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Technical Report Series

DISTRICT GROUNDWATER BROCHURE
PORBANDAR DISTRICT

GUJARAT

Compiled

By

Babu Nair, Scientist-D

Government of India

Ministry of Water Resources

Central Ground Water Board

West Central Region

Ahmedabad

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PORBANDAR DISTRICT AT A GLANCE

SL No.	Items	Statistics	
1	**General Information**		
	i) Geographical Area (Sq Km)	**2316**	
	ii) Administrative Divisions **Number of Taluka** **Number of Villages (Inhabited)**	 **3** **182 (182)**	
	iii) Populations (As per 2011 census)	**585449**	
	iv) Normal Annual Rainfall (mm)	**660**	
2.	**GEOMORPHOLOGY**		
	Major Physiographic Units	**Hills, Plains**	
	Major Drainages	**Principal river is Bhadar**	
3.	**LAND USE (Sq Km)**		
	a) Forest area **b) Net area sown** **c) Cultivable area**	**24400 ha** **119400 ha** **119400 ha**	
4.	**MAJOR SOIL TYPES**	Medium black and shallow black soil	
5.	**AREA UNDER PRINCIPAL FOODGRAIN CROPS**	**Area in '000 ha** **Groundnut 91.9** **Gram 14.1**	
6.	**IRRIGATION BY DIFFERENT SOURCES (Areas and numbers of structures) (Dir of Agri, Guj State, Gandhinagar)**	**No.**	**Area (Sq Km)**
	Dugwells	**22307**	**19.5 '000 ha**
	Canals	**-**	**0.08 '000 ha**
	Net Irrigated area ('000 ha)	**19.5**	
	Gross Irrigated area ('000 ha)	**19.5**	
7.	**NUMBERS OF GROUND WATER MONITORING WELLS OF CGWB (As on 31-08-2013)** **No of Dug Wells** **No of Piezometers**	 **26** **4**	
8.	**PREDOMINANT GEOLOGICAL FORMATIONS**		
	Predominant geological formation is Deccan traps. Others are Gaj Beds, Miliolitic Limestone, Alluvium		
9.	**HYDROGEOLOGY**		
	➢ **Major Water Bearing Formation**: Weathered , jointed & Fractured Basalts, Gaj Beds, Miliolitic Limestone, Alluvium **Depth to water level during 2013 - Range** **Pre-monsoon (May13) 2 (min) to 20 (max) m bgl** **Post-monsoon (Nov 2013) 5 (min) to 20 (max) m bgl**		

11	**GROUND WATER QUALITY**	**Potable**
12.	**DYNAMIC GROUND WATER RESOURCES (2012)- in mcm**	
	Total Annual Ground Water Recharge	**20742.61**
	Net Annual Ground Water Draft	**14113.40**
	Projected Demand for Domestic and industrial Uses upto 2025	**1618.00**
	Stage of Ground Water Development	**71.62% (Semi Critical)**
16	**MAJOR GROUND WATER PROBLEMS AND ISSUES**	
	i) Declining Groundwater levels/ Piezometric heads in user aquifers ii) Increasing depth of tubewells iii) Increasing instances of high fluoride iv) Groundwater contamination due to unplanned construction and poor technical design of tube wells v) Awareness amongst villagers on water conservation techniques vi) Demand supply management	

DISTRICT GROUNDWATER BROCHURE
PORBANDAR DISTRICT

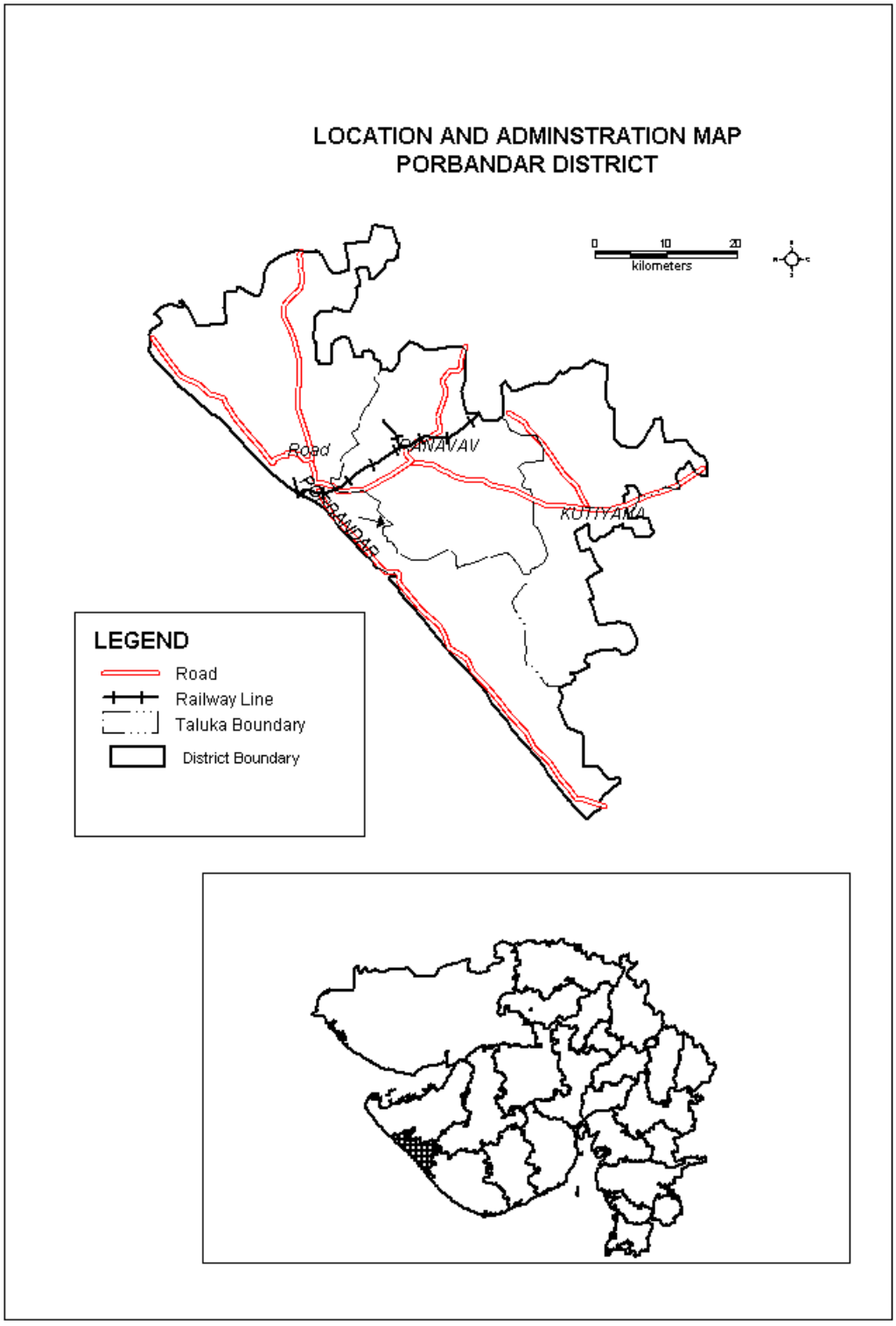
GUJARAT

INTRODUCTION

District Porbandar, situated in the south-western part of the Saurashtra Peninsula is one of the most important districts of the Saurashtra in Gujarat State. The district derives its name from Porbandar city, the birth place of Mahatama Gandhi, the father of the Nation. This district has been carved out from the district Junagadh during 1998. The district is primarily agrarian with major occupation being agriculture and animal husbandry. The present report deals with the salient features of the hydrogeological conditions in the district and also outlines the ground water development vis-à-vis the water requirement for irrigation, domestic and industrial needs.

Location, Extent and Accessibility

Porbandar district has a geographical area of about 2316 sq. km (Census 2011). It lies between Latitude 20°45' & 22°05' North and Longitude 69°20' & 70°10' East and falls in Survey of India Toposheet Nos 41G/5, 41G/9, 41G/10, 41G/13, 41G/14, 41G/15, 41K/1, 41K/2 and 41K/3. It is bounded by Jamnagar district in the north, Junagadh district in the east and south-east, Arabian sea in the south. The district comprises of three talukas, namely, Porbandar, Kutiyana and Rana Vav. The administrative divisions of the district have been reconstituted in 1998 by bifurcating Junagadh district. Figure 1 shows the administrative divisions of the Porbandar District. There are 182 villages and 4 towns in the district. The district has fairly good network of roads and all the Taluka headquarters are connected with all weather roads. The district headquarter, Porbandar, is connected with Ahmedabad through a National Highway-8C. The district is also connected by broad gauge railway line.



Demography

The population of the district according to the census of 2011 is 585,449. There was change of 9.06 percent in the population compared to population as per 2001 Census. The initial provisional data released by census India 2011, shows that the population density of Porbandar district for 2011 is 253 people per sq. km. In 2001, Porbandar district density was at 234 people per sq. km.

