



For Official Use

Technical Report Series

**DISTRICT GROUNDWATER BROCHURE
SURENDRANAGAR DISTRICT
GUJARAT**

Compiled

By

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Ministry of Water Resources
Central Ground Water Board
West Central Region
Ahmedabad
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SURENDRANAGAR DISTRICT AT A GLANCE

SL No.	Items	Statistics
1	General Information	
	i) Geographical Area (Sq Km)	10489
	ii) Administrative Divisions Number of Taluka Number of Villages	10 651
	iii) Populations (As per 2011 census)	1755,873
	iv) Average Annual Rainfall (mm)(1961-2010)	587.35
2.	GEOMORPHOLOGY	
	Major Physiographic Units	Hilly areas, Piedmont slopes, Alluvial plains (main land)
	Major Drainages	No major river (only small tributaries)
3.	LAND USE (Sq Km)	
	a) Forest area	531
	b) Net area sown	7062
	c) Cultivable area	7624
4.	MAJOR SOIL TYPES	Medium black soils Red Sandy soils and Silty soils.
5.	AREA UNDER PRINCIPAL FOODGRAIN CROPS	Area in Sq Km Food grains 1060 Oil seeds 1330 Cotton 4300
6.	IRRIGATION BY DIFFERENT SOURCES (Directorate of Economic and Statistics, Govt. Gujarat)	Area ('00 ha)
	Dugwells & Tubewells	1958
	Canals	96
	Tanks	9
	Other Sources	4
	Net Irrigated area ('00 ha)	2067
	Gross Irrigated area ('00 ha)	2527
7.	NUMBERS OF GROUND WATER MONITORING WELLS OF CGWB (As on 31-03-2013) No of Dug Wells No of Piezometers	48 9
8.	PREDOMINANT GEOLOGICAL FORMATIONS	
	Geological formations ranges in age from Cretaceous to Recent, Nearly 50% area underlain by alluvium, 20% by Basalt and 30% by Sandstones / Limestones of Dhrnagandra - Wadhwan formation.	

9.	HYDROGEOLOGY	
	Major Water Bearing Formation: Alluvium, Sandstones of Dhrnagandra –Wadhwan group, Deccan traps . Depth to water level during 2012 - Range Pre-monsoon (May12) 0.67 (min) to 20.53 (max) m bgl Post-monsoon (Nov 2012) 0.85 (min) to 20.75 (max) m bgl Long term (10 Years) Water Level Trend (as on 2002 -2012)	
	Trend	Pre - Monsoon
	Rise (m/Yr)	0.01(kherwa) – 1.36 (Malaniyad) Total -32
	Fall (m/Yr)	0.07 (Kharaghoda) – 0.59 (Dalia) Total - 5
		Post - Monsoon
		0.02 (Shiyana) – 1.23 (Halvad) Total - 29
		0.02 (Bajana) – 0.43 (Dhrangardha) Total - 8
10	GROUND WATER EXPLORATION BY CGWB (As on 31-03-2011)	
	No of wells drilled (EW, OW, Pz, SH, Total) EW 16 ,OW 7, PZ 1, Total: 24	
	Depth Range(m)	25.36 to 611
	Discharge (Litres per minute)	8 to 720 lpm
	Storativity (S)	-
	Transmissivity (m ² /day)	104-2965 m ² /day
	Specific capacity lps/m of dd	19- 1658 m ³ /day/m
11	GROUND WATER QUALITY	Fresh, Brackish and Saline
12.	DYNAMIC GROUND WATER RESOURCES (2011)- in mcm	
	Total Annual Ground Water Recharge	629.8743
	Net Annual Ground Water Draft	374.9830
	Projected Demand for Domestic and industrial Uses upto 2025	39.3600
	Stage of Ground Water Development	59.53% (Safe)
16	MAJOR GROUND WATER PROBLEMS AND ISSUES	
	i) The groundwater quality in alluvial area is saline due to the presence of Little Rann ii) Ground water quality in Wadhwan sandstone is saline due to inherent salinity iii) Several short streams mostly disappear into Rann area The surface run-off needs to be effectively diverted to ground water recharge . iv) Feasibility of Artificial Recharge Projects.	

DISTRICT GROUNDWATER BROCHURE SURENDRANAGAR DISTRICT GUJARAT

INTRODUCTION

Surendranagar district is located in the north western part of Saurashtra Peninsula of Gujarat State .The Rann of Kachchh towards north, the vast low lying alluvial tract plains of North Gujarat towards east and uplands of the central Saurashtra towards south and west encircle the district.The district covers an area of 10,489 Sq.Km .A major portion of the district is drought prone. This brochure deals with the salient features of hydrogeological conditions and ground water potential of Surendranagar district. This district is essentially an underdeveloped district having diverse terrain conditions and varied but limited endowments of nature.

Location, Extent and Accessibility

Surendranagar district has a geographical area of about 10,489 sq. km and falls in the Survey of India Degree sheets 41N and 41M, between North latitudes $22^{\circ} 8'$ and $23^{\circ} 3'$ and East longitudes $70^{\circ} 58'$ and $72^{\circ} 12'$ shown in figure no.1.The district has 651 villages and 11 towns (populations greater than 1,00,000) spread over 10 talukas ,namely Wadhwan , Limbdi, Dasada, Dhrangadhra, Chotila, Chuli, Halvad Muli, Sayla and Lakhtar.

