INCEPTION REPORT

Augmenting Groundwater Resources by Artificial Recharge

Research Site at Aravalli Hills, Gujarat, India

SUMMARY

The collaborative research project '***Augmenting Groundwater Resources by Artificial Recharge***' (AGRAR) aims at gaining improved knowledge on the impacts of artificial recharge structures in different physical and socio-economic settings leading to the development of decision-support guidance on the scope and effectiveness of artificial recharge activities. As part of the project, VIKSAT is carrying out the research study in the Aravalli Hills region of Gujarat, India. The artificial recharge structures identified for the research study are three check dams (in Mumanvas, Bhanavas and Samrapur villages), a pond (in Nana Kothasana village) a percolation tank (in Nedardi village) and two sub-surface check dams (in Samrapur village) of Satlasana taluka, Mahesana district. The study area is surrounded by the Aravalli Hills and forms a clear-cut catchment boundary. The area extends from North latitude 24^{o} 2′17″ to 24^{o} 5′17″ and East longitudes 72^{o} 45′00″ to 72^{o} 47′13″. The catchment area covers approximately 25.25 sq km.

The area lies in the transition zone between a semi-arid and an arid agro-climatic region. The average annual rainfall is about 650mm which occurs in a period of 100 days and the actual rainy days are only 30-35. A good monsoon year will bring cheer on the face of the farmers as agriculture is the primary livelihood of the people. Even though multi-cropping system is followed, due to erratic and less than average rainfall in the last four years (1999-2002) has pushed down people's economy. Migration of people and change over of profession to non-agriculture for livelihood earning has become common. The extensive groundwater development by the most affluent farmers has also caused decline in groundwater level. The dug wells have dried during the last 10 years and the depth of the bore wells has increased to about 150m.

Hard rock Granite forms the Geology of the area. The rock is highly weathered and allows for rapid percolation of rainwater into the ground. However, there is water imbalance in terms of groundwater recharge and over-extraction.

The research project offers an opportunity to scientifically look into the effectiveness of artificial recharge structures and its impact on the livelihood of the people.

The research study requires installing scientific equipments to collect data on weather, groundwater levels and water levels in the recharge structures. Water level monitoring and the weather data are the key parameters for computing the water balance in the recharge area.

The social composition of the study area is characterised by a hierarchy of various caste/community in the villages. Darbars and Thakores constitute the majority communities in the project villages. However, Muslims form a substantial section in one village.
People in the study area used to depend on groundwater for drinking purpose until 2001. For the last two years most of them have access to drinking water from Dharoi dam, which

is located about 12 km. away from the study villages. Groundwater is not potable due to high salt and fluoride contents.

Agriculture is the primary occupation of majority of households. However, during the recent consecutive droughts (1999-2002), due to drastic depletion of groundwater, people were forced to seek alternative livelihood options. There has been high incidence of temporary as well as permanent migration of people due to loss of livelihoods within the region. Animal husbandry and labour work emerged as alternatives during the drought period.

The project endeavours to bring out results of scientific analyses on the augmentation of groundwater by artificial recharge, which shall lead to dissemination of the research findings to people, CBOs, Panchayat members and the other NGOs for strategically adopting such structures to increase the groundwater availability for judicious by the people. The findings and the scientific results will leverage NGOs and CBOs to policy advocacy with the government.

1 INTRODUCTION

Overview of the Study:

VIKSAT has been working in the area of natural resources management (NRM) particularly in wasteland development and participatory forest management since its establishment in 1977. In 1993, the NRM programme in VIKSAT was expanded to cover water management with special focus on groundwater in Satlasana. During the consecutive droughts of 1999-2002, VIKSAT initiated drought-proofing programmes in eight villages in Gadhwada Region out of the 23 villages where it is working. During this period, many soil and moisture conservation structures were constructed including surface check dams, sub-surface check dams, gully plugs, trenches, storage tanks, farm bunds, gabion structures and percolation tanks. All these structures are known to augment groundwater.

In order to facilitate policy advocacy in water management at various levels it is necessary to have scientific accuracy in the knowledge regarding the extent of groundwater recharge in the given geo-climatic context. This includes understanding of geo-physical parameters, groundwater systems, effectiveness of various groundwater recharge structures in vogue and its impacts on livelihood systems of the people. This has been initiated through the research project "***Augmenting Groundwater Resources by Artificial Recharge***" (AGRAR). AGRAR is a collaborative project funded by the Department for International Development (DFID), U.K. under the Knowledge and Research Programme initiated by British Geological Survey (BGS).

The project aims at gaining improved knowledge of the impacts of artificial recharge structures in different physical and socio-economic settings leading to the development of decision-support guidance on the scope and effectiveness of Artificial Recharge activities.

The second phase of the project started in July 2003 and will be completed in July 2005. The study intends to increase the knowledge and disseminate guidelines on the effective application and operation of schemes that aim to augment groundwater resources by artificial recharge. VIKSAT is carrying out the research study in the Aravalli Hills region of Gujarat, India.

Organisation and the Expertise of Staff:

VIKSAT is working in the area of natural resources management (NRM). Its initial experience was in wasteland development later enlarged to participatory Joint Forest Management (JFM) in two talukas namely, Bhiloda and Satlasana in Sabarkantha and Mehsana districts respectively. In 1993, the NRM programme in VIKSAT was expanded to look into water management with special focus on groundwater. VIKSAT has been conducting research studies on water management with focus on groundwater and has established different models for rainwater harvesting for recharge and reuse, in the urban, peri-urban and rural Gujarat.

VIKSAT has a team of specialists from various disciplines such as Hydrogeology, Geophysics, Civil Engineering, Geographical Information System (GIS) and Remote Sensing, Economics, Agriculture, Forestry, Environmental Science and other Social Sciences. The organisation has established three field offices, which are strategically located in the low rainfall and often drought prone North Gujarat and Kachchh regions. The experience of the staff in various types of research and implementation of programmes ranges between 5 and 25 years. The list of staff members who are engaged in AGRAR project with their areas of expertise and years of experience is given in Annexure-1.

Role Played by Local Communities

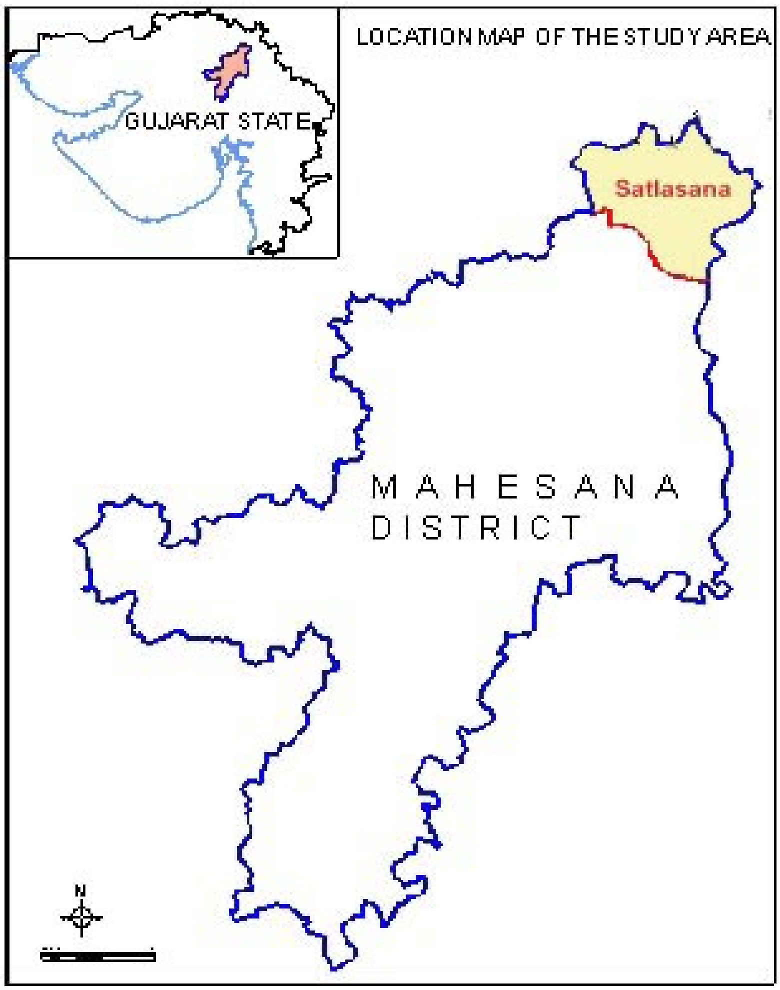
In the early 1990s, VIKSAT facilitated the formation and strengthening of Tree Growers' Co-operative Societies (TGCS), the People's Institutions at the village level, aimed at conservation and regeneration of forest resources. These village level people's institutions have federated at the taluka level as *Gadhwada Jal Jameen Sanrakshan Sangh* (meaning the 'Association for the Conservation and Protection of Land and Water in the Gadhwada Region'). Some of the TGCSs are as old as 15 years while others were established subsequently. Presently, there are 20 TGCSs in this region. VIKSAT has facilitated the *Sangh* to take up regional level developmental programmes and to liaison with the taluka/district level government departments. The Sangh and the TGCSs are protecting the forest in the respective villages and taking up plantation activities every year.

The Sangh initiated drought relief and drought proofing programmes in the region directed at both short term and long-term impacts. This included construction of check dams and deepening/desilting of ponds. In the current year (2003), the Sangh initiated implementation of Sardar Patel Jal Sanchay Yojana of the Government of Gujarat. Under this programme, six water-harvesting structures (check dams) were constructed in the region. Twelve more water-harvesting structures are in the process of sanctioning under this project. One of the check dams constructed as part of this project has been selected for the AGRAR research study. VIKSAT has played a facilitating role in these initiatives of the Sangh by providing critical technical and managerial support.

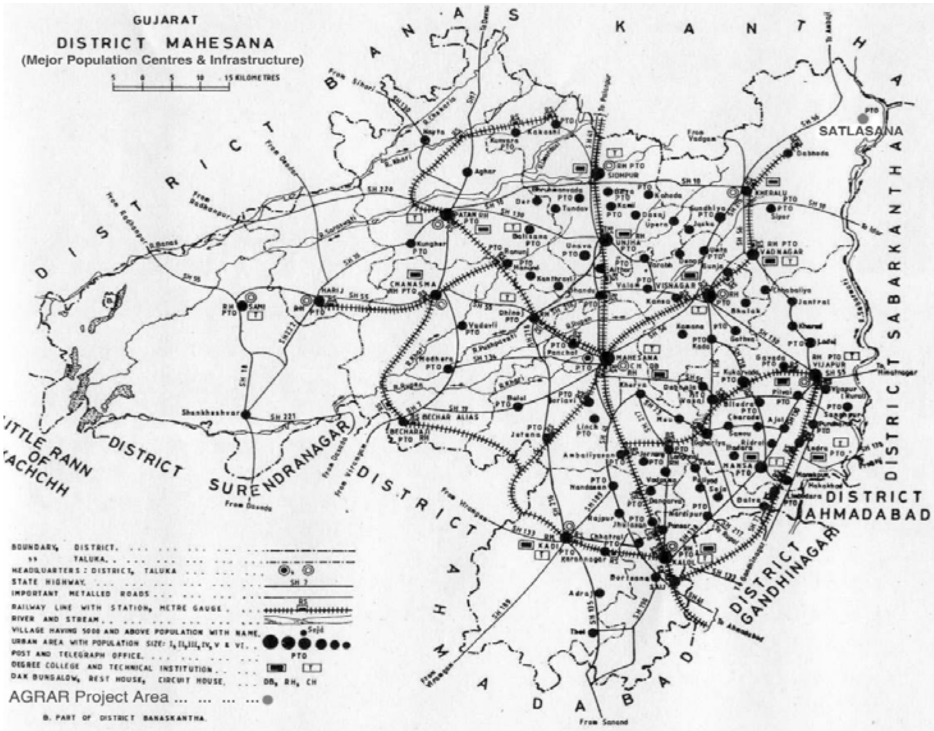
The Sangh is also taking up other development activities in the region such as provision of drinking water and sanitation facilities by accessing funding support from various government schemes. The Sangh as well as the TGCSs at the village level are also engaged in environmental awareness programmes and various initiatives in water management and agricultural extension.

2. District-scale

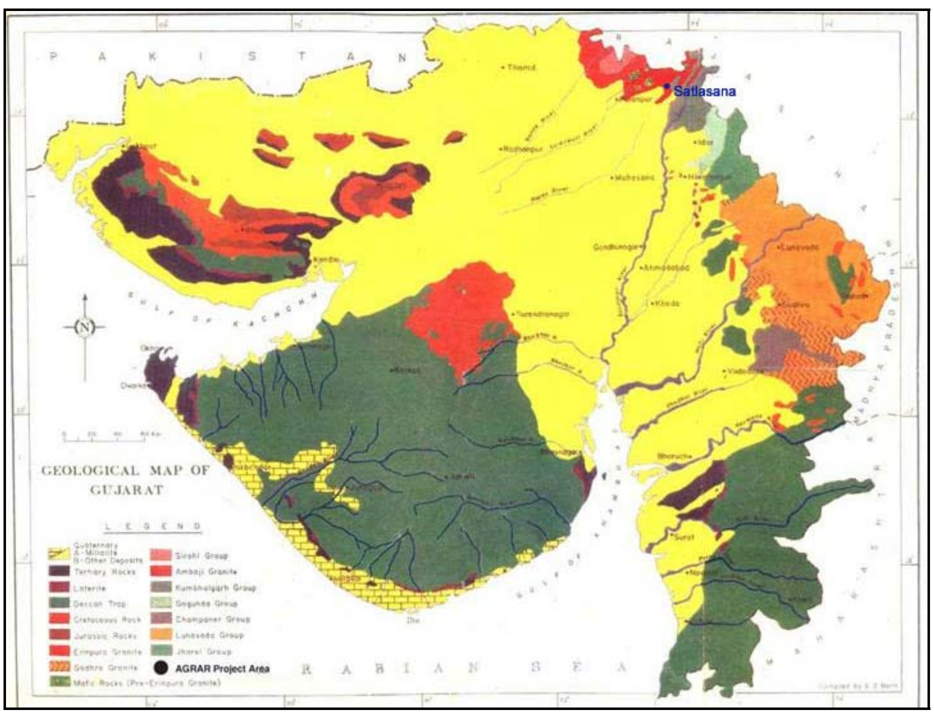
AGRAR research area is in Mehasana District in North Gujarat. There are 9 talukas (Sub-divisions) in the district. Satlasana Taluka is located in the North-eastern part of the district. It is adjoining the Sabarkantha taluka in the eastern side and Banaskantha taluka in the western side. The geographical area of the district is 9027 Sq.km. The location of Mehsana district in Gujarat is shown in the following Map 1.



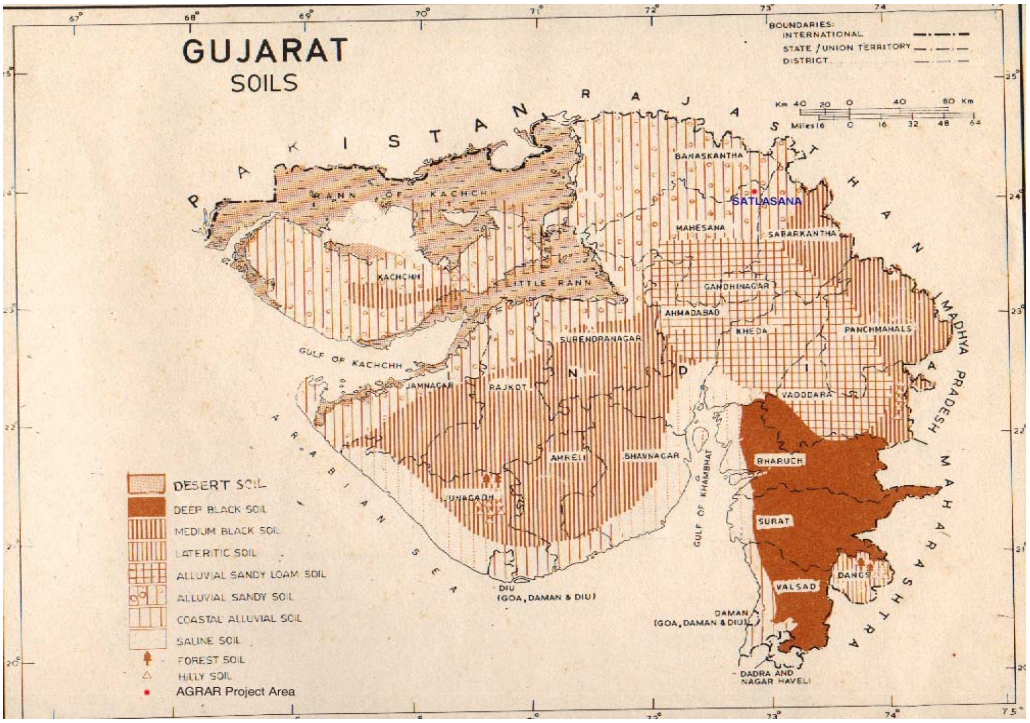
Map. 1 Study area in Gujarat


GUJARAT
DISTRICT MAHESANA
(Mejor Population Centres & Infrastructure)
SATLASANA
DISTRICT SABARKANTHA
DISTRICT AHMADABAD
DISTRICT GANDHINAGAR
DISTRICT SURENDRANAGAR
AGRAR Project Area

