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Ministry of Jal Shakti
Department of Water Resources, River Development and Ganga Rejuvenation.

Report
On

AQUIFER MAPPING AND GROUNDWATER MANAGEMENT PLAN, TAPI DISTRICT, GUJARAT STATE

by
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AQUIFER MAPPING AND GROUNDWATER MANAGEMENT PLAN, TAPI DISTRICT, GUJARAT STATE

1. INTRODUCTION

Tapi district is lying between latitude 20°30 ″ - 21°35″ N and longitude 73°05 ″ - 74°20 ″ E and has a total geographical area of 3139 sq. km. The district is situated in the southern part of the state. It is boundedby the Surat district on the west, Narmada in the north, the Navsari district in the south, The Dang districtin the south-east, and Maharashtra state in the east. The district has been divided into seven talukas, i.e., Kukarmunda, Nizar, Songadh, Uchhal, Valod, Vyara and Dolvan.

Table 1. Taluka wise Geograpical Area of Tapi district

Sl. No	Taluka	Geographical Area (Sq. Km.)
1	Nizar	401
2	Songadh	1155
3	Uchhal	565
4	Valod	204
5	Vyara	813
Total Area		3139

The administrative divisions of the district have been reconstituted recently by bifurcating Surat district on 27th September 2007 into two districts namely Surat and Tapi. The district receives an average rainfall of 1926 mm. maximum temperature raises upto 45 degree centigrade. Tapi district is bordered by four rivers, Tapi, Midoda, Purna and Ambika. Vyara and Songadh in Tapi district are known for dense forests with a major production of bamboos. The district Tapi has headquarter at Vyara and has fairly good network of roads and all the taluka headquarters are connected with all weather roads. Index and Administrative Map of the Tapi district as shown in Figure 1 and 2 respectively.

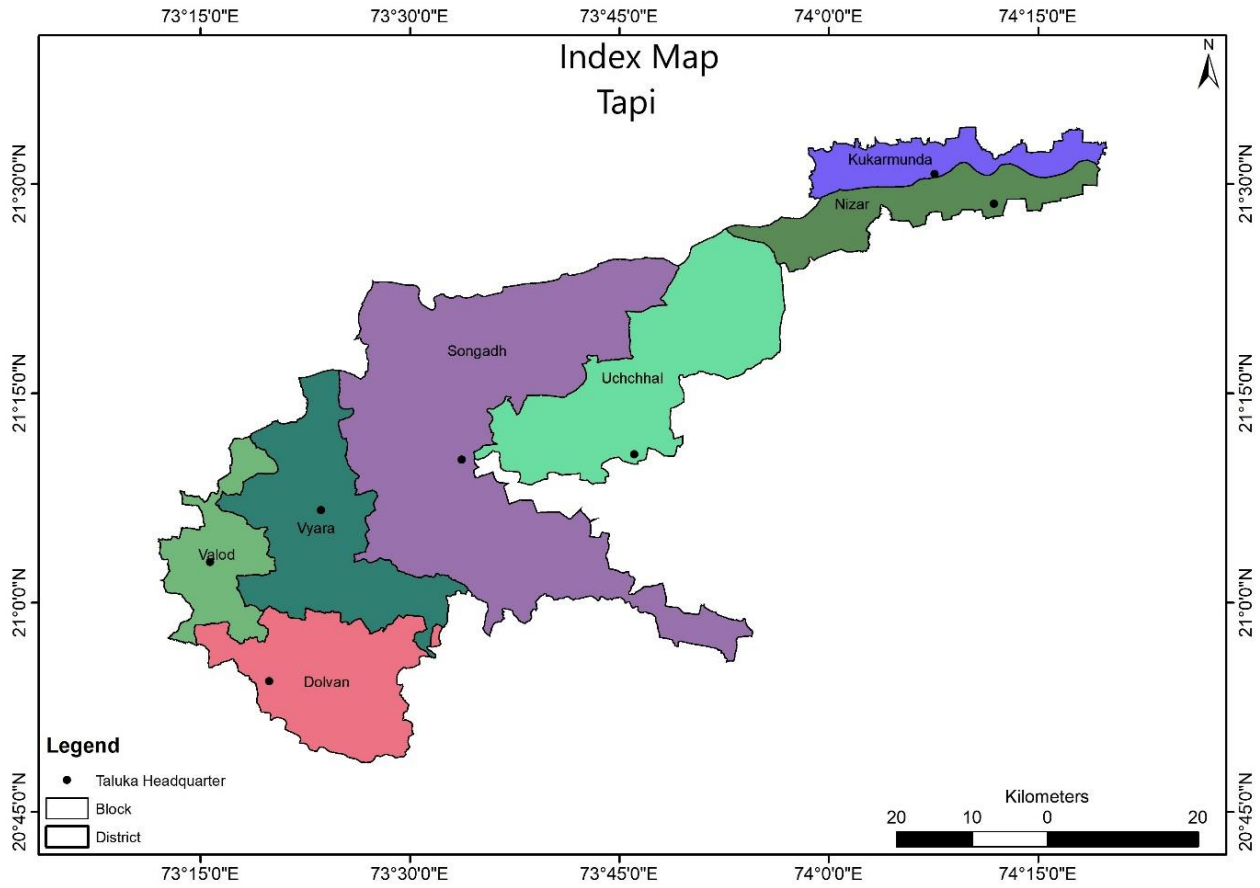

Figure 1. Administrative map of Tapi district, Gujarat

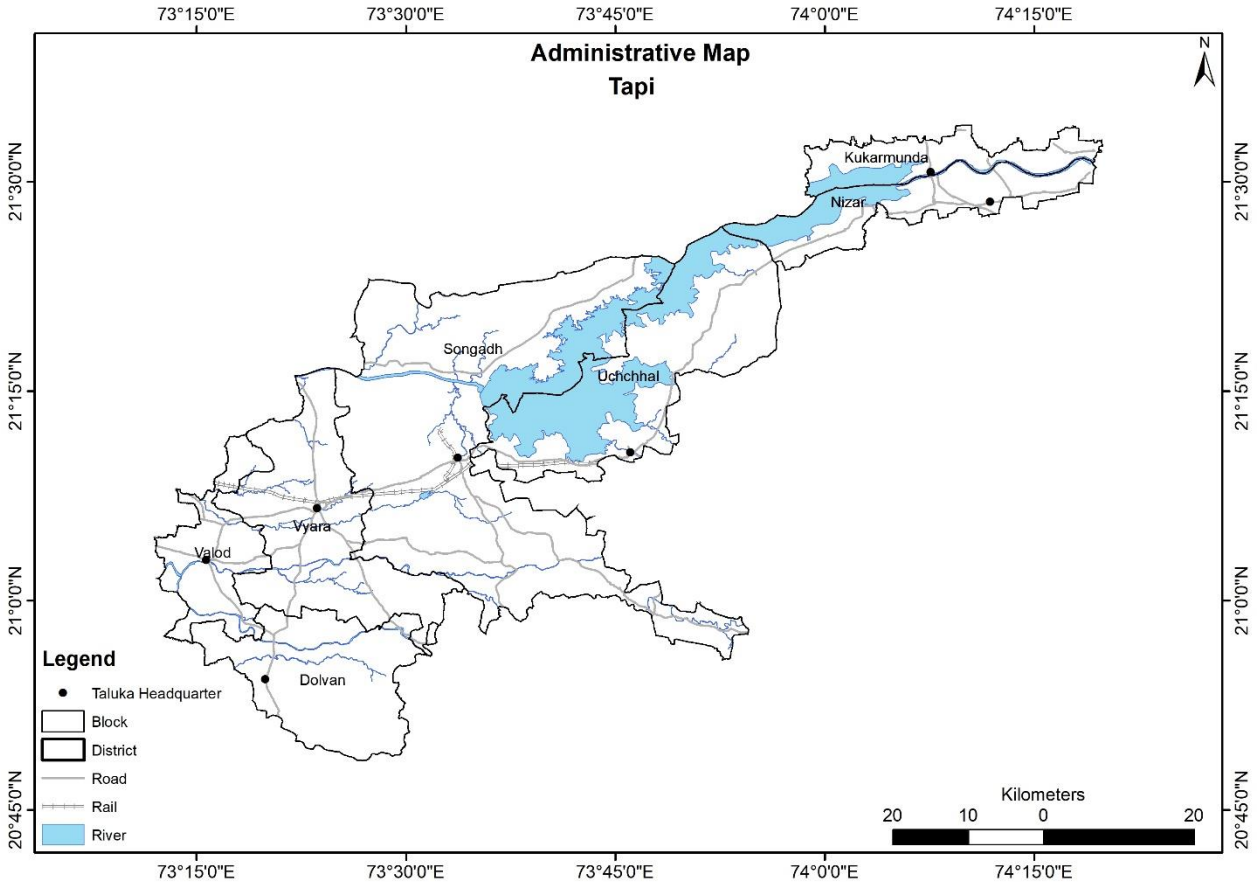

Figure 2. Administrative map of Tapi distric, Gujarat

With a view to run the administration of the State smoothly, it has been divided into Districts, which in turn have been further sub-divided into Talukas (Tahsils). In the State of Gujarat, the community development blocks are co-terminus with the Talukas. The Talukas contain large number of villages and possibly several towns. The villages have Village Panchayats to run the local administration. A Village Panchayat may constitute one revenue village, several revenue villages or a part of a large village. Similarly, the towns have Municipality or Municipal Corporation as of local self-government. The District Collector looks after the general administration, maintenance of collection of land revenue and settlement of law related disputes, civil supplies, district planning, mid-day meal scheme, etc at the district level. At the Taluka level, Mamlatdar looks after the land development, revenue collection, civil supplies and law and order. The functions of administration of law and order and control with investigation of crime are done by the Superintendent of Police of the district with the help of Police Stations working under him. The Panchayati Raj institutions are fairly strong and most of the development works have been transferred to the District Panchayats and its subordinate bodies. The District Panchayat has an elected President and District Development Officer appointed by the Government, works as its Secretary, who looks after day-to-day work related to the development. Similarly, at the Taluka level, Taluka Panchayats have been constituted which have an elected President. The Taluka Development Officer, placed by the Government as Secretary of the Taluka Panchayats and he conducts the regular administrative work. Likewise, an elected President heads the Municipality and the Chief Officer works as the Secretary of the Municipality, who looks after the day-to-day work. In case of the large cities, the State Government has constituted Municipal Corporation, which are headed by an elected Mayor and the Municipal Commissioner, appointed by the Government, looks after the routine work. At the Village level, the Sarpanch is the elected Chief and the Talati (Village Mantri) works as the Secretary to the Village Panchayat and looks after the day today work. In view of the expanding role of the public administration in a state like Gujarat, the Government has taken-up many activities and has set up several offices. Such offices which came into the existence are as under:

i) Education (Primary and Higher Education)
ii) Agricultural and Research
iii) Animal Husbandry and Poultry
iv) Forest and Environment
v) Roads and Buildings, Bridges
vi) Co-operation and Co-operative Societies
vii) Industries, Small and Large as well as Cottage
viii) Health and Medical Services, Medical Education and Research, Family Welfare and Nutrition
ix) Information Department,

x) Irrigation Minor and Major

xi) Social Welfare and Social Defense

The functions of above offices are managed and controlled by concerned Head of Departments and in some cases also by District and Taluka Panchayats. The task of providing primary education in rural areas has been entrusted to District Panchayats. The functions related to Government of providing primary education is assigned to District Primary Education Officer of District Panchayat who works under District Development Officer. The secondary education is looked after by District Education Officer of Education Department. Primary education as well as higher secondary education of all types is governed by District Education Officer.

Table 2. Taluka wise number of villages

Taluka	Number of villages	
	Total	Inhabited
Nizar	79	51
Uchchhal	45	40
Songadh	175	172
Vyara	149	148
Valod	40	40
Total	**488**	**451**

Source: Census of India, 2011

1.1 Objective:

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.

1.2 Methodology:

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

The activities of the Aquifer Mapping can be grouped as follows.

1.2.1 Data Compilation & Data Gap Analysis:

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

1.2.2 Data Generation

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

1.2.3 Aquifer Map Preparation:

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

1.2.4 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 and presented in figure 3.

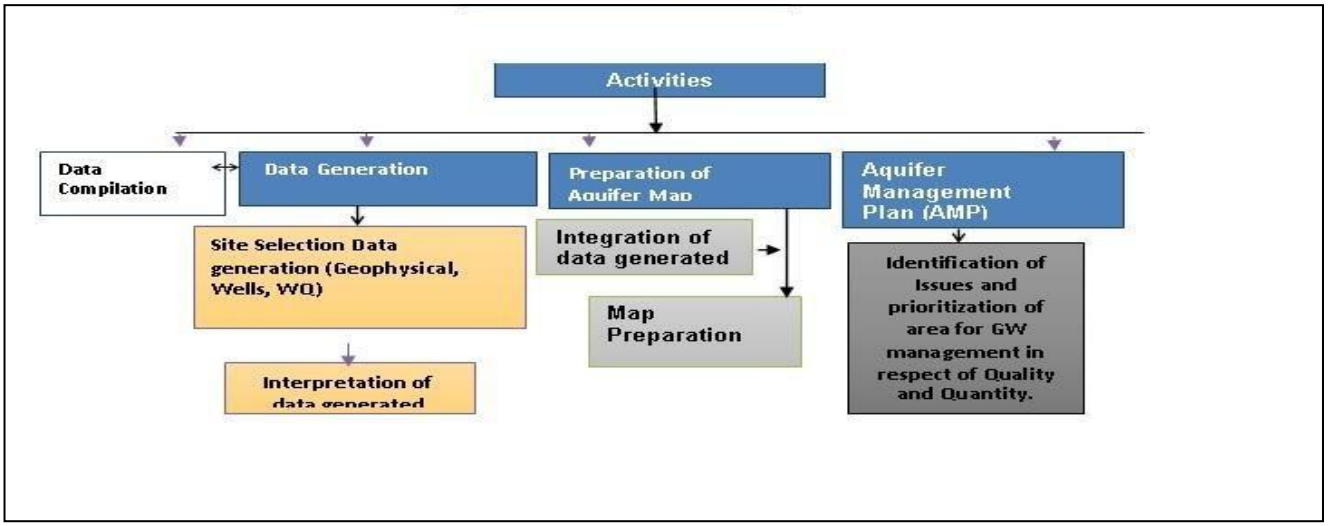

Figure 3. Activities under National Aquifer Mapping Programme

1.4 District Demography

As per 2011 census, the total population of the district is 8,07,022 out of which population of female and male are 4,04,834 and 4,02,188 respectively. Tapi district is the 4 thlowest in terms of population in the state. District is predominantly rural and around 90% of the population resides in rural area. Tapi ranks 1 stin terms of sex-ratio in the state i.e. 1007 females per 1,000 males as against 919 females per 1,000 males of state average. Compared to 2001 census, the decadal growth in population of Tapi has been 12.14%, i.e. 1.214% growth per annum. The district has a literacy rate of 68.26%. The literacy rate of female is 61.16%. Sub-district Valod has the highest literacy rate of 74.92% and Uchchhal has the lowest literacy rate of 57.47% among all sub-districts of Tapi.

The population density of Tapi district as recorded by 2011 census is 257 people per sq. km. which is 22% increase in density as compared to 210 people per sq. km as per 2001 census. Compared to the population density of the State (308 person per sq.km.), the current population density of Tapi is on lower side.

Table 3. Demography of Tapi district

Name of Talukas	Population				Total	
		M	F	CH* (1-14 years)	NHH	NM
Nizar	Total	64433	65536	16464	27917	129969
	Rural	64433	65536	16464	27917	129969
	Urban	0	0	0	0	0
Uchchhal	Total	43670	44746	10783	20619	88416
	Rural	43670	44746	10783	20619	88416
	Urban	0	0	0	0	0
Songadh	Total	115185	114597	26304	49427	229782
	Rural	94689	95395	21388	40975	190084
	Urban	20496	19202	4916	8452	39698
Vyara	Total	133335	134954	26553	58960	268289
	Rural	113191	115309	22442	50349	228500

	Urban	20144	19645	4111	8611	39789
Valod	Total	45565	45001	8971	20168	90566
	Rural	45565	45001	8971	20168	90566
	Urban	0	0	0	0	0
District Total		**402188**	**404834**	**89075**	**177091**	**807022**

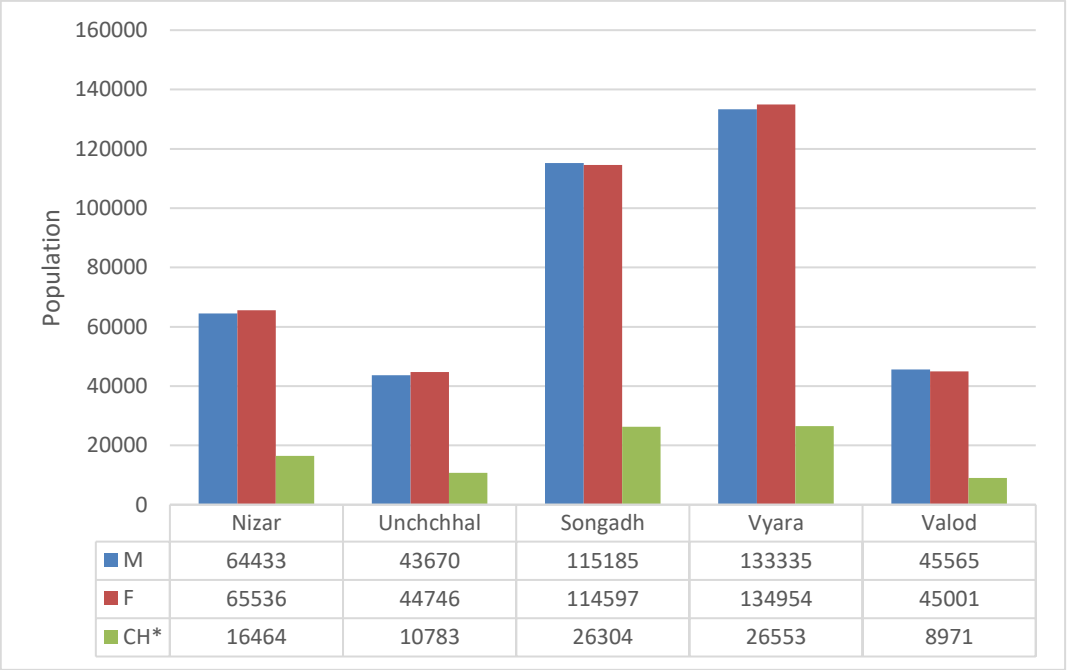

Figure 4. Representation of Demography of Tapi district

1.5 Hydrometorology

The Tapi district experienced cold between late November to middle of February, usually December and January is the coldest month. In winter season the temperature goes down up to 15 ℃ and in summer season it goes up to 45 ℃. July to September are the month of South-West monsoon. October to November are the months of post monsoon i.e., transition to winter. Except for July to September, air is generally dry and April to June witness hot desiccating winds (loo) and dust- storms.

1.5.1 Climate and Rainfall

Ecology, Climate, Hydrology and Topography etc. are the basic factors determining the delineation of agro-climatic zones. Gujarat as a whole falls in agro-climatiz Zone no. 13- Gujarat Plains and Hills. Taking into consideration, the rainfall pattern, topography, soil characteristics, the climate in general and the cropping pattern, eight agro-climatic zones have been identified for Gujarat. A brief description of agro ecology and climate

of Tapi is given below;

Table 4. Agro climatic zones of Tapi distric

Agro-climatic Zone	Characteristics
South Gujarat Heavy Rainfall Zone-I	• It consists of three talukas of Tapi district i.e. Songadh, Vyara and Valod taluka • It has an intensive rainfall over 1500 to 2200 mm per annum • Rain mostly received during month of July- August • The zone has clyey soil with normal pH and Ec, medium organic carbon and phosphorous and high potash
South Gujarat Rainfall Zone-II	• It consists of two talukas i.e. Uchchhal and Nizar. • Rainfall of the area varying between 1000 to 1500 mm per annum • This zone has black soil of medium to heavy texture • 75 per cent of the area is rainfed

Tapi district as a whole falls in Hot and semi-arid South Eastern Agro climatic Zone and grows crops like paddy and orchard crops. Tapi is further divided into two Agro Ecological Situations (AES) i.e. AES I and AES II. 58% area of Tapi District is under AES I while the rest area of Tapi District is under AES II. The general features of these agro-ecological situations are as under.

Table 5. AES Classification of Tapi district

AES	Soil texture	Rainfall (mm)	Principal crops	Special features	Taluka cover
Deep black soil with Heavy rainfall (Ghed)	Clayey	2700-3300	Sugarcane, Cotton, Chick pea., Paddy, Sorghum, Tuber, Horticulture Crops	Water logging during monsoon	85 % Soil of Tapi District is Deep Black With Heavy Rainfall
Mixed Red & black soil with medium rainfall	Sandy clay loam to clay loam	2200-2700	Groundnut, Sugarcane, Paddy, Horticulture Crops Cotton, Sorghum	15% Soil of Tapi Undulating land is Read & problems	District Black soil with medium Rainfall

General gradient of land mass of Gujarat from South-East to the South - West changes southern part of the state where slope is towards East. This leads saucer like depression in the eastern part of Tapi district. So, low lying areas have been adversely affected by water logging, salinity, efflorescence, alkalinity etc. basically near about. Soils are of three types viz., fine loam, course loam and relatively sandy loam. There is nothing particular about the flora and fauna of the district. Some area is under forests. Weather can be divided into four seasons. It is cold between late November to middle of February, usually December and January is the coldest month. In winter season the temperature goes down up to 15℃ and in summer season it goes up to 45℃. July to

September are the month of South-West monsoon. October to November are the months of post monsoon i.e., transition to winter. Except for July to September, air is generally dry and April to June witness hot desiccating winds (loo) and dust- storms.