Average literacy rate of Porbandar in 2011 is 75.78 compared to 68.62 of 2001. Gender wise, male and female literacy are 83.45 and 67.75 respectively. For 2001 census, same figures stood at 78.36 and 58.42 in Porbandar District. Total literate in Porbandar District are 393,678 of which male and female were 221,621 and 172,057 respectively. The Sex Ratio in Porbandar is 950 per 1000 male in 2011 Census compared to 2001 census figure of 946. The average national sex ratio in India is 940 as per latest reports of Census 2011 Directorate. In 2011 census, child sex ratio is 903 girls per 1000 boys compared to figure of 898 girls per 1000 boys of 2001 census data.

Out of the total Porbandar population for 2011 census, 48.80 percent lives in urban regions of district. In total 285,674 people lives in urban areas of which males are 146,949 and females are 138,725. Sex Ratio in urban region of Porbandar district is 944 as per 2011 census data. The total rural population in Porbandar District is 299,775 (51.20%) and the male and female population of rural areas is 153,260 and 146,515 respectively. In rural areas of Porbandar district, sex ratio is 956 females per 1000 males.

SOIL

The soils of Porbandar district may be classified into two main categories:

a. Shallow to Medium black soils
b. Deep black soil (Ghed area)
c. Coastal alluvial soils

Shallow to Medium black soils are very widespread and occurs in 75 % of the area and are found almost in all the talukas. They are more productive and are rich in lime, magnesia and alumina raid poor in phosphorous, nitrogen and organic matters. They can retain considerable moisture and are much suitable for agricultural.

Coastal alluvial soils are found in coastal parts of Porbandar Taluka where the soils are less productive as they are saline.

Land Use, Cropping Pattern and Irrigation

Land Use

The economy of Porbandar district is mainly agriculture based with more than 75% of area under cultivation. The Land use pattern of the district is given below:

Land Use Pattern in Porbandar district

S No.	Land Particulars	Total Area ('000ha.)	Area %
	Geographical area	229.5	
	Cultivated area	119.4	
1	Forest area	24.4	
	Land under non- agricultural use	15.4	

	Permanent pastures	25.5	
	Cultivable wasteland	4.7	
2	Land under Misc. Tree crops and grooves	-	
3	Barren & un-cultivable Land	18.6	
6	Current fallows	21.5	
7	Net sown Area	119.4	
8	Area sown more than once	6.0	
9	Gross cropped Area	125.4	

(Source; (Source; Statistical Handbook)

Cropping Pattern

Major crops being grown in the district are Groundnut, Gram, Cotton, Wheat, Bajri and Jowar, , Pulses and Sugarcane. Groundnut is the most important crop of the district with about 66% of total cultivated area under this crop. This has given rise to development of oil mills-producing and processing groundnut oil. Second most important crop in the district is Gram grown on about 17% of the cultivated land. The calendar being adopted for major crops in the district is as given in table.

Crop Calendar

S. No	Crop	Months of Sowing	Months of Harvesting
1.	Bajri	June – July	August – September
2.	Jowar	June – July	September – October
3.	Wheat	October – November	February – March
4.	Groundnut	June – July	September – October
5.	Cotton	June – July	November – December
6.	Sugarcane	October-November	October-November

Source: Census Handbook 1991

Irrigation

The net irrigated area in Porbandat district is 19500 ha. 99500 ha area is rainfed. Open dugwells are the primary sources of irrigation in the district(14.3% of the total irrigated area). A very small area is irrigated by canals and tanks/ponds (0.007%). As per minor Irrigation Census (2000-2001) the total of 22307 dug wells were being used for irrigation. There are 22307 lifting device out which 9770 are electric motors,12202 are Diesel pumps , 39 are wind mills and 24 are man/ animal operating animal. In addition it also include 272 other devices. There are 872 shallow tube wells and 776 deep tube wells being used in the district for irrigation. There are a total number of 103 tanks/ponds, of these none is

being used for irrigation. There are 8 canals is the district totalling 16 km length.

HYDROMETEOROLGY

The district has the meteorological station in the district town Porbandar. There are several rain gauge stations being monitored by different state government agencies. The Water Resources Investigation Circle (WRI) under the department of Narmada Water Resources, Govt. of Gujarat, monitors most of the rain gauges stations and also collects and compiles the rainfall data collected by different agencies.
Long term mean monthly climatological parameters (IMD 1951-80) like maximum and minimum temperatures, relative humidity, wind speed and rainfall are given in Table and depicted in Figure.

IMD Climatological Data

Month	Max Temp	Min Temp	Relative Humidity	Wind Speed	PET	Rainfall
	(°C)	(°C)	(%)	(km/h)	(mm/d)	(mm)
January	28.8	13.7	50.0	9.4	4.8	1.3
February	30.1	15.4	54.5	10.3	5.4	1.6
March	32.6	18.9	59.5	12.4	6.4	3.4
April	33.4	22.2	67.5	15.1	6.6	0.0
May	33.0	25.7	74.0	20.2	6.5	0.4
June	32.5	27.4	78.0	21.6	5.7	128.5
July	30.9	26.6	82.0	20.3	4.4	245.0
August	30.1	25.7	83.5	17.3	4.0	149.5
September	30.9	24.6	78.5	13.1	4.5	71.3
October	34.3	22.1	66.0	9.0	5.2	27.6
November	33.6	19.3	53.0	7.8	5.1	9.9
December	30.5	15.6	47.5	8.5	4.8	1.4
Total	-	-	-	-	-	639.9
Average	31.7	21.4	66.2	165.1	5.3	-

General climate of the district is sub-tropical and is characterised by three well-defined seasons, i.e. summer - from April to June, monsoon - from July to September, and winter - from October to March.

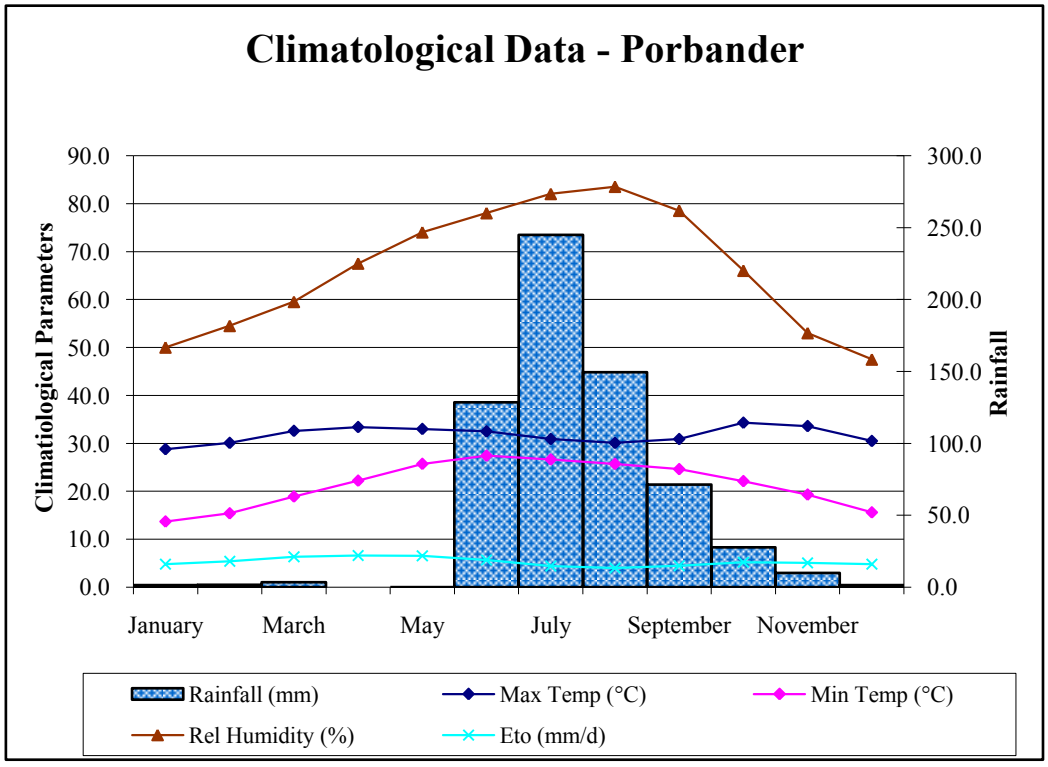
Temperature

Mean maximum daily temperatures range from 29 to 34°C and mean minimum daily temperatures from 14 to 27 °C. April and May are the hottest months when the temperatures may exceed 33°C. The winters are generally pleasant with minimum temperatures around 13.7°C, however, at times temperatures may drop further.

Humidity
The relative humidity is highest in the early morning, which reduces as the day advances. In the monsoon season the humidity is high reaching up to 83%, during winters it may drop down to 47%.

Wind
Light winds, mainly from southern and south-western directions blow during summer. In winter light winds blow from north-west and north-east. During monsoon however, moderate to heavy wind prevail from south and south-western directions. Mean wind speed ranges from 8 km/h during winters to more than 20 km/h during summer and monsoon.

Potential Evapo-transpiration
Potential Evapo-Transpiration (PET) has been calculated from other climatological data using Penman method. The PET is maximum during summer months. It ranges from 4.0 mm/d during August to 6.6 mm/d during April. The average monthly PET is about 5.3 mm/d.



Climatological Data – Porbandar IMD station

Rainfall
Long term normal rainfall (1943-80) for the Porbandar IMD station is about 639.9 mm.

