Chapter 1
Introduction

1.1 Problem Definition and Motivation

Karjat taluka of Raigad district has contrasting situations. Being less than 100 km from Mumbai, it has a substantial urban and peri-urban population which relies on the industry and service sector for employment. On the other hand, it is also the home to a large agrarian population, much of which is tribal. Many of these hamlets face a severe problem of resources such as electricity, fodder, water and so on. Present study focuses on the drinking water availability in Karjat taluka, it's distribution to the people through government built water resource infrastructures, groundwater use, domestic water demand pattern and its possible shift in future, and analysis of all these to look for alternative strategies that would assist to ensure safe and secure adequate domestic water supply to village.

Karjat taluka is located in Konkan region of Maharashtra which receives an annual average rainfall of 3495 mm [1]. Despite of this, wells become dry during mid winter and summer months because of a peculiar geology of this region. This causes a severe drought condition in the area and the rural people then have to depend only upon nearby river water or dams. In many villages of this region the situation is so grave that people have to spend 5-6 hours a day to fetch water for domestic use over a long distance.

After primary interactions with the Tehsildar office and a local NGO, Disha Kendra, it was revealed that there exists a substantial disconnection between government officials and villagers. In many cases, the administration is unaware of the exact ground situation in some of the water-scarce hamlets. They also have a limited set of interventions to offer, such as a new well, a piped water scheme or tanker supply, all of which are either unreliable or unable to meet the needs. On the other hand, villagers are unaware of even these schemes and involved technicalities therein. Such interaction also showed that there is no proper knowledge about groundwater availability and technical knowledge of schemes.

1.2 Aim and Scope of the Work

Considering drinking water problem and interaction with government officials, Disha Kendra and villagers, some objectives are conceived such as

1. To assess the groundwater potential in Karjat

2. To assess the reasons for failure of drinking water schemes and identify best practices.

3. To develop a system of documentation and information transfer from Gram-Panchayat to taluka offices

Towards meeting the objectives, analysis of the data and documents pertaining to observation well data from GSDA, taluka level data, GP level data etc. were gathered. The complete paucity and unreliability of data forced us to scale down our objectives to:

1. To design and initiate a Gram-Panchayat level water document which will help

    i. To estimate yearly supply and demand

    ii. To predict stress periods

    iii. To give suggestions for further interventions.

2. To propose and execute a simple test to analyze a well as a source for drinking water.

3. To produce a historical analysis of a particular Gram-Panchayat and the water interventions therein.

1.3 Methodology

To identify and analyze water resource availability and existing water resource infrastructures in karjat block, various meetings were conducted with Block government officials and Disha Kendra. Based on these interactions, study objectives were identified and Khandas Gram-Panchayat was selected as a study area. To analyze the existing water resources scenario, domestic water demand and supply, and probable future water resource infrastructure interventions, mainly three kinds of field investigations were carried out.

1) Village level water resources and water resource infrastructures were identified by using web based Google Earth tool. Water resource oriented maps of each hamlet in

Khandas grampanchayat was drawn. This has helped in locating wells, rivers, and small dams while carrying out field level survey.

2) Yield tests were carried out on identified wells to find out water resource capacity of that well. Due to severe water scarcity of this region, existing standard procedure of yield test was not possible in Khandas. Therefore a new yield test method was proposed and used. To identify water table level, electrical resistivity test was carried out at six different locations in khandas.
3) A questionnaire survey was carried out to find out domestic water resource usage pattern of village. A trend-line tool of PRA exercise was utilized to draw a chronological trend in water resources of village over last two decades.

Based on analysis of these investigations, a water resource document was designed to gather water resource related data for a village. A framework was proposed to analyze this data to plan for future water resource infrastructures in village.

1.4 Outline of the Report

Chapter 2 discusses background work done for preparation of water planning document. It also explains standard methodology for yield test and ER test. Chapter 3 includes data collected from GSDA department, Alibag. It gives brief description about water levels in various observation wells of Karjat taluka. In Chapter 4 field survey for water demand and trend line is explained. It also includes yield test and ER tests which are conducted at field. Chapter 5 lists framework of water planning document and actual document. Results and discussion is explained in Chapter 6. It also summarizes the report.

Chapter 2
Background Study

2.1 Study Area

The Karjat tribal block is in the Raigad district of Maharashtra representing a belt of uneven topography between the western foothills of Western Ghats and western coastal areas. It is situated between east longitudes 73°20’ and 73°35’ and north latitude 18°55’ and 19°5’[1] . It covers a surface area about 360 sq. km. It includes 175 villages and 49 Gram-Panchayats. The total population of Karjat is 184420 out of which 75% population live in rural areas [2].

Khandas Gram-Panchayat of Karjat block is selected as study area (Figure 1 Appendix I). Its population is nearly 4500. It comprises 16 tribal hamlets and a revenue village. Most of the families are agrarian and paddy cultivation during rainy season is a major livelihood. It is having an average annual rainfall of 3500 mm. This region faces acute water scarcity during summer season. The area is deficient in drinking water during dry months on account of considerable loss of soil moisture and decreased in subsurface water storage. A part of the rainfall infiltrates down to join actual water table but its major portion runoffs to remote areas. The local physiographic and rock structure do not permit the monsoon water to be retained in the areas as a result of which drinking water problems arises from mid-winter to summer and continues till the onset of subsequent monsoon.

2.2 Existing Methods to Assess Groundwater Resource

There are several methods and techniques are used for assessment of groundwater. Some of them are explain below.

2.2.1 Water Balance Method

Kumar C.P., explained about water balance method for assessment of groundwater. Water balance techniques have been extensively used to make quantitative estimates of water resources. The study of water balance is defined as the systematic presentation of data on the supply and use of water within a geographic region for a specified period. Water balance method gives contribution of water by various sources over different period of time.

The basic concept of water balance is: Input to the system - outflow from the system = change in storage of the system (over a period of time) [4].

Ground water balance equation

Considering the various inflow and outflow components, the terms of the ground water balance equation can be written as:

$$Ri + Rc + Rt + Rr + Si + Ig = Et + Tp + Se + Og + \Delta S \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

Where,

Ri = recharge from rainfall; Rc = recharge from canal seepage;

Rr = recharge from field irrigation; Rt = recharge from tanks;

Si = influent seepage from rivers; Ig = inflow from other basins;

Et = Evapotranspiration; Tp = draft from ground water;

Se = effluent seepage to rivers; Og = outflow to other basins; and

ΔS = change in ground water storage.

This equation considers only one aquifer system and thus does not account for the interflows between the aquifers in a multi-aquifer system. All elements of the water balance equation are computed using independent methods wherever possible. Computations of water balance elements always involve errors, due to shortcomings in the techniques used.

2.2.2 Assessment of Groundwater Potential Zones using GIS Technique

Singh S (March 2009) explained about use of GIS in assessment of groundwater potential. ccA case study is conducted to find out groundwater potential zones in Kattakulathur block, Tamil Nadu, India over area of 360 km2. For assessment thematic maps such as geology, geomorphology, soil hydrological group, land use /land cover and drainage maps are prepared for the study area. The Digital Elevation Model (DEM) is generated from the 10 m interval contour lines and obtained the slope (%) of the study area. ArcGIS 9.2 is used for overlying of thematic maps. During weighted overlay analysis, the ranking has been given for each individual parameter of each thematic map and weights are assigned according to the influence such as soil –25%, geomorphology – 5%, land use/land cover –25%, slope – 15%, lineament – 5% and drainage /streams – 5% and find out the potential zones in terms of good, moderate and poor zones with the area of 49.70 km^2, 261.61 km^2 and 46.04 km^2 respectively. Such potential zones are overlaid on village boundary and potential groundwater zones are identified [5].

2.3 Standard Methods to Estimate Water Availability

2.3.1 Yield Test

Well Yield Test Procedures Private Wells (2005) a booklet published by Bureau of Environmental Protection discusses about yield test and its applications. Yield test is the process of determining the maximum amount of water that can be drawn out of a well, and amount of water recharge back into the well from surrounding areas. If the water level within the well continues to drop to the level of the intake without stabilization occurring, the draw down from the well is exceeding the natural recharge rate of the surrounding aquifer. If this happens, the pumping rate is too much and must be reduced. Hence drawdown of water should not be more than yield of well [6].

If the data of yield test is available for some consecutive years then it is possible to predict the future recharge of from the well. It will give water available in future for given population. In addition to that these two quantities yield and drawdown, find direct application in selecting the element of a permanent pump that are fitted to the operating characteristics of the well. Yield test can be measure in terms of m^3/hr or liter/hr.

Standard Yield Test Procedure

For yield test, initially preliminary data regarding well specifications and location is to be documented. The major steps involved to conduct the yield test are briefed below:

1) Collect the prior information about dimensions of well before staring yield test.

2) Locate the discharge of water from well at appropriate location. It should be at least 50 feet from well so as the recharge should not add in well.

3) Measure the discharge rate of the pump and water level drawdown in the well for 24 hours. Measure the pumping level (depth to water) after every 15 minutes during the first hour of pumping, and hourly for the next 9 hours. The pumping water level shall also then be measured after 23 hours, 23.5 hours, and finally after 24 hours.

4) Record these measurements along with the date and time of each reading. Pumping rate is to be measure in liter per minute. The water level drawdown is measured in meter and it is measured from some reference point, such as the top of the well casing. Drawdown (lowering of the water table) increases with time as shown in Figure 2.1

5) Formula for calculating yield test is given below

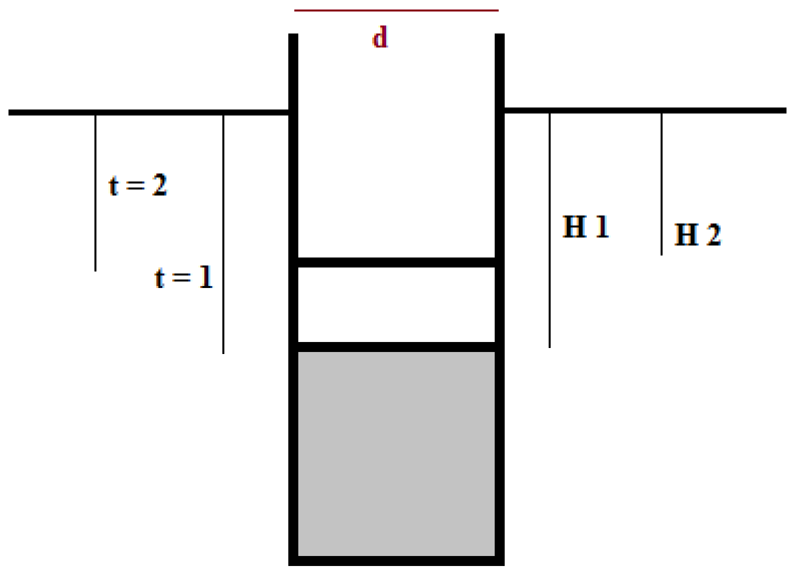

Figure 2.1: Yield Test of the Well

Preliminary Information of Well

Whether testing a new or existing well, certain background information must be obtained to allow setting up the pump test and to ensure meaningful results. Such information is required to determine the volume of water in well and water drawn out.

Preliminary Information:

a) Total depth of the well: ____________ meter

b) Diameter of the well: ______________meter

c) Power of Pump (if available): ___________HP

d) Diameter of hose pipe of pump: __________meter

e) Depth down to natural non-pumped water level (called static water level): _____ meter;

g) Maximum expected pumping rate: _____ liters per minute.

h) Drawdown of water from well: _________

Calculation of Yield Test

Figure 2.2 shows the yield test observations of water level from time interval of t=1 to t=2. Here H_1 and H_2 initial and final water levels at time t=1 and t=2 respectively. Formula for calculating yield test is given below:

Increase of height $\Delta h = H_1 - H_2$

Initial volume of water $= \pi r^2 H_1$

At time t =1, volume of water $= \pi r^2 H_2$

Difference of water column is $= \pi r^2 \Delta h$……………………………………………………. (2.2)

Where H_1 – Static water level at time t_1

H_2- Final water level after discharge in time t_2

2.3.2 Electrical Resistivity Test

Introduction

This test is based on the principle that every substance has a physical property (electrical conductivity) depending on which substance can be classified and corresponding material can be predicted based on this proportion. Different earth materials have different electrical conductivity/resistivity varying with the mineral composition, compactness and the nature of fluid content.