Table 6. Rainfall of Tapi district (in mm) from 1987-2021

Years	Stations				
	Nizar	Songadh	Unchchhal	Valod	Vyara
1987	431	119	748	619	492
1988	868	2578	1780	1954	1776
1989	841	1762	1334	1437	1464
1990	931	1726	1259	1446	1323
1991	806	1262	983	874	94
1992	67	1938	1110	1596	1490
1993	1116	873	1335	1523	1435
1994	1479	1930	1770	2071	2732
1995	591	830	664	1027	1104
1996	719	1686	1031	1340	1717
1997	1121	1278	1192	1175	1563
1998	961	1369	1283	1822	1822
1999	547	867	795	991	1037
2000	620	1053	615	927	804
2001	893	2318	615	1544	1643
2002	706	2087	1034	1157	1145
2003	1361	3183	980	2258	2216
2004	1070	3561	1580	1797	1996
2005	1303	4661	1592	2716	3980
2006	2123	3468	1692	2077	3385
2007	1057	1579	1284	1505	1379
2008	824	1683	1176	1775	1676
2009	689	1308	1177	1059	1220
2010	699	1638	742	1388	1226
2011	619	958	723	1441	1078
2012	621	950	678	1145	1056
2013	1192	2184	1284	1806	2690
2014	424	877	576	978	1212
2015	750	970	550	1010	1148
2016	697	1215	802	1110	1158
2017	738	1207	977	945	1272
2018	625	1272	822	1576	1366
2019	1474	2165	1445	1986	2056
2020	951	1484	803	1718	1729
2021	1049	957	588	1125	2065
Minimum	67	119	550	619	94
Maximum	2123	4661	1780	2716	3980

Average	885	1686	1058	1455	1573
District Average	1331				

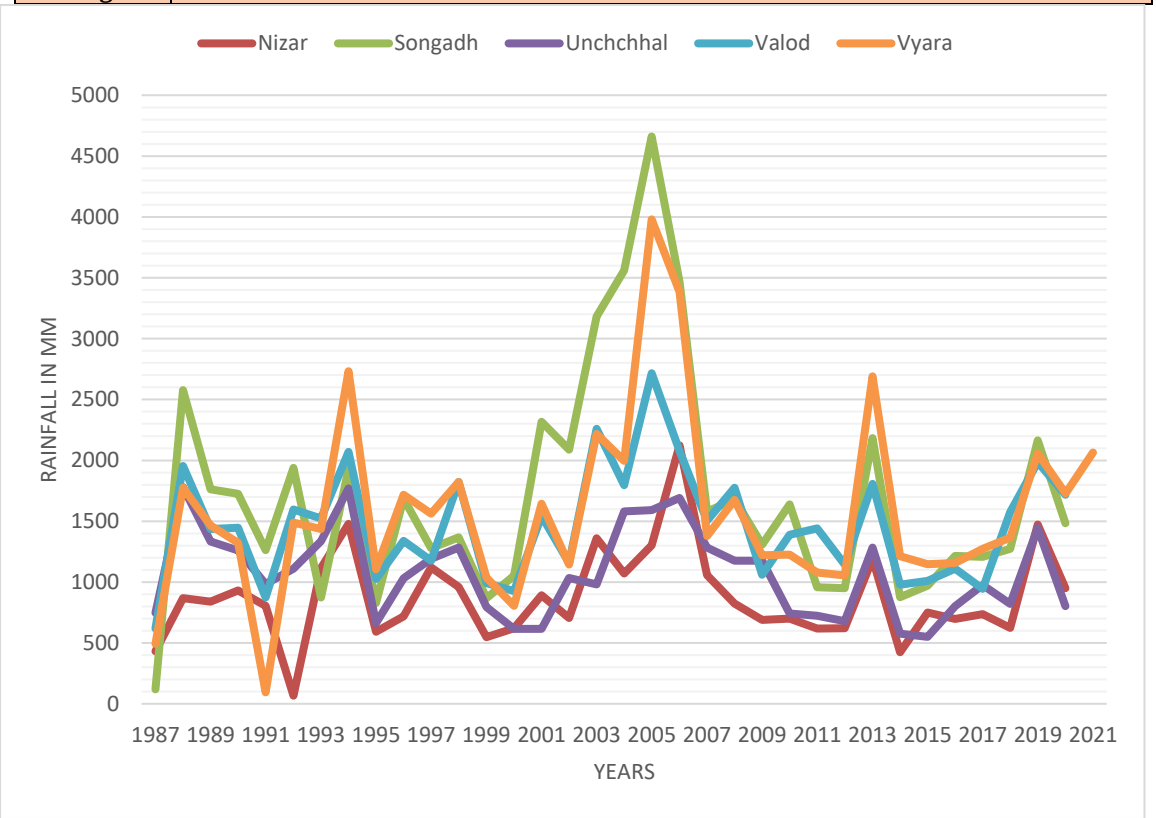

Figure 5. Rainfall variation of Tapi district (1987-2021)

The graphical presentation of rainfall of the district is shown in the figure 5. In this figure it observed that the district has received minimum rainfall in 1987. The Songadh taluka has received maximum rainfall (4661 mm) in 2005. The overall trend of the district showing rising trend from 1987 to 2021.

1.6 GEOMORPHOLOGY

1.6.1 Physiography

Geographically, the district belongs to the western coastlands of the Deccan peninsula. The main Sahyadri scarp is at a little outside the limits of the district towards east, but it gives the district its orientation, landscape features and drainage pattern. The district has five zones, viz., hilly areas, piedmont slopes, alluvial plains and coastal plains.

Hilly areas: The northern, north-eastern parts of the district fall in this category. Here the generalelevation is more than 100m amsl. The topography is rugged with low to moderate high hills and steep hill slopes. This parts are poorly populated and are infested by dense jungle of teak and bamboo. The highest elevation of the district is 569.0m amsl.

Piedmont slopes: East-central parts of the district fall in this category. Here the elevation range between 60 and 100m.amsl. This part has a gentle slope towards west. Topography is mainly plain with moderateto deep cutting river valleys and occasional hillocks.

Alluviual plains: Alluvial plains occupies in the central parts of the district and is characterized by flood plains of the Tapi, Kim, Mindola and Purna rivers. Tapi has a meandering channel entrenched fairly deep and has cut deep terraces. The topography is generally plain with gentle slope towards west. The general elevations are below 60 m.amsl, the lowest elevation being 45m.amsl near Madhi.

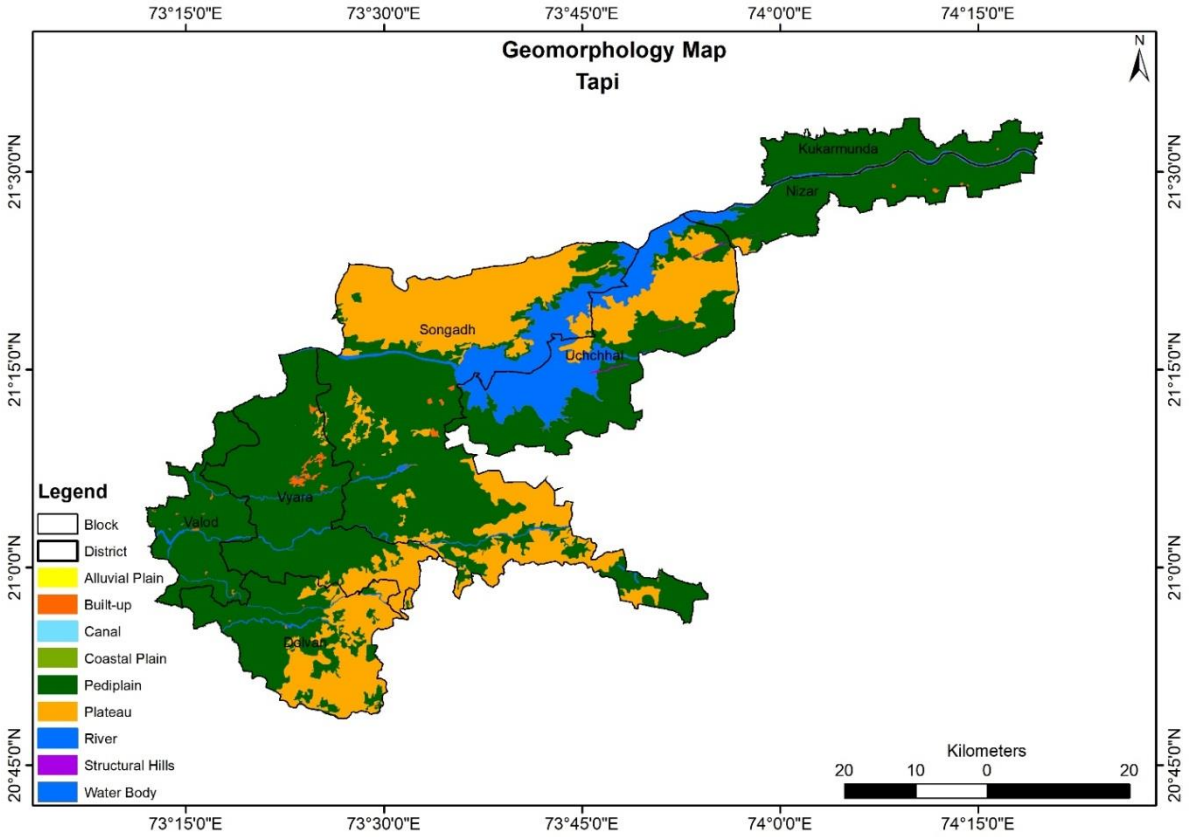

Figure 6.Geomorphological map of Tapi district, Gujarat state

Coastal Plains: The alluvial plains towards west merge into a dry barren sandy coastal plain fringed bymarshy shore line. All the rivers form estuarine mouths. There are sand bars and spits near the shore.

1.6.2 Drainage

The Tapi is the major river which passes through the central parts of the district and flows towards the west. The river is perennial in nature. It originates in Madhya Pradesh near Betul and has about 62225 sq. Km. of catchment area. The average width of the river in the upstream of Kathor bridge is about 500m. Downstream of the bridge the average width increases to 700m. Pickup weir was constructed on the Tapi river in 1954 at Kakarapar about 56km west of Surat. Ukai dam, constructed in 1965, is situated about 25km upstream of Kakarapar weir. Other prominent rivers draining the district are Kim, Ver, Mindola, Jhankhari and Purna. The Ver flows from north-east to south-west and flows parallel to Tapi and then it flows towards west. All other rivers are situated toward south of Tapi and

flow towards west, parallel to Tapi.

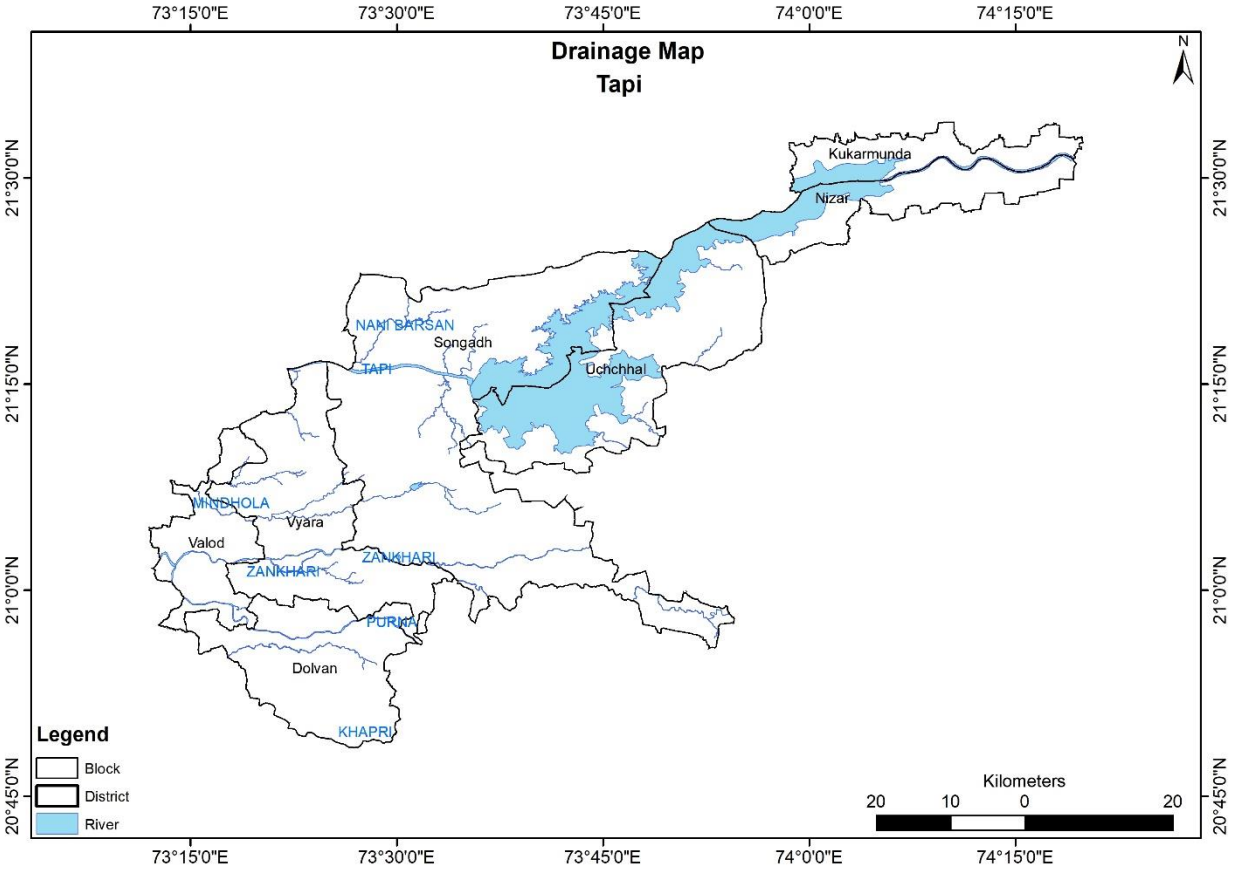

Figure 7.Drainage map of Tapi district, Gujarat state

1.7 Soil Profile

In Tapi district, Nitrogen content is low and the phosphorus content is medium. Potash content is high. So, overall soil properties are satisfactory from point of view of agriculture. Since paddy is grown on a large scale covering substantial area, the soil is deficient in nitrogen. Deficiency of nitrogen can be checked by promoting leguminous plants. Tapi district has 316325 hectares under black soil, 9882 hectares under red soil and 11183 hectares under sandy soil. In black soil category, Songadh taluka has the maximum share which is 124146 hectares followed by Vyara (73513 ha.) and Uchchhal taluka (61245 ha.). Red soil is in only two talukas i.e. Songadh (6207 ha.) and Vyara (3675 ha.). In black soil category, Songadh taluka has the maximum share which is 4199 hectares followed by Vyara (3808 ha.) and Uchchhal taluka (3808 ha.).

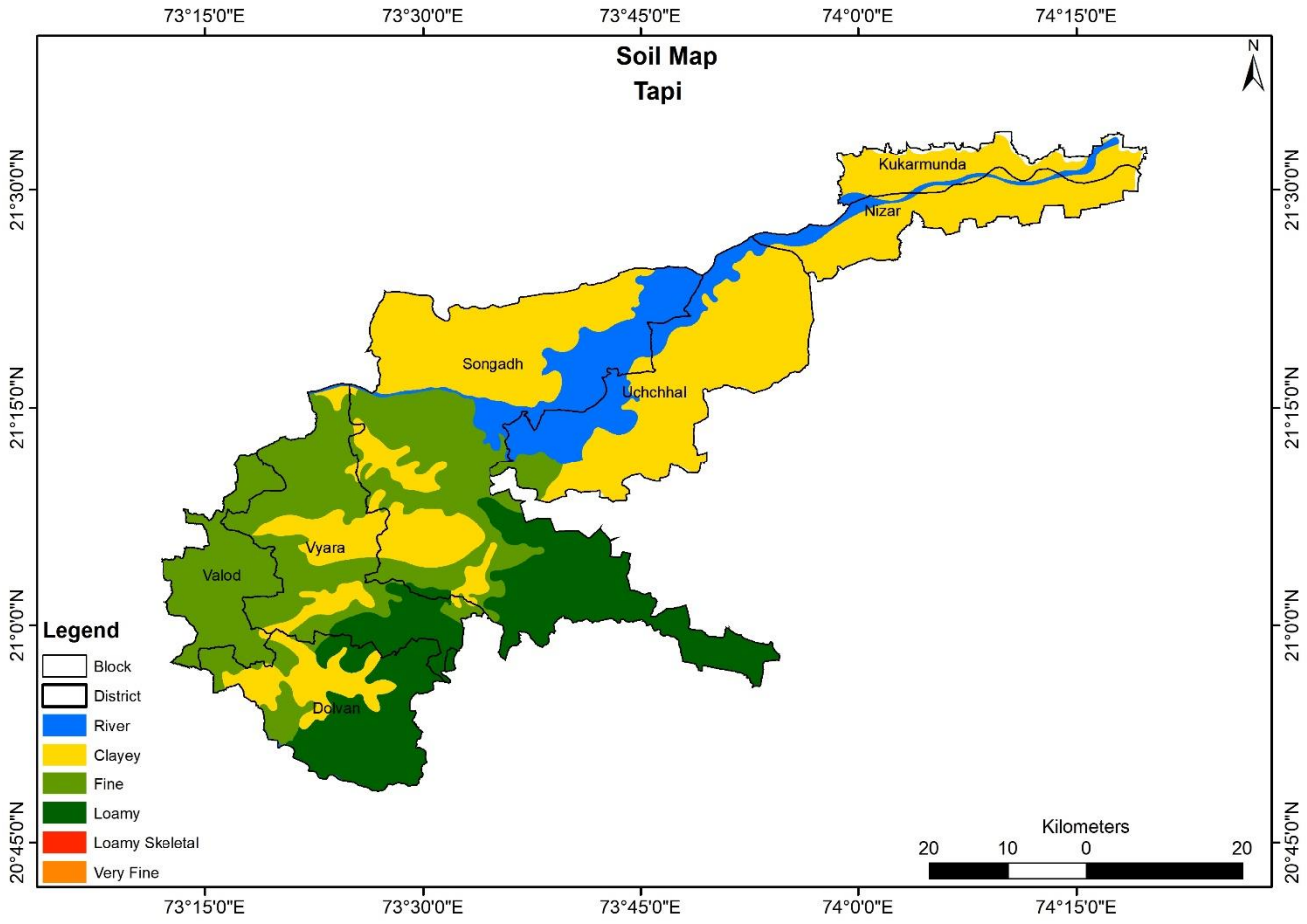

Figure 8. Soil map of Tapi district

Table 7. Soil Profile of Tapi district

Soil Type Area (Ha.)			
Name of the Talukas	Black	Red	Sandy
Nizar	38323	0	791
Uchchhal	61245	0	2053
Songadh	124146	6207	4199
Vyara	73513	3675	3808
Valod	19098	0	332
Total	**316325**	**9882**	**11183**

Source: SREP,DIP Tapi

1.8 Land Use Pattern

The total geographical area (TGA) of Tapi is 3.43 lakh hectares. The largest block of the district is Songadh which is comprise of a TGA of 135404 hectare i.e. about 40% of the TGA of the district.

TGA- Total Geographical Area, GCA- Gross Cropped Area, NSA- Net Sown Area, AST- Area Sown more than once, CI- Cropping Intensity. The Gross Cropped Area of the district is 266212 hectare out of which 90444 hectare i.e. 34% of the area falls in Songadh Taluka. Songadh Taluka also records for maximum net sown area of 73135 hectare i.e. 38% of the net sown area of the district. The highest cropping intensity is in Valod Taluka which is 169.44% followed by Uchchhal (162.81%) and Vyara (143.65%). In other blocks of Tapi, cropping intensity is 140.43% (in Nizar Taluka) and 123.67% (in Songadh Taluka). Tapi is having 74025 ha under forest, forming 21.55% of the total geographical area of 3.43 lakh ha.The highest area under forest is in Songadh block which is 31751 hectare. Area under other uses i.e. uses other than agriculture is 77331 hectare for the district.

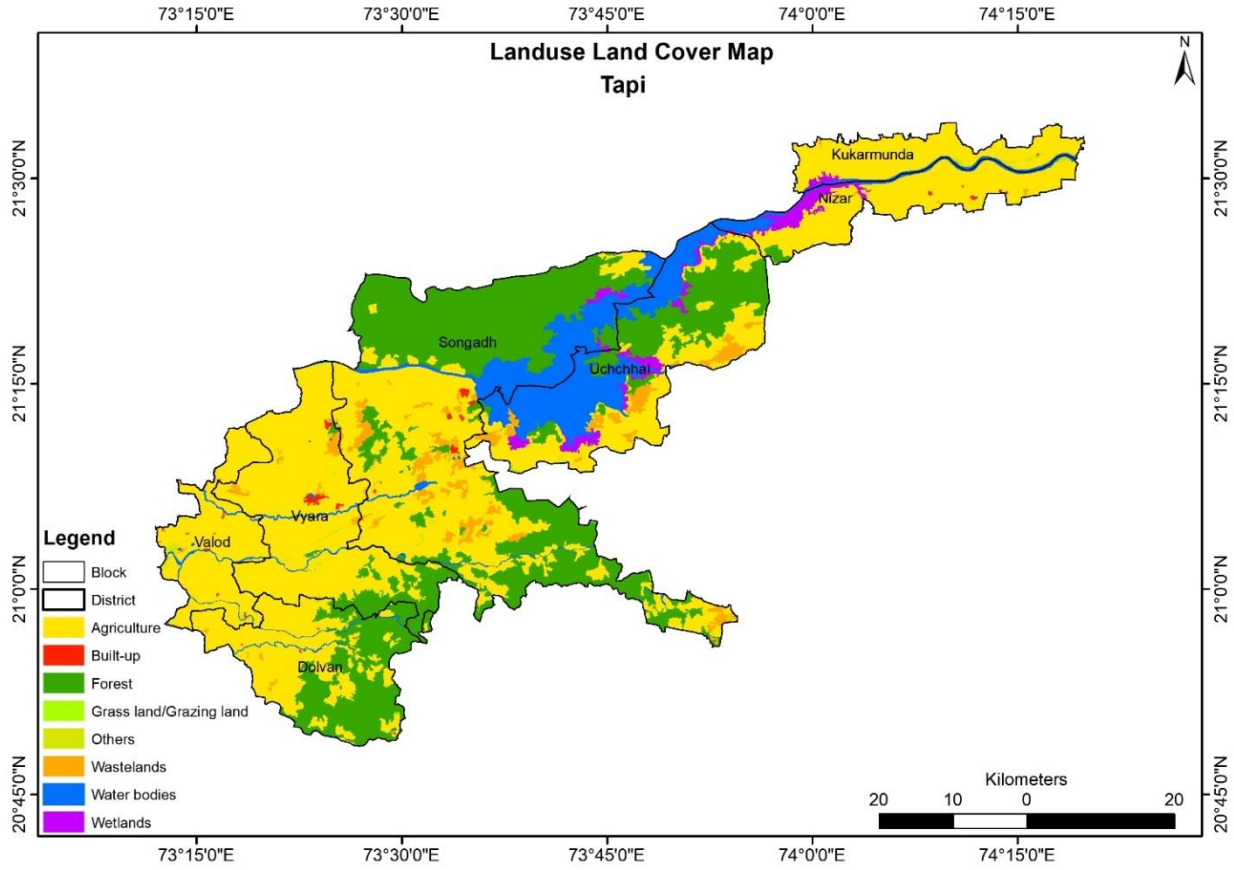

Figure 9. Map showing the landuse landcover in Tapi district of Gujarat district

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Table 8. Land use pattern in Tapi district

Taluka	TGA	Area under Agriculture				Area under forest	Area under wasteland	Area under other uses
		GCA	NSA	AST	CI (%)			
Nizar	40079	**39935**	28438	11497	140.4283	332	61	11248
Uchchhal	66503	**26183**	16082	10101	162.809352	23447	33	26941
Songadh	135404	**90444**	73135	17309	123.667191	31751	29	30489
Vyara	81260	**86112**	59946	26166	143.649284	18495	220	2599
Valod	20228	**23538**	13892	9646	169.435646	0	282	6054
Total	343474	266212	191493	74719	139.01918	74025	625	77331

Source: District Statistical Handbook 2014-15, DIP 2016-2020, Tapi

1.9 District Agriculture Status

Cereals are the major crop among agricultural crops of the district. The area under cereals cultivation during 2014-15 was 90609 hectare which was around 60% of the total area under agricultural crops. Kharif is the main crop season for agricultural crops. Out of total 234686 hectare area under agriculture, 159951 hectare was cultivated during Kharif while 55359 hectare was cultivated during Rabi. In case of summer, the total area under agriculture is 19376 hectare only

Table 9. Crop wise status of irrigated and rainfed area in Tapi District (2014-15)

Crop Type	Kharif (Area in ha.)			Rabi (Area in ha.)			Summer (Area in ha.)		
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	
Cereal	2240	57866		867	45	871	161	0	161
Coarse Cereal	0	20	20	0	5	5	0	0	0
Pulse	12	23531		266	316	582	203	0	203
Oil Seed	0	861	861	25	3	25	1149	0	1149
Fibr	384	783	1168	0	0	0	0	0	0
Any other crop	423	31400		3738	316	4055	423	0	423

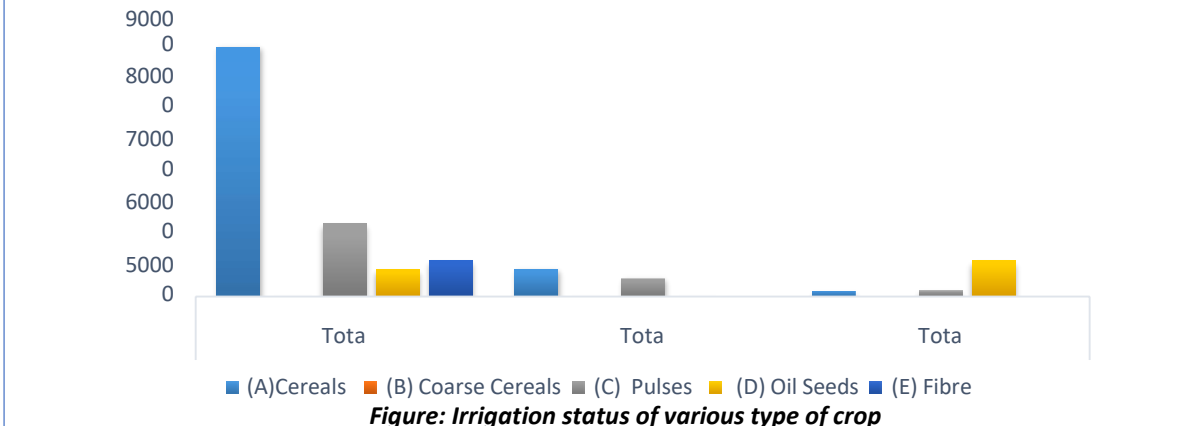

Figure: Irrigation status of various type of crop

In Tapi, 42.12% of the cultivated land i.e. 98854 hectare is irrigated. Out of 98854 hectare of irrigated land, the cereals crops are cultivated in 22405 hectare in Kharif while 8674 hectare of cereals are cultivated under irrigated land during Rabi. In summer a total of 11496 hectare area is cultivated with oil seeds on irrigated land which is 60% of the total area cultivated in summer.