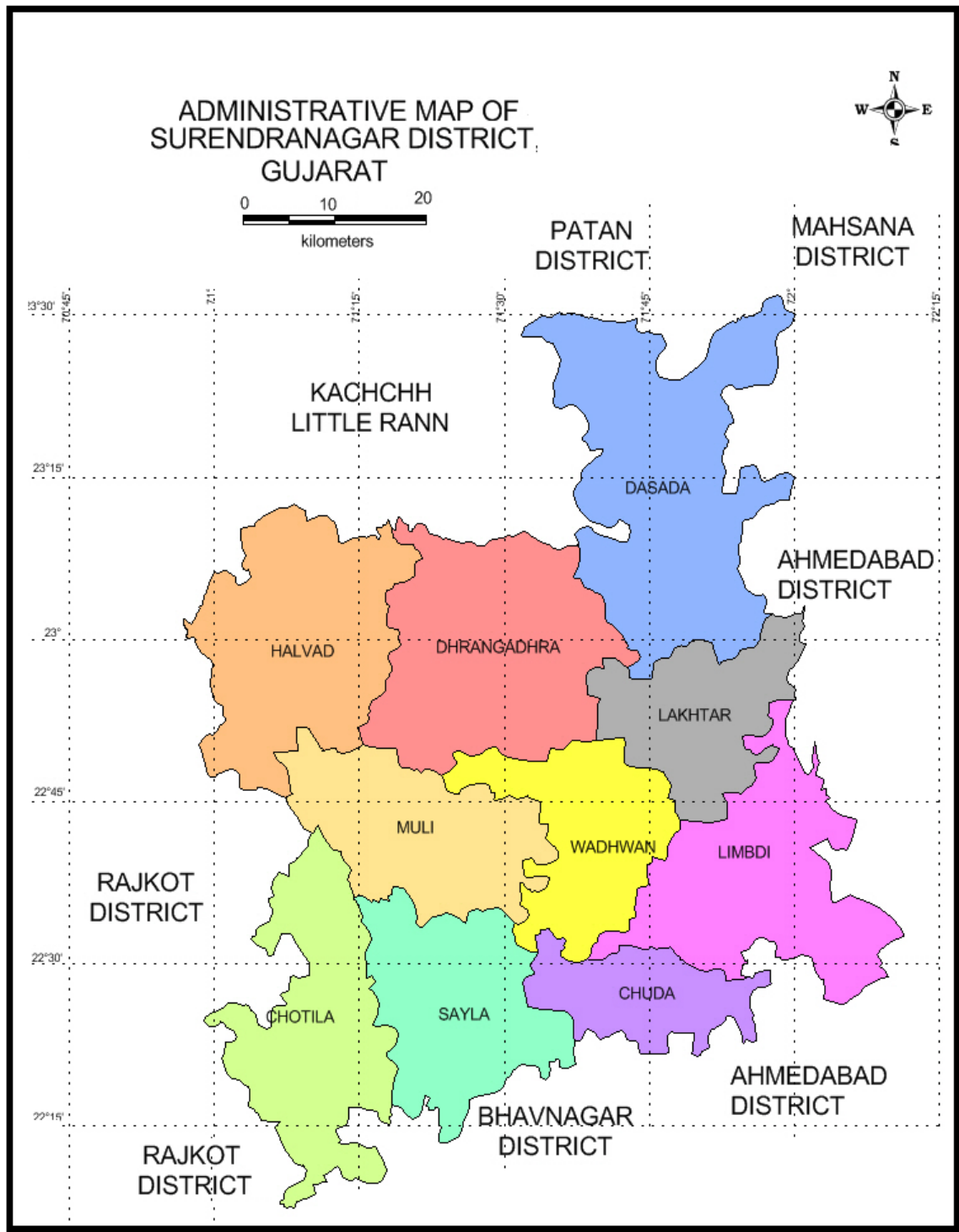
SOIL

The soils of Surendranagar district may be classified into three main categories:

- a. Medium black soils
- b. Red Sandy soils
- c. Silty soils

Medium black soils generally occur at shallow depths (less than 5m) where basalts/shale forms the main rock unit and is exposed on the surface in the south, southwest and central part of the area. These soils are good in fertility but not suitable for heavy irrigation. The red sandy soils occur in north east, east and south east part of the area. The silty soils are found along a narrow strip close to the little Rann of Kachchh in the north east and along shallow alluvial tracts and hard rock areas in central uplands has appreciable content of sand.

Fig-1



Land Use in cropping and Irrigation

The land utilization pattern in the district is given below as table no. I

Land Use in cropping Pattern in Surendranagar district

S No.	Land Particulars	Total Area ('00ha.)
	Geographical area	10489
1	Forest area	526
2	Land under non- agricultural use	547
3	Permanent pastures	460
6	Cultivable wasteland	157
7	Barren & un-cultivable Land	1245
8	Current fallows	330
9	Net sown Area	5389
10	Area sown more than once	1011
11	Gross cropped Area	6400

(Source; (Source; Statistical Handbook 2011)

The crops grown in the district mainly cotton 59%, Cereals 12%, Sesamum 11%, Bajra 8% and wheat 4%.

Irrigation

Most of the rivers in the district are ephemeral .Many small reservoirs and tanks are constructed to meet the irrigation and domestic requirements of the area but most of them dry up during the summer. There are five minor irrigation schemes in the district namely Ghanshamgad, Satapar, Kankvati, Ramgadh and Vaodi. Water storage capacity of all Minor Irrigation Schemes taken together is 9.168MCM. The total cultivable command under all these schemes taken together is 2280 acres. The distribution of water in these schemes is effected through a network of various canals. There are four Medium Irrigation Schemes namely Wadhwan- Bhogava-I, Wadhwan- Bhogava-II, Brahmini and Limbdi- Bhogava in the area. Water storage capacity of all Medium Irrigation Schemes taken together is 139.05 MCM. The total cultivable command under these scheme taken together is 92638 acres.

In the district 58854 in use open and tube wells irrigated about 195800 hectare of land.

Temperature

The period from March to May records gradual increase in temperature and May being the hottest month. The maximum temperature in summer reaches 46° Celsius with an average of 41.9° Celsius. With the onset of the south west monsoon, by about June, there is an appreciable drop in the day temperatures. From the beginning of November month onwards, both day and night temperatures drop rapidly (even up to 5°C) till January which is being the coldest month. The mean daily maximum and minimum temperatures works out to be 28.3° C and 12.9° C respectively for period of observation.

Humidity

The relative humidity are generally over 60% in the south west monsoon .In the rest of the year the air is comparatively dry ,especially in the afternoons. During the period of November to May the relative humidity varies between 20% and 30%.

Wind

In the south west monsoon season, the wind direction is westerly to south westerly. In the post monsoon/cold season, wind blow from the north-north east direction. In summer seasons the direction of the wind is mainly between north west and south west. The wind speed gradually increases from February and reaches the peak of 20.3 km/hr in July when the south west monsoon is most active. It again decreases from August and becomes as low as 6.7 km/hr.

Rainfall

The rainfall data of surendernagar, Chotila, Dasada, Dharangadhra, Halvad, Sayla, Lakhtar, Limbdi and Muli , Raingage stations published by the Water Resources Investigation Circle, Department of Irrigation, Gujarat have been utilized for this writ up. More than 90% of the rainfall occurs during the monsoon. Rainfall during the winter and summer months is negligible. The average annual rainfall of the district is 587.35 mm and in the 2012 it is 298 mm only which is less than 49 % of the average annual rainfall.

GEOMORPHOLOGY

The physiography aspect of the district varies in different talukas. The Wadhvan , Limbdi, Sayla, Lakhtar, Dasada talukas are mostly plain country, Dharangadhra and Halvad are gently undulating, while chotila and Muli are hilly. The district can be divided into following three main geomorphic units shown in figure no.2.

- (i) Almost the entire eastern half is a plain alluvial area with elevations varying from 5 m above mean sea level (amsl) to 40 m amsl.
- (ii) The north western part forms the gently undulating terrain comprising mainly the semi consolidated sedimentary rocks with elevations varying from 30 m to 144m amsl, except in the extreme north where there is sudden fall in elevation to 8 m amsl near Little Rann of Kachchh.
- (ii) The south western part forms rugged topography with many isolated hill ranges and hillocks of Deccan traps rising to heights ranging from 100 m to 3m amsl (Chotila hill).

