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Technical Report Series

GROUNDWATER BROCHURE

KACHCHH DISTRICT

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Profile of Kachchh District – Gujarat State

Sr No.	Particular / Items	
1	**General Information** i. Geographic Area (Sq km) : 45,652 Sq Km ii. Administrative Units : 10Taluaka – Bhuj, Mundra, Mandvi,Abdasa, lakhpat, Nakhatrana,Rapar, Bhachau, Anjar&Gandhidham iii. No of Villages / Towns : 884 Inhabitated Villages, 69 Unhabitated villagesand 8 Towns iv. Population (2011 Census) : 20,90,313 ; 10,96,343 Males &9,93,970 Females ; Decennial Growth Rate of population 32.03 % v. Climate : Semi-arid vi. Average Rainfall : 378. 2 mm	
2	**Physiographic Features** i. Physiographic Zones :High land ,Plain and Rann ii. Drainage :Bharud, Kali, Suri, , Khari, , Mithi, Rukmavati and BhukhiLuni, Rupen, Kankawati and Malwan	
3	**Agriculture & Irrigation (‘000 Ha.)** i. Total area : 1958 ii. Cultivable area: 680 iii. Forest: 307 iv. Irrigated area a. Net irrigated area : 107 b. Gross irrigated area : 341.2 c. Rainfedarea : 502	
4	**Geology & Hydrogeology** i. Major Geological Formation : Mesozoic formation, Deccan Trap ,Tertiary and Quaternary ii. Aquifer System: Both Unconfined & Semi to Confined system iii. Groundwater Monitoring : 45 Open wells & 19 Piezometers iv. Depth to water level : 1.20 to 53.64 m bgl (Pre monsoon) and 0.65 to 98.80 m bgl (Post monsoon) v. Groundwater Quality : Fresh to brine vi. Groundwater Exploration : 70 Exploration Wells , 31 Observation Wells , 31 Piezometers and 13 slimholes	

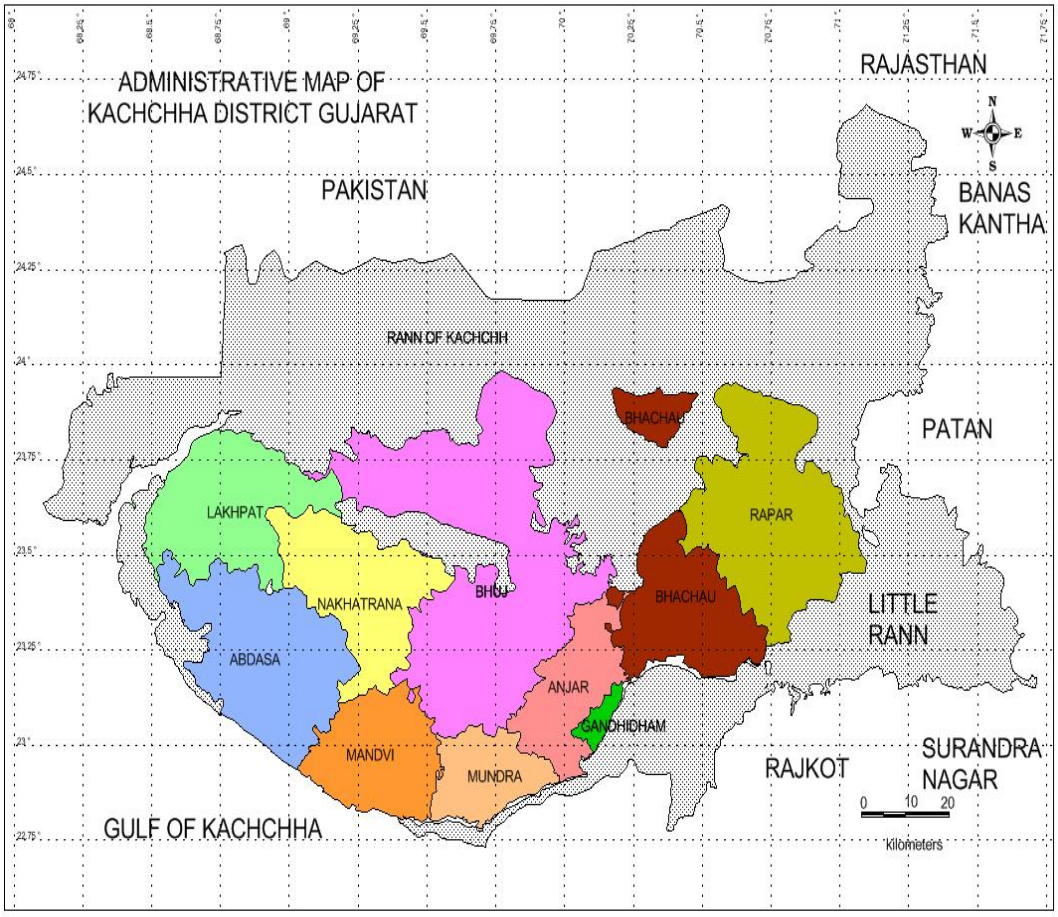
	vii. Groundwater Resources : a. Total Annual Ground Water Recharge : 838.11 mcm b. Net Annual Ground Water Availability : 796.20 mcm c. Gross Annual Draft : 631.69 mcm d. Stage of Ground Water Development(District)-79.34 % - Semi-critical Category i. Abdasa : 61.15 % - Safe Category ii. Anjar: 92.62 % - Critical Category iii. Bhachau : 107.98 % - Over-exploited Category iv. Bhuj : 94.12 % - Critical Category v. Gandhidham : Saline vi. Lakhpat: 24.40%- Safe Category vii. Mandvi: 101.23%- Over-exploited Category viii. Mundra: 63.28%- Safe Category ix. Nakhtrana : 85.62%- Semi-critical Category x. Rapar: 54.73%- Safe Category	
5	Awareness & Training Activity of CGWB i. Mass Awareness Program Organized : 1 ii. Water Management Training Program Organized : 1	
6	Groundwater Development Regulation i. Notified Area / Blocks : Nil ii. Measures Required : a. Regulation for further development in over exploited and critical blocks. b. Specific Monitoring Network to ascertain impact of development activity and extent of pollution	
7	Major Groundwater Related Issues i. Uneven distribution and development of ground water resources ii. Salinity and fluoride problem. iii. Coastal zone aquifer having limited thickness of fresh quality ground water iv. Possibility of groundwater pollution due to industrial development of the district	

Introduction

Kachchh district, located on the westernmost tip of India is the largest district of Gujarat,the total area of the district is 45,652 sq. km, that is more than 23% of the total area of the state, and lies in the extreme western part of the state. Kachchh district is situated between north latitudes 22°44'11" & 24°41'25" and east longitudes 68°09'46" & 71°54'47" and falls in the Survey of India degree sheet No. 40D, H, L and P and 41A, B, E, F, I, J and M. The district is bounded on the north and northwest by the Sindh Province of Pakistan and on the northeast by Rajasthan state. The southern boundary of the district is marked by the Gulf of Kachchh and towards west and southwest by the Arabian Sea. There are several small ports all along the coast, which are mainly used as fishing ports. Kandla and Mundra are the two important port in the district and supports the industrial and commercial activities in the state.