Purpose of carrying electrical resistivity test is to know the water saturation depth in Khandas region. Generally government implements the schemes without any background work. Hence most of the wells are gone dry from month of March. If electrical resistivity method is used before digging any well then it will help to identify the exact location of well or bore well. This method is very useful to,

- Characterize subsurface hydrogeology,
- Determine depth to bedrock/overburden
- Determine depth to groundwater
- Quantitative assessment of groundwater reserve of unconfined aquifer
- Map vertical extent of certain types of soil and groundwater contamination.
- Estimate landfill thickness.
- To understand the location of abandoned coal mine.

Theory [7]

As stated earlier that every substance have different resistivity/conductivity. If it is considered that earth is homogeneous then current will flow from hemispherical surface. By considering the Ohm's law ($V = IR$) and defining R can be define in terms of resistivity ρ and area of the shell.

$$dV = i(R) = I\left(\rho\frac{L}{A}\right) = I\left(\rho\frac{dr}{2\pi r^2}\right) \quad (2.3)$$

Where V is the voltage (or electrical potential), I is the current, ρ is the resistivity, and r is the radius of surface.

Survey Methods and Electrode Configurations

There are two types of conducting electrical resistivity test as either sounding or profile. A sounding is used to determine changes in resistivity with depth. The electrode spacing is varied for each measurement, but the center point of the array is constant. A resistivity profile is used to detect on the side variations in resistivity. For this configuration, the electrode spacing is fixed while the center of the array is varied. There are various electrode configurations which can be used in resistivity surveying. The majority of resistivity surveys use two current electrodes and two potential electrodes. The two main array configurations are the Wenner array and the Schlumberger array. In the Wenner array electrodes are equally spaced. This is shown in Figure 2. The Schlumberger array is more complex with the spacing between the current electrodes not equal to the spacing between the potential electrodes. The Schlumberger array is shown in Figure 2.3. In general, the potential electrode spacing is negligible compared to the current electrode spacing for this type of array.

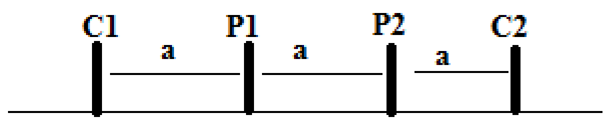

Figure 2.2: Arrangement of Wenner Array

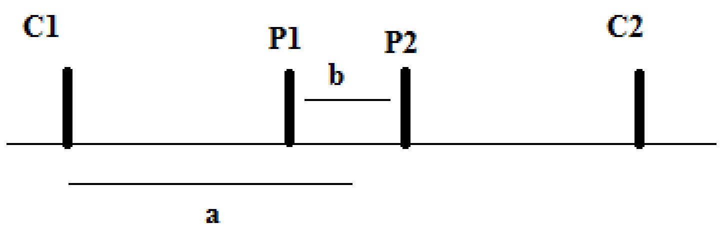

Figure 2.3: Schlumberger Array Arrangements [8]

2.4 Participatory Rural Appraisal (PRA)

Honlakaskar V. (2009) explained about PRA methodology which was used in Gawanwadi village of Karjat block. Participatory Rural Appraisal is a methodology for interacting with villagers, understanding them and learning from them. It involves a set of principles, a process of communicating with them using a set of menu of methods for seeking community participation.

It describes a growing family of approaches and methods to enable local people to share enhance and analyze their knowledge of life and conditions, to plan and to act. Participatory methods include mapping and modelling, matrix scoring, seasonal calendars, trend and change analysis, well-being and wealth ranking and grouping, and analytical diagramming etc. PRA applications include natural resources management, agriculture, poverty and social programs, and health and food security. It is a process which extends into analysis, planning and action. For the present study a trend line tool of PRA is utilized. [9]

2.4.1 PRA Tools

1. Resource map: This map indicates all potential resources are as especially for agriculture and its related activities available to this community. This can lead to identification of key informants, and then to discussions with them.

2. Social map: This helps to learn about social and economic differences between the households. It gives an idea of assets owned by people and its distribution among villagers.

3. Seasonal calendar: This looks at different activities carried out by the community and their time of implementation over a year.

4. Timeline: This tool looks at some of the important trends in food security, environmental health, forest cover, precipitation etc. that took place within the community within a given period and their effects on people's life.

5. Venn diagram: This tool is expected to generate are presentation of village and other institutions that exist within or work with the community, as well as representing the linkages between the institutions. This will enable the project to identify potential partners in specific areas.

6. Problem ranking: This exercise let the villagers to think on their live livelihood problems and priority order of these problems.

7. Trend line: This tool looks at some of the important trends in food security, environmental health, forest cover, precipitation, etc. that took place within the community within a given period and their effects on people's life. Trend lines are helpful to understand the people’s perception of significant charges in the communities over time. Trend lines can be discussed with community representatives including elders, long term residents, women groups, and self help groups. Trends can also be discussed to find out explanations behind changes. This helps to identify underlying problems and traditional techniques to correct the situation.

Trend lines provide useful baseline information for researchers operating on micro level follow ups of such aspects as population, food availability, school enrollment etc. It forms the basis upon which problem identification and options assessment is made during the preparation of the community action plan. For the present study trend lines of water resources availability, water resource structures and water consumption pattern are found out.

Chapter 3

GSDA Data Collection and Data Analysis

3.1 Observation Wells Data

3.1.1 GSDA Overview

The GSDA closely monitors the ground water regime in the Country through approx. 15640 ground water observation wells [10]. It monitors changes in water level through these stations 4 times a year (Jan/May/Aug/Nov) and collects water samples once a year in May for water quality analysis. This water resource data can be analyzed to ascertain seasonal and long-term water level changes. Depth to water and water level fluctuation maps are prepared to study the ground water regime for the whole country. GSDA has 1496 observation wells in

Maharashtra out of those 28 are in Raigad district. The regional office of GSDA of Raigad district is in Alibag [11].

3.1.2 Observation Wells

Observation wells are useful to know groundwater level in respected regions. These wells are also use to find water quality. Hence observation wells are important in assessment of groundwater. Water level data of observation wells is collected from district level office of GSDA at Alibag. There are total 28 monitoring wells in Raigad district. Out of which Karjat block has got eight observation wells. Appendix I shows the location and current status of observation wells. By monitoring these wells ground water level variation of this region is measured. GSDA is responsible for monitoring these wells. The data obtained from GSDA is given in Appendix II. Data of observation well is monitored in four times (Jan/March/Jun/Sept) a year. Water level of observation well in Khandas gram-panchayat is explained below.

3.1.3 Analysis of Observation Well

Khandas

Figure 3.1 shows variation of water level for eleven consecutive years for particular months. It can be observed from graph that water level in observation well for Jan-2004 is documented as 6.05 m when annual rainfall was 2550 mm. For its consecutive year, although there was just lesser rain fall (2352 mm), documented water level was far lower (14.3 m). Such large difference in water levels can possible only if there is a sudden increase in demand of water or a sudden increase in human population. This shows that there are some flaws in measurements. Water level during March-2010 was 5.8 m which is much higher than water level during March-2009. There was no rainfall in March 2010; hence sudden increase in water level can’t be possible. It shows that the documentation is not reliable.

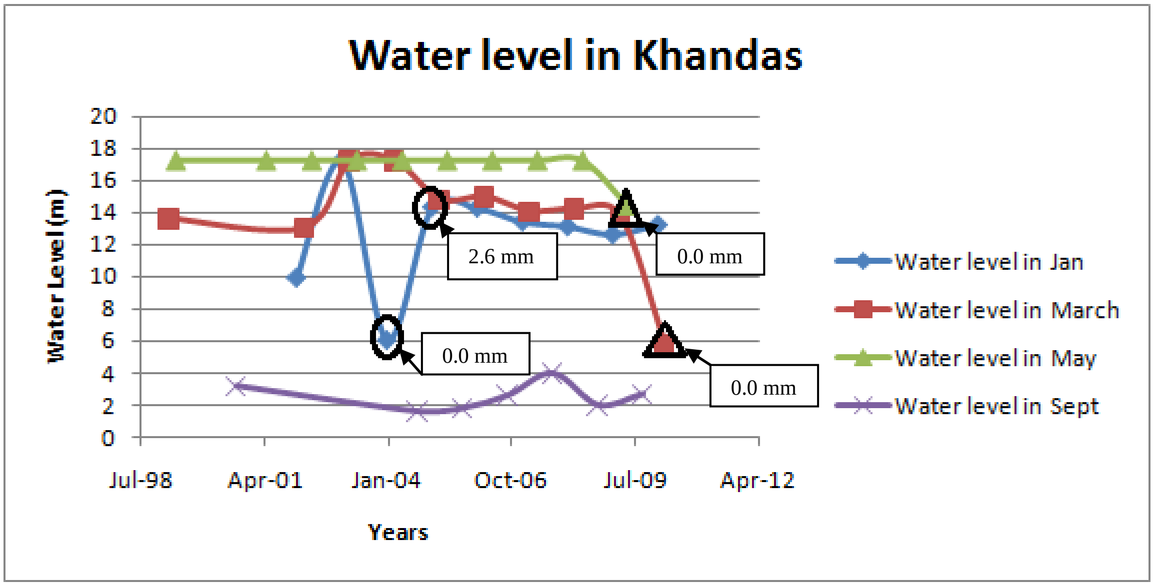

Figure 3.1: Water Level in Khandas Observation Well

Karjat

Figure 3.2 shows the observations of water level in observation well of Karjat. In April rainfall was 2004 water level was 4.05m but there is sudden increase in water level up to 2.6 m in May 2006. It shows that the reading may be wrong or may be due to rain or water pouring in well which increased water level. Water level in March 2008 is same as in May 2008. It could happen only if there is rainfall in the month of May but there was no rainfall in May 2008 (Refer Annexure VII)

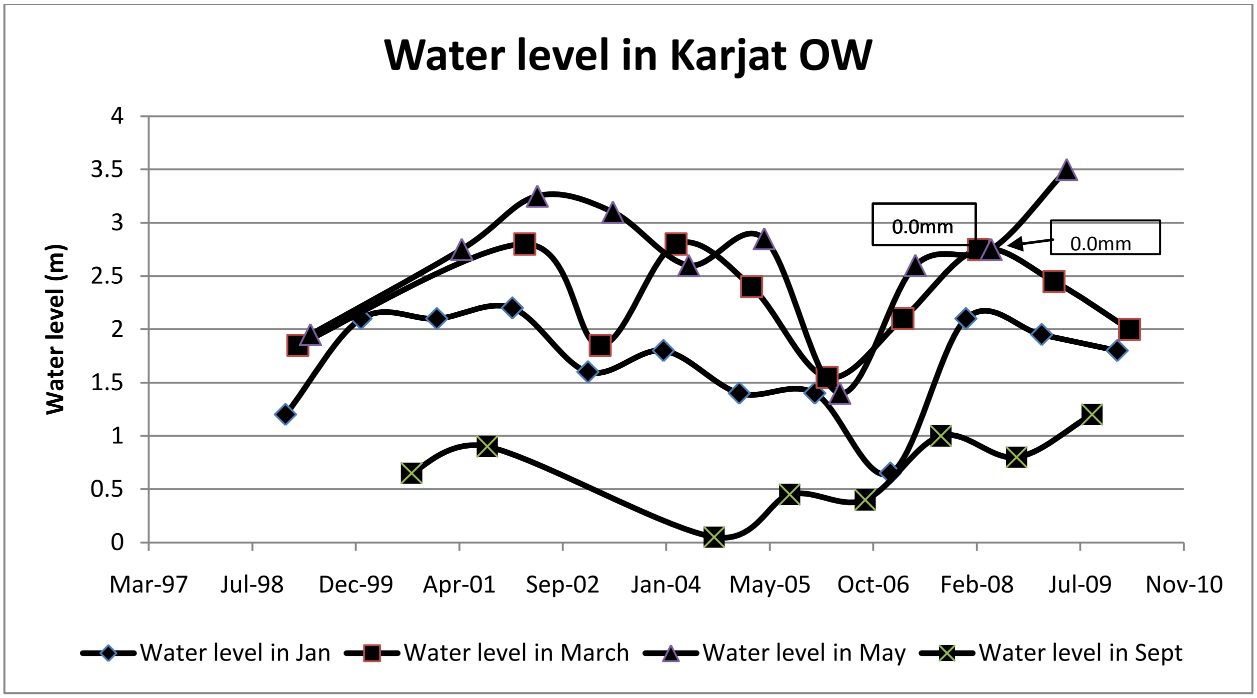

Figure 3.2: Water Level in Karjat Observation Well

Kashele

Figure 3.3 shows the observations of water level in the well of Kashele. The observations show that the difference in water level in November 1999 and January 2000 is 4.4m and the annual rainfall in 1999 was 3299.1 mm. Also difference in water level in November 2001 and January-2002 is 1.7 m and the annual rainfall in 2001 was 2931 mm which is less than annual rainfall in year 1999. It shows that even though rainfall in year 1999 was more than year 2001but water level was more in year 2001 than year 1999.

