**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

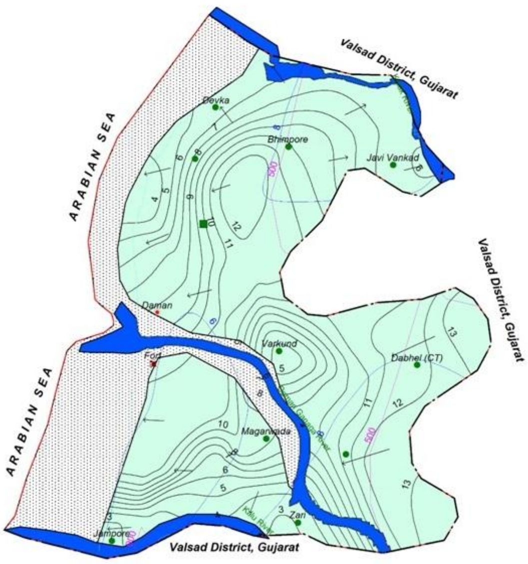
# AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

## DAMAN DISTRICT
## UT OF DAMAN AND DIU

पश्चिम मध्य क्षेत्र, अहमदाबाद

West Central Region, Ahmedabad

**Government of India**
**Ministry of Jal Shakti**
**Department of Water Resources, River Development, and Ganga Rejuvenation**




# AQUIFER MAPPING AND GROUNDWATER MANAGEMENT PLAN OF DAMAN DISTRICT UT OF DAMAN AND DIU

**CENTRAL GROUND WATER BOARD**
**WEST CENTRAL REGION**
**AHMEDAAD, GUJARAT**
**August 2022**

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# DISTRICT DAMAN AT A GLANCE

| S. No. | Items | Statistics | |
|---|---|---|---|
| 1 | General Information | | |
| | i) Geographical Area | 72 Sq.Km | |
| | ii) Administrative Divisions (As on 31/3/2007)<br>Number of District (Admn Area)<br>Number of Villages | 1<br>1<br>22 | |
| | iii) Populations (As per 2011 census)<br>iv)Sex ratio<br>v) Literacy rate | 1,91,173<br>534<br>88.06 % | |
| | vi) Average Annual Rainfall (Decadal Average(2001-2011) | 1900 mm | |
| 2. | GEOMORPHOLOGY | | |
| | Major Physiographic Units | Gently undulating topography with small hillocks | |
| | Major Drainages | Daman Ganga | |
| 3. | LAND USE | | |
| | Urban Area (ha)<br>Rural Area (ha)<br>Gross Cropped Area<br>Irrigated (ha)<br>Unirrigated (ha)<br>Forest Area (ha) | 650<br>6550<br>3131<br>242.44<br>288.71<br>123.45 | |
| 4. | MAJOR SOIL TYPES | Black cotton soils & Alluvial soil | |
| 5. | AREA UNDER PRINCIPAL FOODGRAIN CROPS | 27.85 Sq. Km. | |
| 6. | IRRIGATION BY DIFFERENT SOURCES (Areas and numbers of structures) (Source :Statistical abstract Gujarat 2006) | No. | Area |
| | Dugwells | 68 | |
| | Tube wells/Bore wells<br>Borewells with hand pump | 11<br>601 | |
| | Canals | | 2.87 Sq.Km |
| | Other Sources | | |
| | Net Irrigated area (Sq Km) (2002-03) | 2.29 Sq.Km | |
| | Gross Irrigated area (Sq Km) (2002-03) | 2.42 Sq.Km | |
| 7. | NUMBERS OF GROUND WATER MONITORING WELLS OF CGWB (As on 2018-19)<br>No of Dug Wells<br>No of Piezometers | <br>8<br>1 | |
| 8. | PREDOMINANT GEOLOGICAL FORMATIONS | | |
| | **a)** Deccan trap (Hard rock)<br>**b)** Coastal Alluvium | | |

| **9** | HYDROGEOLOGY | | | | |
|---|---|---|---|---|---|
| | Major Water Bearing Formation: Deccan trap and AlluviumDepth to Water level during 2021<br>Pre-monsoon: 1.67-7.95 (m bgl)<br>Post-monsoon: 1.3- 4.4 (m bgl) | | | | |
| **10.** | GROUND WATER EXPLORATION BY CGWB (As on 31 -03 -2012) | | | | |
| | No of wells drilled (EW, OW, Pz, SH, Total) | | | | |
| | EW | OW | Pz<br>1 | SH<br>None | Total |
| | Depth | | | | 32 mbgl |
| | Discharge | | | | 1.65 lps |
| | Storativity (S) | | | | - |
| | Transmissivity ($m^2$/day) | | | | - |
| **11** | GROUND WATER QUALITY | | | | |
| | Presence of chemical constituents more than permissible limit. | | | | For drinking – EC in deeper aquifer is more than permissible limit.<br>For Irrigation: Sodium Alkalinity Hazard Ion toxicity |
| | Type of water | | | | Potable to slightly brackish |
| **12.** | DYNAMIC GROUND WATER RESOURCES (2020 ) | | | | |
| | Total Annual Ground Water Recharge | | | | 2655.31(ham)<br>. |
| | Net Annual Ground Water Availability | | | | 2522.54 (ham) |
| | Gross Annual Ground Water Draft | | | | 3082.10 (ham) |
| | Annual GW Allocation for for Domestic Use as on 2025 | | | | 1412.67 (ham) |
| | Stage of Ground Water Development | | | | 122.18 % (Over exploited)) |
| **15** | GROUND WATER CONTROL AND REGULATION | | | | |
| | Number of OE Blocks | | | | 1 |
| | Number of Critical Blocks | | | | NONE |
| | Number of blocks notified | | | | NONE |

# AQUIFER MAPPING AND GROUNDWATER MANAGEMENT PLAN, OF DAMAN DISTRICT, UT OF DAMAN

# 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 have been generated through scientific investigations by Central Ground Water Board 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 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 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 also 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 attempts 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:
  1) Delineation of lateral and vertical disposition of aquifers and their characterization
  2) Quantification of ground water availability and assessment of its quality
  3) to formulate aquifer management plans
  4) 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:
  1) Identifying the aquifer geometry
  2) Aquifer characteristics and their yield potential
  3) Quality of water occurring at various depths
  4) Aquifer wise assessment of ground water resources
  5) Preparation of aquifer maps and
  6) 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:

1) Compilation of existing data (Central & State Govt.)
2) Generation of different thematic layer
3) Identification of Primary Aquifer
4) Identification of data gaps
5) Data generation (water level, exploration, geophysical,
6) Aquifer Maps with 3D disposition
7) Preparation of Aquifer Management Plan
8) 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 aspect 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 is depicted/elaborated in Annexure –I and presented in figure 1.

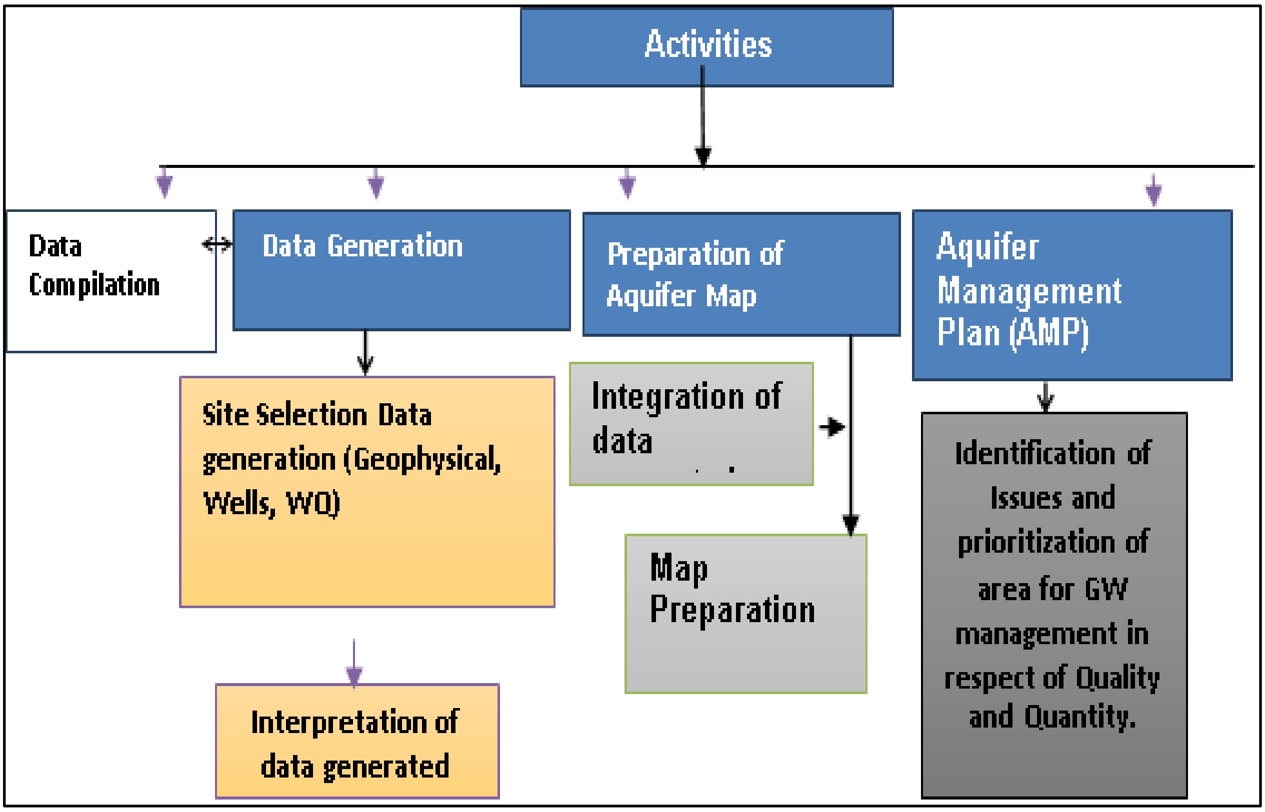



*Figure 1- Activity under National Aquifer Mapping Programme*

## 1.4 Area Details and Brief Description

Daman is a small port on the Arabian Sea. It is a Union Territory under UT of Daman & Diu and the capital of the UT. Daman is situated between north latitudes 20°22' & 20°29'58" and east longitudes 72°49'42" & 72°54'43"and falls in Survey of India topo-sheet No. 46 D/15. It covers an area of 72 sq. km. Its length measures 11 km from extreme north to south and the width measures 8 km. from east to west. The UT is bounded on the north, east and south by Valsad district of Gujarat state and west by Arabian Sea (Fig. 2).
There are 22 villages, 10 village panchayats, one municipal council and one town under the Daman district.

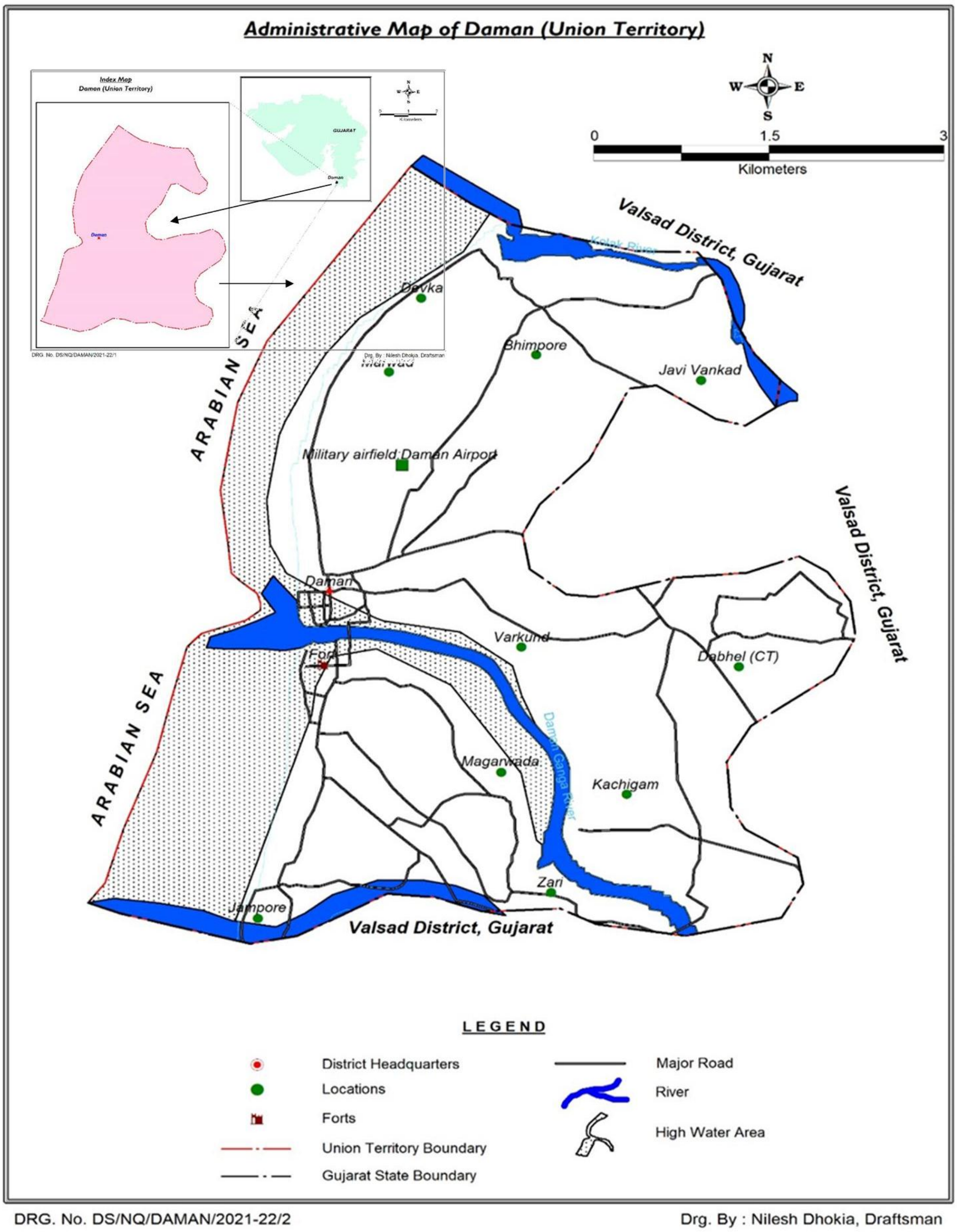



*Figure 2 Administrative Map of UT of Daman*

## 1.5 Demography

The total population of the district as per 2011 census is 1, 91,173, which includes 1, 24,659 males and 66,514 females. The sex ratio is about 591 females per 1000 males. The rural population is 32,313 and urban population is 1, 58,860.

## 1.6 Studies / Activity by CGWB

A report on Hydrogeological conditions, Groundwater Resources and Development Possibilities of the Union Territories of Daman & Diu compiled by Sh. P. N. Phadtare, Director, West Central

Region, Ahmedabad, year 1988. WCR, CGWB constructed one piezometer to the depth of 32 mbgl and fitted with automatic water level recorder for regular monitoring of groundwater. Apart from this groundwater brochure is also prepared by CGWB. Year Book of Gujarat State and Daman & Diu is being issued yearly by CGWB. CGWB monitors four times water level in a year for entire district by National Hydrograph stations and also collected water sample for quality analysis during Pre-monsoon monitoring in each year.

## 1.7 Hydrometeorology and Climate

The rainfall occurs during the southwest monsoon, starting from June and extending up to October. The rainfall is inconsistent, with average annual rainfall 1900 mm. Long term monthly means of annual rainfall distribution shows that over 95 % of the rainfall occurs between mid-June to mid-September due to southwest monsoon. July is the rainiest month with nearly 900 mm of average rainfall. The rainfall characteristics have a strong impact on the groundwater level and quality of UT of Daman.

The mean minimum temperature is 12ºC and the mean maximum temperature is 37ºC. Due to proximity of the sea the humidity is generally high being 100% in the monsoon period and around 24% during summer. The winds are generally moderate except during late summer and monsoon period when they are very strong. The maximum wind speed is 30 km/hr.