GEOMORPHOLOGY

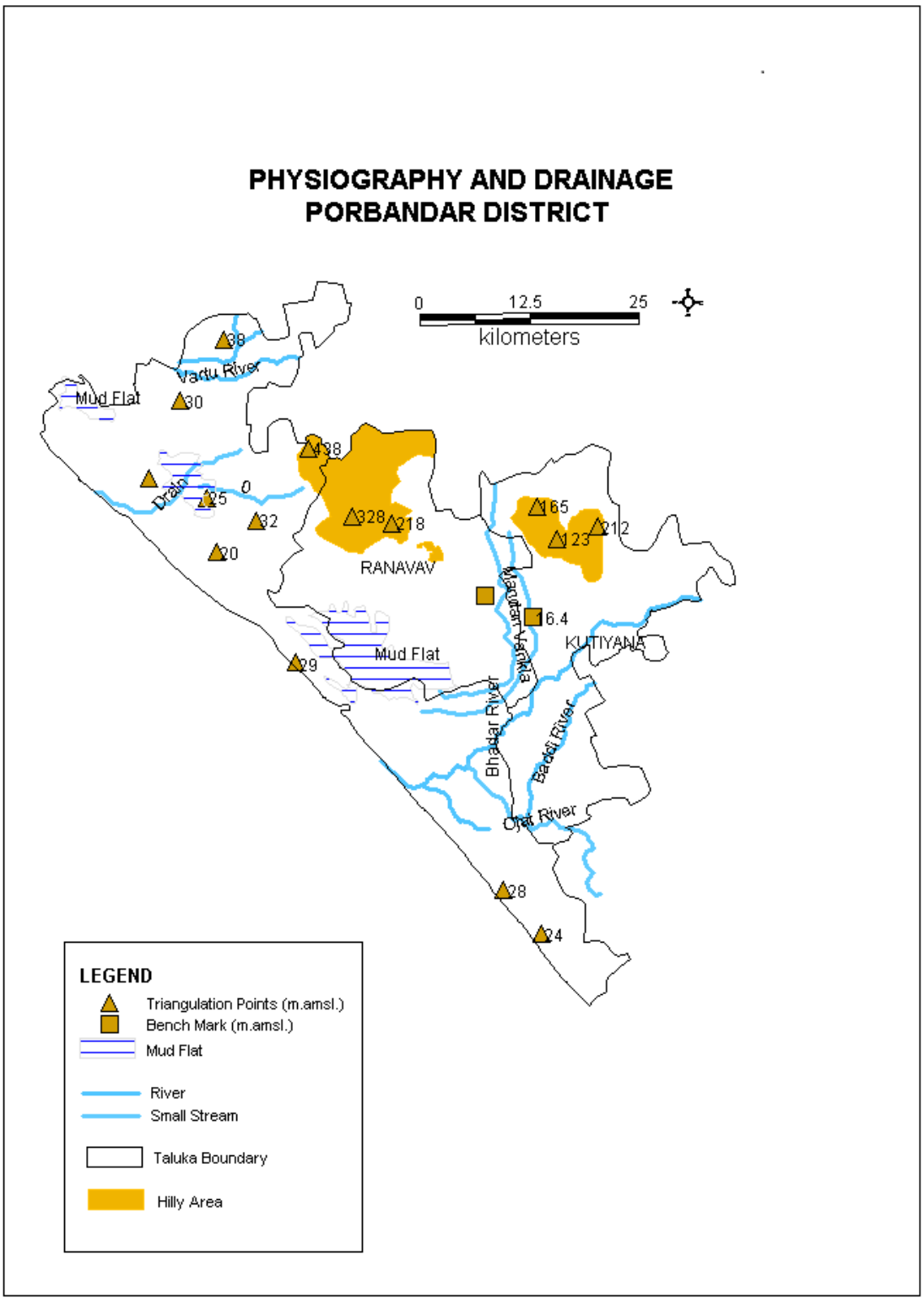
Porbandar district is situated in the south-western part of Saurashtra peninsula. The highest elevation of about 328 m amsl is seen in the Barda

Hills. The district is mainly plain except for a few isolated small hill ranges. The northern part comprising Ranavav Taluka is characterised by undulating terrain with isolated hillocks. The master slope in the district in the northern, central and southern parts is towards south, and south-east respectively.

Drainage

The drainage in the district is controlled by the topography and the lineaments. The major river draining the district in the north and eastern part is Bhadar River. The other rivers draining the eastern part of the district are Bobadi River, Minsar River and Kalinder nadi. These rivers flow from north to south except the Ojat river which meets Bhadar River and flows from south west to north east in direction.

The rivers draining the area in northern part of the district are Kaman river and Vartu River. The river has flow direction from east to west.



GEOLOGY

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

Table : Geological Succession in Porbandar District, Gujarat

Era	Age	Formation	Lithology
Quaternary	Recent to Sub-Recent	Surface Soil/ Alluvium	Wind blown sand and black cotton soil at surface. Clay, silt, sand, boulders, etc, at depth.
	Pleisto-cene	Miliolite Limestone	Sandy limestone with shells of Milolina
--Unconformity--			
Tertiary - Mesozoic	Lower Miocene	Gaj Beds	Limestone, Marl and Gypseous Clay
	--Unconformity--		
	Eocene	Supratrappean	Sandstone, sand, conglomerate and erosnal products of basalt (laterite)
	--Unconformity--		
	Lower Eocene to Upper Cretace ous	Deccan trap	Basalt as stratified lava flows comprising amygdalolidal basalt, fine grained porphyritic basalt and basaltic/doleritic dykes.

Major geological formations occurring in the district are Deccan Trap lava flow, supra-trappeans, Gaj Beds, Miliolite limestone and recent unconsolidated deposits.

The Alluvium

About 63% of the area of the district is covered by alluvium. It has a thickness ranging from few meters to about 50 m. The alluvium which primarily rests of the basalt mainly comprise of the sand and clays along with the carbonate nodules (kankar) and weathered pieces of basalt. Weathering of basalt has also given rise to black cotton soils and generally it is difficult to distinguish between in situ weathering product of basalt and alluvium.

Deccan Trap

About 32%, part of district is covered by Deccan Trap lava flows. The trap rock is mostly basalt and dolerite, though trachytes are also found at places. The Deccan Trap occurs in the form of lava flows with thickness of individual flows ranging from few meters to more than 30 m. Each individual lava flow can be sub divided into three distinct units -

(1) greyish red clay and reddish clayey vesicular basalt, (2) vesicular and amygdaloidal basalt and (3) jointed and massive basalt. The top of the individual flow is often marked by greyish red to reddish brown clayey material. The thickness of this horizon varies from few centimetres to few metres, at places clayey horizons up to 20 m thickness have also been observed. These horizons are in situ product of weathering and baking of basalt representing a time gap between two successive lava flows. The Vesicular/Amygdaloidal horizons range in thickness from few meters to as much as 10 m. Vesicles were formed due to escape of gas bubbles from the upper part of the flow during cooling of lava. The vesicles are generally filled with secondary minerals like calcite, zeolites and quartz. The lower most horizon of each flow is represented by jointed and massive basalt. This horizon is fine to medium grained, compact dark greenish to grey in colour and forms 60 to 70% of the flow unit. The upper part of this horizon is often jointed and fractured. At places, the massive basalt is underlain by thin pipe amygdaloidal unit.

The lava flows are generally horizontal in disposition. However, at places, they are found to be dipping by about 7° towards SSE and SSW direction. The Deccan Trap lava flows have been intruded by a large number of basic and acidic dykes. The basic dykes are generally composed of basalt and dolerite, whereas, the acidic dykes are generally composed of rhyolite and felsite. The doleritic dykes are generally porphyritic in nature. In Saurashtra Region, the dykes generally 2 to 5m thick, but dykes of as much as 250m thickness are also encountered. These dykes appear to be structurally controlled are generally oriented in three main directions, i.e., ENE-WSW, E-W and NE-SW.

In Deccan Traps, the joints are also quite well developed at places. Columnar jointing is also quite common. Principal joint directions observed are N-S, E-W, NE-SW, and NW-SE. The faults are generally not seen within the basalt out crops, however, there are indications of several faults lying below the overlying formations.

Supra-trappean

These are minor formations comprising laterite, sandstone and conglomerate occurring as patches exposed along the nalla cuttings in the coastal plains. These formations are not very thick, less than 20 m.

Gaj Beds

Gaj beds occur along the coastal areas. It covers nearly 3% of area in the district These are marine deposited during Lower Miocene Period. These beds comprise highly fossiliferous dirty yellow limestone, grit, sand, silt and clay. The top member of this formation is the ochreous earthy limestone, easily distinguishable from the overlying Miliolite limestone.

