1. INTRODUCTION

Water is the 'elixir of life' and considered to be the most important natural resource required for the development of any area. The very existence of life is impossible without the availability of water.

Water is the most complex natural resource demanding a comprehensive understanding of its inherent features in occurrence and distribution for an integrated planning aimed at an optimum national development for agriculture, health, industry, power, transport and number of other such activities. Demand for water is constantly increasing with increasing population, better living conditions, more irrigation facilities, industrial, nuclear and space programmes. However, water is a finite source, i.e., in hydrosphere, roughly constant amount of water is in circulation at any one time but much less than 1 per cent is actually available for human use. Since cyclic hydrologic turn–over cannot be increased, the solar energy input being constant, there is no alternative but to make most efficient utilization of the available water.

It is said that "At the end of the twentieth century, the world faces a number of challenges affecting the availability, accessibility, use and sustainability of its fresh water resources. These could have serious implications for the present and future generations of humanity as also for natural ecosystems. India, which was 16% of the world's population, has roughly 4% of world's water resources and 2.45 percent of world's land area. The distribution of water resources in the country is highly uneven over space and time. Over 80 to 90 percent of the runoff in Indian rivers occurs in four months of the year and there are regions of harmful abundance and acute scarcity. Vast populations live in latter areas. The country has to grope with several critical issues in dealing with water resource development and management…" (MoWR, Report of the National Commission for Integrated Water Resources Development, Volume-I, Sept 1999)

1. SIGNIFICANCE OF WATER

Water acquires more significance when we talk about arid regions due to its meagerness. During post independence period numerous water resource development projects have been implemented by the government with a sole aim of surface water resource development through the major river valley projects and their centralized management system. This adopted uni-focused policy of water resource development by grossly neglecting the localized resource development has manifested variety of problems of socio-economic relevance.

Increased pace of development, population out burst and growing water demand have caused adverse effect on an overall efficiency of management system that ultimately made people more dependent. Further, paucity of resources led to much hardship to the local inhabitants in earning their livelihood, tremendous impact on landuse pattern, large scale migration (both human and livestock) and over exploitation of resources.

Realizing this fact of never lasting degenerating state of environment and people's suffering; an individual's vision emphasizing development of local resources, for local inhabitants through active participation of local people has yielded extra-ordinary success. Experimental works of Ralegaon Sidhi, Maharashtra and Tarun Bharat Sangh, Rajasthan bears testimony to this fact. Perhaps, very inception of the concept of Micro Watershed Development in India was the out come of these maiden attempts, which already acquired a national level movement through the active participation of the Non Government Organisations (NGO).

The Kutch region not remained exceptional, where some dedicated NGOs' viz. Sahjeevan and Shree Vivekanand Research and Training Institute (VRTI), Krishi Vigyan Kendra (KVK), Arid Communities and Technologies (ACT), etc and semi-government organizations like Central Arid Zone Research Institute (CAZRI) and Water and Soil Management Organisation (WASMO) have been working actively and have made significant contributions in the field of water conservation and recharge in the region and thus resulting in improvement of rural conditions through the development of local area resource.

The arid district of Kutch is the ideal example for over-exploitation of groundwater resource and development of centralized water supply system. Even though major rock formations of the district are of marine deposited sedimentaries the district has a good ground water bearing sandstones of Cretaceous age. Over the last four decades exploitation of groundwater resources has gradually increased with the pace of development. Inspite of such development of water resources, the district is severely vulnerable to drought. The governments' efforts in the last four decades in the development of Kutch water resources has enabled it to bring mere 2 % land under intensive agricultural development, against 14 % of defined agriculture land of the district. This has proved beyond any doubt that the solution to this intricate problem lies with the emphasis on local area resource development i.e. micro-watershed level. (Jadeja (2005))

For this adopting strategy of micro-watershed development and management for drought mitigation; understanding on potential of local resources, their strengths and weaknesses is pre-requisite. Also detailed knowledge on various aspects of the area, like impact of climatic factors, extent and severity of natural hazards, terrain characteristics, livelihood pattern, and socio-economic analysis, is prime need of planning exercise for development of local area resources and their management.

The availability of water from various sources is estimated by the knowledge of hydrology. Computing a reasonably accurate estimate of rainfall excess for a given storm, making forecast of floods for the estimation of total yields from a basin and for computing design discharge, so vital for the formulation of projects, is important. Thus, it becomes the bounden duty of all those concerned with water resources development to have in–depth study of hydrology for the design and operation of engineering projects.

The author's endeavor to study Kutch region is an attempt to develop co-relations between rainfall, runoff, surface water and groundwater so that these co-relations can be used for further development of water resources in the region for local area water development.

1.1 GENERAL COMPARISION

1.1.1 Statistics For World

The total water resources on earth are estimated 1460 Million km^3 of which sea water is 1420.6 million km^3 (97.3 %). Hence, only 39.4 million km^3 (2.7 %) is sweet water on earth. Figure 1.1 shows the Map for fresh water resources of the world. Figure 1.2 shows areas of physical and economic water scarcity of the world.

