केंद्रीय 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

PATAN DISTRICT, GUJARAT

पश्चिमी मध्य क्षेत्र, अहमदाबाद

West Central Region, Ahmedabad

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Technical Report Series

AQUIFER MAP AND MANAGEMENT PLAN
PATAN DISTRICT
GUJARAT STATE

Government of India
Ministry of Jal Shakti
Department of Water Resources, RD and GR
Central Ground Water Board
West Central Region
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Chapter I

1 Introduction

Aquifer mapping study addresses the issues related with quantity and quality of groundwater in the aquifer systems of an area and problems arising due to development of groundwater resources. In order to resolve the issues arising from development of the aquifer system, information on the vertical and lateral extent of the aquifers, characteristics of aquifers and recharge and discharge mechanisms of the aquifer system is much required.

The aquifer mapping study has been carried out since 2012 (Fig. 1) and had contributed to 1) collection of data from previous studies 2) descriptions of the geologic and hydrogeological characteristics of the aquifer system 3) conceptualisation of the aquifer system 4) development of the numerical model for existing conditions and finally 5) to bring out aquifer management plan for effective management of the groundwater resources.

The study area forms a part of the Cambay Basin which is the most productive aquifers in north Gujarat area. The aquifer consists of regionally extensive alternate layers of sand, clay, silt, gravels etc.

1.1 Objectives

The aquifer mapping is primarily based on the existing data that are collected compiled, analyzed and interpreted from available sources. In order to represent the heterogeneity of groundwater system, the complexity of aquifer map is simplified based on the availability of data for generation of information to be depicted in Aquifer maps broadly representative of the area. The data gaps analysis carried out helped in to propose/generate additional data from new data-collection activities such as exploratory drilling, geophysical investigations, water level measurements and groundwater quality analysis. By integrating and analysing the existing data and the data generated, regional hydrogeological maps, thematic maps, water quality maps, cross-sections, 2D and 3D aquifer dispositions and maps of the potentiometric head were generated. Theses maps were utilized for the defining the aquifer geometry and computation of groundwater resources and possible interventions.

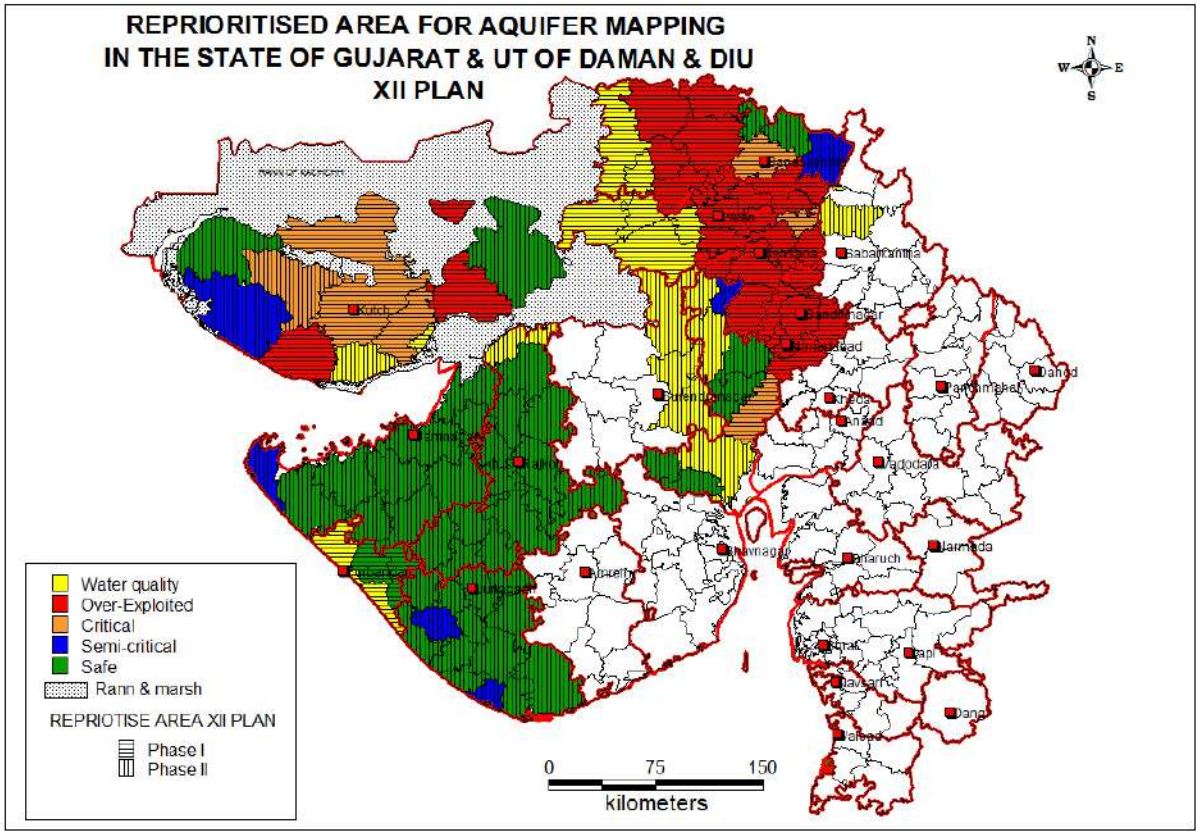


Figure 1. Aquifer mapping area in Gujarat state (XII plan)

1.2 Scope of the Study

Scope of the study is limited to the extent defining the defining the geometry of aquifer system in space i.e. lateral and vertical distribution of aquifer system, based on existing data. Defining characteristics of aquifer system wherever available and its significance in development and management of groundwater resources in terms of quantity and quality of groundwater of the area depicting groundwater regime in Two and Three dimensional form for easy understanding, quantification of available groundwater resources, demand and supply of groundwater and its use in the area. Identification of issues related with development and use of groundwater to meet the competing water demand and its depiction for addressing the issue in terms of quantity and quality. Groundwater management strategies for addressing the issues by introducing management interventions (on demand and supply side) into the system.

Finally it's the user, whose participatory perspective of groundwater development, use and management based on available Aquifer information system by the user as a stakeholder himself is envisaged.

1.3 Approach and Methodology

Methodology involves creation of database for each of the principal aquifer. Delineation of aquifer extent (vertical and horizontal). Standaardzed output for effective presentation of scientific integration of Hydrogeological, geophysical, geological, hydrochemical 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.

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, analysed, examined, synthesized and interpreted from available sources. These sources were predominantly non-computerized data, which was converted into computer based GIS data sets. On the basis of available data, Data Gaps were identified.

1.3.2 Data Generation

There was also 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 exploratory drilling, geophysical techniques, hydro-geochemical analysis, remote sensing, besides detailed hydrogeological surveys. CSIR-NGRI has been hired as consultant to carry out geophysical studies including advance Heliborne Transient Electro Magnetic Method (Heli-TEM) 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 Characterization of Aquifers, which can be termed as Aquifer maps providing

spatial variation (lateral & vertical) in reference aquifer extremities, quality, water level, potential and vulnerability (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 the given table 1 and Fig. 2.

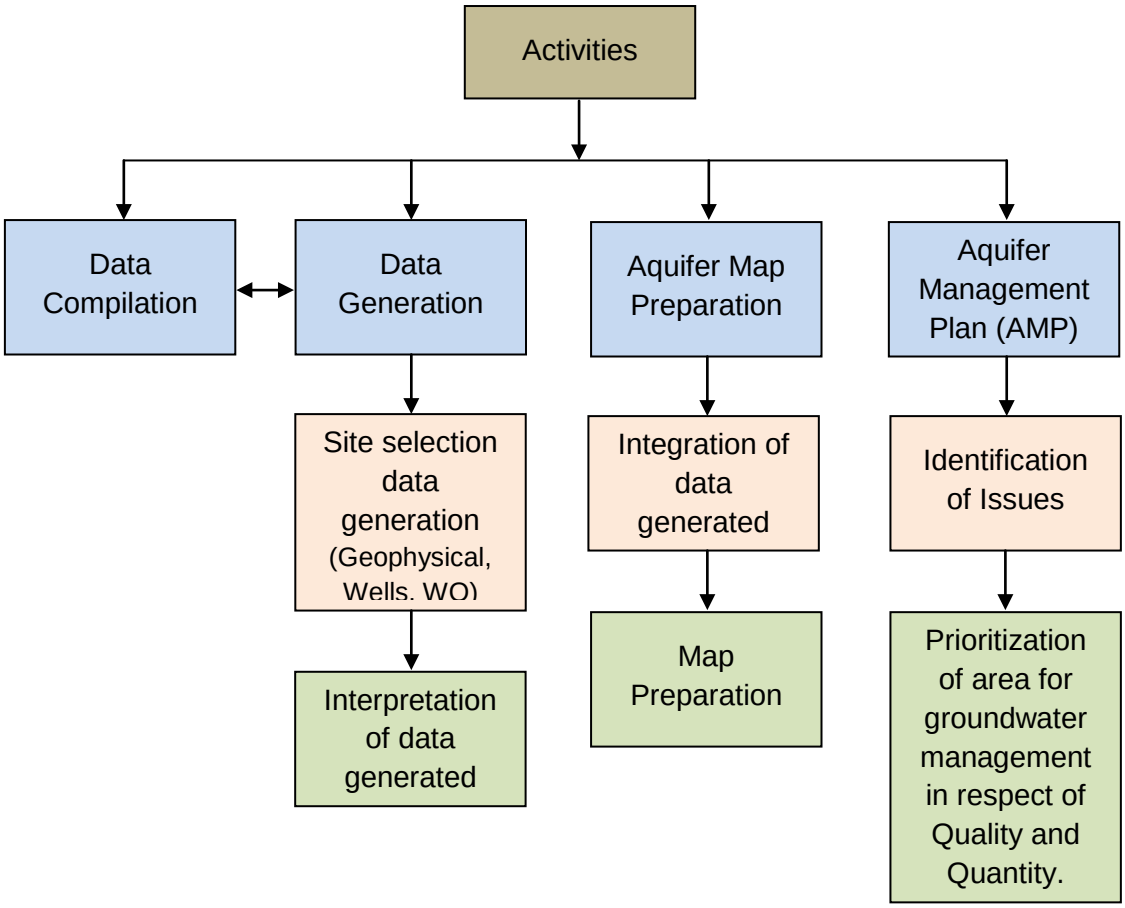


Figure 2. Activities under National Aquifer Mapping Programme

Activities

Step 1: No activity needed

Step 2: Data generation

Step 3: Aquifer map preparation

Step 4: Preparation of management plan

Table 1. Major activities in aquifer mapping programme

Sl. No.	Activity	Sub Activity	Task
I	Compilation of Existing Data/ Identification of Principal Aquifer Units & Data Gap	Compilation of Existing groundwater Data	Preparation of Base map and thematic layers
			Data base of Exploration wells
			Compilation of Geology, Geophysics, Hydrogeology, Geochemical, Hydrology
			Delineation of principal aquifers (Vertical & Lateral)
			Compilation of Aquifer wise Water Level data
			Compilation of Aquifer wise Draft Data
		Identification of Data Gap (as per the need of the Terrain & determine the density of data requirement)	Data Gap in thematic layer
			Data gap in Sub-surface Information & aquifer parameters
			Data gap in information on Geology, Geophysics, Hydrogeology, Geochemical, Hydrology
			Data gap in delineation aquifers (Vertical & Lateral)
			Gap in Aquifer wise Water Level data
			Data gap in Aquifer wise Draft Data
II	Generation of Data	Generation of Geological layers in1: 50,000 scale	Preparation of Geological Map in 1:50,000 scale.
			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
			Advanced Geophysical Methods
		Hydrological information	Demarcation of water bodies
			Soil Infiltration studies
		Parameters on groundwater recharge	Rainfall data analysis, Canal flow, recharge structures etc
		Preparation Hydrogeological maps in 1: 50,000	Water Level Monitoring
			Exploratory drilling
			Pumping tests

		scale	Sub-surface lithological data generation from existing wells
		Generation of additional water quality parameters	Analysis of groundwater for pesticide, Bacteriological contamination
			As and F in groundwater
III	Aquifer Map Preparation (1: 50K scale and for identified areas in 1:10,000 scale)	Analysis of data base and preparation of GIS layers	Integration of Hydrogeological, Geophysical, Geological, Hydro-chemical data
		Preparation of Aquifer Maps	
IV	Aquifer Response Model/Aquifer Management Plan	Model Conceptualisation	Integration of Aquifer Geometry, Aquifer units, Aquifer parameters, Groundwater Draft & Recharge.
		Model Simulation	From field study, data from secondary sources (state GWD & Local agencies)
		Preparation of Aquifer Management Plan	Information of aquifer to public, villagers.
V	IEC Activity & Implementation of Aquifer Management Plan	A. Capacity building	Involvement of PRIs, local administration, state government, community & NGO's
		B. Participatory Groundwater Management	

1.4 Area Details

Patan is one of the agriculturally, socially and economically advanced districts, situated in the northern part of Gujarat State (Fig. 3). Regionally, it forms part of North Gujarat Region and is bounded towards north by Banaskantha, towards south by Surendranagar Towards west by Little Rann of Kachchh and towards east by Mahesana districts. The Patan district lies between 23°20'51" N & 24°05'19" N Latitudes and 71°01'12" E & 72°27'53" E Longitudes and falls in the SOI degree sheet nos. 41M, 46A, 40P & 45D is part of north Gujarat alluvium Plain. The district is administratively divided into 9 talukas (Patan, Sidhpur, Saraswati, Harij, Sami, Shankheshwar, Chanasma, Santalpur and Radhanpur) and covers 604 villages that include 10 abandoned villages (Fig. 4). Salient features of the district are summarised in table 2.

Groundwater occurs under phreatic and confined conditions and is developed extensively from Quarternary alluvium through dug wells, dug cum bore wells and tube wells for irrigation and domestic purpose. The open wells tapping shallow aquifer are few in areas as water table is very deep particularly in central and eastern part of the district. In such areas, groundwater development is through TW. Groundwater development from phreatic aquifer is low to moderate due to limited saturated aquifer thickness and at place due to low yield and/or salinity.

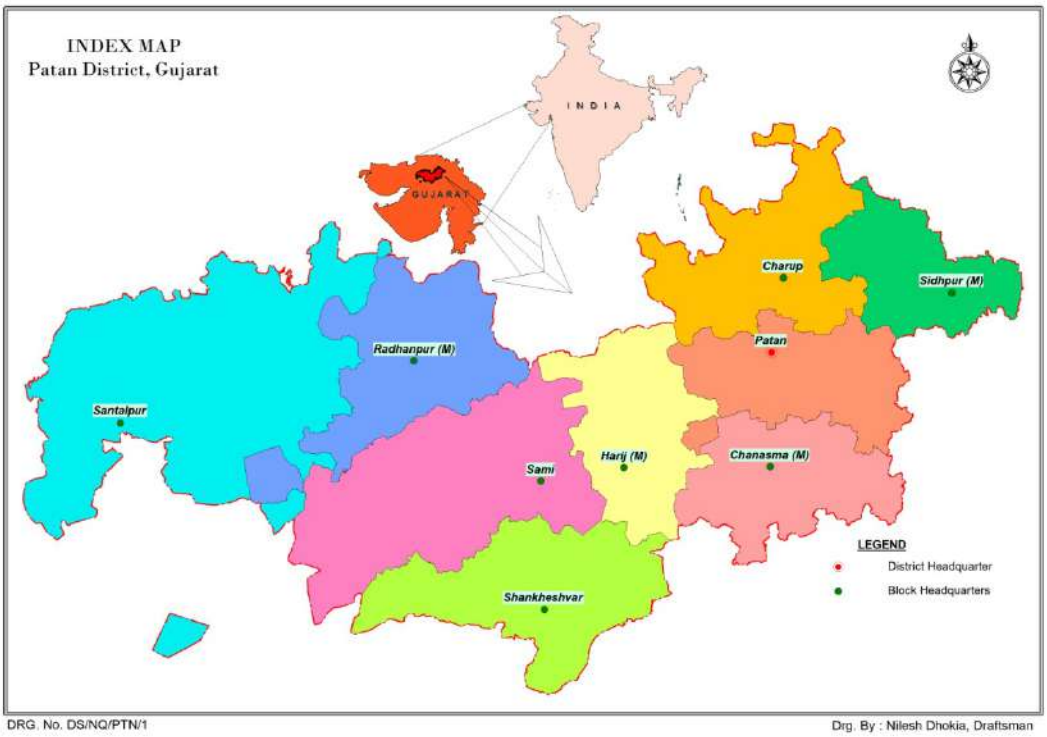


Figure 3. Location map of Patan district

Table 2. Salient features of Patan district

Geographical Area	5971 km ^{2}	
No of Blocks/ Talukas	9	
Population (2011 Census)	13,42,746	
Average annual rainfall	603 mm	
Range of average temperature	21-31 °C	
Major drainage system	Saraswati, Rupen, Banas and Khari	
Major/ medium irrigation scheme		
Major geological formation	Soft Rock: Alluvium	
Utilizable groundwater resources	FRESH 382.59 MCM/Yr	SALINE 934.49 MCM/Yr

Net groundwater draft	385.67 MCM/Yr	389.78 MCM/Yr
Stage of groundwater development	100.80 %	41.71%
Blocks showing intensive groundwater development saline blocks	Chanasma, Patan, Sidhpur, Saraswati Harij, Sami, Radhanpur, Santalpur, Shankheshwar	

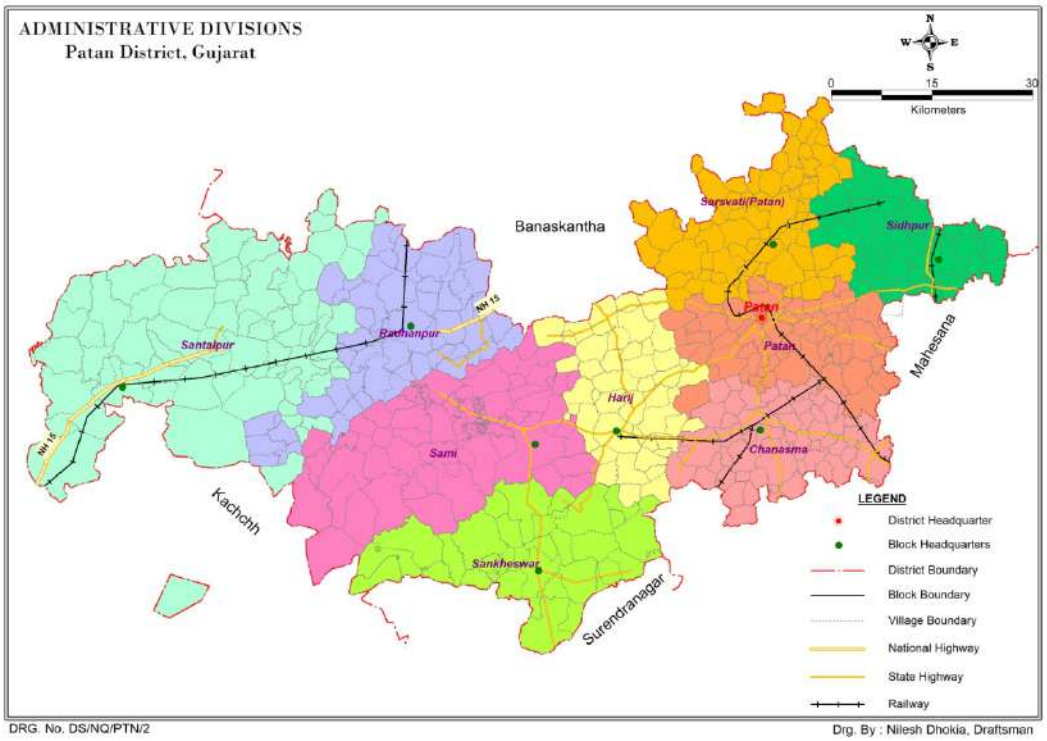


Figure 4. Administrative divisions of Patan district

1.5 Data Availability

Geological, Geophysical, Hydrogeological and Hydrochemical data generated during Groundwater exploration, Systematic Hydrogeologial studies, Reappraisal Hydrogeological studies, Groundwater Management studies, Micro level hydrogeological studies and special studies by the Central Ground Water Board since its inception has by central and state government and other institutions have been collected and considered. In preparation of Aquifer Map and Groundwater management plan. The data available on soil, Drainage, Geomorphology, Land use and Land cover compiled and integrated to generate respective thematic maps and summarized in Table 3.

Table 3. Data availability and utilized for preparation of aquifer map and management plan

Sl. No	Themes	Data available/considered			
	Aquifer /Aquifer Group	I		II	III
		Up to 120 m		Between 120 to 200 m	>200 m
1	Groundwater level data Long term	DW	PZ	PZ	PZ
	CGWB	07	02	09	03
	GWRDC +	00	11	15	13
	Total	07	13	24	16
2	Groundwater quality data				
	CGWB	07		00	00
	GWRDC+	11		15	13
	Total	18		15	13
3	Groundwater exploration data Aquifer parameters/ pumping test	CGWB -105 GWRDC –25			
4	Borehole Lithology data upto 300 m (SR)/200m (HR)	CGWB -16 GWRDC - 09			
5	Geophysical data Resistivity log	Electrical Log - 20 VES - 112			
6	Land use and Land cover	Information available GIS data set with limited attributes			
7	Geomorphology				
8	Drainage				
9	Soil				
10	Irrigation/Minor Irrigation Data	Available from State Water Resources Data centre			
11	Water conservation structures	Statistical data available from State Water Resources Department			
12	Soil conservation structures	Statistical data available from State Government departments			
13	Cropping pattern data	Zilla Panchayat			
15	Hydrological data	Available from State Water Resources Data centre			
14	Rainfall data				

Source: Government of Gujarat.

1.6 Data Adequacy, Data Gap Analysis and Data Generation

Table 4. Data adequacy, data gap analysis and data generation

Sl. No	Taluka	Proposed Village	Toposheet No. & Quadrant	EW 300 m	EWI 300 m	OW I 300 m	EW II 180-210 m	OW II 180-210 m	EW III 100 m	OW III 100 m	Longitude	Latitude
1	Chanasma	Finchal	46A/02-1C	Yes							72.2206	23.7364
2	Chanasma	Khari Dhariyal	46A/02-1A	Yes							72.0398	23.7101
3	Chanasma	Vadavali	46A/02-2B		Yes	Yes	Yes	Yes	Yes	Yes	72.1252	23.6422
4	Harij	Jamanpur	41M/14-1C	Yes							71.9594	23.7072
5	Harij	Piplana	41M/13-3C	Yes							71.9372	23.7935
6	Harij	Roda	41M/13-2B		Yes	Yes	Yes	Yes			71.8805	23.8606
7	Patan	Jaleshwar Paldi	46A/01-2B		Yes	Yes	Yes	Yes	Yes	Yes	72.1504	23.8846
8	Patan	Khanpur Rajkuva	46A/01-3A	Yes							72.0100	23.8000
9	Patan	Samalpati	46A/01-2B		Yes	Yes	Yes	Yes	Yes	Yes	72.1100	23.8700
10	Radhanpur	Badarpura	41M/09-3C	Yes							71.7019	23.8055
11	Radhanpur	Dehgam	41M/06-1C	Yes							71.4566	23.7224
12	Radhanpur	Lotiya	41M/09-1A	Yes							71.5581	23.9581
13	Radhanpur	Porna	41M/09-2B		Yes	Yes	Yes	Yes			71.6315	23.8819
14	Sami	Jesda	41M/14-3A	Yes							71.7816	23.5704
15	Sami	Jhilvana	41M/14-1A	Yes							71.8057	23.7075
16	Sami	Kukrana	41M/14-2B		Yes	Yes	Yes	Yes			71.8813	23.6354
17	Sami	Lolada	41M/10-3C	Yes							71.6870	23.5537
18	Sami	Mubarakpura	41M/13-3A	Yes							71.7866	23.7763
19	Sami	Rampura	41M/10-1A	Yes							71.5412	23.7221
20	Sami	Tuvad	41M/14-3C	Yes							71.9552	23.5473
21	Sami	Upaliyasara	41M/10-2B		Yes	Yes	Yes	Yes			71.6209	23.6308
22	Santalpur	Antarnes	41M/06-1A	Yes							71.2873	23.6808
23	Santalpur	Daigamda	41M/05-3A	Yes							71.3018	23.7990

24	Santalpur	Eval	41M/01-2B		Yes	Yes	Yes	Yes			71.1199	23.8807
25	Santalpur	Korda	41M/05-2B		Yes	Yes	Yes	Yes			71.3757	23.8666
26	Santalpur	Par	41M/01-3C	Yes							71.2075	23.7843
27	Santalpur	Piparala	41M/02-2B		Yes	Yes	Yes	Yes			71.1169	23.6426
28	Santalpur	Zazam	41M/05-1A	Yes							71.3221	23.9480
29	Sidhpur	Mindroda	46A/01-1C	Yes							72.1900	23.9600

Tentative list of villages as per data gap analysis for generation of data

1.7 Rainfall-Spatial, Temporal and Secular Distribution

Table 5. Rainfall data of Patan district

Year	Name of Taluka								
	Sidhpur	Patan	Chanasma	Harij	Santalpur	Radhanpur	Sami	Saraswati	Shankheshwar
1961	808	669	599	1032	339	665	927	669	927
1962	379	484	680	374	305	180	296	484	296
1963	217	598	600	467	372	399	401	598	401
1964	400	443	361	265	435	422	252	443	252
1965	337	465	335	477	455	526	587	465	587
1966	343	501	306	242	337	183	309	501	309
1967	803	784	514	454	361	272	591	784	591
1968	864	347	365	223	123	402	271	347	271
1969	329	392	340	161	150	553	266	392	266
1970	708	682	733	551	392	600	422	682	422
1971	471	610	563	437	377	549	553	610	553
1972	313	559	412	287	146	153	220	559	220
1973	929	705	699	418	456	630	636	705	636
1974	258	219	163	150	89	114	172	219	172
1975	951	1197	1552	623	682	1152	1091	1197	1091
1976	178	504	561	515	624	632	537	504	537
1977	1528	1280	1420	556	968	1130	1009	1280	1009
1978	483	575	1180	510	521	425	592	575	592
1979	579	521	568	588	488	338	481	521	481
1980	593	387	510	577	426	513	481	387	481
1981	762	565	741	566	518	459	469	565	469
1982	451	621	559	330	466	313	340	621	340
1983	486	607	664	639	772	544	740	607	740
1984	826	574	657	439	318	520	544	574	544
1985	199	188	188	210	149	195	220	188	220
1986	223	187	145	117	107	195	145	187	145
1987	158	118	124	62	32	45	39	118	39
1988	721	818	689	469	764	563	549	818	549
1989	776	459	422	373	348	297	474	459	474
1990	797	643	587	804	956	763	684	643	684
1991	408	308	255	235	161	226	184	308	184
1992	822	609	397	674	700	428	489	609	489
1993	909	602	283	501	530	710	462	602	462
1994	1300	1241	1250	875	619	778	739	1241	739
1995	519	586	295	437	208	391	513	586	513
1996	349	321	331	315	260	315	189	321	189
1997	1366	1488	1991	1278	873	929	1083	1488	1083
1998	836	662	683	511	427	485	565	662	565
1999	230	157	160	177	56	141	96	157	96
2000	372	267	291	334	247	353	362	267	362
2001	566	536	465	338	370	464	489	536	489
2002	238	282	142	180	209	250	163	282	163
2003	541	720	494	805	989	843	880	720	880
2004	468	603	526	517	353	411	356	603	356
2005	1029	750	824	702	427	781	729	750	729
2006	1397	1675	566	766	629	1107	685	1675	685

2007	1290	1005	595	835	560	989	1065	1005	1065
2008	555	736	424	506	311	541	578	736	578
2009	363	287	256	303	254	311	263	287	263
2010	912	671	480	861	482	825	880	671	880
2011	725	765	549	685	688	1083	525	765	525
2012	563	339	276	316	178	451	320	339	320
2013	991	865	641	771	729	1137	672	865	672
2014	1017	851	488	414	311	411	373	851	373
2015	805	769	432	659	506	892	418	769	418
2016	451	377	368	735	341	661	415	651	512
2017	1444	1120	592	868	722	1089	727	1089	741
Average 1967 to 2016 (Fifty Year)	**668**	**620**	**556**	**496**	**433**	**545**	**500**	**620**	**500**
Average 2007 to 2016 (Ten Year)	**767**	**666**	**451**	**609**	**436**	**730**	**551**	**666**	**551**

District Average Long Term (Fifty Year) = 549 mm
District Average (Ten Years) = 603 mm

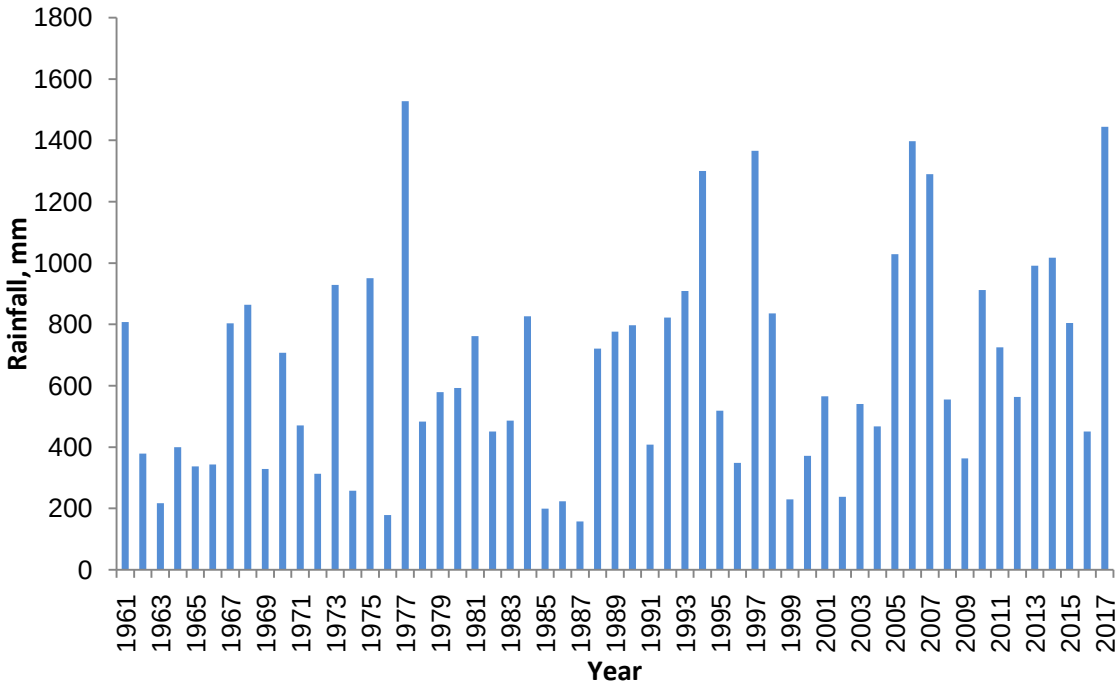


Figure 5. Rainfall of Patan district

Figure 5 shows the rainfall chart from 1961 to 2017. Mean and standard deviation are found to be 546.72 mm and 257.97 mm, respectively. The standard

deviation shows how widely values are dispersed from the average value (the mean). Skewness characterizes the degree of asymmetry of a distribution around its mean. Positive skewness of 0.660 indicates a distribution with an asymmetric tail extending toward more positive values. Positive kurtosis of 0.439 indicates a relatively peaked distribution. This characterizes the relative peakedness of a distribution compared with the normal distribution.

It is evident from the rainfall data that average rainfall has increased in the recent years for the district as a whole and for all the talukas except Chanasma. The intensity of the rainfall has increased in recent years i.e. high rainfall occurrence under short duration. These may be attributed to climate change phenomenon.

1.8 Physiographic Setup

Patan district has undulatory landscape characterized by rolling to gently sloping vast Alluvial-Eolian plain (Fig. 1). Rann fringes the western border of the area. The elevation ranges from less than 10 m in the western and south western part to more than 120 meters above mean sea level in the northeastern part. Master slope of the area is towards southwest.

Physiographically, the area is divided into three major zones namely Alluvial Plain, sedimentary pediplain and Rann & Bets. Major part of the district is occupied by alluvial plain. Alluvial plain is monotonously flat with gradual slope toward south-west, and exhibits mildly undulating dunal landscape.

1.9 Geomorphology

Geomorphologically the district can be divided into three major zones

a) **Alluvial plain**: It is a vast sandy tract characterised by gently sloping, slightly rolling to undulatory topography owing to presence of sand dunes. It is the most prominent unit and covers the most part of the district.
b) **Sedimentary Pedeplain**: It is a featureless, gently sloping sedimentary pedeplain bordering the alluvial plain which merges with the Rann of Kachchh. It consists of marine sedimentary formations of Jurassic and tertiary period. It falls in the western part of the district in Santhalpur Taluka.
c) **Rann and Bets**: These are small isolated and continuous patches of marshy land which are contiguous to the Rann of Kachchh. The terrain is monotonously flat and low lying with elevations less than 8 mamsl with or without salt encrustations. Bets are the small island in the Rann. These are found in the western part of the district.

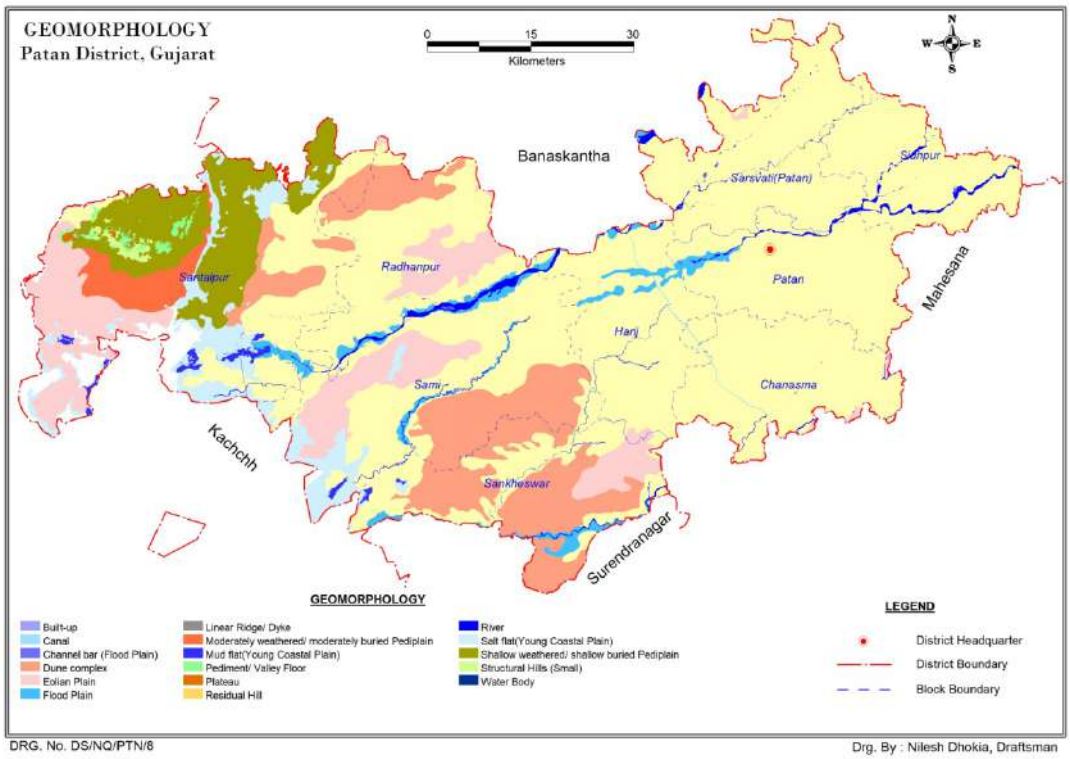


Figure 6. Geomorphology of Patan district

1.10 Land Use Land Cover

Table 6. Land use and Land cover details of Patan district

Taluka	Geographical area (Sq. km.)	Area according to village papers	Area under Forest	Land not available for cultivation			Other uncultivable land excluding fallow				Fallow land			Net area sown	Area sown more than once	Gross cropped area (16+17)	Cropping intensity
				Land put to non agricultural uses	Barren & uncultivable land	Total (6+7)	Permanent pastures & other grazing lands	Land under miscellaneous tree crops & groves not included in net area	Culturable waste	Total (9+10+11)	Fallow land other than current fallow	Current fallow	Total				
2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Patan + Saraswati	1031.57	1023.82	0	106.95	18	124.95	77.51	0	0.46	77.97	0	10.17	10.17	673.05	406.23	1079.28	160.4
Sidhpur	374.78	382.34	0	31.22	4.53	35.75	32.59	0	14.09	46.68	0	5.38	5.38	253.65	173.4	427.05	168.4
Chanasma	457.25	456.8	0	49.5	1.8	51.3	28.7	0	5.9	34.6	0	16.9	16.9	347.7	182.35	530.05	152.4
Harij	407.12	406.97	5.5	27.94	0.53	28.47	24.62	5.5	11.64	41.76	0.15	71.82	71.97	280.85	157.05	437.9	155.9
Sami + Shankheshwar	1514.44	1509.76	87.53	69.07	61.13	130.2	68.63	87.54	50	206.17	0	152.41	152.41	1037.63	212.09	1249.72	120.4
Radhanpur	595.62	591.63	16.9	51.63	15.13	66.76	32.51	16.9	0.16	49.57	0	58.87	58.87	415.9	106	521.9	125.5
Santhalpur	1350.26	1296.4	355.33	115.36	54.26	169.62	18.85	355.33	58.23	432.41	0	24.32	24.32	612.33	436.9	1049.23	171.4
District Total	5731.04	5667.72	465.26	451.67	155.38	607.05	283.41	465.27	140.48	889.16	0.15	339.87	340.02	3621.11	1674.02	5295.13	146.2

Area is in square km. Source : Ankadakiya Ruprekha 2015-16

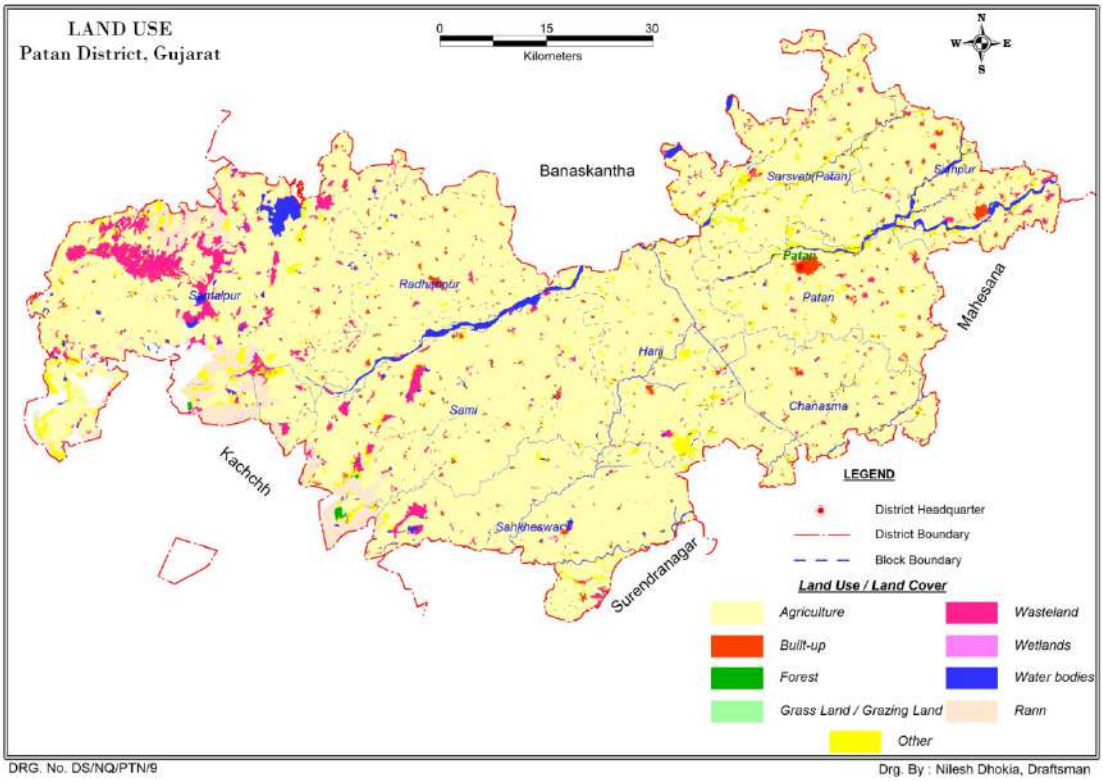


Figure 7. Land use Land cover map

1.11 Soil

In major part of north Gujarat soils are sandy in nature. In general the soils are poor to medium in fertility and water retention capacity. Most soils have good aeration, porosity and permeability. The hydraulic conductivity of the soils ranges from negligible for saline and alkali soils in the western part to more than 7cm/hr for calcareous sandy soils in the north and west. Soils of the area fall in five broad categories as below.

i. **Saline and alkali soils**: These are typically deep, grey calcareous sandy clay loams of low permeability.

ii. **Calcareous sandy loams**: These are generally Deep, light grey or brown sandy loams of moderate to good permeability and drainage.

iii. **Calcareous sandy soils**: These are mostly pale yellow and brown sands & loamy sands of good depth and high permeability.

iv. **Non calcic brown soils**: These are characterised by pale brown to brown deep loamy sands and sandy loams of adequate to good permeability.

v. **Non calcic red brown soils**: These are of mixed colluvial and alluvial derivations from rocks of the Aravali system. Mostly deep loamy sands to sandy loams with adequate to good hydraulic conductivity.

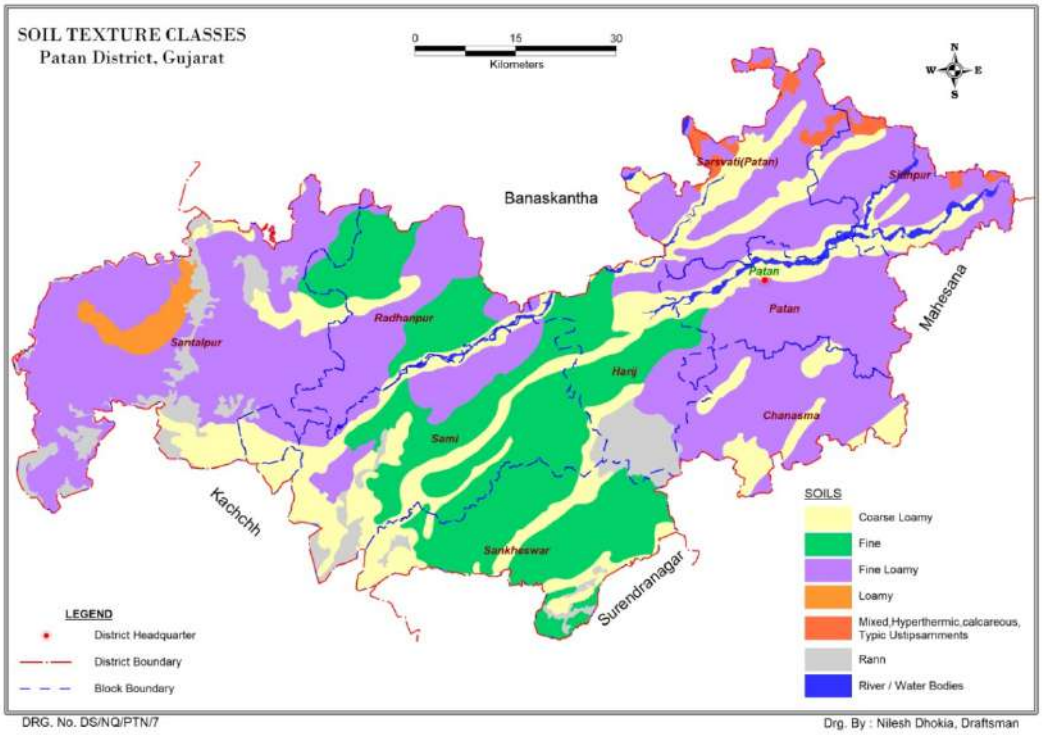


Figure 8. Soil map

1.12 Hydrology

Saraswati and Banas along with their tributaries form the major drainage system of the district. These are ephemeral in nature and the flow is observed only during monsoon when heavy rainfall is there in the catchment area.

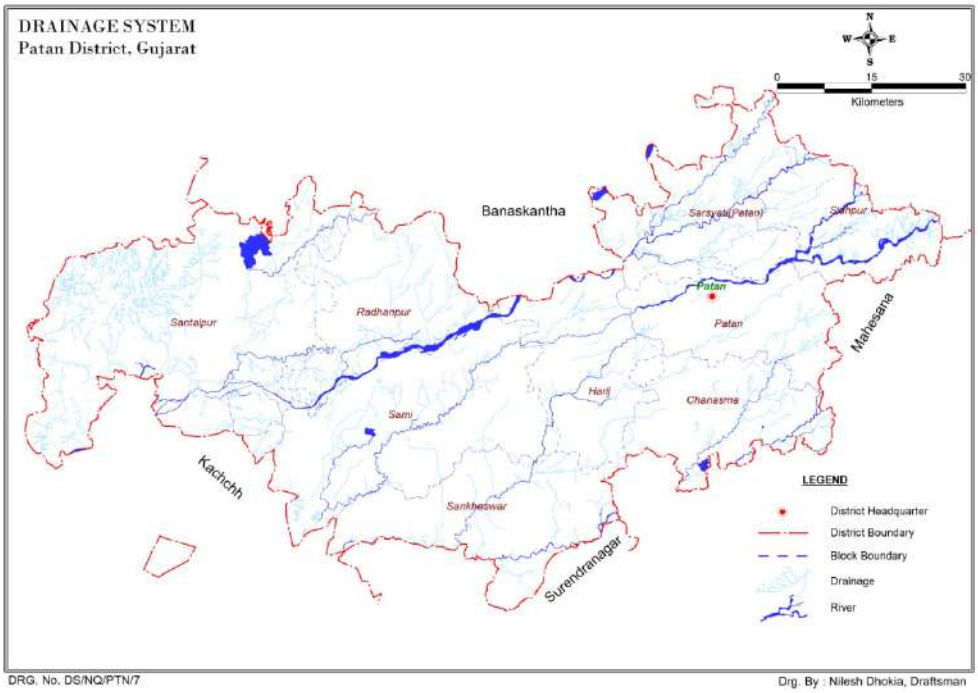


Figure 9. Drainage system

1.13 Agriculture

Table 7. Taluka-wise and crop-wise area details (km^2)

Taluka Name	Total Grains	Total Pulses	Total Oil crops	Vegetables	Cumin	Cotton	Fodder
Patan	71.50	17.75	173.80	9.35	0.30	42.20	146.20
Saraswati	111.30	12.60	212.00	6.50	0.90	53.75	186.70
Siddhpur	73.50	41.25	120.50	8.00	3.70	23.75	127.20
Chanasma	66.95	18.25	173.05	2.60	1.20	72.50	149.50
Harij	56.50	49.55	118.90	2.55	13.35	18.80	154.32
Sami	24.14	95.18	130.51	1.96	118.20	65.65	234.96
Shankheshwar	13.33	54.91	138.91	1.65	56.20	115.33	182.69
Radhanpur	51.25	32.70	125.34	2.05	89.65	8.31	204.45
Santhalpur	24.05	200.50	224.01	1.60	377.60	3.12	212.70
District Total	492.52	522.69	1417.02	36.26	661.10	403.41	1598.72

Source: Ankadakiya Ruprekha Patan-2015-16

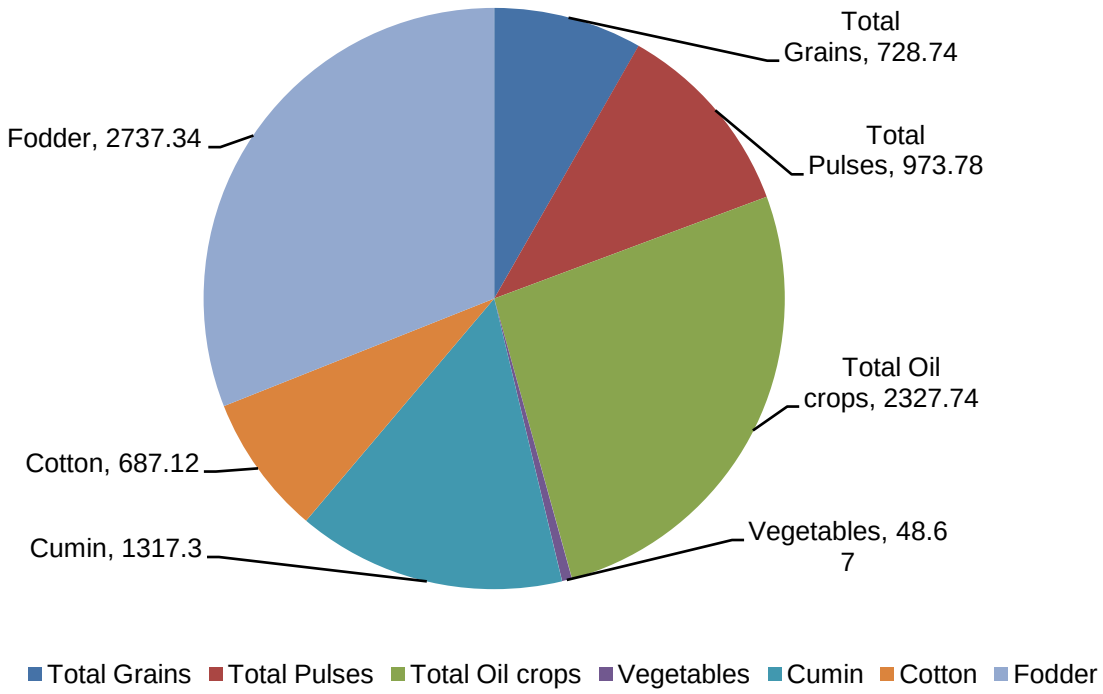


Figure 10. Area under different crops

1.14 Irrigation

Table 8. Taluka-wise source of irrigation details

Taluka	Net Irrigated Area (km^2)	Area Irrigated more than once (km^2)	Gross Irrigated Area (km^2)	Canal Length (km)	No. of Ponds	No. of Dug well	No. of Tubewell (Govt.)	No. of Tubewell (Private)
Patan	251.33	130.15	381.48	54	69	363	30	1830
Saraswati	304.60	179.85	484.45		76	402		
Siddhpur	196.75	101.20	297.95	21	50	1580	30	705
Chanasma	239.00	151.60	390.60	10	79	750	34	1925
Harij	181.57	93.65	275.22	18	47	275	39	310
Sami	149.76	23.90	173.66	52	72	80	55	325
Shankheshwar	74.81	14.13	88.94		73	70		
Radhanpur	150.66	59.96	210.62	32	175	1014	20	210
Santhalpur	403.48	23.17	426.65	26	129	87	15	135
District Total	1951.96	777.61	2729.57	213	770	4621	223	5440

Source: Ankadakiya Ruprekha Patan-2015-16

Table 9. Area irrigated by different source.

Source	Number	Area Irrigated (km^2)
Canal		5.80
Open Wells	4396	14.50
Tube Wells	11143	117.00
Micro Irrigation (GGRC)	12772	29.56

Source: Agriculture Contingency Plan for Patan district 2011

1.15 Prevailing Water Conservation/Recharge Practices

Table 10. Water Conservation structures constructed by different departments in Patan district

Water Resource Department Check Dams (Year ending 2018)		3073
Rural Development Department (Year ending 2014)	Check Dam	912
	Bori Band	4923
	Khet Talavadi	4589
Tribal Development Department (Year Ending 2014)	Check Dam	0
	Bori Band	0
Forest and Environment Department (Year Ending 2015)	Check Dam	26
	Bori Band	0
	Van Talavadi	0
Agriculture Department	Check Dam	775
	Bori Band	0
	Khet Talavadi	1420
Water Supply Department (Year ending March 2015)	Check Dam	0
Total Water Conservation Structures	Check Dam	4786
	Bori Band	4923
	Khet Talavadi	6009

Source: https://guj-nwrws.gujarat.gov.in/downloads/CheckdamVariousDeptt31032018.pdf

Table 11. Construction of check dams in Patan district under various schemes up to 31/03/2018

Sardar Patel Participatory Water Conservation Scheme	On Big River	0
	On Small Kotar/River	3038
Sujlam Suflam	On Big River	22
	On Small Kotar/River	6
Build Your Own Check dam	On Big River	0
	On Small Kotar/River	0
Others Including Panchayat	On Big River	0
	On Small Kotar/River	7
Total Checkdams Completed upto 31 March 2018	On Big River	22
	On Small Kotar/River	3051
	Total	3073

Source: https://guj-nwrws.gujarat.gov.in/downloads/CheckdamNWRDeptt31032018.pdf

Table 12. Deepening of Ponds in Patan District by Different Departments

Water Resource Department	419
Land Development Corporation	103
Land Development Corporation(By Grant of Water Res. Dept.)	15
Land Development Corporation (By the Grant of GHDC)	47
Rural Development Department	163
Registered Sahakari Mandli	1
Forest Department	15
Panchayat Department	13
Total	776

Source: https://guj-nwrws.gujarat.gov.in/showpage.aspx?contentid=1535&lang=English

Chapter II

2 DATA COLLECTION AND GENERATION

Hydrogeological data of the district was collected from CGWB reports, BDRs and unpublished reports. Water level and watr quality data from observation wells/piezometers from CGWB and GWRDC Ltd., Government of Gujarat was collated and combined for preparation of maps. Lithologs of CGWB and GWRDC Ltd., Government of Gujarat wells was completed and selected lithologs long with geophysical logs were used for demarcation of aquifer groups. Details of hydrogeological data of existing wells is presented in table 13.Groundwater level and groundwater quality maps for pre monsoon and post monsoon period of 2018 are also presented.

Exploratory drilling as per the data gap is proposed for Patan district fro generation of subsurface geology data and hydrogeological parameters. The work is awarded to Ms WAPCOS Ltd. and is under way at the time of compilation of the report.

Hydrogeological data (water level, pumping tests, soil infiltration studies, slug tests etc.)

Table 13. Details of hydrogeological data

Sl. No	Longitude	Latitude	Village	Taluka	Depth Drilled (m)	Depth Constructed (m)	Zone Tapped from (m)	Zone Tapped to (m)	Sp. Capacity (lpm/m) of dd	Transmissivity (m^2/day)	Permeability (m/day)	Storage Coefficient	Leakage Coefficient
1	72.2833	23.6167	Panchot I	Chanasma	308	250	119	250	70	144	2.1		
2	71.7750	23.4250	Panchasar	Sami	611	374	209	371	67	104	1.3		
3	72.2833	23.6667	Dhinoj TW	Chanasma	472	463	410	462	1.3	69	1.8	0.0001	
4	72.1333	23.6667	Karora TW-1	Chanasma	213	208	110	208	6.2	210	4.8		
5	72.1333	23.6667	Karora TW-2	Chanasma	98	95	30	95	1104	471	13.9		
6	71.8167	23.4250	Panchasar	Sami	107	107	44	104	3	73	2.5		
7	72.2375	23.8667	Kamliwara TW-1	Patan	62	44	35	54	7.8	239	6.3	7E-05	3.6E-09
8	72.2375	23.8667	Kamliwara TW-2	Patan	226	200	127	196	9.6	239	4.8	0.0012	
9	72.1167	23.7667	Khimiyana	Patan	96	92	35	87	0.3	28	0.8		
10	72.0750	23.9167	Vasna TW-1	Patan	213	195	102	191	8.8	540	11.7	0.0002	1.7E-08
11	72.0750	23.9167	Vasna TW-2	Patan	98	91	59	87	0.7	31	0.7	0.0002	1.6E-09
12	72.1333	23.5167	Charasan PH-3	Chanasma	453	425	401	422	2.7	76	1.7		
13	72.3381	23.8883	Kanesara EW	Sidhpur	200	200	132	196		1.59			
14	72.5273	24.1707	Vanasan	Sidhpur	200	200	102	197		0.4			
15	72.4674	23.9601	Lukhasan EW	Sidhpur	200	200	85	197		68.05			
16	72.4674	23.9601	Lukhasan OW	Sidhpur	200	200	91	198		67.8			
17	72.3983	23.9252	Sidhpur Nadi tat EW	Sidhpur	200	199	110	196		0.96			
18	72.9464	23.9464	Nagwasan EW	Sidhpur	200	195	96	190		59.89			
19	71.7128	23.8133	Badarpura	Radhanpur	305	270	231	270		39.55-75.04			
20	71.5417	23.8633	Bhilot	Radhanpur	305	258	216	254		69.24-158.21			
21	71.4717	23.7417	Dahegam	Radhanpur	305	288	207	284		5.82-27.68			
22	71.5536	23.9519	Lotiya	Radhanpur	305.06	266	236	263		100.49-218.37			
23	72.2050	23.9636	Nindroda	Siddhpur	301.36	252	232	248		54.20-87.92			

2.1 Groundwater level

Groundwater in the area occurs under unconfined condition in the Aquifer Group I and under semi-confined to confined condition in the Aquifer Group II and III. The major source of recharge is through rainfall. Factors like return seepage from irrigation and subsurface inflow also contribute in recharging the groundwater in the area. The area is characterized by occurrence of various grades of sand admixed with Gravel, silt and clay in alluvial sediments forming fairly prolific aquifers. Aquifer group-wise location of observation wells for water level and water quality monitoring is depicted in Fig. 11.

Table 14. Number of observation wells tapping different aquifers (for measurement of groundwater level and quality)

Aquifer Group	DW	Pz	Total
I	17	44	61
II		27	27
III		14	14

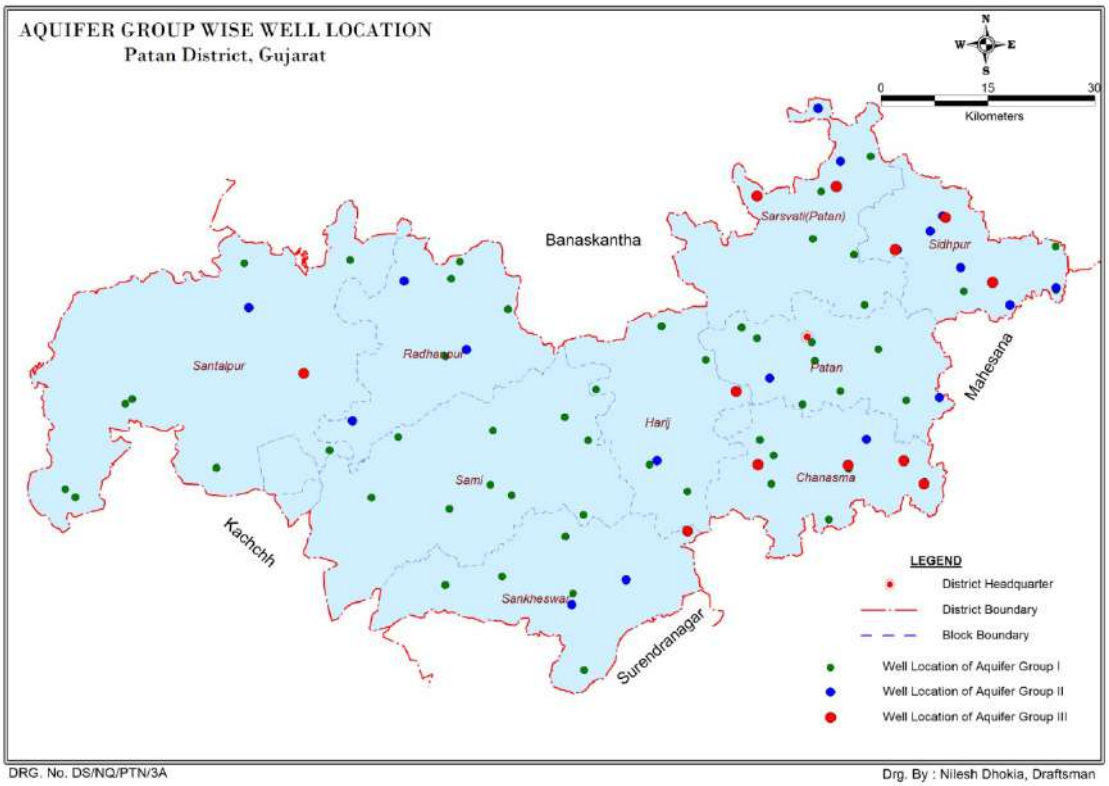


Figure 11. Location of observation wells for water level and water quality monitoring

2.1.1 Depth to Groundwater Level in Aquifer Group I

Depth to groundwater level during premonsoon and Post monsoon period of 2018 is given in Figs. 12 (a and b). Shallowest water level of 0.9 mbgl was recorded at Mota Joravarpura village of Sami Taluka and the deepest water level of 88.50 mbgl was recorded in Muna village of Sarasvati taluka located in the north eastern part of the district. Average pre monsoon water level of the district was 27 mbgl. Water level in the Central, Eastern and North Eastern part in the district in Sami, Patan, Saraswati and Sidhpur taluka are deepest with water level of more than 40 mbgl. At many places the unconfined aquifer is desaturated.Shallowest water levels are observed in the western and south western part of the district in Sami, Santhalpur and Radhanpur Talukas adjoining Rann. The post monsoon water level ranges from 0.4 mbgl (Ved, Sami Taluka) to 87.00 mbgl (Muna, Saraswati Taluka) with average water level of 26.11 mbgl.

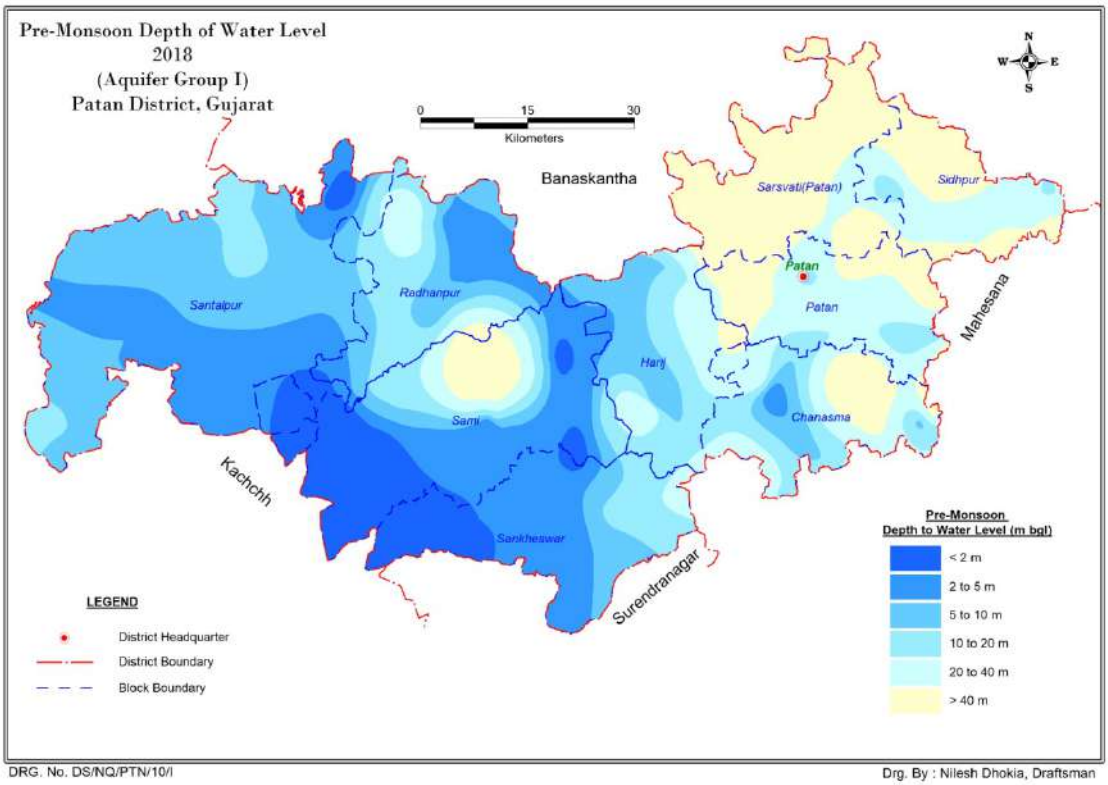


Figure 12(a). Pre monsoon water level map of aquifer group I (Unconfined Aquifer)

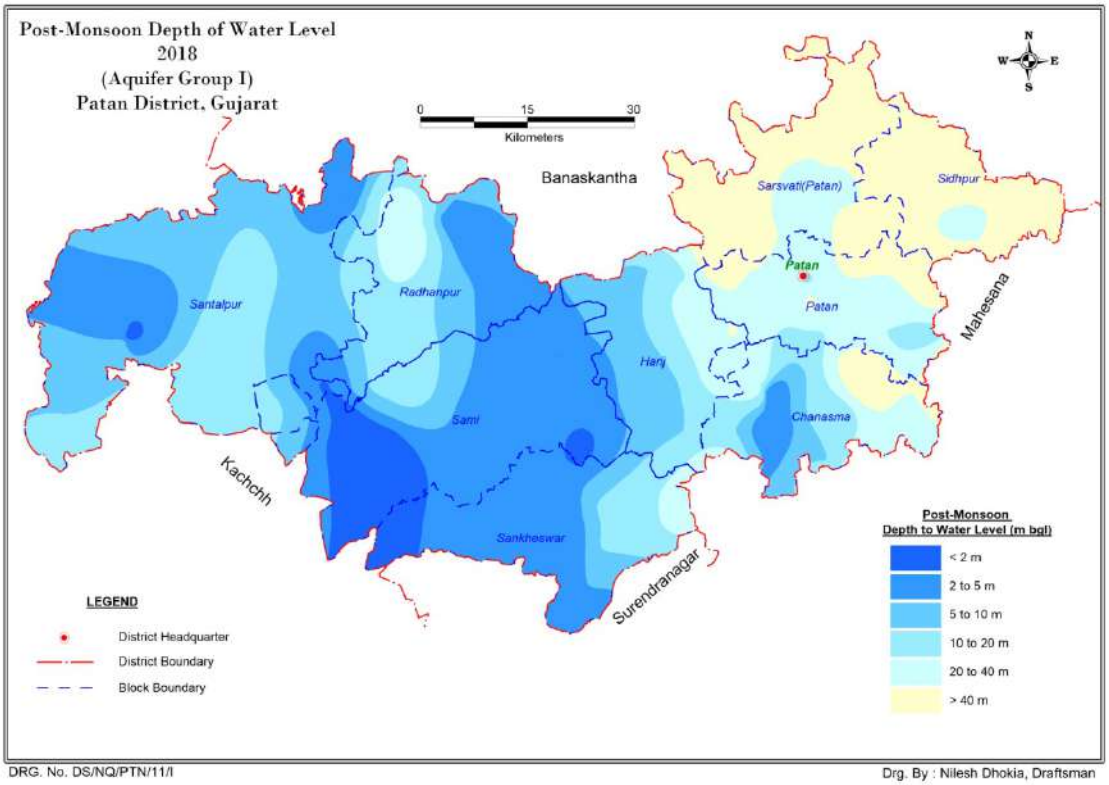


Figure 12(b). Post monsoon water level map of aquifer group I (Unconfined Aquifer)

Water Table

Water Table in Aquifer Group I follows the general topography and regional flow direction is from NE-SW Direction. There is a groundwater mound Near Patan probably ude to recharge from Sujalam sufalam Canal. River Saraswati is effluent near patan and contributes to the groundwater, the flow direction is towards NW towards Kankrej Taluka of Banaskantha district. The same pattern can be observed during post monsoon period too. Pre and Post monsoon water table map is presented in Figs. 13 (a and b) for year 2018.

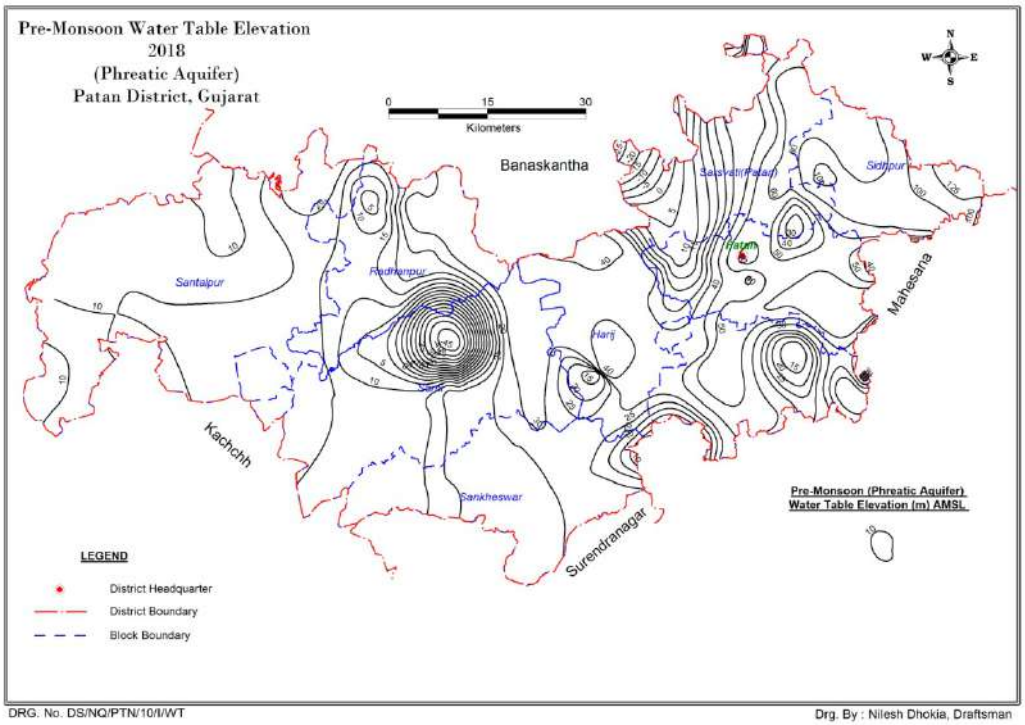


Figure 13(a). Pre monsoon water Table map of aquifer group I (Unconfined Aquifer)

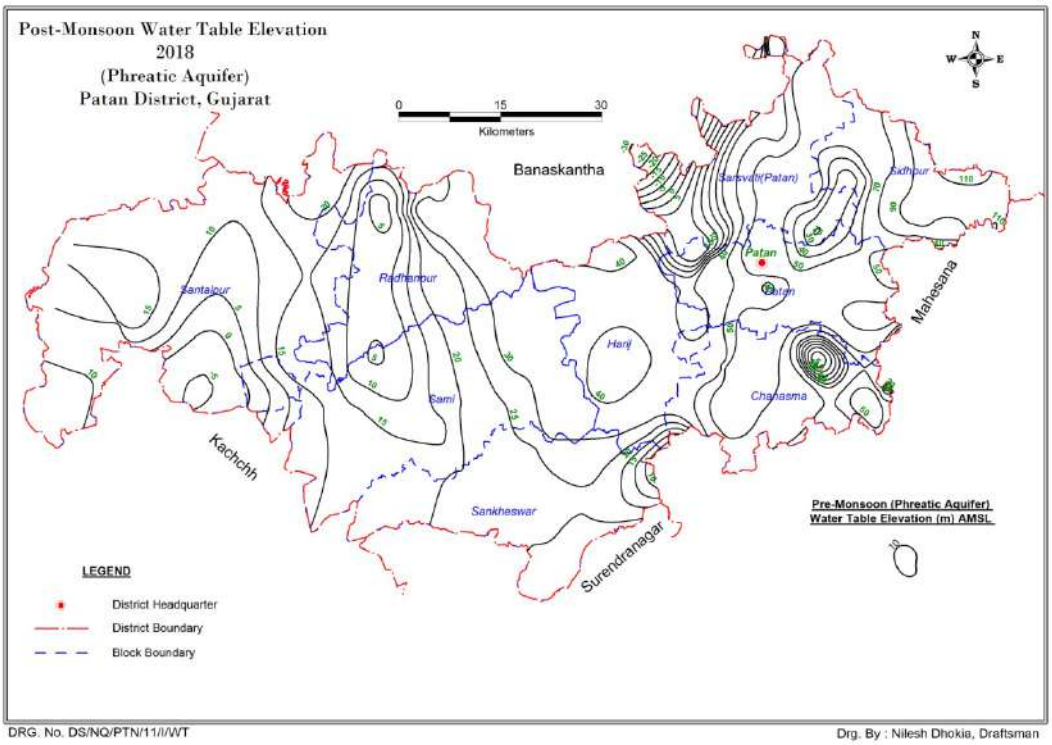


Figure 13(b). Post monsoon water Table map of aquifer group I (Unconfined Aquifer)

2.1.2 Depth to Piezometric surface of Aquifer Group II

Aquifer group II is semiconfined to confined and the Aquifer zone varies between 120-200 m depth in the east and central part to 170-190m depth in the western part of the district. There is gradual reduction of the granular zones from East to west. There are 27 piezometers of CGWB and GWRDC tapping this aquifer group based on the zones tapped. During pre monsoon period of 2018 the depth to piezometric surface varied between 8.40 mbgl (Jamvada Pz, Santhalpur Taluka) to 183.40 mbgl (Sidhpur II Pz, Sidhpur Taluka). Average Depth to Piezometric surface is 91.69m bgl during pre monsoon period. Deepest Depth to Piezometric surface is observed in Hariz, Saraswati, Sidhpur and Patan Talukas where this aquifer is tapped along with the deeper aquifers by the irrigation wells. During post monsoon period also Depth to Piezometric surface Depth to Piezometric surface Depth to Piezometric surface varies between 8.7 mbgl(Jamvada Pz, Santhalpur Taluka) to 197.25 mbgl (Sidhpur II Pz, Sidhpur Taluka). Average post monsoon Depth to Piezometric surface is 95.31mbgl. Pre and Post monsoon water level maps of aquifer group II are placed at Figs. 14 (a and b).

