Rainfall and Groundwater Level Variation in Pune District, India

S. Nandargi, T.A. Patekar, S.S. Mulye

Indian Institute of Tropical Meteorology, Pune-411008, India

nshobha@tropmet.res.in

Abstract

Rapid industrial development, urbanization and increase in agricultural production have led to freshwater shortages in many parts of the Pune district. The availability of groundwater is extremely uneven, both in space, time and depth which will be the case in future also. The present study concerns the impacts of a change in the rainfall regime on surface and groundwater resources in watersheds of Pune district during 2001 to 2012. This study shows that water level in many villages reachs almost bottom of the observatory well during May e.g. Dive Village in Purandar taluka reachs 32.40 m bgl in May 2004 as against 710 mm of rainfall recorded by the taluka. Categorization of groundwater level reveals that although there is rise in water level during October, even then 50% villages experience semi-critical condition. Therefore, there is an urgent need of planned and optimal development of water resources in this district.

Keywords

Rainfall Analysis; Groundwater Fluctuations; Water Resources Development

Introduction

Life on Earth depends on groundwater just as it does on surface water. As a part of the water cycle, groundwater is a major contributor to flow in many streams and rivers and has a strong influence on river and wetland habitats in which plants and animals live. People have been using groundwater for thousands of years and still continue to use it today. The behaviour of groundwater in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations (Manimaran, 2012). It comprises of the major and the preferred sources of drinking water in rural as well as urban areas and caters to 80% of the total drinking water requirement and 50% of the agricultural requirement in rural India (Meenakshi and Maheshwari, 2006; Murhekar, 2012).

The rapid industrialization, population growth and agricultural activities have resulted in over utilization of the fresh water resources, leading to reduction of groundwater level. Rapid urbanization has resulted in less infiltration of rainwater; hence groundwater recharge potential has diminished (Ibrahim, 2009). Vast amounts of water (~ 70%) are lost through seepage, especially where the soil is gravelly and porous and therefore, many states in India experience drought resulting in shortage of water, particularly during the summer months. To prepare a sustainable management strategy for groundwater development, it is important to understand the fluctuation of groundwater levels with reference to natural (through rainfall) or artificial recharge in space and time domain.

The rainfall comprises of an important component of the water cycle and is the prime source of groundwater recharge. In India, the distribution of rainfall however, varies from place to place owing to different physiographic and climatic settings. Although some parts of the country receive abundant rainfall, there are regions which face a meteorological drought condition. In recent decades, the exploitation of groundwater has increased greatly particularly for agricultural purpose, because large parts of the country have little access to rainfall due to frequent failures of monsoon. Thus the increasing population and their dependence on groundwater for irrigation are further inducing heavy stress on groundwater resources, leading to the decline of groundwater levels, mostly in peninsular region. The recurrent drought and concomitant decline in the groundwater levels over the years in some areas of Maharashtra state in peninsular India, necessitate a detailed study to elucidate the behaviour of groundwater level fluctuations in both, spatial and temporal scales.

In view of this, many experts such as Thakur & Raghuvansi, 2008; Prasad et al., 2008; Rokade et al., 2007; Jha et al., 2007 ; Leblanc et al., 2007; Saraf et al., 2004 and Teeuw,1995 used RS & GIS for evaluation and management of groundwater resources of the various terrains. One of the greatest advantages of using remote sensing (RS) data for groundwater investigation and monitoring is its ability to generate information in spatial and temporal domain (Geographic Information System GIS), which is very crucial for successful analysis, prediction and validation (Jaiswal et al., 2003; Murthy, 2000; Saraf and Choudhury, 1998; Krishnamurthy et al., 1996).

Tirkey et al (2012) examined the groundwater level variability and its relationship with rainfall for the drought affecting Palamu District of Jharkhand State, with the sum of least square method. The analysis revealed that the region during the post-monsoon season exhibit shallow depth of water level (2-3 m) which declined up to 8-10 m during pre-monsoon month of May. They also performed the spatio-temporal rainfall trend analysis using interpolation in GIS which provided conceptual understanding for developing large water harvesting structures in those regions which exhibited an increase in rainfall and the need for developing a number of small water harvesting structures to recharge the groundwater in rainfall declining zones.

Wagner et al (2013) analyzed land use changes from 1989 to 2009 and their impacts on the water balance in the Mula and Mutha Rivers catchment upstream of Pune. Land use changes were identified from three multi-temporal classifications for the cropping years 1989/1990, 2000/2001, and 2009/2010. The hydrologic SWAT (Soil and Water Assessment Tool) model was used to assess impacts on runoff and evapo-transpiration. The main land use changes were identified as an increase of urban area from 5.1% to 10.1% and cropland from 9.7% to 13.5% of the catchment area during the 20-yr period.

In the present study, the temporal and spatial fluctuations of the groundwater level were analyzed and compared with the rainfall distribution, and the patterns of the fluctuations were rationalized for different Talukas and villages of the Pune district in Maharashtra state. The work offers a scientific basis for the maintenance of the groundwater level, and provides a valuable insight into the regional ecology and hydrology.

Characteristics of the Study Region

Pune district which is located in the western region of Maharashtra state, comprising of an area of 15642 sq.kms, which is 5% of the area of entire state (see Fig.1). Bhima and Nira are the two main rivers in Pune district. Bhima River originates at Bhima Shankar in Sahyadri hills of Western Ghat and flows towards east side in Pune and Solapur district. Nira River originates in Sahyadri hills in Bhor Taluka and flows through Bhor, Baramati, Indapur Talukas. River Ghod is the major northern tributary and Bhama, Indrayani, Mula, Mutha and Pavana are the southern tributaries of the Bhima River. The Bhima River and Nira River converge at Narsingpur in Solapur district. Generally, there is at least one river flowing in each taluka of the District (Fig.1). There are major and medium irrigation projects such as Khadakwasla, Panshet, Varasgaon, Bhatghar, Vir. Chaskaman which form the main water sources for drinking and irrigation.

The whole of the district lies on the eastern side of the Western Ghats and more or less it presents a hilly topography in the western part of the Junnar, Ambegaon, Mawal, Mulshi, Velhe, Bhor and Purandar talukas. In the eastern part of the district, Daund, Shirur, Baramati and Indapur talukas are located in the plains away from the hill range. The soil has varied slope in different parts of the district broadly from very steeply sloping (slope >50%) in the western part to very gently sloping (1 to 3%) in the eastern part. On the basis of soil depth, drain, soil characteristics, slope etc. following soil types are identified in the district as shown in Fig.2.

Considering the above soil patterns, topography, and drainage system of the district which forms the major tool in groundwater studies, an attempt has been made in the following sections to study the rainfall behaviour and groundwater depth and fluctuations during pre-monsoon month of May and post monsoon month of October for the period of 2001 to 2012.

Data Used

Daily Rainfall Data

Daily rainfall data for 2001 to 2012 of all the stations inside the district have been procured from the National Data Centre (NDC), India Meteorological Department (IMD), Pune and from Department of Agriculture, Govt. of Maharashtra.

Groundwater Data

Central Ground Water Board monitors water levels in 65 National Hydrograph Network Stations (NHNS) stations in the district. These NHNS are measured four times in a year viz., January, May (Pre-monsoon), August and November (Post-monsoon). For the present study, static water level data for the 65 stations (BM) / villages in 14 talukas of the Pune district were obtained from Groundwater Survey and Development Agency (GSDA), Pune for the period of 2001 to 2012 for May and October.

