scenario of shallow aquifer was generated by utilizing water level data of 23 monitoring wells representing shallow aquifer. The **premonsoon** depth to water levels during May 2015 ranged between 2.60 (Silli) and 15.00 m bgl (Kilvani Sharyapada). The shallow water levels within 3 m bgl are observed mainly along the major drainages, whereas water levels between 3 and 6 m bgl are observed in major part. The deeper water levels of more than 9 m bgl are observed in limited areas of south western parts around Khanvel (industrial area) and Mandoli. The pre-monsoon and postmonsoon water level data is presented as **Annexure-V**, whereas depth to water level map is given in **Fig.3.2 and Fig. 3.3**.

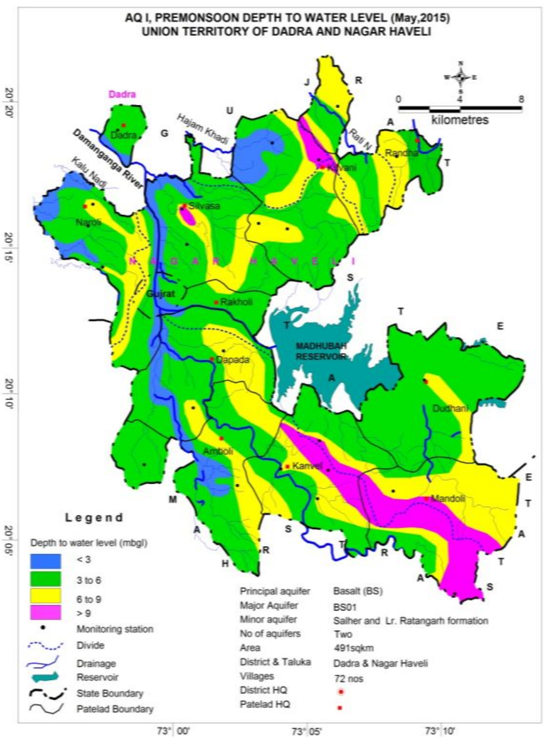


Fig. 3.2: Premonsoon (May 2015) Depth to Water Level of Aquifer-I (Shallow Aquifer)

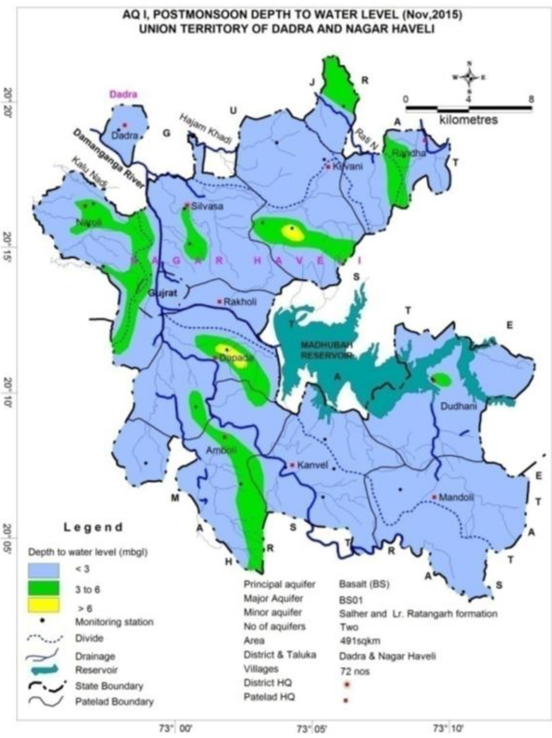
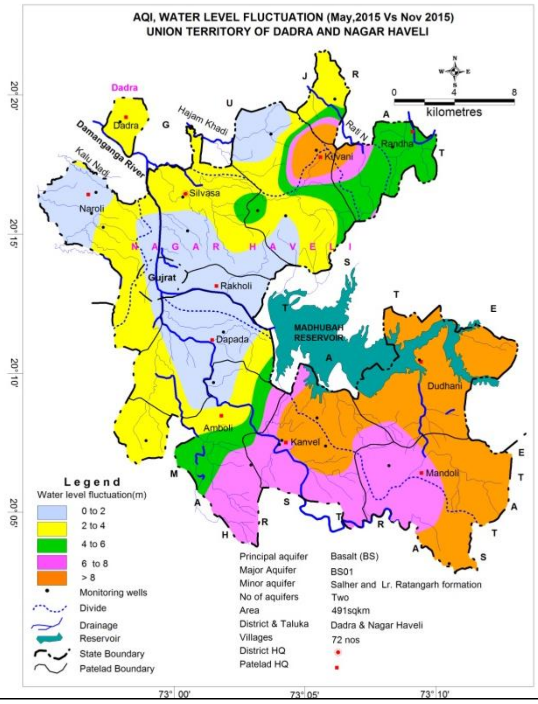


Fig. 3.3: Postmonsoon (Nov. 2015) Depth to Water Level of Aquifer-I (Shallow Aquifer)

The **postmonsoon** depth to water levels during Nov. 2015 ranged between 1.20 (Siphora) and 9.10 m bgl (Dapada). The shallow water levels within 3 m bgl are observed in major parts (88%) of the area. Moderate water levels of 3 to 6 m bgl are observed as isolated patches over entire UT.



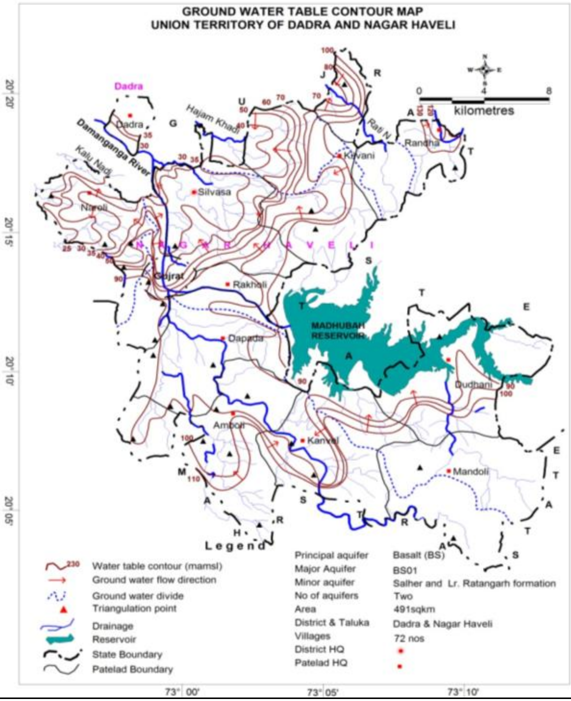


Fig. 3.4: Seasonal Fluctuation of Water Level

Fig. 3.5: Premonsoon Water Table Elevation (May 2015)

The water level measured during pre and post monsoon period (2015) was used to compute the seasonal fluctuation. The analysis of water level fluctuation data indicated that minimum water level fluctuation was observed at Rakhali (0.54m) while maximum water level fluctuation was observed at Kilvani Sharyapada (13.30 m). The water level fluctuations were grouped under three categories i.e., less, moderate and high and the % of wells in each category was analysed (**Table-3.1**).

Table-3.1: Analysis of Water Level Fluctuation

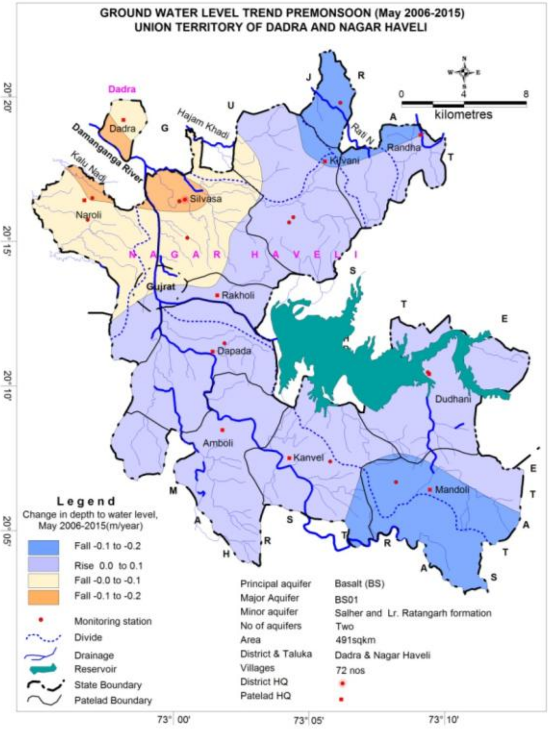
S. No.	Category	Fluctuation Range	% of Wells
1.	Less water level fluctuation	0 to 4 m	52.16%
2.	Moderate water level fluctuation	4 to 8 m	21.74%
3.	High water level fluctuation	8 to >10 m	26.09%

The analysis indicates that majority of the wells (52.16%) are falling in less fluctuation range indicating good aquifer storage, whereas moderate water level fluctuation are observed in 21.74% wells and high water level fluctuation were observed in 26.09 % wells. The seasonal fluctuation map is presented as **Fig. 3.4**, the perusal of map indicates that fluctuation of upto 4 m is observed in major part of the area in central and northern parts, whereas higher fluctuation of more than 4 m is observed in hilly areas and low potential areas occurring in the north east and south eastern parts of the UT of DNH.

The water table elevation map for premonsoon period (May 2015) was also prepared (**Fig.3.5**) to understand the ground water flow directions. The water table elevation ranges from 25 m amsl to 130 m amsl and the flow is mainly towards Damanganga River flowing through the central part of the UT in N-S direction.

3.1.2 Long Water Level Trend (2006-15)

In order to study long term behavior of the water levels and also the effect of various developmental activities with time, the data for the period 2006-15 have been computed and analyzed. The decadal premonsoon water level trend analysis (**Fig 3.6**) indicates that during pre-monsoon period, major area of 400 sq.km., is showing rising trend albeit of negligible range, whereas insignificant declining trend of upto 0.10 cm/year is observed in restricted areas along northwestern. The decadal postmonsoon water level trend analysis (**Fig 3.7**) also indicates similar situation with major area showing rise in water levels that during post-monsoon period, whereas declining trend is observed in western parts.



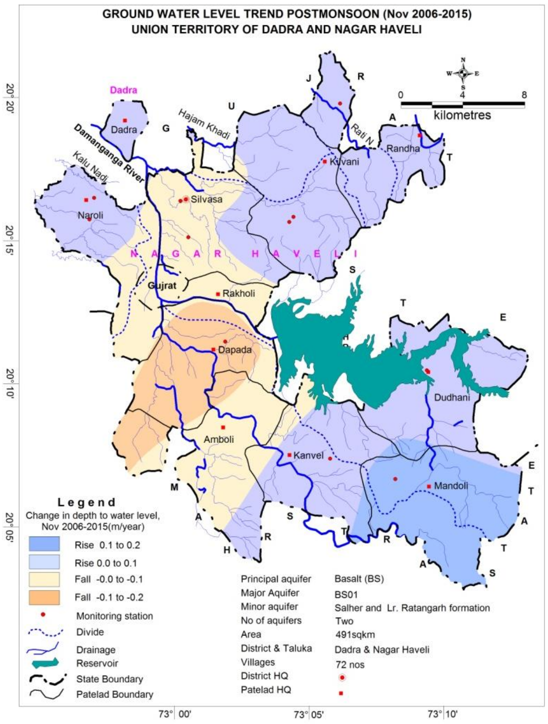


Fig. 3.6: Premonsoon Water Level Trend (May 2006-15) of Aquifer-I (Shallow Aquifer)

Fig. 3.7: Postmonsoon Water Level Trend (Nov. 2006-15) of Aquifer-I (Shallow Aquifer)

3.1.3 Water Level Scenario – Aquifer-II (Deeper Aquifer)

The depth to water level scenario of deeper aquifer was generated by utilizing water level data of 15 exploratory/observation wells representing deeper aquifer. The **premonsoon** depth to water levels ranged between 8.00 (Galonda) and 55.00 m bgl (Kilvani). The shallow water levels within 10 m bgl are observed mainly in western part, whereas in major part of the area the water levels ranging between 10 and 20 m bgl in central part. The deeper water levels of more than 20 m bgl are observed in north eastern parts near Kilwani and south eastern parts near Mandoli. The pre-monsoon and postmonsoon water level data is presented as **Annexure-VI**, whereas depths to water level maps are given in **Fig.3.8 and Fig.3.9**.