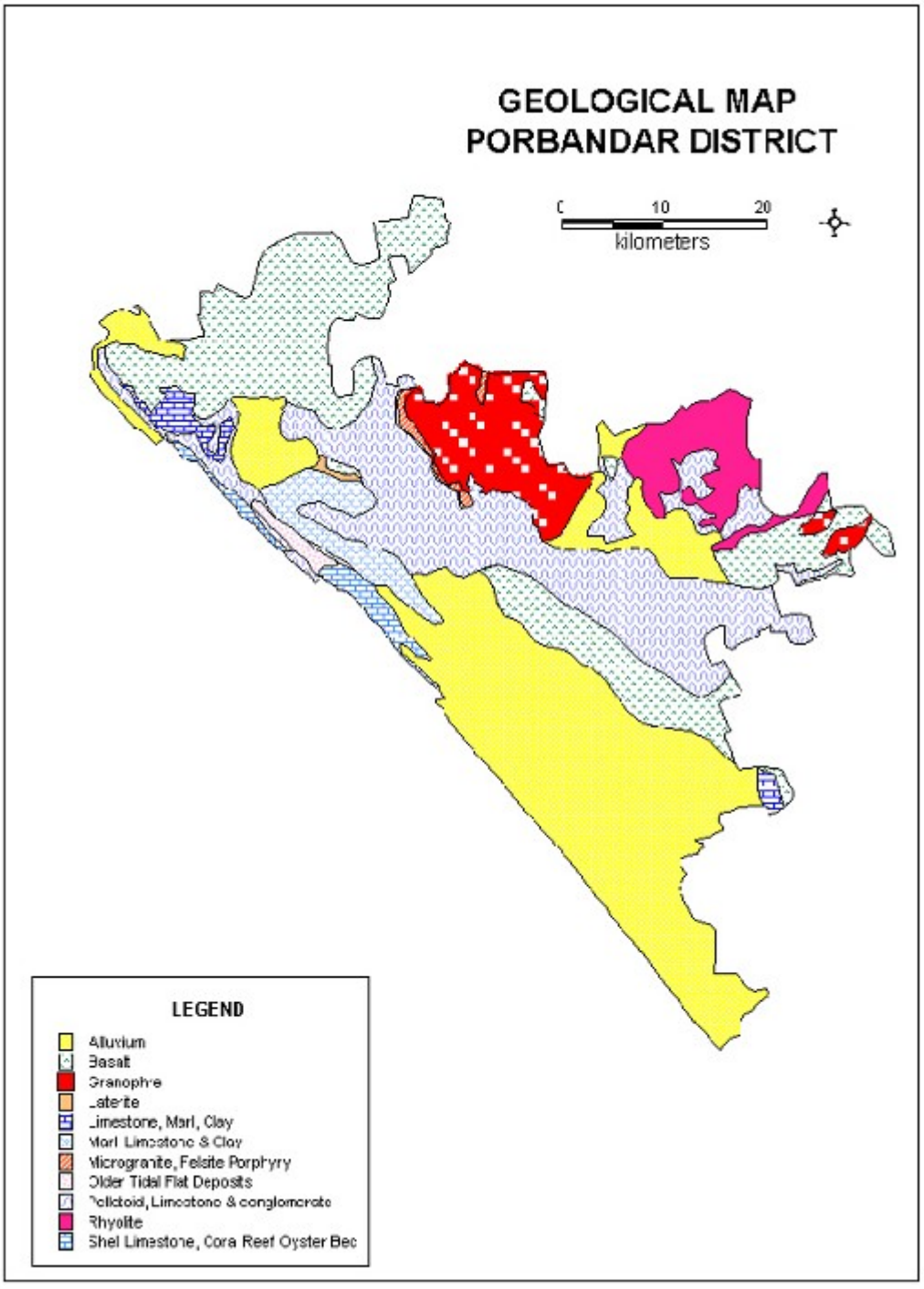
Miliolite

The Miliolite occur as whitish, buff coloured, current bedded limestone in the form of coastal ridge This Limestone primarily comprise of broken shells of foraminifer-Milioline around which calcite grains have been formed. However, this is not a pure limestone and thin horizons of

sandstone, grit and conglomerate are also found within Miliolites. The Miliolite Limestone is karstified at places. The Miliolote are thought to be wind blown deposits and are also found occurring along the hill slopes further inland.

Recent to Sub-Recent Formations

The recent and sub-recent formations in the district are sand dunes, coastal & beach sands, tidal mud flats, coral reefs occurring in the coastal areas and fresh water alluvium occurring mainly along the rivers and streams.



HYDROGEOLOGY

Aquifer System

All the geological formations occurring in the district form aquifer; however, the Deccan Trap are the most extensive aquifers in the district. Alluvium forms a potential but limited aquifer in the central part of the district, whereas, the Gaj beds and Miliolite form limited aquifer in the coastal parts of the district. The Hydrogeological Map of the district is given as Plate- I.

Deccan Trap

Deccan trap basalt occupies a major part of the district and forms the most extensive aquifer system. It generally forms a poor aquifer due to compactness and poor primary porosity. However, the upper weathered parts, which at places are up to 30 m thick, form good aquifer in the district. At deeper levels, the secondary porosity developed as a result of tectonic activities, in the form of joints, and fractures, shear zones, form repository of ground water at many places. Amygdaloidal horizons within basalt also form potential aquifers at places. The dykes, both basaltic and doleritic, play an important role in occurrence and movement of ground water. At places, the dykes are highly weathered and form potential aquifers. At other places where the dykes are more compact, they act as subsurface barrier for the ground water flow and the wells constructed upstream of these dykes have good yields.

The ground water in basalt occurs under phreatic to confined conditions. The ground water is generally tapped through dug wells varying in depth from 5 to 30 m. At places, dug-cum-bored wells are also constructed by drilling bores below the bottom of dug wells. The yield of dug wells and dug-cum-bored wells in basalt generally range from 100 to 500 m3/day. During Rabi (post monsoon) season these wells sustain intermittent pumping of 15 minutes to 12 hours, however, during summer, the yield of these wells is considerably diminished. The vesicular & amygdaloidal horizons within basalt at places may have yields of up to 1000 m3/day.

Supratrappean and Gaj Beds

The Supratrappean formations generally form limited aquifers with wells ranging in depth from 5 to 20 m. Gaj beds form potential but limited aquifers at places, particularly in the coastal areas. The wells tapping this aquifer generally range in depth from 5 to 15 m.

Miliolitic Limestone

Miliolites form potential aquifers in the coastal areas. The depth of the well in this formation range between 4 and 45 m bgl, however, most of the wells are less than 25 m deep. The yields range between 15 and 800 m3/day. At places, very high yields are observed due to karstic nature of this formation.

Alluvium

The alluvium forms very potential aquifer, particularly in the central part. The wells in alluvium range in depth from 4 to 50 m bgl. Drilling of horizontal bores in the wells to increase the yields is quite common. Such horizontal bores generally have 2.5 to 5 cm of diameter and extend laterally to 10 to 15 m. The yield of wells range between 10 and 820 m3/day.

Aquifer Parameters

The aquifer parameters data available with GWRDC from the exploration carried out in different parts of the district was taken into the consideration.

In Alluvial areas the exploratory wells were constructed in depth range of 13 to 80 m bgl. The Specific Capacity ranged from 4.7 to 180 lpm/m and the Transmissivity from 2 to 1900 m2/day.

In Hard Rock areas of Porbandar district, the wells were drilled in depth range of 30 to 200 m bgl. Discharge of the wells ranged from less than 1 (Lakhapadar) to about 1000 lpm (Dharai Vavdi). The Specific Capacity ranged from 0.01 to about 650 lpm/m. The Transmissivity varied between 0.02 and 688 m^2/d.