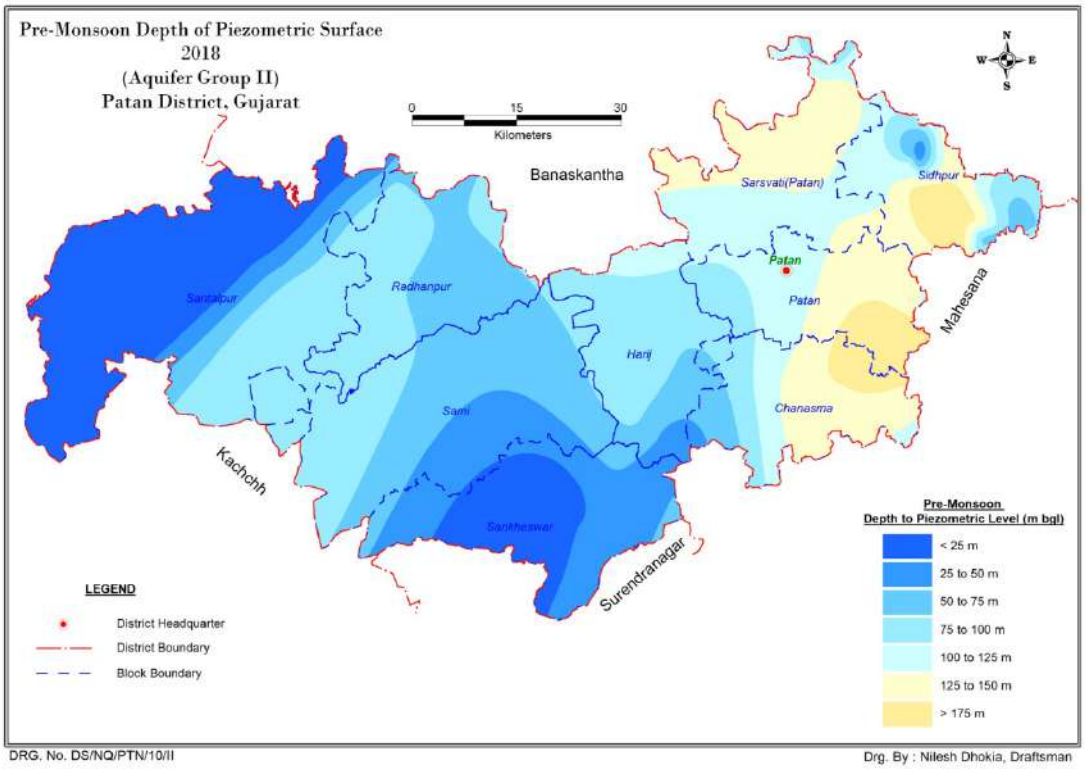


Figure 14(a). Pre monsoon water level map of aquifer group II

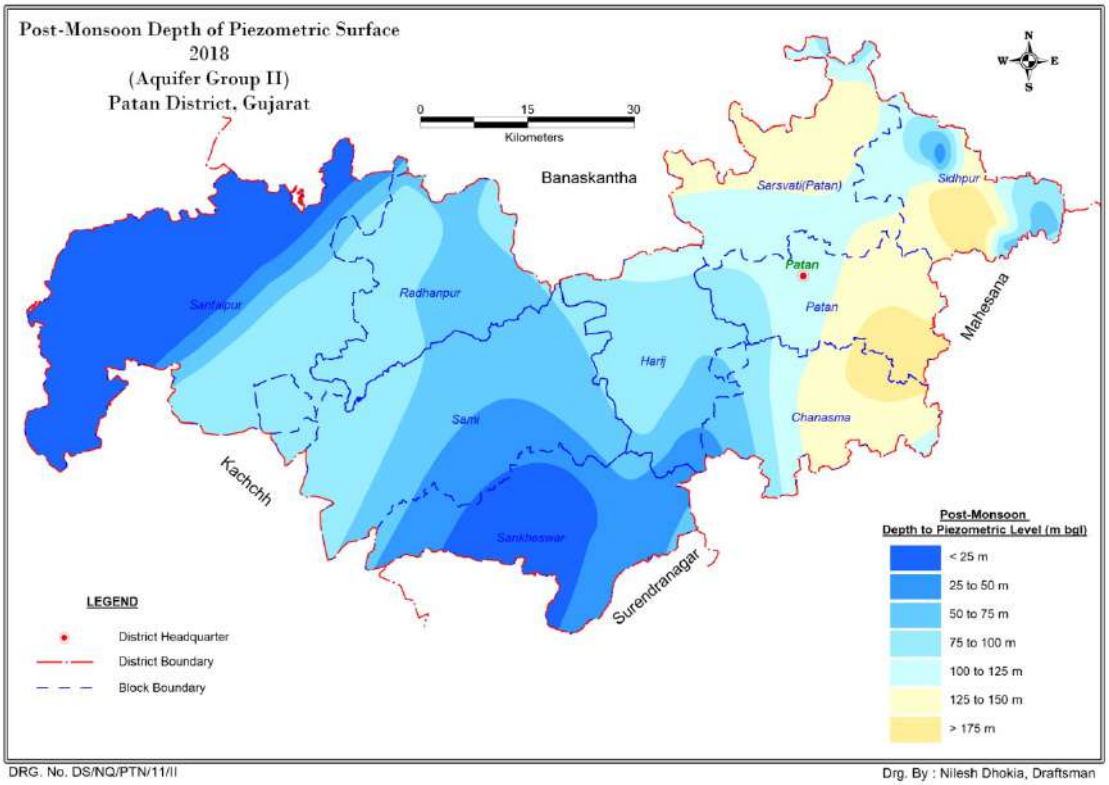


Figure 14(b). Post monsoon water level map of aquifer group II

Elevation of Piezometric Surface

Elevation of Piezometric Surface ranges from 82 mbmsl (Sarsav Pz II, Chanasma Taluka) to 97.54 mamsl (Kakosi Pz II, Patan Taluka). Regional flow direction is East to west in the eastern part of the district, In the central part it is towards south, towards north in the west central part and towards west in the western part of the district. There is a groundwater trough near Chanasma. The same pattern can also be observed during post monsoon Elevation of Piezometric Surface of the district. Pre and Post monsoon Piezometric surface map is presented in Figs. 15 (a and b) for year 2018.

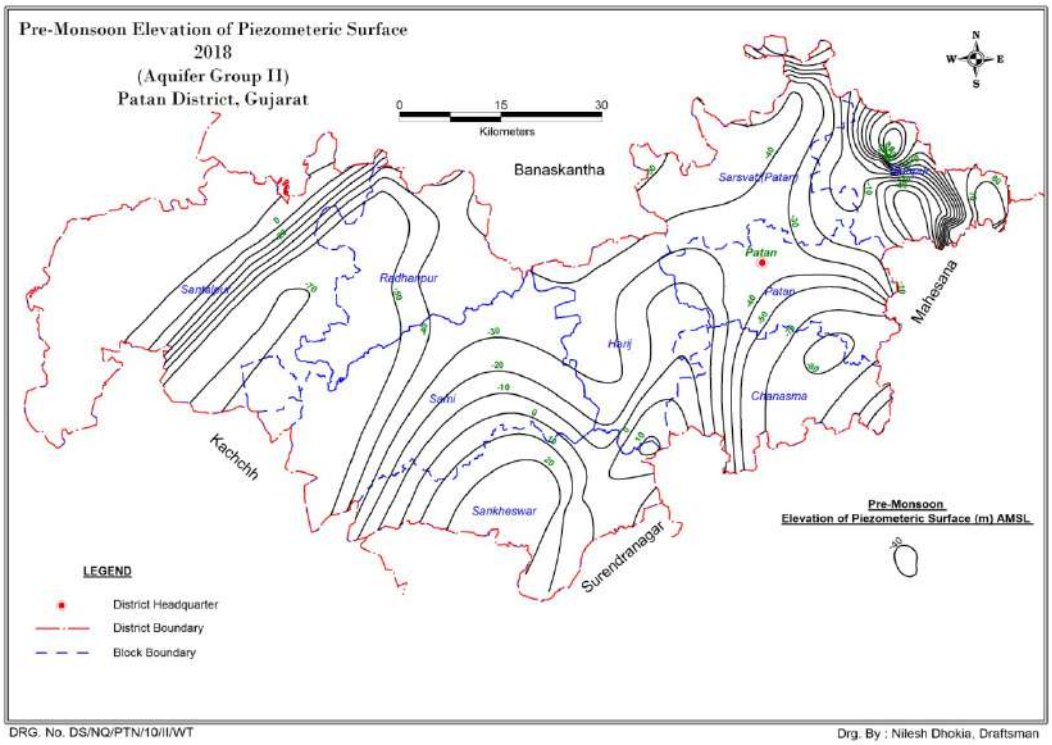


Figure 15(a). Pre monsoon elevation of piezometric surface map of aquifer group II

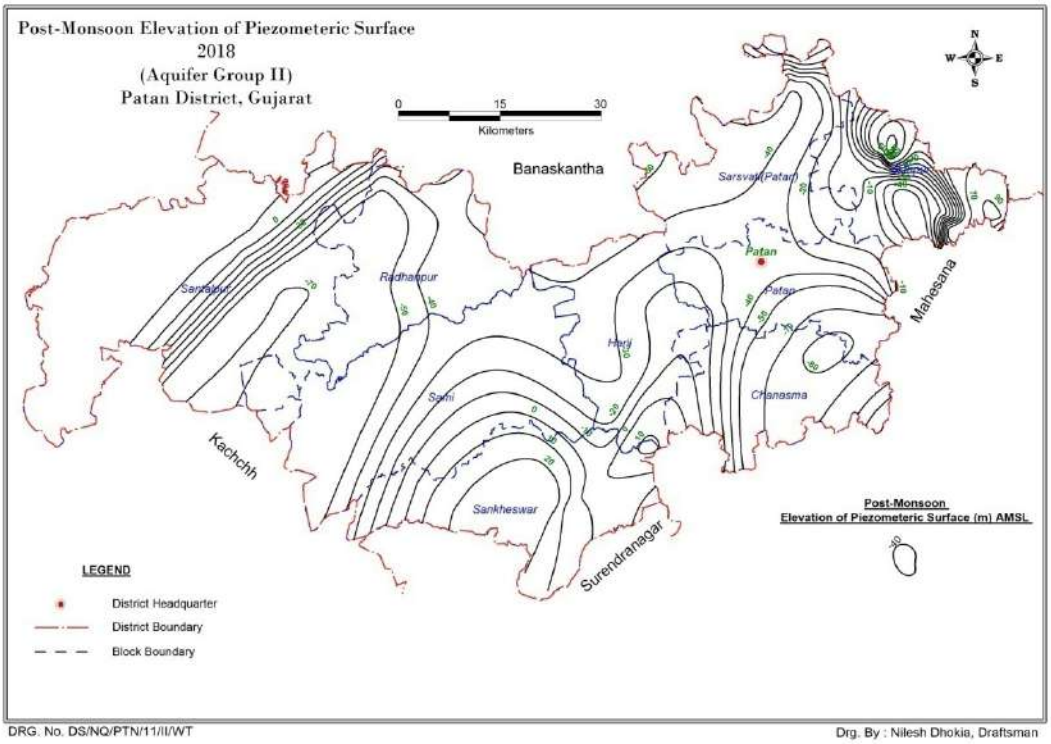


Figure 15(b). Post monsoon elevation of piezometric surface map of aquifer group II

2.1.3 Depth to Piezometric surface of Aquifer Group III

Aquifer group III is confined In nature and the Aquifer zones varie between 220-300 m depth in the east and central part to 250-300m depth in the western part of the district. There is gradual reduction of the granular zones from East to west. There are 13 piezometers of CGWB and GWRDC tapping this aquifer group based on the zones tapped. During pre monsoon period of 2018 the depth to piezometric surface varied between 32.9 mbgl (Varahi III Pz, Santhalpur Taluka) to 196.00 mbgl (KalyanaIII Pz, Sidhpur Taluka). Average Depth to Piezometric surface is 126.00m bgl during pre monsoon period. Deepest Depth to Piezometric surface is observed in Hariz, Saraswati, Sidhpur and Patan Talukas where this aquifer is tapped by the irrigation wells.

During post monsoon period also Depth to Piezometric surface varies between 41.50 mbgl(Varahi III Pz, Santhalpur Taluka) to 185.27 mbgl (KalyanaIII Pz, Sidhpur Taluka). Average post monsoon Depth to Piezometric surface is 123.93 mbgl. In most part of the district in Chanasma, Sidhpur, Sarasvati, Patan, Hariz and Chanasma taluka the depth to piezometric surface is more than 100 mbgl observed during pre and post monsoon period (Fig. 16 a and b).

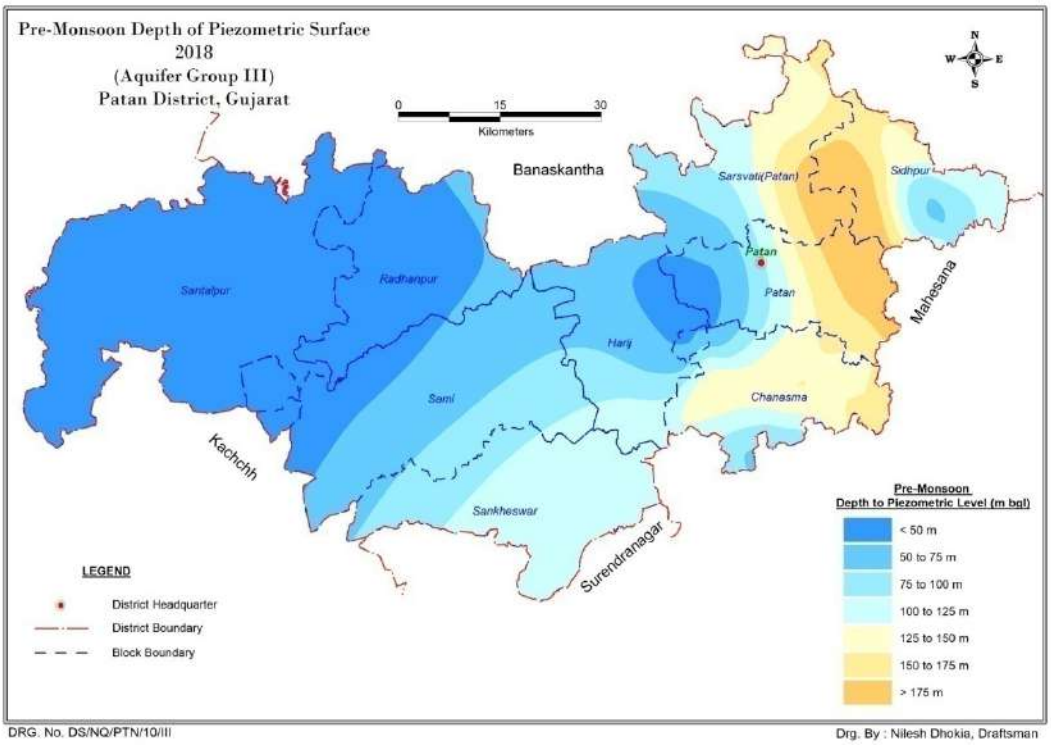


Figure 16(a). Pre monsoon depth to piezometric surface map of aquifer group III

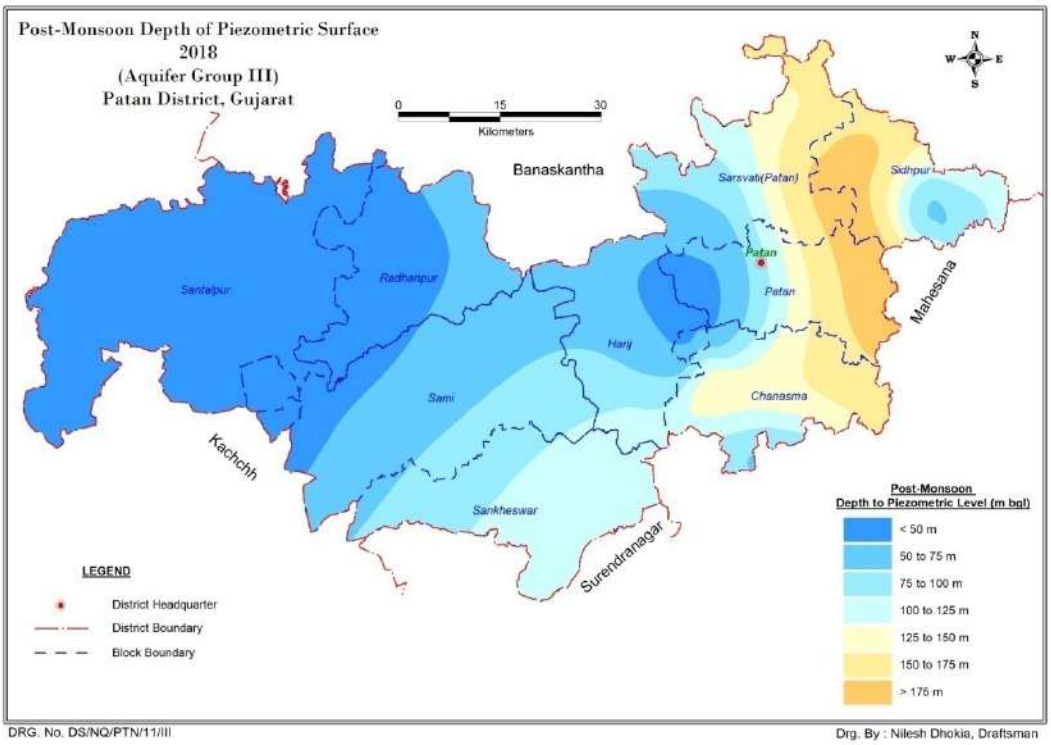


Figure 16(b). Post monsoon depth to piezometric surface map of aquifer group III

Elevation of Piezometric Surface

Elevation of Piezometric Surface ranges from 89.45 mbmsl (Dhinoj Pz, Chanasma Taluka) to 61.68 mamsl (Sidhpur Pz III, Sidhpur Taluka). Regional flow pattern is complex due to less number of observation wells in Aquifer Group III. It is North to South in the west and central part, towards west in the south eastern part. The same pattern can also be observed during post monsoon Elevation of Piezometric Surface of the district. Pre and Post monsoon elevation of piezometric surface map is presented in Figs. 17 (a and b) for year 2018.

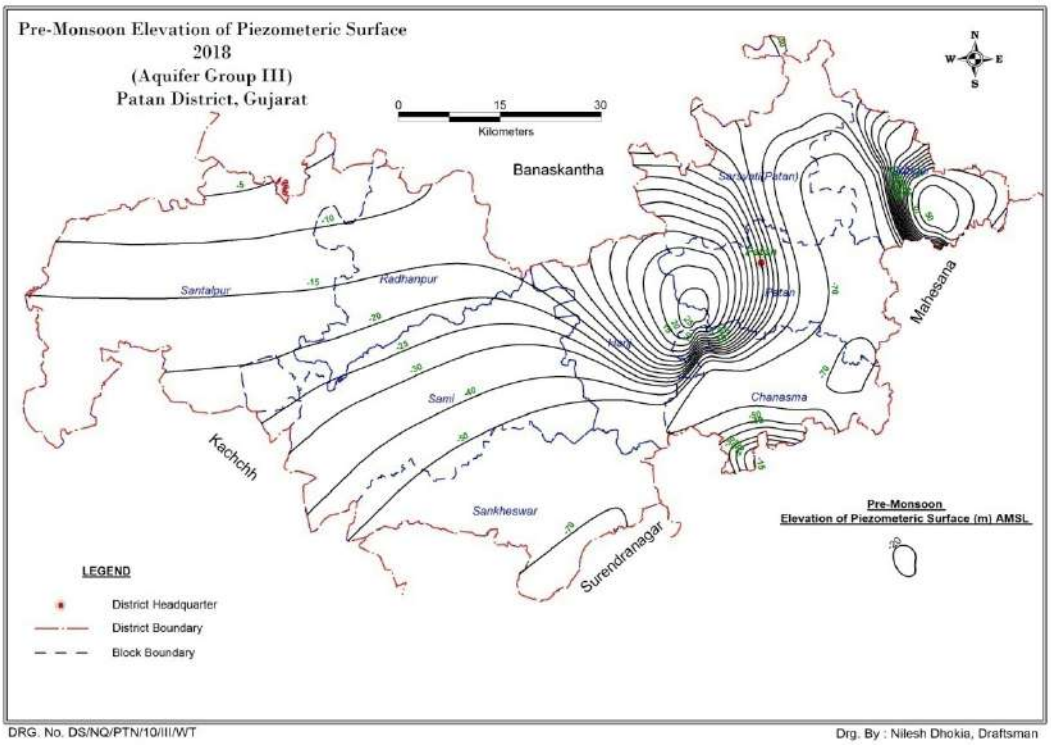


Figure 17(a). Pre monsoon elevation of piezometric surface map of aquifer group III

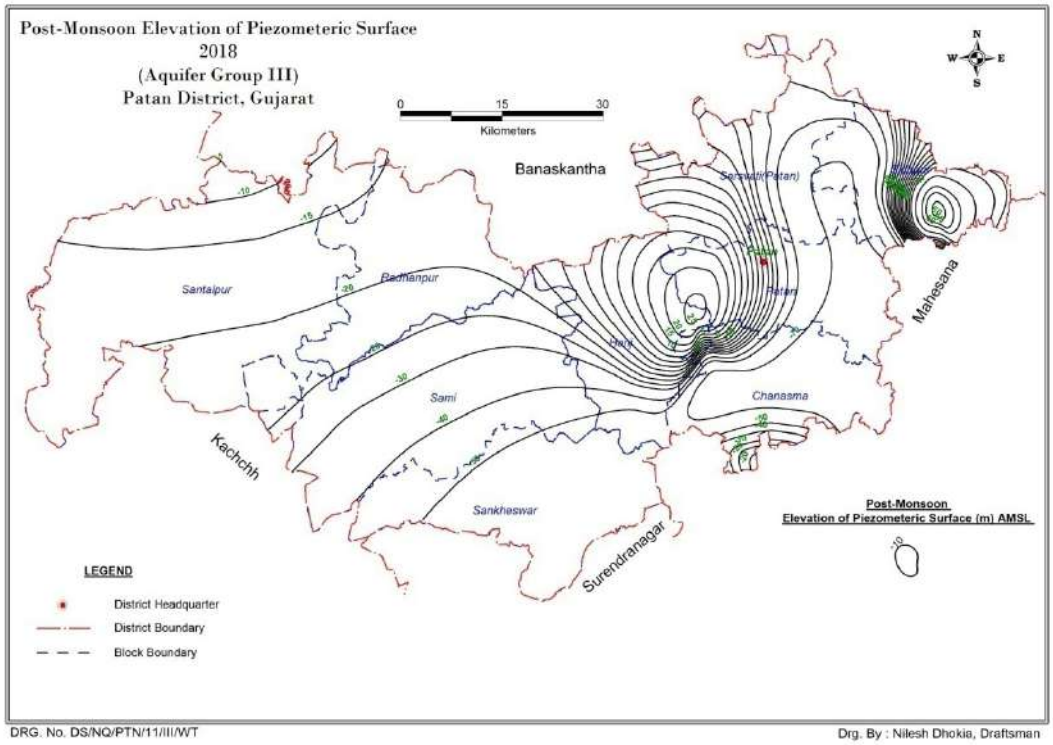


Figure 17(b). Post monsoon elevation of piezometric surface map of aquifer group III

2.2 Hydrochemical data (water quality sampling, number of samples and analysis mechanism etc.)

Groundwater is the most important and essential natural resource for domestic, industrial and agricultural needs. Water quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities. Understanding the quality of groundwater is particularly important as it determines the factors governing the suitability of water for drinking, domestic, agricultural and industrial purposes (Subramanian *et al.,* 2005). Quality of groundwater is as much demanding as its quantity. Suitability of groundwater for drinking and irrigational purpose is important for its safe and effective use. Patan district is mainly dependent on groundwater for the domestic and irrigation demand. The pressure on groundwater is considerable for irrigation requirements in the semi-urban and rural areas. Chemically, the groundwater is an aqueous solution in the sub-surface geological formation. The concentration of the major ions and other dissolved ions in groundwater are functions of the availability of the constituents in the aquifer matrices and their solubility. Rocks, through which water circulate, are composed of minerals and amorphous solids, which in turn are composed of chemical elements that greatly affect the groundwater quality. This chapter is an overview of the chemical quality of groundwater as determined by analyzing water samples collected from different locations spread over the entire area, tapping different aquifer groups.

To study the groundwater chemistry of different aquifers present in the area, Water quality data of 55 groundwater samples were collected from CGWB and GWRDC Dugwells and Piezometers tapping different aquifer groups during pre monsoon 2018. The water samples were collected and stored in 1 liter capacity clean plastic bottles. Before collection of samples, the bottles were properly washed. Prior to collecting the samples, the containers were rinsed by the water to be sampled. The wells were duly purged or disturbed before collecting groundwater sample. A total number of 55 groundwater samples were collected from Piezometers and open dug wells tapping Aquifer Group I, II and III across the study area for chemical analysis of major parameters during the month of May 2018 and October 2018 Out of 55 samples, 28 samples were collected from Dug wells and Piezometers from Aquifer Group I (depth varying from 4.35 to 90 m) and 16numbers from the Piezometers tapping Aquifer Group II (depth varying from 120 to 190 m) and 11 samples collected from the piezometers tapping aquifer Group III (depth ranging from 200 to300 m). Details of sample location

are given in annexure- 3.9a, 3.9b & 3.9c. Salient statistical result of analysis of groundwater from Aquifer Group I, II and III are given in table 15, 16 and 17. These water samples were analysed in chemical laboratory of CGWB WCR, Ahmedabad, and GWRDC Ltd. Chemical Lab for different parameter. Pre monsoon water quality maps of EC, Chloride and Fluoride for aquifer group I, II and III are depicted in Figs 18 (a to c), 19 (a to c) and 20 (a to c), respectively.

Table 15. Classification of groundwater on the basis of electrical conductivity

Electrical conductivity (µmho/cm at 25°C)	**Water Classes**	**Number of groundwater samples**		
		Aquifer Group I	**Aquifer Group II**	**Aquifer Group III**
<250	Excellent (C1)	0	0	0
250-750	Good (C2)	4	0	0
750-2250	Permissible (C3)	14	2	5
>2250	Unsuitable (C4)	10	14	6

Table 16. Classification of groundwater quality on the basis of Fluoride concentration

Aquifer Group	**No. of Samples with Fluoride <1.5 mg/l**		**No. of Samples with Fluoride >1.5 mg/l**	
	Pre monsoon	**Post Monsoon**	**Pre monsoon**	**Post Monsoon**
I	17	6	10	13
II	7	11	4	2
III	6	8	5	3

Table 17. Classification of groundwater quality on the basis of Nitrate concentration

Aquifer Group	**No. of Samples with Nitrate<45 mg/l**		**No. of Samples with Nitrate>45 mg/l**	
	Pre monsoon	**Post Monsoon**	**Pre monsoon**	**Post Monsoon**
I	22	18	4	1
II	13	13	0	0
III	11	11	0	0

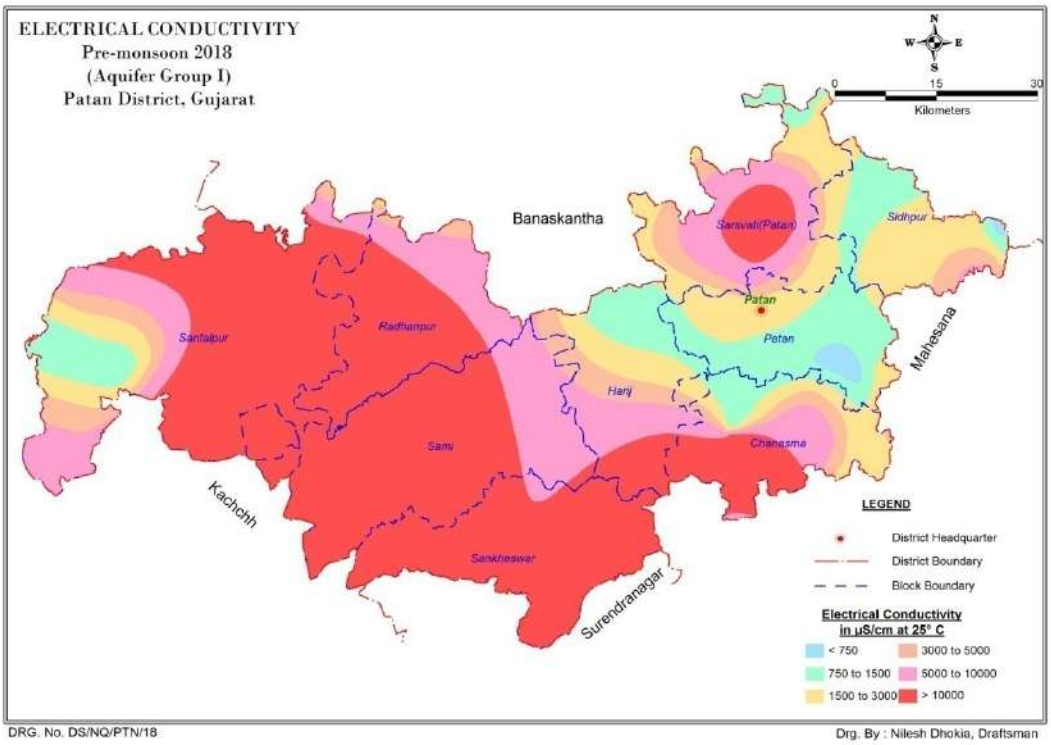


Figure 18(a). Pre monsoon EC map of aquifer group I

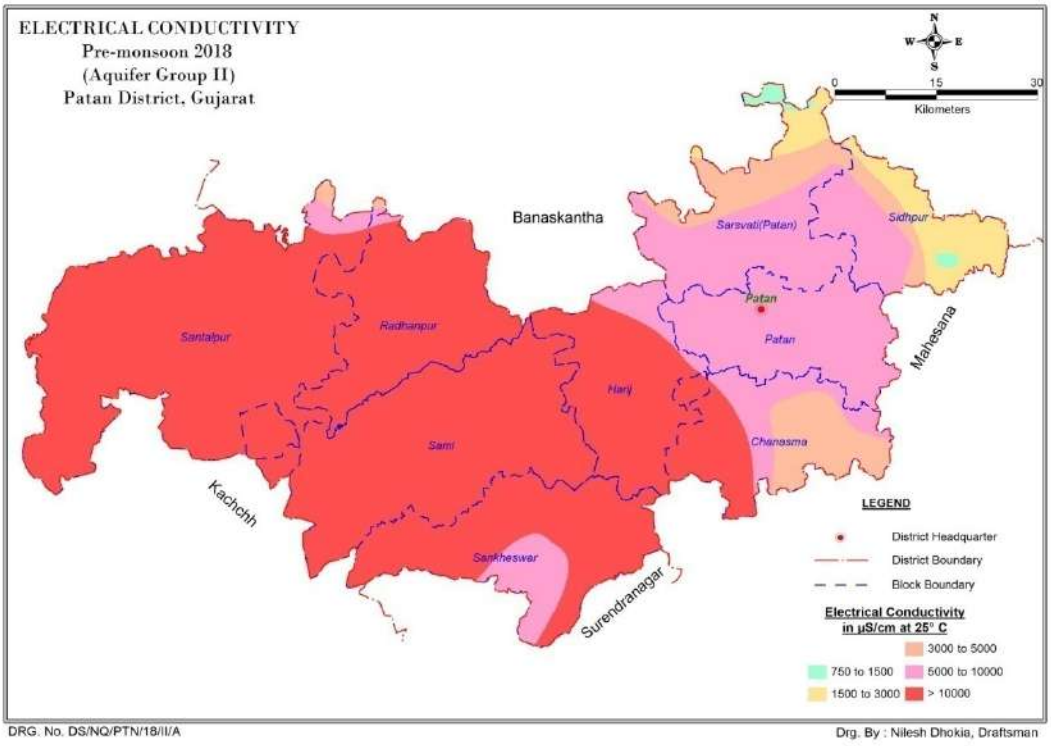


Figure 18(b). Pre monsoon EC map of aquifer group II

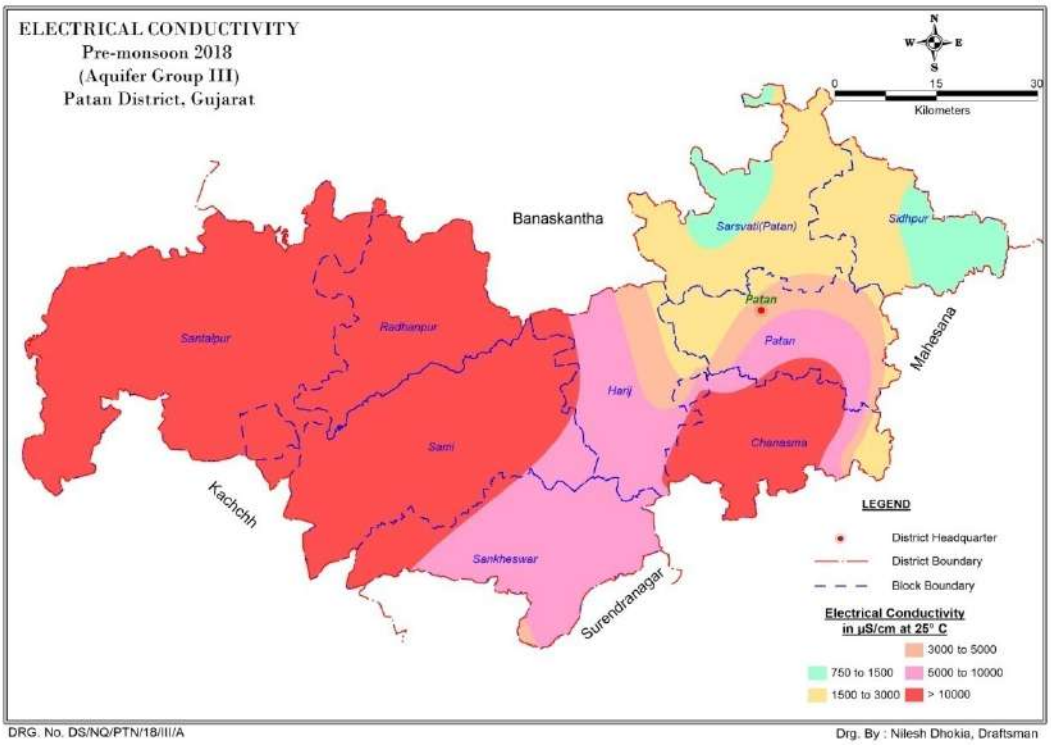


Figure 18(c). Pre monsoon EC map of aquifer group III

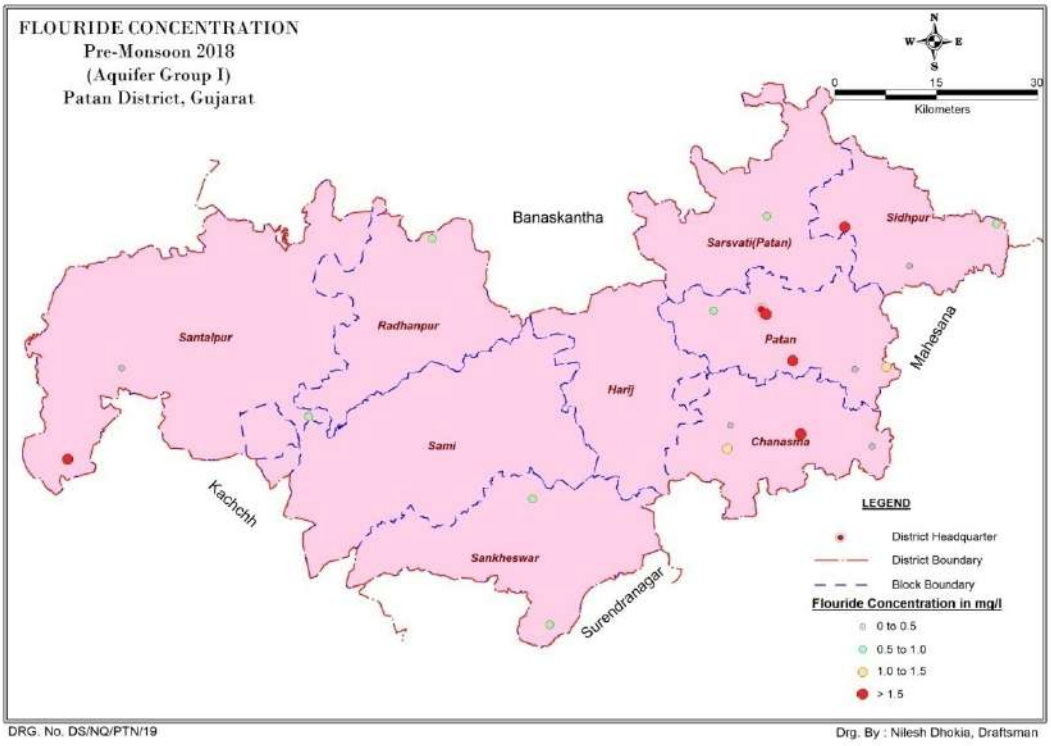


Figure 19(a). Pre monsoon Fluoride concentration map of aquifer group I

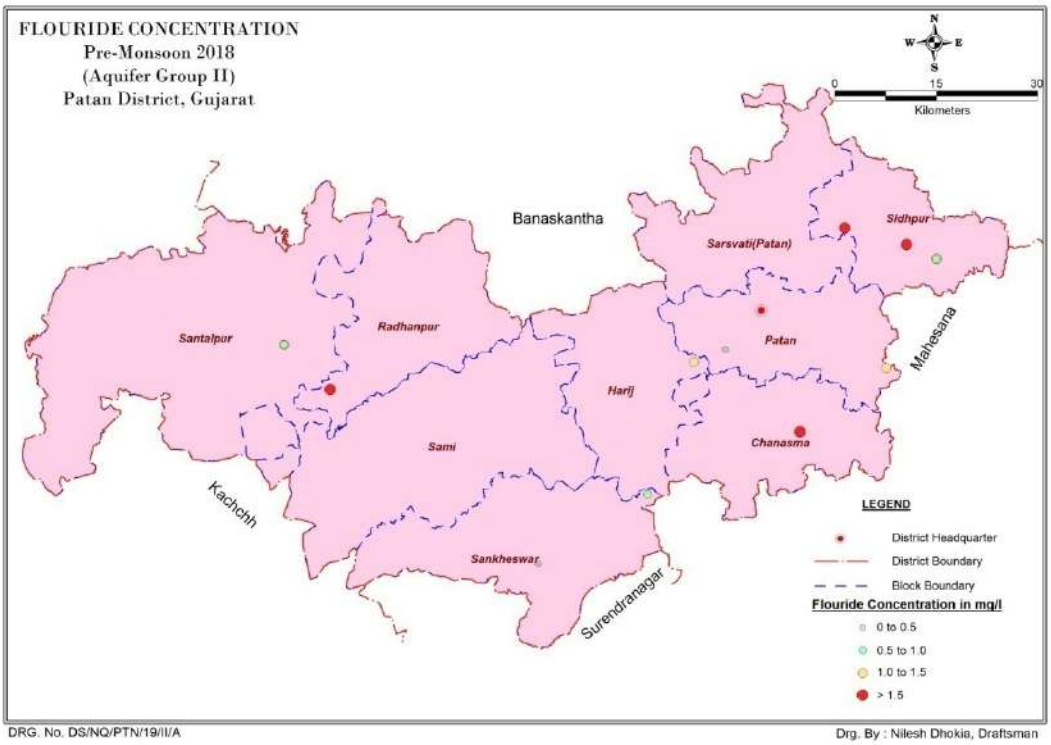


Figure 19(b). Pre monsoon Fluoride concentration map of aquifer group II

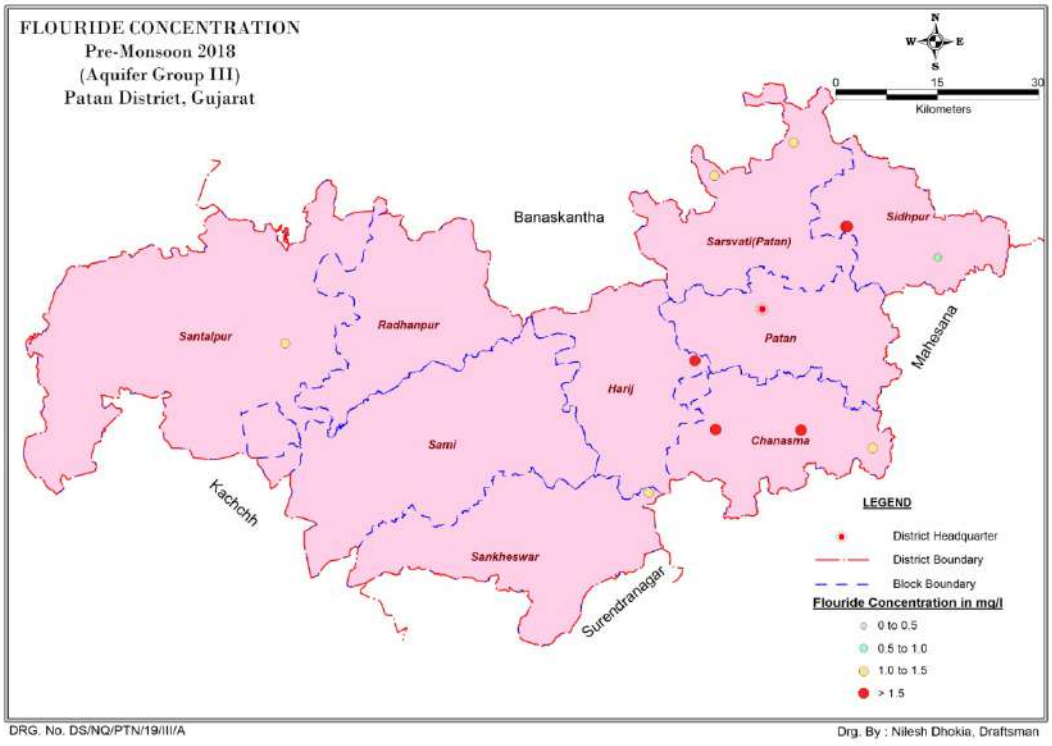


Figure 19(c). Pre monsoon Fluoride concentration map of aquifer group III

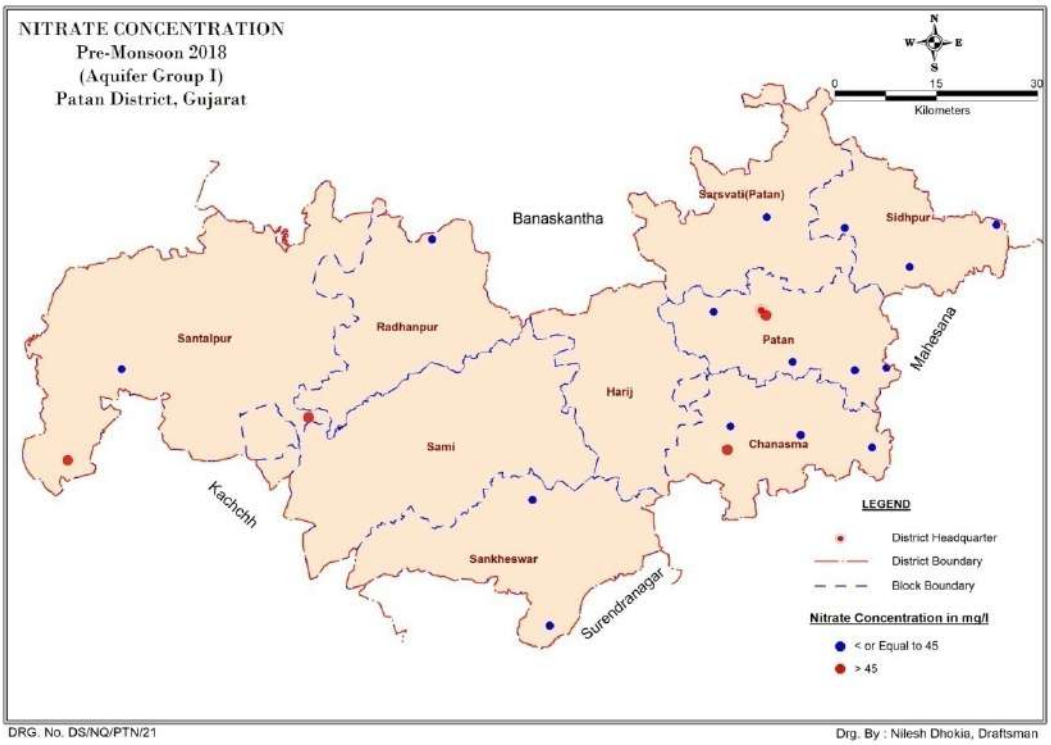


Figure 20(a). Pre monsoon Nitrate concentration map of aquifer group I

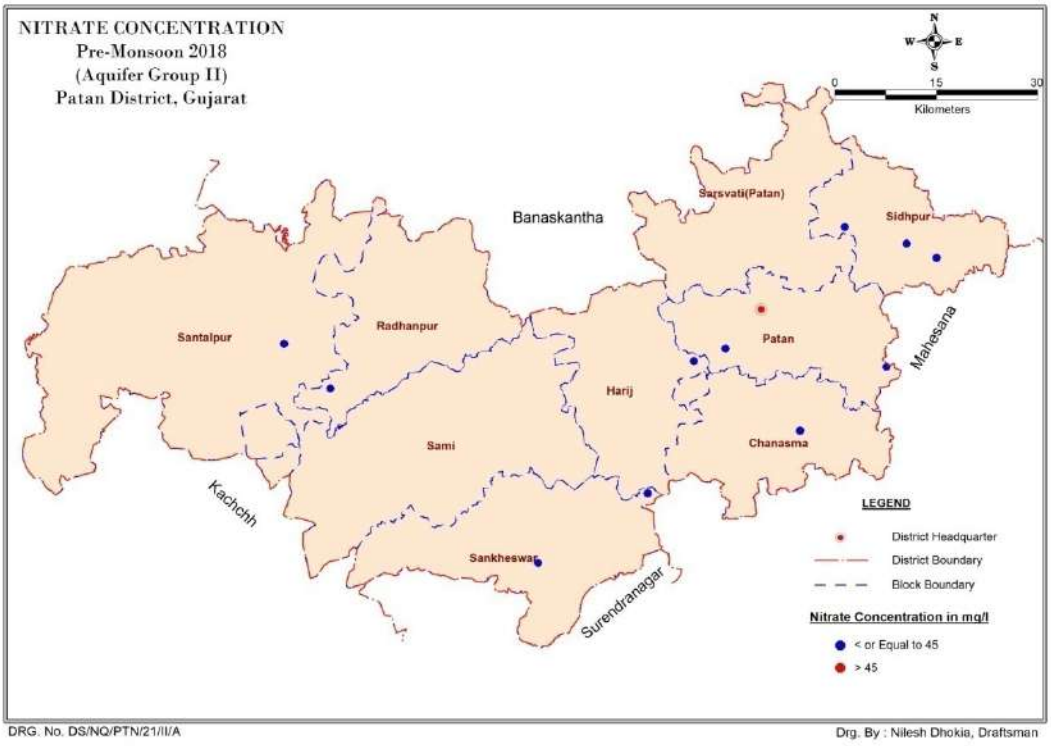


Figure 20(b). Pre monsoon Nitrate concentration map of aquifer group II

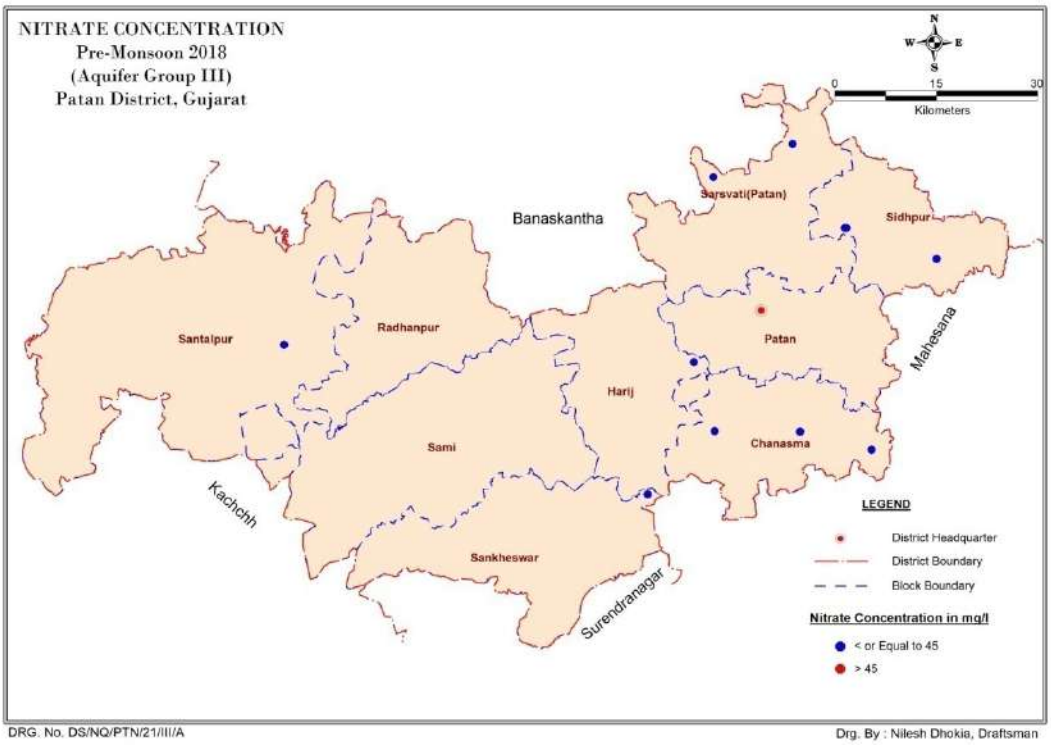


Figure 20(c). Pre monsoon Nitrate concentration map of aquifer group III

2.3 Geophysical data (Location, number, analytical techniques etc.)

To understand the subsurface geometry of Aquifers and quality of groundwater in parts of Patan district in unexplored area for defining the Aquifer geometry and to assess the quality of groundwater geophysical technique was applied. Drilling method is not economical viable to understand above and moreover the time factor is also very essential. Application of Geophysical Survey techniques is best way to achieve the objective. Hence, vide letter No. 03/CGWB/CGC/Pers/2013-7439, dated 24.10.2016 from CHQ; the authors were deputed to carry out the geophysical survey at the pre decided locations which were identified on the basis of data gap in parts of Patan district of the State were allotted to authors. Initially the study was started from Porbandar district but due to some technical problems, the instrument DDR-2, provided by the West Central Region could not be utilised. Later on another Instrument (Terrameter SAS300C) was arranged from the state government department (GWSSB) for the study (Fig. 21).

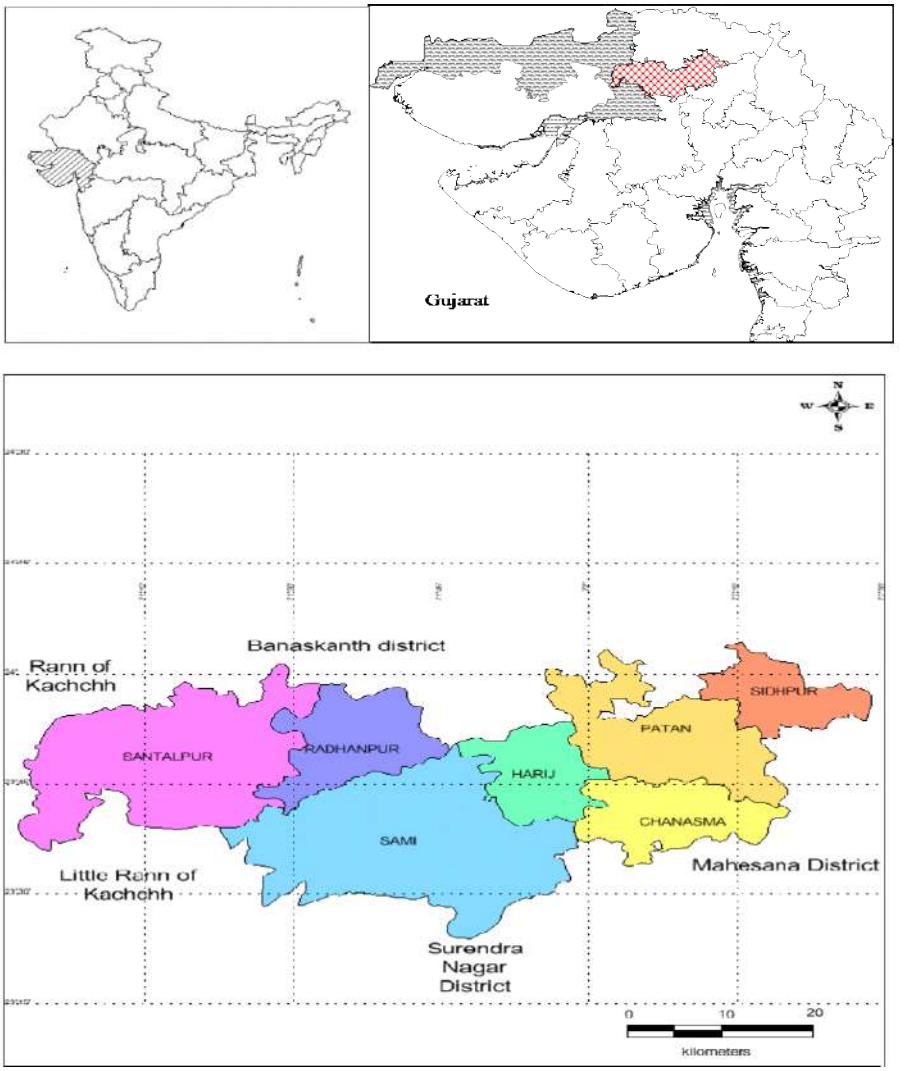


Figure 21. Location map of study area

2.3.1 Interpretation of geophysical data

In the present study, electrical resistivity sounding data were obtained by using Schlumberger array applying increments in the current electrode separations. In order to map deeper layers, increments in the successive current electrode separation (AB/2) were made to increase number of observations. Maximum separations of current electrode (AB) ranging from 600 m to 900 m were used depending upon the availability of space along the sounding line. Data processing and interpretation of resistivity soundings were carried out in two stages. In the first stage quantitative interpretation is involved determination of true resistivity and thickness of the different layers from the field sounding curves. Field curves were compared with the theoretically generated or available standard master curves for known layer parameters of two, three and four layers (Orellana and Mooney, 1966). The VES data was scattered and accordingly the

curves were smoothened. In highly saline area, the depth of information was confined to shallow depth but to facilitate the preparation of geo electric sections and fence diagrams, the depth of information was extrapolated on the basis of apparent resistivity values and local hydro geological information. Initial layer parameters were obtained using partial curve matching technique with the help of master curves and auxiliary point charts (Ebert, 1943). In the second stage all field data have been reprocessed through computer aided software IPI2WIN.

Quantitative interpretation of resistivity data has been made based on the available geological information. It is observed that in loose dry sand, high resistivity values are recorded. Moreover, the resistivity of this top layer is dependent on the degree of moisture.. Sedimentary rocks, which usually are more porous and have higher water content, normally have lower resistivity values. Wet soils and fresh groundwater have even lower resistivity values. Clayey soil normally has a lower resistivity value than sandy soil. There is a overlap in the resistivity values of the different classes of soils. This is because the resistivity of particular soil units depends on a number of factors such as the porosity, the degree of water saturation and the concentration of dissolved salts. The resistivity of fresh groundwater varies from 10 to 100 ohm-m depending on the concentration of dissolved salts. Whereas low resistivity (<1 ohm-m) is due to the relatively high salt content. In hard rock, showing low resistivity is an indicative of high level of weathering and fracture with presence of saline groundwater. In contrary observation like a high resistivity in the soil or weathered rock mass might indicate their dry and resistant situation. This makes the resistivity method an ideal technique for delineating saline and fresh water interface as well as delineation of saturated fracture zones in hard rock area. Therefore, the resistivity values have a much larger range compared to other physical quantities mapped by other geophysical methods. The results concluded in the light of above observations. They are accordingly summarized in this report. Interpreted VES results are discussed in terms of their geological and hydro-geological implications.

Total 78 numbers of VES were conducted in the study area. All the efforts were done to have maximum current electrode separation but at some places, due to uneven surface and bushes etc, the current electrode separation was confined to 250 to 300 meters. The findings of the study is discussed below:

Patan district is situated in the northern part of Gujarat state. The district is carved from Banaskantha and Mahesana district. The district occupies 5740 sq. km. area between 23°24' and 24°09' north latitudes and 71°01' and 72°30' east longitudes. It falls in the survey of India degree sheet numbers 41M, 46A, 40P & 45D. It is bounded by Banaskantha in north, Little Rann of Kachchh in west, Mahesana district in the east and by Surendranagar and Ahmedabad districts in the south. It has seven talukas, having 517 villages. The study area of Patan District is shown in Fig. 22.

Figure 22. Location of VES

Total 78 numbers of VES were conducted in the study area. The geological setup with vast areas affected by salinity present a complex hydro geological pattern in the district. The location of VES points are shown in Fig. 23.

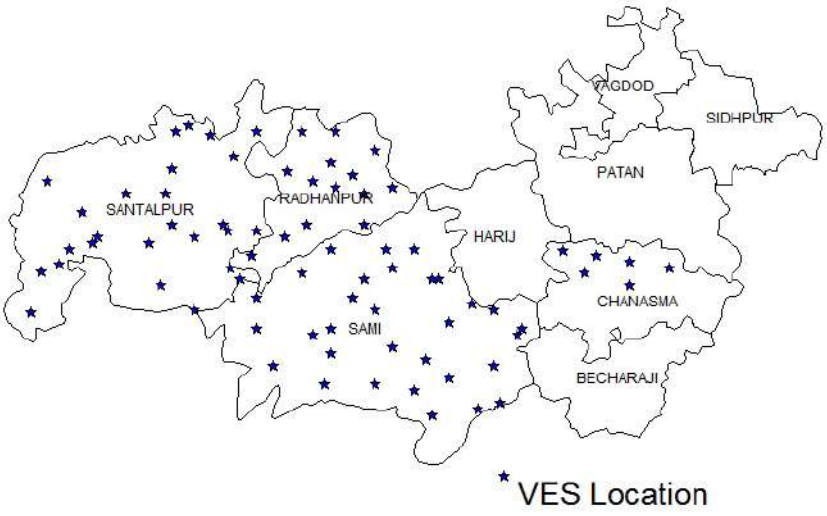


Figure 23. Location of VES points

Total 78 numbers of VES were conducted in parts of Patan District covering Santalpur, Chanasma, Radhanpur and Sami talukas(blocks) of the district . The VES were conducted in Sami, Radhanpur, Chanasma and Santalpur talukas. Out of 78, 5 VES in Chanasma, 31 in Sami,15 in Radhanpur and 27 numbers of VES were conducted in Santalpur talukas of Patan district. Almost the entire Santalpur block is occupied with high to very high saline groundwater. Few locations like Nalia, Lodra, Jamvada and Godha may have marginally saline groundwater at deeper depth ranges (>200meters) as the resistivity of the last layer at these locations are more than 5 Ohm m. Low to very low resistivity value (<2 Ohm m) of the last layer is observed at Digamda, Gohhantar, Varahi and Sadhpur thereby indicating the presence of highly saline groundwater. At Daigamda and Garamdi, the curve is almost parallel to x axis indicating that no penetration of current due to the presence of salt content from ground itself.

The Sami block is also having the identical condition. Presence of marginally saline groundwater was identified at deeper depth at Jhilwna, Khandiya, Padla, Dhanora, Kukrana and Palipur.

At these locations, the resistivity of the last layer is in between 10 to 15 Ohm m which indicates the presence of marginally saline water at deeper depth (>200 meters).Thick clay layer is also identified just above the marginally saline groundwater column which may be protecting the marginally saline groundwater from highly saline groundwater at sshallow depth. Low to very low resistivity value (<2 Ohm m)is observed at Adgaon, Buda, Dhanora and Korda VES locations which indicates the presence of highly saline groundwater. On the basis of results of geophysical survey, 2 numbers of geo electrical section and one fence diagram has been prepared.

2.3.1.1 Geo electrical section AA’

This section starts from Patanka and terminates at Padla. Six numbers of VES locations falls over this section. This section is 72 km long and running in NW-SE direction. The complete section is having saline to marginally saline groundwater.

At other VES locations, due to the presence of highly saline groundwater, no interface could be detected hence clay layers could not be identified**.**

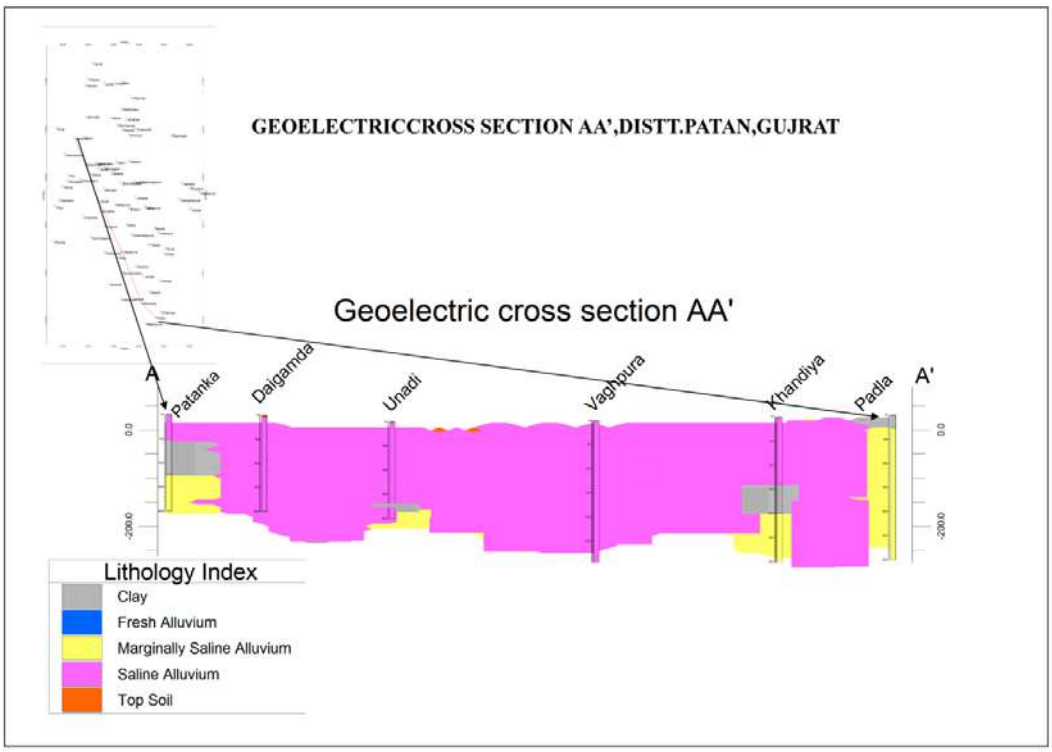


Figure 24. Geoelectric cross section AA’ based on resistivity data

2.3.1.2 Geo electrical section BB’

This section is 50 Km long running in North-South direction. 10 numbers of VES locations falls over this section. This section originates from Piprala and finally terminates at Korda.

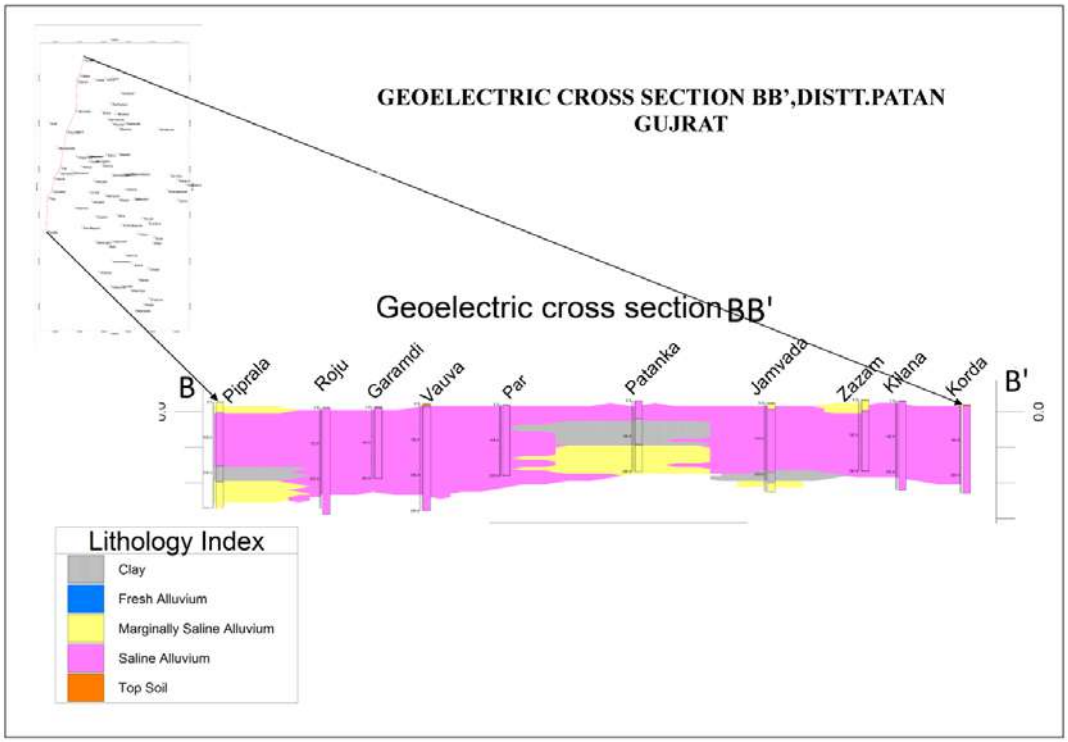


Figure 25. Geoelectric cross section BB’ based on resistivity data

The complete section is occupied with marginally saline to saline groundwater. Clay dominating layers were identified at Piprala and Patanka, where indications of presence of marginally saline water at deeper depth are indicated. At other locations due to presence of saline water form top itself the clay layers could not be identified**.**

2.3.1.3 Fence Diagram

On the basis of results of Resistivity survey, fence diagram has also been prepared. The entire study area is occupying saline to marginally saline groundwater. At Padla (VES 20) and Kharighariyal (VES 9) locations, moderate resistivity is recorded for the last layer which is the indicative of presence of fresh water at deeper depth ranges**.**

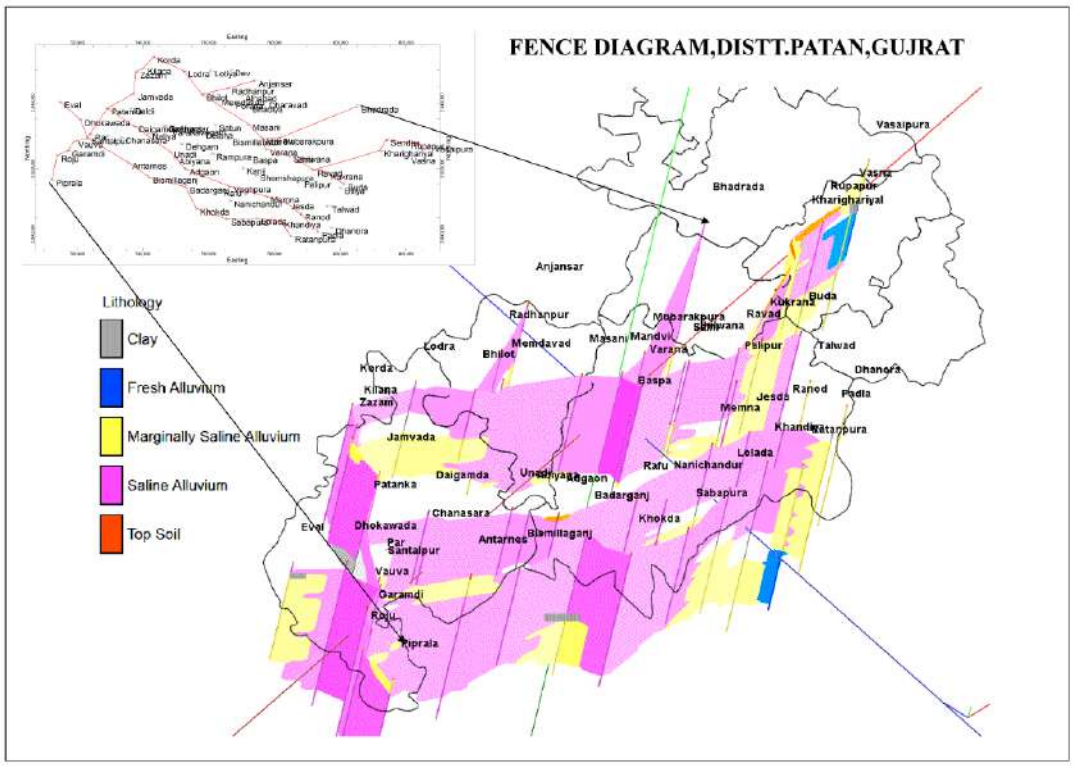


Figure 26. Fence diagram of Patan district based on resistivity data

Chapter III

3 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The alluvial aquifer system of Patan district is mainly composed of the quaternary alluvium with alternate layers of coarse to fine sand making the aquifer and clay beds with various degree of sand mixing form the aquitard. The aquifer system is grouped into four aquifer groups upto 300m depth in the region, but mostly three aquifer groups with aquitard in between has been demarcated based on the Exploratory drilling and the geophysical surveys. The data has been analysed 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 Aquifer Groups and Aquitard up to 300m. Map showing section lines is presented in Fig. 27. The stratigraphic sections depicting aquifer group I, II and III are placed at Figs 28(a to g). Fence Diagram and 3D Solid Model of Patan district is depicted in Fig. 29 and 30, respectively.