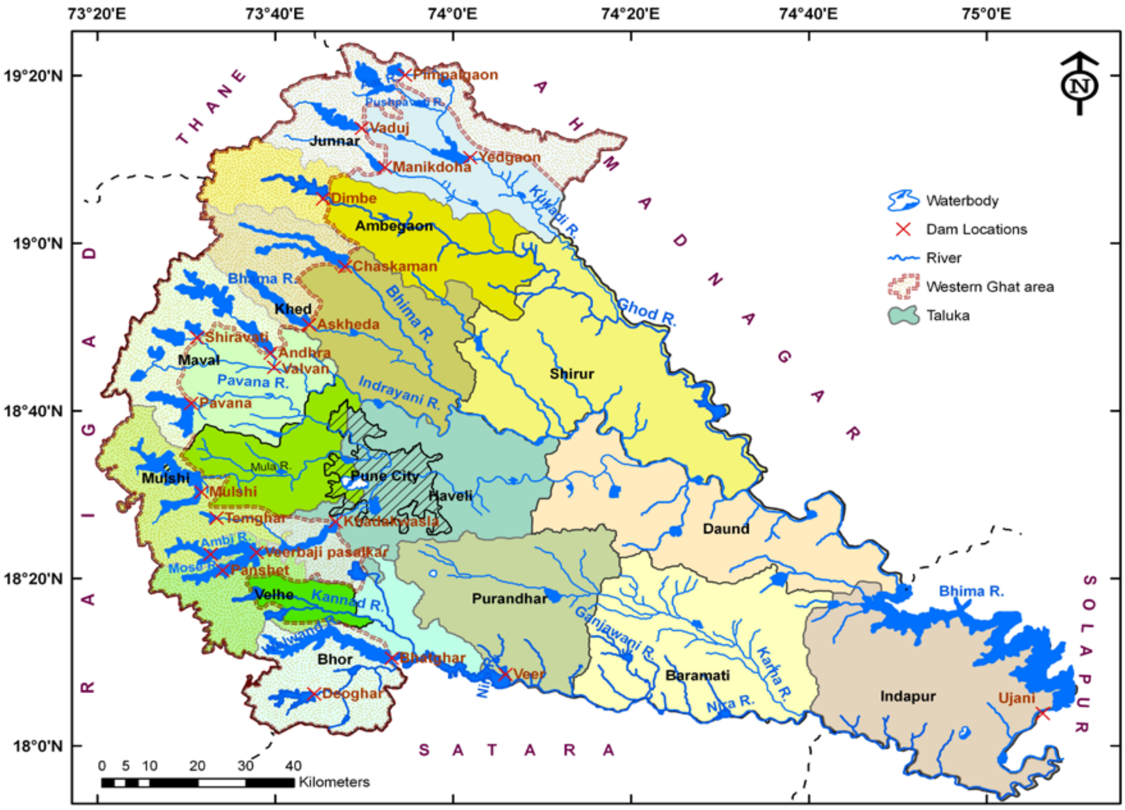

FIG.1: PUNE DISTRICT MAP SHOWING TALUKAS AND MAJOR RIVER SYSTEM

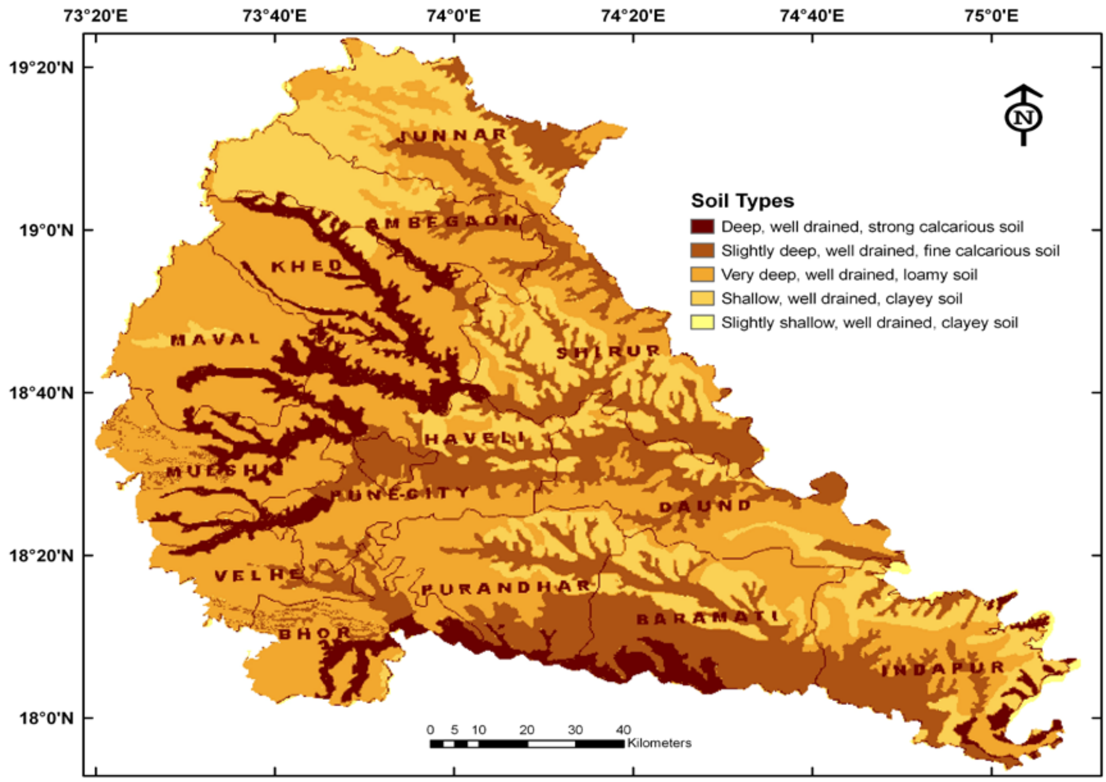

FIG. 2: SOIL TYPES IN THE PUNE DISTRICT (SOURCE: MPCB REPORT, CHAPTER II, 2008)

Methodology

a) On the basis of all the available daily rainfall data, a homogeneous set of rainfall data was prepared excluding all the outliers. This data formed the data base for further analysis. Using this data, average monthly, seasonal and annual rainfall was estimated along with the wet and dry days during the twelve year period for all the talukas of the Pune district.

b) The daily rainfall data was subjected to quality check to remove the outliers in the data sets using extreme rainfall series. All the daily extreme rainfall values for individual stations that differed from their corresponding long-term means by more than 5σ (as extreme rainfall series are positively skewed) was listed and manually examined. Spatial patterns of Coefficient of Variations (CVs) were also considered to compare the variability in extreme rainfall of neighbouring stations to determine whether they can be considered as outliers. Whether such values can be treated as outliers or not were determined by examining the synoptic situations of that day. The outliers so identified were flagged off as missing values and appropriate care had been taken for further computations.

c) Groundwater data were arranged for pre-monsoon and post-monsoon periods and the average, maximum and minimum static water level at village and taluka level were estimated and represented graphically as well as spatially. Well inventory was carried out for the generation of water level fluctuation map within the district. Details of numbers of watersheds in different villages of all the 14 talukas of Pune district are shown in Fig.6.

Rainfall Climatology

Owing to the geographical conditions within the Pune district, it is seen that the rainfall is unevenly distributed in the district. The western part of the district is a hilly area having forest cover, due to which the rainfall intensity is more in this area than the eastern parts. Most of the rain is brought by the southwest monsoon disturbances originating in the Bay of Bengal during the summer monsoon months (Jun-Sept). Monsoon sets in over the district by about 10 June and withdraws by about 1 October comprising of 113 to 115 days. Maximum rainfall is observed during the monsoon months of July and August. The mean monthly, seasonal and annual rainfall distribution for the 2001 to 2012 over the Pune district are given in Table 1 and its spatial distribution is shown in Fig.3. It is seen from Table 1 and Fig.3 that about 90% to 99% of the annual rainfall is received during June to October. Therefore, October also contributes substantial rainfall to the annual total. The lowest mean annual rainfall is recorded by the Baramati (80%) and the highest (96%) by the Velhe Taluka. Depending upon the annual rainfall received, talukas are classified into four major zones (Table 2).

TABLE 1: AVERAGE MONTHLY, SEASONAL AND ANNUAL RAINFALL FOR THE 14 TALUKAS IN THE PUNE DISTRICT (2001 - 2012)

	Talukas													
Months / Season	Velhe	Mulshi	Maval	Bhor	Haveli	Pune	Purandar	Junnar	Ambegaon	Khed	Shirur	Daund	Baramati	Indapur
January	1.0	2.2	0.8	0.6	2.0	2.8	0.4	0.0	2.2	3.2	0.2	0.6	1.4	1.1
February	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	0.0	0.0	0.0	0.0	0.0	0.8	0.5	0.0	5.3	0.0	0.0	0.0	0.0	0.0
April	4.3	18.9	12.6	11.4	0.0	7.7	1.8	11.3	14.2	13.7	0.0	0.0	0.0	0.0
May	30.2	16.8	14.5	34.0	16.6	29.9	9.4	7.8	2.4	17.2	5.6	17.4	30.6	34.4
June	547.4	275.9	271.2	251.4	175.3	176.5	139.7	140.1	144.0	166.9	87.9	94.9	85.4	106.4
July	939.9	614.0	446.8	359.8	196.3	175.5	143.4	212.6	198.9	157.4	73.8	65.6	72.6	77.6
August	720.4	561.3	421.3	309.3	206.1	193.7	125.3	207.6	201.2	150.1	114.0	82.1	68.5	101.6
September	369.1	232.1	212.2	150.9	158.4	149.3	170.2	181.9	152.9	153.4	163.6	145.4	177.1	174.3
October	79.2	81.6	81.4	76.1	98.2	90.8	79.6	65.6	68.0	75.9	58.4	68.0	73.6	68.0
November	36.7	66.3	52.0	46.1	36.6	34.8	32.3	37.3	68.5	56.8	69.5	16.3	21.0	25.9
December	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
June-October	2656.0	1792.2	1432.8	1147.5	829.6	746.9	658.3	807.6	765.0	703.6	497.7	456.0	477.3	527.9
Nov- May (next yr)	35.7	52.4	40.5	47.8	31.4	28.8	22.2	28.7	46.5	46.9	41.4	24.0	24.7	30.9
Annual	2691.7	1815.1	1474.0	1199.8	865.8	832.3	681.2	836.4	811.5	750.5	538.2	479.3	503.3	561.3
Season rainfall as % of Annual rainfall														
June-October	99	99	97	96	96	90	97	97	94	94	92	95	95	94
Nov-May (next yr)	1	3	3	4	4	3	3	3	6	6	8	5	5	6

TABLE 2: RAINFALL INTENSITY ZONES IN THE PUNE DISTRICT

Type of zones	Annual and seasonal rainfall range (mm)	Talukas
Less to moderate rainfall	< 500 mm to 1000 mm	Haveli, Pune city, Purandar, Junnar, Ambegaon, Khed, Shirur, Daund, Baramati, Indapur
Heavy rainfall	1000 mm to 1500 mm	Maval, Bhor
Very heavy rainfall	1500 mm to 2500 mm	Mulshi
Highest rainfall	> 2500 mm	Velhe

