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

Jamnagar District
Gujarat

पश्चिम मध्य क्षेत्र, अहमदाबाद

West Central Region, Ahmedabad

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	Principal Crops	**Area (sq. km)**	
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AQUIFER MAPS

AND

GROUNDWATER MANAGEMENT PLAN

OF

JAMNAGAR DISTRICT,

GUJARAT STATE

Chapter 1
INTRODUCTION

1.1 Introduction

Various development activities over the years have adversely affected the ground water regime in many parts of the country. There is a need for scientific planning in development of ground water under different hydrogeological situations and to evolve effective management practices with involvement of community for better ground water governance. Though a vast amount of hydrological and hydrogeological data has been generated through scientific investigations by Central Ground Water Board (CGWB) and other Central/State agencies, these mostly pertain to administrative units and have addressed the issues of the whole aquifer systems in very few cases. In view of the emergent challenges in the ground water sector in the country, there is an urgent need for comprehensive and realistic information pertaining to various aspects of ground water resources available in different hydro-geological settings through a process of systematic data collection, compilation, data generation, analysis and synthesis.

Systematic aquifer mapping is expected to improve our understanding of the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers and how they change over time, and the occurrence of natural and anthropogenic contaminants that affect the potability of ground water. Results of these studies will contribute significantly to resource management tools such as long-term aquifer monitoring networks and conceptual and quantitative regional ground-water-flow models used by planners, policy makers and other stakeholders. Aquifer mapping at the appropriate scale can help prepare, implement and monitor the efficacy of various management interventions aimed at long-term sustainability of our precious ground water resources, which, in turn, will help to achieve drinking water security, improved irrigation facilities and sustainability in water resources development in the country as a whole. Various on-going activities of Central Ground Water Board, such as ground water monitoring, ground water resource assessment, artificial recharge and ground water exploration in drought, water, scarcity and vulnerable areas can also be integrated in the aquifer mapping project.

Systematic mapping of an aquifer encompasses a host of activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of additional data for filling the identified data

gaps and finally, preparation of aquifer maps at the desired scale. This manual attempt to evolve uniform protocols for these activities to facilitate their easy integration for the country as a whole.

1.2 Objective And Scope Of The Study

The primary objective of the Aquifer Mapping Exercise can be summed up as "Know your Aquifer, Manage your Aquifer". Demystification of Science and thereby involvement of stake holders is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst the stakeholders.

This is an activity where the government and the community work in tandem. Greater the harmony between the two, greater will be the chances of successful implementation and achievement of the goals of the project. As per the Report of the Working Group on Sustainable Ground Water Management, "It is imperative to design an aquifer mapping programme with a clear-cut groundwater management purpose. This will ensure that aquifer mapping does not remain an academic exercise and that it will seamlessly flow into a participatory groundwater management programme. The aquifer mapping approach can help integrate ground water availability with ground water accessibility and quality aspects.

The major objectives of aquifer mapping are

- Delineation of lateral and vertical disposition of aquifers and their characterization
- Quantification of ground water availability and assessment of its quality to formulate aquifer management plans to facilitate sustainable management of ground water resources at appropriate scales through participatory management approach with active involvement of stakeholders.

The groundwater management plan includes Ground Water recharge, conservation, harvesting, development options and other 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 main activities under NAQUIM are as follows:

I. Identifying the aquifer geometry
II. Aquifer characteristics and their yield potential
III. Quality of water occurring at various depths
IV. Aquifer wise assessment of ground water resources
V. Preparation of aquifer maps and
VI. Formulate ground water management plan.

The 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.

1.3 Approach And Methodology

Methodology involves creation of database for each of the principal aquifer. Delineation of aquifer extent (vertical and lateral). Standard output for effective presentation of scientific integration of hydro geological, geophysical, geological, hydro chemical data facts and on GIS platform, identification of issues, manifestation of issues and formulation of strategies to address the issues by possible interventions at local and regional level.

National Aquifer Mapping Programme basically aims at characterizing the geometry, parameters, behavior of ground water levels and status of ground water development in various aquifer systems to facilitate planning of their sustainable management. The major activities involved in this process include compilation of existing data, identification of data gaps, and generation of data for filling data gaps and preparation of aquifer maps. Once the maps are prepared, plans for sustainable management of ground water resources in the aquifers mapped is formulated and implemented through participatory approach involving all stakeholders.

The on-going activities of NAQUIM include hydrogeological data acquisition supported by geophysical and hydro-chemical investigations supplemented with ground water exploration down to the depths of 200 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 utilization for preparation of various thematic maps. The approach and methodology followed for Aquifer mapping is as given below:

I. Compilation of existing data (Central & State Govt.)
II. Generation of different thematic layer
III. Identification of primary aquifers
IV. Identification of data gaps
V. Data generation (water level, exploration, geophysical,
VI. Aquifer maps with 3D disposition
VII. Preparation of aquifer management plan
VIII. Capacity building in all aspects of ground water through IEC activities

The activities of the aquifer mapping can be grouped as follows:

1.3.1 Data Compilation & Data Gap Analysis

One of the important aspects of the aquifer mapping programme was the synthesis of the large volume of data already collected during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set generated that broadly describe an aquifer system. The data were assembled from the available sources, analyzed, examined, synthesized and interpreted. These sources were predominantly non-computerized data, which was converted into computer-based GIS data sets and on the basis of available data, data gaps were identified.

1.3.2 Data Generation

There is a strong need for generating additional data to fill the data gaps to achieve the task of aquifer mapping. This was achieved by multiple activities such as data gap analysis, site selection, exploratory drilling, PYT, pumping test, geophysical techniques, hydro-geochemical analysis, remote sensing, and hydrogeological surveys to delineate multi aquifer system to bring out the efficacy of various geophysical techniques and a protocol for use of geophysical techniques for aquifer mapping in different hydrogeological environs.

1.3.3 Aquifer Map Preparation

On the basis of integration of data generated from various studies of hydrogeology & geophysics, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out details of Aquifers; these are termed as Aquifer maps providing spatial variation (lateral & vertical) in reference to aquifer extremities (i.e., quality & quantity).

1.3.4 Aquifer Management Plan Formulation

Aquifer response Model has been utilized to identify a suitable strategy for sustainable development of the aquifer in the area.

All the above activities under the ground National Aquifer Mapping programme are depicted/elaborated in Annexure –I and presented in figure 1.

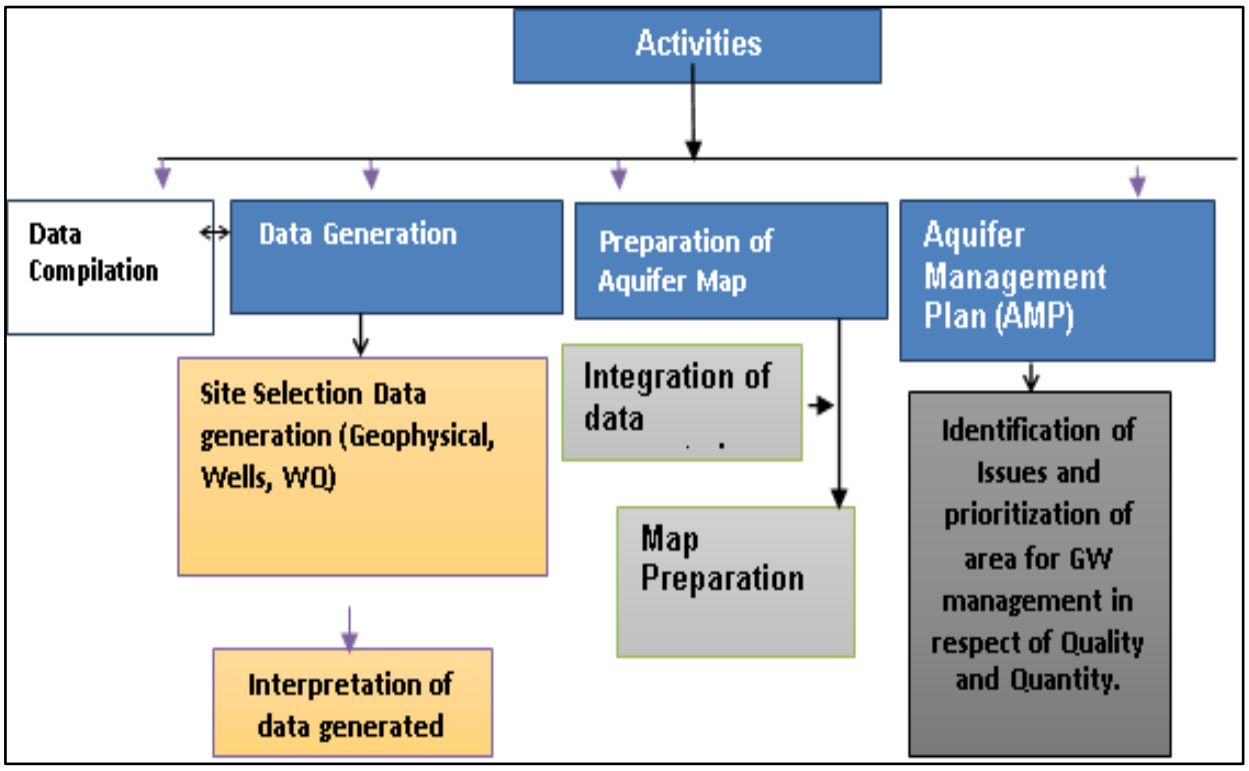

Figure 1- Activity under National Aquifer Mapping Programme

1.4 Area Details And Brief Description

Jamnagar district is located in Saurashtra region of Gujarat state. It is bounded by Gulf of Kutch in North, Devbhoomi Dwarka district in West, Rajkot district in East and Porbandar district in South. The district has a geographical area of 6027 sq. km. It is spread between 22.13^0 to 22.58^0 latitude and 68.56^0 to 70.39^0 longitude. The district comprises of six blocks viz Jamnagar, Dhrol, Jodiya, Jamjodhpur, Lalpur &Kalavad. The district is devoid of any major perennial rivers, most of them being small and flow sluggishly through the low-lying lands. Principal Rivers are Aji, Una, Vartu, Venu, Ghee, Rangmati, Nagmati, Fulzar, Phuljar, Sasoi, Ruparel and Khari.

The district is known for world's largest petrochemical complex of Reliance Industries at MotiKhavadi, Tal: Jamnagar. The district is known for Groundnut & Cotton Production on a large scale. Rozi & Bedi is all weather port where export of Bauxite and import of Coal are taking place. The primary occupation of the district is agriculture in rural area. Digvijay Woolen Mill popularly known as “Digjam” is a major industrial unit at Jamnagar and exporting quality woolen cloths. The district is also famous for marine national park at “Narara” and “Pirotan”. The marine area in north of Jamnagar is famous for corals and marine biodiversity. The presence of three wings of defense i.e., Air Force, Indian Navy & Indian Army. The “Sainik School” is also established at Balachhadi in Jamnagar taluka.

Jamnagar is basically an agrarian district; agriculture and animal husbandry are the predominant economic activities of rural populace in the district. The urban area of Jamnagar is getting employment through small scale industries of Brass part. The ancillary unit's dependent on Reliance Industries is also providing employment opportunities to many people in the Jamnagar taluka. Due to presence of Reliance petrochemical refinery the economic activity and services sector in and around Jamnagar city has increased. The small ancillary unit related to Petrochemical and services required by the refinery have been established in Moti Khavadi and Modpar village which is nearby refinery area. The housing demand in Jamnagar has increased many folds after current expansion of refinery complex. The service-related activities have also mushroomed in and around Jamnagar city.

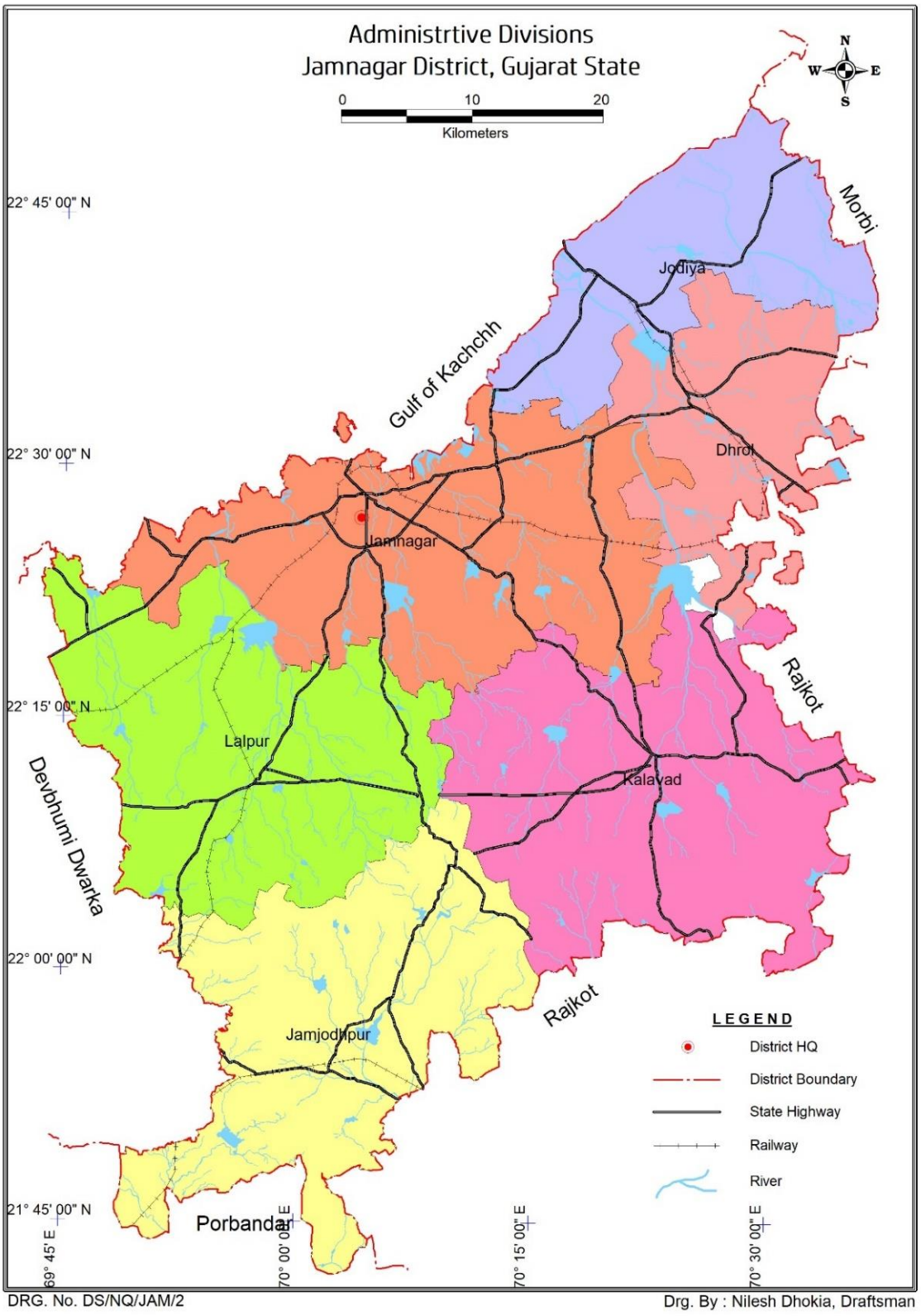

Figure 2Administrative Map of Jamnagar District

1.5 Demography

As per 2011 census of India, Jamnagar District has a population of 1407635 in 2011 out of which 727626 are male and 680009 are female. People living in Jamnagar District depend on multiple skills. Jamnagar District sex ratio is 939 females per 1000 of males. Next Jamnagar District Census will be in 2022-2023.

Table 1 Block wise of male, female population of Jamnagar district

Block	Population		
	Male	Female	Total
Jamnagar - R	1,04,799	97,968	2,02,767
Jamnagar - U	3,38,943	3,10,238	6,49,181
Lalpur - R	60,516	57,671	1,18,187
Lalpur - U	0	0	0
Jodiya - R	43,582	42,376	85,958
Jodiya -U	0	0	0
Dhrol- R	27,377	26,055	53,432
Dhrol - U	13204	12679	25,883
Jamjodhpur - R	55,023	51,583	1,06,606
Jamjodhpur - U	13205	12687	25,892
Kalavad - R	56,267	55,148	1,11,415
Kalavad - U	14,710	13,604	28,314
Total	**7,27,626**	**6,80,009**	**14,07,635**

Source: DIP Jamnagar (Census of India, 2011, R- Rural, U- Urban)

Jamnagar block is the most populated block of the district whereas Dhrol has lowest population. The population density of Jamnagar district as recorded by 2011 census is 152 people per sq. km which is 12.6% increase in density of 135 people per sq. km as compared to 2001 census. The growth in the population of Jamnagar district in 2011 census is 13.44% as compared to 2001 census. However, the sex ratio (per 1000) of the district in 2011 census has been decreased to 939 as compared to 941 in 2011 census.The literacy rate of male and female in 2011 census is 81.50% and 65.33% respectively. The total number of SC and ST in the district is 87,902 and 9,742 respectively. In Lalpur & Jodiya block, the urban as well as SC and ST are zero.

Table 2 Category Wise Population in Jamnagar District

Block	SC	ST	General	Total
	NM	NM	NM	NM
Jamnagar - R	19,965	530	1,82,272	2,02,767
Jamnagar - U	18,065	1817	6,29,299	6,49,181
Lalpur - R	12,325	377	1,05,485	1,18,187
Lalpur - U	0	0	0	0
Jodiya - R	6698	271	78,989	85,958
Jodiya -U	0	0	0	0
Dhrol- R	4730	86	48,616	53,432
Dhrol - U	0	0	25,883	25,883
Jamjodhpur - R	12989	5450	88,167	1,06,606
Jamjodhpur - U	0	0	25,892	25,892
Kalavad - R	13130	1211	97,074	1,11,415
Kalavad - U	0	0	28,314	28,314

Total	87,902	9,742	13,09,991	**14,07,635**

Source: Census of India 2011, Jamnagar, R- Rural, U- Urban

1.6 Studies / Activity By CGWB

Central Ground Water Board has carried out number of studies in the district. The first systematic Hydro geological investigation was carried out by K. K. Prasad during 1958-59 & 1959-60 (GSI). M.M. Oza, 1968-69 (GSI), continued systematic hydrogeological studies in the district.

Further systematic hydrogeological investigations were carried out by Sh. A.R.Pandey (1976-77), Sh.R.N.Meshram (1978-79), Sh. M.R.Kulkarni & Sh. A.Ahmed (1979-80), Sh. R.C.Jain (1984-85 & 1985-86), and Dr. M.N. Khan (1985-86), Central Ground Water Board from time to time covering different talukas of the district. Dr. M.N. Khan (1985-86) and Sh. A. Kannan (2003-04) Central Ground Water Board have carried out Reappraisal survey in different talukas of the district. Sh.R.C.Jain (1988-89) carried out non-conventional survey in the Jamnagar district.

Sh. P. N. Phadtare (1981), CGWB, compiled "hydrogeology of Gujarat State" and discussed groundwater resource potential of the district based on earlier studies.

Groundwater exploration by test drilling in the district commenced in fifties and is continued till 2010-11. Apart from the exploratory wells Piezometer have also been constructed in the district. Representative dug wells and piezometers are monitored periodically for the ground water level and quality changes in the district and is continued till date.

1.7 Hydrometeorology / Rainfall And Climate

Jamnagar is a coastal town in Gujarat and is situated in the Gulf of Kutch. Jamnagar is a city located on the western coast of India in the state of Gujarat in the Saurashtra region. It is the administrative headquarters of the Jamnagar district. Jamnagar is the largest city on the west coast of India and is the fifth largest city of Gujarat, after Ahmedabad, Surat, Vadodara, and Rajkot.

Jamnagar has a hot semi-arid climate (Köppen: BSh).

The main seasons prevailing in the district are

(a) Monsoon - mid of June to September
(b) Winter - December to February
(c) Summer - March to June.

The district has semi-arid climate. Extreme temperatures, erratic rainfall and high evaporation are the characteristic features of this type of climate. The average annual rainfall during 2011-2020 is 614 mm for Jamnagar District (Table 3 and Figure 3).

Table 3 Table depicting the Rainfall in the district from 2011-2020

Rainfall (mm) in Jamnagar District (2011-2020)											
Taluka	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Average (2011 - 2020)**
Dhrol	509	390	744	408	441	1207	524	153	1138	999	651
Jamjodhpur	807	340	1208	555	569	852	677	502	1228	1684	842
Jamnagar	973	380	1473	367	322	380	624	405	1234	1104	726
Jodiya	764	250	769	762	722	538	919	170	1337	1284	752
Kalavad	619	311	801	481	569	647	690	469	1140	1376	710
Lalpur	866	402	887	297	368	766	607	351	886	1413	684
District Average	612	278.5	832.5	428.8	437.2	604	572.3	283.2	1012.8	1074.5	613.583

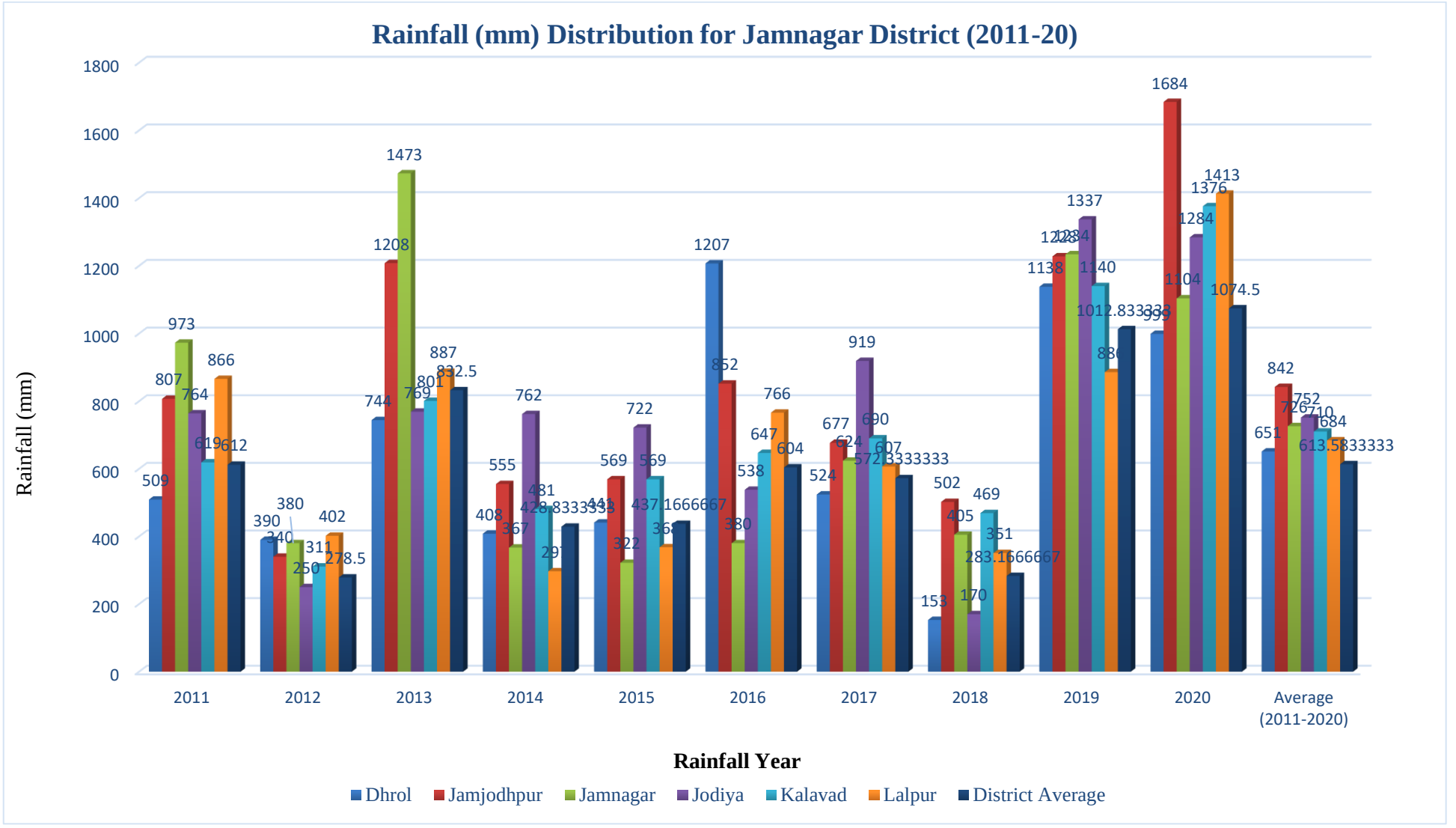

Figure 3 Taluka wise Rainfall map of Jamnagar District from 2016-202

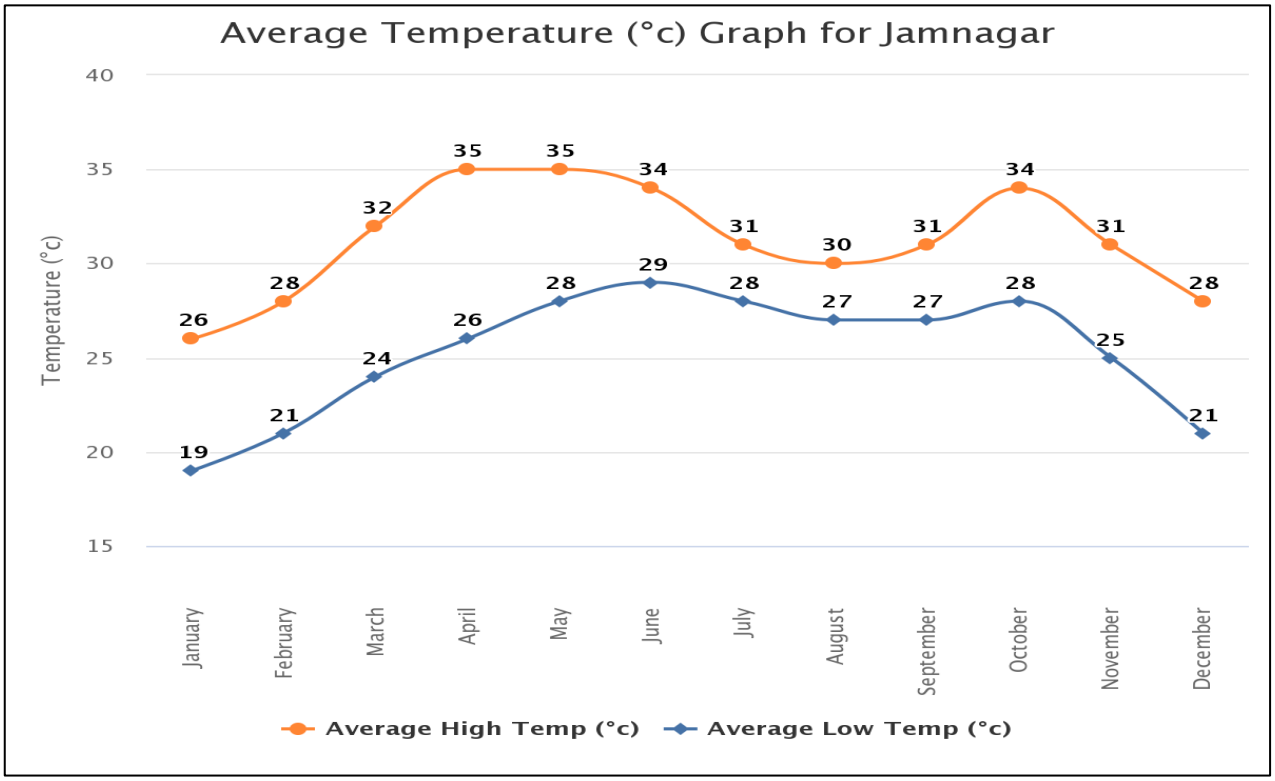

Figure 4 Average High and Low Temperature graph for Jamnagar District.

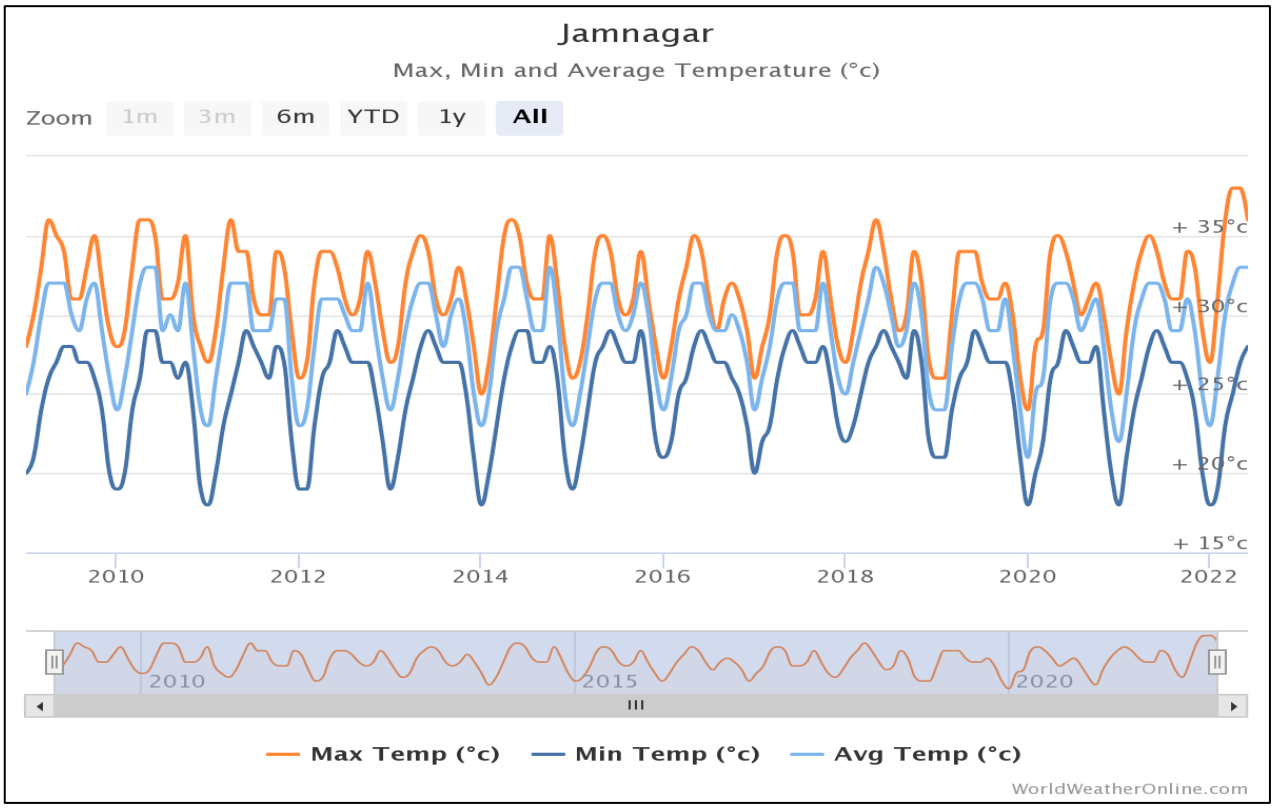

Figure 5 Temperature Map of Jamnagar District

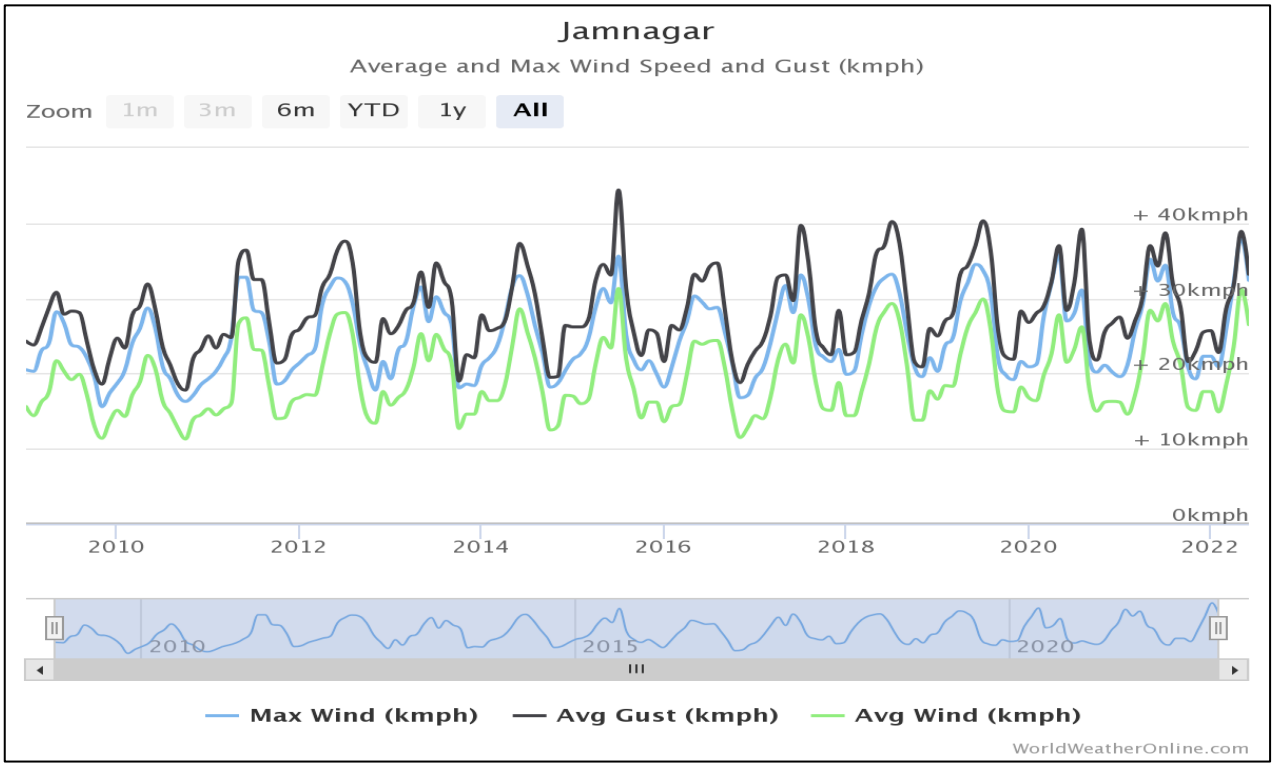

Figure 6 Wind Speed and Gust Map of Jamnagar District

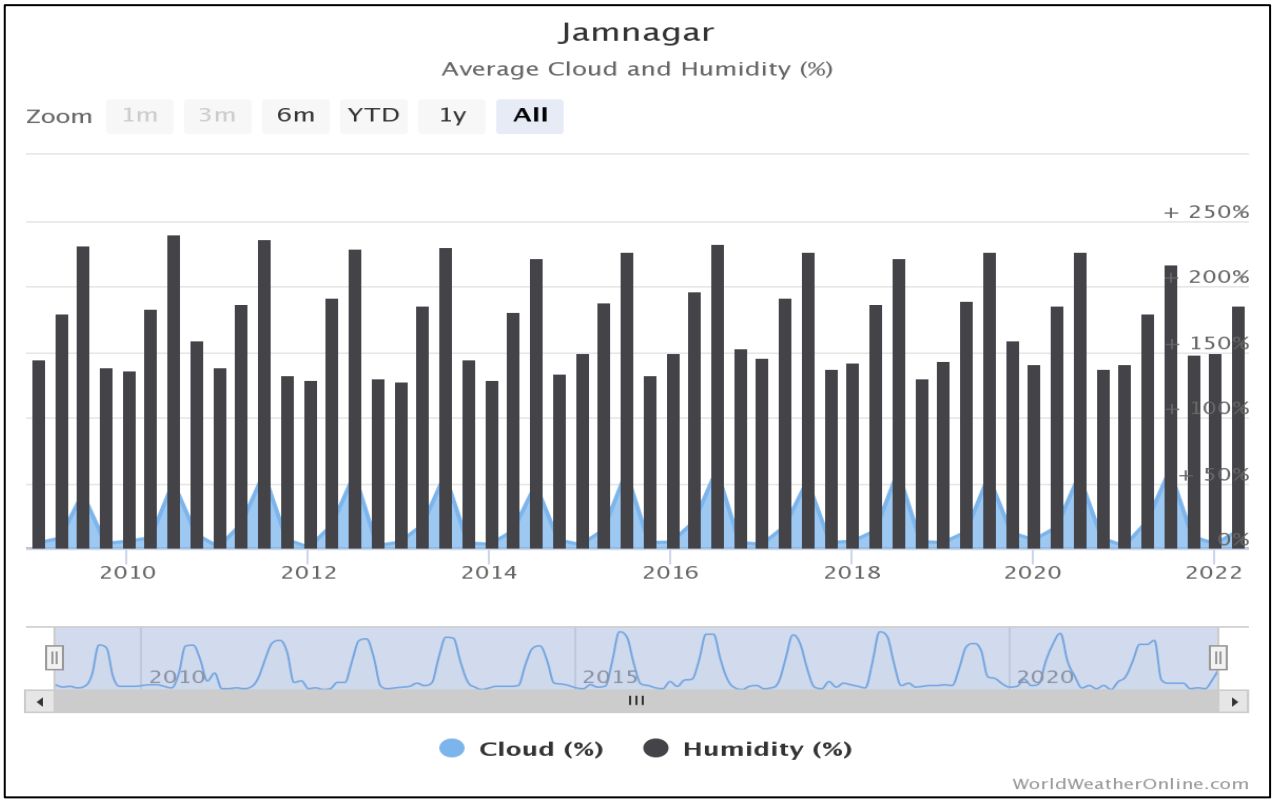

Figure 7 Cloud and Humidity map of Jamnagar District

1.8 Irrigation Practices

Agriculture and horticulture play an important role in rural economy of Jamnagar. The gross irrigated area in the district is 278208.40 ha which around 57.94% of gross cultivated area.