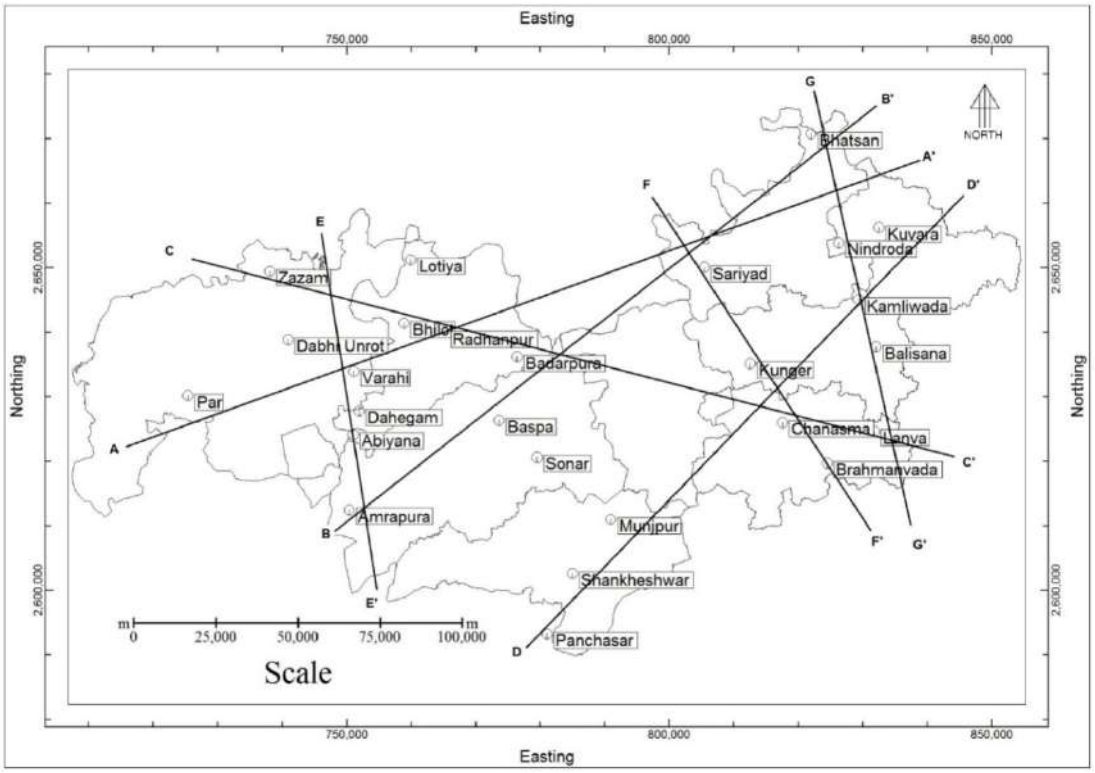
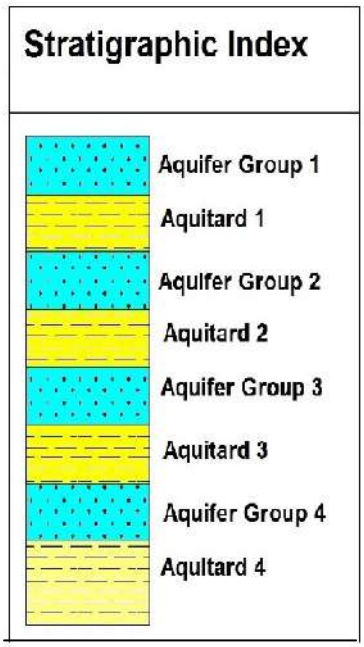
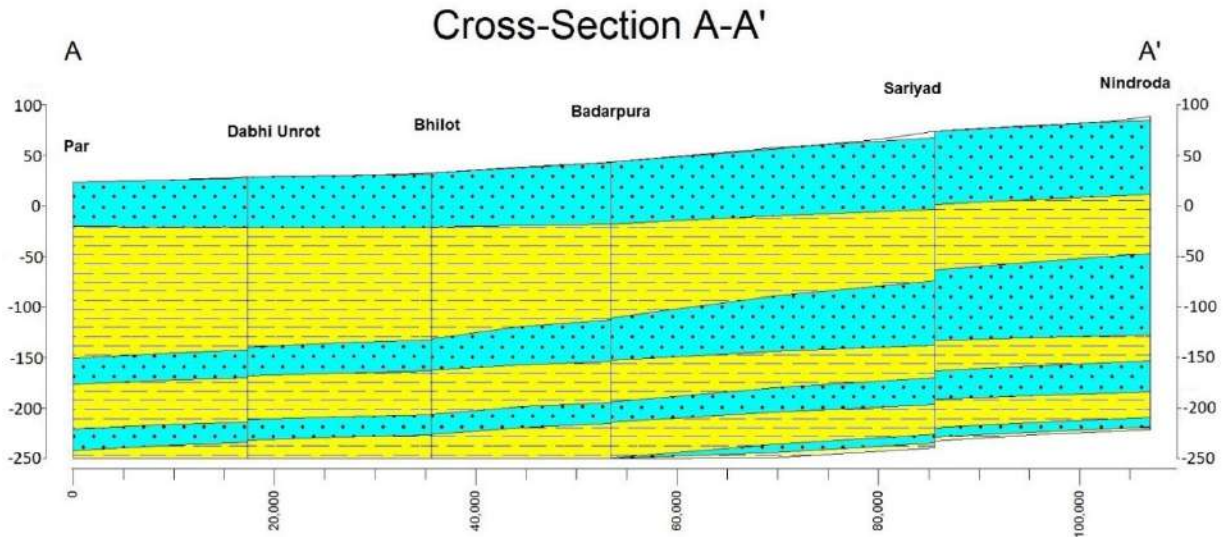


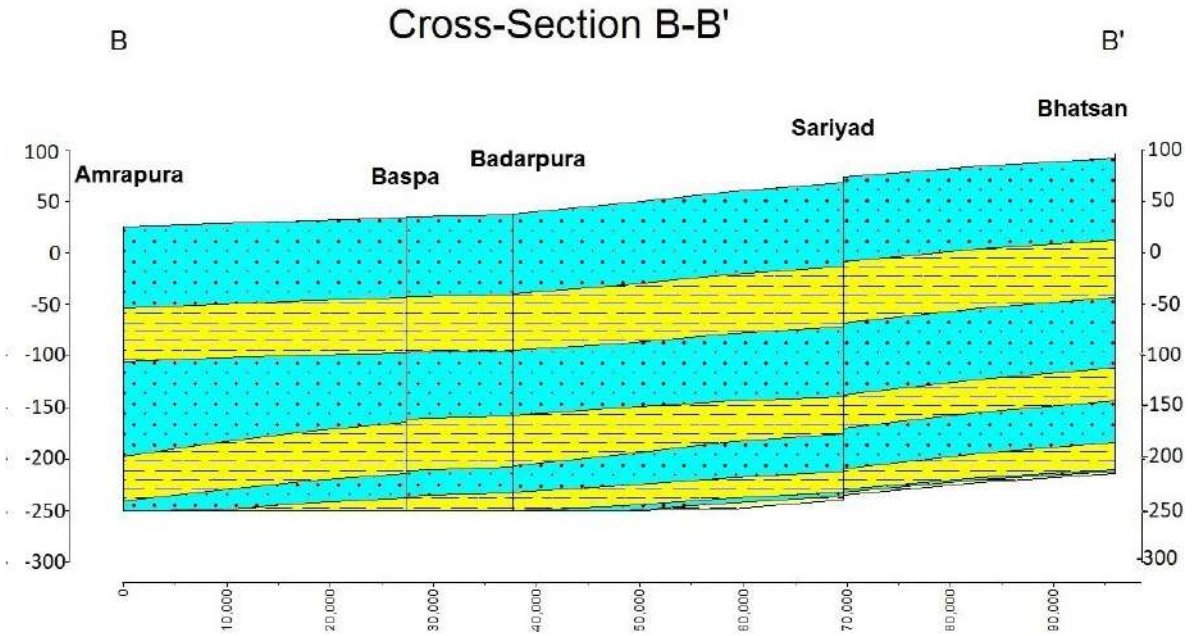
Figure 27. Map showing the section line





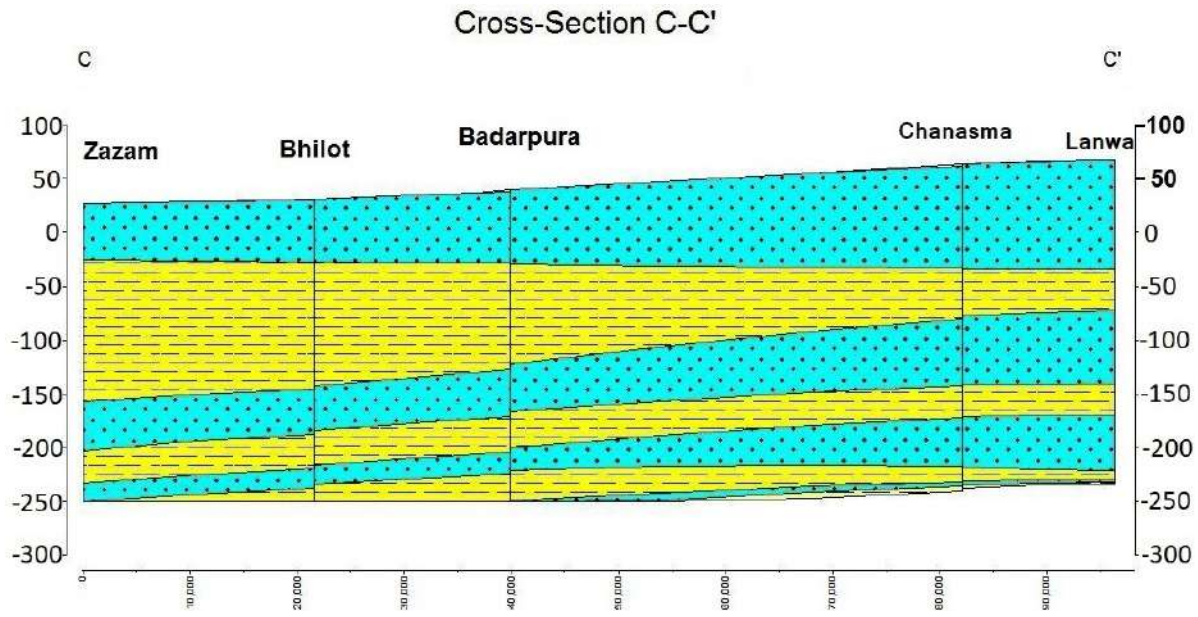
(a)

Section line of more than 100km in EEN-WWS direction showing thickening of aquitard/Clay formation towards WWS in Par at Santhalpur Taluka



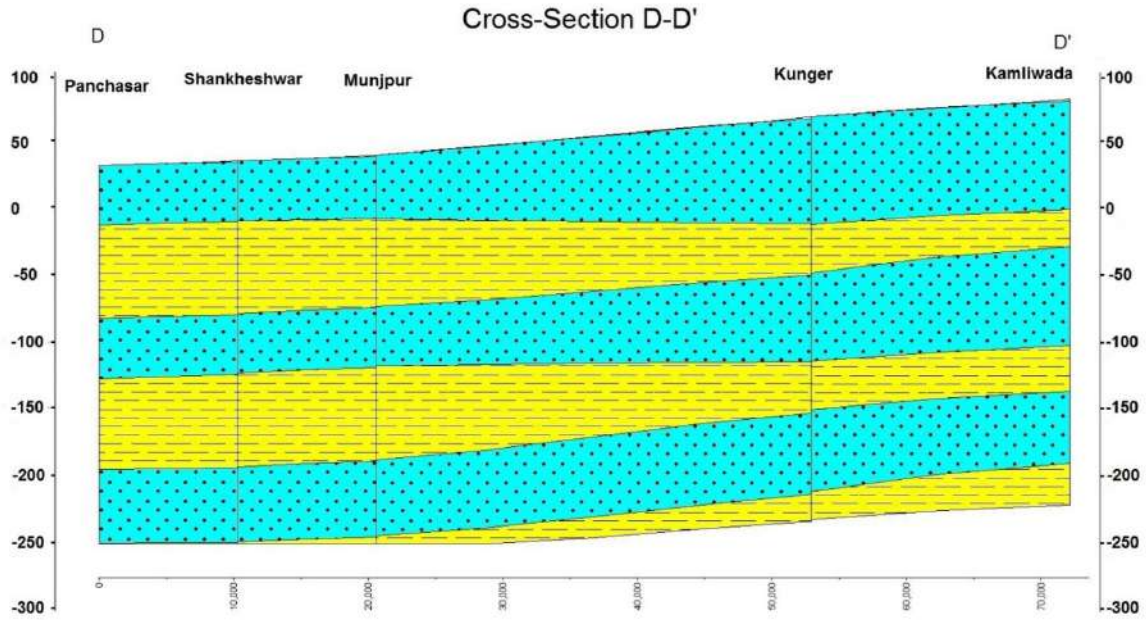
(b)

Section line of about 100km in NE-SW Direction showing general slope towards SW direction with well differentiated Aquifer System



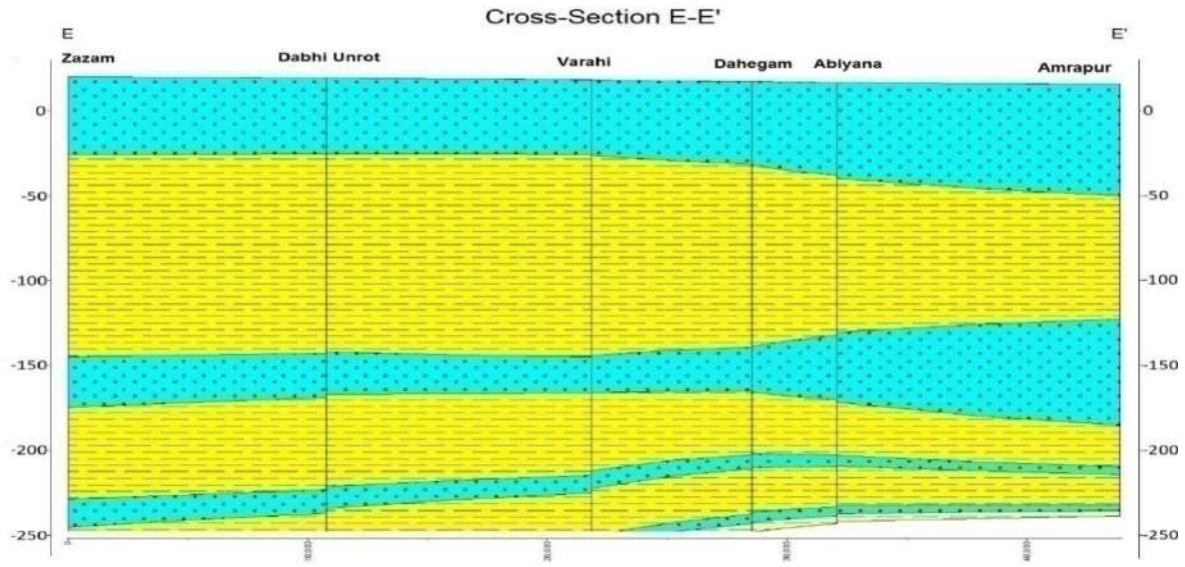
(c)

WNW-ESE Section of approximately 100km showing thinning of aquifers toward western part of the district



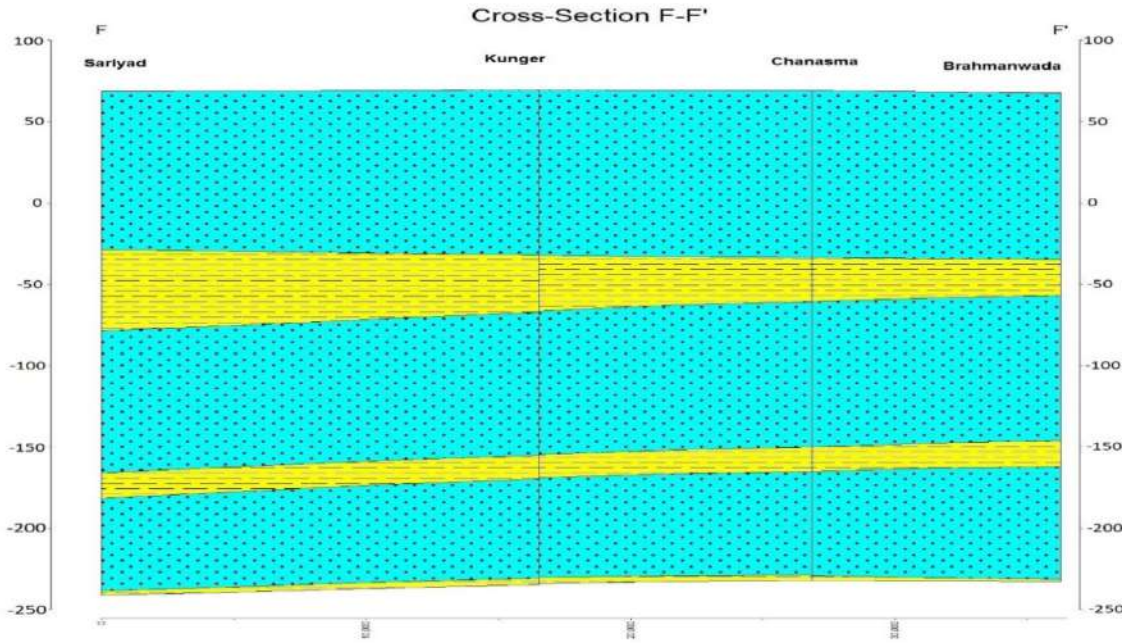
(d)

Section Depicting Aquifer System in the Southern and Eastern part of the district



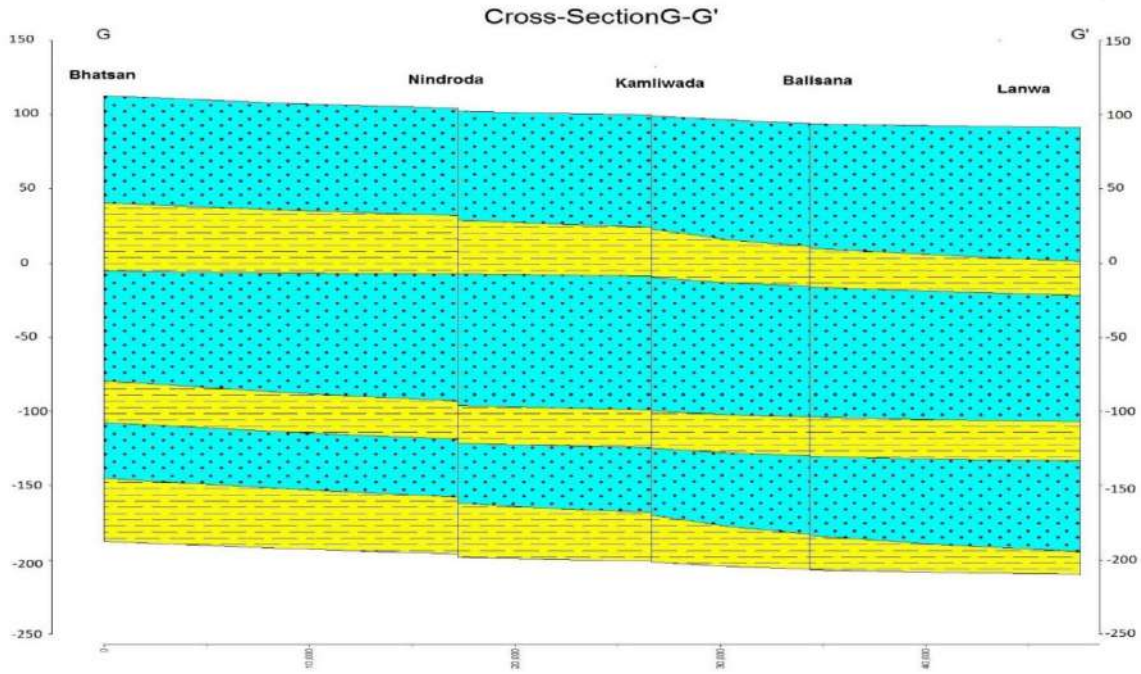
(e)

Almost N-S Section in the western part of the district depicting Aquifer Group I, II and III separated by thick Aquitard



(f)

Almost N-S Section in the mid Eastern part of the district depicting Thick Aquifer Group I, II and III separated by thin Aquitards



(g)

Almost North South Section in the extreme eastern part of the district depicting thick Aquifer Group I, II and III with Aquitards.

Figure 28. The stratigraphic sections depicting aquifer group I, II and III

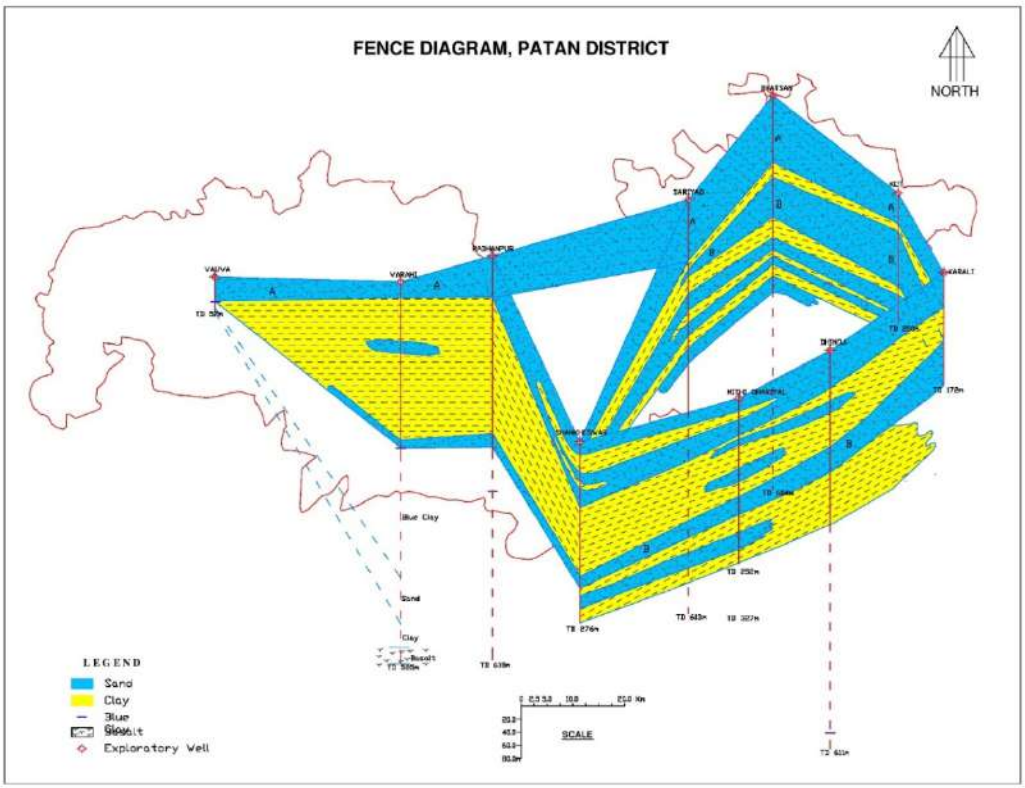


Figure 29. Fence diagram of Patan district showing aquifer groups separated by aquitard Layer

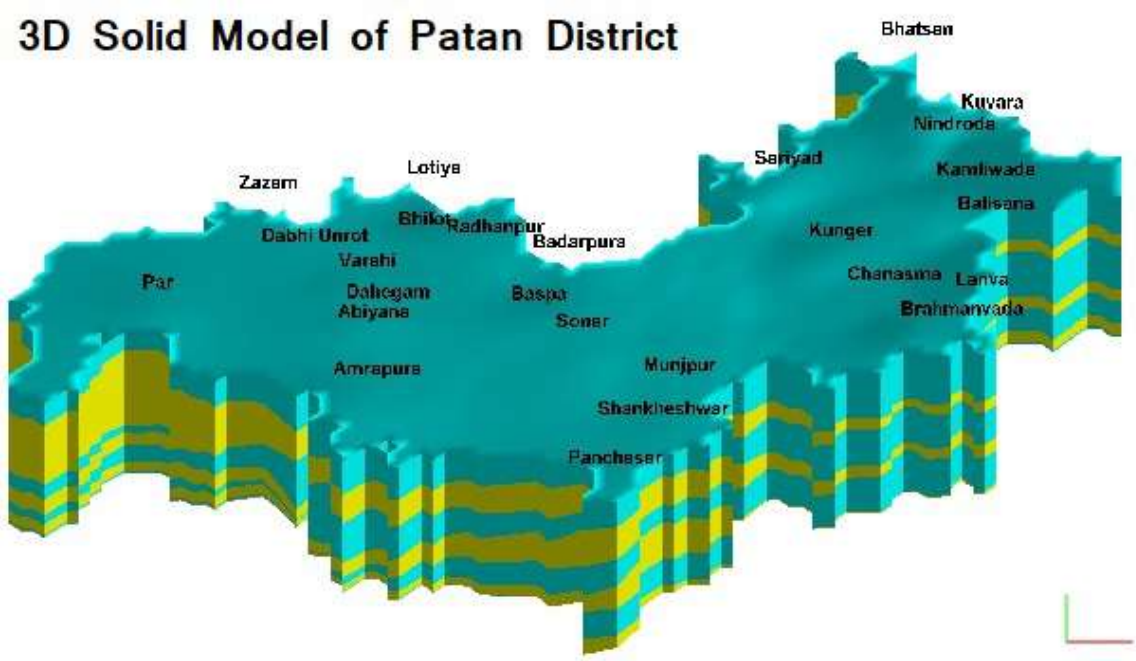


Figure 30. 3D Solid Model of Patan district

3.1 Aquifer Summary and Hydrogeological Framework

Patan district form one of the most critical districts as out of the nine talukas of the district three talukas are categorised as Over Exploited (GWRE, 2017) and one taluka as critical. In the district the multilayer aquifer system is observed, the aquifer are separated by aquitard comprising of clay interbeded with thin sand layers in the area down to about 300 mbgl and they have been grouped into three groups as per general use pattern in the area and for management proposal (Table 18).

Table 18. Aquifer characteristics of Patan district

Aquifer Group	Base of Aquifer (m)	Generalized Thickness (m)	Yield (LPM)	Quality/EC (µS/cm)	Water Level/ Piezometric head (mBGL)	Developed in the area	Aquifer Type
I	90-120	30-85	150-300	700-48000	2-40	N & NE	Phreatic
II	180-210	15-90	600-1200	1100-80000	6.4-169.3	C & EC	Semi Confined/ Confined
III	(300+)	20-80	600-1200	1300-67000	35.40-184.92	C & S and S part	Confined

The panel diagram shows that the clay content increases from eastern part to western part. Also the multilayered aquifer system is well developed in the eastern and south eastern part of the district. In the northern part of the district granular zones are predominant with lack of aquifer differentiation due to absence of clay layers.

Chapter IV

4 GROUNDWATER RESOURCES

4.1 Dynamic Groundwater Resources (Fresh and Saline)

The groundwater resources for the district have been computed by the Government of Gujarat in association with the CGWB based broadly on the guidelines and recommendations of GEC-2015 for Fresh and Saline groundwater. Five talukas are categorized as saline as they have groundwater of more than 2500 TDS namely Harij, Sami, Radhanpur, Santhalpur and Shankheshwar. Three talukas Patan, Chanasma and Sidhpur have both Fresh and Saline Dynamic groundwater resources. Only Sidhpur Taluka has totally fresh dynamic ground water resources. The unit of assessment of groundwater resources has been the administrative unit (Talukas). Out of the 4 talukas for which Fresh resources is computed three talukas are in over exploited category and one is in critical stage of groundwater development Draft and Stage of groundwater development of replenishable resource (Table 19).

Table 19. Taluka-wise groundwater resources, availability, utilization and stage of groundwater extraction (fresh) (2017)

Taluka	Groundwater recharge (MCM)					Total Natural Discharge (MCM) (5 % of 7 WTF & 10 % RIF)	Annual extractable groundwater recharge (MCM) (7- 8)	Current annual ground water extraction (MCM)				Annual groundwater allocation for domestic uses upto 2025 (MCM)	Net groundwater availability for future use (MCM) [(9)-(10+11+14)]	Stage of groundwater extraction (%) (13/9) * 100	Category
	Monsoon		Non Monsoon		Total annual groundwater recharge (3+4+5+6)			Irrigation use	Industrial uses	Domestic use	Total (10 + 11 + 12)				
	Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Chanasma	3.99	3.37	0.00	0.45	7.82	0.39	7.43	8.18	0.01	0.06	8.25	0.08	0	111.04	Over Exploited
Harij	Saline														
Patan	66.01	48.69	0.00	44.39	159.10	7.95	151.14	152.30	0.33	1.89	154.52	2.47	0	102.23	Over Exploited
Radhanpur	Saline														
Sami	Saline														
Sankheswar	Saline														
Santalpur	Saline														
Saraswati	46.52	21.00	0.00	9.96	77.49	3.87	73.61	63.82	0.44	2.48	66.73	3.25	0	90.65	Critical
Sidhpur	97.16	48.91	0.00	12.26	158.33	7.92	150.41	152.69	0.52	2.96	156.17	3.88	0	103.83	Over Exploited
District Total	213.68	121.97	0.00	67.06	402.74	20.13	382.59	376.99	1.30	7.39	385.67	9.68	0	100.80	Over Exploited

Table 20. Taluka-wise groundwater resources, availability, utilization and stage of groundwater extraction (Saline) (2017)

Taluka Wise Ground Water Resources, Availability, Utilization and Stage of Ground Water Development (2017)																
District : Patan																
Sr. No.	Taluka	GROUND WATER RECHARGE (Ham)					Total Natural Discharge (Ham) (5 % of 7 WTF & 10 % RIF)	Annual Extractable Ground Water Recharge (Ham) (7- 8)	CURRENT ANNUAL GROUND WATER EXTRACTION (Ham)				Annual Ground Water Allocation for Domestic uses upto 2025 (Ham)	Net Ground Water Availability for future use (Ham) {(9)-(10+11+14)}	Stage of Ground Water Extraction (%) (13/9) * 100	Category
		Monsoon		Non Monsoon		Total Annual Ground Water Recharge (3+4+5+6)			Irrigation Use	Industrial uses	Domestic Use	Total (10 + 11 + 12)				
		Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Chansma	63.54	22.68	0.00	6.40	92.62	4.63	87.99	64.02	0.31	1.76	66.09	2.31	21.35	75.11	Semi critical
2	Patan	36.69	22.15	0.00	36.74	95.58	4.78	90.80	76.37	0.33	1.86	78.56	2.44	11.66	86.52	Semi critical
3	Harij	57.08	25.08	0.00	18.14	100.30	5.02	95.29	66.43	0.26	1.46	68.15	1.92	26.68	71.52	Semi critical
4	Sami	122.28	15.79	0.00	18.69	156.75	7.84	148.91	31.60	0.36	2.03	33.99	1.97	114.98	22.82	Safe
5	Radhanpur	84.12	17.62	0.00	19.53	121.27	6.06	115.20	24.29	0.35	2.01	26.65	0.00	90.56	23.14	Safe
6	Santalpur	148.02	17.64	0.00	21.42	187.07	9.35	177.72	20.11	0.31	1.73	22.15	2.27	155.03	12.46	Safe
7	Shankheswa	77.47	12.07	0.00	11.95	101.48	5.07	96.41	19.90	0.17	0.95	21.01	1.24	75.11	21.79	Safe
8	Saraswati	62.83	21.27	0.00	44.50	128.60	6.43	122.17	71.28	0.29	1.62	73.18	2.12	48.49	59.90	Safe
Total		**652.02**	**154.28**	**0.00**	**177.37**	**983.67**	**49.18**	**934.49**	**373.99**	**2.37**	**13.42**	**389.78**	**14.27**	**543.86**	41.71	Safe

4.2 In Storage Groundwater Resources

In storage groundwater resources computed for the district considering taluka/block as a unit and conceptual depiction of multilayer aquifer system in parts of Becharji and Mahesana Taluks (Mahesana district) for the computation of in-storage groundwater resources upto 300 m depth is given below and computed resources are given in Table 21.

Table 21. Groundwater resources of Patan district (Fresh)

S No.	Taluka	Total geographical area (SqKm)	Aquifer Group I	Aquifer group II	Aquifer group III	In-Storage groundwater	Annual replanishable groundwater	Total availability of groundwater resources
			(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1	Chansma	457.25	243	487	730	1460	7	1467
2	Harij	407.12	0	0	0	0	0	0
3	Patan	479.71	324	324	973	1621	151	1772
4	Radhanpur	595.62	0	0	0	0	0	0
5	Sami	905.85	0	0	0	0	0	0
6	Santalpur	1350.3	0	0	0	0	0	0
7	Sidhpur	374.78	300	600	899	1799	158	1957
8	Shankeshwar	608.59	0	0	0	0	0	0
9	Saraswati	551.86	381	381	1142	1904	74	1978
	District Total	**5731**	**1248**	**1792**	**3744**	**6784**	**390**	**7174**

Table 22. Groundwater resources of Patan district (Saline/Brackish)

S No.	Taluka	Total geographical area	Aquifer group I	Aquifer Group II	Aquifer group III	In-Storage groundwater	Annual extractable groundwater resources	Total availability of groundwater resources
		(Sq km)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1	Chansma	457.25	321	160.5	107	535	88	623
2	Harij	407.12	511	213.0	128	851	95	946
3	Patan	479.71	115	85.0	100	300	91	391
4	Radhanpur	595.62	536	322.0	214	1072	115	1187
5	Sami	905.85	1123	898.0	225	2245	149	2394
6	Santalpur	1350.3	1815	908.0	303	3025	178	3202
7	Sidhpur	374.78	0	0	0	0	0	0
8	Shankeshwar	608.59	600	350.0	546	1496	96	1592
9	Saraswati	551.86	120	95.0	138	353	122	475
	District Total	**5731.08**	**5141**	**3031.5**	**1761**	**9877**	**934**	**10810**

Summarized in storage groundwater resources and the dynamic groundwater resources are given in Table 23.

Table 23. Availability of groundwater resources in Patan district (Fresh and Saline)

S No.	Taluka	Total geographical area (SqKm)	In-Storage groundwater (MCM)		Annual extractable groundwater resources (MCM)		Total availability of groundwater resources (MCM)	
			F	S	F	S	F	S
1	Chansma	457.25	1460	535	7	88	1467	623
2	Harij	407.12	0	851	0	95	0	946
3	Patan	479.71	1621	300	151	91	1772	391
4	Radhanpur	595.62	0	1072	0	115	0	1187
5	Sami	905.85	0	2245	0	149	0	2394
6	Santalpur	1350.26	0	3025	0	178	0	3202
7	Sidhpur	374.78	1799	0	158	0	1957	0
8	Shankeshwar	608.59	0	1496	0	96	0	1592
9	Saraswati	551.86	1904	353	74	122	1978	475
	District Total	**5731.04**	**6784**	**9876**	**391**	**934**	**7175**	**10811**

Refinement in computation of groundwater resources is also considered based on the improved aquifer geometry and more precise ground water regime and quality maps by increasing the density of information from the data integration of CGWB and GWRDC for the purpose. Conceptual depiction of in storage aquifer system in Mahesana district is depicted in Fig. 31 which is also applicable to Patan district.

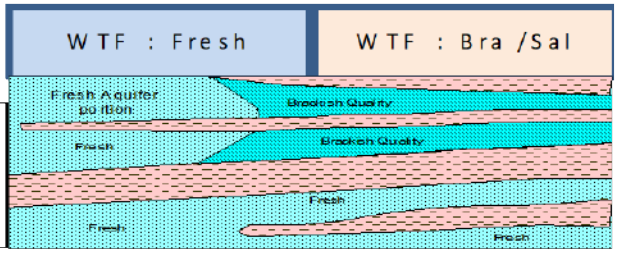
Becharaji Taluka : Multilayer Alluvium

WTF zone : Both Fresh & Saline Area

In Storage Quality	Fresh	Brackish / Saline
Thicjness Granulazone in confined Aquifer	30	20
In Storage Resources	(Fa x 30 x sy) + (Sa x 20 x sy)	Sa x (20) x (sy)

confined aquifer with total 50 m thick granular zone

Conceptual depiction of in storage aquifer system



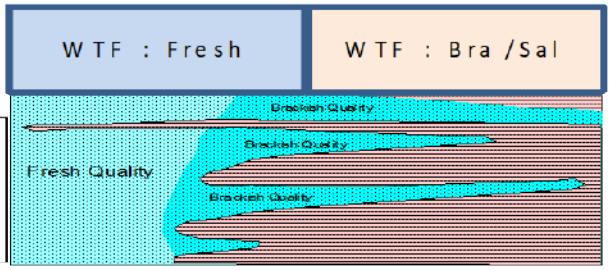
Mahesana Taluka : Multilayer Alluvium

WTF zone : Both Fresh & Saline Area

In Storage Quality	Fresh	Brackish / Saline
Thicjness Granulazone in confined Aquifer	60	10
In Storage Resources	Fa x (60) x (sy)	Sa x (10) x (sy)

confined aquifer with total 60 m thick granular zone

Conceptual depiction of in storage aquifer system



Kankrej Taluka : Multilayer Alluvium

WTF zone : Both Fresh & Saline Area

In Storage Quality	Fresh	Brackish / Saline
Thicjness Granulazone in confined Aquifer	80	18
In Storage Resources	(Fa x 80 x sy) + (Sa x 60 x sy)	Sa x (18) x (sy)

confined aquifer with total 78 m thick granular zone

Conceptual depiction of in storage aquifer system

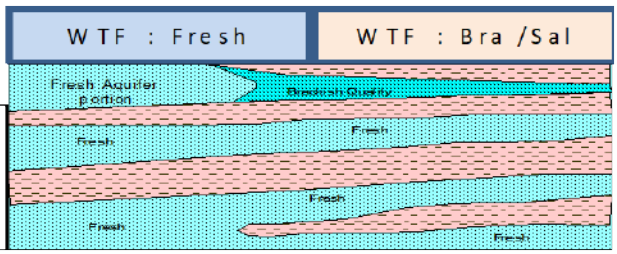


Figure 31. Conceptual depiction of in storage aquifer system

Chapter V

5 GROUNDWATER RELATED ISSUES

5.1 Identification of issues

Traditional agricultural /irrigation practices, flood irrigation practices, increase in water demand, irrigation practices based on power supply. Farmers irrigate the crops when power supply is available rather than waiting for the wilting to start. Following are the issues identified for aquifer management in the area:

- Arid/Semi arid area
- High rate of Evapotranspiration
- Non availability of surface water resources
- Over exploitation of groundwater
- Decline in groundwater levels
- De saturation of Phreatic aquifers
- Deeper Piezometric head of Confined Aquifer-III (Map)
- Decline in Piezometric heads of semi confined/confined aquifer
- Increase in well depth as water levels become deeper
- Increase in depth of prime mover/pump setting
- Decline in well yields
- Large scale groundwater development over the years : Level of groundwater development 2007–144.20%, 2011-122.33%, 2013 – 106.38% and 2017-100.80%
- Water Logging /Shallow Water Level in Command area

5.2 Geographical distribution and quantification with respect to groundwater resources and ground water quality/contamination

The groundwater conditions in the district are unique in the sense that on one side water logging conditions prevail due to recharge from the supply of water from canal and rainfall in the existing shallow aquifers, while in other neighbouring areas, the water levels are very deep. The perched water table conditions due to the presence of clay horizon at very shallow depths, the groundwater management becomes even more important in this area. In the area adjoining Rann in Santalpur, Radhanpur, Sami and Shankheshwar talukas water logging conditions prevail. Recharge from the supply of water from canal in shallow aquifers and occurrence of clay at shallow depth acting as

aquiclude/aquitard is considered as one of the causes for water logging condition.

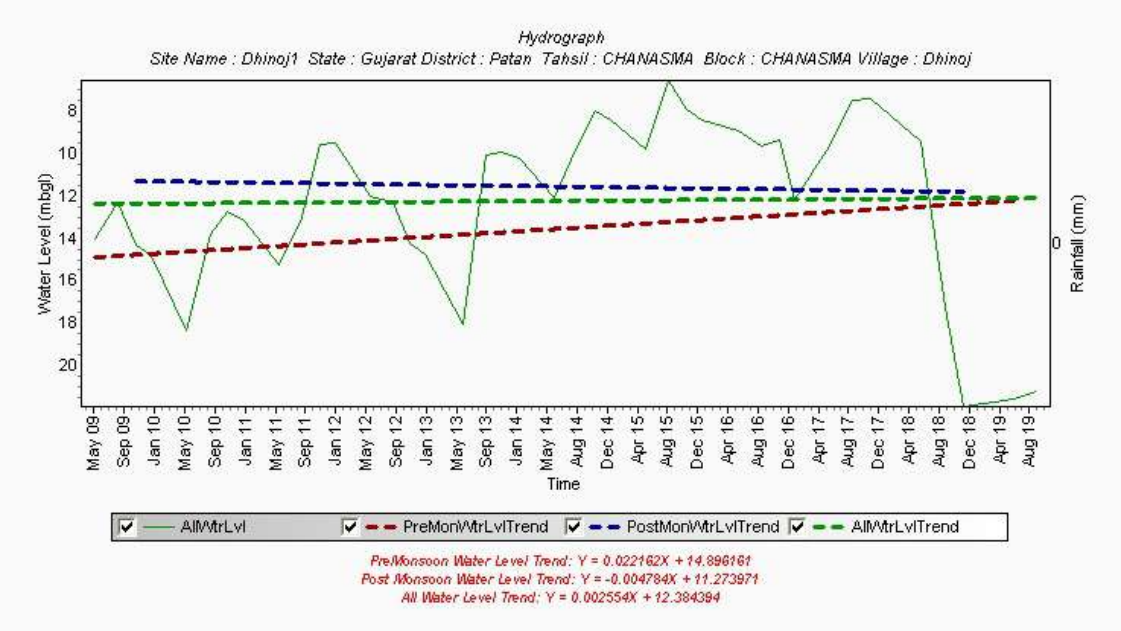
Over exploitation of groundwater, Lateral and Vertical change in groundwater yield and quality, high demand of water for existing irrigation practices are some of the major groundwater related issues in the area. Out of the total area of district about 50% area with fresh groundwater is having deeper water level and 40% area is experiencing steadier decline in groundwater level over the years. The data of the trend in absolute with the time is tabulated below and the hydrographs of selected Observation wells for aquifer group I, aquifer group II and aquifer group III is presented below.

5.2.1 Aquifer Group I

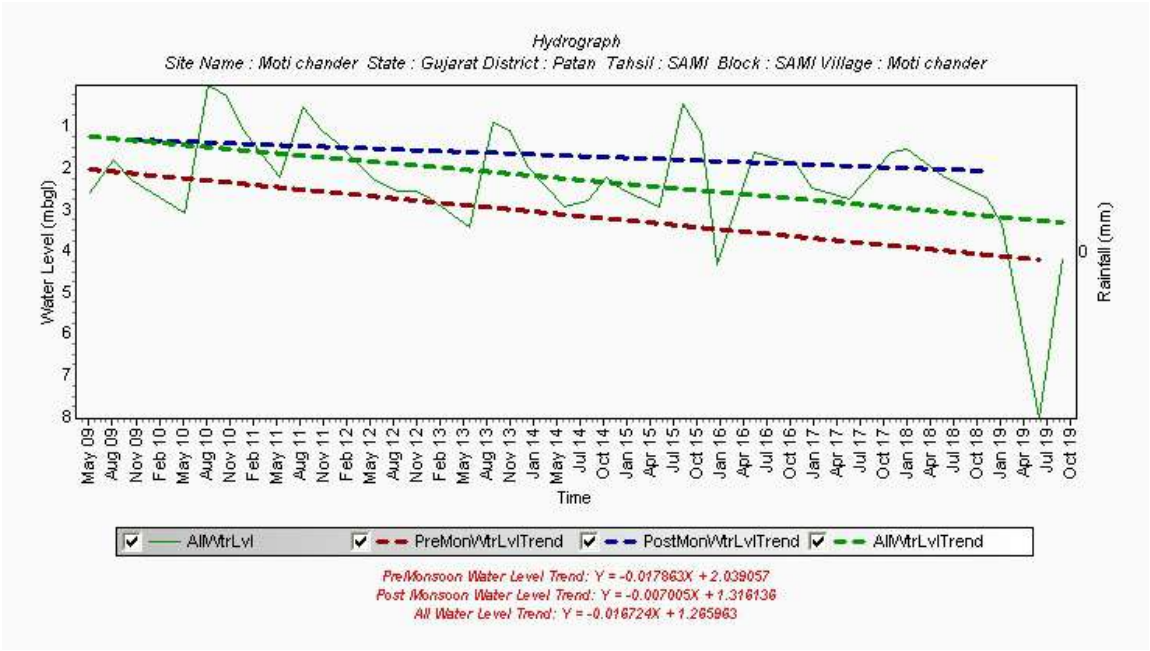
Table 24. Water level trend of aquifer group I.

Observation Well	Taluka	Aquifer Group	Period of Data Analysed	Water Level Trend
Dhinoj	Chanasma	I	2009-2018	0.30m Rise
Moti Chander	Sami	I	2009-18	1.67m Fall
Patan 2	Patan	I	2009-18	1.90m Fall
Sankhari	Patan	I	2009-18	0.18m Fall
Mota Ramanda	Patan	I	2011-19	0.36m Fall
Balisana	Patan	I	2011-19	9.66m Rise
Gulvasana	Patan	I	2011-19	1.90m Rise
Vadu	Patan	I	2011-19	5.31m Rise
Morpa	Patan	I	2011-19	2.12m Fall

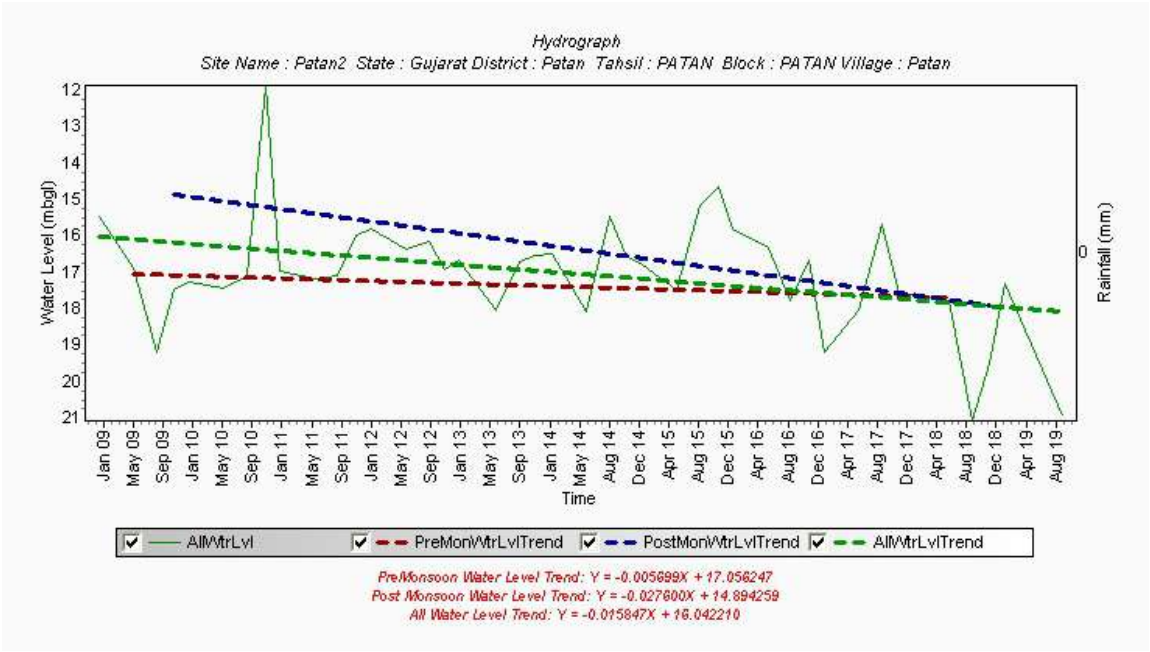
It is observed that the trend of the hydrographs show stable trend. It is also observed that the shallow piezometers tapping Aquifer Group I in the vicinity of Sujalam Sufalam Canal show rise at some places.


Hydrograph
Site Name : Dhinoj1 State : Gujarat District : Patan Tahsil : CHANASMA Block : CHANASMA Village : Dhinoj
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.022162X + 14.896161
Post Monsoon Water Level Trend: Y = -0.004784X + 11.273971
All Water Level Trend: Y = 0.002554X + 12.384394

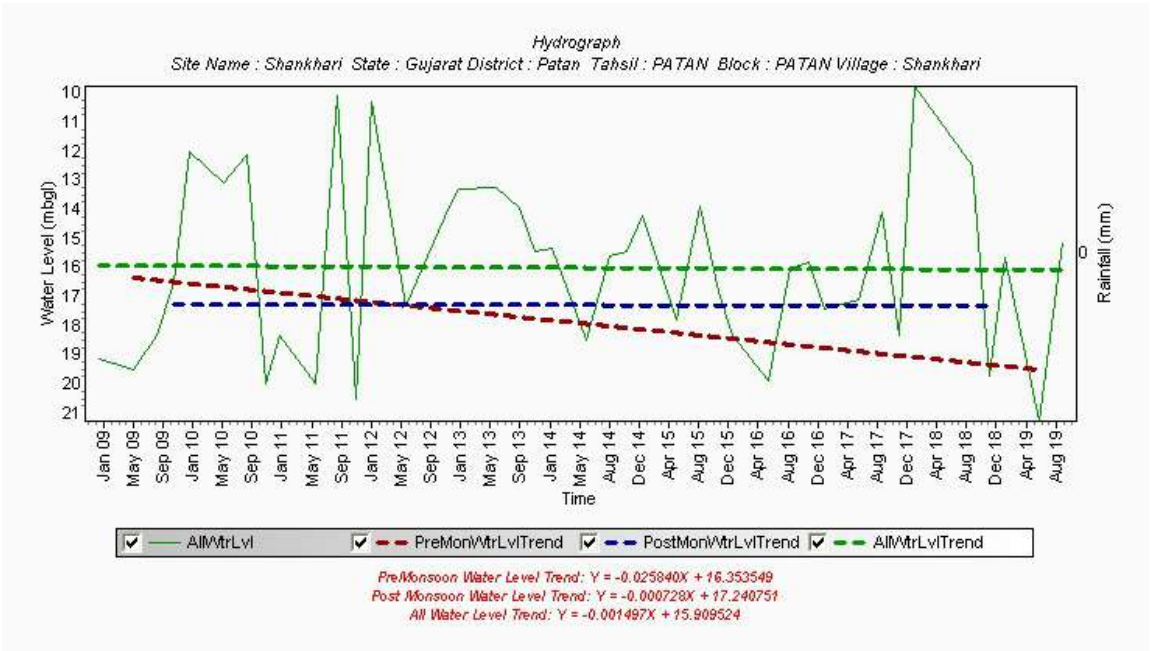
(a)


Hydrograph
Site Name : Moti chander State : Gujarat District : Patan Tahsil : SAMI Block : SAMI Village : Moti chander
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.017863X + 2.039057
Post Monsoon Water Level Trend: Y = -0.007005X + 1.316136
All Water Level Trend: Y = -0.016724X + 1.265963

(b)



(c)



(d)

Figure 32. Typical hydrographs showing in groundwater levels of aquifer group I

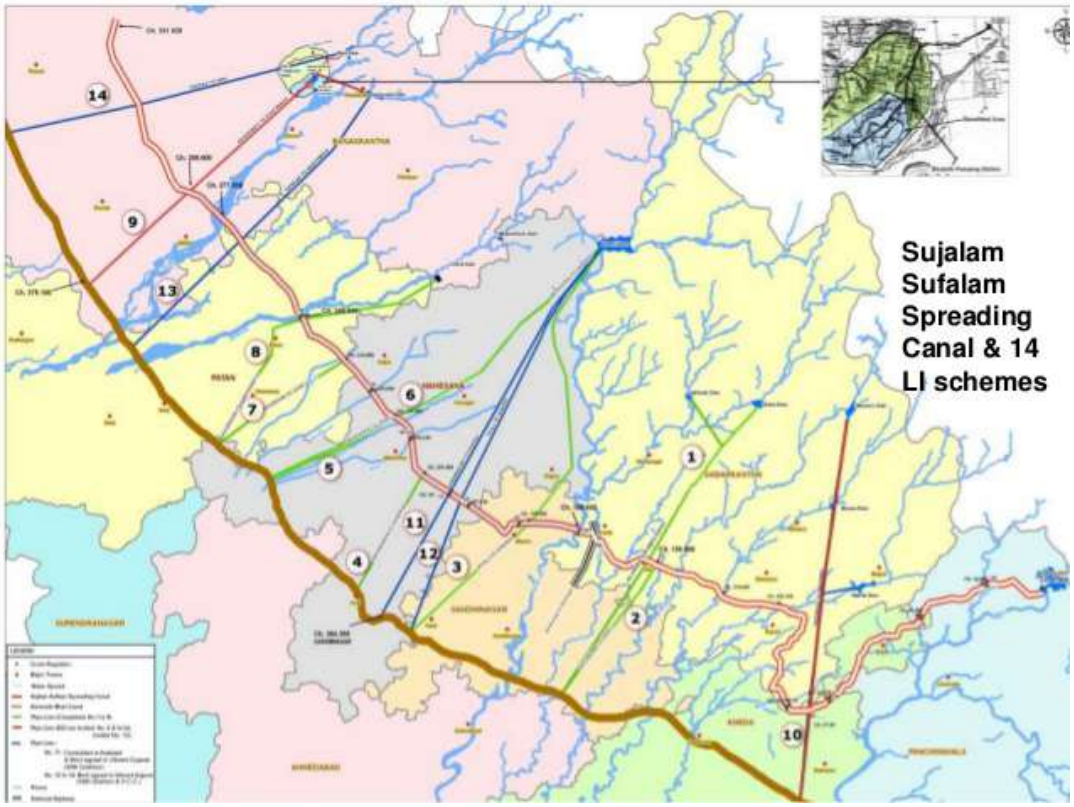
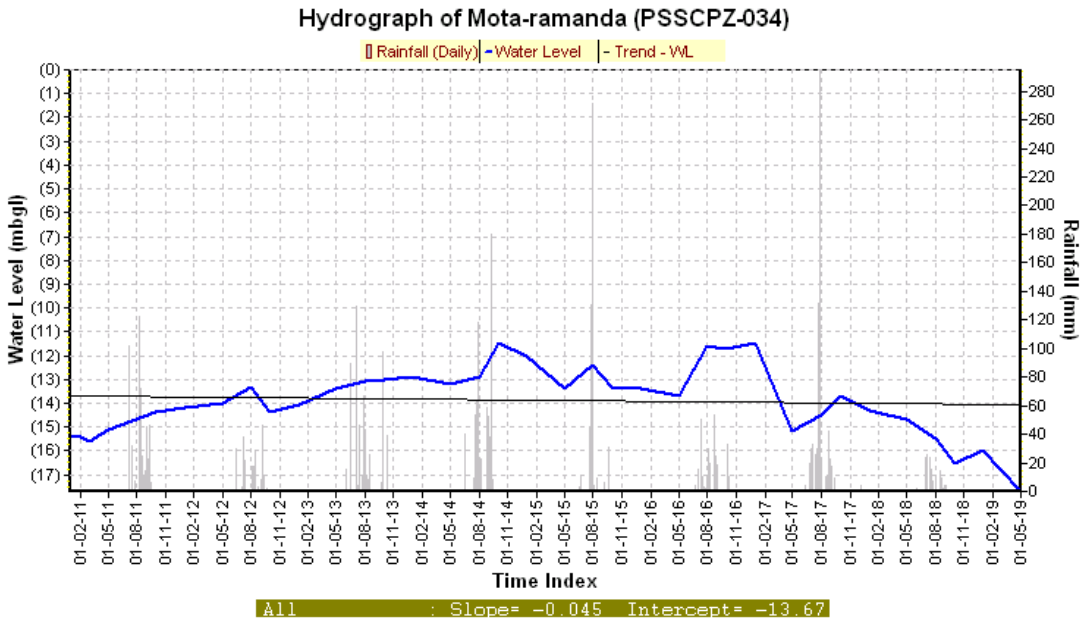
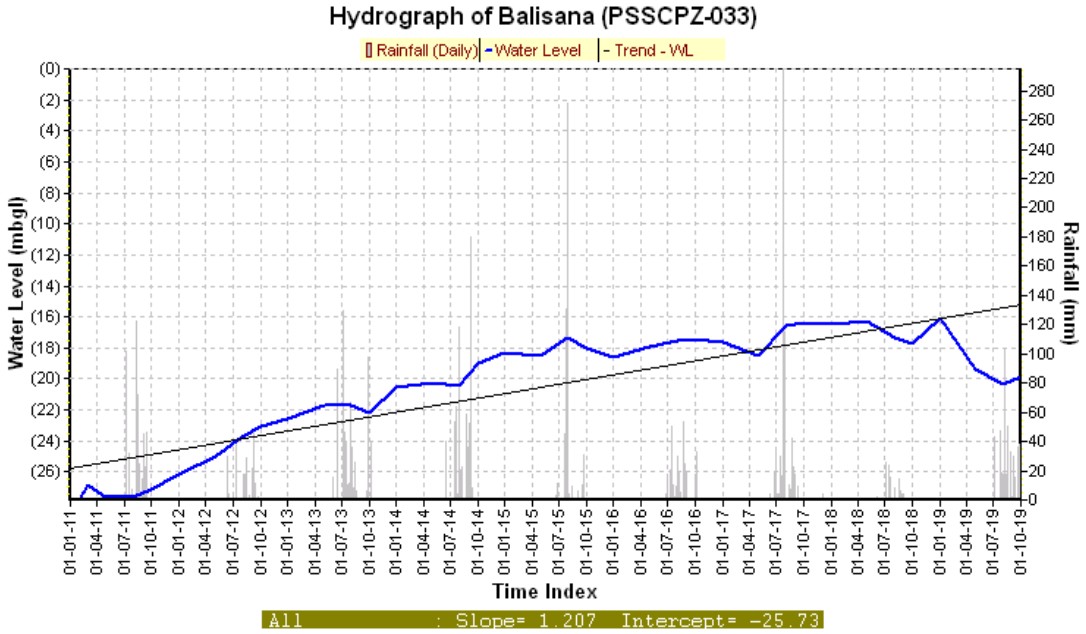


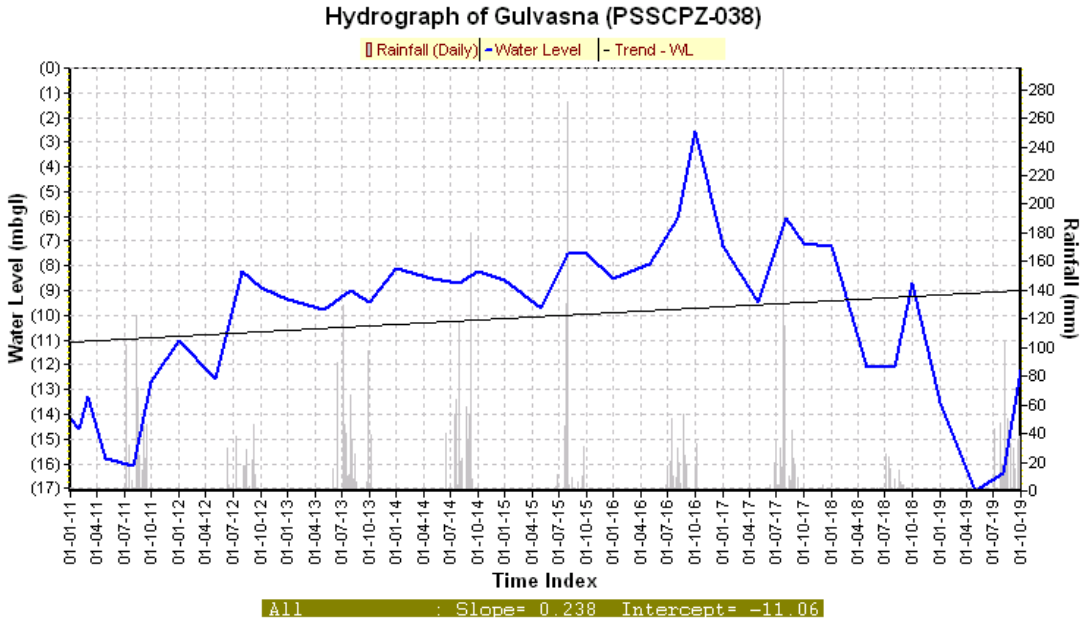
Figure 33. Schematic depiction of Sujalam Sufalam spreading canal scheme



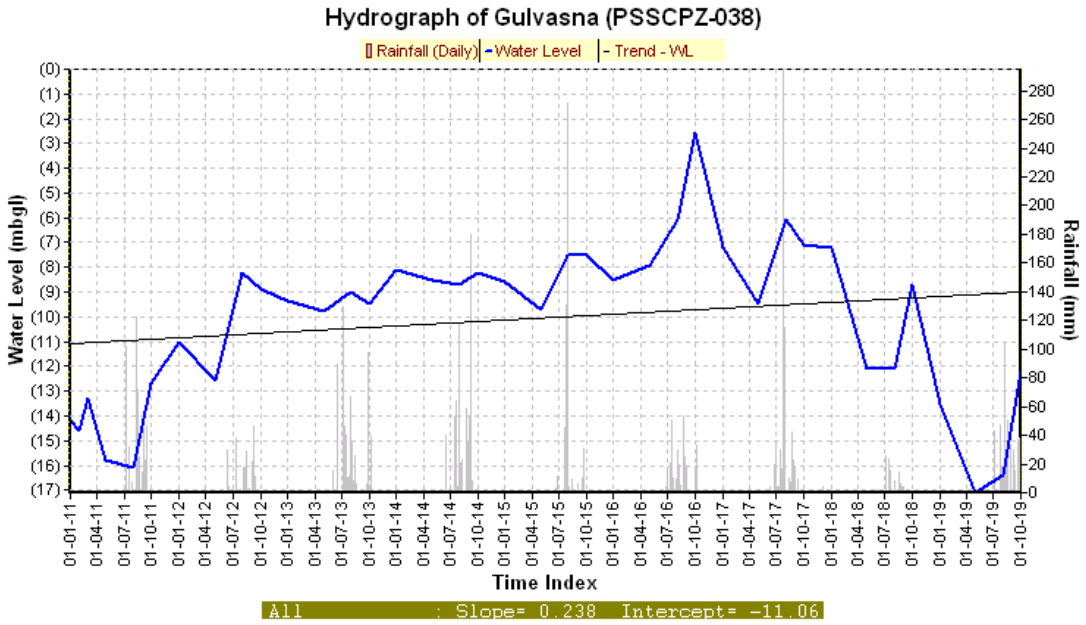
(a)


Hydrograph of Balisana (PSSCPZ-033)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= 1.207 Intercept= -25.73

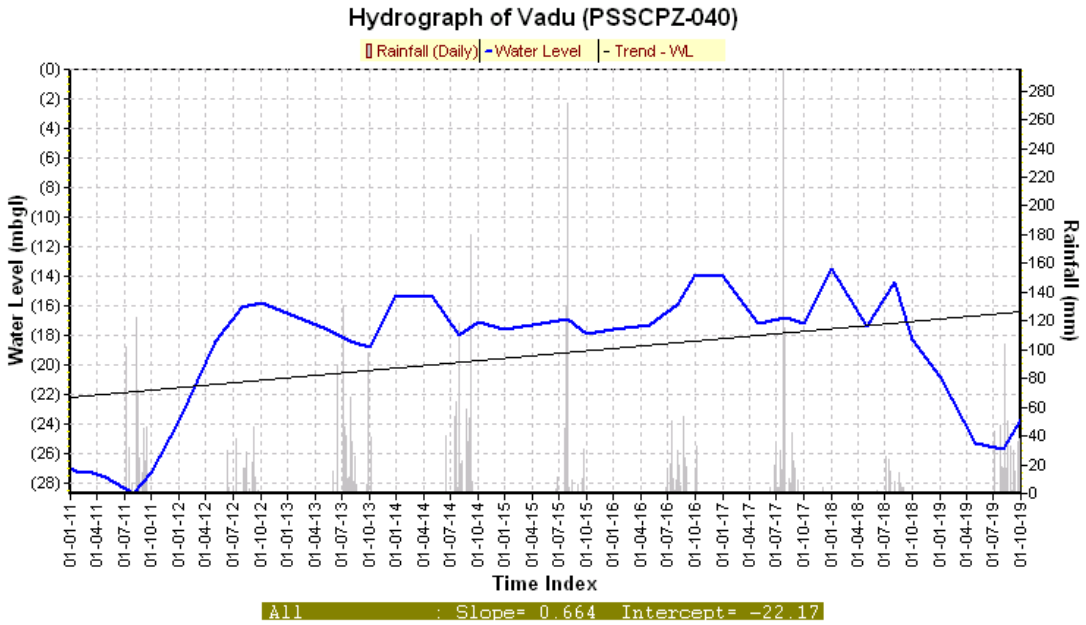
(b)


Hydrograph of Gulvasna (PSSCPZ-038)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= 0.238 Intercept= -11.06

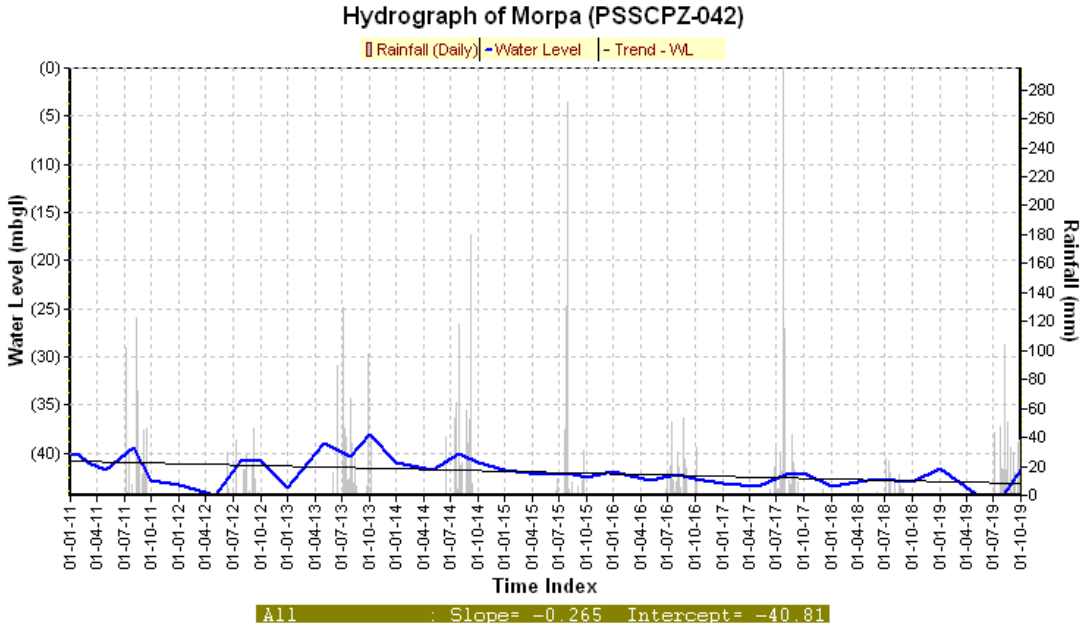
(c)


Hydrograph of Gulvasna (PSSCPZ-038)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= 0.238 Intercept= -11.06

(d)


Hydrograph of Vadu (PSSCPZ-040)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= 0.664 Intercept= -22.17

(e)



(f)

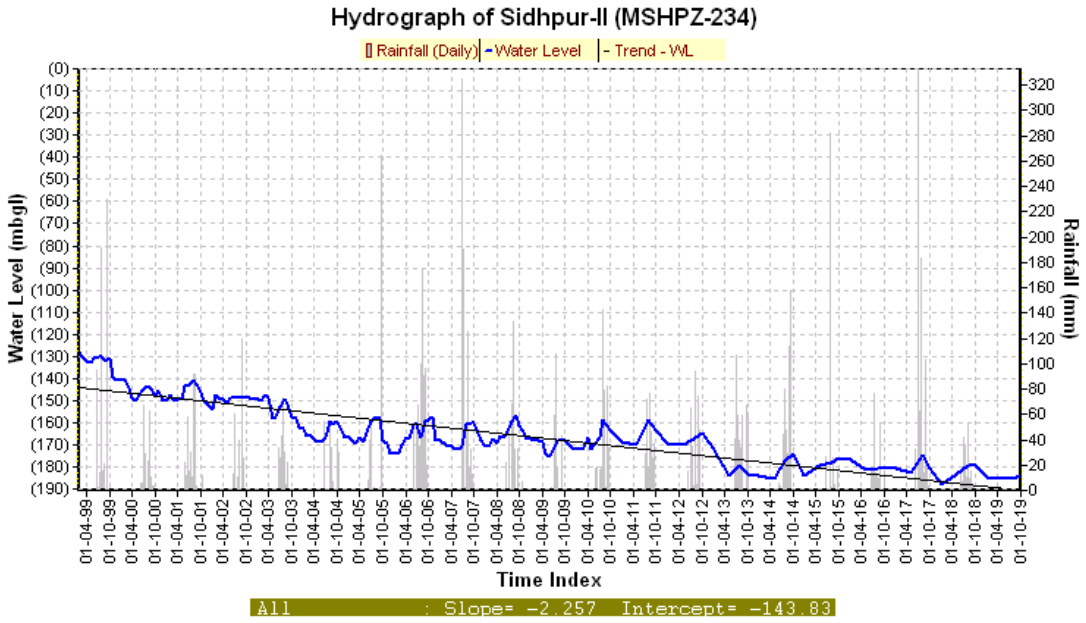
Figure 34. Typical hydrographs showing change in groundwater levels Sujalam Sufalam canal area

5.2.2 Aquifer Group II

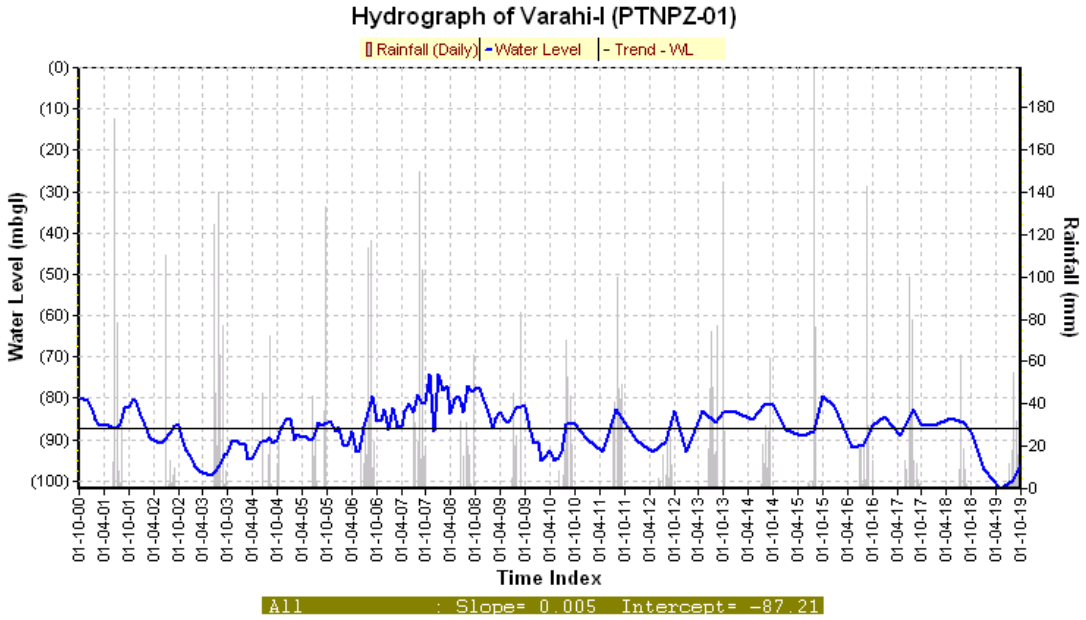
Almost all the piezometers tapping Aquifer Group II show Fall in long term. The data of the trend in absolute with the time is tabulated below and the hydrographs of selected Piezometers is also presented. It can be observed that almost all piezometers show fall except piezometers in Radhanpur and Santalpur Talukas where development of Aquifer Group II is not there on account of poor quality.

Table 25. Water level/Piezometric head trend of aquifer group II.