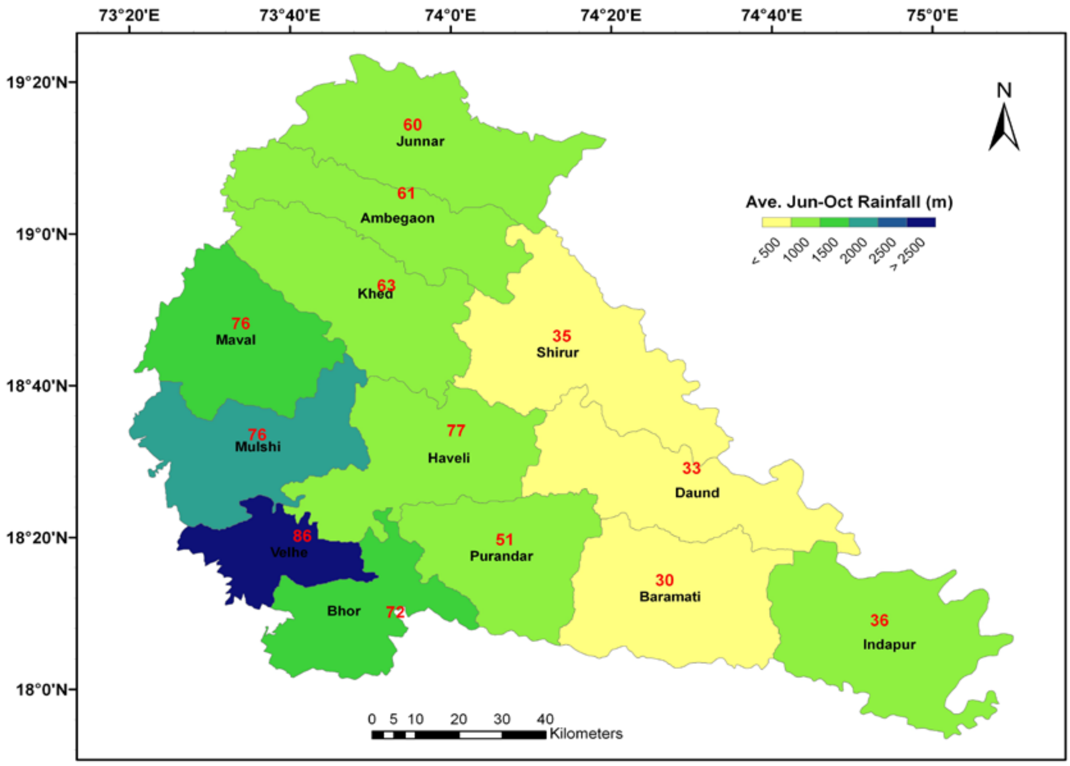

FIG.3: AVERAGE JUN-OCT RAINFALL OVER THE PUNE DISTRICT (2001-2012)
(FIGURES IN RED INDICATE NUMBER OF RAINY DAYS)

Wet and Dry Spells

Estimation of extreme wet and dry weather conditions on the basis of daily rainfall distinguishes the most drastic periods and trends of the rainfall region in the Pune district. The simplest definition of a dry day is zero precipitation while a wet day is a day with precipitation surpassing a certain threshold, which depends on the climate conditions of the observed area. It is seen that average Jun-Sept rainfall over different talukas increases up to 2006 monsoon season and thereafter there is noteworthy decrease in the rainfall activity. No. of wet days (75 to 90) are more in case of Maval, Mulshi, Velhe, Bhor and Haveli talukas whereas No. of dry days (87 to 93) are more in Shirur, Daund, Baramati and Indapur talukas. In case of Junnar, Ambegaon, Khed and Purandar talukas number of wet days are to the higher side in the years 2005, 2006 and 2007 and then there is increase in dry days. During the severe drought year of 2009, all the talukas recorded high number of dry days. Numbers of extreme dry days are recorded mostly in June and extreme wet days are recorded in July and August when there is good monsoon rainfall activity (Table 3).

TABLE 3: COMPARISON OF EXTREME WET AND DRY DAYS AND AVERAGE RAINFALL DURING THE MONSOON SEASON

Talukas	Extreme wet		Extreme dry		Rainfall
	Days	Month	Days	Month	(mm)
Velhe	31	Jul+Aug	23	Jun	2576.8
Mulshi	29	Aug	25	Jun	1683.3
Maval	31	Jul	24	Jun	1351.4
Bhor	31	Jul+Aug	24	Jul	1071.4
Haveli	30	Aug	25	Jun	731.4
Pune	30	Aug	25	Jun	670.5
Purandar	29	Jul	27	Jul	578.6
Junnar	27	Aug	27	Jun	742.0
Ambegaon	29	Jul	29	Jun	697.0
Khed	27	Jul+Aug	26	Jun	627.8
Shirur	16	Jul	30	Jun	439.4
Daund	15	Jul	29	Jul	388.0
Baramati	15	Aug	30	Jun+Jul	398.9
Indapur	16	Jul	28	Jun+Jul	459.9

It is noticed that the number of wet days during the monsoon season (Jun-Sept.) varies from >20% in Velhe, Maval, Mulshi, Bhor, Haveli talukas to <10% in Shirur, Daund, Baramati talukas. During non-monsoon period (Oct-May) all the talukas show hardly 2% wet days. It is also seen that the number of dry days during the monsoon season (Jun-Sept) is >20% in the talukas of Purandar, Shirur, Daund, Banaramati, Indapur and is <12% in Velhe, Maval, Mulshi, Bhor, Haveli talukas. For rest of the talukas, dry days during monsoon season vary between 10%-20%. Therefore, overall, the number of dry days is more than the wet days which is the basic reason for decline in ground water level.

In view of the above rainfall analysis, annual and seasonal variations of the ground water level in each of the talukas have been studied.

Groundwater Analysis

The ground water behavior in the district is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. The influencing factors on the groundwater level are: water source, well pumping, vertical discharge, river flow change, underground runoff recharge and dams in upper reaches of the rivers. The groundwater level dynamics near the river is limited by the river feeding width. It is associated with regional hydrology and geology, river way run-off, time of water passage, peak flow, etc. The peak river flow is in July, and the flood subsides in August. The water stored at the river bank then recharges the aquifer. And the groundwater is recovered and reaches peak level in February and March. The groundwater is recharged periodically by the river water and is dependent on the river flow. The groundwater level is at wave through when the river flow is at wave crest.

Hydrogeology of the Pune District

The entire area of the district is underlain by the basaltic lava flows (> 95%) of upper Cretaceous to lower Eocene age. The shallow alluvial formation of recent age also occurs as narrow stretch along the major rivers flowing in the area. A map depicting the hydrogeological features is shown Fig.4. The water bearing properties of these flows depends upon the intensity of weathering, fracturing and jointing which provides availability of open space within the rock for storage and movement of ground water.

The ground water in the district occurs under phreatic, semi – confined and confined conditions. Generally the shallower zones down to the depth of 20 to 22 m bgl (below ground level) form the phreatic aquifer. The water bearing zones occur between the depth 20 and 40 m bgl when weathered or having shear zones yield water under semi-confined condition. The deep confined aquifers generally occur below the depth of 40 m bgl.

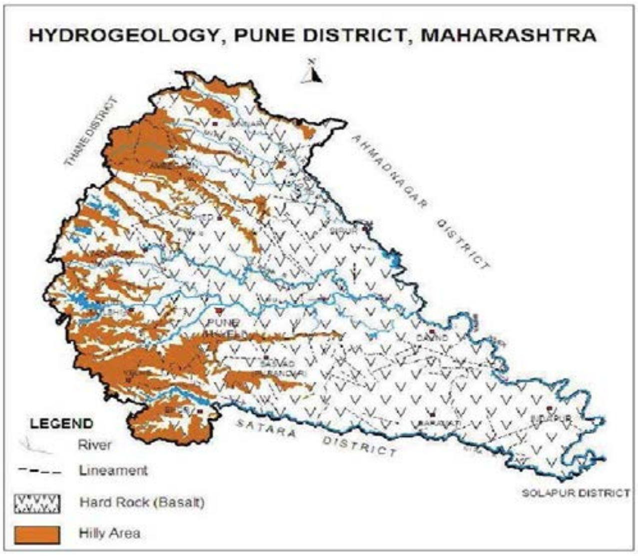

FIG.4: HYDROGEOLOGY OF THE PUNE DISTRICT (COURTESY: CGWB, GOVT. OF INDIA, 2009)

Groundwater Level Fluctuations

The groundwater level fluctuation is controlled by recharge and draft of groundwater and the diverse influences on groundwater levels including meteorology, tidal phenomena, urbanization, earthquakes and external loads, stress and strain in water level due to groundwater recharge, discharge and intensity of rainfall are reflected in groundwater level fluctuation with time (Gopinath & Seralathan., 2008).

As mentioned in Section 3, the static water level data have been used for groundwater analysis obtained from GSDA for pre-monsoon (May) and post-monsoon (October) for 65 observatory wells (see Fig.6) in all the 192 villages of Pune district.

Depth to Water Level – Pre-monsoon (May)

The pre-monsoon depth of water levels monitored during May range between 0.40 m bgl (May 2008, Venavadi, Bhor) and 32.40 m bgl (May 2004, Dive, Purandar). The average depth to water levels of all the talukas during pre-monsoon has been depicted in Fig.5 and 6.