Administrative Divisions

Administratively the district is divided into ten Talukas, Bhuj is the district headquarter



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The Geographical areas and number of villages in different Talukas, as per the census records is given below.

Geographical Area and No of Villages & Towns

Taluka	Area (Sq.Km.)	Inhabitated Village	Unhabitated Village	Total	No. of towns
Lakhpat	**1945**	**86**	**14**	**100**	**0**
Rapar	**3023**	**97**	**0**	**97**	**1**
Bhachau	**1985**	**69**	**2**	**71**	**1**
Anjar	**1174**	**64**	**3**	**67**	**1**
Bhuj	**4500**	**144**	**14**	**158**	**1**
Nakhatrana	**1985**	**119**	**13**	**132**	**0**
Abdasa	**2398**	**150**	**16**	**166**	**0**
Mandvi	**1406**	**90**	**1**	**91**	**1**
Mundra	**888**	**599**	**1**	**60**	**1**
Gandhidham	**174**	**8**	**0**	**8**	**2**

- **Rann Total area-26174 Sq.Kms.**

Previous Work

Geologically the district has been investigated by several workers during last century. The pioneer work was carried out by Wynne &Fedden (1872) during 1868-69). Extensive hydrogeological surveys and investigations have been carried out by the scientists of erstwhile ground water wing of Geological Survey of India (GSI). Exploratory TubewellsOrganisations (Now CGWB) and later by Central Ground Water Board and also by the State Ground Water Departments.

Exploratory drilling and testing for ground water in the district commenced in 1953-54 under Operational Agreement No.12 of the Indo-US Technical Cooperation Mission and continued until 1990-91 under various programs of exploration. After 2001 earthquake more exploratory wells constructed during the years 2001 and 2002. Maximum depth of boreholes drilled by CGWBis 458 m bgl.

Demography

The total population of the district as per 2011 census is 20,90,313, which include 10,96, 343 male and 9,93,970 female. The sex ratio is 907 female per 1000 male as compared to 942 females in 2001. The population density has increased to 46 person per square kilometer from 35. The decadal growth for population during the period 2001-2011 is 32.03%.

Agriculture

The major field crops grown in the district are Bajra, Greengram, Castor, Groundnut, Cotton, Wheat and Mothbean, except wheat all other crops are grown in kharif and are rainfed. Area under major crops (Average of 2004-05 to 2007-08) is as follows

Crop	Khariff, Area('000 Ha.)	Rabi, Area ('000 Ha.)
Bajra	72.8	
Greengram	68.8	
Castor	56.8	
Groundnut	46.5	
Cotton	20.6	
Wheat		19.1
Mothbean	18.3	

Many horticulture crops including vegetables and fruit are grown in the district .For last few years good quality Dates are grown in the district.

Industry

The salient feature of industries in the district is as follows

1. Over 60% of total salt production is contributed by the districtYearly production of salt is 2.5 lakhtonnes and is exportedto countries like Taiwan, Bangladesh and Korea.
2. With large reserves of limestone, bauxite, lignite and bentonite, Kutch district is one of the preferred destinations for most of the mineral based industries .It has largest reserves of limestone, lignite, bauxite, china clay and silica sand inthe country.The district has the highest production of Lignite and Chinaclay in Gujarat.
3 .Largest manufacturer of **Submerged Arc Welded (SAW) pipes**
4. Kutch is also known for handicrafts. Out of total 136 industrial cooperative societies, 71 belong to handicrafts.
5. Presence of 6,128 Small Scale Industry units
6. Kutch accounts for 39.07 percent of the total projectscurrently under implementation in the State
7. Theindustrial estates established by GIDC (Gujarat Industrial Development corporation) are

Industrial estate	**Taluka**	**Area in square mts.**
Mithirohar	Gandhidham	17,19,941
MotiChirai	Bhachau	13,15,962
Nakhatrana	Nakhatrana	47,717
Makhel	Rapar	86,603
Mundra	Mundra	13,355
Dhrub	Mundra	4,49,200
Nagor	Bhuj	64,767
Madhapar	Bhuj	21,233
Durgapur	Mandvi	1,99,398
Gandhidham	Gandhidham	1,06,147
Anjar	Anjar	2,10,546
Bhuj	Bhuj	3,07,500

RAINFALL AND CLIMATE

Temperatures vary considerably from season to season. The summers are generally hot and winters are cool. Mean maximum temperature ranges between 26.7°C during January to about 39.5°C during May and the mean minimum temperatures vary between 9°C during January and 27°C during June.

The relative humidity in Kachchh as per IMD varies between 43.5% during March and 77% during August. The wind velocity in the district varies from about 124 km/d during November and 375 km/d during June.

The potential Evapo-transpiration, calculated using Penman's Method varies between 3.4 mm/d during December and 9.2 mm/d during may.

Long-term average annual rainfall for Bhuj IMD station is 378.2 mm. Most of the rainfall (about 345 mm) is received during south-west monsoon between June and September.The climatological data for IMD station Bhuj is given in followingtable

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Month	Max Temp (Deg.C)	Mini Temp (Deg.C)	Humidity (%)	Wind Spd. Kmpd	Sunshine (Hours)	Solar Rad. (MJ/m2/d)	Eto (mm/d)	Rainfalll (mm)
January	26.7	9.0	47.0	138.2	8.9	16.7	3.6	2.0
February	29.8	12.0	45.5	149.0	9.5	19.5	4.5	1.1
March	34.9	17.6	43.5	177.7	10.1	22.8	6.2	2.9
April	38.7	22.1	44.5	217.2	10.8	25.6	7.9	0.7
May	39.5	25.2	53.5	330.3	11.4	27.1	9.2	1.7
June	37.1	27.0	65.0	375.2	8.7	23.1	7.7	33.9
July	33.6	26.2	75.0	346.5	5.3	17.9	5.4	136.3
August	32.5	25.2	77.0	307.0	5.4	17.6	4.9	120.7
September	33.7	23.8	70.5	229.8	7.9	20.2	5.4	54.2
October	35.9	20.6	52.5	141.8	9.6	20.4	5.3	15.4
November	32.4	15.5	48.0	123.9	9.3	17.6	4.1	7.7
December	28.1	10.5	49.0	131.0	8.9	15.9	3.4	1.6
Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**378.2**
Average	**33.6**	**19.6**	**55.9**	**222.3**	**8.8**	**20.4**	**5.6**	**-**

GEOMORPHOLOGY

Physiographically, the district can be divided into-

a) Central High land and the Upland in the Rann Area.
b) Central Plain in the southern part.
c) Little and Great Rann areas, and the
d) Banni plains.