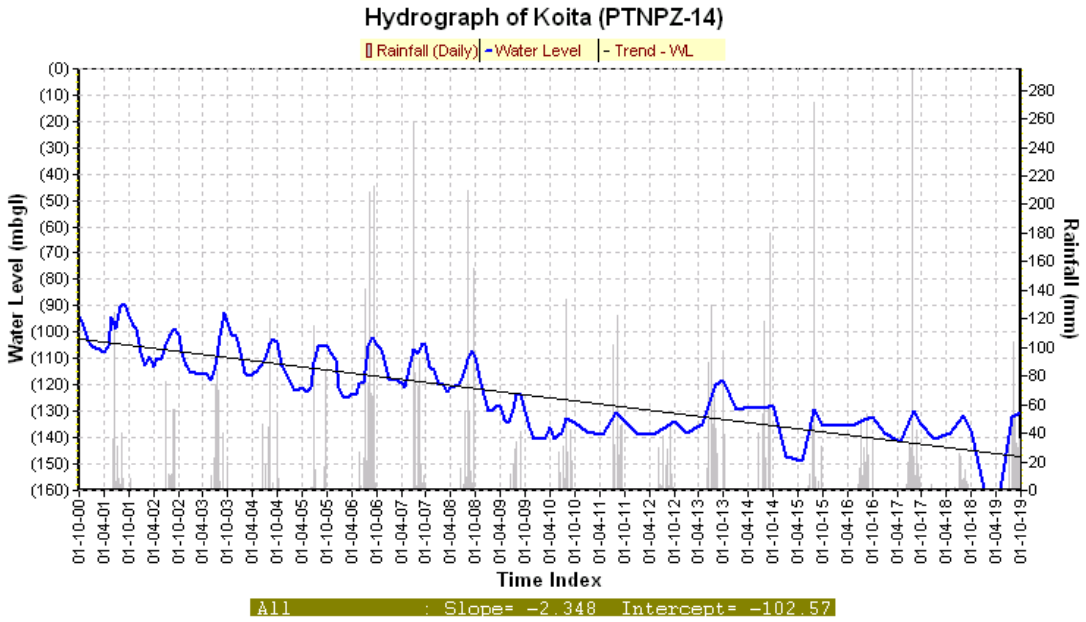
Observation Well	Taluka	Aquifer Group	Period of Data Analysed	Water Level/ Piezometric Head Trend
Jhilia I	Chanasma	II	1999-2019	20m Fall
Sidhpur II	Sidhpur	II	1999-2019	45.14m Fall
Varahi I	Santalpur	II	2000-2019	0.95m Rise
Koita	Saraswati	II	2000-2019	44.61m Fall
Tavadia	Sidhpur	II	2001-2019	24.59m Fall
Adiya II	Harij	II	2000-2019	1.57m Fall
Kungher	Patan	II	2000-2019	2.45m Fall
Kalyana I	Sidhpur	II	2000-2019	6.40m Rise
Gotarka	Radhanpur	II	2001-2019	1.51m Rise
Ruvavi	Patan	II	2001-2019	16.36m Fall


Hydrograph of Sidhpur-II (MSHPZ-234)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= -2.257 Intercept= -143.83

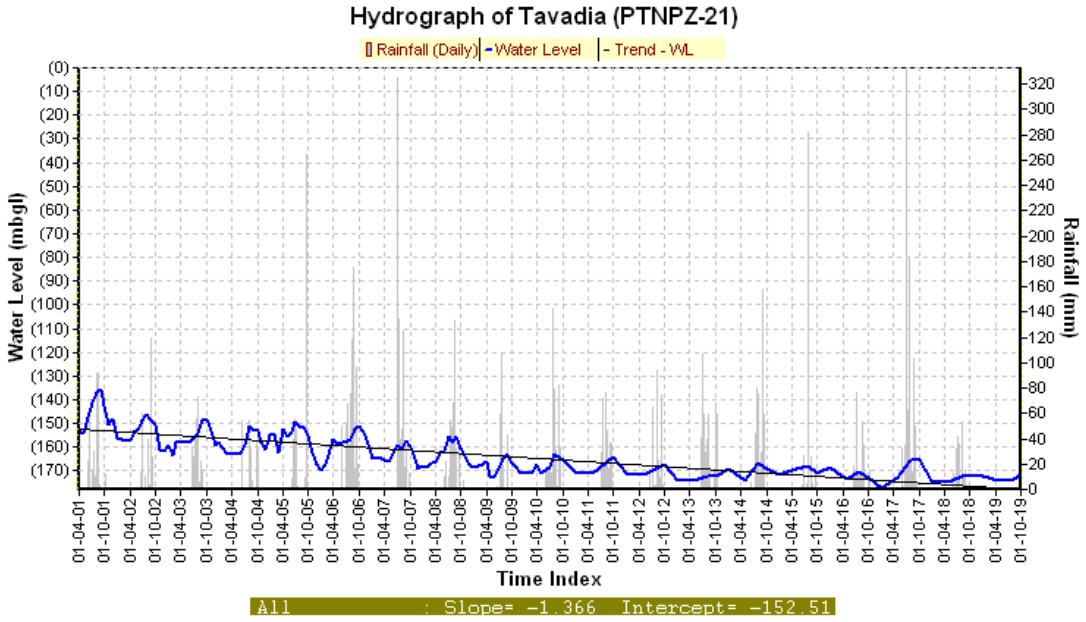
(a)


Hydrograph of Varahi-I (PTNPZ-01)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= 0.005 Intercept= -87.21

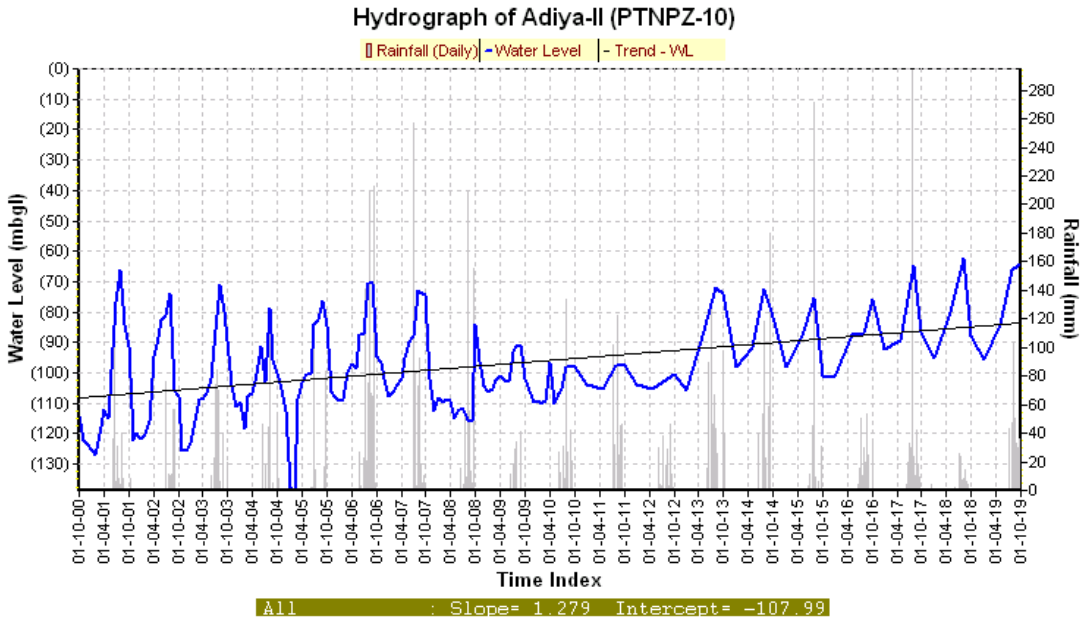
(b)


Hydrograph of Koita (PTNPZ-14)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= -2.348 Intercept= -102.57

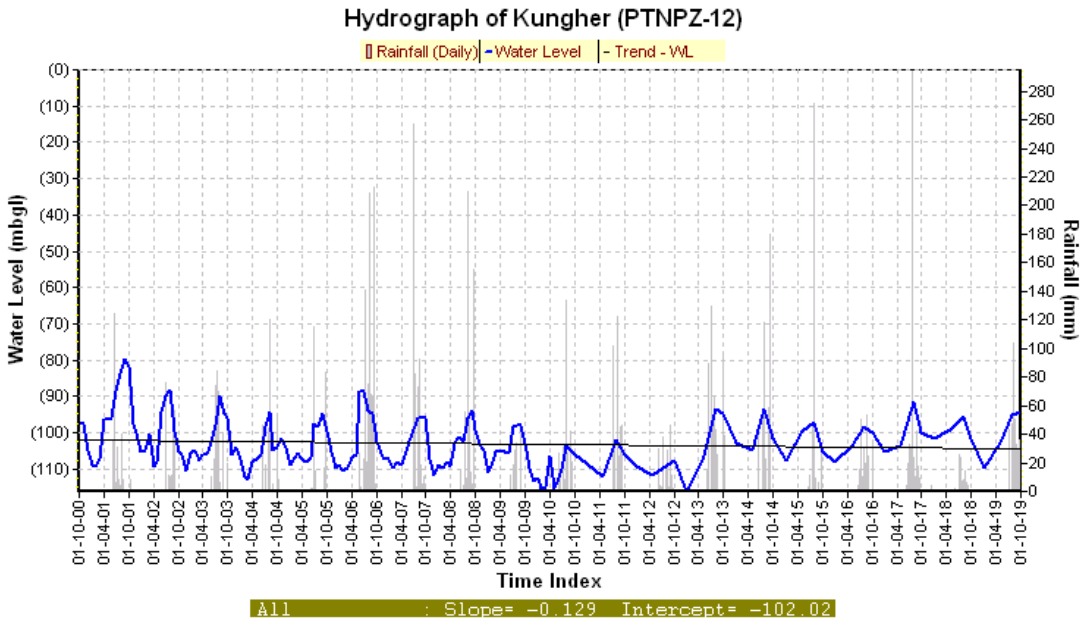
(c)


Hydrograph of Tavadia (PTNPZ-21)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= -1.366 Intercept= -152.51

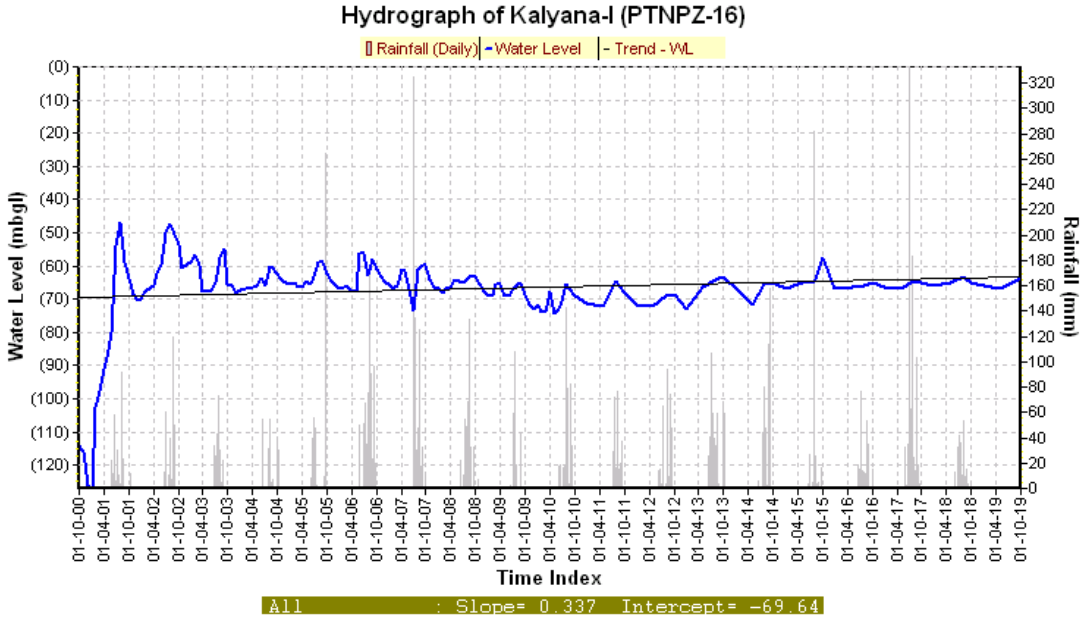
(d)


Hydrograph of Adiya-II (PTNPZ-10)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= 1.279 Intercept= -107.99

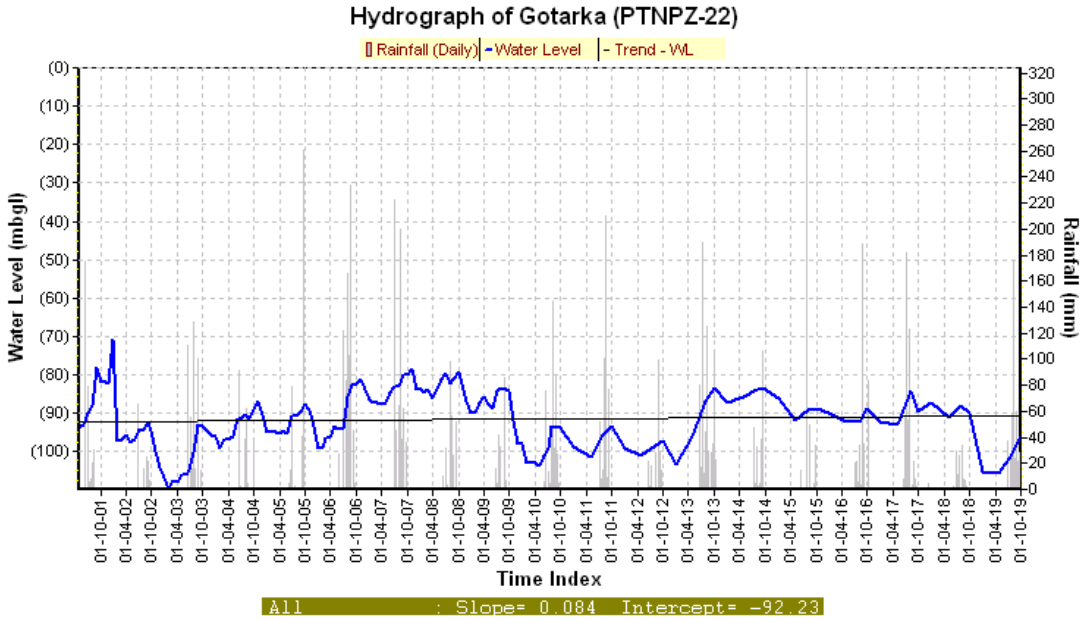
(e)


Hydrograph of Kungher (PTNPZ-12)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= -0.129 Intercept= -102.02

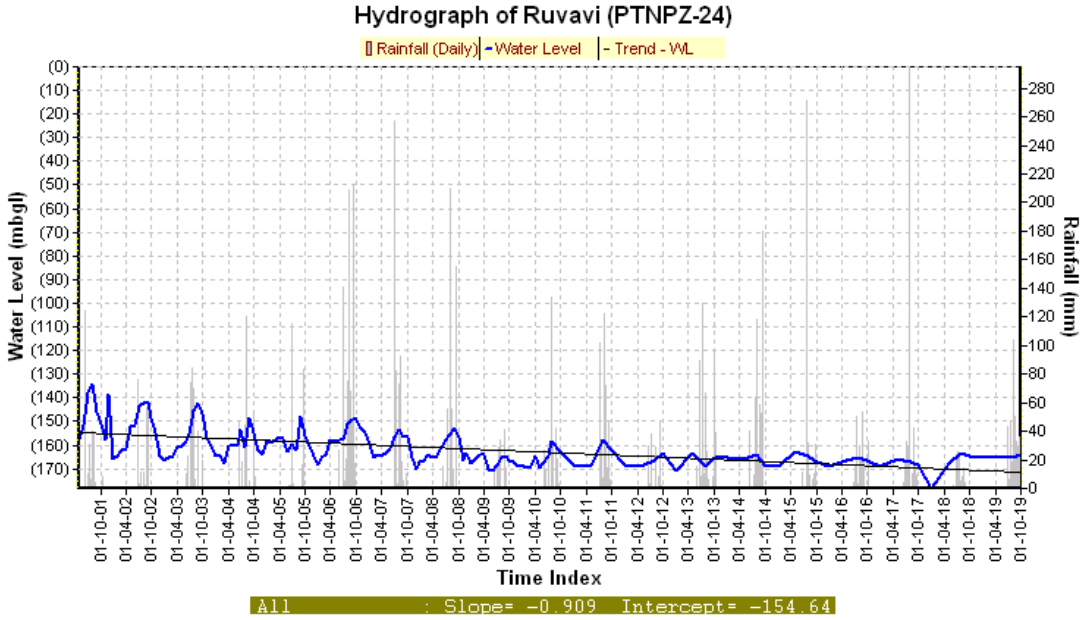
(f)


Hydrograph of Kalyana-I (PTNPZ-16)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= 0.337 Intercept= -69.64

(g)


Hydrograph of Gotarka (PTNPZ-22)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= 0.084 Intercept= -92.23

(h)



(i)

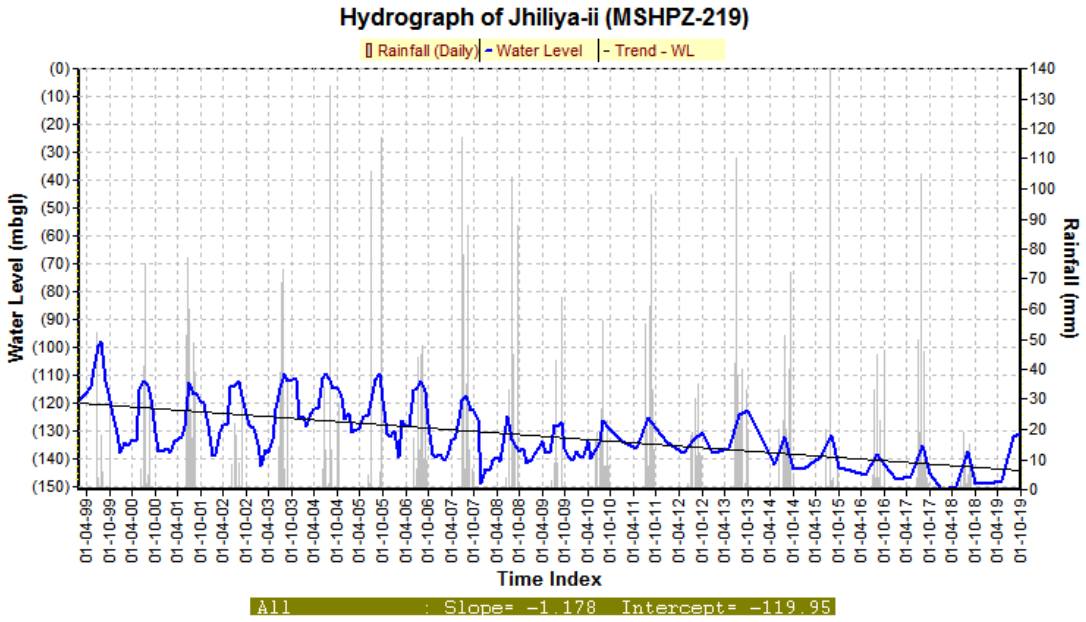
Figure 35. Typical hydrographs showing in groundwater levels/piezometric head aquifer group II

5.2.3 Aquifer Group III

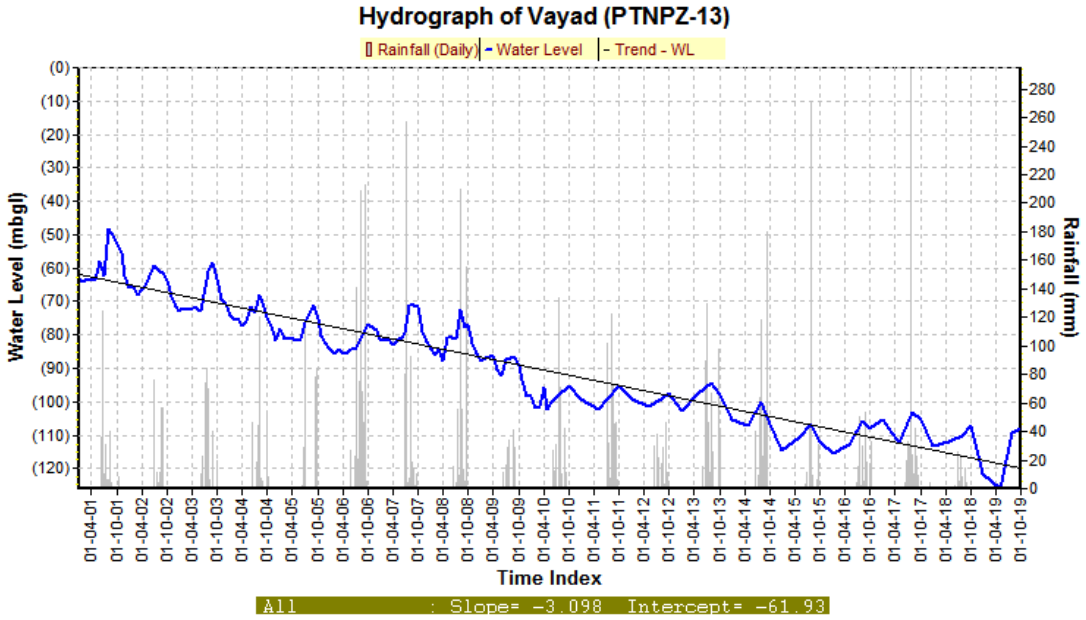
Piezometers tapping Aquifer Group III show varying degrees of Fall in long term. The data of the trend in absolute with the time is tabulated below and the hydrographs of selected Piezometers tapping Aquifer Group III is also presented. This Aquifer Group is the most developed for Irrigation purpose in the district hence we can see large decline with time in absolute term. In the western Part of the district this aquifer is also saline and hence show rising trend in Santalpur and Harij Talukas.

Table 26. Piezometric head trend of aquifer group III

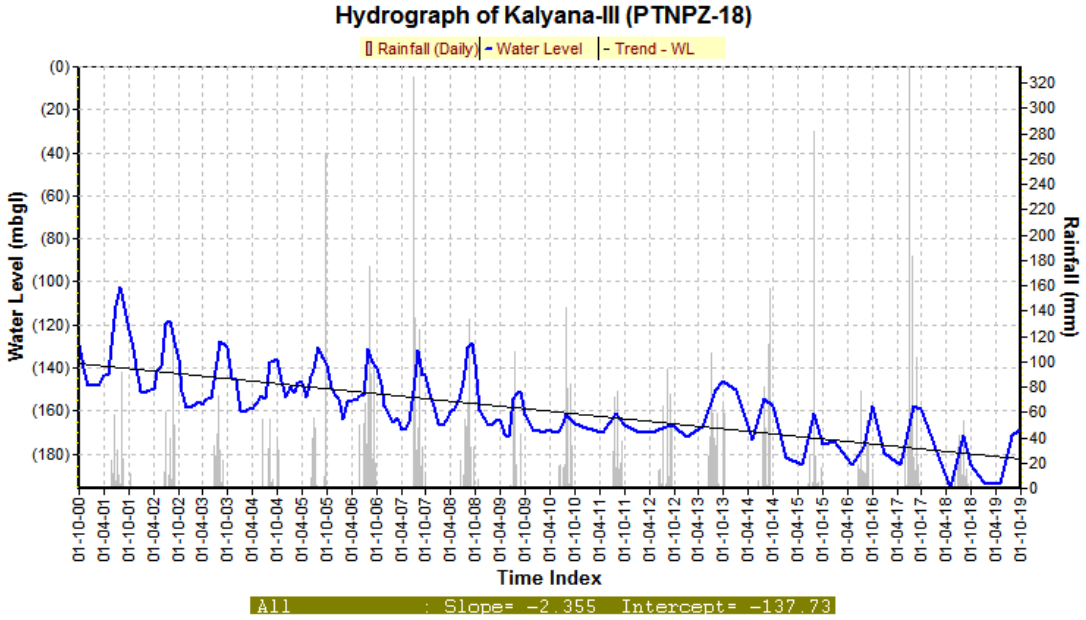
Observation Well	Taluka	Aquifer Group	Period of Data Analysed	Water Level/Piezometric Head Trend
Jhilia II	Chanasma	III	2000-2019	23.56m Fall
Vayad	Saraswati	III	2001-2019	55.76m Fall
Kalyana III	Sidhpur	III	2000-2019	44.75m Fall
Dhinoj	Chanasma	III	2000-2019	36.157m Fall
Kamboi	Chanasma	III	2001-2019	13.19m Fall
Jangral	Patan	III	2011-2019	18.89m Fall
Kakosi	Patan	III	2012-2018	4.04m Rise
Varahi III	Santalpur	III	2000-2019	77.33m Rise
Adiya III	Harij	III	2000-2019	77.37m Rise


Hydrograph of Jhiliya-ii (MSHPZ-219)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= -1.178 Intercept= -119.95

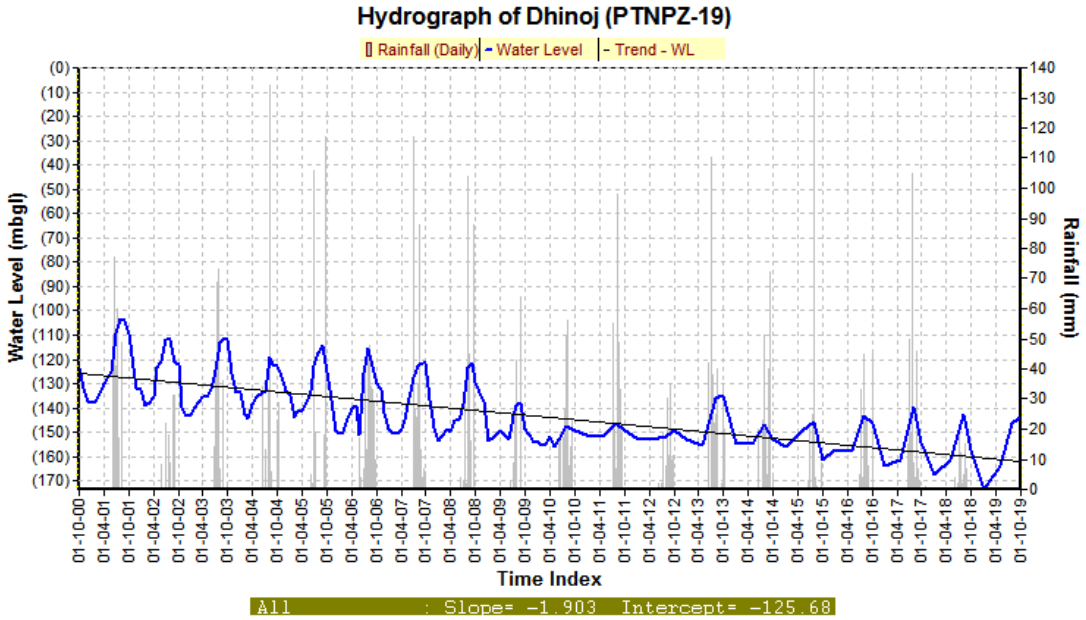
(a)


Hydrograph of Vayad (PTNPZ-13)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= -3.098 Intercept= -61.93

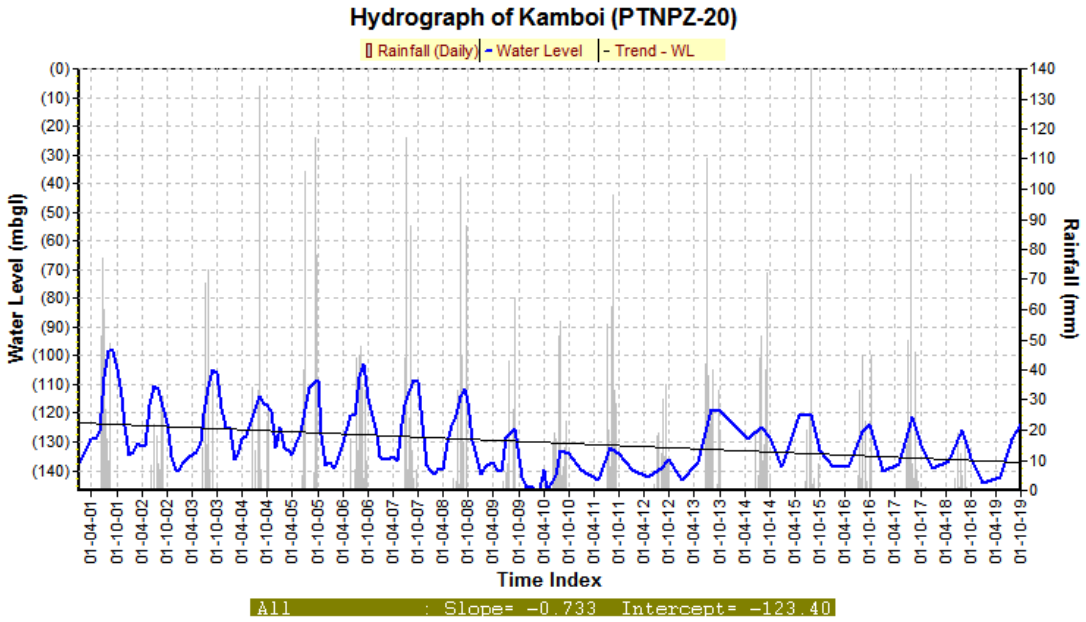
(b)


Hydrograph of Kalyana-III (PTNPZ-18)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= -2.355 Intercept= -137.73

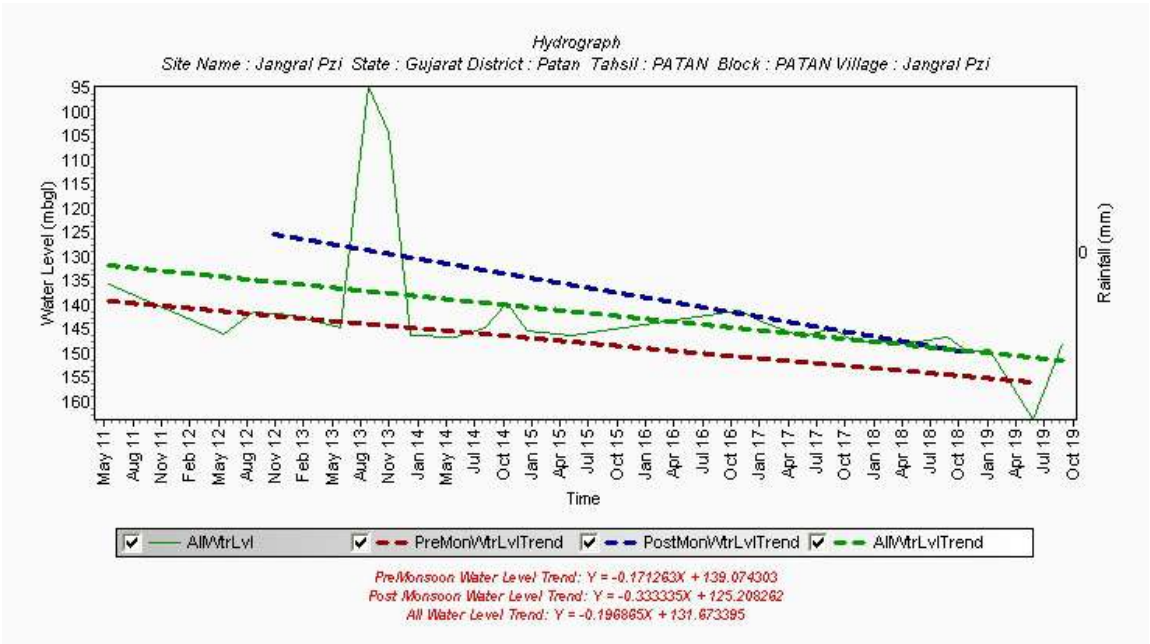
(c)


Hydrograph of Dhinoj (PTNPZ-19)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= -1.903 Intercept= -125.68

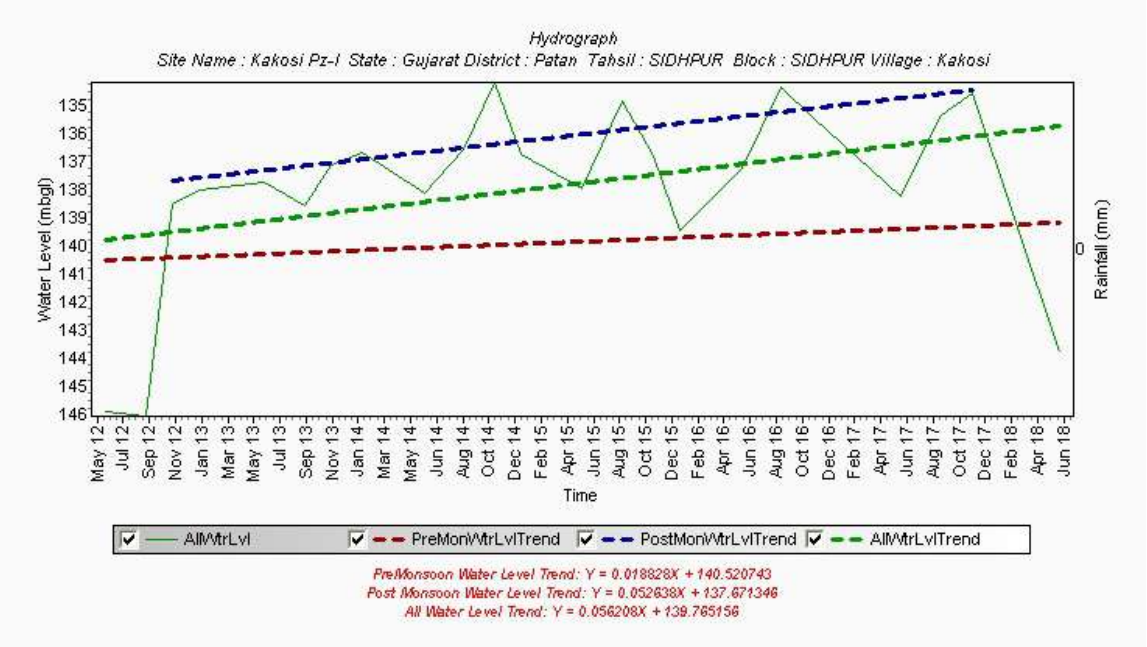
(d)


Hydrograph of Kamboi (PTNPZ-20)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= -0.733 Intercept= -123.40

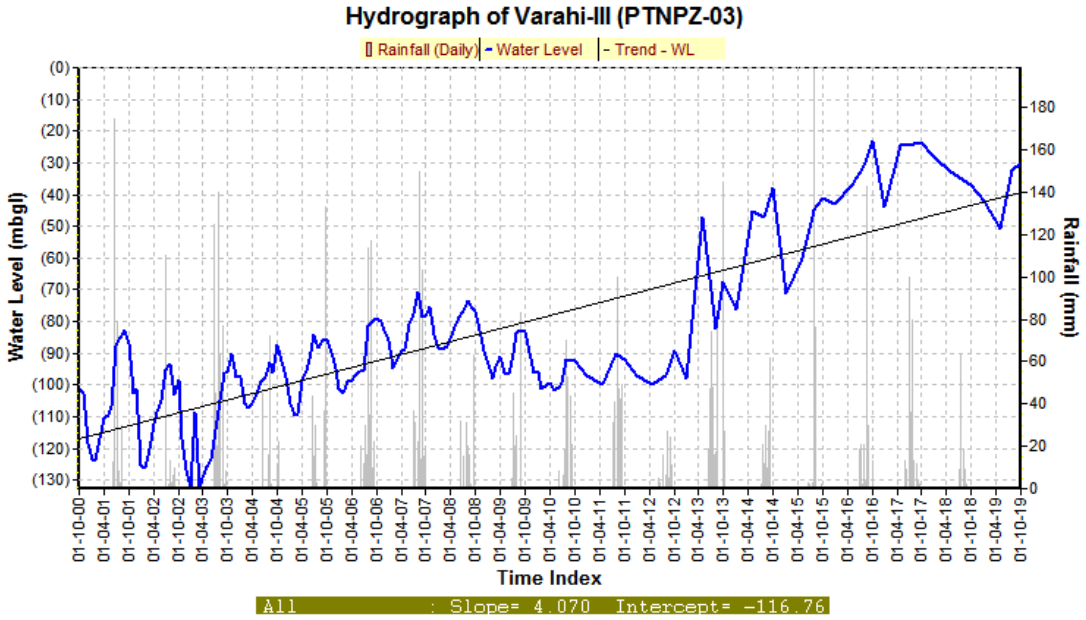
(e)


Hydrograph
Site Name : Jangral Pzi State : Gujarat District : Patan Tahsil : PATAN Block : PATAN Village : Jangral Pzi
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.171263X + 139.074303
Post Monsoon Water Level Trend: Y = -0.333335X + 125.208262
All Water Level Trend: Y = -0.196865X + 131.673395

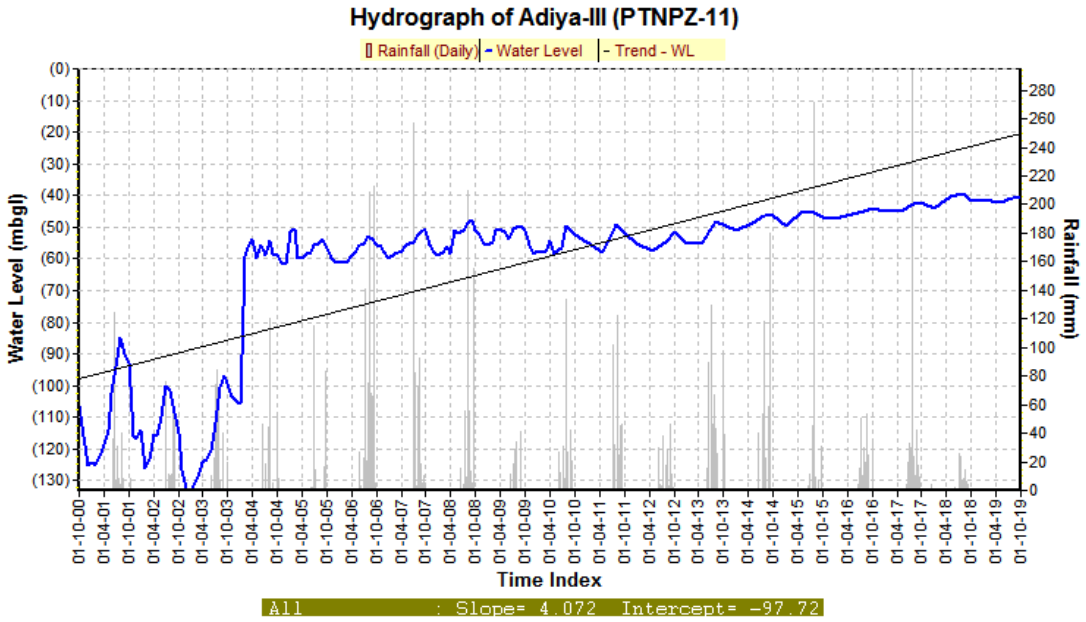
(f)


Hydrograph
Site Name : Kakosi Pz-I State : Gujarat District : Patan Tahsil : SIDHPUR Block : SIDHPUR Village : Kakosi
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.018828X + 140.520743
Post Monsoon Water Level Trend: Y = 0.052638X + 137.671346
All Water Level Trend: Y = 0.056208X + 139.765156

(g)


Hydrograph of Varahi-III (PTNPZ-03)
Rainfall (Daily)
Water Level
Trend - WL
Water Level (mbgl)
Rainfall (mm)
Time Index
All : Slope= 4.070 Intercept= -116.76

(h)



(i)

Figure 36. Typical hydrographs showing in groundwater levels/piezometric head aquifer group III

5.3 Reasons for Groundwater Related Issues

Prevailing agricultural/Irrigation practices; increase in groundwater demand, geogenic reason for variation in groundwater quality and schedule of power supply are some of the major reasons for groundwater related issues in these area.

5.4 Future demand (for 2025 and 2030) scenario and stress aspects of the aquifer

Area is under high stress as the economy of the area is based on agriculture and every individual intend to cash in for market driven cash crop irrespective of availability of water for irrigation. Economy of the area is mainly based on agro & food processing, paper and pulp and cotton based industries textiles and mineral based industries (ceramics).

5.5 Participatory groundwater management issues

As on date participatory groundwater management issues are not much significant as farmers themselves forms cooperative societies of water user groups driven by the economic need of the region and capital requirement for construction of irrigation facility using groundwater. However, defaults and disputes among user groups cannot be ruled out. Lessons learnt from the

existing practice of cooperative societies for sharing of irrigation water kept in mind while implementing management plan with participatory approach.

5.6 Interventions to Enhance Groundwater Resources in Patan District

Patan district is highly dependent on groundwater for drinking, industrial and irrigation water requirement. Under the UNDP assisted programme during 1971-74 in order to investigate and evaluate groundwater potential and quality, identified aquifers were classified. Overexploitation of groundwater was identified as a major issue. A pilot project was taken up in North Gujarat and recharge techniques were developed and demonstrated (1984-85). During 1991 a Master Plan on Artificial Recharge was prepared and for North Gujarat it was observed that sufficient surplus water resource is not available. Subsequently, a Task force was constituted by Government of Gujarat for assessment of aquifer wise potentiality for subsurface storage and non committed runoff availability on river basin approach for increasing groundwater recharge. Following interventions are in place in Gujarat to address the issues related with water resources.

- About 24416 Ha area is brought/covered under Drip irrigation schemes (by GGRC and GWRDC)
- Construction of Sujalam Suflam Canal
- Six bulk water supply pipelines have been commissioned for transferring surplus water of Narmada to North Gujarat Region.
- About 73022 Ha command area of Narmada canal is developed
- 4786Nos Construction of Check dams, 486 nos deepening of Ponds and reservoirs

In order to address the issue of water stressed area of North Gujarat and Kachchh Region it was decided to divert surplus water from Narmada Canal by Government of Gujarat. A scheme was prepared and implemented by diverting excess runoff by supplying water from Mahi and Narmada to the Sujalam Sufalam Canal Scheme in North Gujarat and by diverting flow of Narmada during flood for recharge through canal, filling of village tanks/ponds.

The groundwater availability and quality of water is the issue of serious concern (such as high level of salinity). In order to address the issues and possible measures aquifer map and aquifer management plan is taken up in Patan distict for the area of 5731 km^2 covering 9 Talukas (OE-3,Critical-1 and Saline-5).

Chapter VI

6 MANAGEMENT STRATEGIES AND MANAGEMENT PLAN

Management strategies for the available groundwater resources considering Aquifer as a unit is considered for sustainable management of resources and grouped under the following head.

6.1 Supply Side Aquifer Management

The taskforce identified basins with subsurface space in dewatered vadose zone, computed the volume of space available, estimated volume of water needed to arrest annual groundwater depletion and to stabilize groundwater levels at 8 mbgl. They have also computed the average annual runoff available in different basins. However, the recommendation were made for the basins where there was surplus water available but pleaded non-availability of average annual non-committed surplus runoff for Managed Aquifer Recharge (MAR) where it was badly needed such as in north Gujarat region.

Artificial Recharge by diverting surplus run-off during monsoon into ponds, percolation tanks, Spreading basins, abandoned dug wells etc is implemented. Aquifer wise Plan for sustainable management of the groundwater resource including proposed modeling outputs is also to be considered in a phased manner. It is envisaged that effective utilization of available water resources and moderate use of water will result in higher and better productivity from the existing agriculture land.

6.1.1 Interlinking from surplus to water deficit area

Inter Basin Transfer of water from Narmada Main Canal to en-route rivers by diverting flow of the water of Narmada available during flood through Narmada main canal to eleven rivers of Gujarat viz. Heran, Orsang, Karad, Mahi, Saidak, Mohar, Watrak, Sabarmati, Khari, Rupen and Banas. The filling of about 700 Nos. of small/large village Tanks/Ponds by water of Narmada. This is considered one of the most rewarding scheme of Government of Gujarat for the lager population of water scarce North Gujarat districts.

6.1.2 Recharge through Sujalam-Sufalam spreading channel

Taking into consideration the non availability of surplus water in the North Gujarat Region, Government of Gujarat launched ambitious inter basin water transfer projects of Sujalam Sufalam Recharge canal for this region in order to

augment groundwater through recharge canal and also to supplement irrigation. Thus, augmentation of groundwater resource was the prime objective of the Sujalam Suflam Yojna, the scheme also benefited villages that are facing scarcity of irrigation and drinking water by utilizing surplus water and flood water available in other basins. Salient features of the various schemes planned and being implemented is summarized below**.**

Overflowing flood water from Kadana dam is diverted by gravity to the scarcity hit areas of Panchmahals, Gandhinagar, Sabarkantha, Mehsana , Patan and parts of Banaskantha districts (North Gujarat region).

Sujlam-Suflam Spreading Channel – 332 Km. From Kadana dam to Sabarmati river – 158 km. From Sabarmati to Banas river: 174 km. This recharge canal is helping in recharging 21 rivers which includes Khari, Watrak, Meshwo, Mazam, Rupen, Pushpavati, Saraswati and Banas River extending benefit to 7 Districts, 14 Talukas and about 508 villages. It was estimated that about 70,000 Ha. area to be benefitted by this project. It is envisaged that through Sujalam Sufalam spreading canal Yojana about 700 million cubic meter of flood water will be diverted to water scarce areas from time to time that otherwise used to flow in to the ocean (NWR, WS & K, and Govt. of Gujarat).

Sujalam Sufalam Spreading Canal passing through district (length 34 km) is an unlined canal originating from Kadana Dam having total length of 337 km crossing 21 rivers and with series of check dams and provision of Inter basin transfer of about 735.64 MCM of flood water is diverted to water deficit areas of North Gujarat from time to time which is otherwise use to flow to the ocean. (Bottom Width-12 m, Top width-27.5 m, Depth-4.25 m, Free board 0.95 m and slope 1: 1.5, unlined throughout).

6.1.3 Recharge through canal linking ponds (Patan)

Government of Gujarat implemented schemes on integrated surface and groundwater irrigation approach coupled with recharge to groundwater system by diverting surplus run-off during monsoon into ponds, percolation tanks, Check dams, spreading channels/basins, abandoned dugwells etc. by interlinking either through pipeline or channels from Saradar Sarover Narmada Main canal, Sujalam Sufalam Spreading Canal or through Dharoi- Sabarmati Canal. A Talukawise detail of number of tanks linked/filled with existing capacity is given below in Table 27.

Table 27. Tanks filled–linking ponds, Patan district

Sr. No.	Taluka	SS Narmada Main Canal No of Tanks/ Capacity (MCM)	Estimated Recharge (MCM)
1	Chanasma	63/32.07	9.62
2	Patan	36/21.13	6.34
District Total		**99/53.20**	**15.96**

Perusal of the table indicate that about 99 number of linked structures of about 53.2 MCM capacity are filled once or more whenever surplus water is available. This practice of filling of these structures has also lead to additional availability of about 15.96 MCM in Patan district through recharge to groundwater system. Practice of filling of linked pond to be continued with accrued benefits to the larger population of the area by bringing additional tanks and pond and other similar structures in this area as per feasibility of site and availability of water.

6.1.4 Augmentation of the groundwater resource through artificial recharge and water conservation measures

During the course of surveys and aquifer Mapping utilizing the existing data it is observed that large amount of subsurface storage space is available in the system to accommodate the surplus monsoon runoff viz a viz additional water if made available to the system from any other distance sources, It is estimated that unsaturated zone - about 6423 MCM space is available in the district to accommodate the recharge water in unconfined system. It is estimated that about 770.80 MCM water is required to recharge this unsaturated space against which non-committed surplus of 39.84 MCM water is available. Area feasible and most suitable for Artificial Recharge is given in Fig. 37 and area prioritized and considered feasible for artificial recharge for 2011 and 2017 is placed at Table 29 and 30. However as per the latest master plan for artificial recharge no structure is proposed in view of the rising water level of the observation wells considered for feasibility. However feasibility of each of the recharge structures in these areas and locally identified areas in the rest of the area can only be firmed up after detail hydrogeological investigation specific to site and structure feasible.

It is observed that unsaturated zone available in the deeper Aquifer system can be used for augmenting the groundwater recharge in the area provided sufficient quantity of surplus water is available for recharge. In the areas where surplus source water is not available, recharge to the groundwater system using water

diverted from water surplus area to water deficit area is also considered and implemented. Successful implementation of such projects in the past hold the key for successful completion of additional such recharge project in the area at technically feasible sites.

Looking at the above table there is no further scope of construction of Artificial Recharge structures for augmenting resource of the Unconfined Aquifer System, however deeper Aquifers may be recharged but no surplus runoff is available in the district. Details of existing artificial recharge structure and estimated recharge is given in Table 28.

Table 28. Details of existing artificial recharge structure of Patan district

Taluka	**Percolation Tanks (No.)**	**Check Dam (No.)**	**Quantity of Recharge from Percolation Tanks (@0.14 MCM)**	**Quantity of Recharge from Check Dams (@0.05 MCM)**
Chanasma	25	544	3.50	27.20
Harij	20	210	2.80	10.50
Patan	60	920	8.40	46.00
Radhanpur	03	404	0.42	20.20
Sami	21	273	2.94	13.65
Santhalpur	20	648	2.80	32.40
Saraswati	64	605	8.96	30.25
Shankheshwar	37	393	5.18	19.65
Siddhpur	26	789	3.64	39.45
District Total	**276**	**4786**	**38.64**	**239.30**

Table 29. Area prioritized and considered feasible for artificial recharge in Patan district (AR Master Plan 2011).

Taluka	Area of Taluka in sqkm	Average post monsoon depth to water (2000-09)	Area feasible for artificial recharge sq km	Volume of unsaturated zone available for artificial recharge	Volume of water required for recharge	Balance Volume of surplus local/ distant source available for recharge (MCM)	Additional Percolation Tank Structures Proposed Recharge capacity @ 0.14 MCM	Additional Check Dam / Weir Structures Proposed Recharge capacity @ 0.05 MCM	Unit Cost, Rs Lakh		Total Coast (Rs Crores)
									Percolation Tank	Check Dam / Weir	
Chanasma	486.69		61.19	238.55	23.85	13.28	21	191	5	4	8.69
Harij	400.58		230.22	1347.06	134.71	10.93	17	157	5	4	7.13
Patan	768.48		488.59	2931.56	293.16	20.96	33	301	5	4	13.69
Radhanpur	538.09		65.48	196.44	19.64	14.68	23	211	5	4	9.59
Sami	1586.41		133.30	447.98	44.80	43.27	70	621	5	4	28.34
Santalpur	1360.57		0.00	0.01	0.00	37.11	59	532	5	4	24.23
Sidhpur	358.27		236.84	1421.06	142.11	9.77	16	140	5	4	6.40
Vagdod	246.54		246.54	1479.26	147.93	6.72	11	097	5	4	4.43
Total	**5745.63**	**10.6**	**1462.16**	**8061.92**	**806.20**	**156.72**	**250**	**2250**	**5**	**4**	**102.50**

Table 30. Area prioritized and considered feasible for artificial recharge in Patan district (AR Master Plan 2017).

Area of District in sq km	Decadal Average (2009-18) Post Monsoon Depth to Water Level (m bgl)	Area Feasible for Artificial Recharge	Volume of unsaturated zone avilable for recharge (MCM)	Volume of Water required for recharge (MCM)	Balance Volume of Surplus Local / Distant Sources avilable for recharge (MCM)	Additional Percolation Tank Structure Proposed Recharge Capacity @0.14 MCM
5780.93	10.62	1091.31	6423.33	770.80	39.84	Additional Artificial Recharge Structures are not recommended as most of the area (60 % to 98 %) post monsoon water level is above 6 m bgl and most area (> 80 %) show rising water level trend.

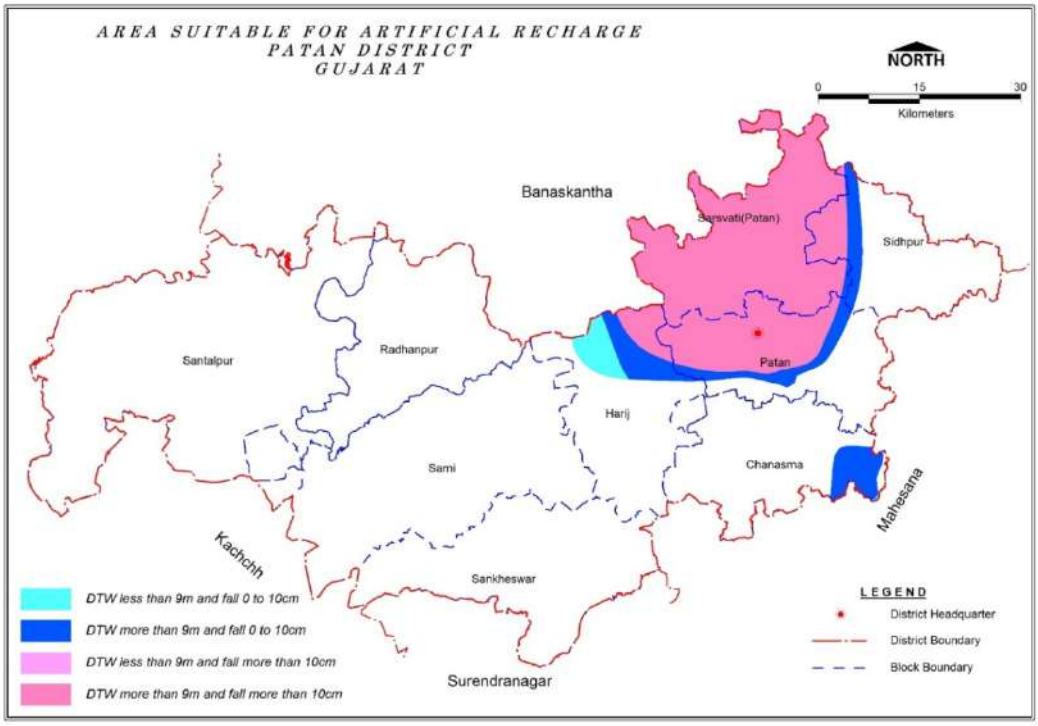


Figure 37. Area prioritized and considered feasible for artificial recharge in Patan district (AR master plan 2017)

Augmentation of groundwater recharge of 0.15 MCM through Rooftop Rain water Harvesting and Artificial Recharge by at the cost of ₹ 10.77 Crore.

This proposal is generalized based on major criteria however other structures may also be feasible i.e Recharge through Shallow tubewell/Dugwells in combination with Pit/Shaft and farm pond as per prevailing site specific condition for eventual recovery during lean period for sustainability of Crops. In the field artificial recharge scheme is implemented coupled with observation well/piezometer for monitoring the impact of Artificial recharge to the groundwater system. Separate budget proposal should be considered on actual basis as per site condition for monitoring and surveillance of the recharge structures on long term basis.

Table 31. Rooftop rain water harvesting proposal for urban area in Patan town (AR Master Plan 2017)

Town having population > 1 lakh	Urban Population (Census 2011)	Urban Household Number (Census 2011)	Area for RWH @ 25% of household @ 90 % suitable area of avg 40 sqm area/ household (sqm)	Average Rainfall of the District 2009-18 (mm)	Volume of Rainwater Harvestable (MCM)	Cost of RWH @ ₹ 10,000 / household (in crores)
1	2,81,081	28,096	2,52,864	602.80	0.15	7.02

6.2 Demand Side Management through Irrigation Efficiency/Groundwater Use Efficiency

Farmers of Patan have realized the importance of high value agriculture and cash crops and are proactive for suitable crop diversification and absorption of micro irrigation technologies. Thus, to enable and to support the transformation of agriculture, the development of land is a must to avoid crop stress on moisture, nutrition, etc.

Demand side management by Micro Irrigation System i.e. Sprinkler and drip irrigation (in practice in about 28% of area irrigated by groundwater), By adding about 15% of the balance area every year in a phased manner, water saving of about 73.5 MCM in Patan can be achieved. It is necessary to bring more and more area of the group of farmers under public tube well/community irrigation by installation of drip/sprinkler irrigation techniques.

Table 32. Volume of water which can be saved by adopting Micro irrigation practices in Patan District

Taluka	**Irrigation draft (MCM)**	**Gross irrigated area by GW (Ha)**	**Area already covered under MIS (Ha)**	**Area Proposed under MIS* (Ha)**	**Irrigation draft after MIS (MCM)**
Chansma	8.18	31248	1520	02972	3.72
Patan	152.30	30518	3516	13501	132.05
Sidhpur	152.69	30537	2635	13951	131.76
Harij	Saline Talukas				
Sami					
Radhanpur					
Santalpur					
Shankheshwar					
Saraswati	63.82	38756	1611	18572	35.96
District Total	**376.99**	**225065**	**34121**	**48997**	**303.49**

*****Irrigation Draft for MIS = (Area Proposed under MIS*Δ GW Requirement*0.3)/100
Chanasma (10%), Patan, Saraswati and Sidhpur (50%) of the remaining GIA proposed for Micro Irrigation

At present, the most suitable water-saving technologies available are Drip Irrigation and Sprinkler Irrigation. All the agencies concerned, including banks, are required to put in their best efforts to promote the activity. Even though subsidy is available for Drip irrigation system, spread of the same is on lower side in the district. The lower spread of Drip irrigation system can be attributed to the fact that irrigation wells are shared by the farmers with different land holdings

on partnership basis and partners do not agree to share irrigation well for Drip irrigation.

6.3 Improvement in Groundwater Development Scenario

Data generation and integration made in groundwater for the preparation of groundwater management plan with information compiled and analysed aquifer group wise is the first of its kind and never done before at this scale for the area as a whole. Groundwater Management Plan thus prepared involving Local bodies, resource persons from Central and State Government Organizational and NGOs, Socioeconomic experts etc. after discussion in corridors of power will take it a long way in redefining the planning activities by the people for the people based on scientific information for the development of groundwater resources in the area for the benefit to the larger population of the area.

It is considered that an integrated water resources management with equitable distribution of available Water. Redistribution of pumping pattern, shift in more water efficient cropping pattern as per locally available water to be adopted. Institutional finance and appropriate technology should be freely made available to any individual or cooperative group of farmers that undertake resource augmentation and management measures. Cooperative irrigation scheme as already existing in the area should be encouraged/ rationalized at PRI level. Expected Change in scenario of groundwater resources through integrated approach/interventions are given in Table 33.

It is observed that by taking demand side intervention in a phased manner, groundwater development in the district can be brought at about 92.79%. Water conservation measures in the district is already adequate with existing structures can recharge all the non committed surplus runoff and artificial recharge interventions over the period of time in long run, stage of groundwater development can be managed within 100% and to some extent relief can be provided to the overexploited area of the district that can be brought under safe category.

Table 33. Expected change in scenario of groundwater resources through integrated approach/interventions in Patan district

Sr. No.	Taluka	Stage of groundwater extraction (2017)	Category (GWRE 2017)	Stage of groundwater extraction after Implementing micro irrigation (2017)	Artificial recharge	Category after the interventions
				Demand side	Supply Side	
1	Chansma	111.04	Over Exploited	51.02	Not proposed as recharge capacity through AR structures in the district is more than the surplus non committed runoff.	Safe
2	Patan	102.24	Over Exploited	88.84		Semi Critical
3	Sidhpur	103.83	Over Exploited	89.92		Semi Critical
4	Harij		Saline			
5	Sami		Saline			
6	Radhanpur		Saline			
7	Santalpur		Saline			
8	Shankheshwar		Saline			
9	Saraswati	90.65	Critical	52.82		Safe
District Total		**100.81**	**Over Exploited**	**92.79**		**Critical**

6.4 Change in Groundwater Scenario

Present change in groundwater development scenario of the area in Patan district table 34 and 35 indicate the trends in the stress aspect against future demand and accordingly development and management proposals can be considered for meeting demand during 2025 and 2030.

Table 34. Change in groundwater draft scenario

Taluka/Year	Groundwater draft (MCM/Yr)				
	2007	2009	2011	2013	2017
Patan	159.825	171.65	156.06	190.74	154.52
Chanasma	55.79	50.38	51.64202	9.43	8.25
Sidhpur	118.906	119.72	101.29	86.57	156.17
Radhanpur	Saline	Saline	Saline		
Santalpur	Saline	Saline	Saline		
Harij	Saline	Saline	Saline		
Sami	Saline	Saline	Saline		
Shankheshwar	Saline	Saline	Saline		
Saraswati					66.73
District Total	**334.52**	**341.75**	**308.99**	**286.74**	**385.67**

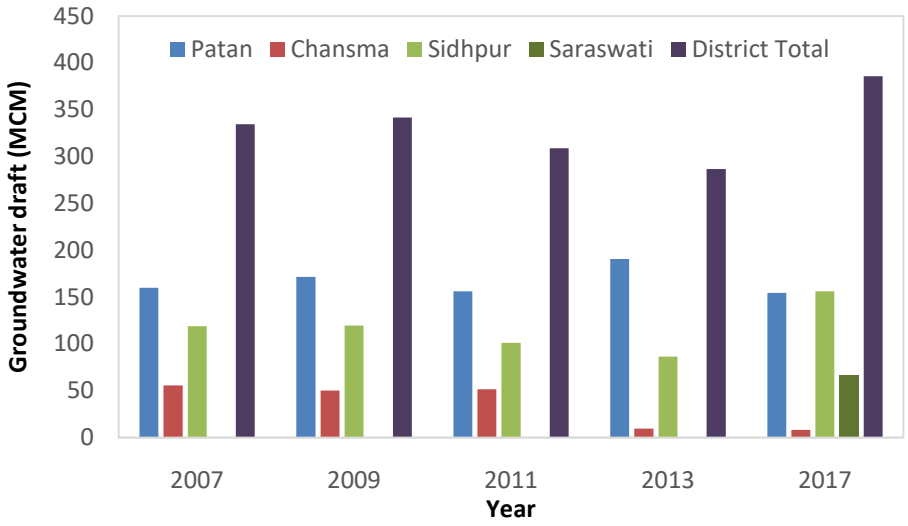


Figure 38. Change in groundwater draft over the period of time.

Table 35. Change in groundwater recharge scenario

Taluka/ Year	Utilisable Groundwater resource (MCM)				
	2007	2009	2011	2013	2017
Patan	124.47	118.97	138.53	179.69	151.14
Chansma	45.17	43.98	43.94	7.62	7.43
Sidhpur	62.34	62.49	70.11	82.24	150.14
Radhanpur	Saline	Saline	Saline	Saline	
Santalpur	Saline	Saline	Saline	Saline	
Harij	Saline	Saline	Saline	Saline	
Sami	Saline	Saline	Saline	Saline	
Shankheshwar	Saline	Saline	Saline	Saline	
Saraswati					73.61
District Total	**231.98**	**225.44**	**252.58**	**269.55**	**382.32**

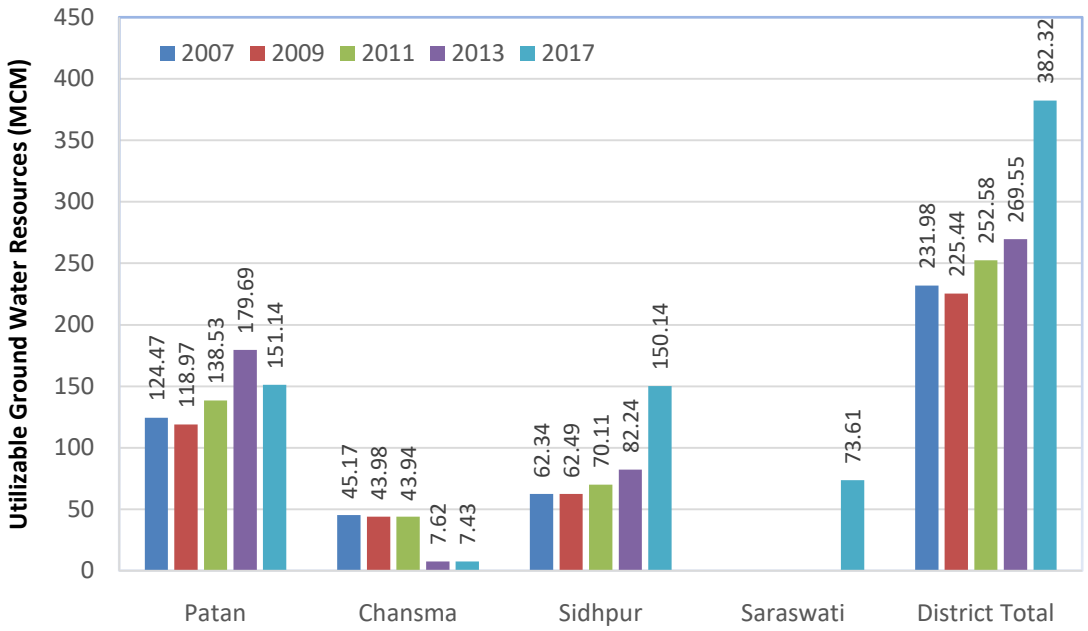


Figure 39. Change in utilizable groundwater resources over the period of time.

Table 36. Change in stage of groundwater development scenario

Taluka	Stage of development as on March 2007 (%)	Stage of development as on March 2009 (%)	Stage of development as on March 2011 (%)	Category as on March 2013 (%)	Category as on March 2017 (%)
Patan	128.41	144.28	112.66	106.15	102.23
Chansma	123.51	114.56	117.52	123.82	111.07
Sidhpur	190.72	191.58	144.47	105.26	103.83
Radhanpur	Saline				
Santalpur					
Harij					
Sami					
Shankheshwar					
Saraswati					90.65
District Total	**144.20**	**151.59**	**122.33**	**106.38**	**100.80**

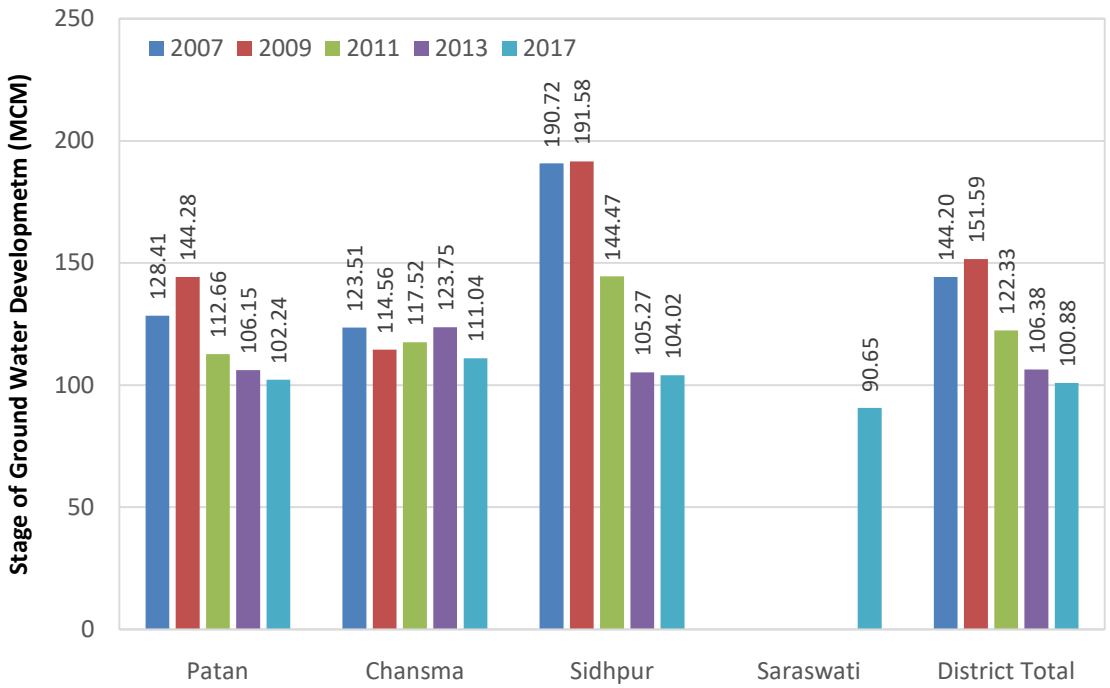


Figure 40. Change in stage of groundwater development

7 SUMMARY AND CONCLUSION

Patan is one of the agriculturally, socially and economically advanced districts, situated in the northern part of Gujarat State. Regionally, it forms part of North Gujarat Region. Groundwater is the main source of irrigation water in the district catering almost 80% of the irrigation water demand.

Groundwater occurs in the alluvium system with sand of various size form the aquifers separated by clay and mixed horizons forming the aquitards. Groundwater occurs both in Phreatic as well as Semiconfined to Confined condition. For the purpose of Aquifer mapping up to 300m, the different aquifer units are grouped in Aquifer Group I, II and III. Aquifer group I is unconfined aquifer whereas Aquifer Group II is semi confined to Confined and Aquifer Group III is confined in Nature. These aquifer groups are regionally extensive and form prolific aquifer system in the district.

Salinity in the groundwater is the major issue in the district. The groundwater quality is highly variable with fresh groundwater in the eastern part of the district to saline in the central and western part of the district. Aquifer group II and III have relatively good quality in the eastern part of the district which gradually deteriorates towards western part in the areas adjoining Rann. The Clay content increases from East to west in the district, evident from the Subsurface Hydrogeological sections.

The Aquifer Group I in eastern parts is desaturated at many places but shows stabilised water level due to the recharge activities and introduction of Narmada water for irrigation as wells as Unlined Sujalam Sufalam Canal passing through Patan and ChanasmaTaluka where many shallow piezometers show rising trend.

Aquifer Group II and III are tapped by irrigation tubewells and there is declining water level trend in most of the piezometers representing these aquifer groups. During last 20 years fall of 2m to 45m in Piezometers tapping Aquifer Group II and fall of 13 to 56m in Pz tapping Aquifer Group III is observed.

A number of activities for augmenting groundwater resources has been done with construction of check dams (4786 nos), deepening of village ponds (776

nos.), Bori Band (4923 nos.), Khet Talavadis (6009 nos.) and interlinking of ponds with the canals and pipeline.

The district has erratic rainfall and there is very limited non committed surplus runoff to harness as the recharge capacity of the structures on the ground is more than required.

Attention has to be given to recharging the deeper aquifers as these are the main source of irrigation water and are heavily pumped, but there is paucity of source water for recharging.

Focus has to be shifted to saving of water through Micro irrigation techniques as in the traditional flooding method a lot of water is wasted.

For saline talukas of Patan district particularly Sami, Radhanpur, Santalpur, Shankheshwar and SamiInjection well commonly called “Holiya” in local language may be useful which is a shallow traditional groundwater recharging can be beneficial for farmers in saline areas. As the top soil is clayey in nature there is water logging condition during monsoon season. The structure is nearly 40 -60 ft deep depending on the field geological condition and having a recharge pit for filter purpose. These structures not only help in recharging but also provide support irrigation for Rabi season crops.

As there is little scope of creating additional recharges structures. It is recommended to increase the area under micro irrigation to about 49000 Ha which may reduce the irrigation draft by 73.5 MCM. And turn the district from Over Exploited to Critical Category.

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MANAGEMENT PLAN OF
CHANASMA TALUKA, PATAN DISTRICT, GUJARAT STATE

<table>
<tr><td>Geographical Area</td><td>4,371 sq. km</td></tr>
<tr><td>No. of Town, villages</td><td>1, 59</td></tr>
<tr><td>Population (2011 Census)</td><td>130743</td></tr>
<tr><td>Average Annual Rainfall</td><td>556 mm- Monsoon Rainfall (IMD) (Long Term 50 years)
451 mm -Average Monsoon Rainfall (2008-17)</td></tr>
<tr><td>Range of Average Temperature</td><td>21-31 °C</td></tr>
<tr><td>Major Drainage System</td><td>Saraswati, Banas</td></tr>
<tr><td>Major/ Medium Irrigation Scheme</td><td>Saraswati Barage</td></tr>
<tr><td>Major Geological Formation</td><td>Alluvium</td></tr>
<tr><td>Major Aquifer</td><td>Sand, Silt, Gravel</td></tr>
<tr><td>Utilizable Ground Water Resources (2018)</td><td>Fresh: 7.43 MCM
Saline: 87.99 MCM</td></tr>
<tr><td>Net Ground Water Draft</td><td>Fresh: 8.25 MCM
Saline: 66.09 MCM</td></tr>
<tr><td>Stage of Ground Water Development</td><td>Fresh: 111.04% (Over Exploited)
Saline:75.11% (Semi-Critical)</td></tr>
<tr><td>Fresh In storage ground water resources</td><td>1467 MCM</td></tr>
<tr><td>Artificial Recharge and Water conservation structures under different schemes by various department in Gujarat</td><td>Check Dams – 544
Percolation Tanks – 25
Tanks - 30</td></tr>
<tr><td>Minor irrigation structures</td><td>Deep Tubewells: 1959
Dug wells:750</td></tr>
<tr><td>Agriculture (2015-16)</td><td><table><tr><td colspan="2">Crop Area (sq.km.)</td></tr><tr><td>Total Grains</td><td>66.95</td></tr><tr><td>Total Pulses</td><td>18.25</td></tr><tr><td>Total Oil crops</td><td>173.05</td></tr><tr><td>Vegetables</td><td>2.6</td></tr><tr><td>Cumin</td><td>1.2</td></tr><tr><td>Cotton</td><td>72.5</td></tr><tr><td>Fodder</td><td>149.5</td></tr></table></td></tr>
<tr><td>Existing and future water demands (MCM)</td><td><table><tr><td>Sector</td><td>Existing</td><td>Future (Year 2025)</td></tr><tr><td>Domestic and Industrial</td><td>0.07</td><td>0.08</td></tr><tr><td>Irrigation</td><td>8.18</td><td>8.18</td></tr></table></td></tr>
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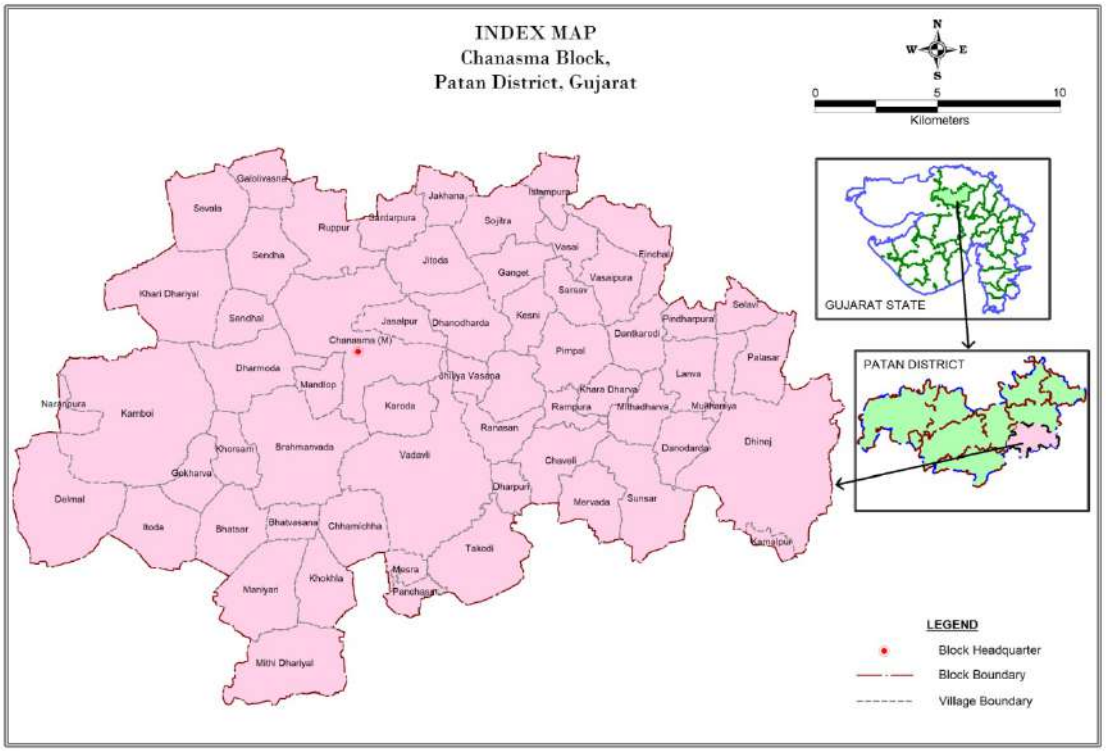


Fig.1: Location Map

1 Land Use Classification

Chanasma Taluka (Area in Sq. Km.)	
Area according to village papers	456.8
Area under Forest	0
Land not available for cultivation	51.3
Other uncultivable land excluding fallow	34.6
Fallow land	20.34
Net area sown	347.7
Area sown more than once	182.35
Gross cropped area	530.05
Cropping intensity	152

2 Hydrogeology

Alluvial formations form aquifers in the area (Fig.2) namely Sand of various sizes and Gravel. The groundwater quality is saline at shallow depths and there is wide variation in quality regionally.