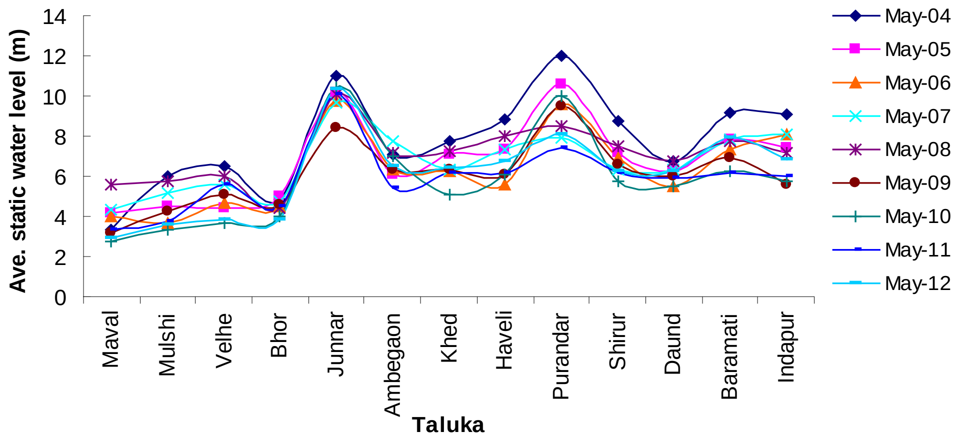

FIG.5: AVERAGE STATIC WATER LEVEL (M) FOR DIFFERENT TALUKAS DURING MAY 2004-2012

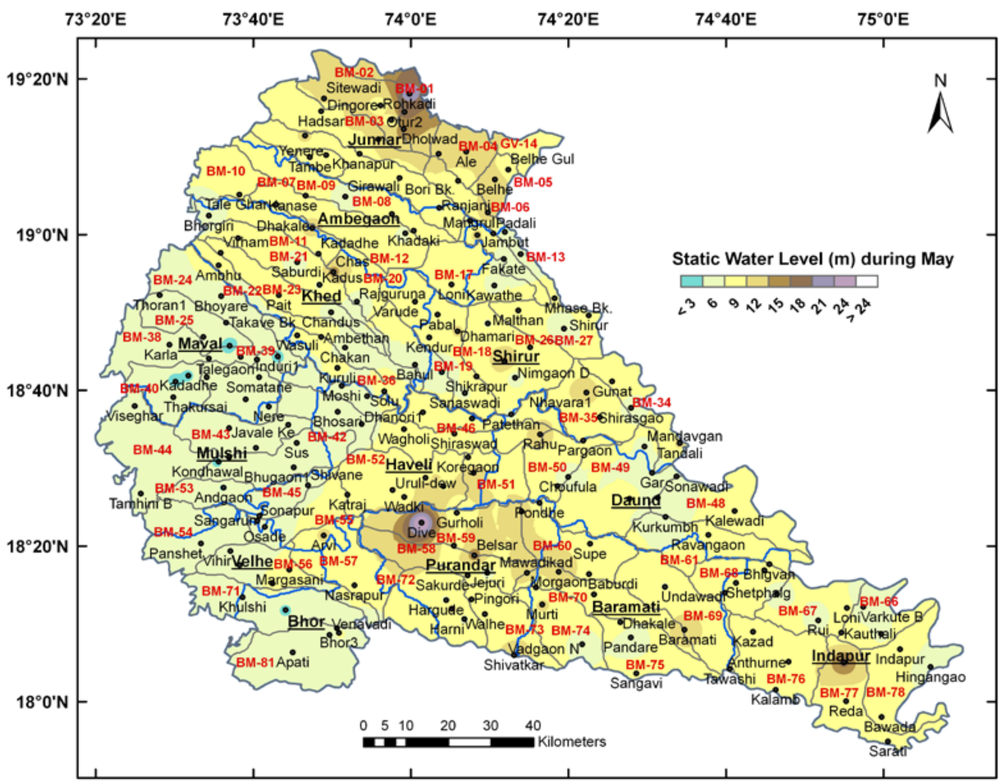

FIG.6: STATIC WATER LEVEL (M) RECORDED BY VILLAGES DURING MAY (NOTE : BM-1 INDICATE WATERSHED NO. IN BHIMA (BM) BASIN)

It is observed from these figures that in major parts of the district the water levels are within 5 m bgl in almost entire western part and south eastern part of the district. The water levels in the range of 5 to 10 m bgl are observed in central, eastern and north eastern parts of the Pune district. The average deeper water levels more than 10m bgl have been observed around Rohkadi village (Junnar, 20.8m) in northern part of the district whereas at Kondhapuri village (Shirur, 12.9m) in east and Dive village (Purandar, 24.7m), Nimbgaon Ketki (Indapur, 15.6m) in south eastern part of the district.

The frequencies of static water level experienced during May in different villages of all the Talukas are given in Table 4. It was seen that about 50 villages recorded ≥ 10 m deep water level during 2001 to 2012 period and they were located mainly in the northern, middle and eastern parts of the district excluding Bhor, Maval, Mulshi, Velhe talukas. As mentioned earlier, the water level of Dive village in Purandar taluka (32.40 m bgl in May 2004) and Rohkadi village (23.9 m bgl in May 2005) in Junnar taluka went very deep, almost reaching bottom of the well. This was mostly due to less rainfall received during the monsoon season of the respective years.

TABLE 4: FREQUENCY OCCURRENCE OF AVERAGE STATIC WATER LEVEL (M) DURING MAY

Taluka	Average Static water level range (m) / No. of villages				
	Upto 5	5-10	10-15	15-20	>20
Maval	15	1			
Mulshi	6	5			
Velhe	3	3			
Bhor	5	2			
Junnar		13	5	1	1
Ambegaon	2	8	1		
Khed	5	12	1		
Haveli	4	14	1		
Purandar	1	10	3		1
Shirur	6	17	2		
Daund	3	8	1		
Baramati	2	8	2		
Indapur	4	15		1	

Depth to Water Level – Post-monsoon (October)

The depth of water level during post-monsoon is between lowest of 0.00 m bgl (Ranjangaon, Shirur) and maximum 13.2m bgl (Rohkadi, Junnar) (see Fig.7 & 8). The water levels between 2 and 5m bgl have been observed in major parts of the district in the south, south eastern, central and north western parts occupying almost entire Purandar, Bhor, Mulshi, Maval and Khed talukas and parts of Daund, Baramati, Velhe and Shirur talukas. The water levels between 5 to 10m bgl are mainly seen in three isolated pockets i.e., in northern, central and south eastern parts of the district in parts of Junnar, Ambegaon, Haveli, Daund and Indapur talukas. Very shallow water levels of less than 2 m bgl are observed in isolated patch in central and eastern part of the district.

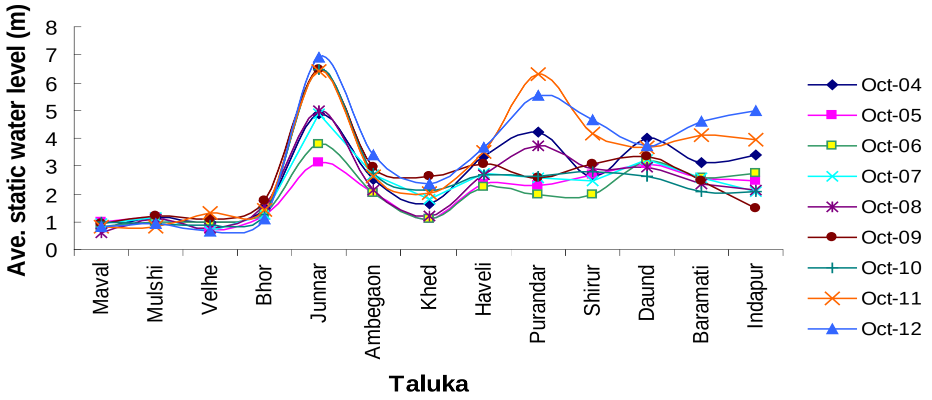

FIG.7: AVERAGE SSTATIC WATER LEVEL (M) FOR DIFFERENT TALUKAS DURING OCT. 2004-2012

FIG. 8: STATIC WATER LEVEL (M) RECORDED BY VILLAGES DURING OCTOBER

TABLE 5: FREQUENCY OCCURRENCE OF AVERAGE STATIC WATER LEVEL (M) DURING OCTOBER

Taluka	Average Static water level range (m) / No. of villages			
	Up to 2	2-5	5-10	>10
Maval	15	1		
Mulshi	9	2		
Velhe	6			
Bhor	6	1		
Junnar	5	8	5	2
Ambegaon	5	5	1	
Khed	13	4	1	
Haveli	8	8	3	
Purandar	2	9	4	
Shirur	7	16	2	
Daund	1	10	1	
Baramati	5	6	1	
Indapur	7	11	2	

As observed, Kolamb (Ambegaon), Morgaon (Baramati), Rahu (Daund), Kohdhapuri (Shirur), Belsar and Parinche (both of Purandar) and Rohkadi (Junnar) villages have shown decrease in water depth even >13 m during post monsoon month of October. This indicates that these villages receive very less rainfall during the monsoon months resulting in less infiltration. The frequency of villages in different static water level range (see Table 5) show that decrease in water depth is highest in Otur and Rohkadi villages of Junnar taluka. In case of Purandar, Baramati, Shirur, Daund and Indpaur talukas water level goes > 6 m deep even after the monsoon season.

Annual Water Level Fluctuation

The above analysis shows that water depth during pre-monsoon month of May falls drastically which results in severe groundwater depletion. During post-monsoon month of October, although there is an increase in water level, there are villages in the district who suffer from scarcity of water level. Therefore, an attempt has also been made to know the exact rise and fall of the water level.