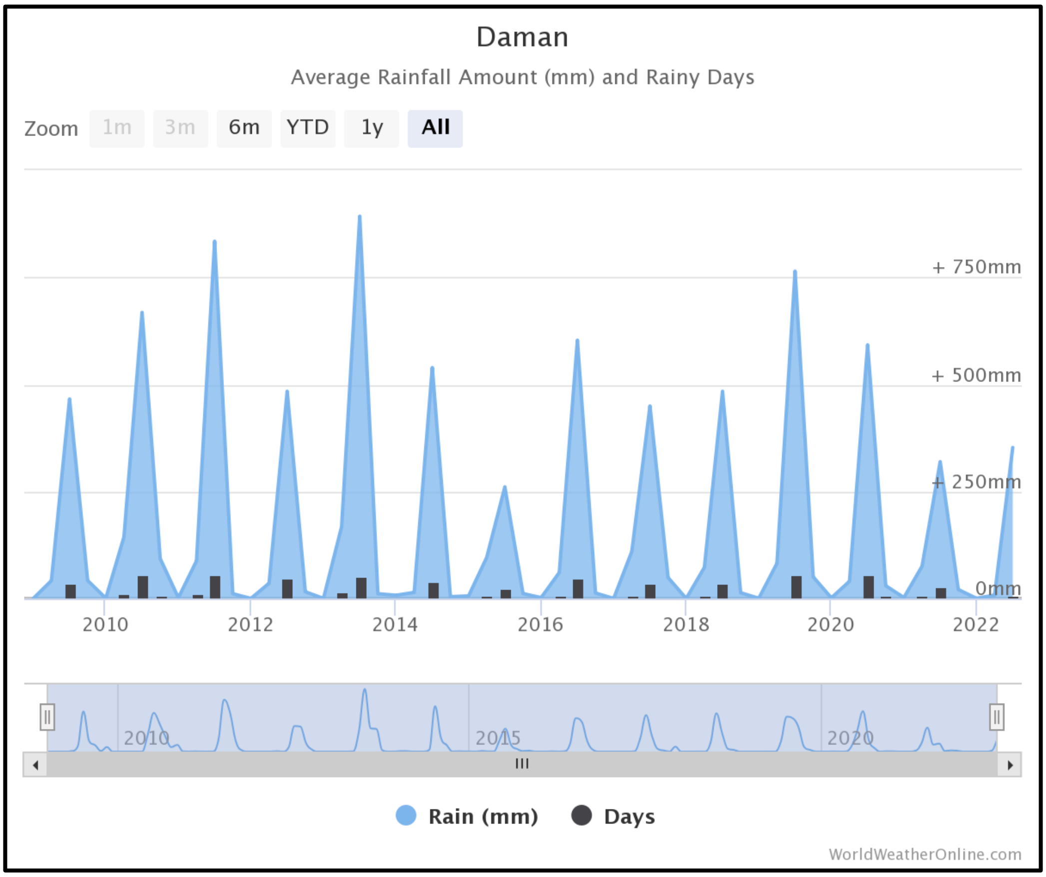



*Figure 3 Average Rainfall and Rain Days Map*

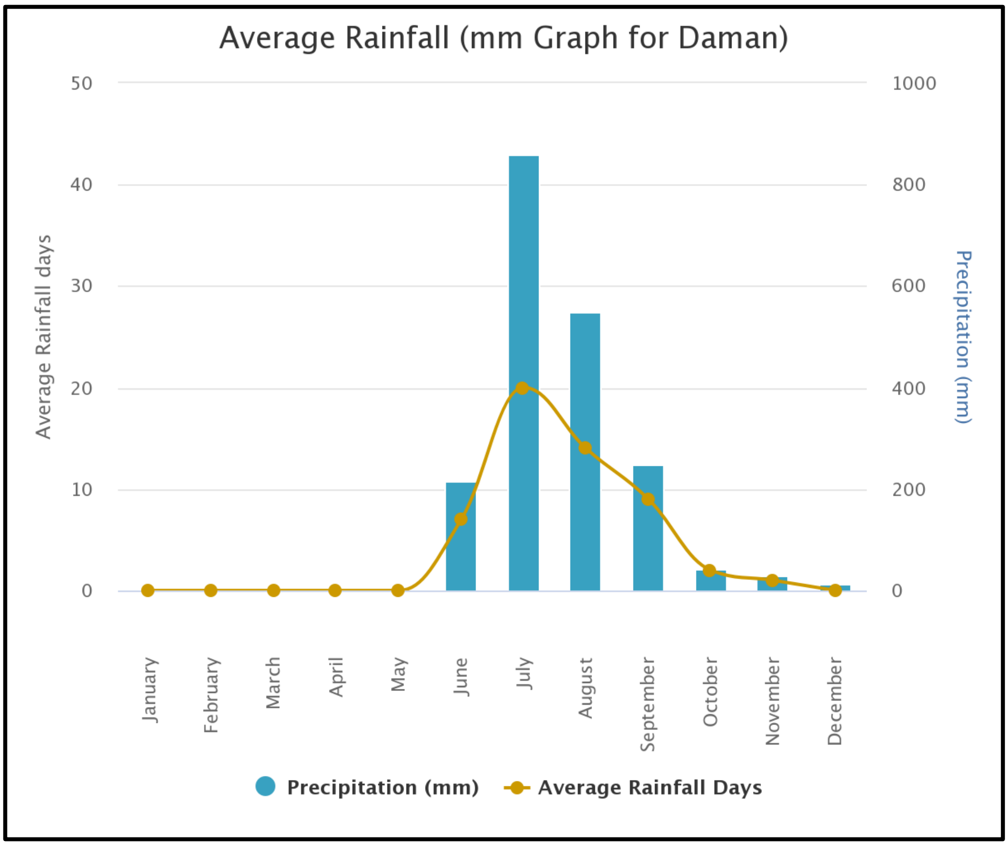



*Figure 4 Average Precipitation and Rainfall days Histograph Map*

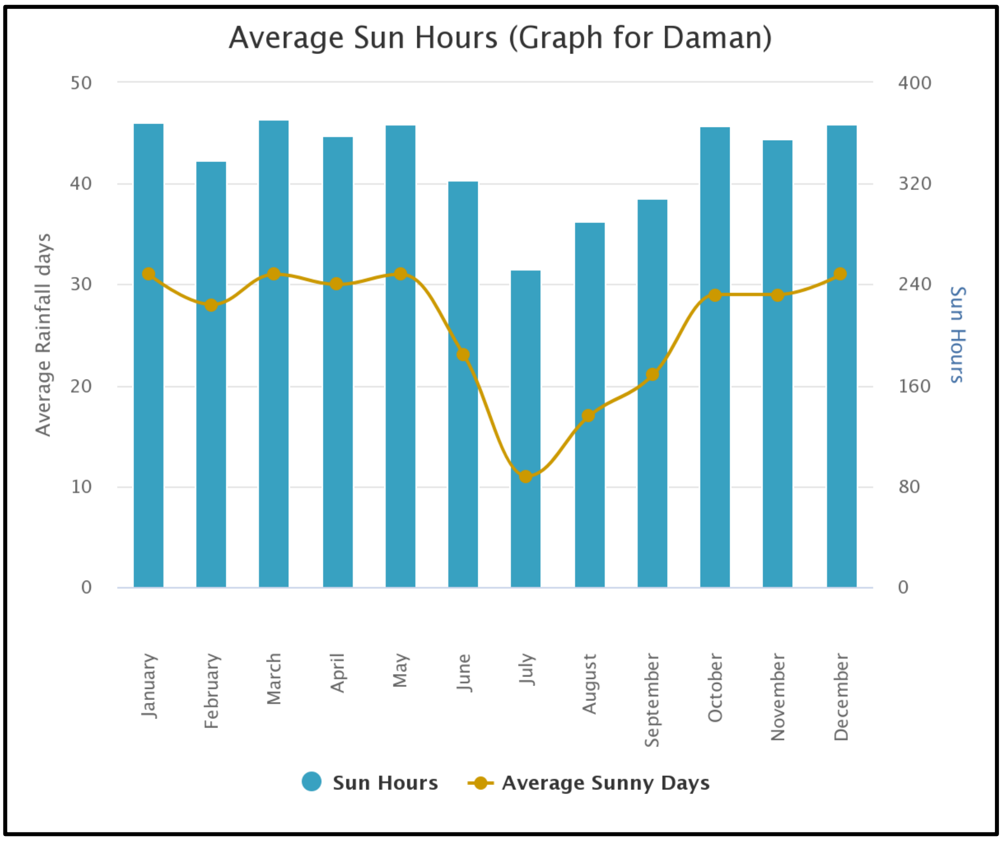



*Figure 5 Average Sun Hours Graph map of DAMAN District*

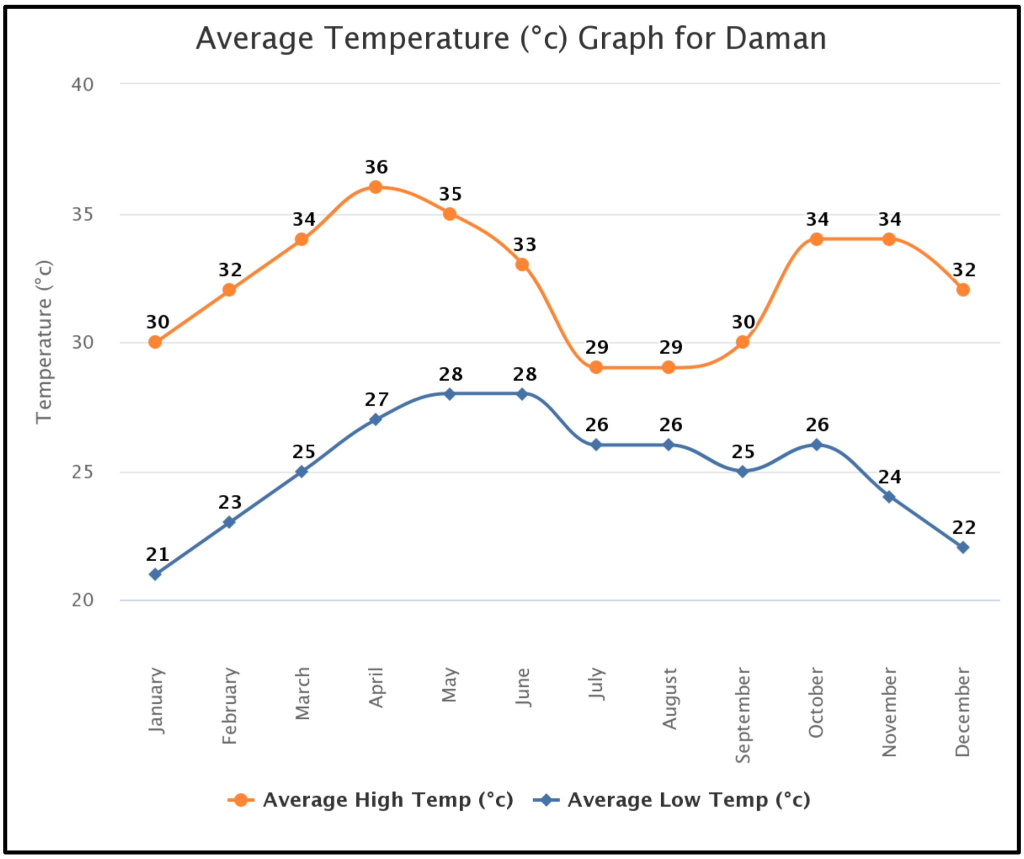



*Figure 6 Average Temperature graph map*

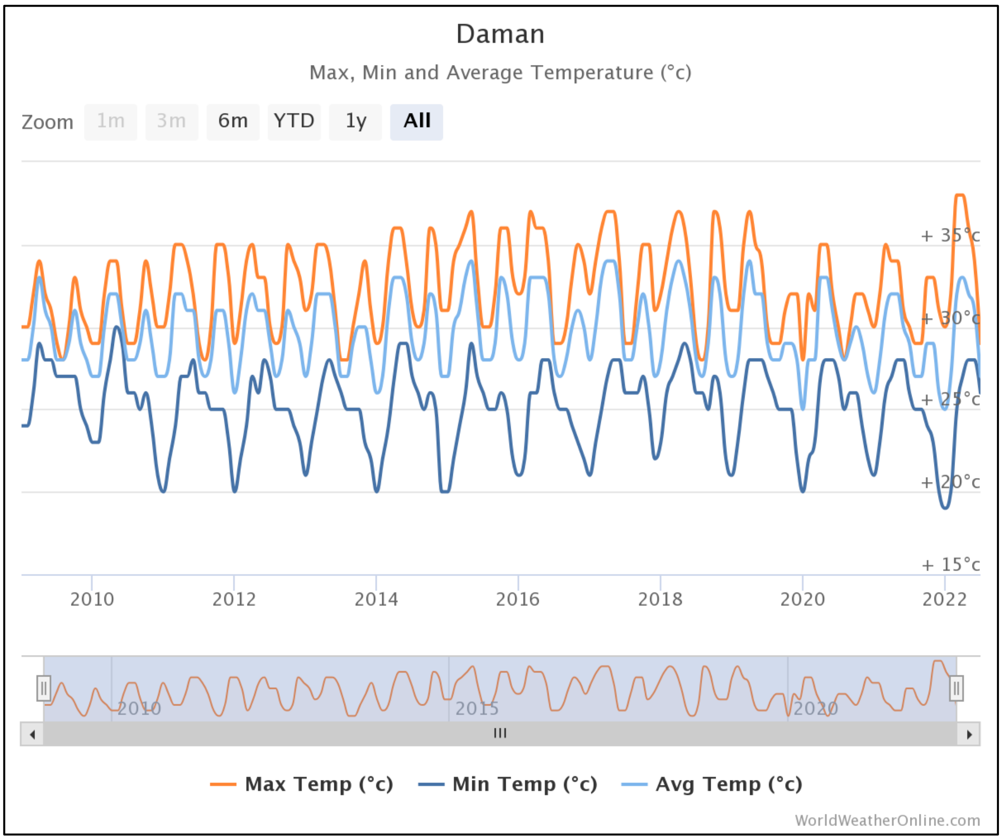



*Figure 7 Min, Max and Average Temperature Map*

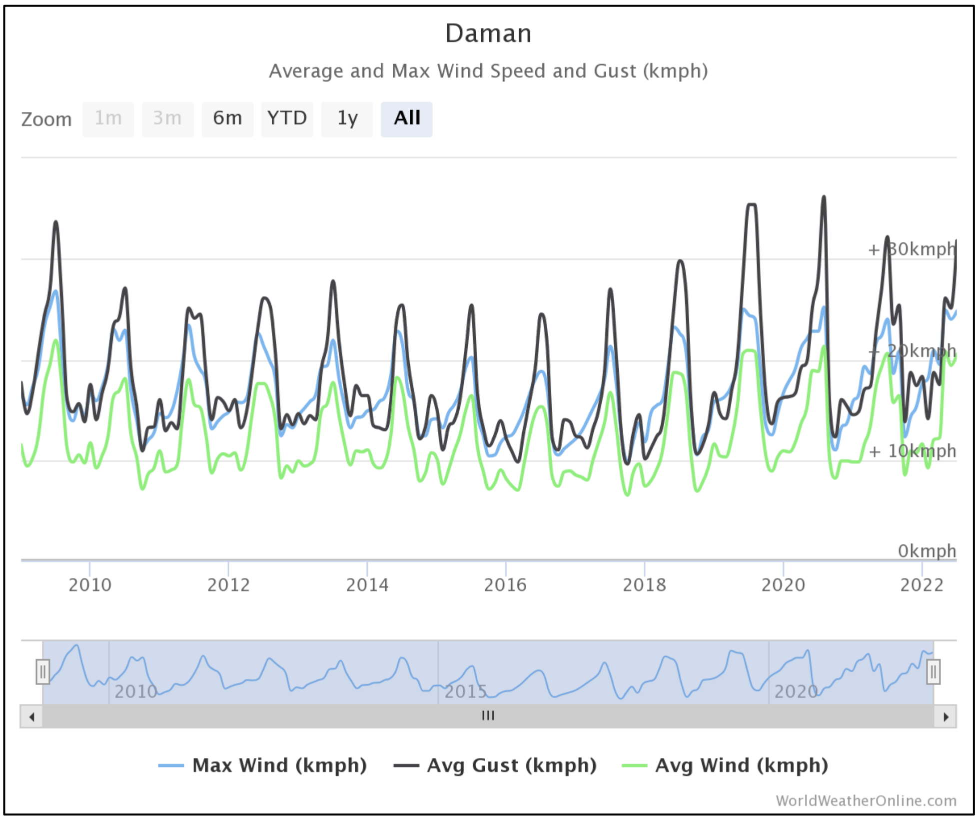



*Figure 8 Max and Average Wind Speed and Average Gust map*

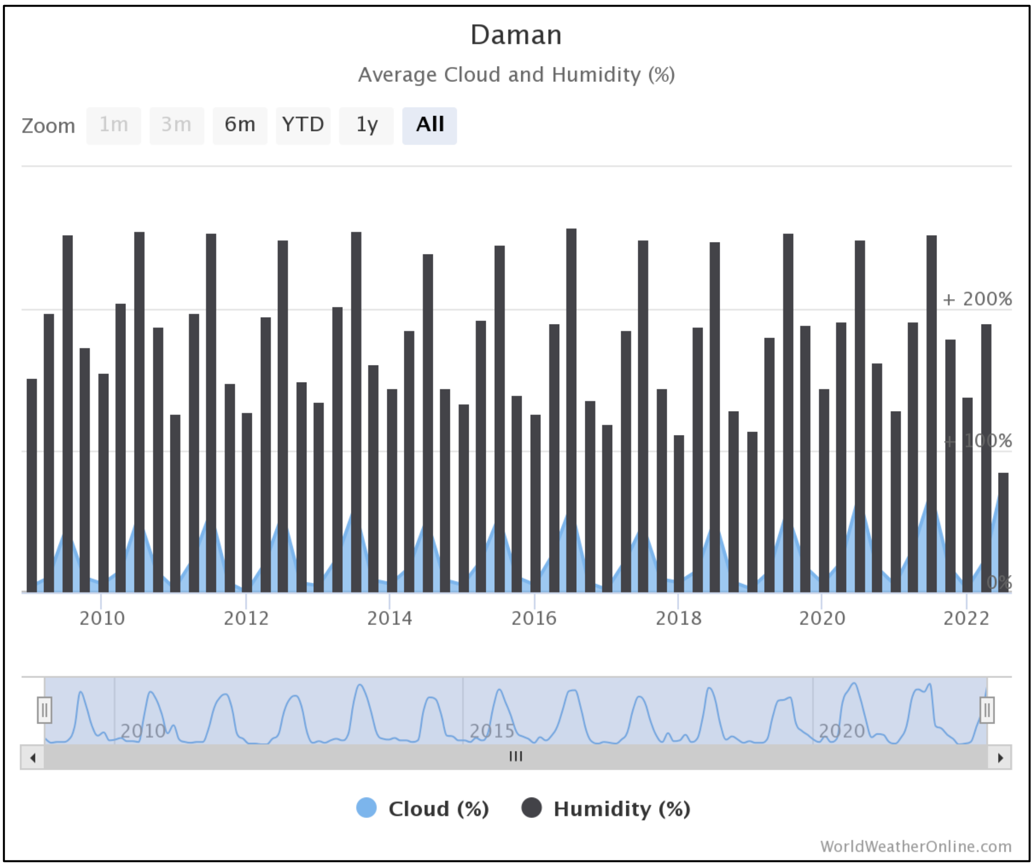



*Figure 9 Average Cloud and Humidity Map*

## 1.8 Irrigation Practices

Daman is primarily an agricultural district with paddy and pulses (red vaal) as the predominant crops. The other major crops cultivated are mango and coconut. However, due to rapid industrialization, the share of agriculture sector in employment is reducing day by day in Daman. About 81% of land holdings are with small and marginal farmers and the average size of the holdings is 0.50 ha.

Daman is having similar climatic condition like Valsad. Hence farmers are cultivating mangoes, sapota and coconuts. Horticulture crop under greenhouse, net house gives good income to farmers. However, technical knowledge and guidance may be provided to farmers by Agri. Department, for successful adoption of such method. Proper grading, sorting, packaging and processing units are also required in district as value addition to such products will enable farmers to get good prices. Dairy is the second largest economic activity after agriculture. There are 29 Milk Co-operative societies in Daman.

## 1.9 Land Use/Land Cover

The rapid urbanization and industrialization during last two decades is observed in change land use pattern of the Daman area. Concurrent groundwater development has also lead to lead to adverse negative impact on the available limited freshwater resources. Under these circumstances, it becomes important to effectively manage the available freshwater resources. For sustainable development and better management of the aquifer system, the information on existing land use pattern, groundwater development structures and hydrogeological features of the area is essential. The brief account of each of these attributes, as per available data is described as follows. The Damn district has total geographical area of 7200 hectares, comprising of Daman as main town and other 20 villages. Out of total areas of 7200ha, nearly 4 % areas is barren and uncultivated land; mostly it is marshy land normally inundated during high tides. 9% of area is urban area in the Daman, only 2% of the area covered by forest and 43% area is falls in cross cropped area (Fig. 10). Food crops, mainly Bajra, wheat and millet are as main crop are depending on rainwater and main crops are comprises Orchards, Coconut, chicku and Mango Plantations and vegetable gardens etc.

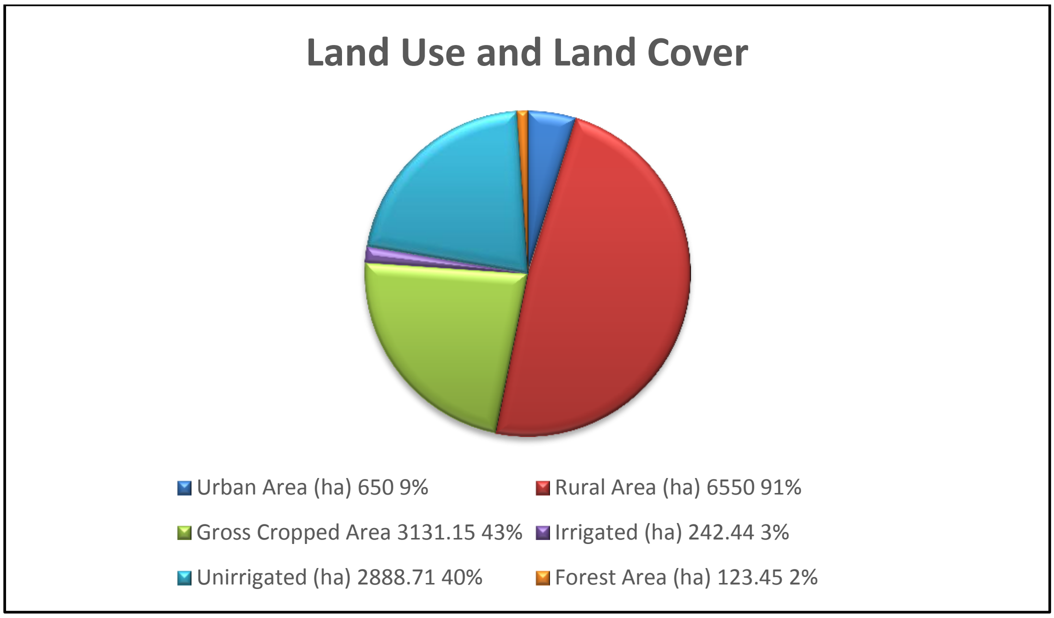



*Figure 10 Pie diagram showing Land use and Land cover Utilization*

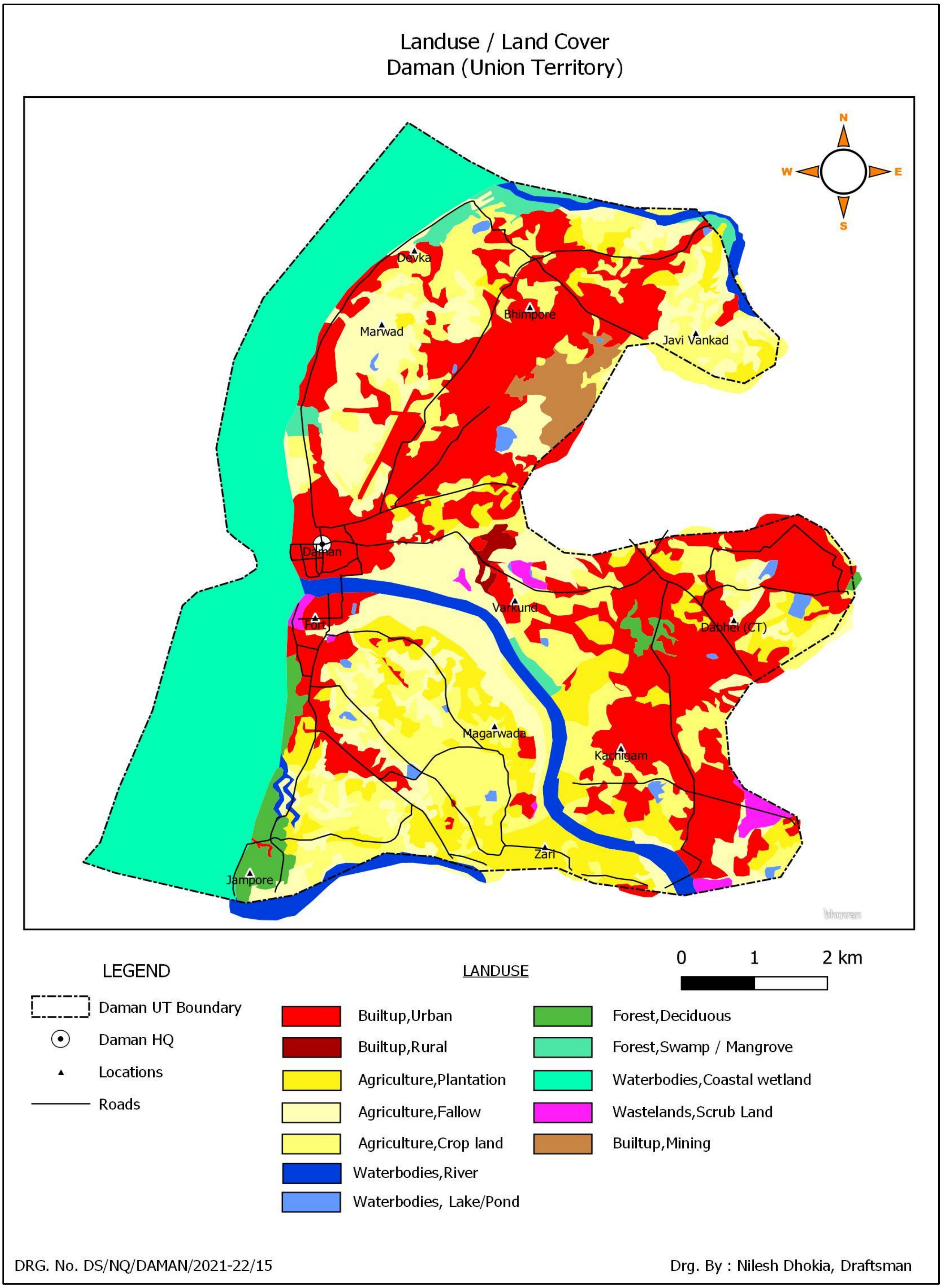



*Figure 11 Land Use Land Cover Map Of Daman District*

## 1.10 Soil Types

The soils in the area can be divided into two groups based on their origin. The soils all along the coast and the banks of the creek are alluvial soils where as in rest of the area the soils are derived from the weathering of basaltic rocks. The coastal soil, as they are deposited in saline water, is saline and alkaline with almost uniform texture which is clayey loam to silty loam. The soils are dark grey to black in color. Both pH and Electrical conductivity values are extremely high. These soils are difficult to reclaim due to higher content, low permeability, high water table and high salinity. Depending upon the degree of weathering, the basaltic soils show wide variation in texture. The first stage of weathering of basalts gives rise to light soil comprising pieces of weathered basalt (locally known as maroom). The depth of such soil varies from few cm to 50 cm. The color of the soil is dark yellowish brown in plateau, and around the hillocks, whereas the color is brownish black to black cotton in the flat valleys. The texture of the soil is medium to fine textured. They are non-calcareous with moderate water holding capacity

## 1.11 Drainage

The river Daman Ganga passing through the middle of Daman divided it in to two parts namely Moti Daman and Nani Daman. The altitude is 12 m amsl. The Kolak river flows along the northern boundary and the Kalu nadi forms the southern boundary. These three rivers flowing almost parallel to each other enter Daman from south east and follow almost westerly course. .(Figure 12)

## 1.12 Geomorphology

It has a gently undulating topography with a few isolated hillocks ranging in height from 34 to 49m amsl with the exception of 111 m high hill occupying an area of more than a sq.km towards east of village Dalwada. The general topographic gradient is towards west-northwest. (Figure 13)

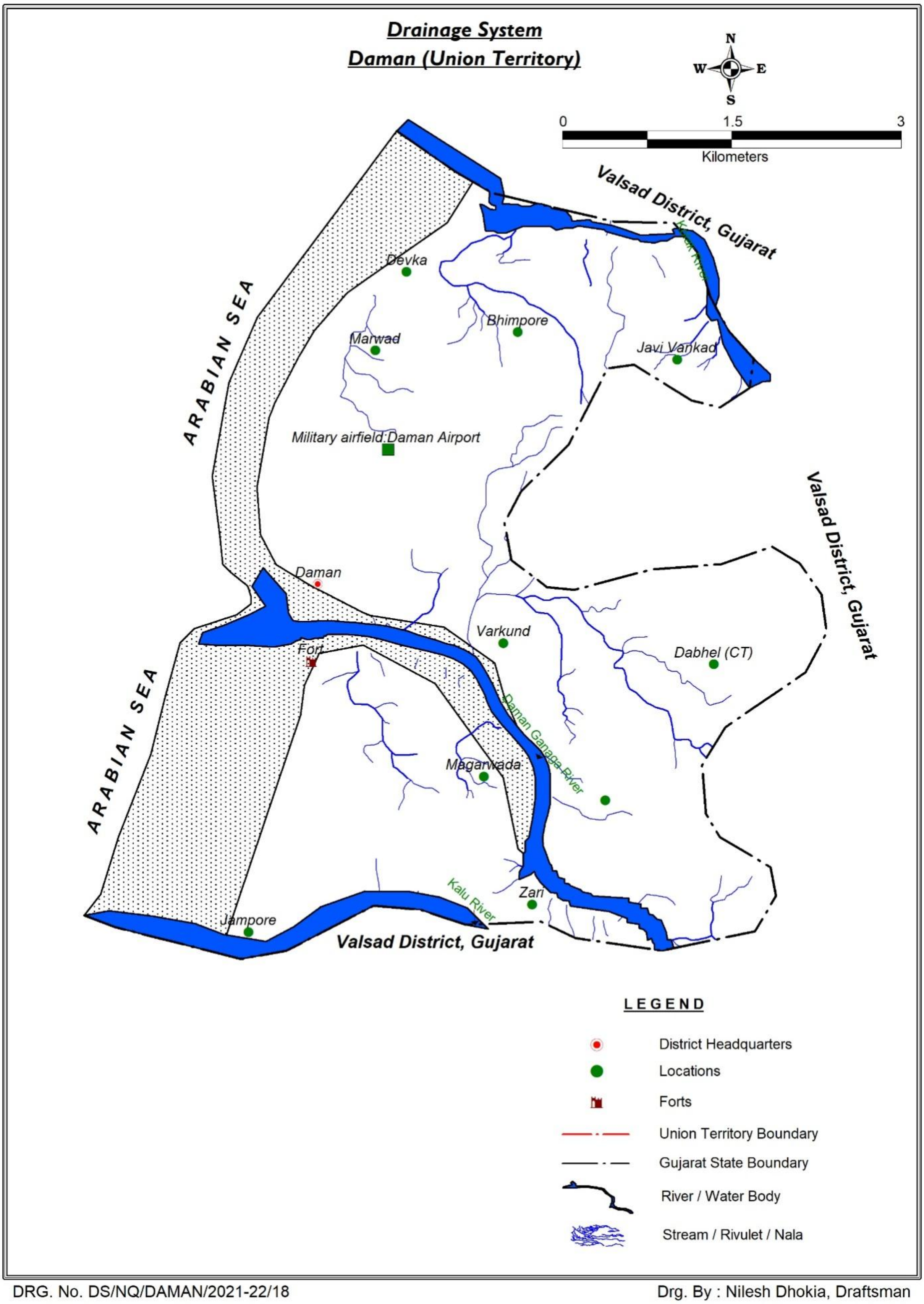



*Figure 12 Drainage System map of Daman*

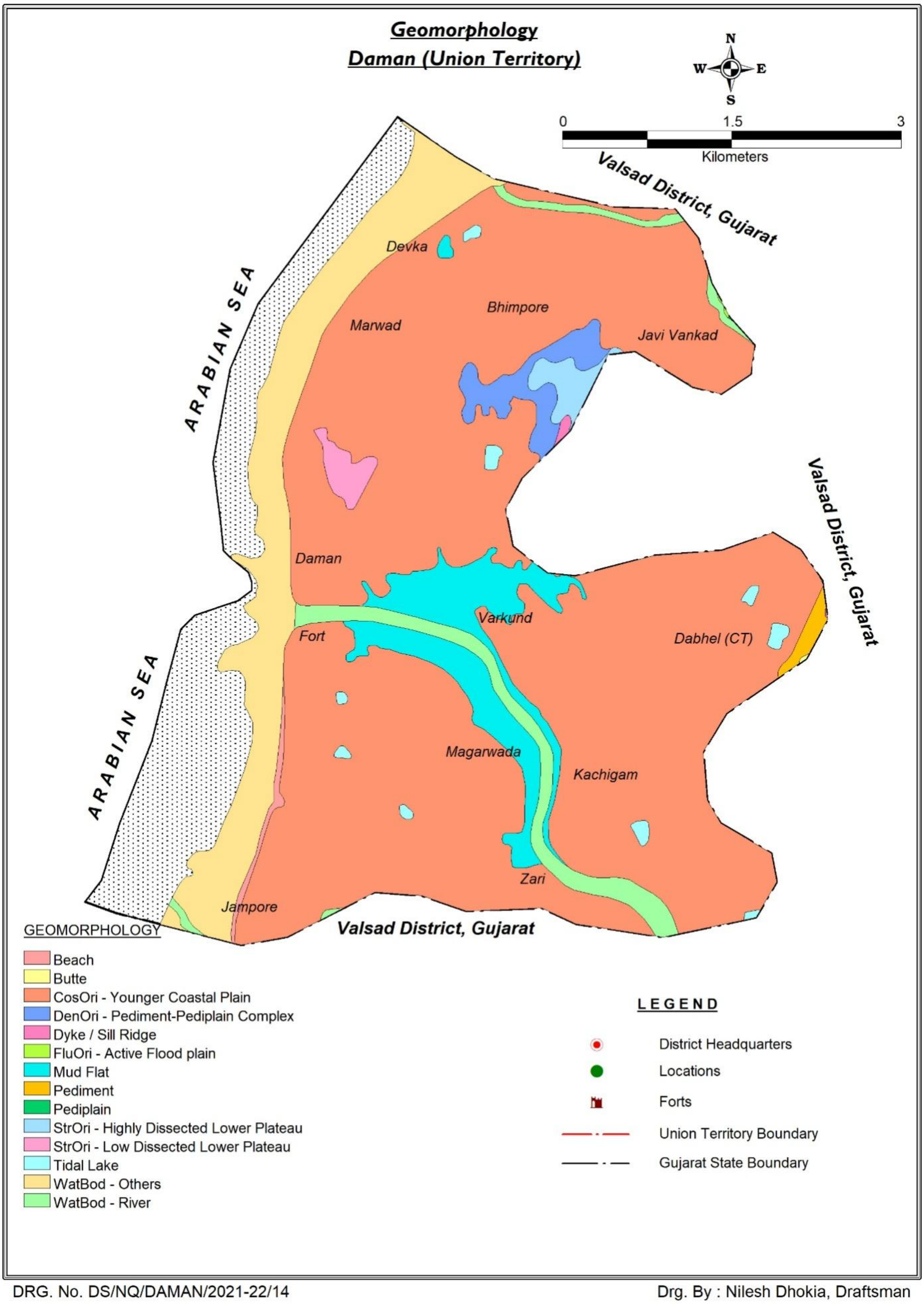



Figure 13 Geomorphological Map of Daman

# Chapter 2
# GEOLOGY

## 2.1 Introduction

Basalt is the main basement rock which occurs at variable depths in most parts of Moti Daman and also exposed at surface in the north west part of Daman namely in Marwad, Devka, Kadiya. Basaltic ridges having elevation of about 111m amsl are exposed in and around Kunta and Wankad villages. Basalt sheet rocks are exposed in river beds of Daman Ganga, Kalu and kolak rivers bordering UT of Daman. Alluvial deposits are found overlying the basalts, all along Moti Daman area and also in Dabhel and Kachigam areas having depth of 12 to 40m bgl. Alluvium deposits are river terrace type along the banks of river Daman Ganga. The basalt occurs in the form of flows comprising massive and compact basalt in the bottom and gradually passes into vesicular basalt at the top. The basalts vary in colour from dark green to pink and show different sets of joints. All the joint systems are restricted to the individual flow seldom cutting across other flows. The surface weathering is characterized by spheroidal weathering.
The stratigraphic sequence in the region is as follows:

*Table 1 Stratigraphic Sequence Of The Area*

| Age | Lithology |
|---|---|
| Recent, sub-recent | Laterite, Black-Brownish black soil, sand etc. |
| Upper Cretaceous to Lower Eocene | Basaltic lavas flows (Deccan Trap Basalt) |

## 2.2 Major formations

Deccan basalt of Cretaceous to Eocene age with terrace like alluvium is exposed in the area.
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).