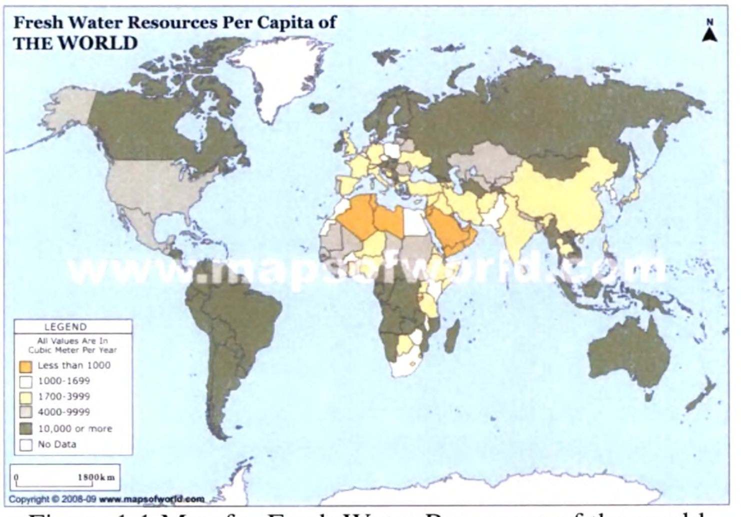

Figure 1.1 Map for Fresh Water Resources of the world
(Source: www.mapsofworld.com)

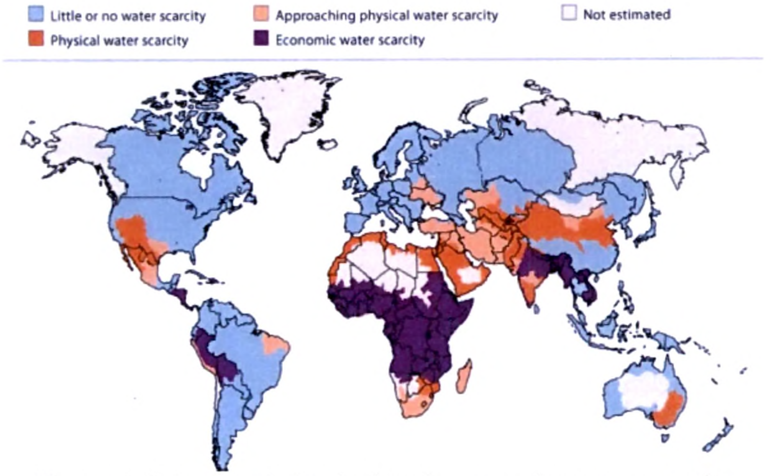

Figure 1.2 Areas of physical and economic water scarcity
(Source: www.mapsofworld.com)

1.1.2 StatisticsFor India

1.1.2.1 Population & Resources

India has 17.23% of the world population (1,167,570,000 as on 13th Aug, 2009) (Indian Population clock). It has 2.45 % of land area 15% of live stock and 4 % of the water resources of the world. Table 1.1 shows the statistics for national water resources of India.

Table 1.1 National Water Resources at a Glance

Items	Quantity (km^3)
Annual Precipitation (Including snowfall)	4000
Average Annual Availability	1869
Per Capita Water Availability (2001) in m^3	1820
Estimated Utilizable Water Resources	1123
(i) Surface Water Resources	690
(ii) Ground Water Resources	433

(Source: Website of Ministry of Water Resources of India)

About 1700 cubic meters of water per capita per annum is required for a comfortable living. When it falls below 1100 cubic meters, the condition is one of serious stress. In India, the average availability of water is expected to drop below 1000 cubic meters by 2050. (Verma Minakshi (2008)).

1.1.2.2 Rainfall

Most of the rainfall in India takes place under the influence of South West monsoon between June to October. The rainfall in India shows great variations, unequal seasonal distribution, still more unequal geographical distribution and the frequent departures from the normal. It generally exceeds 1000 mm in areas to the East of Longitude 78 degree. It extends to 2500 mm along almost the entire West Coast and Western Ghats and over most of Assam and Sub-Himalayan West Bengal. On the West of the line joining Porbandar to Delhi and thence to Ferozpur the rainfall diminishes rapidly from 500 mm to less than 150 mm in the extreme west. The Peninsula has large areas of rainfall less than 600 mm with pockets of even 500 mm. About 75% of the annual rainfall of 4000 billion cubic meters occurs during a short span of monsoon (June to Sept) in a period of about 100 hours duration. Figure 1.3 shows the distribution of average annual rainfall for India.