Annual Water Level Fluctuation (viz. Current Year May to Next Year May)

A comparison between depths to water level during Pre Monsoon of one year with Pre Monsoon of next year (Fig.9) reveals that in general, there is declines in the water levels almost in all the talukas especially talukas in central and eastern part of the district. Most of the wells have shown falls of water level in the range of 0-2 m. However, falls in water level >2 m have also been observed in Ambegaon, Junnar, Khed, Baramati, Shirur, Purandar, Daund, Haveli and Indapur talukas where more than 40% wells are recorded > 2m falls in water level.

Perusal of groundwater level data during the pre-monsoon month of May indicates that generally the depths of water level vary from 2-6 m (bgl). Isolated pockets of shallow water level <2 m bgl have also been observed in west (see Fig.9). In northwestern part of Purandar taluka, eastern parts of Junnar and Shirur taluka, depths of water level generally are found to range from 10-20 m bgl.

Out of 192 monitored wells, about 78% wells show rise and 65% wells show fall in water level <2 m bgl (see Table 6), 22% wells show rise and 31% wells show fall in water level in the depth range of 2-4 m bgl, 9% wells show rise and 15% wells show fall in water level in the depth range of 4-6 m bgl, 6% wells show rise and 4% wells show water level more than 6 m bgl mostly in Junnar and Purandar talukas.

TABLE 6: TALUKAWISE ANNUAL FLUCTUATION IN WATER LEVEL AND FREQUENCY DISTRIBUTION OF DIFFERENT RANGES PRE-MONSOON (MAY)

Taluka	No. of wells analysed	Range (m)				Rise (m)								Fall (m)							
		Rise		Fall		0 - 2		2 - 4		4 - 6		>6		0 - 2		2 - 4		4 - 6		>6	
		Max	Min	Max	Min	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Ambegaon	11	3.88	0.76	3.93	0.24	8	73	3	27					7	64	4	36				
Baramati	12	3.05	0.28	3.57	0.42	9	75	3	25					8	67	4	33				
Bhor	7	2.14	0.65	2.39	0.59	6	86	1	14					6	86	1	14				
Daund	12	2.50	0.45	2.87	0.59	11	92	1	8					8	67	4	33				
Haveli	19	4.80	0.40	3.90	0.43	11	58	7	37	1	5			10	53	9	47				
Indapur	20	2.48	0.05	5.08	0.78	18	90	2	10					14	70	4	20	2	10		
Junnar	20	5.07	0.45	4.69	0.76	12	60	7	35	1	5			8	40	11	55	1	5		
Khed	18	2.83	0.65	3.12	0.63	13	72	5	28					13	72	5	28				
Maval	16	2.12	0.45	2.70	0.57	14	88	2	13					13	81	3	19				
Mulshi	11	2.70	0.35	4.03	0.76	10	91	1	9					8	73	2	18	1	9		
Purandar	15	7.97	0.00	5.36	0.44	9	60	5	33			1	7	8	53	4	27	3	20		
Shirur	25	4.83	0.50	6.05	0.68	17	68	6	24	2	8			14	56	10	40			1	4
Velhe	6	4.28	0.48	4.54	0.53	5	83			1	17			4	67			2	33		

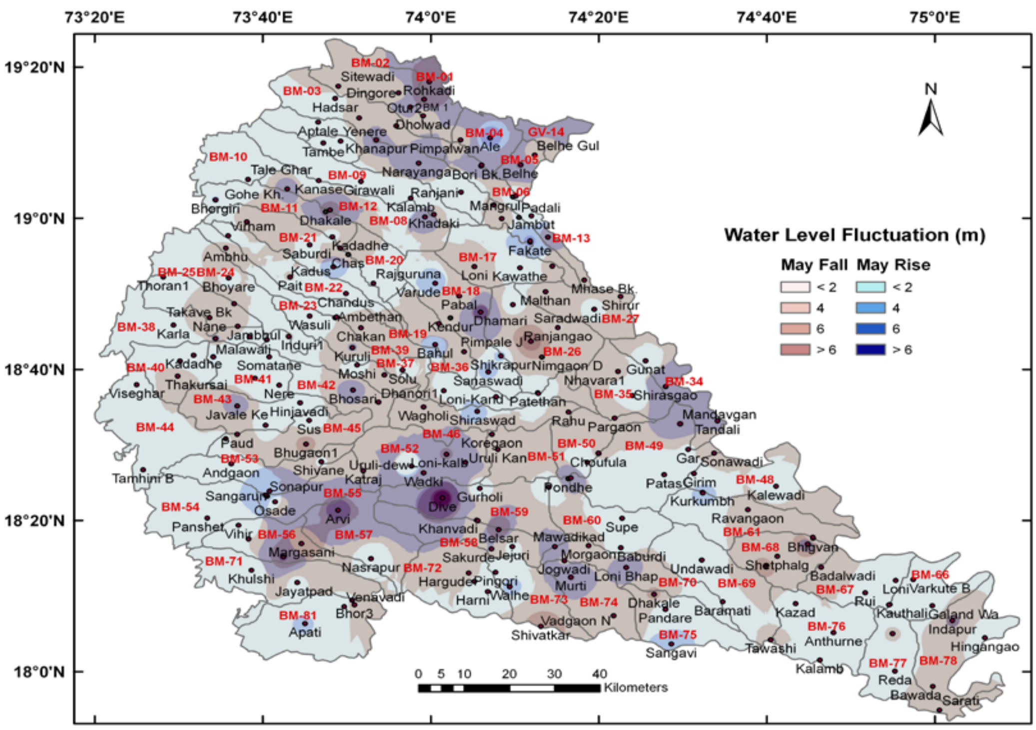

FIG.9: WATER LEVEL FLUCTUATION DURING PRE-MONSOON MONTH OF MAY

TABLE 7: TALUKAWISE ANNUAL FLUCTUATION IN WATER LEVEL AND FREQUENCY DISTRIBUTION OF DIFFERENT RANGES POST-MONSOON (OCTOBER)

Taluka	No. of wells analysed	Range (m)				Rise (m)								Fall (m)			
		Rise		Fall		0 - 2		2 - 4		4 - 6		> 6		0 - 2		2 - 4	
		Max	Min	Max	Min	No	%	No	%	No	%	No	%	No	%	No	%
Ambegaon	11	2.32	0.28	0.99	0.15	10	91	1	9					11	100		
Baramati	12	2.50	0.49	1.92	0.12	8	67	4	33					12	100		
Bhor	7	1.53	0.21	0.96	0.16	7	100							7	100		
Daund	12	2.18	0.58	1.80	0.60	11	92	1	8					12	100		
Haveli	19	2.37	0.17	2.31	0.28	18	95	1	5					17	89	2	11
Indapur	20	2.94	0.54	1.94	0.20	16	80	4	20					20	100		
Junnar	20	4.22	0.49	3.28	0.40	14	70	5	25	1	5			15	75	5	25
Khed	18	8.64	0.08	2.33	0.06	16	89	1	6			1	6	17	94	1	6
Maval	16	0.92	0.11	0.86	0.17	16	100							16	100		
Mulshi	11	0.88	0.06	0.98	0.04	11	100							11	100		
Purandar	15	4.11	0.31	3.33	0.10	11	73	2	13	1	7			11	73	4	27
Shirur	25	4.39	0.26	2.63	0.06	23	92	1	4	1	4			22	88	3	12
Velhe	6	1.10	0.11	1.23	0.33	6	100							6	100		

Annual Water Level Fluctuation (viz. Current Year October to Next Year October)

Analysis of the ground water level data for the October month indicates noteworthy increase in water level along the western region of the district. About 88% wells show water level rise and 94% wells show fall in water level in the depth range of 0-2 m bgl (Table 7), 14% wells show rise in water and 16% wells show fall in the water level in the range of of 2-4 m bgl, 5% wells show rise in water level in the range of 4-6 m bgl, 6% wells show fall in water level more than 6 m (see Fig.10) indicating that eastern part faces water scarcity even after the monsoon.

Seasonal Water Level Fluctuation (May to October)

A comparison of average depths to water level during Pre Monsoon month of May with Post monsoon Month of October reveals that in general, there is rise in the water level in most parts of the talukas except in Junnar, northwestern parts of Ambegaon and Purandar, western and eastern parts of Baramati and Indapur talukas (see Fig.11). Most of the wells have been showing rise of water level in the range of >5 m range (see Table 8).