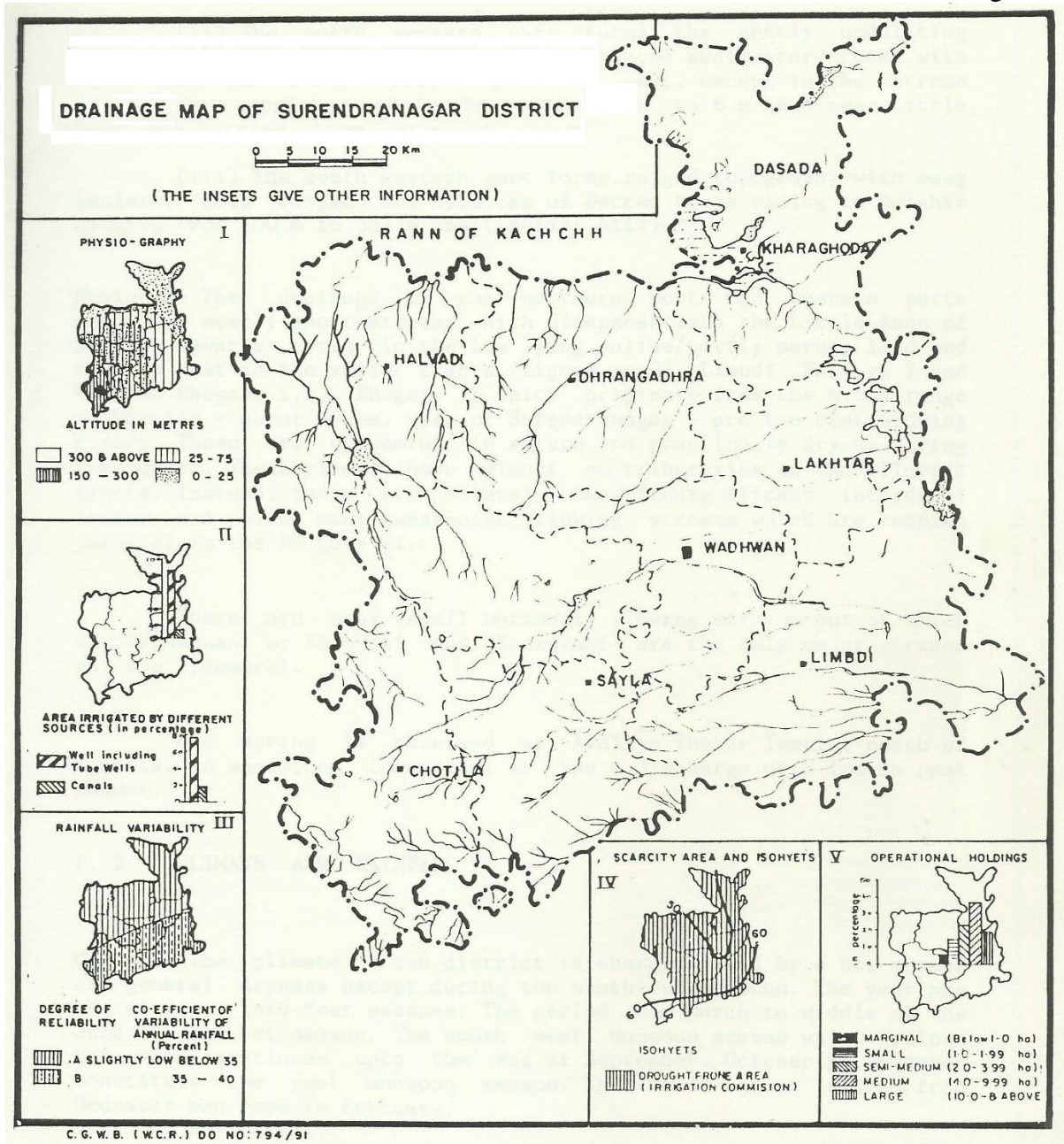
Drainage

The drainage in the northern most and eastern parts comprises mostly short streams which disappear into the Little Rann of Kachchh towards north in the low lying saline/partly marshy land and towards east in the sandy tracts (figure no.2).

Limbdi- Bhogava I and Wadhvan- Bhogava II i.e. , Bhogava II which originate from the hilly range of Chotilla about 64 km. west of Surendernagar are two east flowing rivers. These rivers have almost no tributaries in the alluvial tracts. Instead, here are several small / insignificant interdunal drains and also many west-east flowing streams which are running parallel to the Bhogava II.

There are many small northerly flowing streams out of which the Brahmanani or Bhambani and Kankavati are the only major streams and are ephemeral.

Fig - 2



One spring is observed at Avaliya Thakar temple, north of Chotila, in sandstone formation. It has a discharge of 8 lps in peak summer.

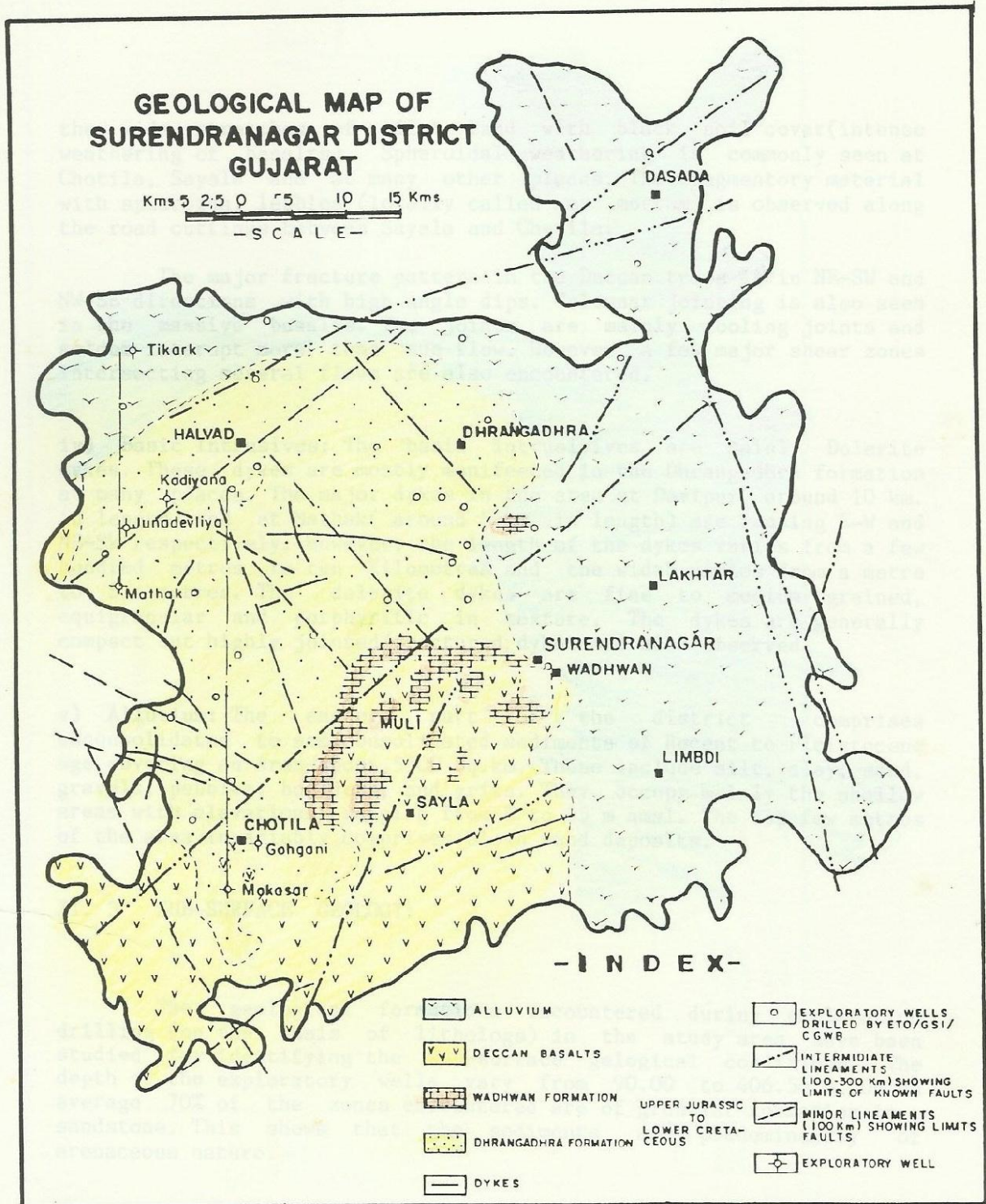
GEOLOGY

The general geological succession of the rock formations occurring in the Surendranagar district is as given below. The geology of the district is depicted in figure 5.1

Table -2 : Geological Succession in Surendranagar District, Gujarat

Age	Formation	Lithology
Pleistocene to Recent	Soil/ Alluvium	Black cotton soil and . Clay, sandy soil, clay, silt, brown sand and gravel.
--Unconformity--		
Upper Cretaceous to Lower Miocene	Deccan Traps and related intrusives	Basalts, volcanic tuff ,pocellanites, Dolerite dykes,& related volcanic rocks
Middle Cretaceous	Wadhwan Formations	Raddish brown to brick red coloured sandstone, fossiliferous cherty limestone and pebbly grit.
Upper Jurrassic to Cretaceous	Dharnghadra Formations	Medium to coarse grained sandstone, ferruginous, current bedded ,intercalated with red, grey and black shales and thin strigers of coal and carbonaceous matter.

