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Case Study of User Centered Aquifer Level Groundwater Management Pilot Project in Khatav Block, Satara District, Maharashtra, India

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Abstract **- This document is the presentation of case study of the part of project of Maharashtra water sector Improvement Project in Satara District in the year 2012-13. The Maharashtra Water Sector Improvement Project (MWSIP) was a comprehensive reform initiative launched by the Government of Maharashtra with financial assistance from the World Bank to modernize the satara district's water management and irrigation systems.In satara district 3 aquifers were selected to study which are located in Khatav block consist of 24 villages , covering an area of 214.57 sq km and the The main objective of project was to create User Centered Aquifer Level Groundwater Management Plan.**

Keyword**- MWSIP, GSDA, Aquifer, groundwater, IEC,**

I. INTRODUCTION

Groundwater is an important natural resource crucial to rural and agricultural development in Maharashtra. In the State about 70% of the rural population depends on groundwater for drinking and agricultural use. The incidences of crop failure and decline in agriculture production are common in the State. Development of groundwater resources is mainly for agriculture use and uncontrolled extraction of groundwater has resulted in reduction of Groundwater availability and depletion in water levels hence by causing severe scarcity of water both for drinking and irrigation. In absence of any effective policy measures, groundwater in many parts of the State are plagued with water scarcity, in-equitable distribution of water and environmental degradation. Presently groundwater rights are attached to the land of the farmer and as such there is no control on groundwater extraction. It has been recognized that farmers need to be provided with knowledge on the availability of groundwater resources and decide how to manage it through self-regulatory measures. The User Centered Aquifer Level Groundwater Management Pilot Project attempted under Maharashtra Water Sector Improvement Project (MWSIP) has focused on the management of groundwater by the community and has achieved the behavioral change leading to voluntary self-regulations for judicious use and reduced extraction of groundwater.

The pilot project has shared the technical data with the community and provided input to improve their skill to collect technical data such as rainfall and groundwater level and has nurtured the community level institution for local governance of groundwater use. Hydrogeologically about 83% of the district is covered by hard rock formations. The ultimate Annual Groundwater Recharge is estimated in the satara is 125059 Ham of which 117007 Ham has been created and utilized by 2024-25. Satara has divided into 50 Watershed units for assessing groundwater potential. Presently groundwater is developed through 60759 Ham private and community owned irrigation wells and 4966 Ham domestic wells/bore wells. the annually replenish able groundwater recharge in the state is 125059 Ham of which 4966 Ham is being utilized for drinking and industrial purpose and 60759 Ham is utilized for Agriculture purpose. The groundwater estimation indicated that groundwater in 11 watershed units from 5 blocks has reached a semi critical stage. This situation is manifested in progressive decline of water level at a rate of 0.15 meter per year.

With increase in number of over exploited areas and progressively declining water table in most parts of the State, Government of Maharashtra (GOM) since 1991 has been emphasizing on conservation and augmentation of groundwater resources through artificial recharge. To prohibit the unrestricted extraction of groundwater by individual farmer, GOM has issued guidelines which included, No financial assistance either from financial institutions or from the Government for private irrigation wells in areas where groundwater is over extracted. Adherence to spacing between two wells particularly to protect public drinking water wells. Subsequently, GOM has promulgated Maharashtra Groundwater (Regulation for Drinking Water Purposes) Act, 2012 to regulate groundwater extraction for protecting public drinking water wells. The rules were made there under in 2012. Important provisions of the Act are as below: Prohibition of Construction of wells within 500m distance of public drinking water source. Regulation of Extraction of water from wells in Scarcity area within a distance of 1 km from the public drinking water source.

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Prohibition of sinking of wells in over-exploited areas. Temporary closing down of existing irrigation well to protect drinking water supply well Government of Maharashtra has prepared draft bill Maharashtra Groundwater (Development and management) Act and has intended to introduce the same in the state to protect drinking water sources as well as to insure sustainable management of available groundwater resources for all uses. Despite various regulations excessive withdrawal of groundwater continues which has resulted in imbalance and inequity among users. This has destabilized the aquifer system and has resulted in unsustainable development of groundwater. The current groundwater management system has failed to recognize that: Groundwater occurs in an aquifer which has its own natural boundaries and groundwater occurrence and movement are not confined to individual land holding. Groundwater occurring in an aquifer is a common natural resource and needs to be shared by different user groups. Despite all measures to augment groundwater recharge, the utilizable groundwater resources in an aquifer are limited and this reality about the finiteness of the resources has to be understood by different users of groundwater, and the communities in an aquifer have to account and allocate the available groundwater recharge for different usages based on the priority. Community initiative is, therefore, emerging as an appropriate alternate option for sustainable management of groundwater in an aquifer. Recognizing the limitations of present groundwater system, a new institutional model has been attempted under User Centered Aquifer Level Groundwater Management Pilot under Maharashtra Water Sector Improvement Project. Groundwater at present is considered as a private resource and continues to be excessively withdrawn by different user groups which have resulted in unsustainable development despite all measures to augment it. Indiscriminate extraction of Groundwater has resulted in scarcity of drinking water and decline in agricultural productivity. Since Groundwater occurs in an aquifer which is not confined to individual land holding or village boundaries, it is necessary to educate the community to consider it as a common natural resource and has to be managed collectively at an aquifer level for sustainable development. The Groundwater recharge to the aquifer could be increased through various Groundwater recharge structures. However, Groundwater availability in an aquifer is not unlimited and Groundwater recharge cannot be increased beyond a certain level. Therefore, all stakeholders in an aquifer have to prioritize utilization of groundwater by different sectors like drinking water, agriculture and industry and allocate the available resources to each users sector for sustainable development.

This requires regulating the demand particularly for agriculture sector. Thus sustainable development and management of groundwater resources in an aquifer has been achieved through community participation. For this, all primary stakeholders in an aquifer have endeavored to collectively manage the groundwater resources. This has helped to develop an alternative institutional model viz. User Centered Aquifer Level Groundwater Management association on an aquifer basis.

Presently Groundwater assessment and planning is based on the watershed as unit and the extraction of Groundwater by individual farmer is based on the assumptions that Groundwater is a private resource and could be extracted to meet the demands. The manifestation of over extraction has become serious cause for un- sustainability of the resource and agriculture. It is realized that the Groundwater occurs in an aquifer and is not confined to individual area. This requires a paradigm shift in realizing that Groundwater is a natural resource and to be utilized by all user groups and its extraction within replenishable recharge to make the development sustainable. The pilot attempts to introduce the concept that the Groundwater is a common natural resource available in an aquifer and has to be utilized through community consensus.

II. Objective

The objectives of the User Centered Aquifer Level Groundwater Management pilot are:

- Mobilize the stakeholders and create awareness about the prevailing groundwater situation in the aquifer.
- Capacity building of the stakeholders to take up responsibility of groundwater management.
- Make the farmers vigilant about groundwater dynamics and consequences of over-extraction and ensure self-regulation for appropriate remedial measures through Information, Education and Communication (IEC).
- Promote crop water budgeting as a tool to empower farmers for deciding appropriate crop system matching with the available groundwater recharge.
- Institutionalize participatory management of groundwater for dealing with issues related to sustainable management.
- Organize the Stakeholders and community members into Grampanchayat Level Committee (GPLC) at Grampanchayat level and Groundwater Management Association (GWMA) at aquifer level and train them to monitor rainfall, groundwater levels and groundwater use for different purposes.

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- Empower the community for financial management of funds in most transparent manner as also for operation and maintenance of the groundwater recharge structures in the aquifer.
- With above objectives three aquifers were selected under MWSIP for User Centered Aquifer Level Groundwater Management Pilot including the Pilot Aquifer in Satara District.

III. METHODOLOGY

3.1 Implementation Of The Process

Selection Of The Aquifer

User Centered Aquifer Level Groundwater Management Pilot, three aquifers were selected based on the following criteria.

Groundwater situation in the aquifer has reached a critical stage of development as has been manifested by the progressive decline of water level and reduced agricultural productivity in the area.The pilot aquifer selected represents regional hydro-geological, agro- climatic and economic conditions prevailing in the region.The area of the aquifer is large enough for detail study on management activities while not being so large that the number of villages covered makes the management infeasible. Based on above criteria, GSDA has selected pilot project area from Satara, district. The details of pilot project area selected in Satara district are given in Table 1.

Table -1 Details of Pilot Aquifer in Satara District

Taluka	River Basin	Area (Sq. km.)	No. of Villages	Stage of Groundwater Utilization	Trend of Groundwater Levels
Khatav	Krishna	214.57	24	99 %	Declining

Delineation Of Aquifer Boundaries

Detail hydro-geological surveys have been conducted by a team of Geologists from the District office of the GSDA. Based on the hydro-geological mapping and after conducting aquifer performance test for deciphering the hydrological aquifer characteristics of the formation, the boundaries of the aquifer have been defined. Wherever necessary, geophysical surveys and Geographic Information System (GIS) maps have been used to revalidate the aquifer boundaries. Based on these surveys the aquifer boundaries have been defined which includes 24 villages covering an area of 214.57 sq km.

3.2 Baseline Survey For Resource Inventory

Baseline surveys have been conducted for resource mapping in the pilot project area which included collecting hydro-geological and agricultural information based on 100% well inventory. Besides, social assessment of the aquifer area has been conducted by engaging a consultant.

Participatory Rural Appraisal (PRA) techniques have been adopted for resource inventory. Important findings of the baseline survey are given below.

Location And Demography

Pilot aquifer area is located 45 km away from district headquarter at Satara and is 20 km from taluka headquarters at Vaduj. Pilot area bounded within 17º41’27” and 17º53’23”north latitudes and 74º13’49” and 74º23’19”east longitudes. The topography of pilot area is hilly and undulating. The altitude of pilot area ranges between 840m and 775m above mean sea level. The pilot area selected covers part area of Khatav taluka in Satara district and includes 24 villages viz Vardhangad , Pawarwadi, Ner, Nagnathwadi, Lalgun, Navlewadi., Shindewadi, Anapatwadi, Pandharwadi, Kalewadi, Chinchani, Manjarwadi, Mol, Diskal, Garawadi, Pangarkhel, Rajapur, Budh, Fadtarwadi (Budh), Katewadi, Vetane, Ranshingwadi, Ner (Fadtarwadi), Pusegaon. Total area of the pilot aquifer is 214.57 sq. km. The location of the pilot project is given in map 1 below.

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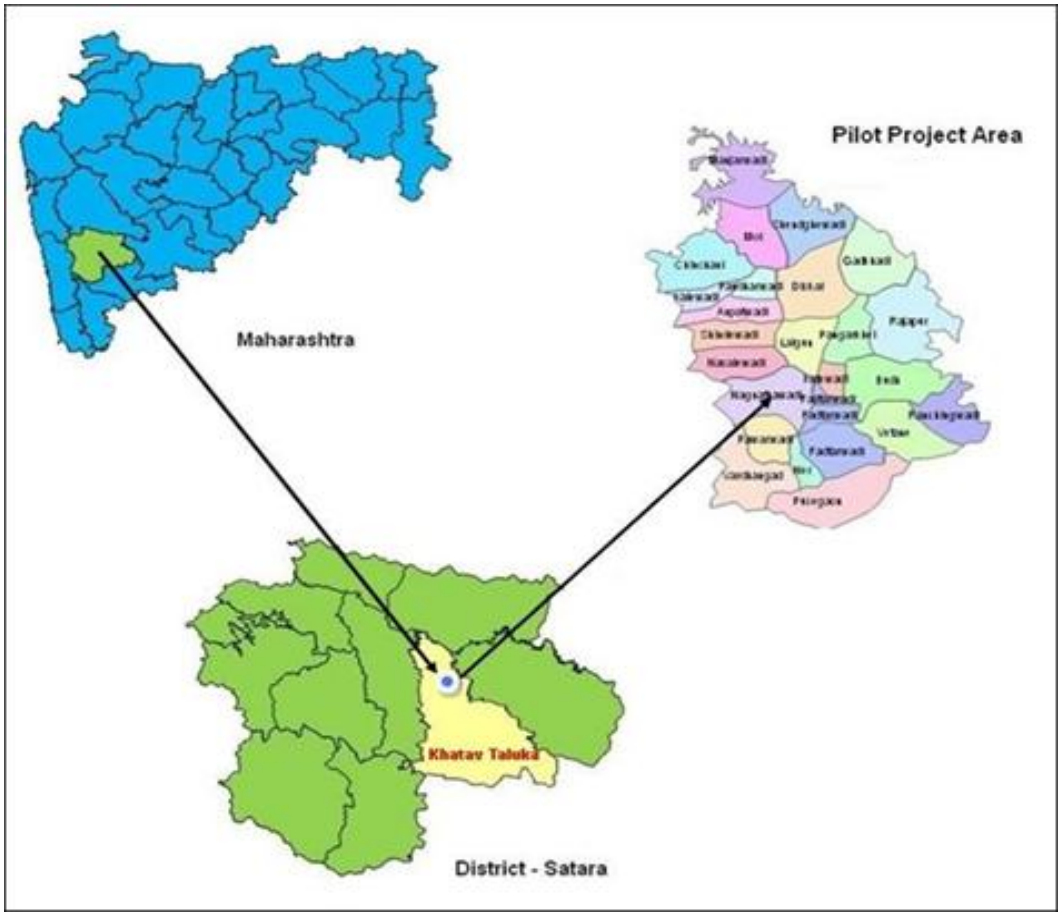

Map 1 Location Map of Pilot Aquifer

Demographic data

The population in 24 villages as per 2001 census is given in Table 2. The density of population is 195 persons per sq.km. Village Budh is most populous (5538) whereas village Pandharwadi is least populous village in the project area.