The mainland of Kachchh is an undulating country with rugged broken ground and broad plains and is marked by hill ranges and isolated peaks. There are three hill ranges in the main land namely Dhinodhar, Jura and Vavar, which rise to 387m and 274m amsl. The other uplands in the main land area are in Wagad area in the east forming part of Bhachau and RaparTalukas. The Pachham, Khadir and Bela islands in the Great Rann in the north also form highlands with maximum elevation of 458 m amsl. All the hill ranges follow a general east-west trend.
Kachchh district has about 350 km long coastline and its coastal plain is about 35-45 km wide and attains the elevation up to 80 m amsl. The coast is generally flat and broken by small and big creeks, viz., Kori, Boacha and Godia.
The Rann forms a unique and conspicuous landform and has been divided into the Great Rann in the north and Little Rann in the east. The Rann mainly comprises marshy land, salt/mud flats and is devoid of vegetation and habitation and has a very hostile environment. The total area of Rann is about 25000 sq. km.
The extensive low lying area south west of Pachchhamisland resembles Rann except for some patches of scanty vegetation. It is known as Banni plain and covers an area of about 2000 sq. km. About 777 sq. km of Banni plain is reported to be superior grassland

Soil

The soils found in Kachchh district can broadly be grouped into four types, i.e., Shallow Black soils, Residual Sandy soils, Coastal Alluvial soils and Desert soils.

The Shallow black soils are found in central and north-central parts of the Kachchh mainland and in Khadir and Bela Islands. These soils have developed from basaltic rocks and rocks of Jurassic period. The depth of soil ranges from a few cm to 30 cm.. Broadly, these soils are poor in fertility.

The Residual Sandy soils have developed in-situ from the parent material originated from red sandstone and shale and are found over the areas underlain by Bhuj Sandstone. All these residual soils are shallow in depth. They are reddish brown in colour with fine weak granular structure to poorly developed one. These soils are sandy to loamy sand in texture dominated by coarse sand. These are non-calcareous, neutral to alkaline in reaction with poor base saturation. They are affected due to salt accumulation. From fertility point of view, they are poorly supplied with plant nutrients and, as such, support the crops with short duration and less water requirement.

The hilly soils occur in the hilly areas central part of the district. The soil profile is not well developed because of the steep slope and erosion. They have developed from the parent materials existing in the respective areas. They are shallow in depth composed of un-decomposed rock fragments and poor in fertility.

The Coastal Alluvial soils are found all along the southern coast. These soils are sandy clay loam to clay in texture. The soil reaction varies with situation ranging from neutral to highly alkaline. These soils are normally medium in fertility. At places, these soils are saline in nature

The two Ranns (deserts) of Kutch namely little Rann and great Rann have the soils which are formed as a result of the geological processes of Pleistocene age. The alluvial deposits due to the river system flowing through the area have subsequently been overlain by the aeolian deposits. These soils are fairly deep, light grey in colour. The texture is sandy to sandy loam with silty clay loam in some areas. The salt content is very high with the sodium chloride as the dominant salt. The profile study reveals the presence of sufficient amount of gypsum throughout the profile.

GROUND WATER SCENARIO

Hydrogeology

Hydrogeological scenario and generalized ground water conditions are discussed here under.

Sedimentary rocks of marine and non marine origin formed under different environmental conditions during middle Jurassic to Recent period occur in the district besides volcanic and intrusive rocks (Deccan Trap) of middle Cretaceous to lower Eocene., the formations forming aquifer or hydrogeological units can be grouped as:

a) Mesozoic formations

b) Deccan trap (Hard rock) as aquifer

c) Tertiary formations

d) Quaternary sediments

The ground water conditions, its occurrence and movement, hydraulic characteristics and chemical quality aspects vary considered in each hydrogeologic group. The pre-cambriangranite

and Aravalli rocks are reported be exposed in a tiny hillock i.e. 'MerudaTakkar' in the northern part of great Rann.

Mesozoic Formations

The sediments belonging to Mesozoic period include both marine and non marine sedimentary formation and occupy almost 60% of the district. Patcham, Chari and Katrol series belong to Jurassic period where as Umia or Bhuj represent lower Cretaceous.

Patcham Series:

The rocks of this series consist of yellow and greyish coloured sandstone, shale, and fossiliferous. limestone and represent marine sedimentary sequence. It occupies largely the island belt of Patcham, Khadir and Bela and small area in northern part in main land of Kachchh. The ground water occurs under water table and confined conditions in the sandstone/shale sequence belonging to this group. The semi-consolidated sandstone exposed in the lower reaches forms phreatic aquifer and is being developed locally for domestic and irrigation purposes. The dug wells tapping this aquifer ranges in depth from 10 to 24 m bglwhere as the depth to water level during summer varies from 15 to 20 meters. Their yield varies from 50 to 175 m3/day. The quality of ground water is potable to slightly brackish and near Rann and lower reaches while the deeper ground water is saline. In Khadir Island, the springs have been observed at Hadibadang and Kakindiya bet. They had about ½ lps discharges and quality of ground water was fresh at Hadibadang and saline at Kakindiya. Exploratory borehole in this formation indicated presence of alternating layers of shale and sandstone with minor bands of limestone down to 150 meter depths. Ground water at deeper levels is under confined conditions and quality is saline, EC up to 9000 µS/cm. Only, shallow aquifer down to 30-35 meter constituted by feldspathic sandstone exposed in the mid-reaches hold some promise for potable ground water in this formation.

Chari Series

The formations belonging to this formation are hard oolitic limestone, sand stone and shale representing marine facie. This formation occurs mostly as inlier in the core of anticlines and constitutes hilly topography. There is no ground water development in formations belonging to Chari series because of marine nature of sediments and its physiographic settings. Not much information is available about occurrence and movement of ground water.