Behaviour of Water Levels

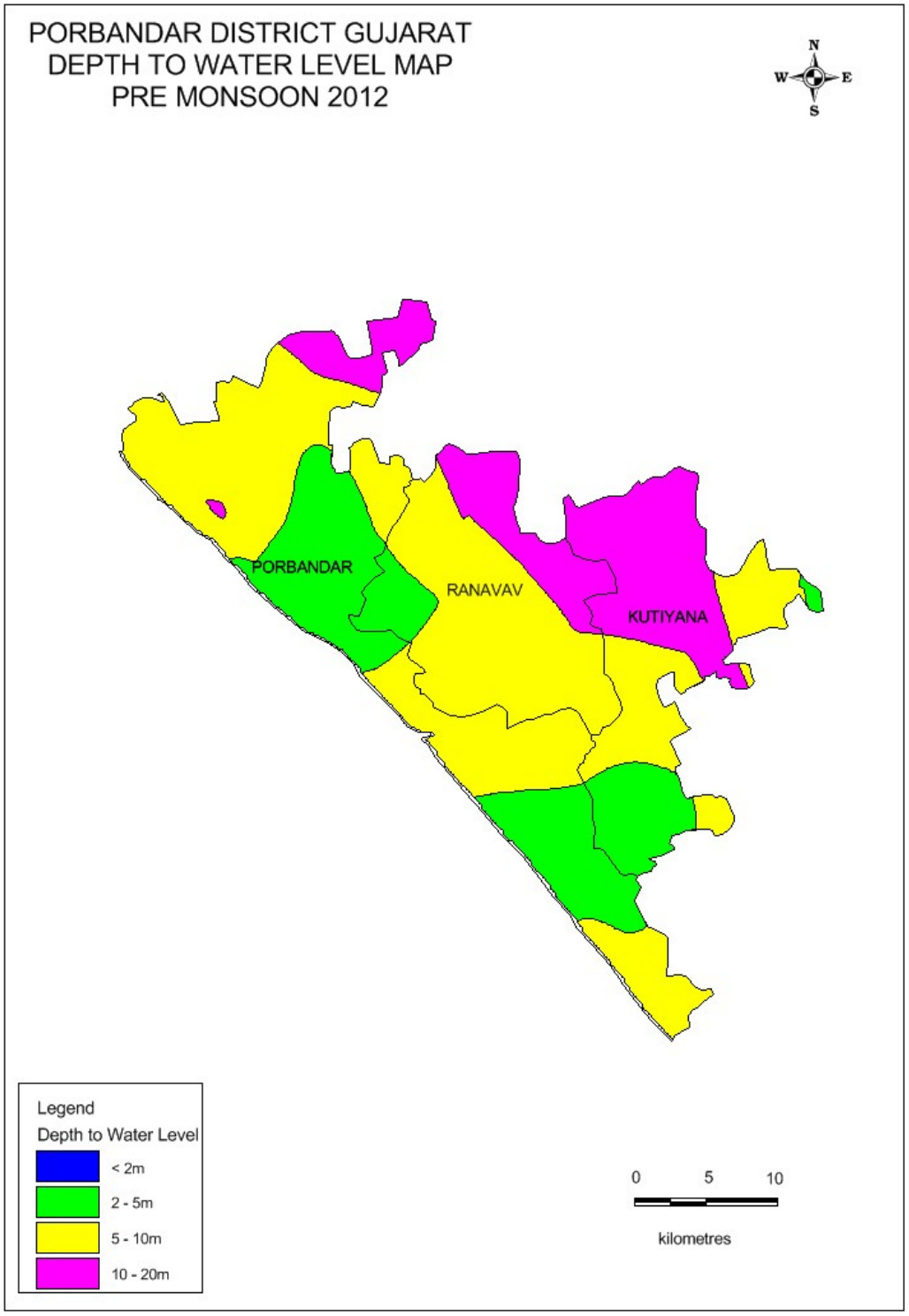
The behaviour of water levels was studied based on the water level data collected from the National Network of Hydrograph Stations (NNHS). There are a total number of 18 monitoring stations in the district which include 16 open wells and 02 piezometers. Gujarat Water Resources Development Corporation (GWRDC) has established 27 Observation Wells.

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)

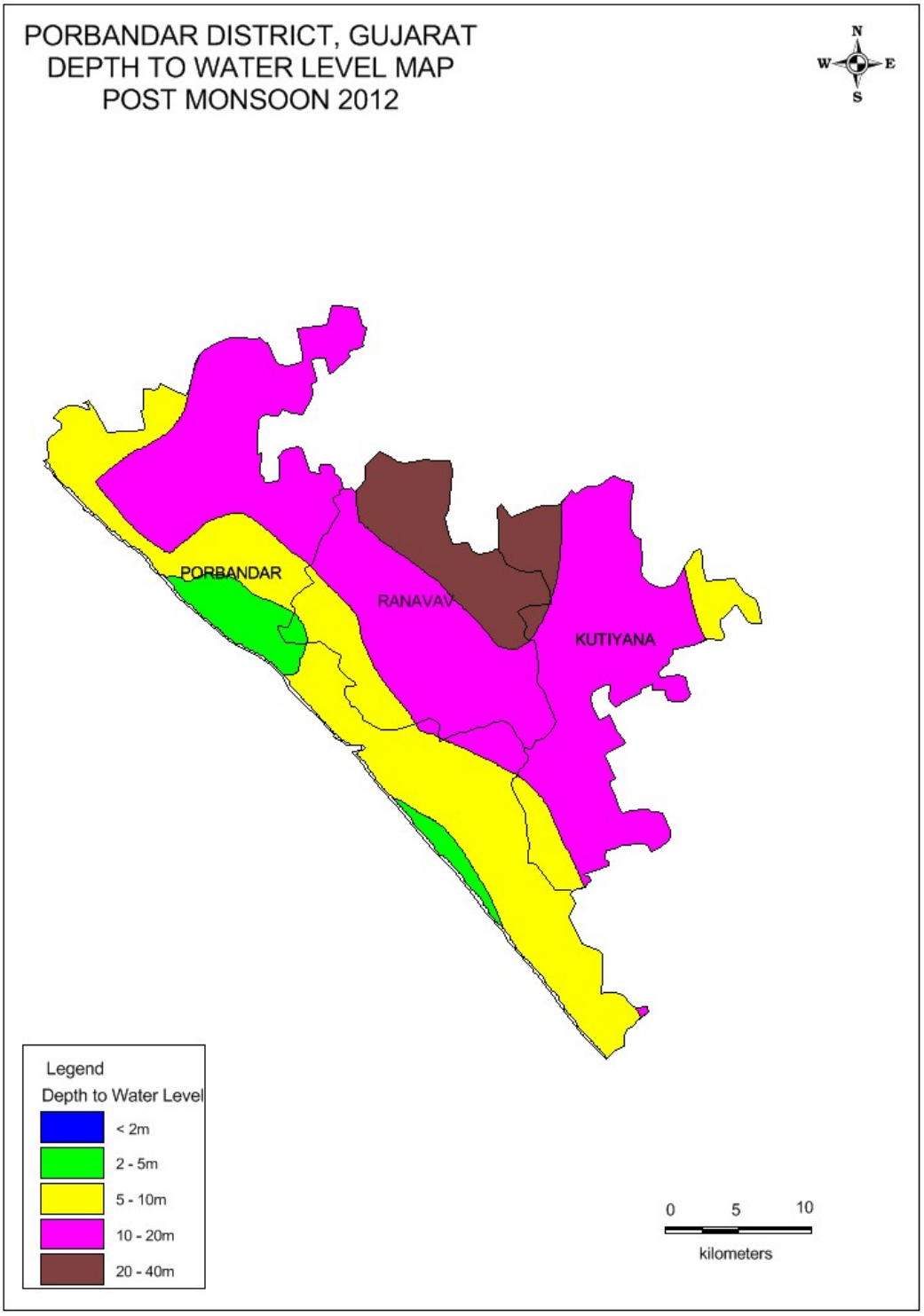
The map depicting the depth to water level (Figure 5.2) has been prepared based on water level data for May 2012 collected from NHS observation wells of CGWB.



The depth to water level during pre-monsoon 2012 in the district ranges between less than 2m to nearly 20m bgl. Nearly 50% area of the district is covered by the water level of less than 5m to 10m bgl. Water levels between 2m to 5m bgl are observed in restricted pockets in Porbandar Taluka adjoining the coastline and extending inland. Deeper water levels are observed in the northern and eastern part of the district. Water levels exceeding 20m bgl are not seen in the district (Figure 5.2).

Post-monsoon period

The depth to water level in the district, in general, ranges between 5m to nearly 20m bgl during November 2012. Water level ranges between 5 m and 10 m bgl are observed along the western central part of the district and water levels ranging from 10m to 20m bgl are observed along the eastern central part of the district. Two isolated patches with water levels