Water level in March 2004 was 6.2m when the rainfall was zero in same month but water level in April 2004 has been increased to 5.8m without rainfall in same month. Hence this reading may also have wrong observations.

In May 2007 water level was 7.25 m when the total rainfall in May was 57 mm. The water level should increase due to rainfall but observations are showing that water level has been decreased.

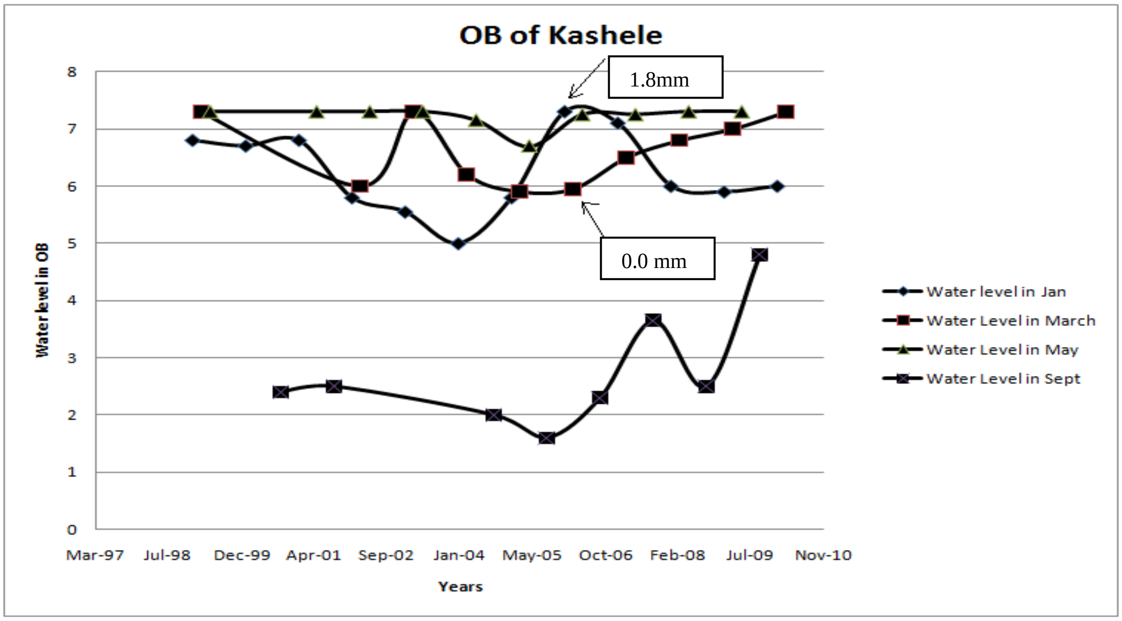

Figure 3.3: Water Level In Kashele Observation Well

Dhamote

- Figure 3.4 shows the observation in Dhamote observation well. Water level difference between January 2003 (rainfall 3.6mm) and January 2004 (no rainfall) is 4.45 m which is much more if compare with other readings on same months of different years.

- In addition to this rainfall in January 2003 was 3.6mm and no rainfall in January 2004. Hence was level in January 2003 should be more than January 2004 but it is showing wrong results.

- Water level in April 2004 shows that water level was increased but there was no rainfall in April. May 2004 had rainfall 57.4 mm but it doesn't show any rise in water level.

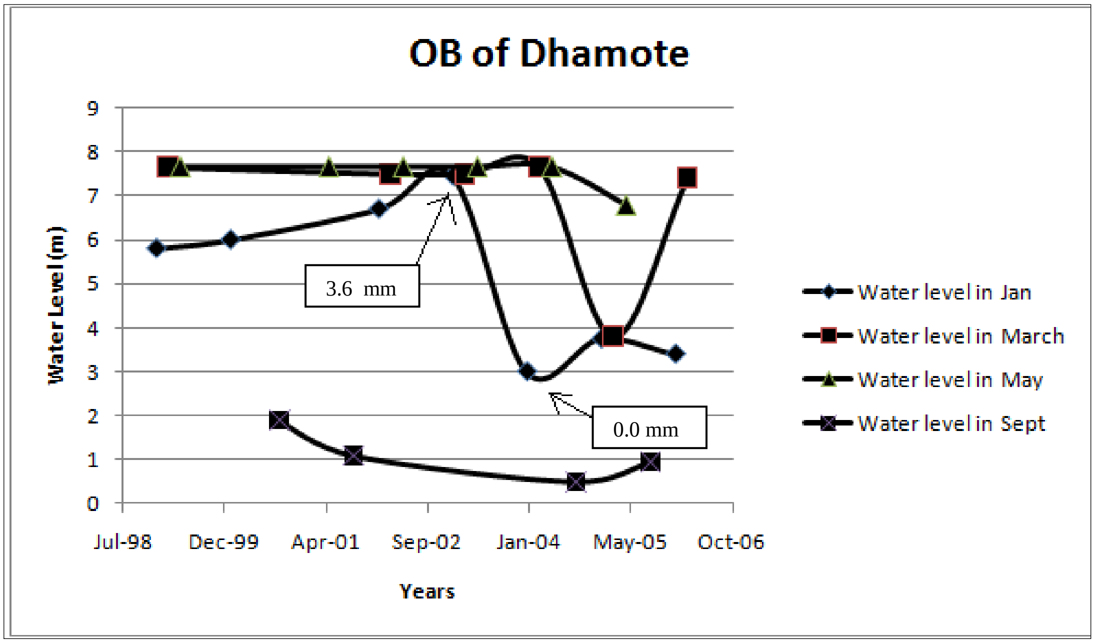

Figure 3.4: Water Level In Dhamote Observation Well

Kalamb

In September 2004 water level was 0.5 m and it decreased up to 5.25 m in September 2005. Such drastic change only happen due to increase in water demand. But it could not possible hence readings may have some errors.

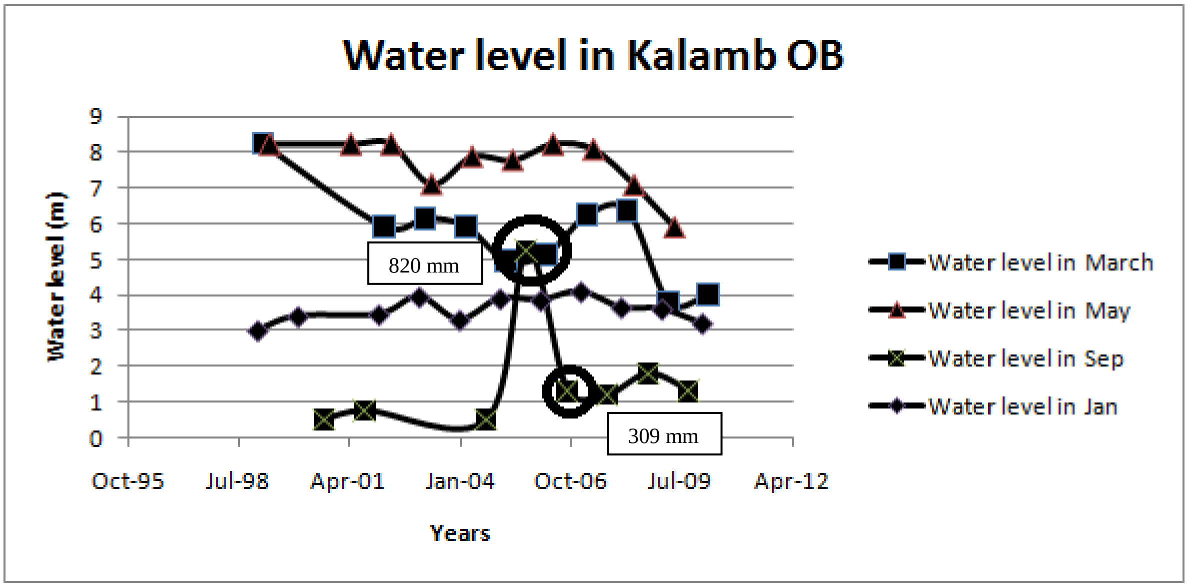

Figure 3.5: Water Level In Kalamb Observation Well

3.2 Conclusion of Data from Observation Wells

Observation wells are reliable source to know ground water level in respective areas. So the readings of water level should measure correctly. But the readings of observation wells measured by GSDA are showing many errors. It may caused due to human errors, instrumental errors etc. To check the status of observation wells in Karjat block a survey was carried out by visiting all observation wells. It is found that observation well in Dhamote is already demolished five years before. Government officers are also not coming to measure readings.

It shows that the readings of observation wells measured by GSDA are not reliable. To overcome such problem it is better if villager measure the reading of their own wells. For that capacity building is necessary. Hence it is decided to prepare a document which will be helpful to know groundwater scenario of village. Procedures to measure water demand and to carry out yield test, electrical resistivity test is discussed in Chapter 4 and Chapter 5.

Chapter 4

Water Resource and Field Survey Analysis

4.1 Water Resources in Khandas Gram-Panchayat

Even though average annual rainfall of Khandas region is about 3500 mm, the region faces scarcity of surface water problem especially during months of summer. Hence groundwater is the only source of drinking water thereby total dependency on wells and bore wells. However these sources also get dried from month of March to May. For analyzing this seasonal availability of water of all wells and bore wells in Khandas Gram-Panchayat were surveyed using GPS and located on Google Maps.

Before going to field all resources were identified by using Google earth (see Appendix III). Google Earth is a virtual globe, map and geographic information program which is available free on the internet. If internet facility is not available then resource map can be drawn to identify water resources in village. After identifying these locations a survey by using GPS tool was carried out in each village of Khandas Gram-Panchayat. Google maps were shown to villagers to identify water resources in respective hamlets. Such maps can be useful to for further interventions of water schemes in villages. In survey dimensions of well were measured to know the capacity of well. In addition to that water level in pre and post monsoon were measured. It gives water fluctuation in groundwater level.

