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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

BHIWANI DISTRICT, HARYANA

उत्तर पश्चिमी क्षेत्र, चंडीगढ़

North Western Region, Chandigarh

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AQUIFER MAPPING AND MANAGEMENT PLAN

BHIWANI DISTRICT (4751 Sq Km)

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1. INTRODUCTION

1.1 Introduction & Physiographic Setup

Bhiwani District lies in South-Western part of Haryana state covering an area of 4750.93 sq.km. There is no perennial river passing through the district. Physiographic-ally the district consists of flat and level plain interrupted from place to place by clusters of sand dunes, isolated hillocks and rocky ridges. A few isolated rocky ridges elevated sharply from the plain occur in the south central portion or the district. Dohan River is the only ephemeral stream in the area and flows in direct response to precipitation. Bhiwani district ranks 3rd in Haryana with a population of 16,34,445 according to 2011 Census. The male population is 866,672 and female is 767,773. The density of population is 342 per sq.km. The literacy rate in the district is around 75.21%. 80% of the population lives in Rural area and the remaining 20% of the population lives in Urban area. Out of 444 villages 437 are inhabited and 7 are uninhabited.

1.2 Rainfall & Climate:

The climate of Bhiwani district can be classified as tropical steppe, semi-arid and hot which is mainly dry with very hot summer and cold winter except during monsoon season when moist air of oceanic origin penetrate into the district. There are four seasons in a year. The hot weather season starts from mid-March to last week of the June followed by the south- west monsoon which lasts up to September. The transition period from September to October forms the post-monsoon season. The winter season starts late in November and remains upto first week of March. The normal annual rainfall of the district is 420 mm which is unevenly distributed over the area 22 days. The south west monsoon sets in from last week of June and withdraws in end of September contributed about 85% of annual rainfall. July and August are the wettest months.Rest15% rainfall is received during non-monsoon period in the wake of western disturbances and thunder storms. Generally rainfall in the district increases from southwest to northeast.

1.3 Soils

The type of soil is an important factor for the growth of plants and crops in any area. The soil system has various criteria to classify the soils of a region such as geology, humidity, rainfall pattern, soil texture, soil salinity etc. The district has two types of soils viz Sierozem and Desert soils. The sierozem soils are found in major parts of the district and desert soils are comparatively found in smaller part of the district especially in southern

part of the district. Sierozem Soil are found in the areas where the normal annual rainfall varies from 300 to 500 mm. These soils vary from sandy loam to loamy sands in texture and are marginally fertile. Degree of salinity and alkali hazards is highly variable, though salinity is majorhazaed. These soils occur mainly in northern parts of the district

1.4 Geomorphology :

The district consists of flat and level plain interrupted from place to place by clusters of sand dunes, isolated hillocks and rocky ridges. A few isolated rocky ridges elevated sharply from the plain occur in the south central portion or the district. Dohan river is the only ephemeral stream in the area and flows in direct response to precipitation. Only the tail of this ephemeral stream falls in the south-central corner of the district and ultimately dies out in sands around village.

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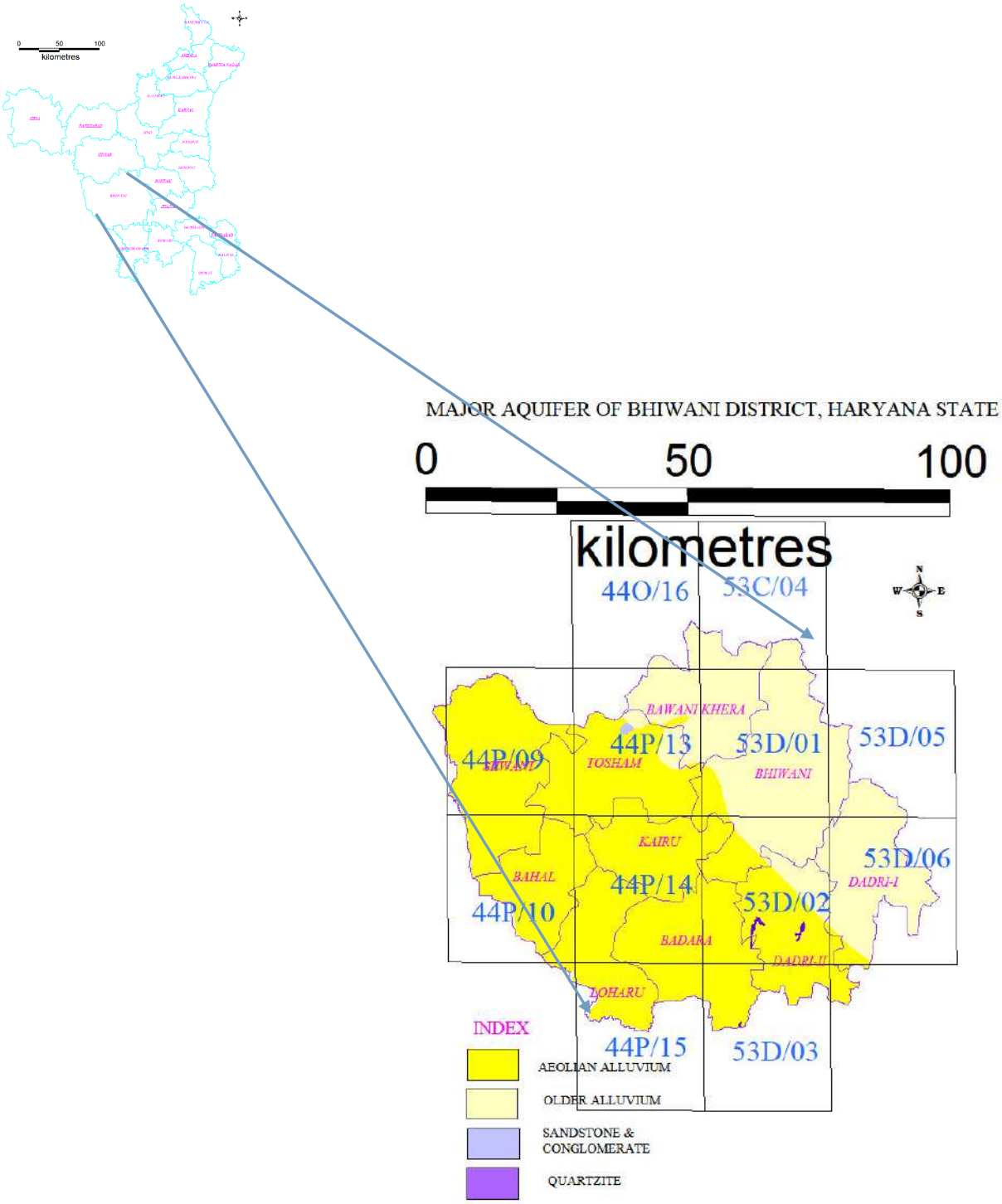
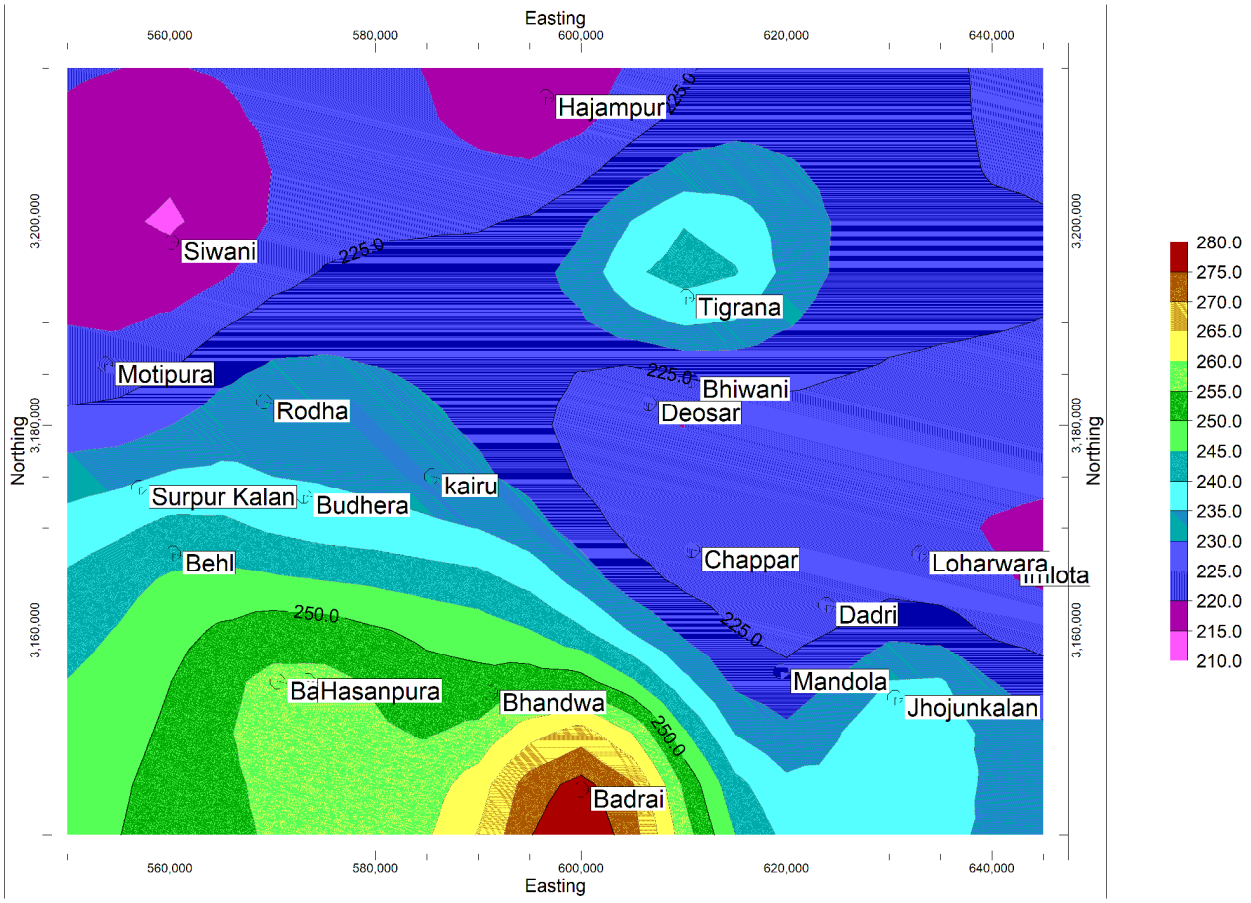
Fig 1: Base Map of Bhiwani District.



1.5 Topography

The topography values ranges between 210 to 280m amsl and has been plotted to prepare the elevation contour map (fig 2).

Fig 2: Elevation Contour Map – Bhiwani district

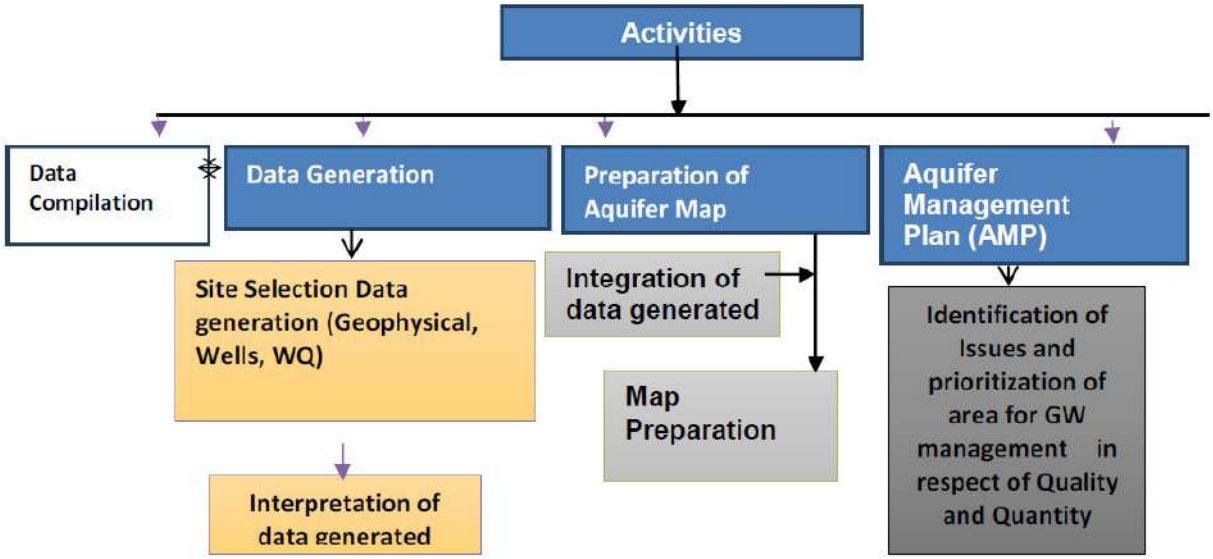


1.6 Objective, Scope of Study & Methodology:

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

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

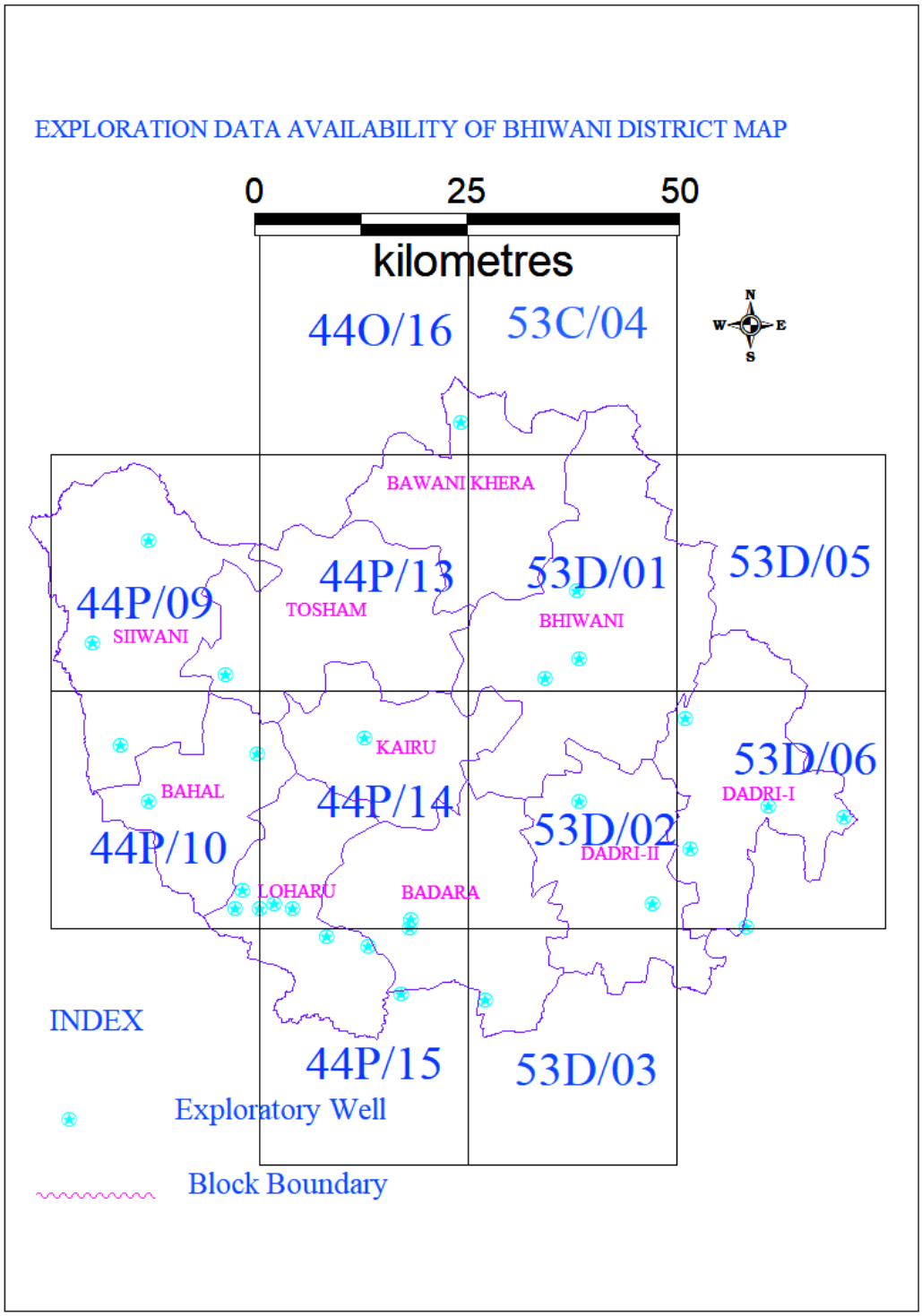
Methodology: Various activities of NAQUIM are as follows:



1.7 Data Availability, Data Adequacy, Data Gap Analysis & Data Generation

The data of CGWB wells (Fig 4) and all the wells from PHED and Private in the area are plotted on the map of 1:50000 scale with 5'X5'grid (9 x 9km) and is shown in fig 5 & 6 respectively. The grids/ formations devoid of SH/PZ/EW are identified as data gaps and these are to be filled by data generation.