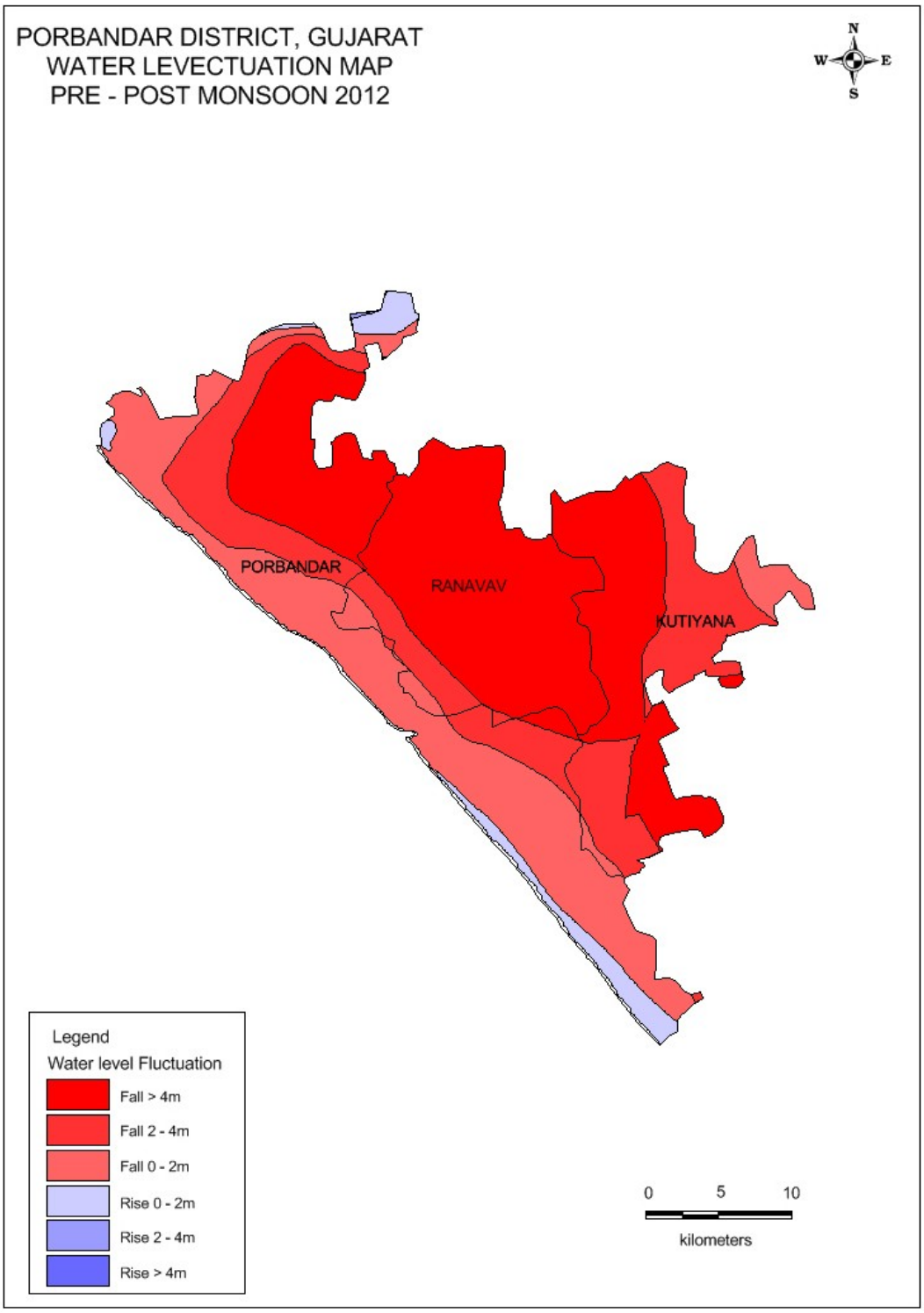


between 2-5m bgl are seen along the western coastline. Deeper water

levels between 20-40 m bgl are observed along the north eastern parts of Ranavav taluka and adjoining parts of north western Kutiyana taluka (Figure 5.3).

Rise And Fall In Water Levels

Rise and fall in water levels between May 2012 and November 2012 has been shown in Figure 5.4.



A perusal of the fluctuation map of Porbandar 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 estimated during 2011 in collaboration with the Government of Gujarat using the methodology suggested by "Ground Water Estimation Committee (GEC-97)". The ground water resources for different Talukas of the district are given in the Table 8.1 below.

Ground Water Recharge and Ground water draft

The Total Annual Ground Water Recharge in the district is 20742.61 mcm and ranges from 6676.23 mcm (Porbandar) to 7092.36 mcm(RanaVav).

The Total Annual Ground Water Draft in the district is 14113.40 mcm and ranges from 4188.20 mcm (Kutiyana) to 5643.20 mcm (Porbandar).

Level of Development & Ground Water Balance

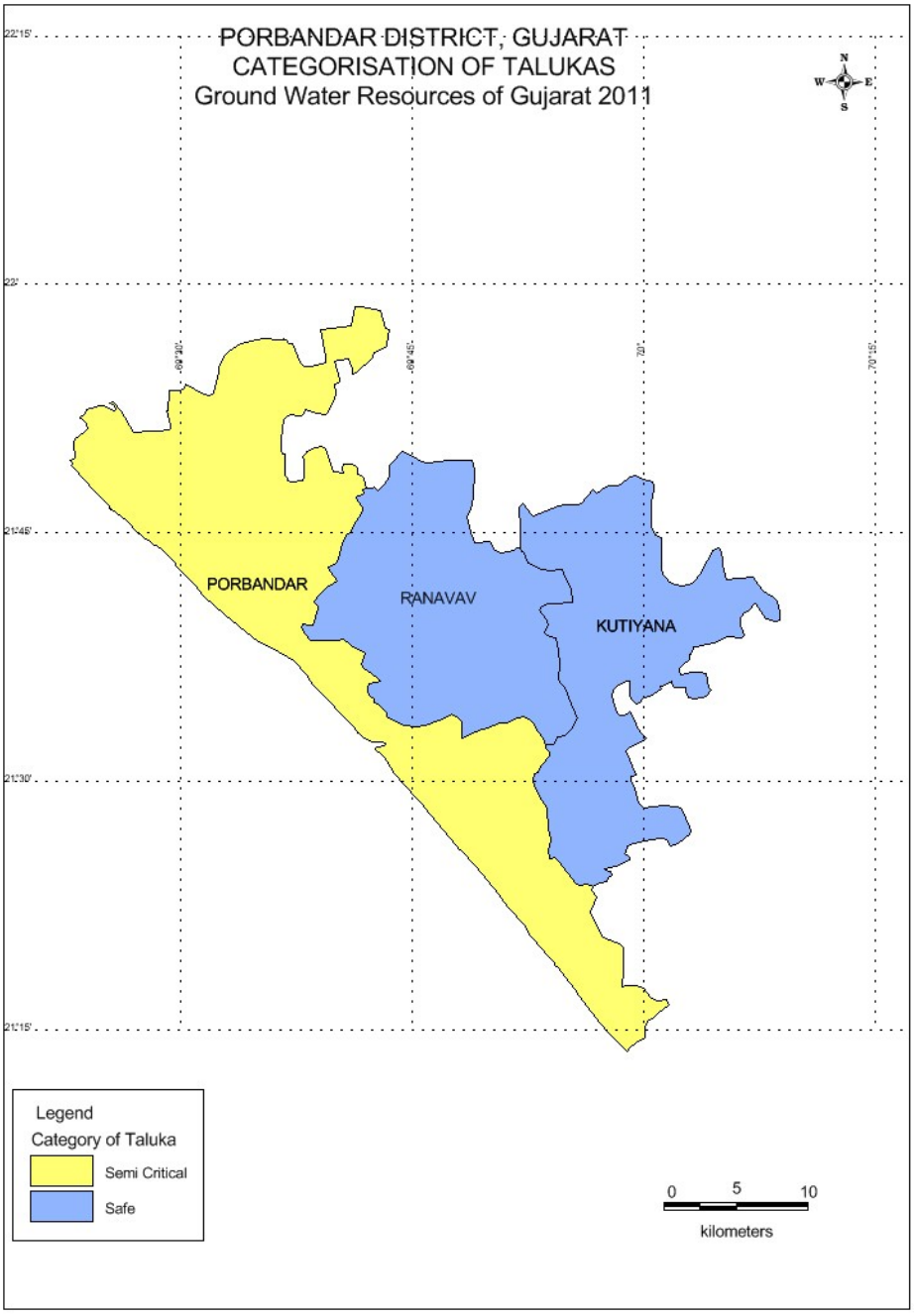
The Ground Water Availability for future irrigation after projecting the demand for domestic and industrial use up to 2025 in the district varies from 82 MCM (Porbandar) to 2375 MCM (Ranavav). The Total Ground Water Availability for the district is 4809 MCM. The Stage of ground Water development in the district ranges from 63.22% (Kutiyana) to 88.98% (Porbandar), overall Level of Development for the district is 71.62%. Kutiyana and Ranava have been categorised as "SAFE" where as Porbandar taluka is categorised as "Semi-critical". The overall category of the district is also "Semi-Critical".

Ground Water Resources As on 2011 (in mcm)

S. No.	Taluka	Total Annual Ground water Recharge	Annual Ground Water Draft			Projected Demand for Dom. & Ind. Use up to 2025	Ground Water Availability for future Irr.
			Irrigation	Dom. & Ind.	Total Draft		
1	Kutiyana	6974.02	3937.20	251.00	4188.20	336.00	2352.12
2	Porbandar	6676.23	5294.20	349.00	5643.20	966.00	82.22
3	RanaWav	7092.36	4047.00	235.00	4282.00	316.00	2374.74
	Total	**20742.61**	**13278.40**	**835.00**	**14113.40**	**1618.00**	**4809.08**

Ground Water Resources And Development

S. No.	Taluka	Level of Ground Water Development (%)	Category
1	Kutiyana	63.22	SAFE
2	Porbandar	88.98	Semi-Critical
3	Ranavav	63.55	SAFE
	Total	**71.62**	**Semi-Critical**



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 9.1.

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

Constituents	Minimum	Maximum	Average
pH	7.43	8.03	7.67
EC (uS/cm)	1195	10900	3776.07
TDS (mg/l)	801	7303	2529.97
CO3 (mg/l)	0	0	0.00
HCO3 (mg/l)	220	561	375.71
Cl (mg/l)	163	3368	909.71
NO3 (mg/l)	24	270	68.57
SO4 (mg/l)	63	710	281.28
F (mg/l)	0	1.50	0.85
Alkalinity (mg/l)	180	460	307.96
Ca (mg/l)	48	960	237.43
Mg (mg/l)	38	300	114.14
TH (mg/l)	380	3650	1069.29
Na (mg/l)	102	980	408.86
K (mg/l)	1	64.0	20.79
Fe (mg/l)	0	2.7	0.35

It is noticed that the ground water is relatively more saline in southern (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 801 mg/l (Ranavav) to about 7303 mg/l (Miyani).

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 7.43 & 8.03 in the district.

Carbonate (CO3) and Bicarbonate (HCO3)

The shallow ground water in Porbandar district does not contain any Carbonate. The Bicarbonate concentration in district varied between 220 mg/l at Miyani and 561 mg/l at Khambodar.