Katrol Series

The rocks belonging to this series occupy the Wagad up land and northern and central parts of main land. It is represented by shale and sand stone sequence with minor bands of limestone. The sandstone is general made up of hard indurated blocks, except in Wagad area where it is feldspathic and soft/friable at places. Ground water development in these formations is confined to only the Wagad area falling in parts of Bhachau and RaparTalukas.

Exploratory drilling in Wagad area has revealed presence of alternate bands of sandstone and shale. The sandstone at shallow depth is generally soft and friable and forms aquifer locally. The ground water in this formation occurs under phreatic to confined conditions. The ground water development is generally through dugwells which, range in depth from less than 10 m to about 25m. At places, the dug-cum-bored wells are also observed with depth of bores ranging between 25 and 60 m. Depth to water level ranges from 10 to 30 m bgl. Yield of dug wells and dug-cum-bored wells range from 60 to 660 m3/day. Though, the formation is hard and compact at deeper levels, at places the ground water may occur in fractures in localized areas. Few

tubewells, ranging in depth from 40 to 140 m are observed in Wagad area tapping the fractured part of the aquifer. The discharge of such tubewells range from 400 to 1000 lpm at drawdowns ranging from 3 to 9 m.
In rest of the district, the formations belonging to Katrol Series do not from aquifer due to hard and compact nature and geomorphological setting.

Bhuj Series
The formations belonging to the Bhuj (Umia) series form the most prolific aquifer system in the district. This aquifer is extensively developed in central part of the district in a belt extends from Gadhuli-Dayapar-Lakhpat area in the west to Bhachau in the east. Lithologically the Bhuj Sandstone comprises of fine to coarse grained sandstone interbedded with siltstone and shale. The sandstone, which mainly forms the aquifer is soft, friable and highly porous/permeable.
The quality of ground water in general is fresh with EC < 3000 µS/cm, excepting in the western Kachchh where it is mostly saline with EC > 5000 µS/cm. Besides this, the quality of the formation water is known to deteriorate with depth in underlying lower Bhuj formations
Ground water occurs both under phreatic and confined conditions. The unconfined of the phreatic aquifers system in this formation extends down to a depth ranging from 20 m to about 100 m depending on the presence of aquitards/confining layers. The ground water in central parts occur mainly in unconfined to semi-confined conditions whereas in the western part, the deeper horizons within this system are under confined conditions and free flow / auto flow conditions are also observed at places. The ground water in phreatic system is generally developed through dug wells, dug-cum-bored wells and shallow tubewells. However, due to excessive development and deepening of water levels, most of the dug wells have gone dry, particularly in Bhachu-Dudhai, Anjar-Khedoi-Vidi, Kera-Sisagadh and Deshalpur-Nakhatrana-Netra areas. In these areas, the ground water is mainly developed through deep and medium depth tubewells ranging in depth from 80 to 250m. Thesetubewells tap aquifer zones in the depth range of 40 to 220m with aggregate thickness of granular zones ranging from 30 to 100m. The discharge of tubewells range between 40 and 360 m3/hr for drawdowns ranging between 3 and 12m. The piezometeric levels / water levels in Bhuj Sandstone ranges from 30 to 70 m bgl.

Deccan Trap
Deccan trap occurs as almost one continuous belt from Anjar to Lakhpat Taluka with a lateral dislocation near the injunctions of Nakhatrana, Abdasa&MandviTalukas. It mainly comprises of Light to dark grey basalt & dolerite as moderately extensive flows.
In the areas underlain by Deccan trap, ground water occurs in the weathered mantle and along the interflow zones, joints and fissures. In this formation, very limited groundwater development is observed due to poor water bearing characteristics and highly saline ground water particularly in the central and western part. At places this formation has limited thickness and acts only as a capping to underlying formations.
Ground water development is meagre in Deccan traps. It occurs in the weathered portions & joints. Dug wells are 11 to 15m deep with depth to water 5 to 9m bgl.

Tertiary Formations
The Tertiary sediments belonging to Eocene to Miocene period are of marine origin & are largely argillaceous and calcareous in nature and do not contain arenaceous members and thus mostly have inferior quality of formation water. However, the grey and mottled sandstone and calcareous grits of the Manchhar series (Pliocene) form moderate aquifer in the coastal areas between Mandvi-Mundra and parts of Abdasatalukas where ground water quality is moderate.

However, occurrence of fluoride more than permissible limits in the coastal tracts of Abdasataluka in general is indicative of non-acceptable quality of ground water. The recent alluvium in the district in the coastal areas contains variable quality of ground water.
Formations of Ranikot Series occur in parts of Mandvitaluka, fringing the southern margin of the Deccan traps. They comprise of soft argillaceous, aluminous and variegated shale, laterite and bauxite. There is very little ground water development in this formation.
Supra Trappeans occur as about 9 m thick ferruginous laterite (iron cap) and aluminous ferruginous laterite derived in situ from Deccan Trap flows in Anjar-Khedoi Region. They locally yield very meager supplies of brackish to saline water to wells. However, generally this formation occurs above the zone of saturation.
In Bhachau region they are as much as 76 m thick at places and locally yields small supplies of brackish water to shallow wells.
Supra Trappeans comprising Laterite, aluminous shale and lateritic clays also occur as narrow belts overlying Bhuj Series in central parts of district. There is no ground water development in the areas underlain by this formation.

Laki Series (Eocene)
Laki Series occurs in parts of Abdasa&LakhpatTalukas. The formations comprise of up to 160 m thick red & mottled clays gypsiferous, pyritiferous& carbonaceous shale with thin seams of lignite & pockets of unconsolidated fine grained sand beds at the bottom of the series.
The formations of this series yield very little quantities of brackish to saline water to dug wells. Ground water occurs in confined conditions also. The confined aquifer is capable of yielding large quantities of highly saline water.

Kirthar Series (Eocene)
Formations of Kirthar Series occur in parts of Abdasa&LakhpatTalukas. They comprise about 325 m thick mainly composed of Nummulitic limestone with occasional thin beds of calcareous shale.
These formations yield very little quantities of poor quality water in wells located in low grounds.