Geologically, the area is occupied by basaltic lava flows of Deccan Traps, Recent alluvial deposits in the south western segment and beach sands all along the coastline. Three flows have been identified in the territory and their general lithological and petrographic characters are described below:

**Flow I**: This basal unit is exposed in the Kalai and Damanganga river sections, in the mounds and knolls north of Dundtela. It comprises massive, dark grey, fine grained basalt showing prominent jointing and spheroidal weathering.

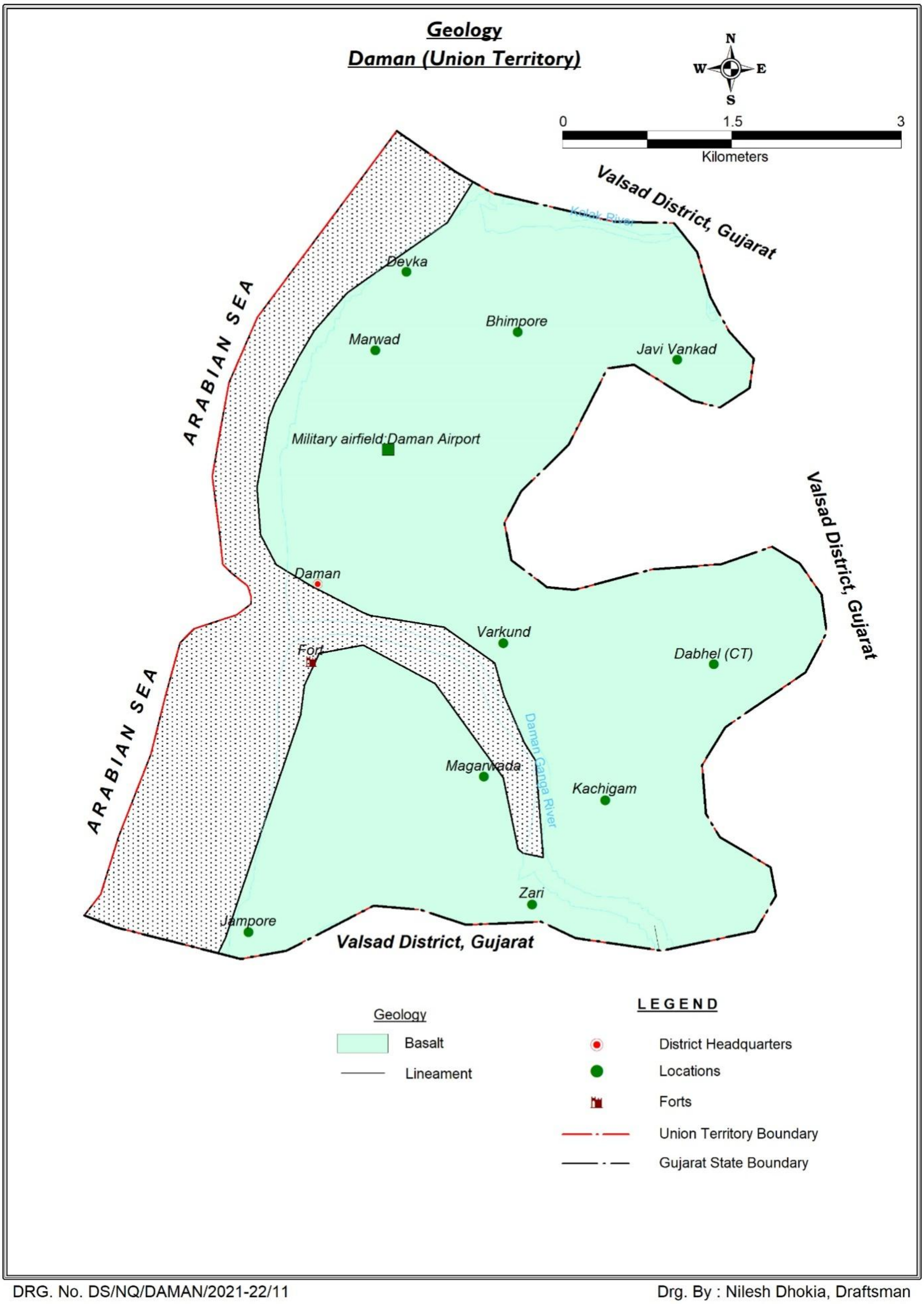



Figure 14: Geological Map of Daman

**Flow II**: It forms mounds near Devka, Dalwada and Kachigaon. It is bluish grey, medium grained basalt with amygdules or zeolite and calcite.

**Flow III**: A major portion of Daman, lying north of the river Damanganga is covered by this unit. Essentially this flow unit is greenish grey, fine grained basalt with vesicles filled with zeolite, calcite, quartz and agate. Sills and plugs intruding the flow units have been recorded. Part of the area is covered by black alluvial soil.

Major Formations in Daman are

### 2.1.1 Basalt (Deccan Traps -Hard rock)

Basalts 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 Alluvium Formation

The area along Daman-ganga River estuary and Kalu Nadi, Moti Daman part, is overlain by 10 to 18 m thick river terrace type alluvium formation.

# Chapter 3
# HYDROGEOLOGY

## 3.1 Introduction

Ground water occurs in both the basaltic and alluvial formations. In Moti Daman area and Warkund, Dabhel and Kachigam areas of Nani Daman, alluvium forms the unconfined aquifer system. However, in Nani Daman area this aquifer has become de-saturated and do not sustain irrigation/domestic requirement.

The area of Daman is underlain by the Cretaceous-Eocene age Deccan Trap formation, which occur as main basement rocks. The area along Daman Ganga River estuary and Kalu Nadi, Moti Daman part, is overlain by 10 to 18 m thick river terrace type alluvium formation. Like Diu Island, Daman area also has shallow groundwater condition with brackish to saline ground water is observed below nearly 19 m depth. Daman area gets piped water supply from Daman ganga Weir projects from in land Vapi area of Gujarat State and for irrigation, canal water is available. Taking into consideration of shallow water level condition and more or less, stable groundwater condition and predominately semi urban and urban types habitat system, roof top rainwater harvesting is suggested for augmenting the availability of water for supply.

### 3.1.1 Weathered and Fractured Zone

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 19 m and the fractured basalts beneath the weathered mantle have given rise to water table aquifers down to 19 m bgl. The depth of water level in the area ranges from 1.67 m bgl to 7.95 bgl during the pre-monsoon period (2021) while during the post monsoon (2021) the water level ranges from 1.3 to 4.4m bgl.

The yield of the wells in both the basaltic and the alluvial formations are moderate, varying from 30 $m^3$/day to 300$m^3$/day

### 3.1.2 Fractured and massive Zone

Dug wells and dug-cum bore wells within the depth range of 6-50 mbgl are constructed. The depth of water level in the zone ranges from 7 to 16 m bgl during pre-monsoon year 2021.

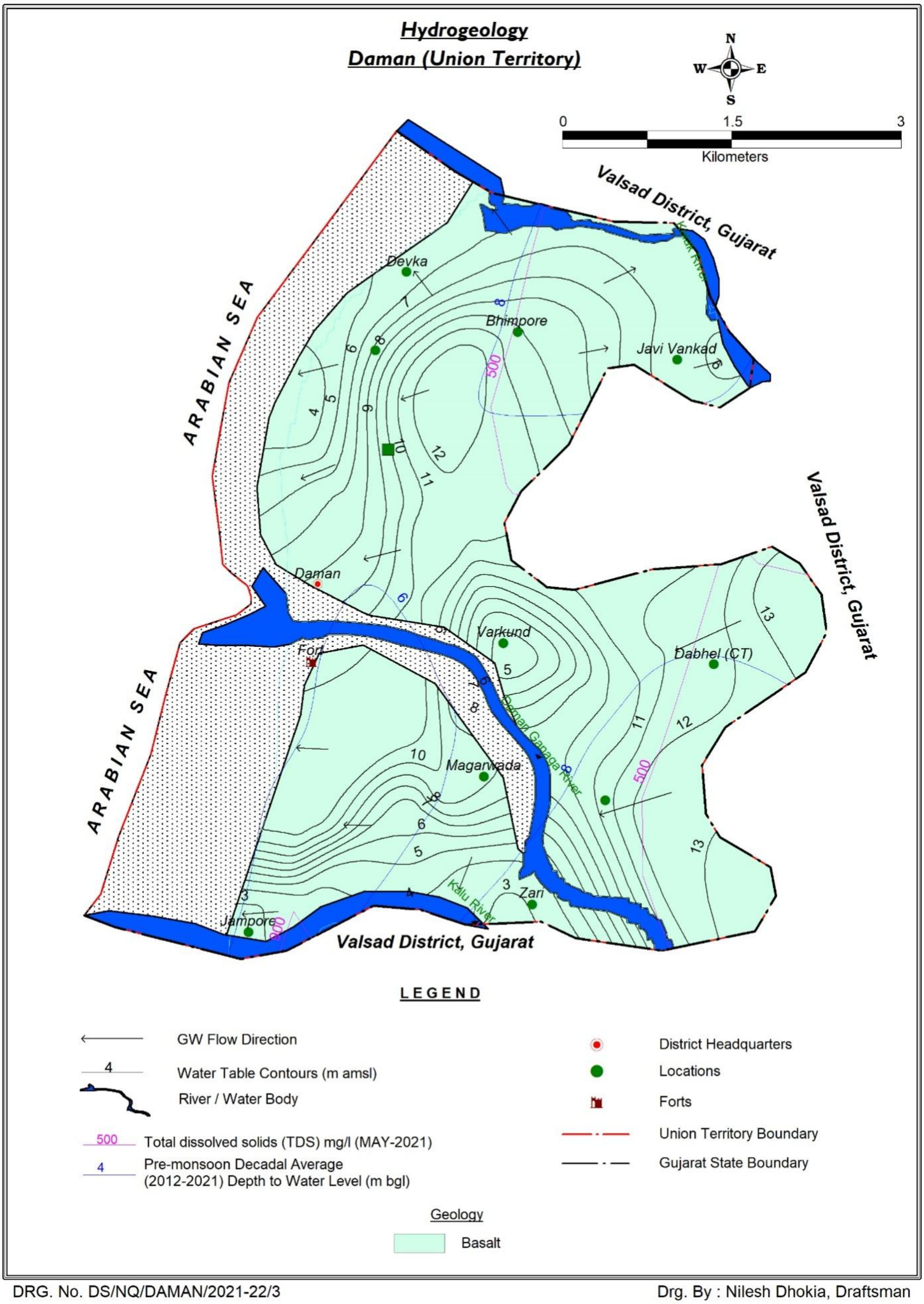



*Figure 15 Hydrogeology of Daman District*

## 3.2 Aquifer System

Two major aquifer systems exist in district up to 50 meter reported depth. Major aquifer bearing formations are weathered/fractured and fractured/massive basalt.

### 3.2.1 Shallow Aquifer

Weathered/fractured basalt is of unconfined nature and ranges from 0 to 19 m bgl. Thickness of this aquifer is 6 to 19 meter. It lies in almost entire district. Quality of water is fresh. In some areas alluvium aquifer also exit but it is in very limited in extent.

### 3.2.2 Deeper Aquifer

Fractured/Massive Basalt layer behaves as confined/Semi Confined aquifer and ranges from 6 to the explored depth of 50 mbgl. Water is fresh to saline. Total thickness of this aquifer varies from 0 to 33 meter.

## 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. The hydro- geological parameters are hidden in the field test data and their identification is possible using the available of physically plausible models suitable for the prevailing field circumstances. Evaluation of aquifer parameters, namely, transmissivity (T), and storage coefficient (S), from aquifer test data has been a continual field research. Several conventional and computer-based methods are available for analyzing (Kruseman and De Ridder, 1991). Due to a different set of assumptions on each method, the hydrogeological parameter estimates are quite different from each other. Efforts have been made to develop simple calculation methods for aquifer parameters since Cooper and Jacob (1946) proposed their simple and widely used method. The main limitation of this method is that the dimensionless time factor (u) should be less than 0.01. However, according to Singh (2000) it cannot be applied to estimate aquifer parameters when most of the data have $u > 0.01$. On the other hand, the curve-matching method proposed by Theis (Lohman, 1972) involves much subjectivity in judging the best match between the observed and theoretical curves, especially when only early drawdowns are considered (Singh. 2000). Furthermore, Sen (1987) proposed a unique storage coefficient determination approach for large diameter wells which experience steady or quasi-steady groundwater flow conditions. The application of the method does not require any complicated mathematical procedure as in the classical-type curve matching procedures. This method becomes very effective when it is coupled with the Theim (1906) formula. Singh (2000) proposed a simple method for explicit determination of confined aquifer parameters from early drawdown data. This method makes use of a few early drawdown data at an observation well and yields accurate values of confined aquifer parameters with no curve matching requirement. The method converges to the Cooper-Jacob method for late drawdown data. Application of the method on published data sets shows that the estimates of the aquifer parameters using only a few initial drawdowns are as good as those obtained by Theis curve matching when all data, including the late drawdowns (u < 0.01), are used. Singh (200 la) has also proposed another robust optimization method for the calculation of aquifer parameters from shorter duration aquifer test data when there is an impervious boundary. Another simple method that uses the temporal derivative of drawdowns was proposed for the explicit evaluation of confined aquifer parameters utilizing the early drawdowns (Singh, 2001b). The method uses an analytical approach to calculate the temporal derivative of drawdowns. The method can analyze the drawdown data on multiple observation wells taken together to obtain averaged aquifer parameters. The method was applied to published data sets and results were com-pared with the traditional methods already available in the literature. Singh (2002) proposed another simple method for the identification of confined aquifer parameters and effective distance to either an impermeable boundary or a recharge from the drawdown observed at an observation well due to pumping at a constant rate.

## 3.4 Groundwater Scenario

Systematic and regular monitoring of groundwater levels brings out the changes taking place in the groundwater regime. The maps so generated are of immense help 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 unfavourable 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 - 20$^{th}$ to 30$^{th}$ (water level of pre-monsoon period).
II. August - 20$^{th}$ to 30$^{th}$ (peak monsoon water level).
III. November - 1$^{st}$ to 10$^{th}$ (water levels of post-monsoon period).
IV. January - 1$^{st}$ to 10$^{th}$ (the recession stage of water level).

Water level data of the ground water monitoring wells collected during the year 2021-22 has been utilized to prepare various maps showing depth to water level and fluctuation of water level. Depth to water level maps are useful in dealing with problems of water logging and artificial recharge, where the relative position of waterlevel 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 inthe 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 in m MSL
V. Groundwater level trend

### 3.4.1 Depth to water level

The depth of water level in the Shallow aquifer ranges from 1.67 m bgl (Dabhel) to 7.95 bgl (Pariyari) during the pre-monsoon period (2021) while during the post monsoon (2021) the water level ranges from 1.3 (Dabhel) to 4.4m bgl (Nani Vankad). 100 % of the stations showing water level less than 10 m (Figure.16 ).

Depth to water level in the deeper aquifer (Reported) ranged from 7 (Jampore Beach) to 16 m bgl(Kunta HP PP) during pre-monsoon period (2021) and 7.0 m (Jani Vankad) to 17 mbgl (Kunta HP PP) during post-monsoon period (2021). About 55% of the station showing water level more than 10m for deeper aquifer (Reported water level) (Figure.17).

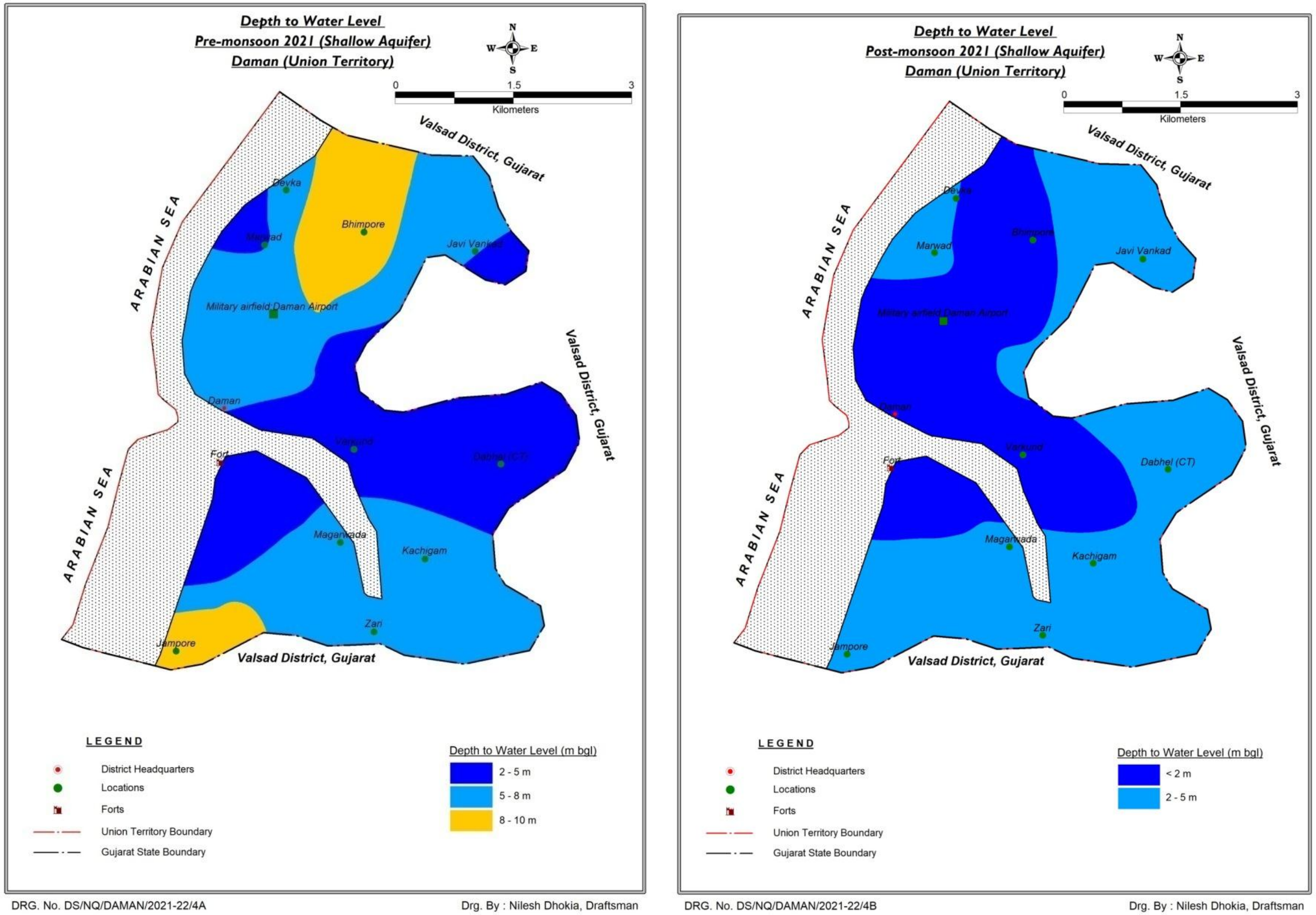



*Figure 16 Depth to water level map Pre-monsoon 2021(Left) and Post-monsoon 2021(Right)of Shallow Aquifer*

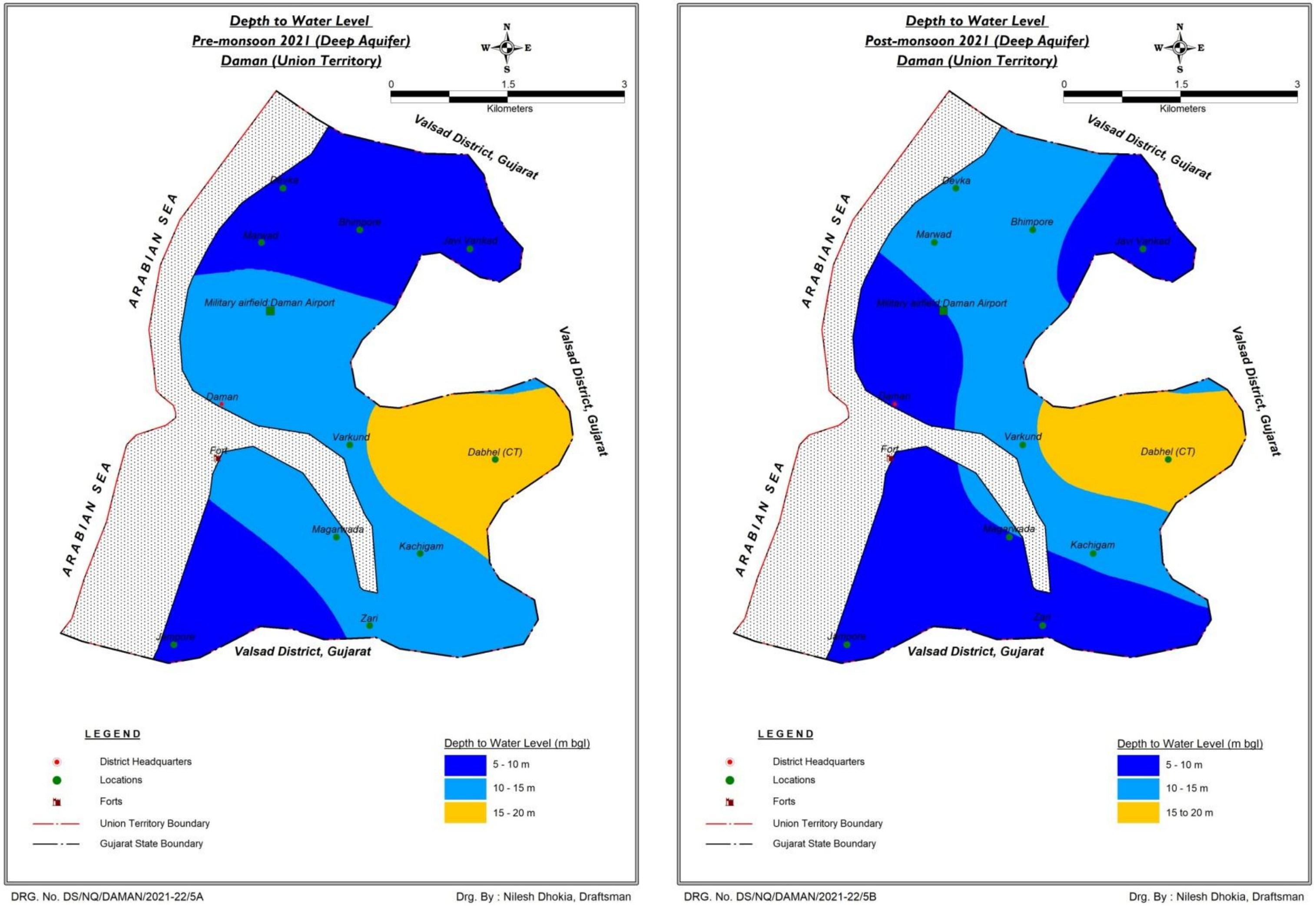



*Figure 17 Depth to water level (Reported) map Pre-monsoon 2021(Left) and Post-monsoon 2021(Right)of Deeper Aquifer*

### 3.4.2 Decadal Average Depth to Water Level

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 tubewells/borewells and for irrigation and industrial purposes. The problem of groundwater depletion is an alarming issue for most parts of India (Asoka et al., 2017; Dhillon et al., 2019; Fishman et al., 2011; Malik and Bhagwat, 2021; Mishra et al., 2018; Panda et al., 2012; Rodell et al., 2009; Sarkar et al., 2020; Sidhu et al., 2021; Singh et al., 2017) and worldwide (Arfanuzzaman and Atiq Rahman, 2017; Chen et al., 2014; Schmidt et al., 2006; Wada, 2016). A regional-scale study on groundwater depletion using GRACE showed that 109 $km^3$ of groundwater had been lost across India's northern states, such as Punjab, Haryana, and Rajasthan, from 2002 to 2008 (Rodell et al., 2009). Water levels in Punjab, particularly in central and southern regions (also known as Malwa region), have been facing severe decline for the past 20 years (Dhillon et al., 2019; Kumar et al., 2018a; Sidhu et al., 2021). Therefore, a study on the spatio-temporal scenario of groundwater resources and estimation of the long-term groundwater levels trend is essential for groundwater resource management.