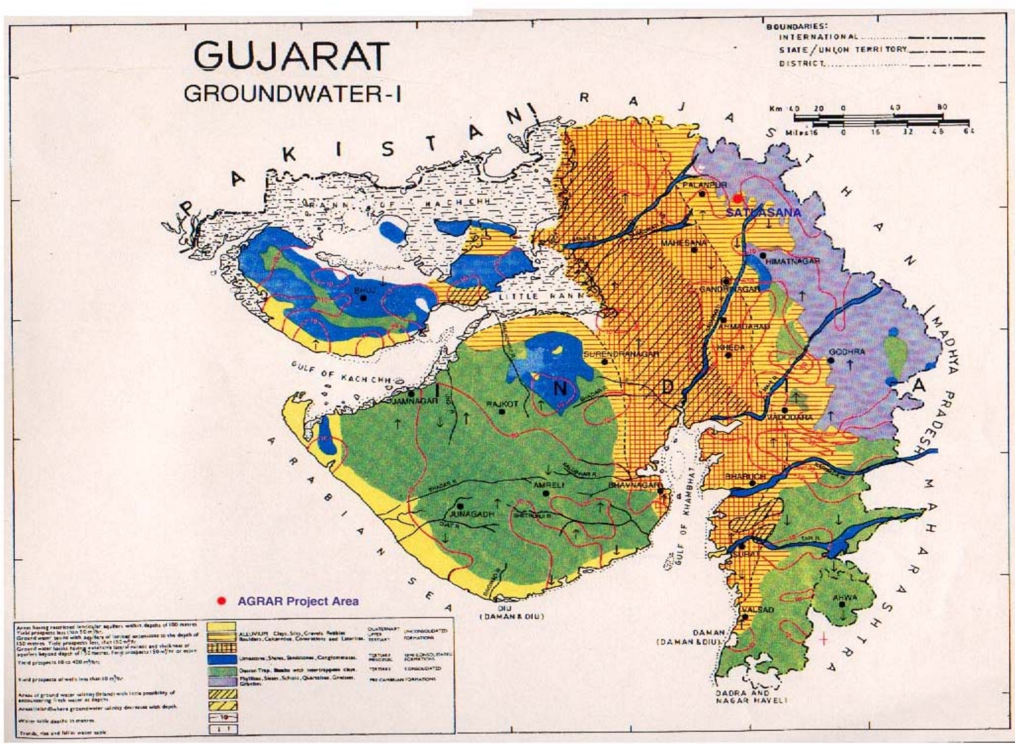
Map-2


P A K I S T A N
Satlasana
GEOLOGICAL MAP OF GUJARAT
LEGEND
Tertiary Rocks
Laterite
Deccan Trap
Cretaceous Rock
Jurassic Rocks
Erinpura Granite
Godhra Granite
Mafic Rocks (Pre-Erinpura Granite)
Sirohi Group
Ambaji Granite
Kumbhalgarh Group
Gogunda Group
Champaner Group
Lunavada Group
Jharol Group
AGRAR Project Area
A R A B I A N S E A

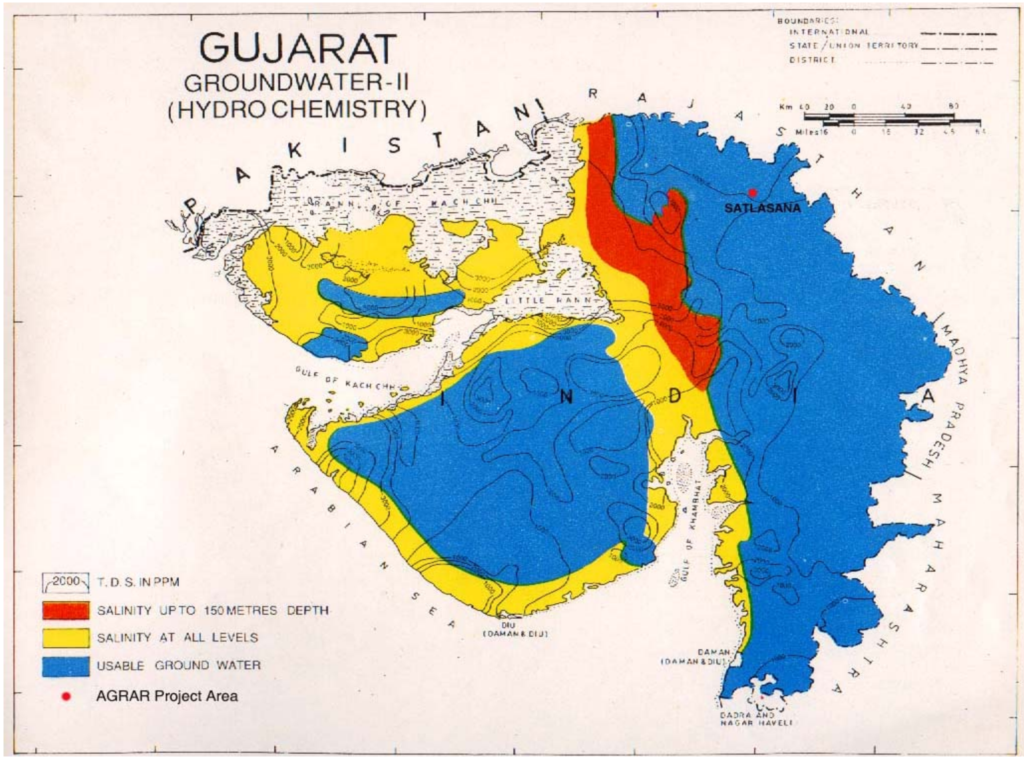
Map-3


GUJARAT
SOILS
BOUNDARIES:
INTERNATIONAL
STATE / UNION TERRITORY
DISTRICT
PAKISTAN
RAJASTHAN
MADHYA PRADESH
MAHARASHTRA
ARABIAN SEA
RANN OF KACHCHH
KACHCHH
LITTLE RANN
GULF OF KACHCHH
BANASKANTHA
SATLASANA
MAHESANA
SABARKANTHA
GANDHINAGAR
AHMADABAD
KHEDA
PANCHMAHALS
SURENDRANAGAR
JAMNAGAR
RAJKOT
VADODARA
AMRELI
BHAVNAGAR
BHARUCH
JUNAGADH
GULF OF KHAMBHAT
SURAT
DANGS
VALSAD
DIU (GOA, DAMAN & DIU)
DAMAN (GOA, DAMAN & DIU)
DADRA AND NAGAR HAVELI
DESERT SOIL
DEEP BLACK SOIL
MEDIUM BLACK SOIL
LATERITIC SOIL
ALLUVIAL SANDY LOAM SOIL
ALLUVIAL SANDY SOIL
COASTAL ALLUVIAL SOIL
SALINE SOIL
FOREST SOIL
HILLY SOIL
AGRAR Project Area

Map-4

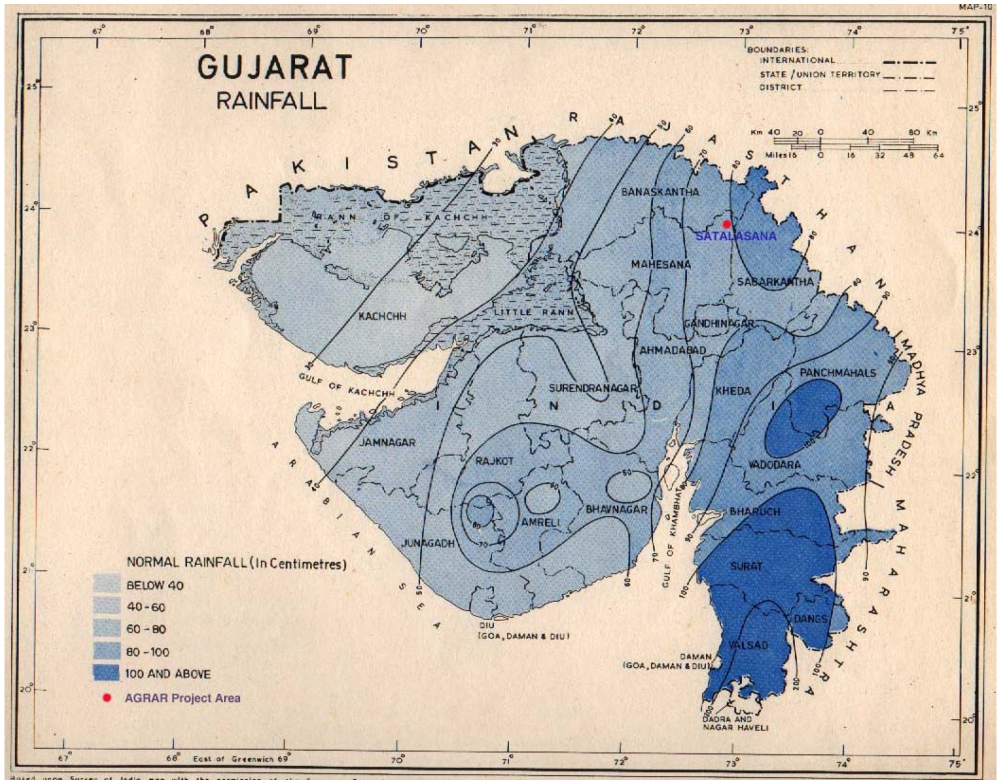

GUJARAT
GROUNDWATER-I
BOUNDARIES:
INTERNATIONAL
STATE / UNION TERRITORY
DISTRICT
PAKISTAN
RAJASTHAN
MADHYA PRADESH
MAHARASHTRA
ARABIAN SEA
RANN OF KACHCHH
LITTLE RANN
GULF OF KACHCHH
BHUJ
PALANPUR
SATLASANA
MAHESANA
HIMATNAGAR
GANDHINAGAR
AHMADABAD
KHEDA
GODHRA
SURENDRANAGAR
JAMNAGAR
RAJKOT
VADODARA
AMRELI
BHAVNAGAR
BHARUCH
JUNAGADH
GULF OF KHAMBHAT
SURAT
AHWA
VALSAD
DIU (DAMAN & DIU)
DAMAN (DAMAN & DIU)
DADRA AND NAGAR HAVELI
AGRAR Project Area

Map-5


GUJARAT
GROUNDWATER-II
(HYDRO CHEMISTRY)
PAKISTAN
RAJASTHAN
MADHYA PRADESH
MAHARASHTRA
INDIA
ARABIAN SEA
GULF OF KACHCHH
GULF OF KHAMBHAT
LITTLE RANN
SATLASANA
DIU (DAMAN & DIU)
DAMAN (DAMAN & DIU)
DADRA AND NAGAR HAVELI
BOUNDARIES:
INTERNATIONAL
STATE / UNION TERRITORY
DISTRICT
2000 T. D. S. IN PPM
SALINITY UPTO 150 METRES DEPTH
SALINITY AT ALL LEVELS
USABLE GROUND WATER
AGRAR Project Area

Map-6

Map-7



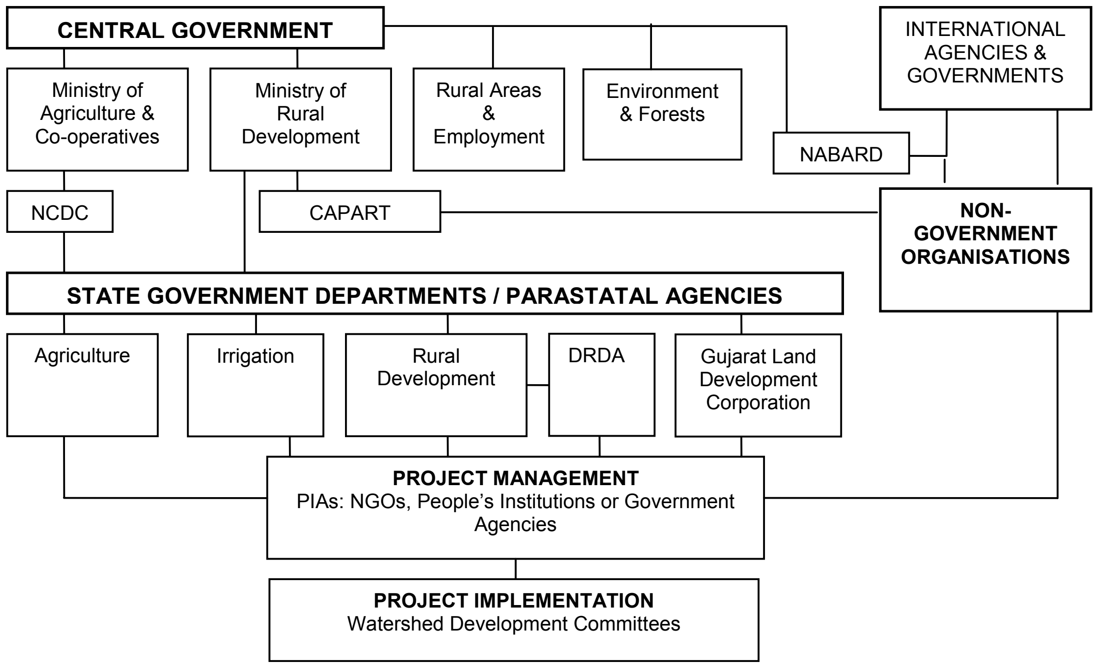
Map-8

Institutions in Watershed Development Sector

There are many agencies working in the area of watershed development in the country. They include governmental, parastatal (semi-government), non-governmental as well as international agencies. Different Ministries of the Central and State governments such as Ministry of Agriculture and Co-operatives, Rural Development, Environment and Forests are engaged in watershed development either directly or through parastatal agencies such as National Co-operative Development Corporation and Council for Advancement of People’s Action and Rural Technology (CAPART). International development agencies such as KFW (Germany) are funding watershed development projects in a major way through NABARD and NGOs. NGOs mostly work as Project Implementation Agencies (PIAs) and access funds from the government as well as international agencies such as OXFAM, SDC, ICEF etc., and private sector corporations in India. The government has comprehensive watershed development programmes as well as specific efforts in soil and moisture conservation as part of drought relief programmes (see the diagram “Institutions in Watershed Development in Gujarat” on the next page).

In the study area in Satlasana, the Gadhwada Sangh, with the facilitation of VIKSAT and funding support from OXFAM and Sir Dorabji Tata Trust (SDTT), implemented drought-proofing programmes during 2000-02. As part of these programmes many soil and moisture conservation structures such as check dams and gully plugs have been constructed in eight villages in Satlasana. Samrapur check dam, one of the observation structures in AGRAR project was constructed with the funding support from OXFAM and Bhanavas check dam was constructed with the funding support from SDTT. During the summer of 2003, the Gadhwada Sangh with technical support from VIKSAT constructed six check dams in Satlasana taluka by accessing funds from the Department of Minor Irrigation, Government of Gujarat under Sardar Patel Sahabhagi Jal Sanchay Yojana.

CHART.1 INSTITUTIONS IN WATERSHED DEVELOPMENT IN GUJARAT



NABARD: National Bank for Agriculture and Rural Development
NCDC: National Co-operative Development Corporation
CAPART: Council for Advancement of People's Action and Rural Technology
DRDA: District Rural Development Agency
PIAs: Project Implementation Agencies

Institutions in Drinking Water Provision

The analysis of the institutions and operators working in the drinking water sector shows that there are many stakeholders (see the diagram “Institutional Structure and Linkages in Water” on next page). They are the various departments and parastatal organisations of the government, private operators who are engaged in drilling tube wells and selling water for irrigation purposes, Panchayati Raj institutions and people’s institutions at the village, taluka and regional levels and non-government organisations that facilitate collective action by the people for resource management, and the village community. In Gujarat, the Gujarat Water Supply and Sewerage Board and Narmada Water Resources and Water Supply Department are in charge of provision of drinking water. The latter, along with Gujarat Water Resources Development Corporation, is expected to provide irrigation water through various minor and major irrigation projects. The Dharoi Dam is meant for providing drinking as well as irrigation water to the people in the command area. It may be mentioned here that the study area villages are benefiting from the Dharoi Reservoir in terms of drinking water for the last two years. At the village level, the Panchayat is directly responsible for providing drinking water to the people. They can do this either through community wells or stand posts at various places in the settlement or through a scheme of piped water supply depending on the financial resources available.

There are private tube well companies operating at taluka and district levels. As there are no regulations about drilling bore wells and tube wells, a large number of bore wells have been drilled in the village by farmers individually and jointly. Some of them were also engaged in selling water (when water was available in plenty) to the neighbouring farmers who paid either in cash or in kind depending upon the type of crops irrigated.

There are people’s institutions in the area having the mandates of natural resource management especially land and water. The Tree Growers Co-operative Societies (TGCS) at the village level and the Gadhwada Jal Jamin Sanrakshan Sangh (GJJSS) at the taluka level and the Sabarmati River Stakeholders’ Forum at a regional level are all examples of this. TGCS is mainly engaged in protection and management of forest resources even though there are many initiatives in groundwater management in the formative stage. The GJJSS is a taluka level federation of the TGCSs at the village level and have carried out soil and moisture conservation initiatives in the village recently as a response to the drought.

Recently the Government of Gujarat has brought out its draft water policy in conformity with the national water policy. The state water policy aims at achieving an equitable, just and sustainable management of water resources. The draft policy is yet to be finalised after consultations with various stakeholders in the sector. The water policy will have implications on the present pattern of water use and management of water resources in the state and the various actors presently engaged in water development, utilisation and management. One of the striking features of the draft water policy is the government’s stated intention to involve private sector in water management.