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Table 2. - Population in Pilot Aquifer Area

Sr. No.	Name of Village	Geographical area (sq.km)	Number of households	Total Population
1.	Vardhangad	9.1213	422	1971
2.	Pawarwadi	7.4678	159	838
3.	Ner	11.93	433	1933
4.	Nagnathwadi	7.4542	144	771
5.	Lalgun	10.57	603	2800
6.	Navlewadi	7.7414	100	435
7.	Shindewadi	5.2719	136	652
8.	Anapatwadi	1.3632	141	882
9.	Pandharwadi	3.0891	79	317
10.	Kalewadi.	2.8285	67	388
11.	Chinchani	9.3344	235	986
12.	Manjarwadi	8.0261	183	781
13.	Mol	19.334	458	2100
14.	Diskal	21.707	934	4410
15.	Garawadi	10.683	198	1069
16.	Pangarkhel	6.17	82	431
17.	Rajapur	18.23	548	2661
18.	Budh	15.602	1108	5538
19.	Fadtarwadi (Budh)	2.0457	102	579
20.	Katewadi	1.362	108	516
21.	Vetane	9.3166	269	1269
22.	Ranshingwadi	10.482	307	1307
23.	Fadtarwadi (Ner)	1.2178	166	768
24.	Pusegaon	14.23	1750	8591
	Total	**214.57**	**8732**	**41943**

Source: Census Data 2011

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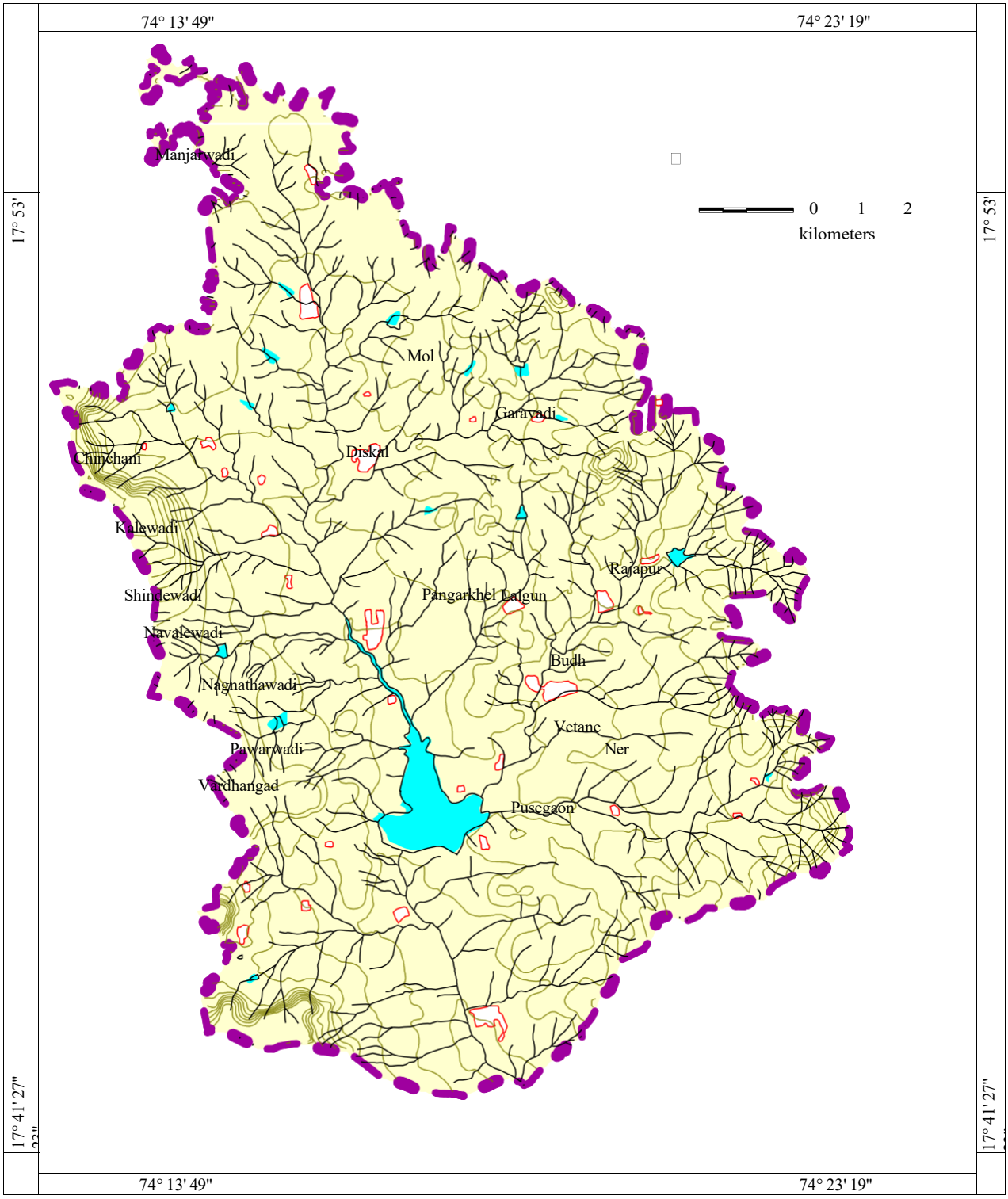
Physiography -



Map 2 Physiography of Pilot area

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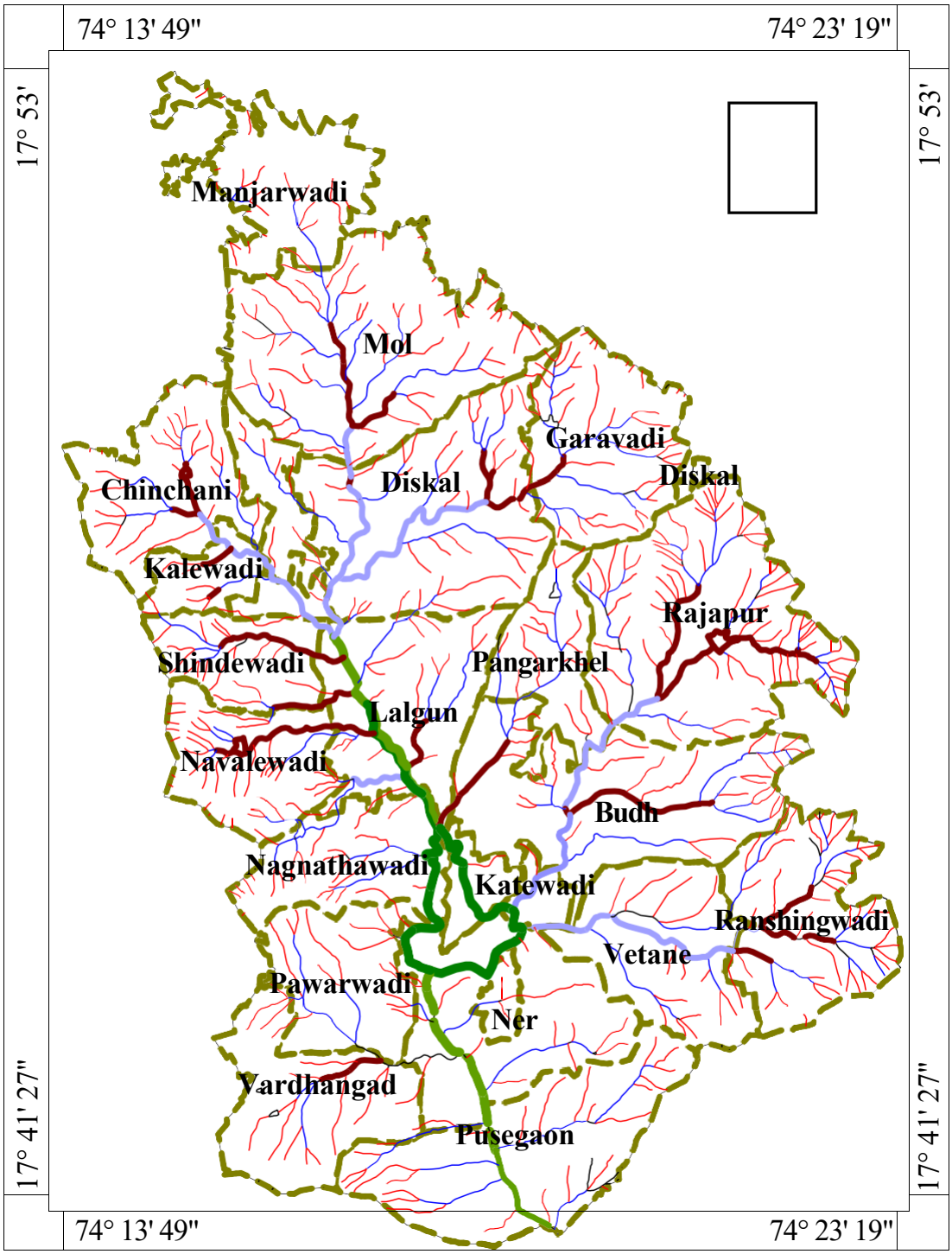
Drainage -

Pilot District: Satara



Map 3 Drainage of Pilot area

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In the pilot, hills are part of Mahadeo hill range. Mahadeo hill range originates at the north of Mahabaleshwar plateau. The altitude of the pilot area ranges between 775m above mean sea level (Pusegaon) and 1066m above mean sea level (Vardhangarh).The area is covered by basaltic lava flows with horizontal dispersion and its typical plateau like topography. Peripheral part of the pilot area has a slope of 35º to 50º towards south. The central and southern part is covered by black cotton soil. The area is drained by Yerala River flows towards south which is tributary of Krishna River. There are 704 small ephemeral streams of different orders flowing across the pilot area. Drainage pattern is dendritic and drainage density is 2.7 km/sq km.

3.3 Climate and Rainfall

The climate in the area is semi-arid. Area receive rainfall mainly from SW monsoon between June and September. Maximum temperature in the area is 40° C during summer and minimum temperature is 10°C during winter. The pilot area comes under rain shadow zone of western Ghats and is a chronic drought prone area in the State. Average annual rainfall is 344 mm. The rainfall data of last eleven years recorded at Vaduj is given in Table 3. This data shows that area receives 75% of rainfall during SW monsoon and 25% of rainfall during non- monsoon months. Average rainy days are 34 during monsoon periods and 9 during non-monsoon season.

Table 3 - Rainfall data in the Pilot Project Area
(Fig. in mm)

Year	Annual Actual Rainfall in Pilot	Rainfall Percentage	Percentage variation
2001	534	155.23	+55.23
2002	419	121.80	+21.80
2003	185	53.78	- 46.22
2004	605	175.87	+75.87
2005	643	186.92	+86.92
2006	632	183.72	+83.72
2007	593	172.38	+72.38
2008	412	121.80	+21.80
2009	899	261.33	+161.33
2010	779	226.45	+126.45
2011	159	46.22	- 53.78
2012	239	69.47	-30.53
Source: GPLC data			

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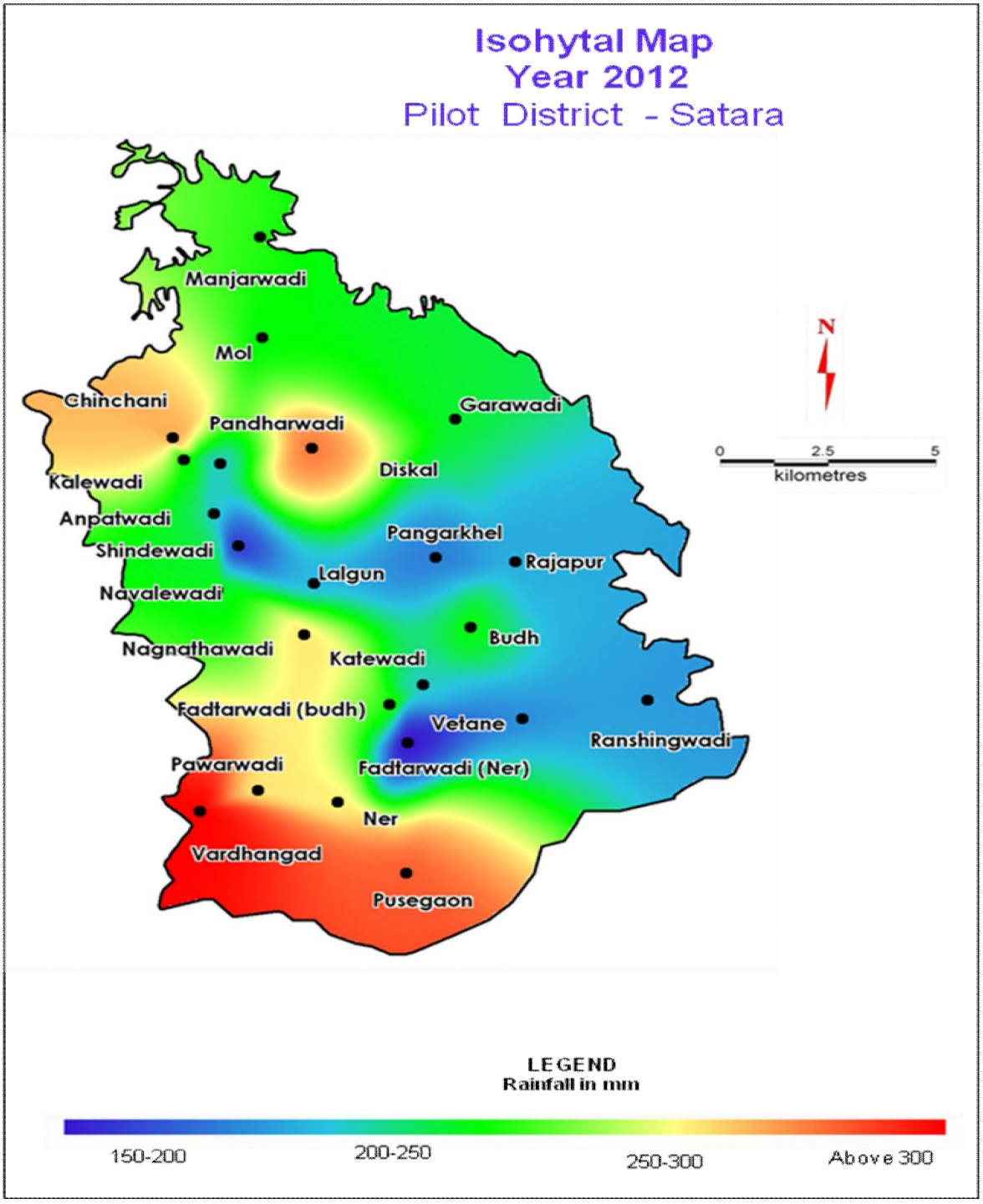

Map 4 Isohytal map of Pilot area -Year 2012

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3.4 Installation Of Rainguage Stations

Prior to the project there was no Raingauge station in the pilot area. Therefore, one raingauge station has been established in each village in the pilot aquifer during July, 2007 under the project.