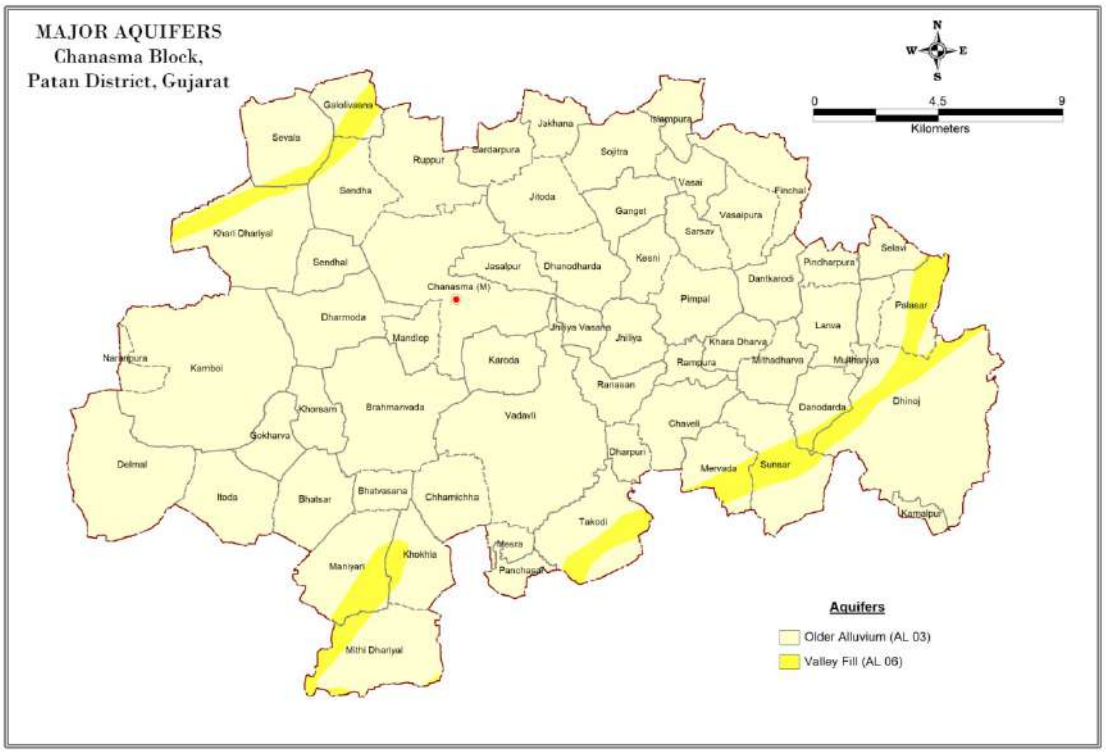


Fig.2: Major Aquifer

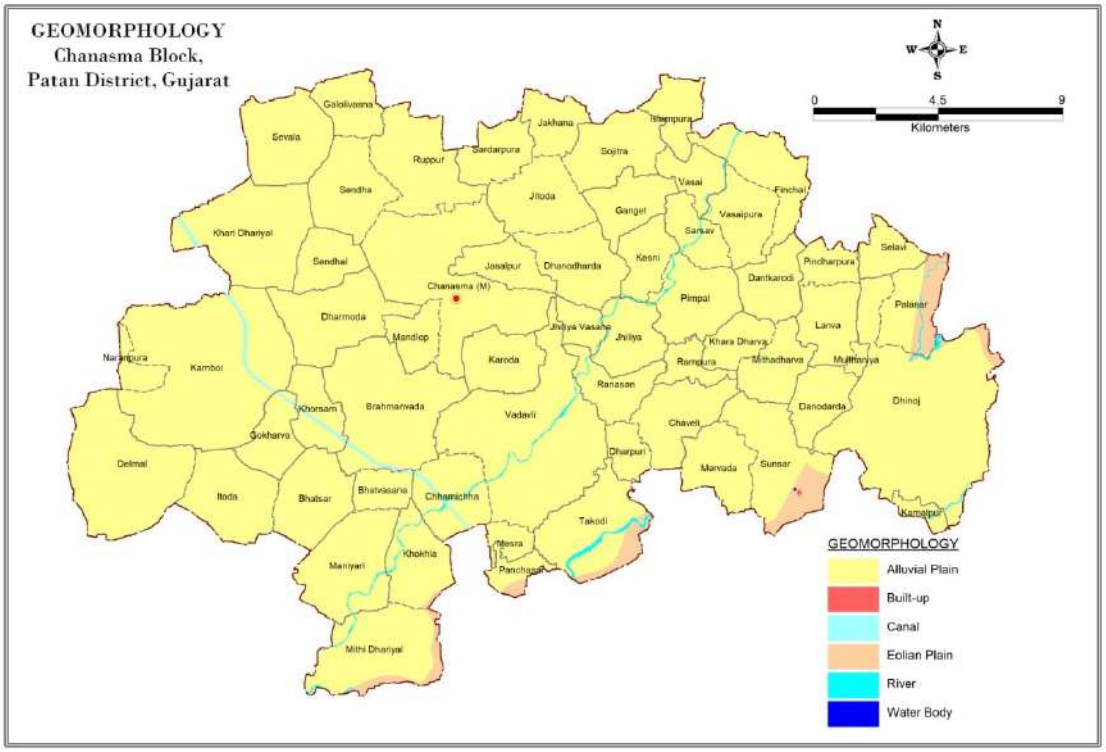


Fig. 3: Geomorphology

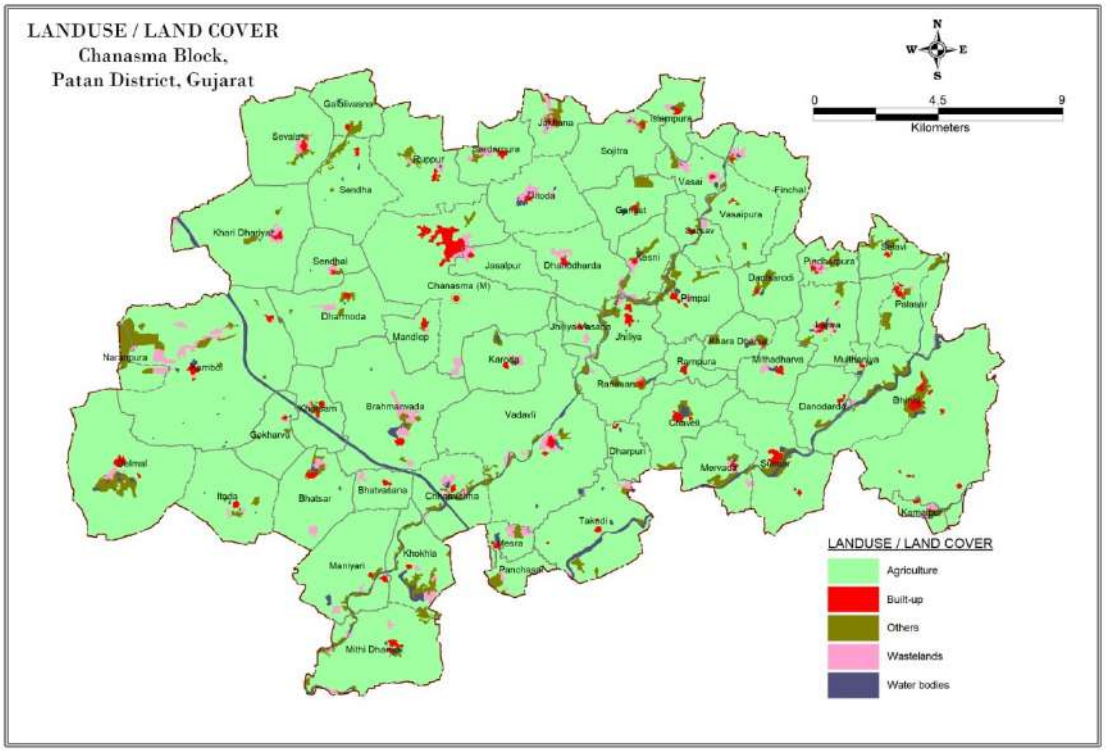


Fig 4: Land Use Land Cover

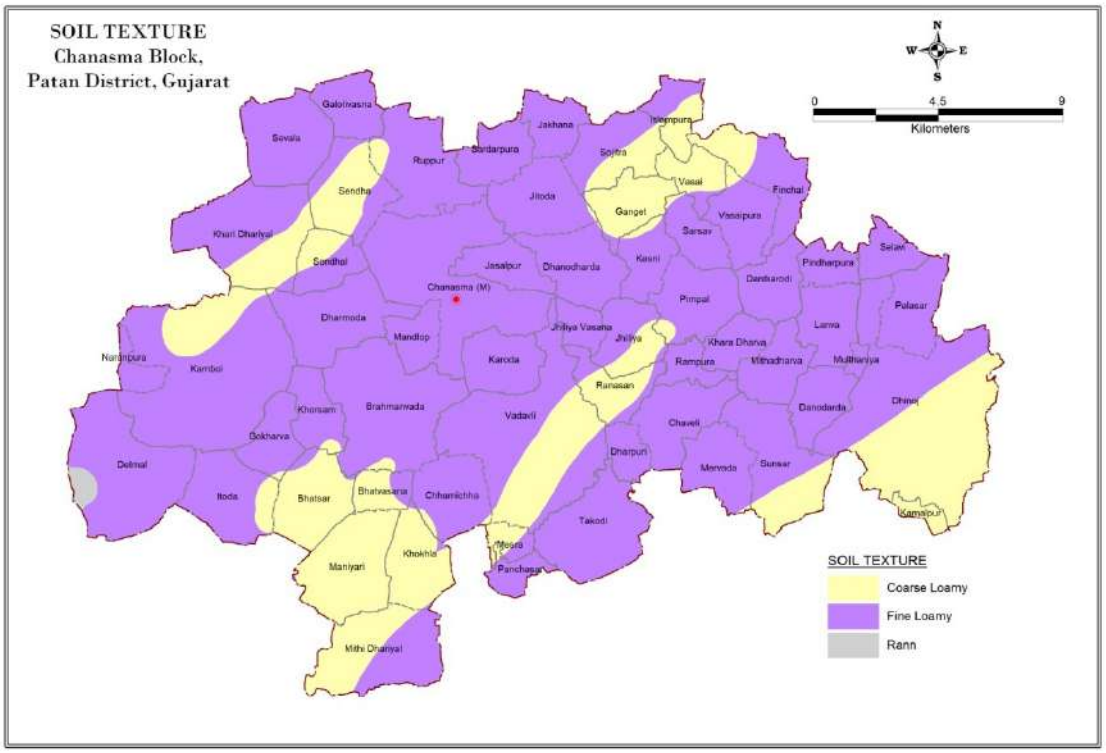
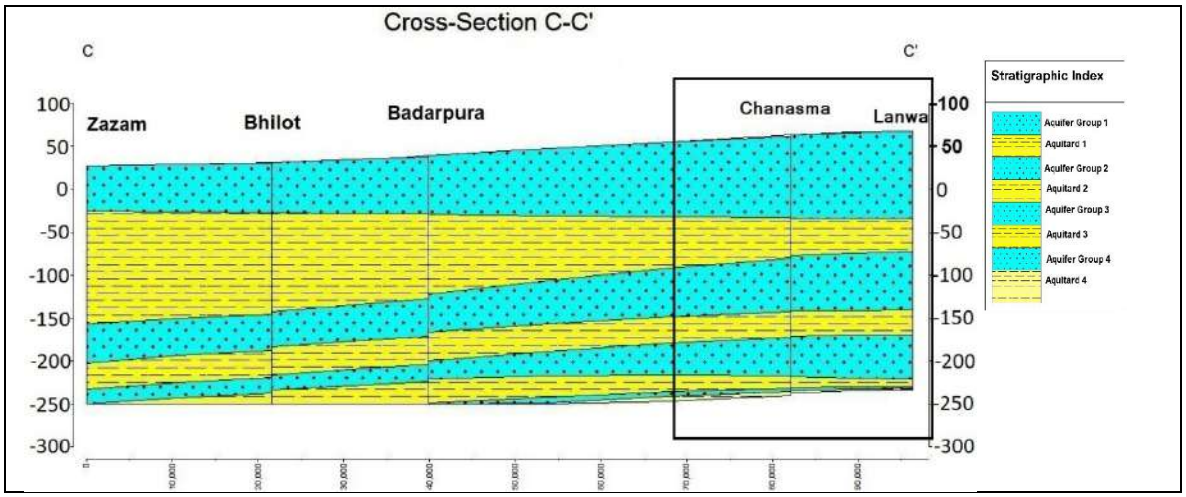


Fig 5: Soil Type

3 Subsurface Hydrogeology

As inferred from borehole data of the Chanasma Taluka, Quarternary Alluvium forms the principal aquifer in the Taluka. The depth of drilling ranges from 60 to 611mbgl and the discharge ranges from 1.0 to 20 lps. Transmissivity value is observed 69 to 471m2/day.

Hydrogeological section for Chanasma Taluka Depicting Aquifer Group I, II and III



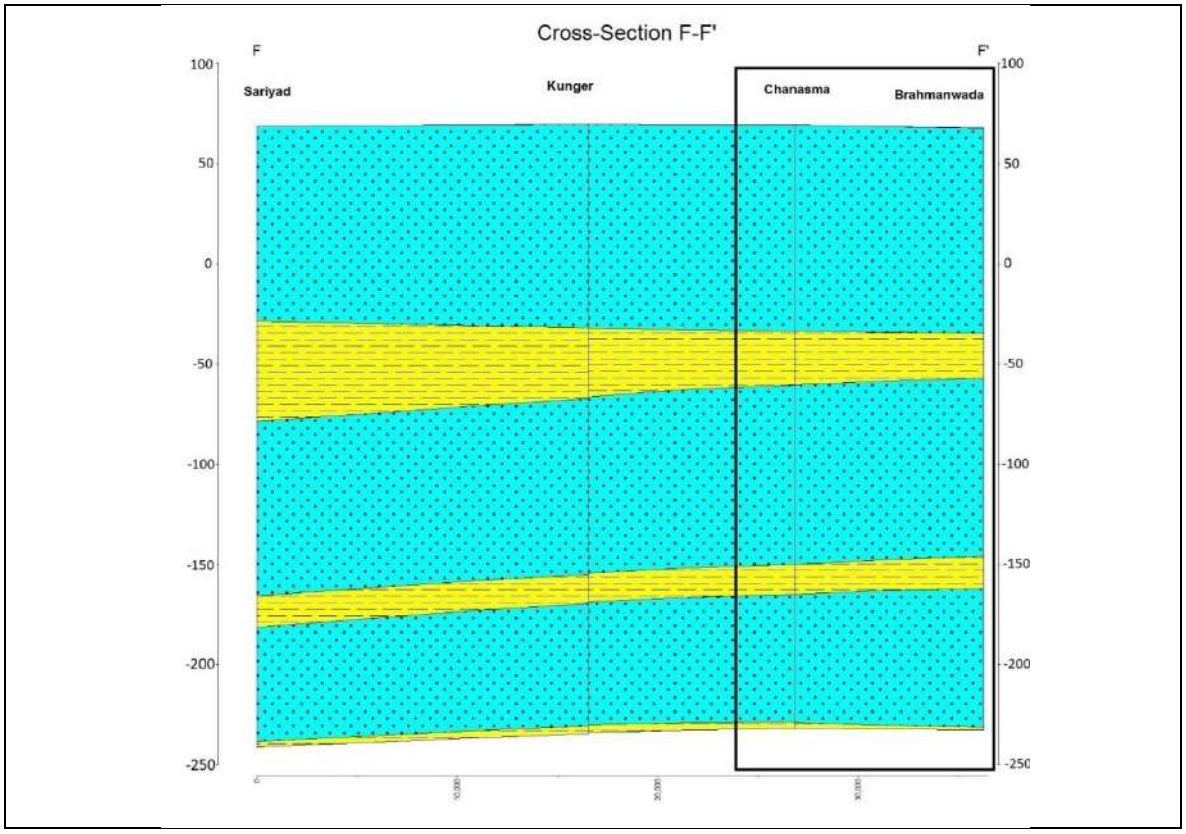
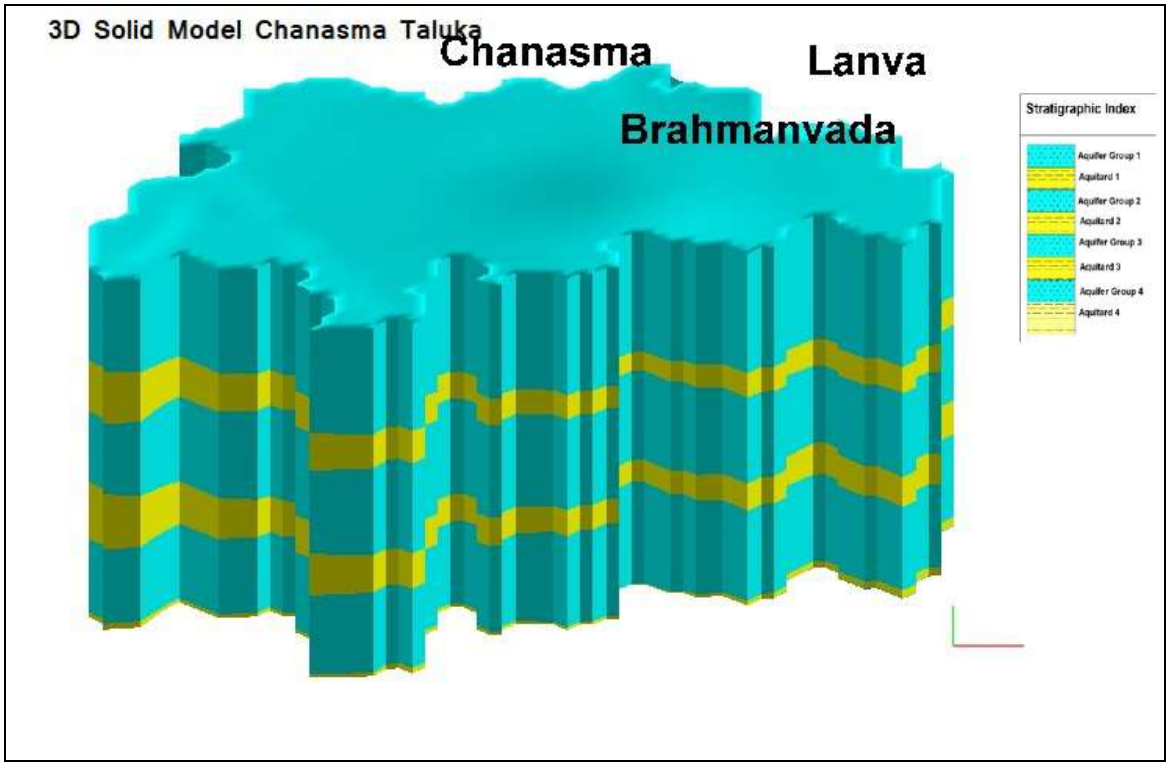


Fig 6 Stratigraphic Section

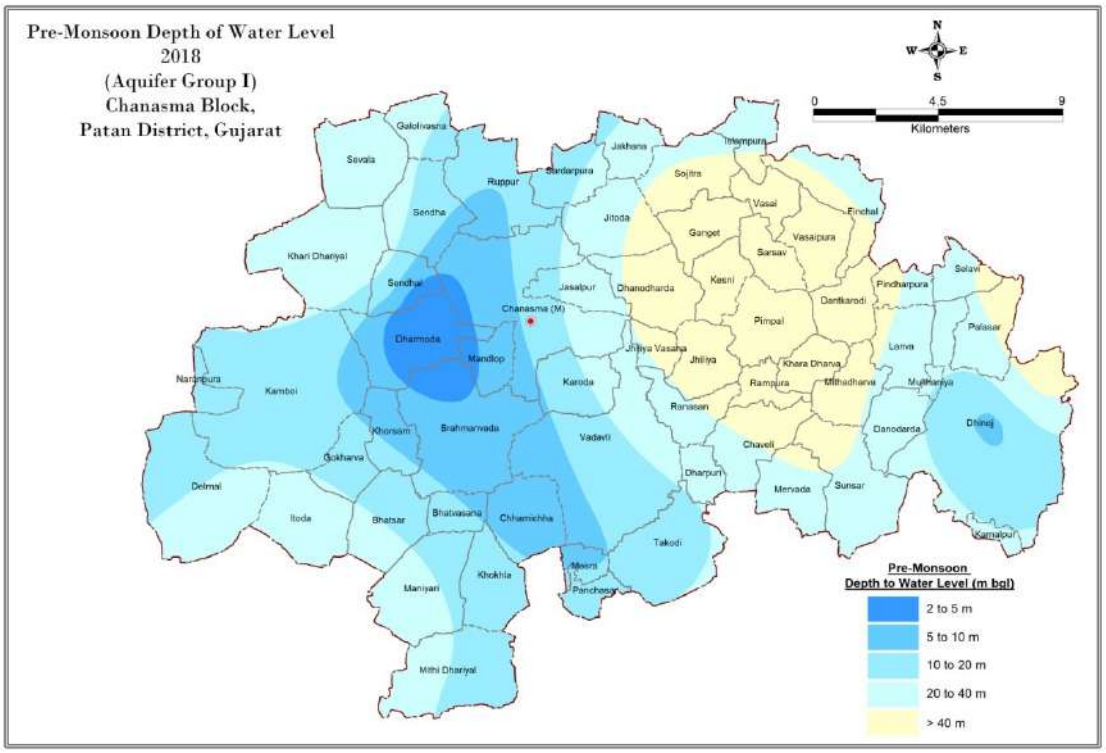


3D Solid Model of Chanasma Taluka Depicting Aquifer Group I, II and III

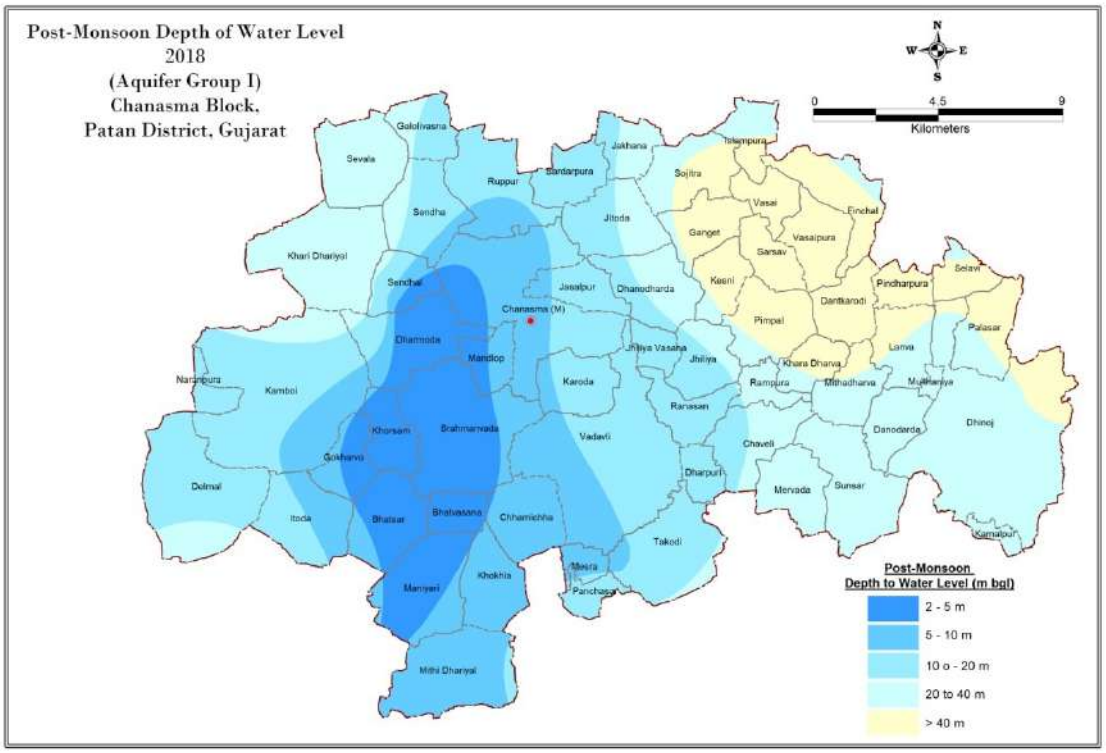
Table 1 Aquifer characteristics

Aquifer Group	Base of Aquifer (m)	Generalized Thickness (m)	Yield (LPM)	Quality/ EC (µS/cm)	Water Level/ Piezometric head (mBGL)	Developed in the area	Aquifer Type
Aquifer-I	80-110	30-85	150-300	700-48000	2-40	N & NE	Phreatic
Aquifer-II	190-210	15-90	600-1200	1100-80000	6.4-169.3	C & EC	Semi Confined/ Confined
Aquifer-III	290-300	20-80	600-1200	1300-67000	35.40-184.92	C & S and S part	Confined

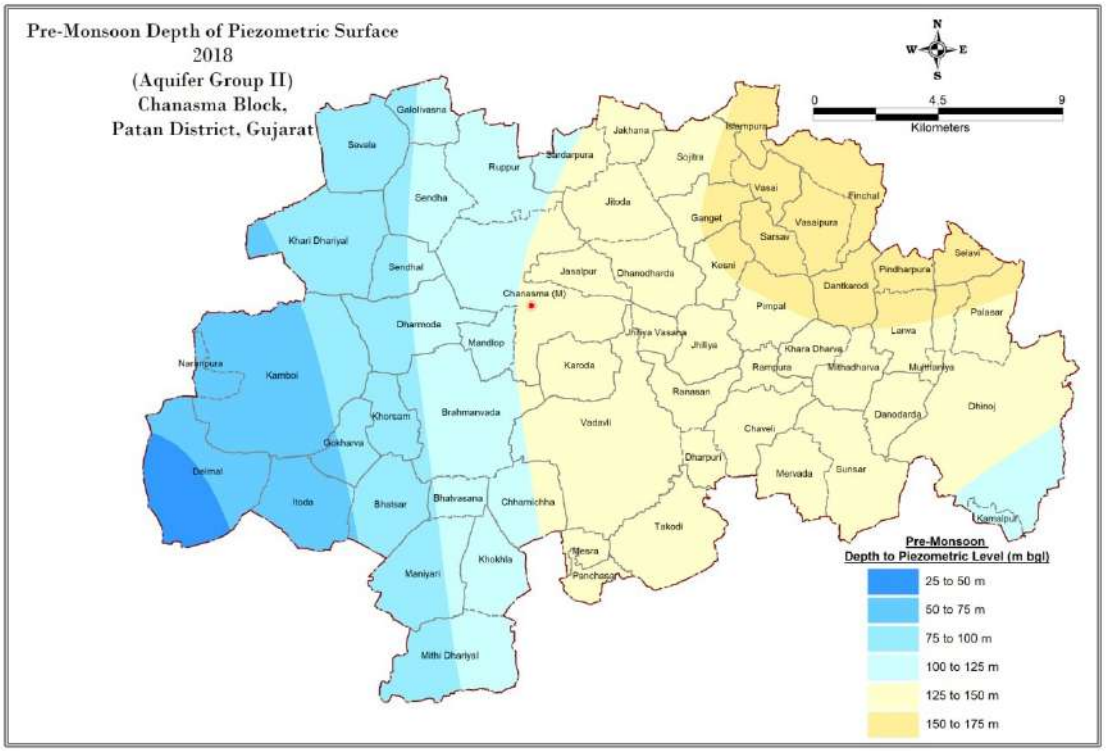
Aquifer Group wise Water Level Maps of Chanasma Taluka



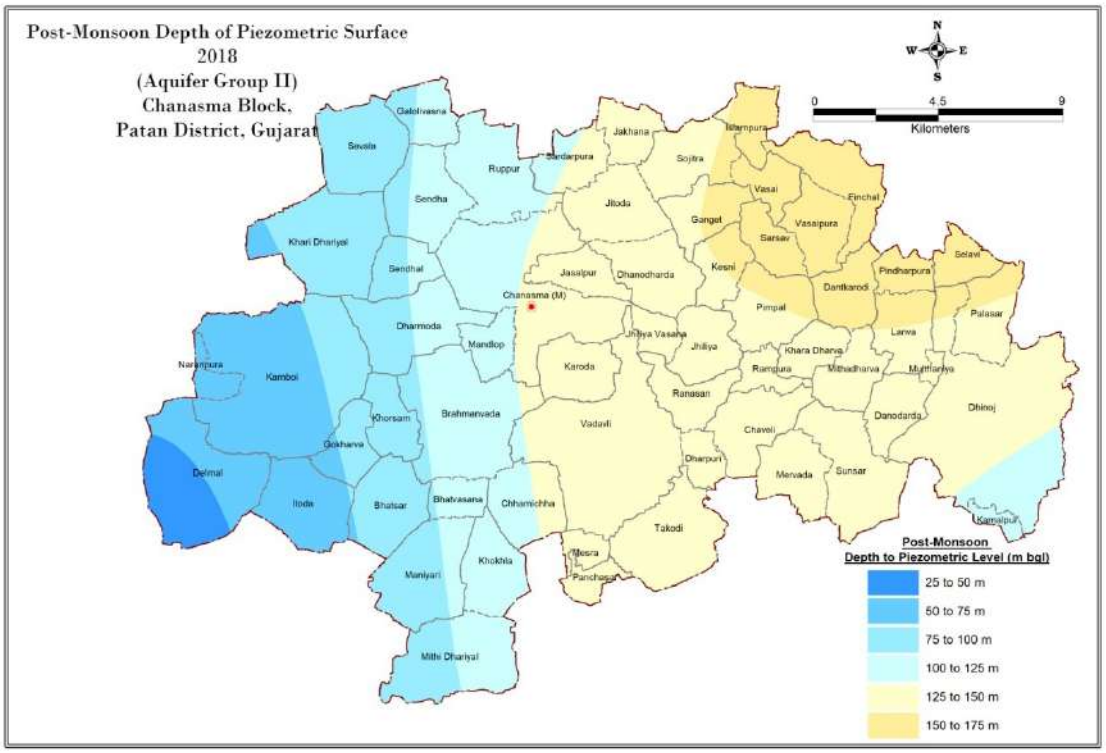
Pre Monsoon Depth to Water Level Map-Aquifer Group I



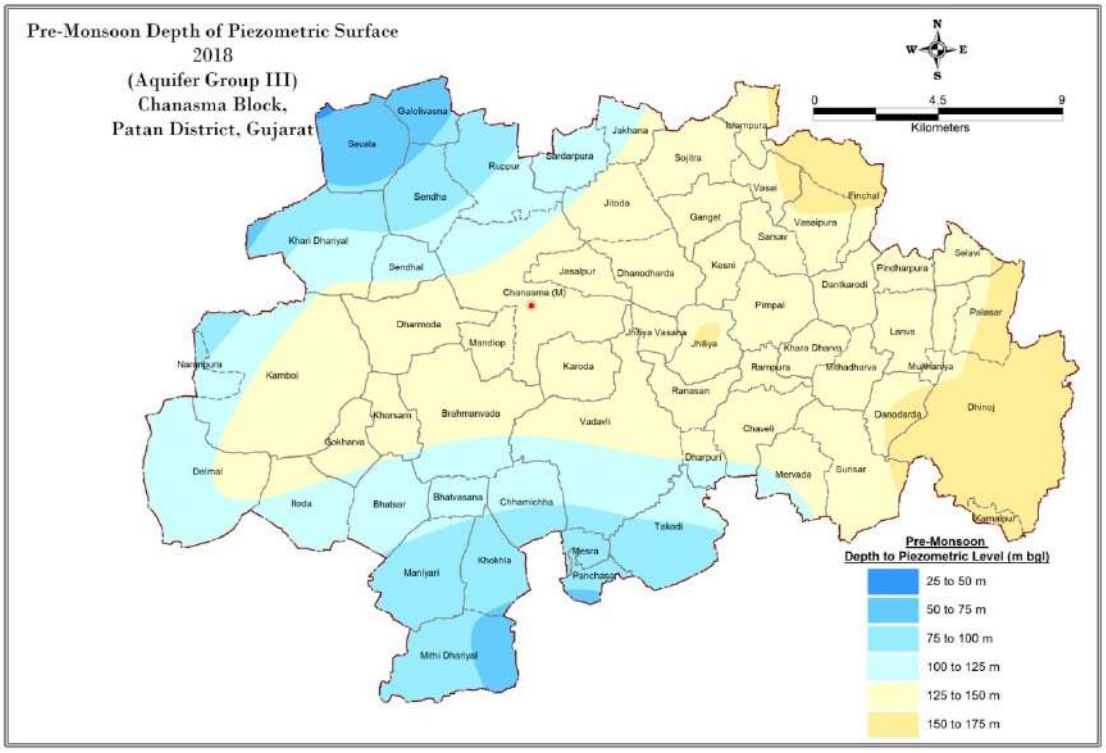
Post Monsoon Depth to Water Level Map-Aquifer Group I



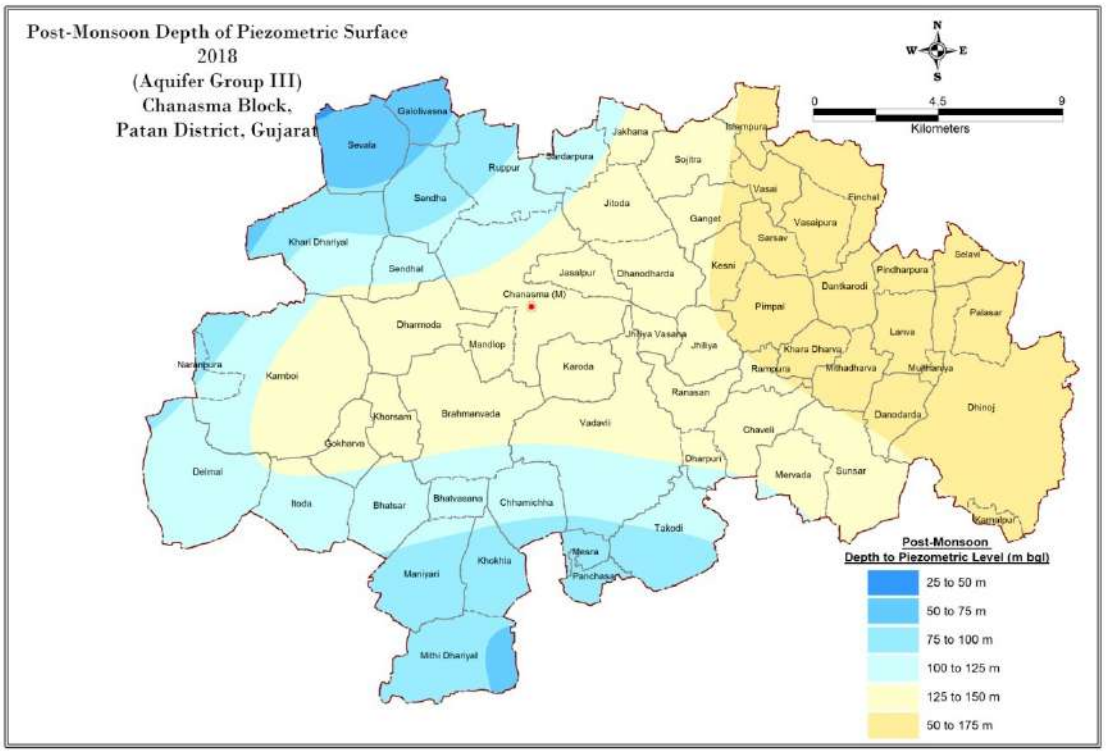
Pre Monsoon Depth to Water Level Map-Aquifer Group II



Post Monsoon Depth to Water Level Map-Aquifer Group II



Pre Monsoon Depth to Water Level Map-Aquifer Group III



Post Monsoon Depth to Water Level Map-Aquifer Group III

4 Groundwater resource extraction, contamination.

Dynamic GW Resources in MCM

Total fresh groundwater availability of the area is estimated in year 2017 is 7.43 MCM and total groundwater withdrawal for all purposes is 8.25 MCM. The stage of groundwater development is 111.07% and the Taluka is categorized “Over Exploited”.

Total Saline groundwater availability of the area is estimated in year 2017 is 87.99 MCM and total groundwater withdrawal for all purposes is 66.09 MCM. The stage of groundwater development is 75.11% and the Taluka is categorized “Semi Critical”.

Table: 2 Dynamic Groundwater resources 2017

S No.	Item	Fresh	Saline	Total
1	Area	36.44	420.81	457.25
2	Total GW Recharge	7.82	92.62	79.18
3	Net GW Availability	7.43	87.99	74.70
4	Gross Draft	8.25	66.09	50.33
5	Net Availability for Future Irrigation	0.00	21.66	23.56
6	Stage of GW Development	111.07	75.11	67.38

Aquifer Group wise Fresh and Saline Ground Water Resources upto 300 m depth are given below in table

In Storage GW Resources (Fresh, MCM)

Aquifer Group I	243.00
Aquifer Group II	487.00
Aquifer Group III	730.00
In-Storage Ground Water	1460.00
Annual Replenishable Ground water	7.43
Total Availability of Fresh Ground Water Resources	1467.43

In Storage GW Resources (Saline, MCM)

Aquifer Group I	321.00
Aquifer Group II	160.50
Aquifer Group III	107.00
In-Storage Ground Water	534.87
Annual Extractable Ground water Resources	87.99
Total Availability of Saline Ground Water Resources	622.86

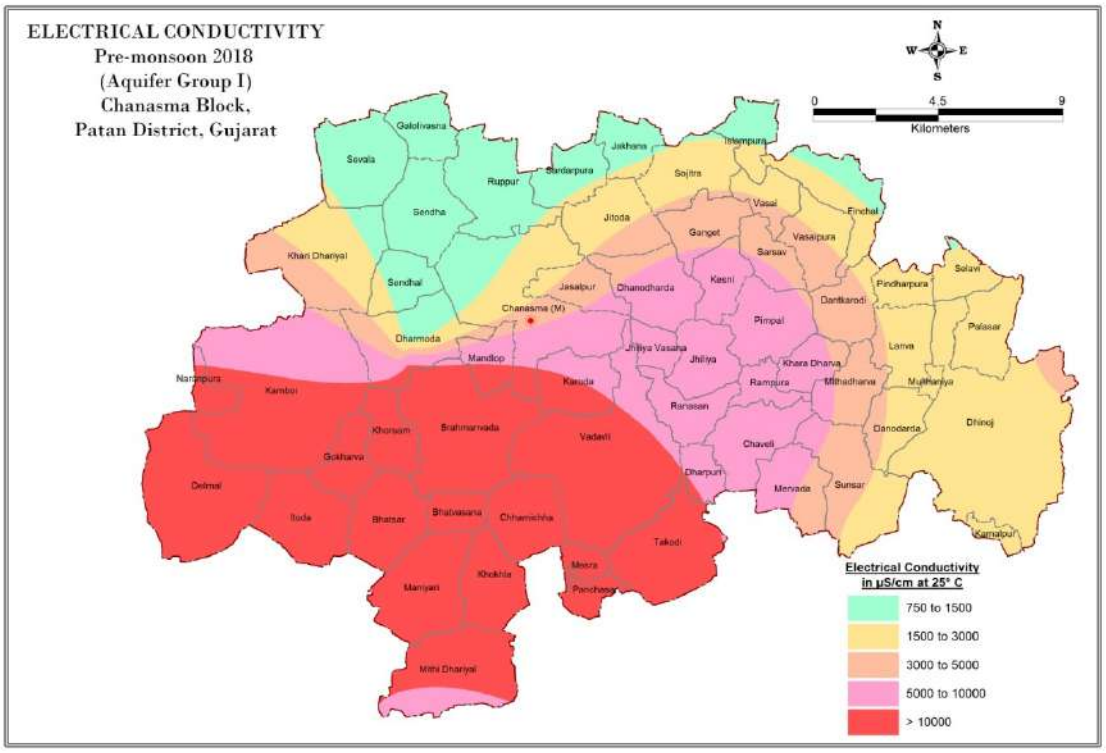
Total Groundwater Resources of Chanasma Taluka

In-Storage Ground Water (MCM)	Fresh	1460.00
	Saline	534.875
Annual Extractable Ground water Resources (MCM)	Fresh	7.43
	Saline	87.99
Total Availability of Ground Water Resources (MCM)	Fresh	1467.43
	Saline	622.865

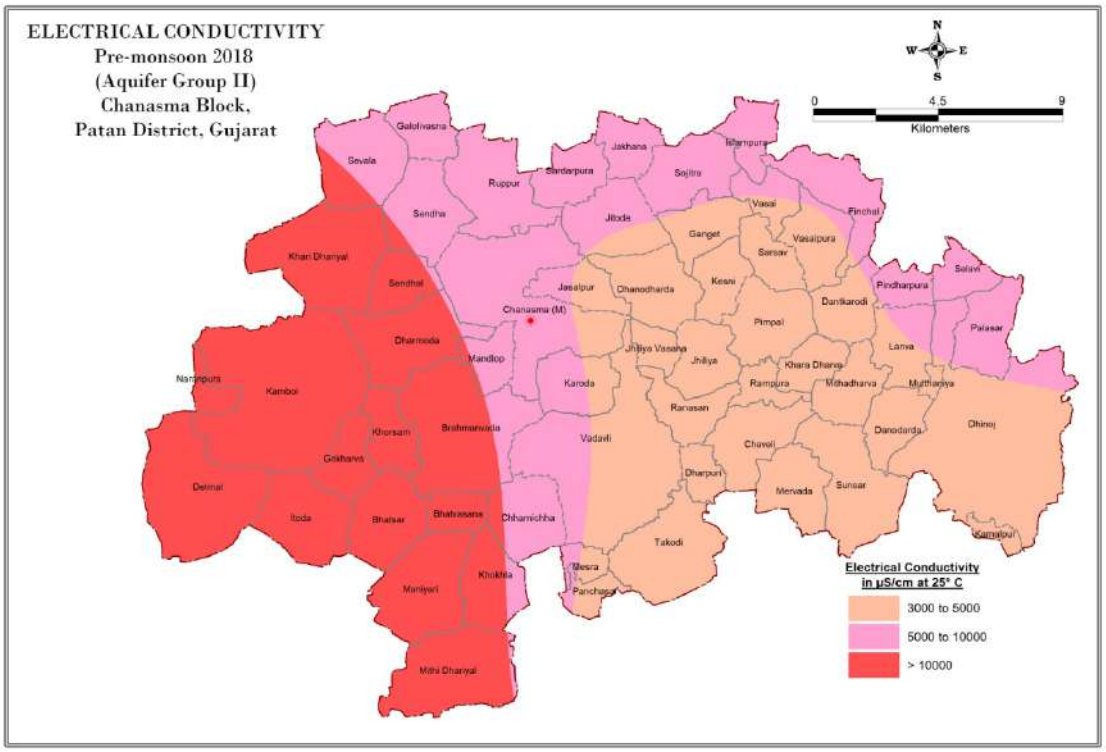
5 Chemical quality of groundwater

Groundwater quality is major issue in the area. Salinity is expressed in terms of total dissolved solids (TDS). About 92% (420.81sq.km) of area (Fig.7) falls TDS more than 2000 mg/litre. Groundwater quality is relatively good in Aquifer Group II and III. Water Quality map for Aquifer Group II and III are prepared based on the water quality data of State Govt. Piezometers where samples were collected by Grab method without purging the Wells hence the maps are debatable.

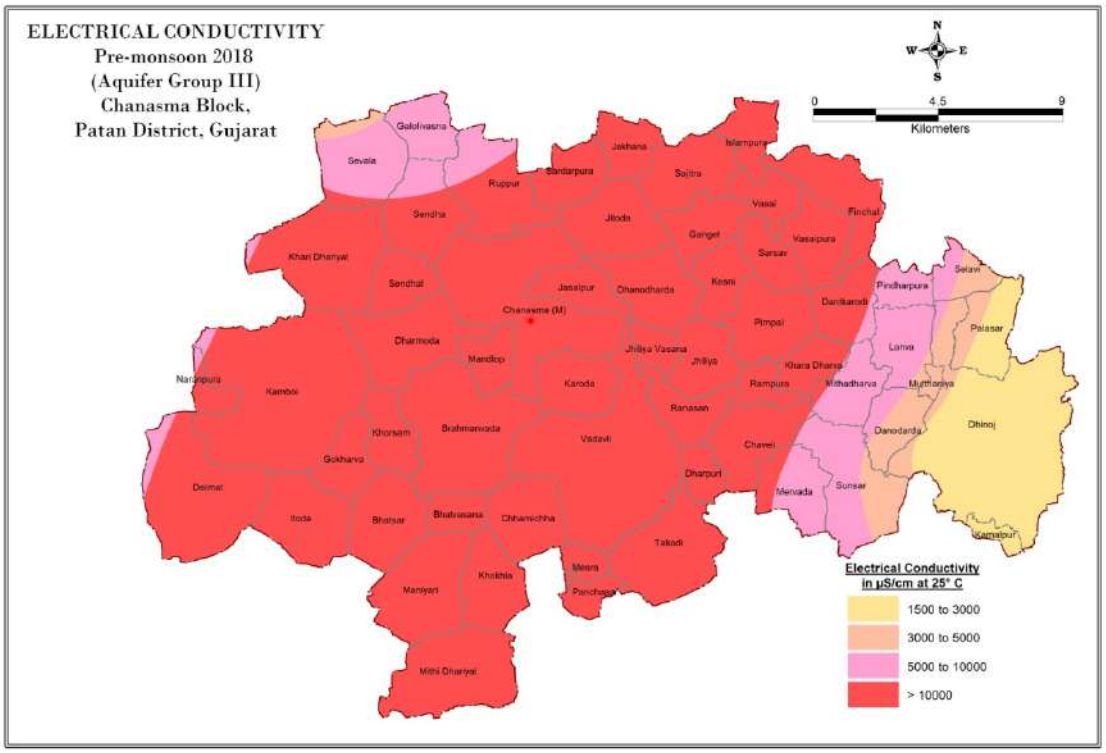
Aquifer Group wise Water Quality Maps of Chanasma Taluka



Pre Monsoon Electrical Conductivity Map-Aquifer Group I

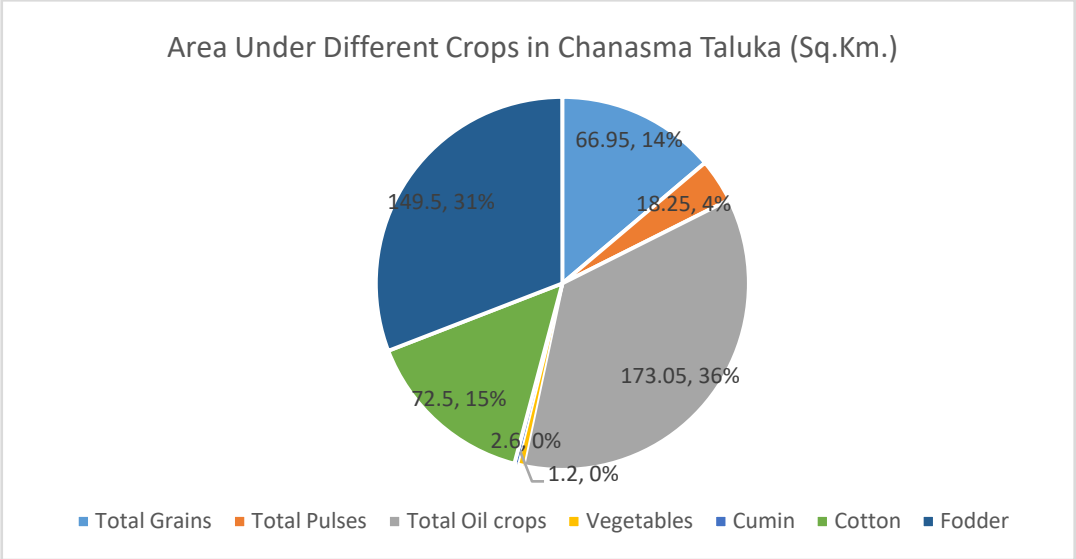


Pre Monsoon Electrical Conductivity Map-Aquifer Group II



Pre Monsoon Electrical Conductivity Map-Aquifer Group III

6 Cropping Pattern

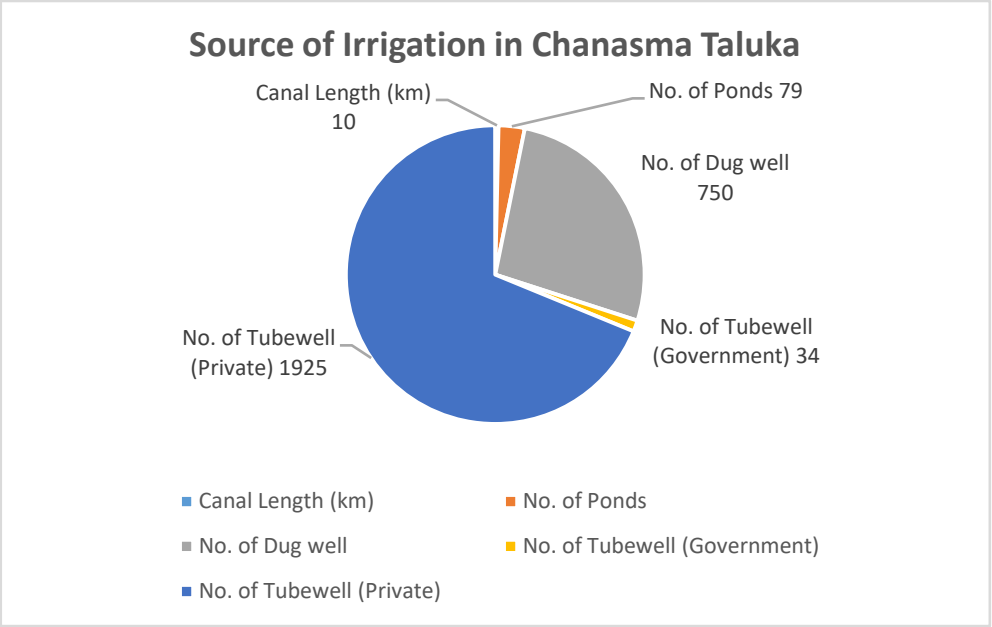


7 Irrigation

Source-wise Irrigation in Chanasma Taluka			
Length of Canal (km)	Govt.		10
	Private		0
Borewell (Nos.)	Govt.		34
	Private		1925
Only Irrigation Dug well (Nos.)	Govt.	Lined	0

		Unlined	0
	Private	Lined	750
		Unlined	0
Dug Well Not In Use (Nos.)			1025
Water Bodies Other Than Ponds			0
Dug wells For Domestic Use Only (Nos.)			181
Pond (Nos.)		Irrigation > 50 Ha	0
		Irrigation < 50 Ha	1
Oil Engine (Nos.)			1420
Electric Motor (Nos.)			763

Source-wise Irrigated Area in Chanasma Taluka	
Net Irrigated Area (Sq. Km.)	239
% Of Net Irrigated Area Agains Gross Cropped area	68.74
Govt. Canal (No.)	1
Length (km)	10
Private /Panchayat Canal	0
Pond (No.)	79
Dug Well (No.)	75
Tube Well (No.)	2734
Area irrigated More than once (Sq. Km.)	151.6
Gross Irrigated Area (Sq. Km.)	390.6



8 Ground Water Issues

Traditional agricultural /irrigation practices, flood irrigation practices, increase in water demand, irrigation practices based on power supply. Farmers irrigate the crops when power supply is available rather than waiting for the wilting to start. Following are the issues identified for aquifer management in the area:

- Arid/Semi arid area

- High rate of Evapotranspiration
- Limited availability of surface water resources
- Over exploitation of ground water
- Decline in ground water levels
- De saturation of Phreatic aquifers
- Deeper Piezometric head of Confined Aquifer-III (Map)
- Decline in Piezometric heads of semi confined/confined aquifer
- Increase in well depth as water levels become deeper
- Increase in depth of prime mover/pump setting
- Decline in well yields
- Lack of awareness and involvement of stakeholder in decision making

9 Groundwater Management

Supply side Management: The Recharging capacity through the number of Recharge Structures are more than sufficient and hence new recharge structures are not proposed to enhance the groundwater. Although feasibility of recharging the deeper User Aquifers (Aquifer Group II and III) may be explored as they show declining water level/Piezometric Head subject to availability of surplus water to recharge. The village ponds linked with Narmada canal water can be used to construct recharge wells in the pond bed for recharging the deeper aquifer.

Table: 4 Rechargestructures.

Recharge Structures in Chanasma Taluka	
Tanks (No.)	30
Percolation Tanks (No.)	25
Check Dam (No.)	544
Quantity of Recharge from Percolation Tanks(@0.14 MCM)	3.5
Quantity of Recharge from Check Dams (@0.05 MCM)	27.2

10 Demand Side Management

As the surface water is not available to improve the supply of water, demand side management is essential.

Water use efficiency by Micro Irrigation System:

At present an area of 1520 ha is covered by micro-irrigation scheme (MIS) under different crops grown in the Chanasma Taluka. By adding proposed area of 2973 Ha under MIS in the Talukathe irrigation draft can reduce from 8.18 MCM to 3.72 MCM with a net saving of 4.46MCM on account of irrigation draft and the stage of groundwater extraction will also improve.

Annual Extractable Ground Water Recharge (MCM)	7.43
Irrigation Draft (MCM)	8.18
Domestic And Industrial uses Draft (MCM)	0.07
Total Draft (MCM)	8.25
Gross Irrigated Area by GW (Ha)	31248
Area already Covered under MIS (Ha)	1520
Area Proposed under MIS* (Ha)	2973
Δ GW Requirement (m)	0.5
Irrigation Draft for MIS (MCM)	4.4592
Irrigation Draft After MIS (MCM)	3.7208
Total Draft after MIS (MCM)	3.7908
Stage of Ground Water Extraction (%) (GWRE 2017)	111.04
Category (GWRE 2017)	Over Exploited
Stage of Ground Water Extraction (%) after MIS	51.02
Category after MIS	Safe

11 Expected Benefits or outcome of the Plan

Ground water recharge and water conservation structures on the ground are more than sufficient at present in Chanasma Taluka, Patan By adopting the micro-irrigation area in the remaining area conserve the 4.46 MCM of groundwater draft in the district.

With the additional recharge and water conservation interventions as proposed in the Plan, it is anticipated that with enhanced recharge and reduction in ground water draft, the stage of ground water development will reduce to 51% from the existing 111%.

12 Summary and Conclusion

Chanasma is one of the agriculturally, socially and economically advanced districts, situated in the northern part of Gujarat State. Regionally, it forms part of North Gujarat Region. Groundwater is the main source of irrigation water in the district catering almost 80% of the irrigation water demand.

Groundwater occurs in the alluvium system with sand of various size form the aquifers separated by clay and mixed horizons forming the aquitards. Groundwater occurs both in Phreatic as well as Semi confined to Confined condition. For the purpose of Aquifer mapping up to 300m, the different aquifer units are grouped in Aquifer Group I, II and III. Aquifer group I is unconfined aquifer whereas Aquifer Group II is semi confined to Confined and Aquifer Group III is confined in Nature. These aquifer groups are regionally extensive and form prolific aquifer system in the district.

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The Aquifer Group I in eastern parts is desaturated at many places but shows stabilised water level due to the recharge activities and introduction of narmada water for irrigation as wells as Unlined Sujalam Sufalam Canal passing through Chanasma Taluka where many shallow piezometers show rising trend.

Aquifer Group II and III are tapped by irrigation tubewells and there is declining water level trend in most of the piezometers representing these aquifer groups.During last 20 years fall of 2m to 45m in Piezometers tapping Aquifer Group II and fall of 13 to 56m in Pz tapping Aquifer Group III is observed.

A number of activities for augmenting groundwater resources has been done with construction of check dams (544 nos), deepening of village ponds (30 nos.), Percolation tanks (25 nos.) and interlinking of ponds with the canals and pipeline.

The Taluka has erratic rainfall and there is very limited non committed surplus runoff to harness as the recharge capacity of the structures on the ground are more than required.

Attention has to be given to recharging the deeper aquifers as these are the main source of irrigation water and are heavily pumped, but there is paucity of source water for recharging.

Focus has to be shifted to saving of water through Micro irrigation techniques as in the traditional flooding method a lot of water is wasted.

As there is little scope of creating additional recharge structures it is recommended to increase the area under micro irrigation to about 2973 Ha which may reduce the irrigation draft by 4.46 MCM. And turn the Taluka from Over Exploited to Safe Category.

MANAGEMENT PLAN OF
PATAN TALUKA, PATAN DISTRICT, GUJARAT STATE

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<tr><td>Range of Average Temperature</td><td>21-31 °C</td></tr>
<tr><td>Major Drainage System</td><td>Saraswati, Banas</td></tr>
<tr><td>Major/ Medium Irrigation Scheme</td><td>SaraswatiBarage</td></tr>
<tr><td>Major Geological Formation</td><td>Alluvium</td></tr>
<tr><td>Major Aquifer</td><td>Sand, Silt, Gravel</td></tr>
<tr><td>Utilizable Groundwater Resources (2018)</td><td>Fresh: 151.14 MCM
Saline: 90.80 MCM</td></tr>
<tr><td>Net Groundwater Draft</td><td>Fresh: 154.52 MCM
Saline: 78.56 MCM</td></tr>
<tr><td>Stage of Groundwater Development</td><td>Fresh: 102.23% (Over Exploited)
Saline:86.52% (Semi-Critical)</td></tr>
<tr><td>Fresh Instorage Groundwater resources</td><td>1621 MCM</td></tr>
<tr><td>Artificial Recharge and Water conservation structures under different schemes by various department in Gujarat</td><td>Check Dams – 920
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<tr><td>Minor irrigation structures</td><td>Deep Tubewells: 1860
Dug wells:775</td></tr>
<tr><td>Agriculture (2015-16)</td><td><table><tr><td>Crop Area (sq.km.)</td><td></td></tr><tr><td>Total Grains</td><td>71.5</td></tr><tr><td>Total Pulses</td><td>17.75</td></tr><tr><td>Total Oil crops</td><td>173.8</td></tr><tr><td>Vegetables</td><td>9.35</td></tr><tr><td>Cumin</td><td>0.3</td></tr><tr><td>Cotton</td><td>42.2</td></tr><tr><td>Fodder</td><td>146.2</td></tr></table></td></tr>
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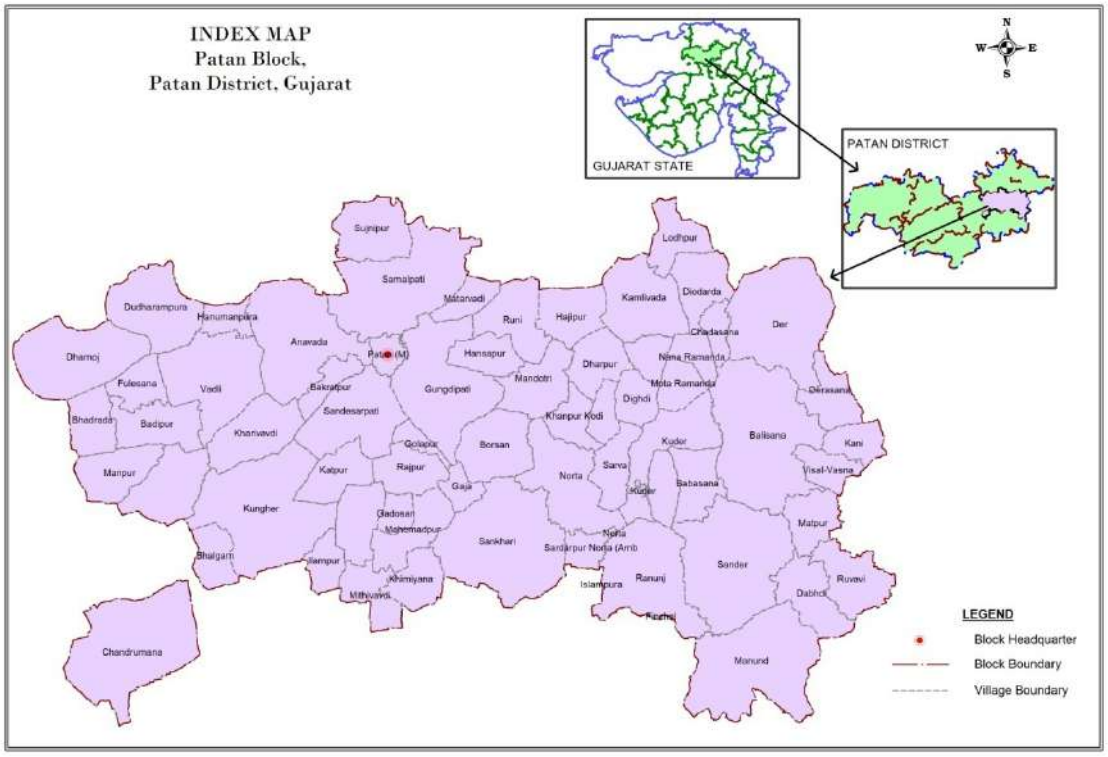

Fig.1: Location Map

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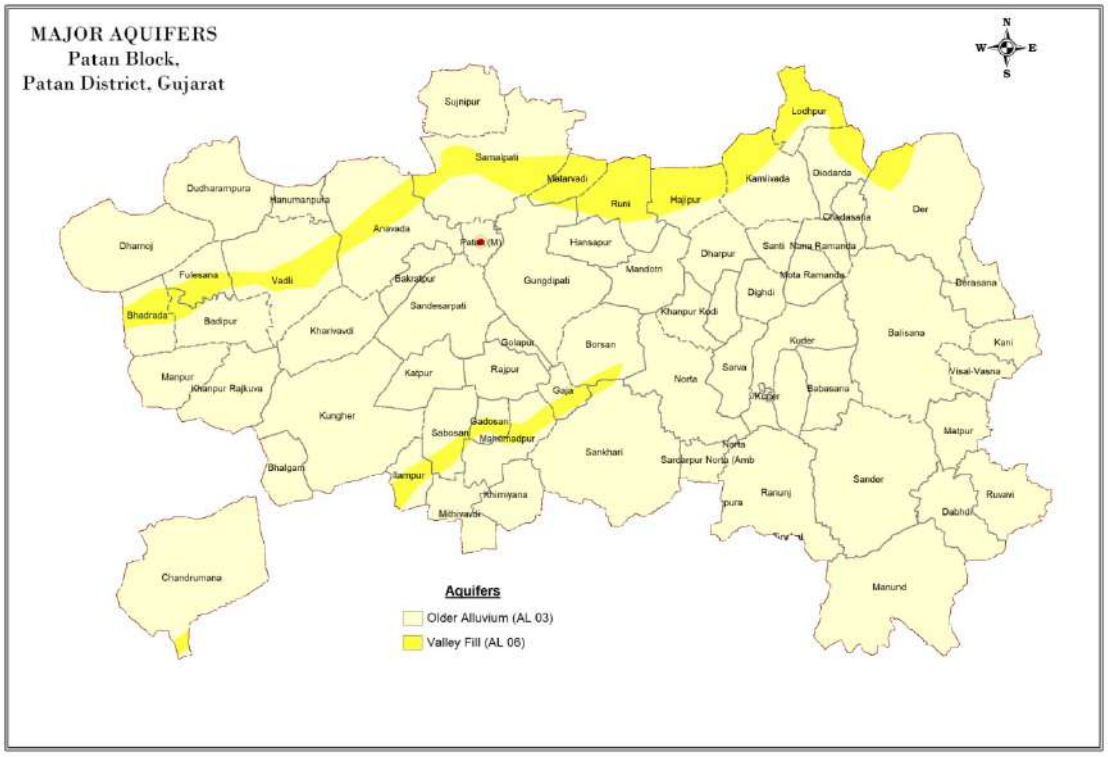
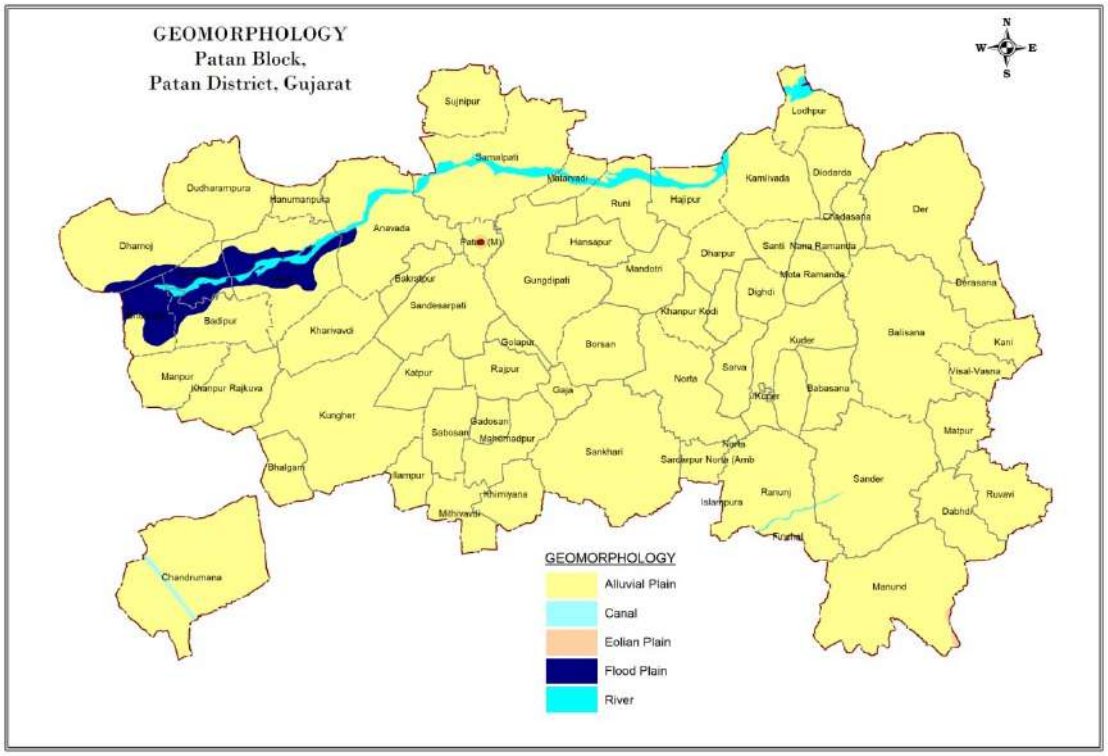


Fig.2: Major Aquifer



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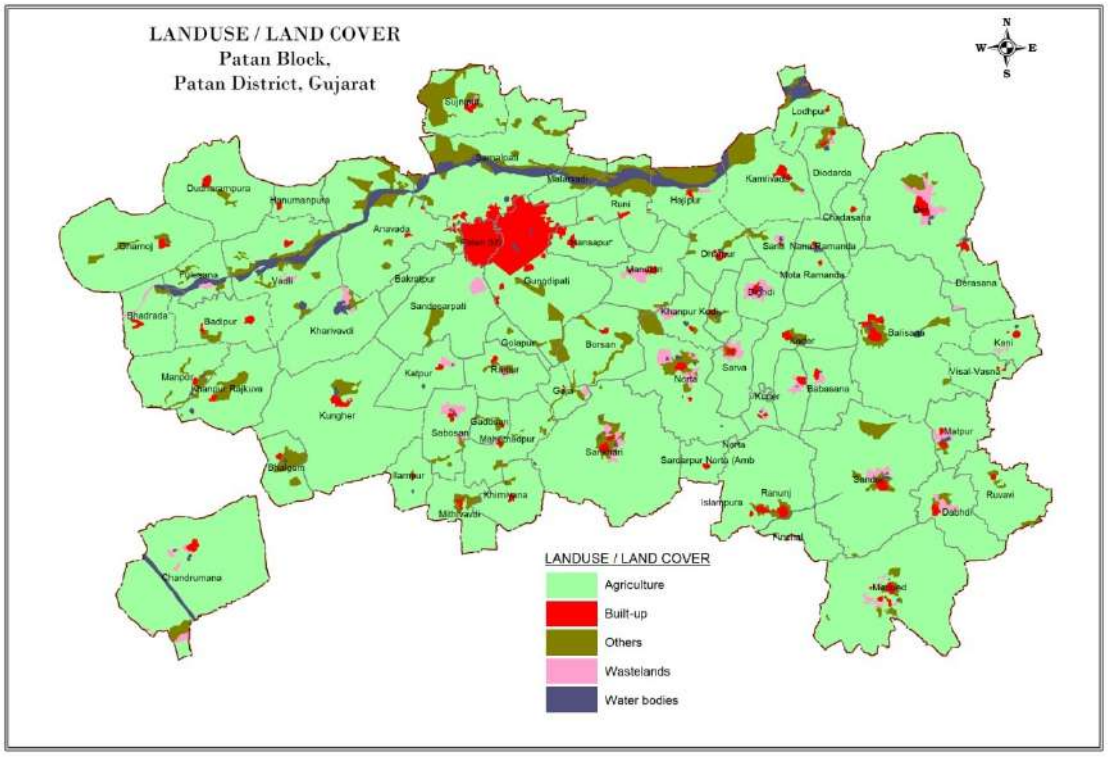

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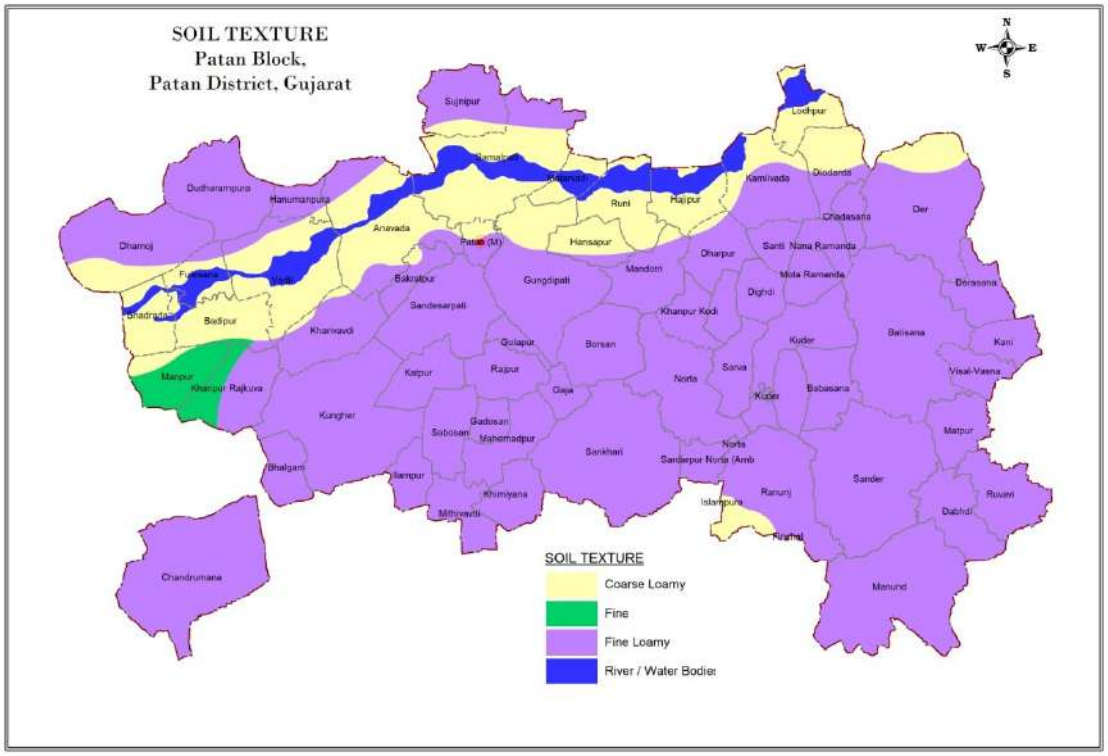

Fig 5: Soil Type

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Hydrogeological section for PatanTaluka Depicting Aquifer Group I, II and III

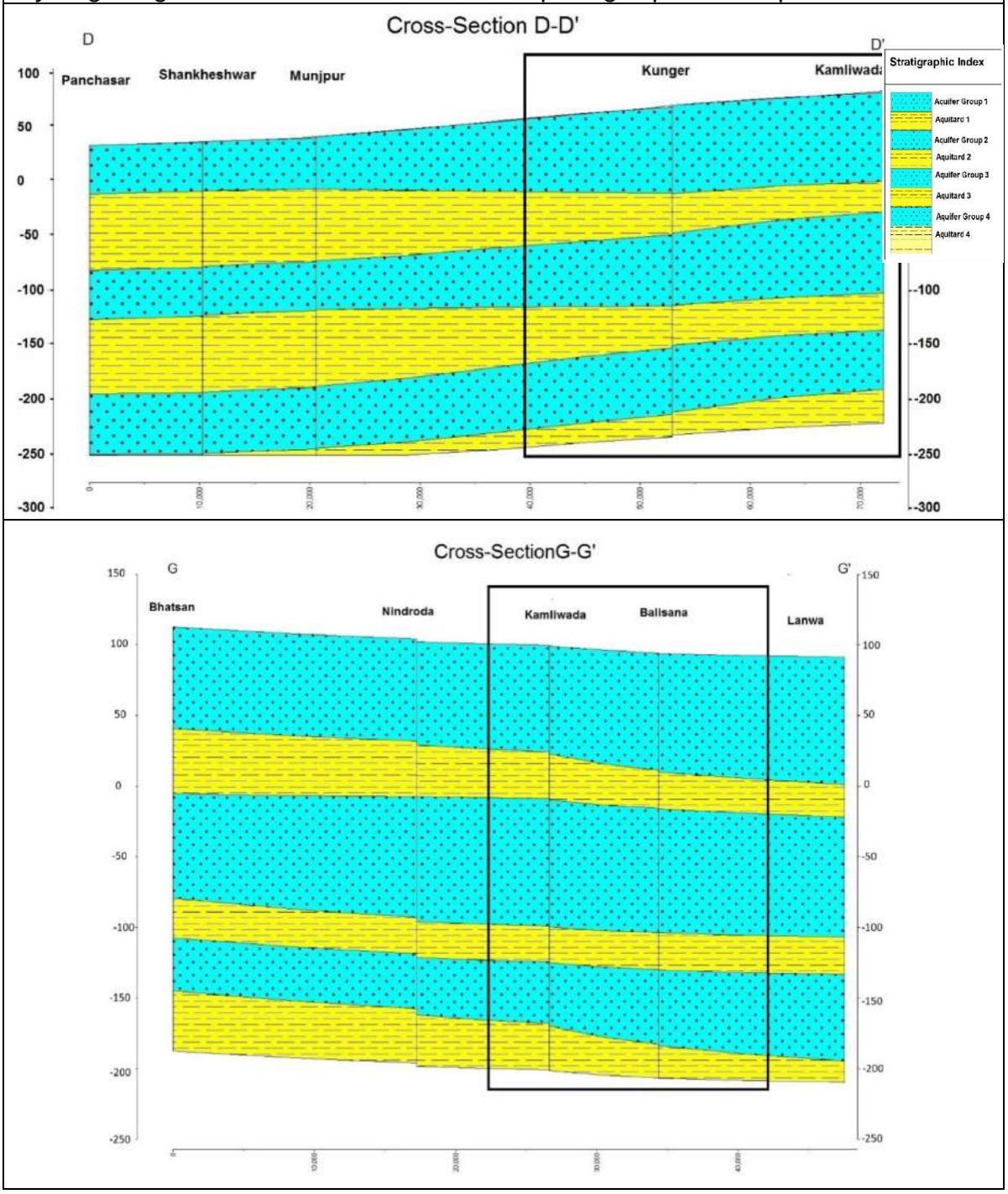
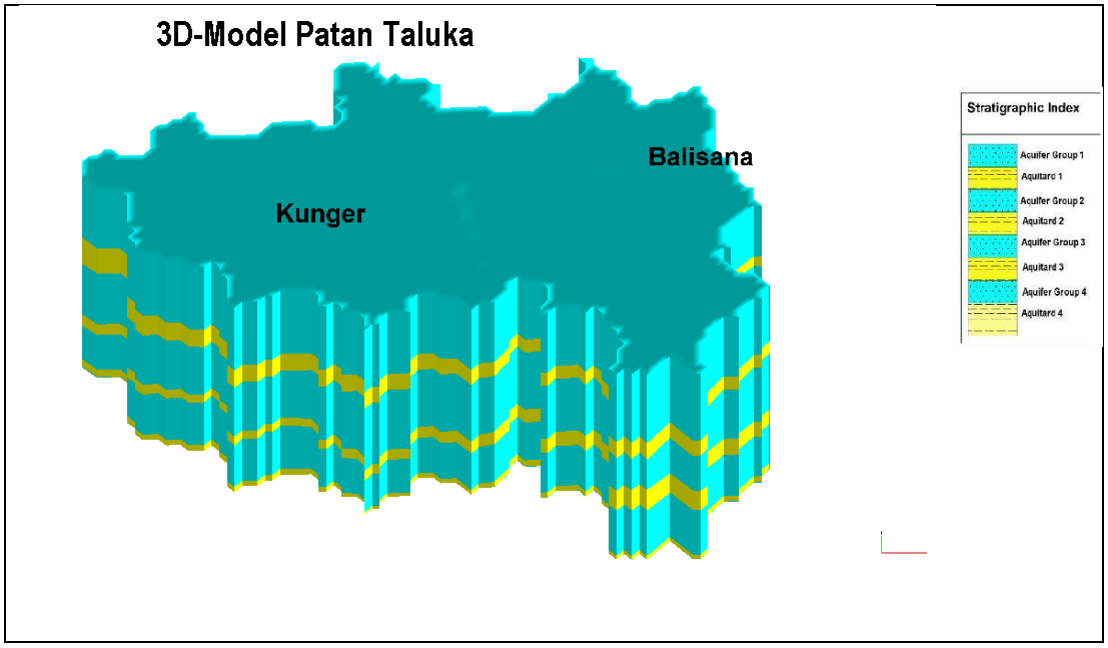