Existing water resource infrastructures are listed in Appendix IV. It can be observed that in Khandas village there are 12 wells, 5 hand pumps and a dam. No well retains water till end of summer. Only one hand pump works during month of May and supply water to nearly half of the total households in Khandas village. Hand pumps and most of the wells have been built up since 1985. Constructed wells have found to reduce drudgery associated with water fetching activity by decreasing the water load carrying distance for monsoon and winter season. But yet an acute water scarcity is faced every summer. There is a problem of siltation in the existing small dam in the village. Due to silt accumulation capacity of dam is reduced and it does not hold sufficient clean water till the end of summer. Sufficient measures are not taken to control siltation of dam. Although it was recommended by GSDA to carry out ER tests before finalizing site for erection of hand pump, it was observed that only one hand pump lies in the region of higher water table location. Other four locations do not have required water table depth.

Table 4.1: Water Resources in Khandas Gram-Panchayat

Sr. No.	Name of village	Population	Sources of water					Duration of Facing Scarcity
			Surface Water	Ground water	No. of Wells	No. of Bore Wells	No. of Dams	
1	Mengalwadi	125	Y	Y	3	2	0	January
2	Tepachiwadi	175	Y	Y	1	0	0	January
3	Wadachiwadi	150	Y	N	1	0	0	January
4	Chafewadi	375	Y	Y	2	0	0	January
5	Padirwadi	150	N	N	1	0	0	January
6	Jambhulwadi	70	Y	Y	0	0	0	January
7	Ghutewadi	120	Y	Y	3	1	1	March
8	Petarwadi	100	N	Y	2	0	0	March
9	Gawandwadi	300	Y	Y	4	1	1	No
10	Bangerwadi	100	N	Y	3	0	0	March
11	Dhabewadi	200	Y	Y	1	1	1	February
12	Kathewadi	300	Y	Y	2	2	0	March
13	Aamberpada	650	Y	Y	4	1	1	March
14	Belachiwadi	200	Y	Y	2	4	1	No
15	Khandas	1300	Y	Y	12	5	1	March
16	Tungi	NA	NA	NA	NA	NA	NA	NA

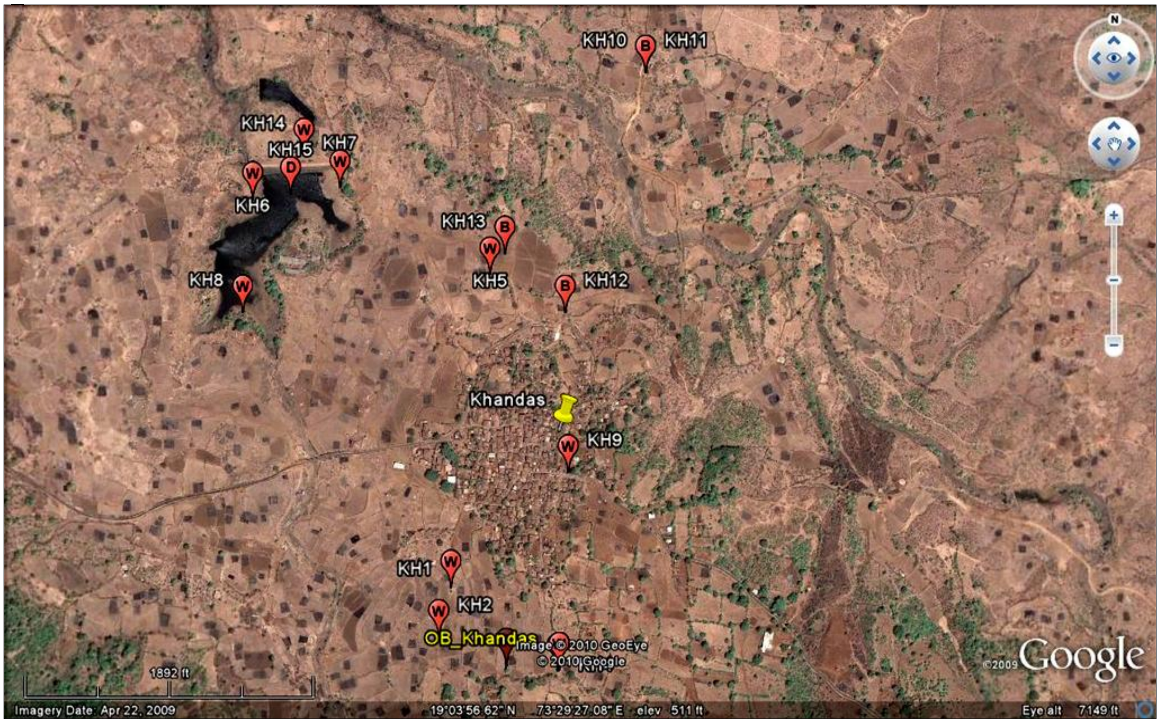

Figure 4.1: Water Resources in Khandas

4.2 Field Level Survey

4.2.1 Domestic Water Consumption

It is the basic data required for designing a water planning document. Such data can give information about water consumption pattern of users. Domestic water demand depends on its availability and population density. Domestic water demand is water requirement of an average household per day. Average water requirement per household varies from 140 to 240 liters per day during rainy season to summers. Yearly average human hours spend per household in water fetching activity are 828. This account for 17% of total human work hours spend during a year in village Gawand-wadi which is one of the sixteen hamlets in Khandas Gram-Panchayat. In terms of energy, expenditure in human work energy is 17.51% [9] of total human work energy spent over a year for all activities carried out there by people.

A questionnaire survey is carried out in three different villages. These are selected on the basis of availability of water resource. Samples of households for questionnaire survey are selected on the basis of their social structure. Questionnaire is shown in Appendix IV.

Table 4.2: Water Usage Pattern for a Family of Six

Water usage	Water consumption (liters/day)
Bath	100
Washing utensils	40
Meal	20
Drinking	10
Extra	15
Total	185

4.3 Trend Line of Water Resource Availability

This trend line gives variation of water resources for domestic usage over last three decades. It helps to analyze the reasons behind these variations and to find out possible solutions. The trend line data is collected by conducting group meetings with elder people in Khandas.

Trend line is one of the tools of PRA. For trend line some meeting with older villagers was arranged in Khandas village. In those meetings some questions about their water situation in past and present were posed. The questions were based on attributes like water availability, distance travel to fetch the water, water demand etc. Answers of these questions were formatted in a chart which is shown below.

Table 4.3: Trend Line of Water Resource Availability

Year	Per household (size~6)water availability per day	Scarcity Level	Water fetching distance	Water resource infrastructures built by Government	Human Population
1975	20 liter	Very High	5-6 Km	No infrastructure	Very Less
1980	60-70 liter	High	2-3 km	Khandas Dam Built	Less
1985	100-110 liter	Slight Less	2-3 km	Wells and Hand-pumps	350 Houses Little more
2000	100-110 liter	Less	1 km	Wells and Hand pumps, tankers	Higher
2010	60-70 liter	Gradually Increasing	1 km	Wells, Hand-pumps, Private bore-well	Much higher.

Trend line shows that water scarcity is decreasing initially but since last ten years due to growing human population it is again slowly increasing. The water fetching distance has reduced from 5 km to 1km for summer season due to development of water resource infrastructures in village. In addition to that, population growth is higher than water resource infrastructure development. Ground water level has reduced over last two decades. Hence it would be possible that this region may face water scarcity problems in future.

4.4 Field Level Yield Testing

4.4.1 Overview

Khandas gram-panchayat has 40 open wells and 15 bore wells. Out of these, only 7 wells and 1bore well have water in the month of May. From literature review it is clear that yield test is useful method to calculate the recharge of well in unit time. To estimate domestic water availability in a village it is important to know the yield of wells during its lowest recharge periods of year. It was not practically possible to empty the well due to dire water scarcity present in this region. Thus standard yield test is not possible to carry out in village.

Therefore the standard yield test procedure is modified by considering local conditions at well and water fetching durations for well without changing basic principle behind yield test. It is essential that no one should take out water at the time of testing. Hence the time for yield test is selected after 2:00 pm to 5:00 pm and from 7:00 pm to 6:00 am. The reason for selecting such time slot is at only this duration people are not coming out to take out the water from well. Wells from Belachi wadi and Gawand wadi are selected for yield testing. In Figure 4.2, BL1 shows the well where yield test is carried out.

Figure 4.2: Location of the Belachi Wadi [13]

4.4.2 Procedure Adopted at Field

The test is started at 2 pm. As people draw water during the morning hours, by noon the water level in the well goes down. This is analogous to the pumping of water for standard yield test. Water level in the well is measured after regular intervals of 15 minutes till evening when people again started drawing water from well for domestic usage. This drawn water therefore can be easily measured by measuring number of pots filled with water carried away from the well and pot volume. Then during night period water level readings are noted after an interval of 15 minutes to calculate the recharge. Water level dropped due to drawn water during evening period is added to each reading noted thereafter. The readings thus obtained are tabulated in Table 4.4.

Table 4.4: Yield Test at Belachi Wadi

Date : 20/05/2010			
Actual time	Time (min.)	Water level from Ground surface	Height (m.) of water column (8.1-water level)
7:00 P.M.	0	4.25	3.85
8:15 P.M.	75	4.21	3.89
9:25 P.M.	153	4.17	3.93
5:30 A.M.	630	4.15	3.95
6:30 A.M	700	4.15	3.95
Date : 21/05/2010			
7:25 P.M.	0	4.22	3.88
8:45 P.M.	80	4.19	3.91
10:10 P.M.	165	4.17	3.94
5:45 A.M.	620	4.16	3.95
6:30 A.M	650	4.16	3.95

Figure 4.3 shows variation of height of water column in well with respect to time. Water level raises from lower level to higher level due to well recharge. It can be observed that initially recharge rate of well is higher and it decreases as water level raises and finally reaches equilibrium. This happens due to increase in pressure head. As the time increases after 10-12 hours the level reached to equilibrium condition. These graphical relations are derived by considering exponential relationship between recharge rate and water column height. A sample calculation is shown in Appendix V. Recharge rate decreases exponentially with increase in water column height.