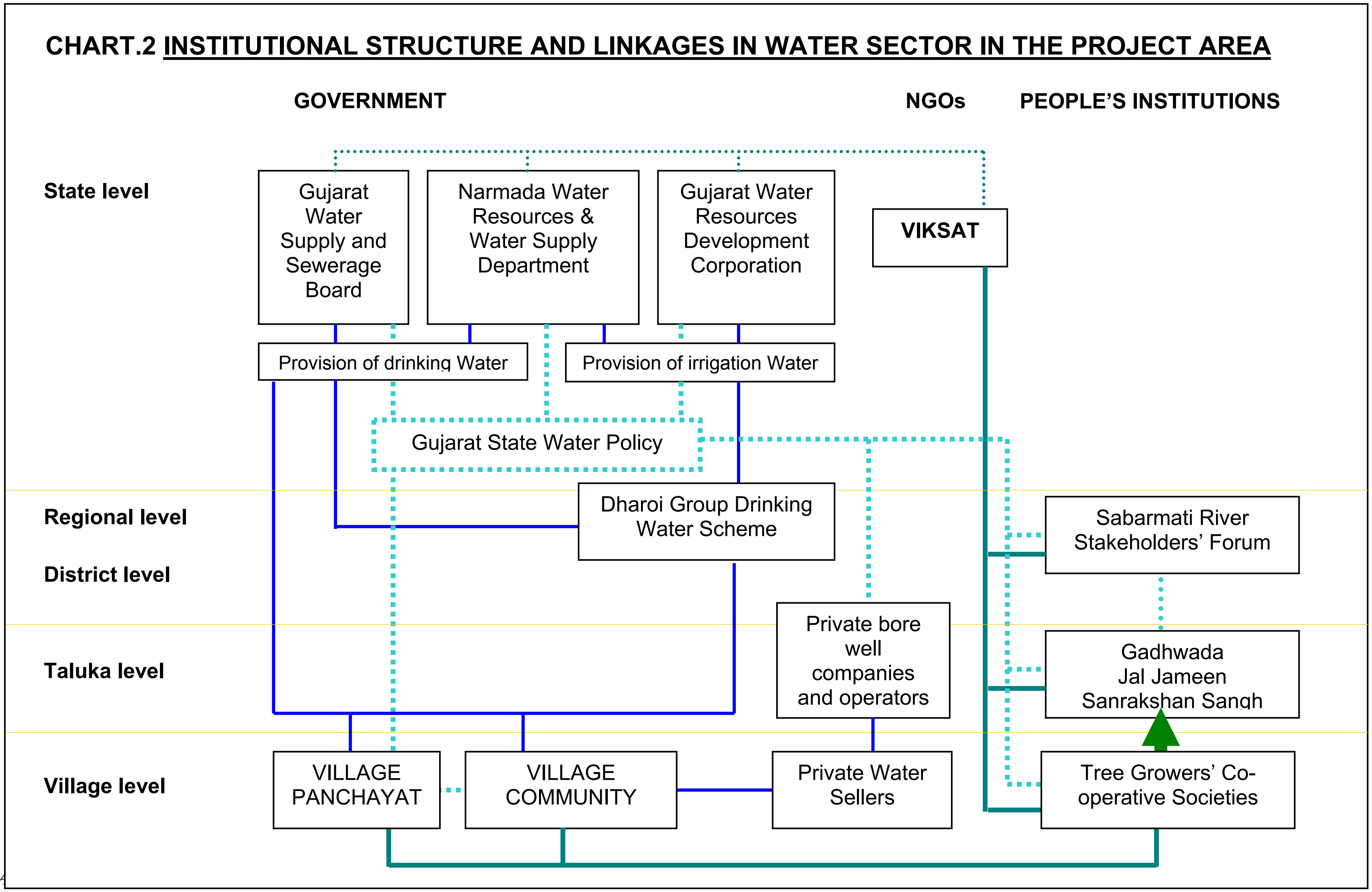


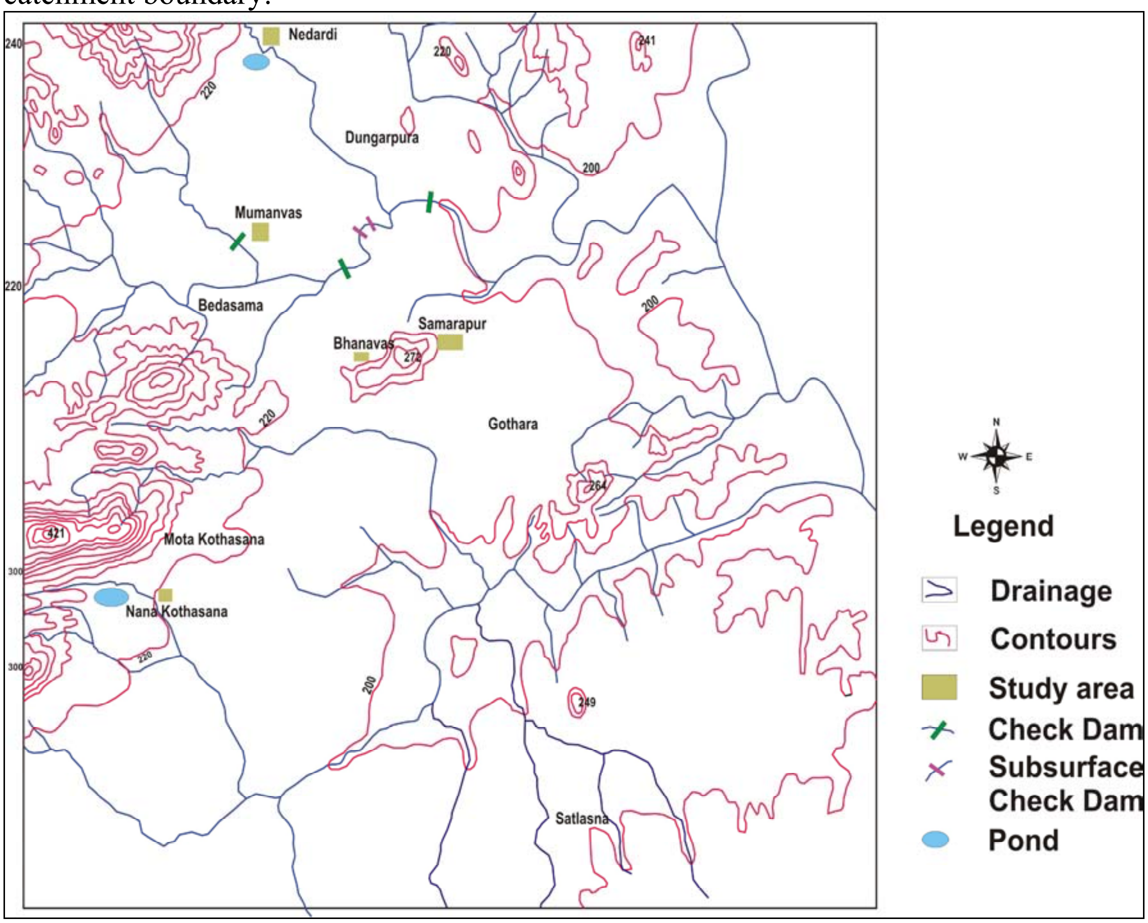
CHART.2 INSTITUTIONAL STRUCTURE AND LINKAGES IN WATER SECTOR IN THE PROJECT AREA
GOVERNMENT
NGOs
PEOPLE'S INSTITUTIONS
State level
Regional level
District level
Taluka level
Village level
Gujarat Water Supply and Sewerage Board
Narmada Water Resources & Water Supply Department
Gujarat Water Resources Development Corporation
VIKSAT
Provision of drinking Water
Provision of irrigation Water
Gujarat State Water Policy
Dharoi Group Drinking Water Scheme
Sabarmati River Stakeholders' Forum
Private bore well companies and operators
Gadhwada Jal Jameen Sanrakshan Sangh
VILLAGE PANCHAYAT
VILLAGE COMMUNITY
Private Water Sellers
Tree Growers' Co-operative Societies

3 Watershed scale

1.1 PHYSICAL

AGRAR research study area in Gujarat is located in the north-eastern part of Mahesana district. The project area in 5 villages is located in Satlasana Taluka and the villages are Bhanavas, Samrapur, Mumanvas, Nana Kothasana and Nedardi (see the location map). The structures identified are three check dams, two sub-surface check dams and two percolation ponds.

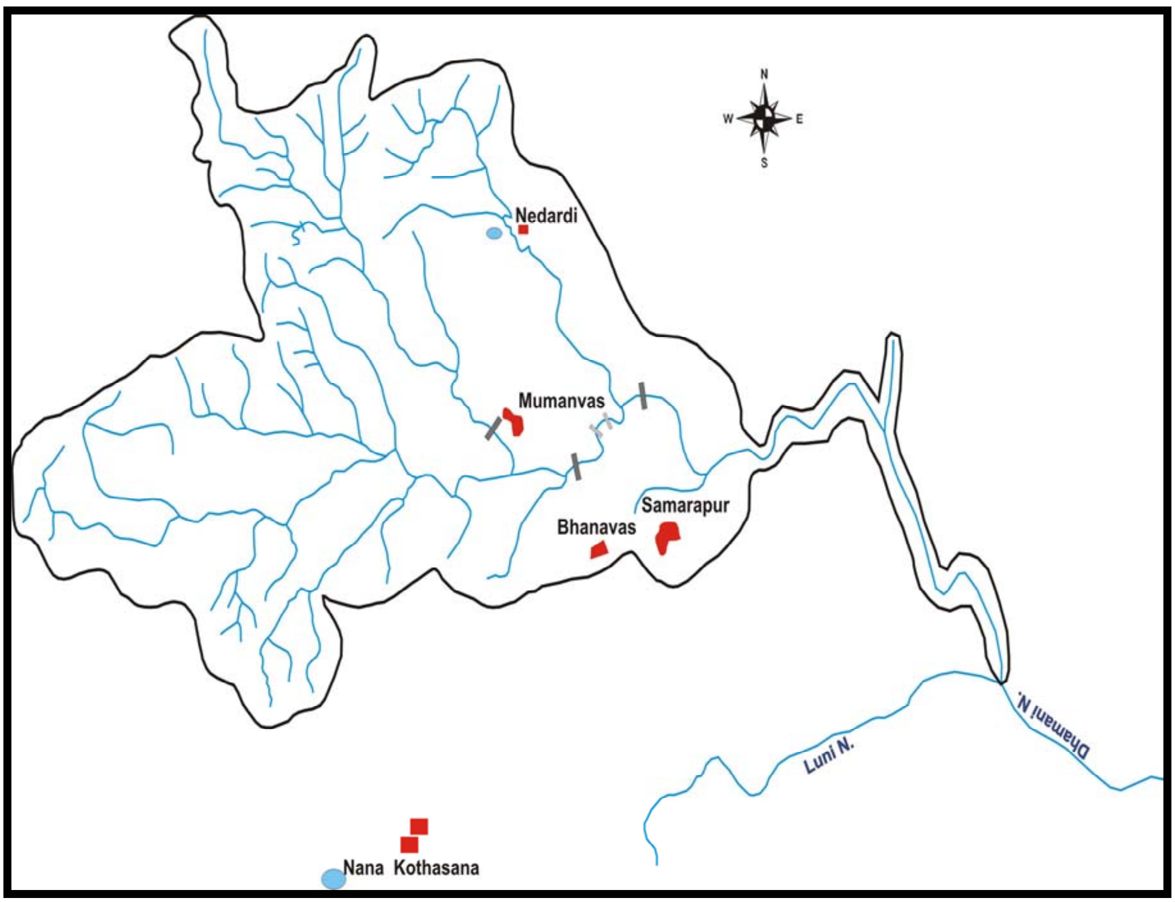
The research area extends from North latitude 24°2′17″ to 24°5′17″ and East longitudes 72°45′00″ to 72°47′13″. The catchment area covers approximately 25.25 sq km and is located in the Survey of India Toposheet number 45 D/16. The drainage map of the recharge area is shown below. The study area is surrounded by the Aravalli Hills and forms a clear-cut catchment boundary.



Map 9: Contour Map of the Study Area with Location of Recharge Structures under Observation

Relief and Drainage

The physiography of the five AGRAR Project villages is characterised by granitic ridges, some of which are partly covered by dry, deciduous vegetative cover. The contours with the drainage lines of the study area with the study area villages are shown in Map 9. Nana Kothasana village is located at the foothills of a NE-SW trending ridge whereas the other four villages are located at the base of an isolated inselberg of granite. The drainage pattern is mostly fine-grained, dendritic in the ridge areas but becomes sparser in the plains (Map 10). Fracture controlled drainage is evident in some parts of the area, where fracture patterns on the underlying granites and gneisses may have controlled the drainage geometry locally. Linear and rectilinear drainage patterns dominate the south-eastern part of the region. Two sets of fractures criss-cross the region. One set trends in the NE-SW direction and the other set trends in the NW-SE direction. Foothills of the granitic ridges are marked by ravines developed through the reworking of colluvial-alluvial material carried down due to erosion of the granitic landscape. Thin alluvial and/or soil cover marks the plains where the drainage pattern is anatomising. The area is criss-crossed by ravines cut by flashy runoff with the associated high land degradation.

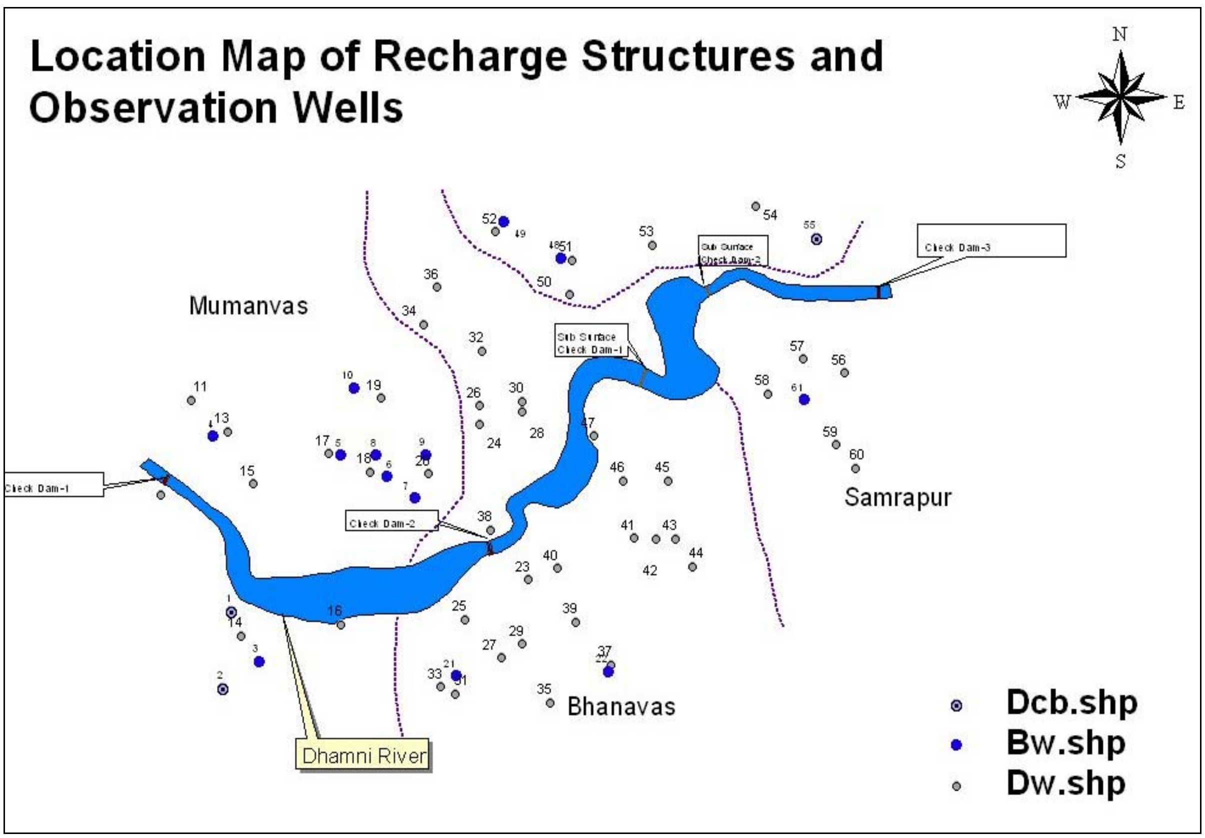


Map 10: Drainage Map of the Study Area and Recharge Structures under Observation

Recharge Structures under Study

As stated above the recharge structures under observation for the AGRAR Project are three check dams (Mumanvas, Bhanavas and Samrapur), a pond (Nana Kothasana) a percolation tank (Nedardi) and two sub-surface check dams (Samrapur). The observation wells consists of dug wells, bore wells and bore wells (see the following Map). The capacity contour surveys of all the recharge structures have been completed. Contours have been drawn for each of the structures to estimate the volume of water stored in the structures depending on the height of standing water. The following table gives the capacity of each of the recharge structures.

Sr. No.	Name of the Structure	Capacity of structures up to FRL in cu.m.
1	Mumanvas Check Dam	6,404
2	Bhanavas Check Dam	21,774
3	Samrapur Check Dam	12,541
6	Nedardi Percolation Tank	27,650
7	Nana Kothasana Pond	31,194



Map-11

Soils

Mostly red sandy soils are seen in the study area. The rate of infiltration through such soils is relatively fast. The thickness of the soil, on the whole is within 1 m, generally less. At some places the soil is silty, sometimes mixed with a clay fraction. Usually the infiltration through these types of soil will be lesser than the sandy soil because the clay would reduce infiltration rates. The presence of badlands and ravines (about 20-30 m deep) immediately at the foothills shows that the region has experienced several cycles of reworking (erosion and deposition) of the colluvial and alluvial materials. From a hydrogeological point of view these ravines could be potential zones for groundwater recharge to the aquifers underlying the plains.