The major crops in the district, in Kharif season are grown under rainfed conditions, where as in summers and rabi cultivation is done in irrigated conditions. Majority of horticulture crops are irrigated, only 10% of the area under fruits production is reported to be rainfed. By enhancing the water resources availability for irrigation purpose through rainwater harvesting, soil & water conservation measures, the productivity of crops can be enhanced further. There are 48905 ha. Of total canal area reported in the district out of which 37769 ha. is developed area. There are large number of tube wells and bore wells reported in the district, along with 7 community ponds for surface irrigation. There are also large number of wells, which were reported to be the most widely used source of irrigation. There are wells in each block and Kalavad block has highest no. i.e., 10067 wells out of 43880 total wells. Cotton, groundnut, bajra, wheat, til, pulses, are the major crops. Under horticulture crops Pomegranate is being grown in Jamnagar, Lalpur &Kalavad block. (DIP: Jamnagar 2016-20).

Table 4 Taluka wise Surface vs. Groundwater irrigation in Jamnagar District

Taluka	Surface water irrigated area(ha)			Total surface water irrigated area in ha	Total surface water irrigated area in %	Groundwater irrigated area(ha)		Total Ground water irrigated area in ha	Total Ground water irrigated area in %	Total area in ha
	Canal	Pond	Dam/Check dam			Well	Tube well			
Jamnagar	1700	0	100	1800	3.856289	10777	34100	44877	96.143711	46677
Lalpur	900	900	150	1950	12.991339	1580	11480	13060	87.008661	15010
Jamjodhpur	1260	0	75	1335	4.9802283	9787	15684	25471	95.019772	26806
Jodiya	500	0	225	725	3.6742347	6592	12415	19007	96.325765	19732
Dhrol	200	495	198	893	6.6651739	2865	9640	12505	93.334826	13398
Kalavad	1330	1245	280	2855	5.1218112	14247	38640	52887	94.878189	55742
Total	5890	2640	1028	9558	5.3888873	45848	121959	167807	94.611113	177365

Source: DIP, Jamnagar 2016-20

1.9 Land Use/Land Cover

Agriculture is the main occupation in the district and provides employment to about 79% workers. The taluka wise land utilization status is presented in the table 3 and 4. It shows that the net sown area is 64.12% of the total geographical area of the district. The average cropping intensity of the district is 118.09%. Majority of district is covered by agriculture and wasteland and spread over all parts of districts (Figure 8).

Table 5 Area under Agriculture (in Ha)

Block/Taluka	Area Under Agriculture		
	TGA	NSA	Cropping Intensity (%)
Jamnagar	117394	82500	126.63
Lalpur	107736	64650	109.05
Jamjodhpur	109132	62500	119.42
Jodiya	86866	53500	109.53
Dhrol	56989	40111	114.93
Kalavad	124437	83123	128.98
Total	**602554**	**386384**	**118.09**

Source: Department of Agriculture & KVK, Govt. of Gujarat

TGA- Total Geographical Area,
NSA- Net Sown Area

Table 6 Area under Forest, Wasteland and other Uses (Ha)

Block	Area under Forest	Area under Wasteland	Non Agri use	Land for grazing	Land under Fallow
Jamnagar	1735	10970	11132	8247	**2196**
Lalpur	5368	7302	13552	7731	**3038**
Jamjodhpur	8517	4590	21221	10436	**727**
Jodiya	8208	3580	13801	6348	**969**
Dhrol	835	3025	7772	4606	**244**
Kalavad	3371	4605	22396	10551	**270**
Total	**28034**	**34072**	**89874**	**47919**	**7444**

Source: Department of Agriculture & KVK, Govt. of Gujarat

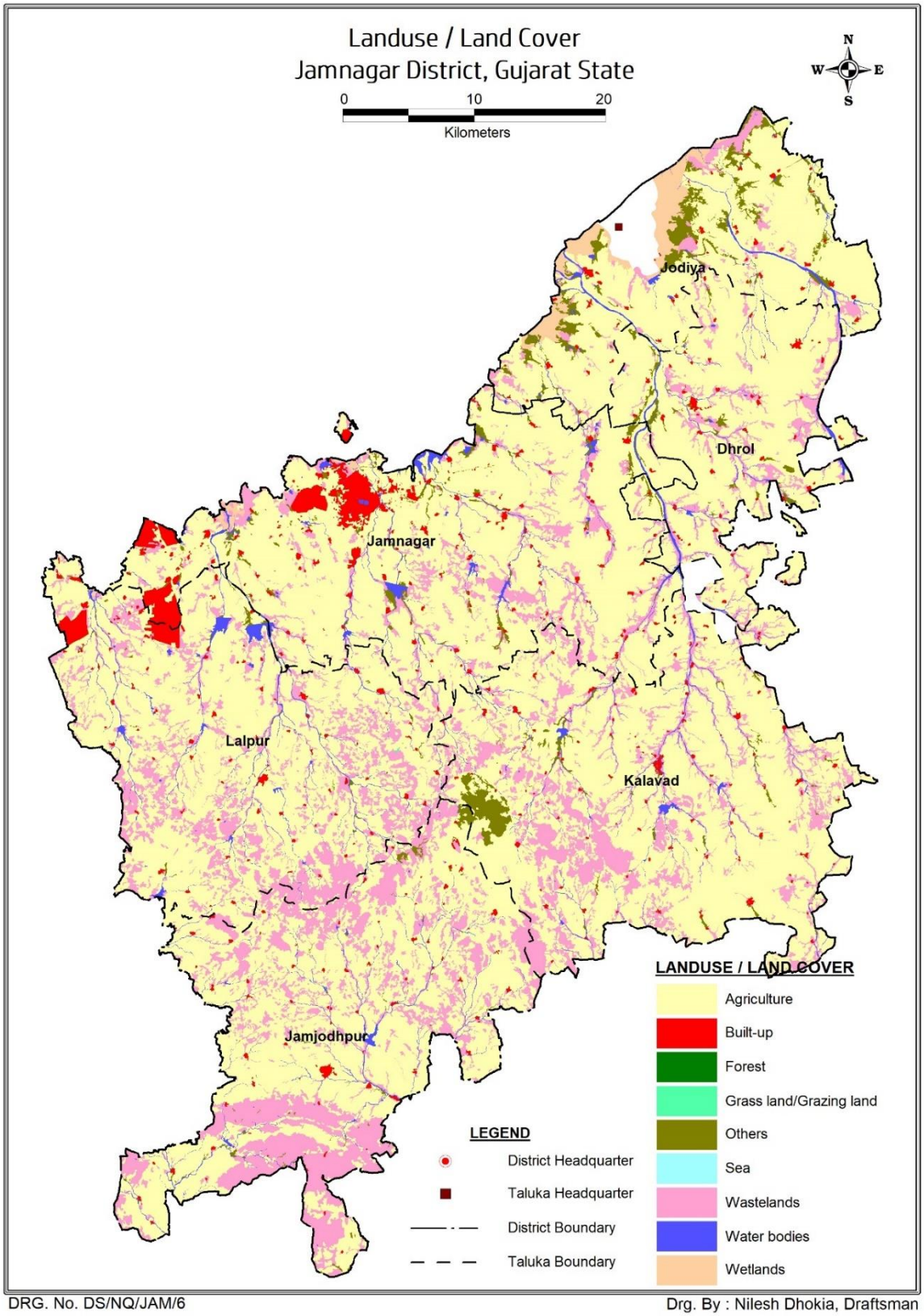

Figure 8 Land Use /Land cover map

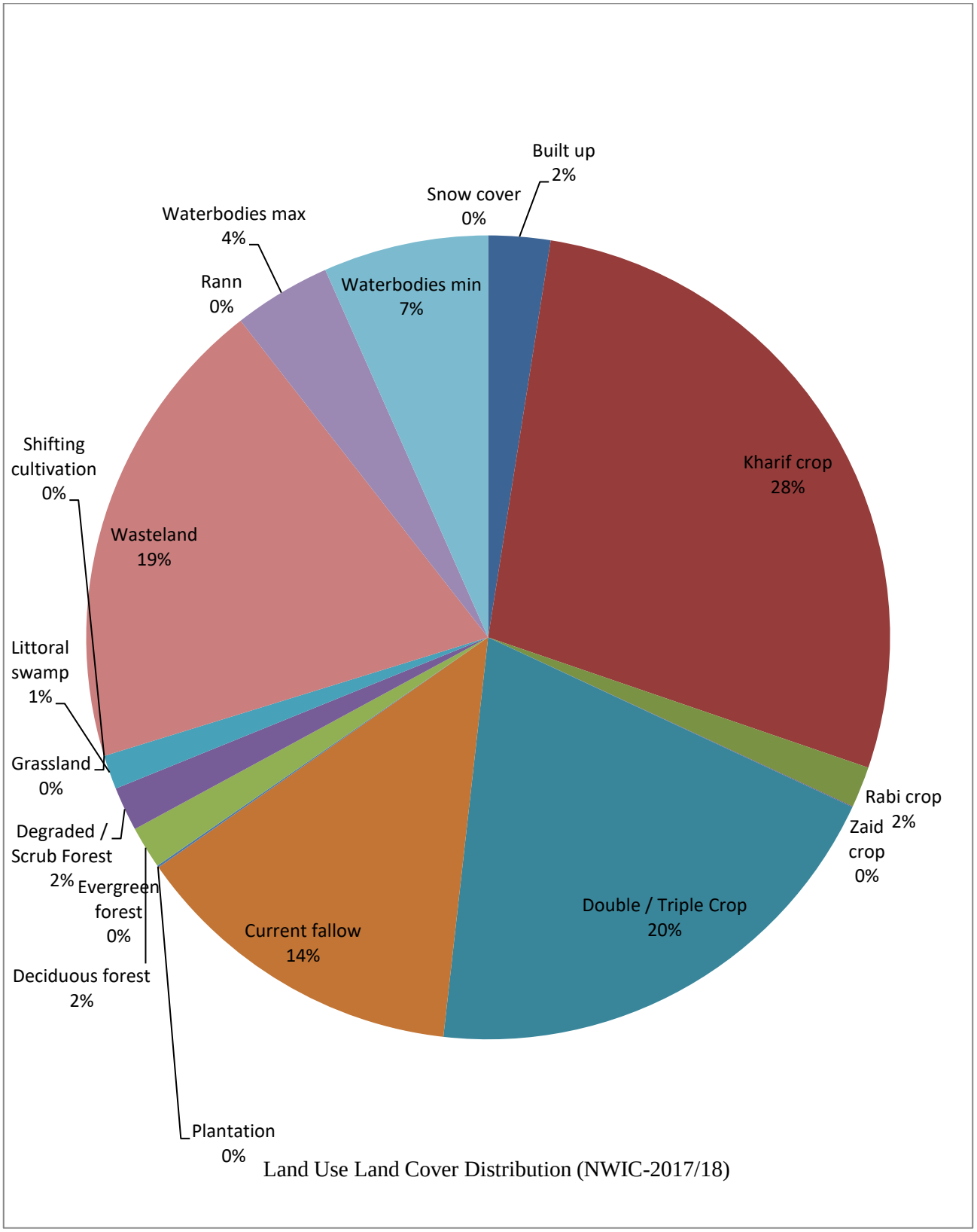

Figure 9. Land Use Land Cover Distribution on Crop Variation Map of Jamnagar District

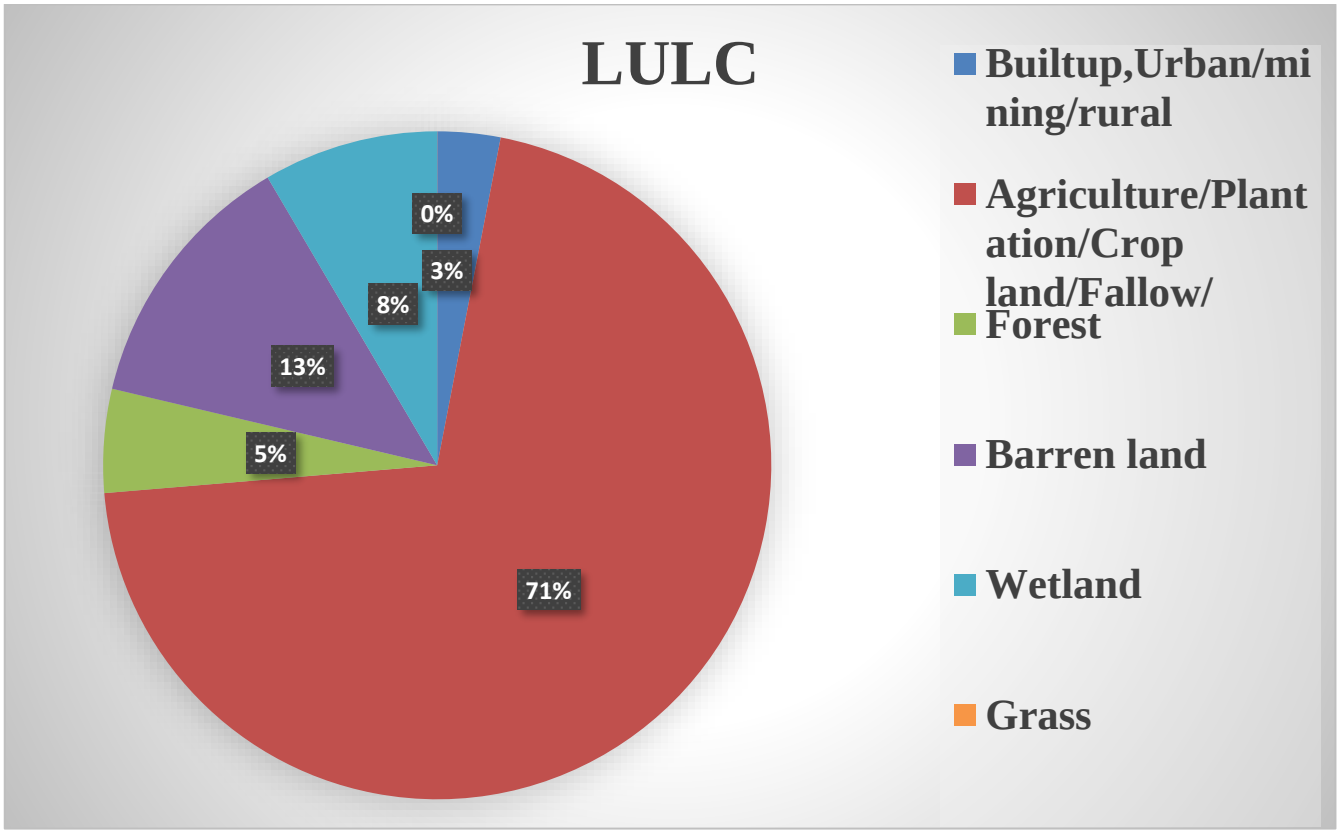

Figure 10 LULC Map with Area Percentage under Different Use

1.10 Soil Types

Soils of the district may be broadly classified as Coastal alluvial, medium black, shallow black and hilly. The medium black and shallow black soils are the main soil type of the district, while the coastal and hilly soils are the sub-soils. The black soil is rich in mineral and organic matter and is more fertile. The medium black soils are found in Dhrol and Jamnagar talukas. These soils are generally 25 to 50 cm deep. Shallow black soils are found in Kalawad, Jam Jodhpur and Lalpur talukas. It is about 25cm deep. The coastal alluvial soils are found in Jamnagar and Jodiya talukas. These soils are mostly saline and alkaline in nature. Hilly soils are found in southern parts of the district, particularly in Lalpur, Jam Jodhpur and Kalawad talukas. Low soil permeability impedes infiltration, percolation, and ground-water recharge and enhances surface runoff whereas high soil permeability enhances these factors. Recharge is likely higher where the permeability of soils remains high to greater depths.

In the study area clayey loam soil is developed over the pediplain and dissected upland underlain by basaltic rock (MOA, 1970). The soil developed over basaltic rocks is generally in situ soil. High drainage density over the basaltic country rock may be ascribed to the least permeable clayey loam soil (montmorillonite rich) developed over them. Thickness of soil varies from 15 to 45 cm over

pediplain and 5 to 15 cm over dissected upland. The basaltic terrain has thin soil followed by thin weathered rock zone. The soil over basaltic rocks is dominated with montmorillonitic clay showing high swelling indices (50 to 80%) and very low permeability. Sandy loam soil is developed over the older tidal flat and parts of the pediplain underlain by Tertiary sandstone and limestone. Calcareous sandy loam of 10 to 30 cm thick is developed in the western part of the pediplain occupied by Tertiary limestone. Sandy clayey loam is developed on the foot hill region of denuded hills derived from acid igneous rocks. This soil has higher effective permeability. (Fig 11)

1.11 Drainage

Major drainage of the district is controlled by Aji, Una, Vartu, Venu, Ghee, Rangmati, Khari rivers. Drainage in the central part of the area is dendritic and in the western part radial. Drainage in the tidal flat area is of dendritic, trellis and parallel type. The older tidal flat area is dominated by distributary channels. Trellis and parallel type of drainage is confined to deltaic areas of Aji and Sasoi rivers reflecting tectonic control. Geology and drainage are controlling geomorphology of the area. (Figure 12).

1.12 Geomorphology

Physiographically the district can be divided into the following units: Hilly areas and Coastal & alluvial Plains of Jamnagar and Jodiya talukas are characterised by plain topography, whereas Jam Jodphur and Lalpur talukas are characterised by hilly terrains. Barda, Alech, Gop etc are famous hill ranges in the district. Mount Venu is the highest summit of Barda hills that attains a height of 617.1 metres. Okha Rann is a low-lying marshy area. Low coastal dunes and sand banks run along the north and west coasts. Jamnagar and Jodiya are plain areas (Figure 13).

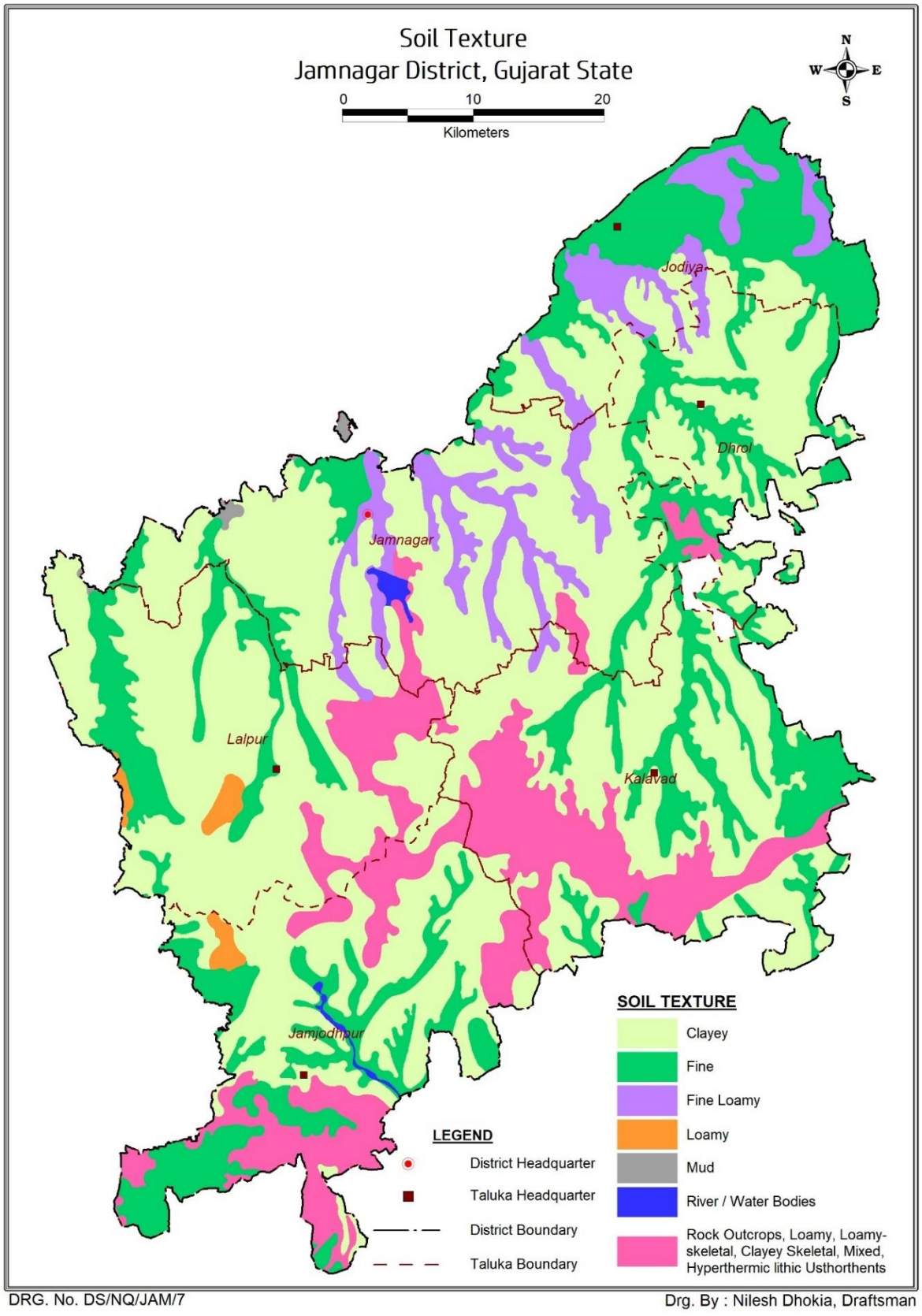

Figure 11 Soil Texture Map of Jamnagar District

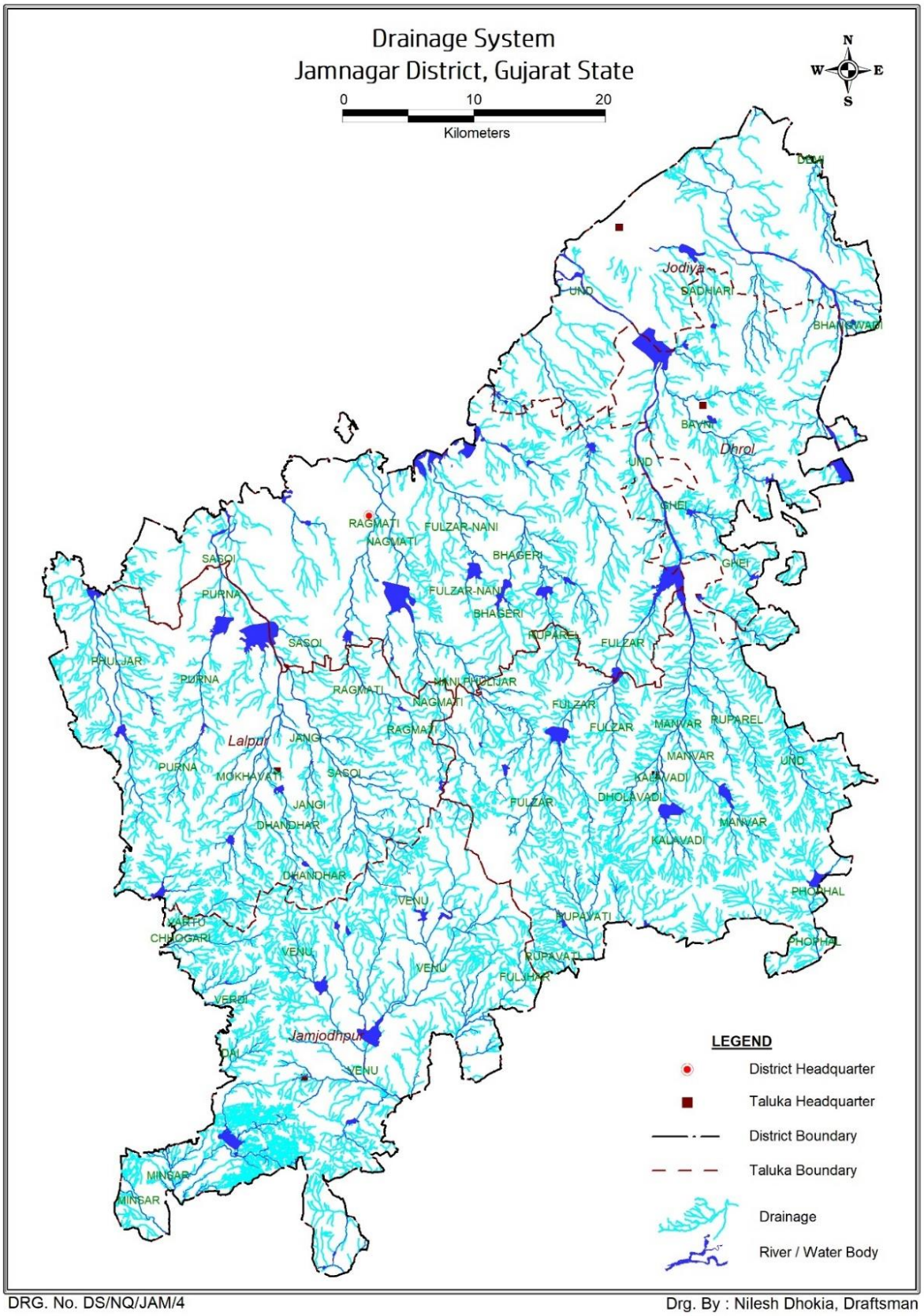

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Figure 12 Drainage Map of Jamnagar District

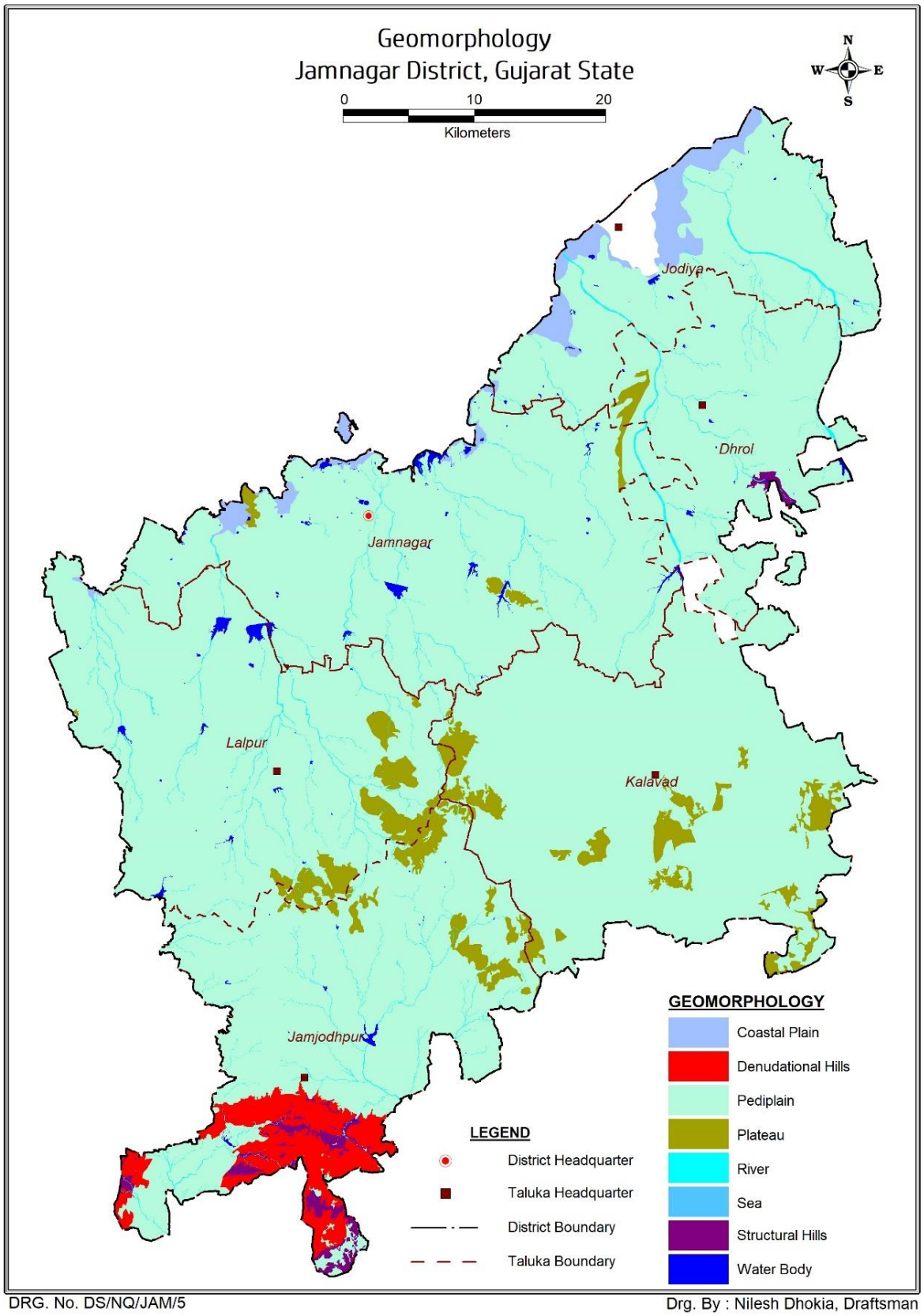

Figure 13 Geomorphologic Map of Jamnagar District

Chapter 2

GEOLOGY

2.1 Geology

Deccan basalt of Cretaceous to Eocene age with Tertiary and Quaternary sediments is exposed in the area. Deccan basalt (tholeiite and picrite) intruded by basic dykes and acid volcanics such as granophyre, felsite and rhyolite occupy 77% area (GSI, 2002). Total thickness of basalt is 500m in the west and 1700m in the east. Thickness of individual flow varies from 12 to 22m. Average thickness of individual flow in southern part is estimated at 20 m (Bohra and Sharma, 1990). Acidic plugs are exposed in the southern part. Picrite basalt (Banerjee et al, 1996) is exposed in the western part of the district covering 240 sq km area.