Nari&Gaj Series (Miocene - Oligocene)
The formations of these series occur in parts of Abdasa&LakhpatTalukas. They comprise of up to 640 m thick, mostly argillaceous formations composed of mottled clays and variegated shale with thin beds of fine grained clayey sandstone and Shelly limestone.
These formations yield very little quantities of brackish to saline water to wells. Quality is potable in wells located near the stream courses or in the vicinity of surface water bodies.
The sediments of Gaj Series unconformabily overlie the Bhuj Series and comprise of grey and yellowish gypseous shale inter-bedded with fossiliferous marls. Due to poor permeability, only limited ground water development has been possible.

Manchhar Series (Pliocene)
This formation occurs in about 259 sq. km area lying between Faradi and Bhadreshwar, overlying the Bhuj Series unconformably and comprises of buff light grey, yellowish clay, mottled sandstone and sandy clays with gypsum.
The Mottled sandstone forms productive aquifer at places. Wells range from 7 to 24m in depth with depth to water 3 to 15 m bgl.
In Mundra Taluka, some scope of ground water development is exists
In Eastern Kachchh, (Wagad Area), there is no ground water development in this formation.
In parts of Bhachau Taluka, this formation occurs as up to 60m thick undifferentiated massive reddish brown gypseous clay, shale, some laminated silt stone, lenses of laterite & trap gravel,

mottled sandstone and occasionally some limestone. This formation yields meagre supplies of brackish to salty water to wells.
In Anjar-Khedoi area, the sediments of Manchar Series occur as 185 m or more thick semi-consolidated clayey sandstone and conglomeratic sandstone. Fossiliferous sandstone with silt stone & conglomerate. Clay shale, lime cemented conglomerate. They yield meagre to small supplies of brackish water to wells. Locally the water is saline.
In parts of Abdasa and LakhpatTalukas, up to 550m thick, semi-consolidated fine to medium grained current bedded sandstone, conglomerate, mottled clay, pink & yellow limestone occur. They yield moderate to large quantities of potable to brackish water. Water is highly brackish/saline near the coast.
In parts of Mandvi&AbdasaTalukas these sediments are generally extensive and have permitted moderate of ground water development by means of dug and dug-cum-bored wells. Ground water occurs under water table conditions down to 25 m and under confined conditions further below down to 180m.
Chemically the ground water has fluoride content exceeding the permissible limits **of** ICMR standards at many places, i.e., around Naliya. DTW ranges from 2 to 29 m bgl with depth of wells ranging from 8 to 90 m.
Tube wells yield about 1.5 m3/minute for drawdowns of 12 to 21m. T ranges from 14 to 173 m2/day and Pf from 2.856 to 11.96m/day. Sp. Capacity ranges between 30 & 110 lpm/day.

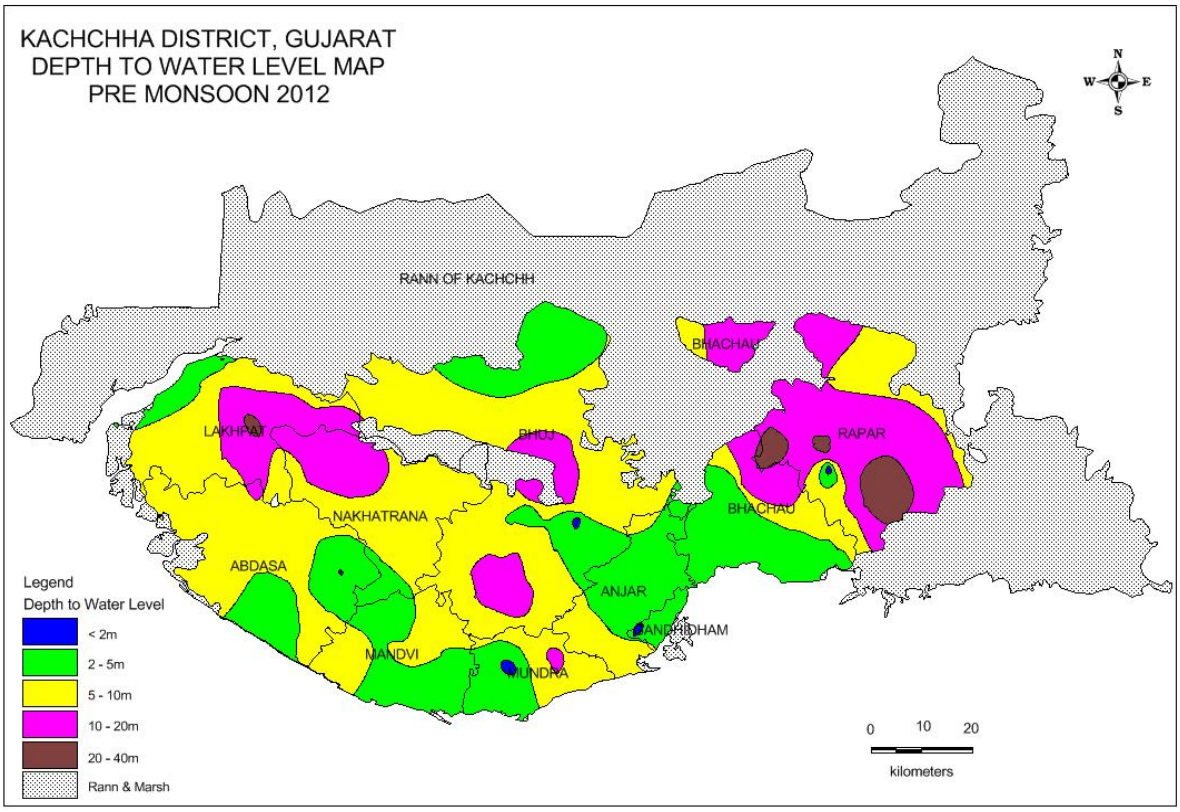
Quaternary Sediments
Milliolite limestone, which is white to dull grey, medium - grained limestone comprising Milliolite Foraminifer, occurs along hill slopes and faulted plains, e.g., near Sukhpur on thenorthern slopes of Khatrod range west of Adhoi, near Ler, etc. There is no ground water development in this formation.

Alluvium occurs in channels of large ephemeral streams, & coastal tracts spread over almost whole district. Th alluvium comprises of brown loamy, kankary. silt, clays, sand, gravel, loam &kankar with a thickness of about 6 m most of the district.. However, in southern parts of the district, i.e., in Mandvi&Mundra as well as Bhachau&AnjarTalukas, the thickness may be considerable.