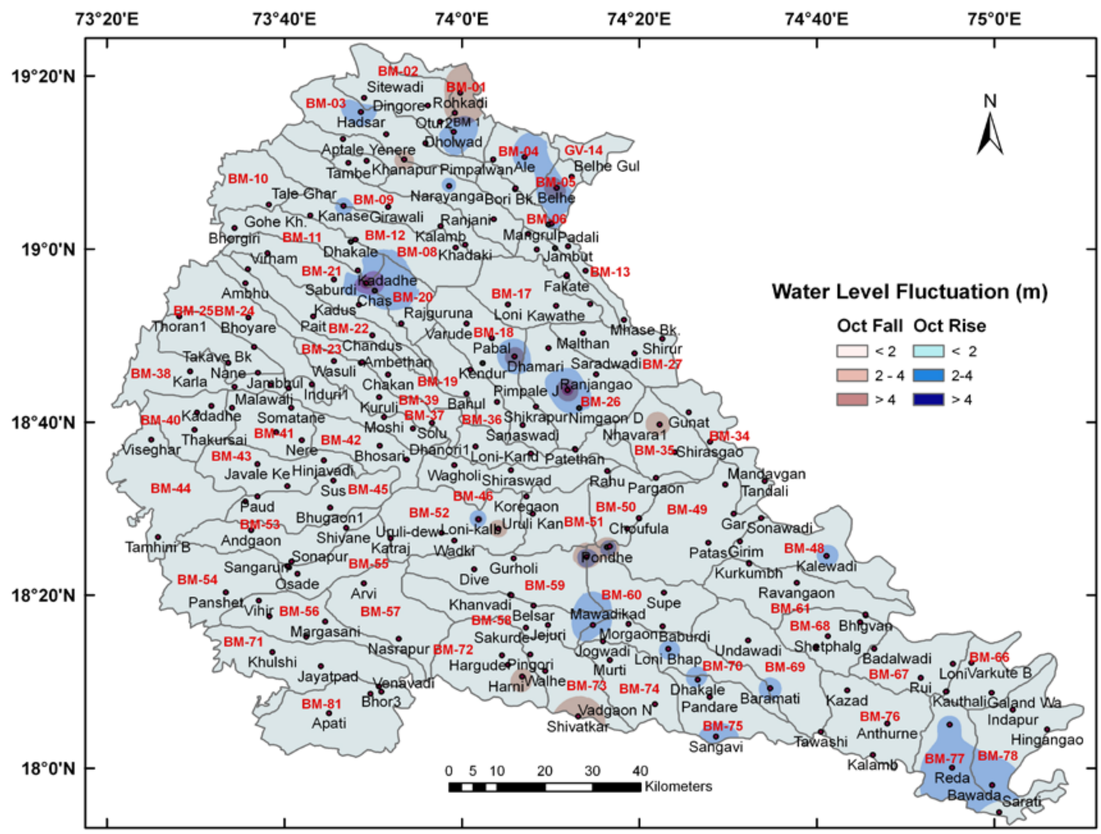

FIG.10: WATER LEVEL FLUCTUATION DURING POST-MONSOON MONTH OF OCTOBER

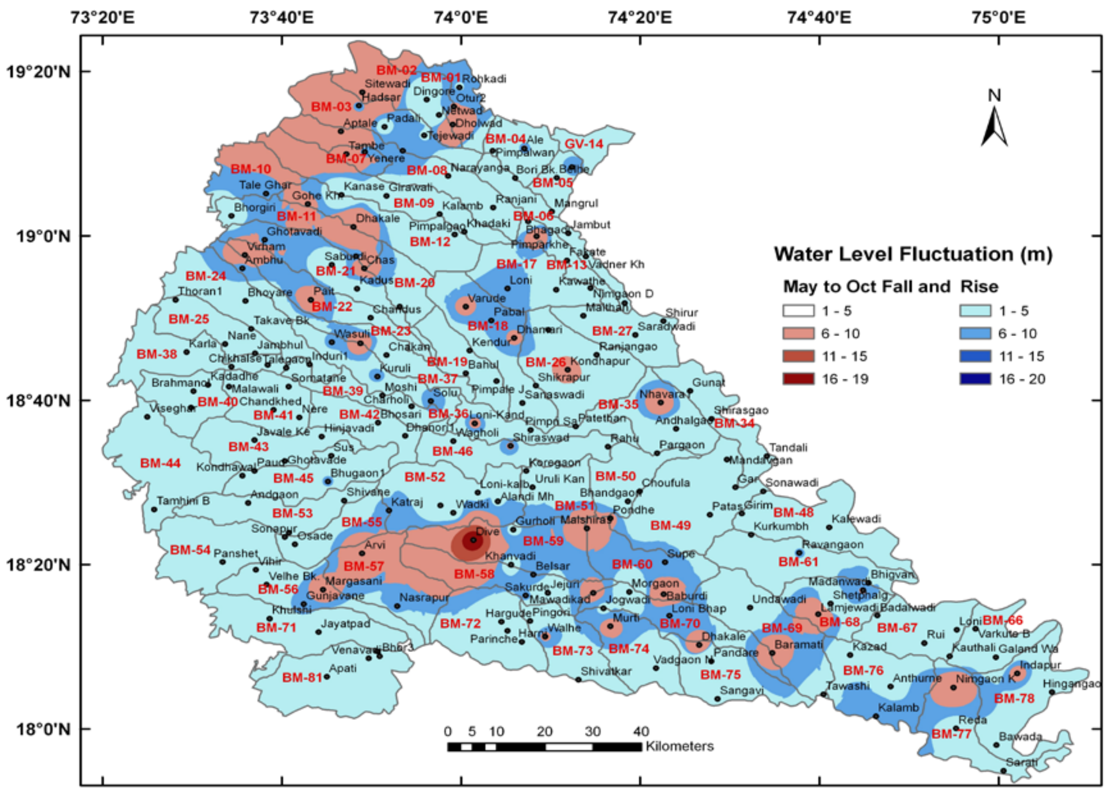

FIG.11: AVERAGE SEASONAL WATER LEVEL FLUCTUATION FROM MAY TO OCTOBER

TABLE 8: TALUKAWISE SEASONAL FLUCTUATION IN WATER LEVEL AND FREQUENCY DISTRIBUTION OF DIFFERENT RANGES (MAY TO OCTOBER)

Taluka	No. of wells analysed	Range (m)				Rise (m)						Fall (m)					
		Rise		Fall		< 5		5 -10		> 10		<5		5 -10		>10	
		Max	Min	Max	Min	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Ambegaon	11	9.0	0.7	9.1	0.9	7	64	4	36			7	64	4	36		
Baramati	12	7.5	2.2	7.7	1.6	6	50	6	50			8	67	4	33		
Bhor	7	5.0	1.7	5.0	1.7	6	86	1	14			6	86	1	14		
Daund	12	5.1	1.4	4.4	1.1	11	92	1	8			12	100				
Haveli	19	7.9	1.4	7.5	1.2	15	79	4	21			15	79	4	21		
Indapur	20	10.8	1.7	8.8	1.8	15	75	4	20	1	5	16	80	4	20		
Junnar	20	8.7	2.7	9.1	2.8	12	60	8	40			10	50	10	50		
Khed	18	8.2	2.7	7.3	2.3	7	39	11	61			7	39	11	61		
Maval	16	4.5	1.5	4.6	1.6	16	100					16	100				
Mulshi	11	5.2	1.9	5.0	1.7	9	82	2	18			10	91	1	9		
Purandar	15	19.9	2.8	19.1	2.1	7	47	7	47	1	7	9	60	5	33	1	7
Shirur	25	8.0	1.4	7.7	1.2	18	72	7	28			19	76	6	24		
Velhe	6	7.2	2.5	6.9	2.3	4	67	2	33			4	67	2	33		

Rise in water level < 2 m and 2 to 5 m has also been observed. Decline in water level in the range of 0-5 m and 5-10 m is observed in Junnar, Ambegaon, Purandar, Indapur talukas. About 70% wells show rise in water level, out of which 33% wells show rise in water level less than 5 m. About 30% wells show rise in water level in 5-10 m range and only 5% wells show rise in water level more than 10 m. About 73% wells show decline in water level, out of which 30% wells show decline in water level in less than 5 m range. This is mostly due to two severe drought years of 2002 and 2009 during which the district received very less rainfall hence over usage of groundwater declined the water levels in the wells.

Decadal Water Level Fluctuation (2001-10 with 2011-12)

A comparison of depth to water level during Pre Monsoon month of May 2011-2012 with decadal mean Pre Monsoon May (2001-2010) reveals (see Table 9) that there is prominent decline in the water level in the two talukas, viz. Junnar (-0.61 m) extreme northern taluka and Purandar (-0.46 m) extreme southern taluka. Remaining talukas showed increase in water level ranging between 0.14 m (Daund) and 2.47 m (Shirur).

TABLE 9: COMPARISON OF AVERAGE GROUNDWATER LEVEL OF 2001-2010 DECADE WITH 2011-2012 YEAR

Depletion of Ground Water Level (May)						Depletion of Ground Water Level (Oct)		
Sr. No.	Name of Taluka	Total No. of observation wells	Decadal average (m) 2001-2010	Ave. of 2011-2012 (m)	(+) increase (-) decrease in water level compared with 2001-2010 decade to may 2011-2012(m)	Decadal average (m) 2001-2010	Ave. of 2011-2012 (m)	(+) increase (-) decrease in water level compared with 2001-2010 decade to may 2011-2012(m)
1	2	3	4	5	6	4	5	6
1	Ambegaon	11	6.99	5.93	1.06	2.43	3.02	-0.59
2	Baramati	12	7.74	6.92	0.81	2.65	4.36	-1.71
3	Bhor	7	4.53	4.16	0.38	1.51	1.24	0.27
4	Daund	12	6.22	6.07	0.14	3.45	3.69	-0.24
5	Haveli	19	6.82	6.46	0.37	2.82	3.58	-0.76
6	Indapur	20	7.69	6.40	1.28	2.73	4.47	-1.74
7	Junnar	20	9.60	10.21	-0.61	4.61	6.64	-2.02
8	Khed	18	6.78	6.29	0.48	1.58	2.18	-0.60
9	Mawal	16	3.81	3.10	0.71	0.87	0.82	0.04
10	Mulshi	11	4.73	3.67	1.05	1.21	0.87	0.34
11	Purandhar	15	8.43	8.89	-0.46	3.22	5.86	-2.65
12	Shirur	25	8.68	6.21	2.47	3.15	4.41	-1.26
13	Velhe	6	5.25	4.72	0.52	0.89	0.98	-0.09
		Avg.	**6.71**	**6.08**	**0.63**	**2.39**	**3.24**	**-0.85**

A comparison of depth to water level of October 2011-2012 with decadal mean October (2001-2010) reveals that there is decline in the water level in all the talukas except Bhor, Maval and Mulshi talukas wherein there is very minute increase in water level. The remaining talukas show decrease in water level in the range of -0.09 m (Velhe) to -2.65 m (Purandar). This shows that Junnar and Purandar talukas are suffering from continuous scarcity of water during the last 12 years.