FIG -3



Description of the rock units:

(i) Dhrangadhra Formations: Dhrangadhra formations constitute the oldest exposed rocks in Saurashtra region, covering an area of about 3000 Sq. Km and 400 m in thickness.

(ii) Wadhwan Formations: The Wadhwan sandstone are exposed around Wadhwan ,Surendernagar, near Doliya and along the Wadhwan Bhogava River covering an area about 300 Sq. Km. It is considered to be younger in age than Dhargandhra formation though apparently no clear demarcation of the boundary exists.

(iii) Deccan Traps: The basaltic lava flows unconfirmably overlying the Wadhwan and the Dhrangadhra formations are exposed in South eastern part of the district covering an area of about 2100 sq. km. The basalts are compact, fin grained to porphyritic and sparsely jointed. The major fracture pattern in the Deccan traps is in NE—SW and NW-SE directions with high angle dips. Columnar jointing is also seen in the massive basalts .The joints are mainly cooling joints and seldom interrupt more than flow. However a few major shear zones intersecting several flows are also encountered.

(iv)Basic Intrusives: The basic intrusives are mainly Dolerite dykes. These dykes are mostly manifested in the Dhrangadhra formation at many places. The dykes are generally compact but highly jointed/fractured dykes are also observed.

(v) Alluvium: The eastern part of the district comprises unconsolidated to semi consolidated sediments of Recent to Pleistocene age covering an area about 5500 Sq. Km. The top few meters of the area invariably comprises blown sand deposits.

HYDROGEOLOGY

Occurrence of Ground Water:

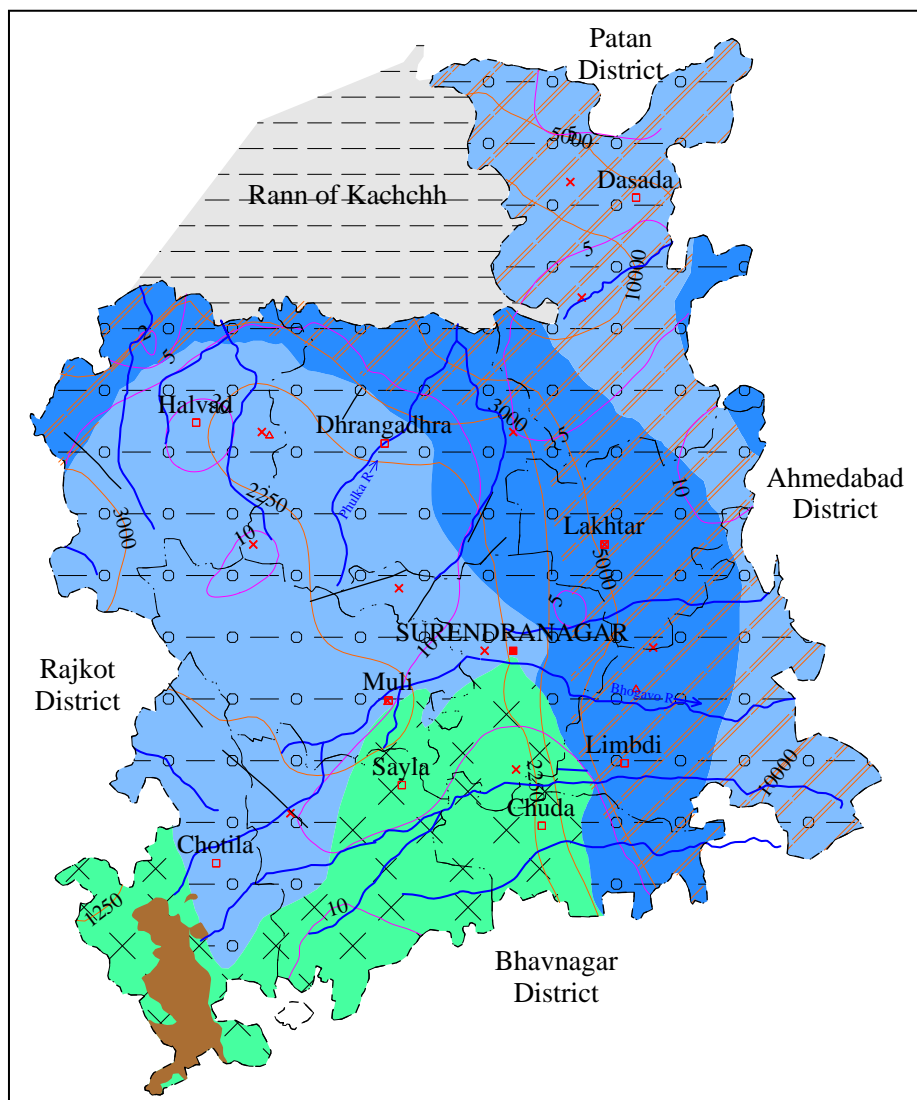
The groundwater in the area occurs phreatic, semi-confined and confined conditions. The ground water occurrence is controlled by topography, drainage, lithology and disposition of fractures and joints. The medium to coarse grained sandstone act as good repository of ground water. The main water bearing formations identified with in the area as follows:

(a) Ground Water in alluvium:

Most of the northern and eastern parts of the district, covering an area of about 5375 Sq. Km, comprise semi and unconsolidated formations. The ground water occurs under unconfined to confined conditions. The depth of the wells in this formation ranges between 2.00 and 30.00 m bgl. The depth of water levels range from 0.20 to 20.0 m bgl. The yield of shallow dugwells varies from 40 to 60 m³/day. The depth of the tube wells ranges from 60 to 300 m. The free flow discharge of these well ranges from 5 to 60 m³/day.

Hydrogeology Map of Surendranagar District

Fig – 4



Legend

	Wells Feasible	Rigs Suitable	Depth of Well (m)	Discharge (lpm)	Artificial Recharge Structure Suitable
Soft Rock Aquifer	Dug Well Tubewell	Manual Direct Rotary Reverse Rotary	15-30 100-300	200-300 600-1000	Percolation Tanks/ Ponds, Recharge Wells, Recharge Shaft
Soft Rock Aquifer	Dug Well Tubewell	Manual Direct Rotary Reverse Rotary	15-30 100-300	200-300 600-1200	Percolation Tanks/ Ponds, Recharge Wells, Recharge Shaft
Hard Rock Aquifer	Dug Well Borewell	Manual Down the Hole Hammer (DTH)	10-25 100-200	80-150 100-300	Percolation Tanks/ Ponds, Recharge Wells, Check Dams, Nalla Bunds.
Hilly Areas	Not Suitable				Check Dam, Nalla Bund, Gully Plug
Saline Areas	Not Suitable except localised fresh water pockets				

(b) Ground Water in Dhragadhra & Wadhwan Sandstone:

The Dhragadhra and Wadhwan sandstone are the most important water bearing formations in the district. They occupy about 2700 Sq.Km. area and situated in the central and north-western parts of the district.