Geologically the district area can be broadly grouped under hard rock's comprising "Deccan traps" and soft rocks comprising "Tertiaries and Alluvium". Nearly 80% of the area is underlain by Deccan Traps, 19% by the Tertiaries and the rest by Alluvium. Columnar and sheet joints are common in the basalt. It is also affected by tectonic joints aligned in the direction of major lineaments and faults. Joints in the limestone are widely spaced vertical. The Deccan trap area is profusely intruded by basaltic dykes trending mainly in NNW-SSW, NE-SW and dykes are 30 kml ong and150 m wide.

Deccan basalt is exposed in major part of the district. Acidic formations are founded in southernmost tip of the district. Coastal aquifer is located in northernmost and southernmost part of the are in very limited extent. Limestones patches are also reported in Southernmost part of the district. Geological characteristics in various litho-units are described below:

2.1.1 Basalt (Deccan Traps -Hard Rock)

Deccan basalts of west-central India are hydro geologically inhomogeneous rocks. A proper understanding of the physical framework of the basalts within which groundwater resides and moves is a key to the hydrogeology of these rocks. Two types of basalt, the vesicular amygdaloidal basalt and the compact basalt, occur as alternate layers in the volcanic pile. Although the rocks are generally inhomogeneous, structures in the basalt, such as sheet joints and vertical joints, serve as zones of groundwater flow. In the shallow subsurface, two groundwater systems are operative. Groundwater system A consists of a vesicular amygdaloidal basalt underlain by compact basalt,

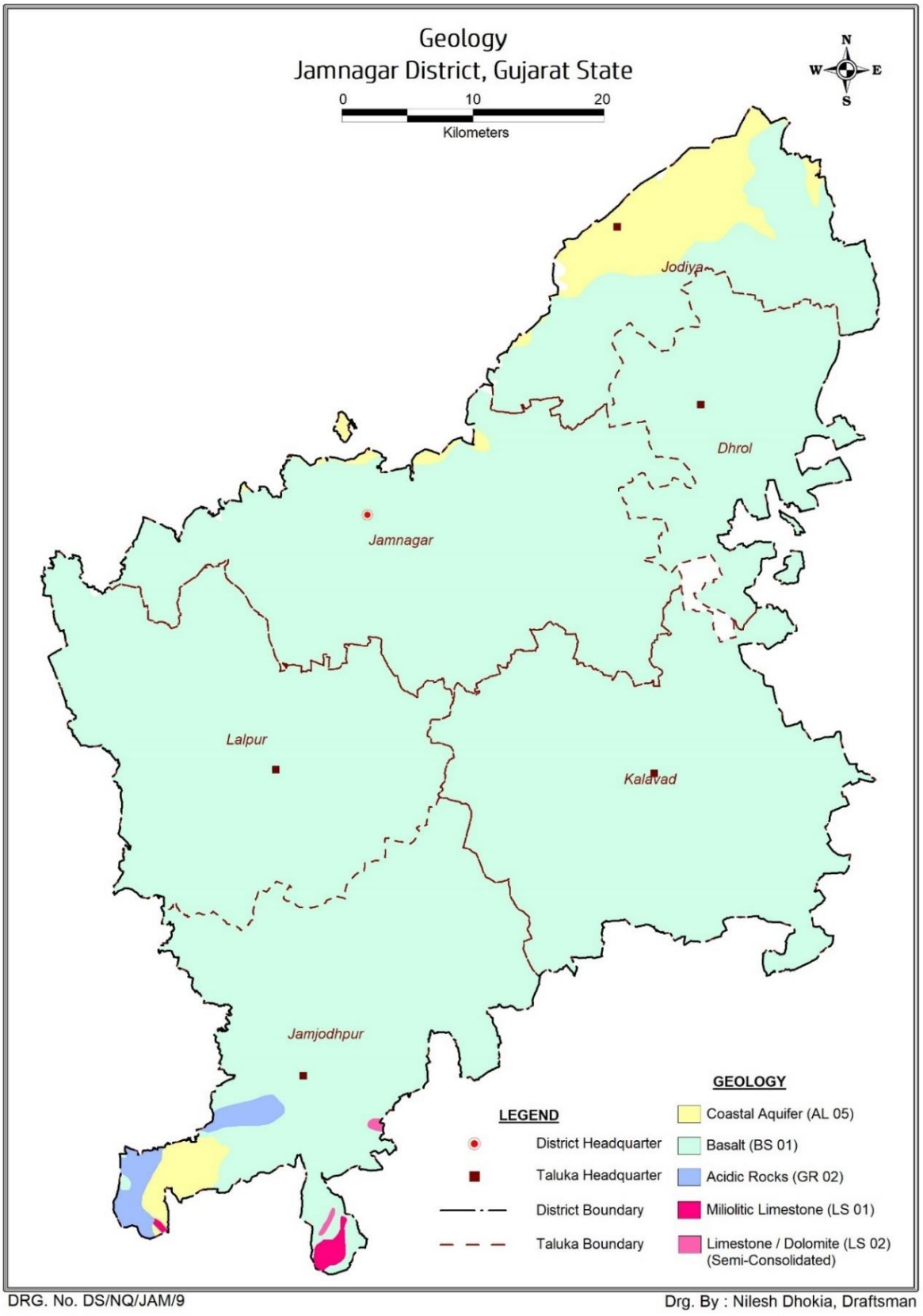

Figure 14 Geology of Jamnagar District

whereas groundwater system B consists of vesicular amygdaloidal basalt overlain by compact basalt. Groundwater system A has a better developed network of openings and, as a consequence, this system has a higher transmissivity and storage coefficient than groundwater system B. Wells tapping groundwater system A have higher yields on average and irrigate more hectares of cropland than do wells tapping groundwater system B. This simple systems concept offers a practical methodology for understanding the geometry of the physical framework that contains groundwater in the Deccan basalts. The efficacy of the concept is in its widespread utility for the region. The concept may also be extrapolated to help understand the hydrogeology of deeper Deccan basalt groundwater systems.

Basalts in district are of amygdular, porphyritic and aphanitic type. Amygdules are generally infilled with calcite, zeolite and chloropheiite glass. Sizes of the amygdules and geoids vary from few mm to 40 cm. Upper part of the amygdular basalt is weathered and permeable. The porphyritic basalt is also weathered at places where large plagioclase phenocrysts are present. Aphanitic basalt is relatively less weathered. Contacts of basaltic flows are sheared and weathered, at places and or marked by red boles and inter-trappean volcano-sedimentary beds

2.1.2 Acidic Rocks

Acidic plugs are exposed in the southern part. Picrite basalt (Banerjee et al, 1996) is exposed in the western part of the district covering 240 sq. km area.

2.1.3 Miliolitic Lime Stone

Miliolite Formation of Pleistocene age comprising limestone and calcareous sandstone of Pleistocene age occurs in the western coastal tract with an average outcrop width of 200 m and maximum thickness of 30 m. It also occurs as isolated patches along the slopes of the denuded hills and dissected upland. Miliolite formation near coast is consolidated calcareous beach-sand associated with foraminifers and marine shell fragments whereas inland it is having fluvio-aeolian character. Both types are having clastic nature with coarse grained and cross stratification. Miliolite limestone is porous and permeable. Holocene sediments in the coastal zone comprise well sorted sand along the western beach coast and fluvial sand, silt and clay in the flood plain area.

2.1.4 Semi Consolidated Limestone/Dolomite

These formations consist of limestone, marl, clay, sandstone with occasional gypsum layers and soft sands with well-rounded grains. Clay dominated layers contain intercalated sand lenses. Both sandstone and clay are associated with gypsum at places. Secondary solution cavities are also present in this limestone.

2.1.5 Coastal Areas

Groundwater occurs under unconfined conditions. The thickness of the coastal alluvium is not more than 20m. Because of its clayey nature, percolation of rainwater is very poor resulting in poor yields. The depth of water level ranges from 2 to 10m bgl (Pre-monsoon). The yield of these wells hardly exceeds 100m3/day.

Chapter 3

HYDROGEOLOGY

3.1 Hydrogeology

Hydro-geologically the district area can be broadly grouped under hard rock's comprising "Deccan traps" and soft rocks comprising "Tertiaries and Alluvium". Nearly 80% of the area is underlain by Deccan Traps, 19% by the Tertiaries and the rest by Alluvium. Hydro-geological conditions in various litho-units are described below-

3.1.1 Basalts

These are essentially basaltic flows having general horizontal to near horizontal disposition over large area. The basaltic flows do not have any primary porosity in the lower massive portion, but the top vesicular portion has some porosity because of the vesicles formed due to escaping gases. Both massive and vesicular portions have no primary permeability, as the vesicules are seldom interconnected. The secondary porosity and permeability developed due to fracturing and jointing provides passage for infiltration, storage and movement of groundwater. The weathered zone extends to about 20m bgl in the surface flows. Weathered flow contacts extend to greater depths. The permeability of these zones is further intensified by fracturing and jointing. These interflow zones and fractured and jointed zones have given rise to stratified aquifer system, which is responsible for occurrence of water even at greater depths. Weathering of basalts, which extends down to 20 meters and the fractured basalts up to 87 meters beneath the weathered mantle have given rise to water table aquifers down to 87 m bgl. The depth of water level in the area ranges from 3.45 m bgl to 51.85 bgl (Weathered and fractured zone –Phreatic aquifer) during the pre-monsoon period while during the post mon-soon period depth to water level varies from the 2.05mbgl to 56.25 mbgl

The yields of the wells tapping this phreatic/unconfined aquifer (weathered and fractured basalt) are in the range of 20-100m3/day. Those in which interflow zones have been tapped 100-400m3/day. The bore wells drilled in the district have yields ranging from 100 to 500m3/day.

3.1.2 Limestones

Groundwater occurs under phreatic conditions. These milliolite limestone acts as a reservoir for shallow groundwater in very limited extent. The depth of water level in milliolite limestones is

generally about 5m bgl. Open wells are about 10m in depth. The yield of these wells' ranges from 100-200m3/day.

3.1.3 Alluvium

Groundwater occurs under unconfined conditions. The thickness of the alluvium is not more than 20m. Because of its clayey nature, percolation of rainwater is very poor resulting in poor yields.

3.2 Aquifer System

Two major aquifer systems exist in Jamnagar district up to 500-meter depth. Major aquifer bearing formation is fractured/fissures basalt.

3.2.1 Shallow Aquifer System

Weathered and fractured basalt are of unconfined nature and ranges from 0 to 87 m bgl. Thickness of this aquifer is 0 to 87 meters. It lies in almost entire district. Quality of water is fresh to Saline. In some areas alluvium aquifer also exit but it is in very limited in extent.

3.2.2 Deeper aquifer System

In the massive Basalt, at some places deep fractures are also encountered maximum to the depth of 438 m in the groundwater exploration of up to the depth of 500 mbgl.

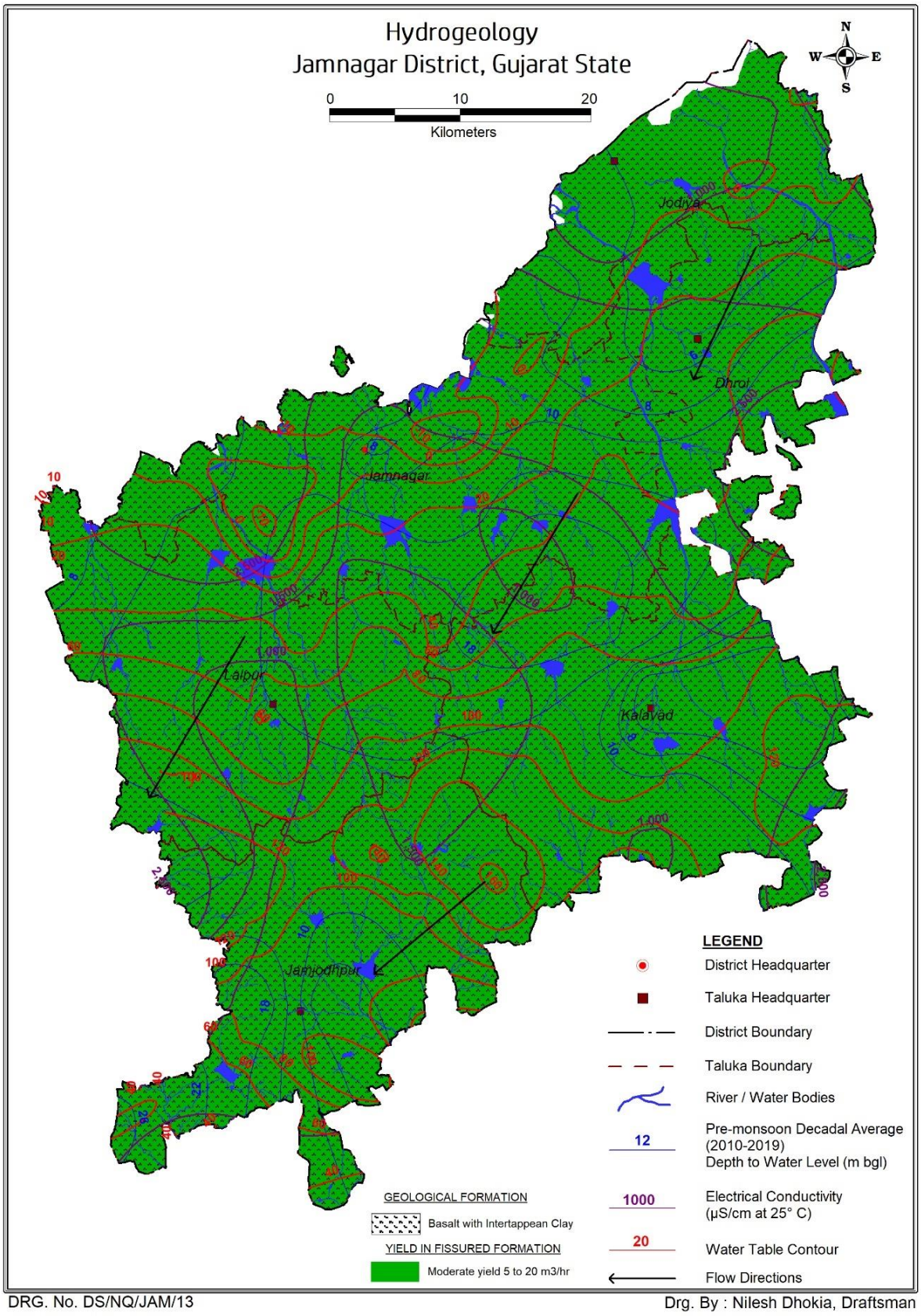

Figure 15 Hydrogeology of Jamnagar District

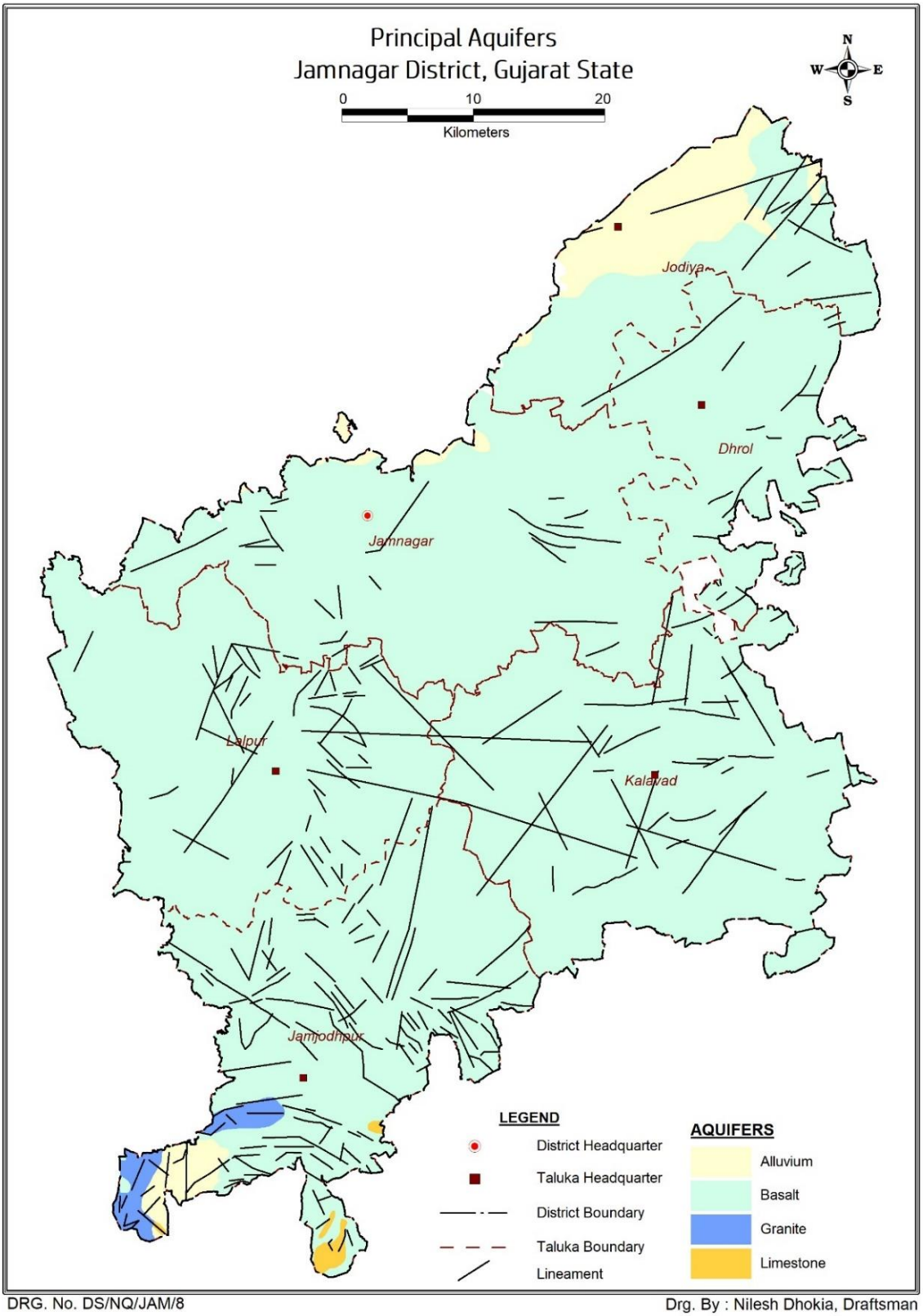

Figure 16 Principal Aquifers of Jamnagar District

3.3 Aquifer Parameters

Movement and abstraction of groundwater in the geological formations are dependent on the hydrogeological parameters of the aquifers. The purpose of any aquifer test is to determine the hydrogeological parameters. Among the basic parameters are the Storativity, transmissivity and leakage coefficients.

Transmissivity of major aquifer (0 to 87 mbgl) in district varies from 0.05 to 102.63 m^2/ day.

3.4 Groundwater Scenario

Groundwater occurs both in hard rock and alluvium. Though ground water occurs in all types of formation, but the most productive aquifer are Fractured/Weathered basalts of Deccan traps and Alluvium formations.

Systematic and regular monitoring of groundwater levels brings out the changes taking place in the groundwater regime. The maps so generated are of immensehelp for regional groundwater flow modelling which serves as a groundwater management tool to provide the necessary advance information to the user agencies to prepare contingency plans in case of unfavorable groundwater recharge situation. The data also has immense utility in deciding the legal issues arising out of conflicting interests of groundwater users.

The monitoring of ground water levels has been carried out at groundwater monitoring wells four times in a year simultaneously throughout the State during the following periods.

I. May - 20th to 30th (water level of pre-monsoon period).
II. August - 20th to 30th (peak monsoon water level).
III. November - 1st to 10th (water levels of post-monsoon period).
IV. January - 1st to 10th (the recession stage of water level).

Water level data of the ground water monitoring wells collected during the year 2020-21 has been utilized to prepare various maps showing depth to water level and fluctuation of water level. Depth to water level maps is useful in dealing with problems of water logging and artificial recharge, where the relative position of water level with reference to the ground surface is of critical importance. Water level fluctuation maps (rise or fall) are indispensable for estimation of change in storage in the aquifer.

The data is analyzed for each set of measurement, and report prepared which include following maps to understand the groundwater regime in the state.

I. Depth to water level
II. Decadal Average Depth to Water Level

III. Decadal fluctuation - water level fluctuation in the month of measurement with reference to the decadal average for the same month.
IV. Water table contour
V. Groundwater level trend

3.4.1 Depth to Water Level

In the recent past, the population growth and overexploitation of groundwater resources have led to rapidly declining groundwater levels (Aggarwal et al., 2009). The aquifers are under tremendous pressure and are vulnerable to depletion, particularly in semi-arid and arid regions where the natural recharge is not adequate to balance the withdrawals (Vörösmarty and Sahagian, 2000). This is further aggravated by uncertain and uneven rainfall patterns causing overdependence of agriculture on groundwater resources.

The depth to water level in the district ranges from 3.45 to 51.85 mbgl during the pre-monsoon period and some patches shows that water level is deep in Kalavad, Jamjodhpur and Jamnagar talukas of District (Figure.17). Sethvadala village (Jamjodhpur) has recorded the shallowest water level whereas the deepest water level was recorded at Jalansar (Kalavad). About 22% samples represent WL below 10 mbgl while 78% above 10 mgbl.

Post-monsoon WL ranges from 0.50 mbgl to 15.10 mbgl, about 4% samples shows water level above 10 mbgl. (Figure 18)

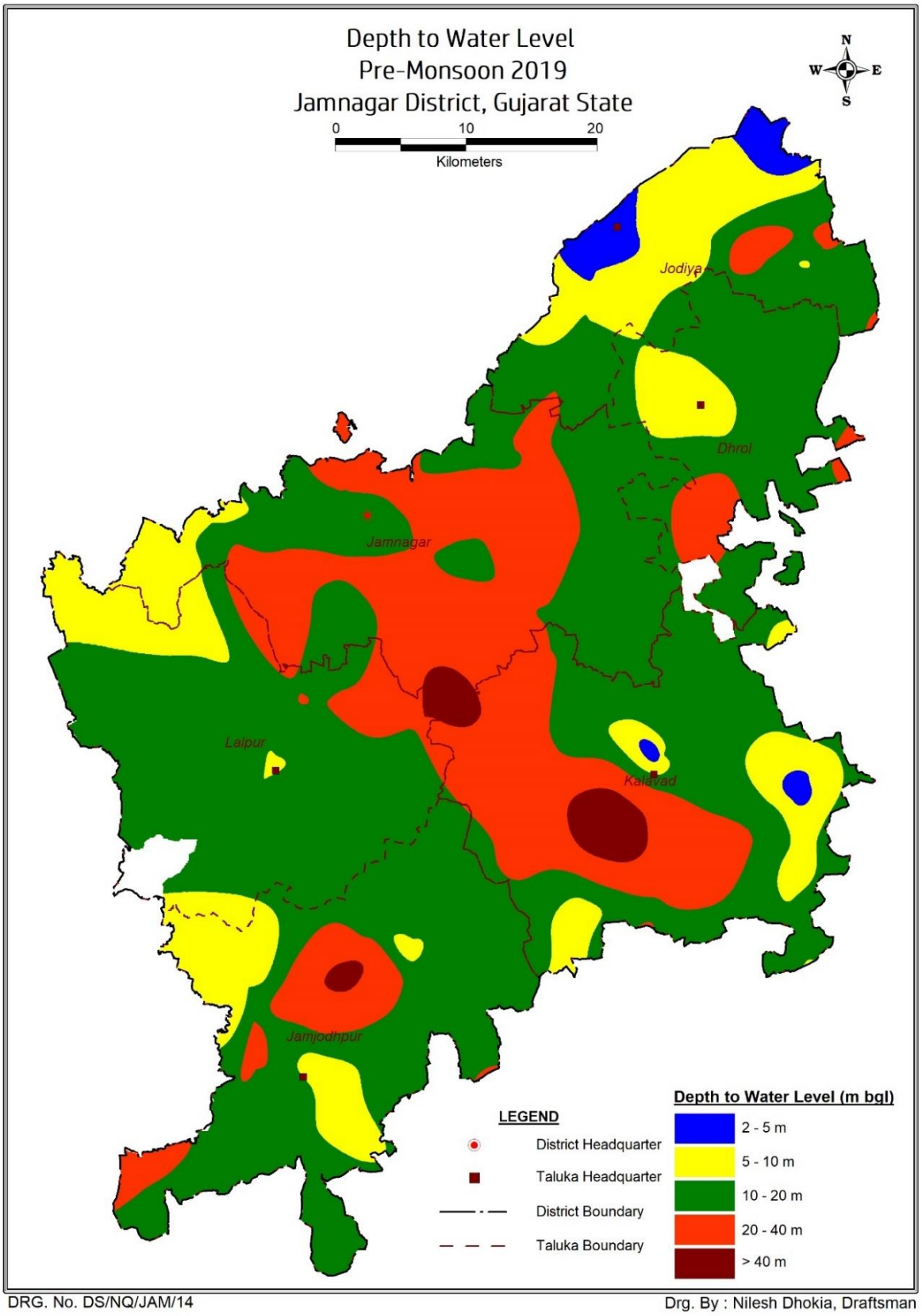

Figure 17 Depth to water level map Pre-monsoon 2019

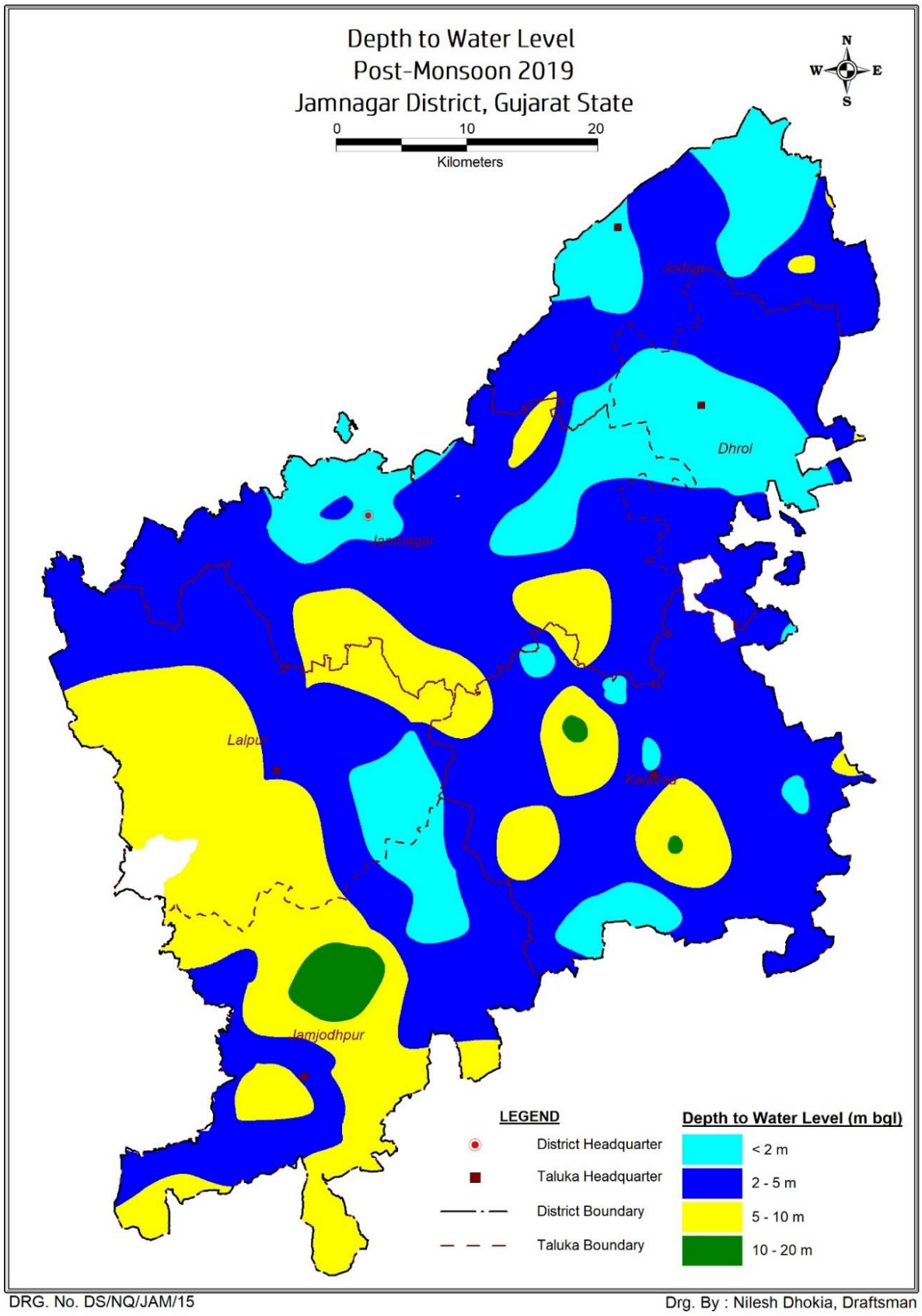

Figure 18 Depth to water level map post-monsoon 2019

3.4.2 Depth to Water Level Decadal Mean

India is the largest groundwater consumer globally, with an estimated usage of about 251 km^3/yr (UNESCO, 2012). The demand of water for irrigation in India will rise up to 56 % by the year 2050 (i.e., 1072 BCM) as indicated by the Ministry of Water Resources (Baweja et al., 2017; CWC, 2000). In the past few decades, most northern states in India have experienced a severe depletion of groundwater due to over-exploitation of groundwater for various purposes (CGWB, 2016).

The exponential growth in agricultural production has come at the cost of deterioration of natural resources, especially groundwater depletion. The key reason for the depletion of groundwater levels is the rapid rise in the number of tube wells/borewells and for irrigation and industrial purposes.

Major part of the district shows decadal average water levels from 5 to 20 mbgl in pre-monsoon few patches has less than 5 mbgl decadal average water level and in some parts decadal average water level is more than 20 mbgl but maximum decadal average water level is not more than 40 mbgl in any part of the district (Figure.19).

In post monsoon, major part of the district shows decadal average water levels from 2 to 10 mbgl few patches have less than 2 mbgl decadal average water level. and in some parts decadal average water level is moe than 10 mbgl but neither area represents decadal average water level more than 20 mbgl (Figure.20).