The village volunteers have been trained in measuring rainfall. Village volunteers have been measuring daily rainfall and recording the same in the registers provided by GSDA. The rainfall data recorded by the community from is given in following graph fig 1.

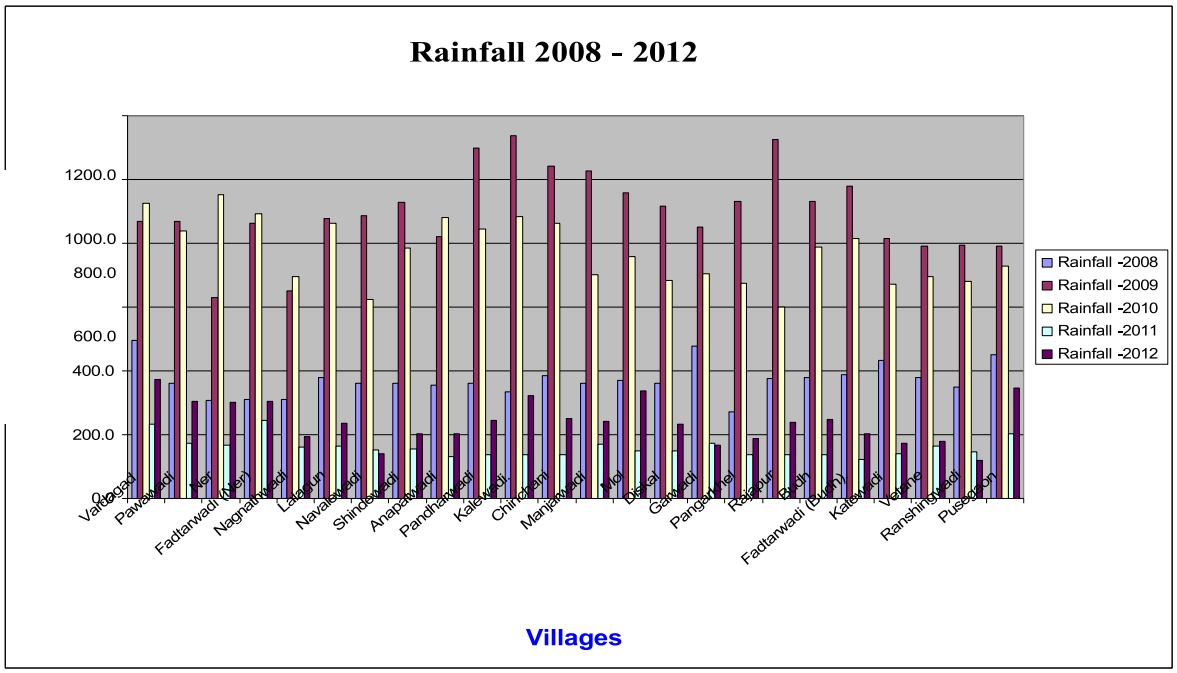

Fig.1 Graph of rainfall from 2008 to 2012 project area

From the above graph it is evident that the rainfall data recorded in 24 villages since 2008 shows variations in the rainfall received each village as well as the average annual rainfall in the aquifer area. Considering the large variation in rainfall data, the rainfall data recorded at rain gauge station in the village has more utility and reliability particularly only rainfall deficit years. The comparative rainfall data between villages and the taluka head quarter are given in Annexure no. 2 to 6.

3.5 Observation Wells And Piezometers

Satara GSDA has established 54 observation wells during 2006 in the pilot area to monitor groundwater levels every quarter.

In addition, GSDA has constructed 6 piezometers under the project to closely monitor changes in the water levels every month. These piezometers are drilled up to 36.60m depth.The water levels are monitored manually every month. In village Pusegaon piezometer nest is constructed to monitored changes in water level at different depths. In this nest, three bores are drilled of 30, 60, 90 m depth. The density of observation wells has been increase to one well per 3.96 sq. km. The water levels in the observation wells and piezometers are presently monitored by the District Geologist..

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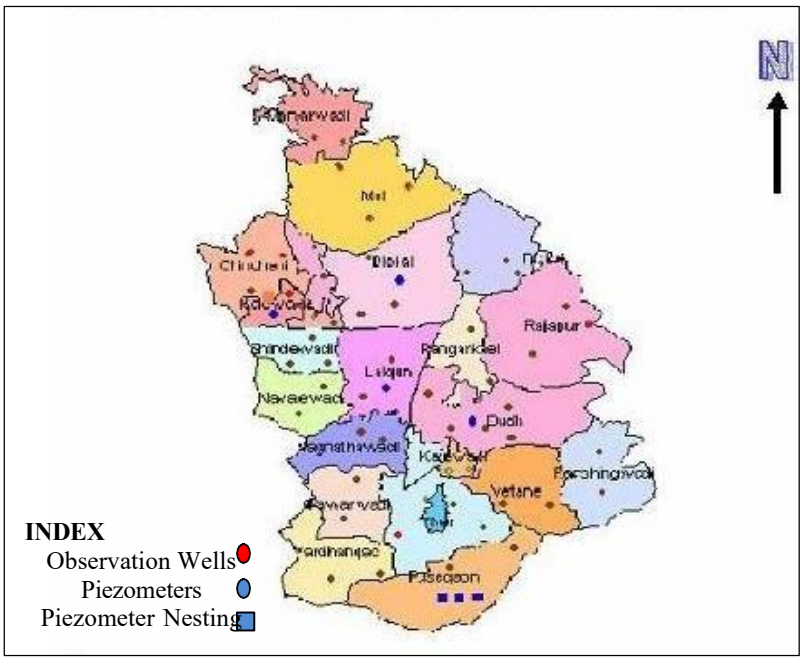

Map.5. Location of Observation Wells and Piezometers in the Aquifer

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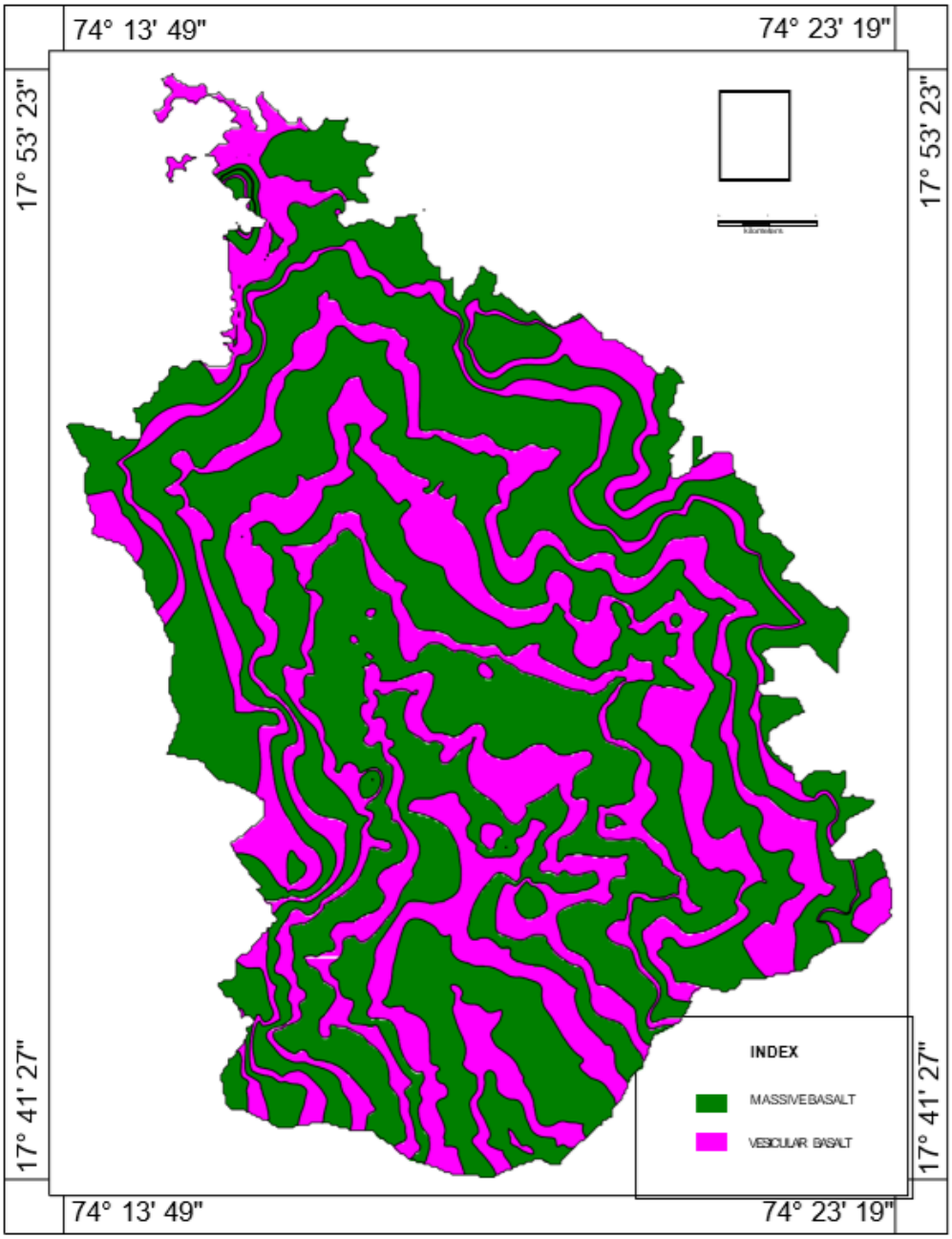

Map.6.Geology of Pilot Project Area

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3.6 Hydrogeology

The aquifer represented by weathered and fractured basaltic formation and the thickness of aquifer varies between 3 m and 8 m from north to south. Specific yield ranges from 0.0012 to 0.04. Trasmissivity of the aquifer ranges from 7.62 to 232.26 sqm/day and Specific capacity 14.34 to 141.3 lit/min/m. the hydro geological characters of this aquifer indicates that groundwater occurs under unconfined condition.Presently groundwater from the aquifer is being extracted by 2456 dug wells and 164 bore wells for agriculture, domestic and drinking water purposes.

The depth of wells ranges from 6m to 21m below ground level and diameter of well vary from 2m to 6m. The water levels in the wells range between 2.5m to 7.7m below ground level during post monsoon season and 4.7m to 16.5m below ground level during summer. The average yield of well varies between 30.76m3/day and 475.56 m3/day depending upon thickness of aquifer penetrated by the well.The hydrogeological characteristics of aquifer deciphered based on the aquifer performance test conducted during base line surveys are given in table 3 below

Table 3 Aquifer Parameters in Pilot Project Area

Sr. No.	Village	Specific capacity of the well (lit/min/meter) of drawdown	Well yield (m3 / day)	Transmissivity Sq.m./day	Specific yield %
1.	Katewadi	41.57	116.74	49.71	0.036
2.	Katewadi	97.58	306.35	75.80	0.0387
3.	Manjarwadi	17.03	40.96	24.19	0.024
4.	Manjarwadi	64.43	111.43	53.69	0.036
5.	Pandharwadi	88.88	153.59	305.42	0.021
6.	Mol	62.26	39.45	51.67	0.033
7.	Garvadi	43.76	107.19	125.89	0.0024
8.	Lalgun	95.51	123.78	35.80	0.0156
9.	Shindewadi	58.59	71.72	33.29	0.0012
10.	Shindewadi	72.04	153.63	49.19	0.036
11.	Nagnathwadi	14.34	30.76	23.91	0.028
12.	Nagnathwadi	53.58	92.59	78.68	0.0027

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13.	Navalewadi	90.48	475.56	22.13	0.0016
14.	Navalewadi	31.39	67.80	21.81	0.0012
15.	Chinchani	81.72	152.98	210.19	0.0065
16.	Diskal	56.24	93.13	117.85	0.0064
17.	Diskal	84.56	103.50	152.72	0.0162
18.	Diskal	55.89	92.55	117.12	0.0075
19.	Vadhangad	141.30	156.68	232.26	0.0133
20.	Pawarwadi	27.77	41.69	7.62	0.041
21.	Ranshingwadi	53.68	154.60	36.198	0.0048
22.	Ranshingwadi	55.05	138.73	57.859	0.0019
23.	Budh	79.95	103.61	15.59	0.0204
24.	Budh	28.77	41.43	10.129	0.0109
25.	Ner	68.46	138.01	49.90	0.005
26.	Fadtarwadi B	31.03	31.28	9.25	0.0358
27.	Pangarkhel	62.73	158.08	5.751	0.0100
28.	Vetane	79.95	103.61	15.595	0.0204
29.	Diskal	87.39	239.10	17.046	0.0158
Source: Baseline Survey by GSDA					

3.7 Land Use Land Holding Pattern

The geographical area of the Pilot aquifer is 214.57Sq.Kms..The land use data of villages covered in the Pilot aquifer for the year 2011-12 has been collected from District Office of Agriculture Department, Government of Maharashtra, at Satara district. The land use pattern in the aquifer area is given in Table 4 below.