The shallow dugwells in the depth range between 5 and 28m, tapping Upper Dhragadhra sandstone have water yielding capacity of 20 to 60 m³/day. The general range of water level in this aquifers is around 4 to 22 m.

A number of tubewells sited ,in Middle Dhrangadhra formations, down to depths ranging between 90 and 157 m are in operation. The yield of tubewells vary from 25 to 80 m³/day. The piezometric head in this aquifers vary from 10 to 30 mbgl.

The Wadhwan sandstone exposed in certain areas near streams and river channels or in the vicinity of surface water reservoirs are yielding fresh water in the order of 15 to 30 m³/day.

(c) Ground Water in Deccan Traps:

The Deccan basalts, unconformably overlying the Dhrangadhra and Wadhwan formations form aquifers in southern part of the district ,covering an area of 2100 Sq.Km.The movement of ground water is controlled by weathered zone, joints and fissures. The groundwater occurs under both water table and semi-confined conditions. The depth of the dug wells in the traps range from 6.0 to 28.0 m and depth to water level rests between 1.0 and 20 m bgl. The yield of shallow dugwells ranges from 20.0 to 50.0 m³/day. The depth of the boreholes tapping interflow zones range from 80 to 110 m, where in the piezometric head rests between 18 and 25 m bgl. As such the yield of the shallow/deep boreholes in the traps are ranging from 35 to 70 m³/day.

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). There are a total number of 57 monitoring stations in the district which include 48 open wells and 09 piezometers.

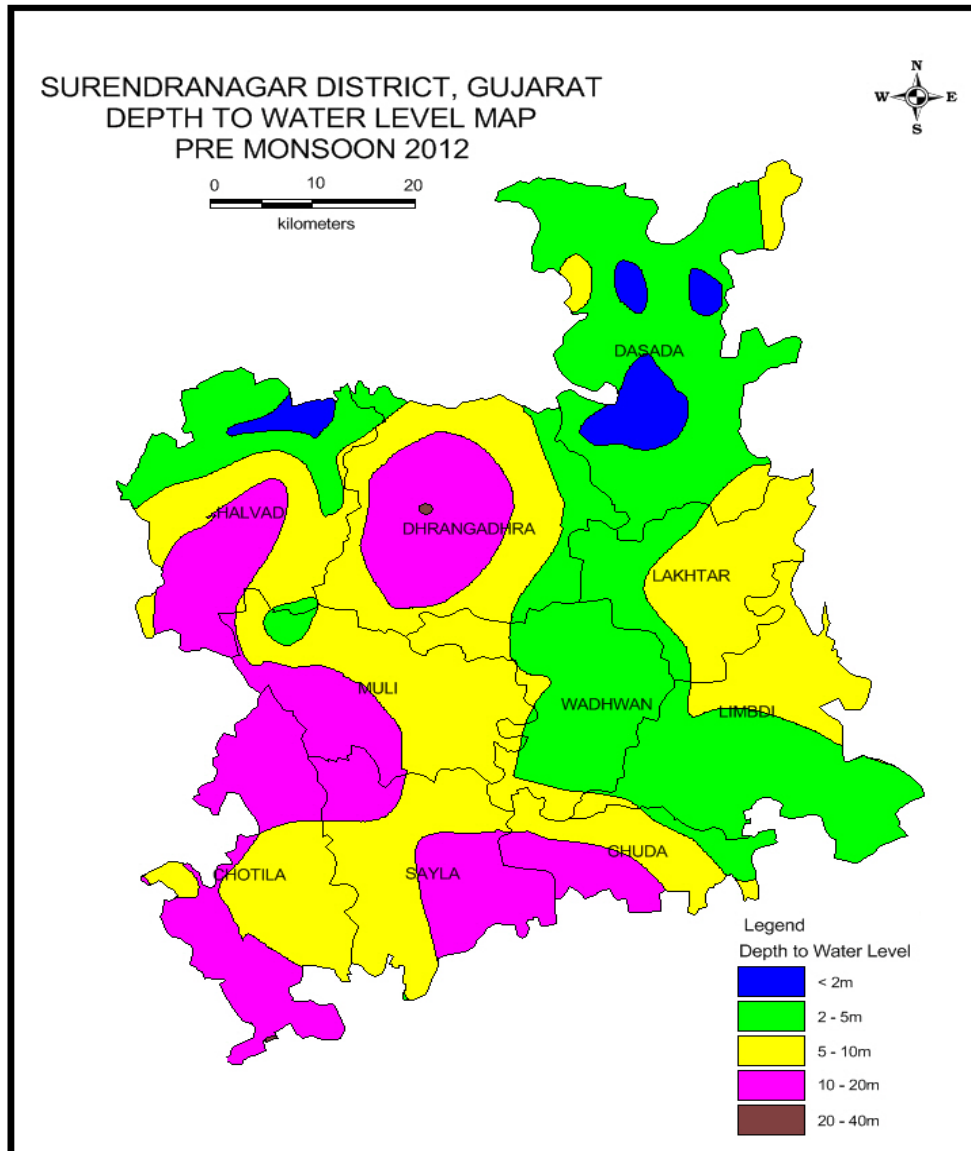
The water level data of May 2012 and November 2012 was used for preparing the depth to water level maps. The seasonal fluctuation in water levels was calculated between May and November 2012.

Depth to Water Level

Pre-monsoon period (May 2012)

The map depicting the depth to water level (Figure 5.2) has been prepared based on water level data for May 2012 collected from NHS observation wells of CGWB.