Categorization of Groundwater Level

The dynamic ground water resources are also known as Annual Replenishable Ground Water Resources since is replenished/ recharged every year. Considering the overall contribution of rainfall to the district and relative groundwater levels, the groundwater assessment figures are computed for the month of May and October. The criteria followed for categorization of villages is –

Category	Safe	Semi-critical	Critical	Over Exploited
Fall in Water level depth (m) (May)	< 5 m	5 – 10 m	10 – 15 m	> 15 m
Fall in Water level depth (m) (October)	< 5 m	5 – 10 m	> 10 m	-

Pre-monsoon Month of May

Out of 192 villages, 4 villages are over exploited, 16 villages are critical, 116 villages are semi-critical and 56 villages are safe (Table 10). It is seen that none of the village is safe in Junnar taluka and only 1 village (i.e.Jejuri) is safe in Purandar Taluka (Fig.11). More than 50% talukas are reeling under semi-critical condition and 8% talukas are under critical condition. About 50% to 94% villages in Bhor, Velhe, Maval, Mulshi talukas are found to be safe as these talukas fall in the high rainfall zone. It is also seen that 2 villages in Junnar taluka (viz. Otur and Rohakadi) and one each in Purandar (i.e. Dive) and Indapur (i.e. Nimgaon) talukas are over exploited (see Fig.11).

Post-monsoon Month of October

The scenario is changed during the month of October and out of 192 villages, only 2 villages are over exploited, but 20 villages are critical, 81 villages are semi-critical and 89 villages are safe. Although 50% villages are found to be safe, 40% villages are under semi-critical and 9% under critical condition (see Table 10). Otur and Rohkadi, the two villages in Junnar talukas are still over exploited indicating that these villages are suffering from drought condition during the last 12 years period (See Fig.12).

It is observed that by the month of May, the water level declines to 10 m. Although there is substantial amount of rainfall in the south eastern region where the water level is near surface conditions during October, the average depth to water level is also deepened by the month of May. This may be due to the hard rock terrain in the region which does not allow water to infiltrate into the deeper aquifer zones, and hence most of the water escapes as runoff and partially gets absorbed into the ground to sustain shallow aquifers.

TABLE 10: CATEGORIZATION OF VILLAGE WATERSHEDS IN PUNE DISTRICT

Talukas	Total No. of assessed units	May								October							
		Safe		Semi Critical		Critical		Over Exploited		Safe		Semi Critical		Critical		Over Exploited	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Ambegaon	11	2	18	8	73	1	9	0	0	5	45	5	45	1	9	0	0
Baramati	12	2	17	8	67	2	17	0	0	5	42	6	50	1	8	0	0
Bhor	7	5	71	2	29	0	0	0	0	6	86	1	14	0	0	0	0
Daund	12	3	25	8	67	1	8	0	0	1	8	10	83	1	8	0	0
Haveli	19	4	21	14	74	1	5	0	0	8	42	8	42	3	16	0	0
Indapur	20	4	20	14	70	0	0	1	5	7	35	10	50	2	10	0	0
Junnar	20	0	0	13	65	5	25	2	10	5	25	8	40	5	25	2	10
Khed	18	5	28	12	67	1	6	0	0	13	72	4	22	1	6	0	0
Maval	16	15	94	1	6	0	0	0	0	15	94	1	6	0	0	0	0
Mulshi	11	6	55	5	45	0	0	0	0	9	82	2	18	0	0	0	0
Purandar	15	1	7	10	67	3	20	1	7	2	13	9	60	4	27	0	0
Shirur	25	6	24	17	68	2	8	0	0	7	28	16	64	2	8	0	0
Velhe	6	3	50	3	50	0	0	0	0	6	100	0	0	0	0	0	0

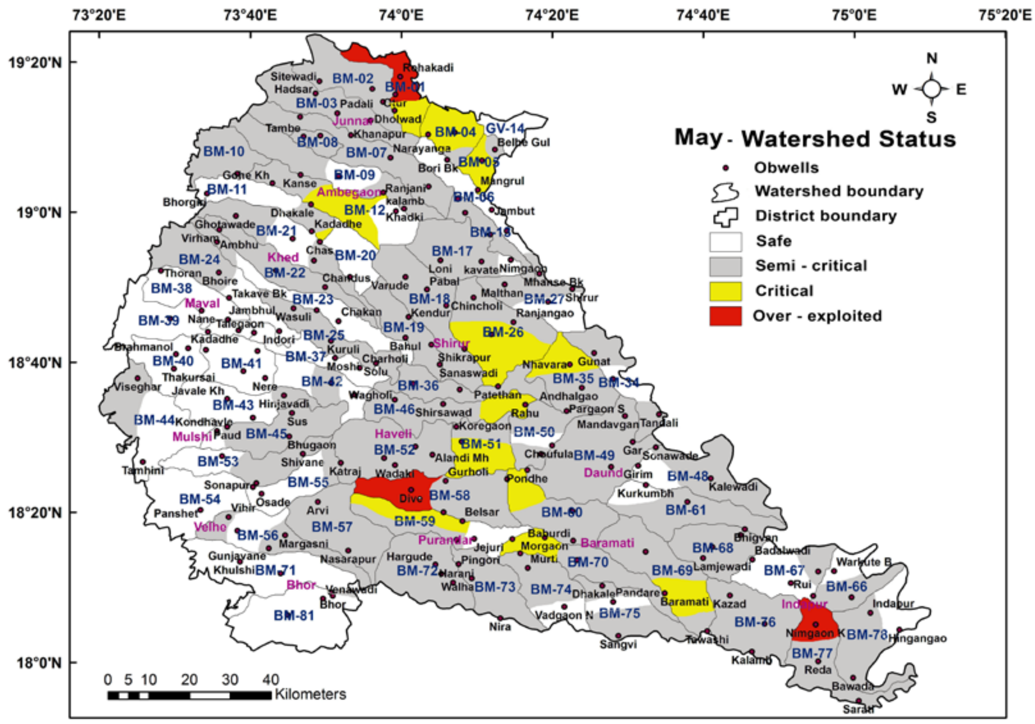

FIG.12: CATEGORIZATION OF VILLAGE WATERSHEDS DURING PRE-MONSOON MONTH OF MAY

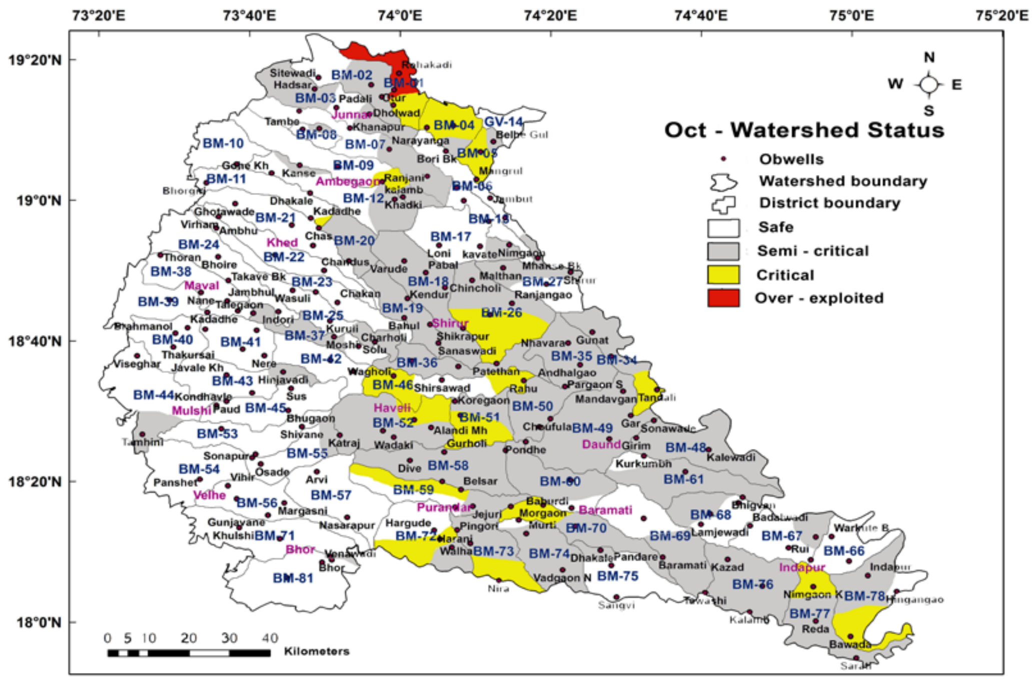

FIG. 13: CATEGORIZATION OF VILLAGE WATERSHEDS DURING POST-MONSOON MONTH OF OCTOBER

It is also observed that although the water levels in the northern, southern and SE regions have risen during October, these regions are still characterized by deep average water level depths. Thus it can be inferred that these regions are more prone to drought like conditions due to constant decline in the water level particularly the places which are at elevation below 300m where small water harvesting structures should be made to augment the ground water. Therefore, it can clearly be seen that rainfall has great impact on surface and groundwater resources of the Pune district.

Summary

In the present study behaviour of rainfall during 2001 to 2012 period and its impacts on groundwater level has been observed over different talukas of the Pune district. The noteworthy findings are –

1. The present research shows that there is a significant change in the rainfall conditions in the study area viz. Pune district. A remarkable decrease in the annual rainfall depth is observed in the last two years, i.e. 2011 and 2012. In addition, there is a substantial change in the monthly distribution of rainfall, characterized by distinct decrease in the seasonal rainfall depth.