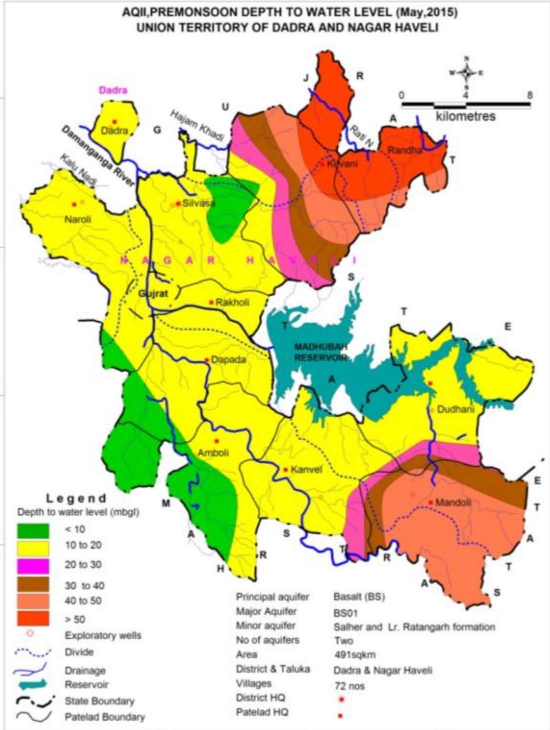


Fig. 3.8: Premonsoon Depth to Water Level of Aquifer-II (Deeper Aquifer)

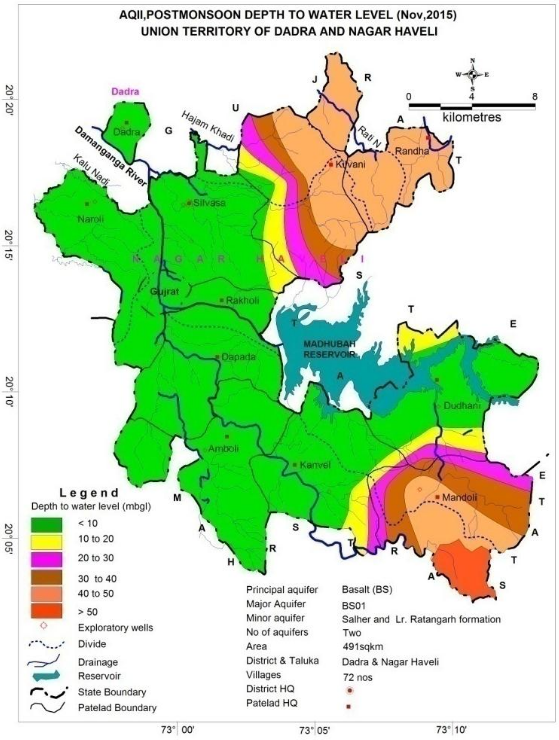


Fig. 3.9: Postmonsoon Depth to Water Level of Aquifer-II (Deeper Aquifer)

The **postmonsoon** depth to water levels ranged between 4.56 (Galonda) and 52.00 m bgl (Kilvani). The spatial distribution of water levels shows that the areas with moderately deeper water levels of 10 to 20 m bgl during premonsoon have migrated to shallow water levels within 10 m bgl in major parts of the area, thereby indicating adequate ground water recharge even in deeper aquifer due to monsoon rainfall. Whereas the area of deeper water level (>20 m bgl) are occurring in the same regions, but their spatial extent / area coverage has reduced due to the monsoon rainfall recharge.

3.2 Ground Water Quality

The suitability of ground water for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water on the growth of human being, animals, various plants and also on industrial requirement. Though many ions are very essential for the growth of plants and human body but when present in excess, have an adverse effect on health and growth. For assessment of ground water quality, samples from 17 KOW's (shallow dug wells representing phreatic aquifer) have been collected during pre-monsoon. Similarly for Aquifer – II, the ground water quality data of 12 exploratory/observation wells drilled during earlier exploration and current exploratory drilling activities were utilised. The ground water samples were analysed for major chemical constituents. The aquifer wise ranges of different chemical constituents present in ground water are given in **Table 3.2.**The details of water quality analysis of Aquifer I and II are given in **Annexure VII and VIII**.

Table 3.2: Aquifer wise ranges of chemical constituents

Constituents	BIS standards for drinking water	Aquifer – I (Shallow aquifer)			Aquifer-II (Deeper Aquifer)		
		Min	Max	No. of samples above MPL	Min	Max	No. of samples above MPL
pH	6.5-8.5	7.3	8.0	Nil	7.6	8.4	Nil
EC	-	217	1193	Nil	89	3804	-
TDS	500-2000	141	775	Nil	308	500	Nil
TH	300-600	80	450	Nil	37	1206	2
Calcium	75-200	28	134	Nil	10	310	2
Magnesium	30-100	2	60	Nil	3	105	1
Potassium	-	0.02	2.07	-	1.0	1.6	-
Sodium	-	2	155	-	22	216	-
Carbonate	-	Nil	Nil	-	Nil	36	-
Bi-carbonate	-	37	378	-	86	488	-
Chloride	250-1000	18	209	Nil	8	1032	1
Sulphate	200-400	12	302	Nil	10	80	Nil
Nitrate	45	ND	27	Nil	NA	NA	NA
Fluoride	1-1.5	0.21	1.17	Nil	NA	NA	NA

Note- All values except EC (µS/cm @ 25°C) and pH are in mg/L.

On perusal of above table, it is observed that in case of Aquifer-I, the maximum values of all the parameters are within permissible range of BIS indicating that the ground water is suitable for drinking purpose. The iso-conductivity map of Aquifer has been prepared and presented as **Fig. 3.10**, major area is having EC upto 750 µS/cm, whereas small area in north-western part is having EC between 750 and 1200 µS/cm.

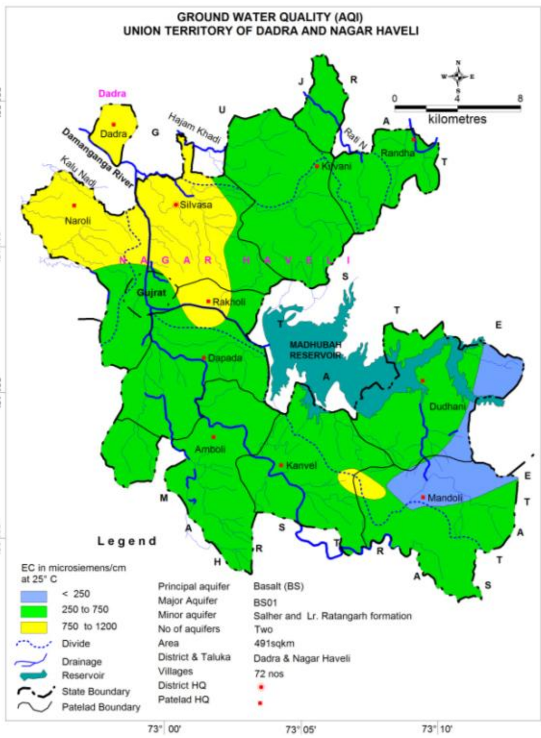


Fig. 3.10: Iso-conductivity of Aquifer-I (Shallow Aquifer)

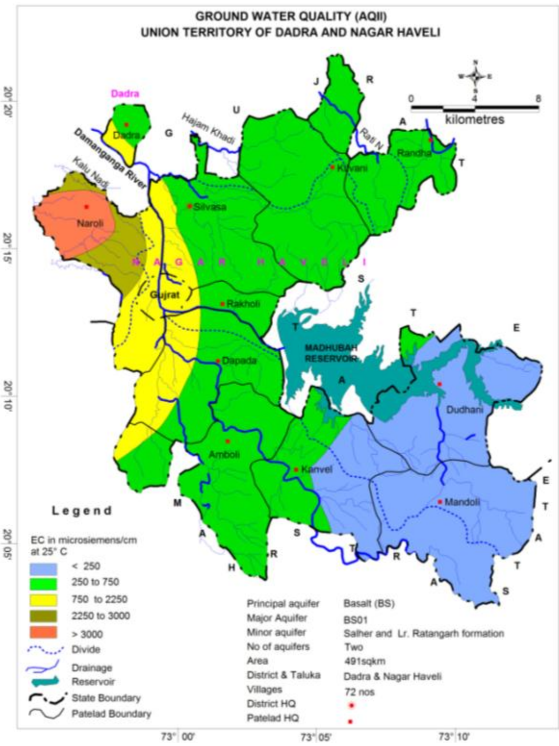


Fig. 3.11: Iso-conductivity of Aquifer-II (Deeper Aquifer)

In case of Aquifer-II, it is observed that Total Hardness, Calcium and Magnesium are above permissible limit at Naroli. The iso-conductivity map of Aquifer has been prepared and presented as **Fig. 3.11**, major area is having EC upto 750 µS/cm, whereas small area in north-western part is having EC between 750 and 3000 µS/cm.

3.3 3-D and 2-D Aquifer Disposition

The data generated from ground water monitoring wells, micro level hydrogeological inventories, exploratory and observation wells, various thematic layers was utilized to decipher the aquifer disposition of the area. This particularly includes the information on geometry of aquifers and hydrogeological information of these aquifers. In the area, Deccan Trap Basalt is the only formation and within it two aquifer systems has been deciphered as listed below:

Deccan Trap Basalt –

a. **Aquifer – I (Shallow Aquifer): 10 to 30m**
b. **Aquifer – II (Deeper Aquifer): 30 to 90 m**

The fence diagram indicating the disposition of various aquifers is presented in **Fig.3.12** and 3-D representation is presented in **Fig. 3.13**. In western part of the area the presence of dyke can be seen, which acts as water barrier structure and is devoid of water. The disposition of Aquifer-I and Aquifer-II followed by massive basalt can be observed in the Fence. In the north eastern parts around Kilwani and southeastern parts around Mandoni, the cumulative depth of Aquifer-I and II is shallow, whereas in centrally elongated parts, the cumulative thickness of aquifer is much more indicating potential areas of ground water.

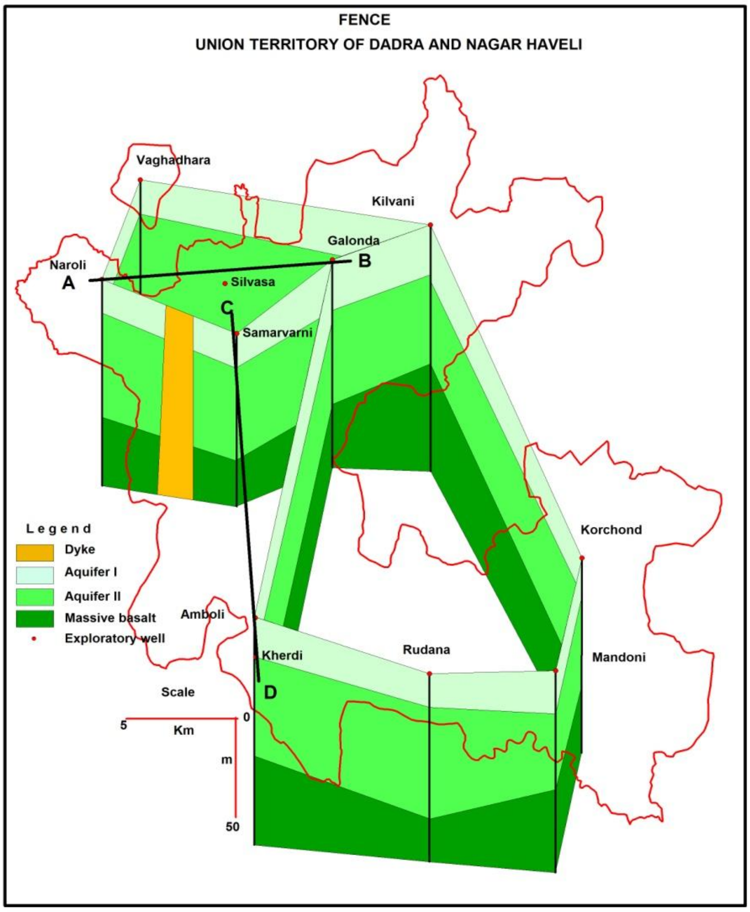


Fig.3.12: Fence Diagram

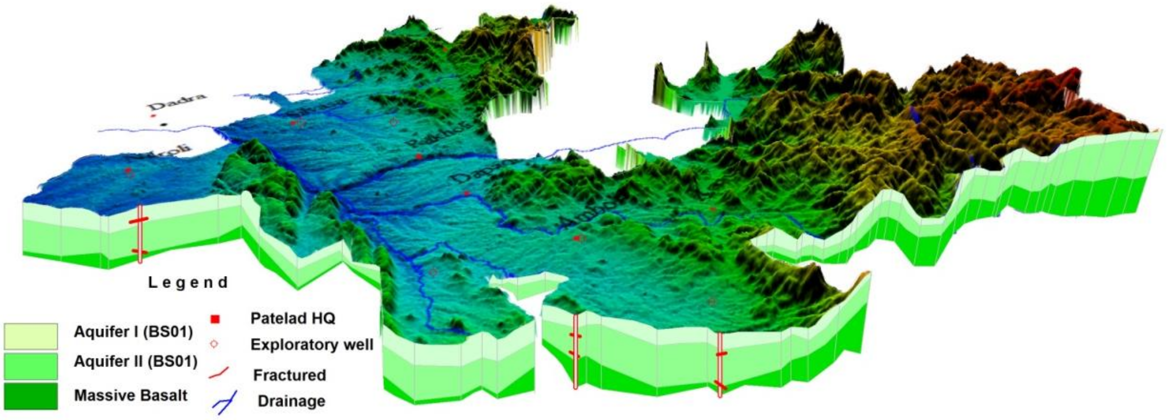
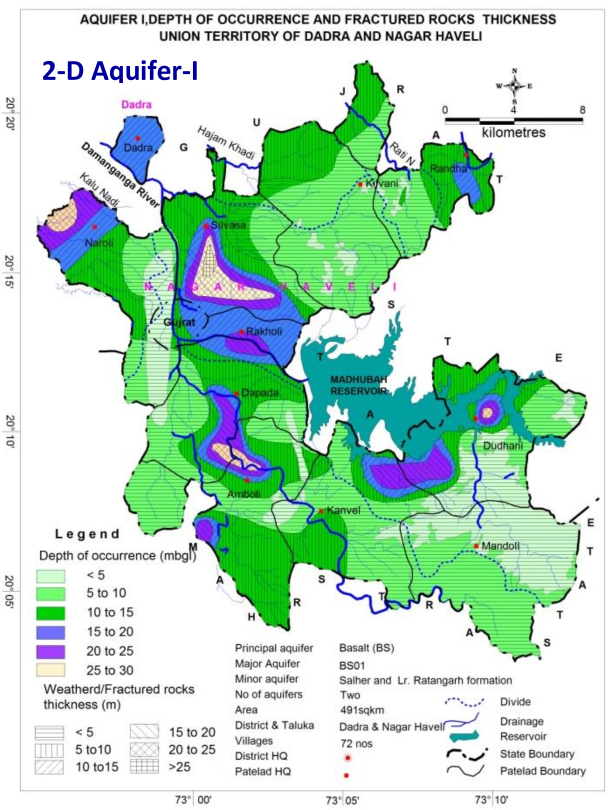


Fig.3.13: 3-D disposition of Aquifers

The 2-D map showing spatial disposition and vertical extent of **Aquifer-I** indicating its depth of occurrence and fractured rock thickness has been generated and shown in **Fig 3.14**, whereas that of **Aquifer-II** is presented in Fig.**3.15.** The perusal of **Aquifer-I map** indicates in major part the shallow aquifer is observed upto 15 m and thickness of the aquifer is upto 10 m. In central part maximum depth (30 m) and thickness (upto 25 m) of Aquifer-I is observed, which implies that this part is having good ground water potential. In north-eastern and south-eastern hilly areas, the aquifer depth is restricted to 10 m and the thickness of aquifer is restricted to 5 m.