Fig - 5

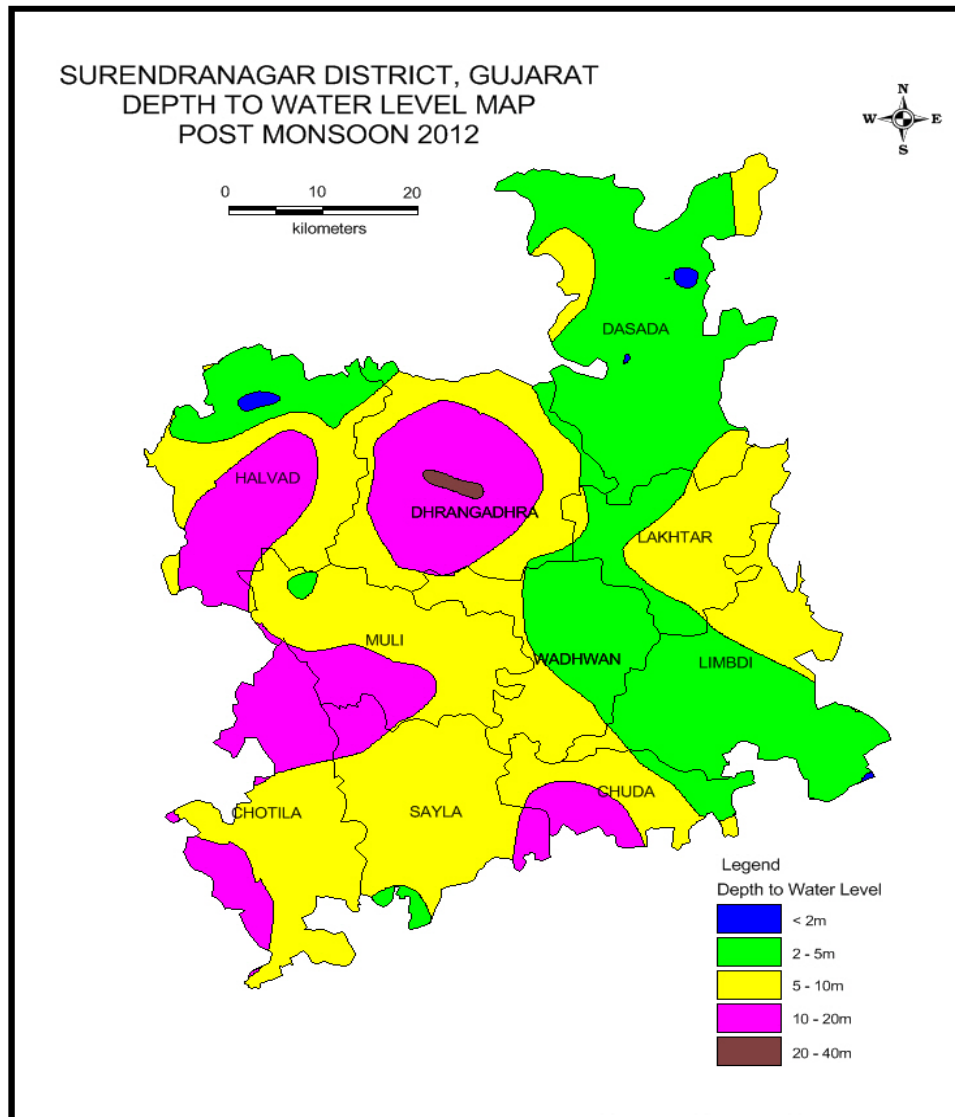


The depth to water level during pre-monsoon 2012 in the district ranges between less than 0.67m to 20.53m bgl. Nearly 50% area of the district is covered by the water level of less than 10m bgl. Water levels between 2m to 5m bgl are observed in restricted pockets in Dasda and Halvad Taluka adjoining the coastline and extending inland. Deeper water levels are observed in central part of the Dhangardha taluka of the district where water levels more 20m bgl are not seen in the district (Figure 5).

Post-monsoon period

The depth to water level in the district, in general, ranges between 0.85m to 20.85m bgl during November 2012. Water level ranges more than 10 m bgl are observed in more than 50% of the wells in the district and water levels ranging from 10m to 20m bgl are observed in the western and south western part of the district. Central part of the Dhangardha taluka has water level more than 20m bgl. Two isolated patches with water levels less than 2m bgl are seen. (Figure 6).

Fig - 6

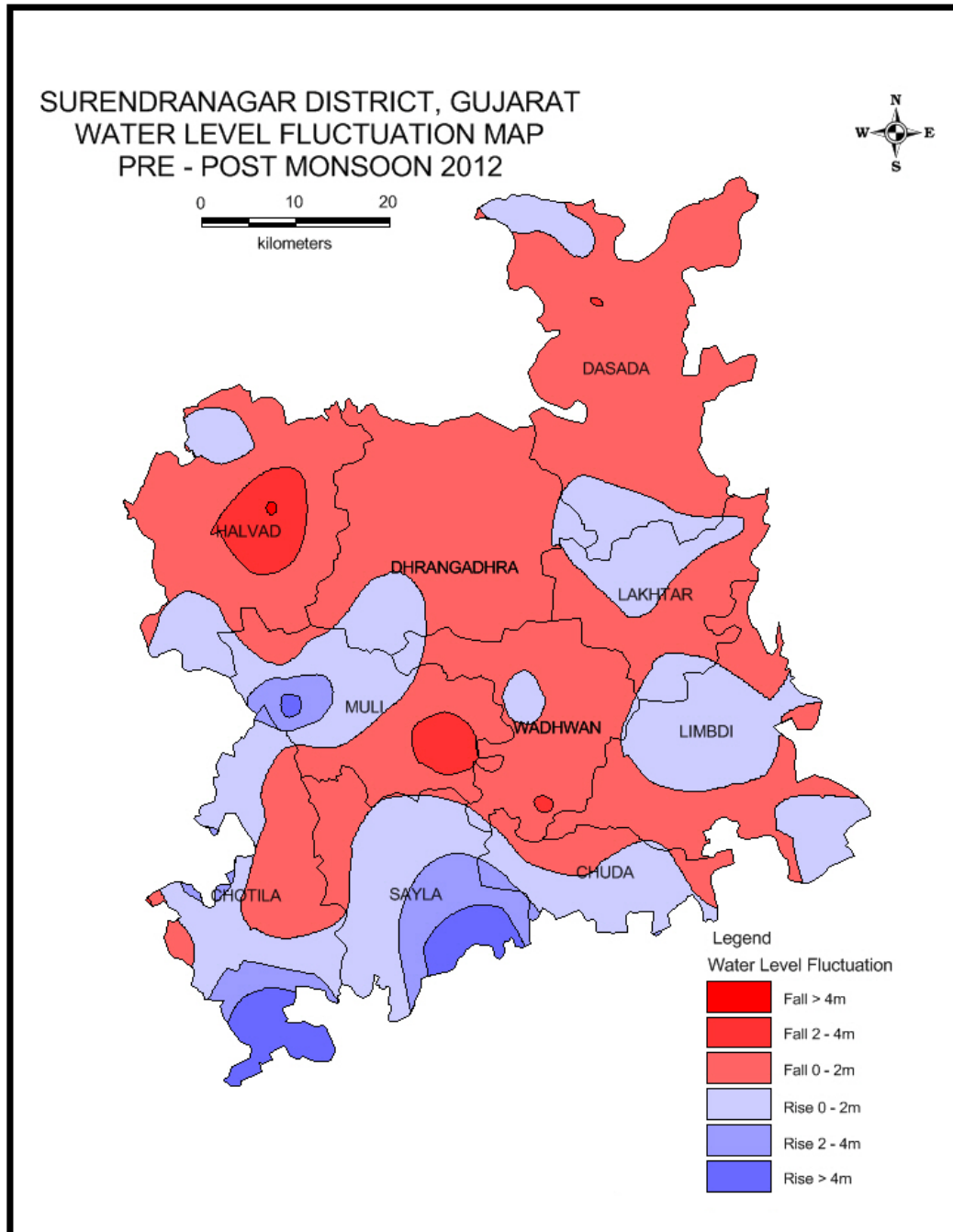


Rise and Fall In Water Levels

Rise and fall in water levels between May 2012 and November 2012 has been shown in Figure 7.

A perusal of the fluctuation map of Surendranagar district reveals that there is a general fall in water levels after the monsoon period. The fall is mostly found in Northern and Central part of the district. Marginal rise of less than 2 m is observed along the coast. Rise in water level mostly found in Southern and Western part of the districts.

Fig - 8



A perusal of the fluctuation map of Surendranagar district reveals that there is a general fall in water levels after the monsoon period. The fall is greater than 4 m in the inland parts and gradually decreases as on moves towards the coast. Marginal rise of less than 2 m is observed along the coast.