Fig 3: Data Availability Location of Exploration Wells Map



2. DATA COLLECTION AND GENERATION

2.1 Hydrogeological Data

2.1.1 Geology of the Area

The geological formation met within the district are ferruginous chiastolite schist associated argillaceous rocks of Aravalli group, Alwar quartzite of Delhi system, Malani suite of volcanics of lower Vindhyan age, Older alluvial deposits of Quarternary age and Aeolian sands of recent age the out crops are, however, limited to small parts of the district, Older alluvium occurs extensively in the area consisting of inter bedded , lenticular, interfingering deposits of gravel sand ,silt, clay and Kanker mixed in various proportions. The youngest formations are aeolian deposits, which are unconsolidated surface sands covering large area in the western part of the district, these deposits occur as sand dunes at the surface and consist of sands.

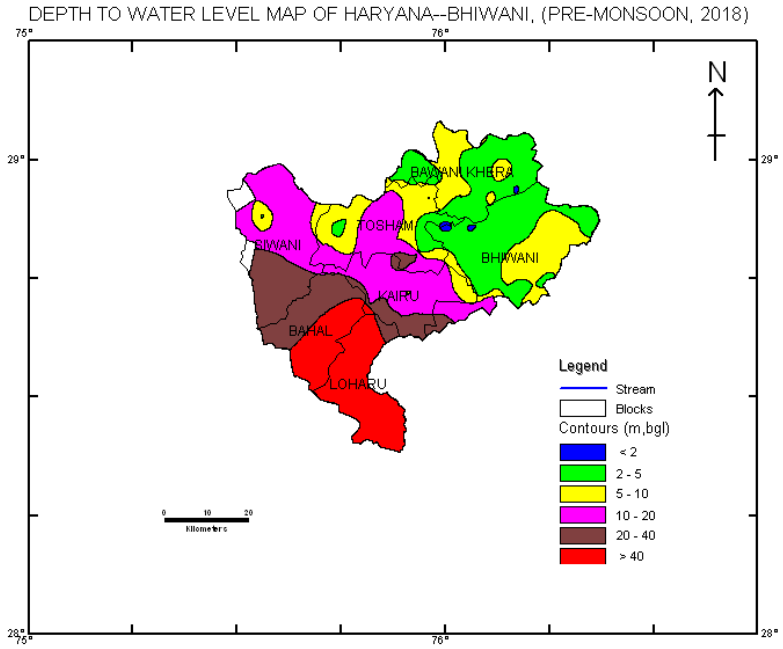
Ground water occurs in alluvium and aeolian sands and underlying jointed and fractured hard rocks formations also form the aquifers, in alluvium, sands, silt, kankar and gravel form the water bearing zones. In-shallow aquifers zones, ground water occurs under water table conditions where as in the deeper zones, confined/semi-confined condition exist, hard rocks comprising of Aravalli group of rocks, Malani suite of volcanics and Alwar Quartzites of Delhi system are water bearing but have yet not been explored thoroughly. Drilling was conducted at 21 locations in the district, with the depth .Out of these 2 were constructed andremaining had to be abandoned due to poor quality of ground water or inadequate thickness of granular zones. In alluvium granular zones exist down to its entire thickness which is of negligible thickness near the out crops as revealed by the lithologs of boreholes. An exploratory tubewell at Budhera taps aquifer zones in the depth range of 52 to 100m and yields 946 LPM for 8.4 m. of drawdown with transmissivity of

1130 m2/day. Another exploratory tubewell located at Jhojukalan taps aquifer zones in the depth range of 52 to 100m yields 632 LPM for 6.5 m. of drawdown with transmissivity of 265 m2/day , 14 Piezometers also been constructed in the district by CGWB for water level monitoring. During the post-monsoon period depth to water in the district varies from 0.84 m bgl at Dhanana, Bhawani khera block (Northern, Northeastern and Eastern part) to 64.19 m.bgl at Singhari, Loharu block (Western). In the pre-monsoon period depth to water table ranged between less than 1.87m.bgl at Dhanana, Bhawani khera block to 65.97 m bgl at Singhari, Loharu block The depth to water level is shallow and range between 0.84 m to 10 m in the Northern, Northeastern and Eastern (Tosham Bhiwani khera Dadri-l and Bhiwani blocks) and 10 to 20 m.bgl in the Southern and Northwestern parts of the district (Badra, Dadri-ll and Siwani). Ground water levels are deeper in the Western and some patches in the Central part ranging from 40 to more than 60 m(Loharu and Siwani blocks). Water level fluctuation for 10 years shows rising water level trend in the Northern blocks and declining water level trend in southern blocks. During pre-monsoon water level rise fluctuates between 0.35 to 4.44 m, while in post monsoon it varies from 1.12 to 3.35 m. The decline varies from 0.71 m to 7.68 m.

2.1.2 Water Level Behaviour (2018)

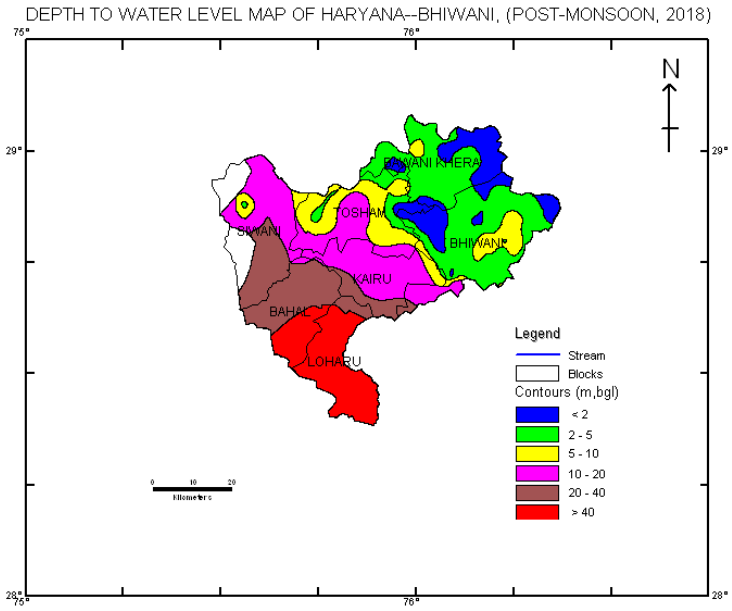
The depth to water level ranges from 1.52m bgl at Dhang PZ to 68.81m bgl at Singhani PZ during pre-monsoon (fig 4) and 1.74m bgl to 69.45m bgl during post-monsoon at Dhanan and BhudhriPZ respectively. The water level fluctuation shows both rise and fall in the water level equally. During post-monsoon, the rise in the water level ranges from 0.04m at Bawani Khera PZ to 2.6m at Bhusan and fall in the water level ranges from 0.45m at Baliyali PZ to 3.88m at Barshi PZ.. Depth to water level map divided whole of district in two equal part Noert eastern part of district less than 10m bgl and South eastern part more than 10m bgl.

Fig 4: Depth to water level map (Pre-monsoon, 2018).



The long term trend in the water level reflected by water level hydrographs is indicative of the change in ground water storage in phreatic zone with time. The ground water observation wells (GWOW) which are indicating a rise in water level trend, this may be due to local hydrological conditions prevailing in the area. Whereas hydrographs showing declining water level trend may be due to over-exploitation of good quality ground water and these area require careful management of surface water and conjunctive use of surface water and ground water. Some of the hydrographs neither showing any substantial rise nor major decline thus indicating that the dynamic storage of phreatic aquifer is being maintained which is being utilized before the monsoon and gets recharged post monsoon.

Fig 5: Depth to water level map (Pre-monsoon, 2018).



2.1.3 Ground Water Flow

The major ground water flow is towards the South eastern part of district from north eastern part of district i.e. towards tosham and loharu block. This is due to high extraction rate in these blocks because of good quality of ground water at the shallow depths.

2.1.4 Exploratory

The Lithologs of Exploratory Well/ Observation well/ Piezometer/ productive wells of CGWB, Public Health and Engineering Department (PHED) & private wells have been collected and those supported electrical logs have been validate for aquifer map preparation. Deeper well data of CGWB is available. The details are shown in table 2. The compromised logs derived from lithologs and geophysical well loggings have been taken as reliable data base.

Table 3: Data availability of Exploration Wells in Bhiwani District

Source of Data	No. Of tubewells as per Depth Range			Total Wells
	<100	100-200	200-300	
PHED	1	6	0	7
CGWB	0	18	5	23
TOTAL	1	24	5	30

Table 4: Validated data of Exploration Wells in Bhiwani District:

Bhiwani District Validated data				
Source of Data	No. Of tubewells as per Depth Range			Total Wells
	<100	100-200	200-300	
PHED	0	1	0	1
CGWB	0	15	5	20
TOTAL	0	16	5	21

2.3 Hydro chemical

Chemical quality data of shallow aquifers reveals that ground water is alkaline in nature and significant number of samples have conductivity values more than 3000µS/cm. Concentration of vital chemical constituents such as fluoride and nitrate in about 50 % of the water samples is within permissible limit assigned by BIS 1991. Among trace metals, arsenic and iron are found in excess at Sui (0.02 mg/l) and tosham (10.83 mg/l) against the maximum permissible limit of 0.01 mg/l and 1.0 mg/l respectively. Among anions, bicarbonates dominate in some wells having low to moderate salinity, chloride dominates in wells with high salinity and in remaining no single anion dominates. It means that the water is of mixed anion type. Among cations sodium dominates in more than 50% wells whereas no individual cation dominates in the remaining water samples.

S. No.	Characteristic	Requirement (Acceptable	Permissible Limit in Absence of Alternate	Remarks
General Parameters and MajorIons (mg/l)				
i)	pH value	6.5-8.5	No	-
ii)	EC(µScm-1)	-	-	Not noted in IS
iii)	Total dissolved solids (mg/l)	500	2000	-
iv)	Turbidity(NTU)	1	5	-
v)	Total Hardness as CaCO3	200	600	-
vi)	Alkalinity as CaCO3 (mg/l)	200	600	-
vii)	Fluoride (as F) mg/l	1.0	1.5	-
viii)	Chloride (as Cl), mg/l	200	1000	-
x)	Carbonate, mg/l	-	-	Not noted in IS
	Sulphate (as SO4) mg/l	200	400	Maybe extended to 400 provided
xi)	Nitrate (as NO3) mg/l	45	No relaxation	-
xii)	Calcium (as Ca) mg/l	75	200	-
xiii)	Magnesium (as Mg) mg/l	30	100	-
xiv)	Sodium (as Na) mg/l	-	-	Not noted in IS
xv)	Potassium (as K) mg/l	-	--	Not noted in IS
xvi)	Iron (as Fe) mg/l	0.3	No relaxation	Total concentration of manganese(as
xxiii	Total Arsenic (as As) mg/l	0.01	0.05	-

The shallow ground water in the district is of Sodium-mixed anion type.

Suitability for Drinking Purposes

Based on the concentration of anions and cations in shallow ground water samples, it is found that in some parts of the district the quality of ground water is not suitable for drinking uses, whereas in others it is of permissible quality.

Suitability for Irrigation Purposes: Plot of USSL diagram used for the classification of Irrigation waters indicates that Ground water fall under C2S,C3S1, C3S2, C3S3, C4S1, C4S2 and C4S4 classes. More than 50% ground water are likely to cause medium salinity hazards when used for customary irrigation and the remaining water falling under C3S4

Annexure--

S	Block	Location	Source	Latitude	Longitude	pH*	EC* in µS/cm at 25^0 C	CO3	HCO3	Cl*	SO4	NO3*	F*	PO4	Ca*	Mg*	Na	K	SiO2	TH *as CaCO3
1	Bhiwani	Dhanana	HP	28.9317	76.1656	7.66	3366	0	464	288	1110	19	3.49	0	162	129	476	4.8	18	936
2	Bhiwani	Manheru	T/W	28.7044	76.2092	7.5	2717	0	256	562	228	161	0.11	0.012	212	56	284	2	39	759
3	Dadri	Naya Atela	T/W	28.5875	76.1038	8.22	1530	0	622	98	116	83	0.25	0.012	25	15	328	1.2	25	125
4	Charkhi Dadri	Charkhi Dadri	HP	-	-	**7.31**	8476	0	354	1446	1030	1600	0.62	0	437	500	581	247	25	3151
5	Charkhi Dadri	Mahana	T/W	28.5569	76.3225	8	1566	0	403	274	34	54	0	0	50	83	150	4.2	25	468
6	Charkhi Dadri	Chiriya	T/W	28.4608	76.2606	7.81	7767	0	561	1811	1310	20	1.51	0	71	225	1396	252	18	1103
7	Bhiwani	Halawas	HP	28.7594	76.1247	8.48	1365	60	476	56	30	128	9.61	0	8.4	10	307	0.8	13	63
8	Bawani khera	Bawani khera	HP	28.9350	76.0356	7.92	3931	0	476	857	376	168	1.97	0	71	134	648	2	18	728
9	Bawani khera	Bohal	HP	28.9644	75.9347	8.23	1264	0	549	105	100	24	4.15	0	50	88	105	14	16	489
10	Tosham	Sagwan	T/W	28.8706	75.9664	7.72	660	0	281	77	1	4	0	0	58	18	36	43	23	219
11	Tosham	Tosham	HP	28.8750	75.9158	7.55	5602	0	478	835	540	1270	0.46	0	57	440	487	50	15	2039
12	Tosham	Miran	T/W	28.8467	75.7369	8.24	1582	0	305	70	530	13	1.11	0.026	105	66	176	4.4	26	534
13	Siwani	Gurera	T/W	28.9208	75.5128	8.15	1015	0	244	168	72	4.3	1.98	0	44	59	77	2	18	354
14	Siwani	Siwani	T/W	28.9114	75.6097	7.87	1724	0	256	337	200	0	1.07	0.003	133	69	132	2	18	616
15	Siwani	Mohila	HP	28.8478	75.6228	7.78	2857	0	195	590	382	164	1.15	0.01	174	204	104	29	30	1273
16	Siwani	Jhumpa Kalan	T/W	28.7733	75.5294	7.9	3448	0	293	470	690	366	0.91	0.014	121	189	392	2	21	1081
17	Kairu	Isharwal	T/W	28.7636	75.7042	7.64	3171	0	134	126	1760	81	0.94	0.01	566	155	62	14	22	2050
18	Tosham	Patandi	T/W	28.7944	75.8106	8.23	2009	0	329	224	200	315	0.14	0	44	54	319	2	21	334
19	Tosham	Laxmanpura	DW	28.8286	75.8719	8.45	2172	108	830	161	100	46	1.22	0.035	16	4.9	540	3	19	55
20	Bawani khera	Sui	HP	28.8631	76.0592	**8.64**	2062	72	451	351	70	46	0.1	0.028	12	12	467	1	22	81
21	Charkhi Dadri	Imlota	WELL	28.6344	76.4142	8.36	513	24	207	21	30	2.6	0	0.031	16	37	38	1.3	20	192
22	Bhiwani	Badala	H/P	28.7572	76.2550	8	4578	0	354	1172	370	62	0.55	0	85	204	454	270	23	1050
23	Dadri	Sanwar	WELL	28.7117	76.2964	8.38	404	12	146	21	14	2.4	1.03	0	40	15	13	0.6	13	162
24	Bonnd Kalan	Bonnd Kalan	H/P	28.7792	76.3358	7.91	377	0	183	35	18	0	0.37	0	48	20	7.6	1	12	202
25	Tosham	Bajina	H/P	28.7658	75.9839	8.02	4002	0	439	723	890	62	0.26	0	40	123	700	240	34	606
26	Kairu	Sungarpur	T/W	28.7528	75.8706	8.28	6527	0	232	870	2022	20	0.61	0	77	279	892	228	36	1340
27	Loharu	Singhani	T/W	28.5292	75.7925	7.89	2531	0	622	295	312	145	1.53	0	57	71	432	5.5	23	434

28	Kairu	Jui Kalan	T/W	28.6319	75.9272	Leakage													
29	Badhra	Gopi	T/W	28.5506	75.9528	8.24	1776	0	451	309	82	93	1.04	0	16	110	189	52	25	495
30	Kairu	Hetampura	T/W	28.7031	75.9864	8.03	3427	0	207	856	450	16	1.53	0	109	211	333	1	31	1142
31	Bhiwani	Lohani	T/W	28.7036	76.0450	7.79	4729	0	98	730	530	1018	0.36	0	356	179	256	242	35	1626
32	Bhiwani	Bamla	WELL	28.8103	76.2503	8.5	1091	36	317	77	178	1.5	5.58	0	16	17	227	9.5	11	111

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Hydrogeological Interpretation & Results

All the available data have been validated for consideration to generate aquifer map. The deepest well in each quadrant is selected and plotted on the map of 1.50000 scale with 5'X5'grid (9 x 9km) and is shown in Fig 12. Details are given in Annexure III.