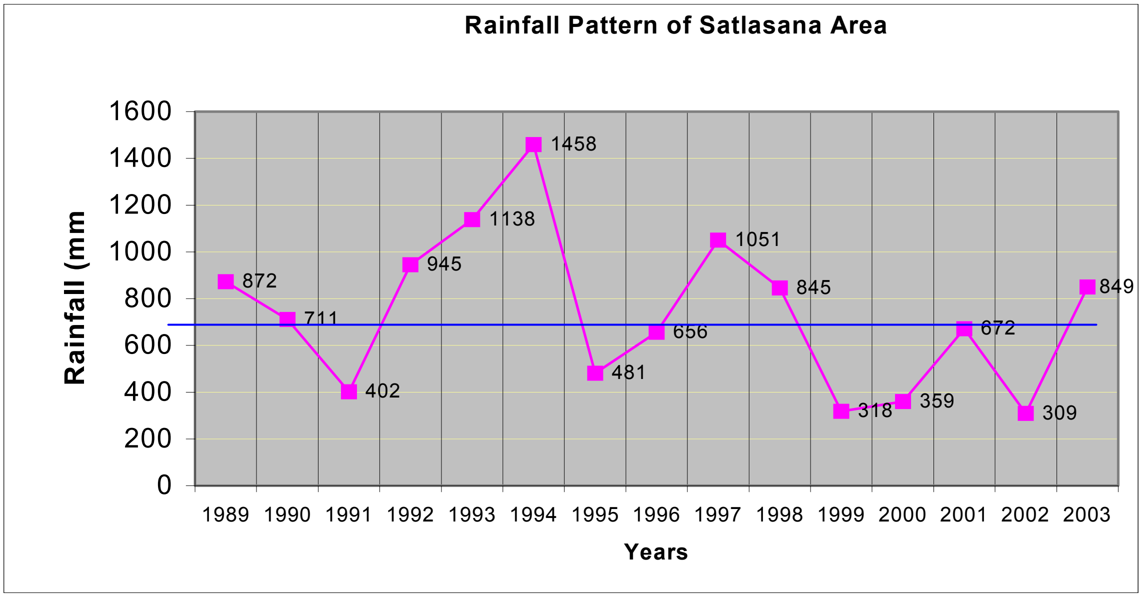
Further south, very much outside the study site, the regional geology changes from a dominantly hard-rock, granitic terrain to the fringe areas of the thick alluvial deposits of the Sabarmati basin. Obviously, the alluvium is resting atop older hard rocks. However, due to the proximity of the alluvial terrain to the study site, the area offers interesting aspects of a typical hard-rock regime at the threshold of a regionally expansive alluvial regime.

Climate

The climate in the region is semi-arid. Extreme temperatures, erratic rainfall and high evaporation are the characteristic features. Three distinct seasons are noticed, summer from mid March to mid June; rainy season from mid June to September, and winter period from November to February.

Rainfall and Evaporation

The average annual rainfall is around 680 mm but is highly variable. The onset of monsoon occurs by the second week of June. July and August are the peak monsoon months. About 80% of the rainfall occurs in these two months. The area does not experience either North–east monsoon or summer showers. The highest rainfall of 1458 mm was experienced in 1994. Similarly, the lowest rainfall of 309 mm was experienced in 2002.



The mean annual potential evaporation is about 1627 mm. Surface water resources are limited and are highly susceptible to the distribution and variability of rainfall.

Temperature

After mid-March, normally there is a rapid rise in temperature. May and first half of June are the hottest months. Temperature shoots up to 45°C in the month of May and remains around that for about a month. Even the night temperature is about 35° C during that period.

With the onset of monsoon the temperature decreases and the weather becomes milder. The temperature during rainy season is about 35°C. With the withdrawal of monsoon by mid-September the day temperature increases again and a secondary maximum day temperature of 35-38°C is reached in October. However, night temperature gradually decreases after the withdrawal of monsoon. After October both night and day temperature decreases to 20°C and 32°C respectively. Cool months are from mid December to mid-February.

Humidity

During the monsoon, the daytime humidity is from 60-80%. On an average, the day time humidity is low of the order of 20-50% during rest of the year. The driest periods of the year occur during summer seasons when relative humidity in the afternoon is less than 30%.

Wind Velocity

Winds are generally high and moderate with some increase in strength in late summer and early part of the monsoon period. The wind velocity around this period reaches 18.7 km/hour. From April to September wind blows mostly from south and west. During October easterly and north-easterly winds are common in the morning and westerly and north-westerly in the afternoon. From November to March, morning winds are mostly from north and east and afternoon winds are generally from northwest. During winter season, the wind velocity is generally below 10 km/hour.

Geology

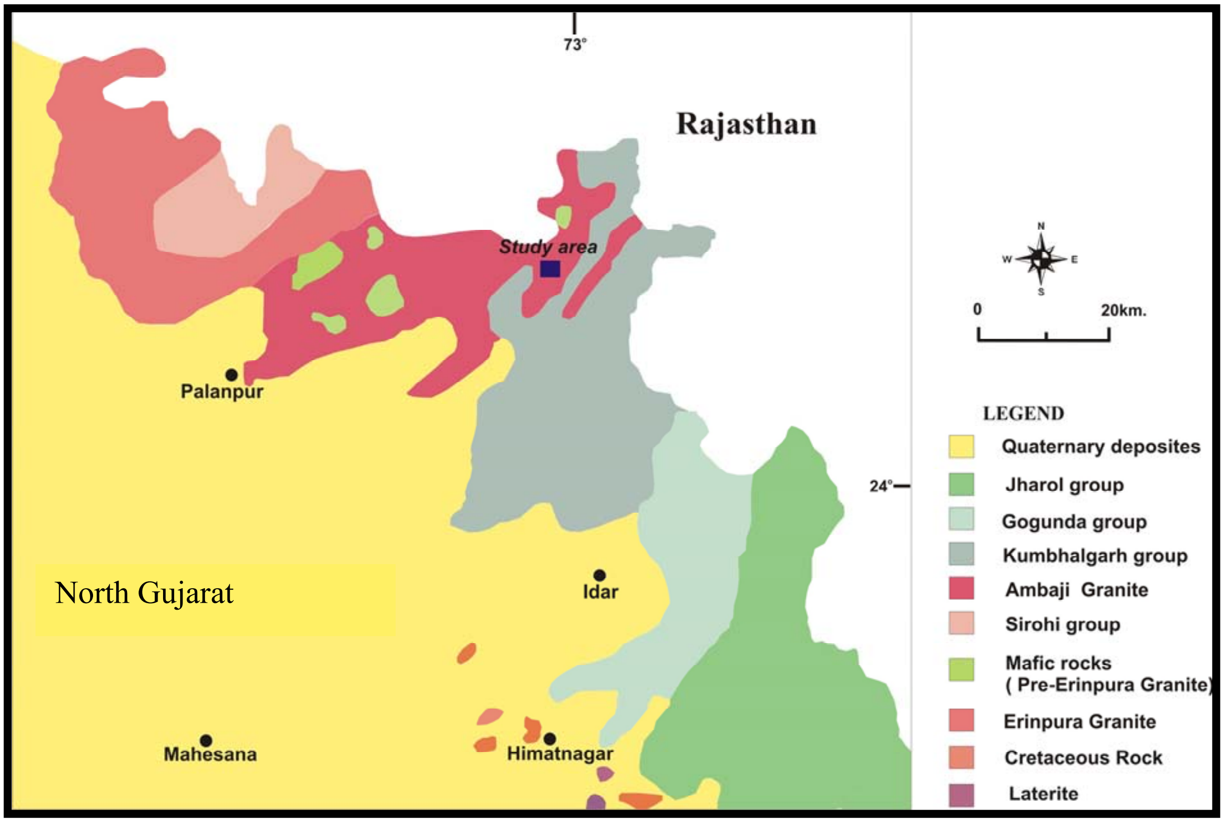
The study area in Satlasana taluka of Mahesana district occupies a position in the northern extremity of Gujarat State. The project area is underlain by the Ambaji Granite of Delhi Supergroup. The granites in the area almost certainly overlie the basement gneisses (Plate 1) although it is difficult to ascertain the depth at which the contact between the granites and gneisses lies. The area is dissected by a large number of fractured Pegmatitic veins. A simple lithological succession of the study area is given below.

Table 1: Lithological succession in the project area

Lithology	**Thickness (in meters)**	**Brief Description**
Alluvium	2	Restricted to portions along river and stream channels, often with Calcrete nodules
Overburden	40	Weathered mantle of Ambaji Granite
Bedrock	Not estimated	Granites, Gneiss and Schist

Plate 1: Outcrops of weathered, NW-SE trending fractured granite

The geological evolution of northern and eastern parts of Gujarat has been controlled by the Precambrian orogenies – the Aravalli and the Delhi cycles. The structural set up of rocks in Gujarat is controlled by two major Precambrian orogenic trends i.e. NE-SW Aravalli trend and ENE-WSW Satpura trend. The Aravalli trend acts as a divider between the Satpura trend in the southern portions and the Delhi trend to the north. The northern and north eastern boundaries of the state are marked by the south western extremity of the Aravalli hills that extend into adjoining Rajasthan. In fact, these boundaries of the state are areas where the oldest rocks (in the state) are exposed. These rock exposures constitute the south-western extremity of the Proterozoic rocks of Rajasthan (Figure 4).



Map 12: Geological Map of North-Eastern Gujarat[1]

Ambaji Granite

Ambaji Granite include a group of rocks belonging to the Delhi Super group, which otherwise dominantly includes meta-sediments belonging to the Gogunda, Kumbhalgarh and Sirohi Groups. The Ambaji granite is also said to include granordiorites and granitic gneisses. This granitic suite of rocks typically forms NE-SW trending ridges that stand out from the almost flat landscape to the south. Heron and Ghosh had considered all the granites and gneisses of North Gujarat to represent one single igneous phase belonging to the Post-Delhi Erinpura Granite. But recent mapping by the GSI and geochronological studies by various organizations have established existence of granites of at least two ages – an older Sendra-Ambaji Granite (partly synchronous with Delhi orogeny) and a younger Erinpura Granite (Post-Delhi). It is this granite which caused wide spread granitisation of Delhi pelitic schist giving rise to biotite-gneiss and granitic gneiss (Merh, 1995).

[1] **Adapted from Merh, 1995**

Hydrogeology

The granite outcrops directly as ridges that make up typical granite topography including ‘granite tors’. The weathered crust of this granite underlies flat plains in the valleys and forms the shallow aquifer in the area. The weathered crust itself bears a highly weathered upper section with a sheet joint underlying it. At places, this sheet joint is underlain by a vertically-subvertically fractured granite rock. The weathered granite is transacted at many places by fractures, often filled with Pegmatites. Such Pegmatite veins, themselves are highly fractured and appear to control groundwater accumulation and movement, especially to deeper levels.

Plate 2: Conglomerates in the stream showing different flood events

There are two distinct aquifers in the area. One is the shallow unconfined aquifer within the weathered, sheet jointed granitic crust and the other is at deeper levels, probably confined (at least partially confined) and formed because of the complex network of fracture zones and sub-vertically disposed pegmatite veins (Figure 5). The depth of the shallow aquifer is about 10-25 m. The deeper aquifer(s) could be at levels of 40-60 m below ground level and maybe deeper at some places. The dug wells situated near the river are around 15 m deep while the wells near the ridges are about 30 m deep. All these wells tap the shallow weathered aquifer. Dug wells are telescoped down to the bases with the upper, soil and highly weathered portions being lined.

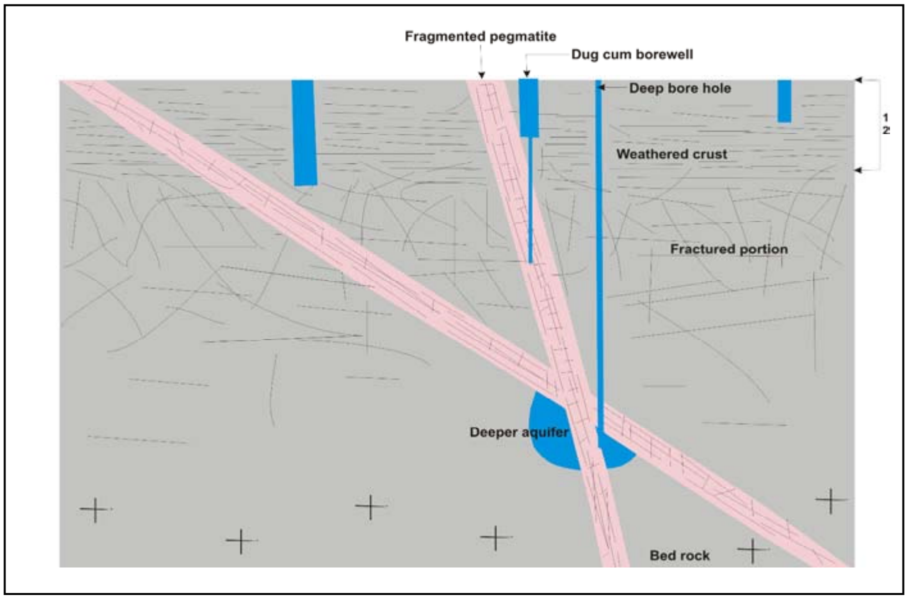


Figure 1: Conceptual model depicting ground water system in Samrapur, Bhanavas and Mumanvas

Fractured Pegmatites are good avenues for groundwater storage and movement. Wells located on these fractured Pegmatitic veins indicate a better yield than wells tapping the weathered granitic aquifer. Permeability within the weathered-fractured granitic aquifer is restricted to sheet jointed zones that are at about 5 to 10 m from the surface. On the other hand, the Pegmatites show consistent fracturing even with depth, making them fairly permeable bodies, capable of carrying groundwater to depths.

The continuous drought situation since 1999 in the region has left shallow aquifers dry up to 20 m. Deep open wells tapping the shallow aquifers were dry till the summer of 2003. The water levels declined drastically during the drought period and the people responded to it by deepening the open wells. Many people invested in drilling new bore wells and drilled bore wells at the base of open wells to chase the falling water level. The bore wells are 23-123m. deep and tap deeper aquifers. Submersible electric pumps of 5HP (eight stages) lift water from these bore wells continuously for about eight hours everyday (incidentally, electricity is supplied for eight hours only in a day for irrigation). Bore well water is used for irrigation purposes (see Plate 3).

The following tables show the total depths of open and bore wells and depth to water level in different months in the year 2003.

Depths of wells and monthly variations in water levels (2003)

Levels	Total depth (m)		Month-wise water levels (m) 2003				
	Dug well	Bore well	June	July	August	September	October
Minimum	6.5	23.0	15.7	4.0	3.9	5.25	3.4
Maximum	20.0	123.0	40.0	28.5	21.0	17.30	20.0

Source: VIKSAT Primary Survey, 2003

Groundwater from bore wells was used for drinking purposes until 2001-02 even though the quality was not suitable for drinking at it contained high TDS and Fluoride[2] levels. When the drinking water supply from the Dharoi reservoir was made available, people are totally depending on piped water supply. One of the reasons for this shift may be inherent groundwater quality problems, including high fluoride content in the region.

Plate 3: Lifting of water from the well for irrigation purposes

Rapid siltation along the stream channels in the river shows the high amount of erosion occurring in the upper reaches of the region. The Mumanvas check dam clearly bears testimony to this fact. The check dam is constructed across Dhamani River in Mumanvas village, which is about 15m wide. The height of the check dam is about 1.5m and the length is about 17m. The rainfall in the year 2003 was 849mm (as recorded at AGRAR Weather Station) and within this rainfall period, two cycles of siltation in the check dam have occurred. The silt was removed once but during the next spell of rains, the check dam was silted up to its brim rapidly again (see Plate 4).

Plate 4. Mumanvas Check dam filled with Sediments to the brim (year 2003)

[2] Fluoride levels are above 1.5 mg/litre.

Installation of Weather Station

The nearest weather station is at Dharoi (12 km away) while the other is at Mahesana (100 km away). Due to local variations, weather data such as rainfall and evaporation vary significantly. In order to minimise the local variations and improve data accuracy for this project, a weather station has been established in Mota Kothasana village about 1 km away from Mumanvas and Bhanavas check dams. The data from these stations would also help compare data from all the three weather stations and understand the degree of variation. The weather station will also help have control on the accuracy of data and measurement on a regular basis.

The following meteorological instruments have been installed:

1. Automatic and Manual Rain gauges
2. Anemometer
3. Pan-evaporimeter
4. Thermo-hygrograph
5. Sunshine Recorder

The following activities have been carried out:

Drainage map and topographic survey: The drainage from the Aravalli hills contributing to the 3 check dams was prepared with the help of Toposheets. Subsequently, the topographic survey was conducted to prepare a base map along with the location of recharge structures, the water storage capacity contours of the structures and the location and elevation of existing wells.

Installation of weather station: The weather station has been equipped with automatic and manual Rain gauges, Anemometer, Pan-evaporimeter, Thermo-hygrograph and Sunshine recorder. Weather data are collected on a daily basis.

Water level monitoring: Monthly monitoring of 60 wells in the surrounding areas (up to 1 km radius) of three check dams at Mumanvas, Bhanavas and Samrapur and 10 wells in the downstream of the percolation pond in Nedardi village have been monitored by using electronic water level recorders.

Plate 5. Groundwater Level monitoring, Mumanvas village

Plate 6. Weather Station at Mota Kothasana

Aquifer performance tests are being carried out for determining the transmissivity values in the research sites.

The data collected regarding the relevant geo-hydrological and climatic data are being analysed. Currently, the livelihood impact assessment surveys are being conducted in the project villages and other activities are going on as per schedule.

Dhamani River is a tributary to Sabarmati River, originating in Aravalli Hills. Many streams originate from the hill

Weather data are collected everyday at 8 o'clock in the morning.

SOCIO-ECONOMIC STATUS OF THE PEOPLE IN THE PROJECT VILLAGES

Households, Population and Density

The population of the project villages according to the 1991 census is given in the following table.

Population and population density of the Project Villages

Villages	Area (in ha.)	Population	Number of households	AFS	Population density/sq km
Bhanavas	122.55	598	109	5.49	487.96
Mumanvas	197.83	982	182	5.40	496.39
Nedardi	626.67	710	131	5.42	113.30
Samrapur	286.90	1006	183	5.50	350.64
Nana Kothasana	243.88	946	183	5.17	387.90
Total	**1477.83**	**4242**	**788**	**5.38**	**287.04**

Note: AFS=Average Family Size

The average family sizes of the study area villages vary between 5.17 and 5.50. This is similar to the average family size of Mahesana district, which is at 5.29. The density of population varies in the project villages. Nedardi registers the lowest population density of 113.30 persons per sq km. The vast chunk of wasteland seen near the Nedardi Pond accounts for the low population density. The average population density of the study area is 287.04 persons per sq km This is lower than the population density of Mahesana district, which is 325 persons per sq km (population density of Gujarat State is 211 persons per sq km).

Social Composition

The social composition of the study area is characterised by a hierarchy of various caste/community groups in the village. The caste distribution of four villages in the study area is given in the following table.