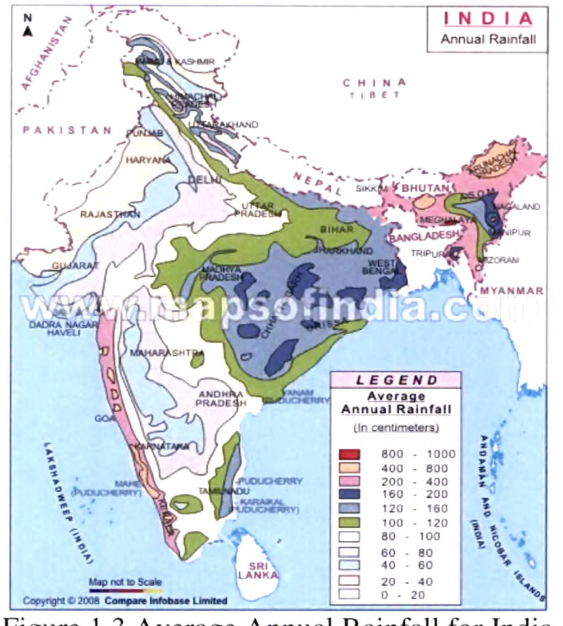

Figure 1.3 Average Annual Rainfall for India
(Source: www.mapsofindia.com)

1.1.2.3 Rivers

India is blessed with many rivers. Twelve of them are classified as major rivers whose total catchment area is 252.8 million hectare (M.Ha). Of the major rivers, the Ganga - Brahmaputra Meghana system is the biggest with catchment area of about 110 M.Ha which is more than 43 percent of the catchment area of all the major rivers in the country. The other major rivers with catchment area more than 10 M.Ha are Indus (32.1 M.Ha.), Godavari (31.3 M.Ha.), Krishna, (25.9 M.Ha.) and Mahanadi (14.2 M.Ha). The catchment area of medium rivers is about 25 M.Ha and Subernarekha with 1.9 M.Ha. catchment area is the largest river among the medium rivers in the country. Table 1.2 shows the basin wise availability of water in India. Figure 1.4 shows the major rivers of India.

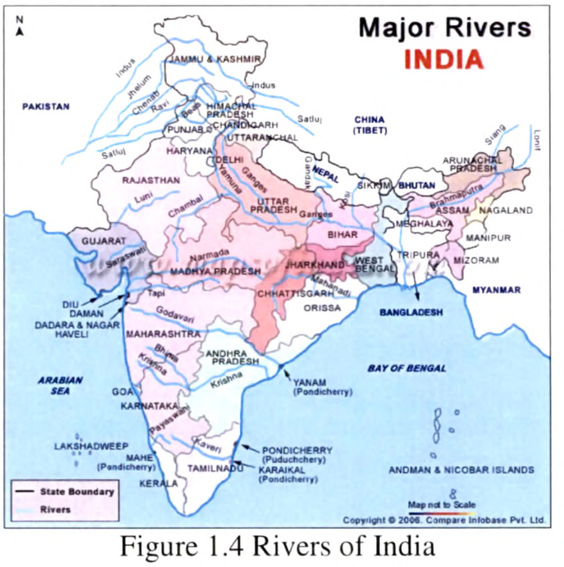

Figure 1.4 Rivers of India
(Source: www.mapsofindia.com)

Table 1.2 Water Availability - Basin wise

Name of the River Basin	Avg. annual availability (km^3/Year)
Indus (up to Border)	73.31
a) Ganga	525.02
b) Brahmaputra ,Barak & Others	585.60
Godavari	110.54
Krishna	78.12
Cauvery	21.36
Pennar	6.32
East Flowing Rivers Between Mahanadi & Pennar	22.52
East Flowing Rivers Between Pennar and Kanyakumari	16.46
Mahanadi	66.88
Brahmani & Baitarni	28.48
Subernarekha	12.37
Sabarmati	3.81
Mahi	11.02
West Flowing Rivers of Kutch, Sabarmati including Luni	15.10
Narmada	45.64
Tapi	14.88
West Flowing Rivers from Tapi to Tadri	87.41
West Flowing Rivers from Tadri to Kanyakumari	113.53
Area of Inland drainage in Rajasthan desert	Negligible
Minor River Basins Draining into Bangladesh & Burma	31.00
Total	1869.35

(Source: Website of Ministry of Water Resources of India)

1.1.3 Statistics For Gujarat

1.1.3.1 Population & Resources

The State of Gujarat covers a total geographical area of 1,95,984 km^2 in western part of India. Gujarat State is situated between 20°06' to 24° 42' North latitude and 68 ° 10' to 74° 28' East longitude. The state has the longest coastline in the country measuring about 1,600 km along western parts of India, extending from Lakhpat in north to Valsad in South. Gujarat State has common borders with the State of Rajasthan, Madhya Pradesh and Maharashtra along North, East and South and with Pakistan in the North-West. It has 4.5 % of India's population (50,596,992, 2004) (Indian Population clock). Figure 1.5 shows the location of Gujarat in India and Figure 1.6 shows the administrative subdivisions of Gujarat.