Table 4
Land use pattern in the aquifer area.

Land use pattern	Area in sq.km.	Percentage to total area
Waste land	12.55	5.85
Forest land	15.31	7.14
Cultivable area i)Unirrigated area 103.99 sq.km ii)Irrigated area 44.07 sq.km iii)Area Under Canal Command 3.24 sq.km	151.30	70.51
Area not available for cultivation	35.39	16.5
Total geographical area	**214.57**	**100**

Source: Revenue and Agriculture department Satara

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Land Holding and Ownership

Majority of the farmers belong to marginal and small category and only 15% farmers are medium category and 7% are large category. Further, cumulatively 22% of farmers, including medium and large categories, together own 56% of land. Whereas, about 80% of farmers, including small and marginal farmers, own about 45% of the land.

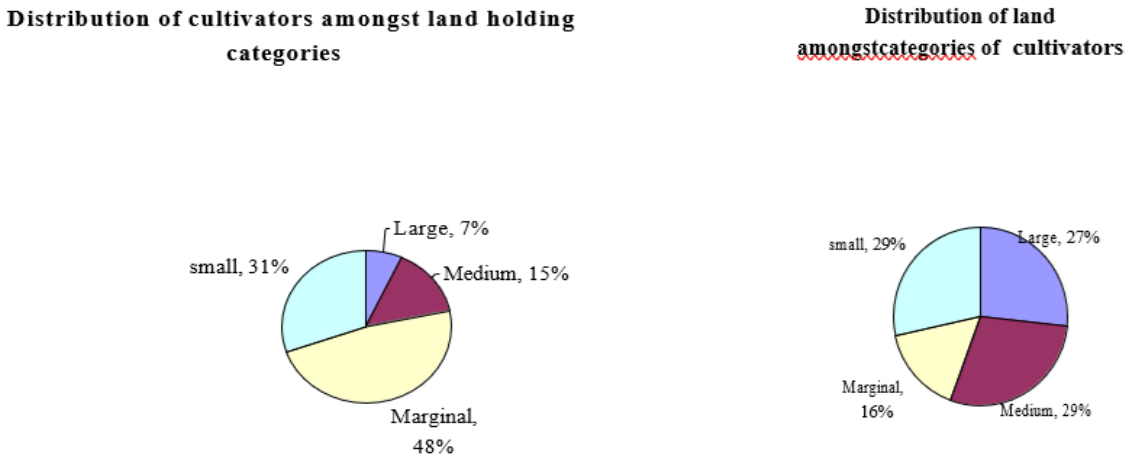

Fig.-2 Land Holding and Ownership

Land holding by medium and large farmer is not consolidated and is distributed in number of small land holdings.The following graph indicates access to groundwater to different category of Farmers.

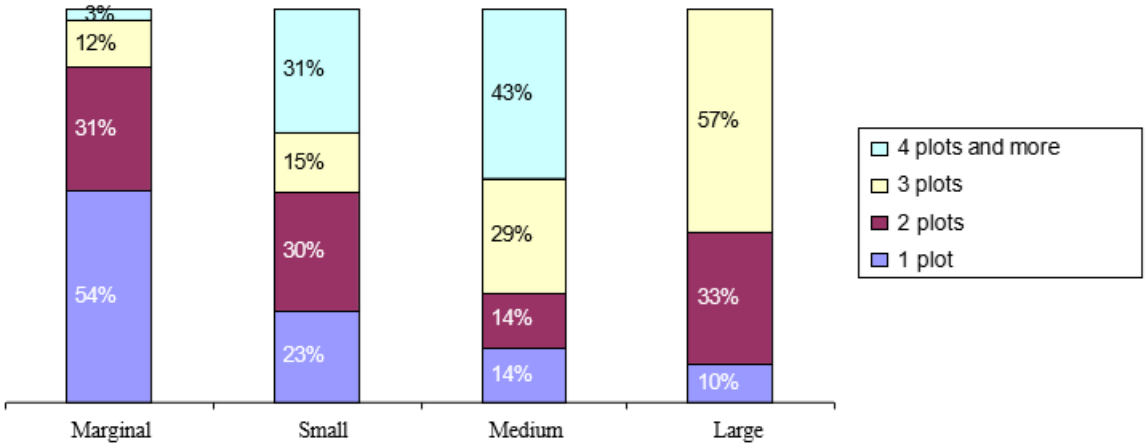

Fig 3 Number of plots are much more than number of Cultivators

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In the Pilot area large and medium farmers i.e about 22% of the total farmers are the main users of groundwater for irrigation, as together they own about 55% of the land. Average land holding as observed in the sample households is 1.61 ha. Among marginal land holders it is 0.54 ha. In small land holders it is 1.50ha. Among medium land holders it is about 3ha, and it is almost 7ha in the category of large land holders.

3.8 Cropping Pattern

In the pilot area Jawar, Bajara, onion and potato are the major crops cultivated during Kharif and Jawar, wheat, onion and Potato are cultivated during rabbi. Sugarcane is major perennial crops in the area irrigated mostly from the surface water source. The average cropping pattern in the pilot area is given in Table 5. below

Table 5
Cropping Pattern in Pilot Project area

Sr. No.	Name of the crops	Area in ha		
		Kharif	Rabi	Perennial/Hot weather
1	Jawar	1356	2080	0
2	Pulses	2437	0	0
3	Bajara	5132	0	0
4	Gram	0	171	0
5	Potato	433	118	0
6	Ground nut	0	0	36
7	Wheat	0	650	0
8	Onion	83	608	0
9	Vegetable	66	82	77*
10	Grapes	0	0	3
11	Horticulture	0	0	5
12	Banana	0	0	3
13	Ginger	28	28	28*
14	Maize	0	7	0
15	Fodder	0	0	4
16	Sugarcane	248	248	248
Total		**9794**	**4003**	**404**

*Source: Baseline survey data * Hot weather*

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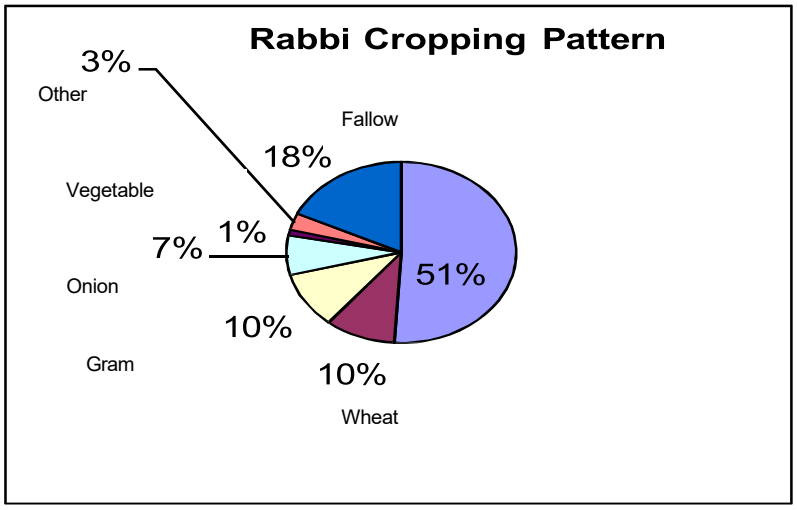

Fig.4 Cropping Pattern in Pilot Project area

3.9 Crop Water Requirement and Irrigation Application

Farmers in the pilot area are supplying excess irrigation to potato and onion during Kharif, wheat during Rabi and sugarcane, ginger are perennial crops. The supplementary irrigation required for these crops for the soil and climatic conditions in the area as per the consumptive use of these crops and the actual water applied by the farmers is given in table below.

Table 6 Irrigation water required and Applied for Rabi and Summer Crops

Crop Season	Water required for supplementary irrigation as per consumptive use (MCM)	Actual application of water for irrigation (MCM)	Excess water applied for irrigation (MCM)
Rabi	7.80	9.18	1.38
Summer	3.34	3.93	5.9
Total	11.14	13.11	1.97

Source: Baseline Surveys; Agriculture Department

It has been observed that during Rabi and summer season farmers in the aquifer have been over irrigating the crops more than what is required for the soil conditions in the area. The excess groundwater used by the farmers has been estimated at 1.97 MCM. This excess use of groundwater could be saved by creating awareness among the farmers and stakeholders through self regulations and motivating them to reduce the groundwater demand for agriculture and adopting advance techniques of irrigation like drip and sprinklers.

3.10 Groundwater

In the pilot project area, groundwater is the major source for agriculture and drinking water supply. The baseline survey data shows that groundwater in the aquifer is developed by 2417 irrigation dug wells and 39 drinking water wells and 164 drinking water bore wells.GSDA has been estimating annually replenishable Groundwater recharge from rainfall and other sources based on the rainfall data and changes in the water level monitored by GSDA.The annually replenishable Groundwater recharge and extraction of different uses as estimated by GSDA from 2006 to 2012 is given in table 7 below.

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Table 7
Annual replenishable Groundwater recharge and extraction

Year	Annually Replenishable groundwater recharge in MCM	Total Draft in MCM
2006-07	18.37	18.25
2007-08	18.02	17.59
2008-09	17.11	14.97
2009-10	19.18	12.35
2010-11	18.99	14.31
2011-12	10.41	8.55

Water Resources Department, GoM has estimated the runoff and present utilization of surface runoff by existing irrigation projects and water conservation structures already constructed in the aquifer area. Water resources department has constructed a medium irrigation tank at village Ner in the aquifer area. The live storage capacity of the irrigation tank is 11.77 MCM. Irrigation water is supplied from the tank to the command area of 45.45 sq.km out of which 80 hectors area falls in two villages namely Ner and Pusegaon in the pilot aquifer. Water from the irrigation tank is supplied through canal system for irrigating kharif, rabbi and perennial crops.Water Conservation Structures. There are 29 Percolation tanks, 128 Nalla Bund,8 village tanks, 4 Farm ponds and 5 Underground Bandhara constructed by Water Conservation Department, GOM in the aquifer area.

The number of water conservation structure constructed in each village and the runoff harnessed by the structures as obtained from water sources department is given in table no 1.12 below. Free runoff available for utilization by additional water conservation structures in these villages has been estimated by water sources department in the district as given below. The Minor Irrigation Department, Zillah Parishad, Satara has constructed 20 Kolhapur type weirs in the aquifer area. However because of poor operation and maintenance, these structures have become defunct. Utilization of surface runoff by different water conservation structures existing in the study area is given in Table 8.

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Table 8 Utilization of the surface water runoff in the Aquifer area

Sr. No.	Village	No. of existing water conservation structures	Runoff utilized by the existing water conservation structures (MCM)	Free yield Available for harnessing by additional water conservation structures (MCM)
1	Vardhangad	4	0.185	0.4426
2	Pawarwadi	3	0.175	0.131
3	Ner	2	0.175	2.8791
4	Nagnathwadi	5	0.0815	1.8268
5	Lalgun	10	0.1525	2.5534
6	Navlewadi	6	0.5128	1.469
7	Shindewadi	5	0.0727	1.2769
8	Anapatwadi	1	0.014	0.335
9	Pandharwadi	8	0.1693	0.8069
10	Kalewadi.	7	0.0853	0.6392
11	Chinchani	11	0.1776	2.212
12	Manjarwadi	8	0.0612	1.582
13	Mol	17	0.5054	5.604
14	Diskal	7	0.377	5.1801
15	Garawadi	22	0.2371	2.498
16	Pangarkhel	8	0.1215	1.4581
17	Rajapur	20	0.8058	3.8611
18	Budh	25	0.3185	4.6116
19	Fadtarwadi (Budh).	0	0	0.6446
20	Katewadi	0	0	0.4298
21	Vetane	9	0.3128	2.0731
22	Ranshingwadi	6	0.4519	2.2315
23	Fadtarwadi (Ner)	0	0	0.3118
24	Pusegaon	10	0.0828	3.56
	Total	**201**	**4.9082**	**48.618**

3.11 Conjunctive use of surface and groundwater

Farmers from Ner and Pusegaon villages coming under the command area of irrigation tank have been using canal water and groundwater conjunctively to irrigate 80 hectors of area. Normally 2 to 3 irrigation cycles are supplied from canal and the balance crop water requirement is met with groundwater extracted from the existing wells within the area. In addition the area beyond the command area 80 hector has been receiving additional recharge from seepage and canal as well as recycles water from the adjoining canal command.

Farmers on the upstream side of the dam have been lifting water from the storage of the irrigation tank by installing pump sets and irrigating area on the upstream of the dam. During baseline survey it has been observed that farmers have installed 39 pump set of an average capacity of 7.5 horsepower and have been lifting and carrying water up to their land to irrigate sugarcane, ginger, potato and wheat crops. Some of these farmers are using surface water pumped from the storage conjunctively with the groundwater extracted from the existing well.

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It has been estimated that about 1.68MCM of water has been pumped annually from the storage of the irrigation tank mainly for irrigating 110 hector of sugarcane and 58 hectors of other crops. This conjunctive use of surface and groundwater practiced by the farmer in the aquifer area has reduced the demand of groundwater for agriculture use.