Caste-wise distribution of households in the project villages

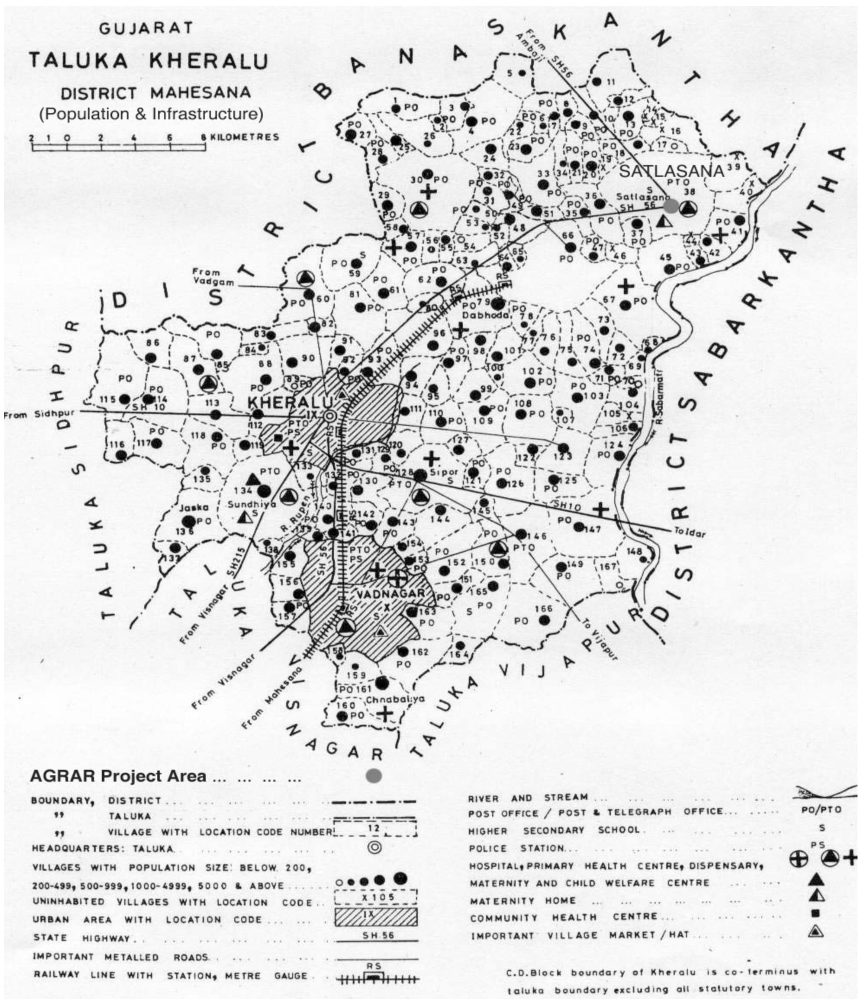
Caste / Villages	Samrapur	Bhanavas	Nana Kothasana	Nedardi
Harijan	49 (29.69)	6 (5.58)	24 (11.06)	16 (19.75)
Shrimali			3 (1.38)	
Nayi	9 (5.45)			
Rabari	6 (3.64)			
Panchal			1 (0.46)	
Prajapati	4 (2.42)		19 (8.76)	1 (1.23)
Darbar	96 (58.18)	87 (93.55)	170 (78.34)	
Thakore				52 (64.20)
Patel				12 (14.81)
Shah	1 (0.61)			
Total	**165 (100)**	**93 (100)**	**217 (100)**	**81 (100)**

Notes: Figures in parentheses denote percentages.
Information about Mumanvas is being collected.

It may be noted that in most of the study villages, Darbars and Thakores constitute the majority community. This is the case in the Gadhwada region as a whole. However, Muslims are the majority community in Mumanvas village. It has been observed that in many villages the Patels and the Prajapatis, though they are a minority, control most of the landed property.

Infrastructure

Social and economic infrastructure available in the study area and in the vicinity are given in the following map.



Satlasana is the headquarters of the newly formed Satlasana taluka. Satlasana was part of Kheralu taluka two years ago but still fall under the State Assembly Constituency of Kheralu. The study area is well connected by road. The study villages are located within five kilometres from Satlasana town. The nearest major town centres are Visnagar and Mahesana (see Mahesana Population and Infrastructure Map). Major agro-service centres are located in these urban centres and hence people have active economic interaction with these places. Satlasana is also getting urbanised with various concentrations of people, services and facilities. Other major facilities include market and market yard. Satlasana has about seven diamond polishing units employing over 1200 people. It is reported that during the last consecutive droughts diamond polishing industries absorbed many potential distress migrants in Satlasana and adjoining villages.

Local Institutions

The major institutions that affect the lives of the people of this area could be classified as government (administrative), political, financial, co-operative, non-governmental and community based. There is considerable overlap and interaction across these institutions. The following table illustrate the positioning of these institutions in the spatial hierarchy.

INSTITUTIONS IN SATLASANA AREA

Levels Institutions	Taluka	Central Village	Village / Community
Government (Administrative)	▪ Taluka Panchayat (Revenue, Development Administration) ▪ Law and Order	▪ Group Gram Panchayat	▪ Village Panchayat (Revenue and Development Administration)
Political	▪ Political Parties	▪ Political Parties	▪ Political Parties
Financial	▪ Co-operative Banks (Kheralu Nagarik Bank; Mahesana District Co-operative Bank) ▪ Commercial Banks (Dena Bank) ▪ Co-operative Credit Societies (Somnath Credit Society; Aravalli Women's Credit Society) ▪ Moneylenders	▪ Co-operative Banks ▪ B M Gramin Bank ▪ Caste-based Informal Savings and Credit Societies (Prajapti Caste) ▪ Moneylenders	▪ Primary Credit Co-operatives ▪ Moneylenders
Education	▪ Colleges	▪ High Schools ▪ Middle Schools	▪ Balwadis ▪ Anganwadi ▪ Primary School
Health	▪ Primary Health Centre ▪ Private hospitals ▪ Trust Hospital	▪ Dispensaries ▪ Private Doctors	▪ Trained Health Workers
Economic	▪ Market (various functions) ▪ Agricultural Producers Market ▪ Association of Diamond Polishing Units	▪ Market (various functions) ▪ Diamond Polishing Units	▪ Market (various functions) ▪ Moral economy transactions
Co-operatives	▪ Krushi Mandali (Agriculture)		▪ Dairy Co-operatives
People's Institutions	▪ Gadhwada Jal Jameen Sanrakshan Sangh (NRM, w.r.t. land, water and forestry)	▪ Women Self-Help Group (SHG) Clusters	▪ Tree Growers' Co-operative Societies (NRM w.r.t. land, water and forestry) ▪ Women SHGs ▪ Pani Samitis
Socio-Cultural	▪ Caste Associations (Wadis)	▪ Religious Trusts (Hindu, Jain, Muslim)	▪ Religious Trusts (Hindu, Muslim) ▪ Caste/Religion based Youth Mandals
Non-Government Organisations	▪ VIKSAT ▪ Sarvodaya Gram Vikas Sanstha (for welfare of handicapped)		

Sources of Drinking Water

People in the study area used to depend on groundwater for drinking purposes until 2001. For the last two years most of them have access to drinking water from Dharoi dam, which is located about 12 km. away from the study villages. All villagers have access to water in their own villages and many have access through private connections. The main sources of drinking water in the villages are public stand posts, private water connection, dug wells and bore wells. Water in the public stand posts and private connections are accessed from the Dharoi dam. However, the people of Bhanavas are not using the Dharoi water even though the water has been made available. They are waiting for a government scheme through which every household will be given access to Dharoi water through private connections and public stand posts in various parts of the settlement. They are still using the bore well water for drinking purposes. The people of Samrapur village are not accessing the Dharoi water as they think it is too costly. In Mumanvas village, pipelines are being laid presently for Dharoi water connection.

It may be noted that the well water contains high levels of fluoride. The incidence of fluoride in Mahesana district is very high. 49.9% of the villages in the district has high incidence of fluoride content of greater than 1.5 mg/litre[3].

Water for Animals: The villages have a substantial livestock of cows, buffalos, camels, goat and sheep. Water from Dharoi is made available in *havados* (cattle troughs) for animal consumption. Some households take their cattle to this tank. However many households stall-feed their cattle and water for those animals is collected from the drinking water sources such as stand posts and bore well with hand pump.

Occupational Pattern

The occupational pattern of the study area shows that agriculture is the primary occupation of the people, followed by labour and animal husbandry. The following table gives the occupational pattern of three villages in AGRAR project area, viz. Nana Kothasana, Bhanavas and Samrapur (corresponding data for other villages in the project area are being collected).

Occupational Pattern of sample households in the Project Villages

N=29

OCCUPATIONS	**Male**		**Female**	
	Number	**%**	**Number**	**%**
Primary occupation				
Agriculture	21	67.74	0	0
Labour	6	19.35	1	2.22
Animal Husbandry	4	12.90	3	6.67

[3] Estimates of Gujarat Water Supply and Sewerage Board, Government of Gujarat

OCCUPATIONS	Male		Female	
	Number	**%**	**Number**	**%**
Service	2	6.45	0	0
Other	5	16.13	1	2.22
Housewives			40	88.89
Total	**31**	**100**	**45**	**100**
Secondary occupations				
Agriculture	3	9.68	0	0
Animal Husbandry	11	35.48	2	40
Labour	10	32.26	1	20
Other	7	22.58	2	40
Total	**31**	**100**	**5**	**100**

Source: VIKSAT Primary Survey 2003

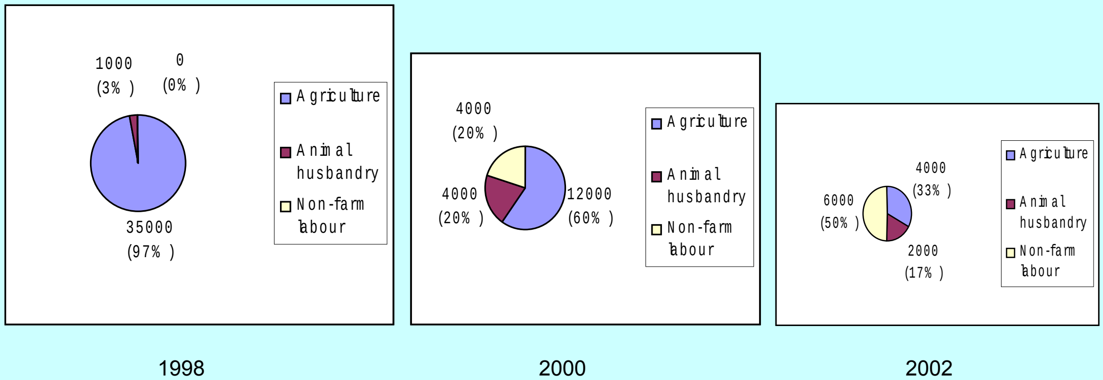
Even though traditionally agriculture is the main occupation of the households, there has been a shift towards animal husbandry as major contributor to the household economy. Due to the consecutive droughts of 1999-2002, agriculture ceased to become the primary occupation. This forced people to look out for alternate sources of income in nearby as well as far off places. Animal husbandry and labour work have emerged as alternatives during the drought period. After this year's (2003) good monsoon, agriculture has regained its primacy as the livelihood option.

Migration

There has been unprecedented migration in the past few years due to decline of agriculture and agri-related activities. Many people have migrated to urban centres in search of non-agricultural occupations and to other districts for sharecropping where canal water is available. For sharecropping people migrated to Patan, Banaskantha and parts of Sabarkantha. For non-farm sector work such as diamond polishing, people migrated mainly to Ahmedabad, Surat and Mumbai. In the urban centres, many of them found employment in construction sectors, public works such as laying of pipelines and roads.

Livelihood Trends

In the last five years livelihood pattern has undergone substantial changes due to consecutive droughts and decline of agriculture. In the study area majority of the people were primarily engaged in agriculture and agri-related sectors. With the depletion of groundwater livelihoods in these sectors dwindled and many people were forced to seek alternative livelihood options such as non-farm sector employment. With the decline in agriculture, animal husbandry and non-farm sector employment gained prominence. A case study (Shri Vajesinh Chauhan) from Bhanavas village sums up the general trend in livelihood shifts in the area during the drought period. Consider the following diagram.



Changes in relative shares of various sources of livelihood of Vijesinh's family through the drought

It could be noted that the returns from agriculture decreased over a period of time in this family and that of non-farm labour increased progressively. Earlier, the family used to sell only a small quantity of milk in the dairy co-operative and home consumption was high. This trend was reversed in the subsequent years. Last year, the milk production was lower than the previous years due to the non-availability of fodder. This accounts for smaller earnings from animal husbandry. However, with this year's (2003) good monsoon, agriculture seems to be regaining its prominence as also the fodder availability.

Livelihood Assessment Survey

Groundwater plays a central role in the livelihoods of the rural people. In order to understand the livelihood impacts of groundwater changes, especially due to the artificial recharge structures, it is essential to conduct field surveys using a judicious mix of participatory and survey research methods. Qualitative as well as quantitative information are essential to assess the *actual* and *potential* impacts on livelihoods of various sections of the village community. Ideally, longitudinal surveys are necessary to assess livelihood impacts of access to and availability of water due to artificial recharge. There are both direct as well as indirect livelihoods impacts. Direct effects are the benefits accrued to various water users such as farmers, agricultural labourers and those whose livelihoods depend on other economic activities depending on water. Indirect benefits could be the effects on the village economy in general.

Survey Methods

Collection of Primary Data:

Primary data will be collected by using the following methods:

- Household Interviews of sample households
- Case Studies of selected households
- Focus Group Discussions

- Key Informant Interviews
- Village Meetings

Household Interviews: The households will be selected by using a stratified random sampling method. For this study, stratification of households into well-being groups will be made based on the following criteria:

- Caste/community groups
- Size of landholding (consider irrigated and unirrigated land as well as the landless)
- Occupational categories and asset status
- Distance from the recharge structures under observation: sample will have a spatial spread to cover areas of recharge influence, such as those that are located within (i) 250 m; (ii) between 250 and 500 m; and (iii) beyond 500 m from the recharge structures
- Ownership of dug wells/bore wells

Case Studies of Selected Households: A few households will be selected for detailed study about livelihood changes. The same households may be selected for a repeat survey in the subsequent years. This would help illustrate the trends in livelihood changes as well as gender dimensions.

Focus Group Discussions: Focus group discussions are essential to collect information about specific groups of people such as the landless, various occupational categories and women.

Key Informant Interviews: Key informants for this study are the knowledgeable people from various water user groups, government officials and other informed individuals.

Village Meetings: Community level information can be collected through village meetings. This can be used for selection of appropriate (representative) households for sample study as well. Village meetings are also essential to explain the purpose of the research and to ward off any misapprehensions and wrong expectations that people might have about the research.

Collection of Secondary Data:

Secondary data consist of various published information available with the government, and other publications. These include information about government policies for the water sector and groundwater in particular, watershed development and strategies, government programmes for artificial recharge, existing studies on impact of artificial recharge structures.

Time Frame for Field Surveys

Two field surveys are planned: the first one will be carried out in December 2003 to capture the effects of kharif (monsoon) crops and later in December 2004 to cover an entire cropping cycle (kharif, rabi and summer crops). The livelihood survey to be conducted in December 2003 will cover the situation of agriculture and its benefits or otherwise in the current year (2003) and it will be compared to the recent consecutive droughts years 1999-2002. The data of December 2003 study will be compared with the 2004 study to determine trends in livelihood changes.

AGRICULTURE

Land Use Pattern

The land use pattern of the study area shows that a substantial portion of the cultivated land is under irrigation. The area under irrigation has increased substantially during the last decade. Major sources of irrigation are dug wells and bore wells.

Land Use Pattern in the Study Area

Villages	Area (in hectares)	Irrigated land	Unirrigated land	% of irrigated land to total cultivated land	Culturable waste	Land not available for cultivation
Bhanavas	122.55	23.00	54.55	29.66	0	45.00
Mumanvas	197.83	40.00	75.08	34.76	1.18	81.57
Nedardi	626.67	70.00	243.14	22.35	47.54	265.99
Vajapur	175.79	40.00	73.47	35.25	44.85	17.47
Samrapur	286.90	95.53	103.96	47.89	7.44	79.97
Nana Kothasana	234.88	70.00	62.39	52.87	30.90	71.59

Source: Census 1991

Cropping Pattern

The cropping pattern in the study area is as given in the following table. Groundnut is the most prominent crop during the kharif (monsoon) season followed by Castor and Bajra (finger millet). The cropping pattern has undergone substantial changes in the recent past. There have been years when people cultivated groundnut in large scales expecting good and consistent rainfall. But the fluctuating rainfalls and monsoon failures led to crop failures in the recent past. People have responded to these vagaries of nature by diversifying the cropping pattern in favour of less water intensive crops. Now they are cultivating combinations of various crops such as groundnut, castor and cluster beans.