Chloride (Cl)

Chloride concentration in the shallow alluvial aquifer varies between 163 mg/l (Ranavav) and 3368 mg/l (Miyani). At 5 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 24 mg/l (Pata) and 270 mg/l (Palkhada). There are six stations where these values are more than the limits as per BIS drinking water standards (45 mg/l). These stations are Bhavpura (125), Miyani (60), Kutiyana (100), Palkhada (270), Kandorna (90) and Ranavav 47.

Sulphate (SO4)
In the district area, the sulphate concentration varies from 63mg/l (Porbandar) to 710 mg/l (Miyani).

Fluoride (F)
Fluoride concentration in ground water varies between almost 0.3 at Adwana and 1.5 mg/l at Kutiyana. High concentration of fluoride exceeding maximum desirable limit of 1(mg/l) is found at Hanumangadh (1.05), Kutiyana (1.5), Oddar (1.40), Khambodar (1.33), Navibandar (1.12) and Ranavav (1.06).

Calcium (Ca)
Calcium concentration in district varies between 48 mg/l (Navibandar) and 960 mg/l (Miyani). The concentration of calcium is more than maximum permissible limits of 200 mg/l (as per BIS norms) at Miyani (960), Palkhada (540), Bhavpura (500), Kandorna (244), and Kutiyana (260).

Magnesium (Mg)
The Concentration of Magnesium in areas ranges from 38 mg/l (Ranavav) to 300mg/l (Miyani). The concentration of magnesium is more than maximum permissible limits of 100 mg/l (as per BIS norms) is recorded at Kutiyana (144), Miyani (300), Odar (252), Kandorna (103) and Bhavpura (204).

Sodium (Na)
Sodium concentration in area varies between 102 mg/l (Ranavav) and 980 mg/l (Miyani).

Potassium (K)
The concentration of Potassium in shallow ground water ranges from 0.8 mg/l (Adwana) to 64.0 mg/l (Kuchhadi).

Iron (Fe)
The Iron concentration in the shallow ground water in the district is generally low, ranging between 0.07 to about 2.7 mg/l which is within the permissible limit.

Total Hardness as CaCO3 (TH)
Total Hardness in ground water in alluvial areas range between 380 mg/l (Naivbandar) and 3650 mg/l (Miyani). At places especially along the coast

a very hard ground water is observed. The total hardness more than maximum permissible limits of 600 mg/l (as per BIS norms) is recorded at Kutiyana (1250) , Miyani (3650), Odar (1450), Palkhanda (1700), and Bhavpur (2100), Kandorna (1040) and Pata (650).

GROUND WATER DEVELOPMENT AND MANAGEMENT

Construction of Wells

In major parts of the district, particularly the areas underlain by Deccan trap basalt, the ground water is usually exploited through medium to large diameter dug wells. These dug wells are generally shallow, about 30 m deep. However, at several places the boreholes are drilled below the bottom of the dug wells to make the Dug Cum Bored wells (DCB). These boreholes are generally drilled vertically below the bottom of the wells do a depth of about 20 to 30 m. At places, however, the horizontal boreholes are also drilled, generally along the fractures. Both these method considerably increase the yields of the wells. The drilling of such boreholes is carried out using a tripod mounted drilling system where the drilling bit is driven by a compressor.

Ground Water Management

There is not much scope for further development of ground water resources in major parts of the district. Thus, there is an urgent need for augmentations and judicious management of ground water resources.

In the entire hard rock terrain, scope exists for augmenting the ground water resources through the artificial recharge. Large scale artificial recharge schemes may not be feasible due to non availability of prolific aquifers and paucity of source water. However, small and cost effective measures like contour bunding, nalla plugging, small check dams may be quite effective in increasing the ground water recharge. Ground water recharge through dug wells is also be feasible and may be adopted at local level. This is a cost effective method to enhance the availability of ground water and improve the ground water quality.

CONCLUSION AND RECOMMENDATIONS

Conclusions

Porbandar district has a geographical area of about 2316 sq. km. It lies between Latitude 20°45’ & 22°05’ North and Longitude 69°20’ & 70°10’ East and falls in Survey of India Toposheet Nos 41G/5, 41G/9, 41G/10, 41G/13, 41G/14, 41G/15, 41K/1, 41K/2 and 41K/3. It is bounded by Jamnagar district in the north, Junagadh district in the east and south-east, Arabian sea in the south.

The population of the district according to the census of 2011 is 585,449. Of these 299,775 persons live in rural areas, whereas, 285,674 persons live in urban areas.

The economy of Porbandar district is mainly agriculture based with more than 75% of area under cultivation. Major crops being grown in the district are Groundnut, Gram, Cotton, Wheat, Bajri and Jowar, , Pulses and Sugarcane. Groundnut is the most important crop of the district with about 77% of total cultivated area under this crop. Second most important crop in the district is Gram grown on about 12% of the cultivated land.

General climate of the district is sub-tropical and is characterised by three well-defined seasons, i.e. summer - from April to June, monsoon - from July to September, and winter - from October to March. Mean maximum daily temperatures range from 29 to 34°C and mean minimum daily temperatures from 14 to 27 °C. April and May are the hottest months. The winters are generally pleasant with minimum temperatures around 13.7°C. The relative humidity ranges from 83% during the monsoon season to 47% during winter. Mean wind speed ranges from 8 km/h during winters to more than 20 km/d during summer and monsoon. Potential Evapo-transpiration (PET) is maximum during summer months. It ranges from 4.0 mm/d during August to 6.6 mm/d during April. The average monthly PET is about 5.3 mm/d.

The surface elevation in the Porbandar district rises to an elevation of about 328 m amsl. in the Barda Hills. Then it is mainly plain except for a few isolated small hill ranges. The northern part comprising Ranavav Taluka is characterised by undulating terrain with isolated hillocks. The master slope of the district in the northern and central parts is towards south and southern part it is toward southeast.

The drainage in the district is controlled by the topography and the lineaments. The major river draining the district in the north and eastern part is Bhadar River. The other rivers draining the eastern part of the district are Bobadi river Minsar river and Kalinder nadi. These rivers flow from north to south in direction except the Ojat river which meets Bhadar river flows from south west to north east in direction. The river draining the area in north of the district are Kaman river and Vartu river. The river flow from east to west in direction.

Geologically, the formations in the district range from Cretaceous to Recent. The basement is formed by Deccan trap which is mostly composed basalt and dolerite, though, trachytes are also found at places. The Deccan Trap occurs in the form of lava flows with thickness of individual flows ranging from few meters to more than 30 m. Other geological formations occurring in the district are Supra Trappeans, Gaj Beds, Miliolite and Alluvium. Supra-trappean are minor formations comprising laterite, sandstone and conglomerate occurring as patches exposed along the nalla cuttings in the coastal plains. The Gaj beds which occur along the coastal areas are marine formations deposited during Lower Miocene Period. These beds comprise highly fossiliferous dirty yellow limestone, grit, sand, silt and clay. The Miliolite occur as whitish, buff coloured, current bedded limestone in the form of coastal

ridge This Limestone primarily comprise of broken shells of foraminifer-Milioline around which calcite grains have been formed. The recent and sub-recent formations in the district are sand dunes, coastal & beach sands, tidal mud flats, coral reefs occurring in the coastal areas and fresh water alluvium occurring mainly along the rivers and steams.

During the month of May-2012, the depth to water level during pre-monsoon 2012 in the district ranges between less than 2m to nearly 20m bgl. Nearly 50% area of the district is covered by the water level of less than 5m to 10m bgl. Water levels between 2m to 5m bgl are observed in restricted pockets in Porbandar Taluka adjoining the coastline and extending inland. Deeper water levels are observed in the northern and eastern part of the district. Water levels exceeding 20m bgl are not seen in the district.

During November 2012 the depth to water level in the district ranges between 5m to nearly 20m bgl. Water level ranges between 5 m and 10 m bgl are observed along the western central part of the district and water levels ranging from 10m to 20m bgl are observed along the eastern central part of the district. Two isolated patches with water levels between 2-5m bgl are seen along the western coastline. Deeper water levels between 20-40 m bgl are observed along the north eastern parts of Ranavav taluka and adjoining parts of north western Kutiyana talukas.

The fluctuation map of Porbandar 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.

The Total Annual Ground Water Recharge in the district is 20742.61 mcm and ranges from 6676.23 mcm (Porbandar) to 7092.36 mcm(RanaVav). The Total Annual Ground Water Draft in the district is 14113.40 mcm and ranges from 4188.20 mcm (Kutiyana) to 5643.20 mcm (Porbandar).

The Ground Water Availability for future irrigation after projecting the demand for domestic and industrial use up to 2025 in the district varies from 82 MCM (Porbandar) to 2375 MCM (Ranavav). The Total Ground Water Availability for the district is 4809 MCM. The Stage of ground Water development in the district ranges from 63.22% (Kutiyana) to 88.98% (Porbandar), overall Level of Development for the district is 71.62%. Kutiyana and Ranava have been categorised as “SAFE” where as Porbandar taluka is categorised as “Semi-critical”. The overall category of the district is also “Semi-Critical”.