Table 10. Status of Irrigation for Horticulture and Plantation crops

Crop Type	Irrigated	Rainfed	Total
Fruits	8951	518	9469
Vegetables	18957	1096	20053
Spices & Condiments	1484	86	1570
Flowers	410	24	434
Total	**29802**	**1724**	**31526**

Source: Department of Horticulture, DIP, Tapi

A total of 31526 area is under this category of which 29802 (94%) is under irrigated condition. Among different types of horticultural crops, vegetables rank first as the total area under vegetables cultivation is 20053 hectare (63.61%). Only 1096 hectare of land cultivated with vegetables is under rainfed condition while remaining 18957 hectare is under irrigated condition. A total of 9469 hectare of land is cultivated with fruits out of which 8951 is irrigated. For flower cultivation where the total area of 434 hectare is under cultivation out of which 410 hectare is irrigated. Among Spices & Condiments, the total area under this category is 1570 hectare of which 1484 hectare is under irrigated condition while remaining 86 is under rainfed condition.

1.9.1 Production and Productivity of Major Crops

Paddy is the major cereal crop in Tapi. The total area under paddy cultivation during the year 2014-15 was 48994 ha and total production was 110856 MT. A total of 46% of the area under paddy cultivation is irrigated while remaining 54% of the area is cultivated under rainfed system. Sugarcane is the major cash crop which covers a substantial area of 26608 ha producing 157306 MT. Mango is among the main fruits grown in Tapi. Mango plantation is highest in Vyara and SongadhTalukas. During the year 2014-15, the district has produced 38397 MT mangoes. Papaya is also another fruit which is grown in large quantity in Nizar block which is 82215 MT which is 95% of the total production of the district. In vegetables, Brinjals and Ladies finger are among the most grown crops in the district for which production is 54992 MT and 132054 MT respectively. IN flowers category, Marigold is the most produced. Out of total 3351 MT of flowers, 1849 MT is contributed by Marigold which is around 55% of the total flower production. Out of 20053 hectare of land under vegetables cultivation, 8901 hectare i.e. 44% is contributed by Vyara Taluka. The Taluka ranks first in utilizing maximum area i.e. 74% under vegetables crops. For other block i.e. Valod, Songadh, Uchchhal and Nizar, the area under vegetables cultivation is respectively 71%, 69%, 60% and 34% of the total area under Horticulture and Plantation crops of the block. Vegetables contribute 64% of the total area under Horticulture and Plantation crops for the whole district.

1.9.2 Irrigation Based Classification

The gross and net irrigated area in the district have been 100000 and 48980 hectares respectively. The total irrigated area in the district is 48980 hectare of which 39% falls in Vyara Taluka only. In Valod Taluka, 81.64% of the area is irrigated while 18.36% is totally rainfed. For all the other talukas, rainfed area is higher than irrigated area. Songadh and Uchchhal Talukas have a huge gap in irrigation. In Songadh 88.52% of the area is totally rainfed while the same has been reported to the extent of 74.4% in Uchchhal.

Table 11. Irrigation based classification

Taluka	**Irrigated (Area in ha.) Rainfed (Area in ha.)**	
	Gross Irrigated Area	Un-Irrigated or Totally Rainfed
Vyara	36223	38270
Valod	16643	1903
Songadh	20686	63363
Uchchal	10104	14677
Nizar	16344	17695
Total	**100000**	**135908**

2. GEOLOGY

Major geological formations exposed in the district are Quaternary alluvium, Tertiary limestone and sandstones and deccan trap basalt. Figure 10 shows the geology of the district and the succession of geological formations in the district, as given by Geological Survey of India in their brochure titled „“ Know Your District-Surat““ is as follows.The geology of the district is depicted in Figure 10.

Table 12. Stratigraphy of Tapi district

Era	**Period**	**Epoch /Series**	**Description**
Cenozoic	Quaternary	Holocene	Soil, Younger alluvium Blown and Fluvio-marine deposits.
	Tertiary	Pleistocene	Older alluvium, conglomerate
		Miocene	Ferruginous sandstone (Gaj)
		Eocene	Numulitic limestone
		Palaeocene	Sub-Numulitic limestone, gypseousshale,Supra-Trappean sediments lateritised and having bauxite pockets.
Mesozoic	Lower Tertiary to Upper Cretaceous	Early Eocene To Upper	Deccan Trap basalt with dykes

2.1 The Deccan Trap

The oldest rocks occurring to the north-east and south- east of the district are Deccan traps of lower Eocene age. These are present in the form of horizontal sheets at places showing gentle dips toward west. The total thickness of different trap flows aggregates

to nearly 200 meters. The traps can be differentiated into two predominant rock types. One is dark gray to bluish black, hard, compact, massive, fine grained basalt which is usually found on the higher reaches of the hills. The other variety is greenish to purplish, soft, medium grained trap which is prone to spheroidal weathering. These flows are characterized by vesicles and amygdaloidal filled with secondary minerals like quartz, amythst, agate and calcite. These type of flows are generally found on hill slopes and in the valleys.

Network of dykes varying in thickess from few centimeters to more than ten meters in width are commonly found intruding the different lava flows and form knife-edge ridges in the „steppe" topography. These dykes are mostly basic in nature but a few of these are also acidic in composition. The usual rock type of these dykes is dolerite or olivine dolerite.

2.2 Alluvium

The alluvium occurs in the form of channel fill deposits (124 Sq Km) and flood plain deposits (298 Sq.Km) in north eastern part of the district.

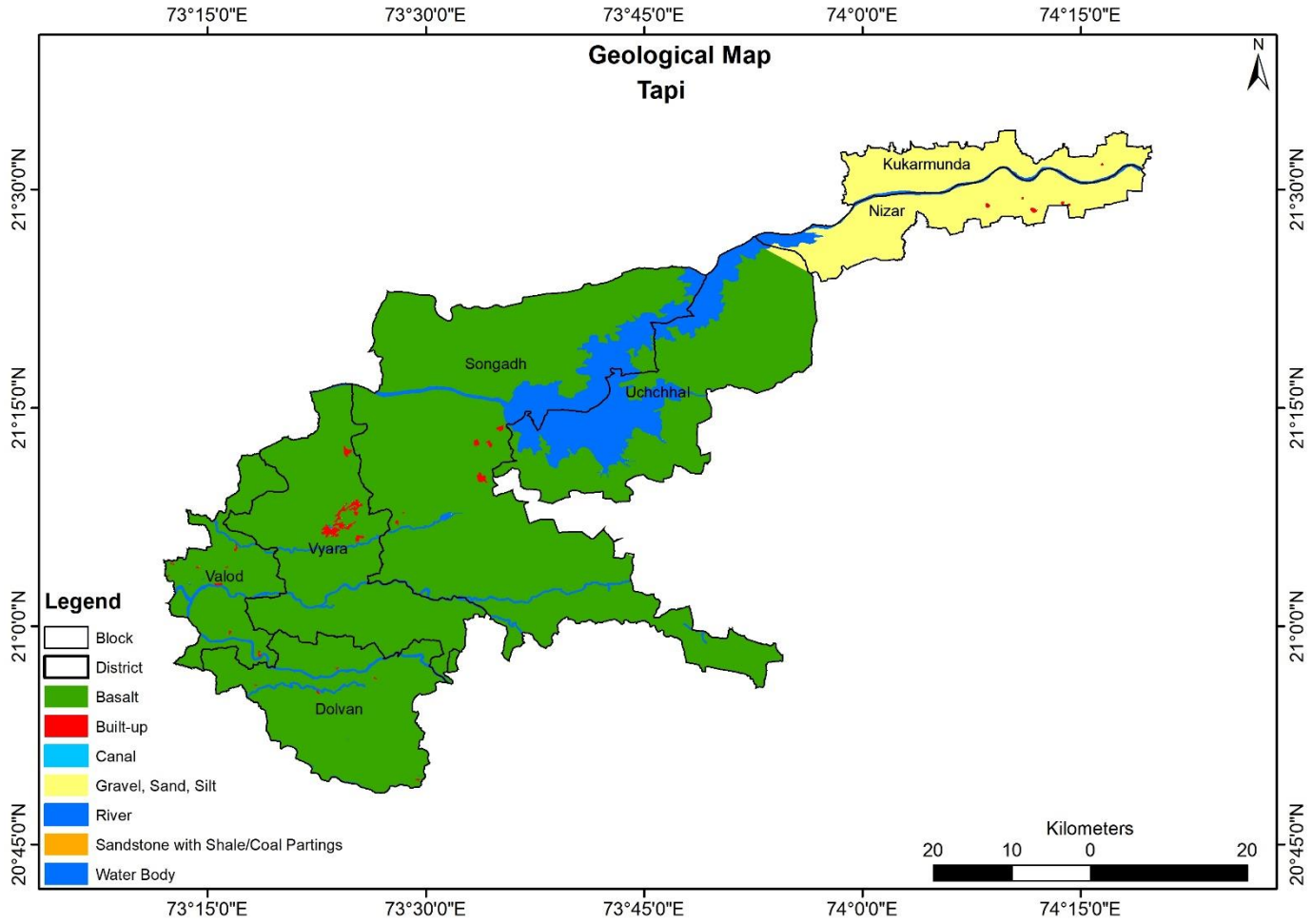

Figure 10. Geological map of Tapi district

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

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

Table 13. Brief activities showing data compilation and generations

S.No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.

		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
2	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern.
		Surface and sub-surface geo-electrical and gravity data generation	Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging etc.
		Hydrological Parameters on groundwater recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters Including fluoride.
3	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.
4	Aquifer Manageme nt Plan	Preparation of aquifer management plan	Information on aquifer through training to Administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

3.1 Data Generation

In order to establish the three-dimensional disposition of aquifer system in the area, the existing data of litho logical logs and Electrical logs of Exploratory wells studies carried out and used in prepare a hydro geological cross section, Fence diagram and 3D Model. The data has been analyzed using Rockworks 16 software and is presented below in the Hydrogeological cross sections A-A' to E-E' and Solid Model of the district showing the depiction of Aquifer Groups and Aquitard up to 200 m. The stratigraphic sections depicting unconfined aquifer, semi confined Aquifer for alluvium and weathered aquifer & fractured aquifer for Basaltic rock are placed at Figs (9 to 12). 3D Solid Model and Fence Diagram and of district is depicted in Fig. 13 and 14, respectively. Data integration in respect to Tapidistrict is represented in table 8.

Table 14. Data integration in respect to Tapi district

Type of Data & source	**No of Wells**
Aquifer Disposition	
CGWB	**27**

Long term Fluctuation	
CGWB+GWRDC	**24+33**
Decadal Analysis water Level	
CGWB+GWRDC	**24+33**
Analysis of water Quality	
CGWB	**61**

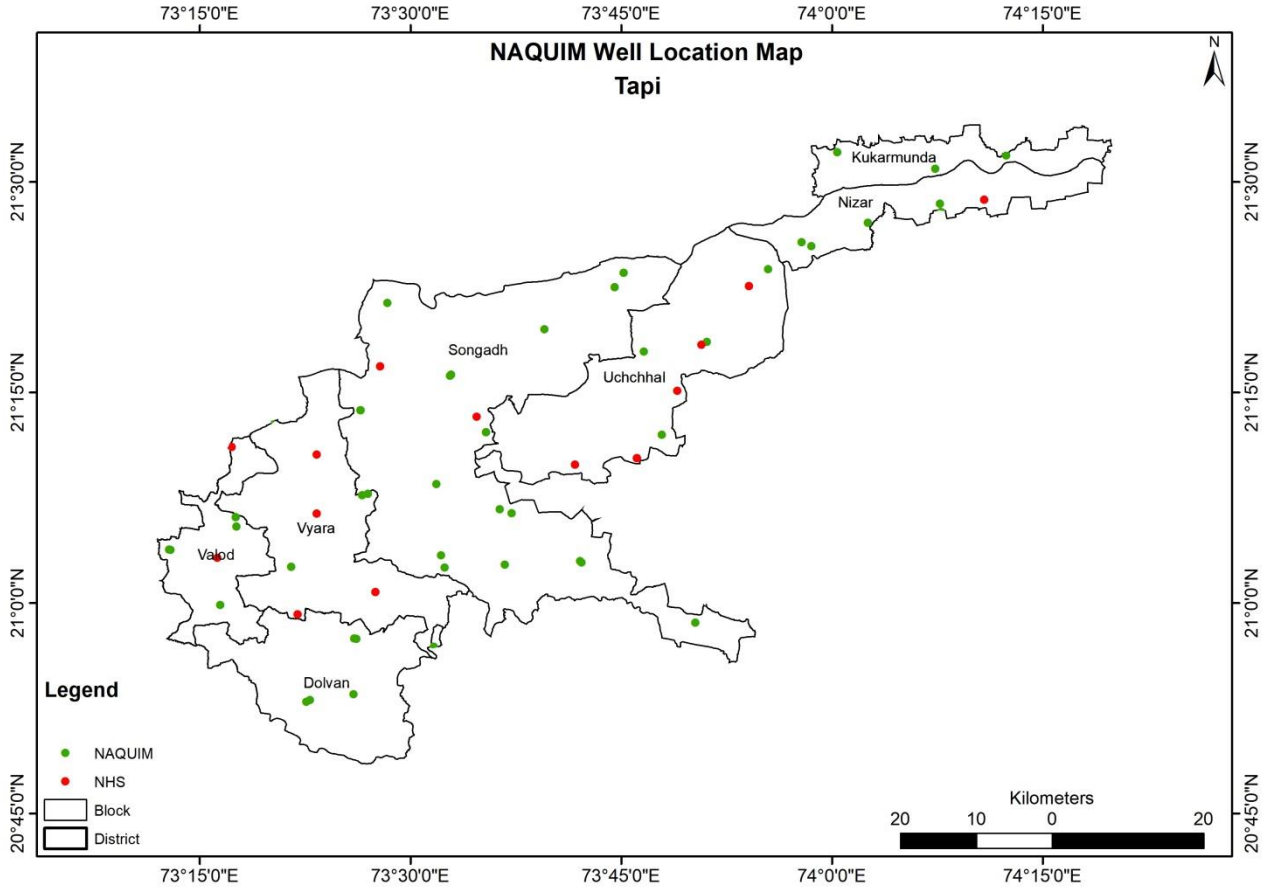

Figure 11. Map showing the well locations which are included in the NAQUIM study of Tapi district

3.2 Conceptualization of Aquifer system in 2D

A total of 27 exploratory wells and piezometers lithologs are utilized to decipher the subsurface geometry of the aquifer by using Rockworks 16 software prepared hydro geological cross sections, Fence diagram and 3D Model up to the depth of 200 mbgl. And five hydrogeological cross sections (2D) are drawn in different direction to cover entire area as per the availability of data point in the district and represented in figure 9 (A-A') to figure 15 (E-E').

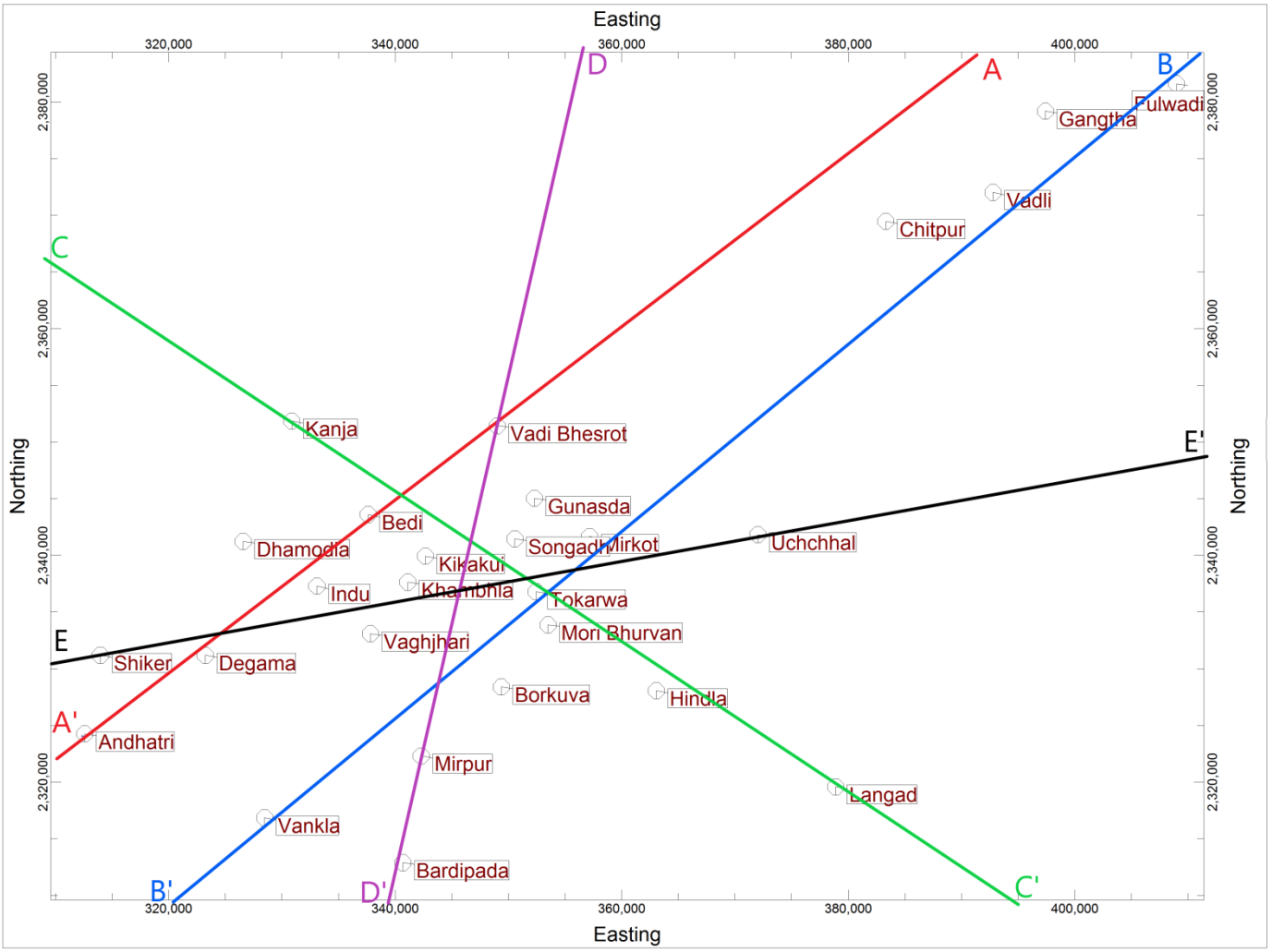

Figure 12. Map showing drawn section lines

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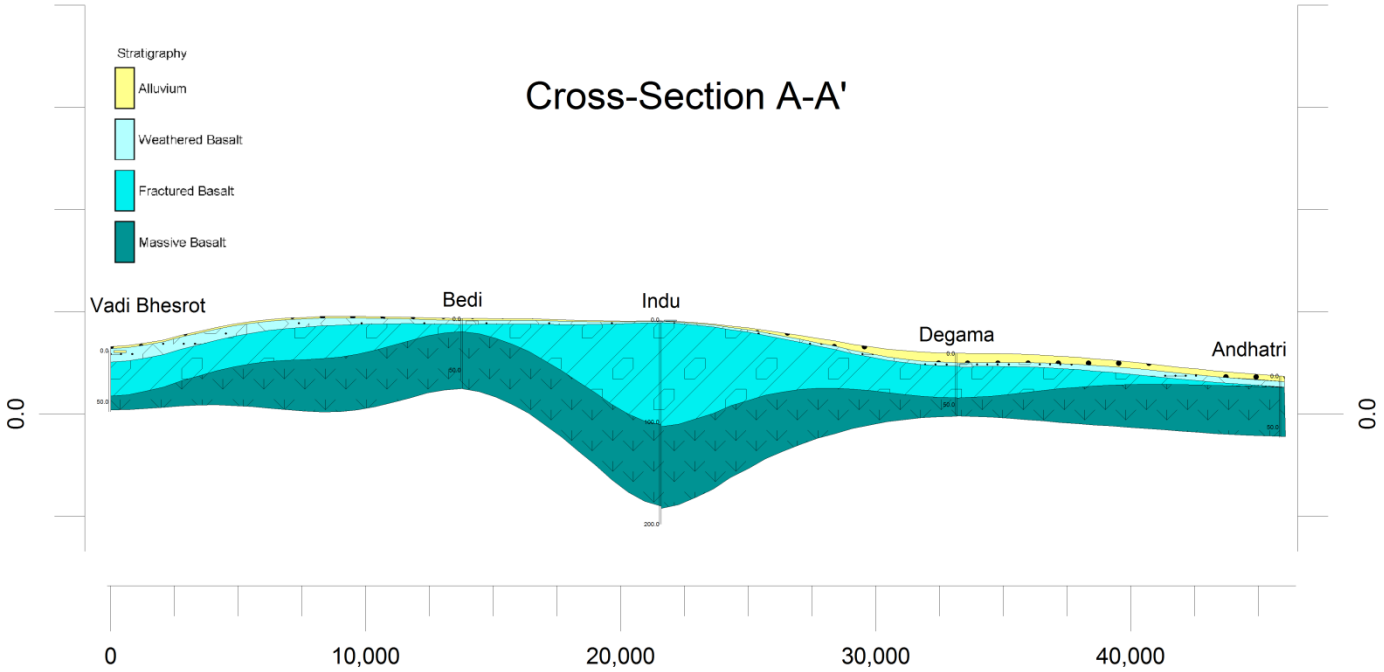


Figure 13. Hydogeological cross section between Vadi Bhesrot and Andhatri (A-A')

Section A-A' (Fig. 13)- Section is drawn roughly NE-SW direction in between Vadi Bhesrot and Andhatri, passing through Bedi, Indu and Degama. Section is represented Stratigraphicaly from Section, it is deciphered that Hard rock formation (weathered basalt & fractured basalt) forms the major aquifer system in the district and rested on Massive basalt along drawn section line.