The trend analysis using statistical techniques has become popular in the last few decades, especially to understand the hydro-climatic time-series' temporal patterns (Kumar et al., 2019; Suryavanshi et al., 2014). The study of groundwater level trends provides better knowledge of the long-term behaviour of hydraulic heads (Le Brocque et al., 2018) and, thus, proper management of irrigational activities (Kshetrimayum and Bajpai, 2012). Several studies around the world have been carried out on trend analysis of groundwater data (Chaudhuri and Ale, 2014; Hodgkins et al., 2017; Hoque et al., 2007; Rahman et al., 2017; Shamsudduha et al., 2009; Tabari et al., 2012). In the Indian context, numerous prior studies on trends of groundwater fluctuation are also available in the literature (Anand et al., 2020; S. Kumar et al., 2018b; Panda et al., 2012; Pathak and Dodamani, 2019; Singh et al., 2015; Singh and Kasana, 2017; Sishodia et al., 2016; Thakur and Thomas, 2011). Lack of regular and reliable data has been the major constraint for the detailed assessment of groundwater, particularly in developing countries (Machiwal and Jha, 2014; Patle et al., 2015). Moreover, data for groundwater is collected from many wells and may result in significantly mixed results for trend or fluctuation analyses. Therefore, clustering or grouping the wells based on similar characteristics may help draw decisive conclusions.

Decadal depth to water level is observed from the period of year 2012 to 2021 and presented in Fig. 18 for pre- monsoon period and in Fig. 19 for the period of post-monsoon period. Range of decadal average depth to water is shown in Table 2.

*Table 2 Decadal Depth to Water level range of Shallow aquifer*

| S.N. | Aquifer | Range (mbgl) | Period |
|---|---|---|---|
| 1 | Shallow | 3.42 – 9.30 | Pre-monsoon 2012-21 |
| 2 | Shallow | 1.09 – 6.10 | Post-monsoon 2012-21 |

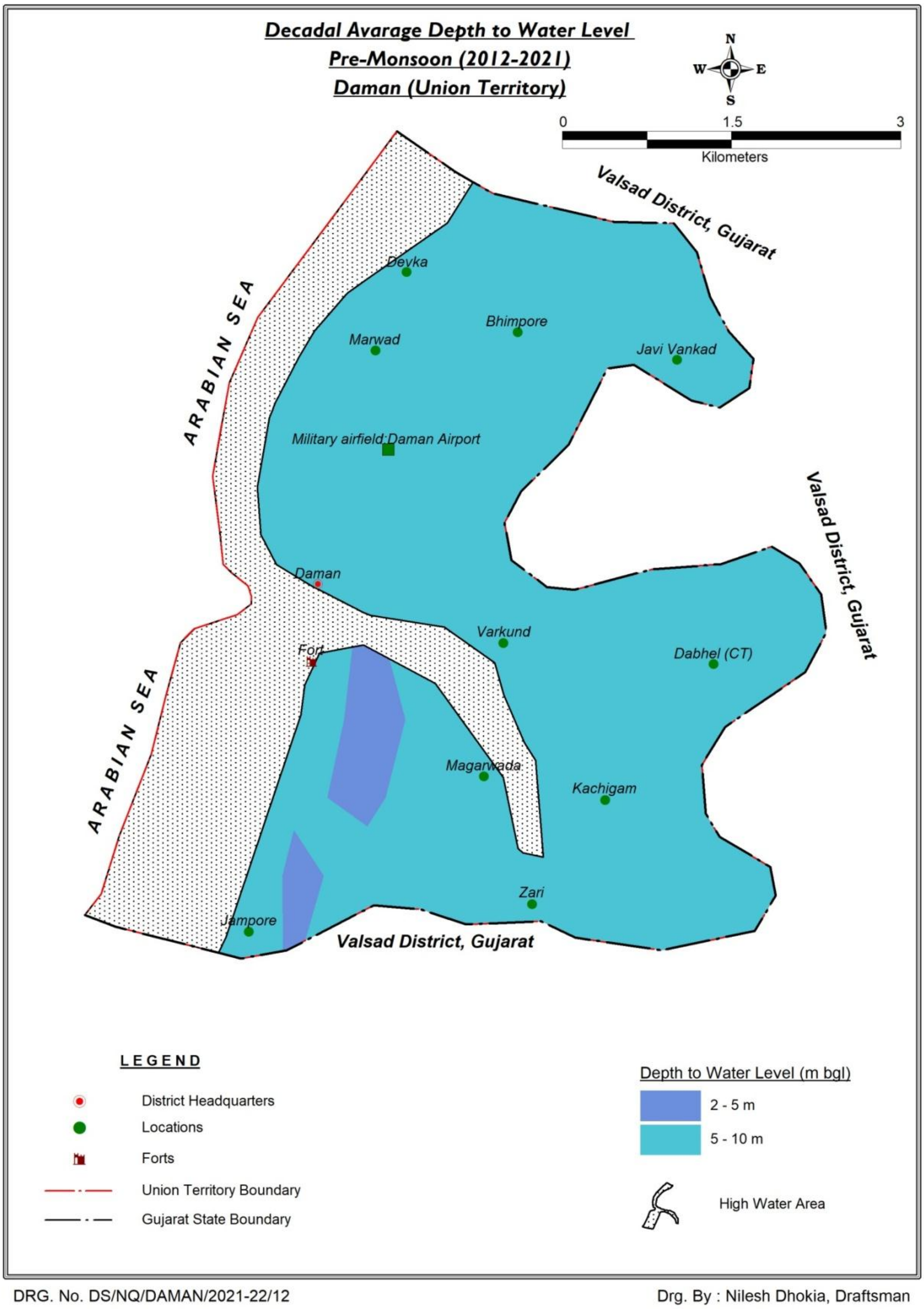



*Figure 18 Decadal Average Depth to Water level (Pre-monsoon 2012-21)*

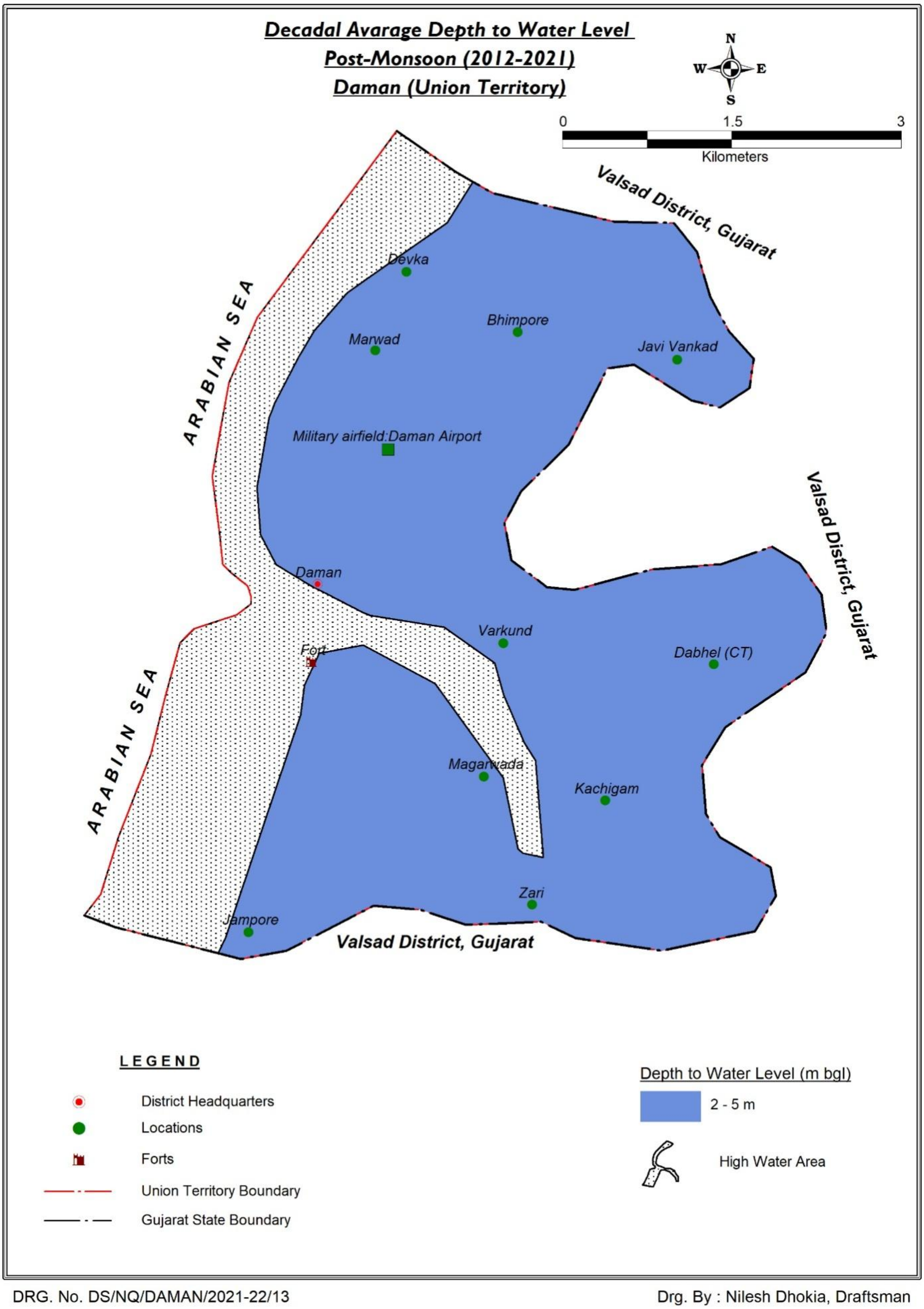



*Figure 19 Decadal Average Depth to Water level (Post-monsoon 2012-21)*

### 3.4.3 Water table fluctuation (May 2021 & November 2021)

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.

In major parts of district water level rises from zero to more than 4 meters. Highest rise is observed in north eastern part of the district whereas south western part indicated lowest rise in water level (Fig. 20).

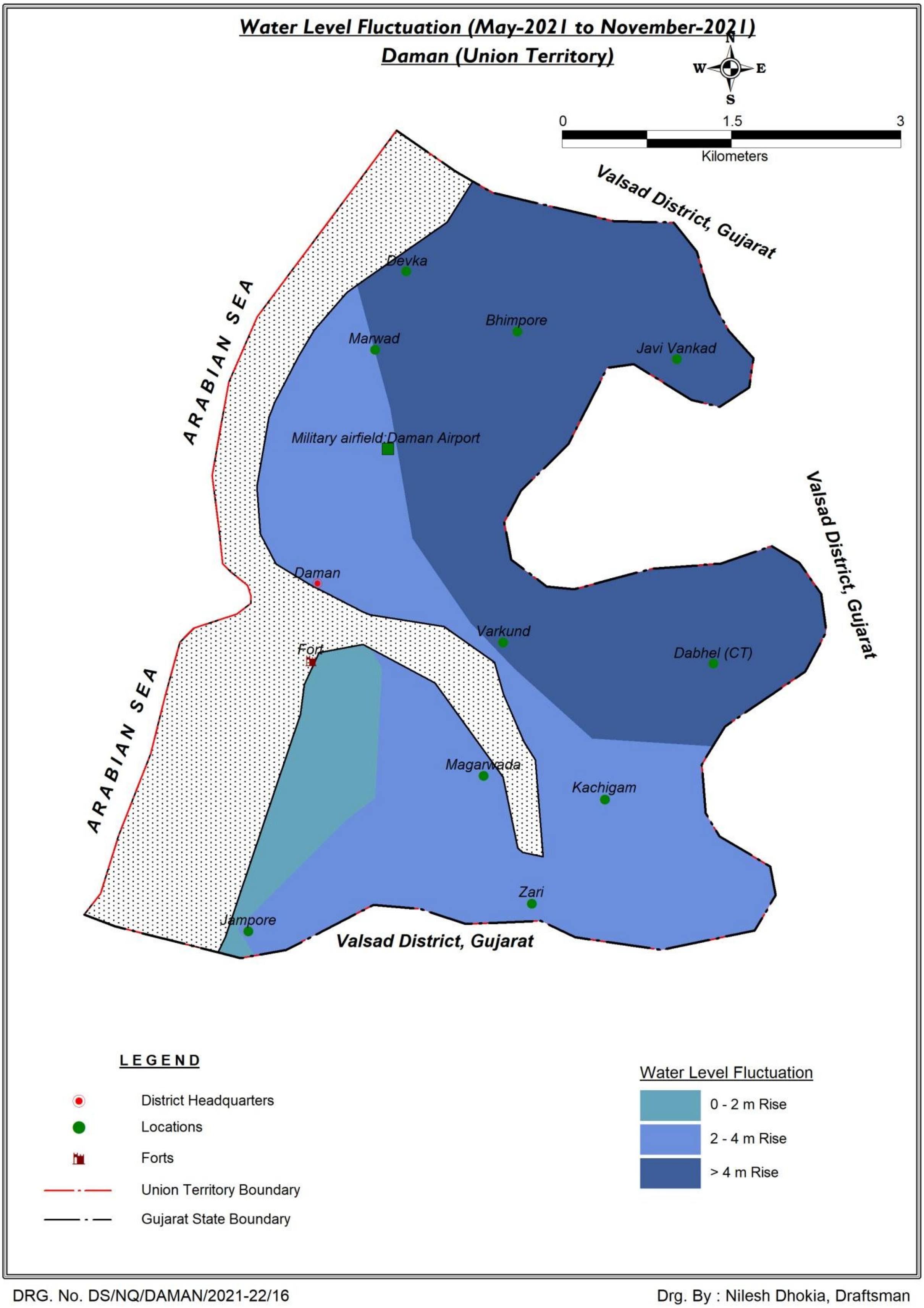


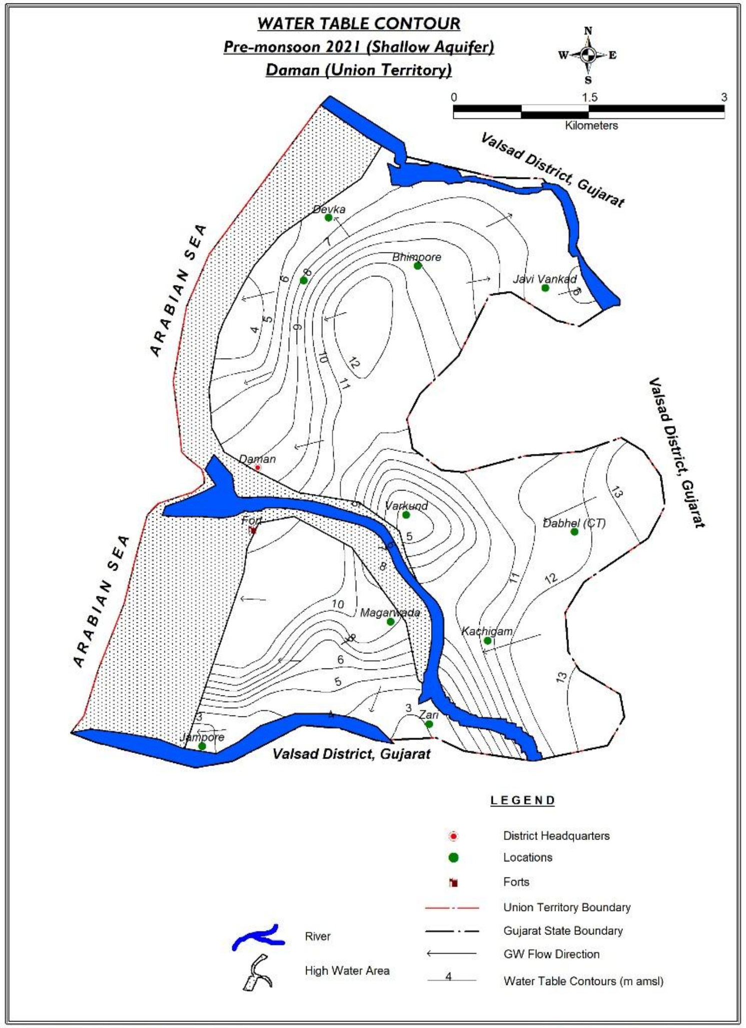

Figure 20 *Pre vs Post Monsoon 2019 Water level fluctuation Map*

### 3.4.4 Water table (in m Mean sea level)

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 show 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.

Water table with reference to mean sea level (MSL) is presented in Fig. 21 for the period of May 2021 separately in shallow and deeper Aquifer to determine the groundwater flow directions in the area. In general groundwater is flowing in all direction from central elevated land at northern part of area (Fig. 21.) whereas in the southern part groundwater flows towards south in shallow aquifer. In Deeper aquifer groundwater flow direction in general from land to sea coast (Fig. 21).

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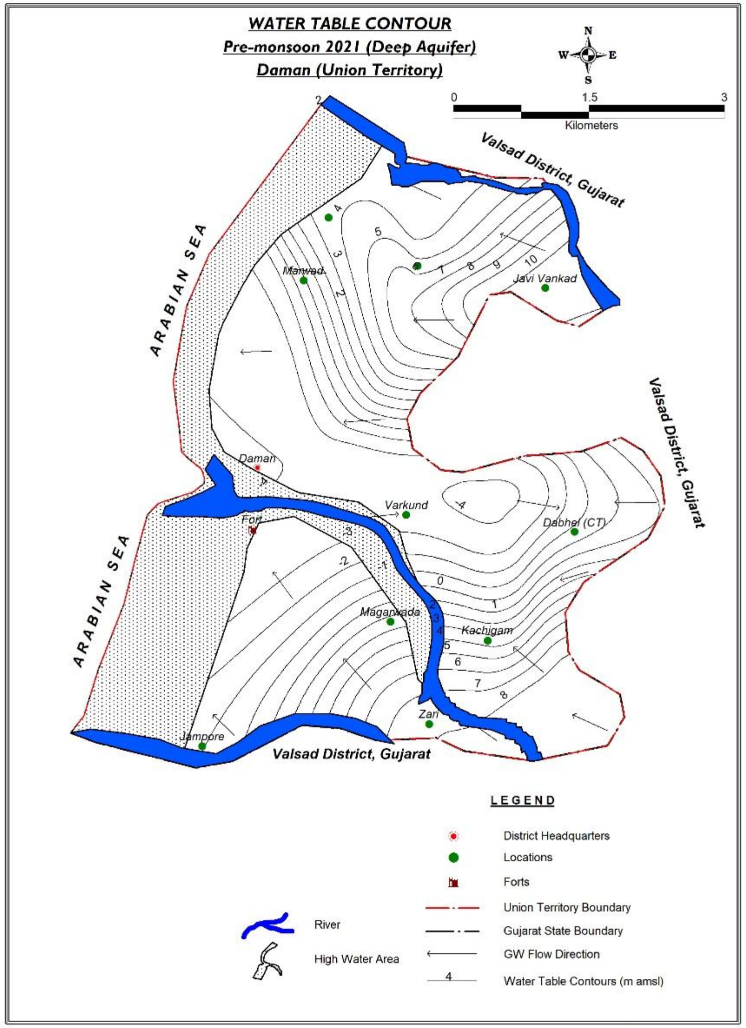


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*Figure 21 Water table contour with flow direction map of Daman District of Shallow Aquifer (Left) and Deeper Aquifer (Right) during Pre-Monsoon 2021*

### 3.4.5 Water Level Trend

Analysis of the long-term groundwater level trend for 10 years (2012-2021) of the district observed both rise and fall in groundwater level. Long term rise in water level during the post-monsoon period ranged from 0.09 (Ambawadi) to 0.28 (Morwad) m/yr while the fall reported is -0.05 (Dalwada) m/yr to -0.90 m/yr in Dabhel (Post Monsoon). The highest rise was recorded is 0.24 m/yr at Daman while the highest fall was recorded is -0.73 m/yr at Dabhel Village (Pre-monsoon). The long term water level fluctuation for the Pre monsoon period reveals that rise in water level ranged from 0.02 to 0.24 m/year and fall -0.21 to -0.73 m/year.

Table 3 Water level trend for Daman 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 | Ambawadi | Daman | Daman | 2012-21 | 0.12 | 0.095 | 0.07 | Rise |
| 2 | Dabhel | Daman | Daman | 2012-21 | -0.73 | -0.90 | -0.33 | Significant Fall |
| 3 | Daman Location | Daman | Daman | 2012-21 | 0.24 | 0.24 | 0.32 | Significant Rise |
| 4 | Jempore | Daman | Daman | 2012-21 | 0.02 | 0.11 | 0.07 | Rise |
| 5 | Morwad | Daman | Daman | 2012-21 | -0.50 | 0.28 | -0.01 | Fall |
| 6 | Dalwada | Daman | Daman | 2012-21 | -0.21 | -0.05 | -0.12 | Fall |
| 7 | Khariwad daman | Daman | Daman | 2012-21 | -0.44 | -0.23 | -0.31 | Significant Fall |
| 8 | Warkund | Daman | Daman | 2012-21 | 0.13 | 0.16 | 0.15 | Significant Rise |