Fig-4: Stratigraphic Section



3 D Solid Model of PatanTalukaDepicting Aquifer Group I, II and III

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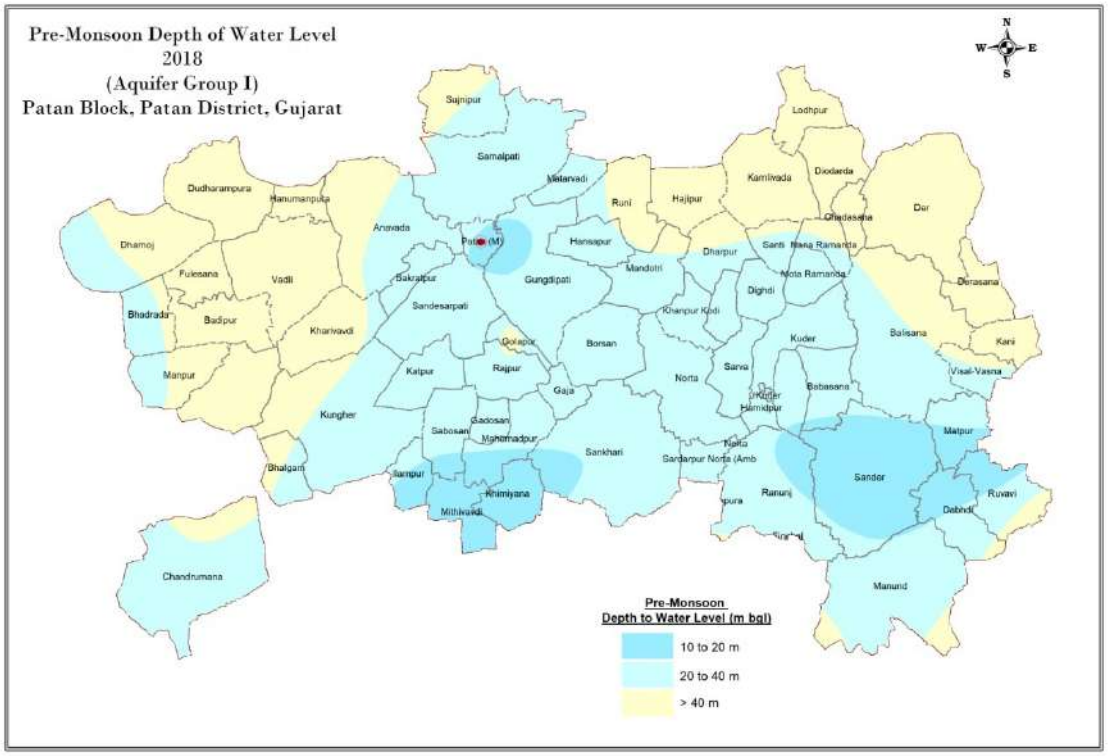
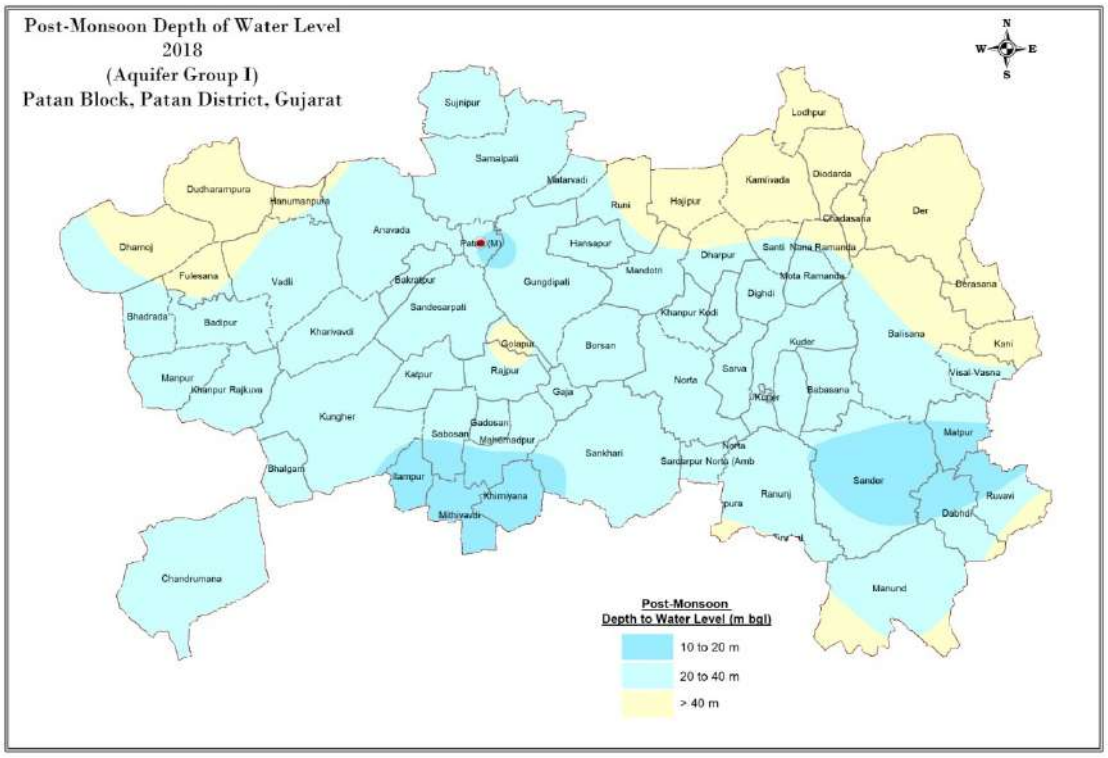
Aquifer Group	Base of Aquifer (m)	Generalized Thickness (m)	Yield (LPM)	Quality/EC (µS/cm)	Water Level/Piezometric head (mBGL)	Developed in the area	Aquifer Type
Aquifer-I	80-110	30-85	150-300	630-2010	12.70-58.00	N & NE	Phreatic
Aquifer-II	190-210	15-90	600-1200	5800-7130	99.10-167.57	C & EC	Semi Confined/ Confined
Aquifer-III	290-300	20-80	600-1200	1190-1650	132.4-147.5	C & S and S part	Confined

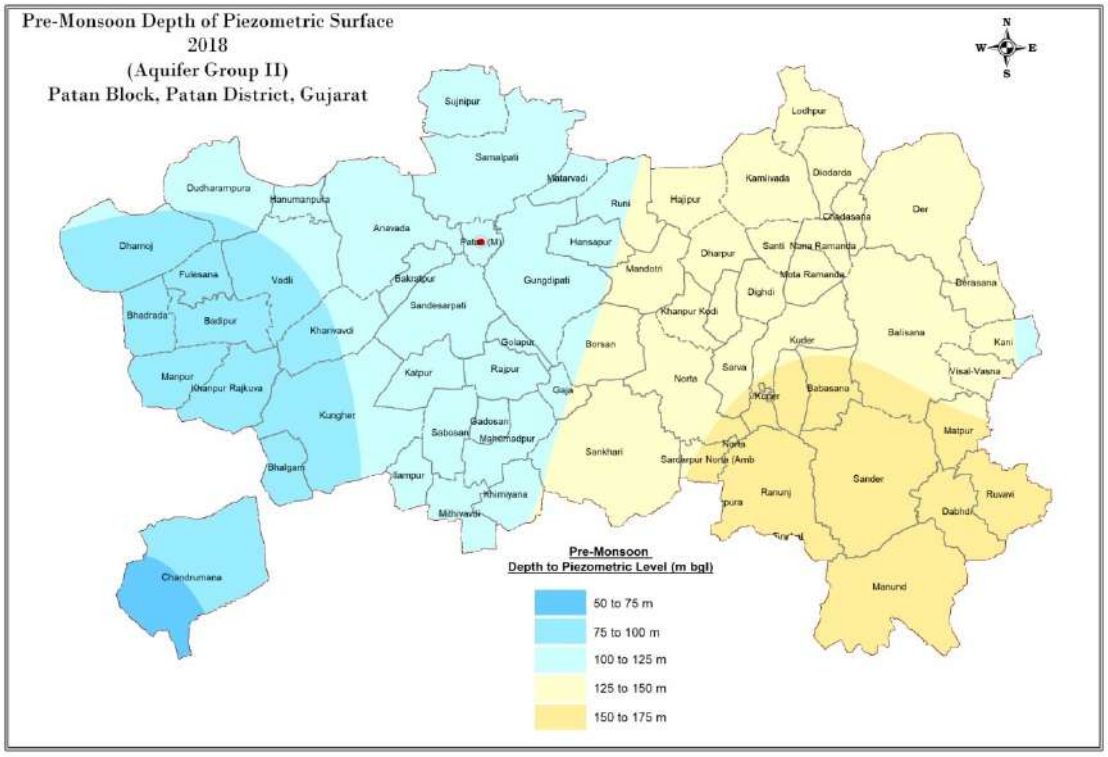
Aquifer Group wise Water Level Maps of Patan Taluka



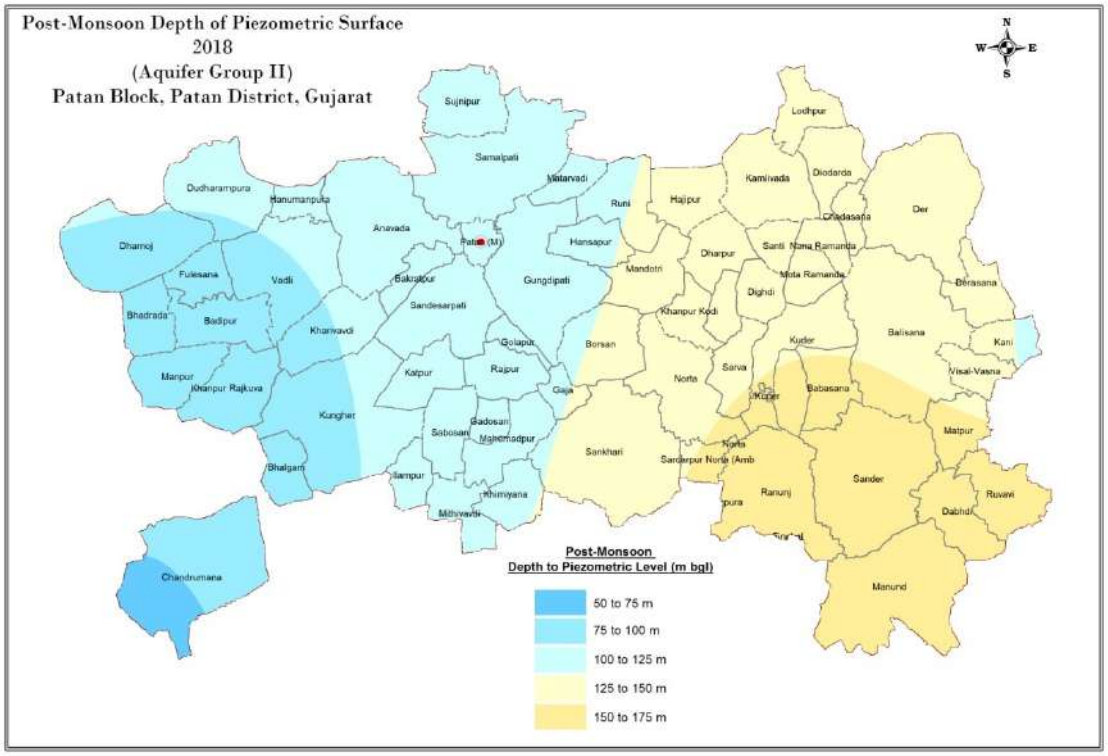
Pre Monsoon Depth to Water Level Map-Aquifer Group I



Post Monsoon Depth to Water Level Map-Aquifer Group I



Pre Monsoon Depth to Water Level Map-Aquifer Group II



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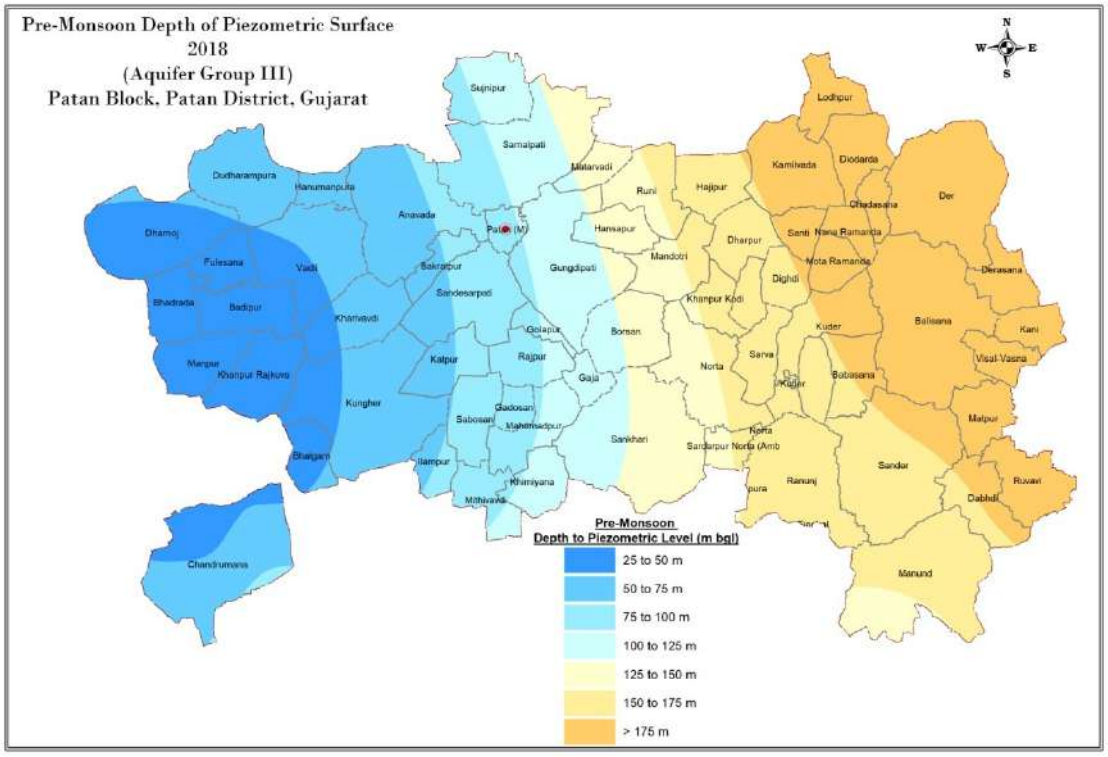
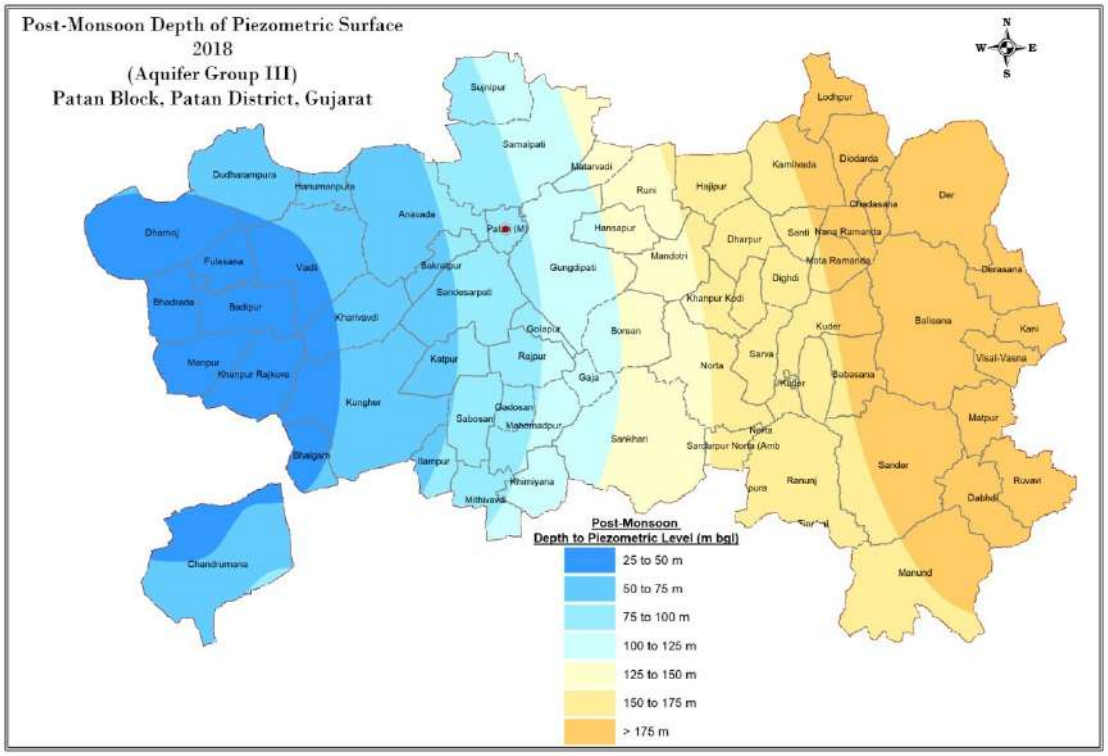


Pre Monsoon Depth to Water Level Map-Aquifer Group III



Post Monsoon Depth to Water Level Map-Aquifer Group III

4 Groundwater resource extraction, contamination.

Dynamic GW Resources in MCM

Total fresh groundwater availability of the area is estimated in year 2017 is 7.43 MCM and total groundwater withdrawal for all purposes is 8.25 MCM. The stage of groundwater development is 111.07% and the Taluka is categorized “Over Exploited”. Total Saline groundwater availability of the area is estimated in year 2017 is 87.99 MCM and total groundwater withdrawal for all purposes is 66.09 MCM. The stage of groundwater development is 75.11% and the Taluka is categorized “Semi Critical”.

Table: 2 Dynamic Groundwater resources 2017

S No.	Item	Fresh	Saline	Total
1	Area	298.91	180.80	479.71
2	Total GW Recharge	159.10	95.58	254.68
3	Net GW Availability	151.14	90.80	241.94
4	Gross Draft	154.52	78.56	233.08
5	Net Availability for Future Irrigation	0.00	11.99	11.99
6	Stage of GW Development	102.23	86.52	

Aquifer Group wise Fresh and Saline Groundwater Resources upto 300 m depth are given below in table

In Storage GW Resources (Fresh, MCM)

Aquifer Group I	324
Aquifer Group II	324
Aquifer Group III	973
In-Storage Groundwater	1621
Annual Replenishable Groundwater	151
Total Availability of Fresh Groundwater Resources	1772

In Storage GW Resources (Saline, MCM)

Aquifer Group I	115
Aquifer Group II	85
Aquifer Group III	100
In-Storage Groundwater	300
Annual Extractable Groundwater Resources	91
Total Availability of Saline Groundwater Resources	391

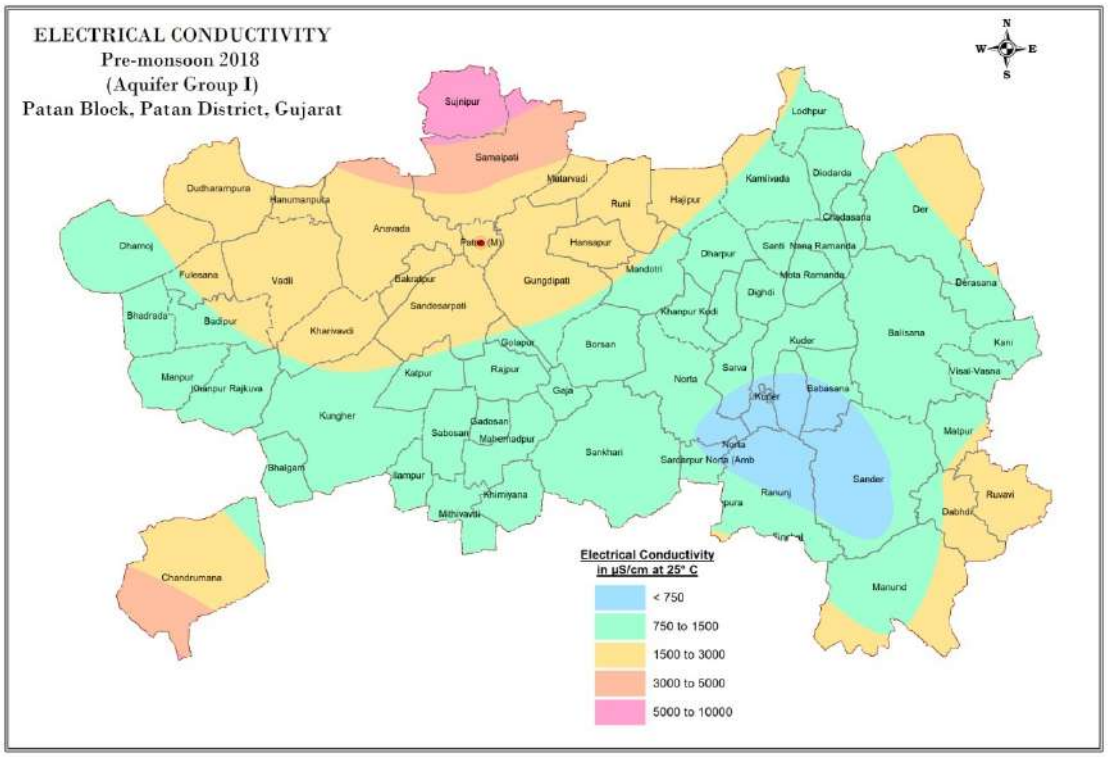
Total Groundwater Resources of PatanTaluka

In-Storage Groundwater (MCM)	Fresh	1621
	Saline	300
Annual Extractable Groundwater Resources (MCM)	Fresh	151.14
	Saline	90.80
Total Availability of Groundwater Resources (MCM)	Fresh	1772
	Saline	391

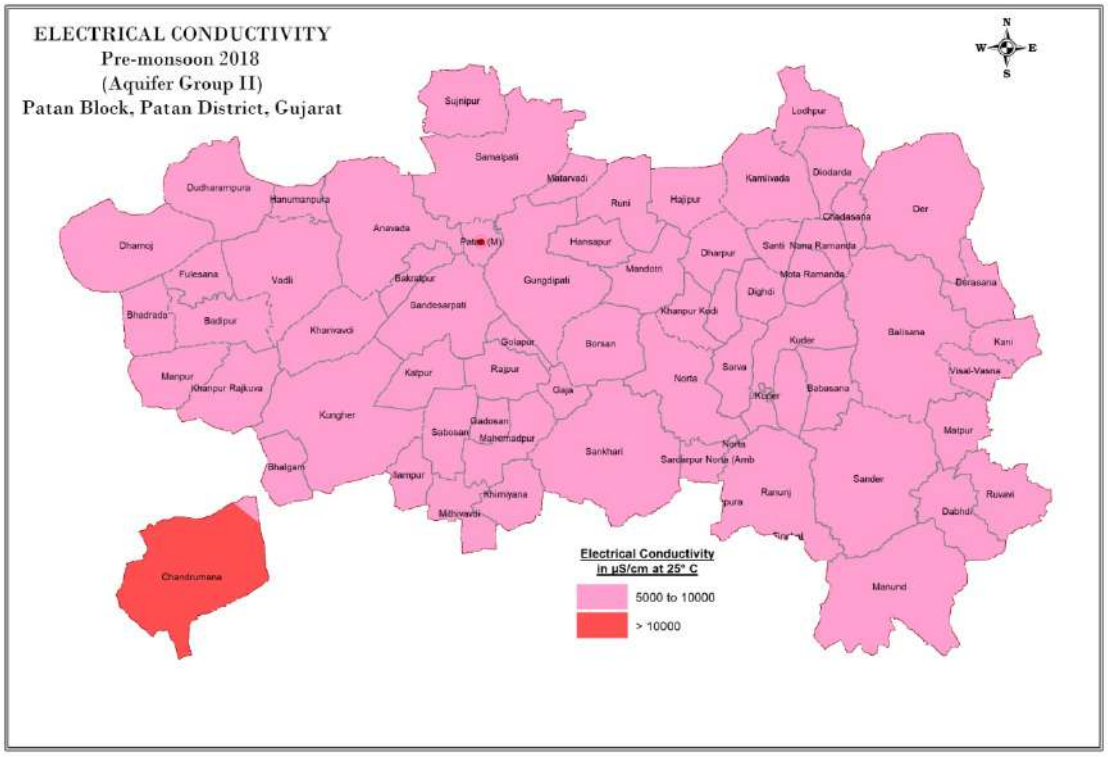
5 Chemical quality of groundwater

Groundwater quality is major issue in the area. Salinity is expressed in terms of total dissolved solids (TDS). About 37% (180.80sq.km) of area (Fig.7) falls TDS more than 2000mg/litre. Groundwater quality is relatively good in Aquifer Group I and poor in Aquifer Group II and III. Water Quality map for Aquifer Group II and III are prepared based on the water quality data of State Govt. Piezometers where samples were collected by Grab method without purging the Wells hence the maps are debatable.

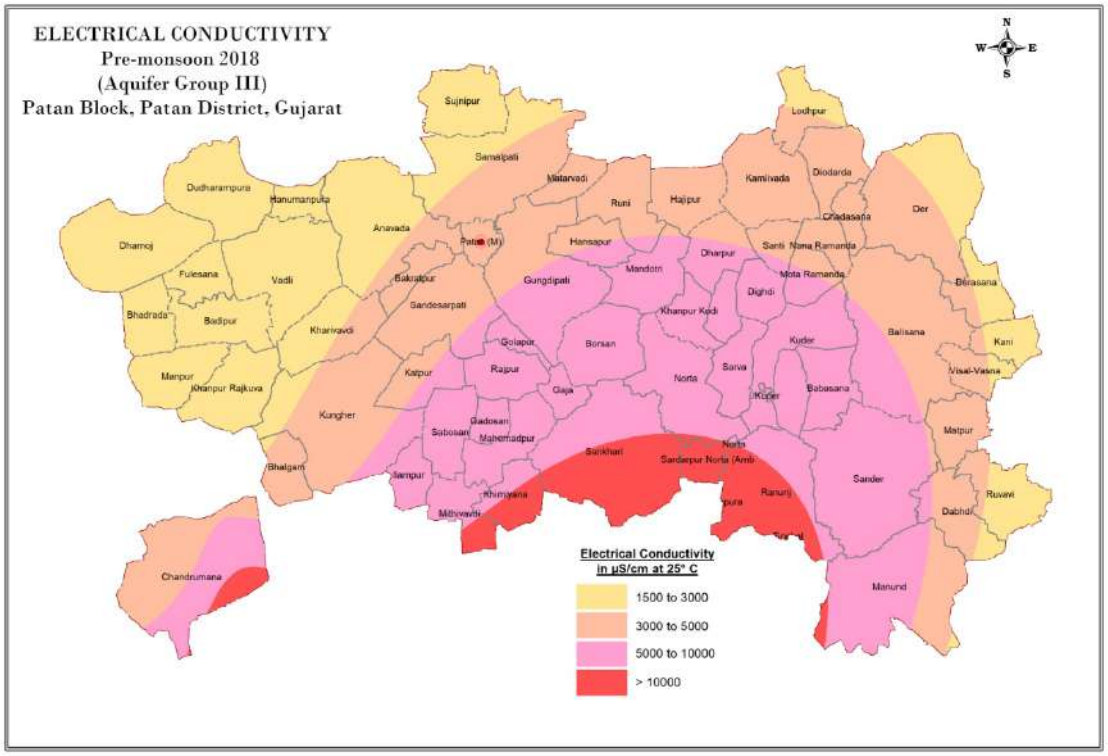
Aquifer Group wise Water Quality Maps of PatanTaluka



Pre Monsoon Electrical Conductivity Map-Aquifer Group I

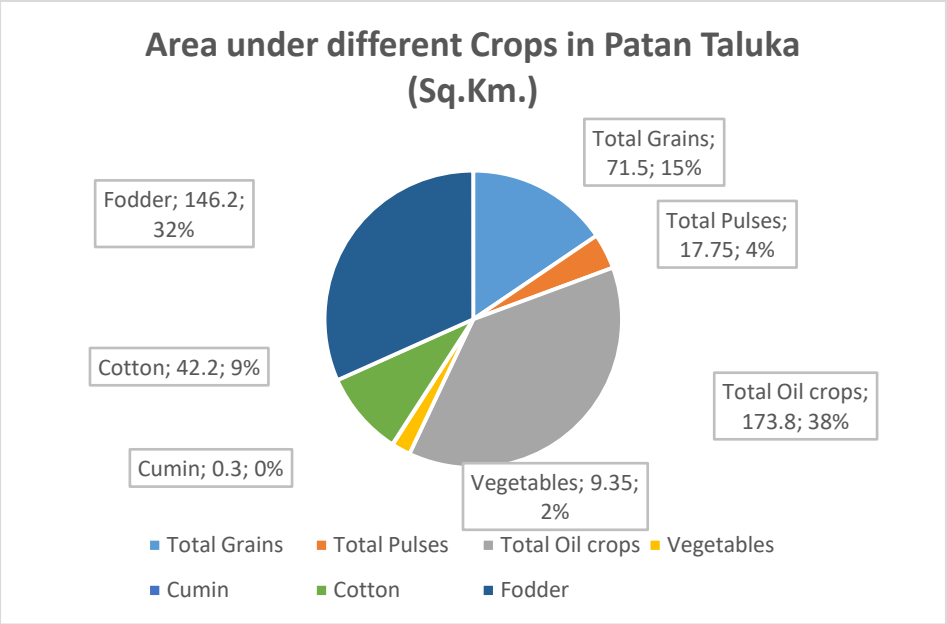


Pre Monsoon Electrical Conductivity Map-Aquifer Group II



Pre Monsoon Electrical Conductivity Map-Aquifer Group III

6 Cropping Pattern

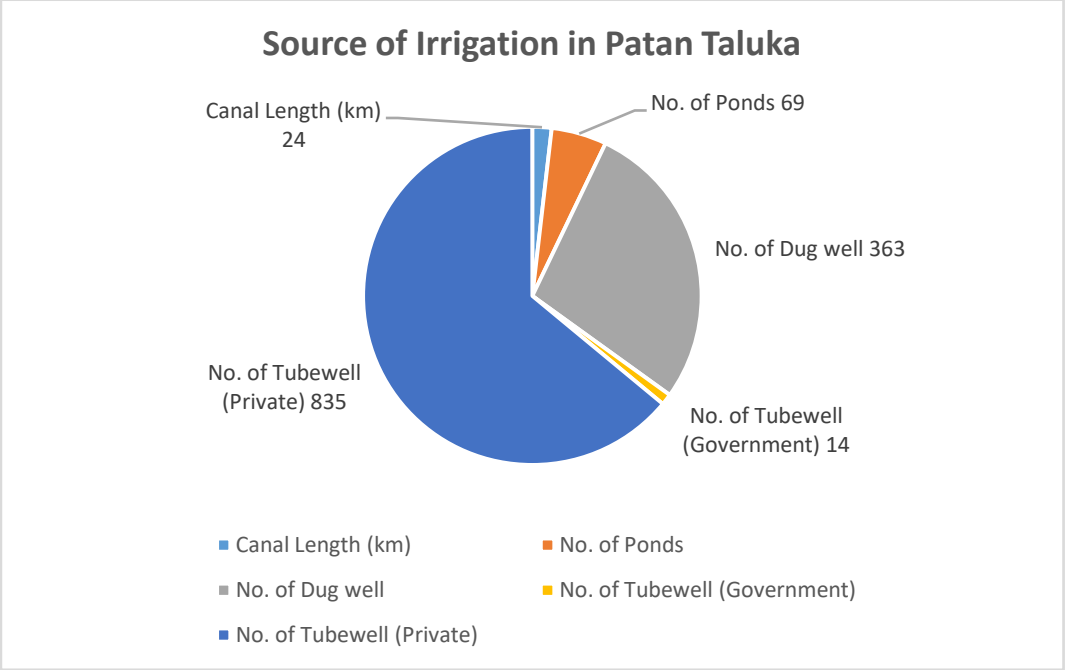


7 Irrigation

Sourcewise Irrigation in PatanTaluka			
Length Of Canal (km)	Govt.		24
	Private		0
Borewell (Nos.)	Govt.		14
	Private		835
Only Irrigation Dug well (Nos.)	Govt.	Lined	0
		Unlined	0
	Private	Lined	350
		Unlined	4
Dug Well Not In Use (Nos.)			1900
Water Bodies Other Than Ponds			0
Dug wells For Domestic Use Only (Nos.)			80
Pond (Nos.)	Irrigation > 50 Ha		0
	Irrigation < 50 Ha		0
Oil Engine (Nos.)			475
Electric Motor (Nos.)			350

Sourcewise Irrigated Area in PatanTaluka	
Net Irrigated Area (Sq. Km.)	251.33
% Of Net Irrigated Area Agains Gross Cropped area	80.88
Govt. Canal (No.)	2
Length (km)	54
Private /Panchayat Canal	0
Pond (No.)	69
Dug Well (No.)	363

Tube Well (No.)	1261
Area irrigated More than once (Sq. Km.)	130.15
Gross Irrigated Area (Sq. Km.)	381.48



8 Groundwater Issues

Traditional agricultural /irrigation practices, flood irrigation practices, increase in water demand, irrigation practices based on power supply. Farmers irrigate the crops when power supply is available rather than waiting for the wilting to start. Following are the issues identified for aquifer management in the area:

- Arid/Semi arid area
- High rate of Evapotranspiration
- Limited availability of surface water resources
- Over exploitation of ground water
- Decline in Groundwater levels
- De saturation of Phreatic aquifers
- Deeper Piezometric head of Confined Aquifer-III (Map)
- Decline in Piezometric heads of semi confined/confined aquifer
- Increase in well depth as water levels become deeper
- Increase in depth of prime mover/pump setting
- Decline in well yields
- Lack of awareness and involvement of stakeholders in decision making

9 Groundwater Management

Supply side Management:The Recharging capacity through the number of Recharge Structures are more than sufficient and hence new recharge structures are not proposed to enhance the groundwater. Although feasibility of recharging the deeper User Aquifers (Aquifer Group II and III) may be explored

as they show declining water level/Piezometric Head subject to availability of surplus water to recharge. The village ponds linked with Narmada canal water can be used to construct recharge wells in the pond bed for recharging the deeper aquifer.

Table: 4 Rechargestructures.

Recharge Structures in PatanTaluka	
Tanks (No.)	80
Percolation Tanks (No.)	60
Check Dam (No.)	920
Quantity of Recharge from Percolation Tanks(@0.14 MCM)	8.4
Quantity of Recharge from Check Dams (@0.05 MCM)	46

10 Demand Side Management

As the surface water is not available to improve the supply of water, demand side management is essential.

Water use efficiency by Micro Irrigation System:

At present anareaof3516hectareiscoveredbymicro-irrigationscheme (MIS) under different crops grown in the PatanTaluka.By adding proposed area of 13501 Ha under MIS in the Taluka the irrigation draft can reduce from 152.3 MCM to 132.05 MCM with a net saving of 20.25 MCM on account of irrigation draft and the stage of groundwater extraction will also improve.

Annual Replenishable Groundwater Recharge (MCM)	151.14
Irrigation Draft (MCM)	152.30
Domestic And Industrial uses Draft (MCM)	2.22
Total Draft (MCM)	154.52
Gross Irrigated Area by GW (Ha)	30518
Area already Covered under MIS (Ha)	3516
Area Proposed under MIS* (Ha)	13501
Δ GW Requirement (m)	0.5
Irrigation Draft for MIS (MCM)	20.25
Irrigation Draft After MIS (MCM)	132.05
Total Draft after MIS (MCM)	134.27
Stage of Groundwater Extraction (%) (GWRE 2017)	102.24
Category (GWRE 2017)	Over Exploited
Stage of Groundwater Extraction (%) after MIS	88.84
Category after MIS	Semi Critical

11 Expected Benefits or outcome of the Plan

Groundwater recharge and water conservation structures on the ground are more than sufficient at present inPatanTaluka, By adopting the micro-irrigation area in the remaining area conserve the 20.25MCM of groundwater draft in the district.

With the additional recharge and water conservation interventions as proposed in the Plan, it is anticipated that with enhanced recharge and reduction in Groundwater draft, the stage of Groundwater development will reduce to 88.84% from the existing 102.24%.

12 Summary and Conclusion

Patan is one of the agriculturally, socially and economically advanced districts, situated in the northern part of Gujarat State. Regionally, it forms part of North Gujarat Region. Groundwater is the main source of irrigation water in the district catering almost 80% of the irrigation water demand.

Groundwater occurs in the alluvium system with sand of various size form the aquifers separated by clay and mixed horizons forming the aquitards. Groundwater occurs both in Phreatic as well as Semi confined to Confined condition. For the purpose of Aquifer mapping up to 300m, the different aquifer units are grouped in Aquifer Group I, II and III. Aquifer group I is unconfined aquifer whereas Aquifer Group II is semi confined to Confined and Aquifer Group III is confined in Nature. These aquifer groups are regionally extensive and form prolific aquifer system in the district.

Salinity in the groundwater is the major issue in the district. The groundwater quality is fresh in the Aquifer Group I of the Taluka. Aquifer group II and III have relatively brackish quality in the eastern and northern part of the taluka which gradually deteriorates towards Southern and western part.

The Aquifer Group I in eastern parts is desaturated at many places but shows stabilised water level due to the recharge activities and introduction of narmada water for irrigation as wells as Unlined SujalamSufalam Canal passing through PatanTalukawhere many shallow piezometers show rising trend.

Aquifer Group II and III are tapped by irrigation tubewells and there is declining water level trend in most of the piezometers representing these aquifer groups.During last 20 years fall of 2m to 45m in Piezometers tapping Aquifer Group II and fall of 13 to 56m in Pz tapping Aquifer Group III is observed.

A number of activities for augmenting groundwater resources has been done with construction of check dams (920nos), deepening of village ponds (80 nos.), Percolation tanks (60 nos.) and interlinking of ponds with the canals and pipeline.

The Taluka has erratic rainfall and there is very limited non committed surplus runoff to harness as the recharge capacity of the structures on the ground are more than required.

Attention has to be given to recharging the deeper aquifers as these are the main source of irrigation water and are heavily pumped, but there is paucity of source water for recharging.

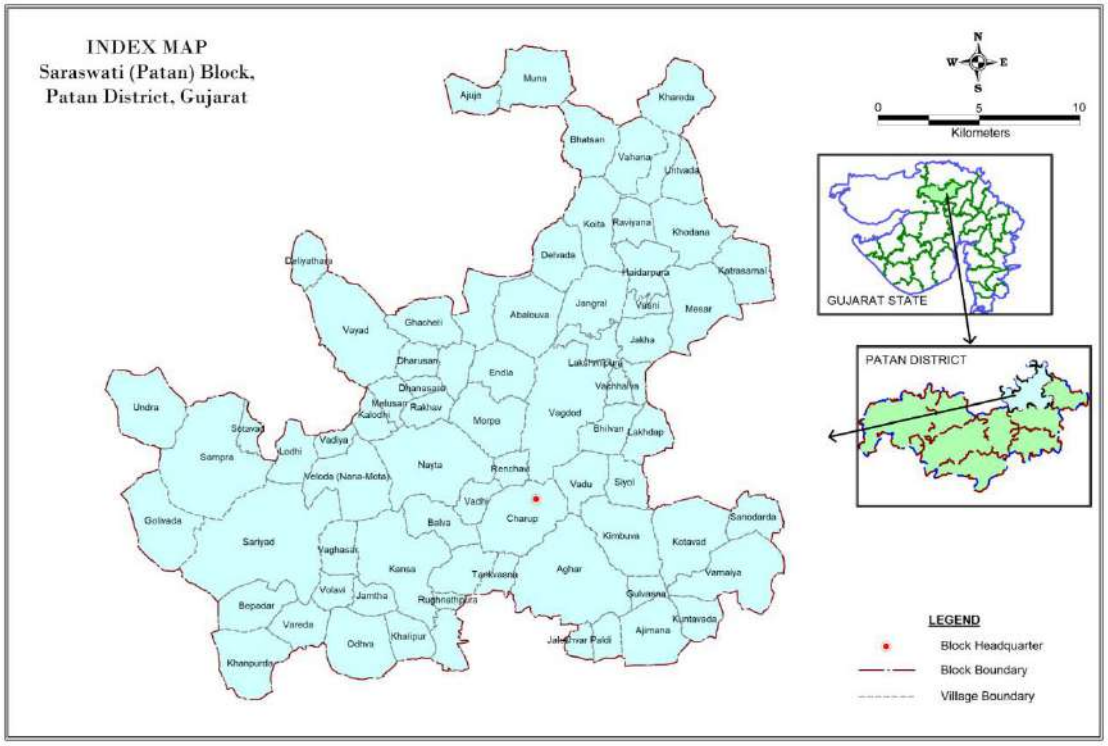
Focus has to be shifted to saving of water through Micro irrigation techniques as

in the traditional flooding method a lot of water is wasted.

As there is little scope of creating additional recharge structures it is recommended to increase the area under micro irrigation to about 13501 Ha which may reduce the irrigation draft by 20.25 MCM And turn the Taluka from Over Exploited to Semi Critical Category.

MANAGEMENT PLAN OF
SARASWATI TALUKA, PATAN DISTRICT, GUJARAT STATE

Geographical Area	551.86 sq. km
No. of Town, villages	0, 76
Population (2011 Census)	213087
Average Annual Rainfall	620 mm- Monsoon Rainfall (IMD) (Long Term 50 years) 666 mm Average Monsoon Rainfall (2008-17)
Range of Average Temperature	21-31 °C
Major Drainage System	Saraswati
Major/ Medium Irrigation Scheme	
Major Geological Formation	Alluvium
Major Aquifer	Sand, Silt, Gravel
Utilizable Groundwater Resources (2017)	Fresh: 73.61 MCM
Net Groundwater Draft	Fresh: 66.73 MCM
Stage of Groundwater Development	90.65% (Critical)
Fresh Instorage Groundwater resources	1904 MCM
Artificial Recharge and Water conservation structures under different schemes by various department in Gujarat	Check Dams – 605 Percolation Tanks – 64 Tanks - 85
Minor irrigation structures	Deep Tubewells: 1011 Dug wells:385
Agriculture (2015-16)	Crop Area (sq.km.) Total Grains 111.3 Total Pulses 12.6 Total Oil crops 212 Vegetables 6.5 Cumin 0.9 Cotton 53.75 Fodder 186.7
Existing and future water demands (MCM)	Sector / Existing / Future (Year 2025) Domestic and Industrial / 2.92 / 3.25 Irrigation / 63.82 / 0.00



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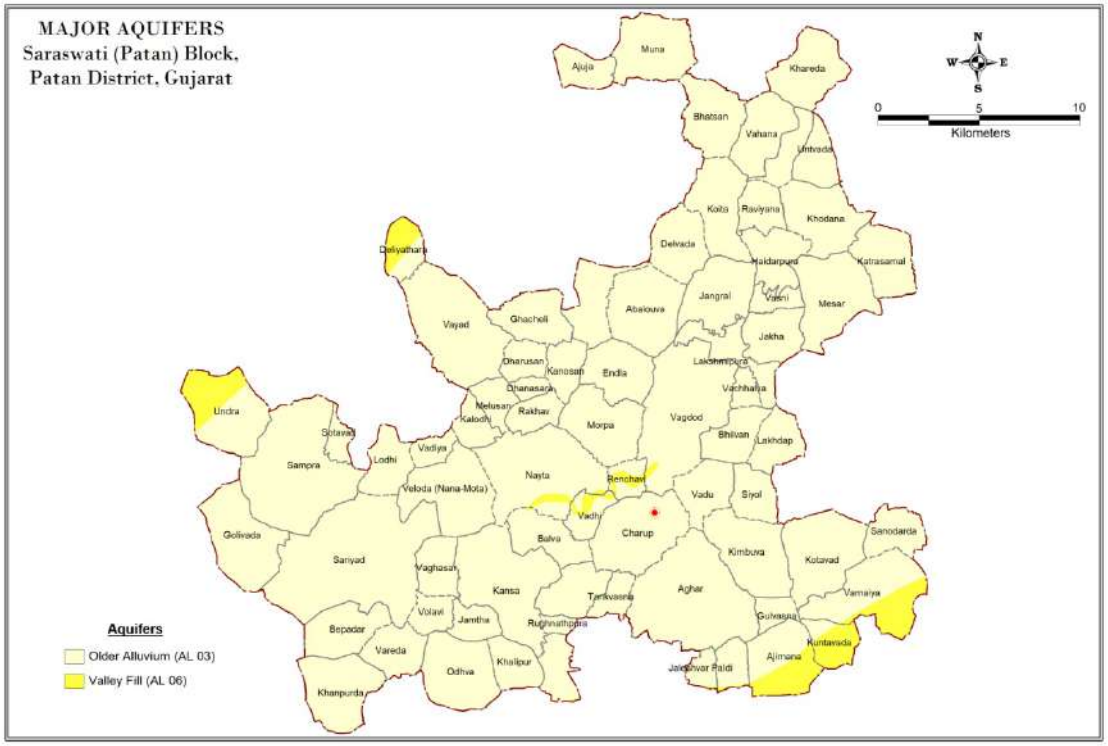

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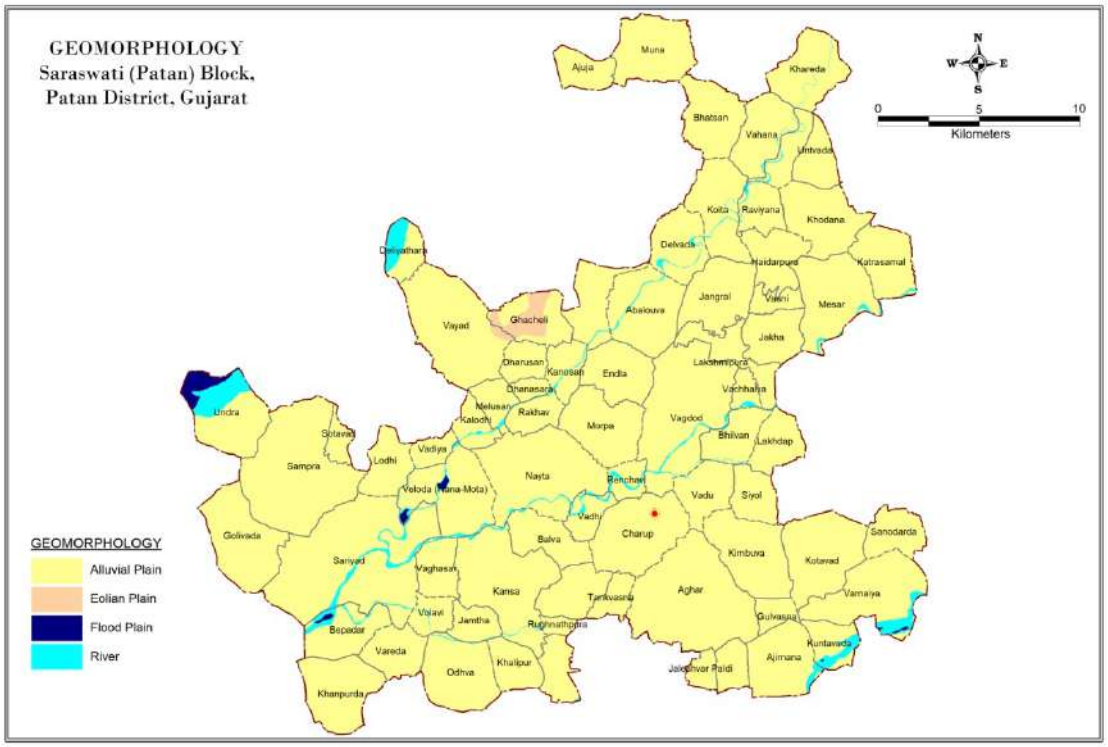

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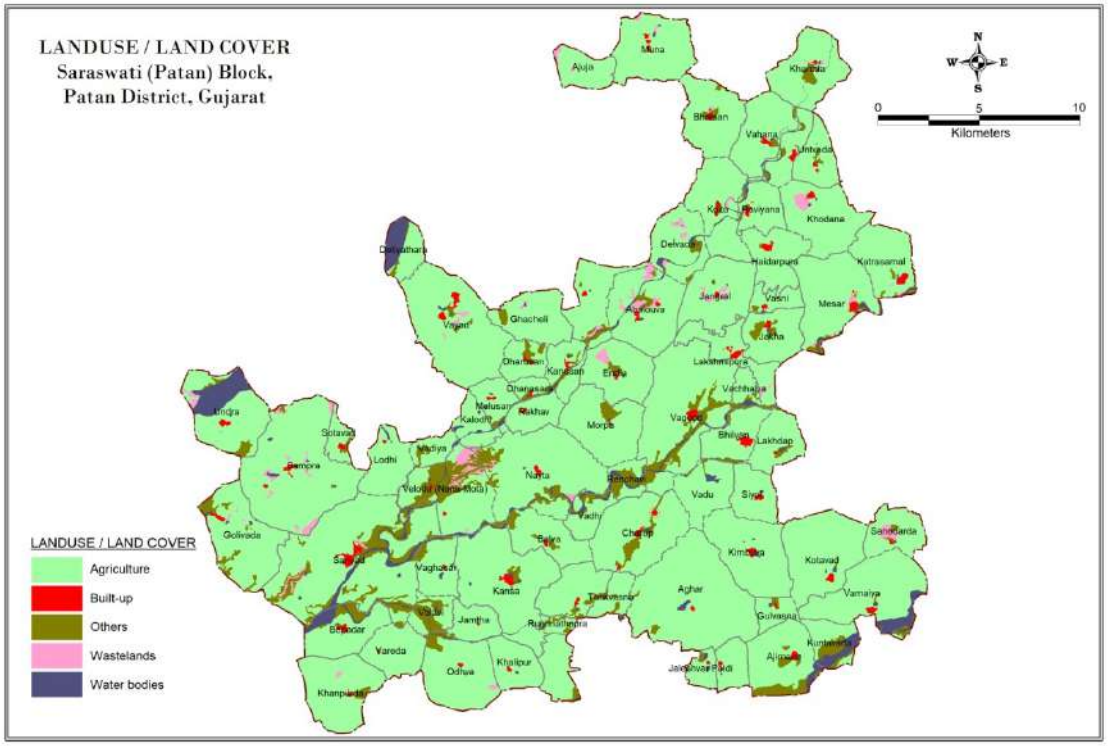

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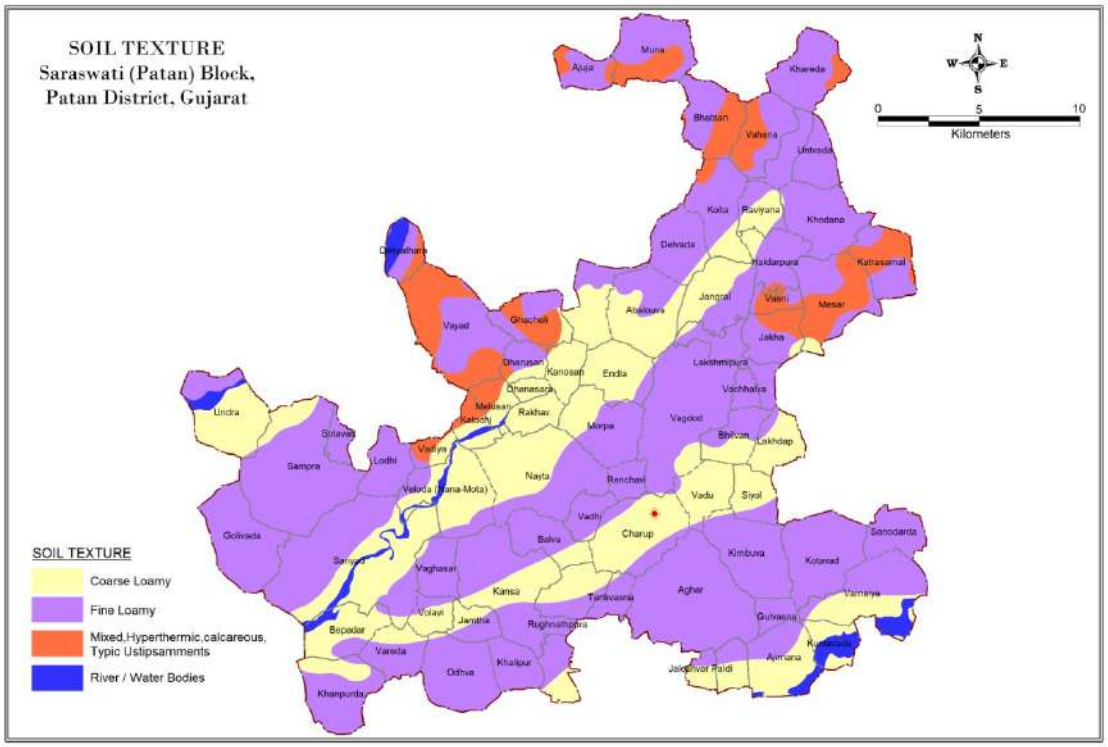

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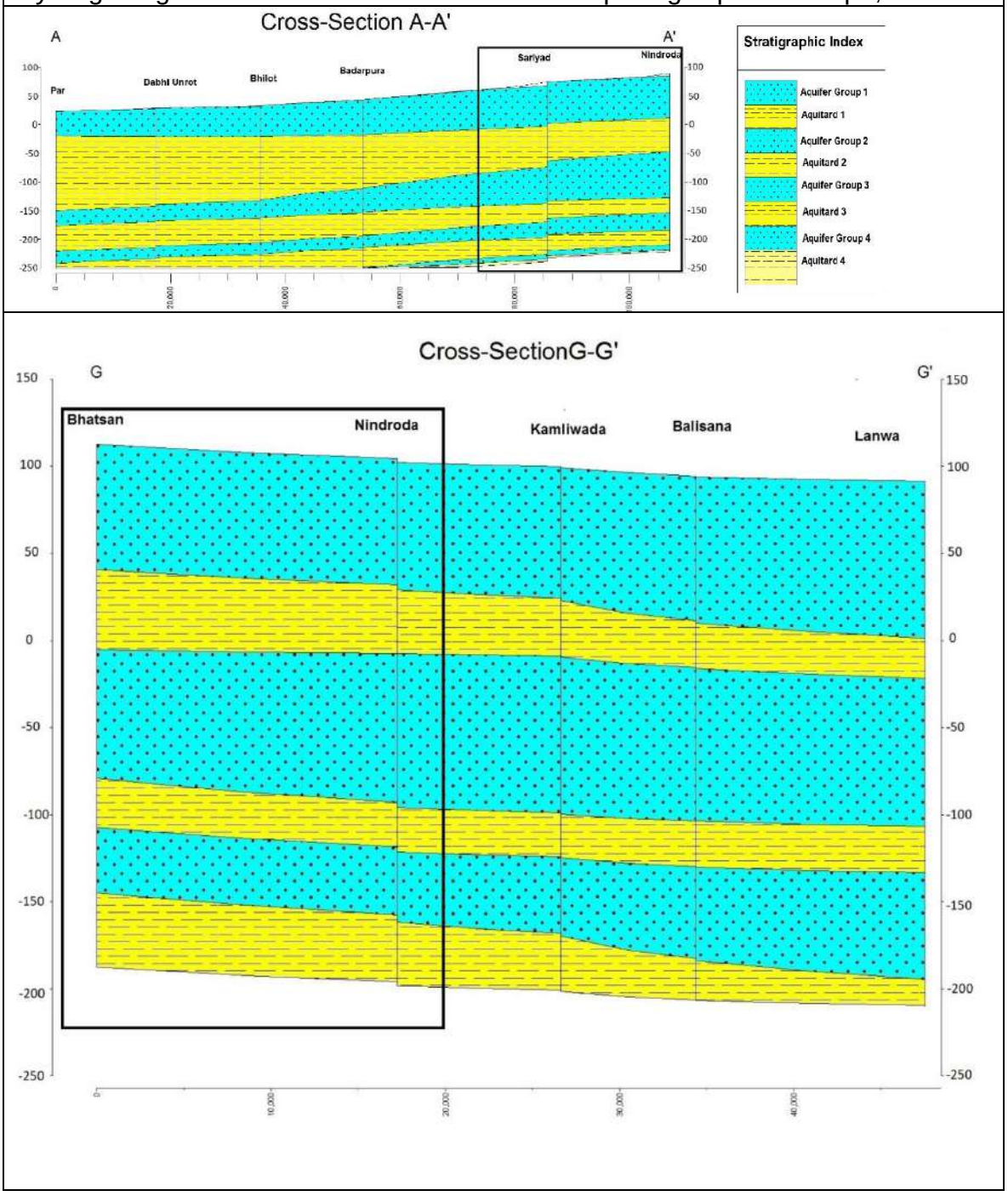

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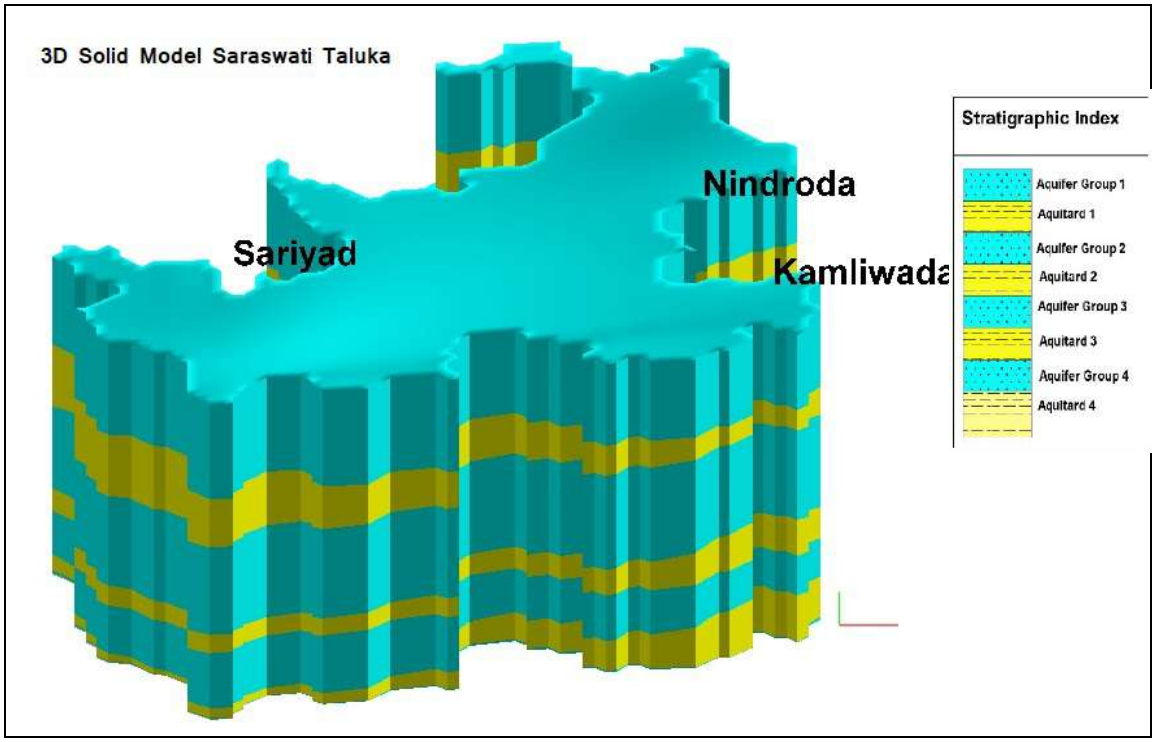

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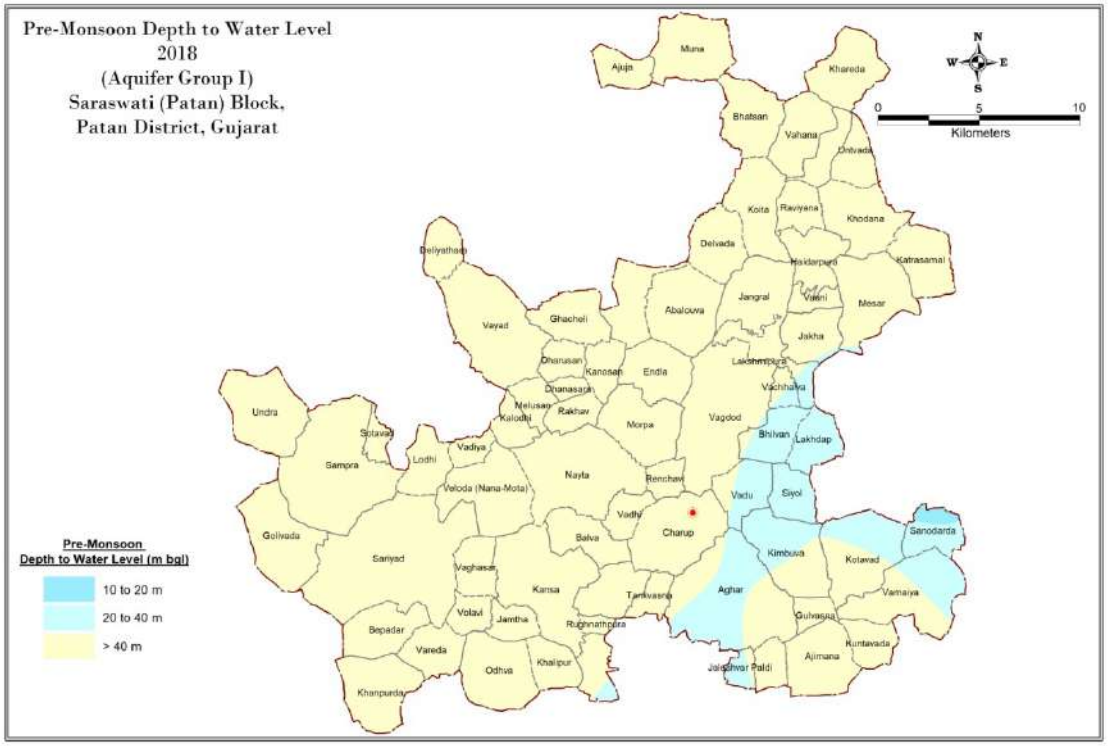
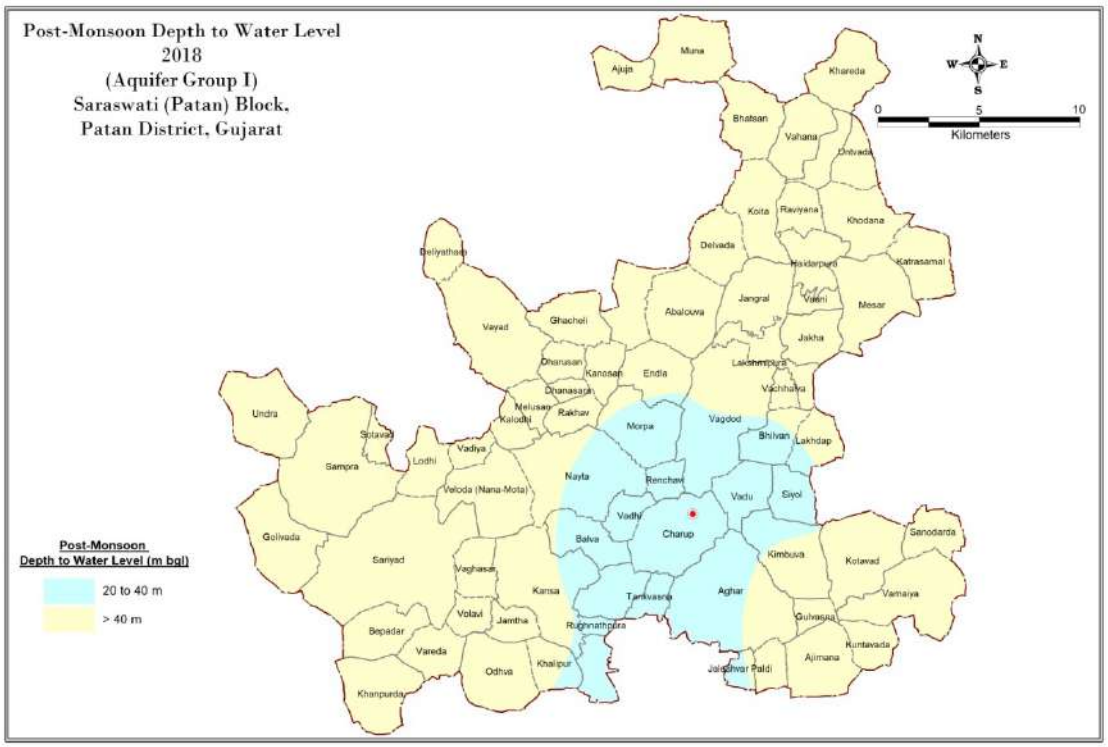
Aquifer-II	190-210	15-90	600-1200	1000->10000	75-150	Whole Taluka	Semi Confined/ Confined
Aquifer-III	290-300	20-80	600-1200	1190-3000	112.08-175	Whole Taluka	Confined

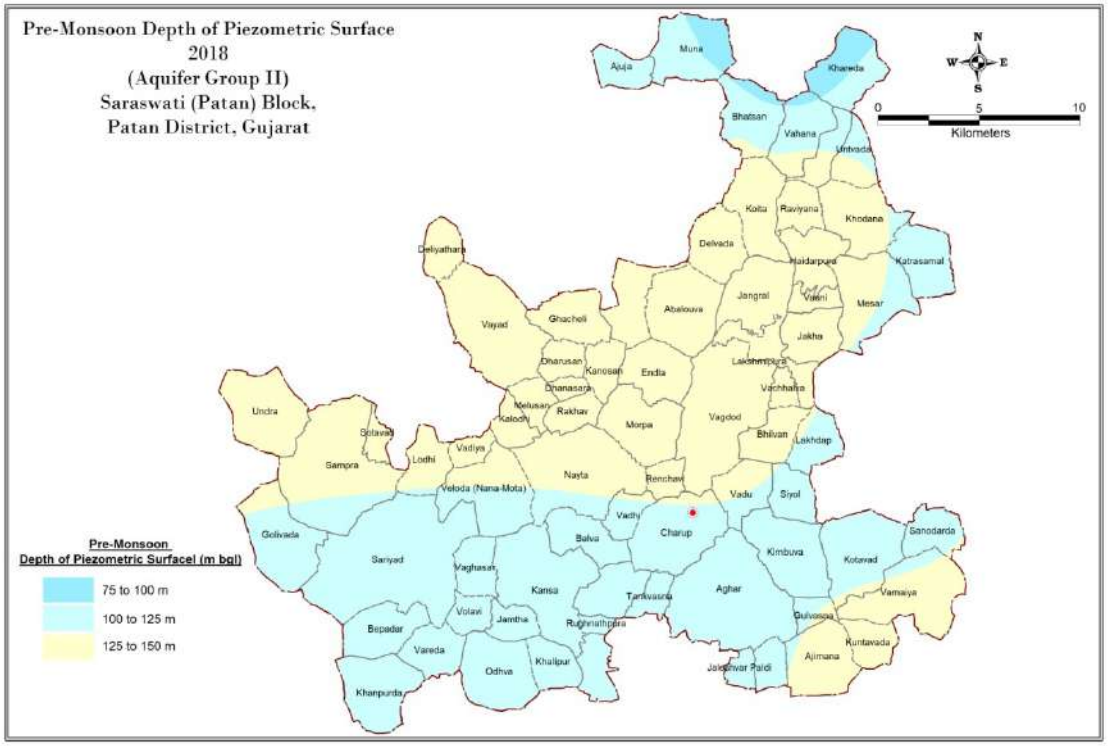
Aquifer Group wise Water Level Maps of Saraswati Taluka



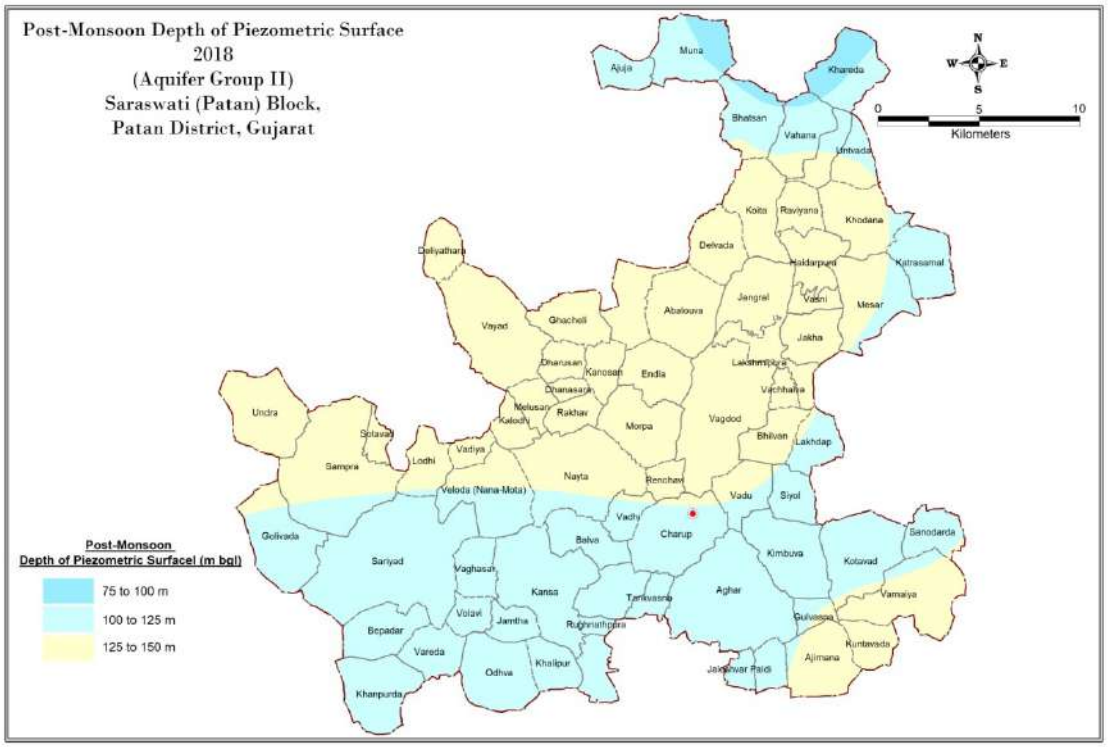
Pre Monsoon Depth to Water Level Map-Aquifer Group I



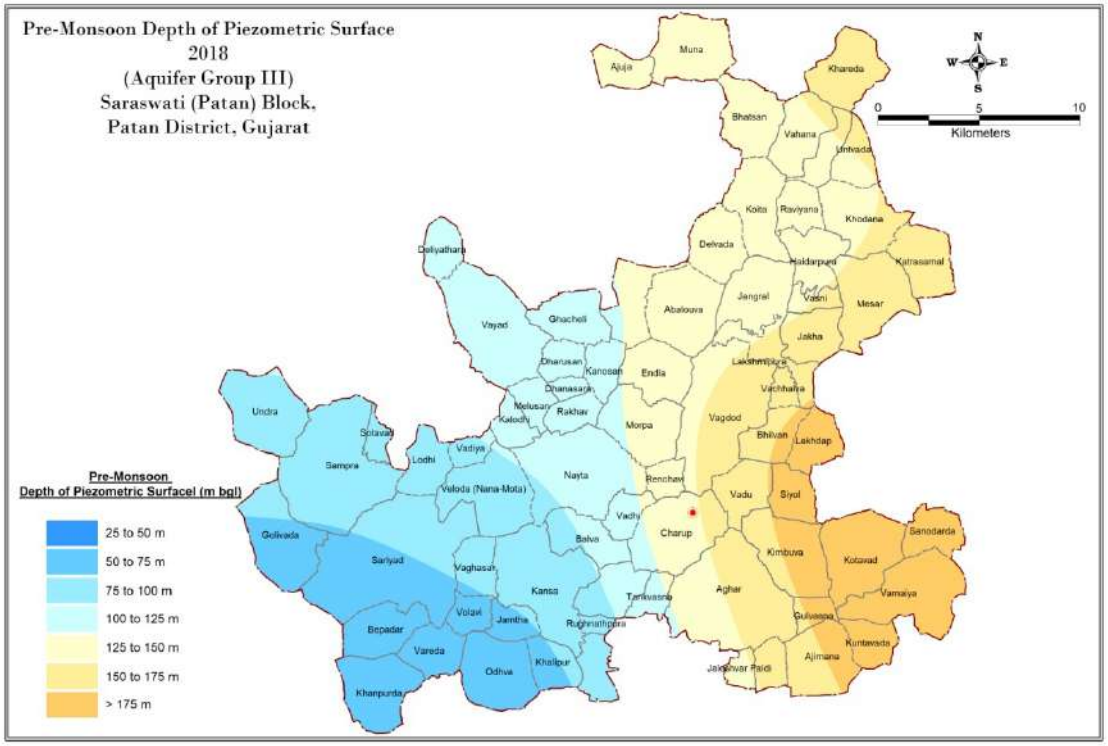
Post Monsoon Depth to Water Level Map-Aquifer Group I



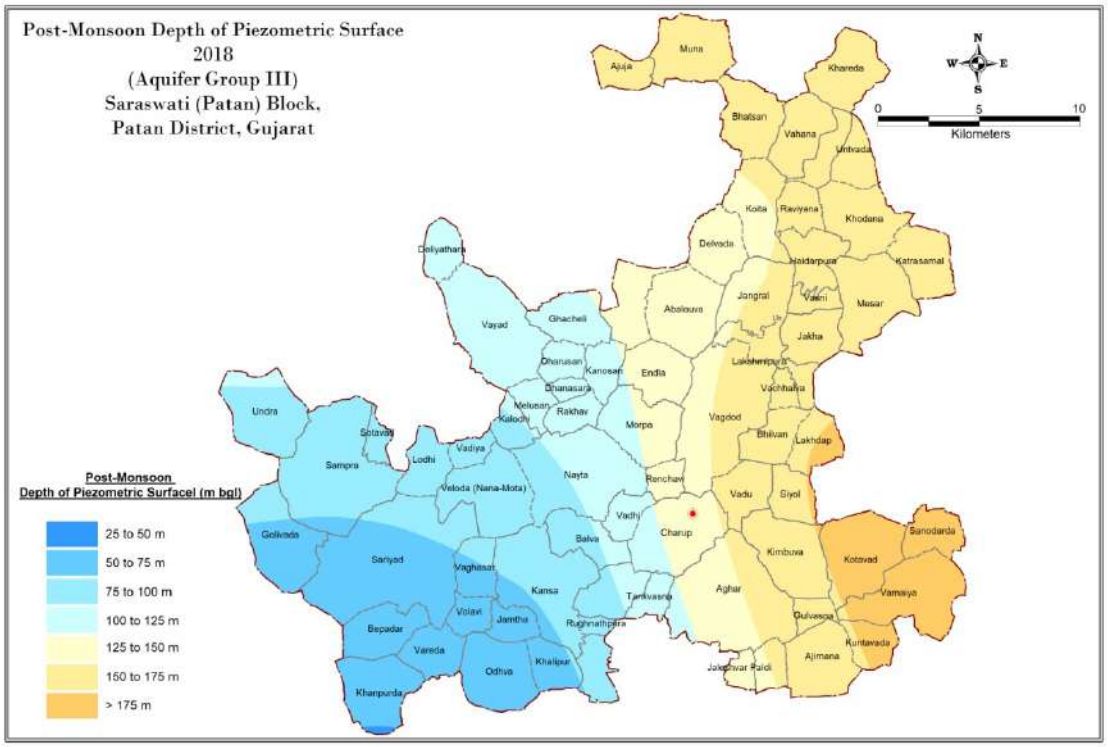
Pre Monsoon Depth to Water Level Map-Aquifer Group II



Post Monsoon Depth to Water Level Map-Aquifer Group II



Pre Monsoon Depth to Water Level Map-Aquifer Group III



Post Monsoon Depth to Water Level Map-Aquifer Group III

4 Groundwater resource extraction, contamination. Dynamic GW Resources in MCM

Total fresh groundwater availability of the area is estimated in year 2017 is 73.61 MCM and total groundwater withdrawal for all purposes is 66.73 MCM. The stage of groundwater development is 90.65%andthetalukaiscategorized“Critical”.