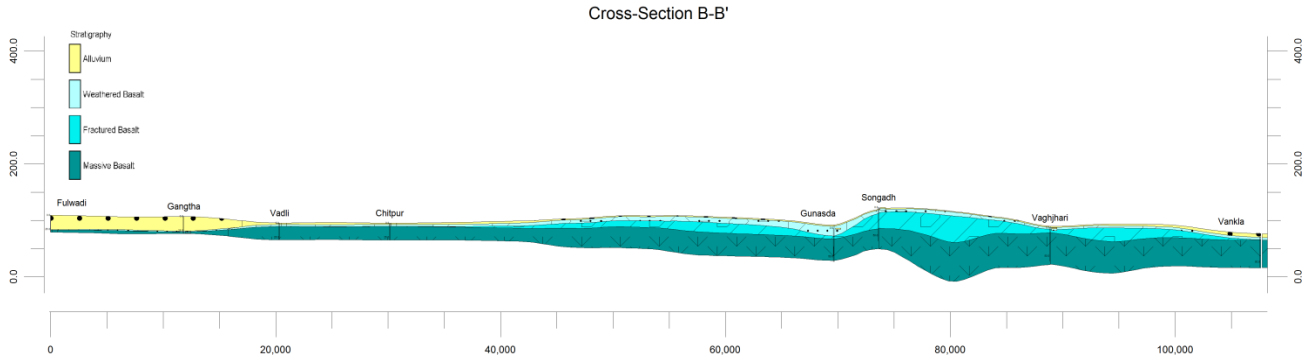


Figure 14. Hydogeological cross section between Fulwadi and Vankla (B-B')

Section B-B' (Fig. 14)- Section is drawn roughly NE-SW direction and in between Fulwadi and Vankla passing through Gangtha, Vadli,Chitpur, Gunasda, Songadh and Vaghjhari. Section is represented Stratigraphicaly, from section it is deciphered that Hard rock formation (weathered & Fractured) along with alluvium forms the major aquifer system in the district and rested on Massive rock along drawn section line.

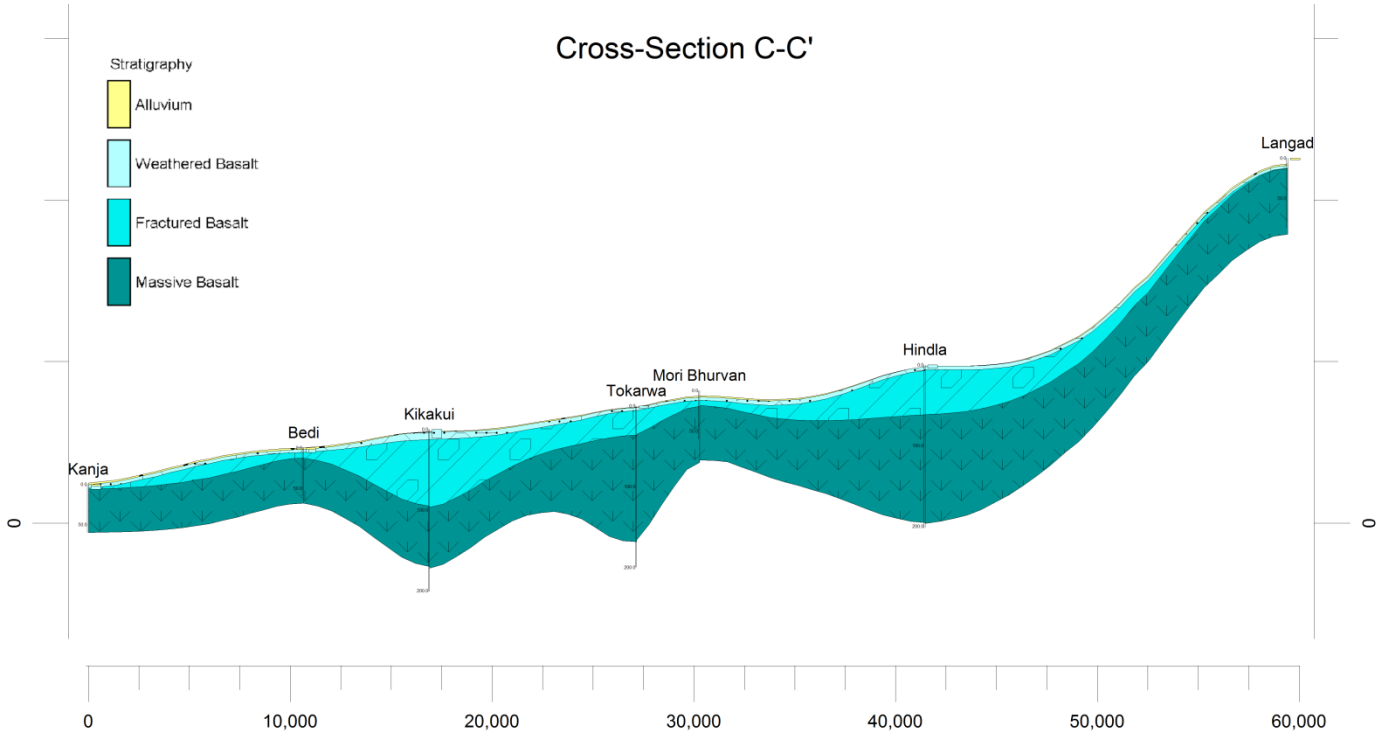


Figure 15. Hydogeological cross section between Kanja and Langadh (C-C')

Section C-C' (Fig. 15)- Section is drawn roughly NW-SE direction and in between Kanja and Langadh, passing through Bedi, Kikakui, Tokarwa, Mori Bhurvan and Hindla. Section is represented Stratigraphicaly, from section it is deciphered that that Hard rock formation (weathered basalt & Fractured basalt) forms the major aquifer system in the district and rested on Massive rock along drawn section line.

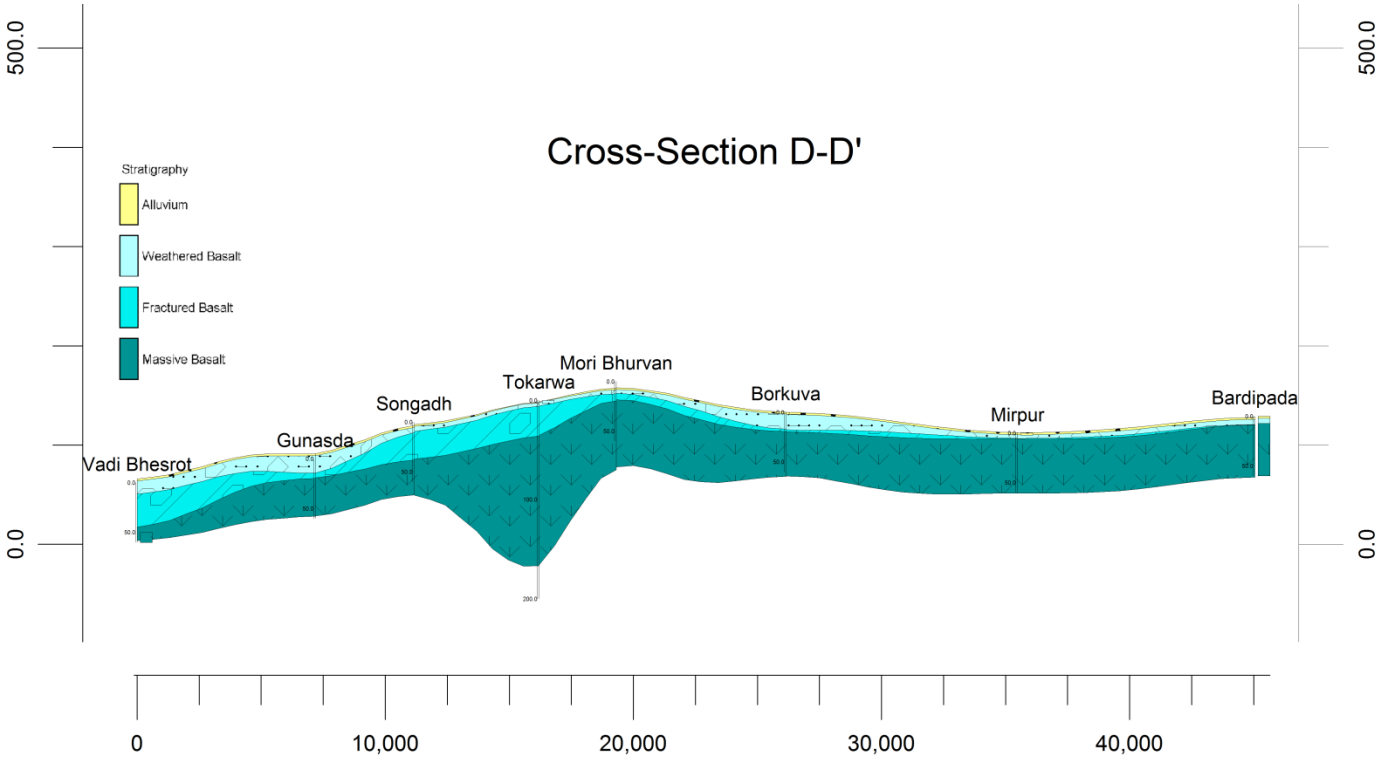


Figure 16. Hydogeological cross section between Vadi Bhesrot and Bardipada (D-D')

Section D-D’ (Fig. 16)- Section is drawn roughly NNE-SSW direction and in between Vadi Bhesrot and Pardipada, passing through Gunasda, Songadh, Tokarwa, Mori Bhurvan, Borkua and Mirpur. Section is represented Stratigraphicaly, from section it is deciphered that Hard rock formation (weathered basalt & Fractured basalt) forms the major aquifer system in the district and rested on Massive rock along drawn section line.

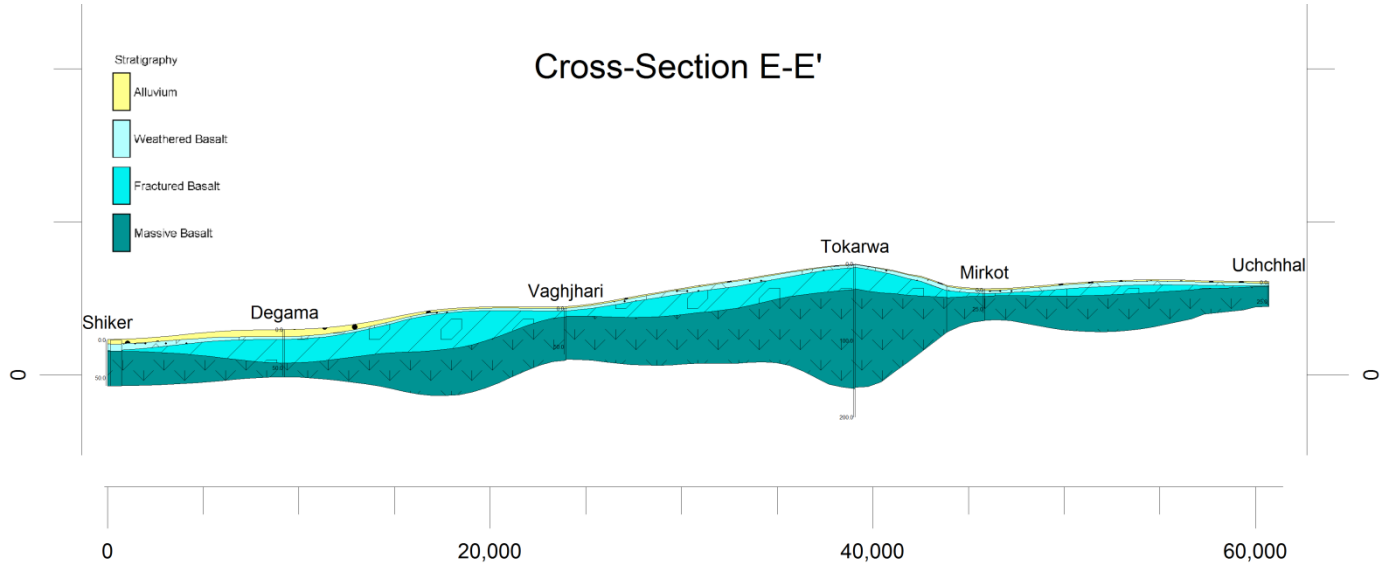


Figure 17. Hydogeological cross section between Shiker and Unchhal (E-E’)

Section E-E’ (Fig. 17)- Section is drawn roughly NNE-SSW direction and in between Shiker and Unchhal, passing through Degama, Vaghjhari, Tokarwa and Mirkot. Section is represented Stratigraphicaly, from section it is deciphered that Hard rock formation (weathered basalt & Fractured basalt) forms the major aquifer system in the district and rested on Massive rock along drawn section line.

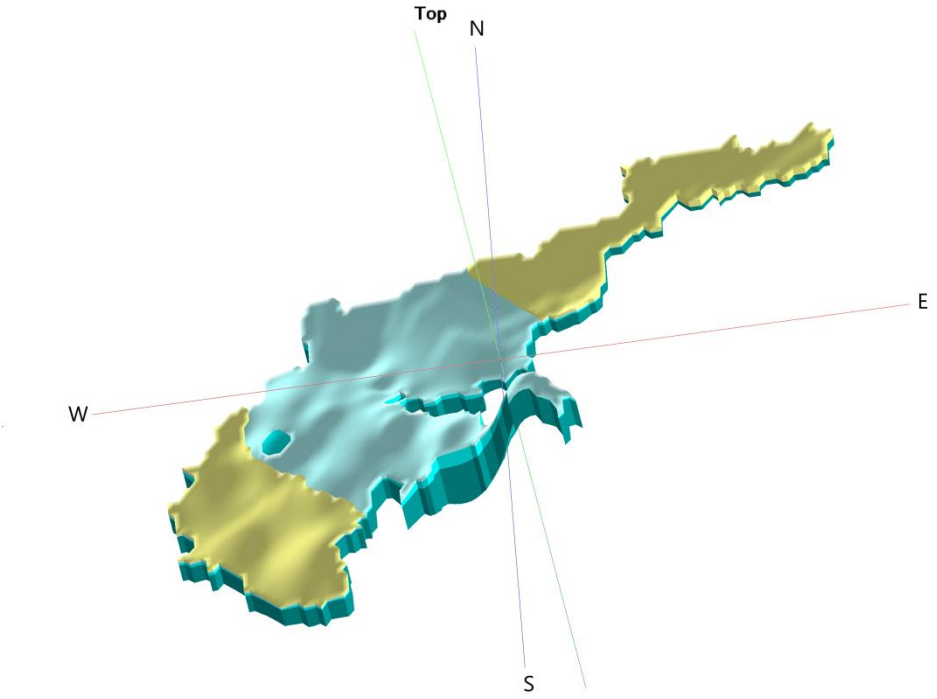


Figure 18. 3D- Aquifer disposition model of Tapi district

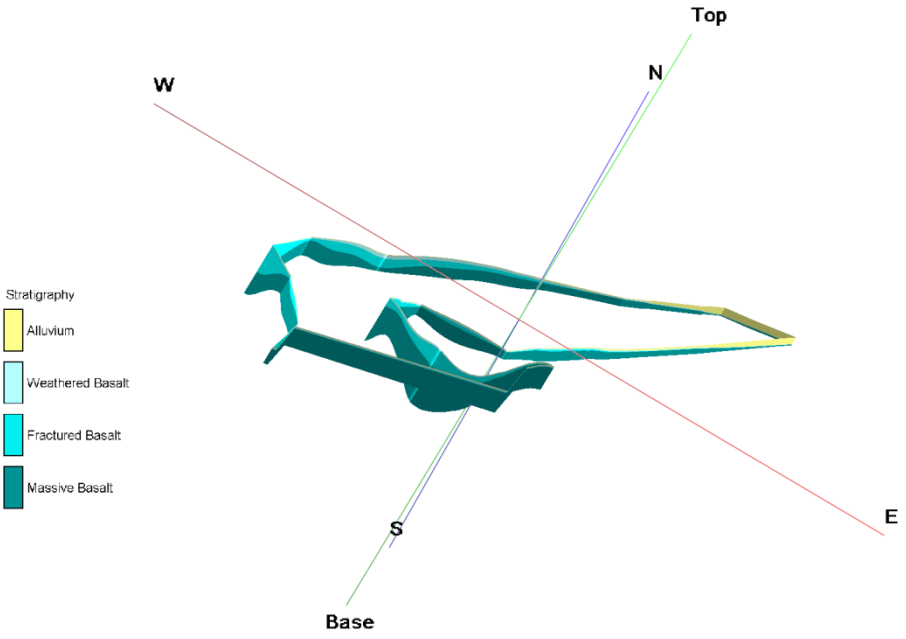


Figure 19. Fence diagram of Tapi district

Table 15. Aquifer characterization and disposition of Tapi district.

Aquifer Characterisation and Disposition (Tapi)										
Stratigraphy	**Aquifer Nomenclature**	**Lithological**	**Depth of occurrence**	**Thickness**	**Water Level (mbgl)**	**Quality**	**Discharge**	**Transmissivity**	**Nature of Aquifer**	**Remarks**
		Characteristics	**Aquifer**	**Range**	**Range**	**(EC)**				
			Range			**Range**	**Range**	**Range**		
			(mbgl)	**(m)**	**(mbgl)**	**µS/cm**	**lps**	**m2/day**		
Quaternary	**Alluvium**	Soil, Younger alluvium Blown and Fluvio-marine deposits.	0 to 25.20	0 to 25.20	1.51 -12.3	496-1369	0.25-0.86	86.07 -196.26	Phreatic	Fresh water
Tertiary		Older alluvium, conglomerate, Ferruginous sandstone, Numulitic limestone, Sub-Numulitic limestone, gypseous shale,Supra-Trappean sediments lateritised and having bauxite pockets								
Mesozoic	**Weathered Basalt**	Basalt	0 to 26.24	0 to 26.24	1.51 -12.3	308-1065	0.03-1.24	30.17-234.16	Phreatic	Fresh water
	Fractured Basalt	Basalt	1 to 119.70	1 to 119.70		321-1710	0.03-1.24	30.17-234.16	Semi confined	Fresh water

4. HYDROGEOLOGY

4.1 Aquifer System

The hydrogeological frame work of the area is essentially governed by geological setting, distribution of rainfall and facilities of circulation and movement of water through inter connected primary and secondaryporosity of the geological units forming the aquifers. The depth to water level in the district ranges between1.50 m to about 12.4 m during April 2022. The major aquifers in the district are formed by alluvium and Deccan trap basalt with Tertiary formations occupying a small patch. The alluvium occurs in the form of channel fill deposits (124 Sq Km) and flood plain deposits (298 Sq. Km) in north eastern part of the district and along the streams whereas in eastern parts weathered and fractured basalt form aquifers. Based on the geological formation the area can be divided broadly into two hydrogeological units:

1. Fissure Formations
2. Porous Formation

Deccan Traps form the aquifers in the district with some Alluvium formations in the Nizar, Kukarmunda Taluka. The ground water occurs in unconfined to semi-confined conditions. The occurrence and movement of ground water is governed by the thickness and extent of weathered zone and the presence of fractures and joints. At places, dykes act as ground water barriers and restrict the flow of ground water. On the other hand, at places, the dykes themselves form good aquifers owing to deeper levels of weathering in them.

Depths of dug wells in Deccan traps ranges from less than 2m to 25m with maximum number of wells about 80%, being 5 to 15m deep. The depths to water levels in the dug wells range from 1.50 to 10.20 m. However, in 90% of the wells, the water levels are less than 10m. bgl. Yields of the dug wells are low to moderate in central parts whereas they are low to very low on the hill slopes. The dug wells generally sustain pumping for 4 to 5 hours with yields of 50 to 150 m^3/day. Recuperation of water levels is generallyslow.

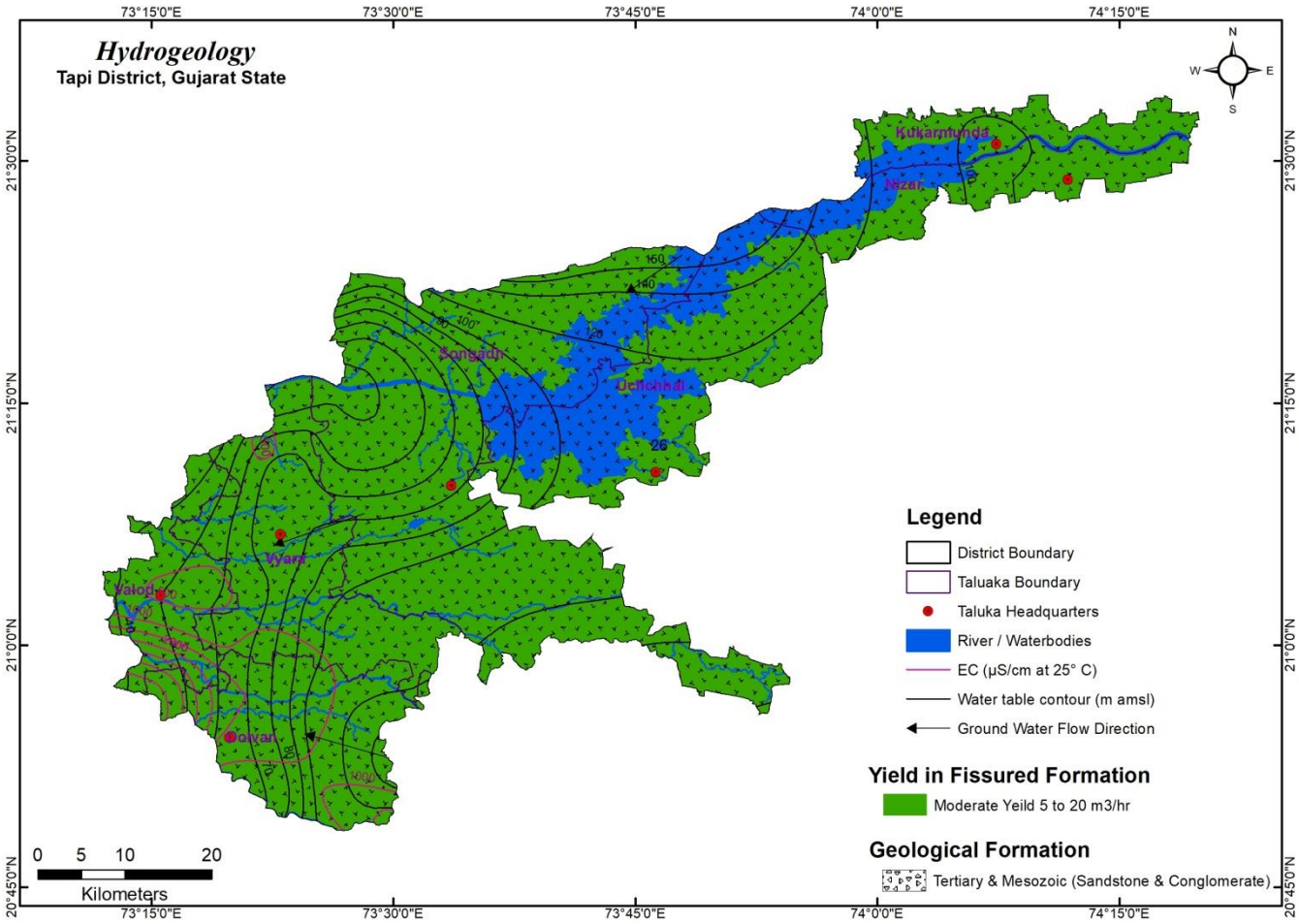


Figure 20. Map showing the Hydrogeological setup of Tapi District

4.2 Water Availability in Tapi

Geographically Tapi is situated in South Gujarat region. Geographically, the district belongs to the western coastlands of the Deccan peninsula. The main Sahyadri scarp is at a little outside the limits of the district towards east, but it gives the district its orientation, landscape features and drainage pattern. The district has four zones, viz., hilly areas, piedmont slopes, alluvial plains and coastal plains.