2. For comparison of rainfall and groundwater level fluctuations, in the present study, the entire year has been divided into two seasons viz. June to October and November to May of the next year. It is seen that compared to Jun to Sept. rainfall, the Jun to Oct. period contributes more than 90% to the annual total. Out of all the 14 talukas, Pune in Haveli taluka record least average rainfall during Jun-Oct months. Whereas Velhe, Maval, Mulshi and Bhor talukas experience more than 95% of heavy rainfall

3. Heavy rainfall zone is observed in the central to southwest region of the district with higher wet days. There is substantial decrease in rainfall as one move from west to east recording highest dry days. Most of the talukas in the eastern region of the district, viz. Daund, Shirur, Baramati, parts of Junnar, Indapur record dry days even during the monsoon season.

4. Most of the rivers have their origins in the Western Ghats and large numbers of dams have been constructed across these rivers in order to meet the needs of increasing population such as drinking water, hydroelectric power generation, irrigation, etc. This has tremendously reduced the groundwater potential of the district.

5. The groundwater level fluctuation study showed that water levels in many villages reach almost bottom of the observatory well (see Fig.13) during May and the depletion in depth continues even after the monsoon season (see Fig.14) especially in case of Junnar and Purandar talukas.

6. The groundwater level fluctuation study also shows that water levels in many villages reach almost bottom of the observatory well during May e.g. Dive Village in Purandar taluka reached 32.40 m bgl in May 2004 and Rohkadi village in Junnar taluka reach 23.9 m bgl in May 2005 as against 710 mm and 1344.4 mm of respective rainfall recorded by these talukas.

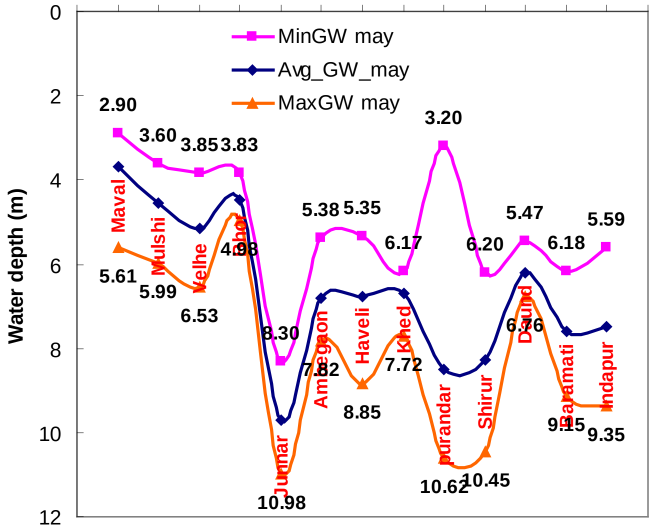

FIG. 14: AVERAGE GROUNDWATER DEPTH (M) OF DIFFERENT TALUKAS DURING MAY

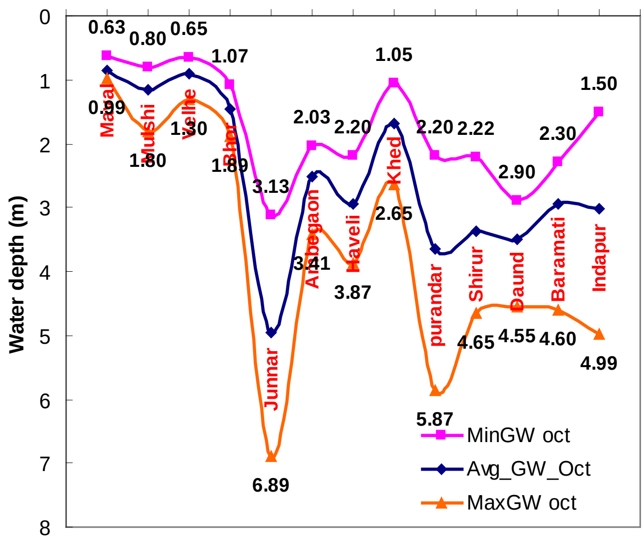

FIG. 15: AVERAGE GROUNDWATER DEPTH (M) OF DIFFERENT TALUKAS DURING OCTOBER

7. The present study shows that although the average rainfall in the south western region (Bhor, Velhe, Maval, Mulshi) of the district is above 2000 m, yet the average depth of water level in this region is less than 5 m particularly during pre-monsoon in May, where the water level lies below 6 m at various places. In October although the average depth to water level lies at 4 m in parts of northern, central, southern, and eastern regions there is deepening in water level by 3-5 m in the central region and shallowing by 1-2 m in parts of northern and eastern region.

8. A comparison of depths of water level of October 2011-2012 with decadal mean October (2001-2010) reveals that there is decline in the water level in all

the talukas except Bhor, Maval and Mulshi talukas wherein there is very minute increase in water level.

Category	Frequency of villages during	
	May	October
Safe	56	89
Semi Critical	116	81
Critical	16	20
Over Exploited	4	2

9. Categorization of groundwater level reveals that although there is decrease in water level depletion during October, still 50% villages are noted under semi-critical condition.

ACKNOWLEDGEMENT

Authors are thankful to Director, IITM for his interests and encouragement in carrying out this study. Authors express their sincere thanks to India Meteorological Department (IMD), Pune and Groundwater Survey and Development Agency (GSDA), Pune for supplying the relevant rainfall and groundwater data.

REFERENCES

Gopinath, G and Seralathan, P. 2008, Studies on Longterm Variability of Groundwater Level in the Hard Rock Crystalline Terrains of a Central Kerala River Basin, IE (I) Journal A G river, 89, pp 4753.

Ibrahim, M.B., 2009, Rainwater harvesting for urban areas: a success story from Gadarif city in central Sudan. Water Res. Manage, 23, pp.2727–2736.

Jaiswal, R.K., Mukherjee, S., Krishnamurthy, J. and Saxena, R., 2003, Role of remote sensing and GIS techniques for generation of groundwater prospect zones towards rural development- an approach. Int. J. Remote Sensing, 24 (5), pp.993-1008.

Jha, K. Madan and Chawdary, V.M., 2007, Challenges of using remote sensing and GIS in developing nations, Hydrogeology Journal, 15 (1), pp.197-200.

Krishnamurthy, J., Kumar, N. Venkatesa, Jayaraman, V. and Manivel, M., 1996, An approach to demarcate ground water potential zones through remote sensing and geographical information system. Int. J. Remote Sensing, 17(10), pp.1867-1884.

Leblanc, M., Favreau, G., Tweed, S., Leduc, C., Razack, M. and Mofor, L., 2007, Remote sensing for groundwater modeling in large semiarid areas, Lake Chad Basin, Africa. Hydrogeology J., 15, pp.97-100.

Manimaran D., 2012, Groundwater Geochemistry Study Using GIS in and Around Vallanadu Hills, Tamilnadu, India, Res.J.Recent Sci., 1(7), pp.52-58.

Meenakshi and Maheshwari R.C., 2006, Fluoride in drinking water and its removal, J. of Hazardous Materials, 1371, pp.456-463.

Murhekar G.H., 2012, Trace Metals Contamination of Surface Water Samples in and Around Akot City in Maharashtra, India, Res. J. Recent Sci., 17, pp.5-9.

Murthy, K.S.R., 2000, Groundwater potential in a semi-arid region of Andhra Pradesh: A geographical information system approach. Int. J. Remote Sensing, 21(9), pp.1867-1884.

Prasad, R.K., Mondal, N.C. and Singh, V.S., 2008, Evaluation of groundwater resources potential using GIS in Kurmapalli watershed of Andhra Pradesh. J. Geol. Soc. India, 71, pp.661-669.

Rokade, V.M., Kundan, P. and Joshi, A.K., 2007, Groundwater Potential Modelling through Remote Sensing and GIS: A case study from Rajura Taluka, Chandrapur District, Maharastra. J. Geol. Soc. India, 69, pp.943-948.

Saraf, A.K. and Chaudhury, P.R., 1998, integrated remote sensing and GIS for groundwater exploration and identification of artificial recharges sites. Int. J. Remote Sensing, 1910, pp.1825-1841.

Saraf, A.K., Choudhury, P.R., Roy, B., Sharma, B., Vijay, S. and Choudhury, S., 2004, GIS based surface hydrological modelling in identification of groundwater recharge zones. Int. J. Remote Sensing, 25, pp.5759-5770.

Teeuw, R.M.., 1995, Groundwater exploration using remote sensing and low cost geo-graphical information system, Hydrogeology J., 3 (3), pp.21 -30.

Thakur, G.S. and Raghuwansi, R.S., 2008, Perspect and assessment of groundwater resources using remote sensing techniques in and around Choral River Basin, Indore and Khargone District, M.P. J. Indian Soc. Remote Sensing , 36 , pp.217- 225.

Tirkey A. S., Pandey A.C. and Nathawat M.S., 2012, Groundwater Level and Rainfall Variability Trend Analysis using GIS in parts of Jharkhand state India for

Sustainable Management of Water Resources Int. Res. J. Environment Sci. 14, 24-3, ISSN 2319–1414.

Wagner, P.D., Kumar, S., and Schneider, K., 2013, An assessment of land use change impacts on the water resources of the Mula and Mutha Rivers catchment upstream of Pune, India, J. Hydrology and Earth System Sciences HESS, doi:10.5194/hessd-10-1943-2013, pp1943-1985.