GROUNDWATER PROSPECT MAPPING OF UPPER KARHA WATERSHED USING GIS WITH SPATIAL REFERENCE TO ARCCN-RUNOFF

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ABSTRACT

Hydrogeomorphological mapping coupled with ground truth investigations has been carried out to delineate groundwater potential zones in the upper Karha watershed of Pune district, Maharashtra. India. The spatial database layers like hydro-geomorphology, landuse/land cover, soil, slope, geology were used. The runoff layer was derived from ArcCN-Runoff. Weighted overlay analysis in Arc-GIS environment was used to integrate the reclassified raster layer. The study showed that the categories of prospect zones are excellent (0.40%), good (20.19%), moderate (64.11%), poor (14.93%) and nil (0.36%) of the study area. The average post monsoon water well depth data was overlaid on groundwater prospect zone map showed positive correlation. The present study shows that spatial technique has been proved to be very efficient in delineation of groundwater prospect zone of the considered area.

Keywords: *Groundwater, ArcCN-Runoff, Weighted overlay.*

INTRODUCTION

In recent times, there has been rapid growth in industrialisation, population and agricultural activities that has lead to tremendous increase in demand for fresh water (Raju, N. Janardhana, 2006). This resulted in creating pressure on the fresh water resources leading to over-exploitation, reducing the groundwater level and increasing the scarcity of water. GIS and remote sensing applications have been used by numerous scientists in mapping of groundwater prospect zones (Thomasa, B.C. et. al., 2009, Prasad, R.K. et. al. , 2008, Vijith, H., 2007, Srivastava, P. K. et. al., 2006).

Vagaries of monsoon and indiscriminate development of groundwater often result in declining trend of groundwater levels. There is an urgent need for artificial recharge of groundwater by augmenting the natural infiltration of precipitation into subsurface formation by some suitable method of recharge. Moreover, the occurrence and movement of groundwater are controlled mainly by porosity and permeability of the surface and underlying lithology. The same lithology forming different geomorphic units will have variable porosity and permeability, thereby causing changes in the potential of groundwater. (S. Shaid et.al., 2000). The study area having elevation of terrain, presence of fine grained basaltic rocks with moderate porosity and increased in urbanization with less green cover (forest cover and agriculture land) due to inadequate water availability is major problem also mapping and water resources potential zone no also done hence, it is necessary to identify the groundwater potential zone for the resource mapping of the area. This study is mainly primitive study of the area, which considered the main themes like hydro-geomorphology, landuse/land cover, Slope, Soil, geology, runoff and groundwater table point data for average post monsoon for cross checking of groundwater prospect map. In this study we used the runoff layer, which will differ from conventional method. This layer was derived layer from soil and landuse. The runoff high curve number means high runoff and low infiltration (water body) whereas a low curve number mean slow runoff and high infiltration (dry soil). (Xiaoyong Zhan et. al., 2009). The weighted overlay will be used by many researchers. An ArcGIS tool, ArcCN-Runoff, is used for runoff calculation. ArcCN-Runoff is designed for any shape of polygon in order to keep irregular boundaries unaltered. Application of dissolving techniques reduces processing time significantly. The curve-number database implemented provides a flexible way to use a reference table for the curve number based on soil and landuse information (Xiaoyong Zhan et. al. 2009).

The present information, depicted in the form of a prospect map would provide firsthand information to local authorities and planners about the areas suitable for searching ground water followed by its suitable exploration based on information given for type of well, well depth, water quality and success rate of wells.

STUDY AREA

The study area is watershed boundary of upper Karha river watershed, which is a part of Pune district, Maharashtra, India. The upper Karha watershed extends from 73^{o}52’07”West to 74^{0}15’06”East longitudes and 18^{0} 25’ 8” South to 18^{0} 13’ 8” North latitude. It is located in the Survey of India topographical maps 47F/15, 47J/3, 47J/4 and 47J/7of 1:50,000 scale. Total geographical area under study is 546 sq. km. The watershed shows south west monsoon which breaks by first week of May and last till November. Average annual rainfall is around 793.2mm (source: IMD). About 96% occurs during the months of May and November and the balance 4% is distributed in winter and summer months. The IMD rain gauge stations within the watershed i.e. Saswad is only one site.