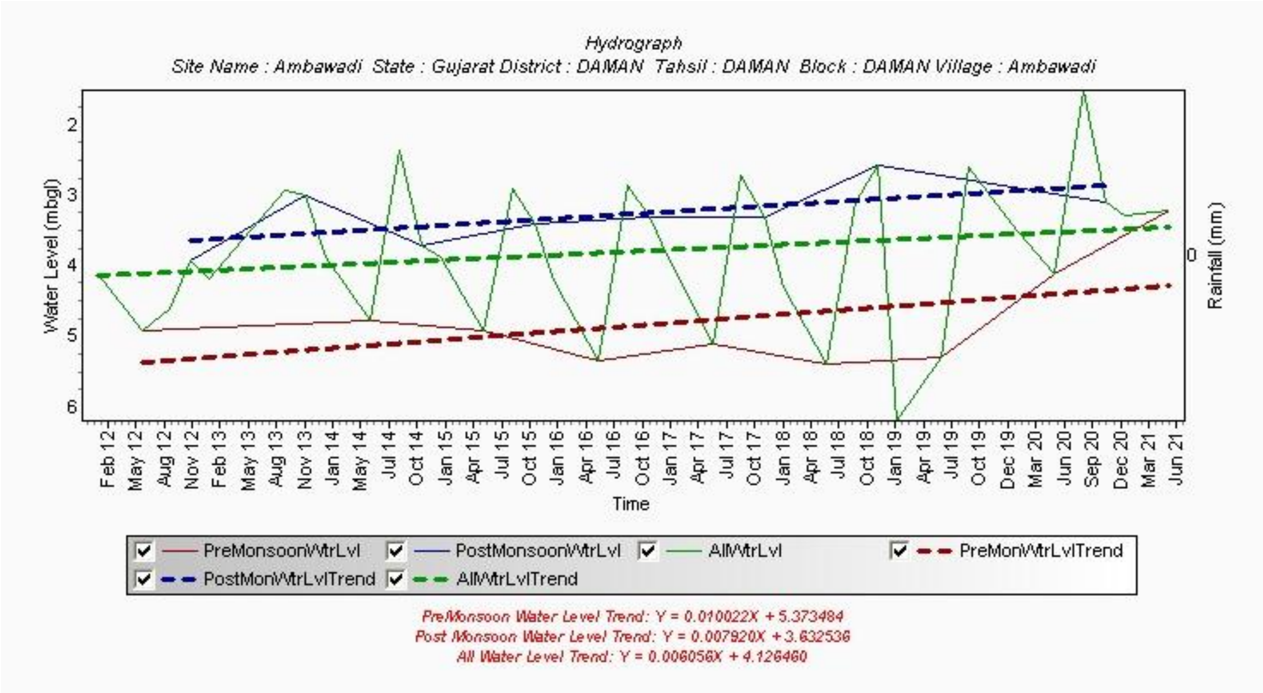


*Figure 22 Hydrograph of Ambawadi village of Daman District*

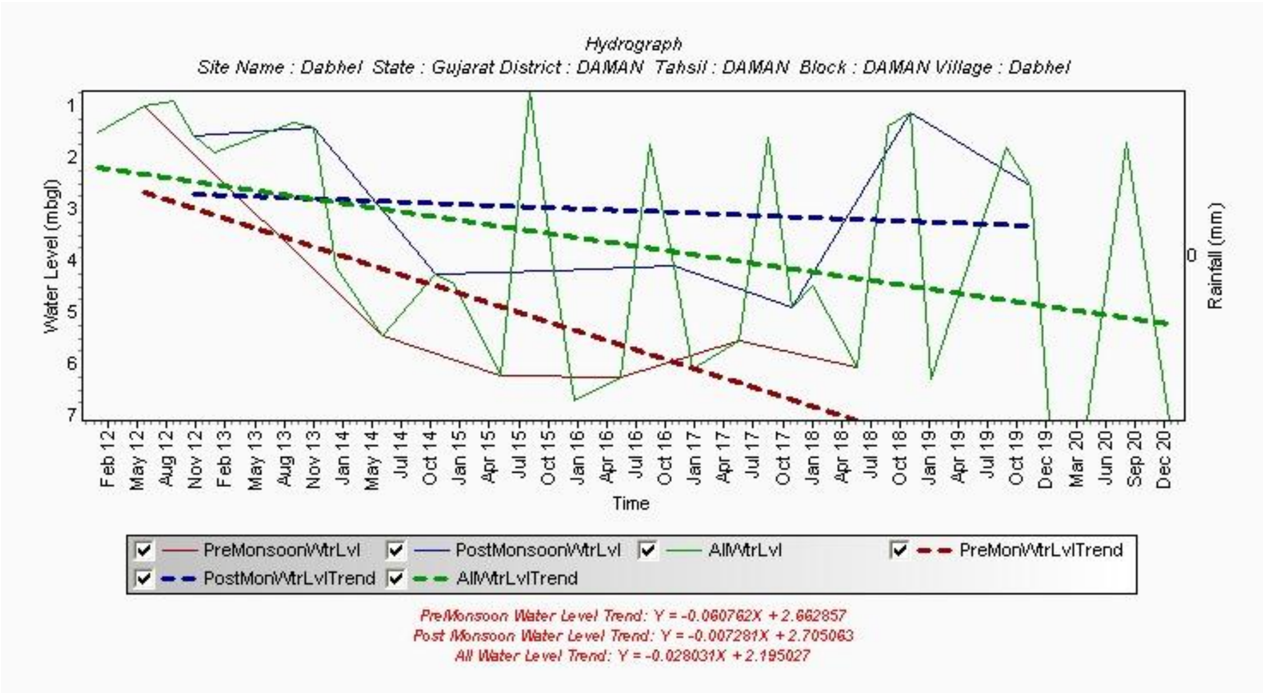


*Figure 23 Hydrograph of Dabhel village of Daman District*

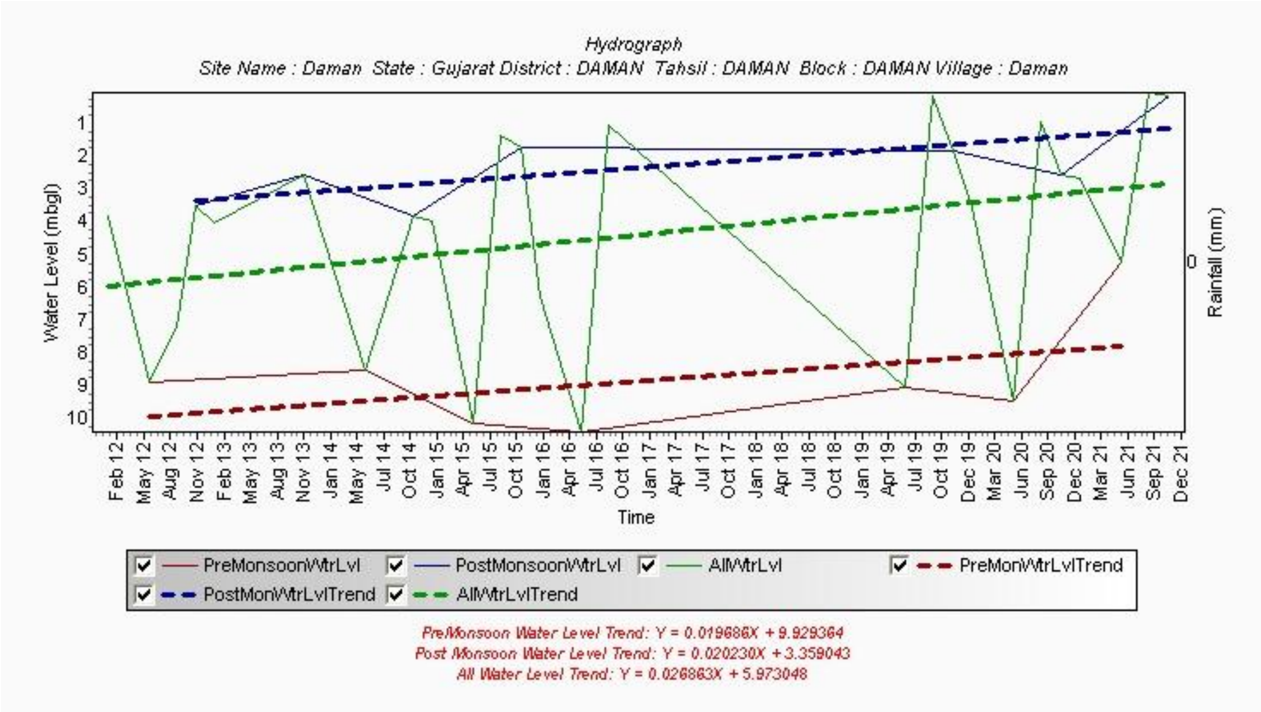


*Figure 24 Hydrograph of Daman Location village of Daman District*

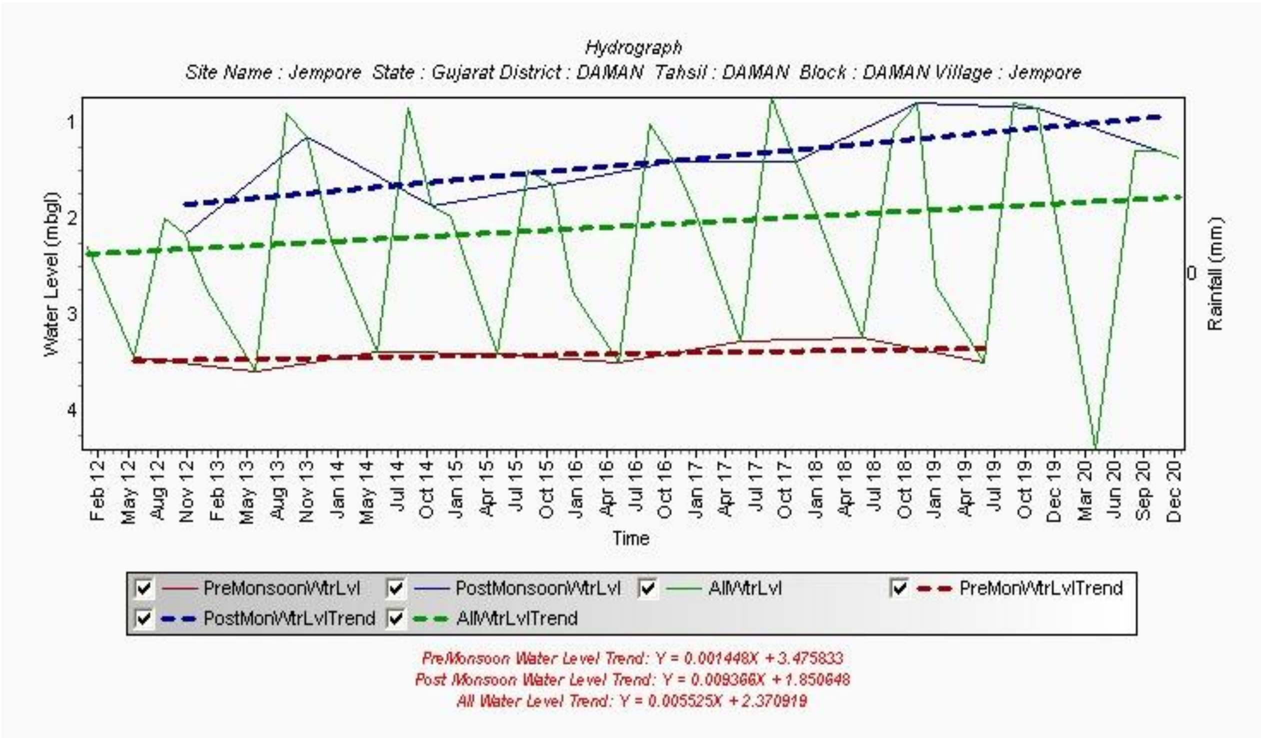


*Figure 25 Hydrograph of Jempore site of Daman District*

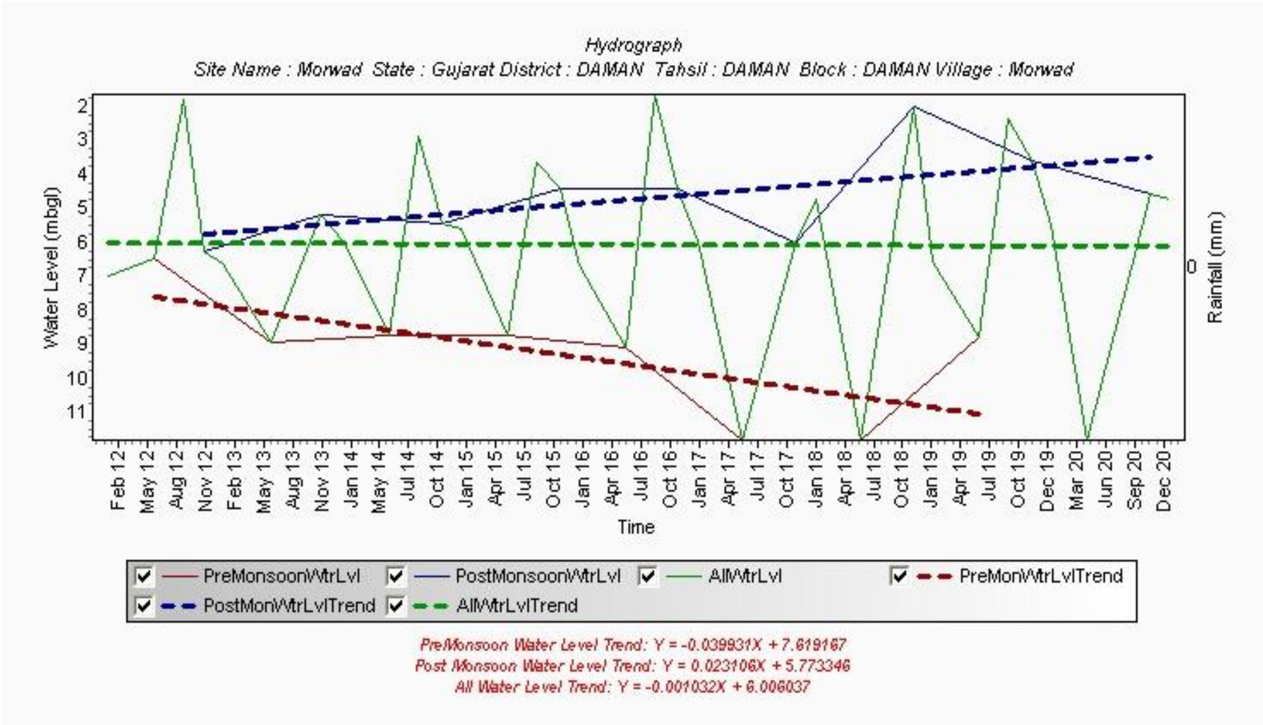


*Figure 26 Hydrograph of Morwad Site of Daman District*

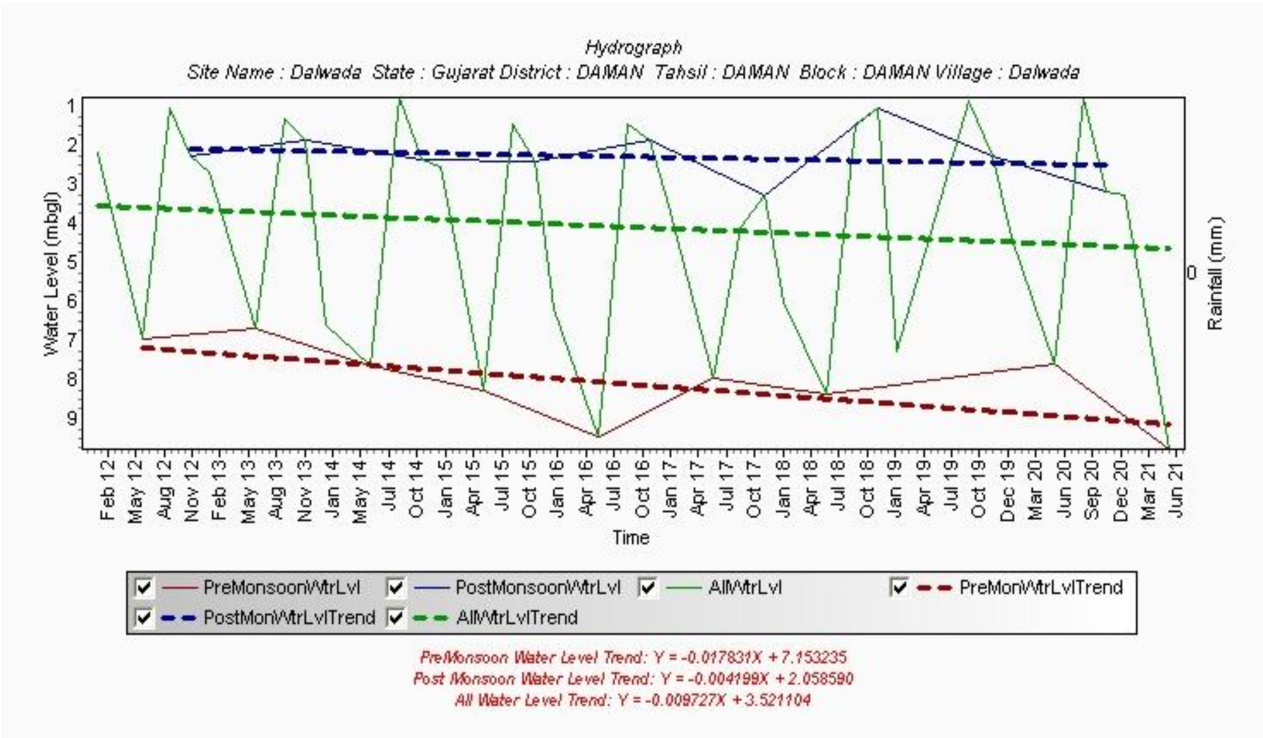


*Figure 27 Hydrograph of Dalwada Site of Daman District*

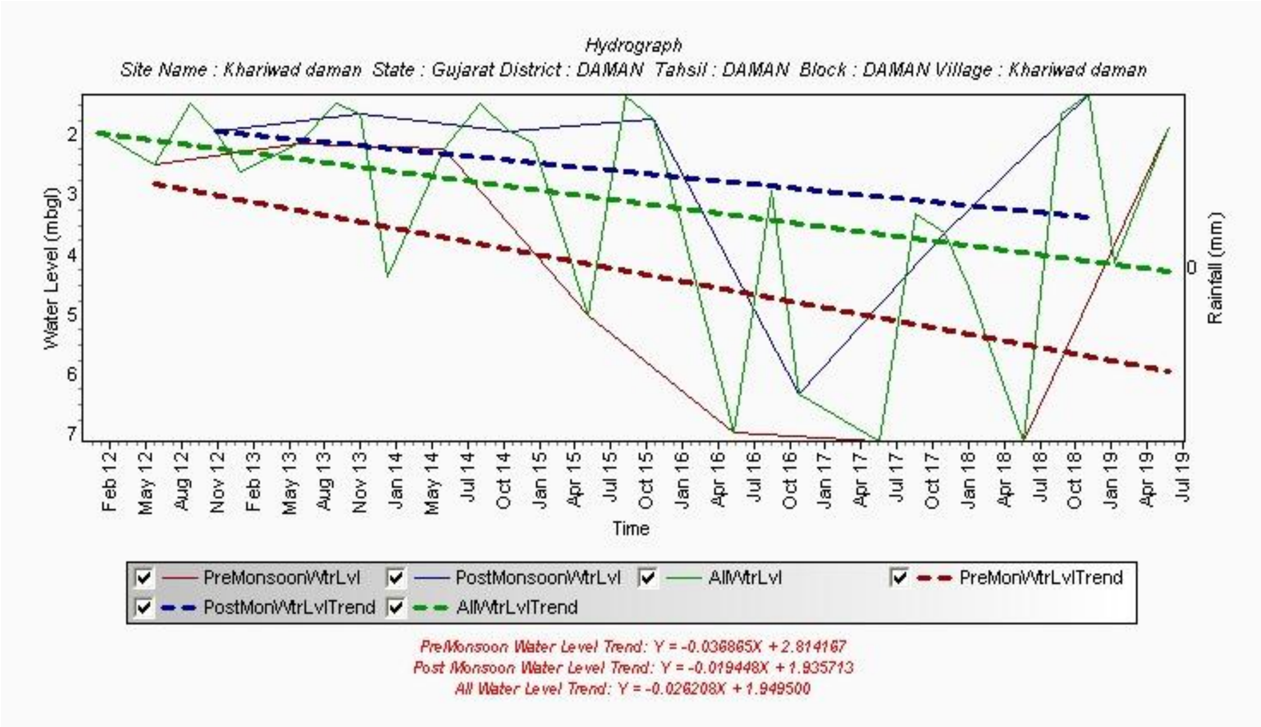


*Figure 28 Hydrograph of Khariwad Daman Site of Daman District*

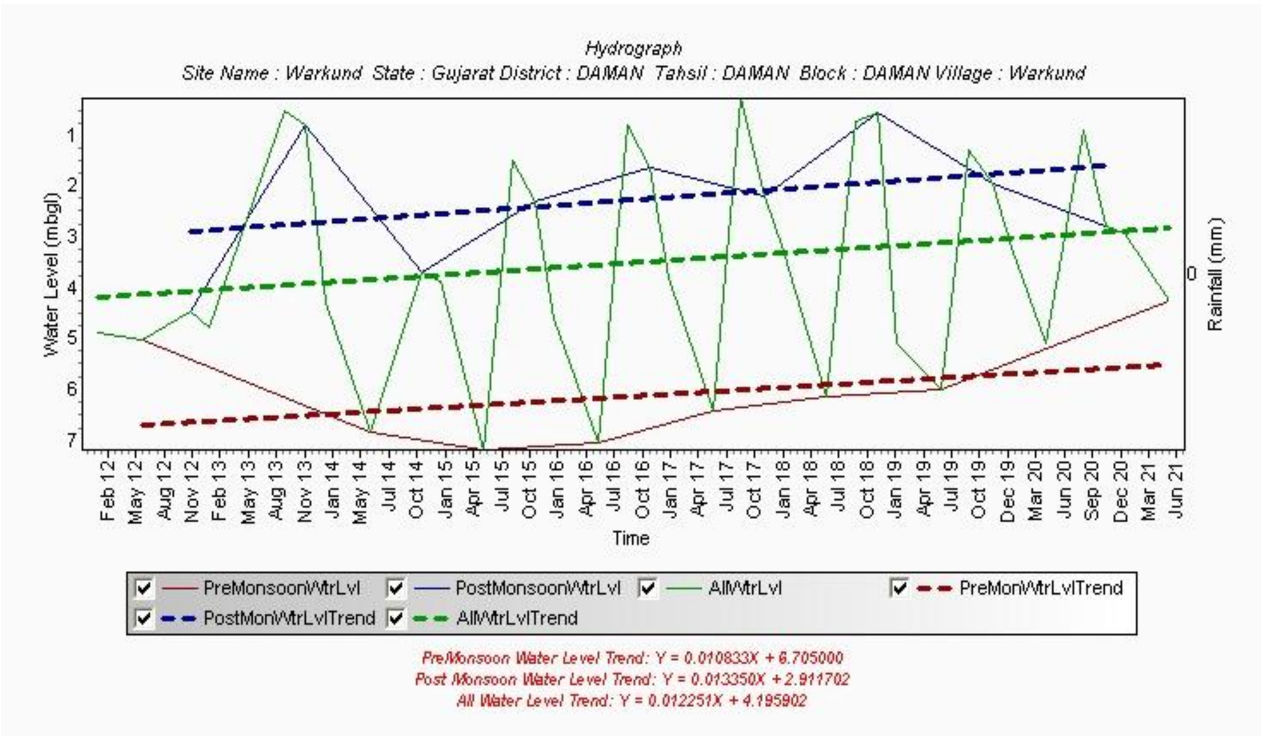


*Figure 29 Hydrograph of Warkund Site of Daman District*

# Chapter 4:
# DATA INTERPRETATION, INTEGRATION 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-4).

Table 4 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. |
| | | Surface and sub-surface geo-electrical and gravity data generation | Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging etc. |
| | | Hydrological Parameters on groundwater recharge | Soil infiltration studies, 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 Generation & Integration.

In order to establish the three-dimensional disposition of aquifer system in the area, the existing data of litho logical logs of 15 exploratory wells studies carried out and used in preparation of stratigraphic Cross sections, Fence diagram and 3D Model.

Data Generation and integration in respect to Daman district is represented in Table no 5 below

Table 5 Data Generation and integration in respect to Daman district

| **Type of Data & source** | **No of Wells** |
|---|---|
| Aquifer Disposition | |
| CGWB | 15 |
| Long term Fluctuation | |
| CGWB | 8 |
| Depth to Water Level | |
| CGWB | 17 |
| Analysis of water Quality | |
| CGWB | 17 |

## 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 G-G' and Solid Model of the district showing the depiction of Weathered & fractured basalts (Aquifers). The stratigraphic sections depicting weathered/ fractured and Fractured/massive zone are placed at Figs (31 and 33 to 37). Fence Diagram and 3D Stratigraphic Solid Model of district is depicted in Fig. 38 and 39 respectively. Figure 32 represents stratigraphic index for cross-sections.

Aquifer Disposition of Daman District UT of Daman is depicted below in Table no 6

Table 6 Depicting Aquifer Disposition of Daman District UT of Daman

| **Aquifer Disposition** | | | | | |
|---|---|---|---|---|---|
| **Stratigraphy** | **Aquifer Nomenclature** | **Lithology** | **Depth of occurance (mbgl) between the depth below** | **Thickness (meter)** | **Nature** |
| **Upper Cretaceous-Lower Eocene** | Weathered /Fractured Basalt | Deccan Basalt | 0-19 | 6-19 | Shallow Aquifer |
| | Fractured /Massive Basalt | Deccan Basalt | 6-50 ( Depth Explored) | - | Deeper Aquifer |

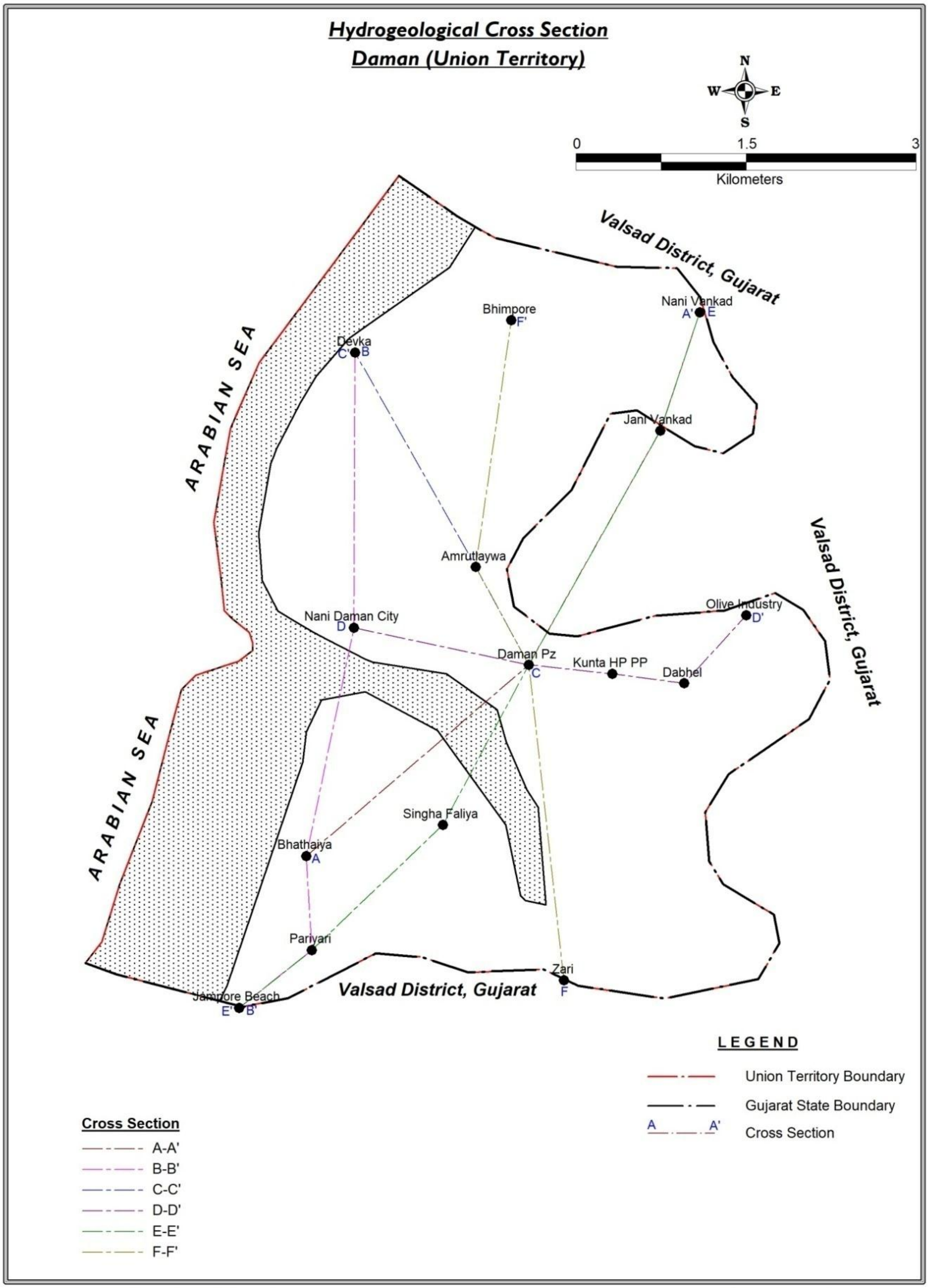


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Figure 30 Hydrogeological Cross section Line Map of UT of Daman

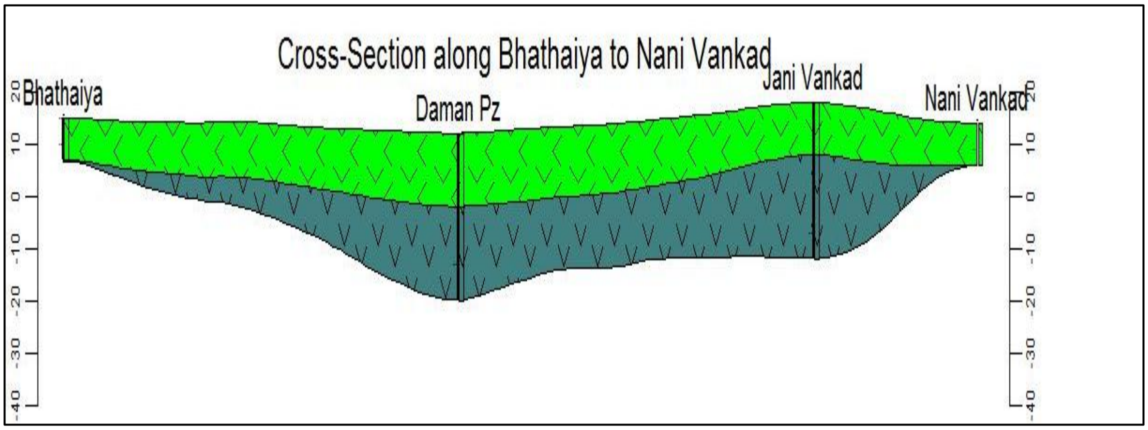



*Figure 31 2D Aquifer Cross-Section (Bhathiya to Nani Vankadl/ A-A') Map of UT of Daman*