GROUND WATER RESOURCES

The Ground Water Resources and Irrigation Potential of the district were calculated as on March 2011 in collaboration with the Government of Gujarat using the methodology suggested by “Ground Water Estimation Committee (GEC-97). These resources were computed after reorganisation of the districts. The ground water resources for different Talukas of the district are given in the Table – III & IV.

The annual ground water recharge varies from 2122.60 ha m. in Limbdi Taluka to 15846.89 ha m. in Dhrangardha Taluka and total gross recharge for the district is 66302.55 ha m. The net available recharge, after leaving natural discharge for non monsoon period varies from 2016.47 (Limbdi) to 15054.54 ha m. (Dhrangardha), the recharge for district is 62987.43 ha m.

Ground Water Draft

The Table – IV also shows the Draft from Irrigation and Domestic/Industrial sources. The gross draft in the district is 37498.30 ha m. and varies from 720.40 ha m. (Limbdi) to 9178.90 ha m. (Dhrangardha).

Ground Water Balance for Irrigation

The irrigation potential available for future use for ground water has been computed leaving the ground water projected for allocation for the domestic and industrial requirements (Next 25 years) for all the talukas. The ground water available for future irrigation varies from 867.44 ha m. in Chuda Taluka to 5750.64 ha m. in Dhrangardha Taluka and total ground water balance for irrigation for the district is 24490.13 ha m.

Level of Ground Water Development & Stage

The level of Ground Water Development varies from 35.73% (Limbdi Taluka) to 65.38% (Chuda Taluka.) and overall Level of Development for the district is 59.53 %. The overall category of the district is also “Safe”

Table :-III Ground Water Resources Potentials as on 2011

S. No	Taluka	Annual Ground Water Recharge	Natural Discharge During Non-Monsoon	Net Annual Available Ground Water (3-4)	Existing Draft for Domestic and industrial Water Supply	Ground Water Draft for Irrigation	Existing Gross Draft For All Uses (6+7)
		(Ha m)	(Ha m)	(Ha m)	(Ha m)	(Ha m)	(Ha m)
1	2	3	4	5	6	7	8
1	Chotila	7583.68	379.18	7204.50	2122.60	106.13	2016.47
2	Chuda	2911.31	145.57	2765.74	9439.53	471.98	8967.55
3	Dasada	2617.99	130.90	2487.09	7248.66	362.43	6886.23
4	Dhrangadhra	15846.89	792.34	15054.54	4291.46	214.57	4076.88
5	Halvad	14240.44	712.02	13528.42	66302.55	3315.13	62987.43
6	Lakhtar			Saline			
7	Limbdi	2122.60	106.13	2016.47	601.40	119.00	720.40
8	Muli	9439.53	471.98	8967.55	5505.90	192.00	5697.90
9	Sayla	7248.66	362.43	6886.23	3738.80	306.00	4044.80
10	Wadhwan	4291.46	214.57	4076.88	1583.20	598.00	2181.20
	Total	66302.55	3315.13	62987.43	57633.79	3525.22	56538.57

Fig - 9

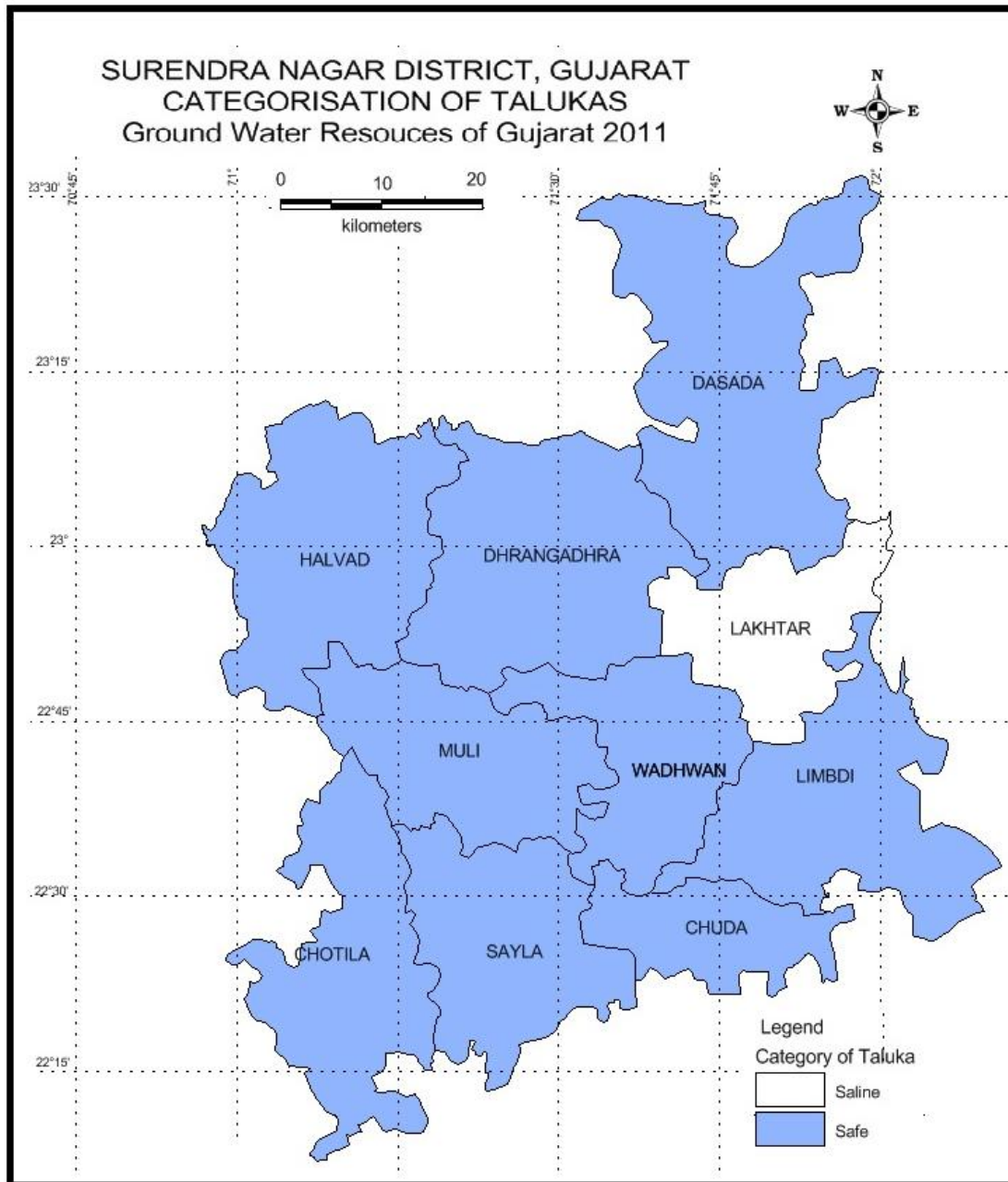


Table :- IV Stage of Ground Water Development

S. No.	Taluka	Net Annual Available Ground Water	Allocation for Domestic and Industrial Requirement (Next 25 Years)	Net Ground Water Availability for future Irrigation	Level of Ground Water Development	Stage of Development
		(Ha m)	(Ha m)	(Ha m)	(%)	
1	2	9	10	11	12	13
1	Chotila	7204.50	700.00	2475.00	63.18	Safe
2	Chuda	2765.74	357.00	867.44	65.38	Safe
3	Dasada	2487.09	171.00	1095.39	54.19	Safe
4	Dhrangadhra	15054.54	494.00	5750.64	60.97	Safe
5	Halvad	13528.42	585.00	5412.82	58.90	Safe
6	Lakhtar	Saline				
7	Limbdī	2016.47	160.00	1255.07	35.73	Safe
8	Muli	8967.55	257.00	3204.65	63.54	Safe
9	Sayla	6886.23	410.00	2737.43	58.74	Safe
10	Wadhwan	4076.88	802.00	1691.68	53.50	Safe
	Total	62987.43	3936.00	24490.13	59.53	Safe

HYDROCHEMISTRY

Quality of Shallow Ground Water

The quality of ground water in the shallow aquifer has been studied based on the chemical analysis of water samples collected from NHS during May 2012. The statistical analysis of the chemical data is presented in Table V.