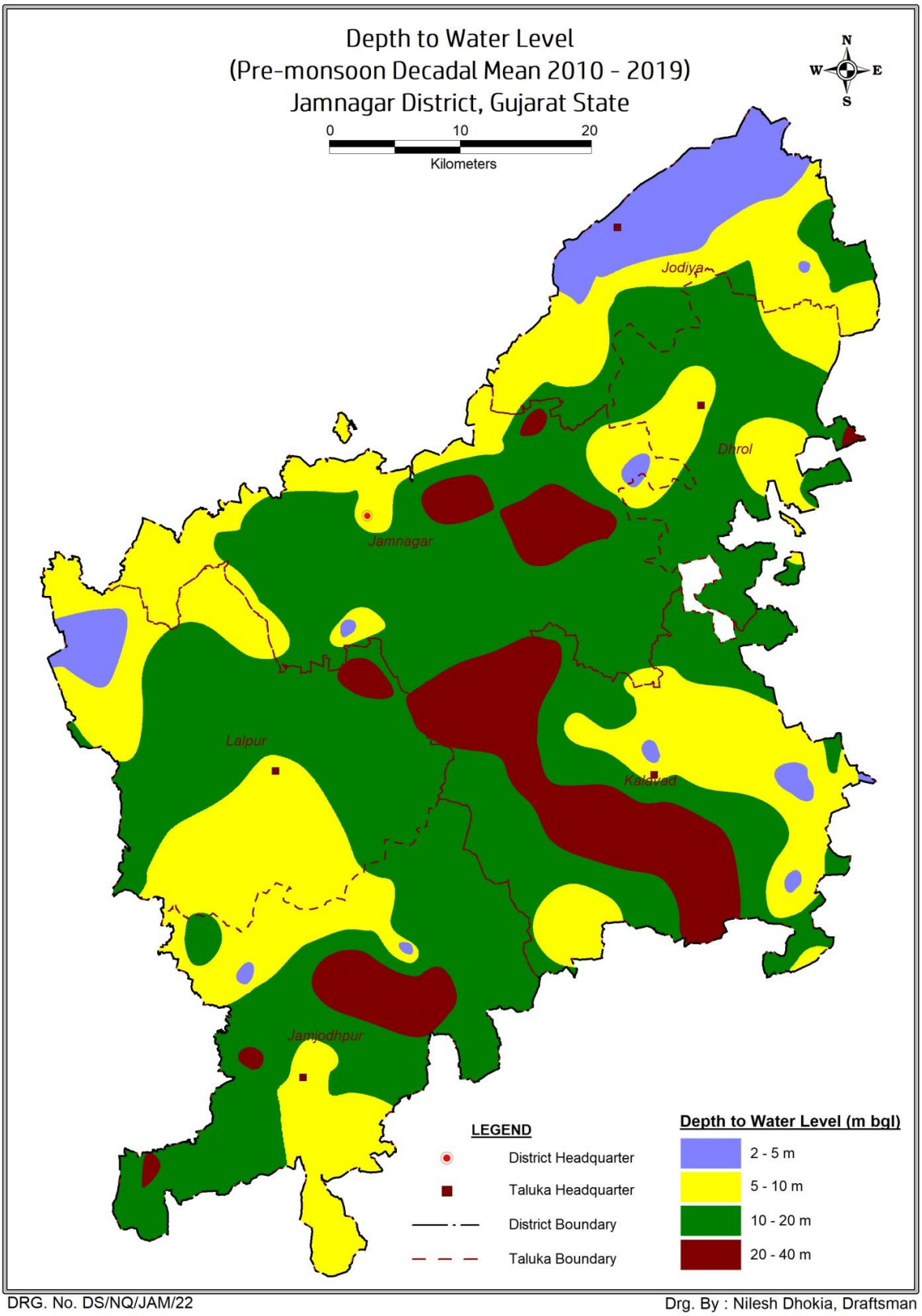

Figure 19 Pre-Monsoon Decadal Mean Map of Jamnagar District

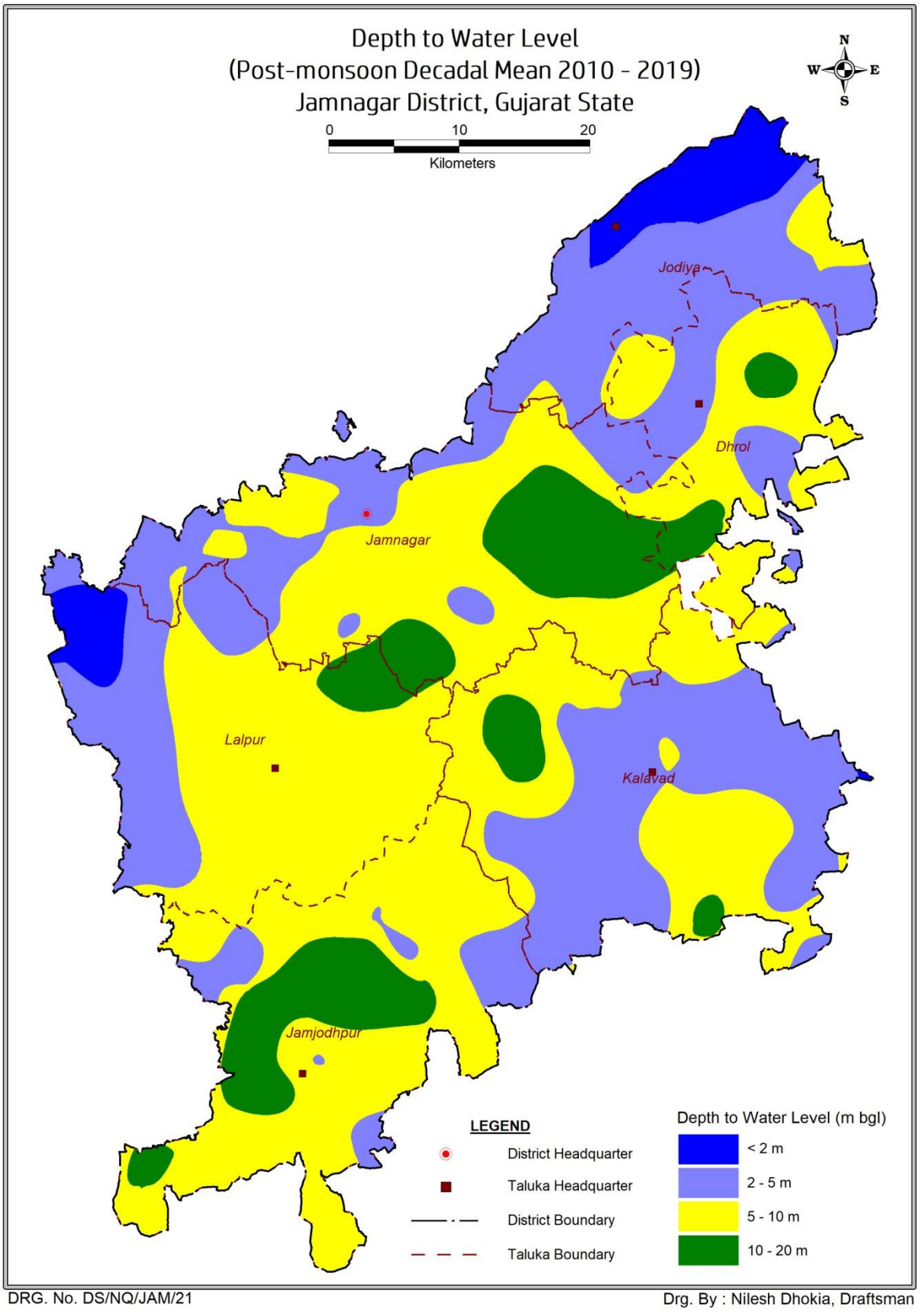

Figure 20 Post-Monsoon Decadal Mean Map of Jamnagar District

3.4.1 Water Table Fluctuation

The groundwater fluctuations result mostly due to withdrawal from bore wells, less recharge compared to discharge, water uptake by the vegetation, and periodic moisture disparity (Rajaveni et al., 2014). Various groundwater-related problems viz., groundwater depletion (Dhillon et al., 2019), groundwater quality deterioration (Lombard et al., 2021; Mukherjee et al., 2021a; Singh et al., 2019), land subsidence, and hydrological droughts arise due to the declining trend of groundwater levels (Anand et al., 2020). Therefore, groundwater level quantification and prediction of the trend can be pivotal for sustainable water management, primarily due to increasing climatic uncertainties. Though there is an urgent need to study the impact of groundwater exploitation under climate change, very few studies exist in the literature (Malakar et al., 2021), mostly due to the lack of large spatial and temporal datasets.

In major parts of district water level rises more than 6 meters. Very small area of district shows fall in water level from 0 to 2 meter. Overall, below map indicates that water is recharging during to groundwater in monsoon (Figure.21).

3.4.2 Water Table-Contour Map /Groundwater Flow

A water table-contour map is an important tool in groundwater investigations because, from it, one can derive the gradient of the water table and the direction of groundwater flow, which is perpendicular to the water table-contour lines. A line drawn on a map to represent an imaginary line in the water table of a definite level. These contours are constructed from the data provided by the water-table levels, corrected for differences in surface level at the respective boreholes. A site investigation or opencast plan sometimes shows water-table contours. A ground water contour map provides important information about ground water movement and flow directions. Different regions facing water scarcity will be identified. The groundwater potential zones are identified to the help of study the geographical factors and groundwater availability.

In general groundwater flows from NE to SW direction for Jamnagar District. (Figure 22)

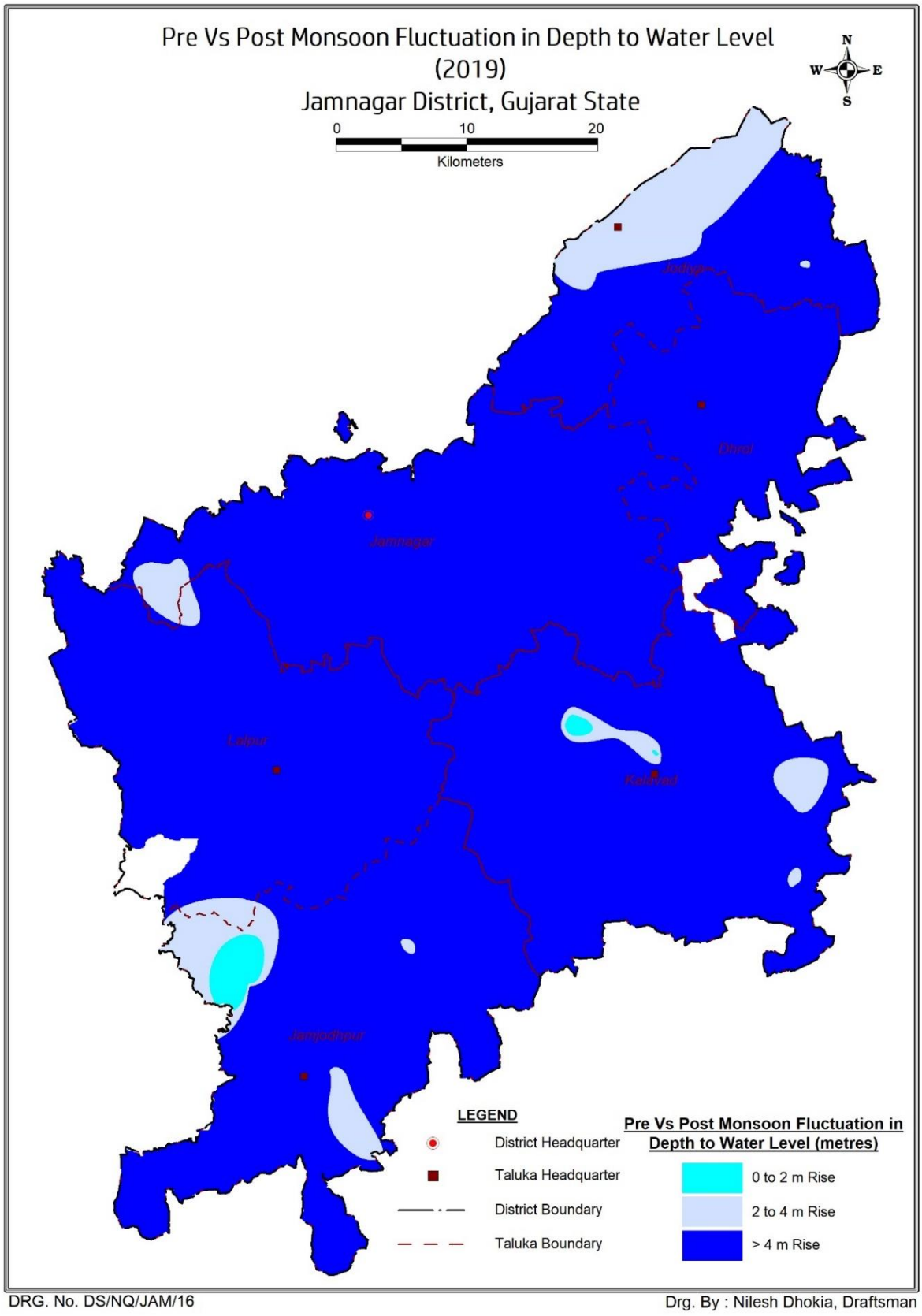

Figure 21 Pre vs Post Monsoon 2019 Water level fluctuation Map

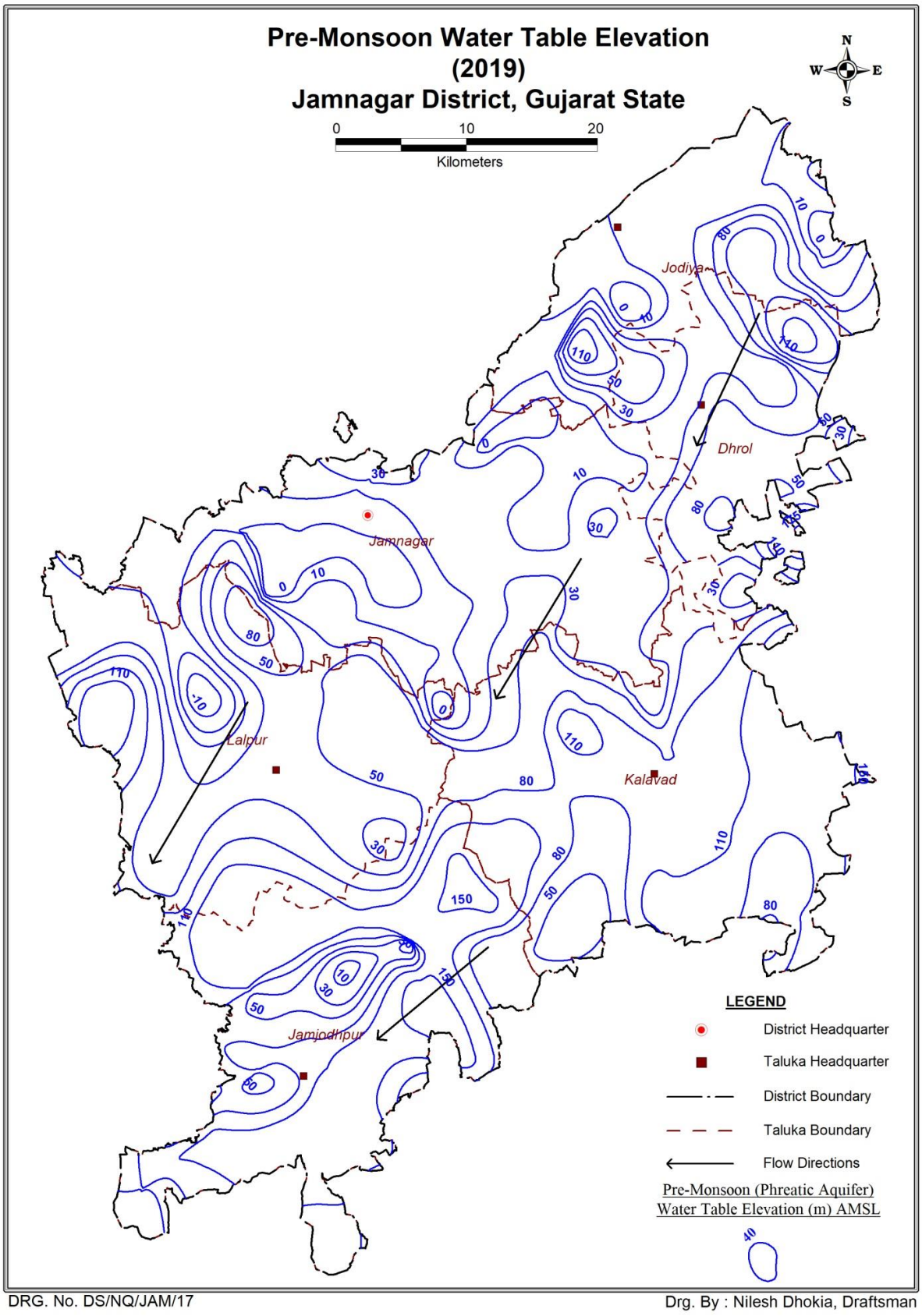

Figure 22 Water Table elevation with Groundwater flow direction map of Jamnagar District

3.4.5 Water Level Trend

Analysis of the long-term groundwater level trend for 10 years (2012-2021) of the district reveals that rise in groundwater level predominant throughout the district. Long term rises in water level during the post-monsoon period ranged from 0.08 to 0.96 m/yr while the fall reported is -0.11 m/yr in Lalpur (Post Monsoon). The highest rise was recorded at Ved Panchsara while the highest fall was recorded at Dudhai Village (Pre-monsoon). The long-term water level fluctuation for the Pre monsoon period also reveals that rise in water level ranged from 0.19 to 0.40 m/yr. (Table 7).

Table 7 Water level trend for Jamnagar District

S.N.	Site	Taluka/Block	District	Period	Pre-Monsoon Rise/Fall (m/year)	Post Monsoon Rise/Fall (m/year)	All Rise/Fall (m/year)	Remarks
1	Amran1	Jodiya	Jamnagar	2012-21	0.19	0.11	0.69	Significant Rise
2	Drafa	Jamjodhpur	Jamnagar	2012-21	0.15	0.08	0.15	Rise
3	Dudhai2	Jodiya	Jamnagar	2012-21	-0.19	0.08	0.02	Rise
4	Lalpur1	Lalpur	Jamnagar	2012-21	-0.12	-0.11	0.01	Fall
5	Seth Vadala	Jamjodhpur	Jamnagar	2012-21	0.21	0.41	0.46	Significant Rise
6	Vadpanchsara	Lalpur	Jamnagar	2012-21	0.40	0.96	0.86	Significant Rise

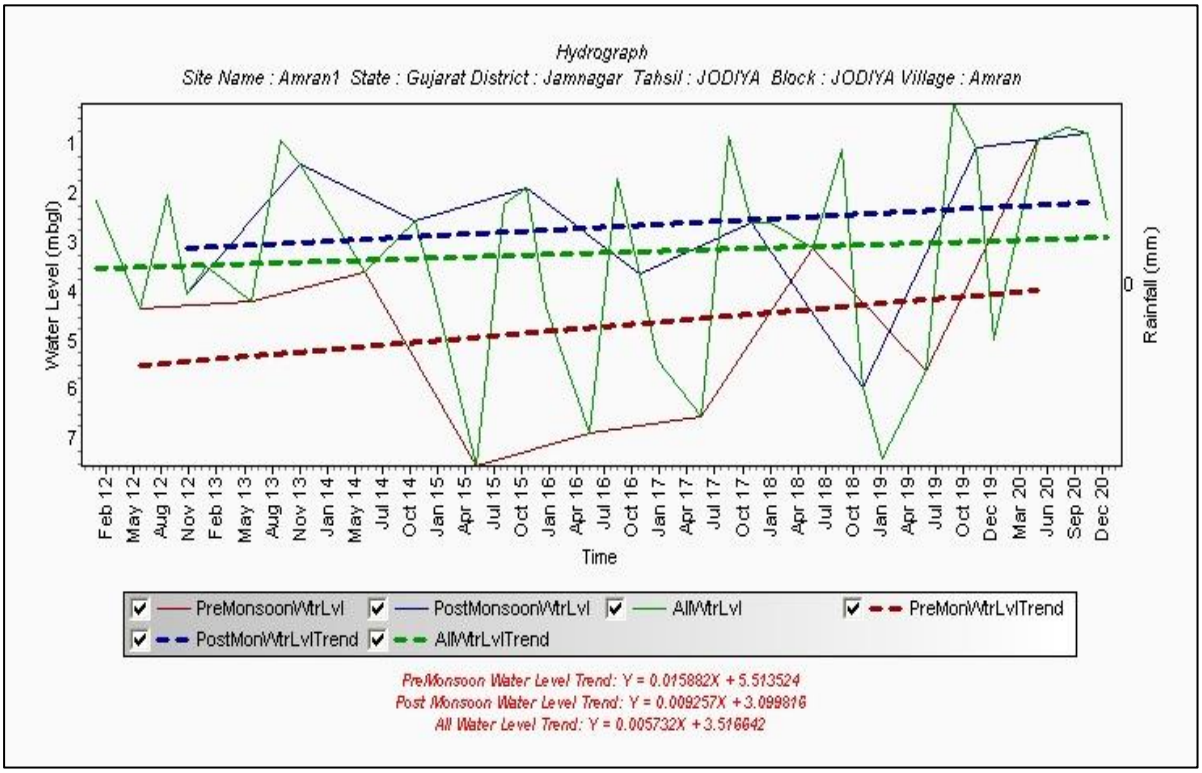

Figure 23 Hydrograph of Amran site of Jodiya Taluka of Jamnagar District.

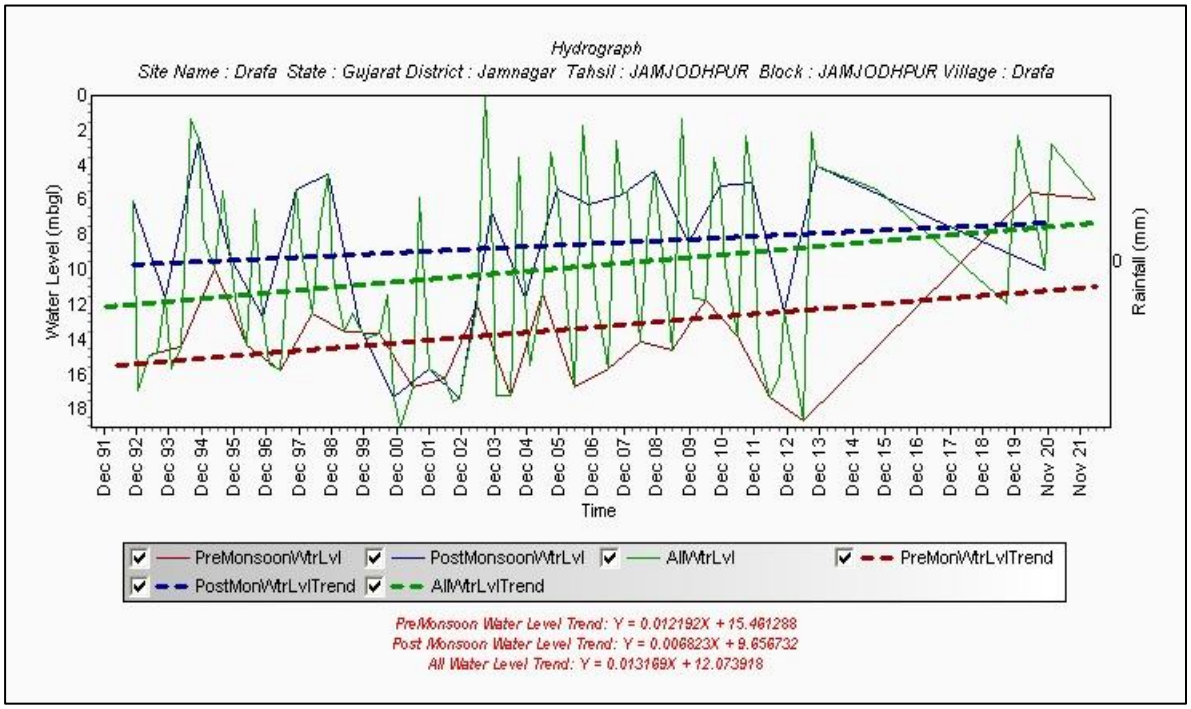

Figure 24 Hydrograph of Drafa site of Jamjodhpur Taluka of Jamnagar District.

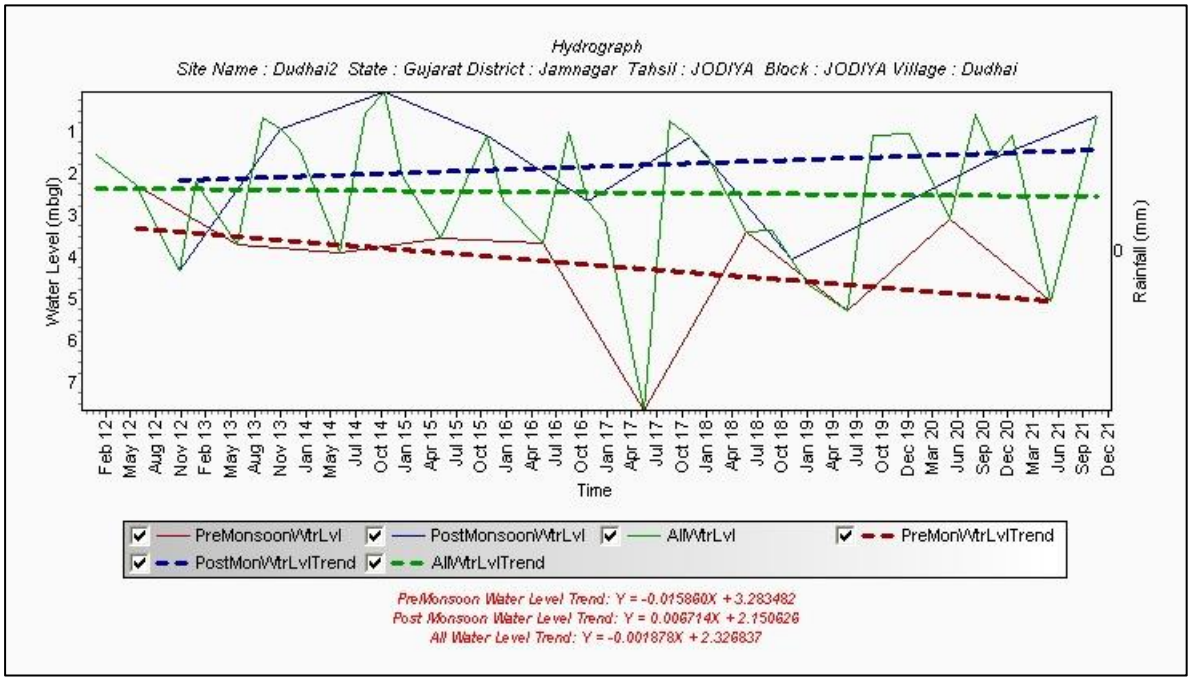

Figure 25 Hydrograph of Dudhai site of Jodiya Taluka of Jamnagar District

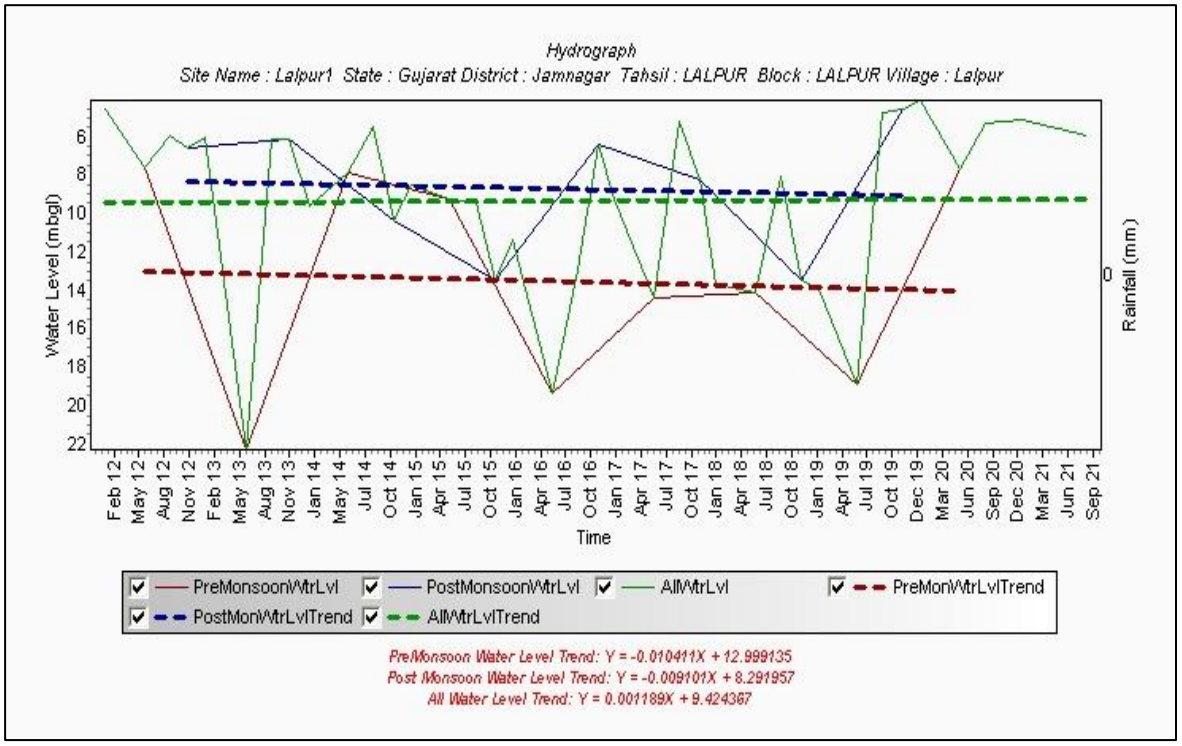

Figure 26 Hydrograph of Lalpur site of Lalpur Taluka of Jamnagar District

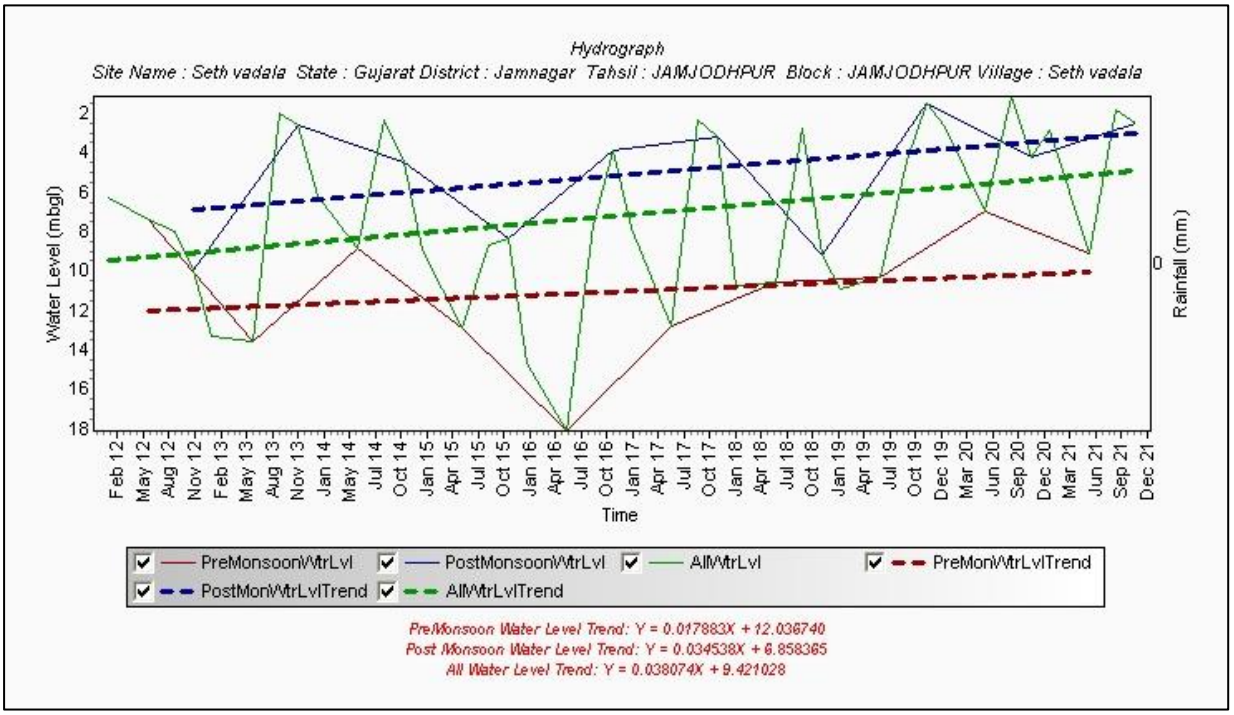

Figure 27 Hydrograph of Seth Vadla site of Jamjodhpur Taluka of Jamnagar District

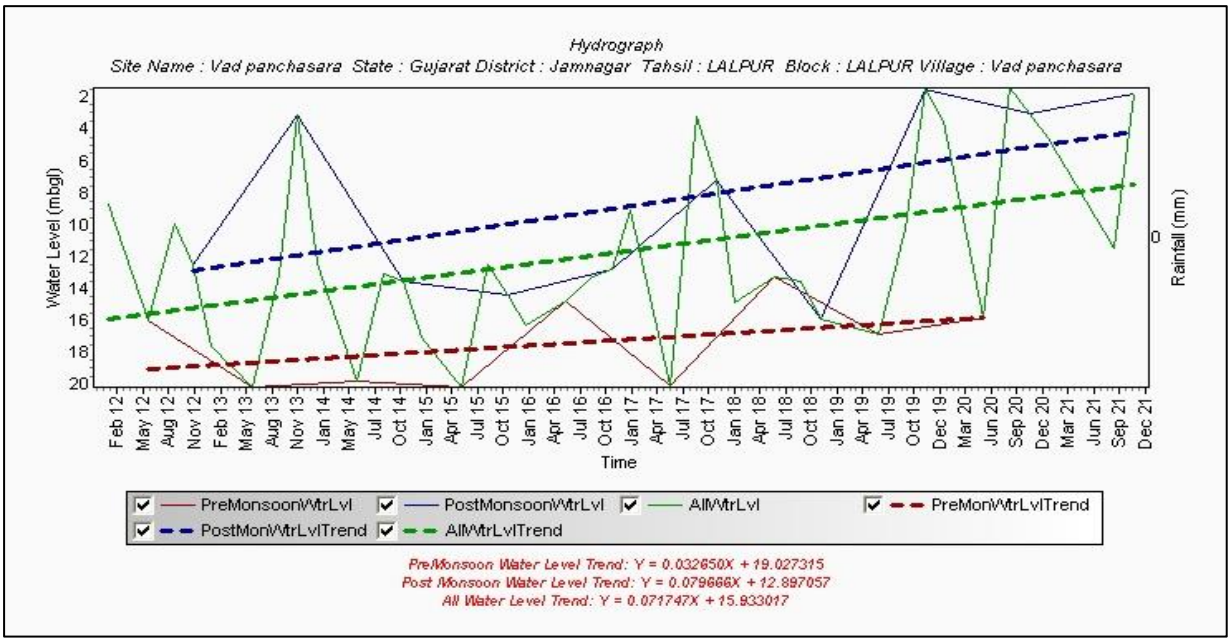

Figure 28 Hydrograph of Vadpanchasara site of Lalpur Taluka of Jamnagar District

Chapter 4
DATA INTEGRATION, INTERPRETATION, AND AQUIFER MAPPING

4.1 Introduction

Collection and compilation of data for aquifer mapping studies is carried out in conformity with Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities (Table-8).