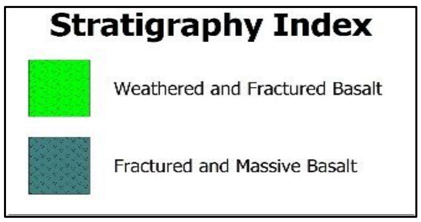



Figure 32 Stratigraphic Legend/Index Map for Cross sections

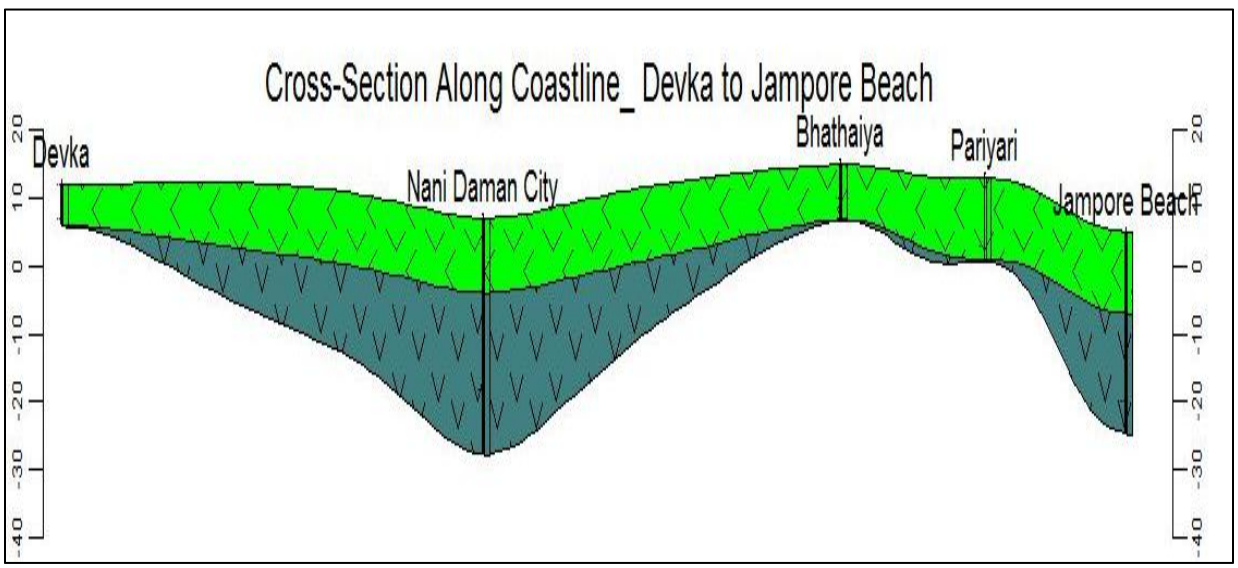



*Figure 33 2D Aquifer Cross-Section (Devka to Jampore/ B-B') Map of UT of Daman*

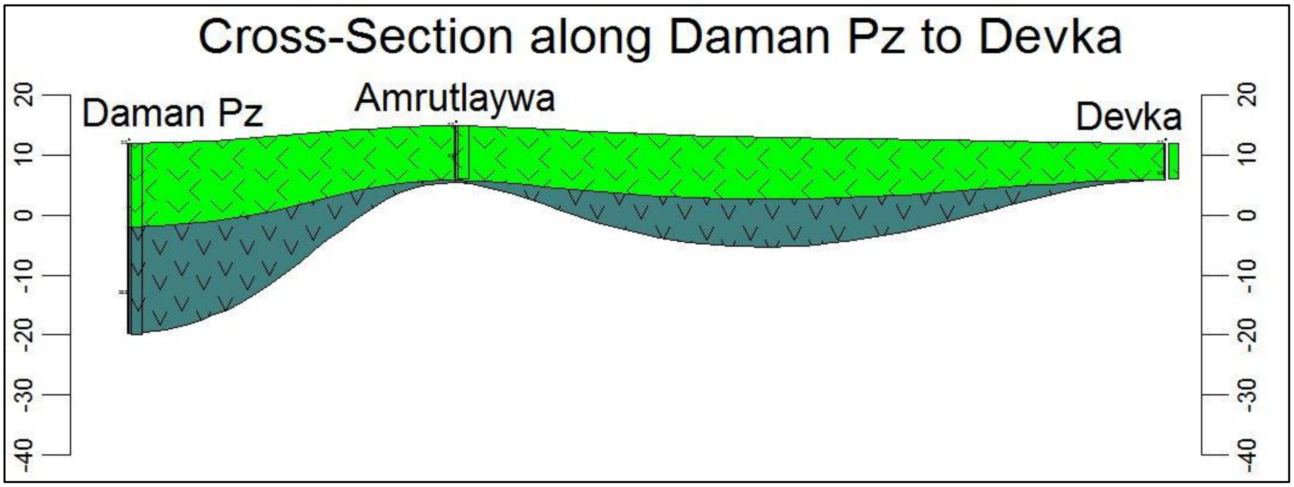



*Figure 34 2D Aquifer Cross-Section (Daman Pz to Devka/ C-C') Map of UT of Daman*

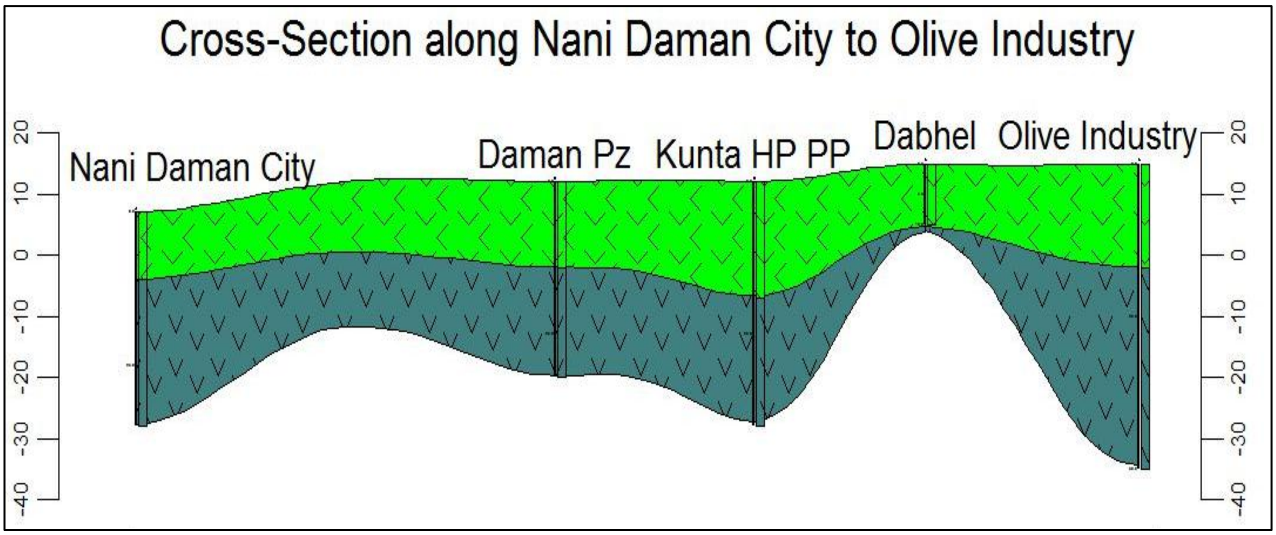



*Figure 35 2D Aquifer Cross-Section (Nani Daman City to Olive Industry/ D-D') Map of UT of Daman*

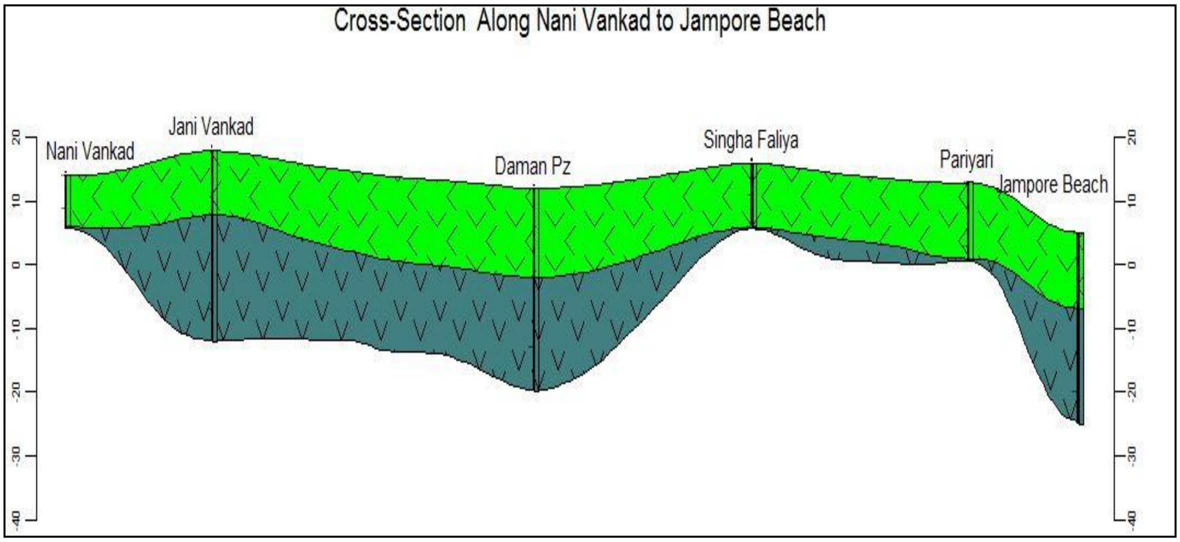



*Figure 36 2D Aquifer Cross-Section (Nani Vankad to Jampore Beach/ E-E') Map of UT of Daman*

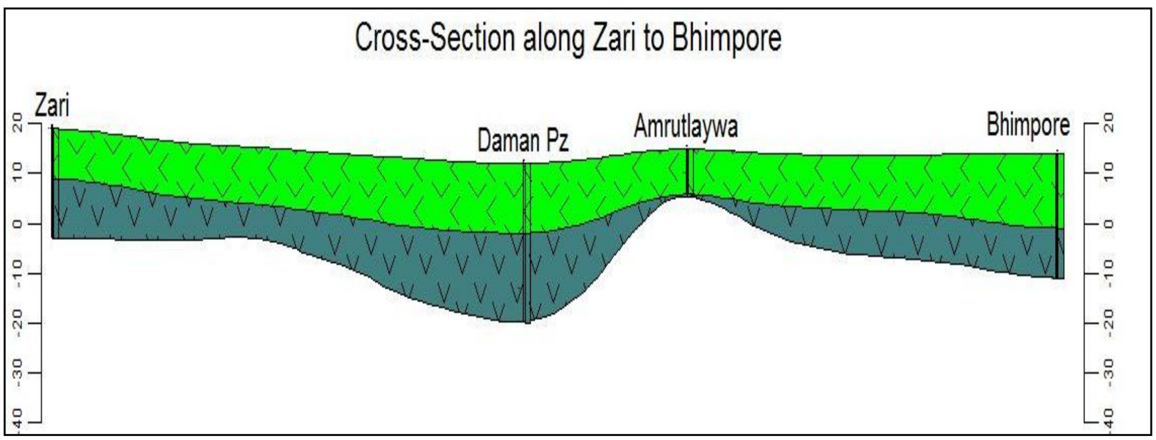



*Figure 37 2D Aquifer Cross-Section (Zari to Bhimpore Beach/ F-F') Map of UT of Daman*

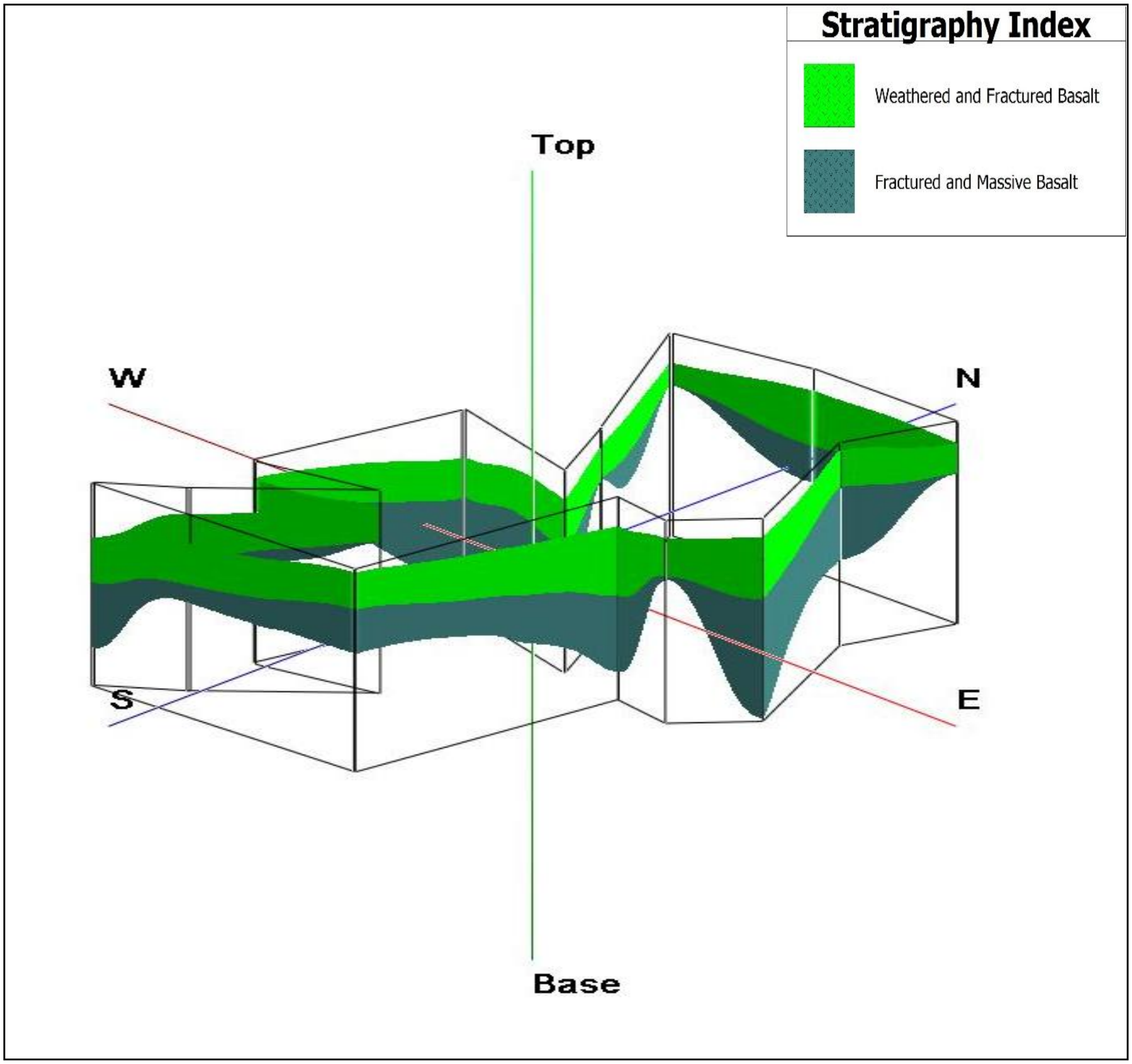



Figure 38 Stratigraphy Index and Fence Diagram of the District

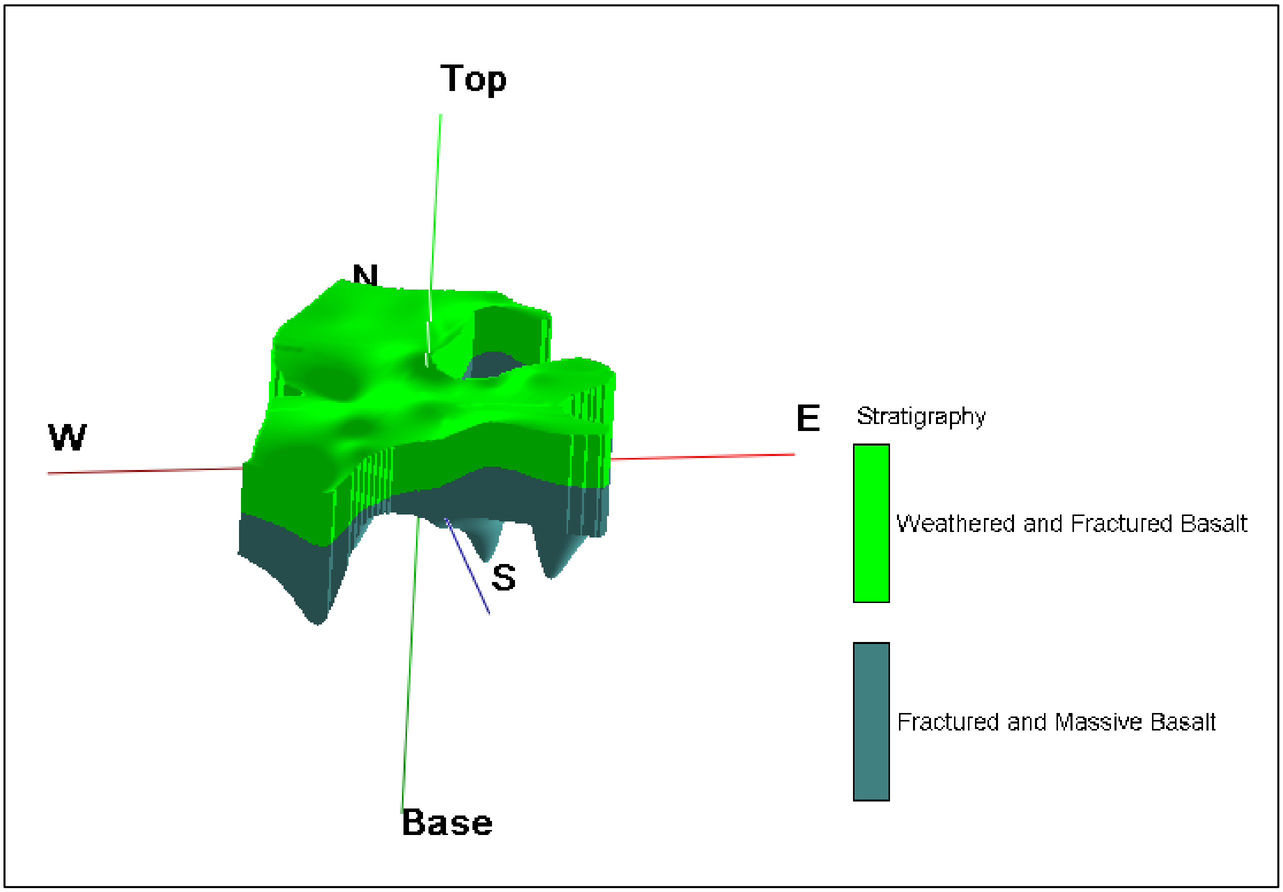



Figure 39 3D Solid Stratigraphic Model of Daman District

## 4.3 Conceptualization of Aquifer system in 2D

A total of 15 wells litho logs are utilized to decipher the subsurface geometry of the aquifer by using Rockworks 16 software prepared hydro geological cross sections, Fence diagram and 3D Model up to the depth of 50 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'** (Fig. 31) - Section is drawn roughly SW-NE direction from Bhathaiya to Nani Vankad, passing through Daman Pz and Janivankad Section. From section, stratigraphically. It is deciphered that Hard rock formation (weathered &fractured) forms the major aquifer system in the district along drawn section line

**4.3.2 Section B-B'** (Fig. 33) - Section is drawn roughly N-S direction and in between Devka to Jampore Beach passing through Nani Daman City, Bhathaiya and Pariyari Section. From section, stratigraphically. It is deciphered that Hard rock formation (weathered

&fractured) forms the major aquifer system in the district along drawn section line

**4.3.3 Section C-C'** (Fig. 34) - Section is drawn roughly SE-NW direction and in between Daman Pz to Devka, passing through Amrutlaya Section. From section, stratigraphically. It is deciphered that Hard rock formation (weathered &fractured) forms the major aquifer system in the district along drawn section line

**4.3.4 Section D-D'** (Fig. 35) - Section is drawn roughly W-E direction and in between Nani Daman City to Olive Industry, passing through Daman Pz, Kunta HP PPand Dabhel Section is represented Stratigraphicaly, from section it is deciphered that that Hard rock formation (weathered & Fractured) forms the major aquifer system in the district along drawn section line.

**4.3.5 Section E-E'** (Fig. 36) - Section is drawn roughly NE-SW direction and in between Nani Vankad to Jampore Beach, passing through Jani Vankad, Daman Pz, Singha Faliya and Pariyari Section is represented Stratigraphicaly, from section it is deciphered that that Hard rock formation (weathered & Fractured) forms the major aquifer system in the district along drawn section line.

**4.3.6 Section F-F'** (Fig. 37)- Section is drawn roughly S-N direction in between Zari to Bhimpore, passing through Daman Pz and Amrutlaya from section it is deciphered that that Hard rock formation (weathered & fractured) forms the major aquifer system in the district along drawn section line.

## 4.4 Aquifer Characterization and its Disposition

Shallow aquifer lies from zero to 19 meter below ground level and water level ranges from 1.67 to 7.95 mbgl (Shallow Aquifer, Pre-monsoon 2021). Quality of water in shallow aquifer is fresh with EC values ranges from 489 and 1562 micro S/cm respectively. Water level in deeper aquifer is reported from 7 to 16 mbgl (Pre-monsoon 2021). Water is fresh to saline with EC values ranges from 588 to 5081 (mS/Cm) at 25°C. EC more than 3000 is reported at 2 locations of total samples (17 for both shallow and Deeper Aquifers).
Aquifer Characterization and Disposition of Daman District is depicted in Table no 7 below

Table 7 Aquifer Characterization and Disposition of Daman District

| Stratigraphy | Aquifer Nomenclature | Lithology | Depth of occurrence (mbgl) between the depth below | Thickness (meter) | SWL (mbgl) | Quality(EC)microS/cm | Nature |
|---|---|---|---|---|---|---|---|
| **Upper Cretaceous-Lower Eocene** | Weathered /Fractured Basalt | Deccan Basalt | 0-19 | 6-19 | 1.67-7.95 | 489-1562 | Shallow Aquifer |
| | Fractured /Massive Basalt | Deccan Basalt | 6-50 ( Depth Explored) | - | 7-16 | 588-5081 | Deeper Aquifer |

# Chapter 5
# HYDROCHEMISTRY

## 5.1 Introduction

The results of chemical analysis of the ground water samples collected during AAP 2021-22 of key wells established and the ground water network monitoring in Daman District UT of Daman & Diu is tabulated in the Table-8 below. EC>3000 mS/Cm has been observed at 2 stations of total 17 stations whereas NO3 and 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 Shallow and Deeper aquifers.