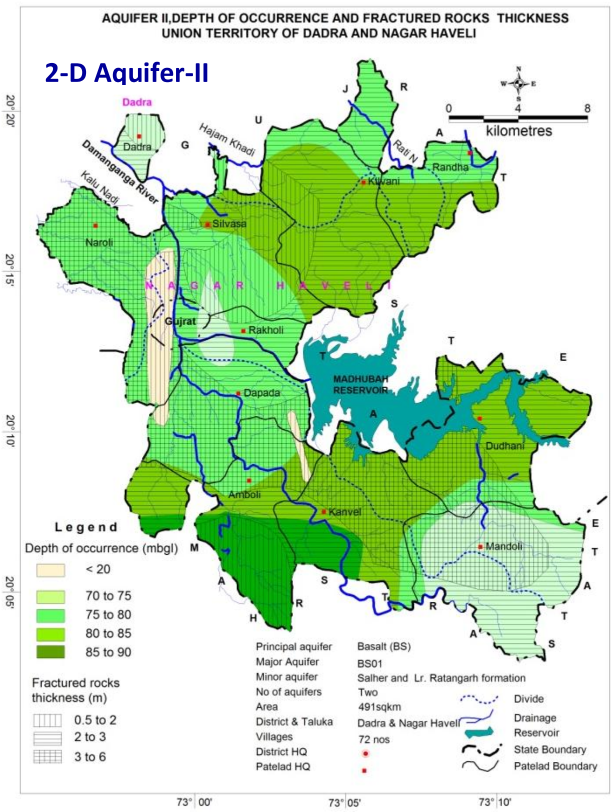


Fig. 3.14: 2-D disposition of Aquifer-I

Fig. 3.15: 2-D disposition of Aquifer-II

The perusal of **Aquifer-II map** indicates in major part the deeper aquifer is observed upto 80 m depth and thickness of upto 3 m. In north eastern part from Kilvani to Silvassa and south eastern - western part around Dudhani to west of Khanvel, maximum depth of Aquifer -II is upto 85 to 90 m, however even in this 90 m depth, the thickness of fractured rock is limited to 3 to 6 m. Thus the water bearing zones in Aquifer-II are limited in the area.

3.3.1 Hydrogeological Cross Sections

To study the aquifer disposition in detail, various hydrogeological cross section indicating aquifer geometry has been prepared viz. A-B representing west – east direction and C-D representing north – south direction.

3.3.1.1 Hydrogeological Cross Section A-B

Hydrogeological cross section A-B (**Fig.3.16**) represents west –east direction and data of 3 exploratory wells i.e., Naroli, Silvassa and Galonda has been utilised. It can be clearly seen from the section that as we move from west to east direction i.e., from Naroli to Galonda, the thickness of Aquifer-I (shallow aquifer) is decreasing. On the contrary, the thickness of Aquifer-II (Deeper aquifer) is increasing. The maximum depth of Aquifer-II is ranging from 61.35 m bgl at Naroli to 76.39 m bgl at Galonda, whereas maximum number of fracture zones (2 no.'s) were encountered at Naroli at 54 m and 60 m depth which yielded a high discharge of 10.28 lps. The water levels of Aquifer-I and Aquifer-II has also been depicted in the section and a close observation of water level indicates that the water table of Aquifer-II has risen above that of Aquifer-I due to high hydrostatic pressure in major part of the section except near Galonda.

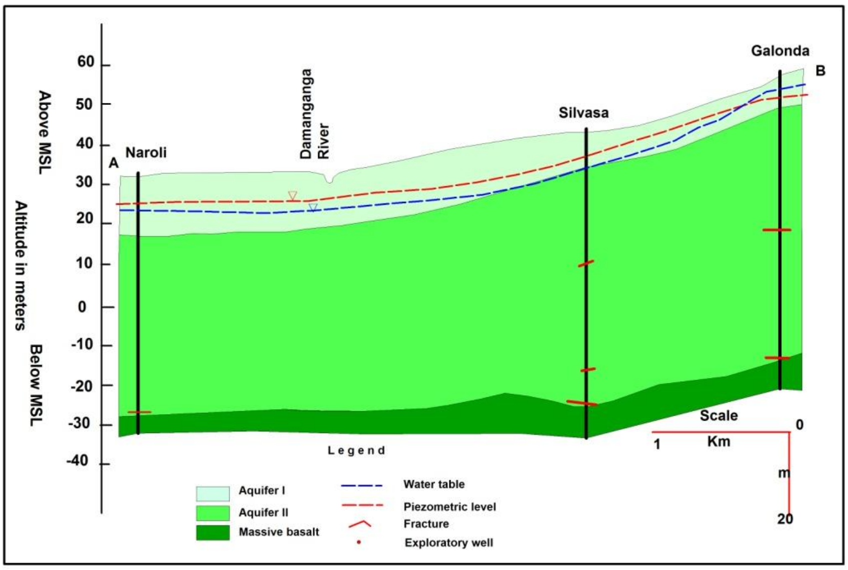


Fig.3.16: Hydrogeological Cross Section A-B

3.3.1.2 Hydrogeological Cross Section C-D

Hydrogeological cross section C-D (**Fig.3.17**) represents north – south direction and data of 3 exploratory wells i.e., Samarvani, Amboli and Kherdi has been utilised. In this section the as we move from north to south direction, i.e., from Samrvani to Kherdi, the thickness of Aquifer-I (shallow aquifer) is increasing. On the contrary, the thickness of Aquifer-II (Deeper aquifer) is decreasing. The maximum depth of Aquifer-II is ranging from 70.91 m bgl at Amboli to 78.39 m bgl at Samrvani, whereas the maximum discharge of 2.86 lps have been observed at Kherdi. The water levels of Aquifer-I and Aquifer-II has also been depicted in the section and a close observation of water level indicates that the water table of Aquifer-II has risen above that of Aquifer-I due to high hydrostatic pressure in northern part of the section.

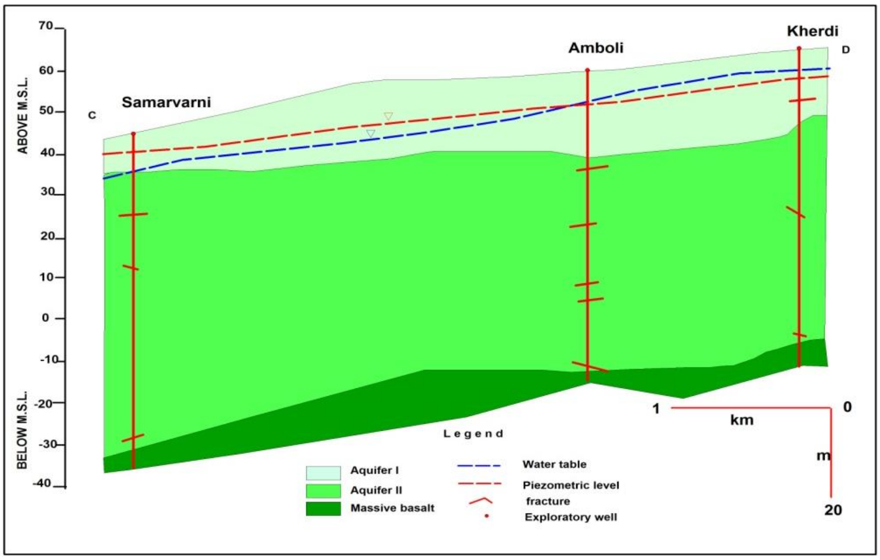


Fig.3.17: Hydrogeological Cross Section C-D

3.4 Aquifer Characteristics

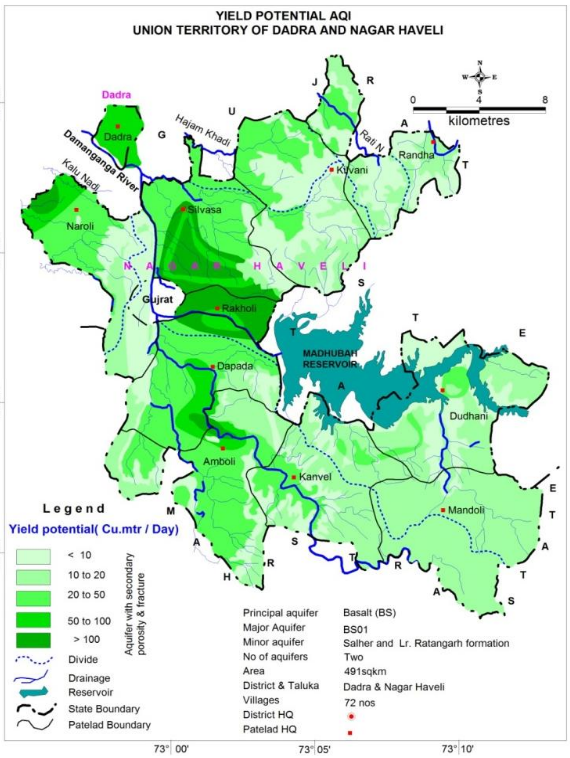
Basalt forms the main aquifer of the area and comprises two distinct units viz, upper vesicular unit and lower massive unit. The massive basalt is hard, compact and does not have primary porosity and hence impermeable. Weathering, jointing and fracturing induces secondary porosity in massive unit of basalt. In vesicular basalt, when vesicles are interconnected constitutes good primary porosity and when the vesicles are filled/ partly filled the porosity is limited. Ground water occurs under phreatic/ unconfined to semi-confined conditions in basalts.

Based on extensive analysis of historical data, micro level hydrogeological survey data generated and ground water exploration carried out in the UT of DNH, the following two types of aquifers can be demarcated and the details are given below in Table-3.3.

Table-3.3: Aquifer Characteristics

Type of Aquifer	Formation	Depth range (mbgl)	SWL (mbgl)	Fractures / weathered Zones encountered (m bgl)	Fractured / weathered rocks Thickness (m)	Yield	Sustai-nability	Aquifer parameter (Transmissivity – m^2/day)	Sy/S	Suitability for drinking/ irrigation
Aquifer-I	Deccan Trap-Weathered/ Fractured Basalt	10 - 30	1.20 – 15.00	Upto 30	3 to 25	10 to 100m^3/day	1 to 5 Hours	9.25-89.04	0.019-0.028	Yes , suitable for both
Aquifer-II	Jointed/ Fractured Basalt	30-90	8-55	Upto 90	0.5 to 6	Upto 3 lps	0.5 to 3 hours	10.85-131.11	1.30×10^{-4} - 5.31×10^{-4}	Yes, suitable for both, except High EC

Aquifer I - Unconfined aquifer occurs in Deccan trap basalt is exposed in major parts of the UT of DNH except where dykes are observed. This aquifer generally occurs down to the depth of 10 to 30 m bgl and within this the weathered and fractured rock thickness is ranging from 3 to 25 m, whereas the water levels are ranging from 1.20 to 15 m bgl. The dugwells tapping this aquifer can sustain pumping for 1 to 5 hours and these are the more feasible structures in the area. The **Aquifer-II** – semi –confined to confined aquifer occurs in the depth range of 30 to 90 m bgl, however the actual water bearing zones i.e., fractured rock thickness is limited to 0.50 to 6.0 m, whereas the water levels are ranging from 8 to 55 m bgl. The borewells tapping this aquifer can sustain pumping for 0.50 to 3 hours. The map showing yield potential of Aquifer-I and Aquifer-II is presented in **Fig 3.18**, whereas the yield potential maps are presented as **Fig.3.19.**



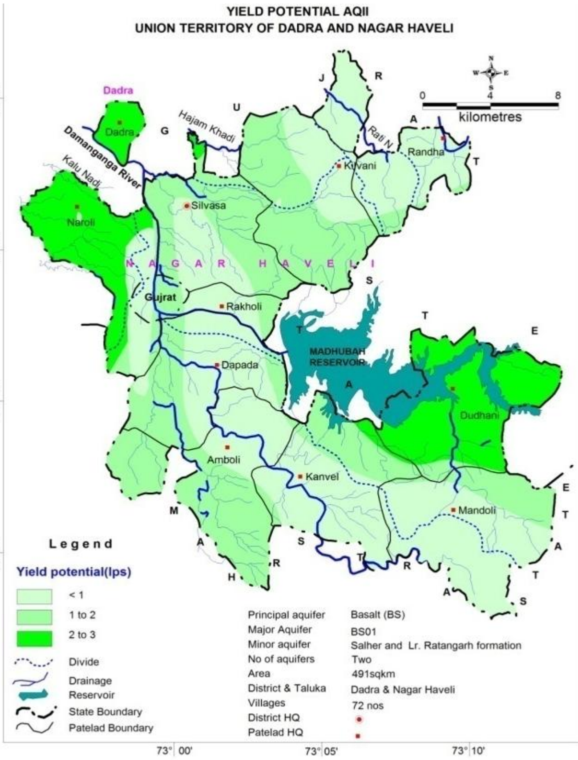


Fig. 3.18: Aquifer-I – Yield Potential **Fig. 3.19: Aquifer-II – Yield Potential**

The perusal of **Fig. 3.18** indicates that in major parts the yield potential of Aquifer-I is within 50 m3/day. The north-central parts near Silvassa and Rakholi and south central parts near Dapada-Amboli are having good/higher yield potential ranging from 50 to more than 100 m3/day. Small areas in north western part around Naroli also show moderate to good yield potential. These areas seem feasible for dug well construction.