The alluvium yields small quantities of brackish water to shallow wells in Bhachau Taluka. Coarse facies may yield small to moderate supplies of brackish water to wells in Anjar-Khedoi region. In parts of Abdasa and LakhpatTalukas, the water table is generally below the formation. In Mandvi&MundraTalukas, the ground water development is extensive.
There is no possibility of further ground water development east and southeast of Lakadiya by means of deep tubewells because exploratory boreholes drilled at Lakadiya&Kumbhariya down to 450 and 305 m bgl respectively have not met with any promising granular zones. Between Bidada and Bhadreshwar in about 450 sq. km area dugwells are 4 to 22 m deep with depth to water 3 to 16 m bgl. The tubewells tap aquifers down to 129m depth. The value of T is 27.327 m2/day.
Between Hand and Kanmer in about 500 sq. km area, dug wells are 7 to 22 m deep with depth to water ranging front 3 to 15 m bgl. They yield 48 to 75 m3/day.

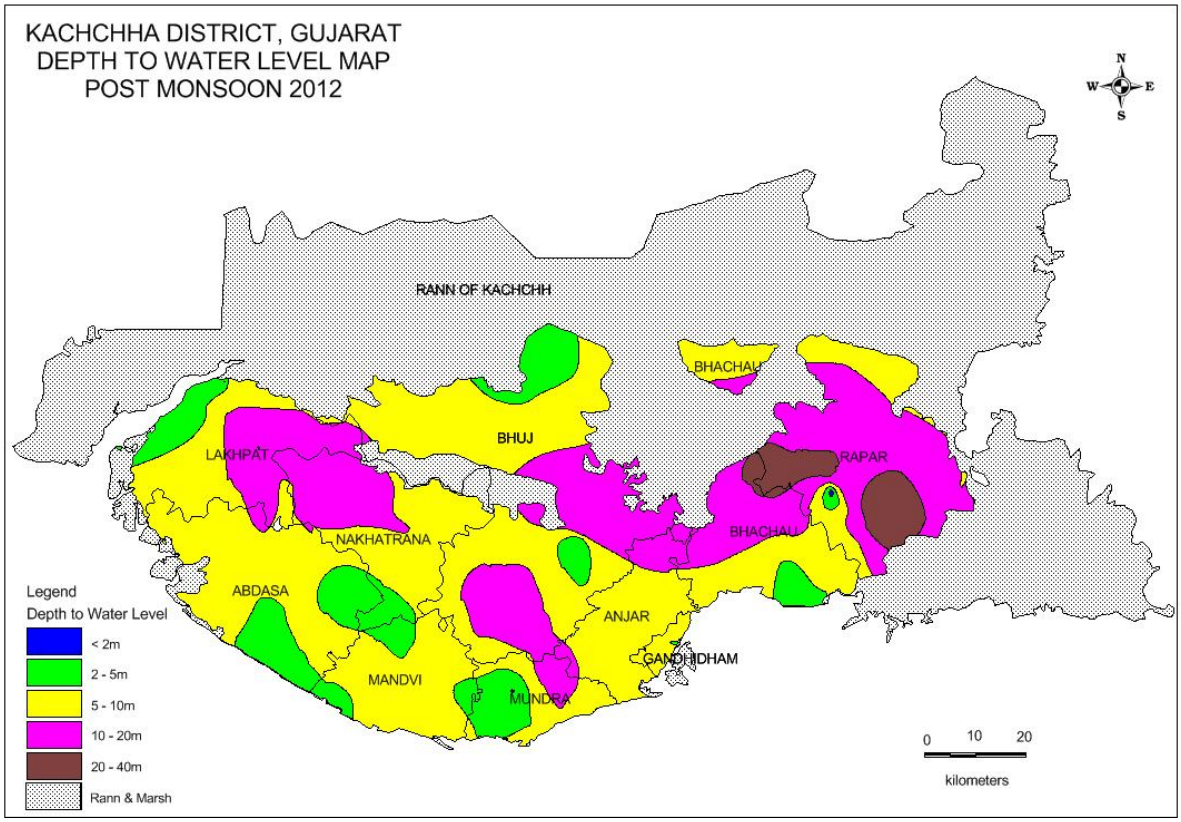
GROUNDWATER REGIME MONITORING

Ground water regime monitoring is the basic component of groundwater management, and it is carried out in Kachchh district four times a year, during January, May, August and November through 48 National Hydrograph Network Stations (NHS). Depth to water level map of pre monsoon and post monsoon period and annual fluctuation of water level are prepared with data of NHS for year 2012. The water level map of the district of pre monsoon 2012 (May) is as follows



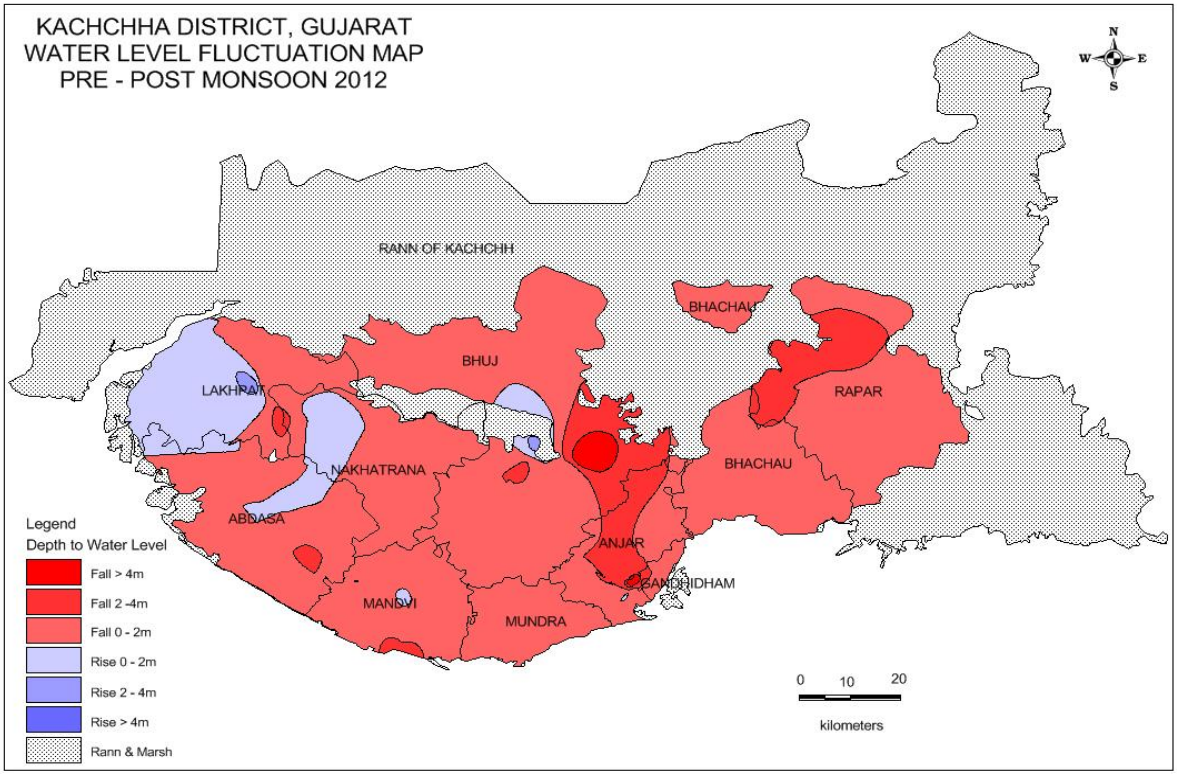
In most of the district the water level during pre monsoon lies within a range of 5 to 10 meters below ground level, where as in some part of central and South East the water level is within a range of 2 to 5meters. In North west and some isolated patches water level is between 10 to 20 and 20 to 40 meters.