3.12 Other Competitive Demand for water

There are no industries in the area except some small hotels in villages like Pusegaon, Diskal etc. the water requirement of these establishment are met either from the nearby well or existing hand pump. Thus there is no competitive demand for groundwater other than domestic and agriculture purposes.

Remote Sensing Data & GIS Maps

GSDA Satara has collected all available data about land, water and agriculture resources in the pilot aquifer. These data was supplemented by remote sensing data for the pilot area purchased from National Remote Sensing Center (NRSC) for pre project scenario.GSDA Satara had contracted NRSC for preparing GIS maps for all the three pilot aquifers including the pilot aquifer in Satara. NRSC has prepared and supplied 7 layers GIS maps for the pilot aquifer. The GIS maps supplied by NRSA have been used by GSDA while preparing groundwater management action plan for the pilot aquifer and implementing various project interventions during the project period.

Social Assessment

The social assessment survey of the pilot project area in Satara was completed by contracting a consultant M/s Primove Consortium, Pune. Groundwater is the main source used for drinking and most of the project villages are partly or fully covered by public drinking water supply systems. Wells are the main source of irrigation and 80% of the wells are jointly owned in the project area.Area around Ner tank is better irrigated compared to other upstream areas. However, overall almost one third (28%) of the total farmers do not have access to well water for irrigation. This lack of access to well water is more prominent amongst marginal farmers; 44% of marginal farmers do not have access to well water for irrigation.Traditionally to combat with the drought, people from the area have invested in education and have sought other opportunities outside their villages. Many villagers from the project area have migrated to urban centers and were mostly employed as skill workers in organized sectors. Many also serve in armed forces and remittances are a common feature of the economy.

People Participation

Participation of people has been important in the development process and management of common property resources. The success of development plan depended on the 'empowerment' of the beneficiaries. This was included through a participatory approach. As far as decision making was concerned; a sense of ownership by the end users was fully vested with the rights and duties regarding the restoration and the development of resources. Similarly transparency was vested as far as management and benefits were concerned. The unequal access to resources could be managed by a set of mutual expectations regarding the usage and the access to resources and were based on the notion of each person's entitlement to manage food resources and therefore the water resources. Villagers were the main stakeholders in the decision making process of Groundwater management. Since they have experienced the variations in the water availability in good and lean rainfall years, they could help promote techniques of Groundwater recharge. Also, they were involved actively in all the activities, they have perceived the problems faced by water scarcity and developed sensitivity towards reducing wastage. They have realized how difficult it was to provide a life saving resource like water. At the same time many villagers were aware of simple techniques of water management and conservation. However, they were never contacted or encouraged to share their knowledge. It was very important that people from all strata were consulted. Therefore, before the pilot project, the decisions were based on the opinions of influential men lead to installing hand pumps at unsuitable places. Similarly, the involvement of women in water resource development was very important because they have a large say in managing water, whether it is for drinking, cooking, washing or for animals. This segment of the community were seldom consulted .Therefore, during the community mobilization exercise under the aquifer pilot, different techniques have been used to make them open up and express their views. One method known as PRA (Participatory Rural Appraisal).In the present study, pictorial methods were used getting people's opinions. Groups of men, women, and underprivileged people (scheduled caste) were given paper and colored pens and asked to locate water resources in their village. They were asked to express the problems faced by them and what would they do to improve the water availability. The participants have done the job very efficiently. In a short period of three hours, they provided information which could have been otherwise collected in three days.

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IV. Discussion

4.1 Groundwater Management Plan

Communities from pilot aquifer realized the critical Groundwater condition and necessity for management of the annually replenishable Groundwater recharge for sustainable use and controlling the Groundwater extraction within the available Groundwater recharge. It was therefore, implied that GWMA shall prepare an action plan for sustainable Groundwater management after considering the views of all GPLCs and village community. GWMA in consultation with GPLCs prepared a Groundwater Management Action Plan (GWMAP) that included supply side interventions to augment groundwater recharge as also demand control measures to reduce groundwater extraction from the aquifer. Therefore, Pilot Team Leader, TSG and NGO assisted GWMA in the preparation of GWMAP and provided technical input required for planning the use of available Groundwater recharge for different purposes like drinking, domestic and agriculture as per their priority. The Groundwater Management Action Plan prepared by GWMA with the help of NGO and assistance from TSG was discussed at the Gramsabha and after incorporating the suggestions made by the community, the plan has been finalized. The GWMAP as finalized by GWMA has been approved by Project Leader after its review by TSG.

Following procedure has been adopted by GWMA and GPLCs for the preparation of GWMAP

i. The baseline survey report prepared by the PTL included inventory of water and agriculture resources available in the area and identified the measures required to improve the Groundwater conditions by both reducing the Groundwater extraction and augmenting Groundwater recharge to rain water harvesting structures. The report also suggested the method to achieve this based on the findings and recommendations made in the report. NGO organized a series of meetings of GWMA, GPLCs and Gramsabha to create awareness about finiteness of augmenting groundwater recharge beyond the hydrological capacity of aquifer and necessity to control over extraction of groundwater particularly for agriculture use and explained the methods to achieve these and the responsibility of each stakeholder.
ii. Control on Groundwater over Extraction: NGO and TSG conducted 3 to 4 meetings of GWMA and GPLCs and the community to deliberate on the present groundwater situation and convinced them about the need to conserve groundwater by reducing groundwater withdrawal. The village animators and community mobilizer engaged by NGO interacted with the community in each village and brought them on board to agree to reduce groundwater extraction.
iii. Augmenting Groundwater Recharge: The baseline survey report has indicated the scope for increasing groundwater recharge through various recharge structures. This was also discussed during Gramsabha and GWMA/GPLC, meetings organized by NGO. During these meetings member of TSG and Pilot Team Leader explained the purpose, scope and limitations of increasing the groundwater recharge beyond a particular limit. GWMA and GPLCs discussed with TSG and NGO about the appropriateness and feasibility of various types and number of groundwater recharge structures proposed by the community. The program purposed by the individual GPLCs was moderated by GWMA such that the works are evenly distributed over the entire aquifer and not concentrated to any particular point. The program was further modified after discussion between GWMA and TSG. The mutually agreed program was deliberated at Gramsabha meeting by the respective GPLCs.
iv. Crop Diversification and Agricultural Practices: The NGO along with Agriculture Expert of NGO and the member of TSG organized a few meetings of the community in each Grampanchayat to discuss the crops cultivated at present and the irrigation methods adopted by the farmers and the present practice of over irrigation to crops than actual water requirement of the crops. These experts have educated the farmers about the need to reduce water application for irrigation, rescheduling of irrigation cycle and selecting low water consuming crops that give same farm income but results in saving in groundwater utilization. Majority of the farmers have been convinced about the change required in the cropping pattern and have agreed to switch over to low water consuming crops than to face water scarcity.
v. After completion of the above exercise, each GPLC with the help of NGO prepared a draft GWMAP incorporating all the three components viz. supply side interventions, demand control measures and the change in cropping pattern.

The GWMAP prepared by the individual GPLC has been consolidated at the aquifer level by GWMA and wherever necessary the program proposed by GPLC has been moderated by GWMA in consultation with GSDA and TSG. This has ensured that the physical works are well distributed over the entire aquifer area.

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Draft. GWMAP was revalidated by Pilot Team Leader and appraised by the members of TSG. After satisfying about the technical feasibility and economic viability of the physical works, the GWMAP has been submitted to TRC for approval. The design and cost of each groundwater recharge structure envisaged in the action plan have been prepared by the civil engineer of the NGO and approved by TRC.

The three major components of GWMAP are

i. Supply side intervention

ii. Demand Control Measures

iii. Crop diversification

4.2 Supply Side Intervention

Each GPLC in the aquifer has held a series of meetings in the village and deliberated on the groundwater situation and identified the activities that are necessary to reduce groundwater extraction as also type and number of groundwater recharge structures necessary to augment groundwater recharge. The proposals were discussed and finalized in the Gramsabha meetings and submitted to GWMA. Therefor, the GWMA in consultation with PTL examined the proposals received from all the GPLC in the aquifer and based on the present situation assessed the need for the type and number of works proposed by each GPLC.

The consolidated GWMAP for the aquifer was finalized in consultation with the GPLC and was submitted to PTL. The GWMAP received from GWMA were discussed with TSG and based on the recommendations the, Action Plan has been approved by PTL. The supply side interventions included different types of groundwater recharge structures. These are small irrigation works for water conservation and groundwater recharge. These have been examined by TSG for technical feasibility. 24 GPLCs from the Pilot area initially proposed 55 groundwater recharge structures over 214.57 sq km area for total cost of Rs. 19.818 millions. TSG after examining the need and feasibility of each structure recommended 55 works after discussion with GWMA and GPLC. These 55 recharge structures for a total cost of Rs. 19.818 millions have been sanctioned on January 14, 2009 and June 29, 2010 by the Technical Review Committee constituted by Government of Maharashtra. Out of the total cost of Rs 19.818 millions,Rs 16.59 million were provided under the project and balance cost of Rs 2.971 million was contributed as a community contribution at 15% of the total cost. Detailed design and estimate for each of these 55 works have been prepared by the Civil Engineers prepared the estimates as per the designed norms recommended by the Minor Irrigation department of Zillah Parishad. The details of groundwater recharge structures sanctioned by TRC are given in Table 9.

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Table 9:Details Groundwater Recharge Structures executed by GPLCs

Sr. No.	Name of GPLCs	No. of Structures Completed	Estimated Cost (Rs. In millions)	Community Contribution (Rs. In millions)	Actual Expenditure (Rs. In millions)
1	Vardhangad	3	1.09	0.16	0.89
2	Pawarwadi	2	0.62	0.09	0.53
3	Ner	2	0.73	0.11	0.62
4	Fadtarwadi (Ner)	1	0.50	0.07	0.42
5	Nagnathwadi	3	0.80	0.12	0.68
6	Lalgun	4	1.34	0.20	1.08
7	Navlewadi	2	0.46	0.07	0.39
8	Shindewadi	3	1.03	0.15	0.88
9	Anapatwadi	2	0.86	0.13	0.73
10	Pandharwadi	3	1.30	0.20	1.07
11	Kalewadi.	2	0.74	0.11	0.63
12	Chinchani	2	0.41	0.061	0.34
13	Manjarwadi	2	0.75	0.11	0.63
14	Mol	3	1.34	0.20	1.13
15	Diskal	4	1.26	0.19	1.02
16	Garawadi	2	0.63	0.09	0.53
17	Pangarkhel	2	0.66	0.10	0.56
18	Rajapur	2	0.68	0.10	0.57
19	Budh	4	1.84	0.28	1.56
20	Fadtarwadi (Budh)	0	0	0	0
21	Katewadi	1	0.34	0.05	0.29
22	Vetane	2	1.15	0.17	0.96
23	Ranshingwadi	2	0.63	0.09	0.54
24	Pusegaon	2	0.67	0.10	0.56
	Total	**55**	**19.818**	**2.971**	**16.61**

4.3 Demand Control Measure

Joint discussions between TSG and members of GWMA/GPLCs about community awareness and situation specific issues have accelerated the decision making skills of GWMA/GPLCs. This has helped to understand the extent of groundwater over extraction and its impact on crop productivity. The process has helped to bound all members to adopt decisions taken by GWMA. During this consultative process between the members of GWMA-GPLCs and TSG, some key community decisions have been taken for reducing groundwater use such as:

- Community agreed to treat groundwater as a common natural resource.
- Community understood that the knowledge about Groundwater recharge and crop water requirement is necessary and should be calculated before selecting suitable crop plan.
- Each farmer has restricted the pumping operations to reduce groundwater extraction.
- Farmers agreed to reduce and ultimately discontinue the cultivation of sugarcane in the area.
- Large and medium farmers agreed to adopt drip and sprinkler irrigation for sugarcane, ginger, vegetable and horticulture crops cultivated in the area.

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- GWMA has decided to prohibit construction of new irrigation wells.
- The community has agreed to adhere to the decisions of GWMA and GPLC.

Accordingly, GWMA in consultation with GPLCs have decided to diversify the crops and switch over to low water consuming crops. As result of the demand control measure adopted by GWMA there has been a significant change in the crop pattern during Kharif, Rabi and Hot weathered season between 2006 and 2012.