The perusal of **Fig. 3.19** indicates that in major parts the yield potential of Aquifer-II is low within 1 lps particularly in central elongated patch extending from Silvassa in north to south of Mandoli in southern part. The north western parts near Dadra, Naroli and south eastern parts near Dudhani exhibit moderate to good ground water potential of 2 to 3 lps. In remaining areas particularly western parts and north eastern parts have moderate ground water potential of 1 to 2 lps.

Along with yield potential, the aquifer parameters viz., transmissivity and specific yield / storativity also form an important aquifer characteristic and provide valuable input on sustainability of the aquifers. The transmissivity of Aquifer-I ranges from 9.25 to 89.04 m^2/day thus indicating vide variation, whereas the specific yield ranges from 0.019-0.028 i.e., 1.9% to 2.8% which is within the norms of 2% to 3% for basaltic aquifers indicating that the yields of the wells in the area are better than the borewells. The transmissivity of Aquifer-II ranges from 10.85-131.11 m^2/day, whereas storativity of the aquifer ranges from 1.30×10^{-4} to 5.31×10^{-4}.

4 GROUND WATER RESOURCES

The ground water resources have been assessed for two types of aquifer existing in the area i.e., Aquifer-I and Aquifer-II. The details of the assessment are discussed below.

4.1 Ground Water Resources – Aquifer-I

The ground water resource assessment has been carried out by considering the UT of DNH as a single unit and the salient features of the resources are given in Table 4.1, 4.2 and 4.3 and the map depicting the distribution of ground water resources and categorisation of the talukas is presented in **Fig 4.1**.

As per Table-4.1, out of the total 49100 ha area, recharge worthy areas are 4235 ha in command areas and 37365 ha in non-command areas, whereas 7500 ha area is not worthy for recharge on account of its hilly nature.

Table-4.1: Ground Water Recharge Worthy Areas for Resource Estimation

Unit	Predominant Formation	Total Geographical Area (ha)	Hilly Area (ha)	Ground Water Recharge Worthy Area	
				Command area (ha)	Non-command area (ha)
UT of DNH	Basalt	49100.00	7500.00	4235.00	37365.00

4.1.1 Recharge Component

During the monsoon season, the rainfall recharge is the main recharge parameter, which is estimated as the sum total of the change in storage and gross draft. The change in storage is computed by multiplying groundwater level fluctuation between pre and post monsoon periods with the area of assessment and specific yield. Monsoon recharge can be expressed as:-

$R = h \times Sy \times A + DG$

where,

h = rise in water level in the monsoon season, Sy = specific yield

A = area for computation of recharge, DG = gross ground water draft

The monsoon ground water recharge has two components- rainfall recharge and recharge from other sources. The other sources of groundwater recharge during monsoon season include seepage from canals, surface water irrigation, tanks and ponds, ground water irrigation, and water conservation structures.

During the non-monsoon season, rainfall recharge is computed by using Rainfall Infiltration Factor (RIF) method. Recharge from other sources is then added to get total non-monsoon recharge.

The season wise assessment of recharge from various components such as rainfall and other sources was done and presented in Table-4.2 and **Fig.4.1**. The recharge from rainfall contributes maximum component (5417.70 ham) during monsoon season and recharge from other sources is 219.90 ham, whereas during non-monsoon season, recharge from rainfall is 966.61 and the recharge from other sources is 441.48 ham. The total annual ground water recharge is 7045.69 ham and net ground water availability after natural discharge is estimated as 6341.12 ham.

Table-4.2: Recharge Components evaluated for Resource Estimation

Command / Non-Command / Total	Recharge from rainfall during monsoon season (ham)	Recharge from other sources during monsoon season (ham)	Recharge from rainfall during non-monsoon season (ham)	Recharge from other sources during non-monsoon season (ham)	Total Annual Ground Water Recharge (ham)	Provision for Natural Discharges (ham)	Net Annual Ground Water Availability (ham)
Command	551.53	150.56	121.66	301.47	1125.22	112.52	1012.70
Non Command	4866.17	69.34	844.95	140.01	5920.47	592.05	5328.43
Total	**5417.70**	**219.90**	**966.61**	**441.48**	**7045.69**	**704.57**	**6341.12**

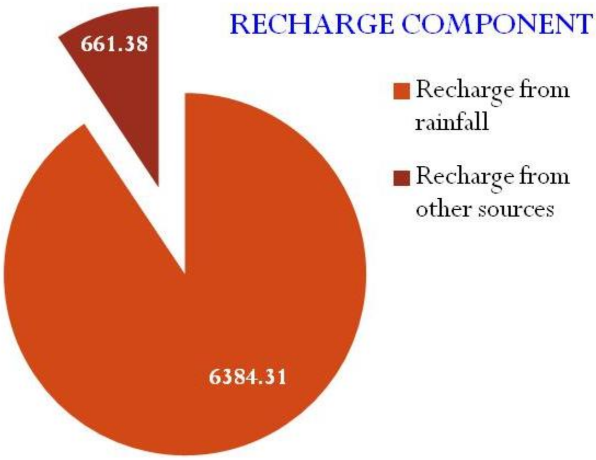


Fig.4.1: Recharge from various sources

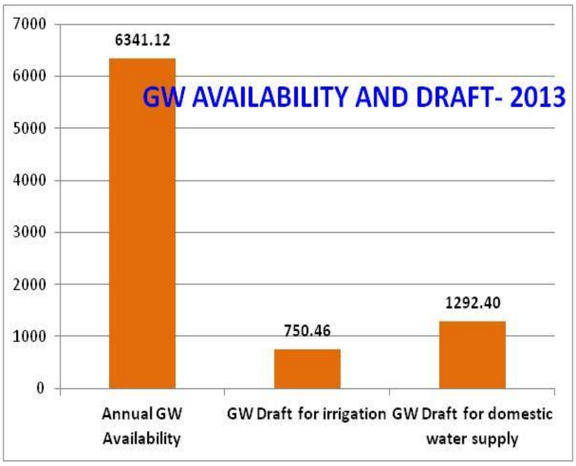


Fig.4.2: GW availability and Draft

The utilisation of available ground water resources for various purposes is provided in Table-4.3 and **Fig.4.2**. The annual gross draft for all uses is estimated at 2042.86 ham with domestic sector being the major consumer having a draft of 1292.40 ham. The annual draft for irrigation use was estimated as 750.46 ham. The allocation for domestic & industrial requirement supply up to next 25 years is about 1398.49 ham and ground water available for future irrigation is 4192.18 ham. The stage of ground water development is low i.e., 32.22%.

Table- 4.3: Ground Water Resources Availability, Draft and Stage of GW Development

Command / Non-Command / Total	Net Annual Ground Water Availability (ham)	Existing Gross Ground Water Draft for irrigation (ham)	Existing Gross Ground Water Draft for domestic and industrial water supply (ham)	Existing Gross Ground Water Draft for All uses (ham)	Provision for domestic and industrial requirement supply to 2025 (ham)	Net Ground Water Availability for future irrigation development (ham)	Stage of Ground Water Development (%)	Category
Command	1012.70	152.29	258	410.14	517.27	343.14	40.50	-
Non Command	5328.43	598.17	1035	1632.72	881.22	3849.04	30.64	-
Total	**6341.12**	**750.46**	**1292.40**	**2042.86**	**1398.49**	**4192.18**	**32.22**	**Safe**

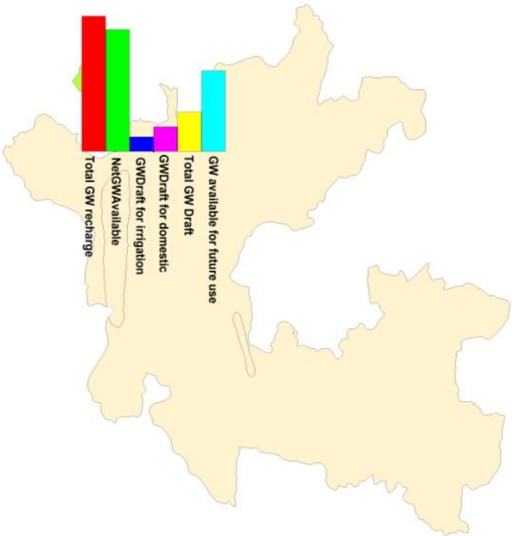


Fig.4.2: Ground Water Resources

4.2 Ground Water Resources – Aquifer-II

The ground water resource of the Aquifer –II was also assessed to have the correct quantification of resources so that proper management strategy can be framed. To assess these resources, the area was divided into various different polygons based on the fractured zones / thickness of aquifer –I occurring below water level in that particular polygon, then the storativity value for the nearest exploratory well was taken into consideration. By applying the formula of deeper ground water resource estimation as given by CHQ during the static ground water resources was utilised i.e.,

GWR = Area x Thickness of aquifer x Storativity

By applying above formula, the ground water resource of Aquifer-II was estimated as 6.99 MCM and are presented below in Table- 4.4.

Table- 4.4: Ground Water Resources of Aquifer-II.

Mean Fractured Rock Thickness (m)	Area (Sq km)	Storativity	Resource (MCM)
1.25	69.68	0.001307	0.113
2.5	231.07	0.00403	2.328
4.5	0.0215	0.001307	0.000127
4.5	190.22	0.005314	4.548
Total	**491.00**		**6.99**

5 GROUND WATER RELATED ISSUES

The study area forms part of predominantly tribal belt wherein villagers have got very small land holdings and they do not find it economical to engage in agricultural activity in comparison to the earning, they earn by working as laborer in industrial units and Govt. Dept.'s. Further, the cultivators are illiterate tribal and are ignorant of improved agricultural practices. As most part of the area comes under the command area of the Damanganga project, there is less demand on ground water for irrigation.

5.1 Low Ground Water Development

As such, UT of DNH is having only one major issue that is low ground water development. At present the overall stage of ground water development is only around 32% and the important part is that in UT of DNH a peculiar scenario is observed where in the withdrawal for domestic purpose is more than the irrigation purpose which is contrary to the pre-dominant agrarian nature reflecting in higher ground water withdrawal for irrigation purpose in other parts of the country. However, in UT of DNH due to the industrial activity and socio-economic set up which is more inclined towards producing food grains only for self consumption, the ground water withdrawal for irrigation is on lesser side. This provides immense scope for ground water development particularly in irrigation sector.

5.2 Low Ground Water Potential / Limited Aquifer Thickness / Sustainability

In UT of DNH, low ground water potential areas have been identified in 310 sq.km. area in north eastern, central and south eastern parts mostly due to hilly areas, restricted depth of weathering (<10m in 405 sq.km.) in Aquifer-I and limited aquifer thickness of Aquifer-II as seen in Fig. 5.1 a-b-c. Sustainability of both the aquifers is limited and the wells normally sustain pumping of 0.5 to 5 hours only.

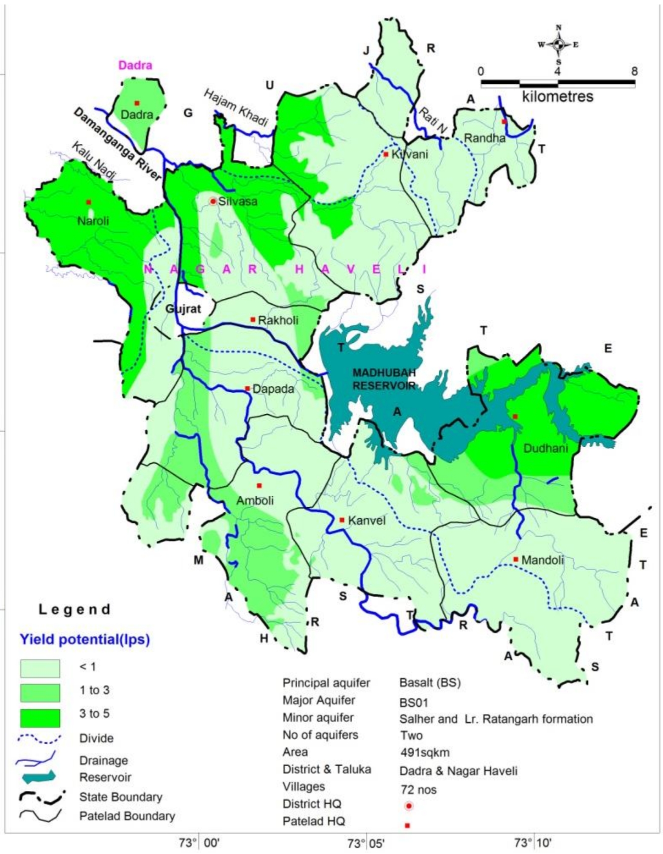
5.3 Deeper Water Levels in Aquifer-II

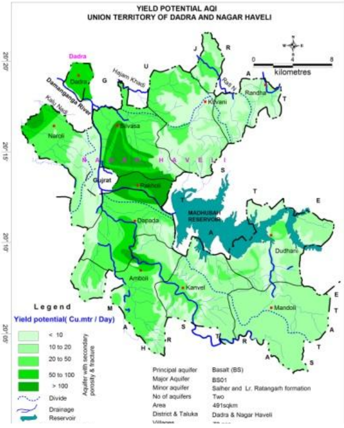
In UT of DNH, deeper water levels of more than 20 m bgl have been observed during premonsoon season in Aquifer II and they are spread over an area of 163 sq. km., particularly so in north eastern parts near Kilwani and south eastern parts near Mandoli which can be also co-related with the low ground water potential of these areas as seen in figure above.