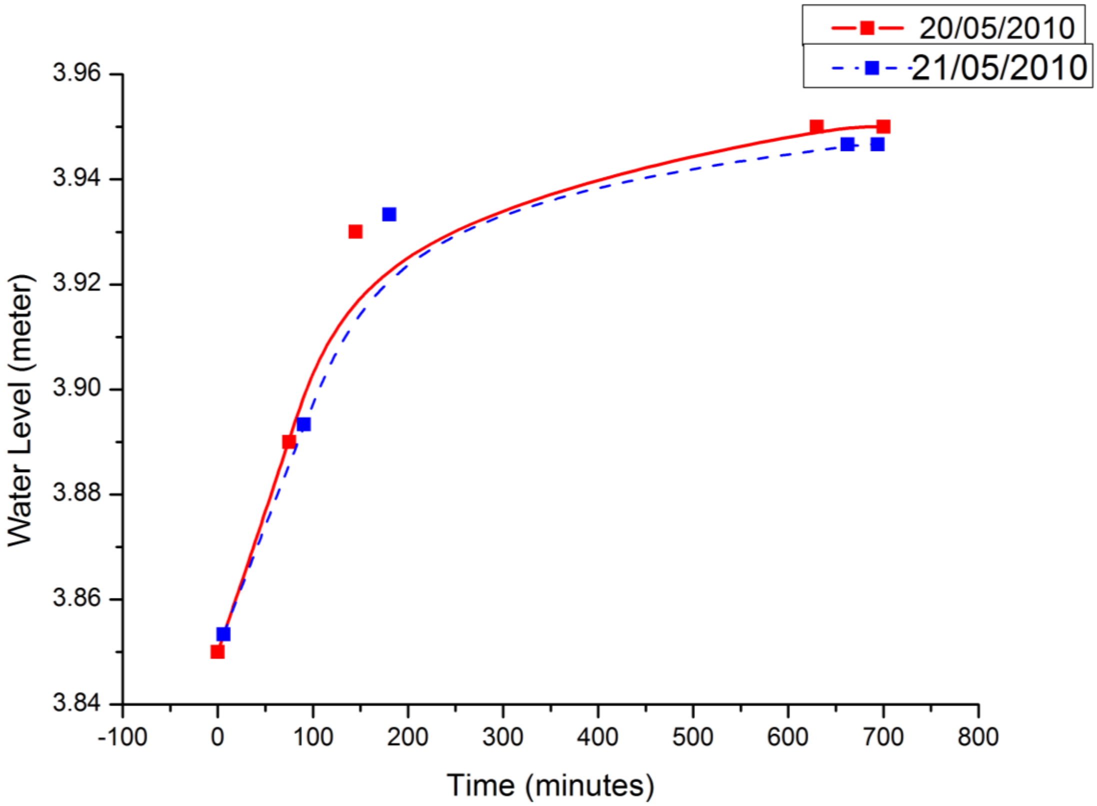

Figure 4.3: Plot of Two Yield Test for Belachiwadi

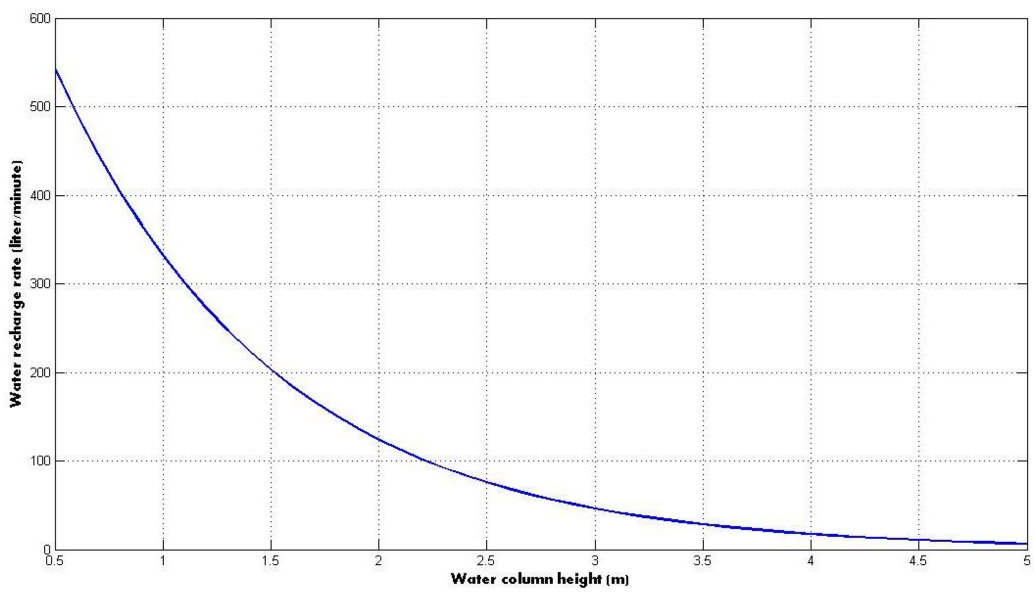

Figure 4.4: Variation of Recharge Rate with Water Column Height

Yield test at Gawandwadi

Yield test was carried out on the well located on the down-stream side of small dam. The results of yield test are listed in Table 4.5.

Table 4.5: Yield Test Data at Gawandwadi

Date : 30/03/2010			
Actual time	Time (min.)	Water level from surface (m)	Height (m.) of water column (7m-water level)
10:15 AM	0	4.2	2.8
1:26 PM	191	3.91	3.09
10:10 AM	1435	3.19	3.81
Date : 27/04/2010			
10:00 AM	0	4.5	2.5
12:30 AM	150	4.23	2.76
06:30 PM	510	3.85	3.14
09:00 AM	1380	3.56	3.43

Variation of water column height with time is shown in Figures 4.6 and 4.8 for months of March and April respectively. Variation of water recharge rate with water column height for months of March and April are shown in Figures 4.7 and 4.9 respectively.

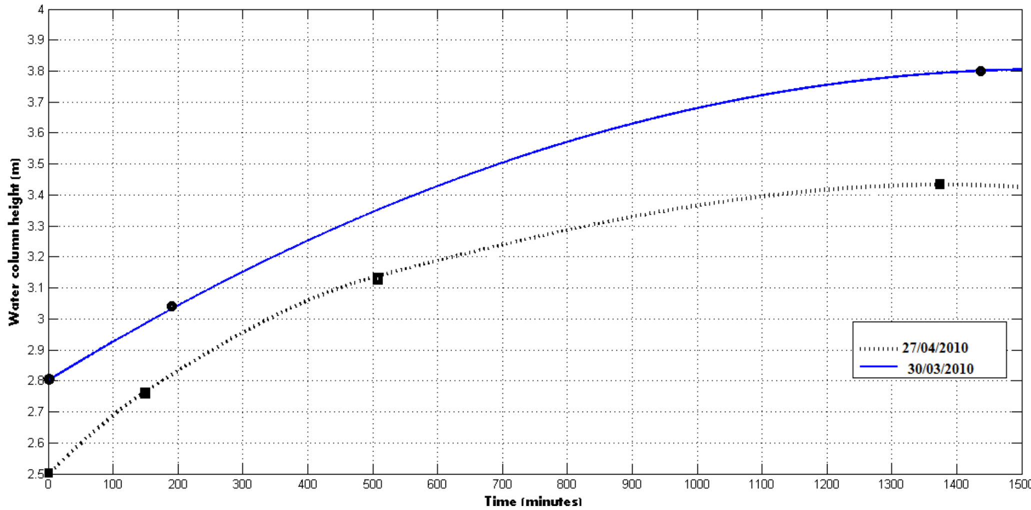

Figure 4.5: Plot of Variation of Water Column Height with Time

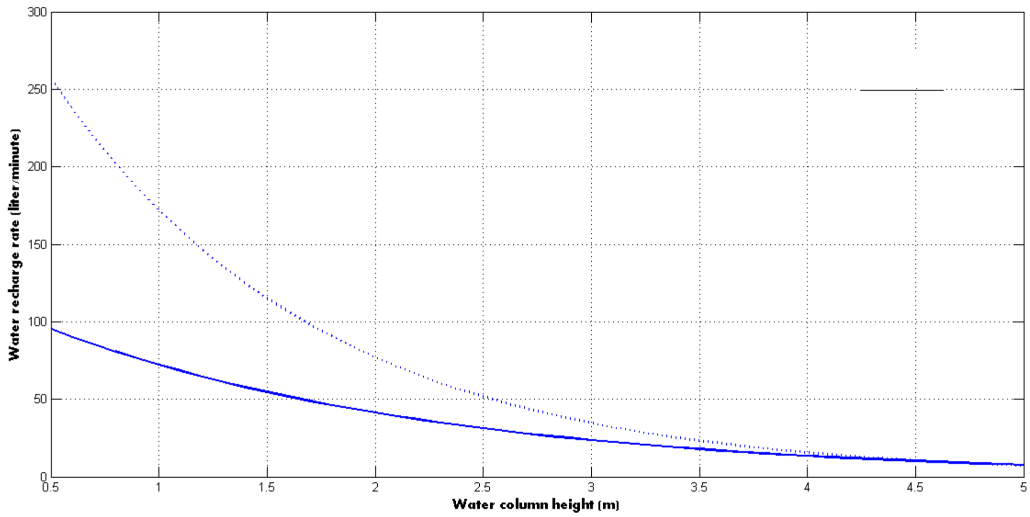

Figure 4.6: Variation of Recharge Rate with Water Column Height

4.4.3 Estimation for Future Water Supply

A survey for water demand was carried out which is explained in section 4.2.1. It is found that per capita water consumption at Belachi wadi is 35 liters for the month of May. Population of Belachi wadi is 200 and it is growing at the rate of 2%. Daily total water demand of Belachi wadi for the month of May is 7000 and is growing at the rate of 2% per year. Estimated population after fifteen years would be around 268. Therefore projected total daily water demand would be 9380 liters. To ensure safe water drawdown, maximum water drawing shall be carried till water column height reduces to 2 meter. Then maximum recharge rate would be 124 liter/minute. Villagers draw water from well for 8 hours a day. Then maximum amount of drawdown would be 59520 liters, which is far above projected need for next 15 years. A similar calculation for Gawand-wadi shows that the projected water demand after 15 years would be around 16000 liters per day. This is again far below than maximum possible drawdown of 62000 liter/day.

There is possibility of systematic errors in the measurements of yield test procedure that adopted in Belachi wadi. These errors are due to human errors in measurement, less amount of readings, and exponential curve fitting of the data. These errors can be reduced by designing more precise experiment and more number of experiments. Each experiment shall pick more number of readings.

4.5 Electrical Resistivity Test

Electrical resistivity test is carried out to know water level saturation level. The electrical resistivity test was conducted along with Sanjiv a student of earth science, IIT Bombay.

4.5.1 Location

Six locations were selected in Khandas village of Khandas gram-panchayat for electrical resistivity test which are shown in Figure 4.7. Selections of location were based on the survey of water resources and also based on questionnaire.

Table 4.6: Location of Profiles for Electrical Resistivity Test

Profile Name	Point A		Point B		Remark
	Latitude (E)	Longitude(N)	Latitude	Longitude	
Profile 1	73° 29.567’	19° 04.392’	73°29.654’	19° 04.230’	Close to Handpump
Profile 2	73° 29.439’	19° 04.381	73°29.505’	19° 04.246’	Close to Handpump
Profile 3	73° 29.387’	19° 04.062’	73°29.213’	19° 04.045’	Close to Dam
Profile 4	73° 29.934’	19° 04.096’	73°29.937’	19° 04.953’	Close to Dam
Profile 5	73° 29.200’	19° 03.829’	73°29.201’	19° 03.653’	People’s Perception
Profile 6	73° 29.361’	19° 03.638’	73°29.201’	19° 03.653’	People’s Perception

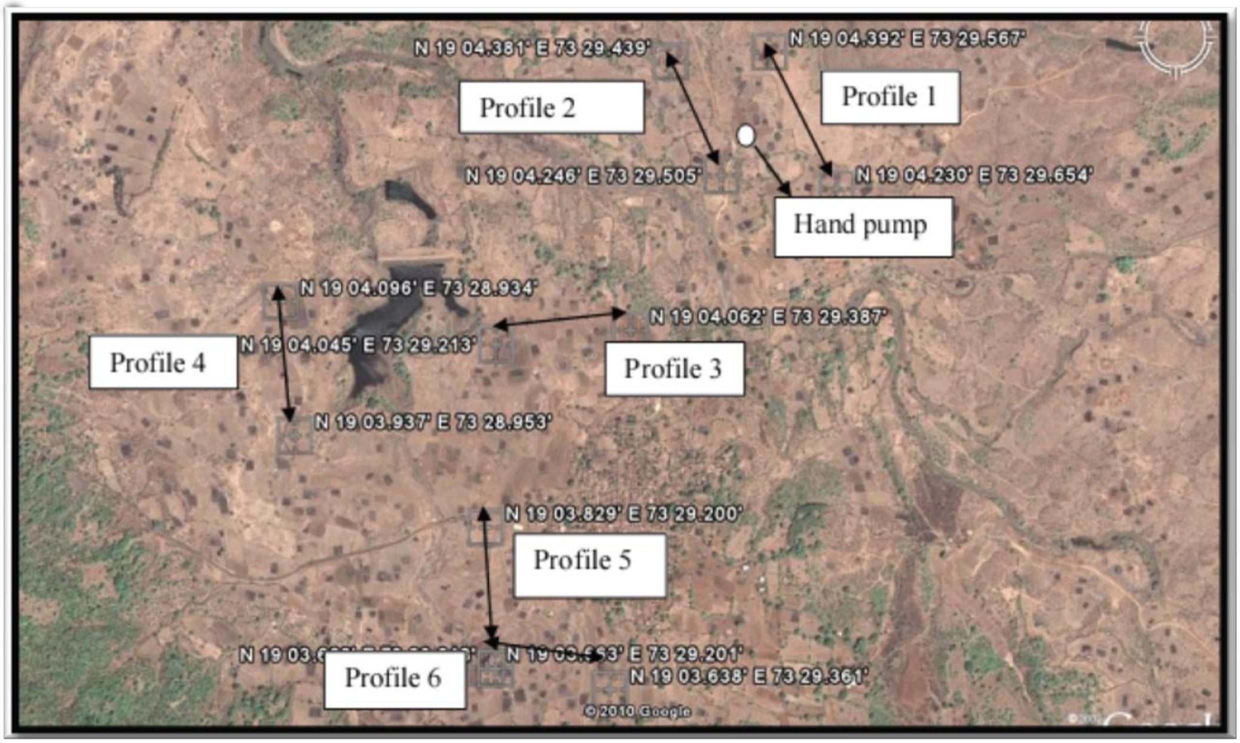

Figure 4.7: Location of Electrical Resistivity Test

4.2.2 Procedure

Standard methodology is explained in Chapter 2. Electrical resistivity profile survey for selected sites has been carried out using Schlumberger array system of electrode configuration and data in terms of apparent resistivity for various electrodes spacing have been obtained. After selecting a location of testing site experiment arrangement has been done. Current and resistivity is measured according to distance between electrodes and is summarized in Appendix VI.