Table 8 **:** Minimum, Maximum and Average of Different Chemical Constituents of Groundwater in Daman District

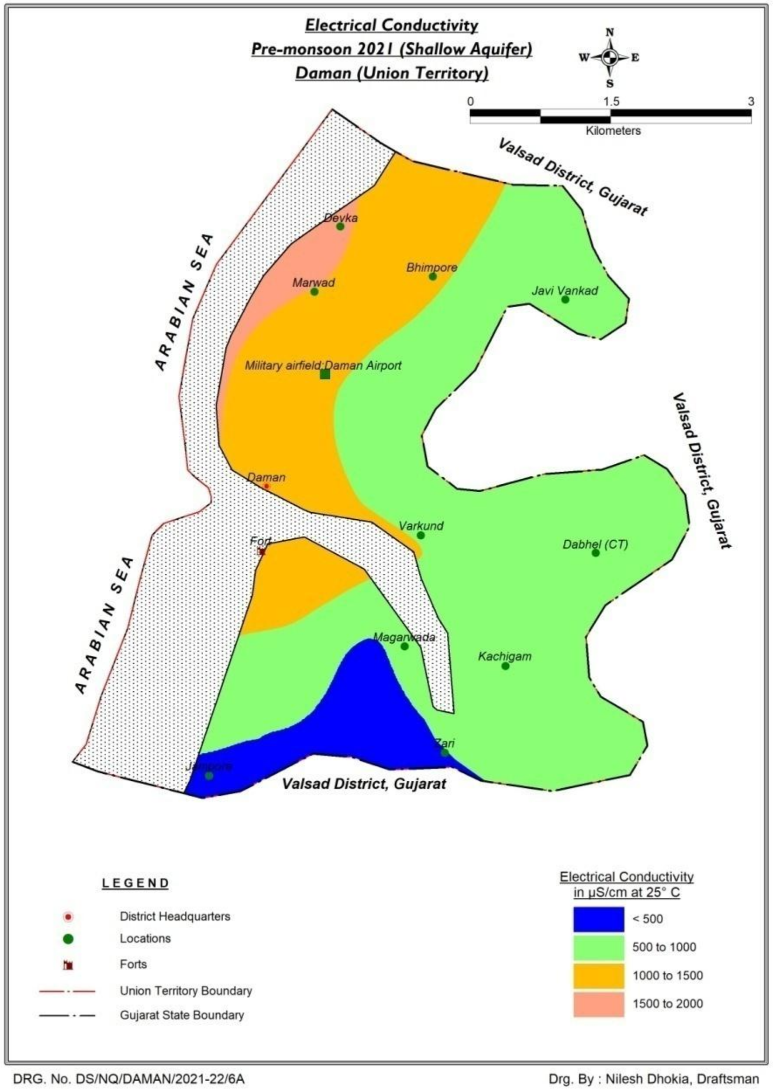
| **Constituents** | **Units** | **Shallow Aquifer** | | | **Deeper Aquifer** | | | **Overall (Shallow and Deeper Aquifer)** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Min** | **Max** | **Average** | **Min** | **Max** | **Average** | **Min** | **Max** | **Average** |
| **pH** | - | 7.1 | 8.48 | 8.096666667 | 7.8 | 8.46 | 8.11375 | 7.1 | 8.48 | 8.08625 |
| **EC** | (mS/Cm) at 25°C | 489 | 1562 | 875.2222222 | 588 | 5081 | 2163.5 | 489 | 5081 | 1514.125 |
| **TDS** | (mg/l) | 327.63 | 1046.54 | 586.3988889 | 393.96 | 3404.27 | 1449.545 | 327.63 | 3404.27 | 1014.46375 |
| **CO3** | (mg/l) | 0 | 60 | 16 | 0 | 84 | 10.5 | 0 | 84 | 13.5 |
| **HCO3** | (mg/l) | 85.4 | 427.07 | 254.8571111 | 97.6 | 402.6 | 268.4 | 85.4 | 427.07 | 260.779375 |
| **Cl** | (mg/l) | 35.5 | 319.5 | 137.9977778 | 42.6 | 1810.5 | 604.3875 | 35.5 | 1810.5 | 370.06875 |
| **NO3** | (mg/l) | 1.29 | 12.01 | 4.566666667 | 0.22 | 18.9 | 8.9125 | 0.22 | 18.9 | 6.840625 |
| **S04** | (mg/l) | 6.87 | 78 | 41.13555556 | 14.45 | 180 | 88.43375 | 6.87 | 180 | 64.480625 |
| **F** | (mg/l) | 0.1 | 0.74 | 0.323333333 | 0.08 | 0.81 | 0.40625 | 0.08 | 0.81 | 0.33875 |
| **Alkalinity** | (mg/l) | 90 | 450.36 | 235.6168889 | 80 | 470 | 237.5 | 80 | 470 | 236.2725 |
| **Ca** | (mg/l) | 28 | 160.32 | 72.48888889 | 32 | 424 | 103.5 | 28 | 424 | 90.02 |
| **Mg** | (mg/l) | 14.592 | 65.664 | 31.616 | 26.752 | 131.328 | 58.064 | 14.592 | 131.328 | 43.472 |
| **TH** | (mg/l) | 170 | 590.472 | 311.192 | 230 | 1600 | 497.5 | 170 | 1600 | 403.7795 |
| **Na** | (mg/l) | 12.17 | 236 | 70.76777778 | 45 | 1080 | 317.43125 | 12.17 | 1080 | 192.7725 |
| **K** | (mg/l) | 0.16 | 66.8 | 10.03444444 | 0.13 | 49.1 | 7.2275 | 0.13 | 66.8 | 9.213125 |
| **SiO2** | (mg/l) | 24.2 | 59 | 39.86888889 | 26.73 | 62.62 | 42.1575 | 24.2 | 62.62 | 41.6925 |
| **SAR** | (mg/l) | 0.341552227 | 5.564737831 | 1.75830862 | 1.213383273 | 23.77735905 | 6.259126177 | 0.341552227 | 23.77735905 | 3.978857439 |

## 5.2 Hydrogen Ion Concentration (pH)

The pH is an indicator of acidity of the water. The ground water in the district is generally alkaline with pH more than 7. The value of pH ranges between 7.1(Dabhel) & 8.48 (Devka) in the district.

## 5.3 Iso Conductivity

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 489-5081 micromhos/cm at 25°c, for the entire district for both aquifers.
Iso conductivity Map of the district shown below in Fig.40, EC in the district are mostly lie within Permissible limit except some small patches (of 2 location in Deeper aquifer of total 17 samples for both shallow and deeper aquifers) in Jampore beach and Nani Daman city where EC values are more than Permissible limit.



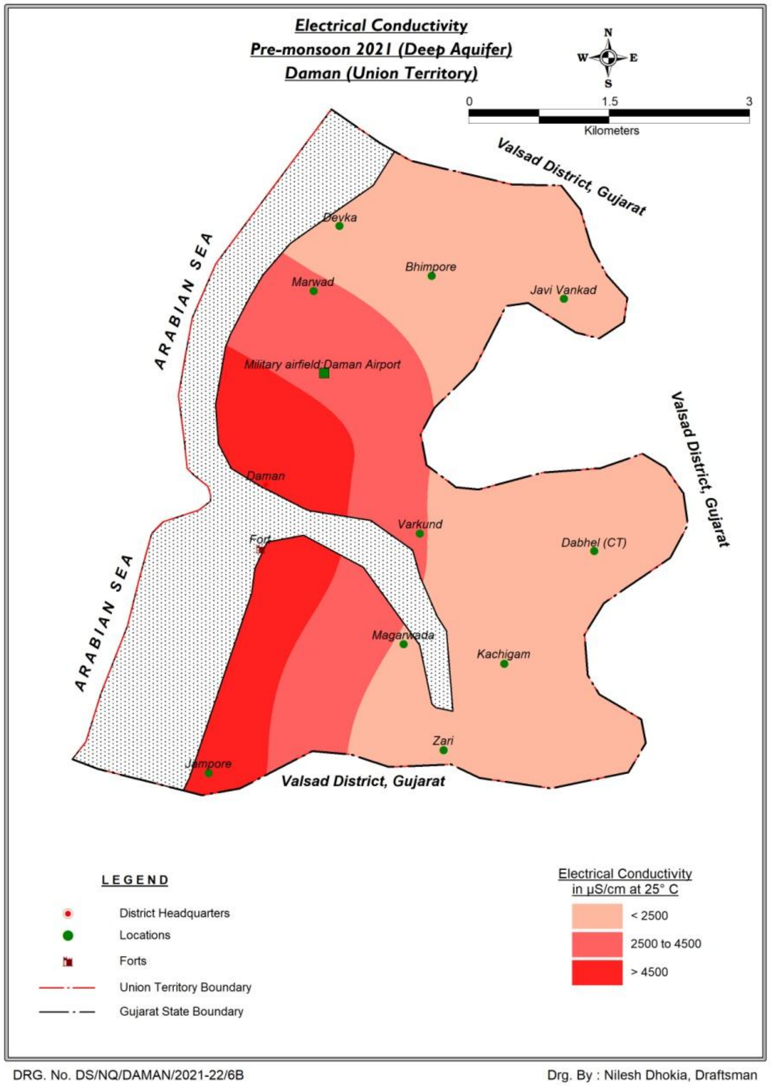




*Figure 40: EC Map of UT of Daman (Shallow and Deeper aquifers)*

## 5.4 Total Dissolved Solid (TDS)

Quality of groundwater in general fresh in terms of Total Dissolved Solid (TDS) in shallow aquifer whereas the quality in deeper aquifer close to coast is marginal saline. TDS of ground water varies from 323 (Singha faliya& Pariyari)-3404 (Jampore Beach) mg/l.

## 5.5 Carbonate (CO3) and Bicarbonate (HCO3)

The Carbonate value is ranges negligible to 84 mg/l (Bhimpore –only one location). The Bicarbonate concentration in district is varies in between 85 mg/l (Pariyarai) to 427 mg/l (Ambawadi).

## 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. Its value ranges from 36-1810.5 mg/l. Minimum value reported in Singha faliya and maximum value in Jampore Beach. (Figure 41)

## 5.7 Nitrate (NO3)

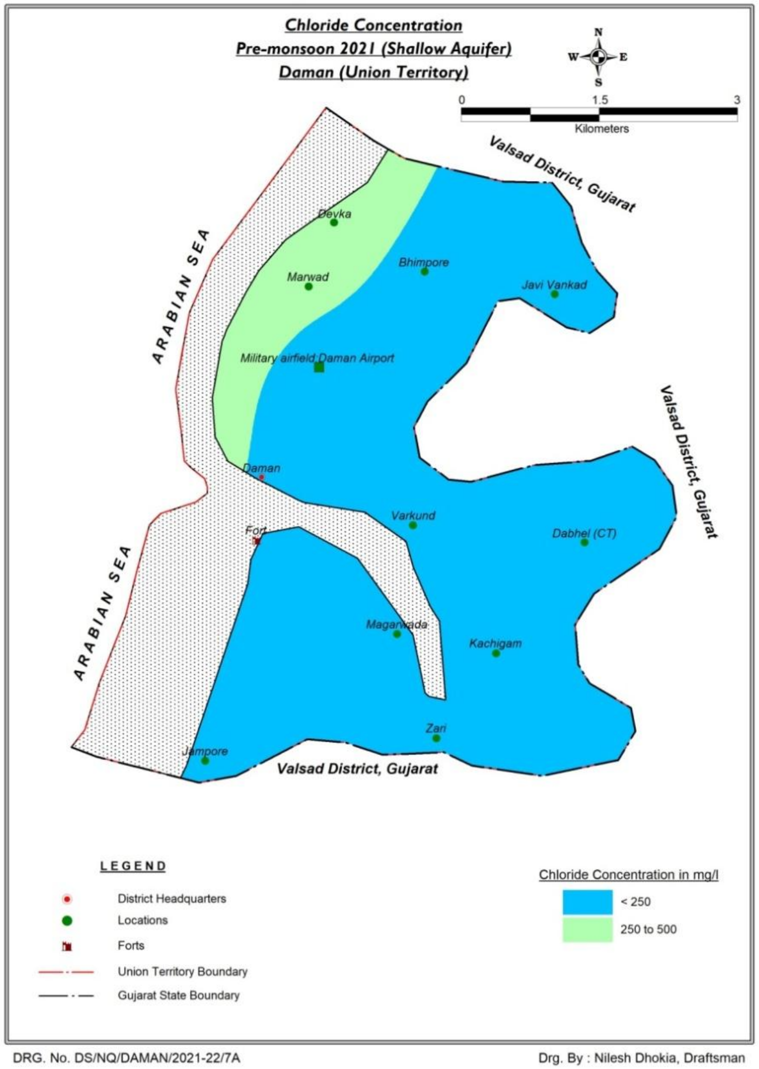
As per the BIS standards [IS 10500: 2012] for drinking water, acceptable limit is 45 mg/l (maximum) and there is no relaxation in permissible limit. No Nitrate concentration is observed beyond the permissible limit of drinking water standards. Nitrate concentration in the ground water in district varies from 0.22-19 mg/l. Minimum Value found in Jani Vankad and Max Value in Olive Industry. (Figure 42)

## 5.8 Sulphate (SO4)

In the district, Sulphate concentration varies from 6.87 mg/l (Singha Faliya) to 180 mg/l (Olive Industry).

## 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. No Fluoride concentration is observed beyond the permissible limit of drinking water standards. Fluoride concentration ranges from 0.08 to 0.81 mg/l. Minimum value reported in Jani Vankad and Max in Bhimpore. (Figure 43)



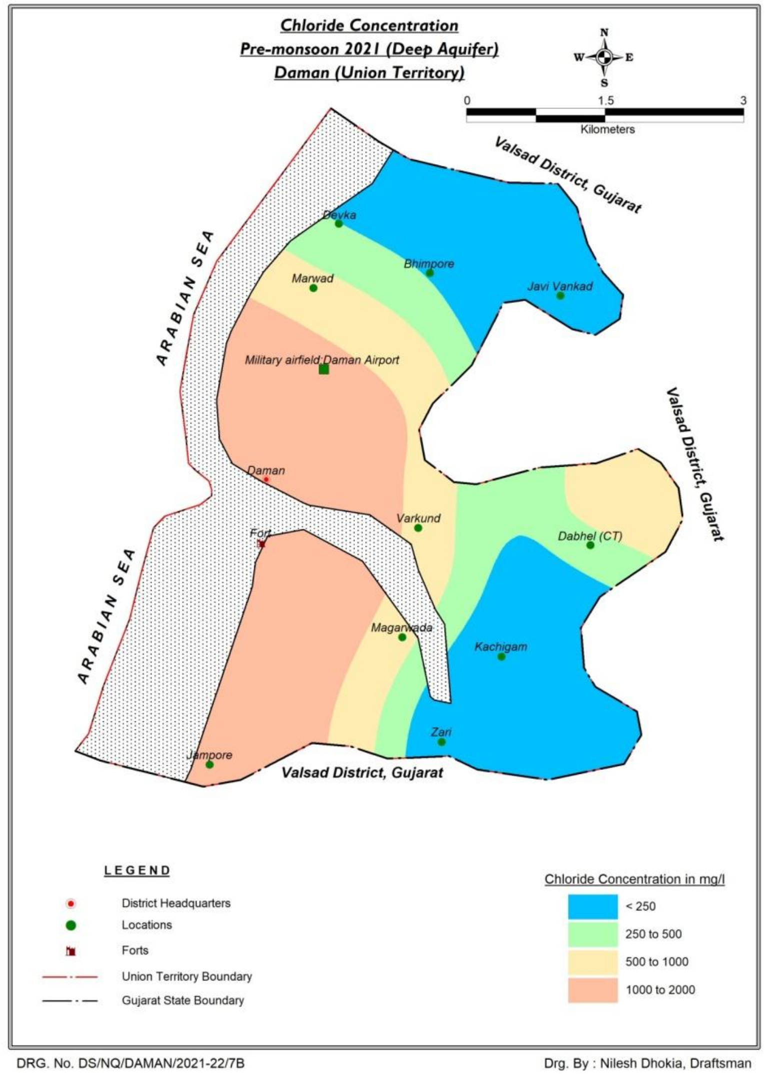




*Figure 41*Chloride Concentration Map of UT of Daman Shallow Aquifer (Left) and *Deeper Aquifer*

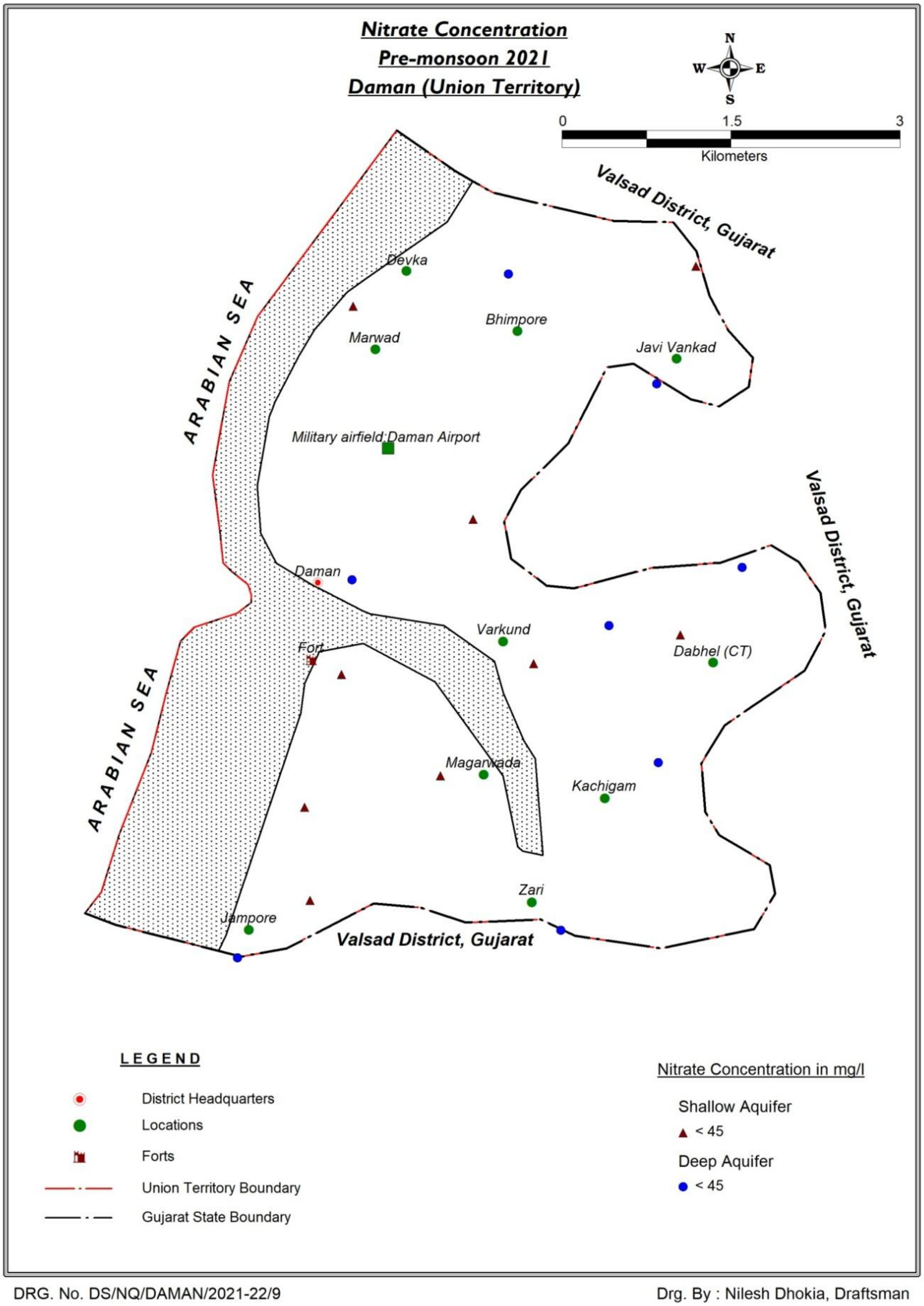



Figure 42 Nitrate Concentration map of UT of Daman

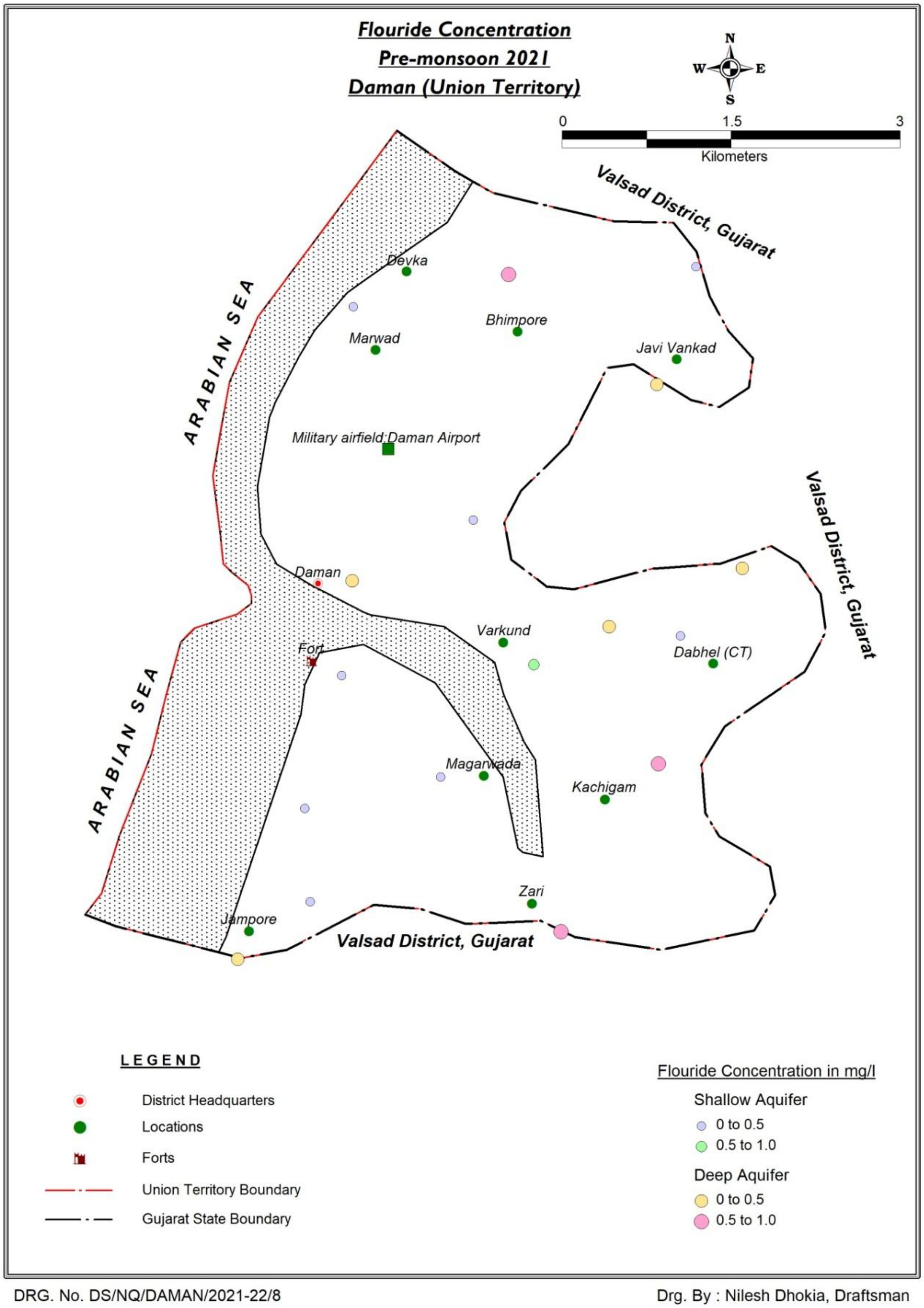



Figure 43 Fluoride Concentration map of UT of Daman

## 5.10 Calcium (Ca)

Calcium concentration in district varies between 28 mg/l (Devka) and 424 mg/l (Jampore beach). The concentration of calcium is found within permissible limits in the district (permissible limit as per BIS norms is 200 mg/l) except one location i.e. Jampore beach.

## 5.11 Magnesium(Mg)

The Concentration of Magnesium in areas ranges from 14.6 mg/l (Singha faliya and Pariyari) to 131 mg/l (Jampore Beach). In one isolated location namely Jampore Beach, the concentration of Magnesium is more than maximum permissible limits of 100 mg/l (as per BIS norms).

## 5.12 Sodium(Na)

Sodium concentration in the district varies between 12.17 mg/l (Singha faliya) and 1080 mg/l (Nani daman City).

## 5.13 Potassium (K)

The concentration of Potassium in shallow ground water ranges from 0.13 mg/l (Jani Vankad) to 66.8 mg/l (Ambawadi)

# Chapter 6
# GROUND WATER RESOURCE POTENTIAL

## 6.1 Introduction

The ground water resources of the district were calculated as on March 2020 using the GEC-2015 methodology suggested by Ground Water Resource Estimation Committee (GWRE-2020). These resources were computed after reorganization of the districts, talukas of the district are considered as Assessment Units (AU) and total area of 72 sq km are taken as area of assessment of the district. It is observed from the Table no 10 that District of Daman as an assessment unit falls under over exploited category and the stage of ground water development of the district is 122.18%.

Computed resource (GWRE-2020) are presented in tabulated form and graphically represented below in Table no 9.

Table 9- Taluka wise Ground Water resources, Availability, Utilization and Stage of Ground Water Development

**District Wise Ground Water Resources, Availability, Utilization and Stage of Ground Water Development (2020) (in Ham)**

**Daman District UT of Daman & Diu**

| S. No. | Name of District | Ground Water Recharge | | | | | Total Natural Discharges | Annual Extractable Ground Water Resource | Current Annual Ground Water Extraction | | | | Annual GW Allocation for for Domestic Use as on 2025 | Net Ground Water Availability for future use | Stage of Ground Water Extraction (%) | Safe/SC/Critical/OE/Saline |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Monsoon Season | | Non-monsoon Season | | Total Annual Ground Water Recharge | | | Irrigation | Industrial | Domestic | Total | | | | |
| | | Recharge from rainfall | Recharge from other sources | Recharge from rainfall | Recharge from other sources | | | | | | | | | | | |
| 1 | **Daman** | 2551.89 | 35.50 | 0 | 67.92 | 2655.31 | 132.77 | 2522.54 | 215.1 | 2867 | 0.00 | 3082.10 | 1412.67 | 0 | 122.18 | Over Exploited |

## 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 2655.31 ham.

## 6.3 Net Ground Water Availability

Annual Extractable Ground Water Resource/ Net Ground Water Availability of the district is 2522.54 ham which computed after deducting total natural discharge of 132.77 ham from total annual ground water recharge.

## 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 3082.10 ham. Approximately 93 % of ground water extraction is used for Industrial purpose and remaining 7% are being extracted for Irrigational purposes (very less). For Domestic purposes no groundwater is used.

## 6.5 Annual GW Allocation for Domestic Use as on 2025

Annual GW Allocation for Domestic Use as on 2025 is in 1412.67 ham.

## 6.6 Ground water Availability for future Irrigation

Net ground water availability for future use in the district is 0 (Zero) ham.

## 6.7 Stage of Ground Water Extraction

As per the Ground Water Resource Estimation (GWRE-2020), the stage of Ground Water extraction of the district is 122.18% which categorized as Over Exploited.

# Chapter 7:
# GROUNDWATER RELATED ISSUES

## 7.1 Major issues related to groundwater

I. Salinity in Ground water near coast and creeks.
II. There is intense ground water development in the area.

## 7.2 Salinity

Groundwater quality deteriorates with depth; deeper aquifer in patches (more than 19 mbgl) has higher EC value than permissible limits.

## 7.3 High Ground water development

District is declared as over exploited as ground water stage of extraction has reached to 122.18%. Of total ground water withdrawal about 93% is used by industrial activities and remaining 3% by irrigation activities.

## 7.4 Pollution

Contamination of groundwater due to effluent generated from industrial activities in around the area need to be periodically monitored for quality purposes.

## 7.5 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 varies veries from very low yield (<2 $m^3$/hr) to 25$m^3$/hr. The yield from bore wells have reduced in a lean period, recoupment time in some Shallow aquifer is low.

## 7.6 Reasons for Issues

De-saturation of weathered zone and fracture zone due to high groundwater extraction for industrial and other uses leads to the over exploitation of Groundwater condition.