5.4 Inferior Ground Water Quality

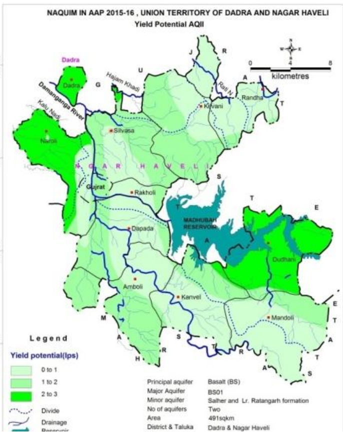
I UT of DNH, the ground water quality of deeper aquifer i.e., Aquifer-II is inferior as compared to other parts with EC > 2250 µS/cm. However these areas are restricted to north western parts (30.21 sq.km) the probable cause may be due to its close vicinity to industrial hub.

ISSUE: LOW GROUND WATER POTENTIAL – COMBINED POTENTIAL OF AQUIFER – I & II





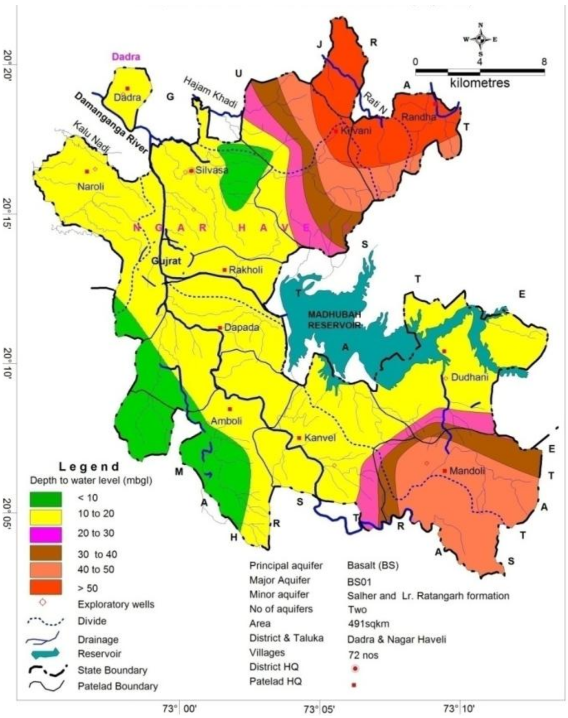
GROUND WATER POTENTIAL AQUIFER – I



GROUND WATER POTENTIAL AQUIFER – II

Fig. 5.1: Low Ground Water Potential Areas (Aquifer-I and Aquifer II)

ISSUE: DEEPER WATER LEVEL IN AQUIFER-II



ISSUE: INFERIOR GW QUALITY IN AQUIFER-II

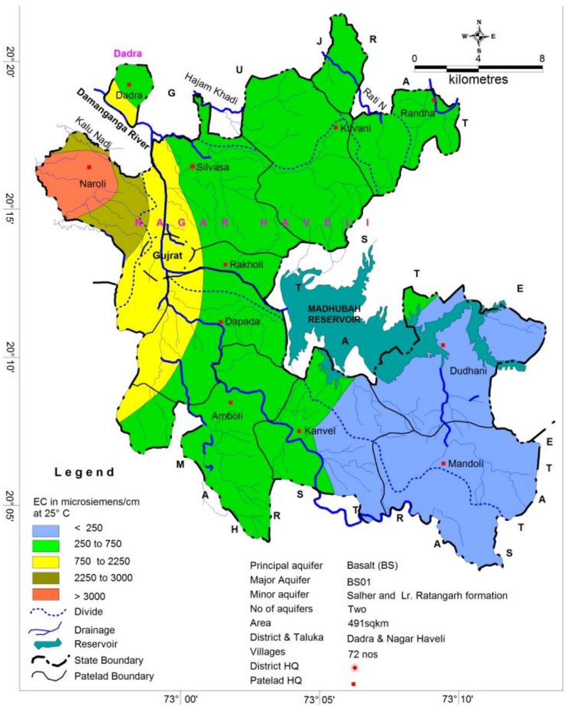


Fig. 5.2:

6 PROPOSED MANAGEMENT STRATEGY

As discussed in previous chapter, the major ground water related issue in the UT of DNH is low ground water development owing to many socio-economic and hydrogeological reasons. To overcome these, it is imperative to have a robust ground water resource development plan for the UT of DNH, which can be implemented in phased manner as indicated in Table-6.1.

6.1 Ground Water Resource Development Strategy

In view of above, the focus of proposed management plan was to up the ante of ground water development from the present 32.22% to 60% in the span of next 6 years in a systematic way by adopting scientific approach. About 38.52 sq.km., area has been identified for ground water development as indicated in **Fig. 6.1**, wherein 1066 dugwells (15-25 m depth; 3 to 5 m diameter @ Rs. 2.50 lakh/dugwell) are recommended to be constructed in feasible areas. Further 56 borewells (60-90 m depth; 100-150 mm dia @ Rs.0.60 lakh/borewell) are also recommended to be drilled in feasible areas. During the first 2 years 299 dugwells and 16 borewells are proposed at the cost of Rs. 7.46 crores and Rs. 0.094 crores respectively. During the next 2 years it is proposed to construct 384 dugwells and 20 borewells at the cost of Rs. 9.59 crores and Rs. 0.12 crores respectively followed by construction of same numbers of wells in the next 2 years. Thus the total cost of the construction / drilling of 1066 dugwells and 56 borewells are estimated as Rs. 26.98 crores over the next 6 years.

Table-6.1: Proposed Ground Water Resource Development Plan

Area Identified for GW Development	**38.52 sq.km**		
Items	**Proposed Structures**		**Total**
Present GW Availability is 63.41 MCM Present Gross Annual Draft is 20.42 MCM Present Stage of GW Development is 32.20%	**Dug wells** Depth: 15 to 25 m Dia: 3 to 5 m Cost -Rs.2.50 lakh, Av. Annual Gross draft - 1.57 ham	**Bore well** Depth: 60 to 90 m Dia – 100 to 150 mm Cost -Rs.0.60 lakh, Av. Annual Gross draft - 1.57 ham	
First two years – To bring **stage of GW development up to 40 %,** 4.93 MCM resources are required and are available.	299	16	**315**
Estimated Expenditure (Rs. in Cr.)	7.46	0.094	**7.56**
Next two year – To bring **stage of GW development to 50%**, 6.34 MCM resources required and are available	384	20	**404**
Estimated Expenditure (Rs. in Cr.)	9.59	0.12	**9.71**
Next two year- To bring **stage of GW development to 60%,** 6.34 MCM resources required and are available	384	20	**404**
Estimated Expenditure (Rs. in Cr.)	9.59	0.12	**9.71**
Total Estimated Expenditure (Rs. in Cr.)	**26.64**	**0.33**	**26.98**

Note- Hydrogeological and scientific intervention is needed for pinpointing the sites for construction of dugwells and Borewells

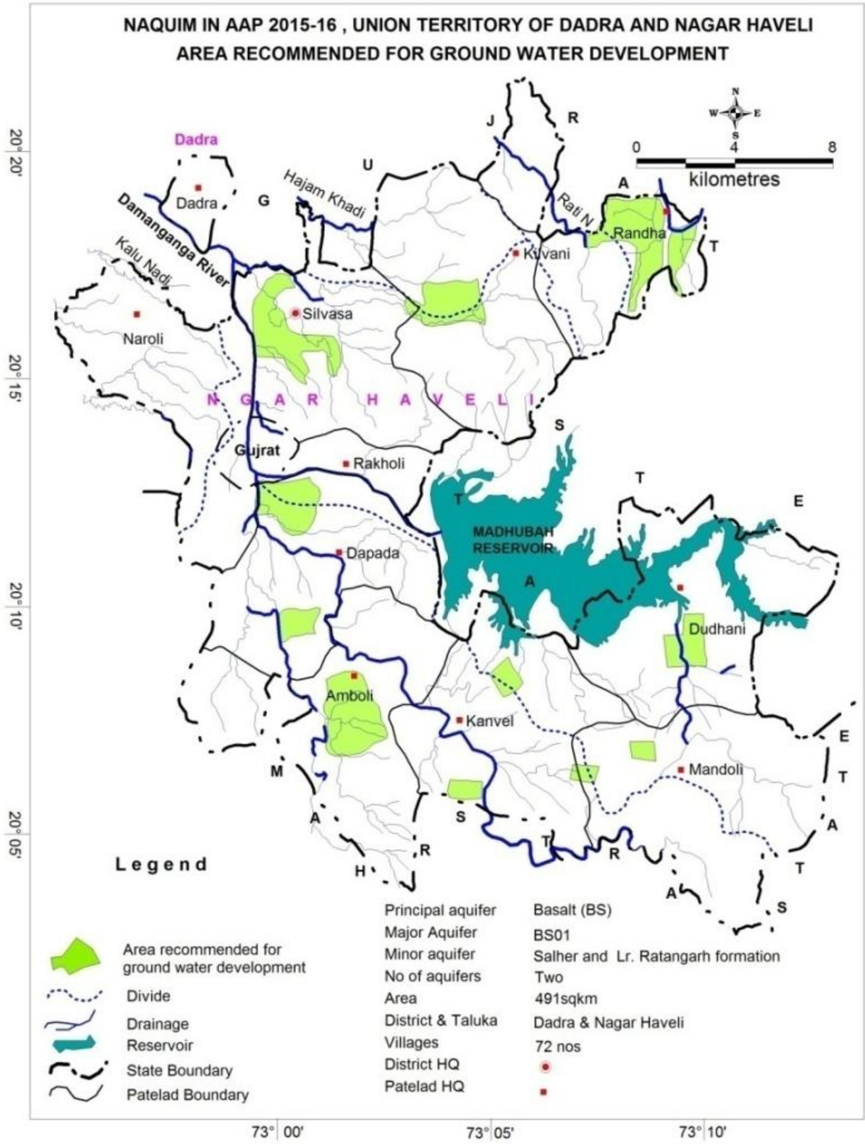


Fig.6.1: Areas Recommended for Ground Water Development

6.2 Supply side Interventions

However, considering the low storage potential of hard rock aquifer in the area the above ground water development plan should also be coupled with ground water augmentation plan, so that there is no stress on ground water regime of the area.

The proposed supply side interventions envisages construction of Rainwater Harvesting and Artificial Recharge structures (**Fig.6.2, Table-6.2 and Annexure-IX**) in the areas feasible for construction of recharge structures based on the long term water level scenario and recharge potential of the aquifer. It envisages construction of 10 percolation tanks @ Rs. 1.50 crore each and 25 check dams @ Rs. 0.30 crores each in feasible areas to fulfil the recharge potential of 2.08 MCM available in the UT of DNH. The proposed expenditure on these structures will be Rs. 22.50 crores.

Similarly Roof Top Rain Water Harvesting (RTRWH) in Hilly Areas of UT of DNH has also been proposed with an objective to cater to the drinking and cooking water requirements of the people residing in these areas. Tentatively about 1000 houses in these areas were considered to have RTRWH scheme for individual household by providing an storage tank of 3000 litres and rainwater harvested / stored in these storage tanks will be 0.003 MCM. The estimated expenditure for RTRWH in these 1000 houses will be around Rs. 3.00 crores @ Rs. 30,000/- per house.