Fig 6: Validated Exploration Data of Bhiwani District

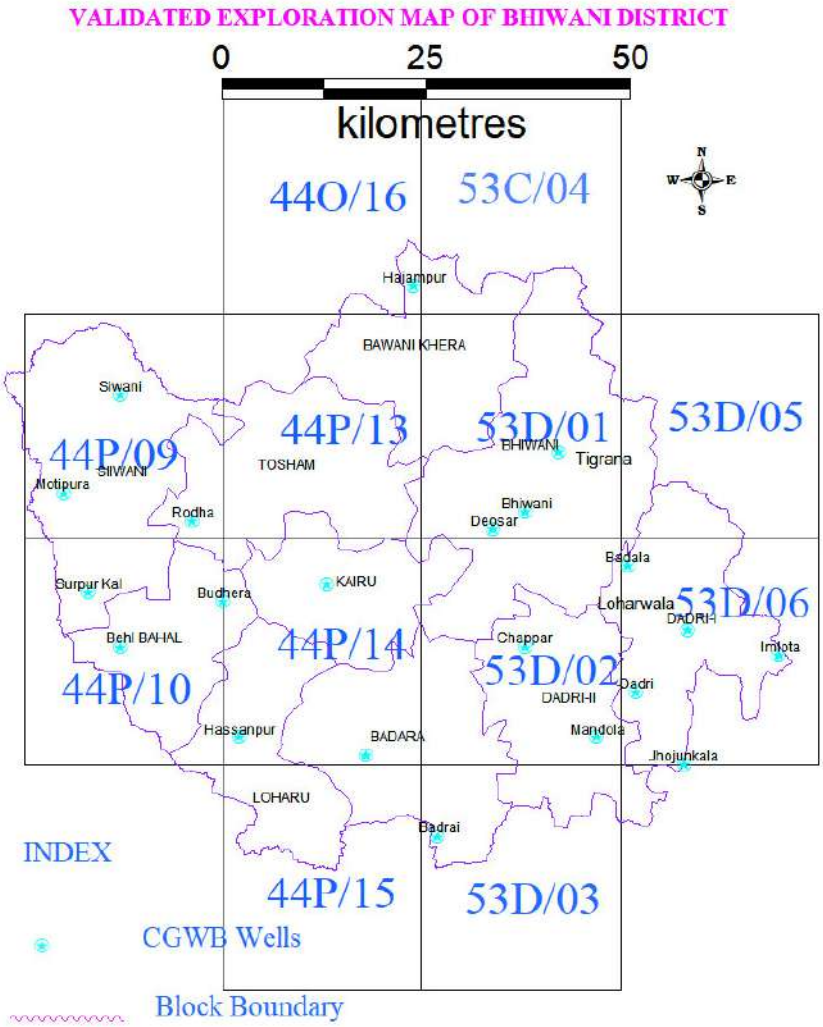
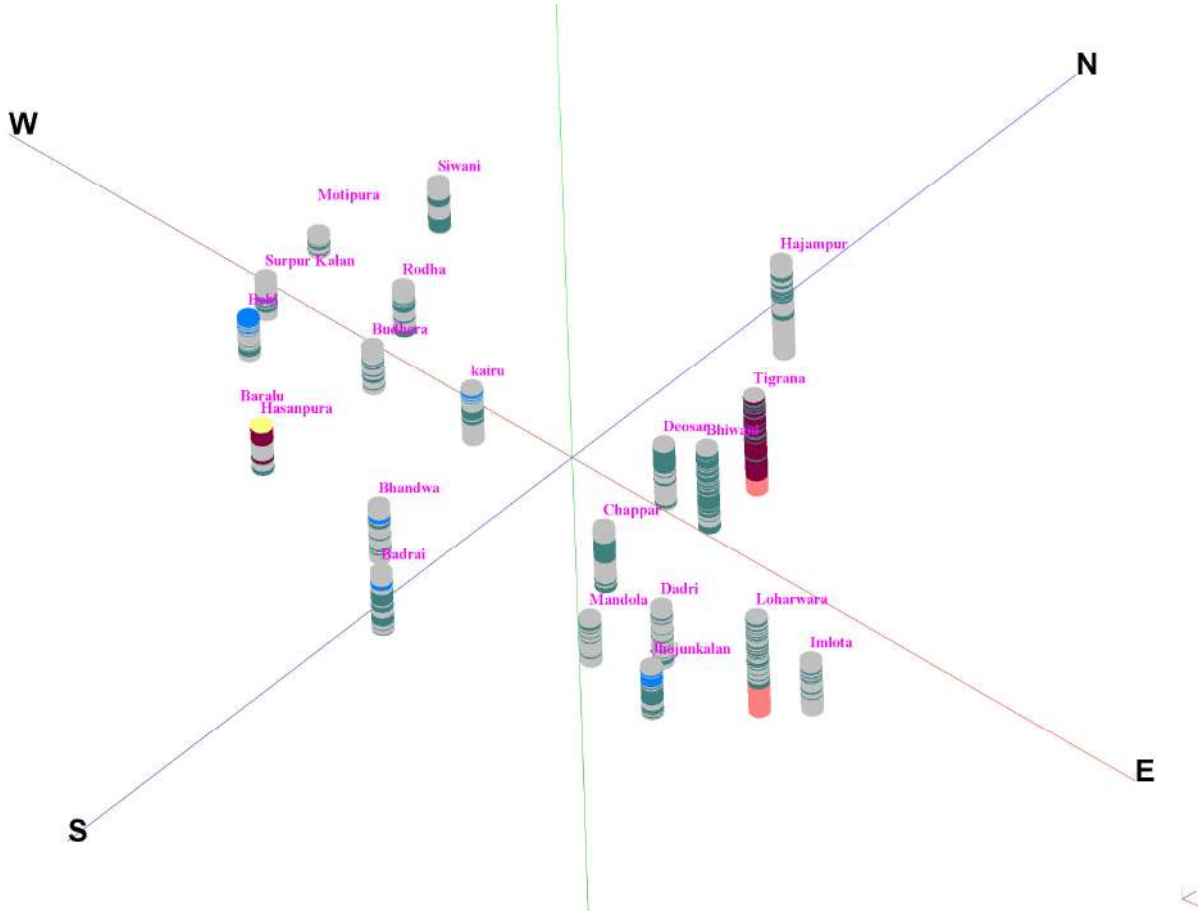


Fig 6: 3Dimension location of validated Exploratory Wells with litholog



Summarized details of the validated and optimized wells are given in table 5.

Table 5: Summary of optimized exploration wells:

Bore	*Longitude*	*Latitude*	*RL*	*Collar Elevation*	*Total Depth*	*Department*	*Block*	*Toposheet*	*Water level*
Bhandwa	75.93139	28.50889	250	250	172	CGWB	Badara	44P/15	40.63
Badrai	76.02083	28.42333	292	292	183	CGWB	Badara	53D/03	40.63
Behl	75.61667	28.63333	250	250	124	CGWB	Bahal	44P/10	69.4
Budhera	75.74722	28.68333	233	233	136	CGWB	Bahal	44P/10	69.4
Hajampur	75.99167	29.03333	214	214	294	CGWB	Bawanikhera	44O/16	6.4
Deosar	76.09167	28.76250	214	214	193	CGWB	Bhiwani	53D/01	4.9
Bhiwani	76.13333	28.78333	219	219	256	CGWB	Bhiwani	53D/01	4.9
Tigrana	76.130	28.856	256	256	300	CGWB	Bhiwani	53D/01	4.9

Jhojunkalan	76.33389	28.50111	249	249	152	CGWB	Dadri-I	53D/06	6
Imlota	76.45000	28.61667	216	216	160	CGWB	Dadri-I	53D/02	6
Dadri	76.26667	28.58333	216	216	180	CGWB	Dadri-I	53D/02	6
Badala	76.26000	28.72000	216	216	212	CGWB	Dadri-I	53D/06	6
Loharwara	76.360	28.628	222	222	300	CGWB	Dadri-I	53D/06	6
Mandola	76.22083	28.52500	223	223	140	CGWB	Dadri-II	53D/06	6
Chappar	76.13333	28.63333	219	219	192	CGWB	Dadri-II	53D/06	6
kairu	75.87500	28.70000	230	230	166	CGWB	Kairu	44P/14	16
Hassanpur	75.76667	28.52500	253	253	111	PHED	Loharu	44P/14	69.45
Surpur Kalan	75.58333	28.69167	233	233	117	CGWB	Siwani	44P/10	13.08
Motipura	75.55000	28.80000	217	217	129	CGWB	Siwani	44P/09	13.08
Siwani	75.61667	28.90833	210	210	143	CGWB	Siwani	44P/10	13.08
Rodha	75.70833	28.76667	233	233	140	CGWB	Tosham	44P/13	6.5

3.1.1 Aquifer Geometry & Disposition

To understand the sub surface lithology and its disposition, the lithological data of the optimized wells drilled by CGWB, PHED and Private Agencies is plotted using the RockWorks15 software and a lithological model has been prepared and is shown in fig 14. The 3D lithological fence diagram has been prepared using the lithology model and is shown in fig 15.

The aquifer material and non-aquifer material in the district is highly variable. The major aquifer material is sand, kankar and gravel and the non-aquifer material is majorly clay, sandstone, chert and granite. The sandstone, chert and granite are found at deeper depth starting from 230m bgl.

Fig 7: 3-Dimension Lithological Model of Bhiwani District

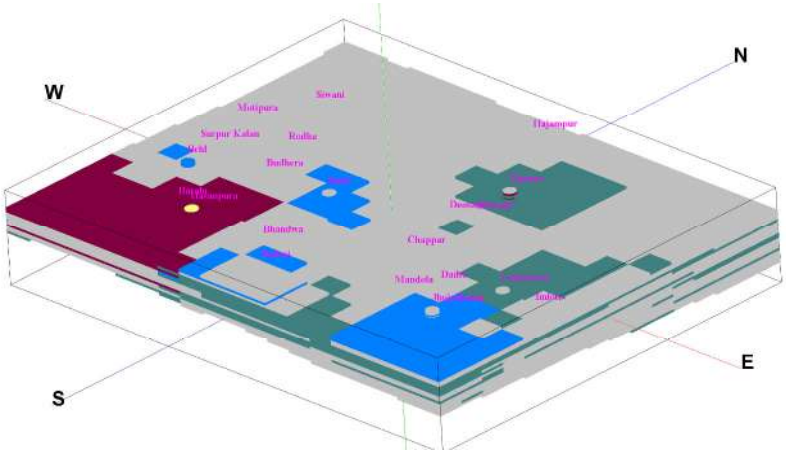
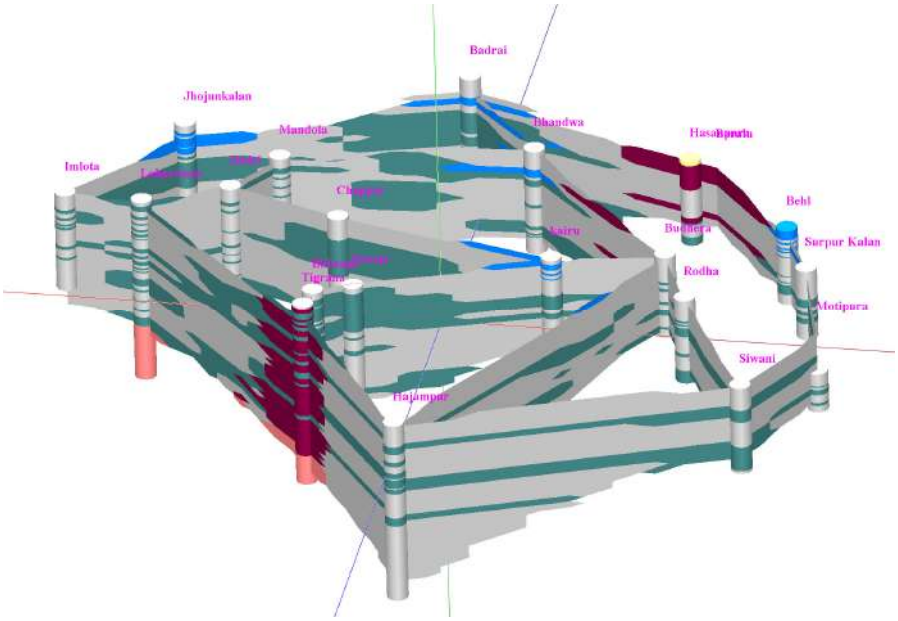


Fig 8: 3Dimensio n Lithological Fence of Bhiwani District



3.2 Geophysical Interpretation:

4. GROUND WATER RESOURCES

4.1 Ground Water Resources of Multiple Aquifer up to 300m Depth

Ground water resource estimation of the area have been carried out by taking Dynamic and Static/In-storage resources of unconfined aquifer and confined aquifers present upto 300m depth. The assessment of dynamic ground water Resources of the study area have been carried out jointly by CGWB and Ground Water Cell, Department of Agriculture, Haryana on the basis of Ground Water Estimation Committee (1997) methodology based on data available and as per the revised methodology for the year as on 31st March 2013.

The occurrence of potential aquifers (productive granular zones) upto 300 m depth has been demarcated on basis of aquifer wise subsurface mapping. The total saturated thickness of granular zones was derived from the exploratory borehole data of a particular block. The granular zones occurring below the zone of water level fluctuation up to the first confining layer has been considered as static unconfined zone. The specific yield value for the unconfined aquifer has been taken as 60% of 0.12 which comes as 0.072 whereas for the confined aquifer, the storativity value has been considered. Since the specific yield is likely to reduce with increase in depth due to compaction of overlying sediments.

Hence, the major data elements considered in this estimation are thickness of granular zones, specific yield/storativity, and area of both fresh water and saline/brackish water. It has been observed that in some of the blocks sufficient data on probable occurrence of granular zones was not available. In those cases, the existing exploratory data of adjoining block/district has been either extrapolated or interpolated to derive such parameters required for estimation. This assessment of total groundwater resources has been computed based on the available data with CGWB & Ground Water Cell, Department of Agriculture, Haryana.

4.1.1 Unconfined aquifers- Dynamic Resources

The assessment of total availability of ground water resources encompasses two components namely dynamic resources and in-storage resources. Block wise dynamic resource figures so obtained based on GEC, 1997 norms have been taken as the 1st

component for unconfined aquifer. Further in pursuance to the methodology recommended by CGWB to assess total availability of Ground Water Resources, the following procedure has been adopted to calculate in-storage resources and total availability of Ground Water Resources.

The block wise ground water resource potential in the district has been assessed as per GEC-97 as on March 2013.The stage of ground water development ranges between 113% (block-Dabwali) to 323% (block- Rania). The total replenishable ground water resource in the district is 636.78 mcm. The net ground water draft is 1116 mcm. The stage of ground water development in the district is 175% (Table 4).

Table4:Dynamic Ground Water Resource&Development Potential (as on 31.03.13)

Sl. No.	Assessment Unit/ District	Net Annual Ground Water Availability(MCM)	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for domestic and industrial water supply	Existing Gross Ground Water Draft for All uses (11+12)	Provision for domestic, and industrial requirement supply to 2025	Net Ground Water Availability for future irrigation development (10-11-14)	Stage of Ground Water Development {(13/10) * 100} (%)
	BHIWANI							
1	Badra	4507	20061	469	20530	456	-16010	456
2	Bhawani Khera	9003	10323	62	10385	197	-1517	115
3	Bhiwani	12202	12798	145	12943	349	-945	106
4	Dadri-I	7279	15477	37	15514	300	-8498	213
5	Dadri-II	6346	8422	105	8527	140	-2216	134
6	Kairu	4445	7224	123	7347	123	-2902	165
7	Loharu	3404	8083	185	8268	185	-4864	243
8	Behal	2090	5749	94	5843	94	-3753	280
9	Siwani	5992	4507	87	4594	134.7	1350.3	77
10	Tosham	6854	10753	435	11188	435	-4334	163
	Total	62121	103397	1742	105139	2413.7	-43689.7	169

*all the given figures are in mcm

4.1.2 Confined Aquifer

The availability of ground water resources in confined aquifer have two components: Storage under pressure (using Storativity concept) and Storage under desaturated (gravity drainage) condition (using Specific Yield concept) (source: Assessment of Ground Water Resources; A Review of International Practices, 2014) and is shown in Fig 21. However, since ground water withdrawals from confined aquifer are known to have serious environmental degradation effects, the preliminary assessment of ground water resources in confined aquifer is restricted to the estimation of ground water storage under pressure conditions only but here the storage under de-saturation is also computed.

Storativity Concept:

ii)	In-storage Ground Water resources (within the Peizometer)	=	Thickness of the water column in Peizometer of particular confined aquifer up to the top layer of same confined aquifer	×	Storativity of the confined aquifer	×	Areal extent of the confined aquifer group	

Specific Yield Concept:

ii)	In-storage Ground Water resources (within the aquifer thickness)	=	Thickness of the confined aquifer (granular/ productive zone) down to the bottom layer of confined aquifer or exploitable depth of 300 m	×	Sp. Yield of the aquifer	×	Areal extent of the confined aquifer group	

Preliminary assessment of the ground water resources in confined aquifer does not imply that the assessed resource is available for exploitation. The objective of this exercise is to have an overview of the ground water regime in the particular confined aquifer. It should be kept in mind that any significant ground water withdrawal from confined aquifer may invoke serious environmental degradation problem. Therefore, in case the preliminary assessment reveals that ground water is being withdrawn in significant quantity for any

confined aquifer, that particular aquifer should be identified for detailed assessment using numerical modelling approach.