In general ground water quality in the district is potable. The Total Dissolved Solid of ground water varies from 801 mg/l (Ranavav) to about 7303 mg/l (Miyani). The shallow ground water in the district is generally alkaline with pH more than 7. The value of pH ranges between 7.43 &

8.03 in the district. The shallow ground water in Porbandar district does not contain any Carbonate. The Bicarbonate concentration in district varied between 220 mg/l at Miyani and 561 mg/l at Khambodar. Chloride concentration in the shallow alluvial aquifer varies between 163 mg/l (Ranavav) and 3368 mg/l (Miyani). At 5 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 concentration in the ground water in district varies between 24 mg/l (Pata) and 270 mg/l (Palkhada). There are six stations where these values are more than the limits as per BIS drinking water standards (45 mg/l). These stations are Bhavpura (125), Miyani (60), Kutiyana (100), Palkhada (270), Kandorna (90) and Ranavav 47. The sulphate concentration varies from 63mg/l (Porbandar) to 710 mg/l (Miyani). Fluoride concentration in ground water varies between almost 0.3 at Adwana and 1.5 mg/l at Kutiyana. High concentration of fluoride exceeding maximum desirable limit of 1(mg/l) is found at Hanumangadh (1.05), Kutiyana (1.5), Oddar (1.40), Khambodar (1.33), Navibandar (1.12) and Ranavav (1.06). Calcium concentration in district varies between 48 mg/l (Navibandar) and 960 mg/l (Miyani). The concentration of calcium is more than maximum permissible limits of 200 mg/l (as per BIS norms) at Miyani (960), Palkhada (540), Bhavpura (500), Kandorna (244), and Kutiyana (260). The Concentration of Magnesium in areas ranges from 38 mg/l (Ranavav) to 300mg/l (Miyani). The concentration of magnesium is more than maximum permissible limits of 100 mg/l (as per BIS norms) is recorded at Kutiyana (144), Miyani (300), Odar (252), Kandorna (103) and Bhavpura (204). Sodium concentration in area varies between 102 mg/l (Ranavav) and 980 mg/l (Miyani). The concentration of Potassium in shallow ground water ranges from 0.8 mg/l (Adwana) to 64.0 mg/l (Kuchhadi). The Iron concentration in the shallow ground water in the district is generally low, ranging between 0.07 to about 2.7 mg/l which is within the permissible limit. Total Hardness in ground water in alluvial areas range between 380 mg/l (Naivbandar) and 3650 mg/l (Miyani). At places especially along the coast a very hard ground water is observed. The total hardness more than maximum permissible limits of 600 mg/l (as per BIS norms) is recorded at Kutiyana (1250) , Miyani (3650), Odar (1450), Palkhanda (1700), and Bhavpur (2100), Kandorna (1040) and Pata (650).

Recommendations

There is not much scope for further development of ground water resources in major parts of the district. Thus, there is an urgent need for augmentations and proper management of ground water resources.

There is not much scope for further development of ground water resources in major parts of the district. Thus, there is an urgent need for augmentations and proper management of ground water resources. However, for the further possibility for the ground water development the

advanced techniques like remote sensing & geophysical surveys may be used for siting the ground water structures. In the coastal area care may be take to properly identify the saline zones through electrical logging and sealing these zone at the time of construction of tubewells. These measures are essential to prevent the existing fresh water zones from getting contaminated.

Systematic geophysical surveys, particularly the geo-electrical soundings, need to be carried out in the coastal areas to ascertain the location of saltwater-freshwater interface as well as depth to bedrock (Basalt).

In the entire are, scope exists for augmenting the ground water resources through the artificial recharge. Large scale artificial recharge schemes may not be feasible due to non availability of prolific aquifers and paucity of source water. However, small and cost effective measures like contour bunding, nalla plugging, small check dams may be quite effective in increasing the ground water recharge.

1.0 Porbandar District

2.0 Legend

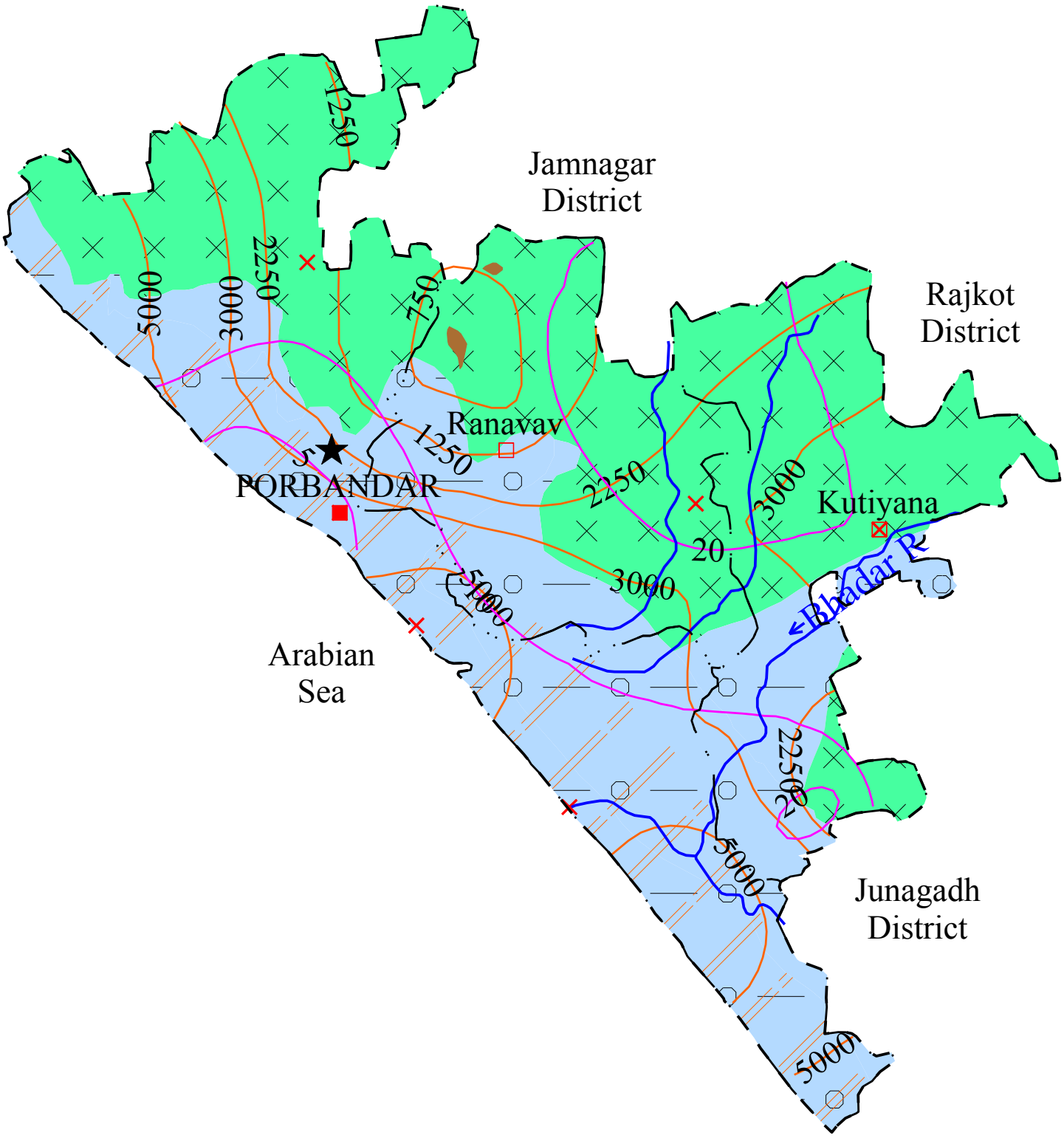
	Wells Feasible	Rigs Suitable	Depth of Well (m)	Discharge (lpm)	Artificial Recharge Structure Suitable
Soft Rock Aquifer	Dug Well Tubewell	Manual Direct Rotary, Reverse Rotary	10-25 50-75	100-200 300-500	Percolation Tanks/ Ponds, Recharge Wells,
Hard Rock Aquifer	Dug Well Borewell	Manual Down the Hole 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				

20	Pre-monsoon Decadal mean (1993-2000) Depth to Water Level (mbgl)	2000	Electrical Conductivity (µS/cm at 25° C)
	Fluoride > Maximum Permissible Limit (1.5 mg/l)		Dark Taluka
	Drainage		District/Taluka HQ

3.0

4.0 Other Information

1.1. GEOGRAPHICAL AREA	**2,018 sq. km**
No of Blocks/ Talukas	**3**
Population (2011 Census)	**5,85,449**
Average Annual Rainfall	**660 mm**
Range of Average Temperature	**20-31 °C**
Major Drainage System	**Bhadar**
Major/ Medium Irrigation Scheme	**Kalindri, Vartu II**
Major Geological Formation	**Soft Rock: Alluvium, Tertiary** **Hard Rock: Deccan Trap**
Utilizable Ground Water Resources	**150 MCM/Yr**
Net Ground Water Draft	**14113.40 MCM/Yr**
Stage of Ground Water Development	**76 %**
Blocks Showing Intensive Ground Water Development	**Porbandar**


Jamnagar
District
Rajkot
District
Ranavav
PORBANDAR
Kutiyana
Bhadar R
Arabian
Sea
Junagadh
District
1250
2250
5000
3000
750
20
2500