# Chapter 8
# PARTICIPATORY GROUNDWATER MANAGEMENT

## 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-

Enhanced capacity of the farmers in utilizing groundwater efficiently Increased groundwater use efficiency in irrigation.

Sustainable exploitation and stabilization of the groundwater by adopting a suitable cropping pattern.

## 8.2 Management Strategies

Mainly groundwater occurs in weathered basalt connected with small fractures. Quality of groundwater in terms of electrical conductivity (EC) value varies from 489 -5081 micro Siemen/cm. Taste of groundwater is brackish in various parts of districts aquifers. Strategy for regular monitoring for planned development and pollution control with adequate enforcement directive is essential to prevent occurrence of pollution incident in future. The major part of the district is highly industrialized. Periodic monitoring of ground water along with quality should be mandatory.

## 8.3 Management plan

The uneven distribution of groundwater availability and its utilization indicates that a single management strategy cannot be adopted and requires integrated hydro geological 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.

1) Ground water development Plan
2) Supply side measures
3) Demand side measures
4) Regulatory measures
5) Institutional measures

### 8.3.1 Ground water Development Plan

As per GWRE 2020 Daman district falls under over exploited category. Ground water stage of exploration is 122.18%. Since district is already in over exploited condition no development plan is required for groundwater withdrawal

### 8.3.2 Supply side interventions

As per Master plan 2020 for Artificial Recharge is provisioned through Roof Top Rain Water Harvesting Technique (RTRWH) in district. Ground water recharge of 52 ham (through RTRWH) is expected for the district.

### 8.3.3 Demand Side Interventions

Total 215.1 hac area is proposed for Irrigation Draft for MIS Water saving (Ham), through which 45.2 Ham water is saved.

### 8.3.4 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.

### 8.3.5 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.

## 8.4 Identification of Recharge Area For Roof Top Rain Water Harvesting (RTRWH)

As per 2011 census data number of urban household in Daman are 52,074. Estimating 25 % houses are suitable for harvesting and considering 40 sq m area per house, total 453384 sq m areas is available for roof top harvesting in Daman. The source water available for harvesting has been taken as 60 % of average annual rainfall of the area, after making allowance for storm rain etc., total source water available for roof top harvesting has been estimated as 0.52 MCM /year. The average cost of making the rooftop harvesting arrangements is @ Rs 10,000 /- per house. In addition, rooftop rainwater harvesting system is also feasible in government and institutional buildings at a unit cost of Rs 50,000/-. The total estimated cost of roof top harvesting in UT of Daman is Rs 1259.40 Lakh. (Table No 10)

*Table 10 Proposed Roof top Rainwater Harvesting in UT of Daman*

| S. No | District | Urban Population (Census 2011) | Urban Household (Census 2011) | Area considering average 40 sq.m @ 25% of House Hold (sq.m) | Average Rainfall (mm) | Roof Volume of harvestable water (MCM) | Unit Cost (Lakh) | Total Cost (Lakh |
|---|---|---|---|---|---|---|---|---|
| 1. | Daman | 191173 | 50376 | 453384 | 1900 | 0.52 | 0.1 | 1259.40 |

## 8.5 Roof Top Rain Water Recharge (RTRWR)

Rooftop rainwater harvesting is the technique through which rain water is captured from the roof catchments and stored in reservoirs. The rooftop rainwater harvesting system is an ideal practice in NE regions where groundwater and surface sources are lacking or insufficient. This rainwater harvesting system has special importance for the hilly farmers. The rainwater is pure and free from bacteriological contamination, organic matter and soft in nature. The quality of the rooftop rainwater harvesting system is being good and could also be used for drinking purposes in addition to agriculture and domestic use.

### 8.5.1 Need for Rooftop Rainwater Harvesting

The main goal of water harvesting is to secure water supply in dry areas where other water resources (surface and ground water) are not available or uneconomical to develop.

The requirements of rooftop rainwater harvesting are;

- To meet the ever increasing demand for water.
- To increase the yield and production of rainfed areas.
- To reduce the risk of crop failure in drought prone areas.
- To give lifesaving irrigation for seasonal vegetables, fruits and plantations.
- To supplement domestic water requirement for peoples, animals, etc.

### 8.5.2 Components of Rooftop Rainwater Harvesting

A typical rooftop rainwater harvesting system comprises of following components

1) Roof catchment
2) Gutters
3) Pipe and first flush pipe
4) Filter unit
5) Storage tank
6) Collection pit
7) Recharge well

1) **Roof Catchment**

Roof of the house serves as the catchment area for harvesting rainwater. Catchment area or simply catchment is defined the area which contributes its runoff to a single point. In case of roof, runoff may be leaving the roof from more than one point or from all along the sides. But all the runoff is channelized to a common point. Roof may be of galvanized iron or asbestos sheet, clay tiles or concrete. If the house is having thatched roof, then it should be covered LDPE (Low Density Poly Ethylene) sheet to generate more runoff and to get clear water. The amount of rain falling on the roof is channelized through guttering and pipe system to a storage tank or recharge pit. In case of rooftop water harvesting the amount of runoff is taken as 90% of the rainfall amount. It is considered that 10% of rainwater is lost through splash and leakage. Information about the annual rainfall pattern of any particular area helps to calculate amount of water could be harvested in a particular catchment area by measuring its length and breadth. Roof should be kept clean to remain pure when rain water is collected. This means the roof will need to be swept and cleaned daily during the rainy season. The runoff from initial few showers should not be stored as it may contain dust particles, bird droppings and/or acids due to polluting gases in the atmosphere. Coarse mesh may also be used to prevent the passage of leaves, dust, small twigs and other organic matter at the roof.

Formula for calculating the quantity of rainwater to be collected:Total quantity of water to be collected (cubic meter) = Roof Top Area (Sq.m.) x Average Monsoon Rainfall (meter) x 0.8 Note: 1 cubic meter = 1000 liters of water

2) **Gutters**

The PVC gutter collects roof water from the roof and conveys the water to the down pipe. Gutter is a semicircular channel which can be fabricated from plain galvanized sheet. Now-a-days a readymade plastic gutters are also available in the market. If plastic gutters are available and it should be preferred as plastic is corrosion resistant. The length of gutter required, will be equal to the running length of all sides of the roof which can be ascertained by measuring the sides. Diameter of gutter is calculated based on the amount of runoff to be conveyed through the gutter. Diameter of gutter is designed for maximum intensity of rainfall for the location. The capacity of gutter for runoff conveyance is calculated by multiplying the flow area of gutter and velocity of flow. Therefore, maximum intensity should consider for calculating the size of gutter. Gutters are fixed below the roof sheet along its length to receive the runoff. A gentle slope, normally of 0.5% towards the outlet is provided along the gutter.

**3) Down Pipe and First Flush Pipe**

Gutters convey the runoff from all sides of roof to a common point. Then from that point runoff is to be conveyed down on the ground and to the storage tanks through pipes called down pipes. The diameter of down pipe may be 100 to 150 mm. An inlet screen (wire mesh) should be fitted at the junction of gutter and down pipe to prevent the entry of dry leaves and other debris into the down pipe. A valve or ninety-degree elbow is fitted at a suitable location in the down pipe to flush out the initial runoff, which may contain impurities in the form of dust, bird droppings or toxic substances. There may be more than one common point to which down pipes are attached depending upon the size of the buildings and accordingly flush valve or elbow may be fitted at multiple locations. Either plastic or soil pipe should be used to avoid rusting and to reduce the cost.

**4) Filter Unit**

Sometimes wind may also accompany rain due to which runoff may contain foreign materials such as leaves and small twigs. Sometimes, rusts from the cast iron pipes may also enter the water tank. These foreign materials may contaminate harvested stored water rendering it unfit for domestic use. A filter unit is a chamber filled with filtering media such as fibre, coarse sand and gravel layers to remove debris and dirt from water before it enters the storage tank. A filtering unit consists of gravel, sand and 'netlon' mesh filter should be designed and placed on top of the storage tank. Charcoal can be added for additional filtration. Therefore, to check such foreign materials from entering the storage tanks, a filter unit should be fitted into the pipe network preferably before the storage tank. Different types of are available in the market. 'Sand filter' is cheap and suitable for relatively bigger foreign particles.

**5) Storage Tanks**

The rainwater storage tank collects all the filtered rainwater and keeps it for future use. Storage tanks can be made above the ground or below the ground as per the requirement and convenience. If the storage tank is constructed below the ground surface, at least 30 cm of the tank should remain above the ground. This is done to avoid ground surface runoff and other contaminants entering the tank. Paint white on the outside to keep the water inside cool and prevent the growth of bacteria. To ensure and maintain the good quality of harvested water, only rooftop water should be allowed to go to the storage tanks. Top of the tank should be sealed, so that the mosquitoes and dust should never be allowed into the stored rainwater tank. Overflow pipe and tap may be attached. The shape of the tank may be cylindrical, square, semi spherical and may be constructed of galvanized iron sheet, brick, stone, masonry, reinforced concrete, ferro-cement, PVC and clay.

**6) Collection Pit**

The harvested rainwater from rooftop may also be diverted in the collection pit for storage. Collection pit is constructed at a suitable location within the premises of the building. The size of pit depends upon the water yield from the roof catchment and water demand. To make the collection pit water tight, in heavy, alluvial soils, soil compaction might be sufficient, but in most soils, lining with brickwork, concrete masonry and cement plaster or with membrane materials will be necessary. Membrane materials are of synthetic rubber, PVC or polythene. The collection pit may be covered to protect the stored water from contamination and evaporation by constructing a roof, made of thatched material, corrugated iron or other material.

### 7) Recharge Well

Recharge of the ground water reservoir is a relatively new concept of rainwater harvesting. Recharge wells of 100 to 300 mm diameter are generally constructed for recharging the deeper aquifers. The harvested rainwater is directed into the well. If ground surface runoff is to be guided into the recharge well, the runoff water should be passed through the filter media to avoid choking of recharge wells. Existing dug wells may also be utilized, as recharge structures and runoff water should be passed through the filter media before putting into the dug well. If the availability of water is limited, the existing hand pumps may be used for recharging the shallow/deep aquifers. In this case also water should pass through the filter media before entering into hand pumps to avoid choking. If an abandoned well is available in the area, the runoff water may be directed to it to recharge the groundwater

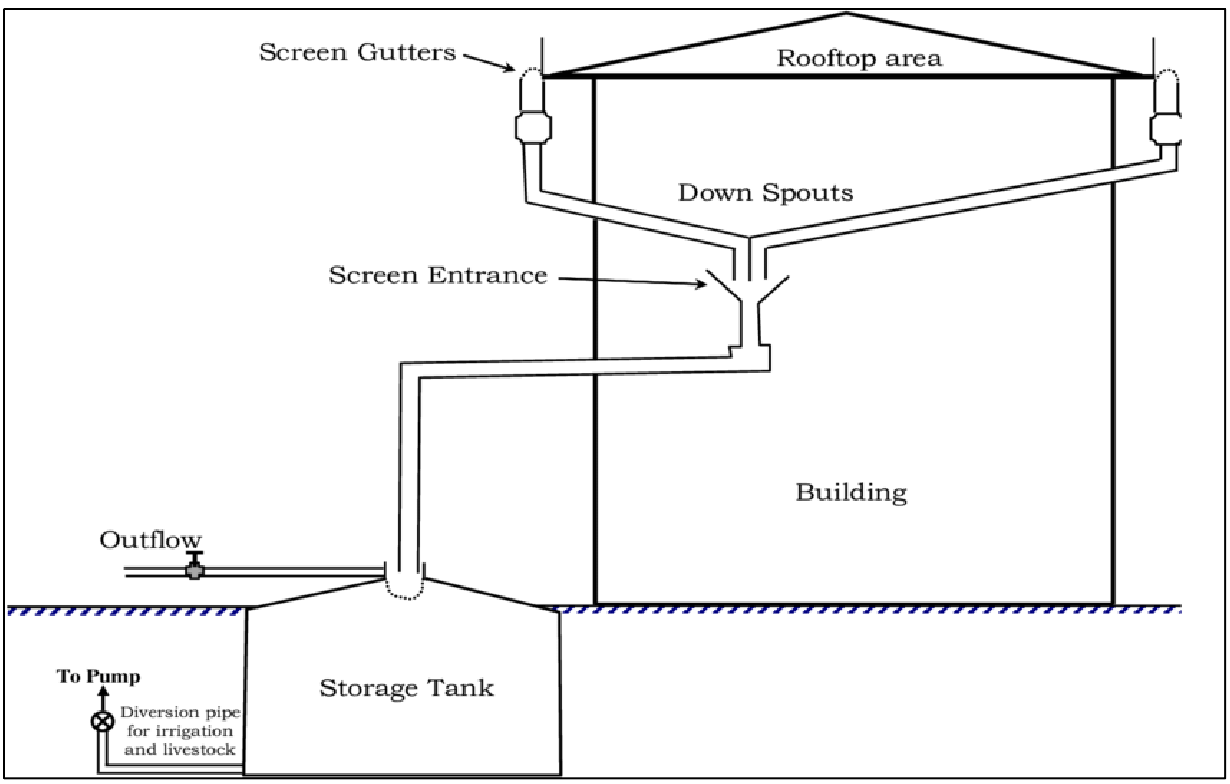



Figure 44 Schematic diagram of RTRWR.

### 8.5.3 Benefits of rooftop Harvesting

Benefits of rainwater harvesting are immense as it offers an ideal solution to problems in areas having adequate water resources. Some specific benefits are-

- Provides self-sufficiency in water supply.
- Reduces soil erosion.
- The rooftop rainwater harvesting is less expensive. Construction, operation, and maintenance are not labor-intensive.
- Fishery and animal husbandry may flourish.
- In hilly terrains, rainwater harvesting is preferred.
- Rainwater harvesting systems are simple and flexible. Poor households can start with a single small tank.
- Rooftop rainwater harvesting systems are easy to construct, operate and maintain.
- It provides an essential reserve in times of breakdown of public water supply systems, particularly during natural disasters

## 8.6 Summary of Interventions and expected benefits and Cost Estimates for Daman District

Total expected cost for implementation of management plan to be Rs 13.85 Crores. By this amount RTRWH for 453384 square meter area along with irrigation draft for MIS water saving for 45.2 ham area is proposed to be completed. Ultimately it will recharge/save 94.2 ham water to groundwater and stage of groundwater extraction also to be under safe category. Over view of this is presented in below given Table no 11 and projected status of groundwater resource after implementation of groundwater management plan, Daman District (UT of Daman) is presented in Table no 12.

Table 11 Summary of Interventions and expected benefits and Cost Estimates for UT of Daman

| **Interventions Recommended** | |
|---|---|
| RTRWH | 453384 Square meter |
| Irrigation Draft for MIS Water saving(Ham) | 45.2 Ham |
| **Expected Benefits** | |
| Expected Annual Recharge | 52 ham |
| Irrigation Draft for MIS Water saving(Ham) | 45.2 Ham |
| **Total Recharge/ Saving** | **94.2 Ham** |
| Total Cost (Crore) | 13.85 |
| ***Grand Total*** | 13.85 |

Table 12-Projected Status of Groundwater Resource after implementation of GW Management Plan, at UT of Daman

| **Projected Status of Groundwater Resource after implementation of GW Management Plan, Daman District (UT of Daman)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Net G.W. Availability (Ham)** | **Additional Recharge from RTRWH (ham)** | **Total Net G.W. Availability after intervention (Ham)** | **Existing G.W Draft for all purpose (ham)** | **Irrigation Draft for MIS Water saving(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(in %)** | **Projected stage of GW development after construction of extraction structures & implementation of conservation & Recharge measures (in %)** | **Additional Irrigation Potential Created (Ha)** | **Additional Surface water required to bring the unit into Safe category** | **Projected stage of GW development after addition of surface water(in %)** |
| 2522.54 | 52 | 2574.54 | 3082.1 | 45.2 | 3036.9 | 122.1824 | 122.1824 | 117.9589 | 0 | 1765 | 69.98207 |

# 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 1900 mm.
2) Geologically, the area is occupied by basaltic lava flows of Deccan Traps, Recent alluvial deposits in the south western segment and beach sands all along the coastline.
3) Major aquifer bearing formations are weathered/fractured and fractured/massive basalt.
4) The depth of water level in the Shallow aquifer ranges from 1.67 m bgl (Dabhel) to 7.95 bgl (Pariyari).
5) Depth to water level in the deeper aquifer (Reported) ranged from 7 (Jampore Beach) to 16 m bgl(Kunta HP PP) during pre-monsoon period (2021).
6) In Deeper aquifer groundwater flow direction in general from land to sea coast.
7) The long term water level fluctuation for the Pre monsoon period reveals that rise in water level ranged from 0.02 to 0.24 m/year and fall -0.21 to -0.73 m/year.
8) Quality of groundwater in general fresh in terms of Total Dissolved Solid (TDS) in shallow aquifer whereas the quality in deeper aquifer close to coast is marginal saline.
9) No Fluoride and Nitrate concentration are observed beyond the permissible limit of drinking water standards.
10) Daman as an assessment unit falls under over exploited category and the stage of ground water development of the district is 122.18% in assessment year 2020.
11) Recharge from RTRWH and Irrigation Draft for MIS Water is proposed in the district to encounter needed surface runoff and implement the recommendations suggested in the Master plan 2020 for Artificial Recharge to Ground Water.
12) Estimating 25 % houses are suitable for harvesting and considering 40 sq m area per house, total 453384 sq m areas is available for roof top harvesting in Daman.
13) The source water available for harvesting has been taken as 60 % of average annual rainfall of the area, after making allowance for storm rain etc., total source water available for roof top harvesting has been estimated as 0.52 MCM /year.
14) Also Irrigation Draft for MIS Water Saving of 45.2 hams is also proposed for the district.
15) Since district is already in over exploited condition no development plan is proposed for groundwater withdrawal.
16) Projected stage of Ground water development after Ground water recharges of 52 ham (through RTRWH) and 45.2 Ham MIS Water saving via Irrigation Draft is 117.96 %.
17) 1765 Ham Additional Surface water is required to bring the district under Safe category 69.98%
18) 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.

19) Since about 93% groundwater withdrawal is through industrial activities, focus to be shifted to use the surface water instead of groundwater in the UT of Daman.
20) The water quality in general is good. However higher EC concentration is observed in isolated pockets in deeper aquifer. Ground water in such areas may be used after blending with surface water
21) 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.
22) Regulatory measures for registration of ground water abstraction structures for industries and their monitoring has to be taken up for sustainable development of the ground water resource.
23) To augment available resources, roof top rainwater harvesting or suitable artificial recharge measures (percolation ponds with recharge shafts) should be made mandatory for the non-polluting industries.
24) Restoration of all the existing tanks should be taken up with the view of accommodating the available surface run off and thus augmentation of the ground water resources by artificial recharge.
25) Periodical maintenance of these tanks is to be ensured.
26) Disposal of industrial effluents, solid waste and urban sewerage sites has to be identified, so that the phreatic aquifer does not get adversely polluted.
27) 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 for Creating awareness (Mass Awareness Campaign for public and farmers, slideshows, display boards on water conservation)

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***Annexure 1*** *Pre- monsoon-2021 Depth to water level and water table data of UT of Daman*

| S. N. | District | Taluka | Site | Latitude | Longitude | Date | Sample Collected | M.P (Mts) | WL (Mts bmp) | WL mbgl | TD (Mts) | Casing (Mtrs) | Dia (Mts) | E.M. (H.P) | Working Hours/ Day | Use | Remarks | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Daman | Daman | Pariyari | 20.376588 | 72.832232 | 6/15/2021 | Yes | 1.25 | 9.2 | 7.95 | | | 8 | 10 | 8 | Domestic | | DW |
| **2** | Daman | Daman | Jampore Beach | 20.369248 | 72.822319 | 6/15/2021 | Yes | | 7 | 7 | 30 | | - | 1 | 4 | Domestic | | TW/BW |
| **3** | Daman | Daman | Bhathaiya | 20.388574 | 72.8315 | 6/15/2021 | Yes | 1.1 | 3.93 | 2.83 | | | 3.5 | - | - | No use | | DW |
| **4** | Daman | Daman | Nani Daman City | 20.417715 | 72.837972 | 6/15/2021 | Yes | | 15 | 15 | 28 | | - | 1 | - | Domestic | | TW/BW |
| **5** | Daman | Daman | Devka | 20.452774 | 72.838114 | 6/15/2021 | Yes | 0.8 | 3.91 | 3.11 | | | 2.50 | 1 | 2 | No use | | DW |
| **6** | Daman | Daman | Bhimpore | 20.456929 | 72.859329 | 6/15/2021 | Yes | | 9 | 9 | 29 | | - | 0.5 | 6 | | | TW/BW |
| **7** | Daman | Daman | Nani Vankad | 20.457925 | 72.88499 | 6/15/2021 | Yes | 0.65 | 6.05 | 5.4 | 12 | | 2.5 | 1 | 6 | Domestic/Irrigation | | DW |
| **8** | Daman | Daman | Jani Vankad | 20.442828 | 72.879644 | 6/15/2021 | Yes | | 7 | 7 | 30 | | - | - | - | | | TW/BW |
| **9** | Daman | Daman | Amrutlaywa | 20.425471 | 72.854539 | 6/15/2021 | Yes | 0.45 | 3.7 | 3.25 | 9 | | 5.55 | - | - | | | DW |
| **10** | Daman | Daman | Olive Industry | 20.41928 | 72.891321 | 6/15/2021 | Yes | | 10 | 10 | 80 | | 6 inc | 5 | 24 | | | TW/BW |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | h | | | | | |
| **11** | Daman | Daman | Dabhel | 20.410623 | 72.882853 | 6/15/2021 | Yes | 1.03 | 2.7 | 1.67 | 10 | | 12 | - | - | | | DW |
| **12** | Daman | Daman | Kunta HP PP | 20.411838 | 72.873101 | 6/15/2021 | Yes | | 16 | 16 | 28 | | 6 inch | 1 | 4 | not active | | TW/BW |
| **13** | Daman | Daman | Kachigam | 20.394297 | 72.879845 | 6/15/2021 | Yes | | 13 | 13 | 27 | | - | - | - | | | TW/BW |
| **14** | Daman | Daman | Singha Faliya | 20.392572 | 72.850057 | 6/15/2021 | Yes | 0.37 | 5.85 | 5.48 | 10 | | 4.2 | 3 | 6 | | | DW |
| **15** | Daman | Daman | Zari | 20.372769 | 72.866525 | 6/15/2021 | Yes | | 11 | 11 | 20 | | 6 inch | 1 | 8 | | | TW/BW |

***Annexure 2*** *Post monsoon-2021 Depth to water level and water table data of UT of Daman*

| **NAQUIM Post monsoon Daman 2021** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **S. N.** | **District** | **Taluka** | **Site** | **Latitude** | **Longitude** | **Date** | **Source** | **M.P (Mts)** | **Dia (Mts)** | **TD (Mts)** | **WL (Mts)** | **E.M.(H.P)** | **Working Hours/ Day** | **Use** | **Formation** |
| **1** | Daman | Daman | Pariyari | 20.376588 | 72.832232 | 12/12/2021 | DW | 1.3 | 8 | 12 | 4.5 | 10 | 8 | Domestic/ Panchayat | Basalt |
| **2** | Daman | Daman | Jampore Beach | 20.369248 | 72.822319 | 12/11/2021 | TW/BW | - | - | 30 | 10 | 1 | 4 | Domestic | Basalt |
| **3** | Daman | Daman | Bhathaiya | 20.388574 | 72.8315 | 12/11/2021 | DW | 1 | 3.5 | 8 | 3.3 | - | - | Not in use | Basalt |
| **4** | Daman | Daman | Nani Daman City | 20.417715 | 72.837972 | 12/12/2021 | TW/BW | - | - | 35 | 9 | 1 | - | Domestic | Basalt |
| **5** | Daman | Daman | Devka | 20.452774 | 72.838114 | 12/11/2021 | DW | 1.00 | 2.50 | 6.0 | 3.70 | 1 | 2 | Gardening | Basalt |
| **6** | Daman | Daman | Bhimpore | 20.456929 | 72.859329 | 12/11/2021 | TW/BW | 0.40 | - | 25.0 | 12.0 | 0.5 | 6 | irrigation | Basalt |
| **7** | Daman | Daman | Nani Vankad | 20.457925 | 72.88499 | 12/11/2021 | DW | 0.7 | 2.5 | 8 | 5.1 | 1 | 6 | irrigation/ Dom | Basalt |
| **8** | Daman | Daman | Jani Vankad | 20.442828 | 72.879644 | 12/11/2021 | TW/BW | - | - | 30 | 7 | - | - | Domestic | Basalt |
| **9** | Daman | Daman | Amrutlaywa | 20.425471 | 72.854539 | 12/12/2021 | DW | 0.5 | 5.55 | 9 | 2.3 | - | - | Not in use | Basalt |
| **10** | Daman | Daman | Olive Industry | 20.41928 | 72.891321 | 12/11/2021 | TW/BW | - | 6 inch | 50 | 15 | 5 | 24 | Industrial/ Dom | Basalt |
| **11** | Daman | Daman | Dabhel | 20.410623 | 72.882853 | 12/11/2021 | DW | 1.1 | 12 | 10 | 2.4 | - | - | Not in use | Basalt |
| **12** | Daman | Daman | Kunta HP PP | 20.411838 | 72.873101 | 12/11/2021 | TW/BW | - | 6 inch | 40 | 17 | 1 | 4 | Domestic | Basalt |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **13** | Daman | Daman | Kachigam | 20.394297 | 72.879845 | 12/11/2021 | TW/BW | - | - | - | - | - | - | - | Basalt |
| **14** | Daman | Daman | Singha Faliya | 20.392572 | 72.850057 | 12/11/2021 | DW | 0.5 | 4.2 | 10 | 2.6 | 3 | 6 | irrigation rise | Basalt |
| **15** | Daman | Daman | Zari | 20.372769 | 72.866525 | 12/11/2021 | TW/BW | - | 6 inch | 22 | 7 | 1 | 8 | irrigation/ Dom | Basalt |