Total Availability of Ground Water Resources = Dynamic Resources + In-storage Resources.

Block wise fresh and saline in-storage ground water resources up to fresh-saline interface in unconfined aquifer is given in table 5 & 6 respectively. Block wise saline in-storage ground water resources below the fresh-saline interface in unconfined aquifer is given in table 7 and Total block wise ground water resources are given in table 8.

Fig 9: Methodology for Resource Estimation in Unconfined and Confined Aquifer System

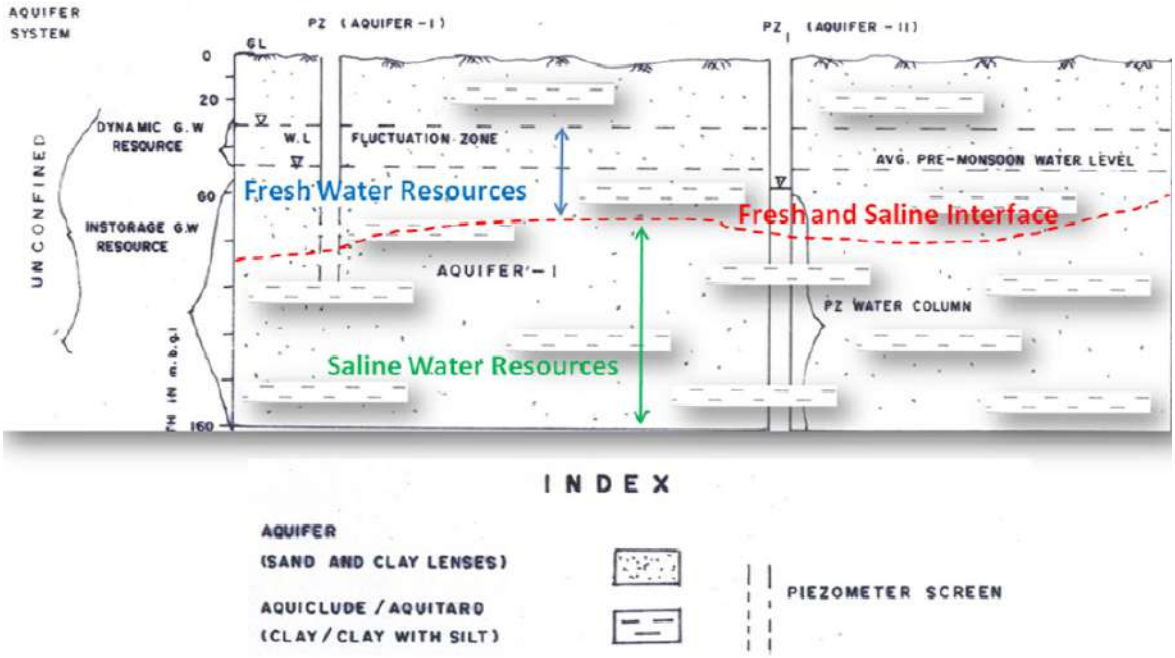


Table 6: Block Wise Instorage Fresh Ground Water Resources in Unconfined Single Aquifer System up to the Fresh-Saline Interface

Name of Assessment Unit	Type of rock formation	Areal extent (sq km)		Fresh-Saline Interface (m bgl)	Average Pre-monsoon Water Level (m bgl)	Total Thickness of formation below Pre-monsoon Water Level up to Fresh-Saline Interface (m) (5-6)	Thickness of the Granular Zone below Pre-monsoon WL up to Fresh Saline Interface (Fresh) (m)	Average Specific Yield	In-Storage Ground Water Resources [4*8*9] FRESH (mcm)
		Total Geo-graphical Area	**Fresh Water Area**						
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Badra	Alluvium	446.67	407.38	53	41.00	12.00	12	0.072	351.9763
Bawani Khera	Alluvium	557.32	449.99	0	6.4	0.00	0	0.072	0
Behal	Alluvium	303.8	263.02	50	41.00	9.00	9	0.072	196.8624
Bhiwani	Alluvium	684.74	510.41	0	3.00	0.00	0	0.072	0
Dadri-I	Alluvium	368.87	223.85	0	8.00	0.00	0	0.072	0
Dadri-II	Alluvium	516.56	318.8	0	6.00	0.00	0	0.072	0
Kairu	Alluvium	418.58	316.62	0	16.00	0.00	0	0.072	0
Loharu	Alluvium	368.73	353.58	0	70.00	0.00	0	0.072	0
Siwani	Alluvium	698.53	546.62	0	13.00	0.00	0	0.072	0
Tosham	Alluvium	387.13	356.67	0	6.50	0.00	0	0.072	0
Distt. Total		**4750.93**	**3746.94**						**548.84**

Table 7: Block Wise In storage Saline Ground Water Resources in Unconfined Single Aquifer System up to the Fresh-Saline Interface

Name of Assessment Unit	Type of rock formation	Areal extent (sq km)		Fresh-Saline Interface (m bgl)	Average Pre-monsoon Water Level (m bgl)	Total Thickness of formation below Pre-monsoon Water Level/Fresh-Saline Interface (m) (5-6)	Thickness of the Granular Zone below Pre-monsoon WL/Fresh Saline Interface (Saline) (m)	Average Specific Yield	In-Storage Ground Water Resources [4*8*9] BRACKISH / SALINE (mcm)
		Total Geo-graphical Area	**Brackish/Saline Water**						
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Badra	Alluvium	446.67	39.29	53	41	12	12	0.072	33.94656
Bawani Khera	Alluvium	557.32	107.33	0	6.4	0	0	0.072	0
Behal	Alluvium	303.8	40.78	50	41	9	9	0.072	26.42544
Bhiwani	Alluvium	684.74	174.33	0	3	0	0	0.072	0
Dadri-I	Alluvium	368.87	145.02	0	8	0	0	0.072	0
Dadri-II	Alluvium	516.56	197.76	0	6	0	0	0.072	0
Kairu	Alluvium	418.58	101.96	0	16	0	0	0.072	0
Loharu	Alluvium	368.73	15.15	0	70	0	0	0.072	0
Siwani	Alluvium	698.53	151.91	0	13	0	0	0.072	0
Tosham	Alluvium	387.13	30.46	0	6.5	0	0	0.072	0
Distt. Total		**4363.8**	**1003.99**						70.372

Table 8: Block Wise In storage Ground Water Resources below Fresh-Saline Interface (Up To 300m Depth)

Name of Assessment Unit	Type of rock formation	Areal extent (sq km) Total Area below Fresh Saline Interface	Fresh-Saline Interface (m bgl)	Average Explored Depth (m bgl)	Total Thickness of formation below Fresh-Saline Interface (m) (5-6)	Thickness of the Granular Zone below Fresh Saline Interface (Saline) (m)	Average Specific Yield	In-Storage Ground Water Resources [(7)*(11)*(12)*] BRAKISH / SALINE (mcm)
1	2	3	4	5	6	7	8	9
Badra	Alluvium	446.67	53	183	130	84	0.072	2701.46
Bawani Khera	Alluvium	557.32	6.4	193	186.6	94	0.072	3771.94
Behal	Alluvium	303.8	50	136	86	30	0.072	656.208
Bhiwani	Alluvium	684.74	3	252	249	67	0.072	3303.19
Dadri-I	Alluvium	368.87	8	210	202	92	0.072	2443.39
Dadri-II	Alluvium	516.56	6	180	174	46	0.072	1710.85
Kairu	Alluvium	418.58	16	166	150	35	0.072	1054.82
Loharu	Alluvium	368.73	70	140	70	25	0.072	663.714
Siwani	Alluvium	698.53	13	143	130	60	0.072	3017.65
Tosham	Alluvium	387.13	6.5	140	133.5	45	0.072	1254.3
Dist. Total		8552.01						**26370**

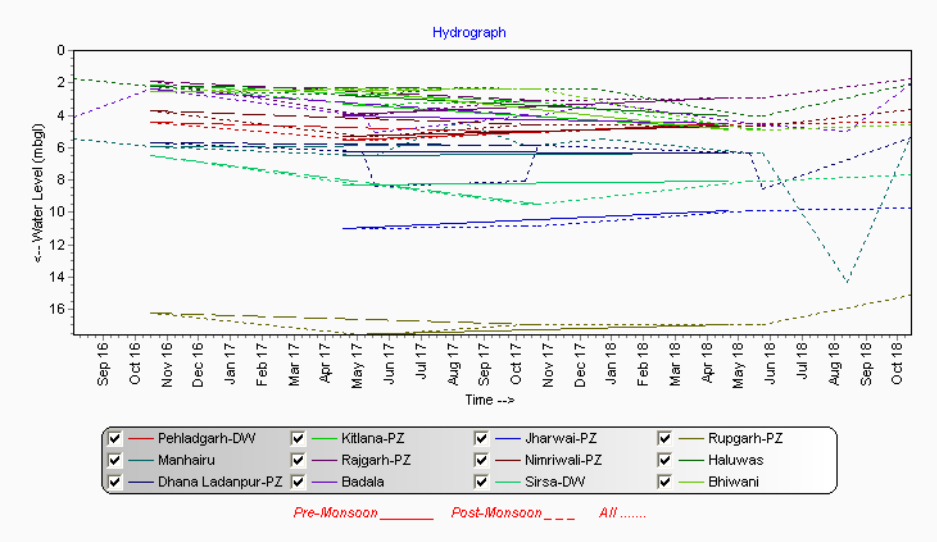
Table 9: Block Wise Total Available Ground Water Resources in Aquifer up to 300m Depth

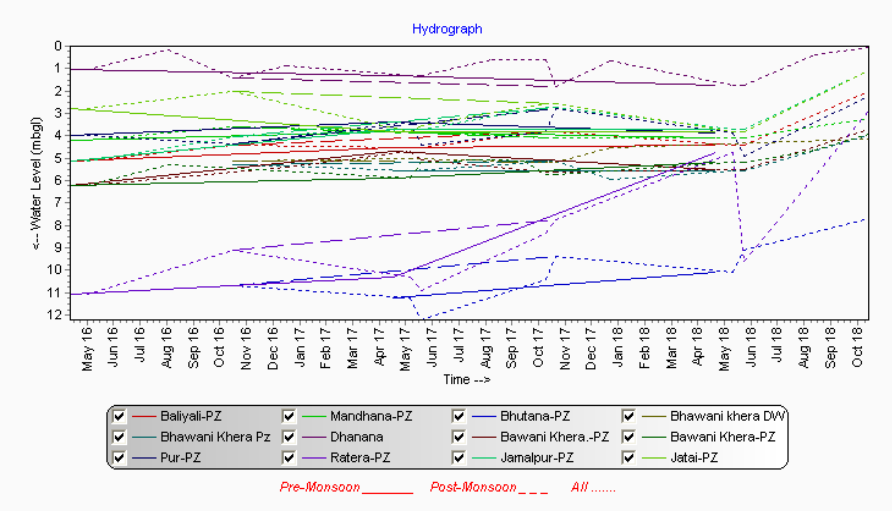
Assessment Unit/Block	Dynamic Ground water Resources (2013)	In-storage Groundwater Resources UPTO FRESH WATER ZONE	Total Groundwater Resources up to Avg. Depth of Fresh Water zone [(2)+(3)]	Total Saline Groundwater Resources up to the depth of wells available in each block	Total Availability of Fresh and Saline Groundwater Resources [(4)+(5)]	Volume of Unsaturated Granular Zones (above Water Level) for Natural Recharge (Considered below 3m bgl to WL)	Unsaturated Zone (in m)
1	2	3	4	5	6	7	8
Badra	45.07	351.976	397.046	2701.46	2735.41	418.083	13
Bawani Khera	90.03	0	90.03	3771.94	3771.94	0	0
Behal	122.02	196.862	318.882	656.208	682.633	174.989	8
Bhiwani	72.79	0	72.79	3303.19	3303.19	0	0
Dadri-I	63.46	0	63.46	2443.39	2443.39	0	0
Dadri-II	44.45	0	44.45	1710.85	1710.85	0	0
Kairu	34.04	0	34.04	1054.82	1054.82	452.066	15
Loharu	20.9	0	20.9	663.71	663.71	0	0
Siwani	59.92	0	59.92	3017.65	3017.65	0	0
Tosham	68.54	0	68.54	1254.301	1254.301	0	0
Total	621.21	548.8387	1170.05	26370.3	26440.67	1045.138	

5. GROUND WATER RELATED ISSUES

The major issue in the district is deteriorated ground water quality (saline water), water logging and high extraction rate where the ground water quality is more or less fresh or marginal. The water logging and the declining water level trend can be seen in the hydrograph shown in fig 22.

Fig 8: Hydrographs of various sites in Bhiwani district.





5.1 Ground Water Irrigation Scenario

As per the data available from minor irrigation census 2006-07 the detailed number of shallow, deep, tube wells, lined, unlined water distribution system, land holdings of wells are given below in table, 10 and shown in fig 23.

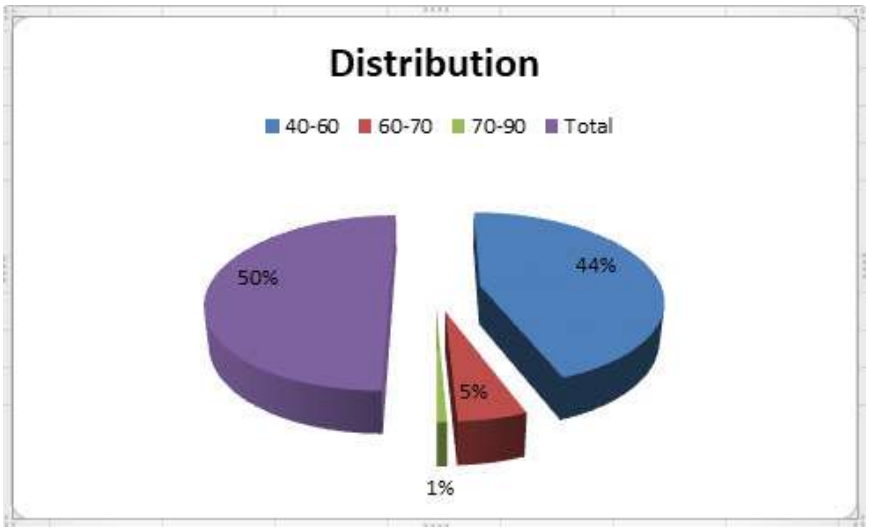
Table 10: Distribution of Tube wells According to Owner's land Holding Size

Table8: Distribution of Tube wells According to Owner's holding Size					
Marginal	Small	Semi-Medium	Medium	>10ha	Total
(0-1 ha)	(1-2 ha)	(2-4 ha)	(4-10ha)		
35	1802	5844	1802	0	9483

Table 11: Type of Ground water distribution device

Open Water Channel		
Lined/pucca	Unlined/kutcha	Total
16714	6513	23227

Fig 9: Irrigation tubewells as per depth range.



6. AQUIFER MANAGEMENT PLAN

Another focus has been given to minimize the gross draft by enhancing ground water use efficiency in irrigation system after replacing the water distribution system from unlined/kutcha channel to Under Ground Pipeline System (UGPS) for the whole Sirsa district.

6.1 Scope of Implementation

This plan is focusing on the technical aspects of the ground water recharge through various means so that various implementing agencies may get the appropriate technical guidelines. The existing/ongoing schemes of the central or state govt. like MANERGA, IWSP, PMKSY (Prime Minister Krishi Sinchai Yojna), NABARD funded schemes, Urban Development schemes, departmentally funded projects etc. may be benefitted from the recharge plan by incorporating the input in the operational guidelines/ design and for locating the specific sites.

Agriculture University, Engineering Collages, Academic and Research Institution, NGO may also take up the pilot or demonstrative projects in the blocks suitable to them to plan at local level as per local conditions. Artificial recharge plan for rural and urban areas, and through recharge pits is given in Table 11, 12 & 13 respectively.