Table 10
Transition in Cropping Pattern between 2006-07 and 2011-12 in the aquifer area

	Year	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
	Crops	Area in Ha	Area in Ha	Area in Ha	Area in Ha	Area in Ha	Area in Ha
Kharif	Bajra	5132	5200	5120	5615	5650	1783
	Beans	2437	2410	2150	2465	2480	278
	Potato	433	425	390	465	419	147
	Onion	83	80	70	59	55	31
	Jawar	1356	1340	1320	1380	1370	579
	Groundnut	1	1	1	15	15	7
	Vegetable	66	60	40	70	78	25
	Grapes	3	3	3	2	2	2
	Horticulture	5	5	5	3	3	3
	Banana	3	3	3	3	3	3
	Ginger	28	28	20	25	20	15
	Sugarcane	248	235	210	220	215	72
	Soyabin	0	0	0	75	110	24
		9795	**9790**	**9332**	**10397**	**10420**	**2969**
Rabbi	Jawar	2080	2050	2010	2090	2110	560
	wheat	650	670	605	666	670	220
	Onion	608	590	503	490	430	120
	Potato	118	110	102	130	145	90
	Gram	171	200	180	262	270	75
	Vegetable	82	82	75	85	90	24
	Maize	7	7	7	26	32	5
	Grapes	3	3	3	3	3	2
	Horticulture	5	5	5	3	3	2
	Banana	3	3	3	3	3	2
	Ginger	28	28	20	25	20	15
	Sugarcane	248	235	210	220	215	72
		4003	**3983**	**3723**	**4003**	**3991**	**1187**
Hot weather	Groundnut	36	36	30	43	48	25
	Vegetable	77	77	75	80	90	30
	Fodder	4	4	4	3	3	2
		117	**117**	**109**	**126**	**141**	**57**
Perinial	Sugarcane	248	235	210	220	215	72
	Ginger	28	28	20	25	20	15
	Horticulture	5	5	5	3	3	2
	Grapes	3	3	3	3	3	2
	Banana	3	3	3	3	3	2
		287	**274**	**241**	**254**	**244**	**93**

Source: Agriculture and Revenue Department data

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In the Pilot area under Bajara, Beans are increased in Kharif season.These crops shows increase in cultivable area during last five years. Whereas,crops like Ginger and Sugarcane in kharif season shows reduction in cultivable area during last five years. In Rabi season crops like Jawar,and wheat are also increased. This definitely shows shifting of area from to higher income crops to lower income crops. The area under low Groundwater required crops are increased except year 2008-09 and 2011-12. These changes are mainly attributed to good rains during 2009 and 2010. However, the groundwater crisis prompted GWMA to educate the farmers about reducing sugarcane as a strategy to reduce groundwater extraction.Bajara,Jawar and Beans are the major crops in the area. However, many farmers have switched over from the flow irrigation to drip irrigation system. This has reduced the water requirement for Sugarcane, Horticulture and Ginger in the area. Farmers in the pilot area have became aware about the benefits of switching over to micro irrigation system. However, because of high cost of system and non availability of subsidy from the Horticultur Department, only a few farmers in the area have adopted sprinkler and drip irrigation.

About 10 % area under Sugarcane and 70 % area under horticulture are irrigated with drip technique. About 26% area under Ginger is irrigated by Sprinkler irrigation system. It is noticed that the manufacturers and suppliers of Drip and Sprinklers are willing to make a tie up with the local farmers without insisting for the full payment and waiting for the release of subsidy. This initiative will particularly benefit the farmers and the conservation of groundwater in turn. The adoption of drip and sprinkler practices has shown that the withdrawal of groundwater is reduced. After completion of 55 groundwater recharge structures in the aquifer area the additional groundwater recharge in the aquifer has been estimated at 0.288 MCM which is only 1.69% of the total groundwater recharge from the rainfall. Thus the impact of groundwater recharge structures proposed and executed by GPLC in the aquifer is marginal and has not changed the groundwater recharge significantly. With the change in cropping pattern and the area under different crops GSDA has estimated the groundwater extraction for groundwater use. The year wise groundwater utilization for agriculture use between 2006 and 2011 is given in table 11 below:

Table 11:
Groundwater Utilization for Agriculture in the Pilot Project Area

(Figures in MCM)

Season	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Khariff	539	536	585	228	290	489
Rabi	836	792	575	641	735	228
Perennial	358	339	245	274	314	98
Total	**1733**	**1667**	**1405**	**1143**	**1339**	**815**
Source: GSDA Satara						

The reduction in groundwater extraction between 2006 and 2011 has been possible through motivation of the farmers. It was realized that the groundwater resource needs to be shared among all stakeholders and crop diversification is required by selecting such crops for which the total crop water requirement is within the available groundwater recharge without the loss of farm income to the farmers. During the year 2010, because of excess rainfall the groundwater recharge has increased and consequently the groundwater extraction also. Effective groundwater management is achieved by integrating supply side and demand side management activities. Augmented recharge is sustainable only if the water demands are controlled, else it is likely to be consumed by expansion in agricultural and other uses. There are numerous activities that help in reducing the water demand are implemented in the pilot project area with the help of NGO appointed.

The main focus of these activities is to strengthen the institutional committees formed and create the awareness of water conservation and related issues.

Since the community is a mixture of people with varying rate of literacy and age group, the strategy adopted was to disseminate the scientific knowledge and demystify the aquifer concepts. Moreover, instead of adopting standardized approaches, the plan was executed by considering the groundwater management needs and options at local levels. NGO with the help of Animators are asked to select the type of activities suitable to local community for initiating groundwater management, in consultation with TSGs. In such a way, a set of few physical activities are implemented in pilot project area that can help in achieving the demand side management objectives.

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The local community in a pilot area is organized initially into Grampanchayat Level Groundwater Management Committees (GPLCs) having village level representation. It has broad representation of people in the area and was entrusted with the responsibility to prepare initial proposal for the management interventions to be implemented in project area according to prevailing problems. Similarly, all the GPLCs within a pilot area is federated into a pilot project level groundwater management body known as Groundwater Management Association (GWMA). The GWMA is entrusted with the responsibility of appraising the proposals received from GPLCs and play a decisive role in planning of pilot area activities. It also has to plan how the available funds are spent on implementation activities, which is crucial to create local ownership of those activities. The GWMA also has to prepare their own byelaws and ensure that all its members abide with the byelaws.

In the above scenario, it was necessary first that the strengthening of this institutional model formed is initiated. Accordingly, regular meetings were started to conduct in respective villages. The frequency was normally once in a month to once in a three months depending upon the grounding of project activities. Particularly, the women representation was ensured in each gathering. These were also supported by corner meetings for focused discussions. Registers are maintained with each GPLC / GWMA and the proceedings are recorded. It is observed from the documented reports that total 283 meetings are conducted in the 24 villages with 12 to 15 member's representation by GPLCs and 26 meetings are conducted by the GWMA with 35 to 40 members representation. The following graph shows year wise meetings held by GPLCs and GWMA. The graph depicts that in the year 2008 all GPLCs conducted more number of meetings with the help of NGO as compare to the year 2010 and 2011. This is due to the formative stage of the institutional model and there were various activities in progress like election of GPLCs, community based hydrological data monitoring, discussion on groundwater management action plan, gramsabha for consensus etc. So also, in the year 2010 GWMA has conducted highest number of meetings that can be attributed to its intervention in implementation of groundwater management action plan. GWMA played a vital role in maintaining co-ordination between all GPLCs.

Community mobilization has been a very fundamental process in the project implementation. In fact, it was the initiation of the community based groundwater management action plan. Lot of orientation workshops and interactive meetings were held and community was encouraged to come forward and build the institutional model in the form of 24 GPLCs and 1 GWMA ('Yerala Groundwater Management Association').

The community was not only mobilized to take up supply and demand side based groundwater management action plan, but also to dovetailing of schemes run by other line departments. This has resulted into converting well flooding and farm pond program of Agricultural Department. Another distinct activity was selection of Animators, who helped in bridging the gap and well connect the community with project authorities. They created wide spread communication within the community of respective villages to generate awareness of groundwater problems, person to person contact for grounding of project activities and disseminating the project concept. In nut shell, the community mobilization was brought with the help of workshops, trainings and out-reach activities. The IEC activity i.e. awareness generated through Information, Education and Communication method is the backbone of demand side groundwater management. Promotion of efficient irrigation, switching over to low water demanding crops and adoption of horticulture crops instead of high water demand crops are generally the top agenda points on IEC campaigning. However, smaller yet important factors like self-regulation, community based hydrological data monitoring, water budgeting have also formed the part of IEC. The NGO, experienced to take up such activities in an effective manner, helped in implementing the IEC strategy. The strategic plan was prepared with the help of separate consultant appointed specially for the purpose, M/s Forefront Infotech Pvt. Ltd., Pune on August 08, 2007. This is where the Animators engaged proved to be of immense use. Focused IEC activities are carried out throughout the project at village level to impress the villagers regarding the benefits of sustainable groundwater usage. Potential audiences namely farmers, women, policy makers and different types of water users were identified to address in the IEC component as they form major stakeholder groups. Comprehensive IEC campaign included tools like video films, posters, booklets, information diary, slogan flex, school awareness program, essay competition, prabhat pheri, and brochures on micro irrigation practices. The targeted message canvassed during the IEC campaign has focused following issues: Groundwater resources in the area are limited but still manageable to meet the demands id supply side recommendations are adopted through community participation. Water conservation is essential for the community's sustenance even during failure of monsoon. Participatory management will attract incentives like subsidy for sprinkler/drip irrigation, groundwater recharge structures and more importantly would ensure drinking water supply.

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Fig. 5 Photos showing IEC campaigning from time to time

Community approach and views to Social Regulations in Groundwater Management

The main concept of the user cantered aquifer level groundwater management under the MWSIP is to provide adequate groundwater to all user groups by developing sustainable and economic, groundwater sources, either newly or by rejuvenation, reconstruction, rehabilitation, or up-gradation of existing ones, through community participation, thereby, promoting self-management, self-correction, self-regulation and thus ensuring sustainable benefits and quality life to the beneficiaries. Social regulation plays a vital role in sustainable development and management of groundwater. This is inevitable when water demands are maximum creating scarcity conditions. Supporting regulations can provide insight to key issues of groundwater pricing, the participation of various stakeholders in the program, policies of water use as an initiative for effective sustainable groundwater management.

The community is approached by project authorities and consultants engaged mainly by conducting meetings, gramsabhas and IEC tool mentioned above. The year wise social consensus achieved is as follows:

V. RESULT- IMPACT ASSESSMENT AND GROUND WATER MANAGEMENT STRATEGY

All GPLC have measured and recorded the rainfall data from the rainguage stations installed in the village. This rainfall data recorded has been used by the district geologist to calculate the groundwater recharge for each year. Additional recharge from the groundwater recharge structures existing prior to the pilot activities and also from the groundwater recharge structures constructed under the pilot project has been considered while calculating groundwater recharge.

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It is observed that from year 2006 to 2011 reduction in groundwater utilization have been due to project interventions and motivation of the farmers for switching over to low water consuming crops and adoption of micro irrigation system.

It reveals that farmers in the study area have shown the demand side control over the utilization of groundwater. The changes in groundwater recharge and withdrawal between the year 2006 and 2011 are given in the table 12 below.

Table 12
Groundwater Estimation during 2006-7 to 2011-12

Year	Rain fall in mm	Ground water Availability in MCM	Groundwater Draft in MCM				Total Draft in MCM (6+7)	Stage of Development (%) (8/3)*100
			Irrigation	surface water contribution	Irrigation (4-5)	Domestic		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
2006-07	632	18.37	19.02	1.68	17.33	0.92	18.25	99.37
2007-08	593	18.02	18.36	1.68	16.67	0.92	17.59	97.64
2008-09	412	17.11	15.74	1.68	14.05	0.92	14.97	87.52
2009-10	899	19.18	13.12	1.68	11.43	0.92	12.35	64.41
2010-11	779	18.99	15.08	1.68	13.39	0.92	14.31	75.38
2011-12	159	10.41	9.84	1.68	8.15	0.40	8.55	82.18

The data also depicts that the stage of groundwater development is decreased from 99.37% to 82.18% from the year 2006 to 2011. Members of GWMA-GPLC and other volunteer groups in the villages have been trained in measurement on daily rainfall and recording this in the register. GWMA regularly supervises this work. The community needs further training in analysis of the rainfall data and relate it to water availability and irrigation scheduling. GSDA has planned training programs for the community during June, 2010. GWMA-GPLC have been trained to measure water levels in he wells and monitor the changes. GSDA has already prepared formats for measurement and recording of water level in the wells every month. and provided with GWMA. The water levels in 4 piezometers would continue to be recorded every month by the District Senior Geologist. This data would be supplied to GWMA. Information on water level variation would be used for calculating groundwater recharge annually and its availability during different seasons. Members of GWMA and GPLC have informed about calculation of groundwater recharge from rainfall and requirement for drinking and agriculture use. This exercise need to be continued and carried forward to enable the community to calculate groundwater recharge and allocation of groundwater for drinking and agriculture. GSDA has prepared guidelines in local language for calculating groundwater recharge and estimating groundwater withdrawal.

These are provided to the community. However it is necessary to organize training program for GWMA-GPLC and train them in the calculation of groundwater recharge every year. Improved knowledge of the farmers and calculation of groundwater recharge, the District Geologist and NGO sharing this information with the community has provided clear understanding of groundwater resource availability. Using the data on rainfall and groundwater recharge, GSDA has organized training program for GWMA, GPLC, and other farmers from the Aquifer area to educate them about crop water budgeting and selection of crops suitable to soil and water conditions. In the beginning budgeting for Rabi season for 2010 was prepared and thereafter GWMA and GPLC were asked to do budgeting and prepare crop plan every year adopting the similar procedure.

GSDA Satara has prepared Guidelines for Operation and Maintenance Management Plan for GPLC's and GWMA under User Centered Aquifer Level Groundwater Management Pilot. This includes roles and responsibilities of GWMA, GPLC's for groundwater management, operation & maintenance of works and for general and financial aspects of various activities involved. These guidelines have been adopted by the community and all registers and records are maintained accordingly.

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VI. CONCLUSION

A systematic assessment of experience of User Centered Aquifer Level Groundwater Management Pilot in Satara district has brought to focus a number of lessons that are valuable while formulating new participatory groundwater management initiatives in other areas in the State. Community mobilization, enabling institutional arrangement, capacity building approach and participatory management strategies for sustainable groundwater development are the main areas of innovative pilot. Right from the beginning, converging the social and technical elements dominated the process of implementation of Use Centered Aquifer level Groundwater Management Pilot. Firstly the communities were organized into GPLC and GWMA adopting PRA process and involving the community in the decision making process at Gramsabha. All groundwater stakeholders were involved in the project 8implementation process at every stage. Technical Support Group was formed to offer technical guidance support to GWMA and GPLC in selection of appropriate groundwater recharge structures and preparing Groundwater Management Action Plan including self regulations for controlling groundwater extraction and O&M of the physical works by the community.The User Centered Aquifer Level Groundwater Management Pilot approach viewed from the present context has been a transition towards sustainable groundwater management by the community and it had created a strong ground for GWMA and GPLC to implement project activities. This aspect is important for replication of the experiences under the pilot in other areas in the State.