4.2.3 Results of ER Test

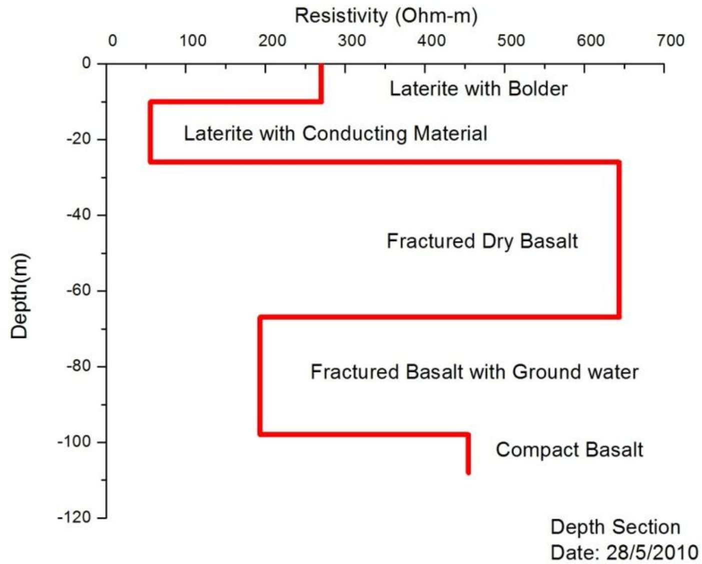

Figure 4.8: Interpretation of Electrical Resistivity Test at Profile 1

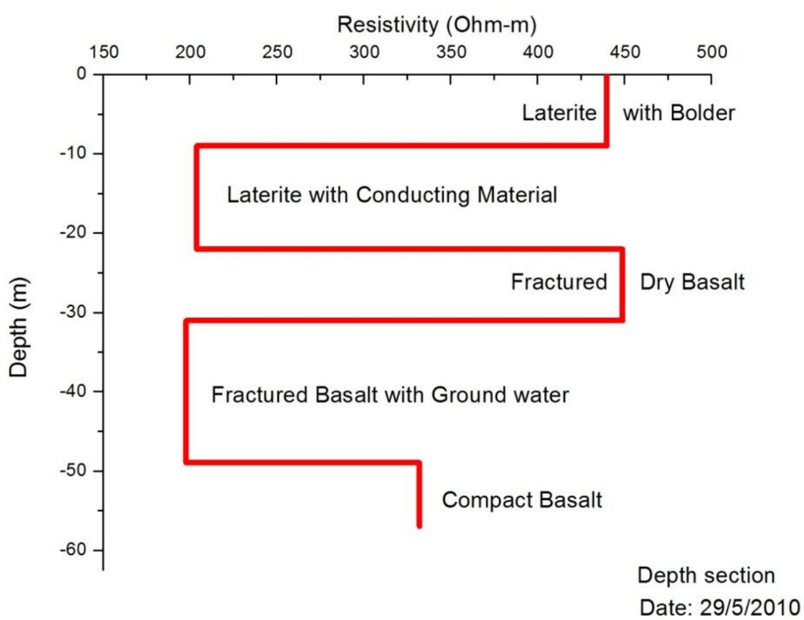

Figure 4.9: Interpretation of Electrical Resistivity Test at Profile 2

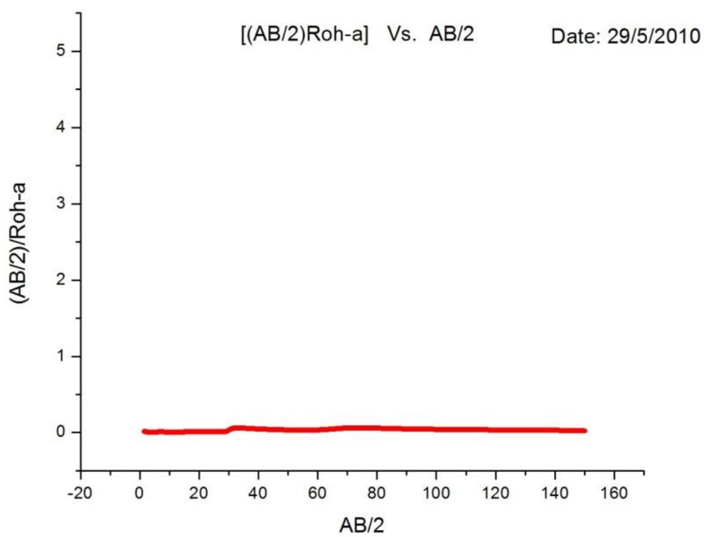

Figure 4.10: Interpretation of Electrical Resistivity Test at Profile 3

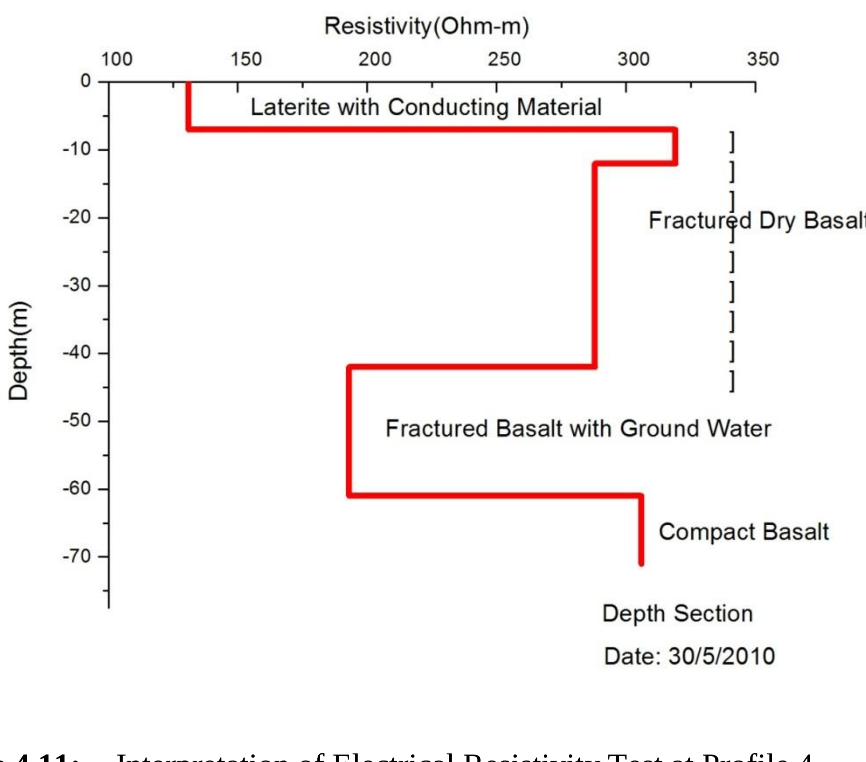

Figure 4.11: Interpretation of Electrical Resistivity Test at Profile 4

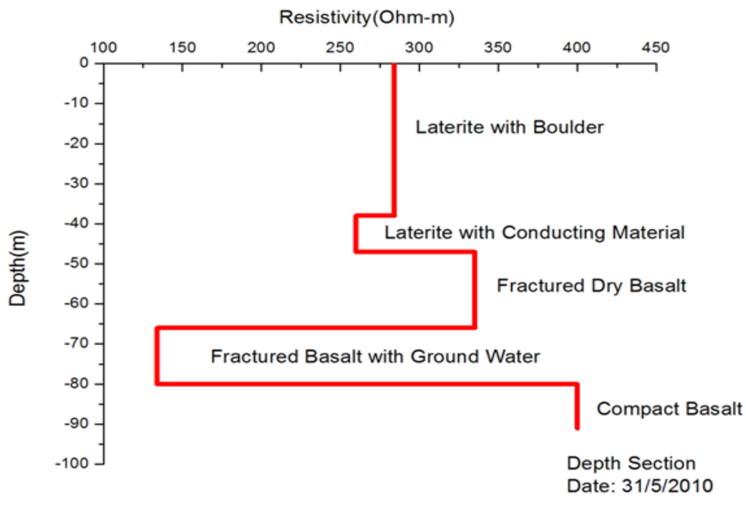

Figure 4.12: Interpretation of Electrical Resistivity Test at Profile 5

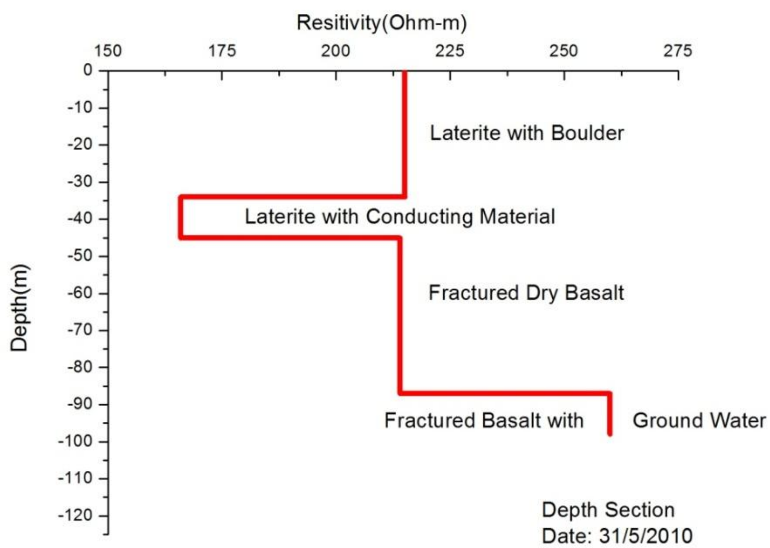

Figure 4.13: Interpretation of Electrical Resistivity Test at Profile 6

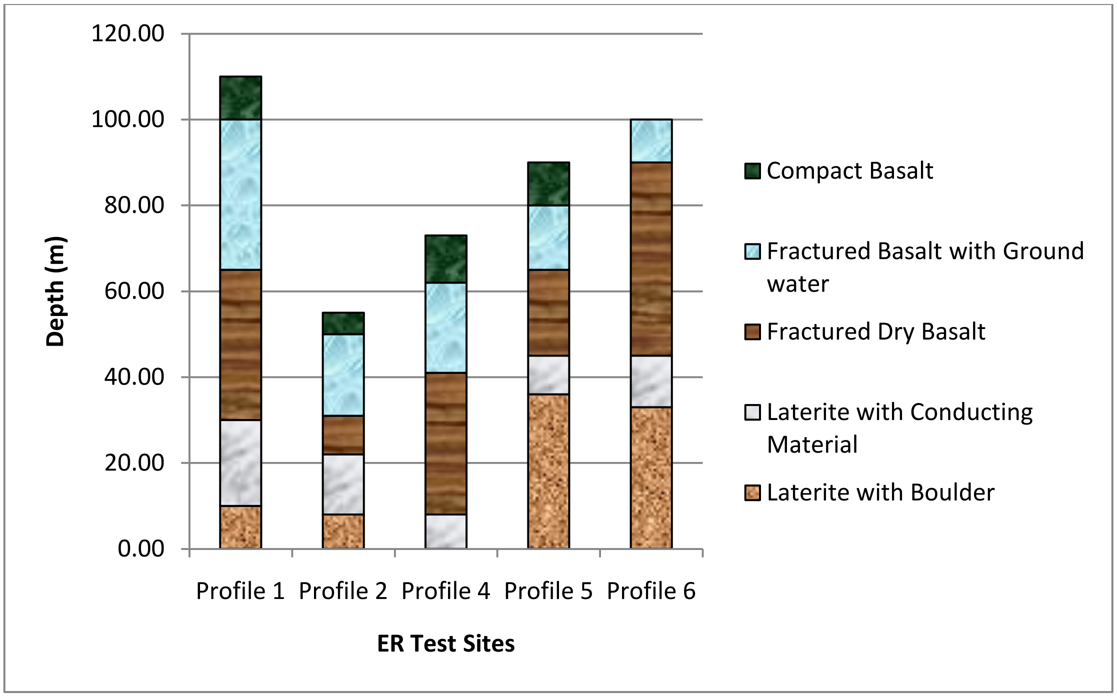

Figure 4.14: Litholog Based on Resistivity Sounding

Table 4.7: Ground Water Saturation Levels

Profile No.	Depth of Water Saturation (m)
Profile 1	65 to 98
Profile 2	32 to 48
Profile 3	-
Profile 4	40 to 62
Profile 5	65 to 80
Profile 6	90 to 100

Figures 4.8-4.13 are showing results of electrical resistivity test. X- Axis is showing resistivity at respective zone and Y- axis is showing depth of ground. Results of electrical resistivity test shows that ground water saturation is vary between depths of 31m to 100m. Profile 2 is showing water saturation at depth of 31m-50m. Only one hand pump have water at a depth of

70m which is close to Profile 2. Hence it is possible to correlated results of ER test in Profile 2 with depth of hand pump. The depth of hand pumps build by gram-panchayat is restricted to 60m but water saturation in Khandas at above 60 m. Hence all hand pumps get dried. To overcome this problem the depth of hand pumps should increase or increase the water table height by recharge.

Chapter 5

Water Document

5.1Motivation

Meetings with Tahasil office and Dishakendra, a local NGO revealed that a substantial disconnection between government and villagers. Also data of observation well measured by GSDA, Alibag was not reliable. As discussed in Chapters 2 that there are many lacuna in existing techniques and documentation. Such data gives wrong interpretation of groundwater. Hence it is necessary to adapt new documentation methodology which can be easier to understand and carry out. Chapter 4 gives the methodology to carry out tests, surveys which are useful for water resource planning. On the basis of that a water planning document was prepared. This document is prepared by considering villager's knowledge and resources available to carry out testing and surveys.

5.2 Objectives and Needs of Water Planning Document

Generally documentation is to be done to know the current scenario of resources which can be useful to overcome future problems. Hence documentation is necessary to do at regular intervals with accuracy. Existing water documents at tahasil level and gram-panchayat level is not adequate. Hence a new water planning document was prepared. Such document is useful for villagers to know their own water resources. It can also give scarcity level in villages. It may also create discourse and discussion which will raise the knowledge of people. It can be a valid document which will be proof for people about water condition. This can be shown to upper government institution for implementation of any government schemes.

5.3 Who has to Maintain?

The attempt has been made to make water planning document so that any villager can understand it. Local language is used for preparation of this document. Any literate from village can carry out such survey. Maharashtra government has formed "Village water supply and Sanitation Committee" by gram-panchayat 1958/9 [15] act. So this committee can also maintain water resource planning document.

5.4 The Water Resource Planning Document

5.4.1 General Information about Document

Which information to collect?

- Collect the information about number of water resources, its location.
- Dimensions of wells and bore wells
- Duration when well gets dry, pre and post monsoon water level in well
- Owner of water resource
- Yield test of well

Flow of work

i. Background study to understand water problems in village
ii. To understand total availability of water resource
iii. Preparation of maps by using Google earth or PRA tool
iv. To analyze water resources
v. To determine village water demand
vi. To predict future water requirement
vii. Yield test of wells
viii. To identify new interventions of water resource

5.4.2 Methodology

Step 1: Background Study

Understanding of Water Problems in Village