Hilly areas: The northern, north-eastern parts of the district fall in this category. Here the general elevation is more than 100m amsl. The topography is rugged with low to moderate high hills and steep hill slopes. This parts are poorly populated and are infested by dense jungle of teak and bamboo. The highest elevation of the district is 569.0m amsl.

Piedmont slopes: East-central parts of the district fall in this category. Here the elevation range between60 and 100m.amsl. This part has a gentle slope towards west. Topography is mainly plain with moderate to deep cutting river valleys and occasional hillocks.

Alluviual plains: Alluvial plains occupies in the central parts of the district and is characterized by floodplains of the Tapi, Kim, Mindola and Purna rivers. Tapi has a meandering channel entrenched fairly deepand has cut deep terraces. The topography is generally plain with gentle slope towards west. The general elevations are below 60 m.amsl, the lowest elevation being 45m.amsl near Madhi.

Coastal Plains: The alluvial plains towards west merge into a dry barren sandy coastal plain fringed by marshy shore line. All the rivers form estuarine mouths. There are sand bars and spits near the shore.

4.3 Status of surface water availability

The Tapi is the major river which passes through the central parts of the district and flows towards the west. The river is perennial in nature. It originates in Madhya Pradesh near Betul and has about 62225 sq. Km. of catchment area. The average width of the river in the upstream of Kathor bridge is about 500m. Downstream of the bridge the average width increases to 700m. Pickup weir was constructed on the Tapi river in 1954 at Kakarapar about 56km west of Surat.

Ukai dam, constructed in 1965, is situated about 25km upstream of Kakarapar weir. Other prominent rivers draining the district are Kim, Ver, Mindola, Jhankhari and Purna. The Ver flows from north-east to south-west and flows parallel to Tapi and then it flows towards west. All other rivers are situated toward south of Tapi and flow towards west, parallel to Tapi. Lower Tapi Basin consists main Tapi stream from Ukai Reservoir to its mouth in the Gulf of Cambay. The Lower Tapi Basin extends over an area of 2920 Sq.Km. The length of the Tapi River in Lower Tapi Basin is 129 Km. There are a series of rapids for a distance of about 32 km. between Kakrapar and Aamalpur. Through the Kakrapar rapids, the river falls by nearly 4.6 mtr. In the last reach, the river passes through the Gujarat plains and after flowing past Surat city, empties into the Gulf of Cambay. The tidal influence is felt up to 25 Km. from its mouth in the Gulf of Cambay. After completion of a Weir cum Causeway at Singanpur near Surat city.

Kakrapar Weir: The project comprises of an Ogee shaped masonry pick up weir constructed across the Tapi River near Kakrapar in Surat district of Gujarat. The weir was constructed at a cost of Rs.20.61 crores. The weir is 621 m long and 14m high. Two canals take off from either bank to irrigate an area of 2.28 lakh ha. This project was commissioned in the year 1954 as stage- I of the Ukai project.

Ukai Dam: This is stage - II of the multipurpose Ukai Project. It consists of 4928m long and 68.6 m high composite earth - cum - masonry dam across the Tapi river near Ukai village inSurat district of Gujarat State. It includes a spillway with power dam constructed on the left bank. Two canals take off from either bank to irrigate an area of 1.58 lakh ha. The power house has an installed capacity of 4 units of 75 MW each. Through Ukai dam, the total water available is 8510 MCM and through Karapar the same was to the tune of 51.51 MCM. The availability of ground water is to the tune of 337 MCM.

4.5 Behaviour of Water Levels

The behaviour of water levels was studied based on the water level data collected from the National Network of Hydrograph Stations (NNHS) established by CGWB and Observation wells established by GWRDC in the district. The water level data of May 2022 and November 2022 was used for preparing the depth to water level maps. The seasonal fluctuation in water levels was calculated between May and November 2022.

4.5.1 Depth to water level (Pre monsoon)

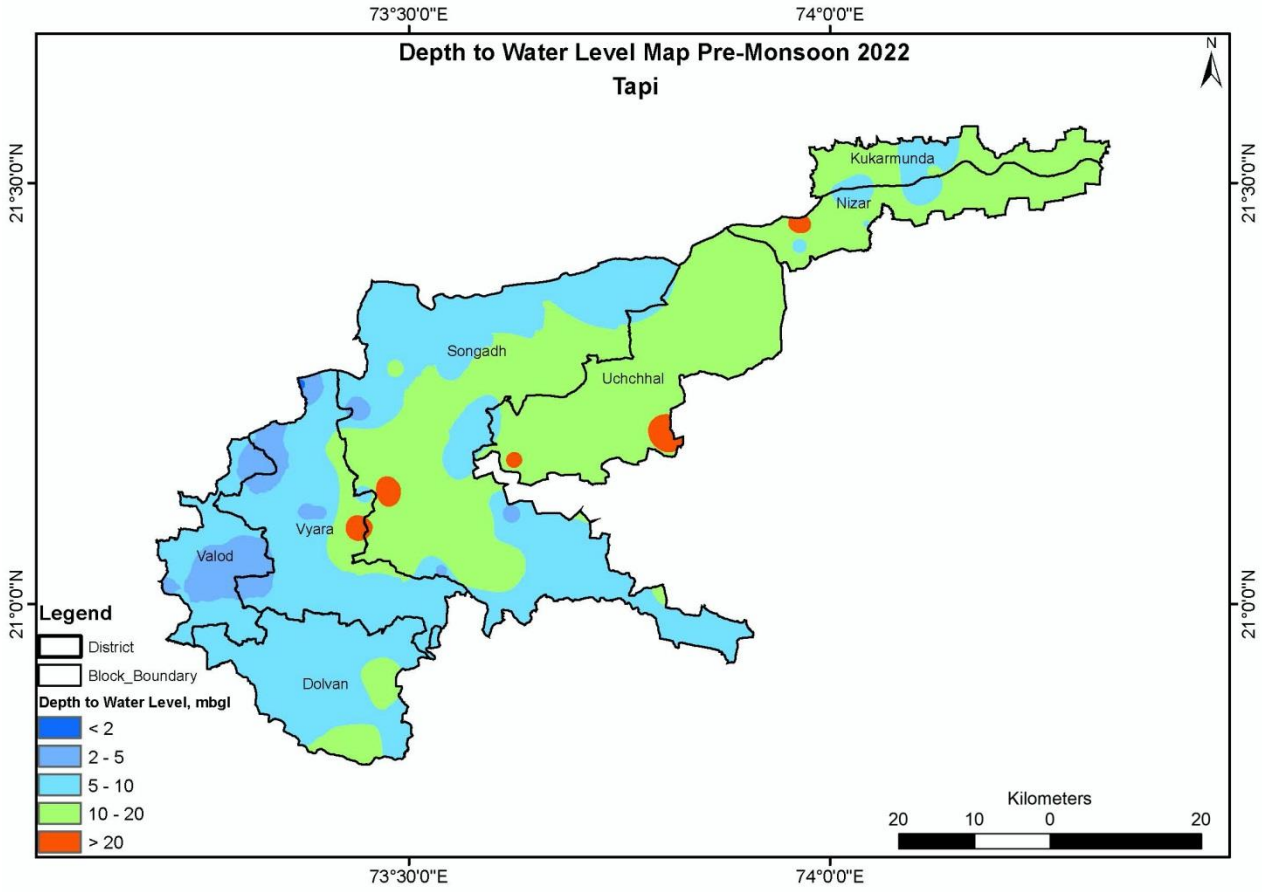


Figure 21. Pre-monsoon (May 2022) depth to water level of Tapi District

Pre monsoon depth to water levels of Tapi district ranges from are shown in the (Fig. 16), which depict that water levels in most part of the district ranges in between 1.51 m bgl and 20 m bgl. Small area in Vyara , Songadh, Unchhal and Nizar taluka, shows deeper water level of more than 20 m bgl. Shallow water level are observed in patches in all talukas of the district except Unchhal.

4.5.2 Depth to water level (Post monsoon)

Post-monsoon water level as shown below in map for the period of November, 2022 (Fig. 17) shows that shallow water level upto 10.0 m bgl are observed in most part of the district which reflect good recharge were taken place due to rainfall.

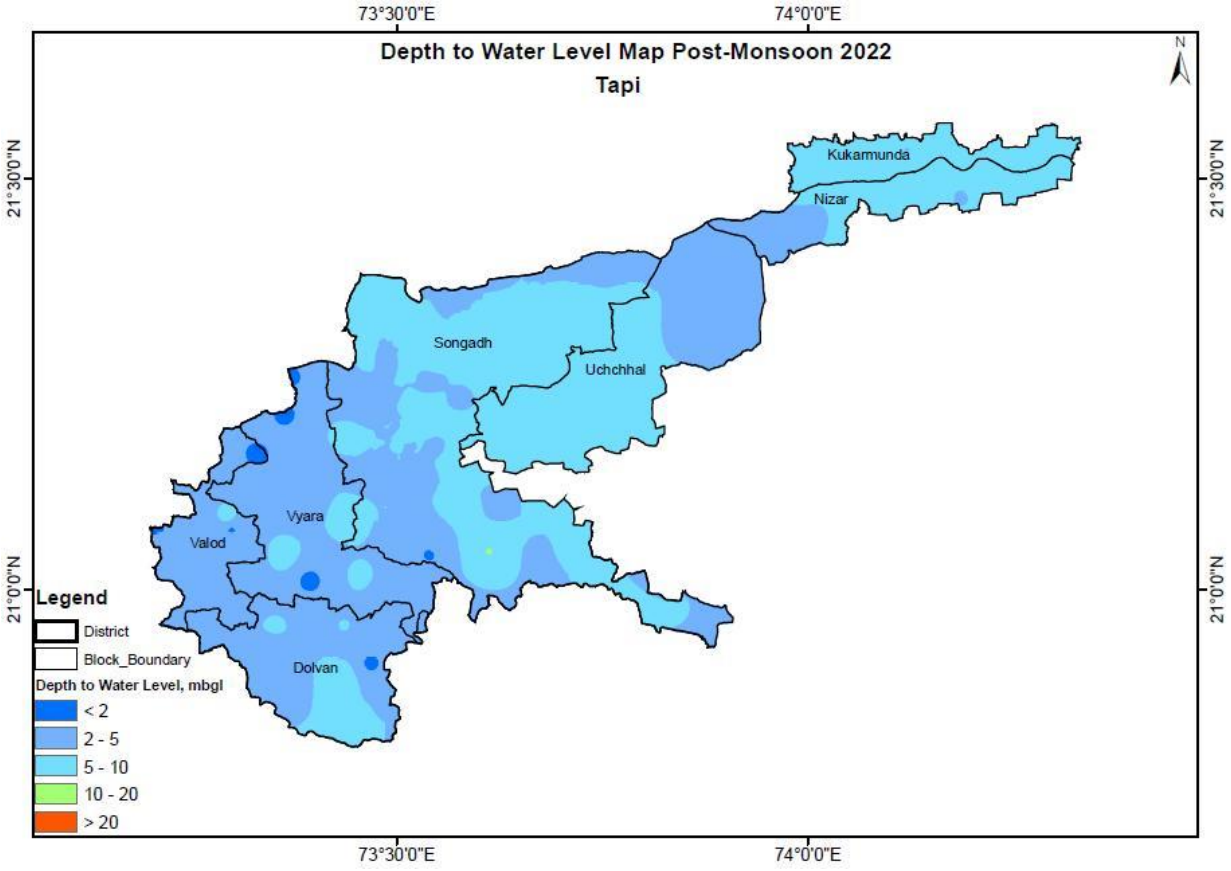


Figure 22. Post-monsoon (Nov-2022) depth to water level of Tapi District

4.5.3 Water table and groundwater movement

The elevation of water table in Pre monsoon 2022 is observed higher along SE adjoining district boundary with Dang district and SE adjoining state boundary with Maharashtra where water table contour ranges in between 70 m amsl to 170 m amsl which flowing towards West and NW direction. (Figure 18).

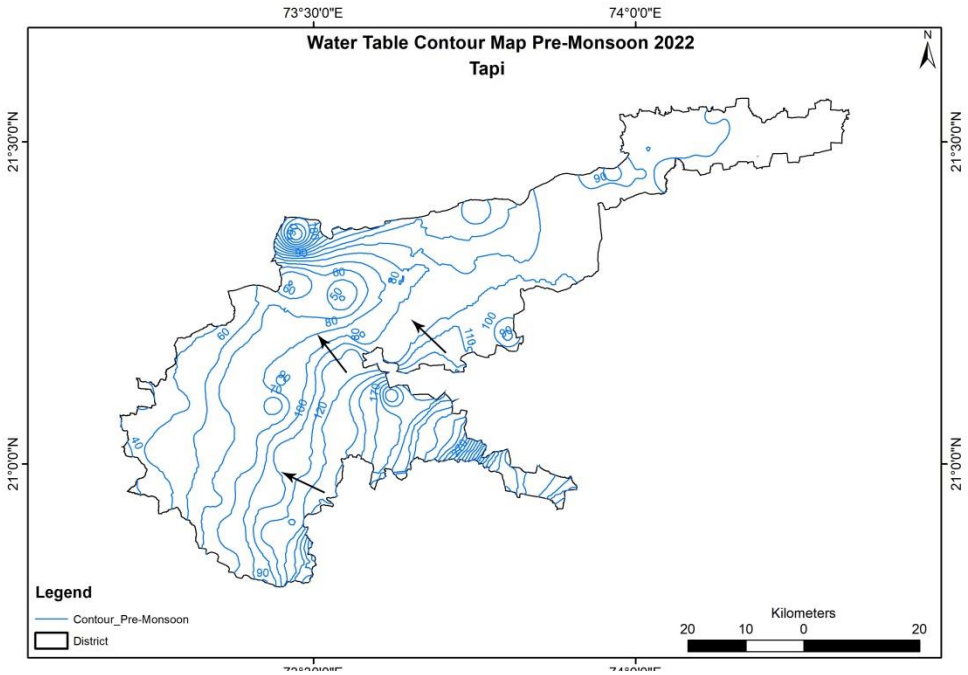


Figure 23. Water level contour map (Post-Monsoon_2022) of Tapi district

4.5.4 Ground water fluctuation of Pre to Post-Monsoon (2022)

The whole district is showing the rising trend of groundwater level from pre to post monsoon. From map its depicted that whole part of the district shows rising trend of more than 4 meters. Most of the part of Valod taluka showing 2 to 4 meter rise but in the southern and south wester part of the taluka is showing more than 4 meter rise in water level. Similarly western and nort wester part of Vyara taluka showing the 2 to 4 meter rise in Water level. Small patches of Songadh, Unchhal and Nizar taluka also showing the fluctuation of 2 to 4 meter rise in Water level.. Figure 19 showing groundwater fluctuation of pre to post monsoon season 2021.

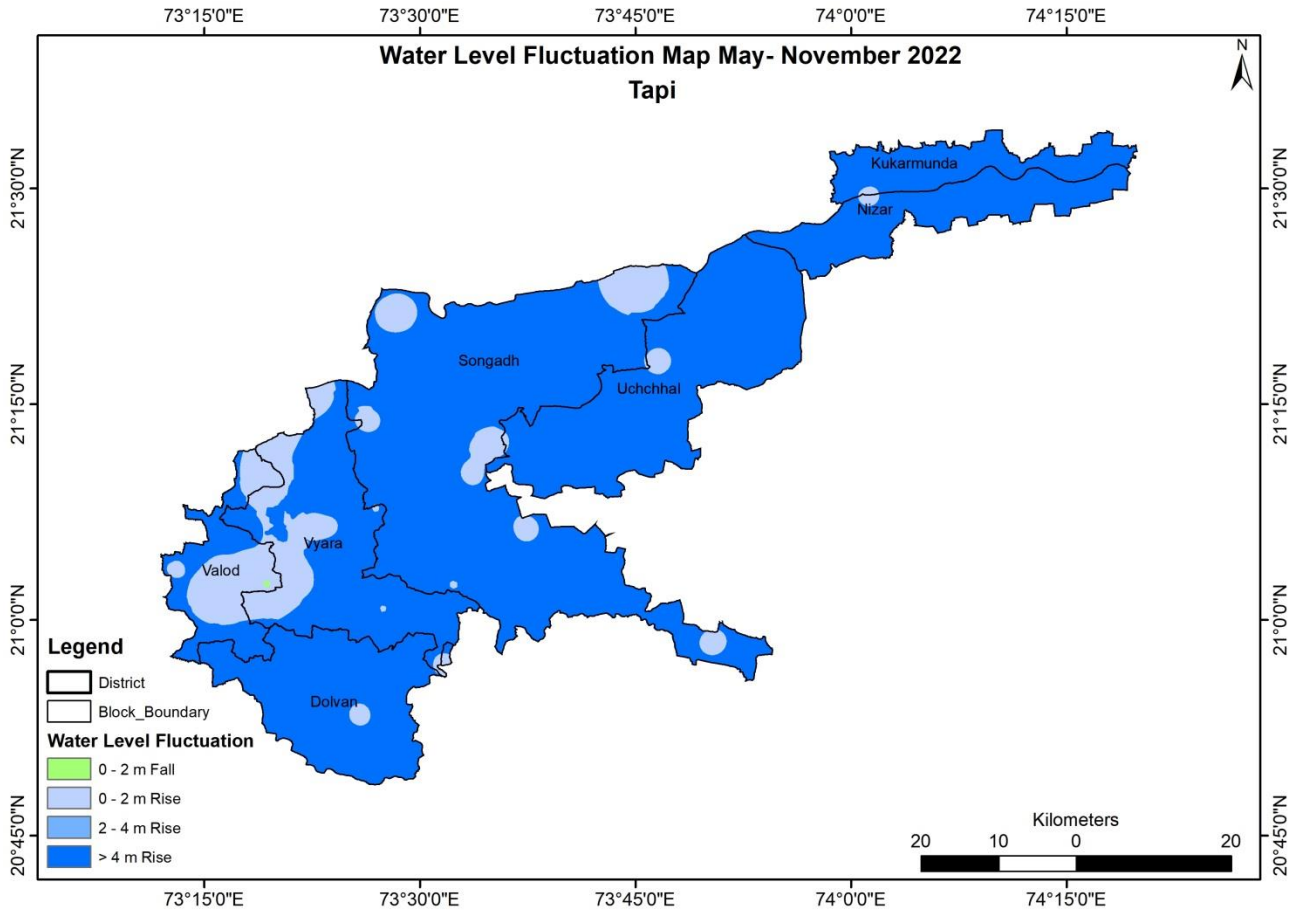


Figure 24. Map showing groundwater fluctuation of pre to post monsoon season 2022

4.6 Hydrograph and water level trend (2012-2021)

From the analysis of water level trend of the Tapi district from 2012 to 2021, it is observed that during pre monsoon season, the water level has a rise of 0.0627 m/year (Vyara) to 0.2916 m/year (Bedchit) and also has fall of 0.0395 m/year (Kelkui) to 0.3324 m/year (Bhurvel) Similarly from the analysis of the post monsoon data of 2012 to 2021 the rise

shown by the water level of 0.0196 m/year (Unchhal) to 0.1979 m/year (Jesinpura) and has fall of 0.0465 m/year (Valod) to 0.3919 m/year (Arda Bortha). Pre monsoon and Post monsoon long term rising and decline trend of water level of various hydrograph stations established by CGWB are also studied in graphic form. The hydrographs are showing falling and rising trend in the pre monsoon as well as post monsoon season.

Table 16. Long Term Trend of Water Level from 2012 to 2021

S. No.	Location	Taluka	District	Pre-monsoon		Post-monsoon	
				Rise	Fall	Rise	Fall
1	Arda Bortha	Nizar	Tapi		-0.1160		-0.3919
2	Bedchit	Vyara	Tapi	0.2916		0.1558	
3	Bhurvel	Songadh	Tapi		-0.3324		-0.0691
4	Jesinpura	Songadh	Tapi		-0.0710	0.1979	
5	Kelkui	Valod	Tapi		-0.0395	0.0627	
6	Nizar	Nizar	Tapi		-0.2662		-0.1746
7	Tawali	Unchhal	Tapi		-0.2036	0.1044	
8	Unchhal	Unchhal	Tapi	0.1254		0.0196	
9	Vyara	Vyara	Tapi	0.0627		0.0427	
10	Valod	Valod	Tapi	0.1030			-0.0465

Historical data of water level were used for preparing the hydrographs as well as for computing long term trend. Few of the hydrographs (Figure 21-28) representing the falling trends of water level of Tapi district are presented below.