Table 9.1 Statistical Analysis of Chemical Constituents
(Shallow Aquifer) May 1012

Constituents	Minimum	Maximum	Average
pH	7.15	8.27	7.85
EC (uS/cm)	495	44000	5996.15
TDS (mg/l)	331.65	29480.00	4017.42
CO ₃ (mg/l)	0	0	0
HCO ₃ (mg/l)	159	903	407.63
Cl (mg/l)	36	14768	1590.93
NO ₃ (mg/l)	3	450	61.33
SO ₄ (mg/l)	3	4280	477.48
F (mg/l)	0.3	4.2	1.28
Alkalinity (mg/l)	130	74	334.14
Ca (mg/l)	36	660	182.22
Mg (mg/l)	10	3721	253.19
TH (mg/l)	180	16950	1500.74
Na (mg/l)	25	4070	757.37
K (mg/l)	0.80	231	26.01
Fe (mg/l)	0.26	1.08	0.49

It is noticed that the ground water is relatively more saline in Northern (Coastal) part comprising alluvium and soft rocks. Occurrence of different chemical constituents in ground water is discussed below:

Total Dissolved Solid (TDS)

Total Dissolved Solid is an overall parameter indicating salinity of ground water. The Total Dissolved Solid of ground water varies from 495 mg/l (Visawadi) to about 44000 mg/l (Kharagodha).

Hydrogen Ion Concentration (pH)

The pH is an indicator of acidity of the water. The shallow ground water in the district is generally alkaline with pH more than 7. The value of pH ranges between 7.15 & 8.27 in the district.

Carbonate (CO₃) and Bicarbonate (HCO₃)

The shallow ground water in Surendranagar district does not contain any Carbonate. The Bicarbonate concentration in district varied between 159 mg/l at Kharagodha and 903 mg/l at Adriyana.

Chloride (Cl)

Chloride concentration in the shallow alluvial aquifer varies between 36 mg/l (Rajsitapur) and 14768 mg/l (Kharagodha). At 9 monitoring stations Chloride concentration was more than 1000 mg/l which is beyond maximum desirable limit of 1000 mg/l as per BIS norms.

Nitrate (NO₃)

Nitrate concentration in the ground water in district varies between 3 mg/l (Bajana) and 450 mg/l (Vithalgarh). There are nine stations where these values are more than the limits as per BIS drinking water standards (45 mg/l). These stations are Adriyana (130), Bamanbore (120), Miyani (135), Muli (100), Shiyani (125), Shukpar (205), Surendranagar (47) Vithalgar (450) and Soldi (50).

Sulphate (SO₄)

In the district area, the sulphate concentration varies from 3mg/l (Vanala) to 4279 mg/l (Kharagodha).

Fluoride (F)

Fluoride concentration in ground water varies between almost 0.3 at Rajsitapur and 4.2 mg/l at Muli. High concentration of fluoride exceeding maximum desirable limit of 1.5(mg/l) is found at Lakhatar (1.60), Mithak (2.1), Miani (2.60), Muli (4.20), Sarla (4.0), Sukhpar (1.55) and Soldi (2.60).

Calcium (Ca)

Calcium concentration in district varies between 36 mg/l (Visawadi) and 660 mg/l (Kharagodha).

Magnesium (Mg)

The Concentration of Magnesium in areas ranges from 10 mg/l (Rajsitapur) to 3721mg/l (Kharagodha).

Sodium (Na)

Sodium concentration in area varies between 25 mg/l (Dasada) and 4070 mg/l (Adriyana).

Potassium (K)

The concentration of Potassium in shallow ground water ranges from 0.8 mg/l (Muli) to 231 mg/l (Vithalgarh).

Iron (Fe)

The Iron concentration in the shallow ground water in the district ranging between 0.26(Halvad) to about 1.08 mg/l (Sukhapar).

Total Hardness as CaCO₃ (TH)

Total Hardness in ground water in alluvial areas range between 170 mg/l (Rajsitapur) and 16950 mg/l (Kharagodha).

Ground Water Management

Ground water occurs under phreatic, Semi-confined and Confined conditions in alluvium, Dhragandhra and Wadhwan sandstone. The artesian conditions are common in the eastern most part of the area in alluvium formation. However the groundwater occurs from unconfined to semi-confined conditions in the Deccan traps.

The depth of the shallow dug wells ranges from 2 to 30 m in alluvium whereas the bore wells pierced up to 300 m. In Dhragandhra and Wadhwan sandstone the depth of the shallow dug wells range from 5 to 28 m and whereas the depth of the tubewells range from 90 to 157 m. The depth of the dugwells in the traps range from 6 to 28 m and whereas the depth of the borewells range from 80 to 110 m. The depth to water level in unconfined aquifer varies from 1 to 20 m bgl in alluvium 4 to 22 m bgl in Sandstone and 1 to 20 m in Basalt formations. The depth to piezometric head of the dug-cum-bored wells and 10 to 30 m bgl in tube wells.

In Alluvium the yield of shallow dug wells as well as of tube wells varies from 40 to 60 m³/day. The free- flow discharge from the artesian well in Dhragandhra sandstone varies from 20 to 60 m³/day and whereas the yield of the tube wells ranges from 25 to 80 m³/day. Where in Wadhwan sandstone the yield ranges from 15 to 30 m³/day. In Deccan traps the yield ranges from 20 to 50 m³/day for shallow dug wells and 35 to 70 m³/day for bore wells.

The ground water quality in alluvium area is saline due to the presence of the Little Rann of Kachchh towards North and the saline tract/marshy area towards East. In Dhragandhra sandstone area, the quality of ground water is generally good above the marker horizon (Carbonaceous shale). In Wadhwan sandstone ,the ground water in Deccan trap area is generally portable whereas in the southern and south-western parts, the quality of ground water deteriorates below the basic sill.

Recommendations

1. For utilization of surplus ground water resources because the stage of ground water development is less than 60% it is recommended that the ground water development should be carried out in phased manner in the area where surface water irrigation is not possible.
2. The surface water resources should be effectively diverted to the ground water reservoirs by constructing artificial recharge structures ie.,check dams, ponds, channel, injection wells and sub- surface dykes.
3. By Participation from the villagers participatory monitoring of their wells can be done and the villagers were educated in such a way that can made their own ground water management plan.
4. Irrigation through drip and other water conservation schemes where partially funded by the Government.
5. Large diameter dug wells in stream beds should be desilted once in 3 to 5 years, especially during scarcity/relief works.