Objective: To understand current water condition in village

Methodology: Meetings with villagers Gram-Sabha

Who has to maintain: Village water supply committee

Table 5.1: Understanding of Water Problems

Problems	Causes	Action

Step 2

Understanding Total Availability of Water Resource

Objectives:

- To find out total water resources in village
- Duration of scarcity of water
- To prepare background to ZP/tahsil office for application of new water schemes

Methodology:

- Meeting with villagers
- Visit water resources in village
- Fill up the following Table

Table 5.2: Total Availability of Water Resource

<table>
<tr><th rowspan="3">Sr. No.</th><th rowspan="3">Name of Village</th><th rowspan="3">Population</th><th colspan="2">Source of Water</th><th colspan="6">No. of Wells</th><th colspan="6">No. of Bore Wells</th><th rowspan="2">Scarcity Duration</th><th rowspan="2">Govt Schemes</th><th rowspan="2">Remark</th></tr>
<tr><th rowspan="2">S</th><th rowspan="2">GW</th><th colspan="3">Govt.</th><th colspan="3">Private</th><th colspan="3">Govt.</th><th colspan="3">Private</th></tr>
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</table>

M: Manual D:Diesel E: Electric

Step 3

Preparations of Maps

Objectives

- To make aware people about their own water resources
- To locate water resources on maps

Methodology

- Download Google maps from Google earth which is a open source
- Select a village and download a village map and mark water resources on same map
- If Google earth is not available then use Resource Maps by PRA
- Draw resource map of village and mark all water resource on map
- Mark both private and government own water resources
- Figure 5.1 showing water resource map of Gawandwadi

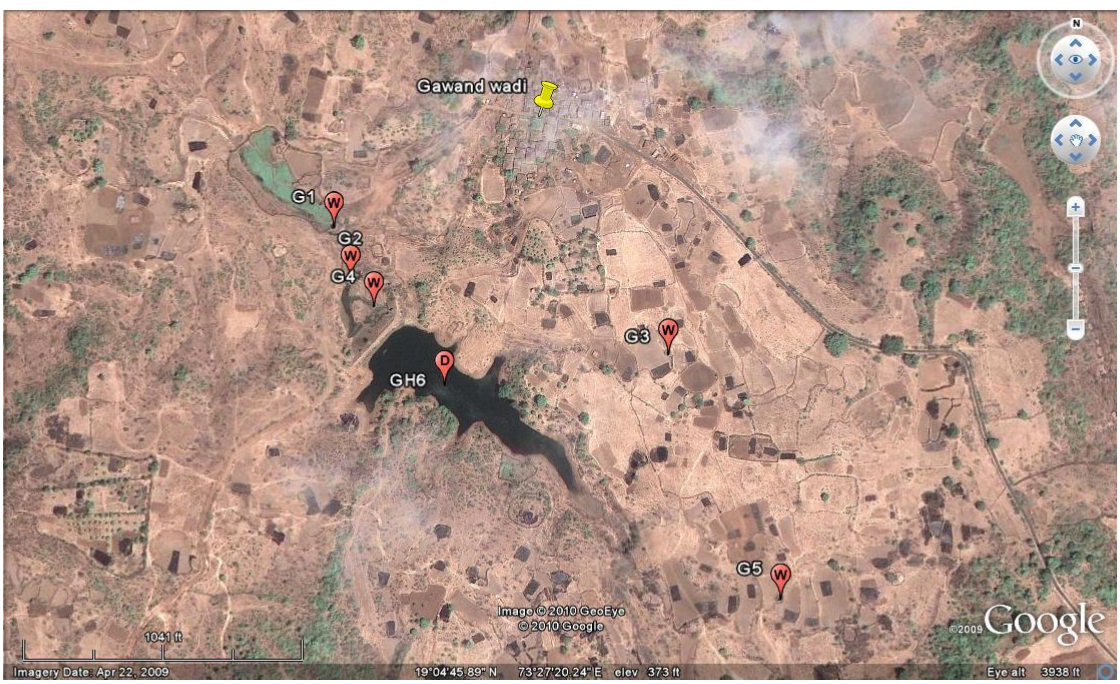

Figure 5.1: Water Resource Map of Gawand Wadi

Step 4

Analysis of Current Water Resource

Objective

- To know current condition of water resources in village

Methodology

- A group of gram panchayat will survey all water resources and discuss with villagers on following issues
    - Current situations of water resource (condition of construction, good or bad)
    - Dimension of water resources, pre and post monsoon water level
    - Seasonal availability of water
    - Number of families depend on well/bore well
    - Use of well/bore well (for drinking/except drinking/cattle)
    - Type of Source Surface water/Ground Water

Table 5.3: Current Situation of Water Resources

<table>
<tr><th rowspan="2">Name of Village</th><th rowspan="2">Source of Water</th><th colspan="3">Location</th><th rowspan="2">G/P</th><th colspan="2">Water Level</th><th rowspan="2">Depth (m)</th><th rowspan="2">Dia. (m)</th><th rowspan="2">Dependent Population On Water Source</th><th rowspan="2">When It Gets Dry?</th><th rowspan="2">Distance (m)</th><th rowspan="2">Remark</th></tr>
<tr><th>Lat</th><th>Lon</th><th>Elev</th><th>Pre-monsoon</th><th>Post monsoon</th></tr>
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</table>

Step 5

Water Demand of Village

1. Name of Interviewer:____
2. Family Size: _______________
3. Fill the table for domestic water

Table 5.4: Water Required for Domestic Water

	Time	No. of Turns	Water Required	Water Available	From where?
Drinking					
Washing Utensil					
Cooking					
Bathing					
Building of House					
Other					

4. For washing clothes, cattle fill below table

Table 5.5: Water Required for Other Than Domestic Use

	Time	No. of Turns	Water Required	Water Available	From where?
Washing Cloths					
Cattles					
Others					

Step 6

Prediction of future water demand

Objective: To know future water requirement

Methodology: Collect following information

- Population
- Number of families
- Average size of family
- Other institutions in Village (School, Gram panchayat, etc)

Table 5.6: Population and Water Growth

Year 1981	Year 1991	Growth Rate	Year 2001	Growth Rate
Population 1354	Population 1894	40%	Population 2461	30%
Average Growth	Population next 20 years	Water requirement	Water Requirement after 20 years	
35 %	4183	40 liters	167320 liters/day	

Water Available		Water Requirement		Future Water Requirement	

Step 7

Yield Test of Well

- What is yield test?

It is the test for recharge of well when certain amount of water is discharge from it.

- Why to determine yield of well?

This test gives how much water to drawn out from well so that the well can sustain for longer duration. If discharge is more than recharge then it may be possible that the village may face water problem. Hence recharge should be more than discharge.

- When to carry out yield test?