Figure1.5 Location of Gujarat in India

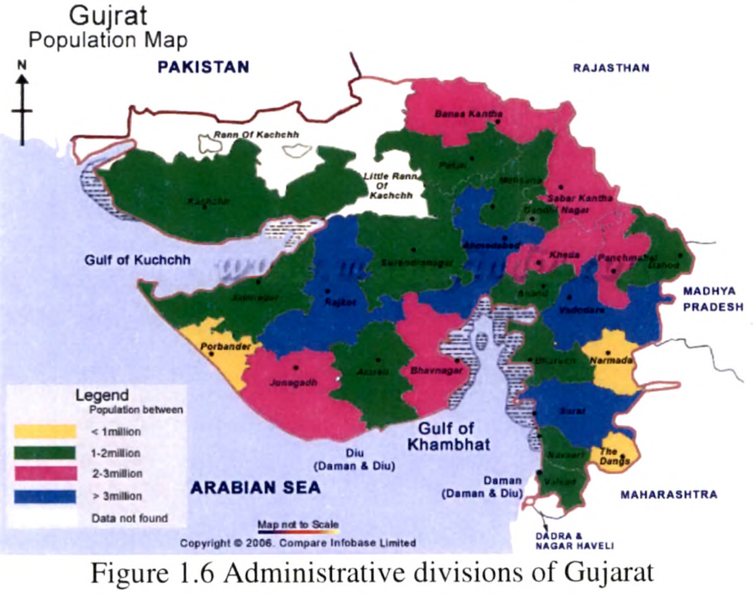

Figure 1.6 Administrative divisions of Gujarat
(Source: www.mapsofindia.com)

1.1.3.2 Physiography of Gujarat

The State of Gujarat can be divided into five major Physiographical zones :

1. Alluvial Plains extending from Banaskantha in north Gujarat to Valsad in the south. The alluvial plains also extend westwards to the little Rann and Banni area of Kutch.
2. The Eastern hilly tract lying between altitude of 300 and 1400 m above msl forms a major divide. Majority of rivers in Gujarat originate from the hills in the east and flow towards south and south-west except Narmada and Tapi (inter state rivers), which cut across the hilly tract along the faulted zones.

3. Uplands of Kutch-Saurashtra comprising sedimentaries and volcanic rocks with elevations of about 150 to 500m. The Mount Girnar is an isolated mountain (1117m above msl) in Saurashtra region.
4. The low-lying coastal tract ranging in elevation from 3 to 25m above msl makes the coastal areas of Saurashtra and Kutch. These low lying areas extend from Rann of Kutch through the Little Rann of Kutch and low lying delta region of Bhadar, Bhogavo, Sabarmati, Mahi Dhadar, Narmada and Tapi rivers.
5. Marshy to saline desert of Rann of Kutch and Little Rann of Kutch extend into the saline tracts around the Gulf of Kutch. This vast expanse of salts mixed with clay is devoid of any vegetation or habitation. The general elevation of this tract varies between 1and 4 m above msl.

1.1.3.3 Climate of Gujarat

Gujarat has varied climate ranging from humid, sub-humid, semi arid to arid type. The summer temperature in many parts of the state rises to as high as 46°C , while the minimum winter temperature of 4°C is also recorded at few locations in the state.

1.1.3.4 Rainfall

The rainfall varies widely in various parts of Gujarat. Maximum rainfall of about 2000 mm is recorded in the southern part, which gradually decreases to about 300 mm in western part in Kutch. The rainfall pattern has conspicuous impact on its economy. The droughts are frequent in north Gujarat, Kutch and Saurashtra regions due to poor and erratic rainfall. Figure1.7 shows the Rainfall and Rainy days for various parts of Gujarat & Figure 1.8 shows Precipitation evaporation ratio in Agro-ecological sub regions of Gujarat.

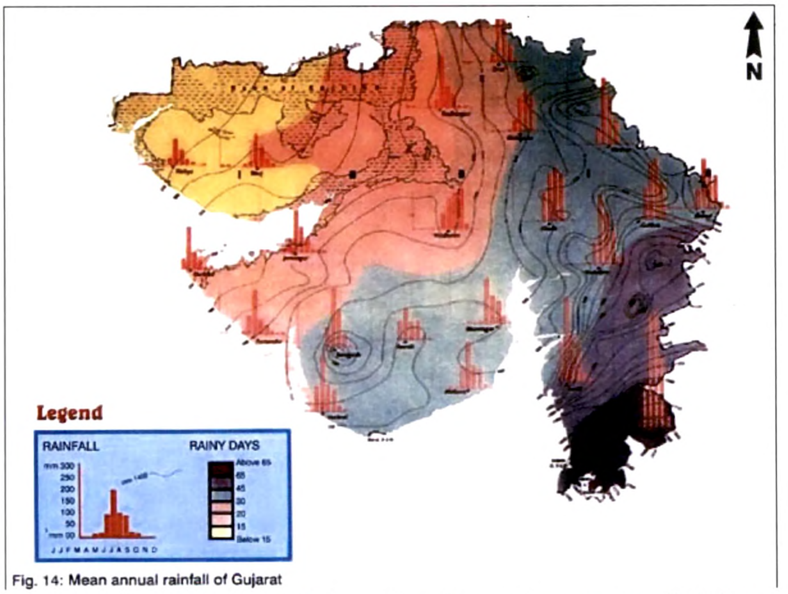

Fig. 14: Mean annual rainfall of Gujarat

Figure 1.7 Rainfall and Rainy days for various parts of Gujarat
(Source: www.agri.gujarat.gov.in)