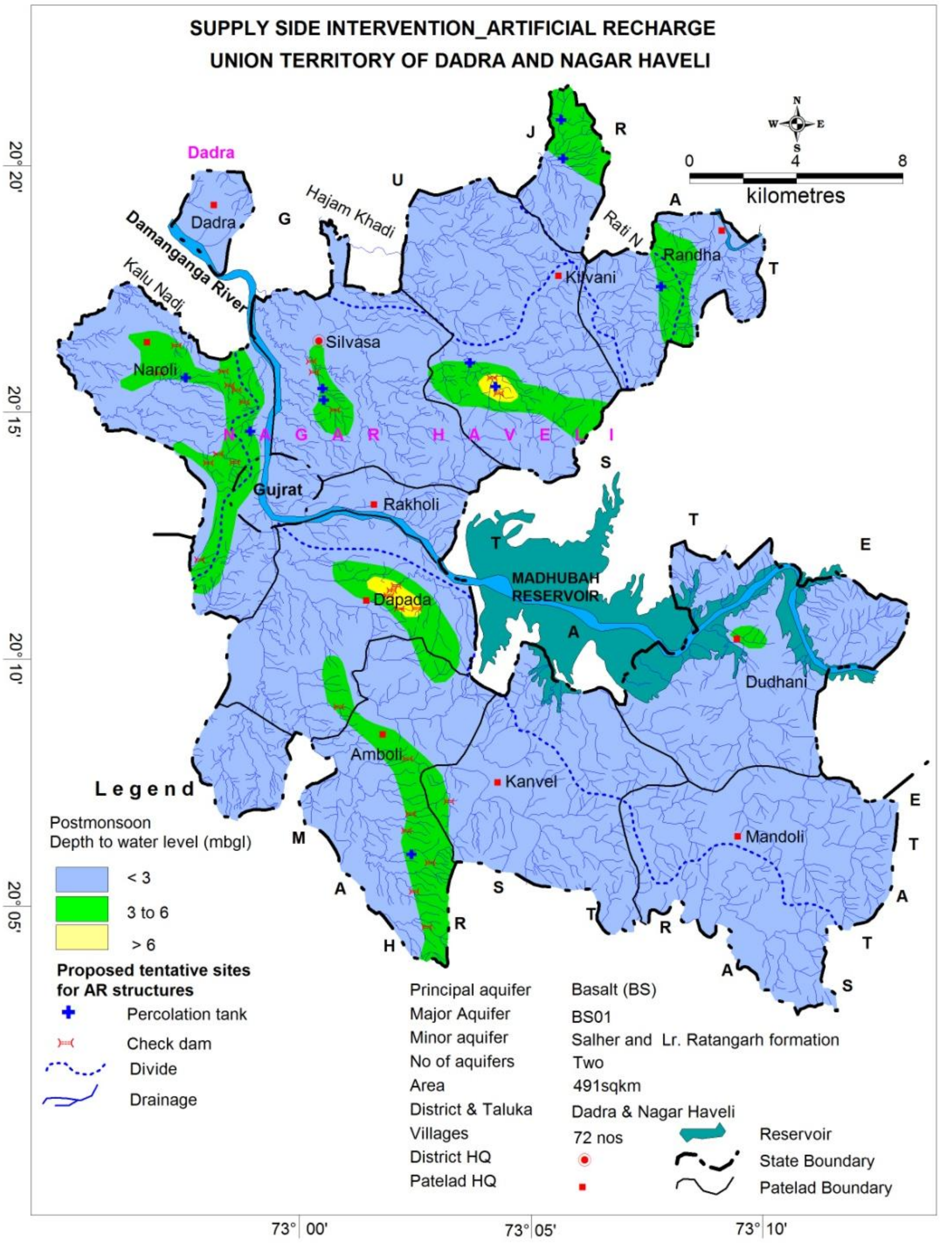


Fig.6.2: Location of Artificial Recharge Structures

Table-6.2: Proposed Supply Side Interventions

Recharge Potential (MCM)	2.08
Surface water requirement @ 75% efficiency (MCM)	2.77
Availability of Surplus surface runoff (MCM)	29.25
Surplus runoff considered for planning (MCM)	2.77
PROPOSED ARTIFICIAL RECHARGE STRUCTURES	
Percolation Tank (@ Rs.150 lakh, Av. Gross Capacity-100 TCM*2 fillings = 200 TCM) **Volume** of Water expected to be conserved / **recharged** @ 75% efficiency Estimated Expenditure	10 no.'s 1.50 MCM Rs. 15.00 Crores
Check Dam (@ Rs.30 lakh, Av. Gross Capacity-10 TCM * 3 fillings = 30 TCM) **Volume** of Water expected to be conserved / **recharged** @ 75% efficiency	25 no.'s 0.56 MCM

Estimated Expenditure	Rs. 7.50 Crores
Total Volume of Water expected to be recharged @ 75% efficiency (MCM)	2.06
Total Estimated Expenditure for Artificial Recharge (Rs. in Cr.)	22.50
ROOF TOP RAIN WATER HARVESTING (HILLY AREAS)	
Households to be covered	1000 no.'s
Total RWH potential (MCM)	0.06 MCM
RW harvested in storage tanks of 3000 litres in 1000 individual houses	0.003 MCM
Estimated Expenditure (Rs. in Cr.) @ Rs. 30000/- per HH	Rs. 3.00 Crore
Total Estimated Expn. for AR in Identified Areas & RTRWH (Hilly Areas)	**25.50**

7 SUM UP & RECOMMENDATIONS

A thorough study was carried out based on data gap analysis, data generated in-house, data acquired from State Govt. 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 of aquifer maps and aquifer management plans of UT of Dadra and Nagar Haveli.

The study area is spanning over 491 sq.km, out of which 203.21 sq.km is forest area and land available for cultivation is 202.12 sq.km. Geologically the entire area is occupied by Deccan Trap Basalt and at places and it is intruded by dolerite and trachyte dykes.

In UT of DNH, the main ground water issues are Low Ground Water Development, Limited Ground Water Potential / Limited Aquifer Thickness / Sustainability, Deeper Water Levels particularly in Aquifer-II which are all inter-related or inter dependent and Inferior Ground Water Quality in Aquifer-II in western parts closer to the industrial hub area.

The present stage of ground water development is merely 32.22 % with net ground water availability of 63.41 MCM and gross draft of 20.42 MCM. In contrary to the other agrarian areas, in UT of DNH, the draft for domestic purpose is more than the irrigation purpose, thus indicating that ground water irrigation needs to be encouraged in the area. Also the less ground water development is most probably linked to the low ground water potential areas (310 sq.km.) occurring in north eastern, central and south eastern parts mostly due to hilly areas, restricted depth of weathering (<10m in 405 sq.km.) in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the Aquifer-I and II is also limited and the wells normally sustain pumping of 0.5 to 5 hours only.

In Aquifer II, the deeper water levels of more than 20 m are also observed in an area of Area 163 sq. km. The ground water quality particularly of Aquifer-II is inferior (EC > 2250 µS/cm) in north western parts covering an area of 30.21 sq.km as compared to other parts.

In UT of DNH due to the industrial activity and socio-economic set up which is more inclined towards producing food grains only for self consumption, the ground water withdrawal for irrigation is on lesser side. This provides immense scope for ground water development particularly in irrigation sector.

Thus the focus of proposed management plan was to up the ante of ground water development from the present 32.22% to 60% in the span of next 6 years in a systematic way by adopting scientific approach. The perusal of above ground water management plan lays stress on ground water development by identifying an area of 38.52 sq.km. wherein 1066 dugwells (15-25 m depth; 3 to 5 m diameter @ Rs. 2.50 lakh/dugwell) are recommended to be constructed in feasible areas. Further 56 borewells (60-90 m depth; 100-150 mm dia @ Rs.0.60 lakh/borewell) are also recommended to be drilled in feasible areas. The total cost of the construction / drilling of 1066 dugwells and 56 borewells is estimated as Rs. 26.98 crores over the next 6 years.

However, considering the low storage potential of hard rock aquifer in the area this ground water development should also be coupled with ground water augmentation plan, so that there is no stress on ground water regime of the area.

In view of this, the proposed management plan also envisages supply side interventions like Rainwater Harvesting and Artificial Recharge structures in the areas feasible for construction of recharge structures based on the long term water level scenario and recharge potential of the aquifer. It envisages construction of 10 percolation tanks @ Rs. 1.50 crore each and 25 check dams @ Rs. 0.30 crores each in feasible areas to fulfil the recharge potential of 2.08 MCM available in the UT of DNH. The proposed expenditure on these structures will be Rs. 22.50 crores.

Similarly Roof Top Rain Water Harvesting (RTRWH) in Hilly Areas of UT of DNH has also been proposed with an objective to cater to the drinking and cooking water requirements of the people residing in these areas. Tentatively about 1000 houses in these areas were considered to have RTRWH scheme for individual household by providing an storage tank of 3000 litres and rainwater harvested / stored in these storage tanks will be 0.003 MCM. The estimated expenditure for RTRWH in these 1000 houses will be around Rs. 3.00 crores @ Rs. 30,000/- per house.

7.1 Tangible and Non Tangible Benefits

The timely and proper implementation of the above suggested management plan will have many tangible and non tangible benefits for the UT of DNH. Some of the major benefits are listed below.

The proposed ground water development by construction / drilling of 1066 dugwells and 56 borewells in feasible areas over the period of next 6 years in phased manner at the estimated cost of Rs. 26.98 crores by utilising part of the available ground water resources (17.61 MCM) has the potential to bring an area of 27.10 sq.km., under assured ground water irrigation considering an average crop water requirement of 0.65 m.

The proposed construction of the artificial recharge structures viz., 10 percolation tanks and 25 check dams at the estimated cost of Rs. 22.50 crores to augment the ground water resources to the tune of 2.06 MCM will probably bring an area of 3.17 sq.km., under assured ground water irrigation considering an average crop water requirement of 0.65 m.

The proposed implementation of Roof Top Rain Water Harvesting in Hilly Areas of UT of DNH by providing RTRWH scheme in 1000 houses at an estimated expenditure of Rs. 3.00 crores will be help in providing water for drinking and cooking purpose to about 4000 persons for 75 days during lean / summer period @ 10 litres/day.

The total area which can be brought under ground water irrigation is 30.27 sq.km. and the same is shown in **Fig. 7.1**.

The implementation of above water conservation, artificial recharge and RTRWH measures will have a positive impact on drinking water sources of the area. It will ensure that the wells don't go dry during summer/lean/stress period in the areas of implementation and sufficient ground water availability is there in the wells even during the summer season. Thus the drinking and domestic water sources will be strengthened. These measures will also be able to arrest the decline in water levels of Aquifer-I and raise the water levels in Aquifer-II. This will result in reduction of electricity consumption as the water will need to be lifted from shallower depths from the borewells.

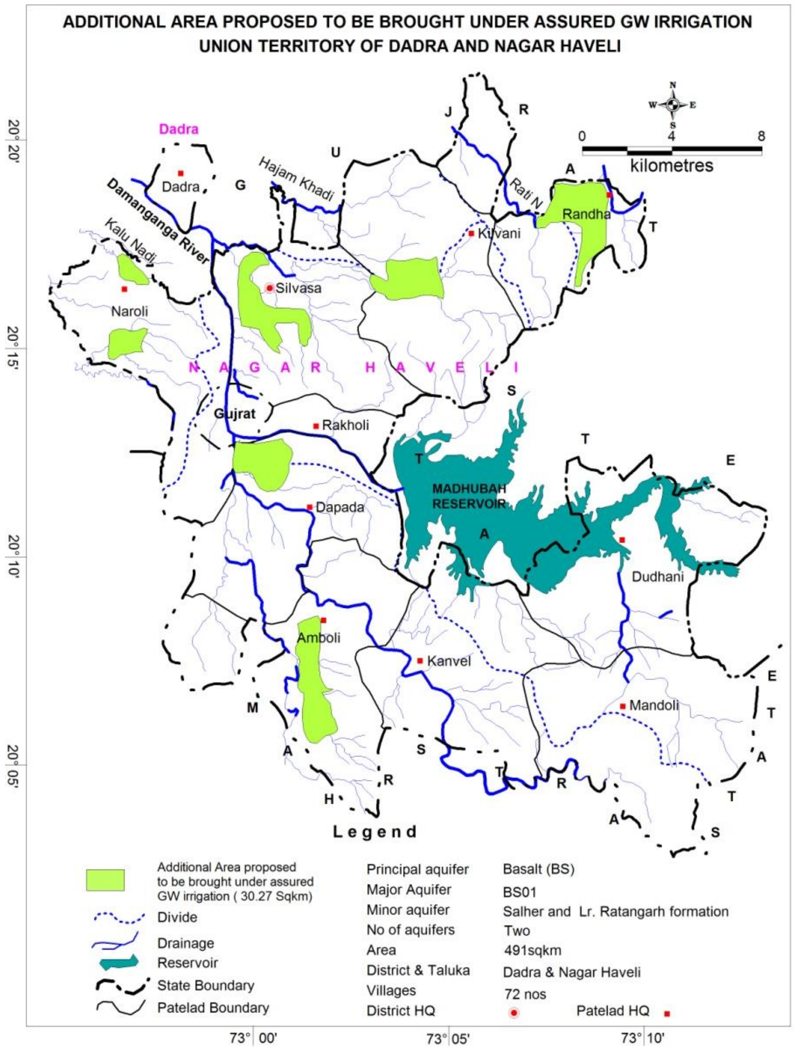


Fig.7.1: Additional Area Proposed to be Brought under Assured Ground Water Irrigation

Further the IEC activities and capacity building activities needs to be aggressively propagated to educate the end user and establish the institutional framework for participatory groundwater management.

The UT of DNH is without any ground water dept./cell, it is proposed that a separate ground water development and water conservation cell under Irrigation Dept./Panchayat Dept., needs to be established with sufficient manpower consisting of Hydrogeologist and Geophysicist and adequate infrastructure considering the heterogeneity of hard rock formation and low yield potential of basaltic rocks so as to cater to the fast emerging demands of water crisis in the UT of DNH.

Annexure-I: Long Term Rainfall Analysis of Silvassa, UT of Dadra & Nagar Haveli.