Table 8 Brief Activities showing Data Compilation and Generation

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on hydrology, geology, geophysics, hydrogeology, geochemical etc. Creation of data base of exploration wells, delineation of principal aquifers (vertical and lateral) and compilation of aquifer wise water level and draft data etc.
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
2	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic Analysis, analysis of land use pattern.
		Hydrological Parameters on groundwater recharge	Rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydro geological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping Tests, preparation of sub-surface hydro geological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters Including fluoride.

3	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydro geological, Geophysical, Geological and Hydro-chemical data.
4	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer through training to Administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

4.2 Data Compilation and Generation

In order to establish the three-dimensional disposition of aquifer system in the area, the existing data of litho logical logs and Electrical logs of 24 exploratory wells studies carried out and used in preparation of stratigraphic cross sections, Fence diagram and 3D Model.

Table 9 Data Generation and integration in respect to Jamnagar district

Type of Data & Source	No of Wells
Aquifer Disposition	
CGWB	**24**
Long term Fluctuation	
CGWB+GWRDC	**50**
Depth to Water Level	
CGWB+GWRDC	**113**
Analysis of Water Quality	
CGWB+GWRDC	**74**

CGWB: Central Ground Water Board
GWRDC: Gujarat Water Resources Development Corporation Limited

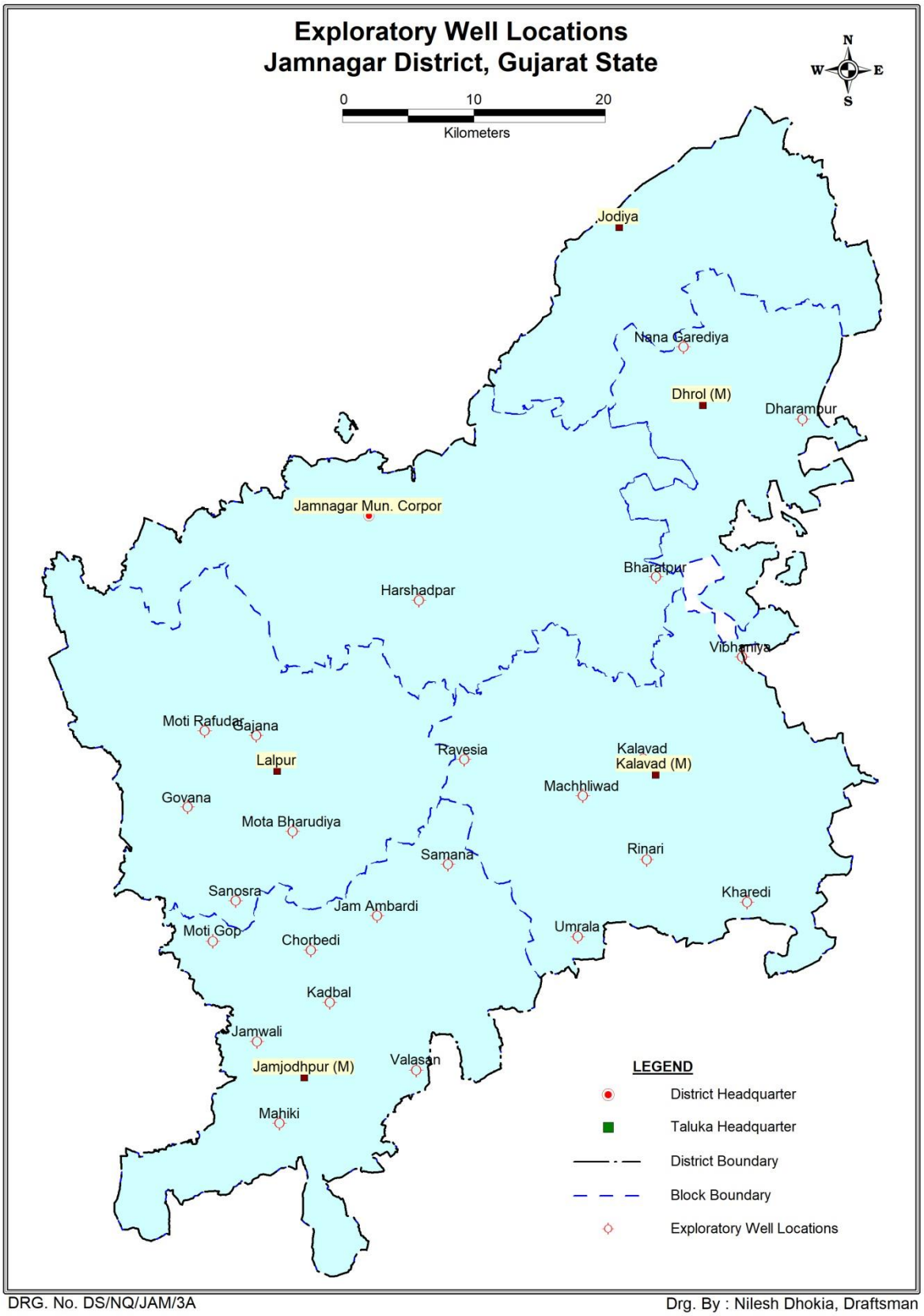

Figure 29 Exploratory wells location Map of Jamnagar District

4.3 Aquifer Disposition

The data has been analyzed using Rockworks 16 software and is presented below in the Hydrogeological cross sections A-A' to E-E' and Solid Model of the district showing the depiction of Weathered, fractured and Massive Basalts. The stratigraphic sections depicting weathered Zone & fractured Zone (up to 87 meters) represents Phreatic/Unconfined aquifer for Basaltic rock with massive basalt are placed below this zone Figures (31, 33 to 37). Stratigraphic index for cross-sectional map is shown in Figure 32. Fence Diagram and 3D Solid Stratigraphic Model of district is depicted in Fig. 38, and 39 respectively.

Table 10 Table depicting Aquifer Disposition of Jamnagar District

Aquifer Disposition					
Stratigraphy	**Aquifer Nomenclature**	**Lithology /Aquifer Materials**	**Depth of occurrence (meter)**	**Thickness (meter)**	**Nature of porosity**
Upper Cretaceous-Lower Eocene	Unconfined (Weathered and Fractured Basalt	Deccan Basalt	0-20 0-87	0-87	Secondary (Weathered & fracture)
	Confined (Massive Basalt with few deep Fractures)	Deccan Basalt	Explore up to the depth of 500 with deepest fractures up to 438 meters	-	Secondary (Fractures, Joints, Shear and flow contacts)

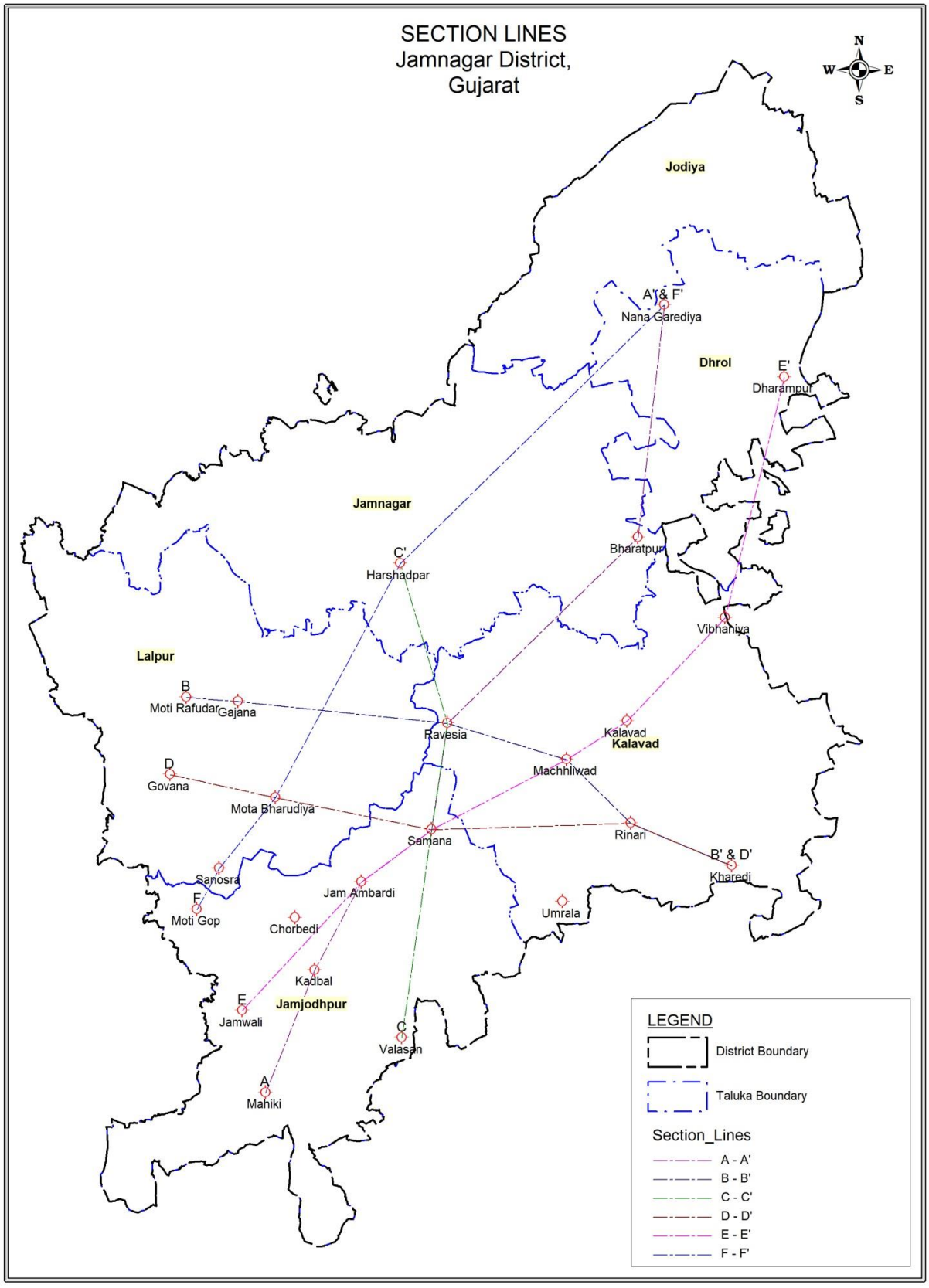

Figure 30 Cross-Section Line Map of Jamnagar District

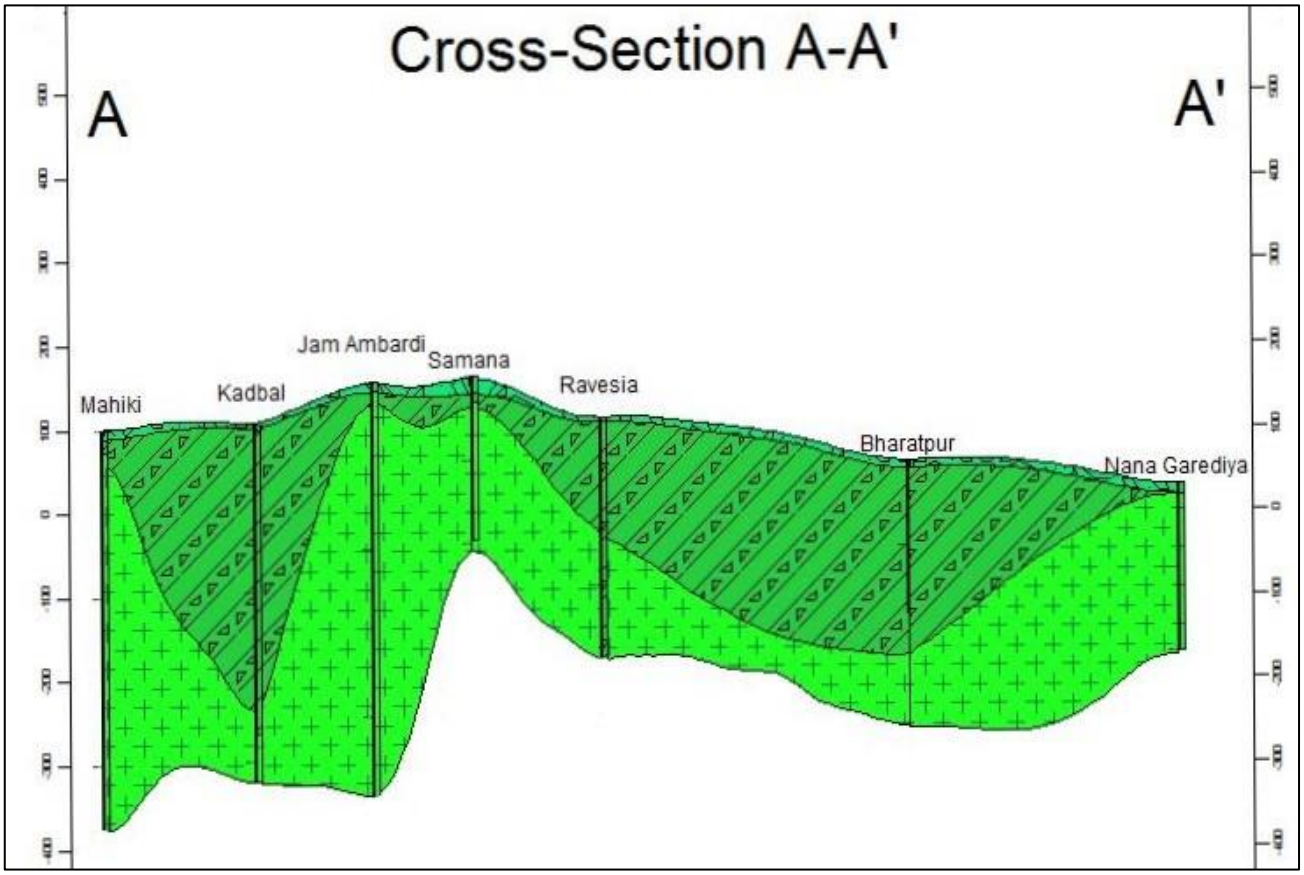

Figure 31 Cross section along A-A'

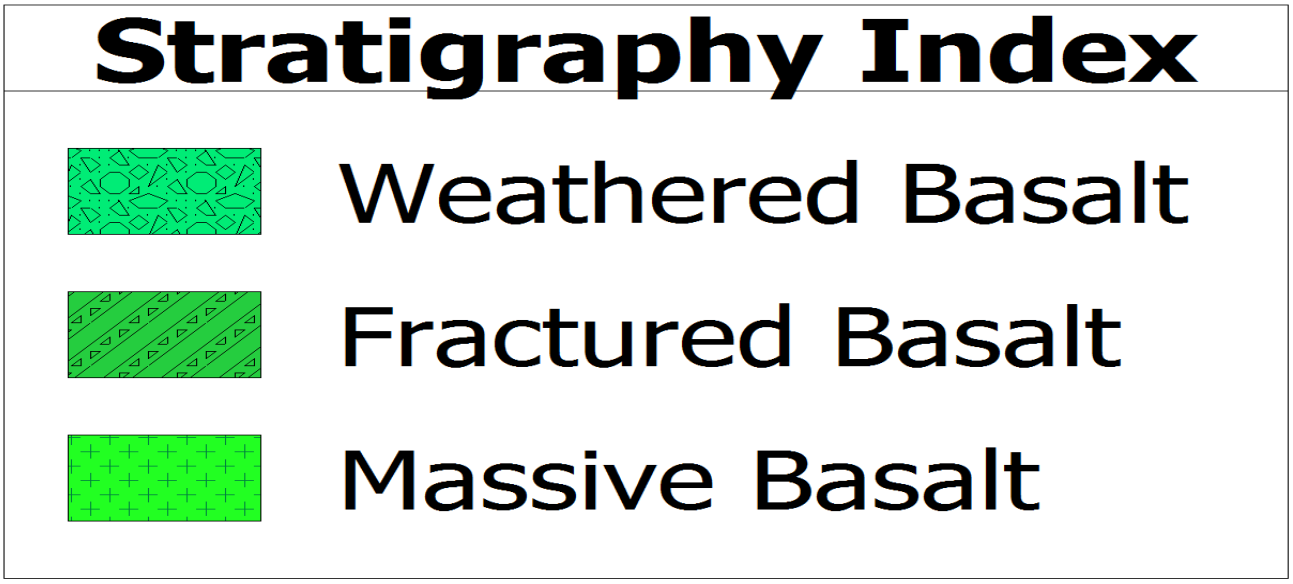

Figure 32 Stratigraphic Legend/Index Map for Cross sections

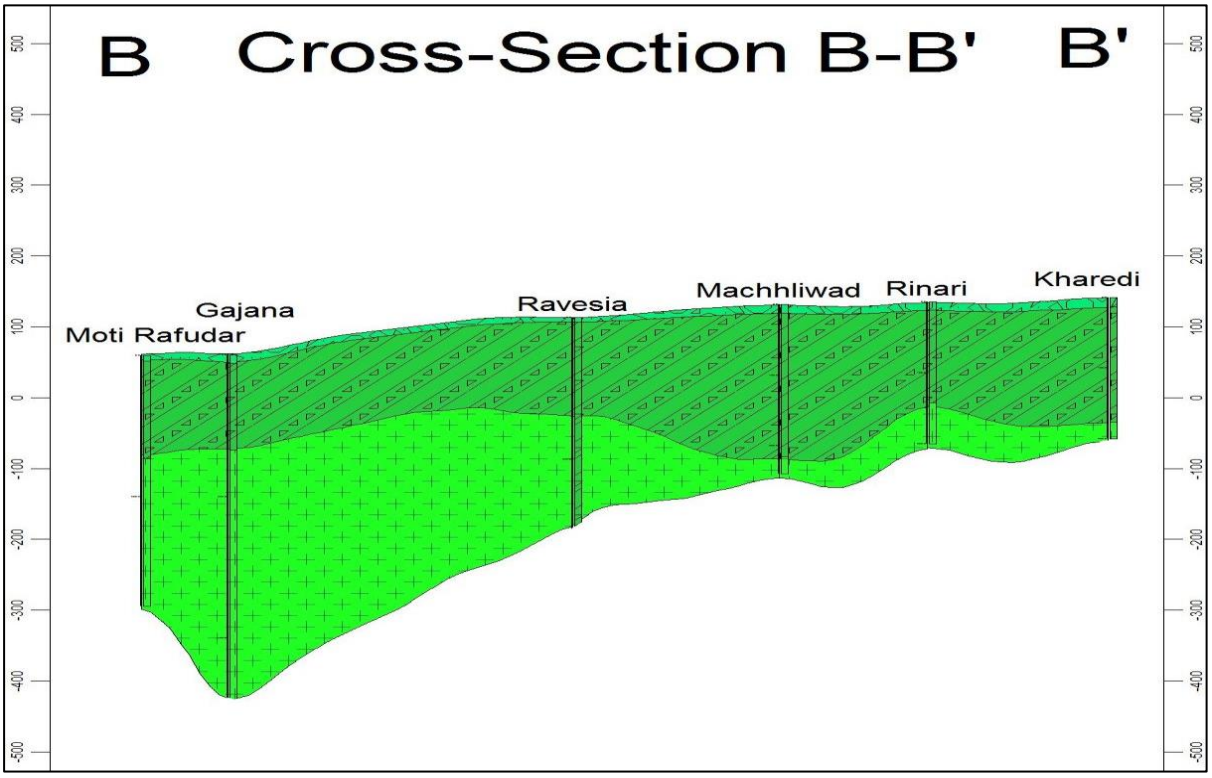

Figure 33 Cross section along B-B'

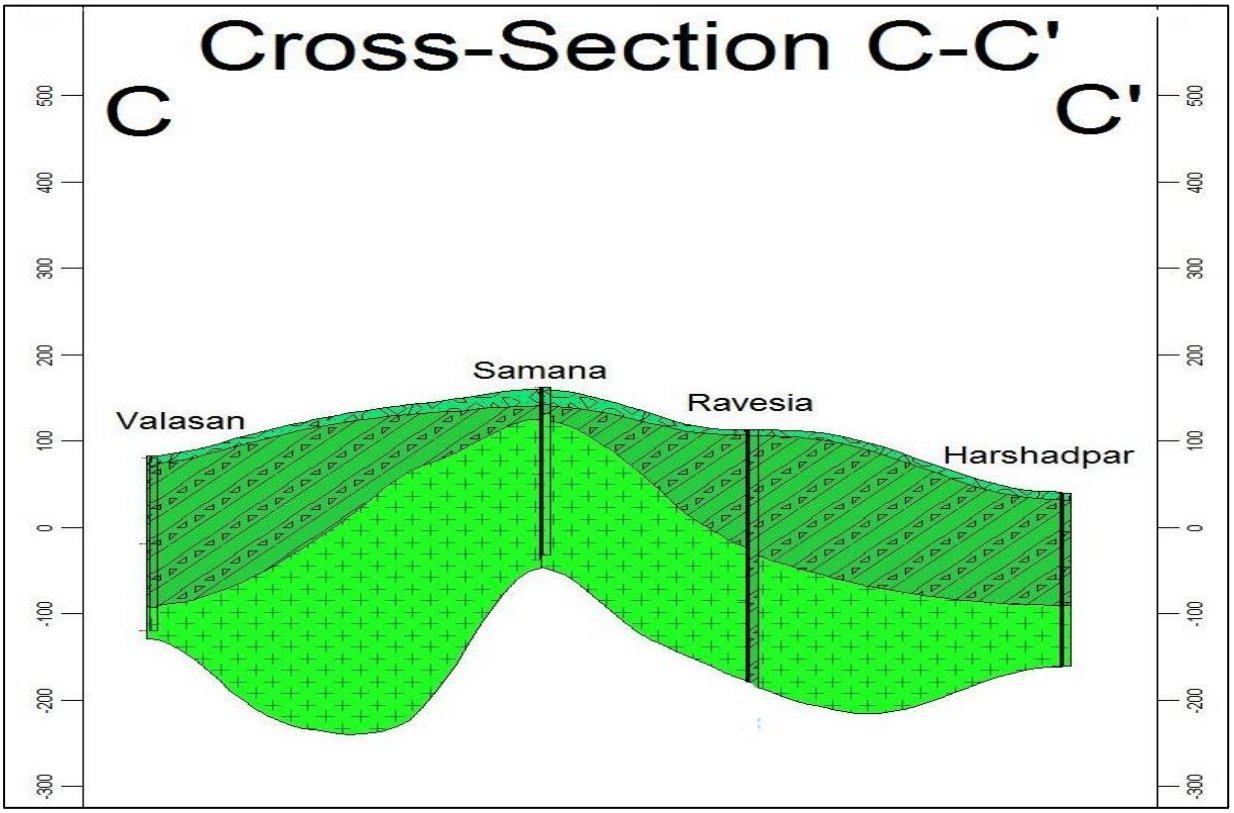

Figure 34 Cross section along C-C'

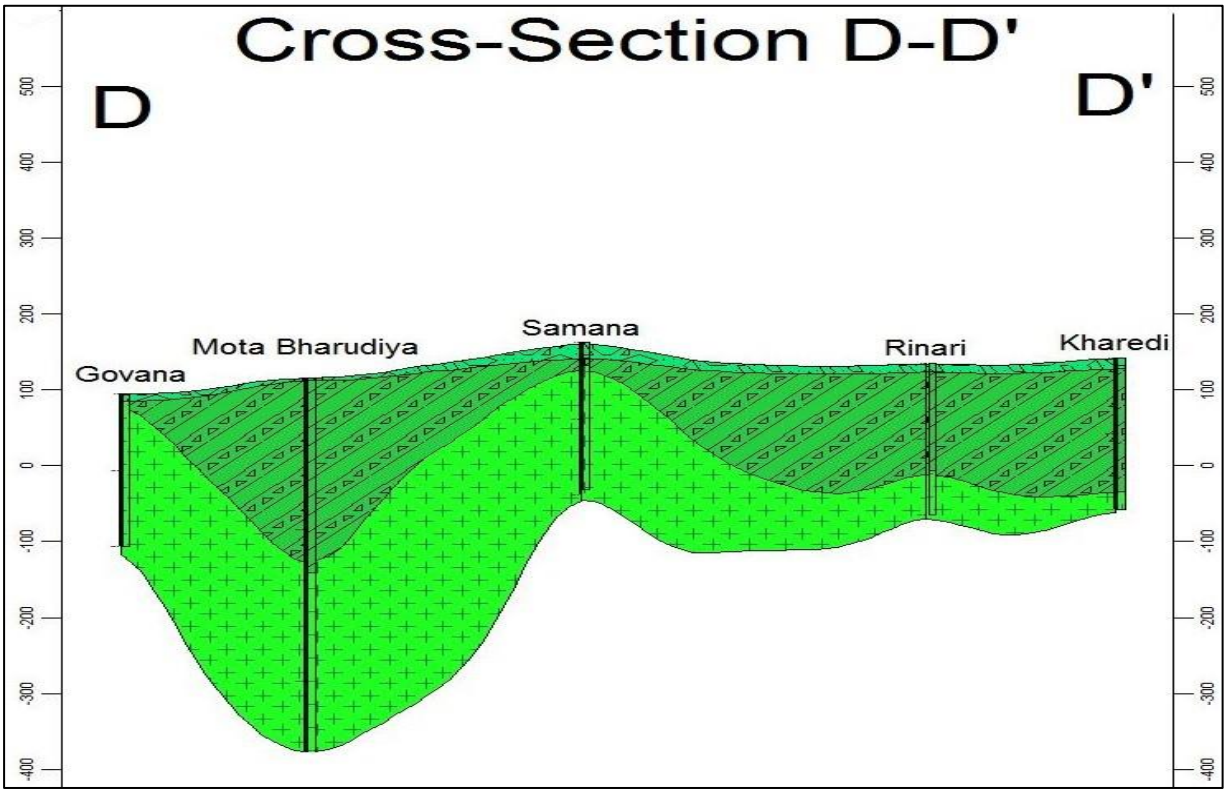

Figure 35 Cross section along D-D'

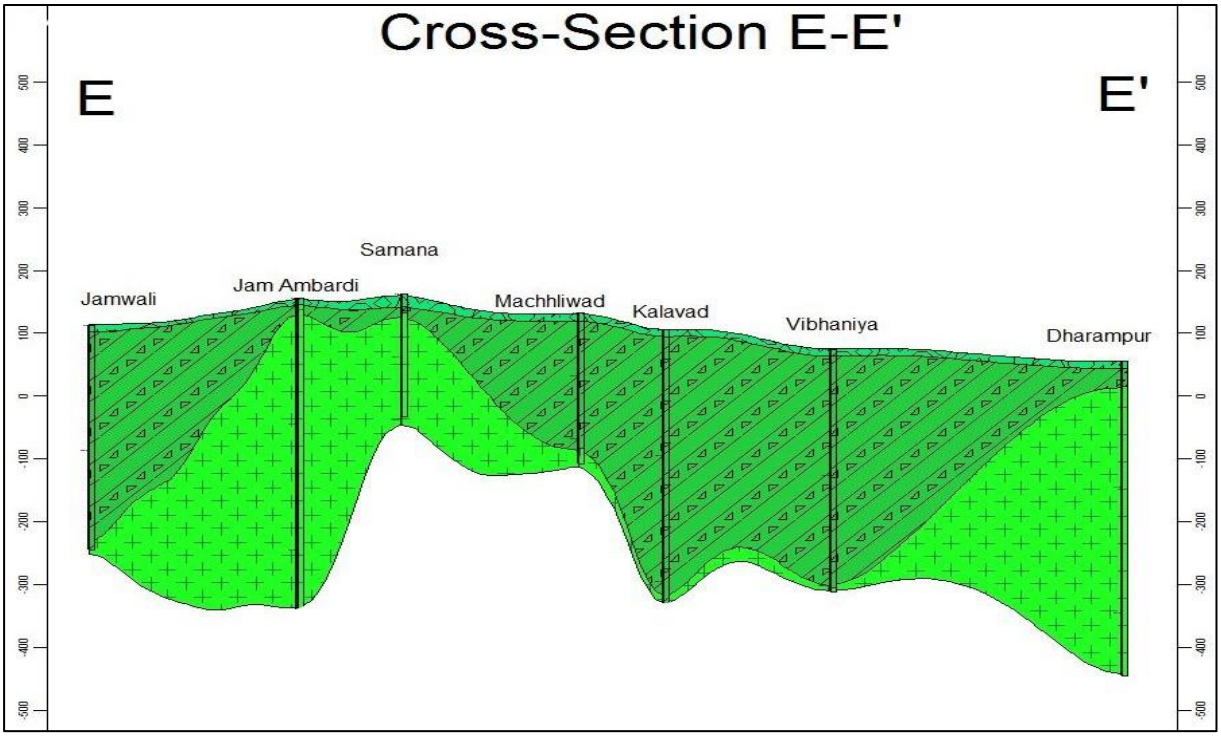

Figure 36 Cross section along E-E'

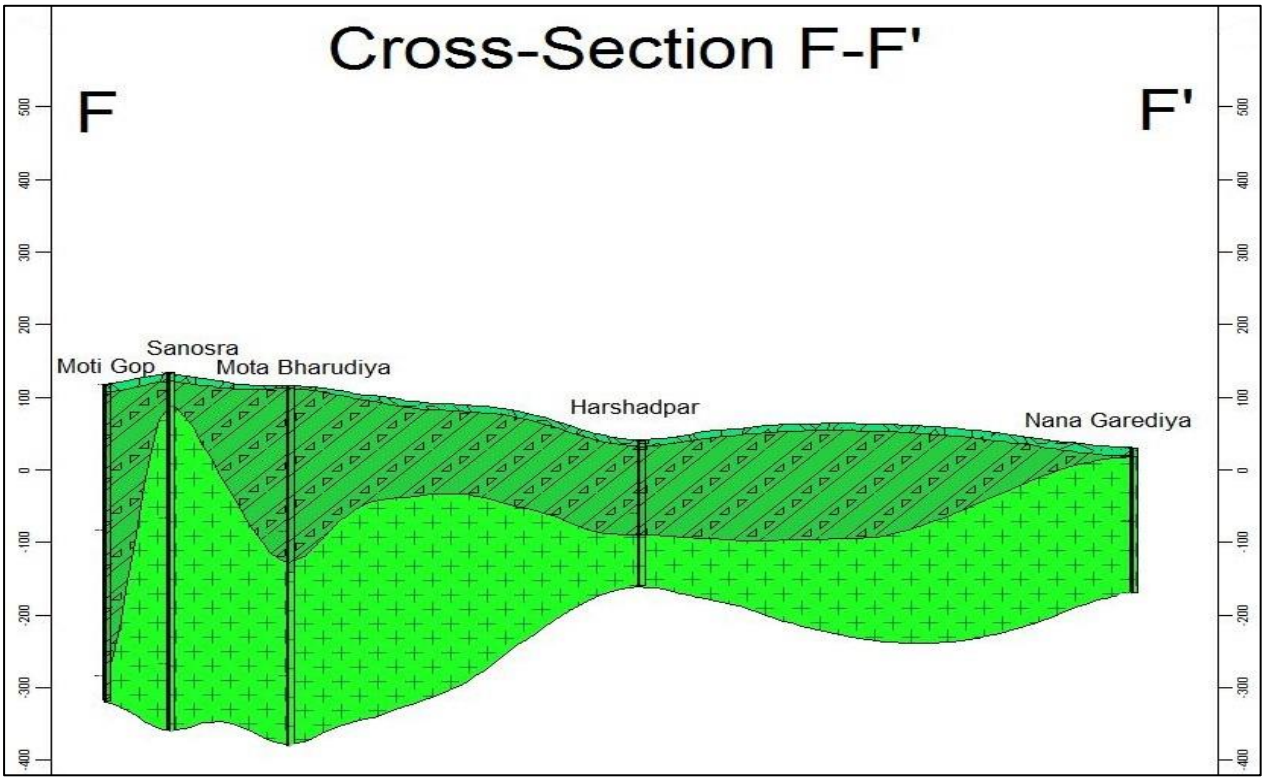

Figure 37 Cross section along F-F'