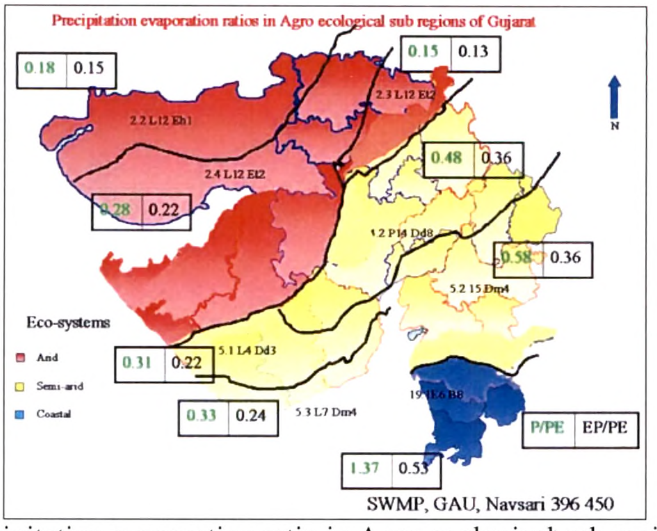

Figure 1.8 Precipitation evaporation ratio in Agro-ecological sub regions of Gujarat
(Source: www.agri.gujarat.gov.in)

1.1.3.4 Surface Water Resources

Drainage of all five physiographical regions of Gujarat State is distinct with the prevailing topographical and physical characteristics of the rock formations. The flow direction of some of the major rivers is controlled by major tectonic activity. All rivers of the state except Tapi, Narmada and Mahi originate in the eastern hilly tract. The rivers flow with highly meandering courses in westerly direction and cut across the alluvial plains. The rivers Narmada and Tapi flow along structural troughs in a westerly direction. The rivers in Saurashtra originate from the central uplands and represent a radial drainage pattern. Table 1.3 shows the details of the surface water resources of Gujarat.

Table 1.3 Details of Surface Water Resources of Gujarat

Name of basins	Narmada, Tapi, Mahi, Sabarmati & others.
Total surface water availability (75% dependability)	18,513 MCM
Contribution from other state Distribution of resources	18,047 MCM
Gujarat Main	16,225 MCM
Saurashtra	2,082 MCM
Kutch	206 MCM

(Source: Central Ground Water Board)

1.1.3.5 Ground Water Resources of Gujarat

By and large the ground water is suitable for drinking, Irrigation and Industrial purpose in the State. The electrical conductivity (EC) ranges from less than 1000 to more than 10000 micro-mho/cm at 25°C. Higher values of EC (more than 3000) is observed in coastal area and in areas with inherent salinity. Chloride ranges from less than 100 ppm to more than 2000 ppm. Higher values of chloride (more than 200 ppm) are observed in coastal area and in areas with inherent salinity. Table 1.4 shows the details of the groundwater resources of Gujarat.

Table 1.4 Details of Ground Water Resources of Gujarat

Dynamic resources	16,060.35 MCM
Utilisable resources for irrigation	12,848.28 MCM
Gross annual ground water draft	9,708.86 MCM
Stage of ground water development	75.57%
Number of Over Exploited Talukas	31
Number of Dark Talukas	8
Number of Grey Blocks	42
Total static resources	1,87,057 MCM
For hard rock area	0.02* 10^6 MCM
For alluvial area	2.56* 10^6 MCM

(Source: Central Ground Water Board)

1.1.3.6 Availability of water

Gujarat has, at present, water availability of 1000 cubic meters per capita per annum which is likely to go down below 600 cubic meters per capita per annum by 2050. The total utilizable groundwater was 17365 MCM in 1984, which declined to 12365 MCM in 1997 registering a drop of 26 percent. The whole of Gujarat falls into the "water stressed" category (GEC 2005: 41)

The state suffers from geo-climatic variations and climate related adversities. In Gujarat, 95 percent of the rainfall occurs during few days of monsoon period, especially during June to September. The visible difference in the rainfall received by the regions leads to a marked disparity in the availability of water. While Kutch gets less than 400 mm of annual rainfall and is a water-starved desert, the Dang area receives very heavy rains. In the Saurashtra region, the annual rainfall ranges from 400 to 800 mm. South Gujarat gets rainfall between 800 to 2000 mm. Therefore, Kutch with 22 percent of the total area has only 2 percent share in the total water resources, while South Gujarat with 25 percent of the total area has access to 71 percent of Gujarat's total water resources. Likewise, Saurashtra has 33 percent of area with water share of only 16 percent and for North Gujarat, the figures are 20 percent and 11 percent, respectively. (GEC 2005: 41).

1.2 ABOUT THE STUDY AREA

1.2.1 Location of Kutch

Kutch is an ancient land possessed of great antiquity, which takes its name from its geographical characteristics and topographical features resembling a tortoise. This crescent shaped region forms part of the northwest Gujarat. Kutch district sprawls in an area of 45,652 km^2 and it forms the northwestern region of India as well as the Gujarat state. The district stretches roughly from 22°44′11″ to 24°41′25″ north latitudes and 68°09′46″ and 71°54′47″ east longitudes. It is bounded on the north and north-west by Sindh (Pakistan), on the north-east by Rajasthan, on the east by the districts of Banaskantha and Mehsana, on the south-east by Surendranagar district, on the south by the Gulf of Kutch and the Rajkot district and on the south-west and west by the Arabian Sea. Administratively, the district consists of nine talukas namely Anjar, Bhachau, Bhuj, Lakhpat, Mandvi, Mundra, Nakhatrana, Naliya and Rapar. The district has its headquarters at Bhuj. Figure 1.9 shows the location of Kutch district in Gujarat State.