PERIOD = 1966 TO 2013

NO OF YEARS = 48

NORMAL RAINFALL = 2285.3 mm

STANDARD DEVIATION = 544 mm

COEFF OF VARIATION = 24 %

SLOPE = 4.737 mm/year

INTERCEPT = 2169.2 mm

EQUATION OF TREND LINE: Y= 4.737 X +2169.2

YEAR	ANNUAL	DEP%	CATEGORY
1966	1750.38	-23	NORMAL
1967	1919.77	-16	NORMAL
1968	1941.9	-15	NORMAL
1969	2408.78	+ 5	NORMAL
1970	2713.8	+ 19	NORMAL
1971	2249.1	-2	NORMAL
1972	1563.3	-32	MODERATE
1973	2745.86	+ 20	NORMAL
1974	1281	-44	MODERATE
1975	2471.86	+ 8	NORMAL
1976	3234.9	+ 42	EXCESS
1977	2433.7	+ 6	NORMAL
1978	1345.98	-41	MODERATE
1979	1755.52	-23	NORMAL
1980	2338.3	+ 2	NORMAL
1981	3434	+ 50	EXCESS
1982	2929.3	+ 28	EXCESS
1983	2984	+ 31	EXCESS
1984	2104.13	-8	NORMAL
1985	1658.2	-27	MODERATE
1986	2142.4	-6	NORMAL
1987	1486.7	-35	MODERATE
1988	2669.5	+ 17	NORMAL
1989	1834.9	-20	NORMAL
1990	2321.5	+ 2	NORMAL
1991	2239.5	-2	NORMAL
1992	2325.3	+ 2	NORMAL
1993	2772.2	+ 21	NORMAL
1994	3829.41	+ 68	EXCESS
1995	1682.87	-26	MODERATE
1996	1976.25	-14	NORMAL
1997	1675	-27	MODERATE
1998	2425.74	+ 6	NORMAL

1999	2360.88	+ 3	NORMAL
2000	2103.22	-8	NORMAL
2001	2103.22	-8	NORMAL
2002	1760.8	-23	NORMAL
2003	2124.75	-7	NORMAL
2004	2399.5	+ 5	NORMAL
2005	2725.66	+ 19	NORMAL
2006	2626.3	+ 15	NORMAL
2007	2612.6	+ 14	NORMAL
2008	2385	+ 4	NORMAL
2009	2006	-12	NORMAL
2010	2547.1	+ 11	NORMAL
2011	2682.4	+ 17	NORMAL
2012	1574.2	-31	MODERATE
2013	3036	+ 33	EXCESS

CATEGORY	NUMBER OF YEARS	%OF TOTAL YEARS
DEPARTURES		
POSITIVE	25	52
NEGATIVE	23	48
DROUGHTS		
MODERATE	8	17
SEVERE	0	0
ACUTE	0	0
NORMAL & EXCESS R/F		
NORMAL	34	71
EXCESS	6	12

Rainfall departure: EXCESS: > +25; NORMAL: +25 TO -25; MODERATE: -25 TO -50; SEVERE: -50 TO -75; ACUTE: < -74

Annexure-II: Details of Ground Water Exploration

Village	Longitude	Latitude	Year	Type	Aquifer	Depth (m bgl)	Casing (m bgl)	Zones (m bgl)	SWL (m bgl)	Discharge (lps)	T (m^2/day)	S	K (m/day)	C
Amboli	73°01'00"	20°08'00"	1977-78	EW	W Basalt	70.91	12.5	17.11 -18.11, 21.59 -22.59, 27.07 -28.07, 36.03 -38.03	7.57	1.06	59	-	-	0.184
Galonda	73°03'00"	20°17'00"	1977-78	EW	F Basalt	76.39	7	9.63 -11.63, 17 -29.55	4.56	2.3	67	-	-	0.16
Karchond	73°09'30"	20°09'30"	1977-78	EW	W Basalt	71	13	7.15 -11, 11 -14.1	5.25	10.16	699	0.001307	0.001307	0
Karchond	73°09'30"	20°09'30"		OW	W Basalt	62.43	17.5	7.15 -11, 11 -14.1	5.26	7.16		-	-	-
Kherdi	73°01'00"	20°07'00"	1977-78	EW	F Basalt	72.51	8.5	4.69 -15.7	4.76	2.86	41.2	-	-	0.18
Korchond			2015-16			71.5		18-20.65	5.25		804	-	-	5.37
Naroli	72°57'00"	20°16'30"	1977-78	EW	F Basalt	61.35	12.5	15 -16.11, 18 -18.6, 54.7 -55.4, 24.2 -25, 60 -60.9	6.34	10.28	131.11	0.00403	0.00403	0
Naroli	72°57'00"	20°16'30"		OW	F Basalt	61.1	13	60 -60.9	6.14	5.5	98.5	-	-	1.61
Rudana	73°05'30"	20°07'30"	1977-78	EW	F Basalt	84.35	5.5	7.30	5.66	-	0.4	-	-	0.02
Samarvarni	73°00'30"	20°15'80"	1977-78	EW	W Basalt	78.39	21.12	17.45 -21.12	5.84	0.58	10.85	-	-	0.034
Silvasa	72°59'30"	20°16'30"	1977-78	EW	W Basalt	74	11.5	0.7 -17	6.79	0.83	0.7	-	-	0.027
Vadhadhara	72°58'00"	20°19'00"	1977-78	OW	J M Basalt	62.43	-	14.7 -17, 59 -60.12	7.05	-	97.2	-	-	1.24
Vaghadhara	72°58'00"	20°19'00"	1977-78	EW	J M Basalt	60.2	7.75	14.7 -17, 59 -60.2	6.76	9.46	97.2	0.005314	0.005314	-
Mandoni	73° 08' 48"	20°06'39"	2015-16	EW	F Basalt	200.00	10.00	38-41.1	43.6	Traces	-	-	-	-
Kilvani	73° 05' 33"	20°17'52"	2015-16	EW	F Basalt	200.00	11.00	146-148	>100	0.14	-	-	-	-

Here, EW- Exploratory Well, OW- Observation Well, W- Weathered, F- Fractured, J- Jointed, M- Massive, T- Transmissivity, S- Storativity, K- Permeability, C- Specific Capacity.

Annexure-III: Micro Level Hydrogeological Data – Aquifer-I (Shallow Aquifer)

S. No.	Village	Lat_deci	Long_deci	Elevation	Formation	Well. Depth (m bgl)	Lining (m bgl)	D.T.W. (m bgl)	EC	Total Thickness weathered portion (m)	Depth to Fractures (m bgl)	Thickness of fracture zone (m)
1.	Khanvel	20.12692	73.06986	95	Deccan Basalt	15.67	7.60	7.60	580	5	7	0.5
2.	Talavali	20.10192	73.07506	104	Deccan Basalt	9.45	3.72	3.72	490	3.72	5	0.5
3.	Amboli	20.14422	73.02611	55	Deccan Basalt	7.68	6.15	5.05	640	6.15	6	0.5
4.	Surangi	20.15319	73.00286	54	Deccan Basalt	6.70	4.96	6.09	687	4.96	5	0.5
5.	Apti	20.15592	72.99453	64	Deccan Basalt	11.45	7.20	10.15	276	7.20	6	0.5
6.	Chikhali	20.18194	73.00158	42	Deccan Basalt	10.50	6.20	5.90	900	6.20	8	0.5
7.	Ambabari	20.16764	73.15272	87	Deccan Basalt	8.70	5.10	4.26	401	5.10	6	0.5
8.	Vaghchauda	20.15814	73.13419	84	Deccan Basalt	12.90	3.95	12.30	348	3.95	5	0.5
9.	Goratpada	20.15392	73.10686	86	Deccan Basalt	11.47	10.55	10.55	406	8.00	11	0.5
10.	Shelti	20.15653	73.094	86	Deccan Basalt	13.75	9.06	10.90	250	9.05	10	0.5
11.	Umarvani	20.16003	73.08086	88	Deccan Basalt	4.66	2.50	2.50	331	1.50	3	0.5
12.	Kherdi	20.11253	73.02622	58	Deccan Basalt	6.95	6.95	5.73	736	4.95	6	0.5
13.	Karachgam	20.12542	73.01292	55	Deccan Basalt	13.90	7.20	7.20	584	5.20	9	0.5
14.	Tinoda Patelpada	20.14947	73.04992	74	Deccan Basalt	13.20	7.80	7.50	780	5.80	8	0.5
15.	Bindrabin	20.13933	73.05761	77	Deccan Basalt	11.50	7.00	4.92	546	4.00	8	0.5
16.	Dapada	20.19008	73.02742	55	Deccan Basalt	12.75	10.45	10.05	566	6.45	11	0.5
17.	Nandi Pati	20.19303	73.04669	48	Deccan Basalt	3.18	1.20	1.44	227	1.00	2	0.5
18.	Chinchpada	20.20597	73.00806	43	Deccan Basalt	13.45	8.05	7.55	821	6.05	10	0.5
19.	Vasona	20.2055	73.02992	55	Deccan Basalt	12.60	12.10	12.40	600	7.90	12	0.5
20.	karad	20.21117	73.04794	43	Deccan Basalt	15.15	12.15	10.10	534	6.15	13	0.5
21.	Kudacha	20.22803	73.01133	40	Deccan Basalt	11.28	10.28	10.71	545	6.28	11	0.5
22.	Masat	20.24275	73.01219	49	Deccan Basalt	16.90	13.40	12.90	540	5.40	15	0.5
23.	Saily	20.226	73.04708	63	Deccan Basalt	18.00	13.00	12.50	568	2		0.5
24.	Umarkul	20.25792	73.07289	92	Deccan Basalt	7.30	6.00	4.50	357	4.00	7	0.5
25.	Falandi	20.26858	73.06814	58	Deccan Basalt	12.35	11.25	10.60	379	6.25	12	0.5

S. No.	Village	Lat_deci	Long_deci	Elevation	Formation	Well. Depth (m bgl)	Lining (m bgl)	D.T.W. (m bgl)	EC	Total Thickness weathered portion (m)	Depth to Fractures (m bgl)	Thickness of fracture zone (m)
26.	Mota Randa	20.305	73.14525	102	Deccan Basalt	12.75	9.05	7.45	398	5.05	10	0.5
27.	Bonta	20.28833	73.12978	183	Deccan Basalt	13.00	6.10	5.40	304	4.10	8	0.5
28.	Luhari	20.19206	72.97097	57	Deccan Basalt	15.90	10.00	8.20	515	6.00	12	0.5
29.	Kharadpada	20.25233	72.96378	38	Deccan Basalt	5.30	5.00	1.48	525	4.00	5	0.5
30.	Naroli	20.27289	72.94661	36	Deccan Basalt	9.30	6.00	8.00	450	4.00	8	0.5
31.	Dhapsa	20.294	72.93931	26	Deccan Basalt	10.04	8.24	2.64	682	5.00	9	0.5
32.	Kelwani	20.28233	73.08522	68	Deccan Basalt	11.34	2.74	9.14	385	2.00	8	0.5
33.	Galonda	20.28406	73.07058	72	Deccan Basalt	8.55	8.00	2.15	424	6.00	8	0.5
34.	Silly	20.29781	73.07331	68	Deccan Basalt	7.00	2.10	2.60	352	2.00	5	0.5
35.	Atholi	20.28289	73.03811	49	Deccan Basalt	5.75	4.10	2.15	424	3.00	5	0.5
36.	Athal	20.26608	72.96719	39	Deccan Basalt	9.50	6.00	3.70	675	4.00	6	0.5
37.	Rakholi	20.22556	73.02314	66	Deccan Basalt	16.30	7.30	3.40	958	2.40	2	0.5

Annexure-IV: Detailed Data of Soil Infiltration Tests conducted at Chisda, Khadoli and Saily

Soil Infiltration Test - CHISDA	
Date	10.3.16
Unique ID No	SITDNH-1
Location	near Govt School Chisda
Taluka	UT of DNH
District	UT of DNH
Coordinates	20°06'40.01", 73°07'22.03"
Elevation / RL (mamsl)	219
Initial Water Level	20
Geology	Deccan Basalt
Final Infiltration Rate (cm/hr)	3.6

S. No.	Clock time	Time Interval (min)	Cumulative time (minutes)	Water level depth(cm)	Infiltrated water Depth(cm)	Infiltration rate(cm/hr)
1	10.01	1	1	17.50	2.50	150.00
2	10.02	1	2	18.80	1.20	72.00
3	10.03	1	3	19.00	1.00	60.00
4	10.04	1	4	19.10	0.90	54.00
5	10.05	1	5	19.50	0.50	30.00
6	10.06	1	6	19.60	0.40	24.00
7	10.07	1	7	19.60	0.40	24.00
8	10.08	1	8	19.70	0.30	18.00
9	10.09	1	9	19.70	0.30	18.00
10	10.10	1	10	19.80	0.20	12.00
11	10.12	2	12	19.60	0.40	12.00
12	10.14	2	14	19.70	0.30	9.00
13	10.16	2	16	19.80	0.20	6.00
14	10.18	2	18	19.80	0.20	6.00
15	10.2	2	20	19.90	0.10	3.00
16	10.25	5	25	19.50	0.50	6.00
17	10.3	5	30	19.50	0.50	6.00
18	10.35	5	35	19.60	0.40	4.80
19	10.4	5	40	19.60	0.40	4.80
20	10.5	10	50	19.20	0.80	4.80
21	11	10	60	19.30	0.70	4.20
22	11.1	10	70	19.40	0.60	3.60
23	11.2	10	80	19.40	0.60	3.60
24	11.3	10	90	19.40	0.60	3.60
25	11.4	10	100	19.40	0.60	3.60
26	11.5	10	110	19.40	0.60	3.60
27	12	10	120	19.40	0.60	3.60

Soil Infiltration Test - KHADOLI	
Date	11.3.16
Unique ID No	SITDNH-2
Location	in the field of Kakada Maji, on Silvassa to Khanvel road
Taluka	UT of DNH
District	UT of DNH
Coordinates	20°09'3.2", 73°03'1.6"
Elevation / RL (mamsl)	78
Initial Water Level	20
Geology	Deccan Basalt
Final Infiltration Rate (cm/hr)	1.8

S. No.	**Clock time**	**Time Interval (min)**	**Cumulative time (minutes)**	**Water level depth(cm)**	**Infiltrated water Depth(cm)**	**Infiltration rate(cm/hr)**
1	10.01	1	1	19.60	0.40	24.00
2	10.02	1	2	19.70	0.30	18.00
3	10.03	1	3	19.80	0.20	12.00
4	10.04	1	4	19.80	0.20	12.00
5	10.05	1	5	19.80	0.20	12.00
6	10.10	5	10	19.60	0.40	4.80
7	10.15	5	15	19.70	0.30	3.60
8	10.20	5	20	19.70	0.30	3.60
9	10.25	5	25	19.70	0.30	3.60
10	10.30	5	30	19.80	0.20	2.40
11	10.35	5	35	19.80	0.20	2.40
12	10.40	5	40	19.80	0.20	2.40
13	10.5	10	50	19.70	0.30	1.80
14	11.00	10	60	19.70	0.30	1.80
15	11.1	10	70	19.70	0.30	1.80
16	11.20	10	80	19.70	0.30	1.80
17	11.3	10	90	19.70	0.30	1.80
18	11.40	10	100	19.70	0.30	1.80
19	11.5	10	110	19.70	0.30	1.80
20	12.00	10	120	19.70	0.30	1.80
21	12.1	10	130	19.70	0.30	1.80
22	12.20	10	140	19.70	0.30	1.80
23	12.3	10	150	19.70	0.30	1.80