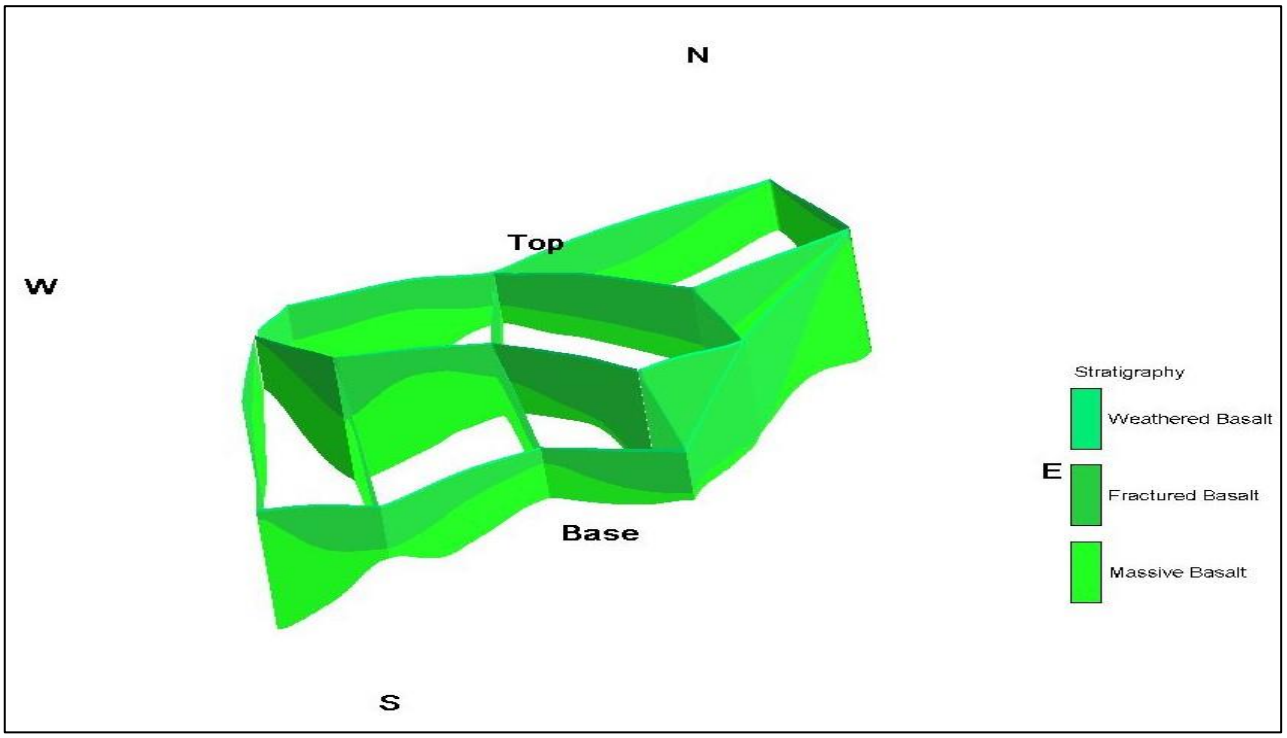

Figure 38 Fence Diagram with Stratigraphy Index of Jamnagar District

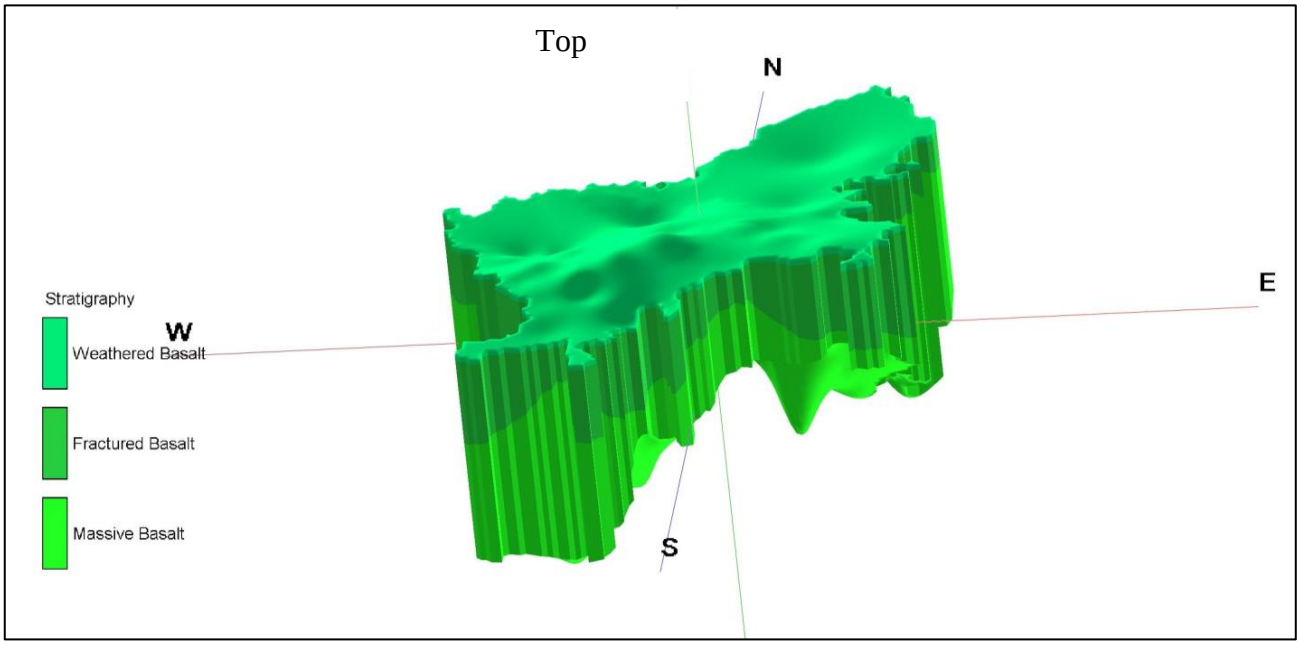

Figure 39 3D Solid Stratigraphic Model of Jamnagar District

4.3 Conceptualization Of Aquifer System In 2D

A total of 24 exploratory wells lithologs are utilized to decipher the subsurface geometry of the aquifer by using Rockworks 16 software prepared hydro geological cross sections, Fence diagram (Figure 38) and 3D Model (Figure 39) up to the depth of 500 mbgl. and six hydrogeological cross sections (2D) are drawn in different direction to cover entire area as per the availability of data point in the district and represented in figure 31(A-A'), 33 (B-B') to figure 37 (F-F').

4.3.1 Section A-A' (Figure 31)

Section is drawn roughly N-S direction from Mahiki to Nana Garediya, passing through Kadbad, Jam Ambardi, Samana, Ravesia and Bharatpur Section, represented Stratigraphically. It is deciphered that Hard rock formation (weathered &fractured forms the major aquifer system in the district and rested on massive rock along drawn section line.

4.3.2 Section B-B' (Figure 33

Section is drawn roughly W-E direction and in between Moti Rafudar and Kharedi passing through Gajana, Ravesia, Machhliwad and Rinari Section is represented Stratigraphicaly. From section it is deciphered that Hard rock formation (weathered &

fractured) forms the major aquifer system in the district and rested on massive rock along drawn section line.

4.3.3 Section C-C' (Figure 34)-

Section is drawn roughly S-N direction and in between Valasan and Harshadpur, passing through Samana and Ravesia, Section represented Stratigraphicaly. From section it is deciphered that that Hard rock formation (weathered & fractured) forms the major aquifer system in the district and rested on massive rock along drawn section line.

4.3.4 Section D-D' (Figure 35)

Section is drawn roughly W-E direction and in between Govana and Kharedi, passing through Mota Bharudiya, Samana and Rinari. Section is represented Stratigraphicaly, from section it is deciphered that that Hard rock formation (weathered & fractured) forms the major aquifer system in the district and rested on massive rock along drawn section line.

4.3.4 Section E-E' (Figure 36)

Section is drawn roughly NE-SW direction and in between Jamwali and Dharampur, passing through Jam Ambardi, Samana, Machhliwad, Kalawad and Vibhaniya. Section is represented Stratigraphicaly, from section it is deciphered that that Hard rock formation (weathered & fractured) forms the major aquifer system in the district and rested on massive rock along drawn section line.

4.4.4 Section F-F' (Figure 37)

Section is drawn roughly NE-SW direction in between Moti Gop and Nana Garediya, passing through Sanosra, Mota Bharudiya and Harshadpur. From section it is deciphered that that Hard rock formation (weathered & fractured) forms the major aquifer system in the district and rested on massive rock along drawn section line.

4.4 Aquifer Disposition And Its Hydraulic Characteristics

Unconfined aquifer lies from zero to 87 meter below ground level and water level ranges from 3.45 to 51.85 mbgl. Quality of water is potable to Saline with minimum and maximum EC values are 456 and 14380 micro-S/cm respectively.

Confined aquifer is also present in fractured basalt between 87 to 500 mbgl in few locations in deeper fractures. In this zone few deep fractures up to the depth of 438 meter below ground levels are reported. Water level is 10.10 to 10.20 mbgl. Water is fresh to saline but relatively less saline than unconfined aquifer water.

Table 11 Aquifer Characterization and Disposition for Jamnagar District

Aquifer Characteristics and Disposition									
Stratigraphy	**Aquifer Nomenclature**	**Lithology/ Aquifer material**	**Depth of occurrence of weathering/ fracture (meter)**	**Thickness (meter)**	**SWL (mbgl)**	**Quality (EC) microS/cm**	**Q(lps)**	**T (m^2/day)**	**Nature of porosity**
Upper Cretaceous-Lower Eocene	Unconfined (Weathered and Fractured Basalt)	Deccan Basalt	0-20 0-87	0-87 -	3.45-51.85 (Weathered and shallow fracture zone)	456-14380	0.3-6.80	0.05-102.63	Secondary (Weathered & fracture)
	Confined (Massive Basalt with very few deep Fractures)	Deccan Basalt	Explore up to the depth of 500 with deepest fractures up to 438 meters	-	10.10-10.20	1.46-6460			Secondary (Fractures, Joints, Shear and flow contacts)

Chapter 5

HYDROCHEMISTRY

5.1 Hydrochemistry

The results of chemical analysis of the ground water samples collected during AAP 2020-21 of key wells established and the ground water network monitoring in Jamnagar district is tabulated in the Table -13 below. EC>3000 □S/Cm has been observed at 7 stations of total 46 stations whereas NO3 > 50mg/l has been observed at 8 stations of total 46 stations. F is within permissible limit in entire district as per data.

The ground water in major part of the district is suitable for domestic, irrigation and industrial purposes. Groundwater in the district is in general potable and fresh, both in phreatic and confined aquifers.

The chemical quality of groundwater of the district has been analyzed based on the water samples collected during National Hydrographs Monitoring Stations (NHS) in Pre-monsoon 2019 form CGWB and Pre-monsoon NAQUIM Field work and Chemical data from Gujarat Water Resources Development Corporation (GWRDC) were also incorporated, and presented in **Table-12**

Table 12 Range of Different Chemical Constituents of Groundwater in Jamnagar District

CONSTITUENTS	UNIT	RANGE
pH	(□S/Cm) at 25°C	7.28-8.90
EC	(mg/l)	556-14380
Total Hardness	(mg/l)	120-4700
Total Dissolved Solids	(mg/l)	373-9635
HCO3 -	(mg/l)	98-964
Cl -	(mg/l)	36-4622
SO4 - -	(mg/l)	50-350
NO3 -	(mg/l)	0-197
Ca ++	(mg/l)	35-80

Mg ++	(mg/l)	18-45
Na +	(mg/l)	157-1451
K +	(mg/l)	0.30-28.60
F -	(mg/l)	0.03-1.34

5.2 Hydrogen Ion Concentration (Ph)

The pH is an indicator of acidity of the water. The shallow ground water in the district is generally alkaline with pH more than 7. The value of pH ranges between 7.28 (Haripar) & 8.90 (Beraja) in the district.

5.3 Iso Conductivity Map

As per the BIS standards [IS 10500: 2012] for drinking water, acceptable limit and permissible limit of Total Dissolve Solid (TDS) are 500 mg/l and 2000 mg/l respectively.

The Electrical conductance of ground water is generally ranges from 556-14380 micromhos/cm at 25°c, for the entire district.

Iso conductivity Map of the district shown below in Fig.40, EC in the district is mostly lie within Permissible limit except some small patches (of 7 location) in Jam jodhpur, Jamnagar, Jodiya and Dhrol taluka where show EC value more than Permissible limit.

5.4 Total Dissolved Solid (TDS)

Total Dissolved Solid is an overall parameter indicating salinity of ground water. The Total Dissolved Solid of ground water varies from 773 (Vijarkhi) to 9635 mg/l (Hadiyana).

5.5 Carbonate (CO3) And Bicarbonate (HCO3)

The shallow ground water in Jamnagar district does not contain any Carbonate. The Bicarbonate concentration in district is varies in between 98 mg/l (Mota Vadiya) to 964 mg/l (Fatsar).

5.6 Chloride (Cl)

As per the BIS standards [IS 10500: 2012] for drinking water, Acceptable limit and Permissible limit of Chloride (mg/l) are 250 mg/l and 1000 mg/l respectively. Small patches in Jodiya, Jamnagar and Jamjodhpur taluka shows Cl concentration is more than permissible limit (Figure 41).

5.7 Nitrate (NO_3)

As per the BIS standards [IS 10500: 2012] for drinking water, acceptable limit is 45 mg/l (maximum) and there is no relaxation in permissible limit.

Nitrate concentration in the ground water in district varies from 0-196.80 mg/l, out of 46 samples 7 samples shows Nitrate above 45 mg/l. Minimum Value found in Mota Vadiya (Jamjodhpur) and Max Value in Bed (Jamnagar). (Figure 42).

5.8 Sulphate (SO_4)

In the district, Sulphate concentration varies from 50 mg/l to 350 mg/l. Dhrol taluka has maximum concentration of sulphate in groundwater in entire district.

5.9 Fluoride (F)

As per the BIS standards [IS 10500: 2012] for drinking water, Acceptable limit and Permissible limit of Fluoride (mg/l) are 1 mg/l and 1.5 mg/l respectively. Fluoride concentration in Jamnagar district ranges from 0 to 1.5 mg/l. Out of 46 samples 14 samples show F under 0.5 mg/l, 27 shows F values from 0.5-1.0 mg/l, and 5 samples represents F values 1-1.5 mg/l. Minimum value reported in Changa (Jamnagar) and Max in Haripar (Kalavad). (Figure 43)

5.10 Calcium (Ca)

Calcium concentration in district varies between 35 mg/l and 80 mg/l. The concentration of calcium is found within permissible limits in the entire district (permissible limit as per BIS norms is 200 mg/l).

5.11 Magnesium (Mg)

The Concentration of Magnesium in areas ranges from 18 mg/l (Salemba) to 45 mg/l. The concentration of magnesium is found within permissible limits in the entire district (Permissible limits of Magnesium of 100 mg/l -as per BIS norms).

5.12 Sodium (Na)

Sodium concentration in the district varies between 157mg/l (Pipar) and 1451 mg/l (Vasai).

5.13 Potassium (K)

The concentration of Potassium in shallow ground water ranges from 0.30 mg/l (Dangra) to 28.60 mg/l(Balambha).

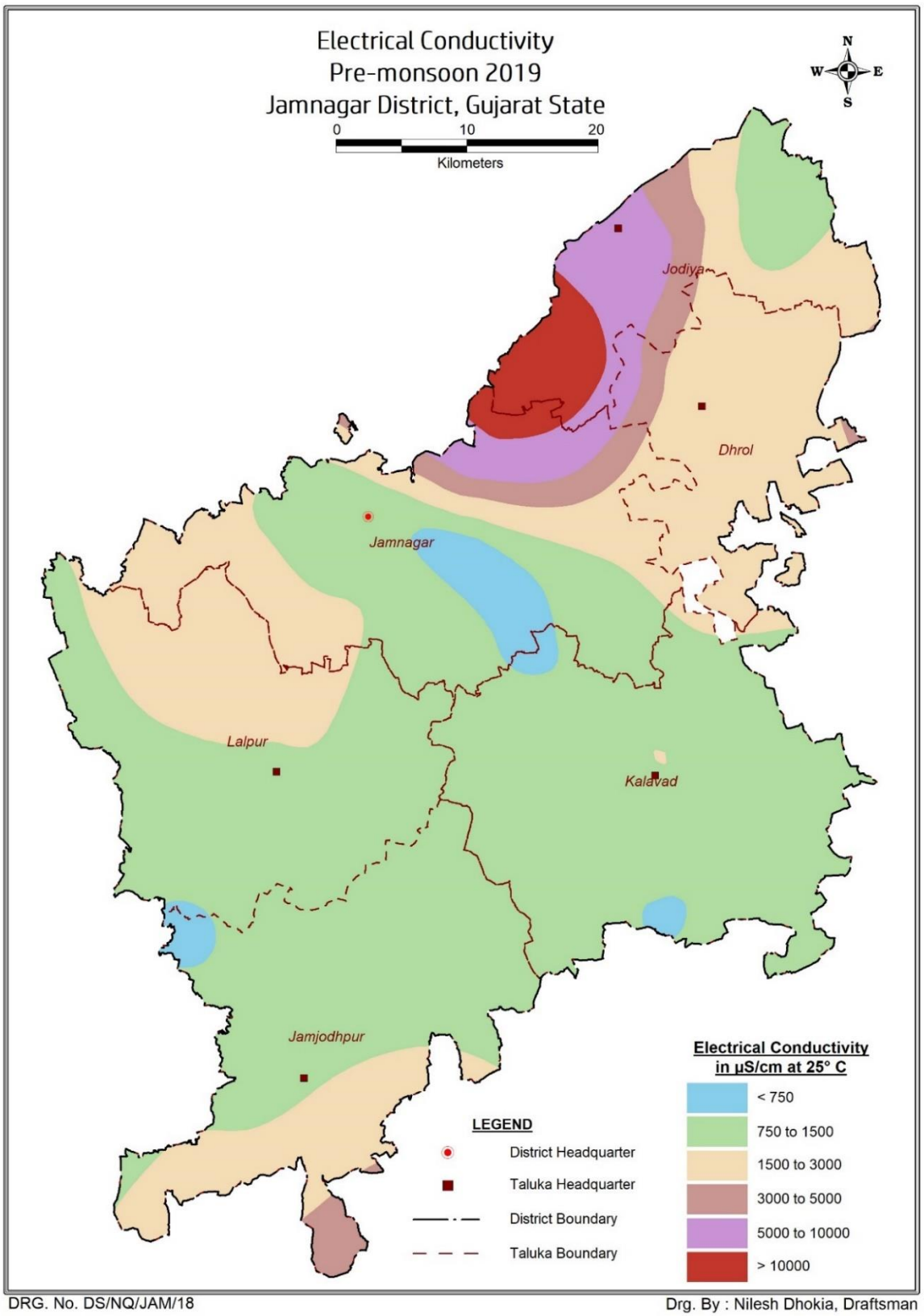

Figure 40 EC Map of Jamnagar District

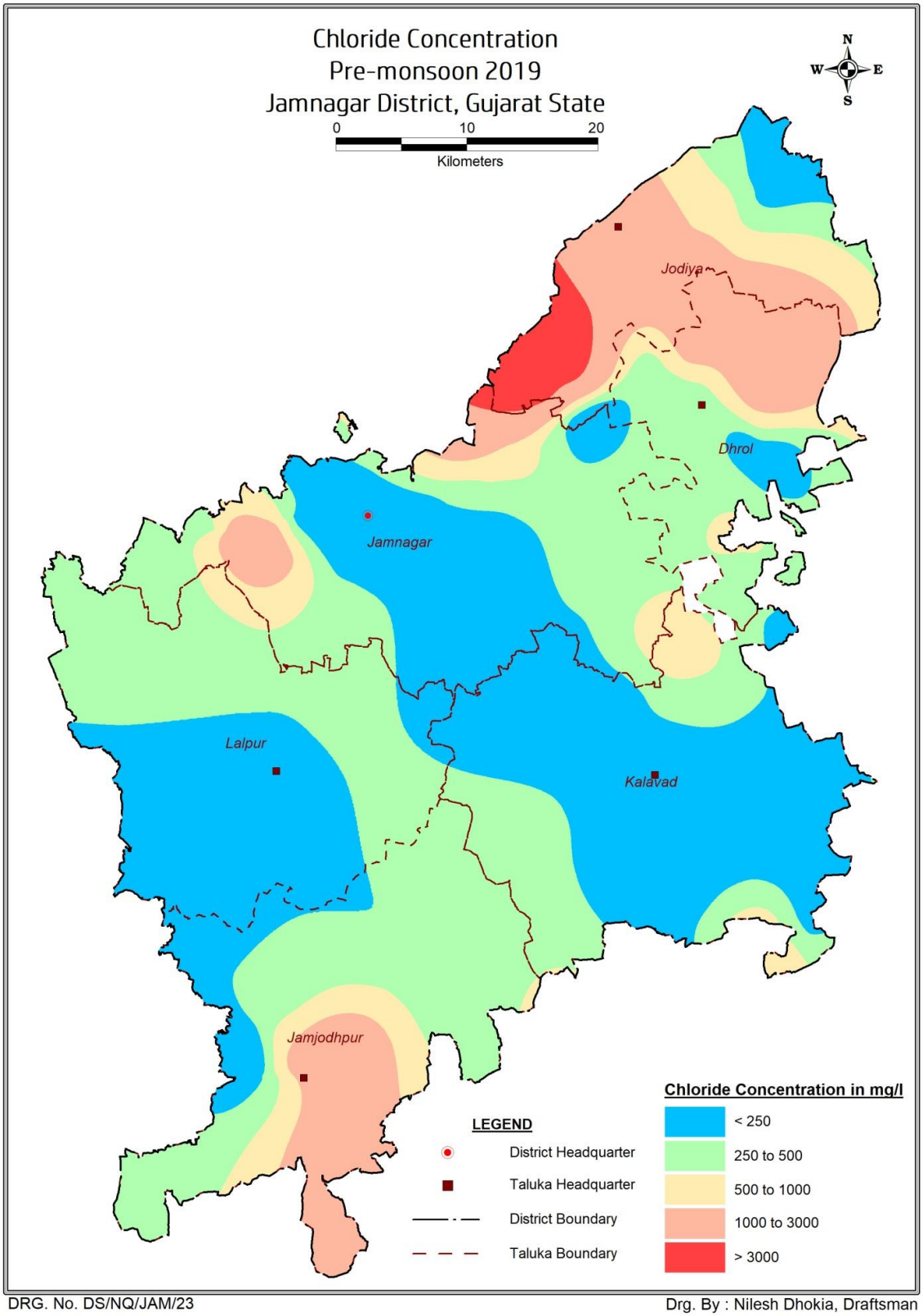

Figure 41 Chloride Concentration Map of Jamnagar

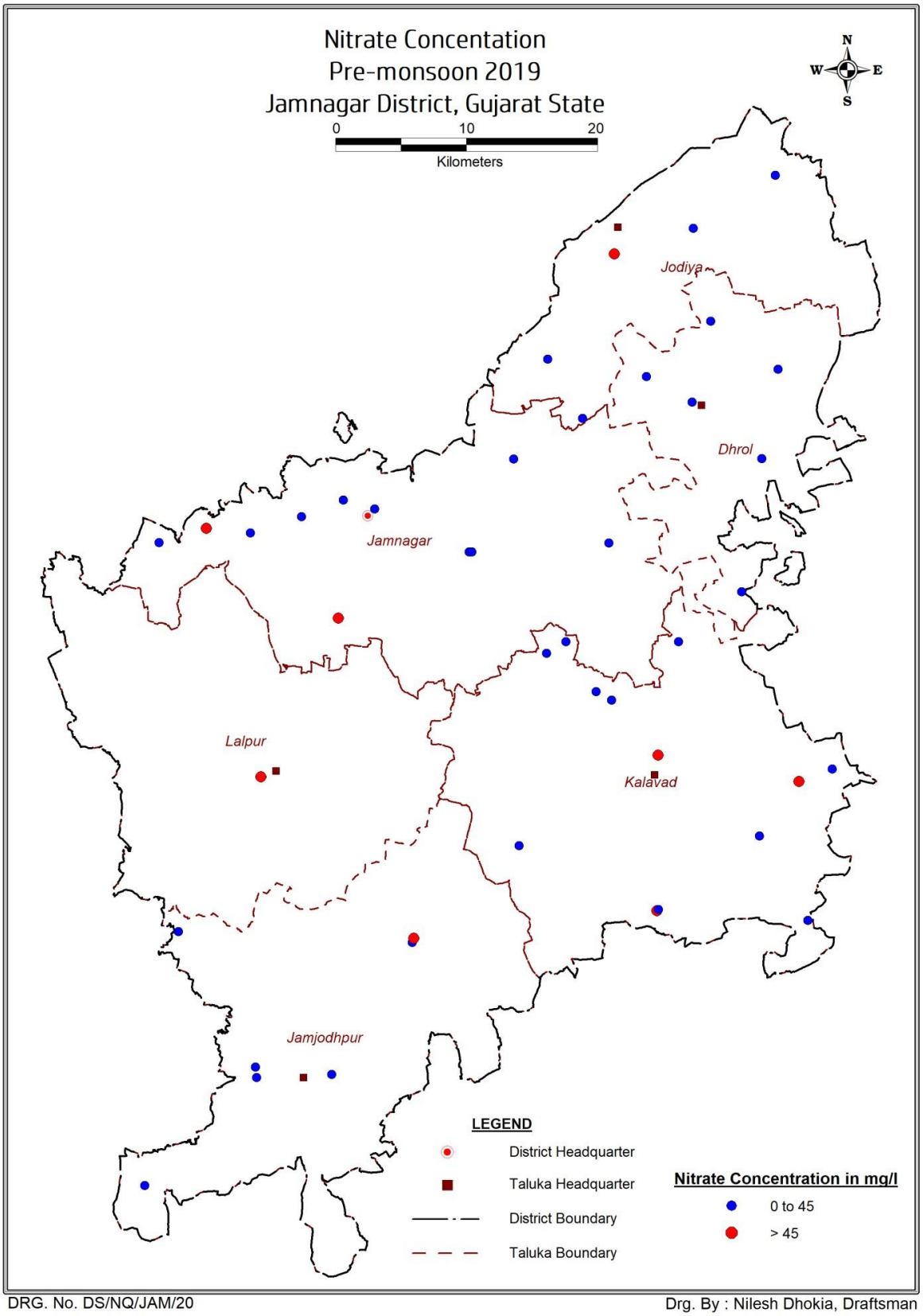

Figure 42 Nitrate Concentration map of Jamnagar

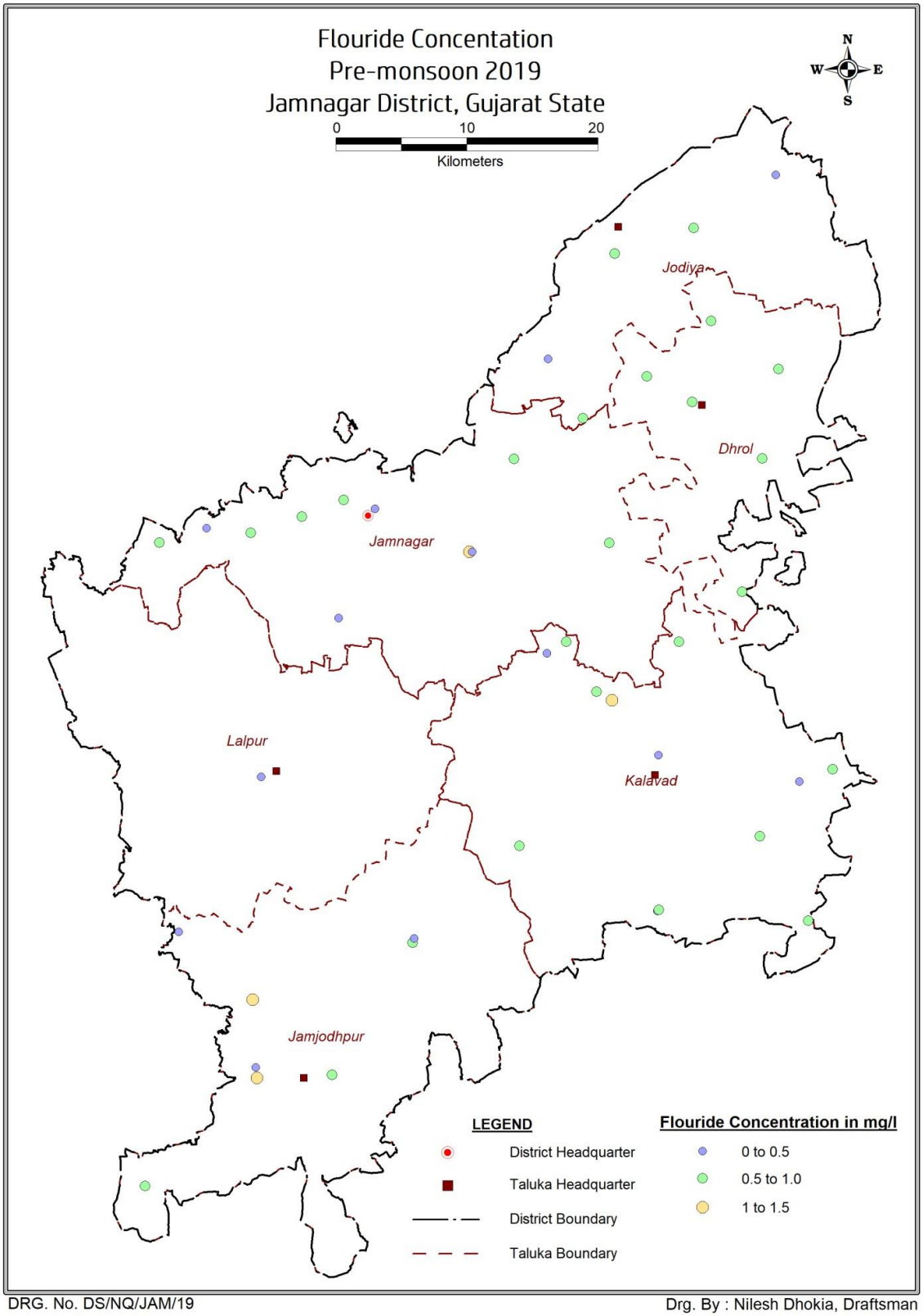

Figure 43 Fluoride Concentration map of Jamnagar

Chapter 6
GROUND WATER RESOURCE POTENTIAL

6.1 Ground Water Resources

The ground water resources of the district were calculated as on March 2017 in collaboration with the Government of Gujarat using the GEC-2015 methodology suggested by Ground Water Resource Estimation Committee (GWRE-2017). These resources were computed after reorganization of the districts, talukas of the district are considered as Assessment Units (AU) and total area of 6020 sq km are taken as area of assessment of the district including 06 talukas. It may be observed from the Table no 13 that all the assessment units (Talukas) fall under safe category and the stage of ground water development of the district is 63.27%.

As per GWRE 2017 the total dynamic ground water resources of the district was in the order of 792.85 MCM/year and utilizable resources are 753.20 mcm/year. The net annual draft of 476.57 MCM/year leaves a balance of 39.65 MCM/year of ground water available for future development. The stage of ground water extraction all over the district is moderate (63.27%).

Computed Taluka wise Ground Water resources, Availability, Utilization and Stage of Ground Water Development for Jamnagar District as per GWRE 2017 are presented in tabulated form below in Table No 13.

Table 13- Taluka wise Ground Water resources, Availability, Utilization and Stage of Ground Water Development.

Taluka Wise Ground Water Resources, Availability, Utilization and Stage of Ground Water Development (2017)															
District: Jamnagar															
Sr. No.	Taluka	ANNUAL REPLENISHABLE GROUND WATER RESOURCE (mcm)					Natural Discharge during non-monsoon season (mcm) (5 % of 7)	Net Annual Ground Water Availability (mcm) (7- 8)	ANNUAL GROUND WATER DRAFT (mcm)			Projected Demand for Domestic and Industrial uses upto 2025 (mcm)	Ground Water Availability for future irrigation (mcm) {(9)-(10+13)}	Stage of Ground Water Development (%) (12/9) * 100	Category
		Monsoon		Non-Monsoon		Total Annual Ground Water Recharge (3+4+5+6)			Irrigation	Domestic And Industrial uses	Total (10 + 11)				
		Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Dhrol	69.02	12.74	0.00	4.74	86.50	4.32	82.17	47.02	1.30	48.32	1.44	33.71	58.80	Safe
2	Jodiya	30.52	19.99	0.00	4.38	54.89	2.74	52.14	32.08	1.01	33.09	1.56	18.51	63.45	Safe
3	Jamnagar	149.87	17.39	0.00	5.05	172.32	8.62	163.70	98.59	11.01	109.60	15.51	49.60	66.95	Safe
4	Kalavad	199.71	20.45	0.00	3.92	224.08	11.20	212.87	127.82	2.29	130.11	2.54	82.51	61.12	Safe
5	Jamjodhpur	120.11	20.00	0.00	4.46	144.57	7.23	137.34	83.83	2.17	86.00	2.41	51.10	62.62	Safe

6	Lalpur	87.16	13.04	0.00	10.30	110.50	5.53	104.98	67.53	1.93	69.47	2.15	35.30	66.17	Safe
District Total		**656.39**	**103.61**	**0.00**	**32.85**	**792.85**	**39.64**	**753.20**	**456.87**	**19.70**	**476.57**	**25.61**	**270.73**	**63.27**	**Safe**

6.2 Ground Water Recharge

Total Annual Ground Water Recharge from Rainfall and other sources for both monsoon and non-monsoon season for the district is 792.85 mcm. And ground water recharge in talukas varies from 54.89 mcm (Jodiya) to 224.08 mcm (Kalavad).

6.3 Net Ground Water Availability

Annual Extractable Ground Water Resource/ Net Ground Water Availability of the district is 753.20 mcm which computed after deducting total natural discharge of 39.64 mcm from total annual ground water recharge.