Figure 1.9 Location map for Kutch District
(Source: www.wikipedia.org)

1.2.2 Administrative Subdivisions

The Kutch district had been divided into nine talukas i.e. Bhuj, Mundra, Mandvi, Abdasa, Lakhpat, Nakhatrana, Rapar, Bhachau and Anjar. Recently, Gandhidham has been added as the tenth taluka. The district had a population of 1,583,225 of which 30% were urban as of 2001. Figure 1.10 shows the administrative subdivisions in Kutch.

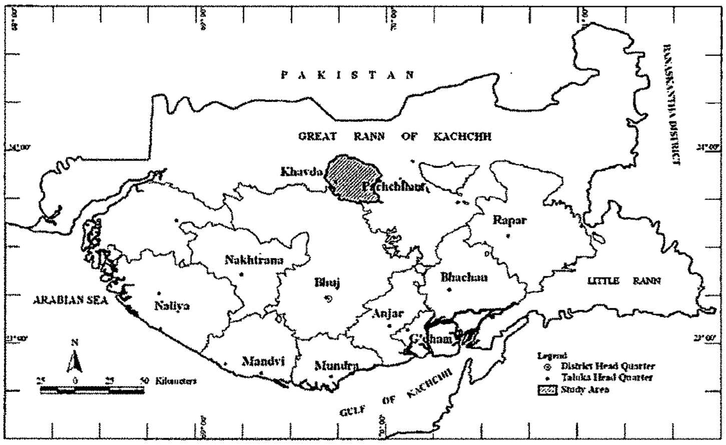

Figure 1.10 Administrative subdivisions of Kutch
(Source: www.act-india.org)

1.2.3 Meteorological Parameters of Kutch

1.2.3.1 Rainfall

The normal rainfall in the district ranges between 300 to 400 mm. Most of annual rainfall in the district is received during the southwest monsoon season, July being the rainiest month. The variation in the annual rainfall from the year to year is very large. On an average there are 14 to 19 rainy days (i.e. days with more than 2.5 mm rainfall) in a year in the district.

1.2.3.2 Wind

Winds are generally light to moderate with some increase in force during the late summer and southwest monsoon seasons. Coastal parts experiences stronger winds, especially during the monsoon season. During the period April to September winds blow mostly from the west or southwest. Rest of the year winds blow from directions between southwest and northwest.

1.2.3.3 Temperature

The day temperatures in the coastal parts of the district in general are less than in the interior. This is particularly so during summer. In the cold season the interior parts are colder by a few degrees. After February temperature rapidly increases till May which is generally the hottest month. The mean daily maximum temperature in May at Bhuj is 38.3°C while at Mandvi it is 32.7°C. In the hot season on some days the day temperature may go above 46°C in the interior and above 41°C in the coastal areas.

1.2.3.4 Humidity

In general, humidity in the coastal parts is high throughout the year, exceeding 60 percent on the average. During the southwest monsoon the humidity of the air over the district in general is high with the relative humidities exceeding 80 percent in the coastal region and over 65 percent in the interior. In the interior of the district, during the rest of the year the air is generally dry with the afternoon relative humidities of the order of 25 percent or less.

1.2.3.5 Cloudiness

The skies are generally heavily clouded and overcast on some days during the southwest monsoon. In the rest of the year skies are mostly clear or lightly clouded.

1.2.4 Physical Features

1.2.4.1 Configuration

The area is on the whole arid, barren and rocky. It has ranges of hills and isolated peaks deeply cut riverbeds and scattered tracks of rich pastureland. On the south, behind a high bank of sand that lines the seacoast, lies a low, fertile, and well-cultivated plain from 32 km to 48 km broad. Beyond this plain, the country is broken by three hill ranges, those of Kutch mainland, of Wagad in the east, and the Rann elevations in the north. The hills of Kutch mainland spread widely in the west, but narrow towards the east. There are three hilly elevations in Rann, namely Pachham, Khadir and Bela. Southwest of Pachham elevation is an extensive low-lying tract known as the Banni, running almost parallel to the coast of Kutch for 104.6 km. It is apt to be covered in times of high flood.

1.2.4.2 The Rann

The Rann of Kutch is a peculiar tract of territory. The entire expanse is covered with a thick salt layer mixed with fine sand and clay devoid of vegetation and habitation. The Rann is characterized by a flat terrain rising up to 4 m above mean sea level and is administratively divided into two parts viz. the Great Rann of Kutch (GRK), occupying the northern parts and Little Rann of Kutch (LRK), forming the eastern and southeastern parts of the Kutch. Out of total area of the district these two Ranns covers about 16691 km^2 area. Some portion of the GRK remains perennially wet and marshy attributed to tidal water ingress that sweeps in during rough whether conditions causing high surge.