Contracting of NGO worked successfully in mobilizing the community. NGO facilitated formation and registration of GWMA and GPLC and enhanced their capacity to become Groundwater Management Institutions. NGO facilitated preparation and implementation of Groundwater Management Action Plan and helped them in preparation of design and estimates of groundwater recharge structures, its execution and supervision. NGO contributed to accomplish following tasks.

i. Educating farmers about collection and storage of technical data such as rainfall, water levels, crop pattern in the aquifer.
ii. Book keeping and financial management
iii. Groundwater accounting and allocation of water for different usages.
iv. Designing and adoption of crop plan

GWMA and GPLC were given intensive training and information on linking the groundwater recharge to rainfall and crop water budgeting and the community have realized its utility for sustainable groundwater management.

IEC has played an important role in the mobilization of the community and achieving success. The IEC strategy and the material canvassed in the aquifer have a positive impact on the community participation at different house hold level. Thus the strategy of outsourcing the professional activities to NGO has its positive effect on the quality of implementation and provided necessary manpower for technical and social assistance which was acceptable to the community. For the first time the concept of aquifer as a unit has been introduced for groundwater management under User Centered Aquifer level Groundwater Management Pilot. The farmers realized the advantages of aquifer management strategies and achieve steady economic growth while establishing balance in the ecosystem. The stakeholders accepted the paradigm shift towards sharing of groundwater among different villages, conjunctive use of groundwater and surface water, necessity to control groundwater extraction for sustainable utilization of the resources. Water conservation practice has been successfully adopted by the community by diversifying the cropping pattern and switching over to low water consuming crops.

Since this project is community based, the mindset of community is found to change. To achieve this change NGO associated with this project, has undertaken IEC activities in the project area. However, the behavioral change would occur with the constant dialogue and awareness amongst the community. The demand side measures like crop diversification, use of efficient irrigation practices, self regulations etc. are being observed to be adopted gradually by the farmers. The change has started to appear and with continued collective efforts and streamlining, the community can achieve sustainable management of groundwater.In the project area supply side activities include mainly the construction of Cement Bandharas at feasible locations. It is observed that water levels in the wells adjoining the cement bandhara are showing rising water level trend. Supply side measures are undertaken with the support of community. Community has realized that the supply side intervention is beneficial and particularly the ridge to valley treatment may be converged in the project area. In nutshell, supply side intervention despite its marginal contribution has revealed positive impact in the Pilot area.

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Farm ponds have been constructed in the project area with the support of Agriculture Department. This effort reveals that the dovetailing of water conservation measures is beneficial for generating better groundwater scenario. It has supported the farming community and their moral. Moreover, farmers in the project area have shown interest in irrigation well recharge activities. So far, 500 irrigation wells have been recharged with the support of Agriculture Department.

This well recharge activity will in turn augment groundwater. Monitoring of observation wells have indicated that the water levels have declined and increased significantly due to rainfall density during certain years. Subsequently, it is observed that crop yields in Rabbi mainly depend on soil moisture retained after monsoon. Few farmers have started growing horticultural crops and adopting advanced irrigation practices like drip and sprinklers in some of the villages.

However, it has been also noted that during Rabbi and Summer season farmers in the area have been over irrigating the crops more than what is required for the soil conditions. This high rate of groundwater utilization has been manifested in progressive decline of water levels both during pre-monsoon and post –monsoon period. This excess use of groundwater could be conserved by creating awareness among the farmers and stakeholders for self regulations and reduce the groundwater demand for agriculture.Areas under Bajara, Beans are increased in kharif season these crops shows increase in cultivable area during last five years. Whereas, crops like Ginger and Sugarcane in kharif season shows reduction in cultivable area during last five years. In Rabi season, crops like Jawar and Wheat are also increased. Nevertheless, the groundwater crisis has provoked GWMA to educate the farmers about reducing Sugarcane cultivation as a strategy to reduce groundwater extraction. The data also depicts that the stage of groundwater development is decreased from 99.37% to 82.94% from the year 2006 to 2011.

Annexure 1

Village wise dug well details

Sr no	Village	Wells Surveyed	Electric motor	Oil engine	Depth range m		Diameter m		SWL m Winter		SWL m Summer	
					From	To	From	To	From	To	From	To
1	Manjarwadi	36	19	8	6.00	15.00	2.50	10.00	1.00	3.50	9.00	16.00
2	Mol	178	80	77	5.00	17.50	5.50	7.00	0.50	4.20	5.00	14.00
3	Chinchani	68	11	48	5.00	16.50	2.00	7.00	1.00	7.85	6.50	13.50
4	Kalewadi	22	10	12	7.00	16.50	5.50	8.60	1.50	5.30	5.50	10.65
5	Pandharwadi	32	9	12	6.00	15.20	5.00	10.00	1.00	3.60	5.00	14.00
6	Diskal	243	148	64	6.00	18.00	6.00	10.00	1.00	3.50	7.00	10.50
7	Garvadi	97	67	24	4.00	18.20	4.00	10.00	0.50	7.70	5.00	10.50
8	Anpatwadi	29	18	11	5.60	16.50	5.00	7.00	1.20	5.70	5.00	15.00
9	Shindewadi	38	23	13	6.30	14.50	5.50	8.00	0.85	7.80	4.70	14.20
10	Navalewadi	58	26	26	5.00	20.00	5.00	7.00	1.50	6.30	5.00	16.50
11	Lalgun	254	196	26	6.00	17.40	5.00	8.00	0.50	7.00	5.00	14.00

12	Pangarkhel	58	40	18	7.00	17.10	5.00	8.00	1.00	4.00	6.00	11.00
13	Rajapur	244	116	66	6.00	20.00	1.70	11.00	1.00	5.00	6.00	10.80
14	Nagnathwadi	68	44	24	7.00	17.90	5.50	7.00	2.50	5.70	5.40	13.10
15	Fadtarwadi B	52	44	0	6.00	18.00	5.00	10.00	1.50	7.00	8.00	12.00
16	Budh	311	195	79	6.00	18.60	5.00	10.00	1.00	7.50	7.00	16.50
17	Katewadi	48	39	5	9.00	21.00	6.00	10.00	1.00	4.90	5.10	10.00
18	Ner	169	92	50	5.50	18.00	5.00	9.00	1.00	8.00	5.50	17.00
19	Fadtarwadi	13	6	4	5.50	14.00	7.00	10.00	1.20	8.00	5.50	12.00
20	Vetane	176	94	61	7.00	23.00	5.00	10.00	1.00	4.00	7.00	11.00
21	Ranshingwadi	118	60	48	7.00	20.00	5.00	10.00	1.00	4.00	7.00	10.50
22	Pawarwadi	137	72	34	6.00	18.00	4.00	10.00	1.00	4.50	6.00	12.00
23	Vardhangad	117	60	23	6.00	21.00	4.50	13.00	1.00	4.90	5.10	10.00
24	Pusegaon	220	157	44	4.50	17.50	2.50	13.00	1.50	6.00	7.50	14.20
	Total	2786	1626	777								

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Annexure 2

Rainfall Deviation in Year 2008			
Taluka HQ Rainfall- 390mm			(Rainfall in mm)
Sr. No.	Name Of Village	Rainfall recorded at Village	Percentage Deviation with respect to Taluka Rainfall
1	Vardhangad	496.2	27.23
2	Pawarwadi	361.7	-7.26
3	Ner	308.4	-20.92
4	Nagnathwadi	311.4	-20.15
5	Lalgun	379	-2.82
6	Navlewadi	512	31.28
7	Shindewadi	512	31.28
8	Anapatwadi	355.2	-8.92
9	Pandharwadi	353.2	-9.44
10	Kalewadi.	335.8	-13.90
11	Chinchani	383.6	-1.64
12	Manjarwadi	512	31.28
13	Mol	512	31.28
14	Diskal	360.1	-7.67
15	Garawadi	478.1	22.59
16	Pangarkhel	270.4	-30.67
17	Rajapur	375.4	-3.74
18	Budh	512	31.28
19	Fadtarwadi (Budh).	387.5	-0.64
20	Katewadi	431.5	10.64
21	Vetane	378.8	-2.87
22	Ranshingwadi	348.2	-10.72
23	Fadtarwadi (Ner)	512	31.28
24	Pusegaon	512	31.28

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Annexure 3

Rainfall Deviation in Year 2009			
Taluka HQ Rainfall- 854mm			(Rainfall in mm)
Sr. No.	Name Of Village	Rainfall recorded at Village	Percentage Deviation with respect to Taluka Rainfall
1	Vardhangad	869.88	1.86
2	Pawarwadi	869.2	1.78
3	Ner	629.3	-26.31
4	Fadtarwadi (Ner)	861.6	0.89
5	Nagnathwadi	651	-23.77
6	Lalgun	876.5	2.63
7	Navlewadi	885.4	3.68
8	Shindewadi	929.6	8.85
9	Anapatwadi	819.5	-4.04
10	Pandharwadi	1099.4	28.74
11	Kalewadi.	1138	33.26
12	Chinchani	1041.4	21.94
13	Manjarwadi	1026.3	20.18
14	Mol	958.2	12.20
15	Diskal	917.7	7.46
16	Garawadi	849.5	-0.53
17	Pangarkhel	931.7	9.10
18	Rajapur	1124.5	31.67
19	Budh	931.2	9.04
20	Fadtarwadi (Budh).	979.5	14.70
21	Katewadi	816.4	-4.40
22	Vetane	791	-7.38
23	Ranshingwadi	794.5	-6.97
24	Pusegaon	790.1	-7.48

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Annexure 4

Rainfall Deviation in Year 2010			
Taluka HQ Rainfall- 839mm (Rainfall in mm)			
Sr. No.	Name Of Village	Rainfall recorded at Village	Percentage Deviation with respect to Taluka Rainfall
1	Vardhangad	932.3	11.12
2	Pawarwadi	844.6	0.67
3	Ner	956.8	14.04
4	Fadtarwadi (Ner)	901.6	7.46
5	Nagnathwadi	699.5	-16.63
6	Lalgun	870.1	3.71
7	Navlewadi	631.4	-24.74
8	Shindewadi	789	-5.96
9	Anapatwadi	891	6.20
10	Pandharwadi	856.4	2.07
11	Kalewadi.	894	6.56
12	Chinchani	870.2	3.72
13	Manjarwadi	707.3	-15.70
14	Mol	765.7	-8.74
15	Diskal	688.1	-17.99
16	Garawadi	713.5	-14.96
17	Pangarkhel	683.2	-18.57
18	Rajapur	605.6	-27.82
19	Budh	793.2	-5.46
20	Fadtarwadi(Budh)	819	-2.38
21	Katewadi	676.5	-19.37
22	Vetane	702.4	-16.28
23	Ranshingwadi	683.4	-18.55
24	Pusegaon	733.6	-12.56

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Annexure 5

Rainfall Deviation in Year 2011			
Taluka HQ Rainfall- 394mm			(Rainfall in mm)
Sr. No.	Name Of Village	Rainfall recorded at Village	Percentage Deviation with respect to Taluka Rainfall
1	Vardhangad	233	-40.86
2	Pawarwadi	173.50	-55.96
3	Ner	166.20	-57.82
4	Fadtarwadi (Ner)	245.50	-37.69
5	Nagnathwadi	161.80	-58.93
6	Lalgun	163.70	-58.45
7	Navlewadi	153.10	-61.14
8	Shindewadi	156.20	-60.36
9	Anapatwadi	130.90	-66.78
10	Pandharwadi	138.20	-64.92
11	Kalewadi.	137.90	-65.00
12	Chinchani	137.20	-65.18
13	Manjarwadi	171	-56.60
14	Mol	149.40	-62.08
15	Diskal	149	-62.18
16	Garawadi	174	-55.84
17	Pangarkhel	137.10	-65.20
18	Rajapur	136.20	-65.43
19	Budh	136	-65.48
20	Fadtarwadi(Budh)	122.50	-68.91
21	Katewadi	140.30	-64.39
22	Vetane	162.80	-58.68
23	Ranshingwadi	145.20	-63.15
24	Pusegaon	201.60	-48.83

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Annexure 6

Rainfall Deviation in Year 2012			
Taluka HQ Rainfall- 275mm			(Rainfall in mm)
Sr. No.	Name Of Village	Rainfall recorded at Village	Percentage Deviation with respect to Taluka Rainfall
1	Vardhangad	374.30	36.11
2	Pawarwadi	305.50	11.09
3	Ner	302.50	10.00
4	Fadtarwadi (Ner)	304.00	10.55
5	Nagnathwadi	192.60	-29.96
6	Lalgun	236.20	-14.11
7	Navlewadi	139.60	-49.24
8	Shindewadi	203.10	-26.15
9	Anapatwadi	203.90	-25.85
10	Pandharwadi	245.80	-10.62
11	Kalewadi.	322.70	17.35
12	Chinchani	249.40	-9.31
13	Manjarwadi	240.60	-12.51
14	Mol	336.70	22.44
15	Diskal	232.30	-15.53
16	Garawadi	166.70	-39.38
17	Pangarkhel	186.70	-32.11
18	Rajapur	238.60	-13.24
19	Budh	248.00	-9.82
20	Fadtarwadi(Budh)	203.30	-26.07
21	Katewadi	173.30	-36.98
22	Vetane	179.20	-34.84
23	Ranshingwadi	120.60	-56.15
24	Pusegaon	346.10	25.85