Table 12: Artificial Recharge in Rural Area

Sr.No.	Name of CD block	Total area of the village (in hectares rounded up to one decimal place)	Number of households (2011 census)	No of Houses taken for Artificial Recharge (10% of total households)	Total No of AR Structures (one structure for 10 house holds)	Total recharge in MCM
1	Badhra	48800	26895	2690	2690	0.117
2	Kairu	31249	14837	1484	1484	0.051
3	Loharu	36873	14986	1499	1499	0.063
4	Tosham	52766	126743	12674	12674	0.450
5	Behal	30380	65340	6534	6534	0.273
	Total	200068	248801	24880.1	24880.1	0.953

Table 13: Artificial Recharge in Urban Area

Name of CD Block	Town Name	Total Households	Total Population of Town	Housholds taken for Atificial Recharge (10%)	Total Roof Top Area (sqm)	Vol of water available for recharge (MCM)
LOHARU	**Loharu (MC)**	**2478**	**13937**	**248**	**49560**	**0.014**
TOSHAM	**Tosham (CT)**	**2915**	**15559**	**292**	**58300**	**0.014**
TOTAL				**540**	**108000**	**0.028**

Table 14: Artificial Recharge through Recharge Pits in Farm

DISTRICT NAME	Block Name	Total area of the village (in hectares rounded up to one decimal place)	10%of village area taken for farm recharge(sq m)	Total number of recharge pits (1 recharge pit / hector) for 10% area	Annual recharge (MCM)= (Area*Runoff 15%*Rainfall in mm/1000000)
BHIWANI	**Badhra**	48800	48800000	4880	2.657
	Kairu	31249	31249000	3125	1.331
	Loharu	36873	36873000	3687	1.925
	Tosham	52766	52766000	5277	2.343
	Behal	**30380**	30380000	3038	1.586
	Total	200068	200068000	20007	9.842

Table 15 BY UNDERGROUND PIPELINE SCHEMES IN BLOCKS HAVING MORE THAN 100% STAGE OF DEVELOPMENT

Blocks of Bhiwani District	Net Annual Ground Water Availability (mcm)	Total Draft (present) (mcm)	Gross Irrigation Draft (present) (mcm)	Gross Ground Water Draft for Domestic and industrial supply (mcm)	Pecentage of unlined channel	Wastage through unlined channel, (mcm) (Col 3 X Col5 X 0.25#)	Potential of Reduced irrigation overdraft (Col3-col6) (mcm)	Gross draft after saving of water (mcm) (Col 7+Col 4)	Present Stage of Development (%)	Stage of development afterwards((Col 8/Col1)X100) (%)	Reduction in stage of development after constructing pucca channel (Col9-Col10) (%)
	1	2	3	4	5	6	7	8	9	10	11
Badra	45.07	205.3	200.61	4.69	27.74	13.91	186.70	191.39	456	425	31
Bhawani Khera	90.03	103.85	103.23	0.62	27.74	7.16	96.07	96.69	115	107	8
Bhiwani	122.02	129.43	127.98	1.45	27.74	8.88	119.10	120.55	106	99	7
Dadri-I	72.79	155.14	154.77	0.37	27.74	10.73	144.04	144.41	213	198	15
Dadri-II	63.46	85.27	84.22	1.05	27.74	5.84	78.38	79.43	134	125	9
Kairu	44.45	73.47	72.24	1.23	27.74	5.01	67.23	68.46	165	154	11
Loharu	34.04	82.68	80.83	1.85	27.74	5.61	75.22	77.07	243	226	16
Behal	20.9	58.43	57.49	0.94	27.74	3.99	53.50	54.44	280	260	19
Tosham	68.54	111.88	107.53	4.35	27.74	7.46	100.07	104.42	163	152	11

6.2 Potential of Enhancing the Ground Water Use Efficiency

The micro level transformation in the ground water management have vast impact potential to counter extensive ground water depletion faced by the state of Haryana, particularly in overexploited blocks. There are around 6513 (out of 23227) tubewells (28%) operated by farmers for irrigation through unlined/Katcha open channel system in Bhiwani district where water from the tubewell is discharge to the agricultural field. In this process huge (up to 20 %) quantity of ground water is wasted in soil moisture and evaporation losses. Around 88% of the tube wells are of shallow depth (40- 60m) and remaining are deeper (60-90 m) depth. Thus majority of wells are tapping Aquifer group-1 which is under stress due to overexploitation.

Dynamic ground water resources (2013) indicate that Gross ground water draft for irrigation in Bhiwani district is estimated at 621.21 MCM. It is expected that around 25% of over draft can be brought down by switching over to underground/surface pipeline based distribution from the prevailing unlined open channels. Thereby draft will be reduced up to 68.6 MCM assuming there is no crop diversification by the farmers. The benefit will lead to saving of precious ground water resources in the area. The measure if implemented will bring down the stage of ground water development. The category of the blocks will also improve drastically resulting in boosting of agriculture and industrial development which may be otherwise not sustainable for future.

The tubewells also consume enormous electricity which is subsidized and government incurs significant revenue on this account. The measures therefore will result in saving of energy and money. Pollution impact will be reduced whenever diesel engines are used by the farmers. The environmental and ecological condition in the irrigated land will improve. Unwanted weed growth will also be controlled inside the farm land. This will also be useful in the waterlogged/ shallow water table areas as the seepage losses in these areas also aggravate the water logging. Government should make/launch a mission mode program for installing the underground pipe lines instead of having *katcha* channel in the entire Haryana. Heavy ground water overdraft can be reduced by these efforts. This will

ensure more crop per drop. Reduction in stage of development after construction of Pucca channels in irrigated land is given in table-14.

6.4 Water Saving Potential from Crop Diversification –

6.4.1 Change paddy to maize/soyabean

As the requirement of water for paddy is much high therefore by changing paddy to maize/soyabean will help in saving of water. For estimating the water saving by crop diversification it is assumed that one mcm of water will be saved in case of maize or soyabean planted in one sq km of land. In case of pulses even higher amount of ground water can be saved. Here Only Dadri-II Block is suitable for crop diversification.

Scope of quantitative impact on stage of development after applying various management strategies is given in Table 16.

Table 16:Scope of Quantitative Impact on Stage of Development after applying various management strategies

Bhiwani District	Net Annual Ground Water Availability (mcm)	Total Draft (present) (mcm)	Present Stage of development (present %)	Reduction in Draft by different water Saving Method			SOD% after Word	% of Paddy area to be converted
				UG(mcm)	AR (mcm)	Maize(mcm)		
Badra	45.07	205.3	456	13.9	2.77	0	418	0
Bhawani Khera	90.03	103.85	115	7.2	0.00	0	107	0
Bhiwani	122.02	129.43	106	8.9	0.00	0	99	0
Dadri-I	72.79	155.14	213	10.7	0.00	0	198	0
Dadri-II	63.46	85.27	134	5.8	0.00	1.33	123	100
Kairu	44.45	73.47	165	5.0	1.38	0	151	0
Loharu	34.04	82.68	243	5.6	2.00	0	221	0
Behal	20.9	58.43	280	4.0	1.86	0	252	0
Tosham	68.54	111.88	163	7.5	2.81	0	148	0

7. BLOCK WISE AQUIFER MAPS

AND

MANAGEMENT PLAN

I. Badara Block (446.67 sq km)

Population (2011) Rural-142184

Urban-0

Total-142184

Rainfall Monsoon -293.06mm

Non Monsoon-50.93 mm

Average Annual Rainfall 345 mm

Agriculture Major Crops- Wheat, Rice, Barley & Bajra

Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

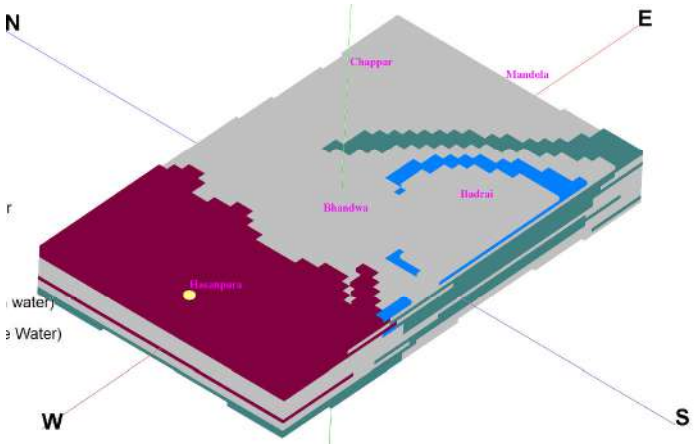
Water level Behaviour (2018):

Pre Monsoon-54.72-60.09 mbgl & Post Monsoon-54.38-59.50 mbgl

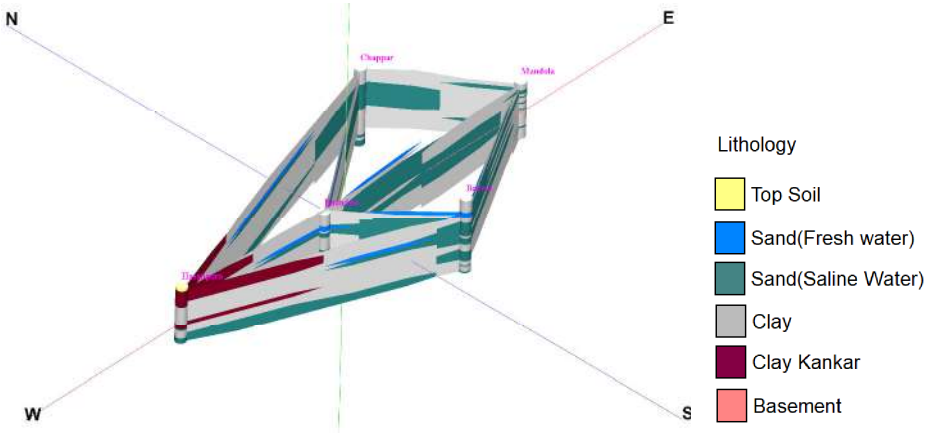
Aquifer Disposition: Single Aquifer System

Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravels. The non-aquifer material comprises of clay. The average depth of the fresh saline interface is at 51m bgl.

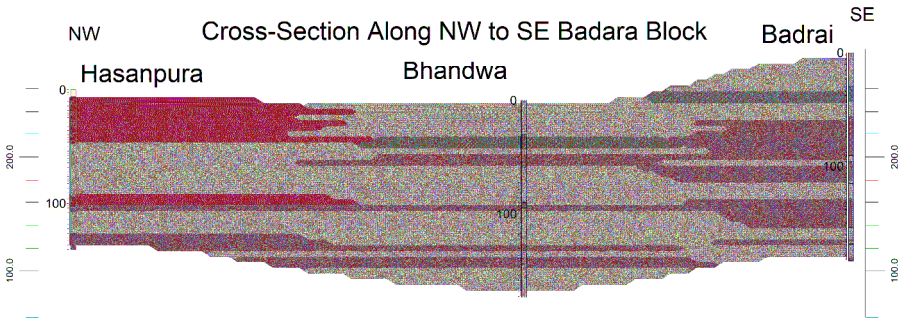
Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmis sivity (m^2/day)	Specific Yield %	Storativity
I (41-183m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	84	1125	0.072	NA

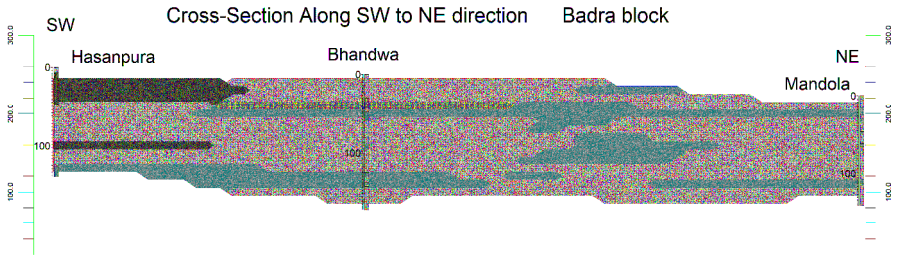


3D Lithology model



3D Fence diagram





Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	45.07
	In-storage Aquifer I	3392.37(F=2001.27, S=1391.10)
	Total	3510.47
Ground Water Extraction (mcm)	Irrigation (2013)	133.74
	Domestic & Industrial (2013)	0.10
Future Demand for domestic & Industrial sector (2025) (in mcm)		0.10
Chemical Quality of ground water		Salinity problem in deeper aquifers
Other issues		Declining ground water level trend

Ground Water Resource Enhancement

Resource enhancement artificial recharge	2.77 mcm water save through artificial recharge technique
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 13.9 mcm volume of water wastage
Change in cropping pattern	NA
Alternate water sources	Tanks, ponds and canals
Regulation and Control	No (Not Notified)
Other interventions proposed, if any	-

II. Bahal Block (368.73 sq km)

Population (2011) Rural-65340

Urban-0

Total-65340

Rainfall Monsoon -328mm

Non Monsoon-51.5mm

Average Annual Rainfall 379 mm

Agriculture Major Crops- Wheat, Rice, Barley& Bajra

Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

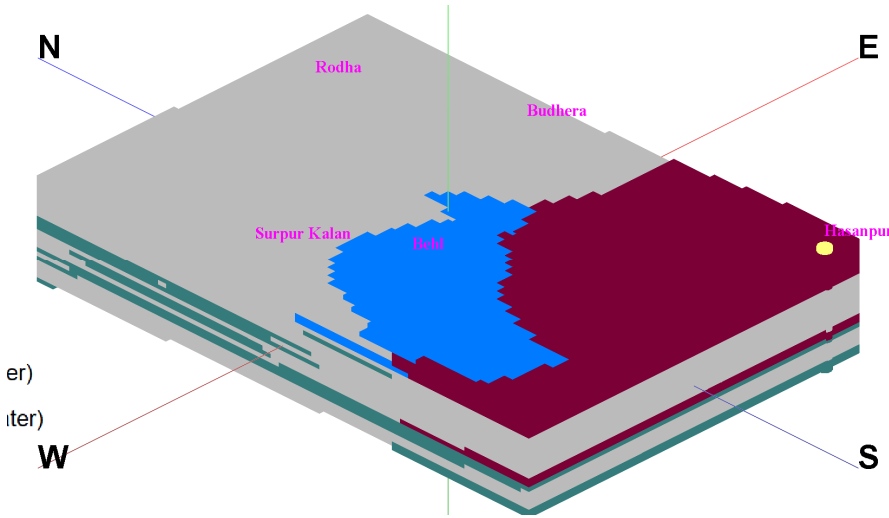
Water level Behaviour (2018):

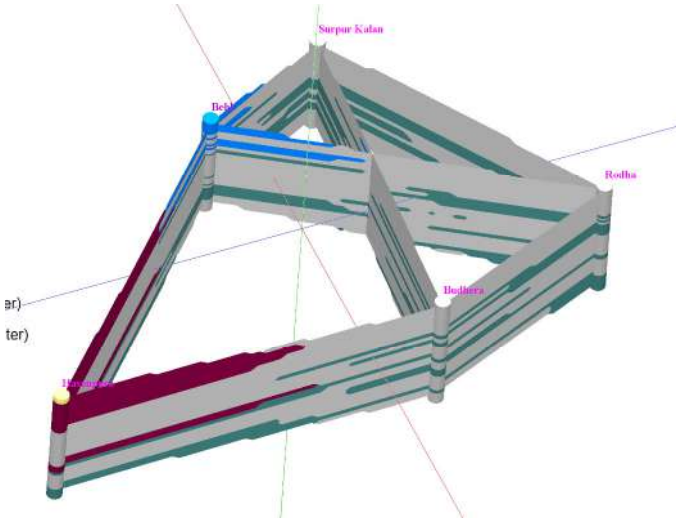
Pre Monsoon-50.5-52.37mbgl & Post Monsoon-52.24-55.21mbgl

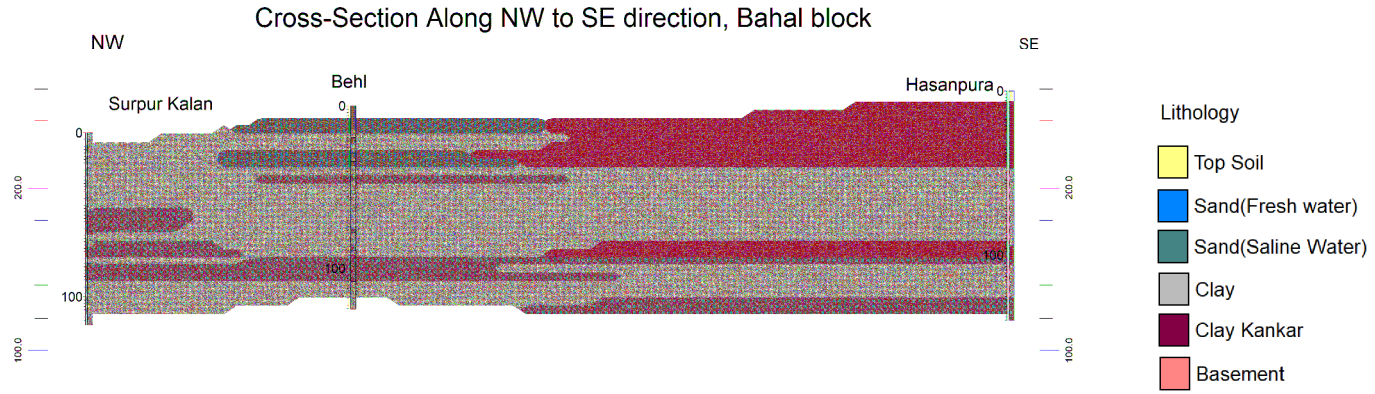
Aquifer Disposition: Single Aquifer System

Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand and kankar. The non-aquifer material comprises of clay. The average depth of the fresh saline interface is at 51m bgl.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (41-136m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	30	1125	0.072	NA