If possible then it should carry out at four times in a year. This can give recharge of well at different season. It should be taken care that no one is discharging water while testing. Hence start yield test at 11:00 am to 4:00 pm or after 7:00 pm to 6:00 am (It may vary according to discharging timings from wells by people)

Requirements: Measuring Tape, Pen, Graph Paper, Watch etc

Methodology

- Calculated water discharged from well in a day (Refer Table 5.7)
- Measure diameter and depth of well
- For first 1 hour measure water level at 15 minutes interval. After that measure water level at 1 hour interval for next 12 hours.
- Fill this data in Table 5.9
- Plot time v/s depth graph on graph paper

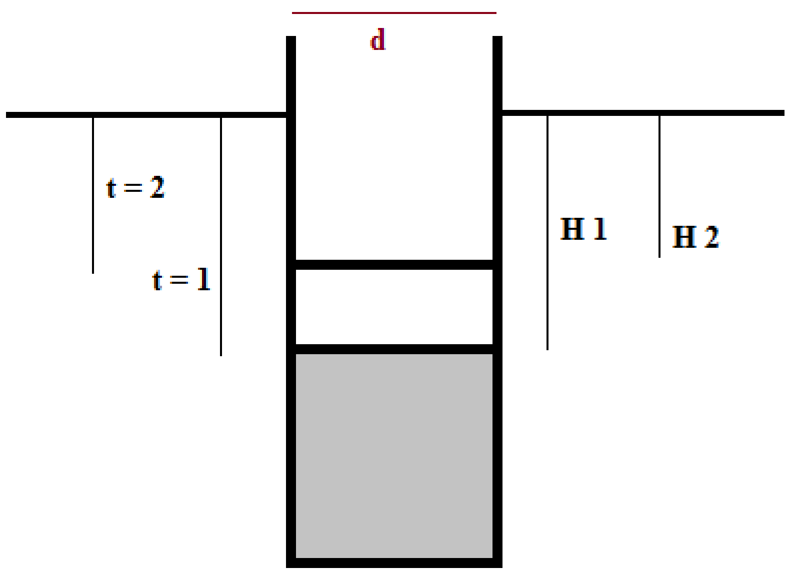

Figure 5.2: Yield Test

Table 5.8: Water Discharge from Well

Time	Bigger Utensil (10 Liters)	Medium Utensil (9.5 Liters)	Small Utensil (4.5 Liters)
Total			

Table 5.9: Yield Test Data

Field Sheet

Section 1 : Well Information	
Village :	
Location :	
Latitude:	Longitude:
Section 2 : Dimensions of Well	
Depth of Well:	
Depth of Water in Well (Static Water Level):	
Diameter of Well:	
Section 3: Pump Data/Information	
Pump Model:	
Type of Pump and HP:	
Depth of pump from water level:	
Diameter of Discharge Pipe:	
Distance of discharge location from well:	

Section 4: Test Information/Parameters
Name of the Village:
Date of Testing:
Pre-Test Static Water Level (m))(say H1)
Reference Point (in m above the ground level) (Say R)
Static Water Level H2= H1-R
Initial Total Reading (m3) (Say V1)
Final Total Reading (m3) (Say V2)
Total Volume of Water Pumped (V3)= (V1-V2) m3
Total Length of Pumping Test (T) (min)=
Final Average Pumping Rate (P) = V3/T

Maximum Depth of Pumping Level (H3) (m) =
Maximum Water Level Breakdown (H) = H3-H2
Specific Capacity of the Well = P/H

Pumping Test Data Sheet

Section 6: Water Level Recover Test				
Date and Time Day	Time (min)	Static Water Level (m) (H1)	Depth of Water Level after time t (H2)	Observations / Comments

5.5 Framework of Water Planning Document

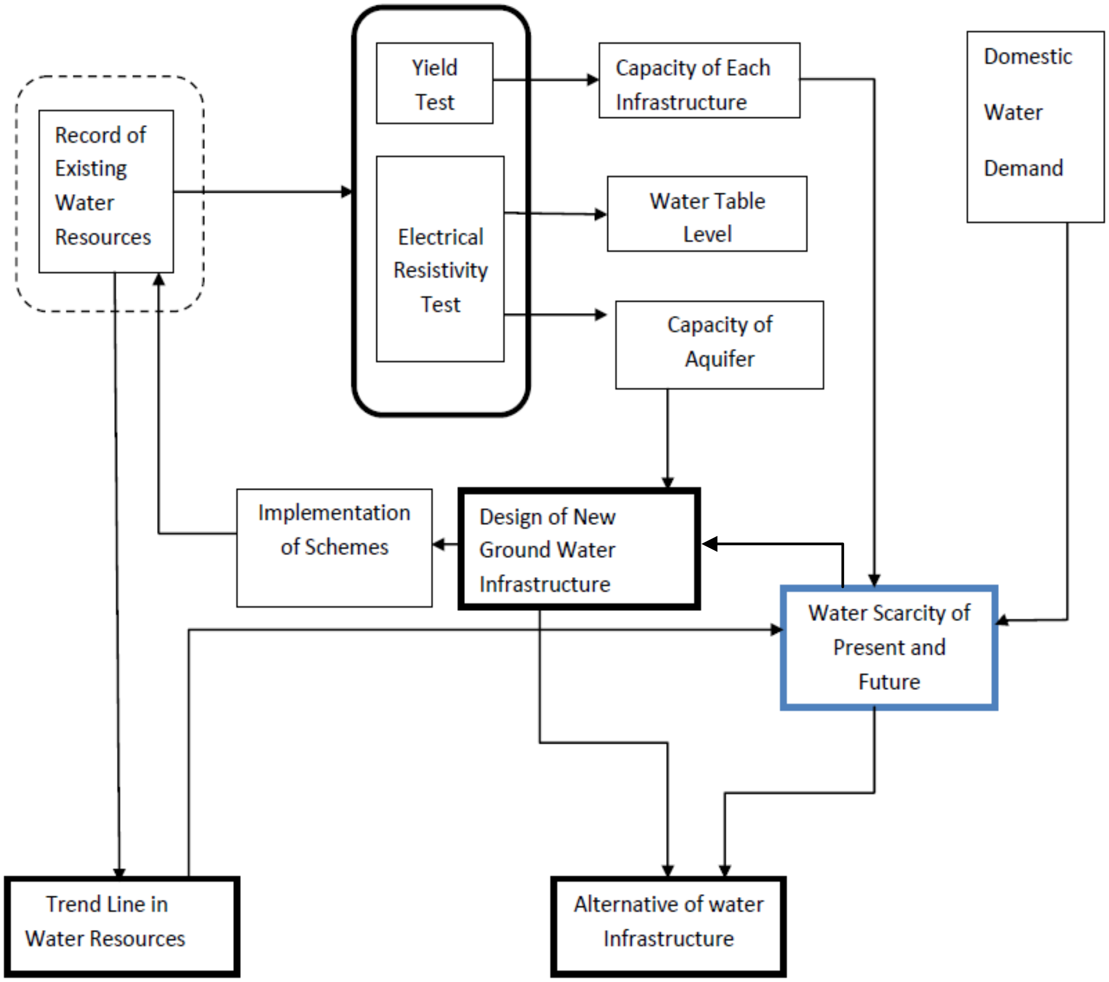

Figure 5.3: Framework of Water Resource Planning Document

This framework is used to analyze the data collected by water planning document. Study for existing water resources is to done to analyze the water availability. It can be done by water resource survey and yield testing of village. Estimation of future water demand can be calculate by such information. A trend line in water resources availability is find out comprehend for its variation in the past and to identify reasoning behind it. Based on this data state of water scarcity for present and future can be estimated.

For planning of new water resources ER test should be carried out. This will give the aquifer capacity and depth of groundwater. Based on this, new probable sites for well and tube well can be proposed by this test According to conditions new long term plans can be proposed based on collected data.

Chapter 6

Results and Discussion

6.1 Analysis of Field Level Data from Khandas

6.1.1 Existing Water Resources Structures

Survey of existing wells and tube wells revealed that there is existence of water scarcity in the village, especially from the months of March to May. Although there have been construction of 12 wells and 5 tube-wells, and a small dam in the village, it is not sufficient to manage domestic water deficiency problem of village. Small dam capacity has been decreasing over last decade due to accumulation of huge amount of silt during rainy season. Therefore dam doesn't hold enough clean water during summer season. The only thing that is achieved through these government interventions is reduction in drudgery associated with water fetching activity during rainy season and winter season. Water resource trend line data revels that there is a trend of decrease in ground water level and its capacity over last two decades. Positive population growth rate has increased domestic water demand for village over last decade. Together these trends have contribution in increasing water scarcity in the village during summer season. And this problem would worsen year by year. To get exact idea of rate of increase of water scarcity, numerical data of trends in water table level, aquifer capacity, population growth rate, and rain fall is required. But it is quite clear that there is need to take measures to build water resources structures to tackle the year by year worsening water scarcity problem.

6.1.2 New Water Resource Infrastructures

Analysis of results of ER tests at Khandas at six chosen locations reveals that there is no sense in building new wells to look for reduction in water scarcity during summers. But it is found that at two identified locations ground water depth is lower than 60 m, which is specified as a depth of tube well for governmental schemes. Therefore new tube wells can be built at these locations. But aquifer capacity shall be derived by 3-D modeling of ER test to get a idea of maximum amount of water that can be drawn by hand pumps per day.

To tackle ever increasing water scarcity problem, long term solutions shall also be tried out in the village. These include afforestation program to increase ground water level and ground water capacity in the village. There is need to increase small dam holding capacity in the village by removing silt accumulation. Small structures of gully plugs can be built on the upstream side of small dam to block incoming silt in to the dam during rainy season.

6.2 Summary and Conclusion

This study focused on designing a Gram-panchayat level documentation frame-work to enable water resource planning for village and to increase people's awareness regarding water resources scenario in the village. The report can be summarized as follows,

1) Government level water resource documentation and water resource infrastructure planning structure is studied and analyzed for its scope and legitimacy. It was observed that analysis of documentation of water levels of GSDA observation wells would give only macroscopic indication regarding water table variation. It cannot be utilized for village level planning purpose. Secondly, it was observed that GSDA has not been following subtle preservation norms for observation wells. Hence the data gathered by GSDA over past few years in Karjat Block is not reliable. In fact it is having discrepancy in its readings when analyzed by considering yearly rainfall and ground water level. Based on these observations it was decided to build a Gram-panchayat level documentation frame-work to assist and sensitize water resource planning in the village.

2) Water resource tests are introduced with testing procedure. This involves yield test to identify capacity of existing water resource infrastructure and electrical resistivity test to identify water table depth and aquifer capacity. A trend line tool of PRA is introduced to estimate trend in water resource availability in the village over last two decades.

3) A Gram-panchayat was selected from Karjat tribal block to carry out field level study and analysis to build documentation fame-work. Water resource structures present in Gram-panchayat were studied. Set of experiments namely, yield test and ER test is carried out at different identified locations. Yield test was modified by consideration of local context without compromising its principle. A questionnaire survey is carried out at three different locations to identify domestic water usage pattern in the village. A PRA tool was utilized to get water resource trend line in the village. This collected data was analyzed to identify water resource conditions in the village and to propose future plan.

4) Based on experience of a Gram panchayat, a generalized framework of documentation of water resources is articulated. A document is prepared to note down water resource related data in the village.

A frame work explained in mentioned in Chapter 5 is proposed to analyze the existing water resources and its trend to cater future domestic water demand. The data gathered from documentation format listed in chapter 5 shall be utilized to analyze water resource availability and supply scenario for present and future. This frame work can also be used to assist in preparation of water resource infrastructure plans for the village. The utility of frame work is explained below.

1) Existing water resource structures: Study the existing water resource structures for their capacity to supply domestic water at present and in future. The capacity of existing water resource structures can be found by yield tests. Estimate domestic water demand and its probable shift in future by questionnaire surveys. Find out A trend line in water resources availability to comprehend for its variation in the past and to identify reasoning behind it. Based on this data state of water scarcity for present and future can be estimated.

2) Planning for new ground water structures: ER test was carried out to find water table level and aquifer capacities at different identified locations. Based on this, new probable sites for well and tube well can be proposed by this test. Capacity of tube wells and wells can also be designed to cater current and future need for domestic water supply.

3) Other long term plans: A long term plans namely, forestation, surface water structures etc. can be prepared to increase ground water recharge and water availability in future.

4) The major contribution of this microscopic documentation is to sensitize villagers towards their own water resources and its future.