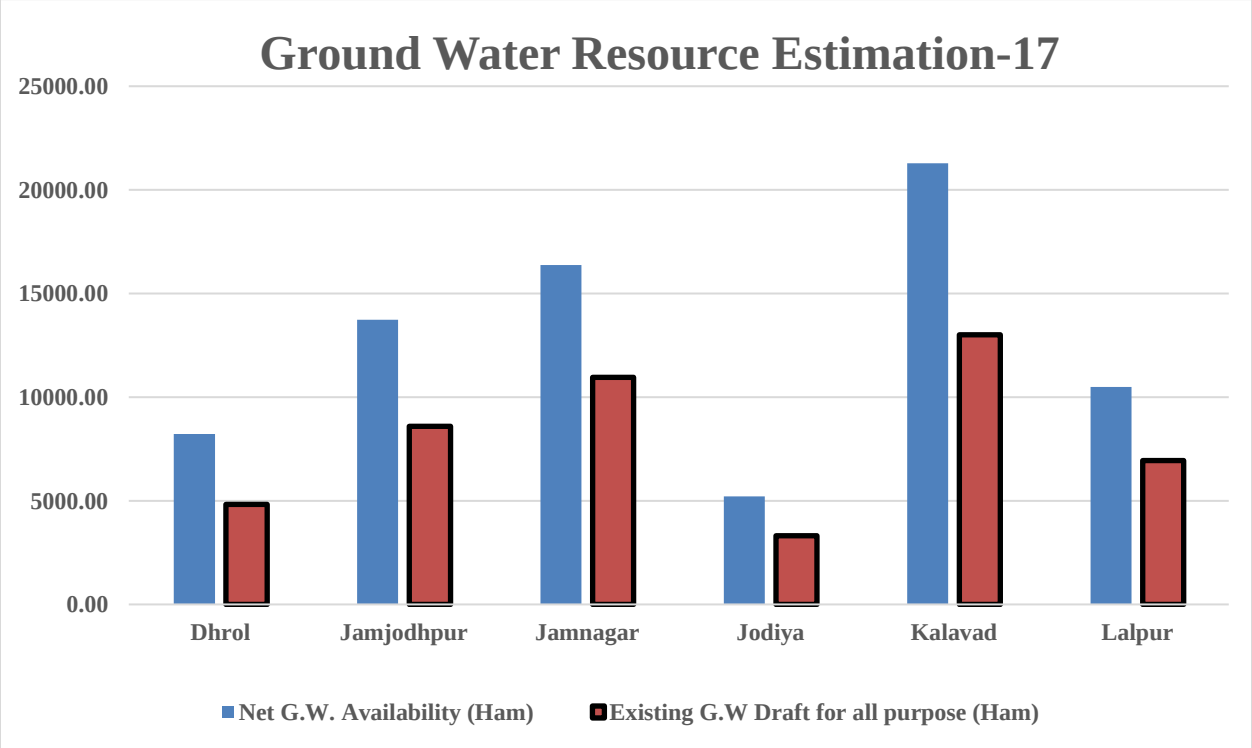

Figure 44 Taluka wise Net GW Availability vs Existing GW Draft (Ham) for all purposes

6.4 Annual Ground Water Draft

The gross ground water draft for all uses (i.e., Irrigation, Domestic and Industrial uses) in the district is 476.57 mcm. The existing gross ground water extraction for all uses varies from 33.09 mcm (Jodiya taluka) to 130.11 mcm (Kalavad Taluka). Approximately 96 % of ground water extraction is used for Irrigational purposes; remaining 4% are being extracted mainly for Domestic and Industrial purposes (very less).

6.5 Projected Demand For Domestic And Industrial Use Upto 2025

The total projected demand of ground water for Domestic and Industrial uses in the district is 25.61 mcm. Projected demand for domestic uses varies from 1.44 mcm (Dhrol taluka) to 15.51 mcm (Jamnagar taluka).

6.6 Ground Water Availability For Future Irrigation

Net ground water availability for future use in the district is 270.73 mcm. Taluka wise it varies from 18.51 mcm (Jodiya taluka) to 82.51mcm (Kalavad taluka).

6.7 Stage Of Ground Water Extraction

As per the Ground Water Resource Estimation (GWRE-2017), the stage of Ground Water extraction of the district is 63.27% which categorized as Safe. Whereas in taluka it varies from 58.80 % (Dhrol Taluka) to 66.95 % (Jamnagar Taluka) and all the 06 talukas of the district are categorized as SAFE.

Chapter 7

GROUNDWATER RELATED ISSUES

7.1 Major Issues

I. Overall dependency of agriculture on groundwater (more than 90%).
II. Saline water in many parts of district.
III. Salinity in ground water both inherent and coastal salinity.
IV. Ground water contamination due to improper/unscientific well construction.
V. People need to be aware of the aquifer system existing in the area.
VI. Awareness among local people regarding water conservation measures required.

7.2 Salinity

Both inherent and coastal salinity is reported in the district. Coastal salinity is a major issue for coastal areas of the district. Due to saline nature of groundwater in coastal areas people are dependent on surface water for their survival.

7.3 Sustainability

Most part of the district has secondary porosity in the form of weathered & fractured rock which forms the good repository or major aquifer of groundwater. Yield in these formation are very low. The yield from bore wells have reduced in a lean period, recoupment time in some phreatic aquifer is very low that's the reason people residing there constructed large daimeter of well for maximum storage.

7.4 Reasons For Issues

Absence of primary porosity and very low development of secondary porosity, de-saturation of weathered zone and permeability and low groundwater extraction.

Chapter 8
SUSTAINABLE GROUNDWATER DEVELOPMENT AND PARTICIPATORY GROUND WATER MANAGEMENT

8.1 Introduction

Objectives of Participatory Ground Water Management (PGWM) are capacity building of farmers and ground water users for efficient monitoring of ground water regime, capacity building of groundwater using farmers for increasing water use efficiency and efficient management of groundwater and informed decision making on cropping pattern and application of water at a collective level so as to benefit all groundwater user farmers.

The outputs that are expected to accrue from PGWM are as follows-

I. Enhanced capacity of the farmers in utilizing groundwater efficiently Increased groundwater use efficiency in irrigation.
II. Sustainable exploitation and stabilization of the groundwater by adopting a suitable cropping pattern.

8.2 Management Plan

The uneven distribution of groundwater availability and its utilization indicates that a single management strategy cannot be adopted and requires integrated hydrogeological aspects along with socio-economic conditions to develop appropriate management strategy. The study suggests notable measures for sustainable groundwater management, which involves a combination of various measures given below.

I. Supply side measures
II. Demand side measures
III. Regulatory measures
IV. Institutional measures

8.2.1 Supply Side Measures

8.2.1.1 Artificial Recharge to ground water and Water conservation plan

As per Master plan 2020 for Artificial Recharge to Ground Water in Gujarat state, 10 MCM of surplus surface water is provisioned for artificial recharge through 333 no of recharge shafts as injection wells in Jamnagar district.

8.2.1.2 Identification of recharge area

There are two major water hydrogeological units bearing geological formations occurring in the district have been categorized broadly in two hydrogeological units, namely, Weathered& Fractured Basalt of Deccan traps. The thickness of available unsaturated zone (below 6 m bgl) is computed on basis of Post monsoon (2010-19) decadal average depth to water level map and Similarly, Post monsoon (2010-19) decadal water level trend map of Jamnagar District is presented as per Master plan 2020 for Artificial Recharge to Ground Water in Gujarat state. On this basis, area suitable for artificial recharge in Jamnagar District is identified taking into consideration of following four categories, and presented as figure 45.

- Area showing declining trend > 0.10 m/year and water level between 6-9 m bgl.
- Area showing declining trend 0 to 0.10 m/year and water level between 6 -9 m bgl.
- Area showing declining trend > 0.10 m/year and water level between > 9 m bgl.

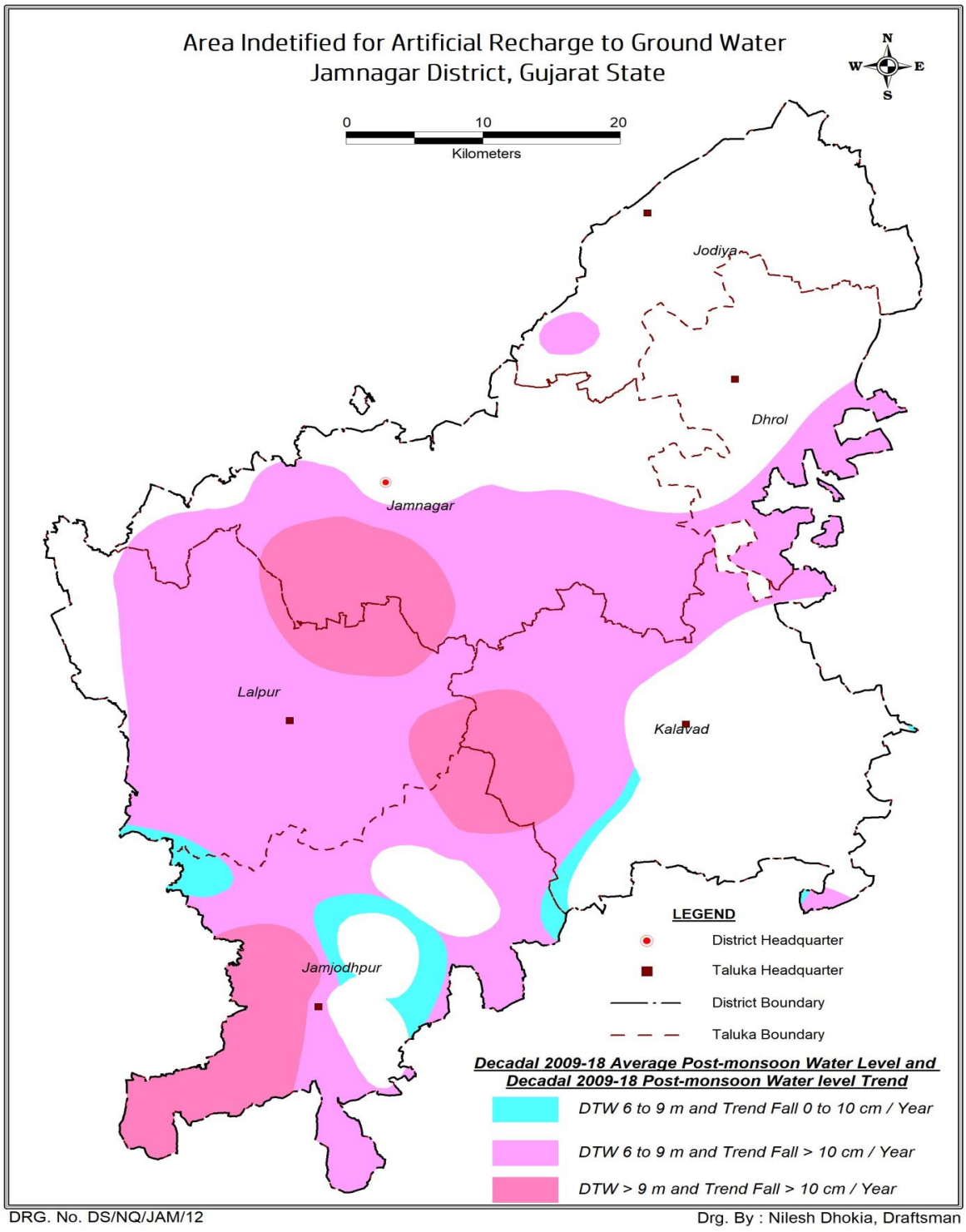

Figure 45 Feasible area identified for artificial recharge in Jamnagar District

Many isolated patches for entire district are identified for artificial recharge. Ground water recharge of 1793.90 hams (through recharge shafts) is expected for the district as show in Table 14.

Table 14 Proposed Artificial Recharge and WUE Interventions in Jamnagar District

Proposed Artificial Recharge and WUE Interventions in Jamnagar District						
Block	**Recharge Shaft Numbers**	**Recharge through Recharge Shaft @3Ham**	**On farm activities (proposed in 20% of total catchment area) (in ha)**	**Conservation through On farm activities (proposed in 15% of total catchment area) (in ha)**	**Water Use Efficiency Measures, (Sprinkler/ Drp irrigation) in Ham**	**Conservation through Water Use Efficiency Measures, (Sprinkler/ Drp irrigation) in Ham**
Dhrol	37	163.20	522	26.1	2285	342.75
Jamjodhpur	63	561.60	3726	186.3	0	0
Jamnagar	67	201.00	0	0	6414	962.1
Jodiya	33	99.00	0	0	2787	418.05
Kalavad	72	361.00	1420	71	5829	874.35
Lalpur	61	408.10	2251	112.55	1223	183.45
District Total	333	1793.90	7919	395.95	18538	2780.7

8.2.1.3 Recharge shaft

This is the most efficient and cost-effective technique to recharge unconfined aquifer overlain by poorly permeable strata. Recharge shaft may be dug manually if the strata are of non-caving nature. The diameter of shaft is normally more than 2 m. The shaft should end in more permeable strata below the top impermeable strata. It may not touch water table. The unlined shaft should be

backfilled, initially with boulders/ cobbles followed by gravel and coarse sand. In case of lined shaft, the recharge water may be fed through a smaller conductor pipe reaching up to the filter pack. These recharge structures are very useful for village ponds where shallow clay layer impedes the infiltration of water to the aquifer.

It is seen that in rainy season village tanks are fully filled up but water from these tanks does not percolate down due to siltation and tube well and dug wells located nearby remains dried up. The water from village tanks gets evaporated and is not available for the beneficial use. By constructing recharge shaft in tanks, surplus water can be recharged to ground water. Recharge shafts of 0.5 to 3 m. diameter and 10 to 15 m. deep are constructed depending upon availability of quantum of water. The top of shaft is kept above the tank bed level preferably at half of full supply level. These are back filled with boulders, gravels and coarse sand. In upper portion of 1 or 2 m depth, the brick masonry work is carried out for the stability of the structure.

Through this technique all the accumulated water in village tank above 50% full supply level would be recharged to ground water. Sufficient water will continue to remain in tank for domestic use after recharge.

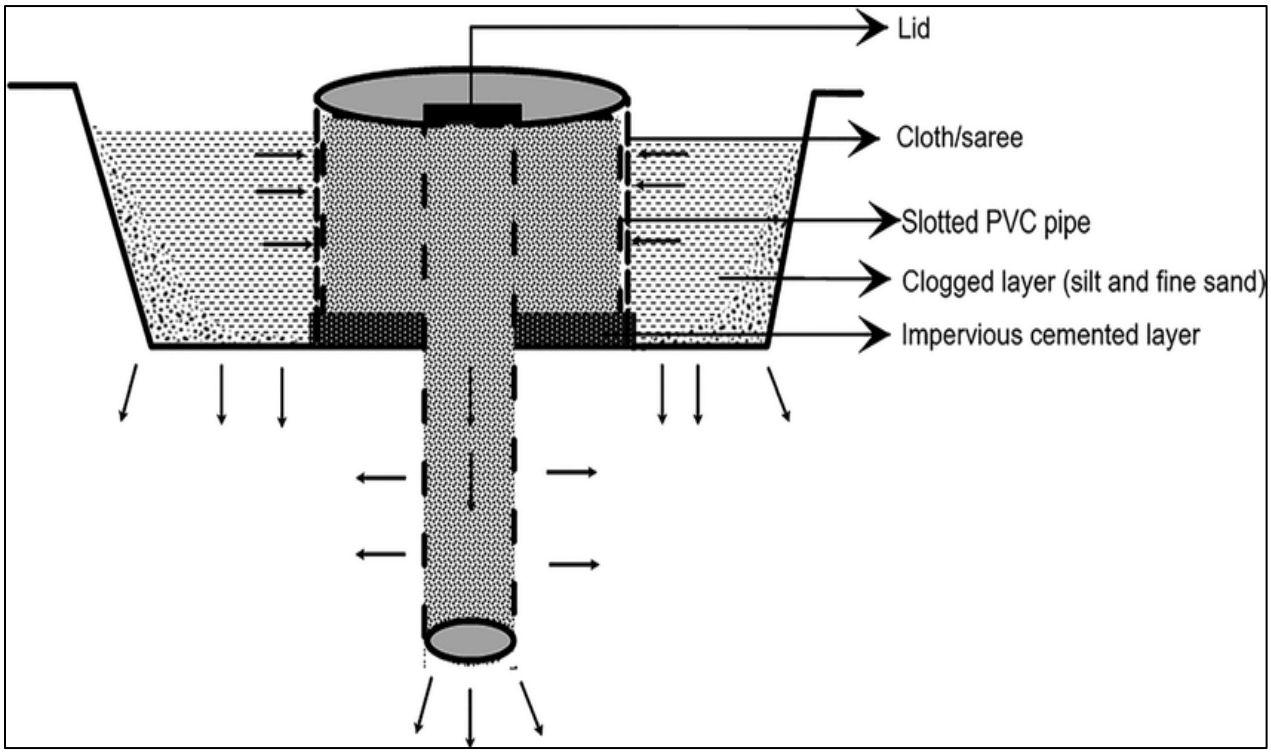

Figure 46 Schematic diagram of Recharge Shaft.

8.2.1.4 Advantages of Recharge Shaft

It does not require acquisition of large piece of land as in case of percolation tanks. There are practically no losses of water in the form of soil moisture and evaporation, which normally occur when the source water has to traverse the vadose zone.

8.2.2 Ground water Development Plan

As per GWRE 2017 Ground water stage of development for the district is 63.19%. which ranges from 58.80% (Dhrol) to 66.95% (Jamnagar). No Development plan is proposed because of hard rock nature of area and its upper limits of safe groundwater development stage (Near to Semi Critical).

8.2.2 Demand Side Measures

Total 7919 hac area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 18538 hac area is proposed for Sprinkler/ drip/ HDPE pipes irrigation. Expected conservation from On-farm Activities, and WUE Measures (Sprinkler/Drip etc) is 3177 ham (Table No. 15).

Table 15 Summary of Interventions and Expected Benefits for Jamnagar District

Summary of Interventions and Expected Benefits	
Interventions Recommended	
Recharge Shaft	333 Nos.
On-farm activities	7919 hac
WUE (Sprinkler/Drip/HDPE Pipes for selected area)	18538 hac
Expected Benefits	
Expected Annual Recharge	1794 ham
Conservation from On-farm Activities, and WUE Measures	3177 ham
Total Recharge/ Saving	**4971 ham**

8.2.3 Regulatory Measures

Unlike several countries, India does not have any separate and exclusive water law dealing with all water resources and covering all aspects. Instead, the water related legal provisions are dispersed across various irrigation acts, central and state laws, orders/decrees of the courts, customary laws and various penal and criminal procedure codes. As a result, understanding of the exact legal position with respect to ground water becomes rather cumbersome. Moreover, India does not have any explicit legal framework specifying water rights.

The Supreme Court of India has, however, reinterpreted Article 21 of the Constitution of India to include the right to water as a fundamental right to life. The Easement Act of 1882 made all rivers and lakes the absolute right of the state. But as per the provisions of the Easement Act 1882 as usually understood and the Transfer of the Property Act of 1882, a land owner is supposed to have a right to ground water beneath his land as it is considered as an easement of the land. So, the land owners own the ground water on their lands. Ground water was considered an easement connected to land: he/she who owns the land: owns the ground water beneath the land. Ownership of ground water, therefore, accrues to the owner of the land above. Ownership of ground water is transferred along with the transfer of ownership of land. Thus, ground water is viewed as an appendage to land. This absolute ownership concept has allowed unlimited withdrawals of ground water beneath the land by the owners. There is no limitation on how much ground water a particular land owner may draw. As a result, a person is free to draw water more than his/her personal requirement and sell the same in the market. Moreover, the landless have no right on ground water. Similarly, the tribals who have no ownership right over land have no right on ground water.

The legal aspects governing ground water resources have continued to remain the same despite substantial changes in ground water scenario that have taken place since then. Rapid expansion in the exploitation of ground water resources in India for irrigation and other uses has led to an over-exploitation of ground water in several parts of the country. As a result, the above law is no longer in harmony with resource sustainability and economic requirement. 26 It may, however, be mentioned that the Directive Principles of State Policy [Article 39 (b)] of the Indian Constitution has made it incumbent on the state to ensure that the ownership and control of the material resources of the community are so distributed as to sub serve the common good in the best possible manner. Moreover, as already pointed out, since the Constitution does not have an entry relating to

'Environment', using the residual powers, the Union has enacted laws on environment and control of pollution, which have effects on water use, including ground water and its exploitation. Moreover, a correct understanding of the Easement Act 1882 implies that it does not give unlimited power to the land owner to exploit ground water regardless of the adverse effects on other users. We examine this aspect in the following section.

The Water (Prevention and Control of Pollution) Act, 1974 was passed by the Parliament in 1974 for prevention of pollution of water due to discharge of liquid effluents from industries. Subsequently, another Act Namely Water (Prevention and Control of Pollution) Cess Act 1977 was enacted for enabling the effective implementation of the earlier Act. All the states adopted the Act by 1990 and State Pollution Control Boards of the respective, states were inter alia set up under the Act. Central and state Pollution Control Boards adopted the 28 environmental norms for water discharge from different types of sources. This Act contains specific provision for prohibiting the use of stream or well for disposal of polluting matter, prescribing restrictions on new outlets and new discharges, laying down rules regarding existing discharge of sewerage or trade effluents, emergency measures in case of pollution of stream or well and power of the Board to make application to courts for restraining apprehended pollution of water in streams or wells. The said Act also incorporates provisions for creating Central and State Pollution Control Boards and prescribing powers and functions of these Boards to take various steps and measures for regulating the prohibition, prevention and control of water pollution. Some states have also enacted separate water pollution Acts, e.g., Orissa River Pollution Prevention Act, 1953 and Maharashtra Prevention of Water Pollution Act, 1969. The Water (Prevention and Control of Pollution) Act, 1974, as amended in 1978, makes even the companies and the Heads of the Government Departments punishable under the said Act, if the offences under that Act are found to have been committed by a company1 or a Government Department, 2 as the case may be. Under the Water (Prevention and Control of Pollution) Act 1974 as amended in 1978, if the State Government, after consultation with, or on the recommendation of the State Boards, is of the opinion that the provisions of this Act need not apply to the entire State, it may, by notification in the Official Gazette restrict the application of this Act to such area or areas as may be declared therein the water-pollution-prevention and control area or areas and thereupon the provisions of this Act shall apply only to such area or areas.

The Environment (Protection) Act (EPA), 1986 was passed by the Union Parliament in 1986 and was notified by the Union Ministry of Environment and Forests. This Act covers different areas of "environment" including water as well as items interrelated to water.

8.2.4 Institutional Measures

Central Ground Water Authority was set up on 14th January, 1997 by the Ministry of Environment and Forests, Government of India in pursuance of an order of the Hon'ble Supreme Court of India dated 10th December, 1996 on a PIL. Authority has been established under sub-section (3) of Section 3 of the Environment (Protection) Act, 1986. Currently Central Ground Water Authority is run by Ministry of Jal Shakti Government of India. The Authority has been empowered to exercise the powers and perform the following functions: - (i) Exercise powers under Section 5 of the Environment (Protection) Act, 1986. The Authority can issue directions in writing to any person, officer or any Authority and such persons, officer or Authority shall be bound to comply with such directions. For example – The Authority has power to direct the closure, prohibition or regulation of any industry or process and also the stoppage or regulation of the supply of electricity or water or any other service. (ii) To resort to the penal provisions contained in Section 15 to 21 of the Environment (Protection) Act, 1986. In Sections from 15 to 21 of the Act, it has been summarized that penalty should be levied in avoidance of the rules, orders and directions of the Act. Also, if this offence is done by companies or Government Departments, every person, who at the time the offence was committed, was responsible and also the company or Govt. Department should be punished accordingly. Also, the Central Govt. may ask from time to time, to the concerned officer, State Government or the authority to furnish the required information, report etc. All the members, officers and employees of such authority working under this Act shall be deemed to be public servants. (iii) To regulate indiscriminate boring and withdrawal of ground water in the country and to issue necessary directions with a view to preserve and protect the ground water.

Areas of Activities of CGWA to achieve the mandate, the Authority have divided its functions into following mentioned four sub-heads. These are detailed as follows.

(a) Regulation of ground water:

(i) Extraction of ground water development
(ii) Construction of wells
(iii) Registration of ground water abstraction structures
(iv) Performance of business of drilling wells

(v) Sale of ground water

(b) Conservation of ground Water Conservation and artificial recharge of ground water including roof-top run-off harvesting storm water recharge and by other means etc.

(c) Protection of ground water:

(i) Protection of ground water quality deterioration from disposal of urban and industrial wastes.

(ii) Management of ground water in coastal aquifers.

(iii) Clearance of solid & liquid waste disposals sites.

(iv) Clearance for setting up of ground water-based industries.

(d) Mass Awareness: Promotion of education & Mass Awareness Programmes.

Detailed literature, in local language, should be published on ground water conditions. Mass contact functions should be organized involving the administration, political persons, schools and the users in the affected area. Operational Modalities the Authority has taken a decision that instead of adopting a policy strategy, it should adopt a pro-active approach and sensitize persons and users at the different levels with regard to need for judicious use and scientific management of ground water. The Authority has, therefore, decided to adopt the following plan of action.

1. Organize mass awareness programmes involving the users and NGOs to explain the objectives of the notification of any area.

The effort shall involve:

(i) Preparation and issue of literature in local languages,

(ii) Establish one to one contact by involving voluntary agencies, and

(iii) Education through schools, etc.

2. Issue of messages through news, media for seeking cooperation of the people in the effort.

3. Organize activities like registration of wells, grant of permission for the replacement of the existing or the construction of new wells, organizing roof-top rain water harvesting without causing any inconvenience to the people.

4. Issue insertions through electronic display boards,

5. Production of films, etc.

6. Issue of notices to offenders giving them sufficient time to explain their position and take corrective actions.

7. Personal hearing before imposition of penalties.

To regulate indiscriminate boring and withdrawal of ground water in the country and to issue necessary regulatory directions with a view to preserve and protect the ground water.

8.3 Summary of Interventions and Expected Benefits for Jamnagar District

Total numbers of recharge shaft proposed are 333 nos as per Master Plan of Artificial recharge of India 2020. In 7919 hac on-form activities to be completed. Sprinkler/Drip/HDPE Pipes for 18538 hac area is also proposed in selected areas of the district. Over view of this is presented in below given Table No 16.

Total annual Recharge from Recharge interventions (Recharge Shafts) is about 1793.90 Ham. Conservation of Ground water through WUE, on farm activity & Sprinkler/Drip Irrigation is expected to be 3176.65 Ham

After the successful implementation of management plan the stage of groundwater development decrease to 57.26% from 63.19% (GWRE 2017) as shown in Figure No 47 and Table No 16

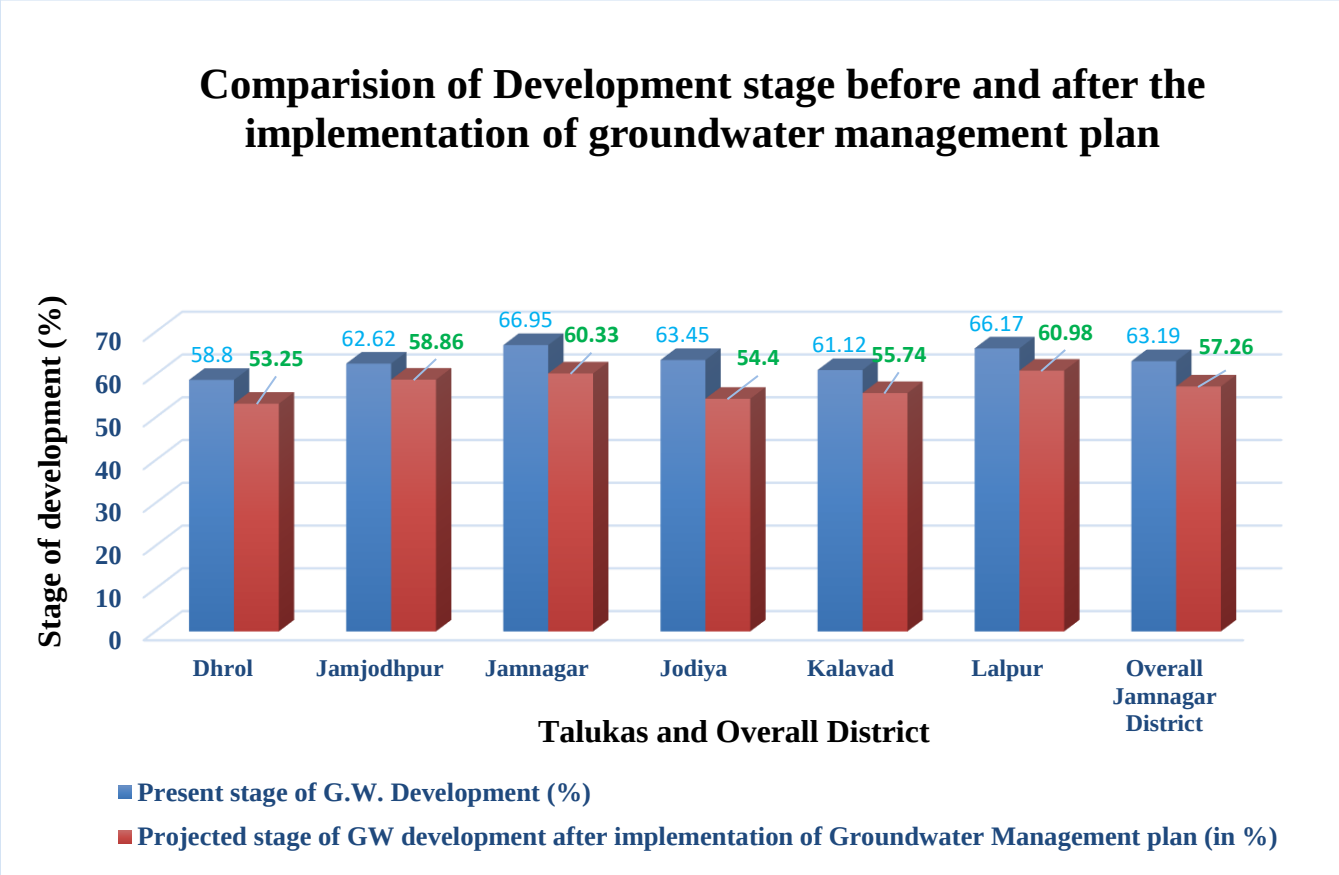

Figure 47 Comparison of Development stage before and after the implementation of groundwater management plan

Table 16 Projected Status of Groundwater Resource after implementation of GW Management Plan, Jamnagar District (Gujarat

Block	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (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)	Conservation of Ground water through WUE, on farm activity & Sprinkler/Drip Irrigation (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures & Recharge measures (in %)
Dhrol	8216.86	163.20	0.00	8380.06	4831.64	368.85	0.00	4462.79	58.80	53.25
Jamjodhpur	13732.89	561.60	0.00	14294.49	8599.83	186.30	0.00	8413.53	62.62	58.86
Jamnagar	16370.00	201.00	0.00	16571.00	10959.60	962.10	0.00	9997.50	66.95	60.33
Jodiya	5214.48	99.00	0.00	5313.48	3308.73	418.05	0.00	2890.68	63.45	54.40
Kalavad	21287.17	361.00	0.00	21648.17	13010.96	945.35	0.00	12065.61	61.12	55.74
Lalpur	10497.49	408.10	0.00	10905.59	6946.62	296.00	0.00	6650.62	66.17	60.98
Jamnagar District	75318.89	1793.90	0.00	77112.79	**47657.38**	3176.65	0.00	**44480.73**	**63.19**	**57.26**

Chapter 9
CONCLUSION AND RECOMMENDATIONS

1) The rainfall occurs during the southwest monsoon, starting from June and extending up to October. The rainfall is inconsistent, with average annual rainfall 613 mm (2011-2020).
2) Basaltic lava flows from the Deccan Traps are the dominant geological formation in the district, with coastal aquifers in the northern part and miliolitic limestones in the southern region.
3) Major aquifer bearing formation is weathered &fractured basalt.
4) Pre-monsoon WL ranges from 3.45-51.85 mbgl. Minimum value reported in Sethvadala (Jamjodhpur) and Max in Jalansar (Kalavad). About 22% samples represent WL below 10 mbgl while 78% above 10 mgbl.
5) Post-monsoon WL ranges from 0.50 mbgl to 15.10 mbgl, about 4% samples shows water level above 10 mbgl.
6) Groundwater flow direction for district in general is from NE to SW direction.
7) In major parts of district water level rises more than 6 meters. Very small area of district shows fall in water level from 0 to 2 meter.
8) The Electrical conductance of ground water is generally ranges from 556-14380 micromhos/cm at 25°c, for the entire district. EC in the district is mostly lie within Permissible limit except some small patches (of 7 location) in Jamjodhpur, Jamnagar, Jodiya and Dhrol taluka where show EC value more than Permissible limit.
9) Nitrate concentration in the ground water in district varies from 0-196.80 mg/l, out of 46 samples 7 samples shows Nitrate above 45 mg/l. Minimum Value found in Mota Vadiya (Jamjodhpur) and Max Value in Bed (Jamnagar).
10) Out of 46 samples 14 samples show F under 0.5 mg/l, 27 shows F values from 0.5-1.0 mg/l, and 5 samples represents F values 1-1.5 mg/l. Minimum value reported in Changa (Jamnagar) and Max in Haripar (Kalavad).
11) Shallow /Unconfined aquifer lies from zero to 87 meter below ground level and Deeper aquifer is also present in fractured basalt. Deep fractures are reported between 87 to 438 mbgl in few places.