Cropping Pattern of the Study Area

(N=29)

CROPS	Kharif		Rabi	
	Area (acres)	%	Area (acres)	%
Groundnut	25.42	40.36		
Castor	13.94	22.13		
Bajra	12.31	19.54		
Maize	7.19	11.42		
Cluster beans	2.91	4.62		
Dal	1.01	1.60		
Isabgol	0.20	0.32		
Wheat			18.61	42.66
Mustard			10.95	25.10

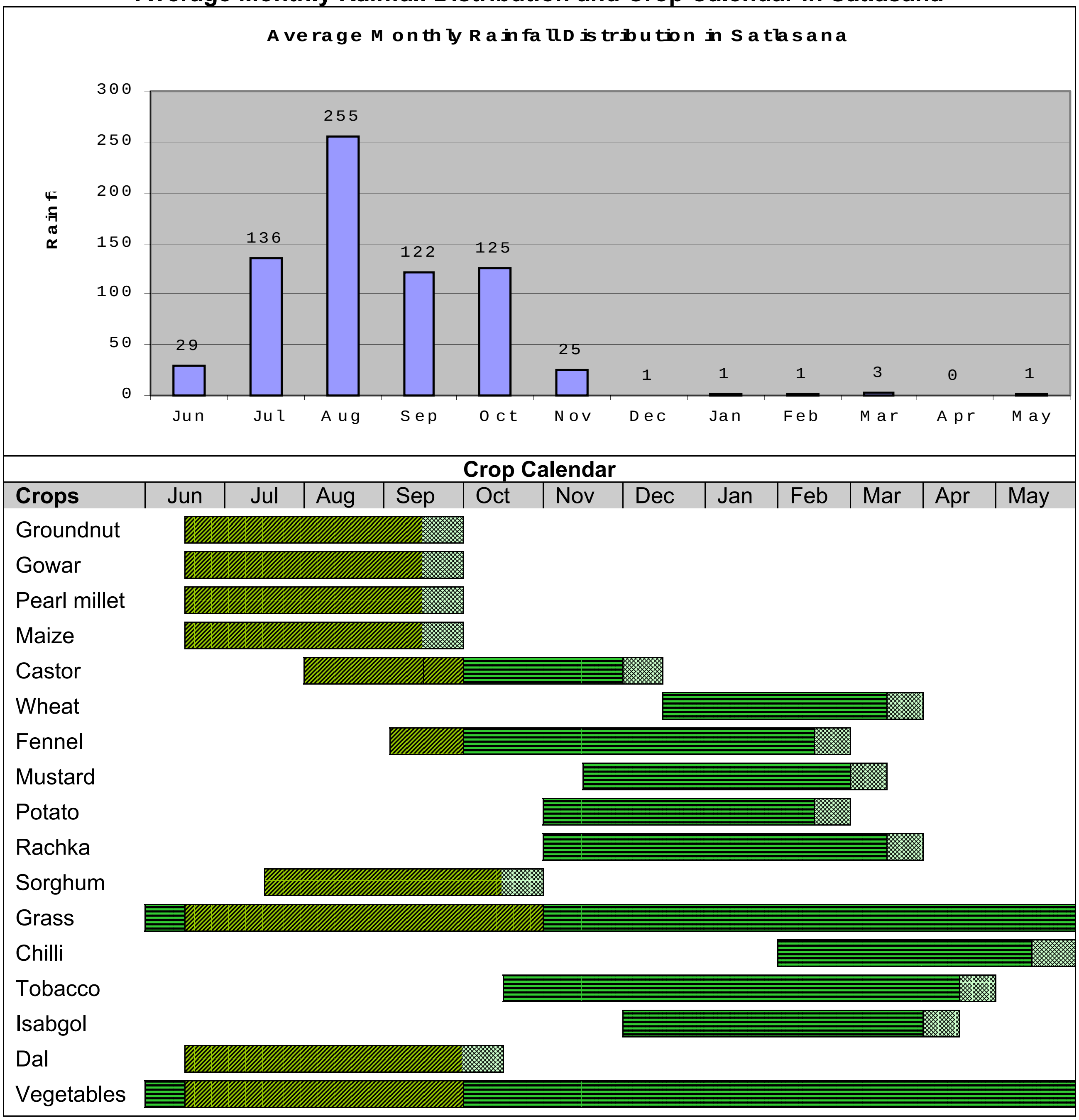
Tobacco			7.85	17.99
Castor			3.04	6.97
Fennel			1.24	2.84
Bajra			0.87	1.99
Chilly			0.57	1.31
Fodder crops			0.29	0.66
Vegetables			0.20	0.46
Total	**62.98**	**100**	**43.62**	**100**

It may be noted that there is normally a small area under summer crops as well.

Crop Calendar

A graphic representation of various crops grown in the project area during a normal rainfall year is given below.

Average Monthly Rainfall Distribution and Crop Calendar in Satlasana



Note: Rachka is used as a fodder crop. Grass varieties are perennial (ratoon) fodder crops, which are irrigated in many cases, and harvested throughout the year at intervals. Vegetables are grown in very small areas.

Index:
= Rain-fed cultivation
= Irrigated cultivation
= Harvesting period

Water Use in Agriculture

Five years ago, i.e. before the recent consecutive droughts, agriculture was the main occupation of majority of the households. They were engaged in agriculture as cultivators and agricultural labourers. Agriculture depended mainly on groundwater, as the rainfall was not sufficient to water the crops. Availability of groundwater was also sufficient to meet the irrigation requirements of the people. According to a survey conducted in early 2003, over 55% of the owner cultivated land and nearly 70% of the leased-in land in the villages were irrigated. The people have depended exclusively on groundwater for irrigation purposes. Groundwater was extracted through dug wells, dug-cum-bore wells (DCBs) and tube wells. These wells were either individually owned or jointly owned.

Dug wells constitute nearly 75% and the remaining were either bore wells dug-cum-bore wells. This could be attributed to the fact that many people cannot afford to drill tube wells because of the heavy costs involved (65,000-70,000 rupees per unit). Last year a sum of 355,000 rupees was spent on new tube wells and submersible pumps at Bhanavas and Samrapur. The money was procured from the local moneylenders at the rate of 3-5% per month and by pawning household jewellery. It may be noted that the joint ownership of wells is restricted to the people belonging to the same family. Joint ownership among different families is also observed in these villages.

Land and Water Management Practices

Small Border Irrigation Practices: Traditionally, the farmers in the area have been practising flood irrigation. With the depletion of groundwater and consecutive failure of monsoons, many villages in the project area have begun to practise small border irrigation. Small border irrigation practice help retain soil moisture and soil protection. Among the project villages, Nana Kothasana, Samrapur and Bhanavas villages are practising small border irrigation. The Gadhwada Jal Jameen Sangh, the people’s institution has facilitated the process.

Plate 7. **Small Border Irrigation, Samrapur Village**

Promotion of Micro Irrigation Systems: A few farmers in the project area recently have adopted micro irrigation systems such as sprinklers and drip irrigation sets. Nearly 150 farmers in the Gadhwada Region have purchased sprinklers in 2002. The government has a scheme to provide 40% subsidy to the farmers to purchase sprinkler and drip irrigation sets. Two farmers in Bhanavas village have purchased drip irrigation sets.

Plate 8. Sprinkler irrigation system installed in the Bajri field, Bhanavas Village

Farmers are using the micro irrigation system for irrigating plant nurseries, groundnut and cotton fields and in some cases fodder crops.

Groundwater Recharge Activities

During the last drought and the post-drought period there has been greater awareness among the people regarding the need for water management. In the last few years, several soil and moisture conservation projects have been implemented in the Gadhwada region. Several check dams and other soil and water conservation structures were constructed in the region as part of drought proofing activities. In the year 2003, six check dams were constructed under the Sardar Patel Jal Sanchay Yojana of the Government of Gujarat wherein 80% of the construction cost is provided by the government and the remaining 20% is to be contributed by the people. Under this scheme, 12 check dams and other water harvesting structures are in the process of sanctioning by the government. It may be noted here that the check dam in Mumanvas has been selected for observation under the AGRAR project.

The soil and moisture conservation activities in this region have been carried out by the people's institutions with facilitation by VIKSAT. The village level Tree Growers' Co-operative Societies (TGCS) and their federation at the taluka level Gadhwada Jal Jameen Sanrakshan Sangh are active partners in implementation of development activities in the area. These institutions follow participatory and democratic approaches. They now have *Implementation and Monitoring Committees* at the village level for construction of soil and moisture conservation structures. The village TGCS maintains close interaction with the village Panchayats which are the democratically elected local government institutions and the committees are formed in *Gram Sabhas*. The committee consists of 11 members and has the representation of all sections of the society including representative of various caste groups, TGCS members, and members chosen through consensus in the village meetings.

Initial Thoughts on Impact of Recharge Structures

The people in the study area in general are very aware of the benefits of water recharge structures. They are aware that check dams are helpful in augmenting groundwater recharge – raising water levels in their wells. The survey carried out for ComMan project has brought out responses that support this perception. A couple of wells and a bore well near the recharge structures in Samrapur were having water during the summer of 2003 when every other well in the village dried up. People think that the check dams at Samrapur and Bhanavas account for the presence of water in those wells. Those farmers could irrigate the winter crops and cultivate fodder crops during summer.

There was initial resistance to share the construction cost of check dams under the SJSY. This was due the deterioration of livelihoods during the consecutive droughts of 1999-2002. The local people feel that along the Dhamani and Luni Rivers many more check dams need to be constructed so that maximum rainwater would be recharged underground. After this year's good monsoon, people have witnessed increase in water levels in the wells near the recharge structures. Many people are now coming forward to share the construction cost (in terms of cash and labour) of check dams and take initiative in construction of check dams under this government scheme.

Recharge Structure Scale

The research study area consists of three Check dams across one single Dhamani rievulet while the two ponds are located in their respective villages. The three check dam sites are in the centre of the project area while Nedardi pond is in the North and Nana Kothasana pond in the South. So, three recharge areas are considered for the project.

The topography and geology have already been explained above.