1.2.4.3 Coastal Areas

The Kutch district has approximately a coastline of 352 km, with nine ports, viz., Kandla, Tuna, Jangi, Kharirohar, Mundra, Mandvi, Jakhau, Koteshwar and Lakhpat. The coast is generally flat and broken by small and broken by small and big creeks. Big creeks have been formed on account of strong currents of water received from the sea, and small creeks have been formed on account of rapid flows of rivers. In some of the creeks, the water stays permanently and some receive water only during tides. These creeks are also useful for coasting crafts and streamers when the sea is rough and stormy.

1.2.4.4. Rivers

There are about 81 non-perenial or seasonal rivers in Kutch. All the rivers or streams start from its central portion and flow towards the sea in the south and the Great Rann in the north and the Little Rann in the southeast. Broadly speaking, the rivers flow northwards or southwards because of the ranges in the central area, which serve as watersheds. There are physical contours varying from 16 km to 32 km, which create independent flows of water. As a result, there is one river at every 24 km in the district. The rivers have steep gradients and are flashy. They have therefore formed deep cuts along their courses and rarely spill over their banks. Some rivers are called by different names of villages by which they pass. This is particularly the case with small rivers.

1.2.4.5 Structure And Stratigraphy

Kutch region forms an important site for the Mesozoic and Cenozoic rocks. The rock types are mainly sandstones, shales and limestones. The Mesozoic rocks ranging in age from Middle Jurassic to lower Cretaceous occur conspicuously in the various major uplifts, and are exposed extensively in the Kutch Mainland, Wagad, the islands of Pachcham, Bela and Khadir.

The Deccan trap is restricted only to the Kutch Mainland bordering Mesozoic highlands extending from Lakhpat in the west to Anjar in the east. Lava flows overlie the Jurassic sandstone, occupying the southern and south-western slopes of the central highland. The Teritary rocks are exposed along the coastal belt of southern and western Kutch bordering the Mesozoic rocks. These also occur in the northern islands, i.e., Pachcham, Bela and Khadir. The Quaternary deposition in Kutch is rather poor and fragmentary. The related marine sediments are represented by Aeolian accumulation of Miliolite far inland from the coastline.

The main structural features responsible for the present architecture of Kutch are group of East – West trending faults viz.

(i) The Allah Bund Fault
(ii) The Island Belt Fault
(iii) The Kutch Mainland Fault and
(iv) Katrol - Bhuj Fault

A very comprehensive description of various aspects of geology of Kutch has been given in the book entitled "Geology of Gujarat" by S.S.Merh. published by the Geological Society of India, Banglore in 1995.

1.3 PROBLEMS OF THE STUDY AREA

1.3.1 Earthquakes

The Kutch has a long history of earthquake of varying magnitudes. Kutch falls in seismically active Zone V of the Indian sub-continent outside the Himalayan belt as per the Seismic Zoning Map of India (IS : 1893 – 1984). A disastrous earthquake of magnitude 6.9 struck Bhuj and adjoining areas of Kutch district in Gujarat in the morning of January, 26, 2001 which took a toll of human lives exceeding 18000 and caused extensive damage to over 6 lakh houses. The damage was maximum in Bhachau, Bhuj, Anjar, Gandhidham and Rapar talukas of Kutch.

1.3.2 Ingress of Desert Of Kutch

The Rann ingress into the 'Banni Plains' of Kutch district, Gujarat which is famous for the sprawling grasslands supporting significant cattle population is taking place at an alarming rate. This has resulted in the desertion of many villages due to intrusion of Rann waters. In the present investigation multi-date satellite data has been analysed to map and monitor the Rann ingress during the period 1975 to 1989. Detailed analysis has brought out that the inundation is quite rapid affecting about 244 km^2 area during 1960–1989 period. Mapping of the creeks has also been done to understand the possible mechanism of 'Rann ingress'.

1.3.3 Banni Grassland of Kutch

The Banni Grass Plain is a vast salt affected region that represents an embayment between the Kutch Mainland in the south, the Linear Trench Zone, and island chain in the north. This geomorphic unit covers about 3000 km^2 area. The Banni plain forms a low alluvial tableland rising about 03 to 10 m above the sea level. The soils of Banni are sandy to silty loam with lenses of clay. On account of high silt and clay content, the overall permeability of the soils is low and as a result the vertical as well as lateral movement of surface and sub surface water is considerably inhibited causing inundation during rainy season. The Mainland area and the islands from the south and north respectively constitute the catchment area for the Banni Grass plains. During the monsoon with good rainfall the Banni area gets inundated that supports varieties of grasses and shrubs.