12) The stage of ground water extraction all over the district is safe but 63% in GWRE 2017 hence no further development of groundwater is proposed.
13) Artificial recharge via 333 recharge shaft structures is proposed.
14) On farm activities and Sprinkler and Drip irrigation are also proposed in the district to encounter needed surface runoff.
15) As per Master plan 2020 for Artificial Recharge to Ground Water in Gujarat state, 10 MCM of surplus surface water is provisioned for artificial recharge through 333 no of recharge shafts as injection wells in Jamnagar district.
16) Groundwater recharge of 1793.90 ham through recharge shafts are expected for the district.
17) To prevent Over Exploitation water conservation activities such as on farm activities (Laser levelling/Bench terracing/Contour banding) in 7919 hac area and Sprinkler/ drip/ HDPE pipes irrigation in 18538 hac area is proposed.
18) 3177 ham conservation of ground water through WUE measures and on farm activities is expected for the district.
19) Projected stage of Ground Water development after Artificial Recharge and additional conservation activities is 57.26 % for 06 no blocks in Jamnagar district.
20) As a conservation measure, farmers should be encouraged and educated to adopt modern irrigation techniques like drip, sprinkler irrigation etc. to effect minimum withdrawal and maximum utilization of groundwater.
21) The water quality in general is good. However higher EC, Nitrate and fluoride concentration is observed in isolated pockets. Ground water in such areas may be used after blending with surface water. In areas where ground water has higher concentration of Nitrate is observed, necessary sanitation measures should be adopted.
22) The ‘Mass Awareness Programme’ and 'Water Management Training Programme' should be organized in regular basis in the district for awareness on the depletion of groundwater resources and quality problems.
23) Present supply side interventions are suggested based on availability 16 MCM non committed source of water is referred by State Government (Reference Master Plan of Artificial recharge 2020). Proposed enhancements of present Groundwater development stage are subjected to

implementation of recharge interventions, availability of cultivable land and yield of Groundwater structures.

24) These interventions also need to be supported by regulation, so that the ground water 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.
25) Farmers should be encouraged and educated to adopt modern irrigation techniques to effect minimum withdrawal and maximum utilisation of groundwater.
26) The water quality in general is good. The ground water in major part of the district is suitable for domestic, irrigation and industrial purpose. But in area of saline aquifer, RTRWH should be adopt vigorously.
27) In demand side management Bore Blasting Technology (BBT) to be implemented to open up some new fractures as well as expand existing fractures to increase the bore well yield in Hard rock area.
28) Testing of existing defunct wells should be carried out to draw inference about the connectivity with the aquifer targeted to be recharged so that its efficacy can be established before going for the actual recharge.
29) Metering of ground water abstraction should be carried out in areas where MIS is practiced /proposed for effective monitoring of actual reduction in draft.
30) Conjunctive use of surface and ground water should be encouraged. Wherever surface water availability is there, it should be given precedence over ground water so as to preserve the precious resource for emergency utilization.
31) Roof Top Rain Water Harvesting technique to be implemented in urban area to enhance ground water storage through recharge.
32) Uniformity in pumping pattern is required.
33) People need to be aware of the aquifer system existing in the area and regarding water conservation measures required.
34) Demand Vis-a vis supply management.

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Annexure 1 Pre monsoon_2019 Key well Establishment Data of Jamnagar District

SR..N0.	LATITUDE	LONGITUDE	SOURCE/TYPE OF WELL	TOPOSHEET NO.	MEASURING POINT (MP)	DEPTH	DEPTH TO METER (SWL)	DIAMETER	TYPE OF MOTOR/H.P.	USE	OWNER NAME	VILLAGE NAME	TEHSIL NAME	DISTRICT
1	21°33'16.60"N	70°26'4.10"E	BW	41J/06	NIL	73m	18m	NIL	Electric - 5	Irrigation	Ramjibhai Mohanbhai Parmar	Dhrol	Dhrol	Jamnagar
2	22°33'15.90"N	70°23'23.10"E	DW	41J/06	0.33m	16m	3.90m	4.55m	Electric - 5	Irrigation	Hashmukhbhai Jethabhai Kalavadiya	Vankiya	Dhrol	Jamnagar
3	22°26'58.20"N	70°0'42.60"E	BW	41J/03	NIL	52m	18m	NIL	Electric - 2	Irrigation	Devshibhai Natubhai Makwana	Naghedi	Jamnagar	Jamnagar
4	22°26'59.80"N	70°0'44.90"E	DW	41J/03	Ground Level	18m	1.87	5.30m	Diesel - 8	Irrigation	Devshibhai Natubhai Makwana	Naghedi	Jamnagar	Jamnagar
5	22°26'44.70"N	70°0'9.20"E	DW	41J/03	0.43m	18m	3.80m	4.90m	NIL	Domestic	Panchayat	Gordhanpur	Jamnagar	Jamnagar
6	22°27'6.10"N	69°57'18.30"E	DW	41J/03	0.43m	9m	4.35m	4.90m	NIL	Irrigation	Pravin Singh Prabhatsigh Jadeja	Sarmat	Jamnagar	Jamnagar
7	22°26'9.20"N	69°53'58.50"E	BW	41J/03	NIL	82m	60m	NIL	Electric - 1	Irrigation	Jagdish Gopalbhai Chav	Bed	Jamnagar	Jamnagar
8	22°25'55.90"N	69°54'4.80"E	DW	41J/03	0.98m	18m	6m	3.10m	Electric - 5	Irrigation	Jagdish Gopalbhai Chav	Bed	Jamnagar	Jamnagar

9	22°21'19.00"N	69°49'31.30"E	BW	41F/15	NIL	45m	20m	NIL	Electric - 1	Domestic	Bhagirath Vada	Jogvad	Lalpur	Jamnagar
10	22°15'38.50"N	69°48'29.80"E	DW	41F/15	0.90m	18m	5.85m	3.20m	Electric - 3.5	Irrigation	Ramdevbhai daranbhai Kabariya	Modhpur	Jamnagar	Jamnagar
11	22°15'38.20"N	69°48'30.00"E	BW	41F/15	NIL	106m	60m	NIL	Electric - 3	Irrigation	Ramdevbhai daranbhai Kabariya	Modhpur	Jamnagar	Jamnagar
12	22° 27' 5.99"N	69° 57' 18.12"E	DW	41F/15	0.40m	18m	7.05m	3.70m	NIL	Irrigation	Pradeep singh Jadeja	Vasai	Jamnagar	Jamnagar
13	22°24'33.00"N	70°04'39.00"E	BW	41J/03	NIL	167m	90m	NIL	Electric - 7.5	Irrigation	Arifbhai Makwana	Jamnagar	Jamnagar	Jamnagar
14	22°22'0.80"N	70°05'25.60"E	DW	41J/03	0.55m	29m	7.75m	5.1m	Electric - 5	Irrigation	Kantaben Chandubhai	Naranpur	Jamnagar	Jamnagar
15	22°22'0.80"N	70°05'25.60"E	BW	41J/03	NIL	76m	45m	NIL	Electric - 7.5	Irrigation	Vijabhai Nakwa	Naranpur	Jamnagar	Jamnagar
16	22°18'34.50"N	70°05'10.40"E	DW	41F/16	0.80m	21m	15m	5.40m	Electric - 3	Irrigation	Hiralal Ratilal Raithata	Veraval Moti	Lalpur	Jamnagar
17	22°15'57.20"N	70°05'53.40"E	BW	41J/03	NIL	306m	65m	NIL	Electric - 10	Irrigation	Ramjibhai Gordhanbhai Rabadiya	Pipartoda	Lalpur	Jamnagar
18	22°10'13.30"N	70°07'59.10"E	BW	41J/04	NIL	121m	18m	NIL	Electric - 1	Domestic	Basharbhai Maleka	Khatiya	Lalpur	Jamnagar
19	22°05'40.00"N	70°09'34.00"E	BW	41J/04	NIL	73m	60m	NIL	Electric - 10	Irrigation	Hameerbhai Ramshibhai Dangar	Narmana	Jamjodhpur	Jamnagar
20	22°02'25.56"N	70°07'26.00"E	DW	41J/04	0.75m	15m	13.70m	4.55m	NIL	Domestic	Panchayat	Seth Vadala	Jamjodhpur	Jamnagar

21	21°57'53.54"N	70°05'20.60"E	DW	41K/01	0.75m	18m	13.90m	3.90m	Electric - 07	Irrigation	Kishorsingh Tembha Jadeja	Dhrafa	Jamjodhpur	Jamnagar
22	21°55'16.18"N	69°59'39.73"E	DW	41J/04	0.74m	24m	10.90m	3.90m	Electric - 04	Irrigation	Mahendra Khimji Karena	Vasantpur	Jamjodhpur	Jamnagar
23	21°58'24.00"N	69°57'8.00"E	BW-Handpump	41G/03	NIL	167m	75m	NIL	NIL	Domestic	NIL	Mota Vadiya	Jamjodhpur	Jamnagar
24	21° 58' 24.3" N	69°57'08.4"E	BW	41G/03	NIL	106m	45m	NIL	Electric - 7.5	Domestic	Panchayat	Mota Vadiya	Jamjodhpur	Jamnagar
25	21°53'58.72"N	70°02'14.76"E	DW	41K/01	0.63m	18m	2.66m	Unmeasurable due to site	Electric - 5	Irrigation	Bhupatbhai Patel	Jamjodhpur	Jamjodhpur	Jamnagar
26	22°25'0.01"N	70°10'25.33"E	BW	41J/03	NIL	122m	61m	NIL	Electric - 1	Domestic	Shree Gangev Gosala Mandir Trust	Vijarkhi	Jamnagar	Jamnagar
27	22°24'15.10"N	70°11'26.30"E	DW	41J/03	0.74m	30m	1.95m	3.90m	Electric - 10	Irrigation	Govindbhai Tapabhai Lokhil (Haribhai Tapubhai Lokhil)	Vijarkhi	Jamnagar	Jamnagar
28	22°22'35.71"N	70°13'39.64"E	DW	41F/15	0.85m	27.43m	5.95m	6.25m	NIL	Irrigation	Megjibhai	Modpar	Jamnagar	Jamnagar
29	22°19'3.25"N	70°16'5.35"E	DW	41J/07	1m	18m	3.60m	6.30m	NIL	Domestic	Panchayat	Moti Matli	Kalavad	Jamnagar
30	22°14'49.11"N	70°16'4.27"E	DW	41J/08	0.55m	15m	7.60m	4.85m	NIL	Irrigation	Ravji Bhada	Krishnapur	Kalavad	Jamnagar
31	22°15'48.00"N	70°20'13"E	DW	41J/08	0.52m	14m	5.8m	3.85m	Electric-10	Irrigation	Kantibhai	Haripar	Kalavad	Jamnagar
32	22°9'0.67"N	70°22'40.53"E	BW	41J/08	NIL	244m	8m	NIL	NIL	Irrigation	Vallabh bhai Nariya	Makrani Sanosara	Kalavad	Jamnagar

33	22°4'8.65"N	70°23'5.49"E	DW	41J/08	0.75m	18m	5.35m	3.90m	NIL	Irrigation	Narendrasingh Bapalal Bapubhai	Toda	Kalavad	Jamnagar
34	22°4'33.56"N	70°20'37.29"E	DW	41J/08	0.58m	15m	3.95m	4.95m	NIL	Irrigation	NIL	Fagas	Kalavad	Jamnagar
35	22°2'53.05"N	70°19'26.29"E	DW	41J/08	0.85m	18m	15.80m	5.80m	NIL	Irrigation	Kababhai Radabhai	Navagam	Kalavad	Jamnagar
36	22°8'2.30"N	70°18'33.34"E	DW	41G/13	0.43m	21m	5.10m	4.50m	NIL	Domestic	Panchayat	Jamval	Jamjodhpur	Jamnagar
37	22°7'40.04"N	70°13'17.79"E	BW	41J/08	NIL	106m	76m	NIL	Electric - 2.5	Domestic	Hanuman Mandir Trust	Chattar	Kalavad	Jamnagar
38	22°14'56.21"N	69°59'34.31"E	DW-Pumping	41F/16	0.50m	15m	4.30m	NIL	Electric - 3	Irrigation	Damjibhai Khodadasbhai Kothia	Arikhana	Lalpur	Jamnagar
39	22°11'18.49"N	69°57'22.14"E	BW	41F/16	NIL	85m	18m	NIL	Electric - 1.5	Irrigation	Kishor Prabhadas Tanna	Lalpur	Lalpur	Jamnagar
40	22°13'32.56"N	69°53'10.51"E	DW	41F/16	0.80m	12m	5.45m	3.40m	NIL	Domestic	Panchayat	Moti Rafudar	Lalpur	Jamnagar
41	22°15'20.67"N	69°54'30.94"E	DW	41F/15	0.75m	15m	8.70m	4m	Electric - 7.5	Domestic	Panchayat	Dabasang	Lalpur	Jamnagar
42	22°09'50.69"N	69°57'44.56"E	BW	41F/16	NIL	122m	12m	NIL	Electric - 5	Irrigation	Haddaas Ranmal Karangiya	Nanduri	Lalpur	Jamnagar
43	22°06'59.70"N	70°00'55.05"E	BW	41J/03	NIL	152m	30m	NIL	Electric - 12	Irrigation	Josab Sumar Sama	Babariya	Lalpur	Jamnagar
44	22°08'5.01"N	70°06'20.72"E	BW	41J/04	NIL	152m	24m	NIL	Electric - 1	Domestic	Ukabhai Virabhai Viram	Sajadiyali	Lalpur	Jamnagar

45	22°03'4.81"N	70°12'24.99"E	DW	41J/04	0.76m	15m	2.10m	3.90m	NIL	Domestic	Mansukh becha kesa/Jothariya	Sadodar	Jamjodhpur	Jamnagar
46	22°06'5.49"N	70°10'21.88"E	DW	41J/04	0.53m	18m	7.52m	5.50m	NIL	Domestic	Panchayat	Dal Devaliya	Jamjodhpur	Jamnagar
47	22°33'45.40"N	70°12'4.64"E	BW	41J/02	NIL	109m	76m	NIL	Electric - 2	Irrigation	Haroonbhai Kasam Sodha	Sachana	Jamnagar	Jamnagar
48	22°37'42.67"N	70°16'58.28"E	BW	41J/06	NIL	18m	12m	NIL	Electric - 5	Irrigation	Mandir Trust	Limbuda	Jodiya	Jamnagar
49	22°41'50.89"N	70°18'4.86"E	BW-Hand pump	41J/06	NIL	6m	3m	NIL	NIL	Domestic	Panchayat	Jodiya	Jodiya	Jamnagar
50	22°41'9.26"N	70°19'35.17"E	DW	41J/06	0.35m	20m	1.55m	3.35m	NIL	Irrigation	Mohan Bogha Santoki/Odhavji Mohan	Badanpar	Jodiya	Jamnagar
51	22°39'54.85"N	70°26'11.96"E	DW	41J/06	Ground Level	21m	7m	4.5m	Two Electric Motor- 5 & 7.5	Irrigation	Sukhdevsingh Natubhai Jadega	Hadotada	Dhrol	Jamnagar
52	22°47'43.97"N	70°30'22.91"E	DW	41J/05	0.80m	17m	2.75m	3m	NIL	Domestic	Panchayat	Dudhai	Jodiya	Jamnagar
53	22°42'6.65"N	70°24'4.60"E	BW	41J/06	NIL	61m	45.72m	NIL	Electric - 1	Irrigation	Lagdhir Singh	Keshiya	Jodiya	Jamnagar
54	22°38'55.31"N	70°28'29.94"E	DW	41J/06	0.60m	36m	1.90m	3.9	NIL	Irrigation	Panchayat	Bhensdad	Dhrol	Jamnagar
55	22°37'11.40"N	70°31'08"E	DW	41J/10	0.85m	24m	7.70m	4.40m	NIL	Irrigation	Hiteshbhai Nathabhai	Latipur	Dhrol	Jamnagar
56	22°31'50.49"N	70°18'31.57"E	DW	41J/06	0.80m	18m	4.50m	4.5m	NIL	Irrigation	odhavji Arjan Bhalodia	Falla	Dhrol	Jamnagar
57	22°30'38.24"N	70°12'30.46"E	DW	41J/02	0.67m	30m	3.50m	3.80m	NIL	Irrigation	Narandevshibhai Panara	Jambuda	Jamnagar	Jamnagar

58	22°26'29.81"N	70°12'50.58"E	BW	41J/03	NIL	160m	76m	NIL	Electric - 7.5	Irrigation	Jawahar Navoday Vidyalay	Aliabada	Jamnagar	Jamnagar
59	22°22'4.22"N	70°18'28.42"E	DW	41J/07	0.45m	12m	1.40m	3.35m	NIL	Domestic	Panchayat	Medi	Jamnagar	Jamnagar
60	22°14'16.12"N	70°21'57.62"E	DW	41J/08	0.45m	26m	16m	4.36m	NIL	Domestic	Ashwin Patel	Nani Vavdi	Kalavad	Jamnagar
61	22°15'52.73"N	70°28'19.83"E	DW	41J/07	0.62m	25m	8m	3.54m	NIL	Irrigation	NIL	Mota Vadala	Kalavad	Jamnagar
62	22°12'58.50"N	70°28'30.11"E	DW	41J/08	0.85m	16m	10.17	5.6m	NIL	Irrigation	Yuvrajsingh Jadega	Sisang	Kalavad	Jamnagar
63	22°11'37.59"N	70°32'17.66"E	BW	41J/12	NIL	61m	15m	NIL	NIL	Domestic	Jiteshbhai Ajaliya	Nikava	Kalavad	Jamnagar

Annexure 2 Post monsoon_2019 Depth to water level and water table data of Jamnagar District

WELL INVENTORY FOR NAQUIM AREA DISTRICT - JAMNAGAR 2020-21

SR.NO	SAMPLE NO.	DATE OF SAMPLE COLLECTION	LATITUDE	LONGITUDE	SOURCE/TYPE OF WELL	TOPOSHEET NO.	MEASURING POINT (MP)	DEPTH	DEPTH TO METER (SWL)	DIAMETER	TYPE OF MOTOR/ H.P.	USE	OWNER NAME	VILLAGE NAME	TEHSIL NAME	DISTRICT
1	1	12/15/2020	21°33'16.60"N	70°26'4.10"E	BW	41J/06	NIL	73m	18m	NIL	Electric - 5	Irrigation	Ramjibhai Mohanbhai Parmar	Dhrol	Dhrol	Jamnagar
2	2	12/15/2020	22°33'15.90"N	70°23'23.10"E	DW	41J/06	0.33m	16m	3.90m	4.55m	Electric - 5	Irrigation	Hashmukhbhai Jethabhai Kalavadiya	Vankiya	Dhrol	Jamnagar
3	3	12/16/2020	22°26'58.20"N	70°0'42.60"E	BW	41J/03	NIL	52m	18m	NIL	Electric - 2	Irrigation	Devshibhai Natubhai Makwana	Naghedi	Jamnagar	Jamnagar
4	4	12/16/2020	22°26'59.80"N	70°0'44.90"E	DW	41J/03	Ground Level	18m	1.87	5.30m	Diesel - 8	Irrigation	Devshibhai Natubhai Makwana	Naghedi	Jamnagar	Jamnagar
5	5	12/16/2020	22°26'44.70"N	70°0'9.20"E	DW	41J/03	0.43m	18m	3.80m	4.90m	NIL	Domestic	Panchayat	Gordhanpur	Jamnagar	Jamnagar

6	6	12/16/2020	22°27'6.10" N	69°57'18.30 "E	DW	41J/03	0.43m	9m	4.35m	4.90m	NIL	Irrigation	Pravin Singh Prabhatsigh Jadeja	Sarmat	Jamnagar	Jamnagar
7	7	12/16/2020	22°26'9.20" N	69°53'58.50 "E	BW	41J/03	NIL	82m	60m	NIL	Electric - 1	Irrigation	Jagdish Gopalbhai Chav	Bed	Jamnagar	Jamnagar
8	8	12/16/2020	22°25'55.90"N	69°54'4.80" E	DW	41J/03	0.98m	18m	6m	3.10m	Electric - 5	Irrigation	Jagdish Gopalbhai Chav	Bed	Jamnagar	Jamnagar
9	9	12/16/2020	22°21'19.00"N	69°49'31.30 "E	BW	41F/15	NIL	45m	20m	NIL	Electric - 1	Domestic	Bhagirath Vada	Jogvad	Lalpur	Jamnagar
10	10	12/16/2020	22°15'38.50"N	69°48'29.80 "E	DW	41F/15	0.90m	18m	5.85m	3.20m	Electric - 3.5	Irrigation	Ramdevbhai daranbhai Kabariya	Modhpur	Jamnagar	Jamnagar
11	11	12/16/2020	22°15'38.20"N	69°48'30.00 "E	BW	41F/15	NIL	106m	60m	NIL	Electric - 3	Irrigation	Ramdevbhai daranbhai Kabariya	Modhpur	Jamnagar	Jamnagar
12	12	12/16/2020	22° 27' 5.99"N	69° 57' 18.12"E	DW	41F/15	0.40m	18m	7.05m	3.70m	NIL	Irrigation	Pradeep singh Jadeja	Vasai	Jamnagar	Jamnagar
13	13	12/16/2020	22°24'33.00"N	70°04'39.00 "E	BW	41J/03	NIL	167m	90m	NIL	Electric - 7.5	Irrigation	Arifbhai Makwana	Jamnagar	Jamnagar	Jamnagar
14	14	12/17/2020	22°22'0.80" N	70°05'25.60 "E	DW	41J/03	0.55m	29m	7.75m	5.1m	Electric - 5	Irrigation	Kantaben Chandubhai	Naranpur	Jamnagar	Jamnagar
15	15	12/17/2020	22°22'0.80" N	70°05'25.60 "E	BW	41J/03	NIL	76m	45m	NIL	Electric - 7.5	Irrigation	Vijabhai Nakwa	Naranpur	Jamnagar	Jamnagar

16	16	12/17/2020	22°18'34.50"N	70°05'10.40"E	DW	41F/16	0.80m	21m	15m	5.40m	Electric - 3	Irrigation	Hiralal Ratilal Raithata	Veraval Moti	Lalpur	Jamnagar
17	17	12/17/2020	22°15'57.20"N	70°05'53.40"E	BW	41J/03	NIL	306m	65m	NIL	Electric - 10	Irrigation	Ramjibhai Gordhanbhai Rabadiya	Pipartoda	Lalpur	Jamnagar
18	18	12/17/2020	22°10'13.30"N	70°07'59.10"E	BW	41J/04	NIL	121m	18m	NIL	Electric - 1	Domestic	Basharbhai Maleka	Khatiya	Lalpur	Jamnagar
19	19	12/17/2020	22°05'40.00"N	70°09'34.00"E	BW	41J/04	NIL	73m	60m	NIL	Electric - 10	Irrigation	Hameerbhai Ramshibhai Dangar	Narmana	Jamjodhpur	Jamnagar
20	20	12/17/2020	22°02'25.56"N	70°07'26.00"E	DW	41J/04	0.75m	15m	13.70 m	4.55m	NIL	Domestic	Panchayat	Seth Vadala	Jamjodhpur	Jamnagar
21	21	12/17/2020	21°57'53.54"N	70°05'20.60"E	DW	41K/01	0.75m	18m	13.90 m	3.90m	Electric - 07	Irrigation	Kishorsingh Tembha Jadeja	Dhrafa	Jamjodhpur	Jamnagar
22	22	12/17/2020	21°55'16.18"N	69°59'39.73"E	DW	41J/04	0.74m	24m	10.90 m	3.90m	Electric - 04	Irrigation	Mahendra Khimji Karena	Vasantpur	Jamjodhpur	Jamnagar
23	23	12/17/2020	21°58'24.00"N	69°57'8.00"E	BW-Handpump	41G/03	NIL	167m	75m	NIL	NIL	Domestic	NIL	Mota Vadiya	Jamjodhpur	Jamnagar
24	24	12/17/2020	21° 58' 24.3" N	69°57'08.4"E	BW	41G/03	NIL	106m	45m	NIL	Electric - 7.5	Domestic	Panchayat	Mota Vadiya	Jamjodhpur	Jamnagar
25	25	12/17/2020	21°53'58.72"N	70°02'14.76"E	DW	41K/01	0.63m	18m	2.66m	Unmeasurable due to site	Electric - 5	Irrigation	Bhupatbhai Patel	Jamjodhpur	Jamjodhpur	Jamnagar

26	26	12/18/2020	22°25'0.01"N	70°10'25.33"E	BW	41J/03	NIL	122m	61m	NIL	Electric - 1	Domestic	Shree Gangev Gosala Mandir Trust	Vijarkhi	Jamnagar	Jamnagar
27	27	12/18/2020	22°24'15.10"N	70°11'26.30"E	DW	41J/03	0.74m	30m	1.95m	3.90m	Electric - 10	Irrigation	Govindbhai Tapabhai Lokhil (Haribhai Tapubhai Lokhil)	Vijarkhi	Jamnagar	Jamnagar
28	28	12/18/2020	22°22'35.71"N	70°13'39.64"E	DW	41F/15	0.85m	27.43 m	5.95m	6.25m	NIL	Irrigation	Megjibhai	Modpar	Jamnagar	Jamnagar
29	29	12/18/2020	22°19'3.25"N	70°16'5.35"E	DW	41J/07	1m	18m	3.60m	6.30m	NIL	Domestic	Panchayat	Moti Matli	Kalavad	Jamnagar
30	30	12/18/2020	22°14'49.11"N	70°16'4.27"E	DW	41J/08	0.55m	15m	7.60m	4.85m	NIL	Irrigation	Ravji Bhada	Krishnapur	Kalavad	Jamnagar
31	31	12/18/2020	22°15'48.00"N	70°20'13"E	DW	41J/08	0.52m	14m	5.8m	3.85m	Electric-10	Irrigation	Kantibhai	Haripar	Kalavad	Jamnagar
32	32	12/18/2020	22°9'0.67"N	70°22'40.53"E	BW	41J/08	NIL	244m	8m	NIL	NIL	Irrigation	Vallabh bhai Nariya	Makrani Sanosara	Kalavad	Jamnagar
33	33	12/18/2020	22°4'8.65"N	70°23'5.49"E	DW	41J/08	0.75m	18m	5.35m	3.90m	NIL	Irrigation	Narendrasingh Bapalal Bapubhai	Toda	Kalavad	Jamnagar
34	34	12/18/2020	22°4'33.56"N	70°20'37.29"E	DW	41J/08	0.58m	15m	3.95m	4.95m	NIL	Irrigation	NIL	Fagas	Kalavad	Jamnagar
35	35	12/18/2020	22°2'53.05"N	70°19'26.29"E	DW	41J/08	0.85m	18m	15.80 m	5.80m	NIL	Irrigation	Kababhai Radabhai	Navagam	Kalavad	Jamnagar

36	36	12/18/2020	22°8'2.30" N	70°18'33.34 "E	DW	41G/13	0.43m	21m	5.10m	4.50m	NIL	Domes tic	Panchayat	Jamval	Jamjodh pur	Jamnagar
37	37	12/18/2020	22°7'40.04" N	70°13'17.79 "E	BW	41J/08	NIL	106m	76m	NIL	Electric - 2.5	Domes tic	Hanuman Mandir Trust	Chattar	Kalavad	Jamnagar
38	38	12/19/2020	22°14'56.2 1"N	69°59'34.31 "E	DW-Pumping	41F/16	0.50m	15m	4.30m	NIL	Electric - 3	Irrigati on	Damjibhai Khodadasbh ai Kothia	Arikhana	Lalpur	Jamnagar
39	39	12/19/2020	22°11'18.4 9"N	69°57'22.14 "E	BW	41F/16	NIL	85m	18m	NIL	Electric - 1.5	Irrigati on	Kishor Prabhadas Tanna	Lalpur	Lalpur	Jamnagar
40	40	12/19/2020	22°13'32.5 6"N	69°53'10.51 "E	DW	41F/16	0.80m	12m	5.45m	3.40m	NIL	Domes tic	Panchayat	Moti Rafudar	Lalpur	Jamnagar
41	41	12/19/2020	22°15'20.6 7"N	69°54'30.94 "E	DW	41F/15	0.75m	15m	8.70m	4m	Electric - 7.5	Domes tic	Panchayat	Dabasan g	Lalpur	Jamnagar
42	42	12/19/2020	22°09'50.6 9"N	69°57'44.56 "E	BW	41F/16	NIL	122m	12m	NIL	Electric - 5	Irrigati on	Haddaas Ranmal Karangiya	Nanduri	Lalpur	Jamnagar
43	43	12/19/2020	22°06'59.7 0"N	70°00'55.05 "E	BW	41J/03	NIL	152m	30m	NIL	Electric - 12	Irrigati on	Josab Sumar Sama	Babariya	Lalpur	Jamnagar
44	44	12/19/2020	22°08'5.01" N	70°06'20.72 "E	BW	41J/04	NIL	152m	24m	NIL	Electric - 1	Domes tic	Ukabhai Virabhai Viram	Sajadiyal i	Lalpur	Jamnagar
45	45	12/19/2020	22°03'4.81" N	70°12'24.99 "E	DW	41J/04	0.76m	15m	2.10m	3.90m	NIL	Domes tic	Mansukh becha kesa/Jothariy a	Sadodar	Jamjodh pur	Jamnagar

46	46	12/19/2020	22°06'5.49" N	70°10'21.88 "E	DW	41J/04	0.53m	18m	7.52m	5.50m	NIL	Domes tic	Panchayat	Dal Devaliya	Jamjodh pur	Jamnagar
47	47	12/20/2020	22°33'45.4 0"N	70°12'4.64" E	BW	41J/02	NIL	109m	76m	NIL	Electric - 2	Irrigati on	Haroonbhai Kasam Sodha	Sachana	Jamnaga r	Jamnagar
48	48	12/20/2020	22°37'42.6 7"N	70°16'58.28 "E	BW	41J/06	NIL	18m	12m	NIL	Electric - 5	Irrigati on	Mandir Trust	Limbuda	Jodiya	Jamnagar
49	49	12/20/2020	22°41'50.8 9"N	70°18'4.86" E	BW-Handpump	41J/06	NIL	6m	3m	NIL	NIL	Domes tic	Panchayat	Jodiya	Jodiya	Jamnagar
50	50	12/20/2020	22°41'9.26" N	70°19'35.17 "E	DW	41J/06	0.35m	20m	1.55m	3.35m	NIL	Irrigati on	Mohan Bogha Santoki/Odh avji Mohan	Badanpar	Jodiya	Jamnagar
51	51	12/20/2020	22°39'54.8 5"N	70°26'11.96 "E	DW	41J/06	Ground Level	21m	7m	4.5m	Two Electric Motor- 5 & 7.5	Irrigati on	Sukhdevsing h Natubhai Jadega	Hadotada	Dhrol	Jamnagar
52	52	12/20/2020	22°47'43.9 7"N	70°30'22.91 "E	DW	41J/05	0.80m	17m	2.75m	3m	NIL	Domes tic	Panchayat	Dudhai	Jodiya	Jamnagar
53	53	12/20/2020	22°42'6.65" N	70°24'4.60" E	BW	41J/06	NIL	61m	45.72 m	NIL	Electric - 1	Irrigati on	Lagdhir Singh	Keshiya	Jodiya	Jamnagar
54	54	12/20/2020	22°38'55.3 1"N	70°28'29.94 "E	DW	41J/06	0.60m	36m	1.90m	3.9	NIL	Irrigati on	Panchayat	Bhensda d	Dhrol	Jamnagar
55	55	12/20/2020	22°37'11.4 0"N	70°31'08"E	DW	41J/10	0.85m	24m	7.70m	4.40m	NIL	Irrigati on	Hiteshbhai Nathabhai	Latipur	Dhrol	Jamnagar

56	56	12/20/2020	22°31'50.49"N	70°18'31.57"E	DW	41J/06	0.80m	18m	4.50m	4.5m	NIL	Irrigation	odhavji Arjan Bhalodia	Falla	Dhrol	Jamnagar
57	57	12/21/2020	22°30'38.24"N	70°12'30.46"E	DW	41J/02	0.67m	30m	3.50m	3.80m	NIL	Irrigation	Narandevshi bhai Panara	Jambuda	Jamnagar	Jamnagar
58	58	12/21/2020	22°26'29.81"N	70°12'50.58"E	BW	41J/03	NIL	160m	76m	NIL	Electric - 7.5	Irrigation	Jawahar Navoday Vidyalay	Aliabada	Jamnagar	Jamnagar
59	59	12/21/2020	22°22'4.22"N	70°18'28.42"E	DW	41J/07	0.45m	12m	1.40m	3.35m	NIL	Domestic	Panchayat	Medi	Jamnagar	Jamnagar
60	60	12/21/2020	22°14'16.12"N	70°21'57.62"E	DW	41J/08	0.45m	26m	16m	4.36m	NIL	Domestic	Ashwin Patel	Nani Vavdi	Kalavad	Jamnagar
61	61	12/21/2020	22°15'52.73"N	70°28'19.83"E	DW	41J/07	0.62m	25m	8m	3.54m	NIL	Irrigation	NIL	Mota Vadala	Kalavad	Jamnagar
62	62	12/21/2020	22°12'58.50"N	70°28'30.11"E	DW	41J/08	0.85m	16m	10.17	5.6m	NIL	Irrigation	Yuvrajsingh Jadega	Sisang	Kalavad	Jamnagar
63	63	12/21/2020	22°11'37.59"N	70°32'17.66"E	BW	41J/12	NIL	61m	15m	NIL	NIL	Domestic	Jiteshbhai Ajaliya	Nikava	Kalavad	Jamnagar