Table: 2 Dynamic Groundwater resources 2017

S No	Item	Fresh	Saline
1	Area	247.75	304.11
2	Total GW Recharge	77.49	128.60
3	Net GW Availability	73.61	122.17
4	Gross Draft	66.73	73.18
5	Net Availability for Future Irrigation	0.00	48.77
6	Stage of GW Development	90.65	59.90

Aquifer Group wise Fresh Groundwater Resources upto 300 m depth are given below in table

In Storage GW Resources (Fresh, MCM)

Aquifer Group I	381
Aquifer Group II	381
Aquifer Group III	1142
In-Storage Groundwater	1904
Annual Replenishable Groundwater	74
Total Availability of Fresh Groundwater Resources	1978

In Storage GW Resources (Saline, MCM)

Aquifer Group I	120
Aquifer Group II	95
Aquifer Group III	138
In-Storage Groundwater	353
Annual Extractable Groundwater Resources	122
Total Availability of Saline Groundwater Resources	475

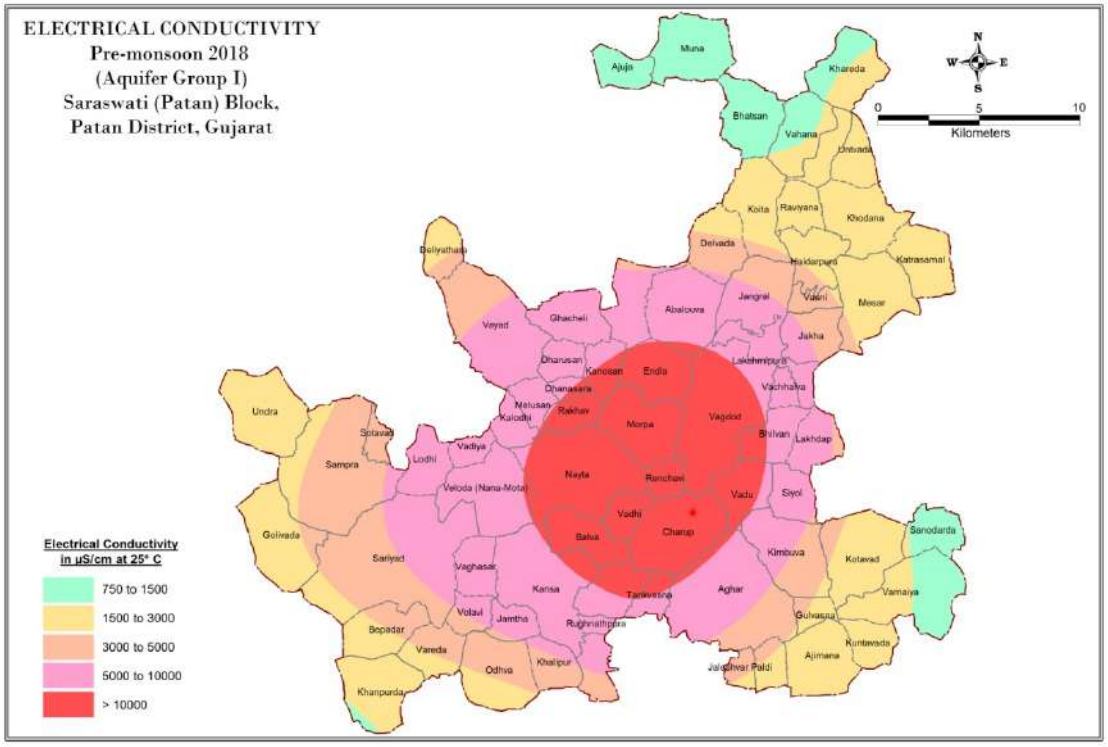
Total Groundwater Resources of Chanasma Taluka

In-Storage Groundwater	Fresh	1904
	Saline	353
Annual Extractable Groundwater Resources	Fresh	74
	Saline	122
Total Availability of Groundwater Resources	Fresh	1978
	Saline	475

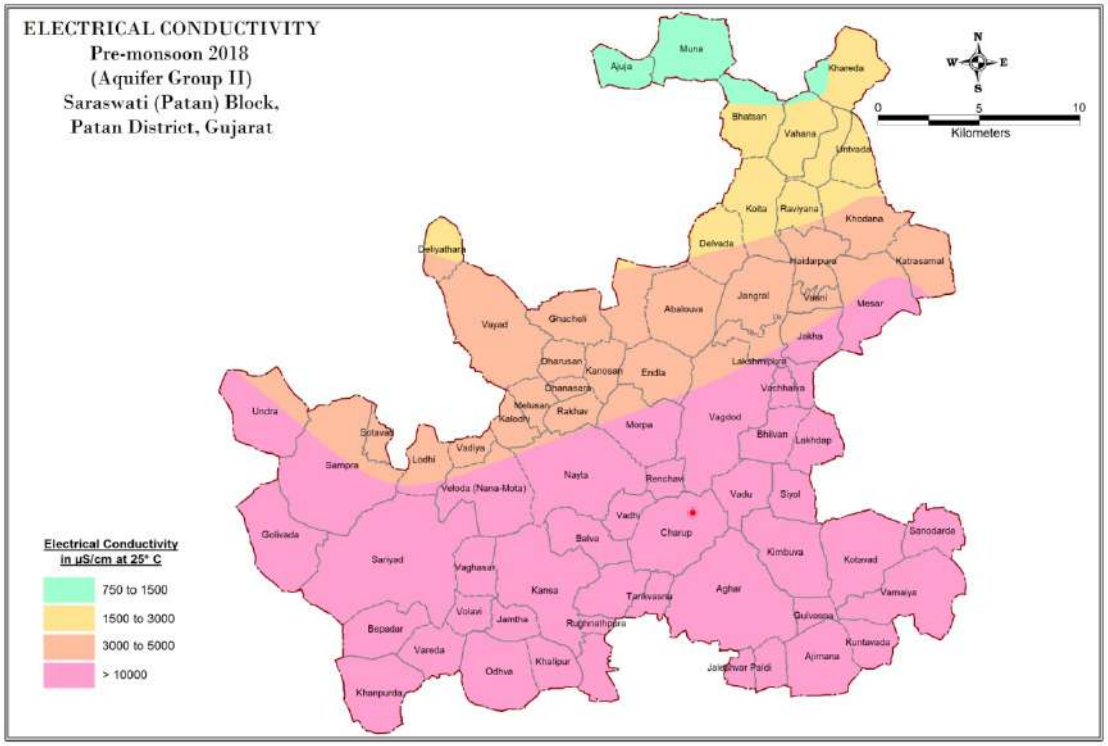
5 Chemical quality of groundwater

Groundwater quality is one of the major issues in the area. The taluka has both fresh water and Brackish groundwater considered for Dynamic Groundwater Resource Assessment however brackish water in the phreatic aquifer is reported

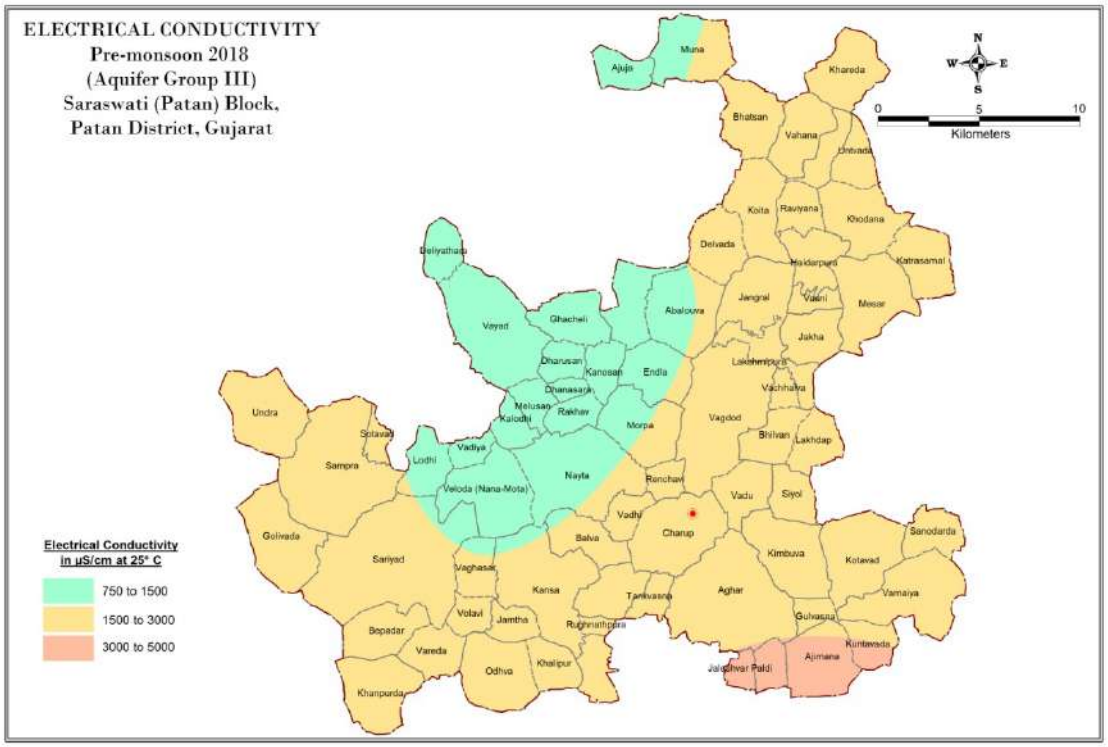
in Central and western part of the taluka with EC morethan3000µS/cm.As per Water Quality map for Aquifer Group II is brackish to saline in southern and western part of the taluka and is entirely fresh in the Aquifer Group III.Water Quality map for Aquifer Group II and III are prepared based on the water quality data of State Govt. Groundwater samples from Piezometers were collected by Grab method without purging the Wells hence the maps are debatable.Aquifer Group wise Water Quality Maps of Saraswati Taluka is presented below.



Pre Monsoon Electrical Conductivity Map-Aquifer Group I

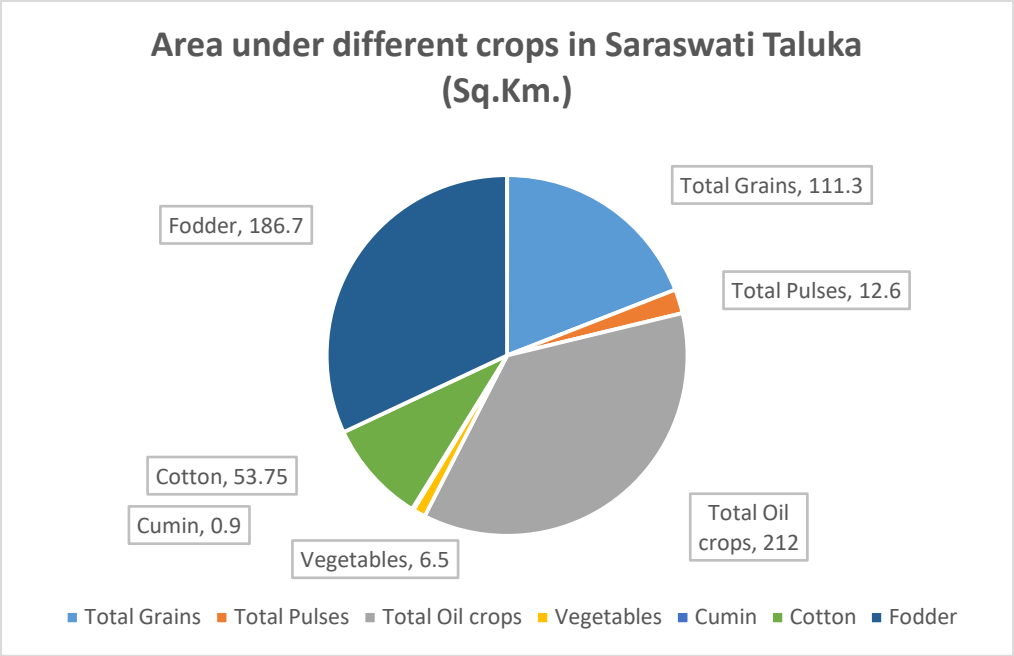


Pre Monsoon Electrical Conductivity Map-Aquifer Group II



Pre Monsoon Electrical Conductivity Map-Aquifer Group III

6 Cropping Pattern

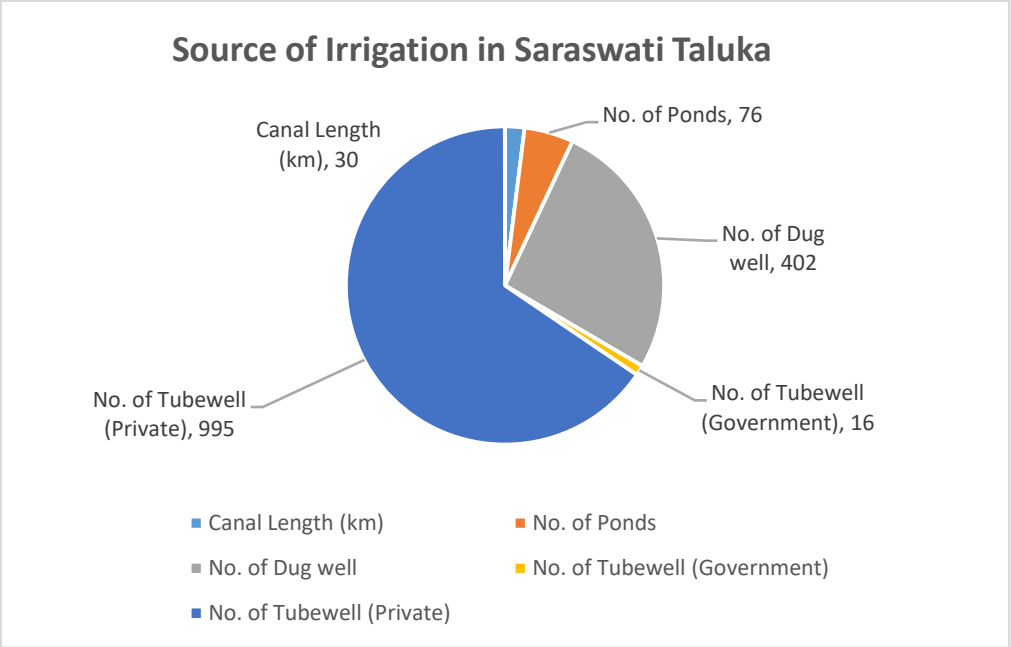


7 Irrigation

Source-wise Irrigation in Saraswati Taluka			
Length Of Canal (km)	Govt.		30
	Private		0
Borewell (Nos.)	Govt.		16
	Private		995
Only Irrigation Dug well (Nos.)	Govt.	Lined	0
		Unlined	0
	Private	Lined	385
		Unlined	6
Dug Well Not In Use (Nos.)			1967
Water Bodies Other Than Ponds			0
Dug wells For Domestic Use Only (Nos.)			99
Pond (Nos.)	Irrigation More Than 50 Ha		0
	Irrigation Less Than 50 Ha		0
Oil Engine (Nos.)			500
Electric Motor (Nos.)			375

Source-wise Irrigated Area in Saraswati Taluka	
Net Irrigated Area (Sq. Km.)	304.6
% Of Net Irrigated Area Against Gross Cropped area	84.07
Govt. Canal (No.)	1

Length (km)	30
Private /Panchayat Canal	0
Pond (No.)	76
Dug Well (No.)	402
Tube Well (No.)	1394
Area irrigated More than once (Sq. Km.)	179.85
Gross Irrigated Area (Sq. Km.)	484.45



8 Groundwater Issues

Traditional agricultural /irrigation practices, flood irrigation practices, increase in water demand, irrigation practices based on power supply. Farmers irrigate the crops when power supply is available rather than waiting for the wilting to start. Following are the issues identified for aquifer management in the area:

- Arid/Semi arid area
- High rate of Evapotranspiration
- Limited availability of surface water resources
- Over exploitation of ground water
- Decline in Groundwater levels
- De saturation of Phreatic aquifers
- Deeper Piezometric head of Confined Aquifer-III Decline in Piezometric heads of semi confined/confined aquifer
- Increase in well depth as water levels become deeper
- Increase in depth of prime mover/pump setting
- Decline in well yields
- Lack of awareness and involvement of stakeholders in decision making

9 Groundwater Management

Supply side Management: Recharging capacity through the number of Recharge Structures are more than sufficient and hence new recharge structures are not proposed to enhance the groundwater. Although feasibility of recharging the deeper User Aquifers (Aquifer Group II and III) may be explored as they show declining water level/Piezometric Head subject to availability of surplus water to recharge. The village ponds linked with Narmada canal water can be used to construct recharge wells in the pond bed for recharging the deeper aquifer.

Table: 4 Rechargestructures.

Recharge Structures in Saraswati Taluka	
Tanks (No.)	76
Percolation Tanks (No.)	64
Check Dam (No.)	605
Quantity of Recharge from Percolation Tanks(@0.14 MCM)	8.96
Quantity of Recharge from Check Dams (@0.05 MCM)	30.25

10 Demand Side Management:

As the surface water is not available to improve the supply of water, demand side management is essential.

Water use efficiency by Micro Irrigation System:

At present an area of 1611 ha is covered by micro-irrigation scheme (MIS) under different crops grown in the Saraswati Taluka. By adding proposed area of 18573 Ha under MIS in the Taluka the irrigation draft can reduce from 63.82 MCM to 35.96 MCM with a net saving of 27.86MCM on account of irrigation draft and the stage of groundwater extraction will also improve.

Annual Extractable Groundwater Recharge (MCM)	73.61
Irrigation Draft (MCM)	63.82
Domestic And Industrial uses Draft (MCM)	2.92
Total Draft (MCM)	66.73
Gross Irrigated Area by GW (Ha)	38756
Area already Covered under MIS (Ha)	1611
Area Proposed under MIS* (Ha)	18573
Δ GW Requirement (m)	0.5
Irrigation Draft for MIS (MCM)	27.86
Irrigation Draft After MIS (MCM)	35.96
Total Draft after MIS (MCM)	38.88
Stage of Groundwater Extraction (%) (GWRE 2017)	90.65
Category (GWRE 2017)	Critical
Stage of Groundwater Extraction (%) after MIS	52.82
Category after MIS	Safe

11 Expected Benefits or outcome of the Plan

Groundwater recharge and water conservation structures on the ground are more than sufficient at present in Saraswati Taluka, By adopting the micro-irrigation area in the remaining area conserve the 27.86 MCM of groundwater draft in the district.

With the additional recharge and water conservation interventions as proposed in the Plan, it is anticipated that with enhanced recharge and reduction in Groundwater draft, the stage of Groundwater development will reduce to 52.82% from the existing 90.65%.

12 Summary and Conclusion

Saraswati is one of the agriculturally, socially and economically advanced districts, situated in the northern part of Gujarat State. Regionally, it forms part of North Gujarat Region. Groundwater is the main source of irrigation water in the district catering almost 80% of the irrigation water demand.

Groundwater occurs in the alluvium system with sand of various size form the aquifers separated by clay and mixed horizons forming the aquitards. Groundwater occurs both in Phreatic as well as Semi confined to Confined condition. For the purpose of Aquifer mapping up to 300m, the different aquifer units are grouped in Aquifer Group I, II and III. Aquifer group I is unconfined aquifer whereas Aquifer Group II is semi confined to Confined and Aquifer Group III is confined in Nature. These aquifer groups are regionally extensive and form prolific aquifer system in the district.

The groundwater quality is variable in the taluka. The groundwater quality is fresh in the Aquifer Group Iin the periphery of the Taluka and central part is saline. Aquifer group II has brackish to saline water water in the taluka except few areas in the northern part. Aquifer Group III have fresh groundwater in all the villages.

The Aquifer Group I in desaturated at many places and water level is more than 40mbgl, shallow water level of 20-40mbgl is observed in South eastern part of the Taluka.

Piezometric head/Water level in Aquifer Group IIis deep in northern part with observed head more than 125mbgl; in Central and South Eastern part observed head is 100-125mbgl.

Piezometric head in Aquifer Group IIIis deep in eastern and northern part with observed head between 125-175mbgl; in western part observed head is 50-125mbgl.

Aquifer Group II and III are tapped by irrigation tubewells and there is declining water level trend in most of the piezometers representing these aquifer groups. During last 20 years fall of 2m to 45m in Piezometers tapping Aquifer Group II and fall of 13 to 56m in Pz tapping Aquifer Group III is observed.

A number of activities for augmenting groundwater resources has been done with construction of check dams (605 nos), deepening of village ponds (76 nos.),

Percolation tanks (64 nos.) and interlinking of ponds with the canals and pipeline.

The Taluka has erratic rainfall and there is very limited non committed surplus runoff to harness as the recharge capacity of the structures on the ground are more than required.

Attention has to be given to recharging the deeper aquifers as these are the main source of irrigation water and are heavily pumped, but there is paucity of source water for recharging.

Focus has to be shifted to saving of water through Micro irrigation techniques as in the traditional flooding method a lot of water is wasted.

As there is little scope of creating additional recharge structures it is recommended to increase the area under micro irrigation to about 18573 Ha which may reduce the irrigation draft by 27.86 MCM and turn the Taluka from Critical to Safe Category.

MANAGEMENT PLAN OF
SIDHPUR TALUKA, PATAN DISTRICT, GUJARAT STATE

<table>
<tr><td>Geographical Area</td><td>374.78 sq. km</td></tr>
<tr><td>No. of Town, villages</td><td>1, 55</td></tr>
<tr><td>Population (2011 Census)</td><td>213087</td></tr>
<tr><td>Average Annual Rainfall</td><td>668 mm- Monsoon Rainfall (IMD) (Long Term 50 years)
767 mm -Average Monsoon Rainfall (2008-17)</td></tr>
<tr><td>Range of Average Temperature</td><td>21-31 °C</td></tr>
<tr><td>Major Drainage System</td><td>Saraswati</td></tr>
<tr><td>Major/ Medium Irrigation Scheme</td><td></td></tr>
<tr><td>Major Geological Formation</td><td>Alluvium</td></tr>
<tr><td>Major Aquifer</td><td>Sand, Silt, Gravel</td></tr>
<tr><td>Utilizable Groundwater Resources (2017)</td><td>Fresh: 150.41 MCM</td></tr>
<tr><td>Net Groundwater Draft</td><td>Fresh: 156.17 MCM</td></tr>
<tr><td>Stage of Groundwater Development</td><td>103.83% (Over Exploited)</td></tr>
<tr><td>Fresh In storage groundwater resources</td><td>1799 MCM</td></tr>
<tr><td>Artificial Recharge and Water conservation structures under different schemes by various department in Gujarat</td><td>Check Dams – 789
Percolation Tanks – 26
Tanks - 26</td></tr>
<tr><td>Minor irrigation structures</td><td>Deep Tubewells: 735
Dug wells:1580</td></tr>
<tr><td>Agriculture (2015-16)</td><td><table><tr><td colspan="2">Crop Area (sq.km.)</td></tr><tr><td>Total Grains</td><td>73.5</td></tr><tr><td>Total Pulses</td><td>41.25</td></tr><tr><td>Total Oil crops</td><td>120.5</td></tr><tr><td>Vegetables</td><td>8</td></tr><tr><td>Cumin</td><td>3.7</td></tr><tr><td>Cotton</td><td>23.75</td></tr><tr><td>Fodder</td><td>127.2</td></tr></table></td></tr>
<tr><td>Existing and future water demands (MCM)</td><td><table><tr><td>Sector</td><td>Existing (MCM)</td><td>Future (MCM) (Year 2025)</td></tr><tr><td>Domestic and Industrial</td><td>3.49</td><td>3.88</td></tr><tr><td>Irrigation</td><td>152.69</td><td>0.00</td></tr></table></td></tr>
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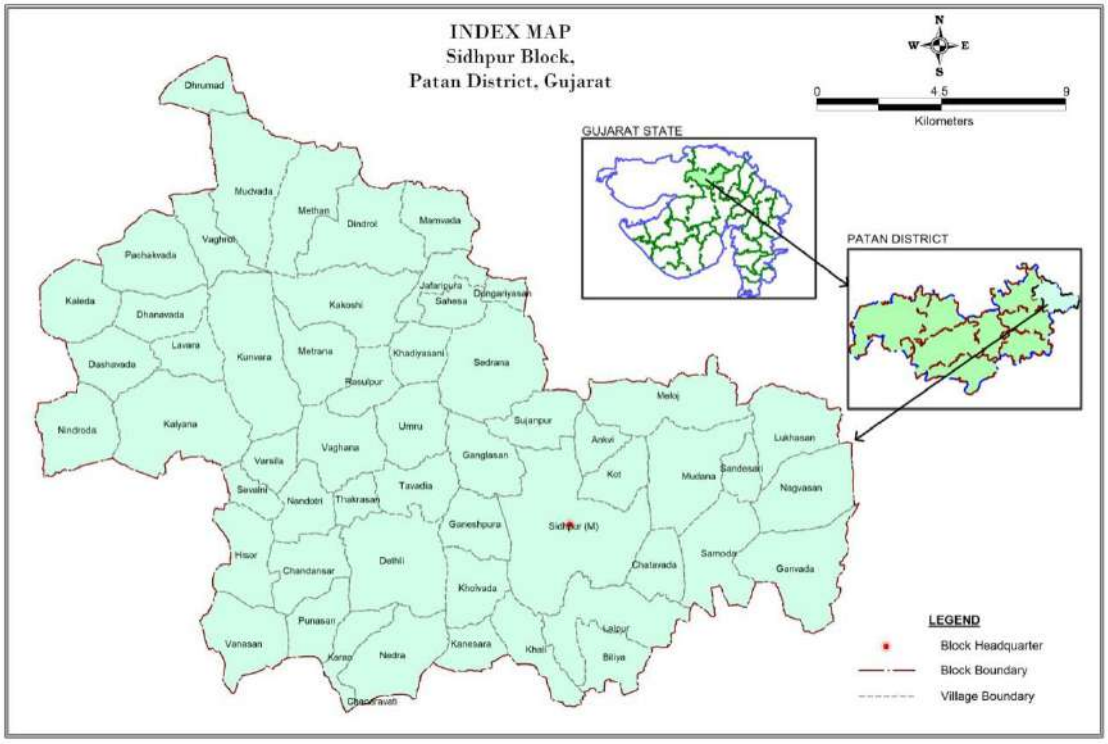


Figure 1. Location Map

1 Land Use Classification

Sidhpur Taluka (Area in Sq. Km.)	
Area according to village papers	382.34
Area under Forest	0
Land not available for cultivation	35.75
Other uncultivable land excluding fallow	46.68
Fallow land	5.38
Net area sown	253.65
Area sown more than once	173.4
Gross cropped area	427.05
Cropping intensity	168

2 Hydrogeology

Alluvial formations form aquifers in the area (Fig.2) namely Sand of various sizes and Gravel. The groundwater quality is saline at shallow depths and there is wide variation in quality regionally.

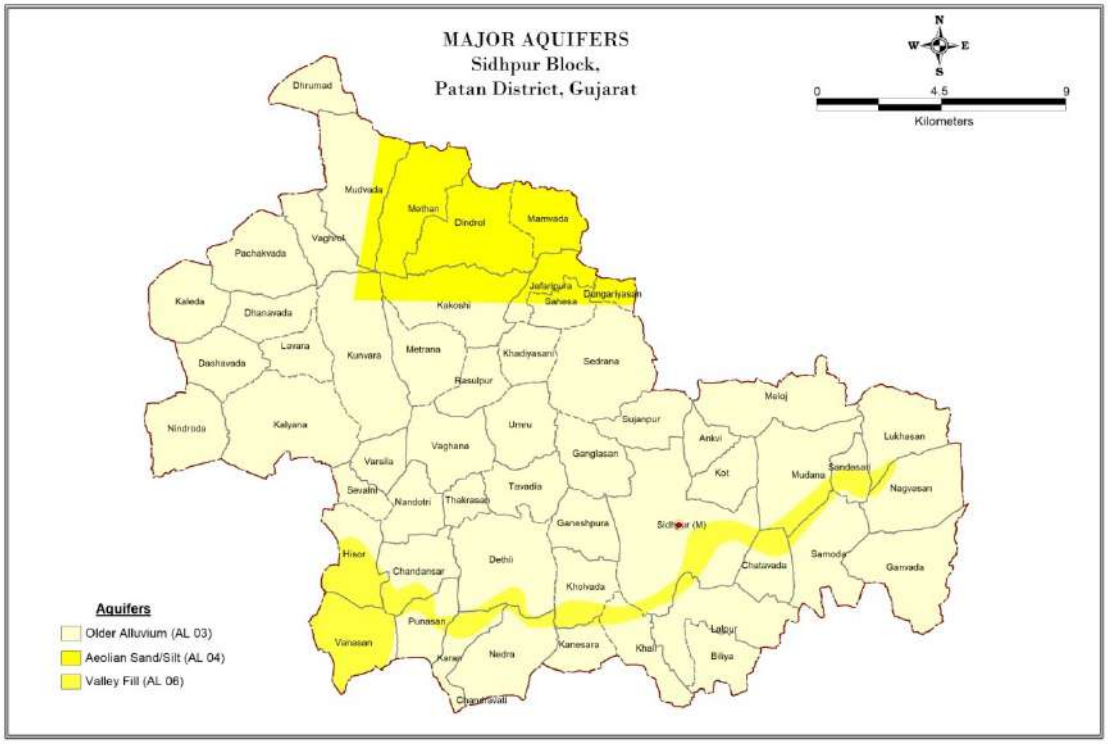


Fig.2: Major Aquifer

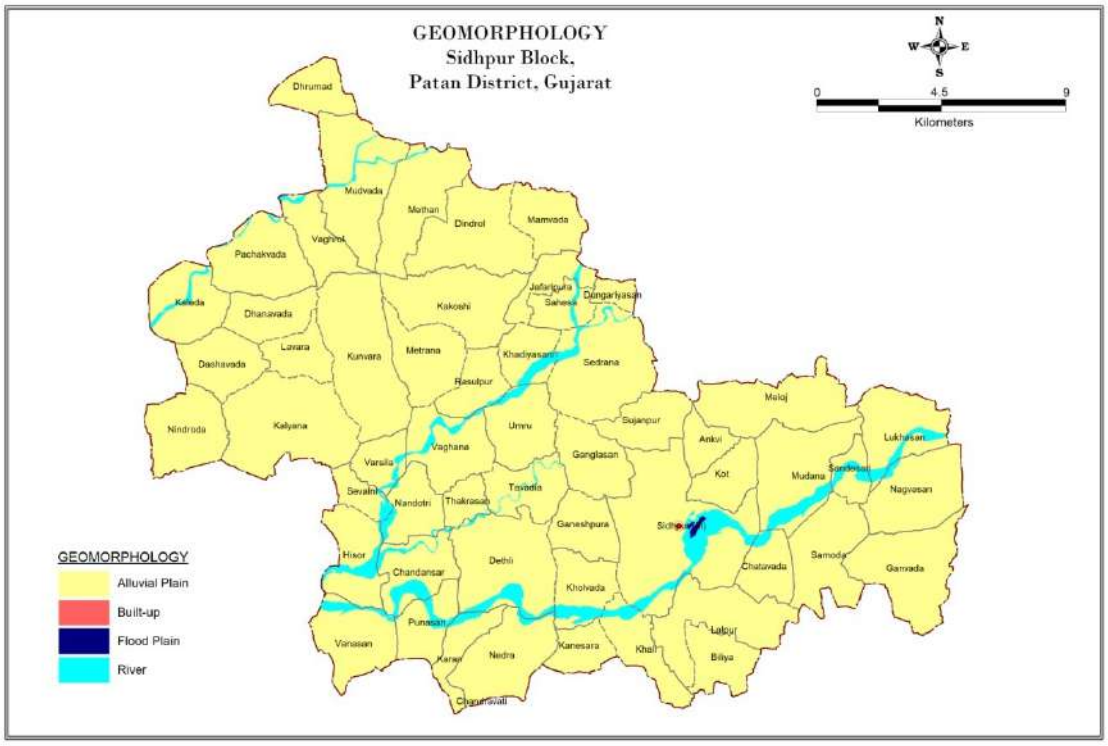


Fig. 3: Geomorphology

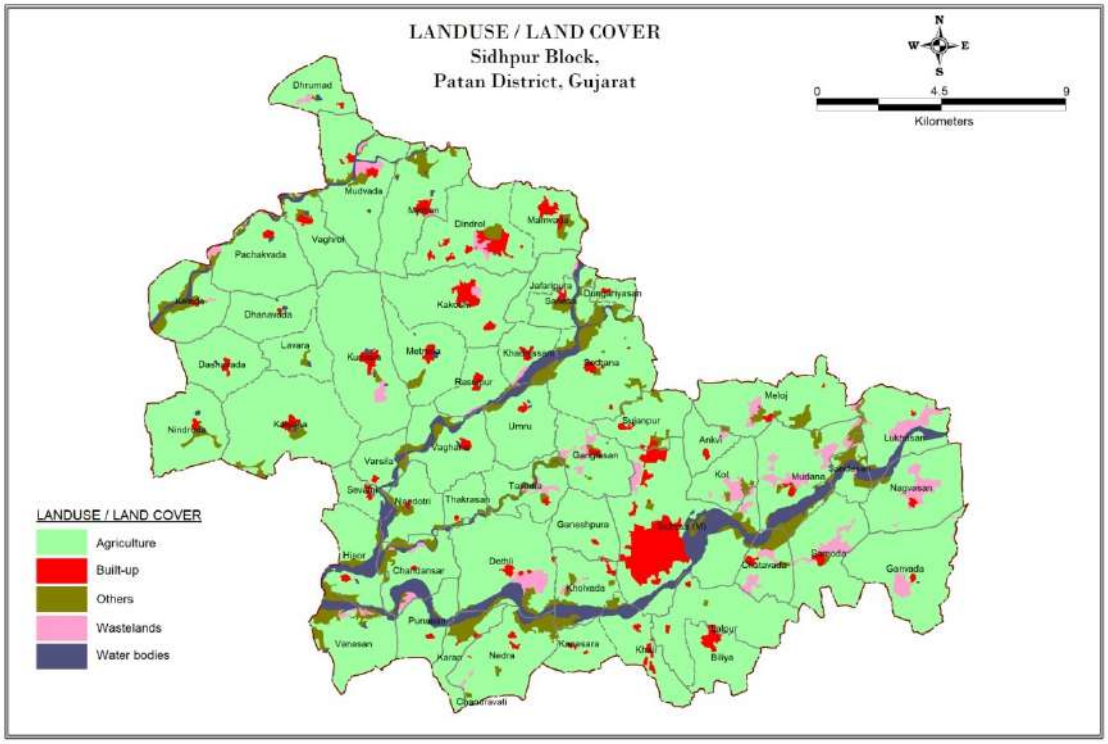


Fig 4: Land Use Land Cover

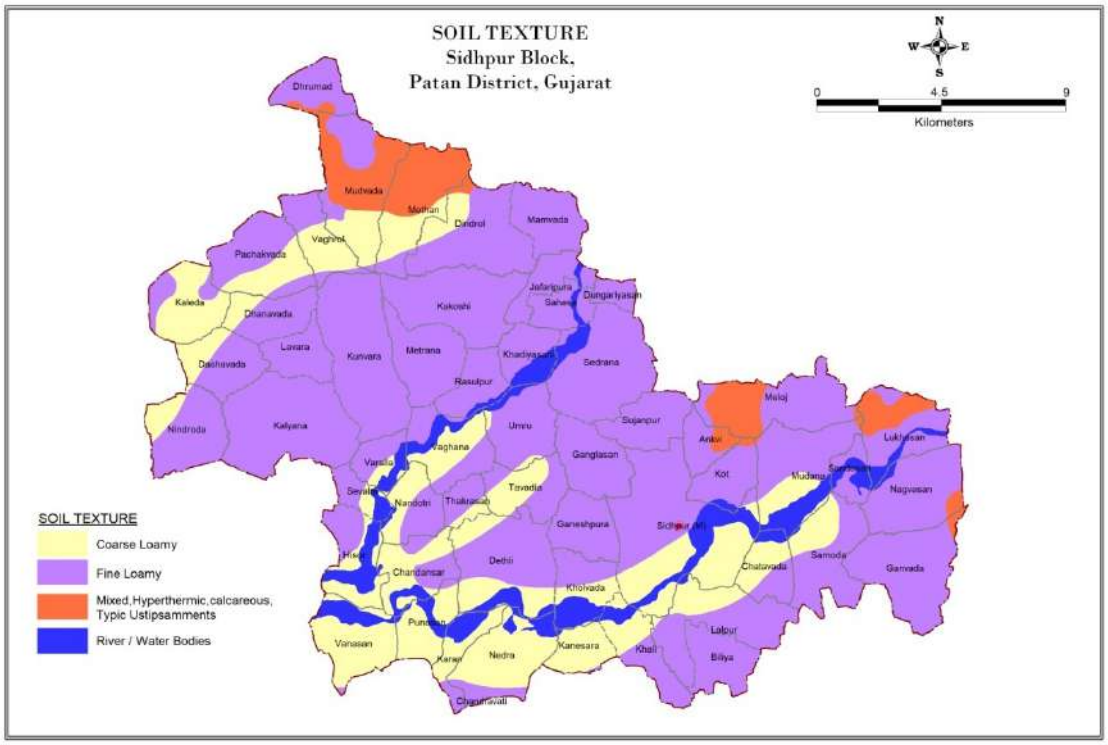


Fig 5: Soil Type

3 Subsurface Hydrogeology

As inferred from borehole data of the Sidhpur Taluka; Quarternary Alluvium forms the principal aquifer in the Taluka. The depth of drilling ranges from 61 to 450 mbgl and the discharge ranges from 1.0 to 20 lps.

Hydrogeological section for SidhpurTaluka Depicting Aquifer Group I, II and III

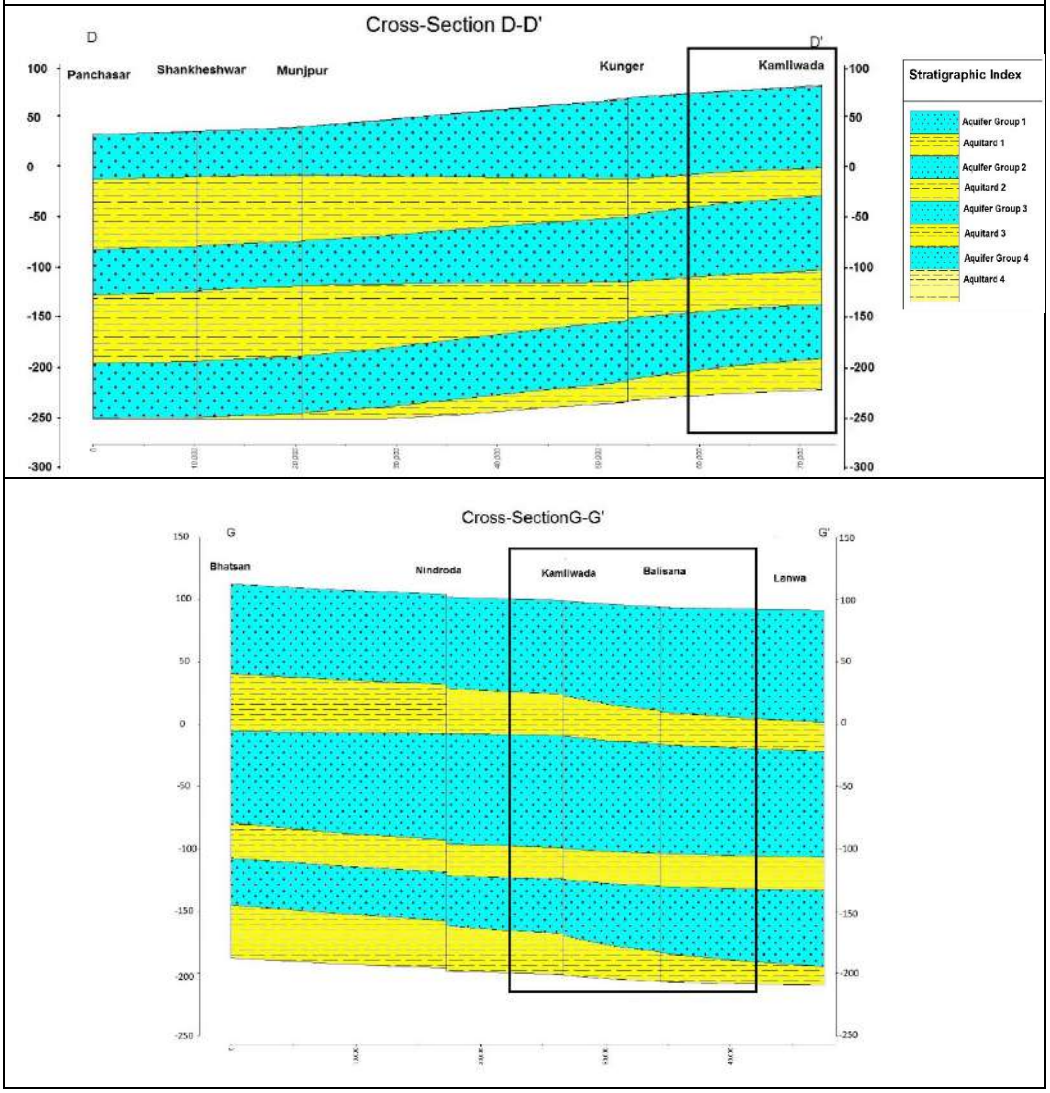


Fig 6. Stratigraphic Section

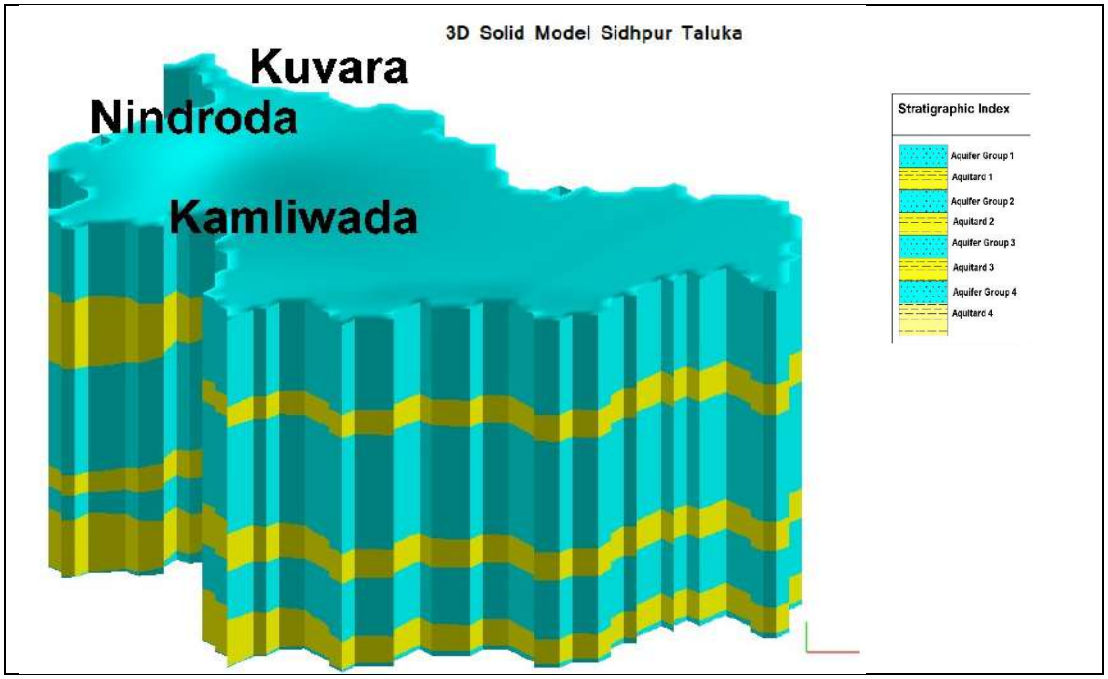
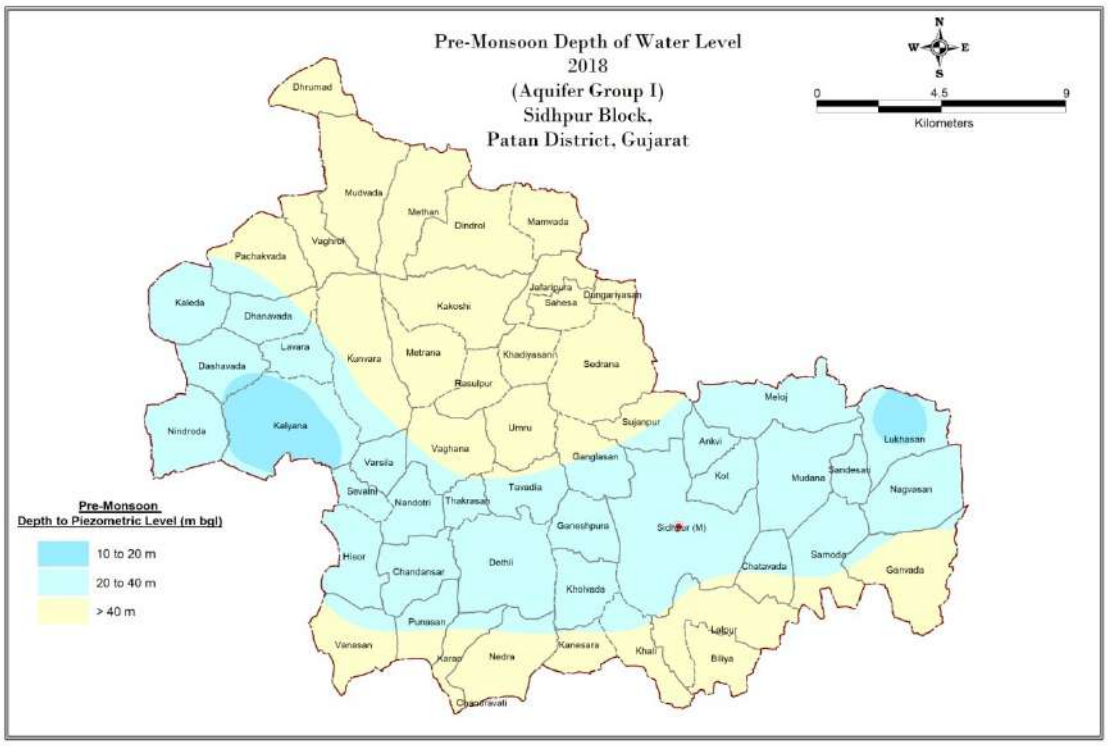


Figure 7. 3D Solid Model of SidhpurTaluka Depicting Aquifer Group I, II and III

Table 1. Aquifer characteristics

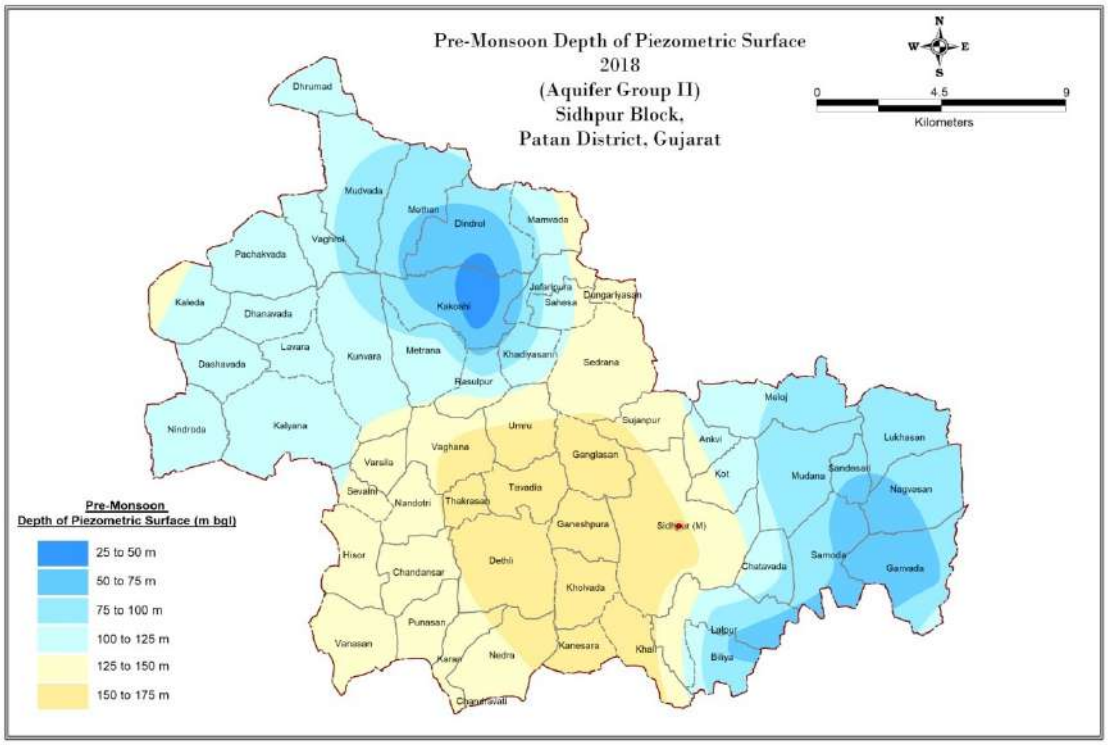
Aquifer Group	Base of Aquifer (m)	Generalized Thickness (m)	Yield (LPM)	Quality/EC (µS/cm)	Water Level/Piezometric head (mBGL)	Developed in the area	Aquifer Type
Aquifer-I	80-110	30-85	150-300	630-2010	12.70-58.00	N & NE	Phreatic
Aquifer-II	190-210	15-90	600-1200	5800-7130	99.10-167.57	C & EC	Semi Confined/ Confined
Aquifer-III	290-300	20-80	600-1200	1190-1650	132.4-147.5	C & S and S part	Confined

Aquifer Group wise Water Level Maps of SidhpurTaluka

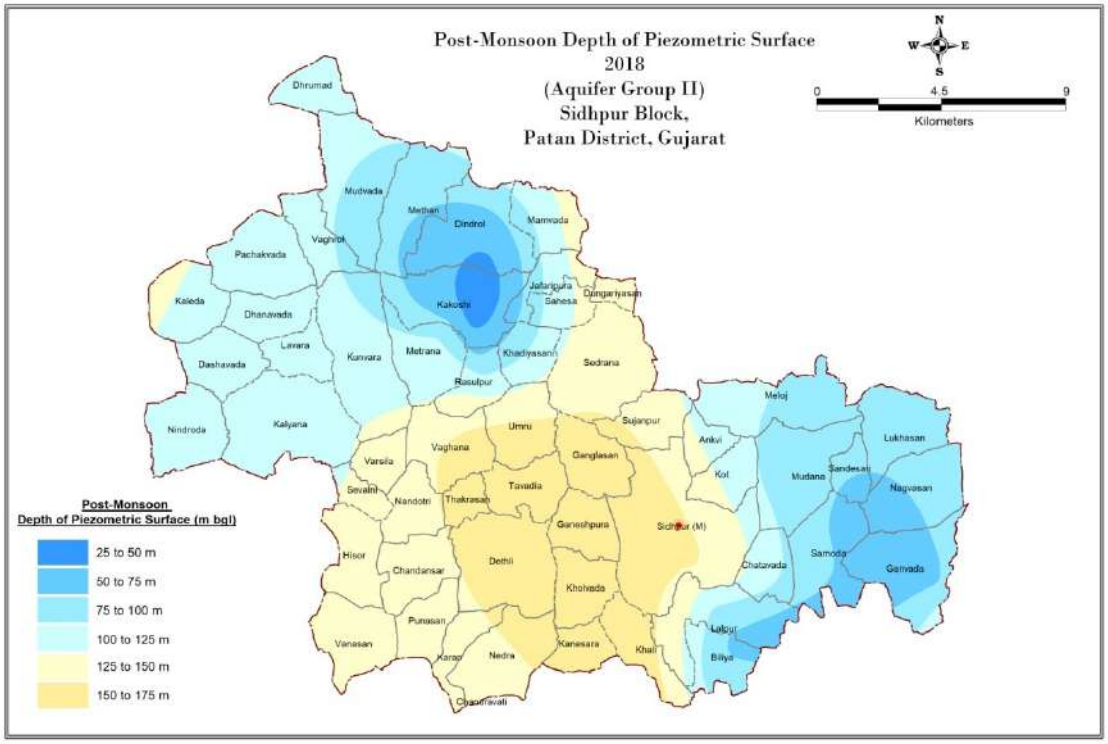


Pre Monsoon Depth to Water Level Map-Aquifer Group I

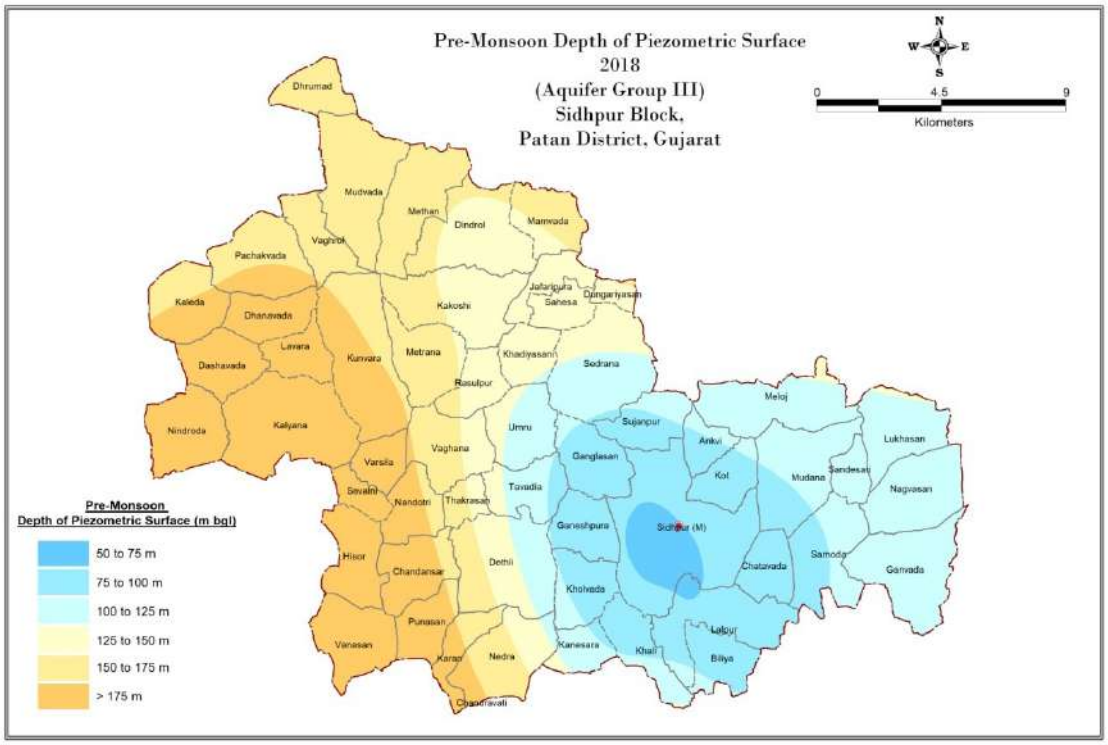
Post Monsoon Depth to Water Level Map-Aquifer Group I



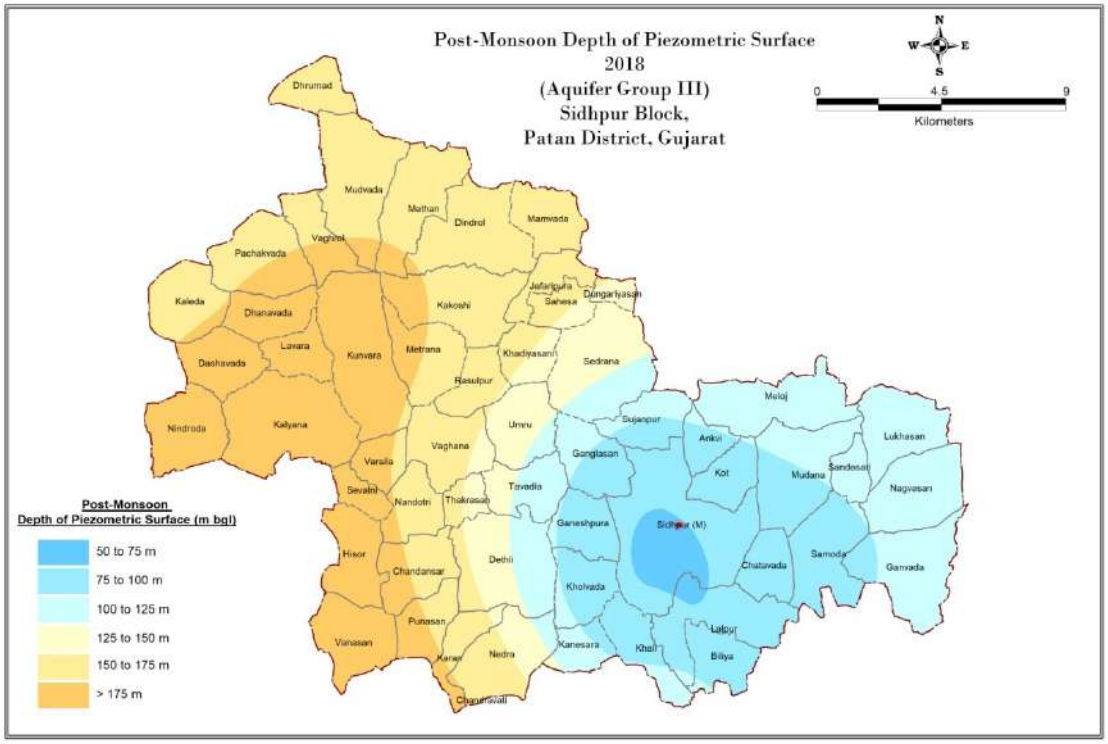
Pre Monsoon Depth to Water Level Map-Aquifer Group II



Post Monsoon Depth to Water Level Map-Aquifer Group II



Pre Monsoon Depth to Water Level Map-Aquifer Group III



Post Monsoon Depth to Water Level Map-Aquifer Group III

4 Groundwater resource extraction, contamination

Dynamic GW Resources in MCM

Total fresh groundwater availability of the area is estimated in year 2017 is 150.41 MCM and total groundwater withdrawal for all purposes is 156.17 MCM. The stage of groundwater development is 103.83% and the Taluka is categorized “Over Exploited”.

Table: 2 Dynamic Groundwater resources 2017

S No	Item	Fresh
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2	Total GW Recharge (MCM)	158.33
3	Net GW Availability (MCM)	150.41
4	Gross Draft (MCM)	156.17
5	Net Availability for Future Irrigation (MCM)	0.00
6	Stage of GW Development (%)	103.83

Aquifer Group wise Fresh Groundwater Resources upto 300 m depth are given below in table

In Storage GW Resources (Fresh, MCM)

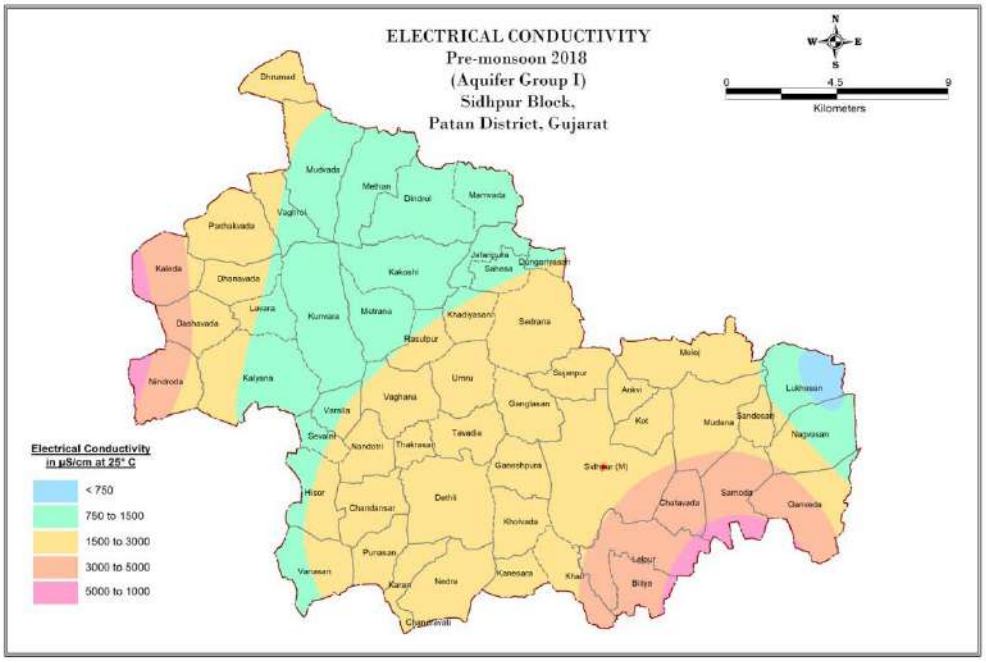
Aquifer Group I	300
Aquifer Group II	600
Aquifer Group III	899
In-Storage Groundwater	1799
Annual Replenishable Groundwater	158
Total Availability of Fresh Groundwater Resources	1957

Total Groundwater Resources of Sidhpur Taluka (MCM)

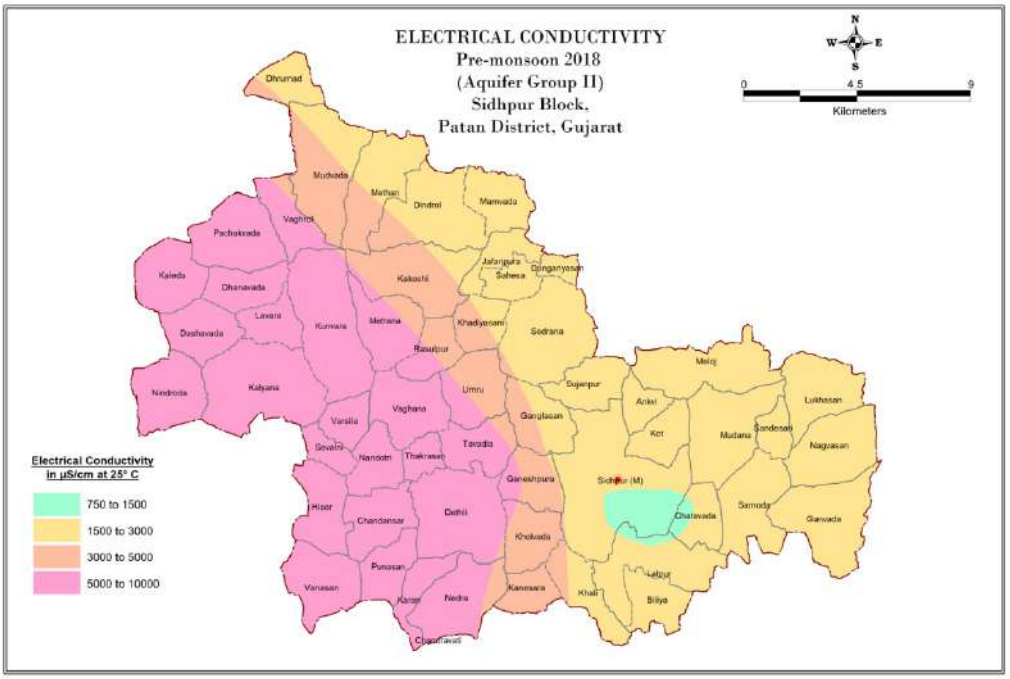
In-Storage Groundwater	Fresh	1799
Annual Extractable Groundwater Resources	Fresh	150.41
Total Availability of Groundwater Resources	Fresh	1949.41

5 Chemical quality of groundwater

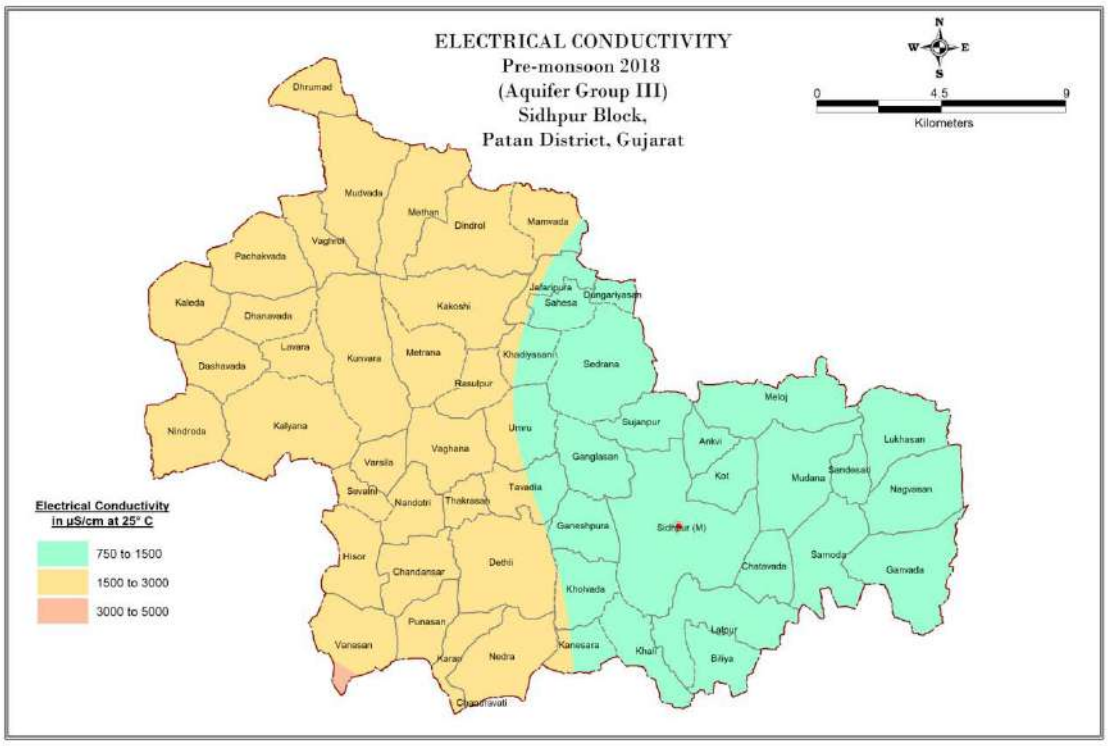
Groundwater quality is one of the major issues in the area. The taluka is considered fresh for Dynamic Groundwater Resource Assessment however brackish water in the phreatic aquifer is reported in South eastern and western part of the taluka with EC more than 3000µS/cm. Water Quality map for Aquifer Group II is brackish in western part of the taluka and is entirely fresh in the Aquifer Group III. Water Quality map for Aquifer Group II and III are prepared based on the water quality data of State Govt. Groundwater samples from Piezometers were collected by Grab method without purging the Wells hence the maps are debatable. Aquifer Group wise Water Quality Maps of Sidhpur Taluka is presented below.



Pre Monsoon Electrical Conductivity Map-Aquifer Group I

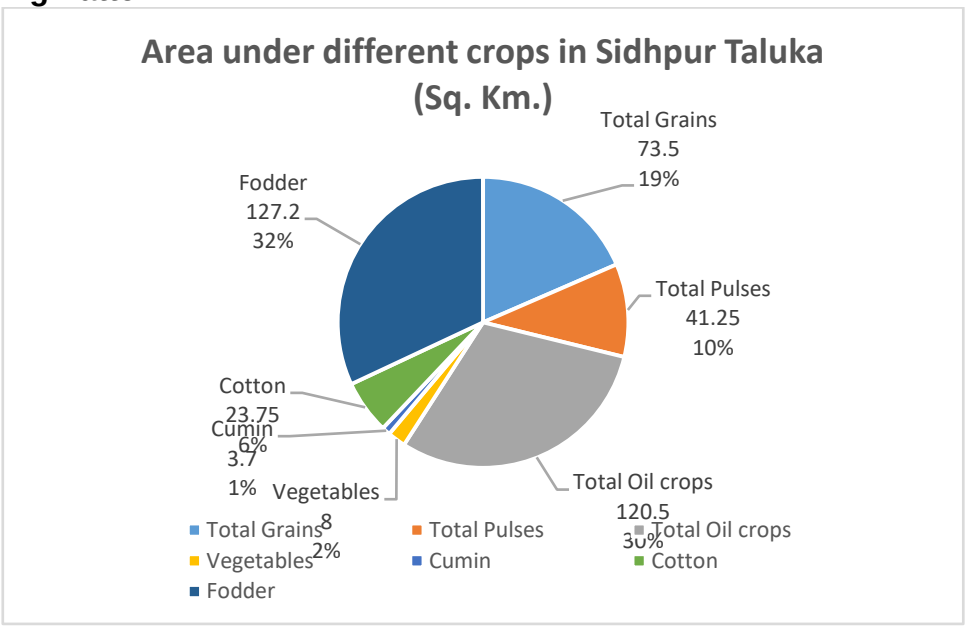


Pre Monsoon Electrical Conductivity Map-Aquifer Group II



Pre Monsoon Electrical Conductivity Map-Aquifer Group III

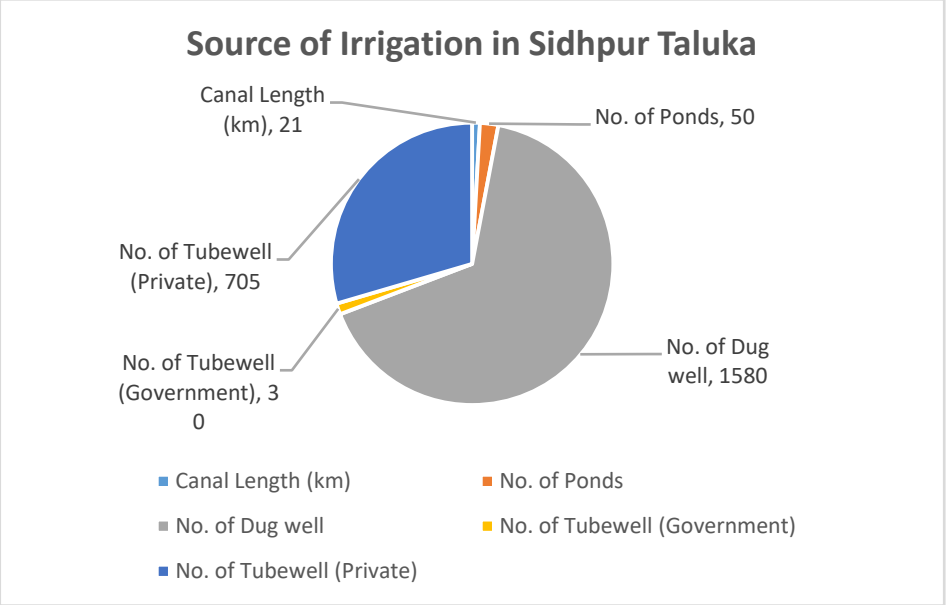
6 Cropping Pattern



7 Irrigation

Source-wise Irrigation in Sidhpur Taluka			
Length Of Canal (km)	Govt.		21
	Private		0
Borewell (Nos.)	Govt.		30
	Private		705
Only Irrigation Dug well (Nos.)	Govt.	Lined	0
		Unlined	0
	Private	Lined	1580
		Unlined	0
Dug Well Not In Use (Nos.)			135
Water Bodies Other Than Ponds			0
Dug wells For Domestic Use Only (Nos.)			180
Pond (Nos.)	Irrigation > 50 Ha		0
	Irrigation < 50 Ha		0
Oil Engine (Nos.)			130
Electric Motor (Nos.)			1610

Source-wise Irrigated Area in Sidhpur Taluka	
Net Irrigated Area (Sq. Km.)	196.75
% Of Net Irrigated Area Agains Gross Cropped area	77.57
Govt. Canal (No.)	1
Length (km)	21
Private /Panchayat Canal	0
Pond (No.)	50
Dug Well (No.)	158
Tube Well (No.)	2333
Area irrigated More than once (Sq. Km.)	101.2
Gross Irrigated Area (Sq. Km.)	297.95



8 Groundwater Issues

Traditional agricultural /irrigation practices, flood irrigation practices, increase in water demand, irrigation practices based on power supply. Farmers irrigate the crops when power supply is available rather than waiting for the wilting to start. Following are the issues identified for aquifer management in the area

- Arid/Semi arid area
- High rate of Evapotranspiration
- Limited availability of surface water resources
- Over exploitation of groundwater
- Decline in groundwater levels
- De saturation of Phreatic aquifers
- Deeper Piezometric head of Confined Aquifer-III Decline in Piezometric heads of semi confined/confined aquifer
- Increase in well depth as water levels become deeper
- Increase in depth of prime mover/pump setting
- Decline in well yields
- Lack of awareness and involvement of stakeholders in decision making

9 Groundwater Management

Supply side Management: Recharging capacity through the number of Recharge Structures are more than sufficient and hence new recharge structures are not proposed to enhance the groundwater. Although feasibility of recharging the deeper User Aquifers (Aquifer Group II and III) may be explored as they show declining water level/Piezometric Head subject to availability of surplus water to recharge. The village ponds linked with Narmada canal water can be used to construct recharge wells in the pond bed for recharging the deeper aquifer.