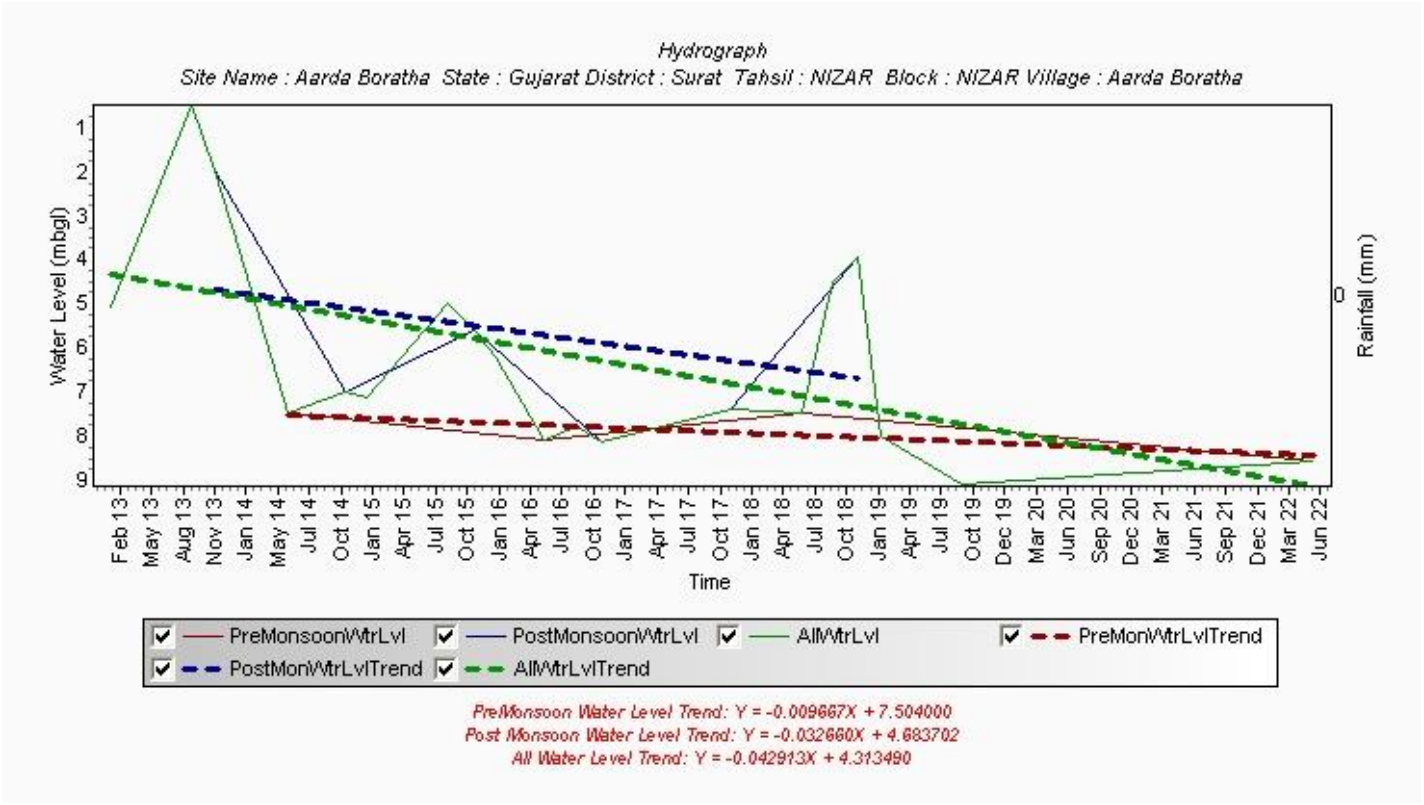


Figure 25. Hydrograph and water level trend at Aarda Boratha site of Tapi district

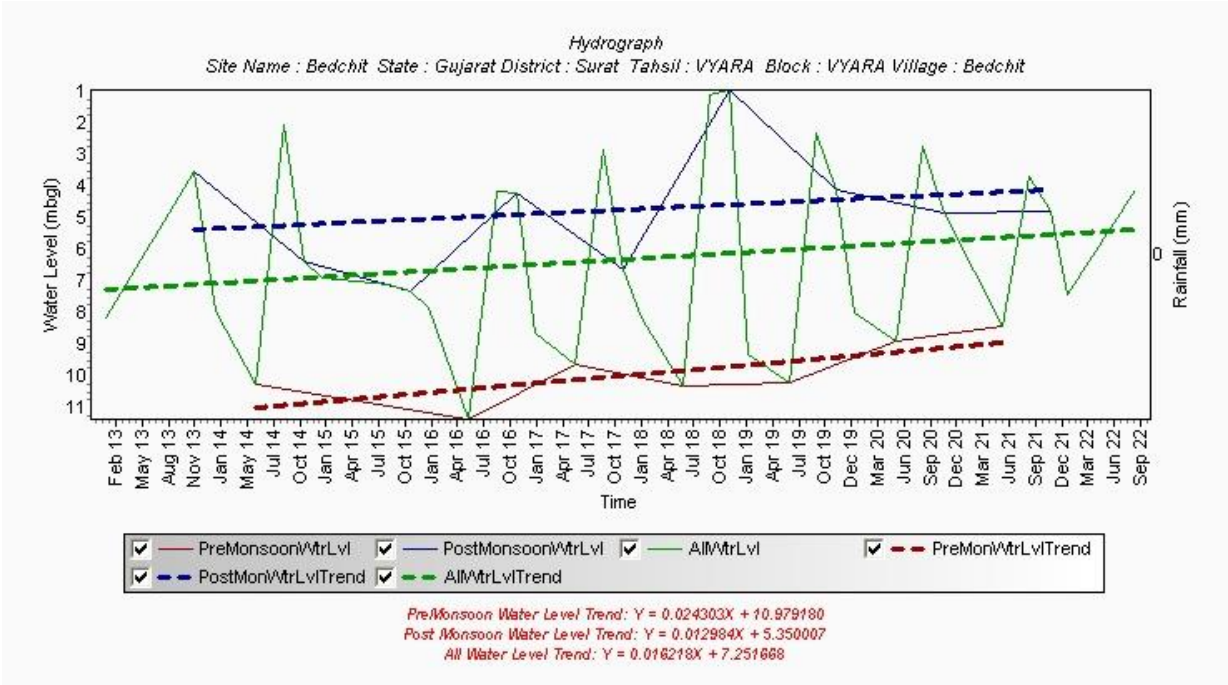


Figure 26. Hydrograph and water level trend at Bedhit site of Tapi district

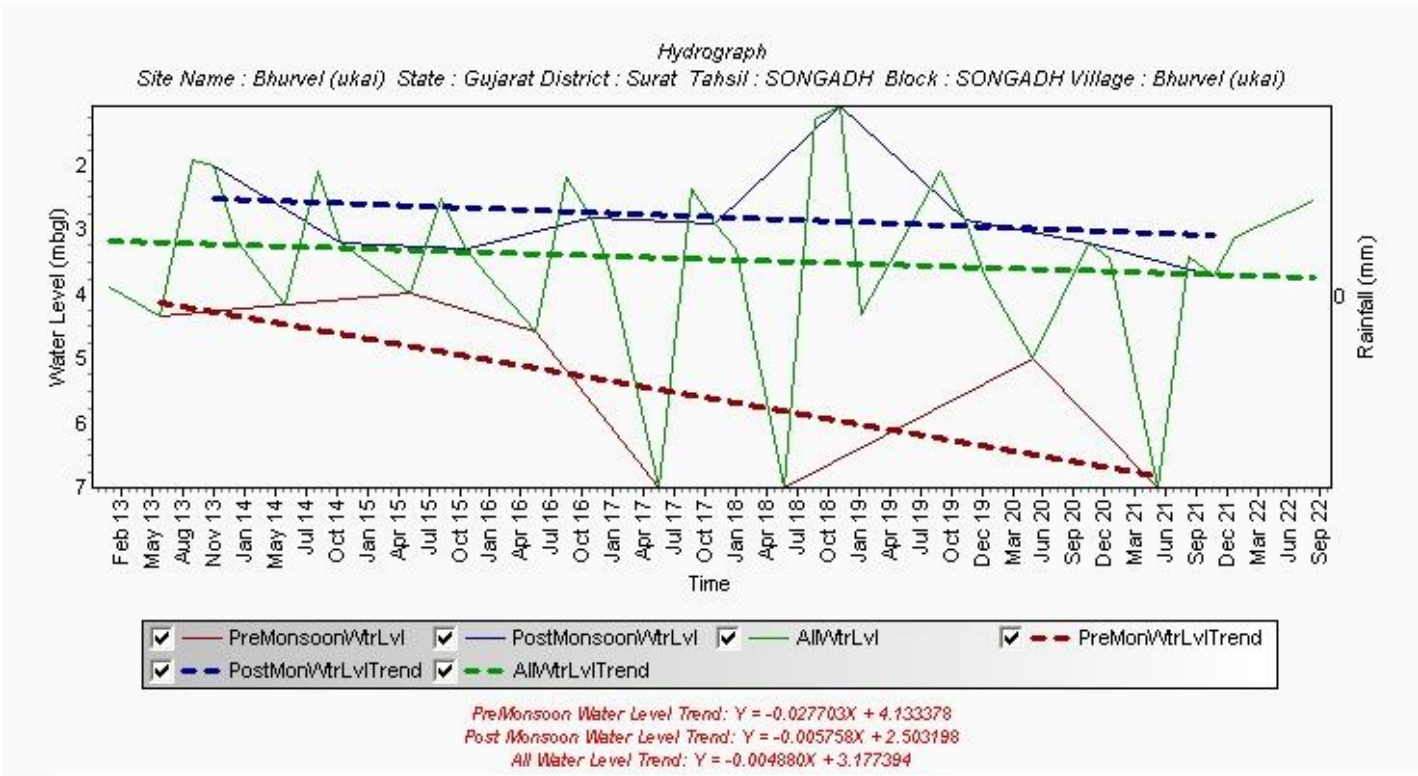


Figure 27.Hydrograph and water level trend at Bhurvel site of Tapi district

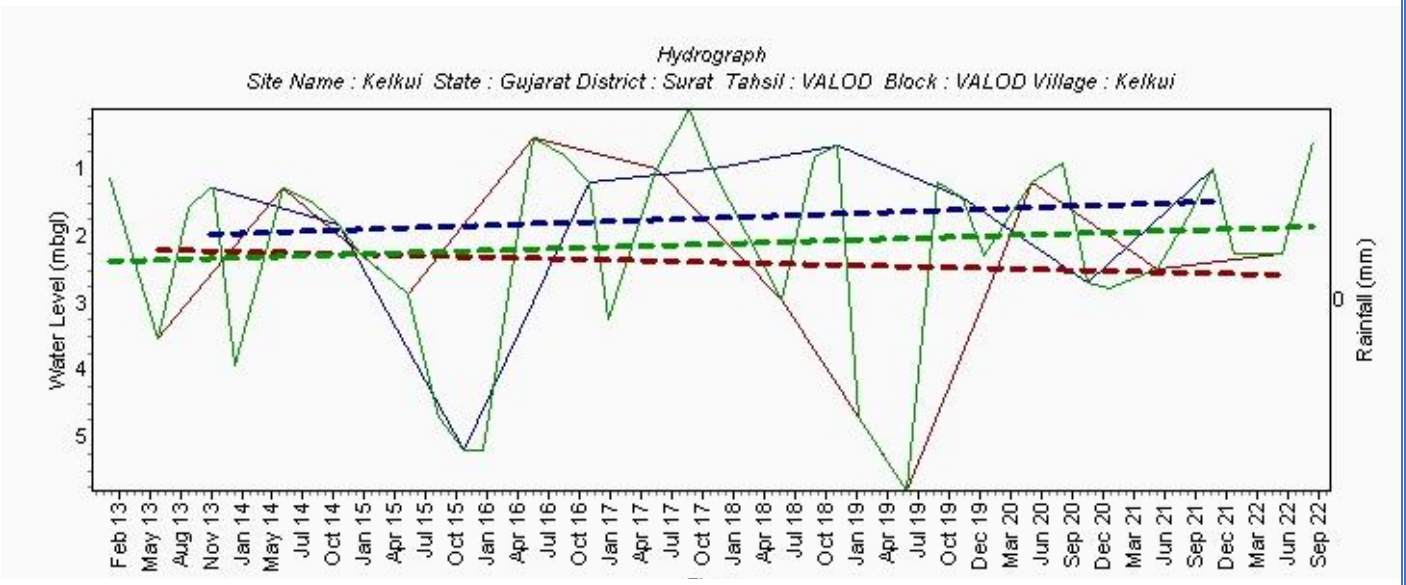


Figure 28. Hydrograph and water level trend at Jesingpura site of Tapi district

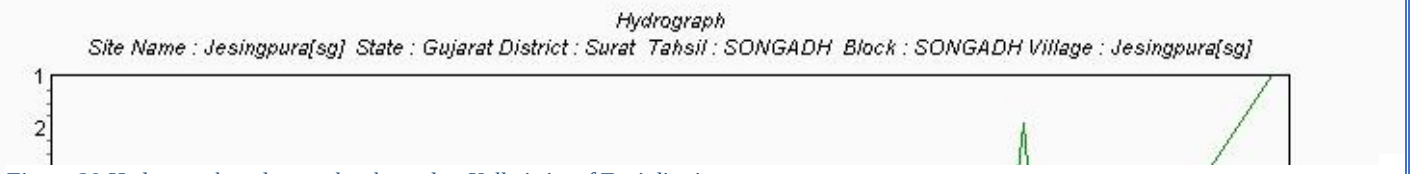
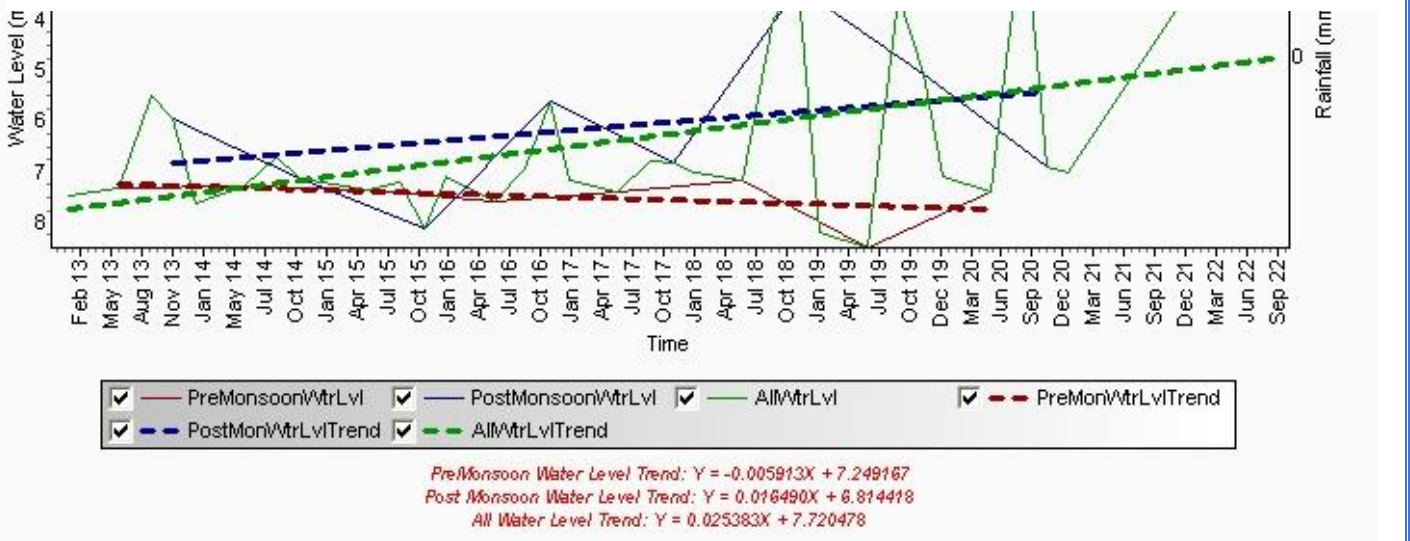


Figure 29.Hydrograph and water level trend at Kelkui site of Tapi district



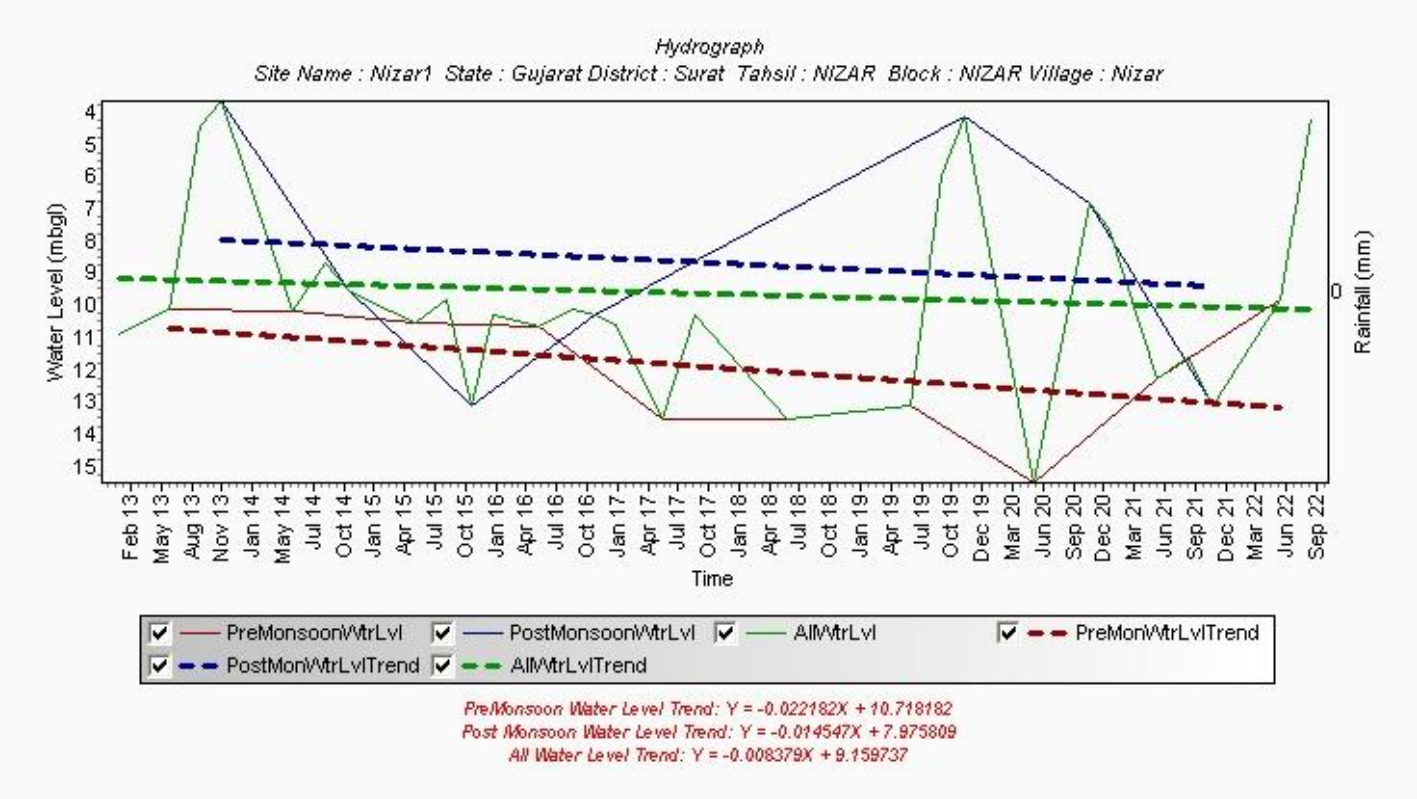


Figure 30. Hydrograph and water level trend at Nizar site of Tapi district

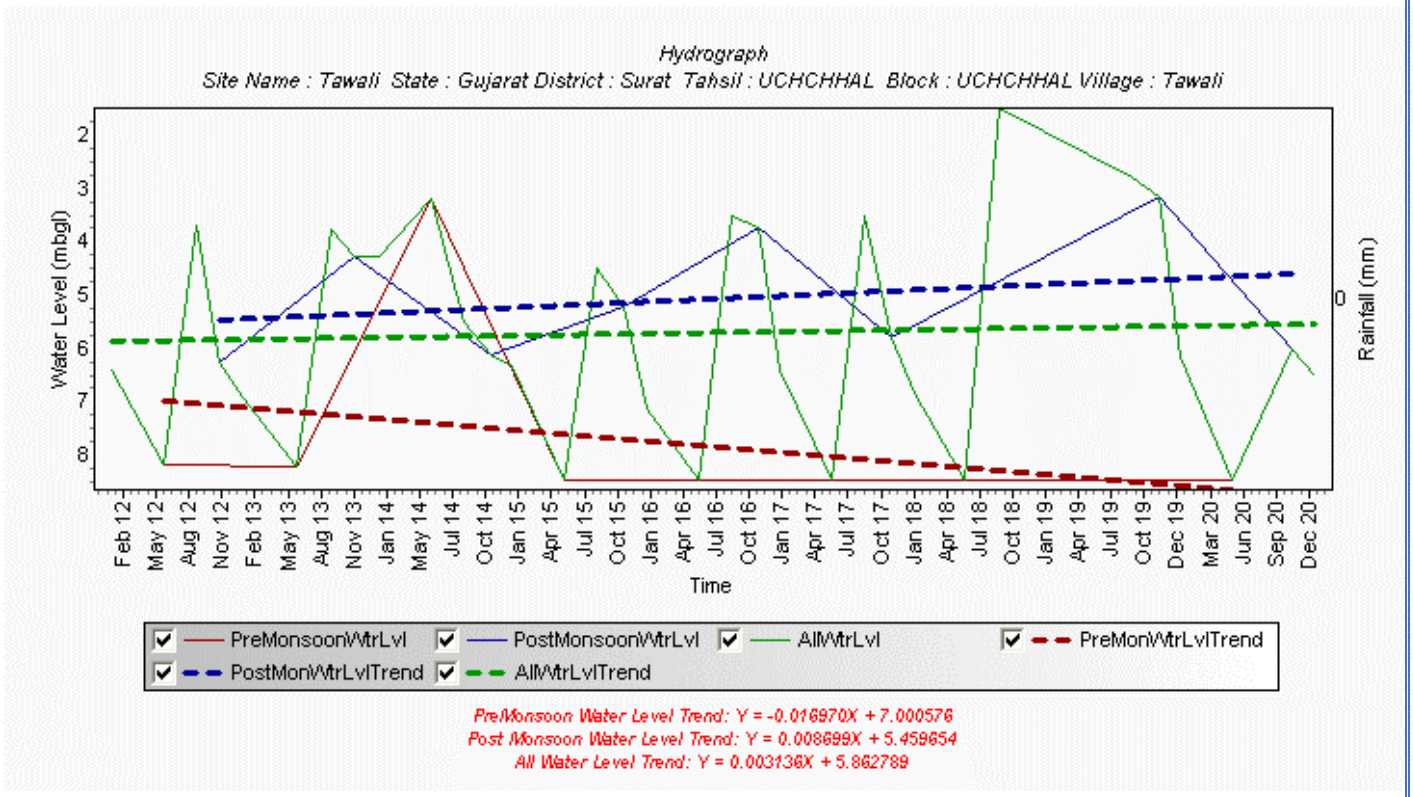
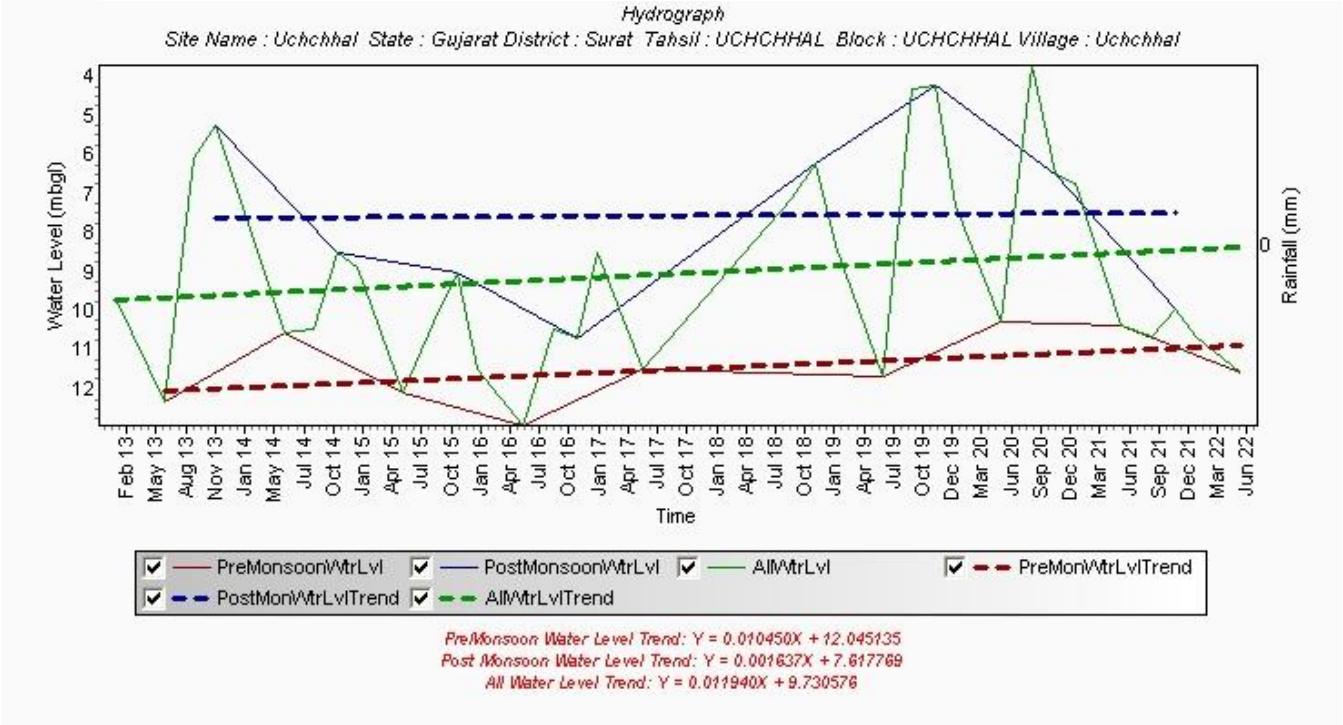