Recharge Site 1 – Mumanvas, Bhanawas and Samrapur Check dams

Topographic Survey Drawings

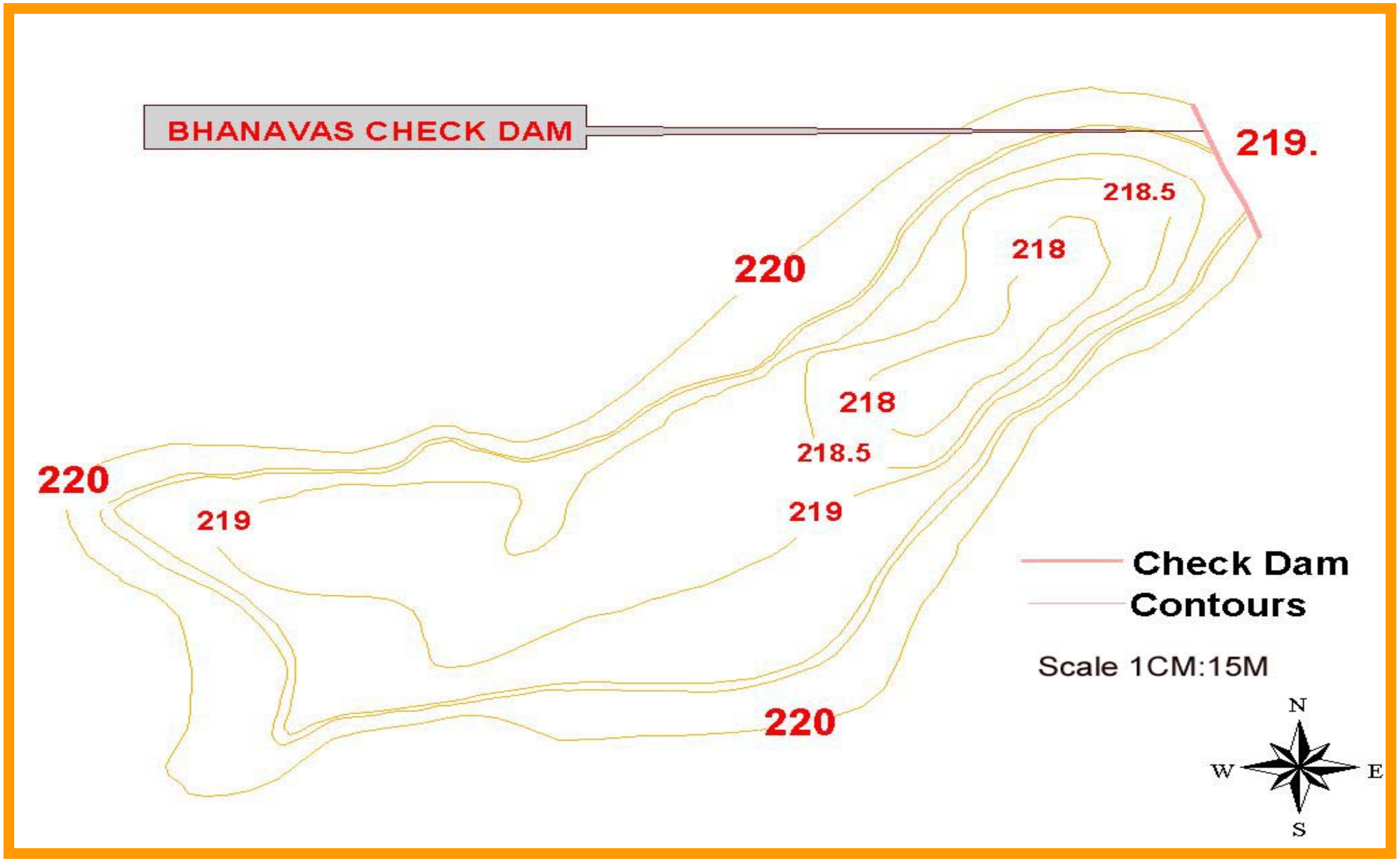


Figure-2 Contours - Bhanavas Check dam

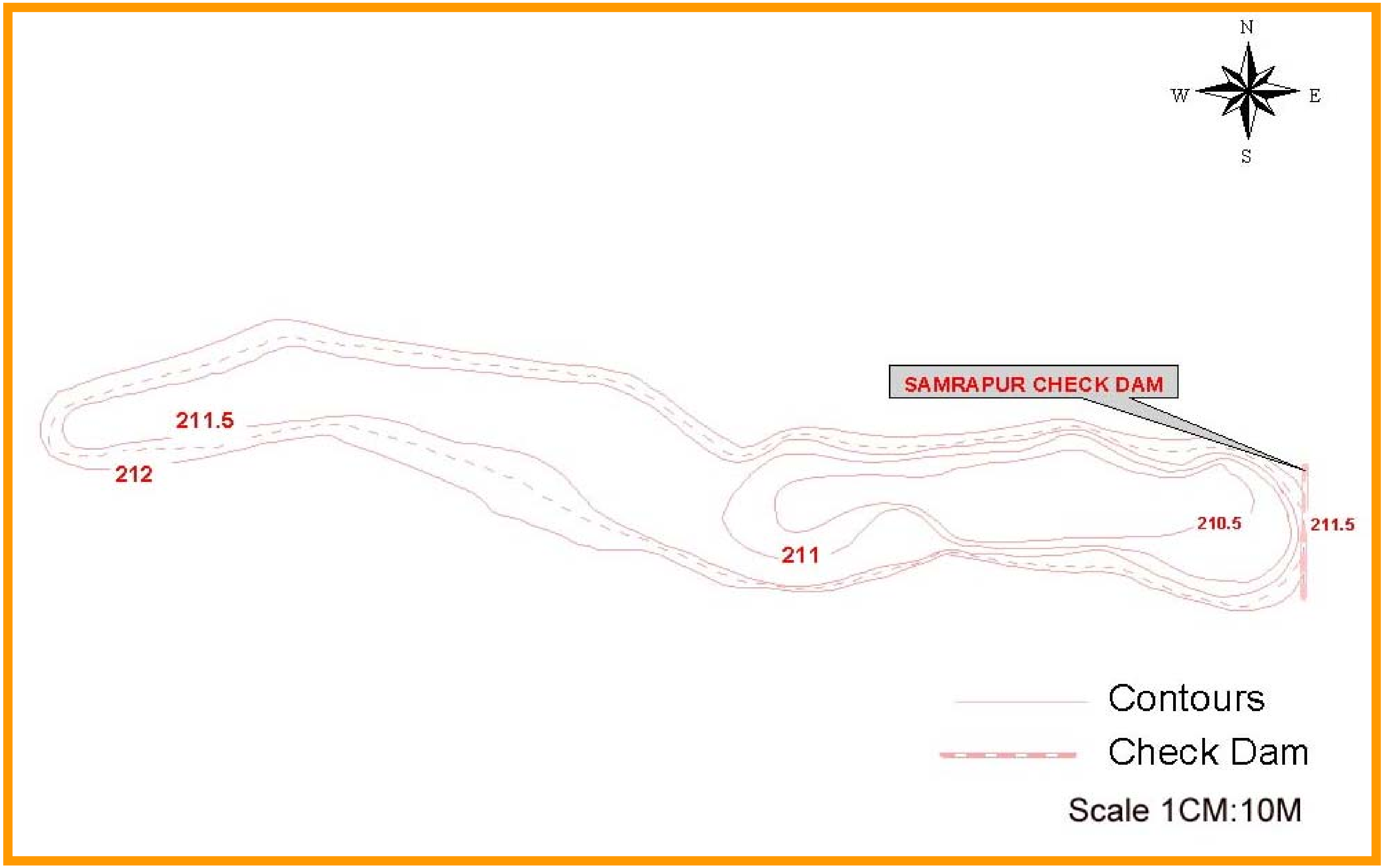


Figure-3 Contours - Samrapur Check dam

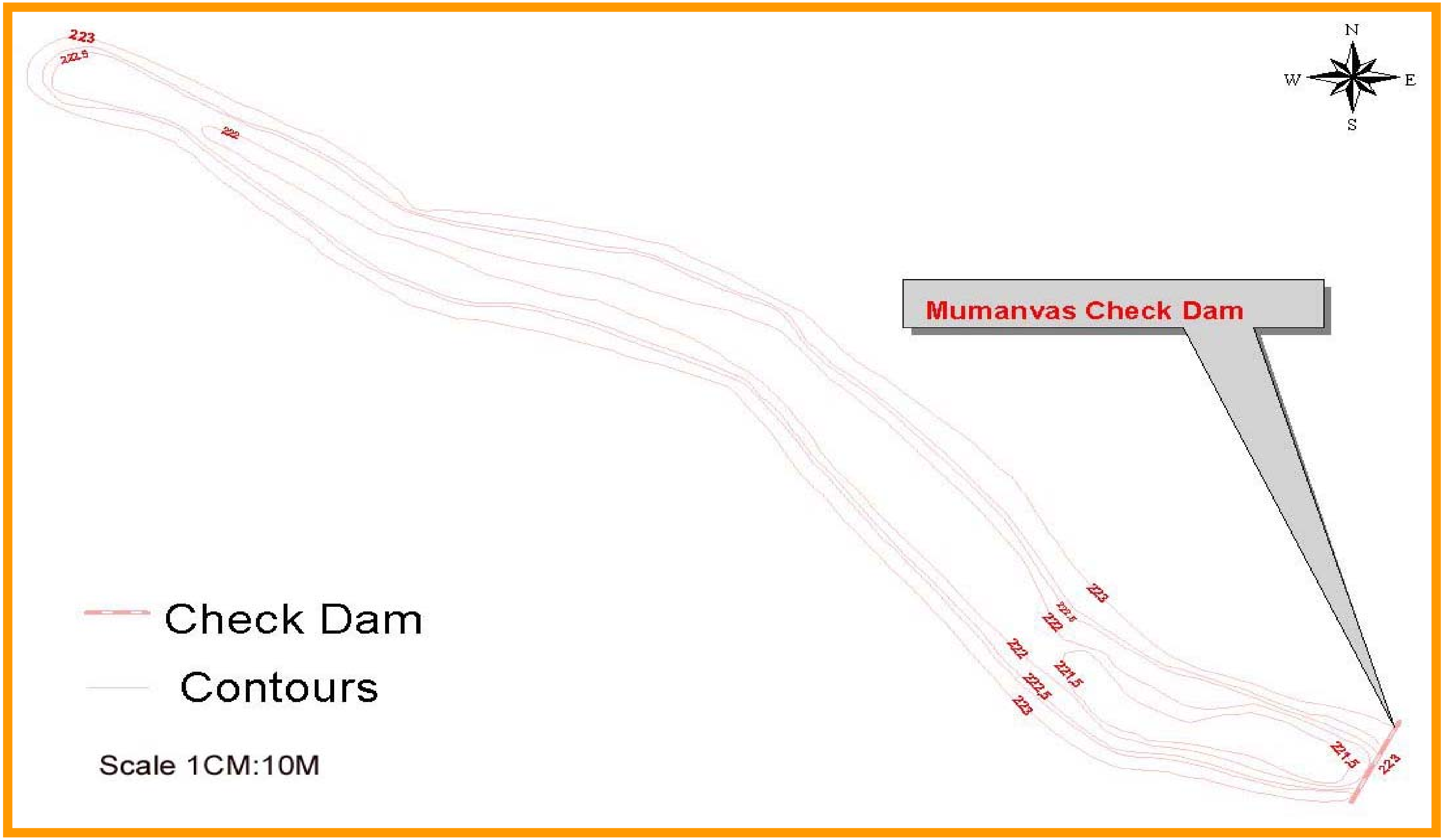


Figure-4 Contours Drawing - Mumanvas Check dam

MONITORING OF PHYSICAL PARAMETERS

Details of all installations

Piezometers : It is planned to drill Piezometers near Mumanvas and Bhanavas recharge structures. Two shallow depth Piezometers until touching the hard rock are planned to drill at about 10m. from the check dam. One medium depth Piezometer upto 45m. in the highly fractured rock will be drilled. Two deep Piezometers at 100m. from the recharge structure will be drilled. The shallow Piezometer are cased unto the loose soil and further down kept open. Whereas the shallow and deep Piezometers will be cased upto the hard rock encountered. The Piezometers will be capped by threaded metal caps for safety. Water level in the Piezometers will be taken on a weekly basis. The field Office staff have already been trained in taking the water level reading by using electronic water level indicators.

Water level recorder in the recharge structures: Water level gauges have been painted on the wall of the check dams. Scale is painted on the overflow wall to measure the quantity of overflow during monsoon.

Plate 9. Water level Gauge in the check dam, Bhanawas

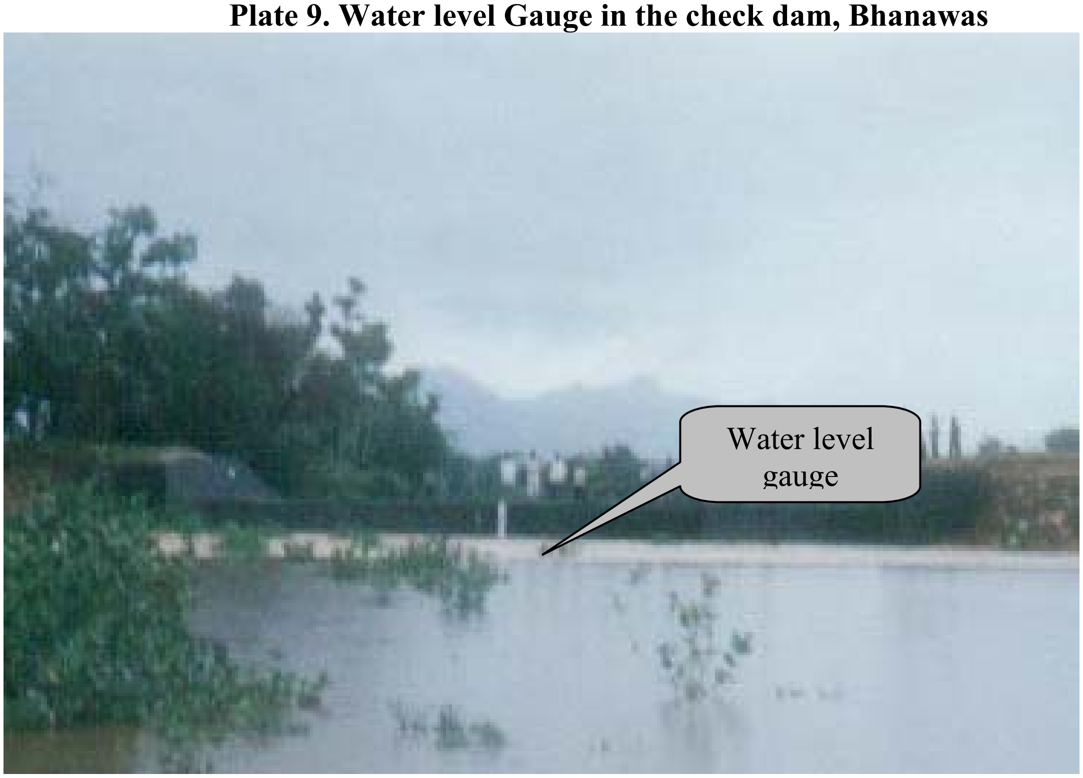


Plate 10. Check dam filled with water and the level gauge, Bhanawas village

Gauging post: Two sedimentation gauge posts are placed in the check dams in Bhanavas and Samrapur villages.

Plate 11. Sedimentation Gauge fixed in Bhanawas check dam

Surface water outflow from the dam: Scale is painted on the overflow wall of the check dam. During the monsoon Water level data logger will be placed for collecting water level data. Security of the instrument will be discussed with the villagers.

Automatic Weather station: Data collected from the Weather Station already established in Mota Kothasana will be used. Additionally, one manual raingauge will be installed very close to the recharge structure during the next monsoon.

Evaporimeter: Data collected from the Pan Evaporimeter installed in the weather station will used for compiling annual evaporation for the study area. It is too risky to install floating evaporimeter in the dam water due to security problem.

PARAMETERS BEING MONITORIED

Raingauge network:

Apart from the data recorded in the established weather station, weather parameters such as rainfall and evaporation will be collected form the Dharoi Dam weather station which is about 8kms. from the recharge structures. There are no other weather station in the district to collect all the required weather data. Rainfall data is available from government established raingauge station in Visnagar and Mehsana, at about 60 and 100kms. respectively from the recharge structures. This data may be used for comparison purpose only.

Surface water in- and out-flows at recharge structure:

Gauging scale is painted on the walls of both body wall of the dam and the over-flow wall in all the three check dams. In addition, automatic water level recorder will be placed on the check dam during the monsoon. The over-flow from the check dam will be monitored during the monsoon period by fixing the over-flow recorder.

Groundwater level monitoring:

In the three villages around the recharge structures, 45 dug wells, 3 dug cum bore wells and 13 shallow to deep bore wells have been identified for collecting groundwater level on monthly basis. The wells are owned by the respective village farmers and their consent is obtained for collecting groundwater level data on monthly basis.

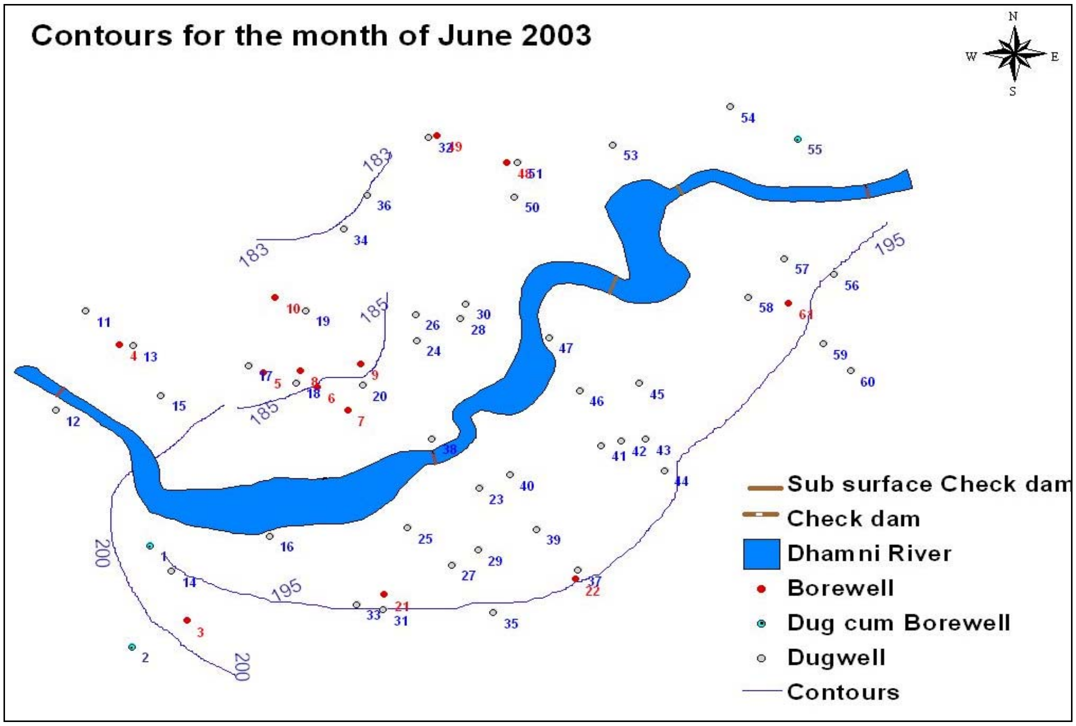
Groundwater abstraction from wells and bore wells in the vicinity:

In good monsoon years farmers use groundwater for winter crops. Only when it becomes very essential, farmers use groundwater for the last part of Kharif (rainfed) crop. Many of the farmers have obtained electricity connection an d installed centrifugal pumps. Some farmers are using Diesel engine pumps. All the bore wells and dug cum bore wells are fitted with submersible pumps. The electricity department supplies current for only 8 hours in a day. SO, all the pumps run for completely 8 hours in a day. Farmers have laid pipes to carry water to the end of their agriculture plot.

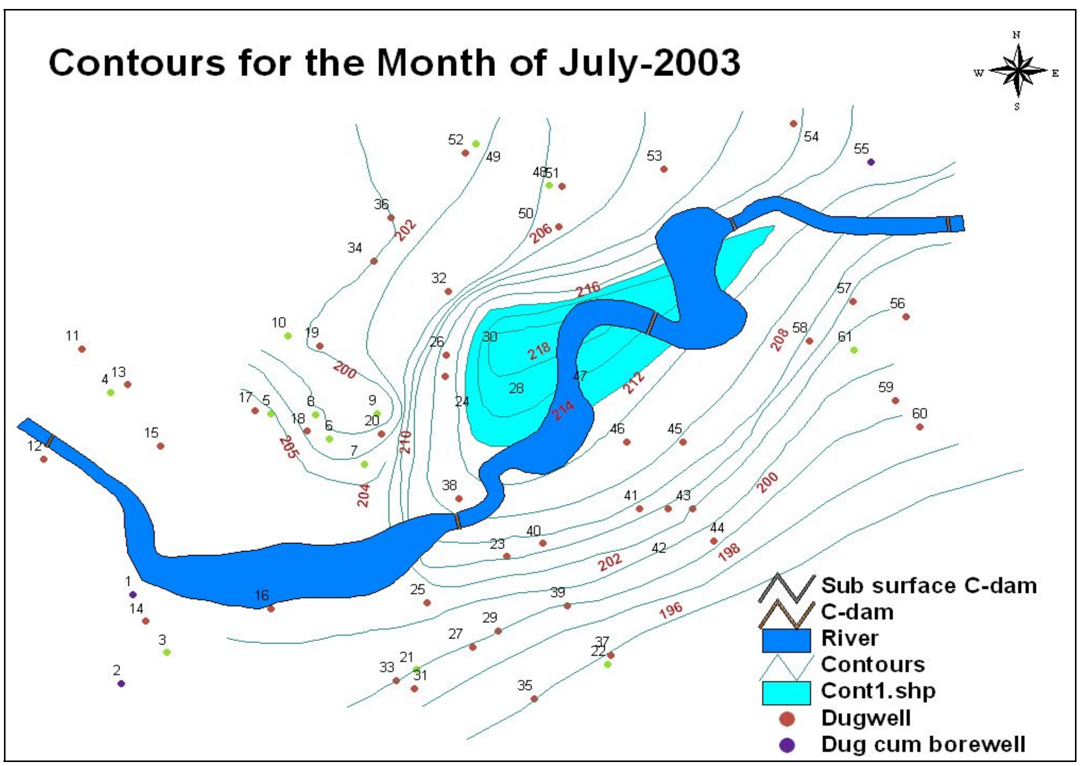
Water level in recharge structures:

As described earlier, the sediments carried by rainwater during the monsoon has filled to a depth of 1-2ft. in the Dhamini river bed. The soil is also loamy-sandy type allowing for immediate percolation. The weathered zone is also quite thick of 25-30m. and is mostly unsaturated due to deep groundwater level, hence faster percolation of rainwater.

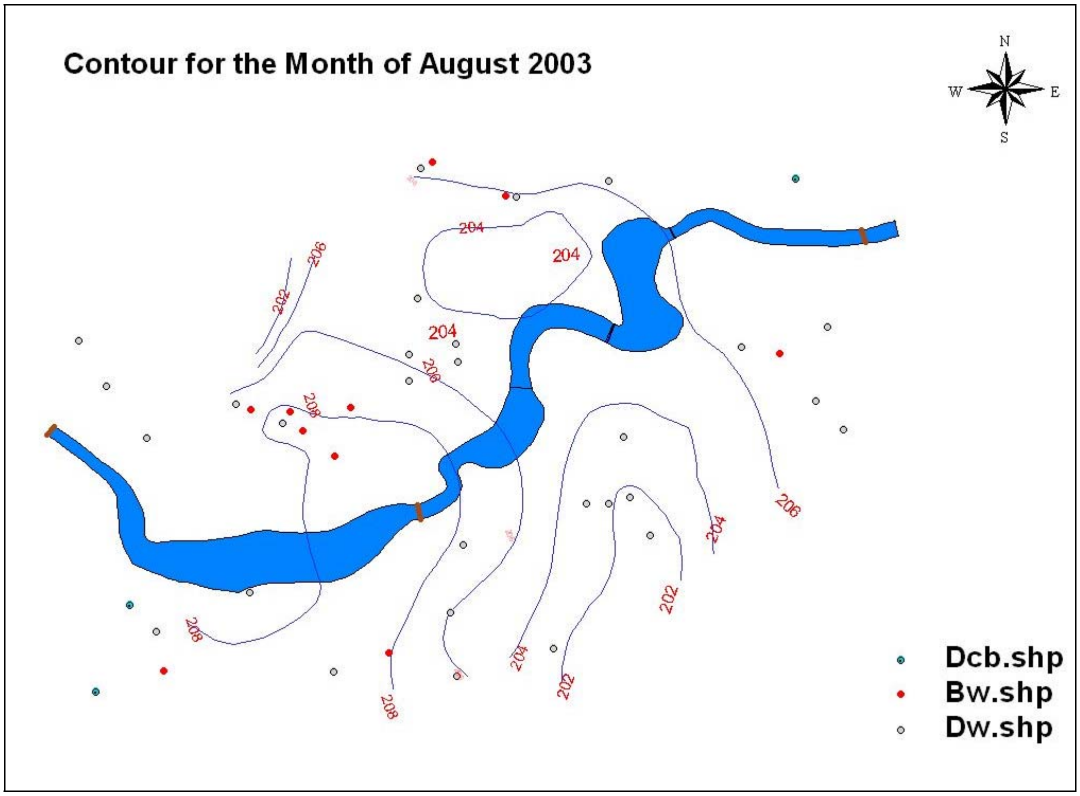
During the good monsoon of 2003, in the first heavy shower, water stayed for not more than 3 days in Mumanvas and Bhanawas check dams. In the second shower, water stood for 7-10 days only. This indicates the rate of percolation. We can also observe the similar trends of raise in water level in the wells and bore wells during this period. It has been observed that after the last monsoon in the third week of September 2003, water in the Bhanawas stood for one month as also can be observed from the water level readings in the monitoring wells.