1.3.4 Increase in Growth Of "Gando Bawal"

The people of Kutch in Gujarat call it the gando bawal (the mad tree). Brought to India in 1877 by the British, it was introduced in the 1950s and the 1960s in Kutch to check the spread of the Little Rann of Kutch. Now, the problem is the thorny tree's unrestricted spread in the shrinking pastures. P juliflora started becoming gando bawal after it began spreading where it was not wanted. One such area is the 3,847-sq km Banni of Kutch on the edge of the Great Rann of Kutch, considered India's most extensive grassland. Though it has lost much of its greenery, the Banni still sustains a population of 30,000 milch cattle and 25,000 sheep and goats and camels. Also threatened by the mad tree are the traditional water storage systems, such as Virda, in the villages of Banni. The water table in these structures is going down, and fallen leaves and pods of P juliflora make water unfit for drinking. The well-developed root system of P juliflora is reported to have choked and damaged pipes supplying water to villages.

1.3.5 Sea Water Intrusion

The inherently saline belt includes region of Rann and Banni in the Kutch district. Besides, the relatively scanty-erratic rainfall (between 300 to 400 mm) with the river basins of this region having almost no water in the non-monsoon seasons are the compounding factors increasing the salinity ingress.

With scarce water supply from surface water sources, there is no other option for the people of Kutch to use other than ground water. Ground water accounts for about 85 percent of the water supply for irrigation, industrial as well as domestic purposes. The indiscriminate groundwater exploitation is primarily responsible for the pathetic and alarming problem of salinity ingress in the region. Also, excessive irrigation through groundwater aggravates the inherent characteristic of salinity. Coastal regions are found to have TDS values as high as 7000 to 8000.

1.4 BACKGROUND FOR STUDY

Kutch is an arid region with low rainfall and scarce water resources. Various other historical, geological and political reasons make Kutch a region dependent on its own resources. There are very limited options to draw upon any external resources. The arid conditions of the region allow limited supplies of water and there is a need to provide for the growing demand.

With scanty and erratic rainfall pattern, scarcity of water and excessive exploitation of ground water, Kutch is an ideal region for study of water resources for future planning and management. There are about 81 seasonal rivers flowing through the region. Perennial rivers are non-existent. Inspite of having 20 medium irrigation schemes, 165 minor irrigation schemes and number of other micro structures, sufficient quantity of surface water is not available for domestic as well as irrigation purposes. Further, with Kutch having the largest coast line of Gujarat, there are number of ports in the region. Therefore, the demand for industrial use of water is also increasing by each day. The region offers tremendous development potential and it can only be realized when the available resources are optimally used.

Ground water accounts for 80 to 90 % of the water supplied for irrigation and drinking water supply. This over exploitation of ground water has resulted in brackish water, i.e deterioration of ground water quality and depletion of ground water table. Due to excessive lowering of ground water table, problems like intrusion of sea-water into the soil have become aggressive. In the coastal regions, the TDS values of ground water are as high as 8000. Inspite of such high values of TDS, the farmers are using the saline water for irrigation with less options available, making the soil further infertile. Bulk water supply scheme providing water from Narmada river through Maliya branch canal has recently started providing water for domestic purposes. In some of the villages, the frequency of potable water supply is almost once in a week. The opportunity of bringing external sources of water has been exhausted with the Narmada project.

Due to the earthquake on 26th January, 2001, there was severe damage to all the medium irrigation schemes of Kutch region. As a part of a research project given by International Commission on Irrigation and Drainage (ICID-CIID), I had conducted a study on effect of the earthquake on the medium irrigation schemes of Kutch. During my visits to the dams, I realized the intensity of the problem of water scarcity of the region and decided to take up a detailed study for the region.

1.2 OBJECTIVES OF STUDY

Kutch is a very typical region with complex soil and geology. It has scanty and erratic rainfall. Though the rainfall is scanty, it gives flash floods causing runoff for a very short duration. This runoff should be tapped in every possible way. The region has sandy strata with high permeability results in groundwater recharge due to surface storage structures. Therefore, further possibilities of tapping of surface water should be explored and the effect of existing storage structures on the groundwater fluctuations should be studied.

This situation therefore necessitates a detailed study of the existing water resources of the region and determine the surface and groundwater potential for the region.

Realizing the intensity of the problem of water scarcity of Kutch it was decided to take up a detailed study for the region.

The main objectives of the study are as follows:

1. To study in detail the rainfall pattern for the region.
2. To estimate the stormwater runoff for the region.
3. To develop relationship between rainfall and runoff.
4. To study the groundwater table fluctuations for all the talukas and evaluate the effect of rainfall on the ground water table fluctuations.

1.3 METHODOLOGY ADOPTED

The step by step methodology adopted for the purpose of this study is described as follows:

1. Collection of relevant data for all the talukas from government and semi-government offices and NGOs.
2. Analysis of the rainfall data for the region using STATISTICA for Windows version 5.0.
3. Preparation of landuse map using Landsat Thematic Mapper (TM) data at 90 m resolution with the help of software Arc GIS 9.2 and ArcView GIS 3.2.
4. Estimation of runoff for the region using SCS-CN method.
5. Analysis of pre-monsoon and post-monsoon groundwater level fluctuations for all the talukas using software Surfer version 8.00.
6. Estimation of groundwater draft for all the talukas using equation developed during the study.
7. Development of relationship between rainfall and runoff for all the talukas STATISTICA for Windows version 5.0.
8. Development of relationship between rainfall and groundwater recharge for all the talukas STATISTICA for Windows version 5.0