N
E
W
S
Rodha
Budhera
Surpur Kalan
Behl
Hasanpura


Surpur Kalan
Rodha
Budhera


Cross-Section Along NW to SE direction, Bahal block
NW
SE
Surpur Kalan
Behl
Hasanpura
Lithology
Top Soil
Sand(Fresh water)
Sand(Saline Water)
Clay
Clay Kankar
Basement

Ground Water Resource, Extraction, Contamination and other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	122.02
	In-storage Aquifer I	852 (F=196, S=656)
	Total	975
Ground Water Extraction (mcm)	Irrigation (2013)	57.49
	Domestic & Industrial (2013)	0.94
Future Demand for domestic & Industrial sector (2025) (in mcm)		0.94
Chemical Quality of ground water		Salinity problem in deeper aquifers
Other issues		Declining water level trend

Ground Water Resource Enhancement

Resource enhancement through artificial recharge	1.86 mcm water save through artificial recharge technique
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 4.0 mcm volume of water wastage
Change in cropping pattern	NA
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Not Notified
Other interventions proposed, if any	-

III. Loharu Block (418.58 sq km)

Population (2011)	Rural-80510 Urban- 0 Total-80510
Rainfall	Monsoon -328mm Non Monsoon-51.5mm
Average Annual Rainfall	379 mm
Agriculture	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

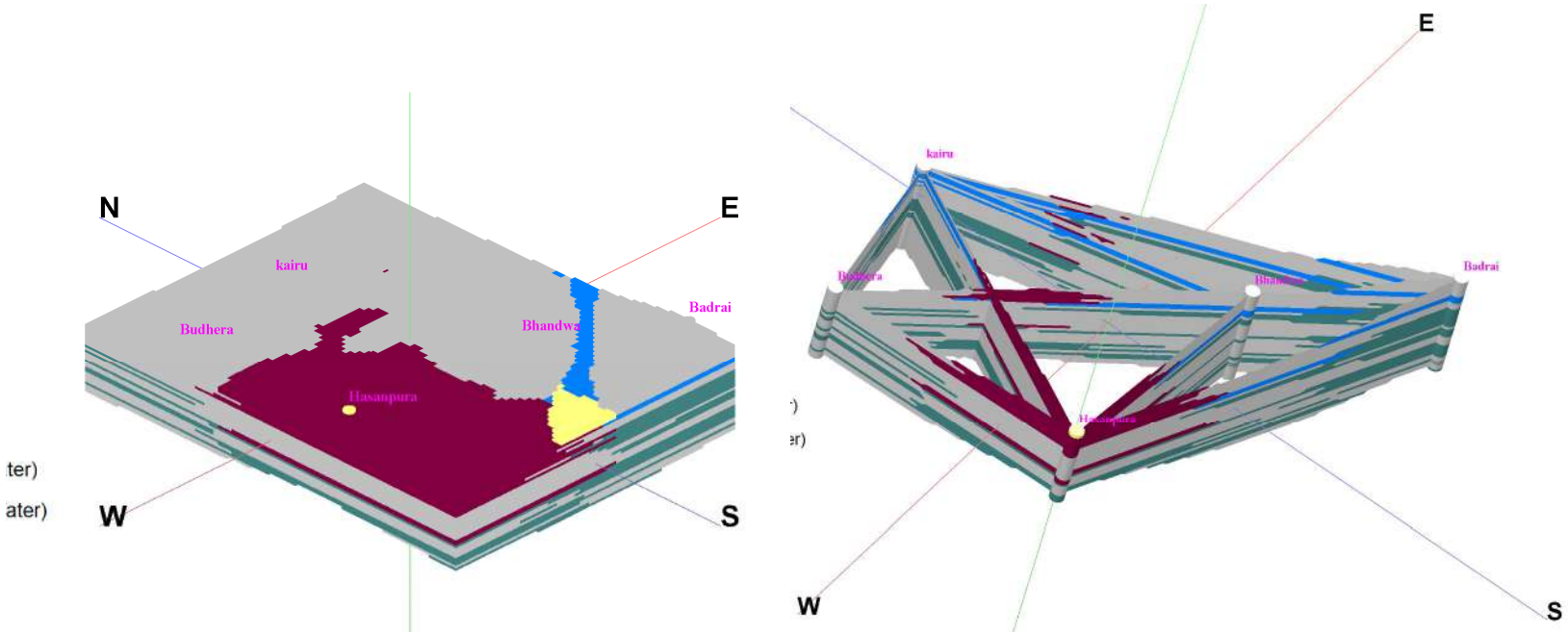
Water level Behavior(2015):

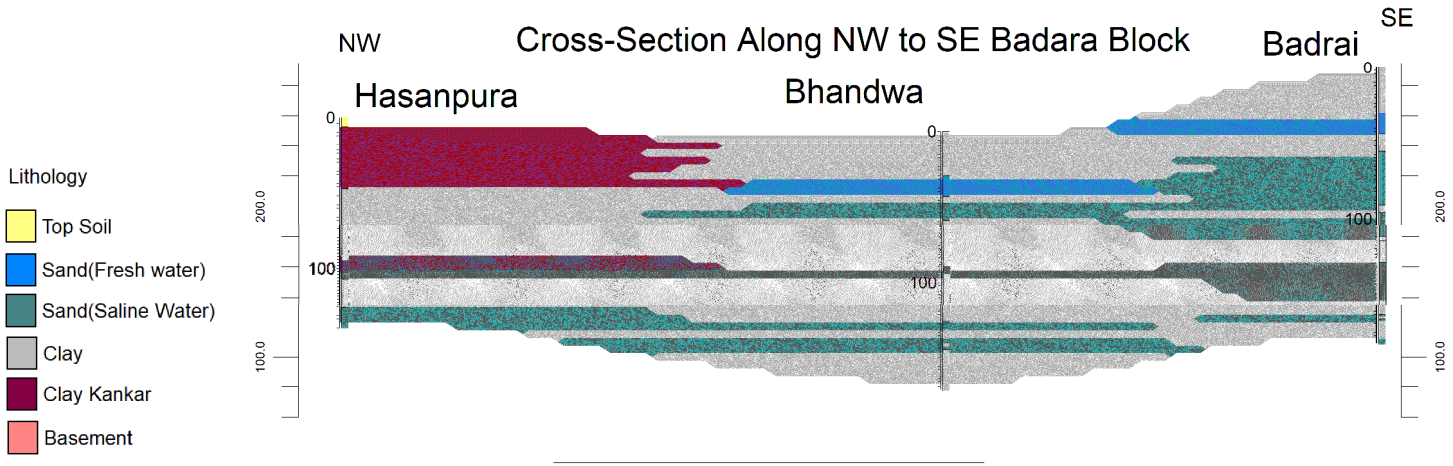
Pre Monsoon-56.54 -56.47 mbgl&Post Monsoon-56.93- 57.97mbgl

Aquifer Disposition: Single Aquifer System

Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravels. The non-aquifer material comprises of clay, chert and sandstone. The average depth of the fresh saline interface is at 51m bgl.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield	Storativity
I (70-140m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	25	1125	0.072	NA


N
E
W
S
kairu
Budhera
Bhandwa
Badrai
Hasanpura
ter)
ater)


Cross-Section Along NW to SE Badara Block
NW
SE
Hasanpura
Bhandwa
Badrai
Lithology
Top Soil
Sand(Fresh water)
Sand(Saline Water)
Clay
Clay Kankar
Basement
200.0
100.0
100

Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	20.9(Fresh)
	In-storage Aquifer I	664(Saline=664)
	Total	685
Ground Water Extraction (mcm)	Irrigation (2013)	80.83
	Domestic & Industrial (2013)	1.85
Future Demand for domestic & Industrial sector (2025) (in mcm)		1.85
Chemical Quality of ground water		Salinity problem in deeper aquifers
Other issues		Declining water level trend

Ground Water Resource Enhancement

Resource enhancement through artificial recharge	2.0 mcm water save through artificial recharge technique
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 5.6 mcm volume of water wastage
Change in cropping pattern	NA.
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Non Notified
Other interventions proposed, if any	-

IV. Siwani Block (698.53 sq km)

Population (2011)	Rural-89240 Urban-0 Total-89240
Rainfall	Monsoon -233mm Non Monsoon-33mm
Average Annual Rainfall	266 mm
Agriculture	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

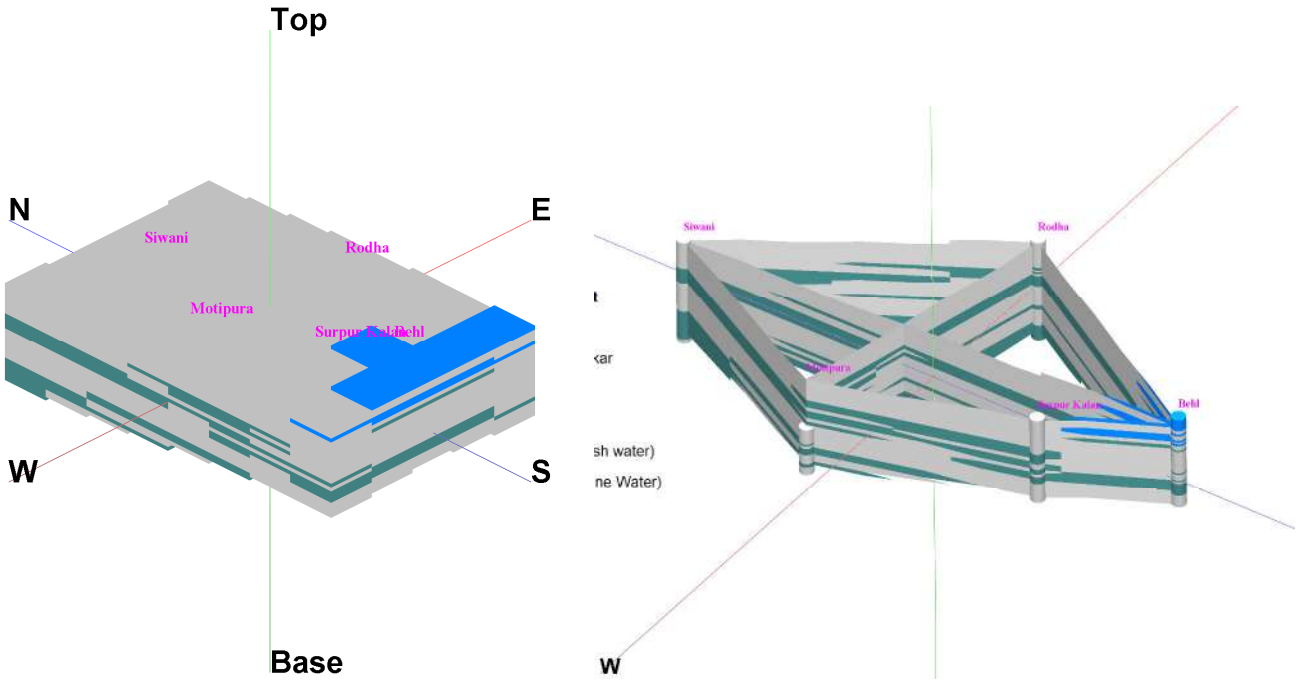
Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

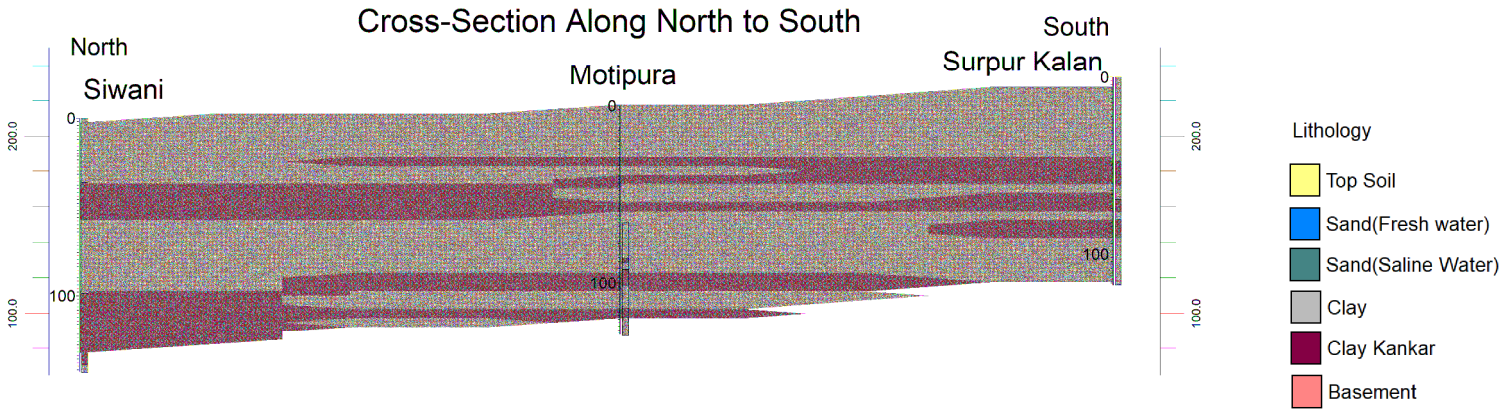
Water level Behavior(2015): Pre Monsoon-29.53- 30.4mbgl&Post Monsoon-28.64-30.28 mbgl

Aquifer Disposition: Single Aquifer System

Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravels. The non-aquifer material comprises of clay. The throughout drilled depth saline water existed.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (13-143m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	60	1125	0.072	NA


Top
N
E
W
S
Base
Siwani
Rodha
Motipura
Surpur Kalan
Behl
W


Cross-Section Along North to South
North
Siwani
Motipura
South
Surpur Kalan
0
100
200.0
100.0
Lithology
Top Soil
Sand(Fresh water)
Sand(Saline Water)
Clay
Clay Kankar
Basement

Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	59.92(Fresh)
	In-storage Aquifer I	3018(Saline)
	Total	3078
Ground Water Extraction (mcm)	Irrigation (2013)	45.07
	Domestic & Industrial (2013)	0.87
Future Demand for domestic & Industrial sector (2025) (in mcm)		1.35
Chemical Quality of ground water		Salinity problem
Other issues		Declining ground water level trend

Ground Water Resource Enhancement

Resource enhancement through artificial recharge	NA
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 8.76mcm volume of water wastage
Change in cropping pattern	NA
Alternate water sources	Tanks, ponds and canals
Regulation and Control	No (Not Notified)
Other interventions proposed, if any	-

V. Dadri-I Block (684.74 sq km)

Population (2011)	Rural-143425 Urban-0 Total-143425
Rainfall	Monsoon -421.4mm Non Monsoon-86.5mm
Average Annual Rainfall	508mm
Agriculture	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

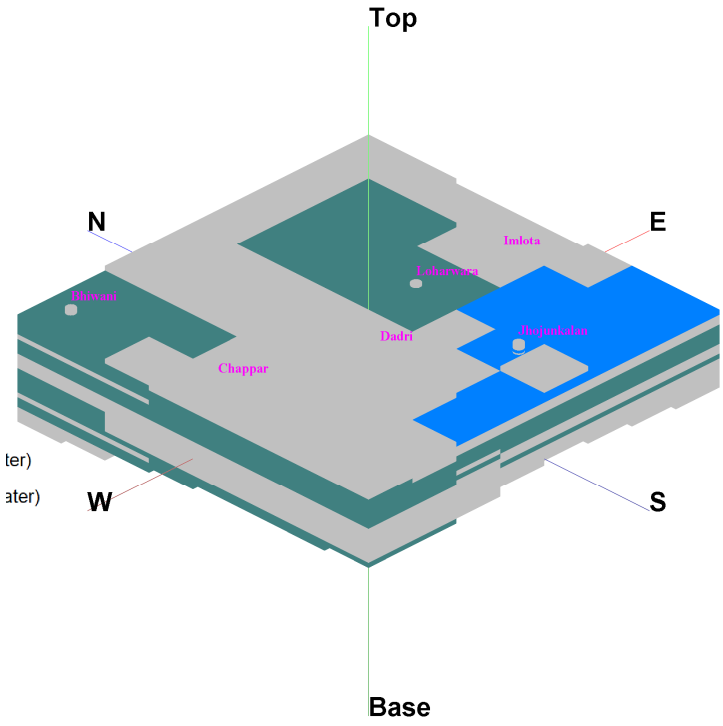
Water level Behavior (2018): Pre Monsoon-5.83-7.36 mbgl &Post Monsoon-5.3-6.73mbgl

Aquifer Disposition: Single Aquifer System

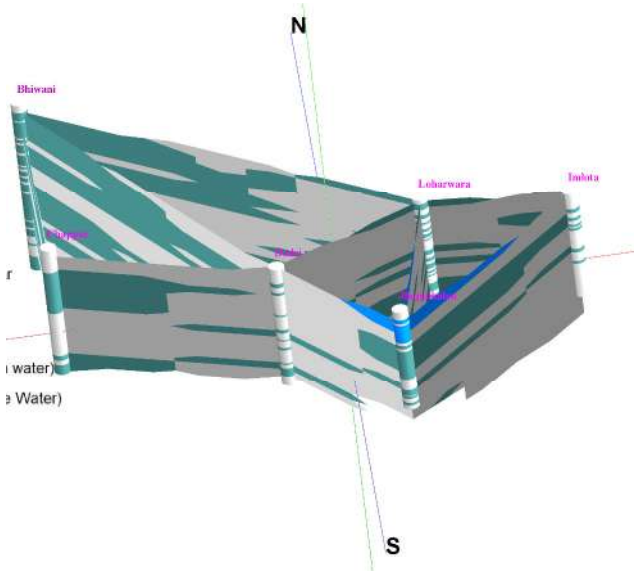
Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravels. The non-aquifer material comprises of clay. The average depth of the fresh saline interface is at 90m bgl.