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Annexure 7

Village wise Water Level Fluctuation in Aquifer

Sr. No	Village Name	Fluctuation 2006-07 in Mtr	Fluctuation 2007-08 in Mtr	Fluctuation 2008-09 in Mtr	Fluctuation 2009-10 in Mtr	Fluctuation 2010-11 in Mtr	Fluctuation 2011-12 in Mtr
1	2	3	4	5	6	7	8
1	Vardhanagad	4.88	5.80	4.33	6.00	5.50	1.03
2	Pawaradi	5.80	5.70	5.90	5.80	5.90	3.65
3	Ner	4.73	2.55	4.80	5.50	5.75	5.20
4	Nagnathwadi	3.20	4.90	4.77	4.90	4.70	0.90
5	Lalagun	4.00	4.58	4.95	4.95	4.60	1.90
6	Navalewadi	3.80	3.90	3.30	3.70	3.80	0.95
7	Shindewadi	4.00	3.83	3.73	4.00	3.70	2.00
8	Anapatwadi	4.20	3.25	0.50	4.95	3.50	0.75
9	Pandharwadi	4.85	4.78	4.57	4.80	4.85	0.75
10	Kalewadi.	4.70	3.95	4.10	4.90	3.00	0.90
11	Chinchani	4.90	4.80	4.90	4.90	4.90	1.95
12	Manjarwadi	4.70	4.60	4.75	4.55	4.90	0.25
13	Mol	4.45	4.75	4.66	4.80	4.73	2.97
14	Diskal	6.00	5.37	5.04	5.87	5.97	1.33
15	Garwadi	2.38	3.94	3.80	3.08	3.67	1.87
16	Pangarkhel	4.80	4.80	3.62	4.22	4.90	3.67
17	Rajapur	4.79	5.00	5.00	4.87	5.10	1.03
18	Budh	5.90	5.23	5.87	5.80	5.40	0.40
19	Fadtarwadi (Budh).	5.90	5.95	4.30	5.90	5.50	4.70
20	Katewadi	5.83	5.68	1.47	5.80	5.90	4.90
21	Vetane	4.45	3.90	2.75	3.60	4.50	4.30
22	Ranshingwadi	4.90	4.90	4.90	4.95	4.10	4.50
23	Fadtarwadi (Ner)	4.65	2.95	5.45	3.45	4.90	4.50
24	Pusegaon	5.25	4.65	4.67	5.40	4.55	4.00

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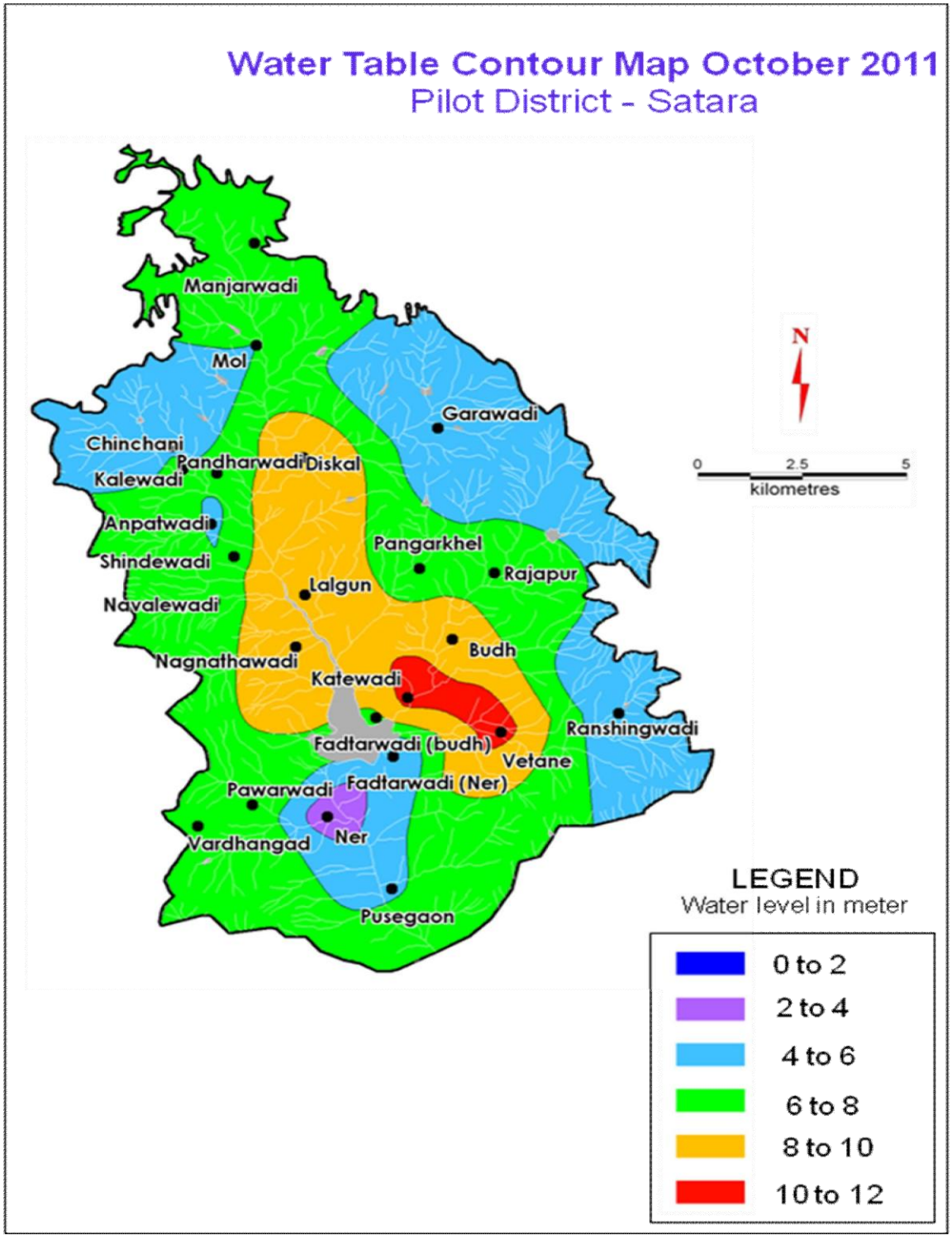

Map7.Water table Contour map October 2011

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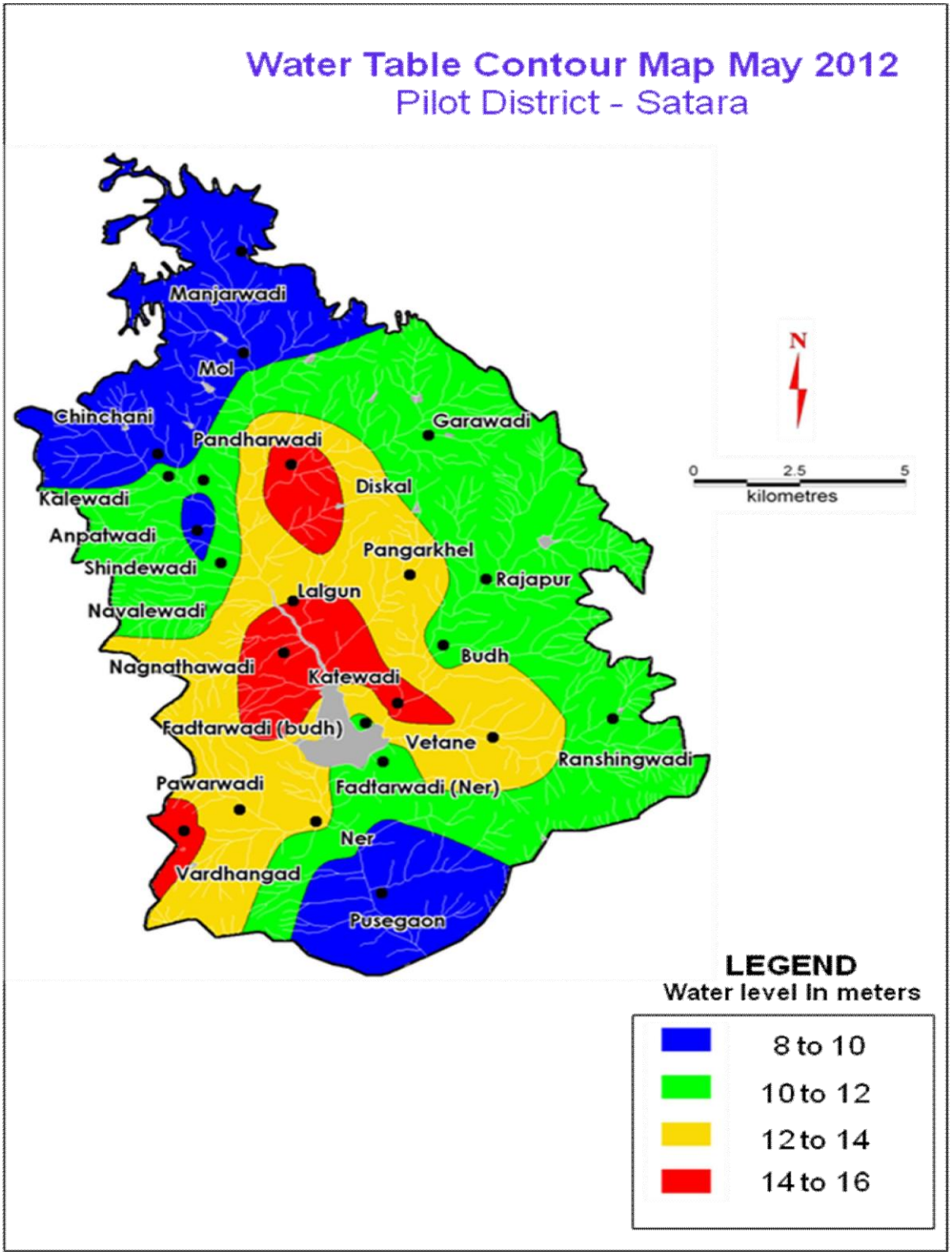

Map 8.Water table Contour map May 2012

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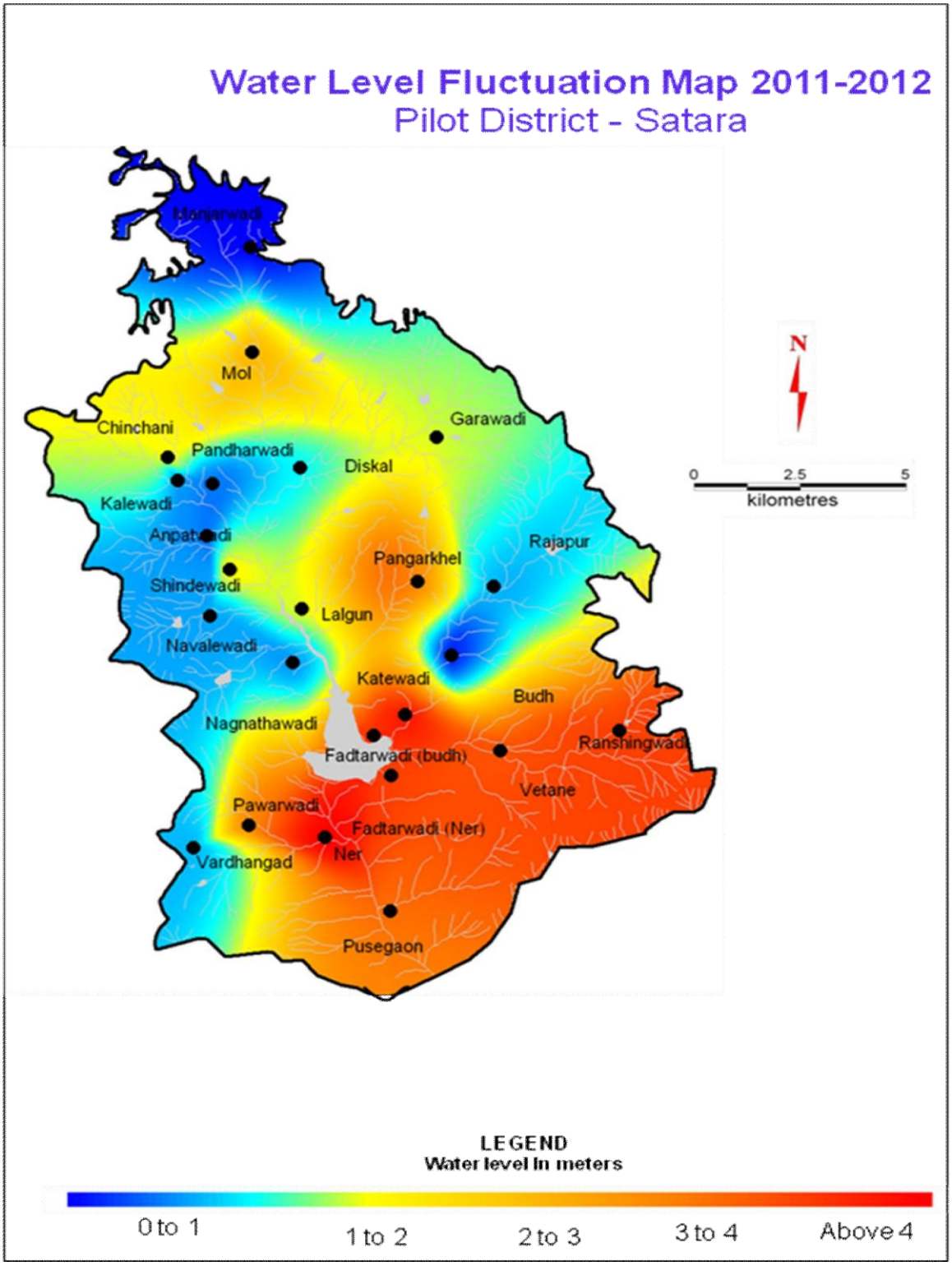

Map 9.Water level Fluctuation map 2011-12