Table 4. Recharge structure

Recharge Structures in SidhpurTaluka	
Tanks (No.)	26
Percolation Tanks (No.)	26
Check Dam (No.)	789
Quantity of Recharge from Percolation Tanks(@0.14 MCM)	3.64
Quantity of Recharge from Check Dams (@0.05 MCM)	39.45

10 Demand Side Management

As the surface water is not available to improve the supply of water, demand side management is essential.

Water use efficiency by Micro Irrigation System:

At present anareaof2635hectareiscoveredbymicro-irrigationscheme (MIS) under different crops grown in the SidhpurTaluka. By adding proposed area of 13951 Ha under MIS in the Taluka the irrigation draft can reduce from 152.69 MCM to

131.76 MCM with a net saving of 20.93MCM on account of irrigation draft and the stage of groundwater extraction will also improve.

Annual Replenishable Groundwater Recharge (MCM)	150.41
Irrigation Draft (MCM)	152.69
Domestic And Industrial uses Draft (MCM)	3.49
Total Draft (MCM)	156.17
Gross Irrigated Area by GW (Ha)	30537
Area already Covered under MIS (Ha)	2635
Area Proposed under MIS* (Ha)	13951
Δ GW Requirement (m)	0.5
Irrigation Draft for MIS (MCM)	20.93
Irrigation Draft After MIS (MCM)	131.76
Total Draft after MIS (MCM)	135.25
Stage of Groundwater Extraction (%) (GWRE 2017)	103.83
Category (GWRE 2017)	Over Exploited
Stage of Groundwater Extraction (%) after MIS	89.92
Category after MIS	Semi Critical

11 Expected Benefits or outcome of the Plan

Groundwater recharge and water conservation structures on the ground are more than sufficient at present in Sidhpur Taluka, By adopting the micro-irrigation area in the remaining area conserve the 20.93 MCM of groundwater draft in the district.

With the additional recharge and water conservation interventions as proposed in the Plan, it is anticipated that with enhanced recharge and reduction in groundwater draft, the stage of groundwater development will reduce to 89.92% from the existing 103.83%.

12 Summary and Conclusion

Sidhpur is one of the agriculturally, socially and economically advanced districts, situated in the northern part of Gujarat State. Regionally, it forms part of North Gujarat Region. Groundwater is the main source of irrigation water in the district catering almost 80% of the irrigation water demand.

Groundwater occurs in the alluvium system with sand of various size form the aquifers separated by clay and mixed horizons forming the aquitards. Groundwater occurs both in Phreatic as well as Semi confined to Confined condition. For the purpose of Aquifer mapping up to 300m, the different aquifer units are grouped in Aquifer Group I, II and III. Aquifer group I is unconfined aquifer whereas Aquifer Group II is semi confined to Confined and Aquifer Group III is confined in Nature. These aquifer groups are regionally extensive and form prolific aquifer system in the district.

The groundwater quality is good in the taluka. The groundwater quality is fresh in the Aquifer Group I of the Taluka except few villages in south east and western part. Aquifer group II has brackish water in the western part of the talukaand Aquifer Group III have fresh groundwater in all the villages.

The Aquifer Group I in eastern parts is desaturated at many places but shows stabilised water level due to the recharge activities and introduction of narmada water for MadhuPavdi Recharge project in Saraswati river bed near Sidhpur town.

Aquifer Group II and III are tapped by irrigation tubewells and there is declining water level trend in most of the piezometers representing these aquifer groups. During last 20 years fall of 2m to 45m in Piezometers tapping Aquifer Group II and fall of 13 to 56m in Pz tapping Aquifer Group III is observed.

A number of activities for augmenting groundwater resources has been done with construction of check dams (789nos), deepening of village ponds (26 nos.), Percolation tanks (26 nos.) and interlinking of ponds with the canals and pipeline.

The Taluka has erratic rainfall and there is very limited non committed surplus runoff to harness as the recharge capacity of the structures on the ground are more than required.

Attention has to be given to recharging the deeper aquifers as these are the main source of irrigation water and are heavily pumped, but there is paucity of source water for recharging.

Focus has to be shifted to saving of water through Micro irrigation techniques as in the traditional flooding method a lot of water is wasted.

As there is little scope of creating additional recharge structures it is recommended to increase the area under micro irrigation to about 13951 Ha which may reduce the irrigation draft by 20.93 MCM And turn the Taluka from Over Exploited to Semi Critical Category.

Annexure I

Aquifer I pre monsoon water levels

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	Elevation of Ground Level	Water Level	Water Table
MSH-040	Kalyana	Sidhpur	23.959444	72.240000	120.25	14.60	105.65
MSH-043A	Sankhari	Patan	23.779167	72.162778	84.00	15.40	68.60
NEW-01	Lukhasan	Sidhpur	23.962222	72.463056	162.00	18.70	143.30
NEW-05	Dev	Radhanpur	23.945556	71.634444	33.00	4.95	28.05
NEW-06	Kalyanpur	Santalpur	23.770000	71.178889	19.00	3.70	15.30
NEW-08	Ruvavi	Patan	23.770278	72.300278	92.71	16.90	75.81
NEW-09	Mithi Vavadi	Patan	23.762500	72.110000	70.00	12.70	57.30
BKPZ-070	Abiyana	Santalpur	23.705278	71.453056	20.18	1.70	18.48
PTNPZ-09	Adiya-I	Harij	23.779444	72.017778	67.89	44.04	23.85
HPIIPTN013	Kholvada (m)	Sidhpur	23.906111	72.335000	125.00	29.70	95.30
G_1_PTN_003	Khari Dhariyal	Chanasma	23.717222	72.050556	62.00	28.10	33.90
G_1_PTN_004	Sarsav-i	Chanasma	23.717222	72.198611	74.00	62.40	11.60
G_1_PTN_006	Takodi	Chanasma	23.615000	72.146111	55.00	10.20	44.80
G_1_PTN_007	Harij-i	Harij	23.691389	71.907500	51.00	6.10	44.90
G_1_PTN_009	Kumbhana	Harij	23.782500	71.823333	40.00	4.60	35.40
G_1_PTN_010	Masa	Harij	23.863056	71.914444	52.00	9.40	42.60
G_1_PTN_011	Sankra	Harij	23.819722	71.975833	59.00	27.30	31.70
G_1_PTN_012	Abalouva	Saraswati	24.034167	72.137222	97.00	61.00	36.00
G_1_PTN_013	Ajimana	Saraswati	23.889167	72.196667	98.00	72.50	25.50
G_1_PTN_014	Dudharampura	Patan	23.860833	72.025833	64.00	58.00	6.00
G_1_PTN_015	Digadi	Patan	23.832500	72.215833	91.00	32.65	58.35
G_1_PTN_016	Golapura	Patan	23.817778	72.127222	80.00	40.65	39.35
G_1_PTN_017	Khodana	Saraswati	24.078889	72.206389	121.00	50.70	70.30
G_1_PTN_018	Muna-I	Saraswati	24.140278	72.133333	125.00	88.50	36.50
G_1_PTN_021	Sankhari	Patan	23.779167	72.162778	79.00	26.15	52.85
G_1_PTN_022	Siyol-I	Saraswati	23.953611	72.182500	97.00	32.70	64.30
G_1_PTN_027	Arjansar	Radhanpur	23.885000	71.700833	40.00	3.80	36.20
G_1_PTN_028	Bandhawad	Radhanpur	23.923889	71.622222	37.00	4.20	32.80
G_1_PTN_030	Javantri-I	Radhanpur	23.921111	71.556389	32.00	28.60	3.40
G_1_PTN_035	Sinad-I	Radhanpur	23.833611	71.643333	28.00	5.20	22.80
G_1_PTN_037	Aritha	Sami	23.651667	71.949722	42.00	10.40	31.60
G_1_PTN_039	Kathi	Sami	23.621944	71.805556	32.00	1.30	30.70
G_1_PTN_041	Kunvar	Shankheshvar	23.532778	71.613611	14.00	1.10	12.90
G_1_PTN_042	Kuvarad-I	Shankheshvar	23.539167	71.864167	38.00	11.50	26.50
G_1_PTN_044	Lolada	Shankheshvar	23.543611	71.692500	24.00	2.30	21.70
G_1_PTN_046	Mota Joravarpura	Sami	23.746944	71.779722	35.00	0.90	34.10
G_1_PTN_048	Nayka	Sami	23.647222	71.705833	28.00	4.15	23.85
G_1_PTN_049	Rampura	Sami	23.721667	71.548056	19.00	14.50	4.50
G_1_PTN_050	Samsherpura	Sami	23.660556	71.676111	23.00	2.55	20.45
G_1_PTN_051	Upaliyasara-I	Sami	23.630278	71.619444	16.00	3.25	12.75
G_1_PTN_053	Ved	Sami	23.644444	71.510833	16.00	1.20	14.80
G_1_PTN_054	Jhilvana	Sami	23.717222	71.811944	35.00	3.20	31.80
G_1_PTN_063	Jamvada-I	Santalpur	23.887222	71.340556	20.00	10.90	9.10
G_1_PTN_068	Lodra	Santalpur	23.947778	71.481667	25.00	1.40	23.60
G_1_PTN_069	Piparala	Santalpur	23.644444	71.100000	15.00	7.70	7.30
G_1_PTN_070	Santalpur	Santalpur	23.764167	71.169167	13.00	5.40	7.60
G_1_PTN_071	Zazam-I	Santalpur	23.943611	71.334444	20.00	10.20	9.80
G_1_PTN_073	Ganvada-i	Sidhpur	23.906944	72.463333	159.00	49.10	109.90
G_1_PTN_075	Metrana-I	Sidhpur	23.983056	72.288889	127.00	64.90	62.10
W235318072235504	Biliya(Temple)Pz_II	Sidhpur	23.888333	72.398611	132.3	46.9	85.40
W233917071050901	Piprala_1	Santalpur	23.654722	71.085833	22.7	10.47	12.23
W233119071472701	Sankheshwar	Sami	23.521944	71.790833	25.7	2.49	23.21
W234930071365002	Radhanpur2	Radhanpur	23.825000	71.613889	27	5.1	21.90

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	Elevation of Ground Level	Water Level	Water Table
W234600072151501	Sander	Patan	23.766667	72.254167	89	15.63	73.37
W235030072072501	Patan2	Patan	23.841667	72.123611	80.7	17.78	62.92
W234111071535003	Harij iii	Harij	23.686389	71.897222	43.7	30.35	13.35
W234150072041001	Dharmoda	Chanasma	23.697222	72.069444	60.2	3.57	56.63
W233945072164501	Dhinoj1	Chanasma	23.662500	72.279167	80	9.4	70.60
W233540071465001	Moti chander	Sami	23.594444	71.780556	27.3	2.23	25.07

Annexure II

Aquifer I post monsoon water levels

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	Elevation of Ground Level	Water Level	Water Table
MSH-040	Kalyana	Sidhpur	23.959444	72.240000	120.25	14.00	106.25
MSH-043A	Sankhari	Patan	23.779167	72.162778	84.00	16.20	67.80
NEW-05	Dev	Radhanpur	23.945556	71.634444	33.00	5.00	28.00
NEW-06	Kalyanpur	Santalpur	23.770000	71.178889	19.00	1.70	17.30
NEW-08	Ruvavi	Patan	23.770278	72.300278	92.71	16.10	76.61
NEW-09	Mithi Vavadi	Patan	23.762500	72.110000	70.00	13.00	57.00
BKPZ-070	Abiyana	Santalpur	23.705278	71.453056	20.18	1.90	18.28
PTNPZ-09	Adiya-I	Harij	23.779444	72.017778	67.89	40.24	27.65
HPIIPTN002	Khorsam	Chanasma	23.660833	72.066389	58.00	3.10	54.90
HPIIPTN003	Jhiliya-iii	Chanasma	23.680000	72.173889	64.34	16.10	48.24
HPIIPTN004	Vadli	Patan	23.846944	72.047222	71.50	34.40	37.10
HPIIPTN005	Vagdod	Saraswati	23.973889	72.125556	82.50	28.30	54.20
HPIIPTN008	Panchasar	Shankheshvar	23.424167	71.805833	30.50	4.10	26.40
HPIIPTN013	Kholvada (m)	Sidhpur	23.906111	72.335000	125.00	33.00	92.00
G_1_PTN_003	Khari Dhariyal	Chanasma	23.717222	72.050556	62.00	28.30	33.70
G_1_PTN_004	Sarsav-i	Chanasma	23.717222	72.198611	74.00	72.60	1.40
G_1_PTN_006	Takodi	Chanasma	23.615000	72.146111	55.00	9.90	45.10
G_1_PTN_007	Harij-i	Harij	23.691389	71.907500	51.00	6.40	44.60
G_1_PTN_009	Kumbhana	Harij	23.782500	71.823333	40.00	5.10	34.90
G_1_PTN_010	Masa	Harij	23.863056	71.914444	52.00	10.30	41.70
G_1_PTN_011	Sankra	Harij	23.819722	71.975833	59.00	28.10	30.90
G_1_PTN_012	Abalouva	Saraswati	24.034167	72.137222	97.00	61.80	35.20
G_1_PTN_013	Ajimana	Saraswati	23.889167	72.196667	98.00	73.20	24.80
G_1_PTN_014	Dudharampura	Patan	23.860833	72.025833	64.00	57.50	6.50
G_1_PTN_015	Digadi	Patan	23.832500	72.215833	91.00	33.70	57.30
G_1_PTN_016	Golapura	Patan	23.817778	72.127222	80.00	41.80	38.20
G_1_PTN_017	Khodana	Saraswati	24.078889	72.206389	121.00	52.20	68.80
G_1_PTN_018	Muna-I	Saraswati	24.140278	72.133333	125.00	87.00	38.00
G_1_PTN_021	Sankhari	Patan	23.779167	72.162778	79.00	27.00	52.00
G_1_PTN_022	Siyol-I	Saraswati	23.953611	72.182500	97.00	33.10	63.90
G_1_PTN_027	Arjansar	Radhanpur	23.885000	71.700833	40.00	3.00	37.00
G_1_PTN_028	Bandhawad	Radhanpur	23.923889	71.622222	37.00	3.30	33.70
G_1_PTN_030	Javantri-I	Radhanpur	23.921111	71.556389	32.00	28.90	3.10
G_1_PTN_035	Sinad-I	Radhanpur	23.833611	71.643333	28.00	5.30	22.70
G_1_PTN_037	Aritha	Sami	23.651667	71.949722	42.00	10.00	32.00
G_1_PTN_039	Kathi	Sami	23.621944	71.805556	32.00	1.60	30.40
G_1_PTN_042	Kuvarad-I	Shankheshvar	23.539167	71.864167	38.00	13.10	24.90
G_1_PTN_044	Lolada	Shankheshvar	23.543611	71.692500	24.00	3.00	21.00
G_1_PTN_046	Mota Joravarpura	Sami	23.746944	71.779722	35.00	2.00	33.00
G_1_PTN_048	Nayka	Sami	23.647222	71.705833	28.00	4.20	23.80
G_1_PTN_049	Rampura	Sami	23.721667	71.548056	19.00	14.30	4.70
G_1_PTN_050	Samsherpura	Sami	23.660556	71.676111	23.00	3.00	20.00
G_1_PTN_051	Upaliyasara-I	Sami	23.630278	71.619444	16.00	3.90	12.10
G_1_PTN_053	Ved	Sami	23.644444	71.510833	16.00	0.40	15.60
G_1_PTN_054	Jhilvana	Sami	23.717222	71.811944	35.00	3.10	31.90
G_1_PTN_056	Antarnes	Santalpur	23.682500	71.296111	12.00	17.30	-5.30
G_1_PTN_063	Jamvada-I	Santalpur	23.887222	71.340556	20.00	11.10	8.90

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	Elevation of Ground Level	Water Level	Water Table
G_1_PTN_068	Lodra	Santalpur	23.947778	71.481667	25.00	2.00	23.00
G_1_PTN_070	Santalpur	Santalpur	23.764167	71.169167	13.00	6.00	7.00
G_1_PTN_071	Zazam-I	Santalpur	23.943611	71.334444	20.00	8.00	12.00
G_1_PTN_073	Ganvada-i	Sidhpur	23.906944	72.463333	159.00	49.20	109.80
G_1_PTN_075	Metrana-I	Sidhpur	23.983056	72.288889	127.00	64.30	62.70
W235318072235504	Biliya(Temple)Pz_II	Sidhpur	23.888333	72.398611	132.30	48.00	84.30
W233917071050901	Piprala_1	Santalpur	23.654722	71.085833	22.70	10.25	12.45
W234600072151501	Sander	Patan	23.766667	72.254167	89.00	17.85	71.15
W235030072072501	Patan2	Patan	23.841667	72.123611	80.70	19.48	61.22
W234150072041001	Dharmoda	Chanasma	23.697222	72.069444	60.20	2.22	57.98
W233945072164501	Dhinoj1	Chanasma	23.662500	72.279167	80.00	21.95	58.05
W233119071472701	Sankheshwar	Sami	23.521944	71.790833	25.70	2.39	23.31
W233540071465001	Moti chander	Sami	23.594444	71.780556	27.30	2.70	24.60

Annexure III

Aquifer II pre monsoon water levels

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	Elevation of Ground Level	Water Level	Water Table
MSHPZ-218	Jhiliya-i	Chanasma	23.684444	72.173056	64.36	141.50	-77.14
MSHPZ-233	Sidhpur-I	Sidhpur	23.916944	72.375000	133.18	127.70	5.48
MSHPZ-234	Sidhpur-II	Sidhpur	23.916944	72.375000	133.07	183.40	-50.33
PTNPZ-01	Varahi-I	Santalpur	23.803333	71.417222	17.83	84.92	-67.09
PTNPZ-02	Varahi-II	Santalpur	23.803333	71.417222	17.75	92.15	-74.40
PTNPZ-04	Biliya-I	Shankheshvar	23.601111	71.949722	50.37	39.50	10.87
PTNPZ-07	Shankheshvar-i	Shankheshvar	23.507500	71.788889	38.15	9.00	29.15
PTNPZ-10	Adiya-II	Harij	23.779444	72.017778	67.90	80.25	-12.35
PTNPZ-12	Kungher	Patan	23.795833	72.064444	68.12	99.10	-30.98
PTNPZ-14	Koita	Saraswati	24.072778	72.164167	97.26	138.10	-40.84
PTNPZ-16	Kalyana-I	Sidhpur	23.959444	72.240000	113.60	64.90	48.70
PTNPZ-21	Tavadia	Sidhpur	23.936111	72.330833	129.46	174.80	-45.34
PTNPZ-22	Gotarka	Radhanpur	23.742778	71.484722	23.75	91.12	-67.37
PTNPZ-24	Ruvavi	Patan	23.770278	72.300278	92.71	167.57	-74.86
HPIIPTN010	Kalyana-2-a	Sidhpur	23.959444	72.242778	113.60	174.90	-61.30
G_1_PTN_005	Sarsav-ii	Chanasma	23.717222	72.198611	74.00	156.00	-82.00
G_1_PTN_008	Harij-II	Harij	23.691389	71.907500	51.00	81.00	-30.00
G_1_PTN_019	Muna-ii	Saraswati	24.140278	72.133333	125.00	100.40	24.60
G_1_PTN_031	Javantri-II	Radhanpur	23.921111	71.556389	32.00	88.50	-56.50
G_1_PTN_036	Sinad-ii	Radhanpur	23.833611	71.643333	28.00	64.40	-36.40
G_1_PTN_043	Kuvarad-ii	Shankheshvar	23.539167	71.864167	38.00	39.80	-1.80
G_1_PTN_064	Jamvada-ii	Santalpur	23.887222	71.340556	20.00	8.40	11.60
G_1_PTN_074	Ganvada-Ii	Sidhpur	23.909444	72.463056	159.00	64.30	94.70
G_1_PTN_076	Metrana-ii	Sidhpur	23.983056	72.288889	127.00	112.20	14.80
W240006072182102	Kakosi Pz-II	Sidhpur	24.002000	72.306000	136.00	38.46	97.54
W235318072235503	Biliya(Temple)Pz_I	Sidhpur	23.888000	72.399000	133.00	73.10	59.90

Annexure IV

Aquifer II post monsoon water levels

Well No	Village	Tahsil / Taluk	Latitude	Longitude	Elevation of Ground Level	Water Level	Water Table
MSHPZ-218	Jhiliya-i	Chanasma	23°41'04"	72°10'23"	64.36	132.30	-67.94
MSHPZ-233	Sidhpur-I	Sidhpur	23°55'01"	72°22'30"	133.18	123.80	9.38
MSHPZ-234	Sidhpur-II	Sidhpur	23°55'01"	72°22'30"	133.07	179.25	-46.18
PTNPZ-01	Varahi-I	Santalpur	23°48'12"	71°25'02"	17.83	88.07	-70.24
PTNPZ-02	Varahi-II	Santalpur	23°48'12"	71°25'02"	17.75	94.60	-76.85
PTNPZ-04	Biliya-I	Shankheshvar	23°36'04"	71°56'59"	50.37	40.00	10.37
PTNPZ-07	Shankheshvar-i	Shankheshvar	23°30'27"	71°47'20"	38.15	9.90	28.25
PTNPZ-10	Adiya-II	Harij	23°46'46"	72°01'04"	67.90	87.90	-20.00
PTNPZ-12	Kungher	Patan	23°47'45"	72°03'52"	68.12	101.65	-33.53
PTNPZ-14	Koita	Saraswati	24°04'22"	72°09'51"	97.26	137.45	-40.19
PTNPZ-16	Kalyana-I	Sidhpur	23°57'34"	72°14'24"	113.60	65.20	48.40
PTNPZ-21	Tavadia	Sidhpur	23°56'10"	72°19'51"	129.46	171.75	-42.29
PTNPZ-22	Gotarka	Radhanpur	23°44'34"	71°29'05"	23.75	90.02	-66.27
PTNPZ-24	Ruvavi	Patan	23°46'13"	72°18'01"	92.71	164.37	-71.66
HPIIPTN010	Kalyana-2-a	Sidhpur	23°57'34"	72°14'34"	113.60	169.00	-55.40
G_1_PTN_005	Sarsav-ii	Chanasma	23°43'02"	72°11'55"	74.00	158.45	-84.45
G_1_PTN_008	Harij-II	Harij	23°41'29"	71°54'27"	51.00	83.20	-32.20
G_1_PTN_019	Muna-ii	Saraswati	24°08'25"	72°08'00"	125.00	98.00	27.00
G_1_PTN_031	Javantri-II	Radhanpur	23°55'16"	71°33'23"	32.00	91.60	-59.60
G_1_PTN_036	Sinad-ii	Radhanpur	23°50'01"	71°38'36"	28.00	63.80	-35.80
G_1_PTN_043	Kuvarad-ii	Shankheshvar	23°32'21"	71°51'51"	38.00	40.60	-2.60
G_1_PTN_064	Jamvada-ii	Santalpur	23°53'14"	71°20'26"	20.00	8.70	11.30
G_1_PTN_074	Ganvada-Ii	Sidhpur	23°54'34"	72°27'47"	159.00	64.40	94.60
G_1_PTN_076	Metrana-ii	Sidhpur	23°58'59"	72°17'20"	127.00	113.80	13.20
W235318072235503	Biliya(Temple)Pz_I	Sidhpur	23°53'18"	72°35'03"	76.00	74.70	1.30
W235206072085002	Matarwadi I	Patan	23°52'06"	72°08'50"	86.00	99.12	-13.12
W240006072182102	Kakosi Pz-II	Sidhpur	24°00'06"	72°18'21"	136.00	82.30	53.70

Annexure V

Aquifer III pre monsoon water levels

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	Elevation of Ground Level	Water Level	Water Table
MSHPZ-219	Jhiliya-ii	Chanasma	23.684444	72.173056	64.34	150.00	-85.66
MSHPZ-235	Sidhpur-III	Sidhpur	23.916944	72.375000	133.38	71.70	61.68
PTNPZ-03	Varahi-III	Santalpur	23.803333	71.417222	17.59	32.90	-15.31
PTNPZ-05	Biliya-II	Shankheshvar	23.601111	71.949722	50.19	119.30	-69.11
PTNPZ-11	Adiya-III	Harij	23.779444	72.017778	67.78	40.40	27.38
PTNPZ-13	Vayad	Saraswati	24.028611	72.047778	85.35	112.08	-26.73
PTNPZ-18	Kalyana-III	Sidhpur	23.959444	72.240000	113.60	196.02	-82.42
PTNPZ-19	Dhinoj	Chanasma	23.660000	72.278056	71.65	161.10	-89.45
PTNPZ-20	Kamboi	Chanasma	23.685833	72.048056	54.53	136.60	-82.07
W234141071413801	Jangral Pzi	Patan	24.040590	72.158700	103.00	147.50	-44.50
W234220071403001	Jangral Pzii	Patan	24.040590	72.158700	103.00	132.40	-29.40
W234112072145501	Lanwa Pz-I	Chanasma	23.690000	72.250000	77.00	128.35	-51.35
W240006072182101	Kakosi Pz-I	Sidhpur	24.000000	72.310000	136.00	143.80	-7.80

Annexure VI

Aquifer III post monsoon water levels

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	Elevation of Ground Level	Water Level	Water Table
MSHPZ-219	Jhiliya-ii	Chanasma	23.684444	72.173056	64.34	149.00	-84.66
MSHPZ-235	Sidhpur-III	Sidhpur	23.916944	72.375000	133.38	71.55	61.83
PTNPZ-03	Varahi-III	Santalpur	23.803333	71.417222	17.59	36.80	-19.21
PTNPZ-05	Biliya-II	Shankheshvar	23.601111	71.949722	50.19	110.00	-59.81
PTNPZ-11	Adiya-III	Harij	23.779444	72.017778	67.78	41.50	26.28
PTNPZ-13	Vayad	Saraswati	24.028611	72.047778	85.35	107.18	-21.83
PTNPZ-18	Kalyana-III	Sidhpur	23.959444	72.240000	113.60	185.27	-71.67
PTNPZ-19	Dhinoj	Chanasma	23.660000	72.278056	71.65	157.00	-85.35
PTNPZ-20	Kamboi	Chanasma	23.685833	72.048056	54.53	135.60	-81.07
W234141071413801	Jangral Pzi	PATAN	24.040590	72.158700	103.00	149.80	-46.80

Annexure VII

Aquifer I pre monsoon water quality

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	EC	NO_3	F
BKPZ-070	Abiyana	Santalpur	23.705278	71.453056	56350	211.33	0.70
MSH-040	Kalyana	Sidhpur	23.959444	72.240000	1380	4.04	1.78
MSH-043A	Sankhari	Patan	23.779167	72.162778	900	2.95	1.29
NEW-01	Lukhasan	Sidhpur	23.962222	72.463056	610	3.08	0.67
NEW-05	Dev	Radhanpur	23.945556	71.634444	5110	23.00	0.81
NEW-06	Kalyanpur	Santalpur	23.770000	71.178889	910	1.17	0.41
NEW-08	Ruvavi	Patan	23.770278	72.300278	2010	14.20	1.12
HPIIPTN002	Khorsam	Chanasma	23.660833	72.066389	37580	107.30	1.25
HPIIPTN003	Jhiliya-iii	Chanasma	23.680000	72.173889	7730	4.53	1.53
HPIIPTN004	Vadli	Patan	23.846944	72.047222	1630	1.26	0.57
HPIIPTN005	Vagdod	Saraswati	23.973889	72.125556	14330	1.15	0.55
HPIIPTN008	Panchasar	Shankheshvar	23.424167	71.805833	21170	6.54	0.89
HPIIPTN013	Kholvada (m)	Sidhpur	23.906111	72.335000	2250	0.98	0.09
W235030072072501	Patan2	Patan	23.842000	72.124000	1930	47.00	2.96
W234645072094501	Shankhari	Patan	23.779000	72.163000	665	8.00	1.60
W234600072151501	Sander	Patan	23.767000	72.254000	630	21.00	0.50
W234130072041501	Dharmoda1	Chanasma	23.692000	72.071000	1105	14.00	0.38
W233945072164501	Dhinoj1	Chanasma	23.663000	72.279000	1579	9.00	0.20
W233850071060001	Piprala	Santalpur	23.647000	71.100000	6012	190.00	2.96
W233540071465001	Moti chander	Sami	23.594000	71.781000	9988	15.00	0.51

Annexure VIII

Aquifer II pre monsoon water quality

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	EC	Depth of Sampling	NO_3	F
MSHPZ-218	Jhiliya-i	Chanasma	23.684444	72.173056	4300	144.60	6.56	1.85
MSHPZ-233	Sidhpur-I	Sidhpur	23.916944	72.375000	1780	130.70	42.40	1.30
MSHPZ-234	Sidhpur-II	Sidhpur	23.916944	72.375000	1180	186.50	31.00	0.83
PTNPZ-01	Varahi-I	Santalpur	23.803333	71.417222	49990	86.40	5.01	1.39
PTNPZ-02	Varahi-II	Santalpur	23.803333	71.417222	34650	93.65	12.89	1.00
PTNPZ-04	Biliya-I	Shankheshvar	23.601111	71.949722	47742	41.00	4.32	0.99
PTNPZ-07	Shankheshvar-i	Shankheshvar	23.507500	71.788889	6330	10.50	0.90	0.35
PTNPZ-09	Adiya-I	Harij	23.779444	72.017778	9050	41.30	6.12	1.45
PTNPZ-12	Kungher	Patan	23.795833	72.064444	7130	102.10	1.26	0.28
PTNPZ-16	Kalyana-I	Sidhpur	23.959444	72.240000	7700	66.40	1.83	1.72
PTNPZ-21	Tavadia	Sidhpur	23.936111	72.330833	5380	178.10	4.82	1.55
PTNPZ-22	Gotarka	Radhanpur	23.742778	71.484722	94923	92.50	7.65	1.55
PTNPZ-24	Ruvavi	Patan	23.770278	72.300278	5800	170.60	8.41	1.22

Annexure IX

Aquifer II post monsoon water quality

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	EC	Depth of Sampling	NO_3	F
MSHPZ-218	Jhiliya-i	Chanasma	23.684444	72.173056	4850	133.80	8.94	1.39
MSHPZ-233	Sidhpur-I	Sidhpur	23.916944	72.375000	1100	125.30	20.20	1.01
MSHPZ-234	Sidhpur-II	Sidhpur	23.916944	72.375000	1300	180.75	43.20	2.59
PTNPZ-01	Varahi-I	Santalpur	23.803333	71.417222	45480	89.55	2.40	0.92
PTNPZ-02	Varahi-II	Santalpur	23.803333	71.417222	32870	96.10	3.47	0.81
PTNPZ-04	Biliya-I	Shankheshvar	23.601111	71.949722	44210	41.50	4.36	1.02
PTNPZ-07	Shankheshvar-i	Shankheshvar	23.507500	71.788889	6800	11.40	1.88	0.68
PTNPZ-09	Adiya-I	Harij	23.779444	72.017778	8140	41.70	0.76	1.79
PTNPZ-12	Kungher	Patan	23.795833	72.064444	6990	103.00	1.28	0.58
PTNPZ-16	Kalyana-I	Sidhpur	23.959444	72.240000	5510	66.70	196.00	1.25
PTNPZ-21	Tavadia	Sidhpur	23.936111	72.330833	2280	173.25	4.91	1.08
PTNPZ-22	Gotarka	Radhanpur	23.742778	71.484722	99999	91.40	2.43	1.44
PTNPZ-24	Ruvavi	Patan	23.770278	72.300278	5850	165.80	10.19	1.17

Annexure X

Aquifer III pre monsoon water quality

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	EC	Depth of Sampling	NO_3	F
MSHPZ-219	Jhiliya-ii	Chanasma	23.684444	72.173056	15930	152.90	7.69	1.51
MSHPZ-235	Sidhpur-III	Sidhpur	23.916944	72.375000	1230	73.30	15.90	0.98
PTNPZ-03	Varahi-III	Santalpur	23.803333	71.417222	31700	34.40	1.47	1.26
PTNPZ-05	Biliya-II	Shankheshvar	23.601111	71.949722	8360	123.10	3.69	1.09
PTNPZ-11	Adiya-III	Harij	23.779444	72.017778	2600	41.90	1.97	1.81
PTNPZ-13	Vayad	Saraswati	24.028611	72.047778	1190	115.10	15.30	1.37
PTNPZ-14	Koita	Saraswati	24.072778	72.164167	1650	141.40	2.73	1.29
PTNPZ-18	Kalyana-III	Sidhpur	23.959444	72.240000	2200	199.60	5.44	1.90
PTNPZ-19	Dhinoj	Chanasma	23.660000	72.278056	1900	164.40	3.09	1.16
PTNPZ-20	Kamboi	Chanasma	23.685833	72.048056	27210	138.80	22.80	2.00
HPIIPTN010	Kalyana-2-a	Sidhpur	23.959444	72.242778	2280	180.10	3.61	1.58

Annexure XI

Aquifer III post monsoon water quality

Well No	Village	Tahsil / Taluk	LAT_Y	LONG_X	EC	Depth of Sampling	NO_3	F
MSHPZ-219	Jhiliya-ii	Chanasma	23.684444	72.173056	12880	150.50	8.00	1.56
MSHPZ-235	Sidhpur-III	Sidhpur	23.916944	72.375000	1420	73.00	18.60	1.24
PTNPZ-03	Varahi-III	Santalpur	23.803333	71.417222	39730	38.30	1.35	1.25
PTNPZ-05	Biliya-II	Shankheshvar	23.601111	71.949722	7960	111.50	4.34	1.11
PTNPZ-11	Adiya-III	Harij	23.779444	72.017778	4280	43.00	6.34	1.51
PTNPZ-13	Vayad	Saraswati	24.028611	72.047778	1980	108.50	2.83	0.59
PTNPZ-14	Koita	Saraswati	24.072778	72.164167	1270	138.90	2.74	0.89
PTNPZ-18	Kalyana-III	Sidhpur	23.959444	72.240000	1410	186.85	5.43	1.76
PTNPZ-19	Dhinoj	Chanasma	23.660000	72.278056	1960	158.50	3.87	0.99
PTNPZ-20	Kamboi	Chanasma	23.685833	72.048056	21720	137.10	39.80	0.62
HPIIPTN010	Kalyana-2-a	Sidhpur	23.959444	72.242778	1700	170.50	2.44	1.17

Annexure XII

Location details of wells used for section and 3D

Sl. No.	Village	Elevation, m	Collar Elevation, m	Total Depth, m	Longitude	Latitude
1	Abiyana	11.70	11.70	296.00	71.461667	23.708889
2	Amrapura	13.70	13.70	300.00	71.453611	23.603333
3	Balisana	101.00	101.00	300.00	72.258333	23.816667
4	Baspa	27.00	27.00	611.73	71.683330	23.725000
5	Bhatsan	126.00	126.00	608.99	72.166670	24.116670
6	Brahmanvada	64.40	64.40	300.00	72.180556	23.655556
7	Chanasma	72.00	72.00	304.00	72.113889	23.713889
8	Kamliwada	96.00	96.00	593.10	72.233333	23.883333
9	Kunger	70.30	70.30	274.00	72.066667	23.797222
10	Kuvara	122.00	122.00	304.00	72.266667	23.983333
11	Lanva	76.90	76.90	330.00	72.252778	23.698611
12	Munjpur	36.00	36.00	600.15	71.850000	23.583330
13	Panchasar	25.00	25.00	610.82	71.750000	23.425000
14	Radhanpur	28.20	28.20	618.00	71.602778	23.848611
15	Sariyad	67.64	67.64	613.00	72.000000	23.933333
16	Shankheshwar	31.20	31.20	295.66	71.790278	23.508611
17	Sonar	28.90	28.90	280.00	71.740278	23.672222
18	Varahi	17.86	17.86	586.91	71.463889	23.797222
19	Badarpura	34.00	34.00	305.00	71.712778	23.813333
20	Bhilot	28.00	28.00	305.00	71.541667	23.863333
21	Dahegam	16.00	16.00	305.04	71.471667	23.741667
22	Lotiya	35.00	35.00	305.06	71.553611	23.951944
23	Dabhi Unrot	20.00	20.00	304.30	71.365278	23.843056
24	Par	11.00	11.00	303.43	71.211667	23.766944
25	Zazam	21.00	21.00	308.75	71.339181	23.939340
26	Nindroda	100.00	100.00	301.36	72.205000	23.963611

Annexure XIII

Location-wise classification of aquifer groups

Village	Depth, m		Aquifer Group/Aquitard
	From	To	
Abiyana	0	50	Aquitard 1
Abiyana	50	66	Aquifer Group 1
Abiyana	66	95	Aquitard 2
Abiyana	95	105	Aquifer Group 2
Abiyana	105	128	Aquitard 3
Abiyana	128	158	Aquifer Group 3
Abiyana	158	218	Aquitard 4
Abiyana	218	296	Aquifer Group 4
Amrapura	0	85	Aquifer Group 1
Amrapura	85	135	Aquitard 1
Amrapura	135	280	Aquifer Group 2
Amrapura	280	300	Aquitard 2
Amrapura	300	300	Aquifer Group 3
Amrapura	300	300	Aquitard 4
Amrapura	300	300	Aquifer Group 4
Balisana	0	79	Aquifer Group 1
Balisana	79	87	Aquitard 1
Balisana	87	217	Aquifer Group 2
Balisana	217	232	Aquitard 2
Balisana	232	300	Aquifer Group 3
Balisana	300	300	Aquitard 4
Balisana	300	300	Aquifer Group 4
Baspa	0	31	Aquifer Group 1
Baspa	31	50	Aquitard 1
Baspa	50	81	Aquifer Group 2
Baspa	81	257	Aquitard 2
Baspa	257	300	Aquifer Group 3
Baspa	300	300	Aquitard 4
Baspa	300	300	Aquifer Group 4
Bhatsan	0	74	Aquifer Group 1
Bhatsan	74	124	Aquitard 1
Bhatsan	124	183	Aquifer Group 2
Bhatsan	183	215	Aquitard 2
Bhatsan	215	257	Aquifer Group 3
Bhatsan	257	300	Aquitard 3
Bhatsan	300	300	Aquitard 4
Bhatsan	300	300	Aquifer Group 4
Brahmanvada	0	102	Aquifer Group 1
Brahmanvada	102	117	Aquitard 1
Brahmanvada	117	193	Aquifer Group 2
Brahmanvada	193	211	Aquitard 2
Brahmanvada	211	306	Aquifer Group 3
Brahmanvada	300	300	Aquitard 4
Brahmanvada	300	300	Aquifer Group 4
Chanasma	0	103	Aquifer Group 1
Chanasma	103	130	Aquitard 1
Chanasma	130	245	Aquifer Group 2
Chanasma	245	260	Aquitard 2
Chanasma	260	300	Aquifer Group 3
Chanasma	300	300	Aquitard 4
Chanasma	300	300	Aquifer Group 4
Kamliwada	0	73	Aquifer Group 1
Kamliwada	73	90	Aquitard 1

Village	Depth, m		Aquifer Group/Aquitard
	From	To	
Kamliwada	90	175	Aquifer Group 2
Kamliwada	175	213	Aquitard 2
Kamliwada	213	251	Aquifer Group 3
Kamliwada	251	300	Aquitard 3
Kamliwada	300	300	Aquifer Group 4
Kamliwada	300	300	Aquitard 4
Kunger	0	106	Aquifer Group 1
Kunger	106	133	Aquitard 1
Kunger	133	203	Aquifer Group 2
Kunger	203	214	Aquitard 2
Kunger	214	290	Aquifer Group 3
Kunger	290	300	Aquitard 3
Kunger	300	300	Aquifer Group 4
Kunger	300	300	Aquitard 4
Kuvara	0	76	Aquifer Group 1
Kuvara	76	99	Aquitard 1
Kuvara	99	197	Aquifer Group 2
Kuvara	197	225	Aquitard 2
Kuvara	225	261	Aquifer Group 3
Kuvara	261	278	Aquitard 3
Kuvara	278	300	Aquifer Group 4
Kuvara	300	300	Aquitard 4
Lanva	0	114	Aquifer Group 1
Lanva	114	141	Aquitard 1
Lanva	141	186	Aquifer Group 2
Lanva	186	221	Aquitard 2
Lanva	221	296	Aquifer Group 3
Lanva	296	302	Aquitard 3
Lanva	302	302	Aquifer Group 4
Lanva	302	302	Aquitard 4
Munjpur	0	32	Aquifer Group 1
Munjpur	32	119	Aquitard 1
Munjpur	119	154	Aquifer Group 2
Munjpur	154	245	Aquitard 2
Munjpur	245	300	Aquifer Group 3
Munjpur	300	300	Aquitard 3
Munjpur	300	300	Aquifer Group 4
Munjpur	300	300	Aquitard 4
Panchasar	0	60	Aquifer Group 1
Panchasar	60	140	Aquitard 1
Panchasar	140	208	Aquifer Group 2
Panchasar	208	234	Aquitard 2
Panchasar	234	294	Aquifer Group 3
Panchasar	294	329	Aquitard 3
Panchasar	329	329	Aquifer Group 4
Panchasar	329	329	Aquitard 4
Radhanpur	0	45	Aquifer Group 1
Radhanpur	45	259	Aquitard 1
Radhanpur	259	287	Aquifer Group 2
Radhanpur	287	304	Aquitard 2
Radhanpur	304	304	Aquifer Group 3
Radhanpur	304	304	Aquitard 3
Radhanpur	304	304	Aquifer Group 4
Radhanpur	304	304	Aquitard 4
Sariyad	0	92	Aquifer Group 1
Sariyad	92	159	Aquitard 1
Sariyad	159	251	Aquifer Group 2
Sariyad	251	269	Aquitard 2

Village	Depth, m		Aquifer Group/Aquitard
	From	To	
Sariyad	269	317	Aquifer Group 3
Sariyad	317	317	Aquitard 3
Sariyad	317	317	Aquifer Group 4
Sariyad	317	317	Aquitard 4
Shankheshwar	0	27	Aquifer Group 1
Shankheshwar	27	77	Aquitard 1
Shankheshwar	77	98	Aquifer Group 2
Shankheshwar	98	204	Aquitard 2
Shankheshwar	204	253	Aquifer Group 3
Shankheshwar	253	274	Aquitard 3
Shankheshwar	274	274	Aquifer Group 4
Shankheshwar	274	274	Aquitard 4
Sonar	0	114	Aquifer Group 1
Sonar	114	126	Aquitard 1
Sonar	126	153	Aquifer Group 2
Sonar	153	187	Aquitard 2
Sonar	187	280	Aquifer Group 3
Sonar	280	280	Aquitard 3
Sonar	280	280	Aquifer Group 4
Sonar	280	280	Aquitard 4
Varahi	0	21	Aquifer Group 1
Varahi	21	234	Aquitard 1
Varahi	234	248	Aquifer Group 2
Varahi	248	300	Aquitard 2
Varahi	300	300	Aquifer Group 3
Varahi	300	300	Aquitard 3
Varahi	300	300	Aquifer Group 4
Varahi	300	300	Aquitard 4
Badarpura	0	73	Aquifer Group 1
Badarpura	73	136	Aquitard 1
Badarpura	136	144	Aquifer Group 2
Badarpura	144	194	Aquitard 2
Badarpura	194	204	Aquifer Group 3
Badarpura	204	261	Aquitard 3
Badarpura	261	282	Aquifer Group 4
Badarpura	282	305	Aquitard 4
Bhilot	0	42	Aquifer Group 1
Bhilot	42	205	Aquitard 1
Bhilot	205	257	Aquifer Group 2
Bhilot	257	277	Aquitard 2
Bhilot	277	285	Aquifer Group 3
Bhilot	285	305	Aquitard 3
Bhilot	305	305	Aquifer Group 4
Bhilot	305	305	Aquitard 4
Dahegam	0	41	Aquifer Group 1
Dahegam	41	146	Aquitard 1
Dahegam	146	157	Aquifer Group 2
Dahegam	157	191	Aquitard 2
Dahegam	191	213	Aquifer Group 3
Dahegam	213	262	Aquitard 3
Dahegam	262	284	Aquifer Group 4
Dahegam	284	305	Aquitard 4
Lotiya	0	61	Aquifer Group 1
Lotiya	61	180	Aquitard 1
Lotiya	180	206	Aquifer Group 2
Lotiya	206	227	Aquitard 2
Lotiya	227	263	Aquifer Group 3
Lotiya	263	305	Aquitard 3

Village	Depth, m		Aquifer Group/Aquitard
	From	To	
Lotiya	305	305	Aquifer Group 4
Lotiya	305	305	Aquitard 4
Dabhi Unrot	0	41	Aquifer Group 1
Dabhi Unrot	41	125	Aquitard 1
Dabhi Unrot	125	134	Aquifer Group 2
Dabhi Unrot	134	229	Aquitard 2
Dabhi Unrot	229	241	Aquifer Group 3
Dabhi Unrot	241	304	Aquitard 3
Dabhi Unrot	304	304	Aquifer Group 4
Dabhi Unrot	304	304	Aquitard 4
Par	0	36	Aquifer Group 1
Par	36	204	Aquitard 1
Par	204	216	Aquifer Group 2
Par	216	242	Aquitard 2
Par	242	280	Aquifer Group 3
Par	280	298	Aquitard 3
Par	298	303	Aquifer Group 4
Par	303	303	Aquitard 4
Zazam	0	51	Aquifer Group 1
Zazam	51	186	Aquitard 1
Zazam	186	233	Aquifer Group 2
Zazam	233	267	Aquitard 2
Zazam	267	292	Aquifer Group 3
Zazam	292	308	Aquitard 3
Zazam	308	308	Aquifer Group 4
Zazam	308	308	Aquitard 4
Nindroda	0	60	Aquifer Group 1
Nindroda	60	195	Aquitard 1
Nindroda	195	216	Aquifer Group 2
Nindroda	216	232	Aquitard 2
Nindroda	232	248	Aquifer Group 3
Nindroda	248	301	Aquitard 3
Nindroda	301	301	Aquifer Group 4
Nindroda	301	301	Aquitard 4

Annexure XIV

Well inventory details in Patan district

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
1	Dhinoj	DW	Panchayat	Chanasma	Near Narayan Bhavani (Ashapura Mata Temple) Rahatio Kuwo	46A/6	2A1	23°39'39"	72°16'59"	22.1	5.4	0.5	12.25	
2	Palasar	TW	Shardaben Babaldas Patel	Chanasma	On RHS of the approach road to the village Palasar from the highway towards Mahesana, Before entering the village in the field on the road side in the owner's land	46A/6	1A3			300	0.25		120	
3	Shelavi	DW	Panchayat	Chanasma	Infront of Primary School and near Ambaji Temple	46A/6	1A4	23°42'42"	72°16'19"	18.5	3.9		6.6	
4	Manund	TW	Panchayat	Patan	Near CharRasta Society gate, near overhead tank infront of Primary School	46A/6	1A5			300	0.2		165	
5	Balisana	DW	Patel Babalbhai Devchandbhai	Patan	About 1 km South of balisana village,About 750m NE of Balisana-Sander Road near Right bank of Sujalam	46A/5	1C5	23°48'37"	72°15'18"	23.2	2.85	0.35	21.6	2000

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
					Sufalam Canal in Owners farm									
6	Balisana 2	TW	Patel Babalbhai Devchandbhai	Patan	About 1 km South of balisana village,About 750m NE of Balisana-Sander Road near Right bank of Sujalam Sufalam Canal in Owners farm	46A/5	1C6	23°48'37"	72°15'18"	305	0.3		164.59	600
7	Der	TW	Prabhuji Bhemaji	Patan	About 700m NE of Village, South of Der-Mangalpura road in Owner's Farm	46A/5	2A1	23°51'44"	72°16'58"	279	0.3		152.4	600
8	Wanasan	TW	Sadrubhai Mamjibhai Momin	Sidhpur	About 500m SW of Wanasan Village, North of Kacha track to Lotpur	46A/5	2A2	23°53'25"	72°15'37"	168	0.25		91.44	2000
9	Karan 1	TW	Wasantbhai Dwarkadas Patel	Sidhpur	North of Patan-Sidhpur highway, near road entrance to village in Owner's Farm	46A/5	2A3	23°53'10"	72°18'02"	305	0.3		60.96	1400
10	Karan 2	TW	Wasantbhai Dwarkadas Patel	Sidhpur	North of Patan-Sidhpur highway, near road entrance to village in Owner's Farm	46A/5	2A4	23°53'10"	72°18'02"	57	0.25	0.4	26.7	1500
11	Varsila	TW	Panchayat	Sidhpur	North of Village near overhead	46A/5	1A1	23°56'38"	72°16'14"	300	0.2		152.4	1500

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
					tank									
12	Kalyana	DW	Panchayat	Sidhpur	Near North East embankment of pond, Near overhead tank, East of village	46A/1	1C1	23°57'38"	72°14'24"	38.6	5	1.75	21.15	700
13	Kalyana 2	TW	Panchayat	Sidhpur	East of village near overhead tank on Sewari Road	46A/1	1C2	23°57'38"	72°14'24"	305	0.2		161.54	1800
14	Kalyana Pz 3	Pz	GWRDC	Sidhpur	In the play Ground behind Kalyana High School	46A/1	1C3	23°57'38"	72°14'24"	245	0.15	1	130.15	
15	Kalyana Pz 2	Pz	GWRDC	Sidhpur	In the play Ground behind Kalyana High School	46A/1	1C5	23°57'38"	72°14'24"	200	0.15	1	161.35	
16	Kalyana Pz 1	Pz	GWRDC	Sidhpur	In the play Ground behind Kalyana High School	46A/1	1C4	23°57'38"	72°14'24"	150	0.15	1	69.48	
17	Kuder	DW	Rajput Shankarjee Banajee	Patan	North of Unjha-Patan Highway, about 300m East of Sujalam Sufalam Canal in Owner's Farm	46A/1	3C1	23°49'36"	72°14'07"	19	2.35	0.4	14.08	1300
18	Dharpur	TW	Panchayat	Patan	South of Village pond near overhead Tank	46A/1	2C1	23°50'41"	72°12'04"	305	0.2		164.59	1500
19	Runi	TW	Panchayat	Patan	Near village name board, North of Patan Sidhpur Highway, near	46A/1	2C3	23°51'28"	72°10'01"	220	0.2		54.86	1300

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
					overhead tank									
20	Kamliwada	TW	Lakhman Lila Desai	Patan	About 1 km West of Kamliwada village, About 200m East of Sujalam Sufalam Canal in Owner's Farm	46A/1	2C4	23°52'07"	72°12'35"	259	0.25		152.4	1500
21	Sonti	DW	Goda Magan Desai	Patan	About 600m NW of Sonti village, Near Left Bank of Sujalam Sufalam Canal in Agricultural Land	46A/1	2C5	23°50'55"	72°13'13"	14.3	2	0.7	9	300
22	Matarwadi Pz 1	Pz	CGWB	Patan	Infront of Hari Hareshwar Mahadev temple	46A/1	2B1	23°52'06"	72°08'50"	194	0.15	0.4	65.2	
23	Matarwadi Pz 2	Pz	CGWB	Patan	Infront of Hari Hareshwar Mahadev temple	46A/1	2B2	23°52'06"	72°08'50"	139	0.15	0.2	108.75	
24	Bhutia Wasna TW 1	Pz	CGWB	Patan	South of Village, About 150m South of Patan Shihori Road in Waste Land	46A/1	2B3	23°54'23"	72°05'55"	30	0.3	0.5	29.76	
25	Kosa	TW	Panchayat	Patan	South of Village near Western Embankment of Pond Locate South of Village	46A/1	1A1	23°55'10"	72°04'21"	305	0.2		91.44	
26	Khalipur	TW	Patan Panjrapole	Patan	In the premises of Khalipur Panjrapole located East of Village	46A/1	2A1	23°53'03"	72°04'10"	299	0.25		121.92	
27	Mota Veloda	TW	Panchayat	Patan	North West of	46A/1	1A2	23°57'37"	72°02'00"	302	0.2		106.68	

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
					Village near Eastern Embankment of Pond									
28	Lodhi	TW	Panchayat	Patan	Near South West Embankment of Pond near village supply Sump	46A/1	1A3	23°58'44"	72°00'52"	229	0.2		106.68	
29	Laxmipura	TW	Panchayat	Patan	In the Centre of the village infront of Panchayat office	46A/1	1A4	23°59'57"	72°00'08"	305	0.2		115.82	
30	Wayad Pz	Pz	GWRDC	Patan	In the Premises of Dantiwada Colony	45D/4		23°01'36"	72°02'47"	250	0.15		104.97	
31	Rakhav (Karsanpura)	TW	Thokore Ganeshji Rawtaji	Patan	20m west of Patan-Shihori Highway behind Karsanpura Prathmik Shal, about 1 km SW of Rakhav village in Owner's Farm	46A/1	1A5	23°59'02"	72°04'14"	204	0.2		60.96	
32	Nayta Nana	TW	Kalyansing Hemsangji	Patan	About 1 km NE of village, West of Approach road to village in Owners Farm	46A/1	1B1	23°58'07"	72°06'15"	213	0.2		91.44	
33	Wagdod Pz	Pz	GWRDC	Patan	In the premises of Dantiwada Colony	46A/1	1B2	23°59'06"	72°08'50"	250	0.15	1	125	
34	Jangral Pz 3	Pz	CGWB	Patan	Near GEB	45D/4	3B2	24°02'26"	72°09'28"	192	0.15	1	137.45	
35	Jangral Pz 1	Pz	CGWB	Patan	Near GEB	45D/4	3B2A	24°02'26"	72°09'28"	442	0.15	0.9	144.72	
36	Wagdod	TW	Kurshibhai Haribhai	Patan	About 500m West of Wagdod,	46A/1	1B3	23°59'29"	72°08'36"	259	0.3		106.68	

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
					50m North of Wagdod-Endla Road in Owner's Farm									
37	Wagdod 2	DCB	Desai Versibhai Kalubhai	Patan	West of Wagdod, Near Left Bank of Dantiwada Main Canal in Owner's Farm	46A/1	1B4	23°59'06"	72°08'43"	15.5	2.1	GL	9	
38	Wadu	TW	Rasulbhai Kadiwala	Patan	About 750m SW of Wadu, South of Wadu-Charup Kacha Track, About 50m South of Sujalam Sufalam Canal in Owner's farm	46A/1	1B5	23°57'30"	72°09'13"	305	0.2		103.63	
39	Charup	TW	Panchayat	Patan	NW of village, near overhead tank and Jain Derasar	46A/1	1B6	23°56'27"	72°07'33"	244	0.2		109.72	
40	Paldi	TW	Umed Pasha	Patan	About 500m NNW of village, West of patan-Deesa Highway in Owner's Farm	46A/1	2B4	23°53'30"	72°09'16"	244	0.25		121.92	
41	Kimbuwa Pz	Pz	GWRDC	Patan	Near the Right Bank of Sujalam Sufalam Canal, South of Approach Road of Kimbuwa village, about 1 km West of Village	46A/1	1C6	23°56'03"	72°10'09"	59	0.15	0.8	23.28	
42	Kimbuwa	TW	Panchayat	Patan	East of Village,	46A/1	1C7	23°55'50"	72°10'43"	366	0.2		137.16	

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
					West of Pond near overhead tank									
43	Sihol Pz 1	Pz	GWRDC	Patan	About 500m NE of Sihol village, South of Wadu-Sidhpur Road in waste Land	46A/1	1C8	23°57'23"	72°10'50"	79	0.15	1	36.58	
44	Sihol Pz 2	Pz	GWRDC	Patan	About 500m NE of Sihol village, South of Wadu-Sidhpur Road in waste Land	46A/1	1C9	23°57'23"	72°10'50"	152	0.15	0.7	42.6	
45	Sihol	TW	Thakkar Dalpatji Keshaji	Patan	About 500m NE of Sihol village, South of Wadu-Sidhpur Road in Owner's Farm	46A/1	1C10	23°57'25"	72°10'51"	366	0.3		121.92	
46	Dhanawada	TW	Panchayat	Sidhpur	Near North Western embankment of Pond and Overhead Tank	46A/1	1C11	23°59'56"	72°14'08"	305	0.2		137.16	
47	Kotawad	TW	Panchayat	Sidhpur	About 300m North of Village, West of Pond and 10m West of Kotawad to Malapur Road	46A/1	1C12	23°55'29"	72°12'48"	305	0.2		137.16	
48	Gulwasna Pz	Pz	GWRDC	Sidhpur	50m North of Kotawad-Aghar Road, Near Canal crossing with Roadand Left bank of Sujalam Sufalam	46A/1	1B6	23°54'27"	72°10'57"	59	0.15	1	9.98	

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
					Canal									
49	Ajumana	TW	Panchayat	Patan	About 500m East of Village on Ajumana to Kuntawada Roadnear overhead tank	46A/1	1B1	23°53'14"	72°12'01"	160	0.25		76.2	
50	Ajumana Pz	Pz	GWRDC	Patan	Near Shmashan Griha, near overhead tank and 50m East of Panchayat TW	46A/1	1B6	23°53'14"	72°12'12"	60	0.15	1	72.6	
51	Golapur Pz	Pz	GWRDC	Patan	About 500m SE of Golapur village, East of Golapur-Sankhari Road, South of canal Crossing (Saraswati Jalashay Yojana Main Canal), on the right bank	46A/1	3B1	23°49'05"	72°07'44"	60	0.15	1	45.05	
52	Rajpur	TW	Godabhai Patel	Patan	About 200m West of Golapur-Sankhari Road, South of approach road to Rajpur in Owner's Farm	46A/1	3B2	23°48'44"	72°07'55"	183	0.3		85.34	
53	Sankhari	DW	Panchayat	Patan	Esat of Pond near overhead tank, Village Water supply well	46A/1	3C1	23°46'47"	72°09'54"	25.5	4	1	16.9	
54	Sankhari	TW	Patel Kuberbhai	Patan	Near Western	46A/1	3C2	23°46'20"	72°10'30"	305	0.3		137.16	

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
			Motibhai		Embankment of Pond on Sankhari Ranunj Road in Owner's Farm									
55	Ranunj	TW	Panchayat	Patan	Opp. Ranunj railway Station near Krishnanagar Society, infront of Ambaji Temple	46A/1	3C3	23°45'33"	72°12'50"	305	0.2		167.64	
56	Norta Wanta	TW	Panchayat	Patan	North of Village near Southern Embankment of village pond	46A/1	3C4	23°48'33"	72°11'16"	326	0.2		146.3	
57	Patan	DW	Dargah	Patan	SW of patan City near Dargah and Old Ruined building, about 500m west of Patan Chanasma highway opposite Mira Datar Dargah	46A/1	2B5	23°50'17"	72°07'35"	22	2	1.2	16.8	
58	Sonti Pz	Pz	GWRDC	Patan	About 1 km NNE of Sonti village near left bank of Sujalam Sufalam Canal	46A/1	2C7	23°50'58"	72°13'10"	57.1	0.15	0.8	25.85	
59	Fichal	TW	Panchayat	Patan	GWSSB Water Supply Well	46 A/2	1C2			305				1875
60	Fichal	DW	Panchayat	Patan	Ab dug well on high side of Road infront of	46 A/2	1C2A			24.4		1.25	17.34	

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
					Patel house Smrati and opp Small Chamunda Mata mandir									
61	Sodhavad	TW		Patan		41 M/13	1C1			274				3100
62	Sariyad Goliwade	TW		Patan		41 M/13	1C2A			259				3200
63	Sariyad Dhanera Road	TW		Patan		41 M/13	1C2B			213				2400
64	Sampra	TW		Patan		41 M/13	1C3			314				1200
65	Undra	TW		Patan		41 M/13	1C4			159				680
66	Koita pz	TW		Patan		45 D/4	3B1							1300
67	Koita pz	PZ	GWRDC/Irrigation	Patan	Canal Colony by the sdie of Road to Delwada	45 D/4	3B1	24°04'22"	72°09'51"	250		1	139.9	
68	Jhangral	TW		Patan		45 D/4	3B2			305				2500
69	Jhangral	PZ-1	CGWB	Patan	Behind Telephone Exchange	45 D/4	3B2							
70	Jhangral	PZ-2	CGWB	Patan	Behind Telephone Exchange	45 D/4	3B2							
71	Jhangral	PZ-3	CGWB	Patan	Behind Telephone Exchange	45 D/4	3B2							
72	Kaleda	TW		Siddhpur		45 D/4	3C1			259				3600
73	Zakha pz	PZ1-3		Patan		45 D/4								
74	Hyderpura	TW		Patan		45 D/4	3C2							3400
75	Wagdord pz	PZ	GWRDC/Irrigation	Patan	Canal Colony by the sdie of Road							0.9	127.4	
76	Edela	TW		Patan		45 D/4	3B4			305				1800
77	Edela	PZ	GWRDC	Patan	Near Water Supply well by the sdie of Road Edela-	45 D/4	3B4A	24°00'24"	72°07'10"	59		0.8	42.7	

Sr. No.	Village	Well Type	Owner	Taluk	Location	Toposheet	Quad	Lat.	Long	Depth, m	Dia	MP	WL mbmp	EC
					Gansehpura Road									
78	Ganeshpura	TW		Patan		45 D/4	3B5			236				1700
79	Deliyathara	TW	Thakur Nagji Bhai Ravji Bhai	Patan	In the field of Ex Sarpanh Thakur Nagji Ravji - cart Track leading his house	45 D/4	3A2			168			104.55	1900
80	Lakshmipura vadhani	TW		Patan		45 D/4	3C3			274				2100
81	Ablauo	TW		Patan		45 D/4	3B6			274				1900
82	Ablauo pz	PZ	GWRDC	Patan	About 200 m from the water supply well on cart track in front of Thakurs fields	45 D/4	3B6A	23°34'05"	72°22'09"	61		0.8	49.7	
83	Wayad	TW		Patan		45 D/4	3A4			186				2800
84	Wayad pz	PZ	GWRDC/Irrigation	Patan	In the Shamshan Ground	45 D/4	3A4A						57 FILLED	
85	Dhanashara	TW		Patan		45 D/4	3A6			213				
86	Gacheli	TW		Patan		45 D/4	3A7			305				2200

Annexure XV

Chemical Data Inventoried wells in Patan district

S. N.	Type	Location	Date	pH	EC, uS/cm	TDS	CO_3	HCO_3	Cl	NO_3	SO_4	F	Alk'y	Ca	Mg	TH	Na	K	SAR
												mg/L							
1	TW	Fishall	11.07.12	8.21	2046	1371	0	366	291	13	245	2.34	300	44	7	140	390	2.50	14.33
2	TW	Sodhavad	11.07.12	7.86	3263	2186	0	92	780	5	407	0.58	75	220	48	750	400	5.70	6.35
3	TW	Sariyadgoliwade	11.07.12	8.27	3440	2305	0	317	780	24	291	1.26	260	200	24	600	506	3.40	8.98
4	TW	Sariyaddhanera	11.07.12	8.23	2494	1671	0	281	518	20	200	0.75	230	40	38	260	431	3.20	11.62
5	TW	Sampra	11.07.12	8.20	1340	898	0	317	206	8	95	1.49	260	40	17	170	227	2.40	7.57
6	TW	Undra	11.07.12	8.24	710	476	0	244	85	12	52	1.13	200	24	12	110	128	1.00	5.31
7	TW	Koita	12.07.12	8.24	1548	1037	0	342	241	24	126	1.48	280	36	17	160	285	1.50	9.80
8	TW	Jhangral	12.07.12	8.20	2690	1802	0	354	553	42	214	1.13	290	44	26	220	515	2.20	15.10
9	TW	Kaleda	13.07.12	8.25	4028	2699	0	561	886	32	229	2.32	460	100	60	500	688	1.40	13.38
10	TW	Hyderpura	13.07.12	8.16	3620	2425	0	354	815	55	330	1.13	290	120	72	600	573	2.50	10.17
11	TW	Edela	13.07.12	8.26	1930	1293	0	427	312	35	146	1.48	350	32	17	150	382	2.50	13.56
12	TW	Ganeshpura	13.07.12	8.28	1806	1210	0	439	269	22	126	1.44	360	24	19	140	348	2.30	12.79
13	TW	Deliyathrara	13.07.12	8.08	2133	1429	0	146	539	23	152	1.68	120	48	26	230	387	2.00	11.09
14	TW	Laxmipura Vadani	14.07.12	8.28	2200	1474	0	439	369	34	146	1.18	360	36	31	220	391	2.10	11.46
15	TW	Ablauo	14.07.12	8.27	1960	1313	0	415	354	39	68	1.29	340	24	24	160	364	2.00	12.51
16	TW	Saviyana	14.07.12	8.24	1280	858	0	427	184	29	30	2.26	350	24	10	100	264	2.10	11.48
17	DW	Wayad	14.07.12	8.16	2990	2003	0	415	574	34	284	1.26	340	40	31	230	578	1.90	16.57
18	TW	Dhanshara	14.07.12	8.19	3940	2640	0	549	1064	36	14	1.28	450	40	55	330	776	3.20	18.57
19	TW	Gacheli	14.07.12	8.04	2210	1481	0	232	503	26	138	0.88	190	48	31	250	380	3.40	10.45
20	DW	Balisana	04.07.12	8.10	3532	2366	0	860	596	80	70	1.33	705	160	63	660	477	49.30	8.07
21	TW	Balisana 2	04.07.12	8.20	2616	1753	0	427	469	32	191	2.60	350	16	29	160	502	2.60	17.26
22	TW	Der	04.07.12	8.20	1652	1107	0	403	263	44	47	2.44	330	24	32	190	279	1.80	8.80
23	TW	Wanasan	04.07.12	8.00	3189	2137	0	512	582	22	272	2.50	420	24	34	200	625	2.40	19.21
24	TW	Karan 1	04.07.12	8.20	2095	1404	0	464	341	42	124	2.30	380	32	29	200	385	3.10	11.84
25	TW	Karan 2	04.07.12	8.00	2332	1562	0	476	426	70	90	1.13	390	48	68	400	346	10.10	7.52
26	TW	Varsila	05.07.12	8.20	1395	935	0	403	206	28	74	2.72	330	20	15	110	286	1.70	11.86
27	DW	Kalyana	05.07.12	8.20	1008	675	0	488	71	28	5	1.20	400	32	24	180	159	5.50	5.15
28	TW	Kalyana 2	05.07.12	8.10	1618	1084	0	403	312	11	53	1.00	330	32	24	180	305	1.90	9.88
29	DW	Kuder	06.07.12	8.10	2011	1347	0	598	320	24	56	1.25	490	20	102	470	257	0.20	5.15
30	TW	Dharpur	06.07.12	8.20	1895	1270	0	476	327	10	97	2.46	390	20	27	160	374	1.30	12.86
31	TW	Runi	06.07.12	8.20	1856	1244	0	439	376	24	9	2.46	360	16	27	150	360	0.50	12.78
32	TW	Kamliwada	06.07.12	8.10	1854	1242	0	610	270	15	31	2.76	500	36	0	90	390	0.60	17.87
33	DW	Sonti	06.07.12	8.20	566	379	0	268	50	13	13	0.80	220	32	24	180	63	0.80	2.04

S. N.	Type	Location	Date	pH	EC, uS/cm	TDS	CO_3	HCO_3	Cl	NO_3	SO_4	F	Alk'y	Ca	Mg	TH	Na	K	SAR
												mg/L							
34	TW	Kosa	18.07.12	7.67	1580	1059	0	354	185	50	106	0.20	290	80	39	360	159	59.70	3.64
35	TW	Kalipur	18.07.12	7.97	1357	909	0	256	185	49	104	0.47	210	52	49	330	135	36.10	3.23
36	TW	Mota Veloda	18.07.12	7.53	2364	1584	0	451	320	65	274	0.55	370	96	102	660	233	2.40	3.94
37	TW	Lodi	18.07.12	7.83	1910	1280	0	415	320	6	216	0.47	340	136	92	720	142	2.10	2.30
38	TW	Laxmipura	18.07.12	7.64	1095	734	0	451	951	19	226	0.46	370	116	253	1330	299	2.90	3.56
39	TW	Rakhav	18.07.12	7.64	1306	875	0	488	135	43	79	0.10	400	120	80	630	37	3.10	0.64
40	TW	NanaNayta	18.07.12	7.75	2626	1759	0	390	540	50	178	0.20	320	132	159	980	155	0.80	2.15
41	TW	Wagdod	19.07.12	7.82	1855	1243	0	610	220	49	139	0.19	500	100	129	780	101	1.70	1.57
42	DW	Wagdod	19.07.12	7.90	1214	813	0	424	142	19	80	0.15	348	64	85	510	64	3.10	1.23
43	TW	Wadu	19.07.12	7.82	1198	803	0	415	135	43	24	0.30	340	116	39	450	66	10.30	1.35
44	TW	Chaeup	19.07.12	7.50	1685	1129	0	476	284	4	15	0.03	390	52	66	400	191	6.90	4.15
45	TW	Paladi	19.07.12	7.59	1500	1005	0	317	256	46	86	0.00	260	64	87	520	107	3.60	2.04
46	TW	Kimbuwa	19.07.12	7.73	1464	981	0	378	213	47	24	0.15	310	84	56	440	109	28.90	2.26
47	TW	Sihol	19.07.12	7.90	1560	1045	0	476	185	49	60	0.50	390	56	78	450	101	73.70	2.07
48	TW	Dhanwada	19.07.12	7.88	1182	792	0	244	163	48	20	0.25	200	52	44	310	84	54.80	2.07
49	TW	Kotawad	20.07.12	7.74	1485	995	0	378	220	49	96	0.09	310	116	78	610	71	1.00	1.25
50	TW	Ajumana	20.07.12	7.33	1486	996	0	573	178	43	21	0.62	470	136	78	650	61	6.80	1.04
51	TW	Rajpur	20.07.12	7.43	1240	831	0	439	163	47	53	0.09	360	108	75	580	49	3.10	0.88
52	TW	Sankhari	20.07.12	7.50	1298	870	0	305	206	47	63	0.08	250	64	75	470	82	1.80	1.64
53	TW	Ranunj	20.07.12	7.56	2250	1508	0	451	440	26	118	0.35	370	68	131	710	199	1.60	3.25
54	TW	Nortawanta	20.07.12	7.52	2217	1485	0	464	105	2	570	0.15	380	60	121	650	219	1.00	3.73
55	DW	Dhinoj	26.07.12	8.16	1700	1139	0	268	355	3	82	0.02	220	40	48	300	237	39.40	5.95
56	TW	Palasar	26.07.12	8.28	4100	2747	0	232	1064	60	185	1.10	190	100	72	550	646	3.90	11.98
57	DW	Chelavi	26.07.12	9.00	693	464	48	244	43	2	36	0.07	280	20	17	120	120	24.50	4.76
58	TW	Manund	26.07.12	8.29	3048	2042	0	159	815	11	153	0.80	130	140	24	450	467	4.90	9.57
59	TW	Mesar	27.04.13	7.7	2185	1464	0	403	476	42	20	1.00	330	24	22	150	422	9.40	14.98
60	TW	Mesar 2	27.04.13	7.9	3538	2370	0	268	959	33	47	0.80	220	76	105	620	482	2.70	8.42
61	TW	Pachakwada	27.04.13	8.1	2837	1901	0	488	653	46	138	1.10	400	44	20	190	610	2.60	19.24
62	TW	Pachakwada 2	27.04.13	8.2	2877	1928	0	403	682	45	71	1.15	330	24	34	200	560	2.50	17.22
63	TW	Hyderpura	27.04.13	8.2	1726	1156	0	464	298	40	29	1.15	380	16	22	130	341	5.00	13.00
64	TW	Untwada	27.04.13	8.0	2518	1687	0	451	511	46	5	0.90	370	20	27	160	453	5.30	15.57
65	TW	Bhatsan	28.04.13	8.1	1873	1255	0	390	398	42	16	1.40	320	24	20	140	369	4.10	13.56
66	TW	Wana	28.04.13	8.2	2061	1381	0	415	433	36	16	1.05	340	20	22	140	399	2.90	14.66
67	TW	Khareda	28.04.13	8.1	1506	1009	0	586	192	34	37	1.50	480	16	12	90	338	6.50	15.49
68	TW	Muna	30.04.13	7.1	1687	1130	0	378	312	37	64	1.20	310	20	15	110	343	5.90	14.22
69	TW	Ajhujha	01.05.13	8.1	1233	826	0	451	135	25	8	1.60	370	20	12	100	228	3.20	9.91

S. N.	Type	Location	Date	pH	EC, uS/cm	TDS	CO_3	HCO_3	Cl	NO_3	SO_4	F	Alk'y	Ca	Mg	TH	Na	K	SAR
												mg/L							
70	DW	Bhadiya	12.05.13	7.6	12140	8134	0	403	4116	46	198	0.35	330	500	340	2650	1750	42.70	14.78
71	DW	Kolahapur	12.05.13	7.9	8180	5481	0	146	2552	50	317	1.05	120	400	281	2150	915	5.90	8.58
72	TW	Methan	30.01.14	7.7	1420	951	0	427	227	36	67	1.50	350	16	12	90	316	1.00	14.48
73	TW	Dhrumod	30.01.14	7.9	5953	3989	0	1183	1385	50	184	5.00	970	100	12	300	1331	0.80	33.41

Central Ground Water Board, West Central Region, Ahmedabad