Contours for the month of June 2003
N
W
E
S
183
185
195
200
Sub surface Check dam
Check dam
Dhamni River
Borewell
Dug cum Borewell
Dugwell
Contours

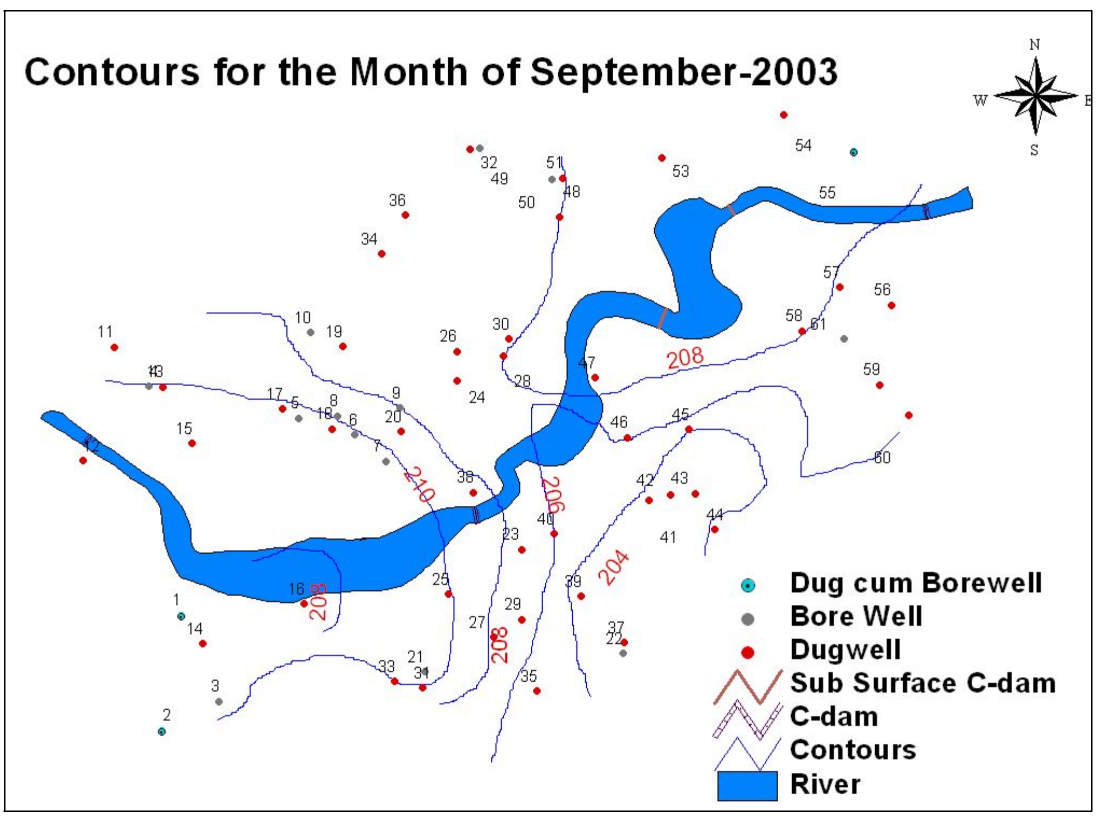
Map-14


Contours for the Month of July-2003
N
W
E
S
Sub surface C-dam
C-dam
River
Contours
Cont1.shp
Dugwell
Dug cum borewell

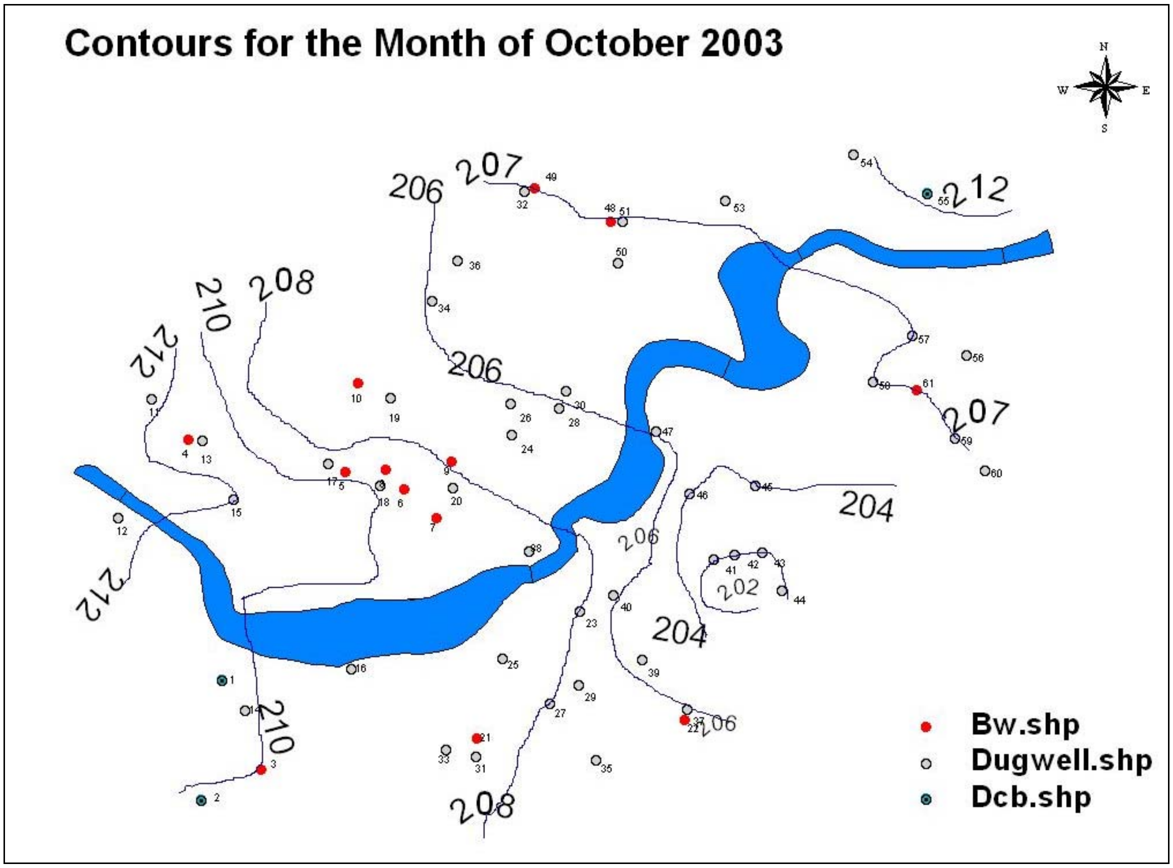
Map-15


Contour for the Month of August 2003
N
W
E
S
204
204
204
206
202
208
208
206
204
202
208
204
202
208
Dcb.shp
Bw.shp
Dw.shp

Map-16


Contours for the Month of September-2003
N
W
S
208
210
206
204
208
208
Dug cum Borewell
Bore Well
Dugwell
Sub Surface C-dam
C-dam
Contours
River

Map-17



Map-18

Storage of rainwater in the check dams

Sediments carried by rainwater has deposited in the Dhamani River to a thickness of 0.4 - 0.6m. Litho-layers below are sandy soil of 1-2m. thickness followed by highly weathered rock upto 18m. Highly permeable thick layer of the upper strata absorbs rainwater quickly i.e. the beginning monsoon rainwater stored in the check dam fully percolated within two to three days in 2003. In the subsequent rains of the same year, the stored water in the check dam stood for a maximum period of 1 month. This showed the high rate of percolation.

Mumanvas had high rate of rainwater percolation where as it was very less in Samrapur check dam. In Bhanawas check dam the last rainwater stood for about 1 1/2 months.

Automatic Weather station

Weather station established in Mota Kotasana village is the main centre for collecting weather date like rainfall, evaporation, relative humidity, temperature, hours of sunshine and wind velocity for these recharge structures.

Direct surface water abstraction from the recharge structure for irrigation

There is no practice of farmers abstracting water directly from all the three check dams for irrigation purpose.

Fine Sediments

There is sedimentation in Mumanvas and Bhanawas check dams. As the catchment area is not treated for controlling soil erosion in the Ambhaji hills there is heavy deposition of sediments in the Mumanvas check dam. During the monsoon period of 3 ½ months in 2003, the dam got filled twice. The first time sediments were removed but, again in the last shower of the monsoon, the check dam again filled up. As most of the sediments are deposited in Mumanvas check dam, there is very less deposition in Bhanawas check dam.

Water Quality

Groundwater quality is being monitored in selected dug wells, ponds and bore wells. It has already been established by the Gujarat Water Supply and Sewerage Board that the groundwater in this region has high TDS and Fluoride. A few water samples from the pond and wells are analysed in the government laboratory. The results are shown in the table below.

Source	Pvt. Well of Becharsinh Shankarsinh 0.5 km away from village Nr. Checkdam DW8BL	Pvt. Well of Nadhusinh Gamansinh 200 mts away from village DW5BR	Pvt. Well of Momin Ibrahim Saburdin 100 mts away DW1ML	Talav 0.5 km away from Village Nedardi
Date of collection	December 12, 2003			
Taluka	Satlasana			
District	Mehsana			
Village	Bhanavas	Bhanavas	Mumanvas	Nedardi
1. Colour (Hazen Unit)	Nil	Nil	Nil	Nil
2. Odour	UO	UO	UO	(Bad smell) Foul Odour
3. Turbidity (NTU)	Nil	Nil	Nil	240
4. pH	8.10	7.70	7.80	7.20
5. Total Dissolved Solids mg/l	238	462	1084	100
6. Total Hardness (as CaCO3) mg/l	152	288	312	48
7. Calcium (as Ca) mg/l	43	82	104	11
8. Magnesium (as Mg) mg/l	11	21	13	5
9. Chlorides (as C1) mg/l	16	48	416	16
10. Sulphate (as SO4) mg/l	Nil	Nil	54	16

Source	Pvt. Well of Becharsinh Shankarsinh 0.5 km away from village Nr. Checkdam DW8BL	Pvt. Well of Nadhusinh Gamansinh 200 mts away from village DW5BR	Pvt. Well of Momin Ibrahim Saburdin 100 mts away DW1ML	Talav 0.5 km away from Village Nedardi
11. Nitrates (as NO3) mg/l	4.43	44.30	2.21	Nil
12. Fluoride (as F) mg/l	2.8	2.02	1.70	0.13
13. Alkalinity (as CaCO3) mg/l	168	244	216	48
OPINION	UF	UF	UF	*UF

* Though chemical quality is fit, the water is unfit due to odour and sludge

Samples for Isotopic and chloride analysis

Four water samples from Nedardi pond, Mumanvas Open well and Bhanawas Bore wells are collected by BGS and being analysed for isotopic and chloride contents in the groundwater.

Recharge Site 2 – Nedardi Pond

Physical

Nedardi is the second recharge structure selected of the research study. Nedardi village is located North of Bhanawas at about 1 ½ kms. It is connected by all weather metal road. The socio-economic profile of the village is described in the earlier chapters.

Nedardi pond is located at about a kilometre from the village. The pond is located at the foothills of the Ambhaji ghat. One of the many streams that has been formed reaches Nedardi pond. The overflow water from this pond flows through a relatively big stream (8m bank to bank) and passes adjacent to the village.

Geology

The Geology of this place is same as the first recharge structure. Same Ambaji Granite underlain the thick sediments deposited at the foothills. The rock is moderately weathered and shallow fractures are encountered in the bore wells. Quartz and Pegmatite veins intruded the country rock. Rock outcrop can be seen in the hills, which is about 300m. from the pond.

Details of installation

Water level Gauge: In the Nedardi pond, water level gauge is installed to collect data on weekly basis.

Evaporimeter: Floating pan evaporimeter will be installed in the pond to find the rate of evaporation on daily basis. There is limitation in using the evaporation data as the pond is open and many grazing animals drink this pond water. It is reported that on an average 200 animals drink water in this pond. However, as there was good monsoon in 2003, about 30cm. water is still there (as on January 2004) in the pond.

Piezometers:

One shallow and one deep Piezometers will be established in the down stream of the pond. Groundwater level will be monitored on a weekly basis in the piezometers. The shallow depth Piezometer will be drilled till hard rock is encountered. The deep Piezometer will be drilled to about 76m. The Piezometer will be capped and locked for security.

Sedimentation gauging will be carried out by fixing MS gauge marked with scale in the centre of the pond.

Raingauge

One manual raingauge will be installed during the monsoon to compare the rainfall data with respect to the main weather station.

Surface water in- and out-flows

Water flow and the height of water in the pond will be measured on a daily basis during monsoon period. After the monsoon, the water level reading will be taken on weekly basis. Overflow form the pond will be measured using a gauge fixed at the centre of spillway.

Groundwater level monitoring

Identified 7 dug wells and 2 bore wells are being monitored on a monthly basis. The network of wells are marked on the base map and contour map prepared for each month record to analyse the recharge and discharge zones as well as movement of groundwater.

Groundwater abstraction wells in the vicinity

Monitoring wells are pumped mostly during Rabi (winter) season for vegetables and Wheat crop. All the dug wells support irrigation for rabi crop cultivation till January-February in a good monsoon years. Bore wells support for summer crop cultivations also. The pumps installed are not more than 5 HP. A few dug wells use diesel pumps.

Direct Water abstraction from the recharge pond

There is no practice of drawing water from the pond for irrigation purpose. However, as explained earlier, about 200 animals drink water from the pond everyday. This needs to be accounted for calculation for water balance studies.

Fine Sediments

As the pond is located at the foot of the hill there is good amount of silt deposited in the pond. This pond was deepened and silt removed by the villagers about 2 years ago with the fund support from VIKSAT. The present silt deposit is very less.

Plate 12. Nedardi Pond, after monsoon of 2003

Water Quality

Water sample collected by BGS during November visit has been analysed and the report is available. Water quality analysis was also conducted at the government laboratory in Mehasana and its report is annexed. Generally, the water quality is good but due to high turbidity it is not potable.

Recharge site 3 – Nana Kothasana tank

Nana Kothasana is a hamlet of main Kothasana village located in the Southern part of the study area. The tank was constructed by the government long ago. It was deepened during the drought of 2000-01 by the villagers. The tank is big in size and located at the foot hills of the Aravallis. The soil in the tank is sandy in texture and thorn bushes are grown at the bed of the tank. This serves as percolation tank for the village agriculture fields and recharges dug wells and bore wells in the down stream area.

Geology

Geology of this village is again Ambaji granites underlaying thick ravine sediments. The land around the tank is rugged and bad land (Ravines). The area adjacent to the tank is marked by deep valleys cut across by streams. There is Aeolian deposit along the lee ward slope of the hill which is facing the tank. There are no rock outcrops in the vicinity of the tank.

Detailed topographic survey is carried out in the tank. The cross section and L-section survey data is used for preparing the contour map of the tank.

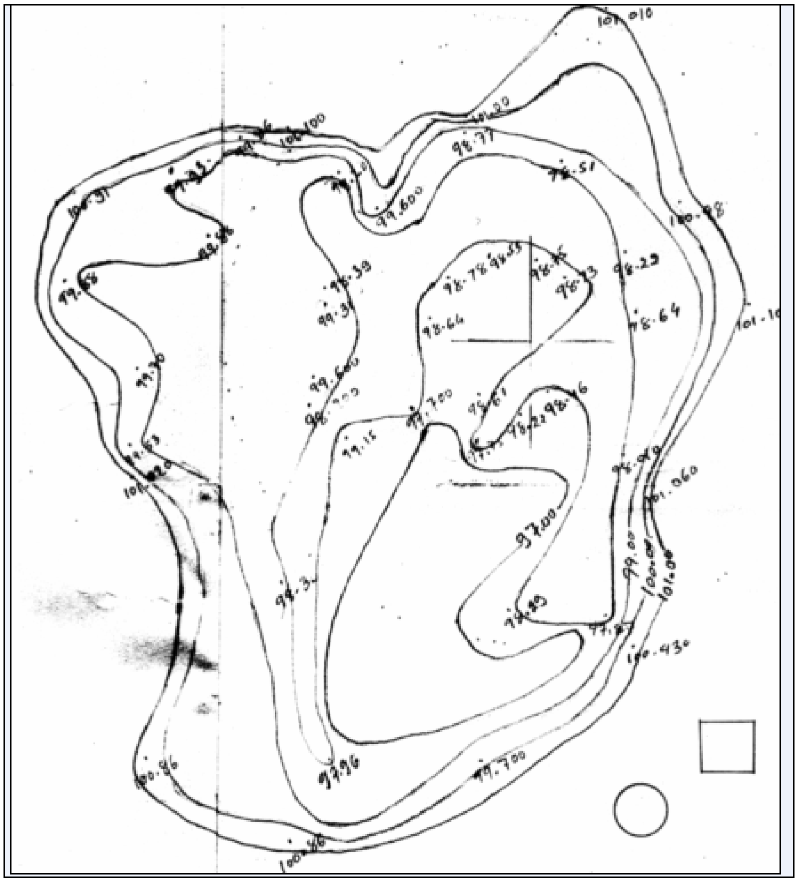


Figure-5 Contour map of Nana Kothasana tank

Monitoring of Physical Parameters

Details of Installations:
Weather station is nearer to this tank (1km.). Hence, the readings taken in the main weather station is used for all computations.

Piezometers
Piezometers will be drilled at three locations in the down stream. The nearest one will be shallow depth, the next one at a distance of 50m. will be upto shallow fractured rock depth of 45m. and the farther one at a distance of 100m. from the tank upto deeper depth of 76-92m. The shallow piezometer will not be cased except upto the loose soil.

Annexure I

Key Personnel Associated with the Project *

Sr. No.	Name of the Employee	Educational Qualifications	Age	Sex	Years of Experience	Designation
1	Srinivas Mudrakartha	M.Sc. Tech. (Geo-physics); PGDCMA, PGDMS	47	M	25	Director
2	Srinath J.	Post M.Sc. (Hydrogeology), M.Sc. (Geology)	44	M	19	Sr. Programme Officer
3	M.P. Madhusoodhanan	M.Sc. (Development Planning), M.A. (Economics)	39	M	12	Project Officer
4	Sanjay Lalchand Pawar	M. Sc. (Agriculture) Soil Science	31	M	5	Sr. Research Associate
5	Pravin Arun Bhope	B.Tec h, PGDRM (IRMA)	34	M	5	Sr. Programme Associate
6	Subrat Kumar Dash	Ph.D (International Relations)	32	M	7	Project Officer
7	Ramesh Gadhvi	B.C.A.	32	M	10	Programme Associate (GIS)
8	Archana Rastogi	M.Sc. (Environmental Science)	25	F	1	Research Associate (GIS)
9	Babubhai K Desai	B.Com.	28	M	5	Library Assistant
10	Bharat Patel	B.Sc. (Forestry)	31	M		Field Supervisor
11	Vibha N Patel	B.R.S.	23	F	2.5	Field Assistant
12	Jyotika K Patel	B.R.S.	24	F	5	Field Assistant

- *This list does not include the administrative support staff*

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