During the post monsoon the water level map for the November 2012 is as follows



The water level during post monsoon is less than 20 meters in most of the district, however the water level is more than 20 meters in North East part of the district.

The map showing fluctuation between May 2012 and Nov.2012 is as below



In major part of district there is fall in water level after rainfall but in South West part there is rise in water level.

Ground Water Resources(2011)

Overall ground water development of the district is 79.34% and the district is categorised as semi-critical. The ground water development varies from as low as 24.40% in Lakhpattaluka to 107.98% in Bhachautaluka. Twotalukas namely Bhachau and Mandvi are categorised as over exploited, two talukas namely Bhuj and Anjarare categorised as critical, Nakhtranatalukaiscategorised as semi critical andLakhpat,Mundra, Abdasa and Rapar are Safe. The Gandhidhamtaluka is saline. The details of Ground Water Resources and irrigation potential of the district is as follows

Name of Taluka	Annual Ground Water Recharge in MCM / Year	Existing Annual Ground Water Draft for all uses in MCM / Year	Stage of Ground Water Development (%)	Category
Abdasa	65.07	37.80	61.15	Safe
Anjar	89.65	78.89	92.62	Critical
Bhachau	57.15	58.63	107.98	Over-exploited
Bhuj	191.67	171.93	94.42	Critical
Gandhidham	SALINE			
Lakhpat	47.72	11.06	24.40	Safe
Mandvi	79.60	76.55	101.23	Over-exploited
Mundra	79.30	47.68	63.28	Safe
Nakhtrana	104.40	84.92	85.62	Semi-Critical
Rapar	123.49	64.21	54.73	Safe
Total	838.11	631.69	79.34	Semi-Critical

Ground Water Quality

The quality of ground water in the district in general is highly variable and has complex character. The chemical quality of groundwater in the phreatic aquifer varies widely from the composition of brine in the Rann to fresh in upland areas or areas occupied by non-marine sedimentary formation and Deccan traps. There is also vertical and lateral variation in chemical quality, In general, the areas underlain by marine sedimentary formations (Both Mesozoic and Tertiary), low lying areas in coastal parts and the Rann are characterised by inferior quality of groundwater. About 60% of the district contain native saline water. The ground water is generally good (EC < 2000 µS) in the area underlain by Bhuj series excepting the western Kachchh where ground water quality in this formation is saline with EC > 5000 µS. The quality of the water in the Tertiary formations is highly saline at all depths except in localised areas in Mandvi – Mundra – AbdasaTalukas where good to brackish ground water quality is observed in Mansar sediments. The value of EC gradually increases towards the coast and Rann. EC value more than 4000 µS/cm is observed in Khavada, Khadir and Bela islands and along the coast and Rann.

In Kachchh, the quality of ground water below depth of 150m shows significant of deterioration. As the brackish water in deeper zones is under confined condition, there is apossibility of up coning of salinity if lowering of piezometric levels (as taking place at present) continues or accelerates due to over exploitation.

Ground Water Quality of Kachchh district in the different lithological formations are tabulated as follows

Chemical Constituents	Minimum	Maximum
PH	7.78	8.29
Ca (ppm)	20	880
Mg (ppm)	14	360
Na (ppm)	5.6	3500
K (ppm)	2.6	51.0
Cl (ppm)	35	7055
No3(ppm)	4	60
So4 (ppm)	44	787
HCO3 (ppm)	122	793
TH (ppm)	170	3500
EC (S/cm)	640	20200
Fluoride (ppm)	0.20	7.50
Alkalinity(ppm)	100	650
SAR	0.1	34.8
Fe	Nil	3.241

Status of Ground Water Development (Taluka wise)

The status of the groundwater development in the district is through dugwells, borewells, Shallow tube wells and tubewells. Their yield potential and suitability of drilling rigs techniques is presented below.

Ground Water Potential & Structures

Taluka	Formation	Wells feasible	Suitable drilling technique	Depth of well (m)	Discharge (lpm)
Rapar Bhachau Bhuj Naliya	Alluvium, Tertiary, Mesozoic Sandstones	Dugwells	Manual	10-30	200-300
Tubewells	Direct Rotary, Reverse Rotary		50-150	400-800	
Naliya Lakhpat Nakhatrana Mandvi MundraAnjar Ghandidam	Alluvium, Tertiary, Mesozoic Sandstones	Dugwells	Manual	10-25	80-150
Tubewells	Direct Rotary, Reverse Rotary		50-150	400-800	
Deecan Trap	Dugwells	Manual	10-25	80-150	
Borewells	Down the Hole Hammer (DTH)		100-200	100-300	

GROUND WATER MANAGEMENT STRATEGY

Ground Water Development

In major parts of the district development of ground water is mainly through dug wells however in central part occupied by Bhuj sandstone ground water development is mostly through tubewells. The semi-consolidated sandstone of Patcham series exposed in the lower reaches forms phreatic aquifer and is being developed locally for domestic and irrigation purposes. The dug wells tapping this aquifer ranges in depth from 10 to 24 m bglwhere as the depth to water level during summer varies from 15 to 20 meters. Their yield varies from 50 to 175 m3/day. There is no ground water development in formations belonging to Chari series because of marine nature of sediments and its physiographic settings. The ground water development in Katrol series is generally through dugwells which, range in depth from less than 10 m to about 25m. At places, the dug-cum-bored wells are also observed with depth of bores ranging between 25 and 60 m. Depth to water level ranges from 10 to 30 m bgl. Yield of dug wells and dug-cum-bored wells range from 60 to 660 m3/day. Though, the formation is hard and compact at deeper levels, at places the ground water may occur in fractures in localised areas. Few tubewells, ranging in depth from 40 to 140 m are observed in Wagad area tapping the fractured part of the aquifer. The discharge of such tubewells range from 400 to 1000 lpm at drawdowns ranging from 3 to 9 m. In rest of the district, the formations belonging to Katrol Series do not from aquifer due to hard and compact nature and geomorphological setting.