Soil Infiltration Test -SAILY	
Date	13.3.16
Unique ID No	SITDNH-3
Location	On Rakholi to Kelvani road, near Govt Public well
Taluka	UT of DNH
District	UT of DNH
Coordinates	20°13'34.7", 73°02'50"
Elevation / RL (mamsl)	37
Initial Water Level	20
Geology	Deccan Basalt
Final Infiltration Rate (cm/hr)	3

S. No.	**Clock time**	**Time Interval (min)**	**Cumulative time (minutes)**	**Water level depth(cm)**	**Infiltrated water Depth(cm)**	**Infiltration rate(cm/hr)**
1	10.01	1	1	19.20	0.80	48.00
2	10.02	1	2	19.40	0.60	36.00
3	10.03	1	3	19.50	0.50	30.00
4	10.04	1	4	19.60	0.40	24.00
5	10.05	1	5	19.60	0.40	24.00
6	10.06	1	6	19.70	0.30	18.00
7	10.07	1	7	19.70	0.30	18.00
8	10.08	1	8	19.80	0.20	12.00
9	10.10	2	10	19.70	0.30	9.00
10	10.12	2	12	19.80	0.20	6.00
11	10.14	2	14	19.80	0.20	6.00
12	10.16	2	16	19.80	0.20	6.00
13	10.18	2	18	19.80	0.20	6.00
14	10.20	2	20	19.80	0.20	6.00
15	10.25	5	25	19.60	0.40	4.80
16	10.30	5	30	19.70	0.30	3.60
17	10.35	5	35	19.70	0.30	3.60
18	10.40	5	40	19.70	0.30	3.60
19	10.5	10	50	19.50	0.50	3.00
20	11.00	10	60	19.50	0.50	3.00
21	11.1	10	70	19.50	0.50	3.00
22	11.20	10	80	19.50	0.50	3.00
23	11.3	10	90	19.50	0.50	3.00
23	11.40	10	100	19.50	0.50	3.00

Annexure-V: Water Level Data of Aquifer-I (Shallow Aquifer)

S. No.	**Location**	**Type**	**Depth** (m bgl)	**Latitude**	**Longitude**	**Water Level** (m bgl)			
						May 14	**Nov 14**	**May 15**	**Nov-15**
1	Chisda	DW	17	20.11125	73.136806	8	2.00	8.90	2.8
2	Dapada	DW	11.15	20.1913	73.0313	9.85	8.90	10.00	9.1
3	Dudhani	DW	14.3	20.1746	73.1563	13.7	3.00	14.25	3.28
4	Kanvel Bhagat Pada	DW	11.3	20.12394	73.066917	9.8	3.50	10.20	3.8
5	Khadak Pada	DW	7	20.25411	72.954694	6.6	4.20	6.80	4.49
6	Khedapa manipada	DW	13.7	20.05258	73.175278	9.8	2.30	11.00	2.42
7	Khedi Ghodamba	DW	13.94	20.1117	73.0488	10.81	4.30	10.80	4.23
8	Kilvani Sharyapada	DW	20	20.30031	73.090583	14	1.60	15.00	1.7
9	Moolpada	DW	9.1	20.1231	73.0964	11	1.80	11.90	2.4
10	Naroli-I	DW	10.6	20.275	72.95	9.14	4.50	6.65	4.9
11	Rakhali	DW	9.2	20.2625	72.9472	5.54	5.90	6.40	5.86
12	Rudana	DW	15.24	20.1264	73.0686	9.43	3.00	11.20	2.9
13	Samarvarni	DW	9.78	20.252	73.0085	3.5	3.09	3.70	3.1
14	Surangi	DW	9.54	20.1611	73.025	8.86	6.20	9.00	7.6
15	Umarkui (Hathpada)	DW	10.3	20.261	73.071	7.71	6.80	9.00	7
16	Wanganpada	DW	12	20.13992	73.091028	10.1	1.89	10.80	1.9
17	Silvasa	DW	10.6	20.2722	73.0054	10.1	7.10	10.20	7.5
18	Morkhal	DW	8.75	20.3309	73.1023	8.03	4.00	8.45	4.7
19	Dadra	DW	8.35	20.3172	72.9654	5.8	2.80	6.20	2.99
20	Silli	DW	5.8	20.31	73.0616	2	0.90	2.60	1.2
21	Velugam	DW	7.3	20.1263	72.982	5.5	2.00	5.80	2.2
22	Falandi	DW	9.75	20.2641	73.0532	8.8	4.00	9.00	4.5
23	Mota Randha	DW	11	20.3022	73.1391	9.2	4.00	9.60	4.3

Annexure-VI: Water Level Data of Aquifer-II (Deeper Aquifer)

S. No.	Village	Longitude	Latitude	Altitude (m)	Depth (m bgl)	Premonsoon Water Level (m bgl)	Postmonsoon Water Level (m bgl)
1	Amboli	73.02	20.13	63.99	70.91	10.00	7.57
2	Galonda	73.05	20.28	59.35	76.39	8.00	4.56
3	Karchond	73.16	20.16	96.68	71.00	10.00	5.25
4	Karchond	73.16	20.16		62.43	10.00	5.26
5	Kherdi	73.02	20.12	63.33	72.51	9.00	4.76
6	Korchond	73.16	20.16	93.68	71.50	10.00	5.25
7	Naroli	72.95	20.28	31.69	61.35	11.00	6.34
8	Naroli	72.95	20.28		61.10	12.00	6.14
9	Rudana	73.09	20.11	107.30	84.35	13.00	5.66
10	Samarvarni	73.01	20.25	44.69	78.39	11.00	5.84
11	Silvasa	73.00	20.27	37.71	74.00	14.00	6.79
12	Vadhadhara	72.97	20.32		62.43	15.00	7.05
13	Vaghadhara	72.97	20.32	34.84	60.20	15.00	6.76
14	Mandoni	73.15	20.11	272.00	200.00	50.00	43.00
15	Kilvani	73.09	20.30	135.00	200.00	55.00	52.00

Annexure-VII: Ground Water Quality Data of Aquifer-I (Shallow Aquifer)

S. No.	Location	Latitude	Longitude	pH	EC	TDS	TH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	NO_3	SO_4	F	SAR	RSC
1.	Chinsda	20.1113	73.1368	7.6	217	141	80	28	2	9	0.36	0	43	25	27	16	0.33	0.4	-0.9
2.	Kanvel Bhagat Pada	20.1239	73.0669	7.8	300	195	145	40	11	10	0.55	0	122	25	11	25	0.48	0.4	-0.9
3.	Wanganpada	20.1399	73.0910	7.9	261	170	120	38	6	10	0.43	0	110	25	17	15	0.48	0.4	-0.6
4.	Kherdi Kathepada	20.1132	73.1320	7.7	873	567	450	134	28	33	0.94	0	98	106	10	302	1.17	0.7	-7.4
5.	Kilvani Sharyapada	20.3003	73.0906	7.8	321	209	165	44	13	12	2.07	0	201	21	10	12	0.86	0.4	0.0
6.	Khadak Pada	20.2541	72.9547	7.9	1193	775	305	44	47	155	1.89	0	378	191	10	37	0.86	3.9	0.1
7.	Khedapa Manipada	20.0526	73.1753	7.3	266	173	115	36	6	12	1.88	0	61	28	13	29	0.36	0.5	-1.3
8.	Rakholi-I	20.2256	73.0231	7.5	876	569	400	114	28	37	0.21	0	183	209	10	53	0.97	0.8	-5.0
9.	Chinsda	20.0903	73.1581	7.8	269	169	150	46	9	2	0.05	0	37	28	1	76	0.81	0.02	-2.4
10.	Shelti	20.1417	73.0972	8.0	382	241	195	40	23	3	0.10	0	116	28	1	61	0.31	0.03	-2.0
11.	Samarvarni	20.2514	73.0083	8.0	957	603	370	50	60	17	0.07	0	189	113	10	99	0.69	0.13	-4.3
12.	Umarkui (Hathpada)	20.2639	73.0736	7.9	447	282	250	52	29	2	0.25	0	134	39	9	107	0.74	0.02	-2.8
13.	Dapada	20.1875	73.0236	7.8	641	404	240	46	30	4	0.27	0	159	57	10	56	0.89	0.04	-2.2
14.	Naroli-1	20.2208	72.9656	8.0	292	184	180	28	27	2	0.07	0	92	18	ND	74	0.21	0.02	-2.1
15.	Khedi Ghodamba	20.1111	73.0472	7.9	526	331	245	54	27	6	0.07	0	92	78	1	60	0.48	0.06	-3.4
16.	Rudana	20.1264	73.0686	8.0	608	383	255	46	34	3	0.02	0	122	74	7	71	0.23	0.03	-3.1
17.	Surangi	20.1611	73.0250	7.6	433	273	210	40	27	3	0.03	0	110	43	1	68	0.33	0.03	-2.4

Here, all parameters are expressed in mg/L except pH, EC (µS/cm @ 25°C) and RSC (meq/L).

Annexure-VIII: Ground Water Quality Data of Aquifer-II (Deeper Aquifer)

S. No.	Village	Longitude	Latitude	pH	EC	TDS	TH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4
1.	Naroli	72°57'00"	20°16'30"	7.8	3804		1206	310	105	0	0	0	317	1032	0
2.	Samarvarni	73°00'30"	20°15'80"	8.2	561	468	140	14	26	61	1	0	260	28	14
3.	Vaghadhara	72°58'00"	20°19'00"	7.6	864		275	105	3	0	0	0	317	168	0
4.	Galonda	73°03'00"	20°17'00"	8.2	586	308	175	65	3	26	1	0	208	40	10
5.	Naroli	72°57'00"	20°16'30"	8	2489		759	215	54	216	1.6	0	244	672	80
6.	Amboli	73°01'00"	20°08'00"	7.8	552		149	35	15	0	0	0	317	32	0
7.	Karchond	73°09'30"	20°09'30"	8	343		149	40	12	0	0	0	158	24	0
8.	Karchond	73°09'30"	20°09'30"	8.4	89		37	10	3	0	0	36	86	8	0
9.	Kherdi	73°01'00"	20°07'00"	8	445		211	35	30	0	0	0	268	24	0
10.	Rudana	73°05'30"	20°07'30"	8	240		137	25	12	0	0	0	146	16	0
11.	Silvasa	72°59'30"	20°16'30"	8.2	1037		0	45	54	0	0	0	488	96	0
12.	Vadhadhara	72°58'00"	20°19'00"	7.8	591	500	235	58	22	22	1	0	238	53	24

Here, all parameters are expressed in mg/L except pH, EC (µS/cm @ 25°C).

Annexure-IX: Location of Artificial Recharge Structures

S. No.	District	Patelad	Village	Longitude	Latitude	Structures
1	DNH	Amboli	Dolara	73.046	20.076	Check dam
2	DNH	Amboli	Tinoda	73.0496	20.161	Check dam
3	DNH	Amboli	Parza	73.0471	20.0977	Check dam
4	DNH	Amboli	Kherdi	73.04	20.1142	Check dam
5	DNH	Amboli	Amboli	73.039	20.1328	Check dam
6	DNH	Khanvel	Chauda	73.0518	20.1203	Check dam
7	DNH	Dapada	Surangi	73.0142	20.1504	Check dam
8	DNH	Naroli	Naroli	72.9558	20.2724	Check dam
9	DNH	Naroli	Athal	72.975	20.259	Check dam
10	DNH	Naroli	Athal	72.9728	20.2637	Check dam
11	DNH	Naroli	Athal	72.9804	20.2533	Check dam
12	DNH	Kilvani	Falandi	73.0513	20.2667	Check dam
13	DNH	Kilvani	Falandi	73.0519	20.2621	Check dam
14	DNH	Kilvani	Umarkui	73.0947	20.2493	Check dam
15	DNH	Naroli	Kharadpada	72.9769	20.2329	Check dam
16	DNH	Silvasa	Samarvaan	73.0129	20.2506	Check dam
17	DNH	Naroli	Luhari	72.9642	20.2001	Check dam
18	DNH	Dapada	Pati	73.0503	20.1783	Check dam
19	DNH	Dapada	Chinchpada	73.0148	20.1936	Check dam
20	DNH	Randha	Motorandha	73.1403	20.2967	Check dam
21	DNH	Dudhni	Dudhni	73.1647	20.1721	Checkdam
22	DNH	Dudhni	Dudhni	73.1581	20.1743	Checkdam
23	DNH	Amboli	Parza	73.0414	20.088	Checkdam
24	DNH	Amboli	Kherdi	73.0386	20.1085	Checkdam
25	DNH	Kilvani	Falandi	73.0651	20.2655	Checkdam
26	DNH	Kilvani	Umarkui	73.0706	20.2585	Percolation tank
27	DNH	Silvasa	Samarvaan	73.0084	20.2579	Percolation tank
28	DNH	Naroli	Naroli	72.9591	20.2615	Percolation tank
29	DNH	Naroli	Athal	72.9823	20.2435	Percolation tank
30	DNH	Randha	Bonta	73.13	20.2924	Percolation tank
31	DNH	Amboli	Parza	73.0403	20.1006	Percolation tank
32	DNH	Kilvani	Umarkui	73.0721	20.2627	Percolation tank
33	DNH	Silvasa	Samarvaan	73.0089	20.254	Percolation tank
34	DNH	Randha	Morkhal	73.0948	20.3355	Percolation tank
35	DNH	Randha	Morkhal	73.0941	20.3486	Percolation tank