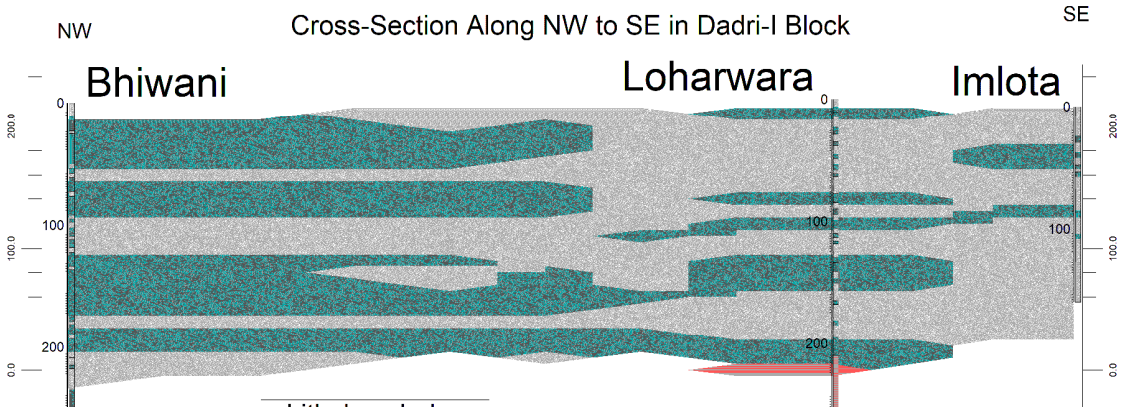
Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (8-210m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	92	1125	0.072	NA

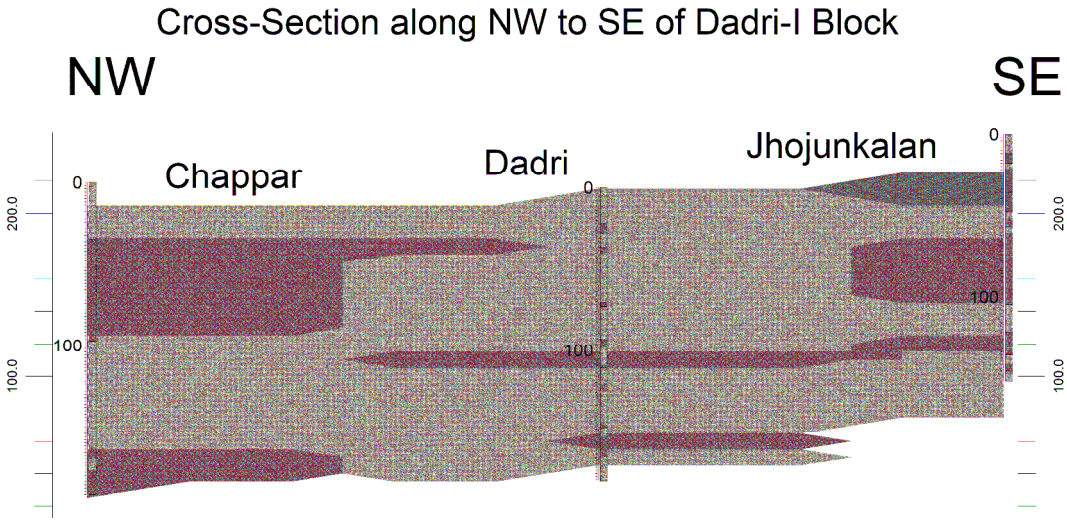
3D Lithology model

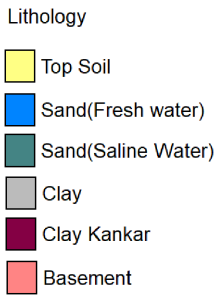


3D Lithology Fence




NW
Cross-Section Along NW to SE in Dadri-I Block
SE
Bhiwani
Loharwara
Imlota
0
100
200
200.0
100.0
0.0


Cross-Section along NW to SE of Dadri-I Block
NW
SE
Chappar
Dadri
Jhojunkalan
0
100
200.0
100.0


Lithology
Top Soil
Sand(Fresh water)
Sand(Saline Water)
Clay
Clay Kankar
Basement

Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	72.79(Fresh)
	In-storage Aquifer I	2443(Saline)
	Total	2507
Ground Water Extraction (mcm)	Irrigation (2013)	154.77
	Domestic & Industrial (2013)	0.37
Future Demand for domestic & Industrial sector (2025) (in mcm)		3.00
Chemical Quality of ground water		Salinity problem
Other issues		Declining ground water level trend

Ground Water Resource Enhancement

Resource enhancement through artificial recharge	NA
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 10.17mcm volume of water wastage
Change in cropping pattern	NA
Alternate water sources	Tanks, ponds and canals
Regulation and Control	No (Not Notified)
Other interventions proposed, if any	-

VI. Kairu Block (516.56sq km)

Population (2011)	Rural-79082 Urban-0 Total-79082
Rainfall	Monsoon -288mm Non Monsoon-65.6mm
Average Annual Rainfall	353 mm
Agriculture	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

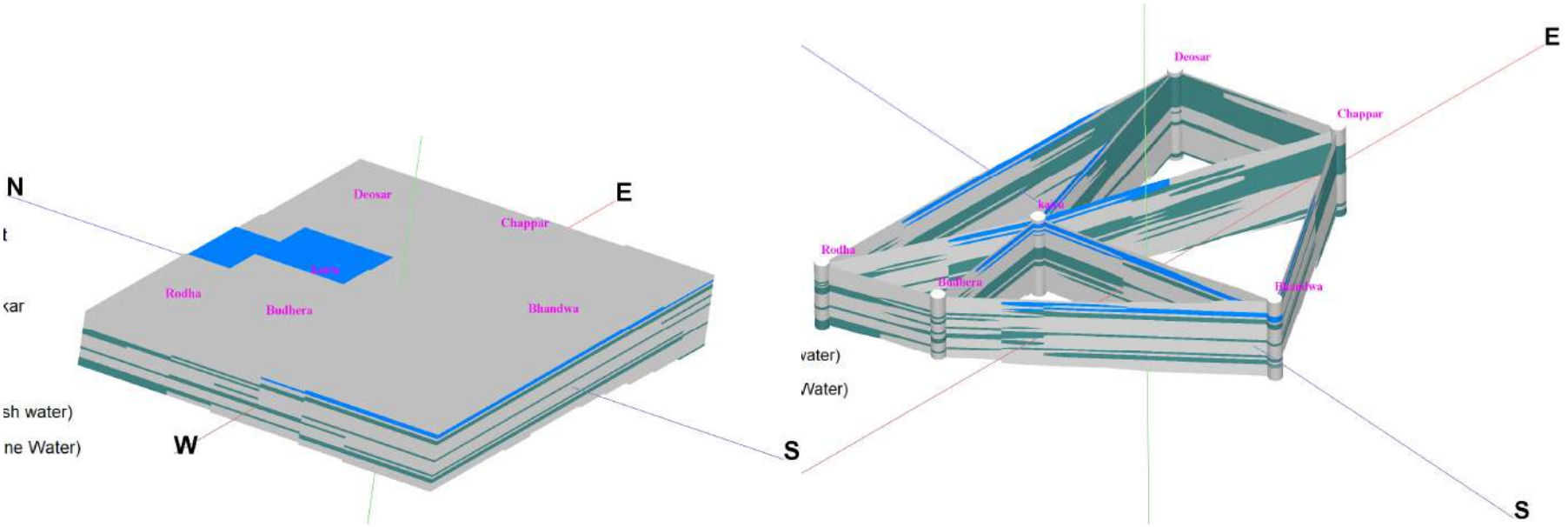
Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

Water level Behavior(2015): Pre Monsoon-19.4-31.4mbgl & Post Monsoon-19.3-32.6mbgl

Aquifer Disposition: Single Aquifer System

Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand and gravels. The non-aquifer material comprises of clay and sandstone. Aquifer is saline.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (16-166m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	50	1125	0.072	NA


N
E
W
S
Deosar
Chappar
Rodha
Budhera
Bhandwa
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sh water)
ne Water)
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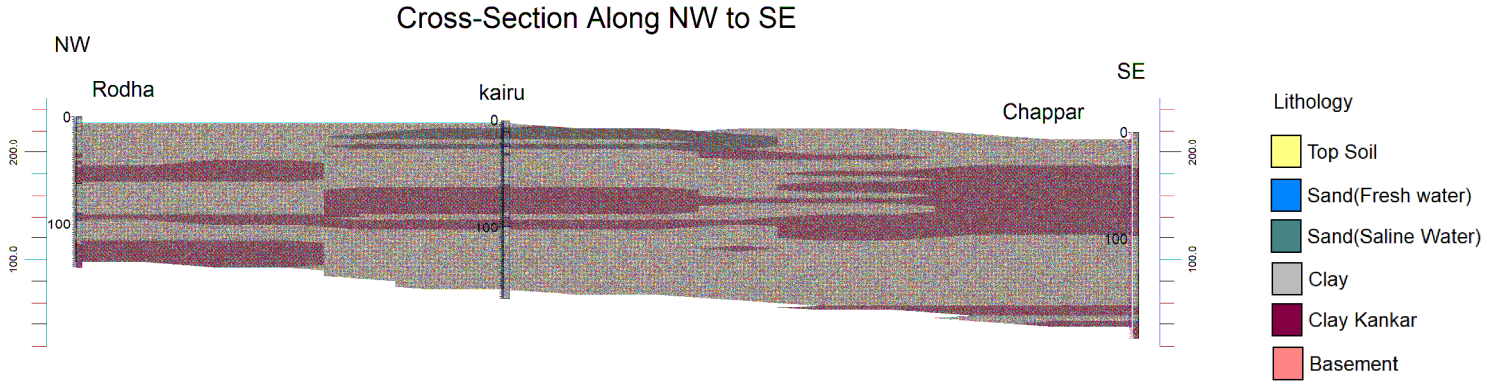

Cross-Section Along NW to SE
NW
SE
Rodha
kairu
Chappar
0
100
200.0
100.0
Lithology
Top Soil
Sand(Fresh water)
Sand(Saline Water)
Clay
Clay Kankar
Basement

Ground Water Resource, Extraction, Contamination and other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	44.45 (Fresh)
	In-storage Aquifer I	1055 (saline)
	Total	1089
Ground Water Extraction (mcm)	Irrigation (2013)	72.24
	Domestic & Industrial (2013)	1.23
Future Demand for domestic & Industrial sector (2025) (in mcm)		1.23
Chemical Quality of ground water		Salinity problem in deeper aquifers
Other issues		Not Potable

Ground Water Resource Enhancement

Resource enhancement through artificial recharge	1.38 mcm water save through artificial recharge technique
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 11.63mcm volume of water wastage
Change in cropping pattern	NA
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Notified (2011)
Other interventions proposed, if any	-

VII. Dadri-II Block (368.73 sq km)

Population (2011) Rural-160330

Urban-0

Total-160330

Rainfall Monsoon -421.4mm

Non Monsoon-86.47mm

Average Annual Rainfall 508mm

Agriculture Major Crops- Wheat, Rice, Barley& Bajra

Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

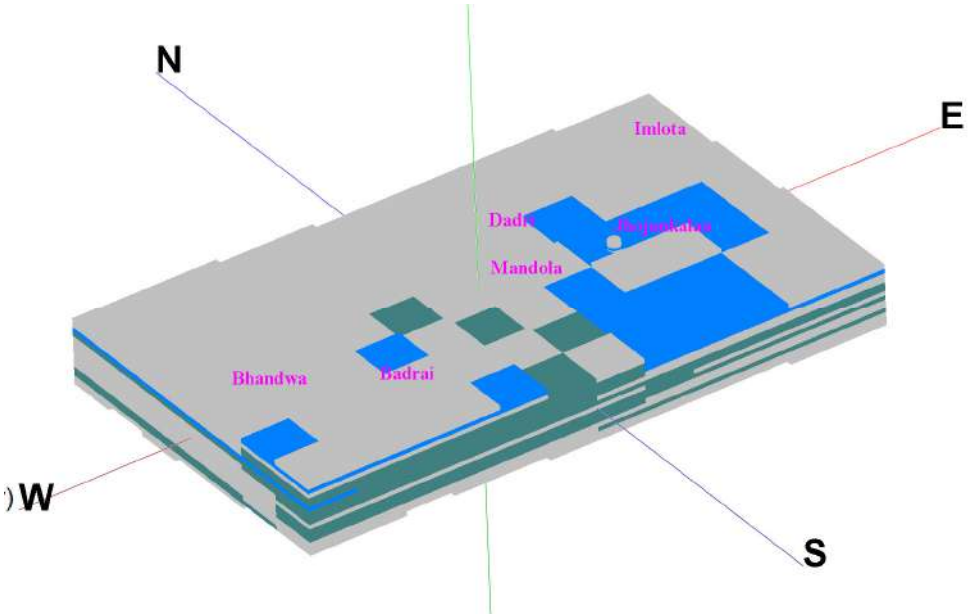
Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

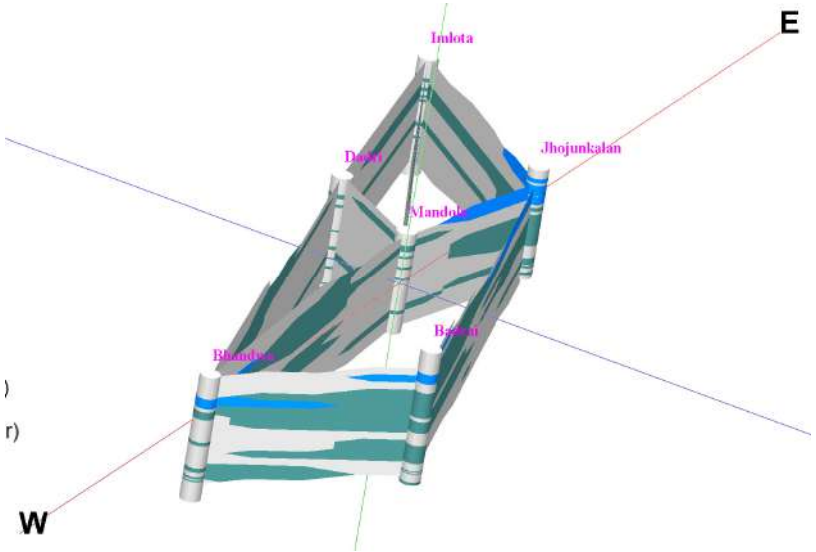
Water level Behavior(2018): Pre Monsoon-9.98-10.13mbgl&Post Monsoon-8.79-9.37mbgl

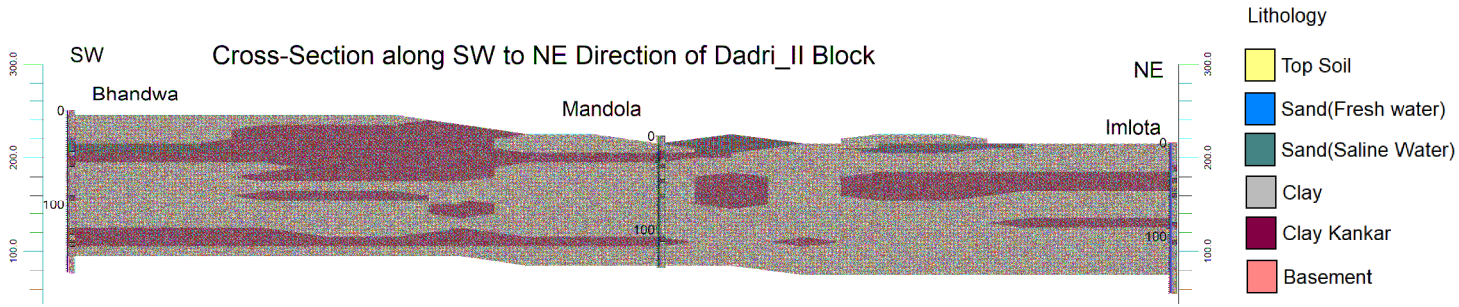
Aquifer Disposition: Single Aquifer System

Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravel. The non-aquifer material comprises of clay, sandstone and granite. The average depth of the fresh saline interface is at 105m bgl.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (6-192m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	94	1125	0.072	NA







Lithology

- Top Soil
- Sand(Fresh water)
- Sand(Saline Water)
- Clay
- Clay Kankar
- Basement

Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	44.45(Fresh)
	In-storage Aquifer I	1711(Saline)
	Total	1755
Ground Water Extraction (mcm)	Irrigation (2013)	84.22
	Domestic & Industrial (2013)	1.05
Future Demand for domestic & Industrial sector (2025) (in mcm)		1.4
Chemical Quality of ground water		Salinity problem
Other issues		Not potable

Ground Water Resource Enhancement

Resource enhancement through artificial recharge	NA
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 5.8mcm volume of water wastage
Change in cropping pattern	1.33mcm water save through change in 100% area form paddy to maize.
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Not Notified
Other interventions proposed, if any	-

VIII. Bhiwani Block (303.8 sq km)

Population (2011)	Rural-310641 Urban-0 Total-310641
Rainfall	Monsoon -351.03mm Non Monsoon-75.2mm
Average Annual Rainfall	426 mm
Agriculture	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

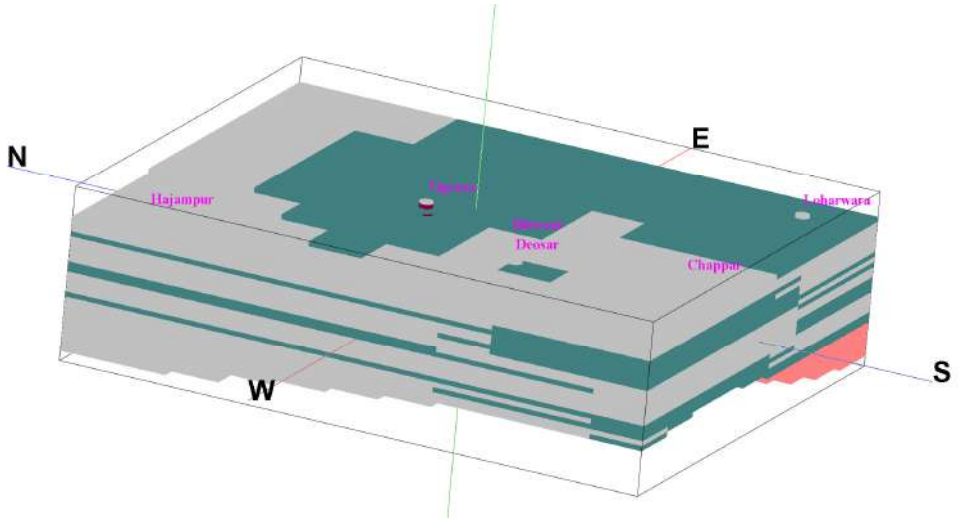
Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

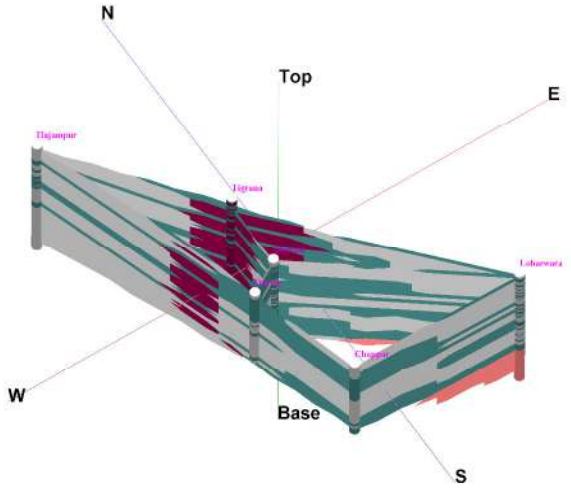
Water level Behaviour (2015): Pre Monsoon-17-19.46mbgl&Post Monsoon-19.45-20.04mbgl

Aquifer Disposition: Single Aquifer System

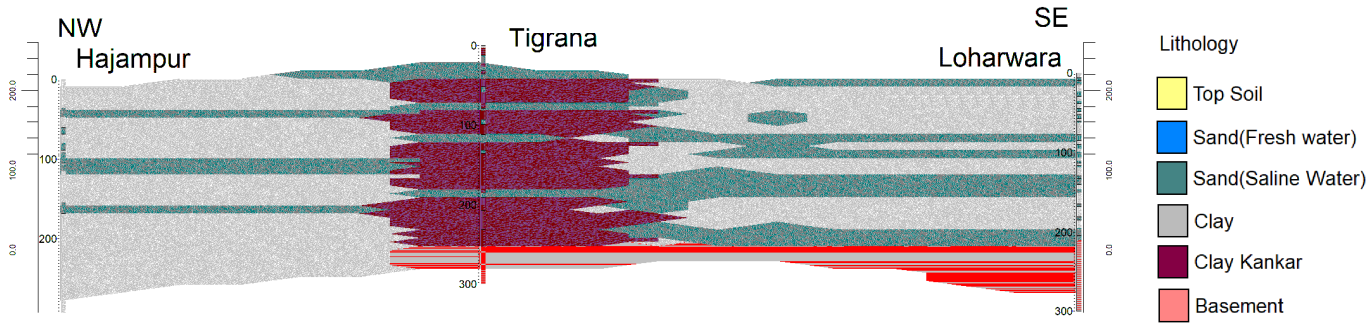
Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravel. The non-aquifer material comprises of clay, sandstone and granite. The average depth of the fresh saline interface is at 105m bgl.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (3-252m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	67	1125	0.072	NA





Cross section along NW to SE of Bhiwani Block



Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	122.02 (Fresh)
	In-storage Aquifer I	3303(Saline)
	Total	3425
Ground Water Extraction (mcm)	Irrigation (2013)	127.98
	Domestic & Industrial (2013)	1.45
Future Demand for domestic & Industrial sector (2025) (in mcm)		3.49
Chemical Quality of ground water		Salinity problem
Other issues		Not potable

Ground Water Resource Enhancement

Aquifer wise space available for artificial recharge and proposed interventions	NA
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 8.9mcm volume of water wastage
Change in cropping pattern	NA
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Not Notified
Other interventions proposed, if any	-

IX. Tosham Block (387.13 sq km)

Population (2011)	Rural-166227 Urban-204629 Total-370856
Rainfall	Monsoon -287.45mm Non Monsoon-65.6mm
Average Annual Rainfall	266 mm
Agriculture	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

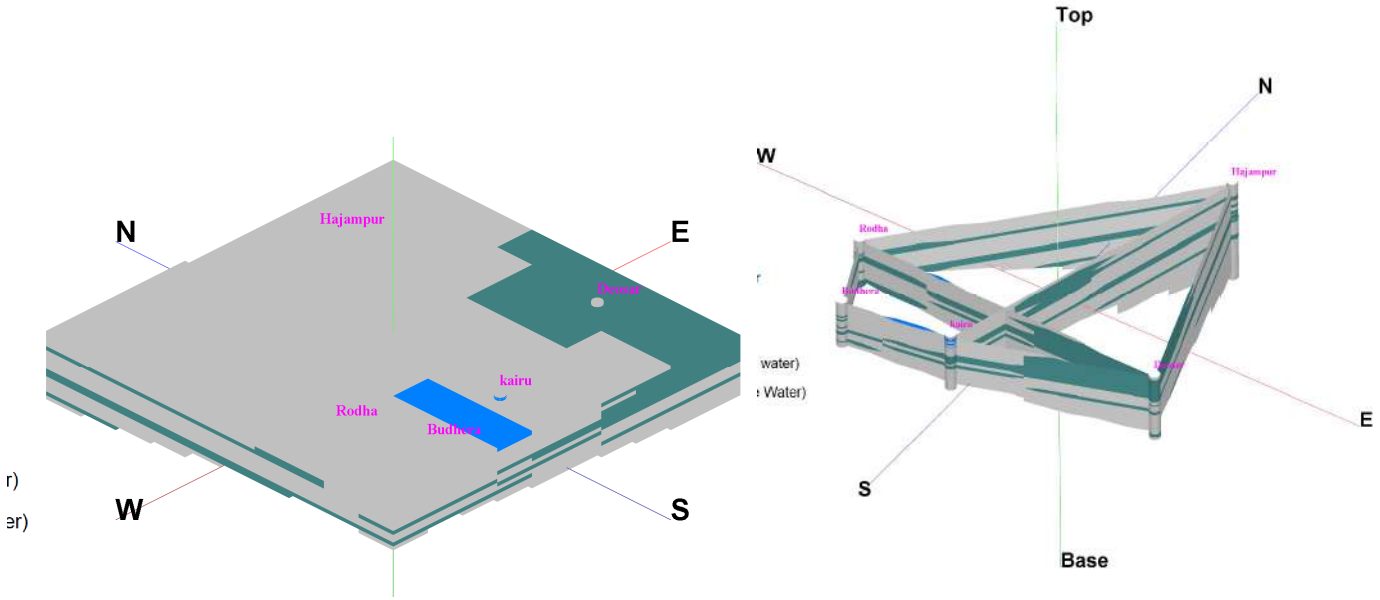
Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

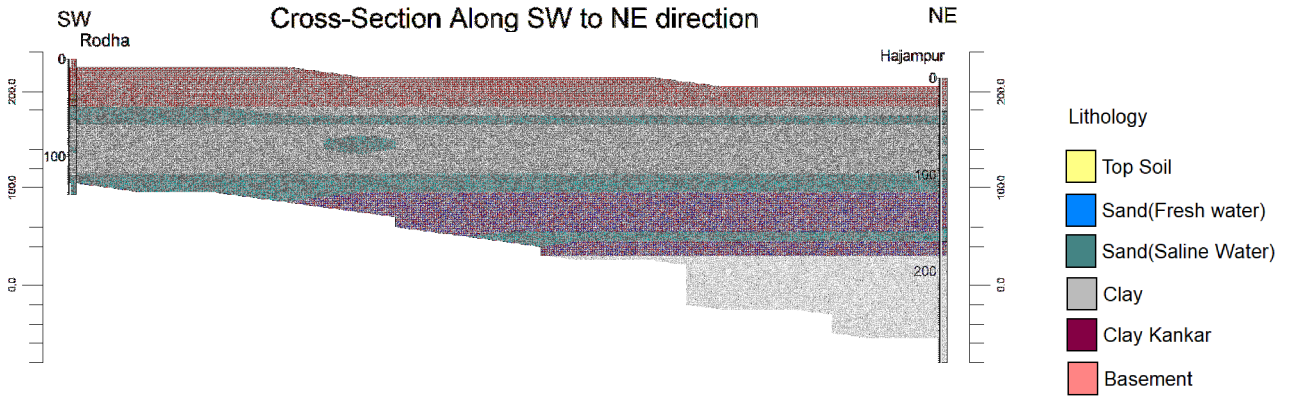
Water level Behaviour (2015): Pre Monsoon-6.15-7.16 mbgl &Post Monsoon-4.29-5.24mbgl

Aquifer Disposition: Single Aquifer System

Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravel. The non-aquifer material comprises of clay, sandstone and granite. Aquifer is saline.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (6.5-140m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	47	1125	0.072	NA


N
E
W
S
Hajampur
Deosar
kairu
Rodha
Budhera
Top
Base
water)
Water)


SW
NE
Cross-Section Along SW to NE direction
Rodha
Hajampur
0
100
200
Lithology
Top Soil
Sand(Fresh water)
Sand(Saline Water)
Clay
Clay Kankar
Basement

Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	68.54
	In-storage Aquifer I	1254(saline)
	Total	1323
Ground Water Extraction (mcm)	Irrigation (2013)	107.53
	Domestic & Industrial (2013)	4.35
Future Demand for domestic & Industrial sector (2025) (in mcm)		4.35
Chemical Quality of ground water		Salinity problem
Other issues		Declining ground water level trend

Ground Water Resource Enhancement

Aquifer wise space available for artificial recharge and proposed interventions	NA
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 14.49mcm volume of water wastage
Change in cropping pattern	NA
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Not Notified
Other interventions proposed, if any	-

X. Bhawani khera Block (557.32sq km)

Population (2011)	Rural-115628 Urban-0 Total-115628
Rainfall	Monsoon -161mm Non Monsoon-24 mm
Average Annual Rainfall	186mm
Agriculture	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

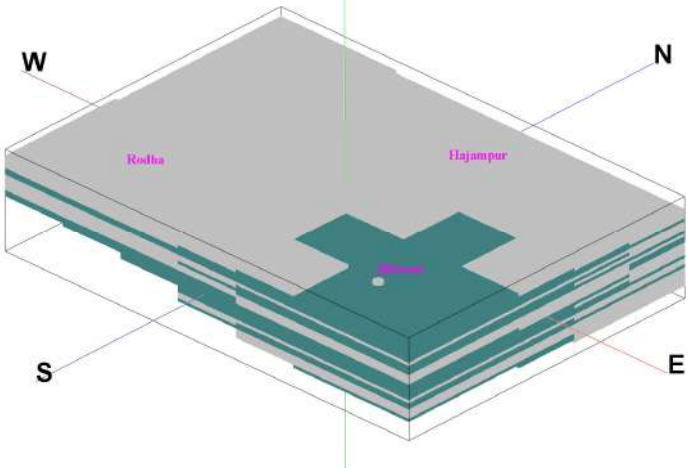
Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

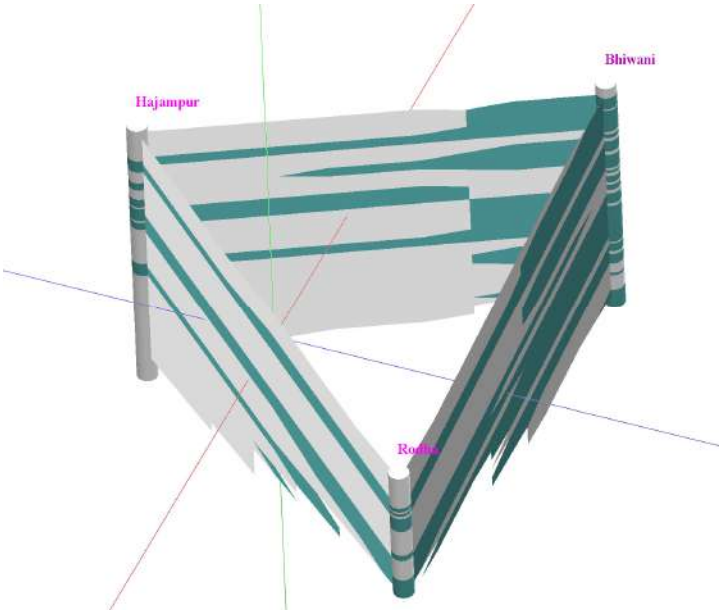
Water level Behavior(2018): Pre Monsoon-32.5-63.5mbgl&Post Monsoon-37.2-67.9mbgl

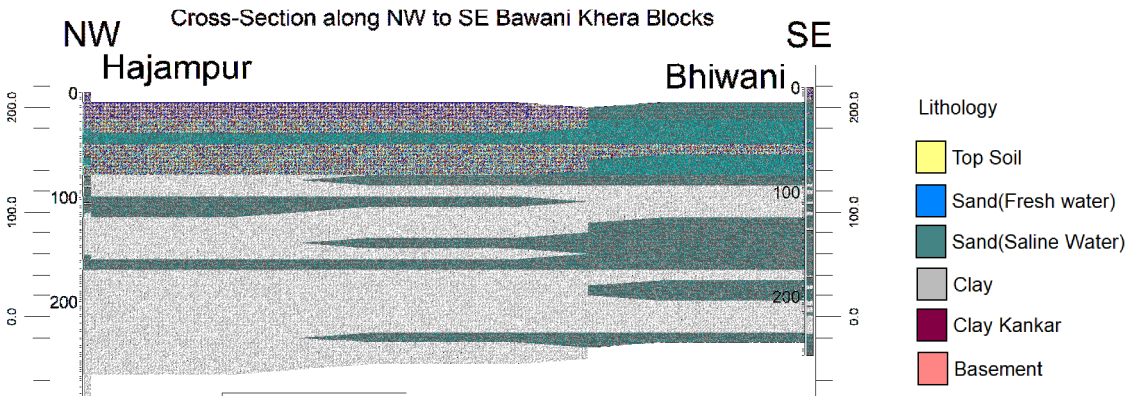
Aquifer Disposition: Single Aquifer System

Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravel. The non-aquifer material comprises of clay, sandstone and granite. The average depth of the fresh saline interface is at 105m bgl.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (6.4-193m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	94	1125	0.072	NA


W
N
S
E
Rodha
Hajampur


Bhiwani
Hajampur
Rodha


Cross-Section along NW to SE Bawani Khera Blocks
NW
Hajampur
SE
Bhiwani
0
100
200
200.0
100.0
0.0
Lithology
Top Soil
Sand(Fresh water)
Sand(Saline Water)
Clay
Clay Kankar
Basement

Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	90.03
	In-storage Aquifer I	3772(Saline)
	Total	3862
Ground Water Extraction (mcm)	Irrigation (2013)	103.23
	Domestic & Industrial (2013)	0.62
Future Demand for domestic & Industrial sector (2025) (in mcm)		1.97
Chemical Quality of ground water		Salinity problem
Other issues		Not potable

Ground Water Resource Enhancement

Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 14.49mcm volume of water wastage
Change in cropping pattern	NA
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Not Notified
Other interventions proposed, if any	-