The ground water in Bhuj series is mainly developed through deep and medium depth tubewells ranging in depth from 80 to 250m. These tubewells tap aquifer zones in the depth range of 40 to 220m with aggregate thickness of granular zones ranging from 30 to 100m. The discharge of tubewells range between 40 and 360 m3/hr for drawdowns ranging between 3 and 12m. The piezometeric levels / water levels in Bhuj Sandstone ranges from 30 to 70 m bgl.

Ground water development in Deccan Trap is meagre. It occurs in the weathered portions & joints. Dug wells are 11 to 15m deep with depth to water 5 to 9m bgl. There is very little ground water development in Ranikot series and Supra trappeans. Lakhi series yield very little quantities of brackish to saline water to dug wells. Ground water occurs in confined conditions also. The confined aquifer is capable of yielding large quantities of highly saline water .Kirthar series yields very little quantities of poor quality water to wells located in low grounds. Nari and Gaj formations yield very little quantities of brackish to saline water to wells. Quality is potable in wells located near the stream courses or in the vicinity of surface water bodies.

The Mottled sandstone of Manchar series forms productive aquifer at places. Wells range from 7 to 24m in depth with depth to water 3 to 15 m bgl. In parts of Mandvi&AbdasaTalukas these sediments are generally extensive and have permitted moderate of ground water development by means of dug and dug-cum-bored wells.

There is no ground water development in Milliolite Limestone.

The alluvium yields small quantities of brackish water to shallow wells in Bhachau Taluka. Coarse facies may yield small to moderate supplies of brackish water to wells in Anjar-Khedoi region. In Mandvi&MundraTalukas, the ground water development is extensive. There is no possibility of further ground water development east and southeast of Lakadiya.

Water Conservation and Artificial Recharge

The availability of sub-surface space and the availability of source water are the prerequisites for artificial recharge. An area of 14915 sq. km has been identified as suitable for artificial recharge in Kachchh district and the sub-surface storage capacity is estimated at 9022 MCM.

To fully recharge this sub-surface storage capacity 12890 MCM of water is required and this water should be available in the form of runoff in different rivers of the districts.
Kachchh district is occupied by only minor rivers and streams and no major rivers occur in the district. The rivers which drain the area though have deep cut river courses are of ephemeral type and carry water only during the period of south west monsoon for a few hours in a day for couple of days in a year. The rivers originate from the central uplands and flow either to the Great Rann in the north and little Rann in the south east and towards the sea in the south. There are about 97 rivers and rivulets having relatively short flow distances of 16 to 32 km at an interval of 24 km. They have a steep gradient as a result, the runoff is high and of short duration. Ten rivers flowing north and eleven rivers flowing south have been harnessed through medium and minor irrigation projects. The storage capacity created for major and minor schemes are the order of 418 MCM. The total runoff from significant rivers is estimated at 648 MCM/yr at 50% dependability in a total catchment area of 11,663 sq. km. This leaves a balance of 230 MCM of runoff, which can be utilised, for artificial recharge.
For artificial recharge purposes an integrated watershed study is suggested at micro level in order to harness the runoff from all possible streams. However, all the artificial recharge schemes should be formulated keeping in view of all the water requirements. Check dams, recharge tanks, recharge wells, spreading channels, gully plugs, nala plugs, bandharas and tidal regulators are the suggested artificial recharge structures in this district.

Ground Water Related Issues and Problems

With a specific combination of geology, climate and topography, there are structural constraints in the quantum of water available in this district. The most common problem is inherent Salinity of geological formations depositing under marine conditions. Water logging in Rann area etc., are the other problems in Kachchhdistrict.Frequent drought is another major problem. Kachchh district receives minimum rainfall in entire Gujarat,.because of erratic rainfall and exploitation the ground water level are declining. The continous fall in water table has resulted into several problems like increasing salinity, problem of fluorides, reduction in bore yields and high failure rate of bores. Perpetually falling water table in mainland, sea water ingress from the gulf in centre and Rann ingression from the north seem to be “squeezing” Kachchh district of its fresh water resources. The prolonged use of saline ground water for irrigation has led to decline in agricultural and horticulture productivity and soil fertility in these regions. Villagers are forced to shift to cash crops like BT cotton and salinity tolerant crops production
Because of the location and geographical set up and non availability of potable water the district has not found any industrial growth. At present the state govt. is encouraging for new industries and as the district is having unique coastal lines, a lot of schemes to develop this coastal line along with coast related new industries are in queue

Salinity ingress is another problem in the coastal Kachchh. Low rain fall, skewed rain fall ratio and over exploitation of ground water have aggravated the salinity ingression. There is an indirect impact on the health of the villagers living in this region. Villagers complain of increasing kidney and gastric problems.
The tubewells constructed of MS have very short life span because of high rate of corrosion, for last few years the RCC tubewells are being constructed as they have longer life and less cost as compared to MS pipe.
Many industrial scale desalinisation units are being established in Kachchh to overcome water crisis.
SardarSarovar project envisages supply of after for drinking, irrigation and industrial use in Kachchh district.

Awareness and Training Activity

One mass awareness programme was conducted on 27th March 2008 in the district. About 200 people attended the awareness programme.

One Water Management Training Programme was conducted in the district at Bhuj on 18 & 19 January 2005 by CGWB.

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RECOMMENDATIONS

- There is an urgent need for management of the limited resources available.
- Creating awareness among the farmers regarding water conservation through judicious use of water and adoption of efficient irrigation techniques like drip/sprinkler irrigation. Soft term institutional finances to the farmers and liberal subsidies in equipments are suggested.
- Taking up artificial recharge on large scale through appropriate techniques on a regional scale with active community participation.
- Institutional finance and appropriate technology should be freely made available to any individual or cooperative group of farmers that undertake resource augmentation and management measures.
- Intervention in terms of improving agricultural practises introducing new salt tolerant variants of crops.
- Efforts should be made to encourage the Dairy industry as it can only give better alternative to the declining agricultural industry.