Figure 31.Hydrograph and water level trend at Tawali site of Tapi district

Figure 32. Hydrograph and water level trend at Unchhal site of Tapi district



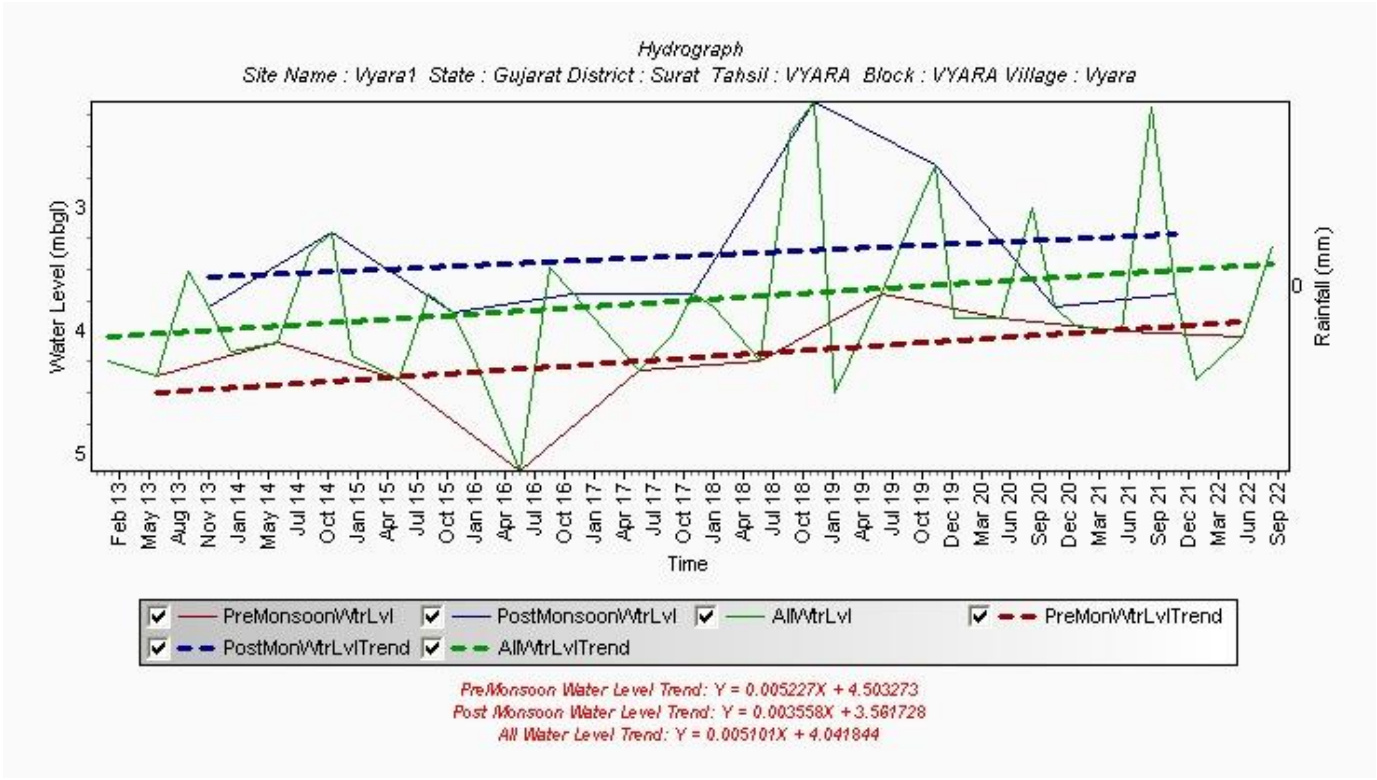


Figure 33. Hydrograph and water level trend at Vyara site of Tapi district

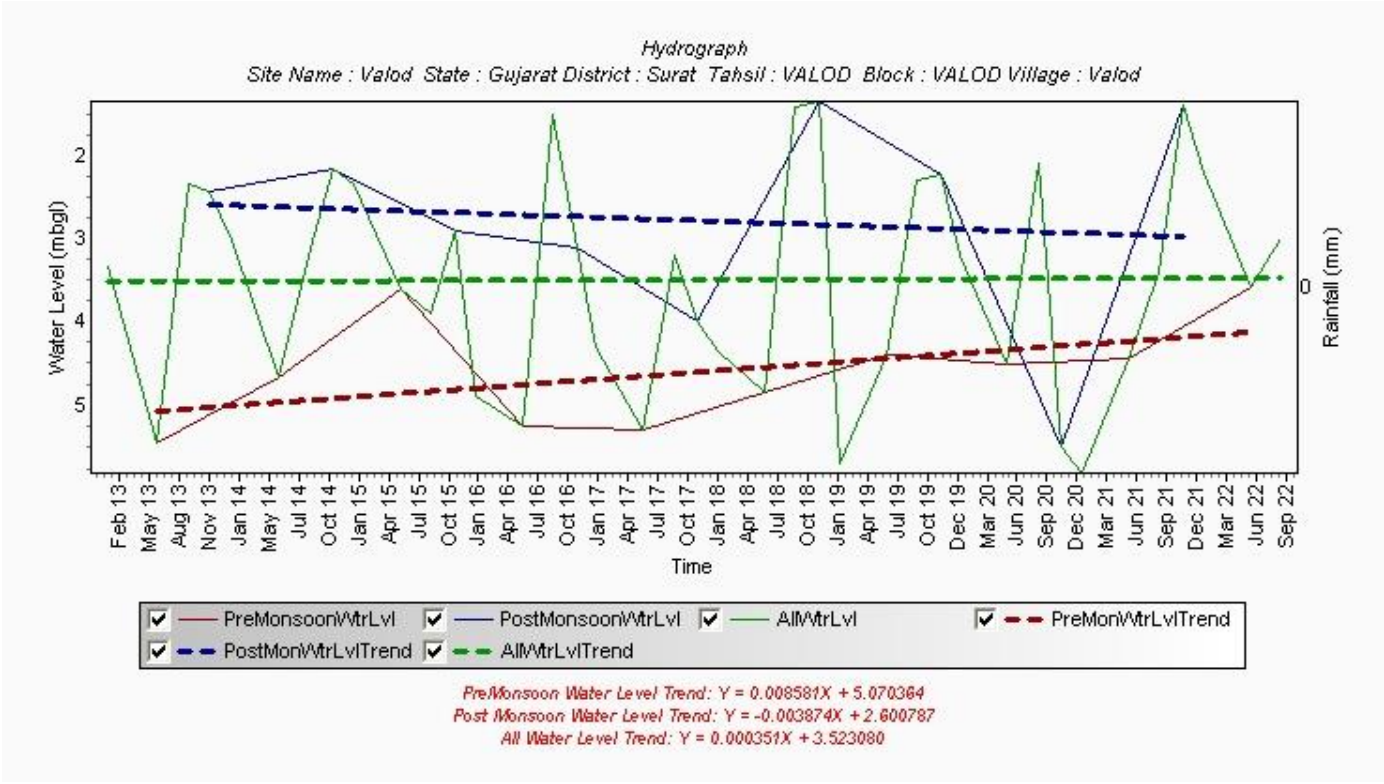


Figure 34.Hydrograph and water level trend at Valod site of Tapi district

5. HYDROCHEMISTRY

Groundwater in the district is in general fresh, both in phreatic and unconfined aquifers within 200 m depth.

The chemical quality of groundwater in shallow aquifer of the district has been analyzed based on the water samples collected during National Hydrographs Monitoring Stations (NHS) and NAQUIM program sampling in April-May 2022 form CGWB and their hydrochemistry is presented in Table-12. The ground water is in general alkaline in nature.

Table 17. Statistical Analysis of Chemical Constituents of Ground Water in Tapi District, May 2022

Parameters	Minimum	Maximum
pH	7.78	8.29
EC (uS/cm)	308.00	1824.00
TDS (mg/L)	206.36	1222.08
CO_3^- (mg/L)	0.00	0.00

HCO_3^- (mg/L)	61.01	683.31
Cl^- (mg/L)	14.18	304.87
F^- (mg/L)	0.06	0.75
SO_4^{2-} (mg/L)	0.61	69.60
NO_3^- (mg/L)	0.00	103.00
Alkalinity (mg/L)	50.04	560.45
TH (mg/L)	140.11	480.38
Ca^{2+} (mg/L)	16.03	128.26
Mg^{2+} (mg/L)	7.30	87.55
Na^+ (mg/L)	12.00	313.00
K^+ (mg/L)	0.00	3.90
SiO_2 (mg/L)	28.17	102.52
SAR (mg/L)	0.35	8.97

5.1 Hydrogen Ion Concentration (pH)

The technical definition of pH is that it is a measure of the activity of the hydrogen ion (H^+) and is reported as the reciprocal of the logarithm of the hydrogen ion activity. In general, a water with a pH < 7 is considered acidic and with a pH > 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5 and for groundwater systems 6 to 8.5. Alkalinity is a measure of the capacity of the water to resist a change in pH that would tend to make the water more acidic. The pH is an indicator of acidity of the water. The value of pH ranges between 7.78 & 8.29 in the district. The result shows that the groundwater water of the district is slightly alkaline in nature.

5.2 Electrical Conductivity

Electrical conductivity is a measure of water capacity to convey electric current. The most desirable limit of EC in drinking water is prescribed as 1,500 μS/cm (WHO 2004) In Tapidistrict the EC Ranges from 308.00 μS/cm to 1824.00 μS/cm.

5.3 Total Dissolved Solid (TDS)

As per the BIS standards [IS 10500: 2012] for drinking water, acceptable limit and permissible limit of Total Dissolve Solid (TDS) are 500 mg/l and 2000 mg/l respectively. Total Dissolved Solid is an overall parameter indicating salinity of ground water Total dissolved solids (TDS) is usually low for freshwater sources, at less than 500 ppm. Seawater and brackish (mixed fresh and sweater) water contain 500–30,000 and 30–40,000 ppm TDS, respectively. The Total Dissolved Solid of ground water varies from 206.36 mg/l to about 1222.08 mg/l. Figure 29 shows the distribution of TDS in Tapi district.

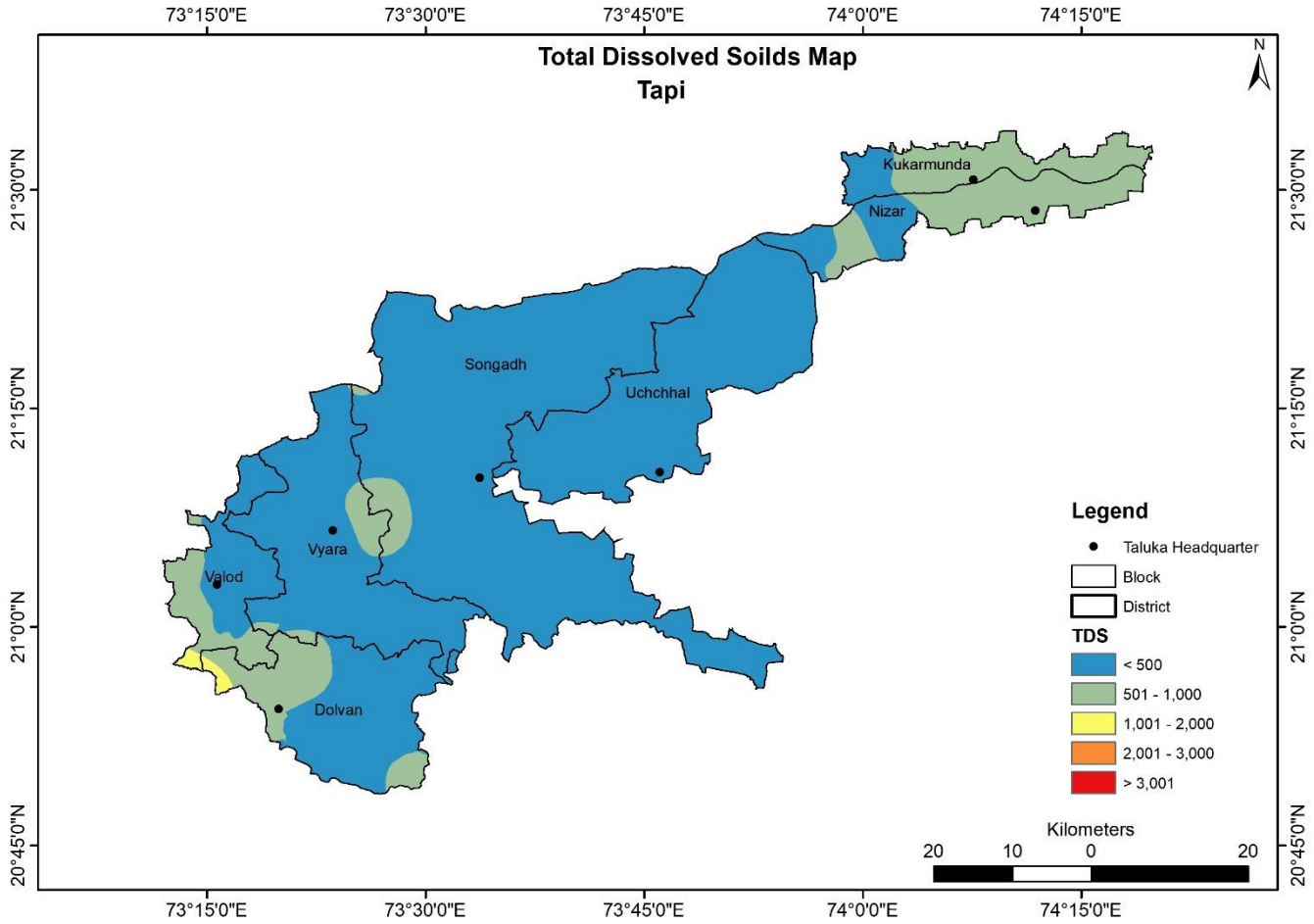


Figure 35. Map showing Taluka wise Total Dissolved Solids (TDS) values of Tapi District.

5.4 Carbonate (CO_3^-) and Bicarbonate (HCO_3^-)

The shallow groundwater in Tapidistrict does not contain any Carbonate. The Bicarbonate concentration in district are varies in between 61.01 mg/l and 683.31 mg/l.

5.5 Map of Chloride (Cl^-)

As per the BIS standards [IS 10500: 2012] for drinking water, Acceptable limit and Permissible limit of Chloride (mg/l) are 250 mg/l and 1000 mg/l respectively.The chloride concentration ranges from 14.18 mg/L to 304.87mg/L. It is depicted from the map shown in figure 30, the small patch in two Talukas namely Dolvan and Valod shows Cl concentration more than permissible limit.

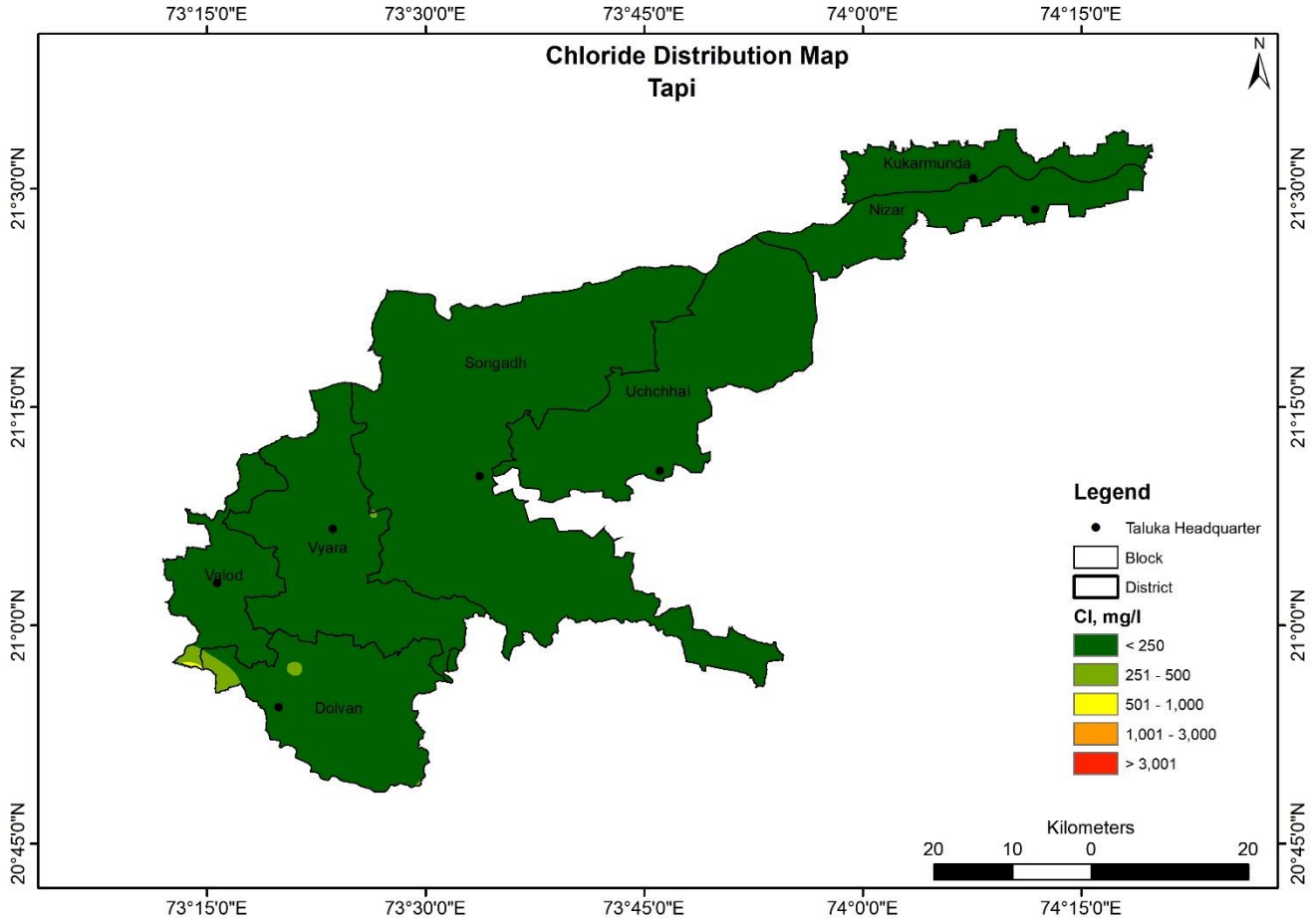


Figure 36.Map showing Taluka wise Chloride (Cl) concentration in Tapi District.

5.6 Nitrate (NO_3^-)

As per the BIS standards [IS 10500: 2012] for drinking water, acceptable limit is 45 mg/l (maximum) and there is no relaxation in permissible limit. Nitrate concentration in the ground water in district varies between 0.0 mg/l and 103.00 mg/l. There are 6 isolated monitoring stations where these values are more than the limits as per BIS drinking water standards (45 mg/l) as shown in figure 31.

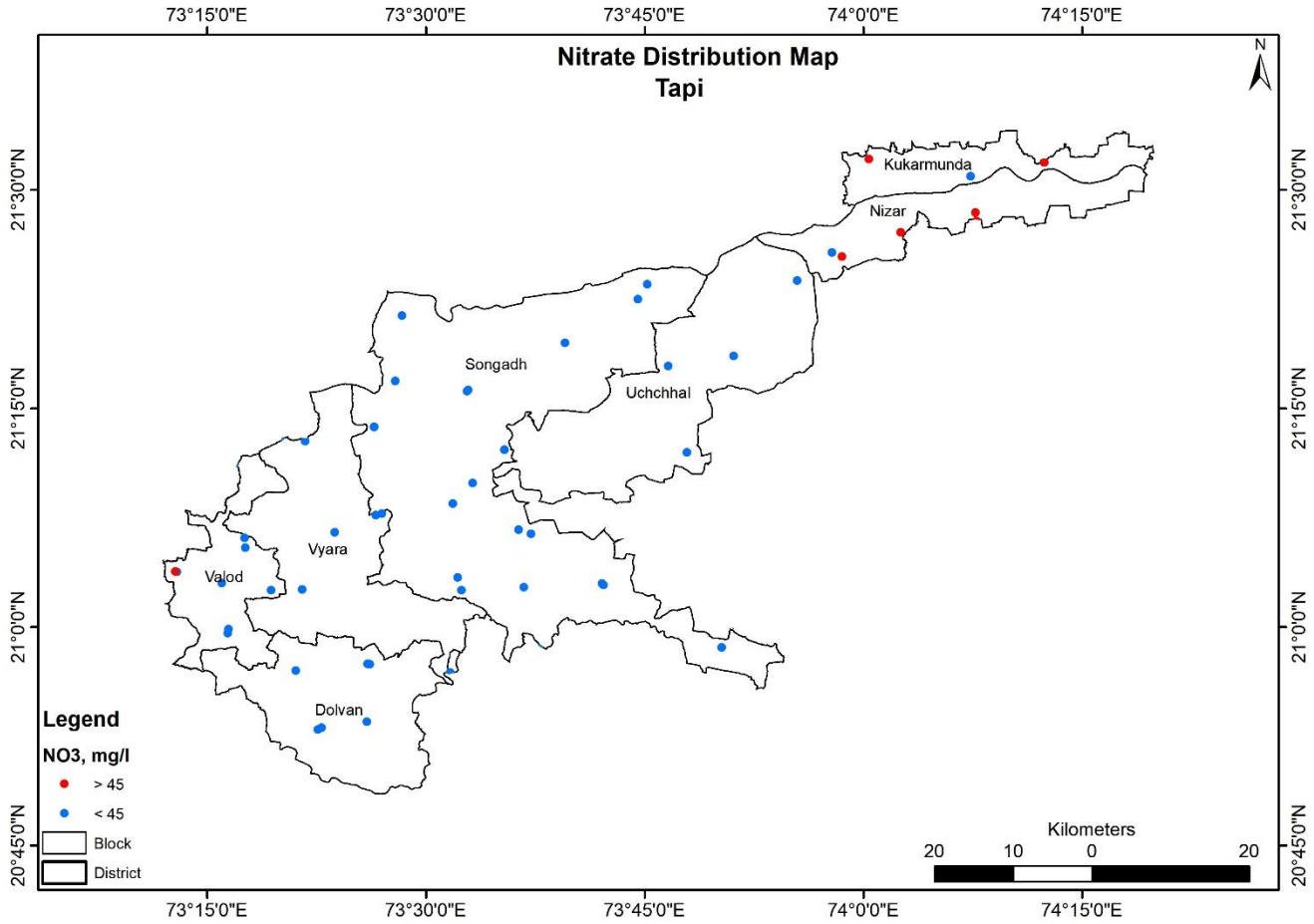


Figure 37. Map showing Taluka wise Nitrate (NO3) concentration in Tapi District.

5.7 Sulphate (SO_4^{2-})

As water moves through soil and rock formations that contain sulphate minerals, some of the sulphate dissolves into the groundwater. Minerals that contain sulfate include magnesium sulphate (Epsom salt), sodium sulphate (Glauber's salt), and calcium sulphate (gypsum). In the district, Sulphate concentration varies from 0.61 mg/l to 69.60 mg/l.

5.8 Fluoride (F^-)

As per the BIS standards [IS 10500: 2012] for drinking water, Acceptable limit and Permissible limit of Fluoride (mg/l) are 1 mg/l and 1.5 mg/l respectively. Fluoride is released to the soil and groundwater by the process of weathering of primary rock or leaching of landfill contaminants. When fluoride is released into the soil and groundwater, the concentration may increase until saturation is reached. Fluoride concentration in Tapi district are varies in between 0.06 mg/l and 0.75 mg/l.

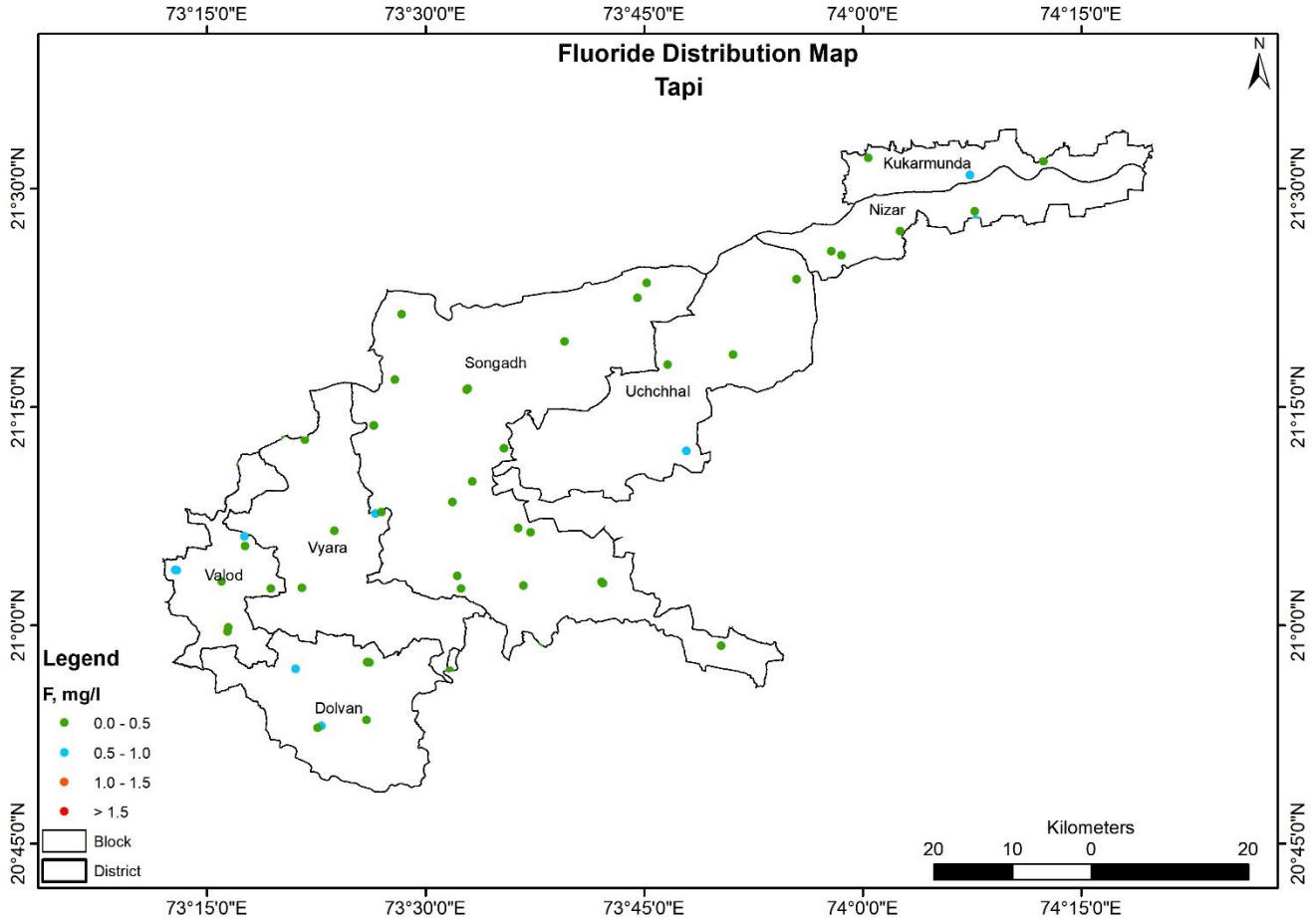


Figure 38. Map showing Taluka wise Flouride (F) concentration in Tapi District.

5.9 Calcium (Ca^{2+})

Calcium concentration in Tapi district varies between 16.03 mg/l and 128.26 mg/l. The concentration of calcium is found within permissible limits in the district (permissible limit as per BIS norms is 200 mg/l).

5.10 Magnesium (Mg^{2+})

The Concentration of Magnesium in areas ranges from 7.30 mg/l to 87.55 mg/l. The concentration of Magnesium is found within permissible limits in the district of 100 mg/l (as per BIS norms).

5.11 Sodium (Na^{+})

Potassium is important ions in ground water and are used to assess quality control for samples and laboratory analysis. Sodium is often naturally found in groundwater. In water, sodium has no smell but it can be tasted by most people at concentrations of 200 milligrams per litre (mg/L) or more. Sodium concentration in the district varies between 12 mg/l and 313 mg/l in the district.

5.12 Potassium (K^{+})

Potassium is important ions in ground water and are used to assess quality control for samples and laboratory analysis. The principal potassium minerals of silicate rocks are the feldspars orthoclase and microcline (KAlSi3O8), the micas, and the feldspathoid leucite ($KAlSi_2O_6$). The potassium feldspars are resistant to attack by water. Presumably they are altered to silica, clay, and potassium ions by the same process as other feldspars, only more slowly. In sediments, the potassium commonly is present in unaltered feldspar or mica particles or in illite or other clay minerals. The concentration of Potassium in shallow ground water ranges from 0.00 mg/l to 3.90 mg/l in the district.

6. GROUND WATER RESOURCE POTENTIAL

The ground water resources of the district were calculated as on March 2022 in collaboration with the Government of Gujarat using the GEC-2015 methodology suggested by Ground Water Resource Estimation Committee (GWRE-2022). These resources were computed after reorganization of the districts, talukas of the district are considered as Assessment Unit (AU) and total area of 3130.55 sq km are taken as area of assessment of the district including 05 talukas. Computed resource are presented in tabulated (table-11) and graphically represented as below.

Table 18. Taluka wise Ground Water resources, Availability, Utilization and Stage of Ground Water Development

Taluka Wise Ground Water Resources, Availability, Utilization and Stage of Ground Water Development- 2022															
DISTRICT- TAPI															
Taluka	ANNUAL REPLENISHABLE GROUND WATER RESOURCES (Ham)				Total Annual Ground water Recharge	Environmental Flows (ham) (5% of 7 for WTF & 10% of 7 for RIF)	Annual Extractable Ground water Resource (ham)	ANNUAL GROUND WATER DRAFT (Ham)				Allocation of Ground Water Resource for Domestic Utilisation for projected year 2027 (ham)	Net Annual Ground Water Availability for Future Use (ham)	Stage of Ground Water Extraction (%)	Categorization of Assessment Unit
	Monsoon		Non Monsoon												
	Recharge from Rainfall	Recharge from Other Sources	Recharge from Rainfall	Recharge from Other Sources				Irrigation	Industrial	Domestic	Total Draft				
VYARA	126.54	19.38	0.00	61.29	207.21	20.72	186.49	72.26	0.03	0.00	72.29	1.65	112.54	38.77	safe
NIZAR	45.63	3.94	0.00	7.40	56.97	4.33	52.64	34.11	0.06	1.03	35.20	1.86	16.61	66.88	safe
SONGADH	254.96	11.70	0.00	53.46	320.12	16.01	304.12	52.24	0.02	3.52	55.78	3.69	248.17	18.34	safe
UCHCHHAL	79.78	2.20	0.00	3.41	85.38	8.54	76.84	13.70	0.00	0.39	14.10	0.41	62.73	18.35	safe
VALOD	28.29	11.87	0.00	40.51	80.67	8.07	72.60	31.73	0.19	0.00	31.92	1.03	39.65	43.96	safe
District Total	535.19	49.09	**0.00**	166.07	750.35	57.67	692.68	204.04	0.30	4.94	209.29	8.64	479.70	**30.21**	safe

6.1 Ground Water Recharge

Total Annual Ground Water Recharge from Rainfall and other sources for both monsoon and non monsoon season for the district is 750.35 mcm. And ground water recharge in talukas varies from 56.97 mcm (Nizar taluka) to 320.12 mcm (Songadh taluka).

6.2 Net Ground Water Availability

Annual Extractable Ground Water Resource/ Net Ground Water Availability of the district is 692.68 mcm which computed after deducting total natural discharge of 57.67 mcm from total annual ground water recharge.

6.3 Annual Ground Water Draft

The gross ground water draft for all uses (i.e. Irrigation, Domestic and Industrial uses) in the district is 209.29 mcm. The existing gross ground water extraction for all uses varies from 14.10 mcm (Unchhal taluka) to 72.29 mcm (Vyara taluka). Approximately 97.50 % of ground water extraction are used for Irrigational purposes, remaining 2.5% are being extracted mainly for Domestic and Industrial purposes (very less).

6.4 Projected demand for Domestic and Industrial use upto 2027

The total Projected demand of ground water for Domestic and Industrial uses in the district is 8.64 mcm. Projected demand for domestic uses varies from 0.41 mcm (Unchhal taluka) to 3.69 mcm (Songadh taluka).

6.5 Ground water Availability for future Irrigation

Net ground water availibilty for future use in the district is 479.70 mcm. Taluka wise it varies from 16.61 mcm (Nizar taluka) to 248.17 mcm (Songadh taluka).

6.6 Stage of Ground Water Extraction

As per the Ground Water Resource Estimation (GWRE-2022), the stage of Ground Water extraction of the district is **30.21**% which categorized as Safe. Whereas in taluka it varies from 18.34 % (Songadh Taluka) to 66.88 % (Nizar Taluka) and all five talukas of the district are categorized as SAFE.

7. SUSTAINABLE GROUNDWATER DEVELOPMENT AND MANAGEMENT

7.1 Groundwater related issue:

7.1.1 Low Ground water development

As per GWRE 2022 the total ground water resources of the district are in order of 750.35 mcm/year and utilizable resources are 692.68 mcm/year. The net annual drafts of 209.29 MCM/year leaves a balance of 479.70 mcm/year of ground water available for future development.

Low Ground Water Development: Stage of Ground water development of the district is 30.21 %, however talukas wise it ranges from 18.34% (Songadh taluka) to 66.88% (Nizar taluka).

7.1.2 Pollution (Geogenic and Anthropogenic)

Groundwater quality of Tapi has a special significance and needs greater attention of all concerned since it is the only major source for domestic, consumption. Occurrence of Nitrate beyond acceptable limit (As per the BIS standards [IS 10500: 2012] for drinking water) in Shallow aquifers identified in localized isolated villages of Kukarmunda, Nizar and Valod. The nitrate problem is also very common in almost all talukas of the district. The elevated nitrate concentration in groundwater of the district may be due to Anthropogenic activity basically from fertilizers.

7.1.3 Sustainability

Most part of the district has secondary porosity in the form of weathered & fractured rock which forms the good repository or major aquifer of groundwater. Yield in these formation varies from very low yield 50m^3/day to 150m^3/day with the maximum sustainable pumping of 4 to 5 hours. The yield from bore wells have reduced in a lean period, recoupment time in some phreatic aquifer is very low that's the reason people residing there constructed large diameter of well for maximum storage.

7.2 Management Strategies

As per the estimate of ground water resources and irrigation potential, there exists a scope for further development of ground water resources in major parts of the district. As per GWRE 2022 all the five (5) talukas of the district are under **safe** category. Stage of Ground water development of the district is 30.21%, however taluka wise it ranges from 18.34% (Songadh taluka) to 66.88% (Nizar taluka). Thus, further ground water development could be augmented in a judicious way.

7.3 Management plan

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

- Ground water development Plan
- Supply side measures
- Demand side measures
- Regulatory measures
- Institutional measures

7.3.1 Ground water Development Plan

To elevate the stage of ground water development to 31.24% in all Talukas, 1550 nos. of Dug wells (15m depth) are proposed as feasible extraction structures table 13. The extraction structures will result as expected annual ground water draft of 775.00 ham which will create 1722.22 Ha additional irrigation potential in the district.

Table 19. Feasible Extraction structures to elevate the Stage of GW development to 31.24%

Extraction Talukas	Feasible Extraction structures to elevate the Stage of GW development to 60.98% (Hard Rock)			G.W Draft from Extraction structures (ham)	Additional Irrigation Potential Created (Ha)
	TW	DW	Total		
Vyara	0	549	549	274.50	610.00
Nizar	0	100	100	50.00	111.11
Songadh	0	455	455	227.50	505.56
Unchhal	0	103	103	51.50	114.44
Valod	0	344	344	172.00	382.22
District	0	1550	1550	775.00	1722.22

7.3.2 Supply side interventions

As per Master Plan 2020, surplus surface water of 601.53 mcm non committed is allocated to suggest artificial recharge in district of Tapi. To harvest the surface water, the different artificial recharge structures are proposed as check dam, Percolation tank and defunct well to recharge the aquifer which is presented in table 14.

Table 20. Proposed Artificial Recharge and WUE Interventions in Tapi District

Recharge / Talukas	Artificial Recharge through Check Dam	Artificial Recharge through Percolation Tank	Artificial Recharge through Defunct Tube well	Additional Recharge from Recharge interventions (ham)
Vyara	23	4	4	773.64
Nizar	13	0	3	344.74
Songadh	20	0	4	439.30
Unchhal	15	0	2	218.30
Valod	8	8	1	384.54
District	23	12	14	2170.63

❖ **IDENTIFICATION OF RECHARGE AREA**

There are two major water hydrogeological units bearing geological formations occurring in the District have been categorized broadly in two hydrogeological units, namely, alluvial deposits and consolidated rock units of Cretaceous Basalt. The thickness of available unsaturated zone (below 6 m bgl) is computed on basis of Post monsoon (2012-2021) decadal average depth to water level map and Similarly, Post monsoon (2012-2021) decadal water level trend map. On basis of these two maps, area suitable for artificial recharge in Gujarat State is identified taking into consideration of following four categories.

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

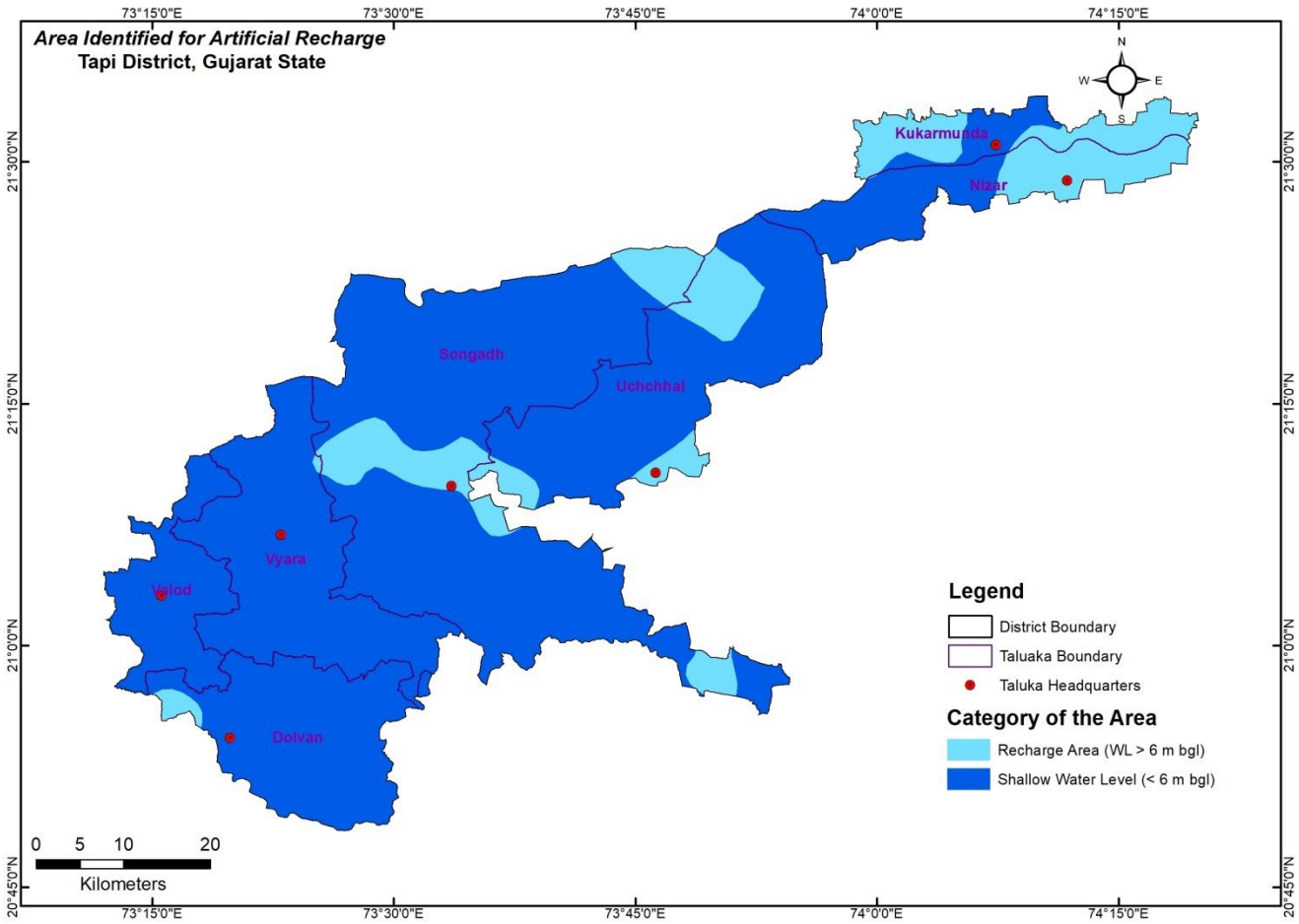


Figure 39. Map showing Area identified for Artificial Recharge in Tapi district

7.3.3 Demand side intervention

Feasible extraction structures are proposed to elevate the stage of ground water development to 31.24%, to avoid further exploitation demand side management is also recommended to restrict the stage of ground water development to 28.62 %. An area of 20000 Ha is proposed for on farm activities (Laser leveling/Bench terracing/Contour banding), area and 977 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water. And expected conservation of ground water through efficiency enhancement measures is 1202.70 ham is expected for the district.

❖ **Farm Ponds**

A farm pond is a large hole dug out in the earth, usually square or rectangular in shape (Fig. 33), which harvests rainwater and stores it for future use. It has an inlet to regulate inflow and an outlet to discharge excess water. The pond is surrounded by a small bund, which prevents erosion on the banks of the pond. The size and depth depend on the amount of land available, the type of soil, the farmer's water requirements, the cost of excavation, and the possible uses of the excavated earth. Water from the farm pond is conveyed to the fields manually, by pumping, or by both methods.

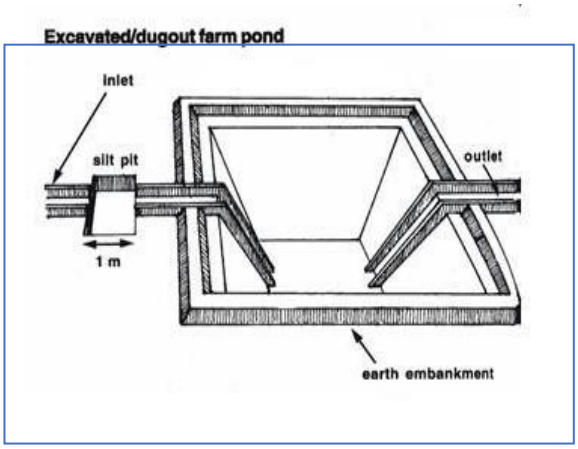


Figure 40. Schematic diagram of Farm pond

Advantages of Farm Ponds

- They provide water to start growing crops, without waiting for rain to fall.
- They provide irrigation water during dry spells between rainfalls. This increases the yield, the number of crops in one year, and the diversity of crops that can be grown.
- Bunds can be used to raise vegetables and fruit trees, thus supplying the farm household with an additional source of income and of nutritious food.
- Farmers are able to apply adequate farm inputs and perform farming operations at the appropriate time, thus increasing their productivity and their confidence in farming.
- They check soil erosion and minimize siltation of waterways and reservoirs.
- They supply water for domestic purposes and livestock
- They promote fish rearing.
- They recharge the ground water.
- The excavated earth has a very high value and can be used to enrich soil in the fields, leveling land, and constructing farm ponds.

Table 21. Projected Status of Groundwater Resource after implementation of GW Management Plan, Tapi District (Gujarat)

Projected Status of Groundwater Resource after implementation of GW Management plan, Tapi District (Gujarat)												
Talukas	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Additional Recharge from Return flow of GW Irrigation	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	Conservation of Ground water through WUE, on farm activity & farm ponds (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of G.W. Development after construction of extraction structures (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation & Recharge measures (in %)	Additional Irrigation Potential Created (Ha)
Vyara	18648.60	773.64	71.37	19493.61	7229.43	419.55	274.50	7084.38	38.77	40.09	36.34	610.00
Nizar	5263.63	344.74	13.00	5621.37	3520.30	216.82	50.00	3353.48	66.88	67.66	59.66	111.11
Songadh	30411.73	439.30	59.15	30910.18	5577.67	264.86	227.50	5540.31	18.34	19.05	17.92	505.56
Unchhal	7684.28	218.30	13.39	7915.97	1409.69	108.91	51.50	1352.28	18.35	18.98	17.08	114.44
Valod	7259.94	384.54	44.72	7689.20	3191.57	191.94	172.00	3171.63	43.96	46.05	41.25	382.22
District	69268.18	2170.63	201.50	71640.31	20928.66	1202.70	775.00	20500.96	30.21	31.24	28.62	1722.22

8. CONCLUSION AND RECOMMENDATIONS

- Artificial recharge structures like check dam, percolation tank and through defunct tube well are proposed in the district to encounter needed surface runoff.
- To elevate the stage of ground water development to 31.24% in all Talukas, 1550 nos. of Dug wells (15m depth) are proposed as feasible extraction structures.
- To prevent Over Exploitation, water conservation activities like On farm activities , farm ponds are recommended.
- 20000 Ha area is proposed for on farm activities (Laser leveling/Bench terracing/Contour banding) and 977 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water.
- Ground water return flow of 201.50 ham is expected from irrigation of fields in the district.
- 1202.70 ham conservation of ground water through WUE measures, on farm activities & farm ponds is expected for the district.
- As a conservation measure, farmers should be encouraged and educated to adopt modern irrigation techniques like drip, sprinkler irrigation etc. to effect minimum withdrawal and maximum utilisation of groundwater.
- The water quality in general is fresh in nature. However higher EC, Nitrate and fluoride concentration is observed in isolated pockets. Ground water in such areas may be used after blending with surface water. In areas where ground water has higher concentration of Nitrate is observed, necessary sanitation measures should be adopted.
- Taking into consideration of tribal domination and drought prone area, the ‘Mass Awareness Programme’ and 'Water Management Training Programme" should be organized in regular basis in the district for awareness on the depletion of groundwater resources and quality problems.
- Present supply side interventions are suggested based on availability 601.53 MCM non committed source of water is referred by State Government (Reference Master Plan of Artificial recharge 2020). Proposed enhancements of present Groundwater development stage is subjected to implementation of recharge interventions, availability of cultivable land and yield of Groundwater structures.
- These interventions also need to be supported by regulation, so that the ground water resources are protected for future generation and also serve as ground water sanctuary in times of distress/drought. IEC activities and capacity building activities needs to be aggressively propagated to establish the institutional framework for participatory ground water management.