The study area is having elevation 634m in eastern part to 1264m in western part. The study area lies in the drought prone area of western Maharashtra. The study area has semi-arid climatic conditions, with a maximum temperature of around 39^{0}c during the months of April and May, and a minimum temperature of around 8^{0}c during the month of December.

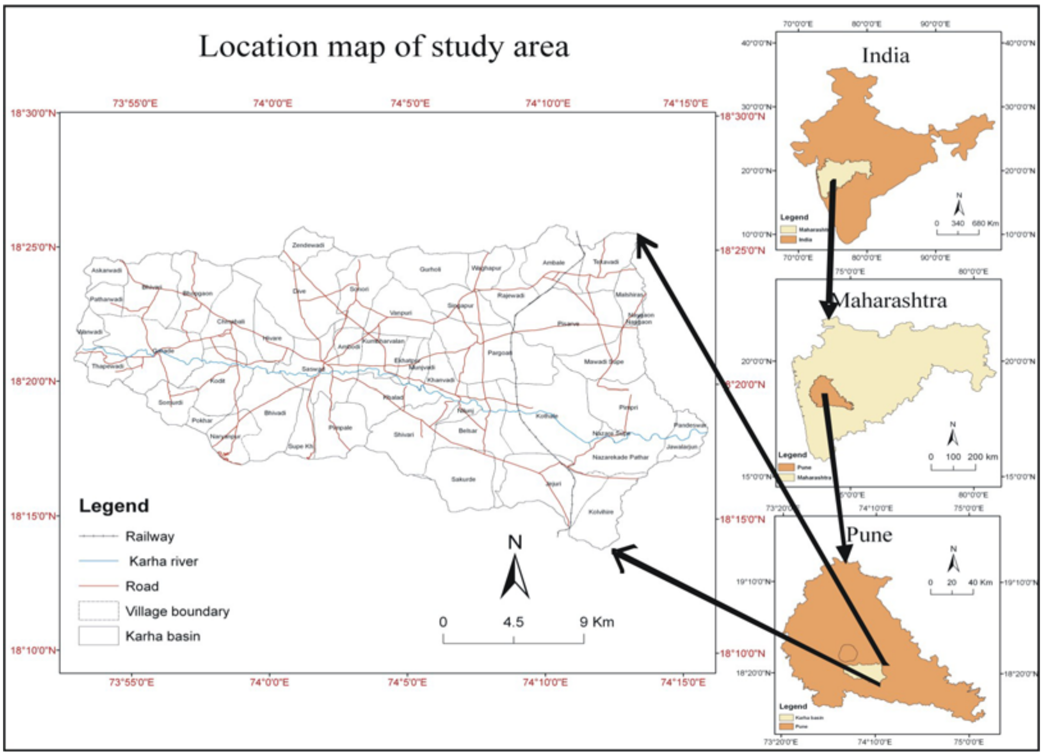

Fig.1 Location map of study area

MATERIALS AND METHODOLOGY

The occurrence and movement of groundwater in an area is controlled by geological and environmental parameters (Thomasa, B.C. et. al. 2009, Jaiswal et al. 2003)**.** In this study, digitally enhanced products of the IRS 1D, LISS III of 16 October 2006 satellite image was used, soil map published by National Bureau of Soil Survey and Landuse Planning (scale 1:5,00,000) and geological map published by Geological Survey of India (scale 1:2,50,000) were used. In order to delineate the groundwater prospect zone base map, landuse/landcover, hydrogeomorphology, soils, contour, geology were derived using various thematic maps and verified with field data. The map of slope and runoff also prepared. Data for 21 wells were collected for water depth used for making point data for cross checking. A weighted approach has been applied during raster overlay analysis in Arc Map GIS environment. Weighted overlays several raster using a common measurement scale and weights each according to its important with respect to groundwater potential (NRSC, 2000). **Fig. 2** depicts a detailed illustration of the methodology of the study. The raster maps had an equal square grid size of 30 m for knowing details groundwater prospect of the study area.

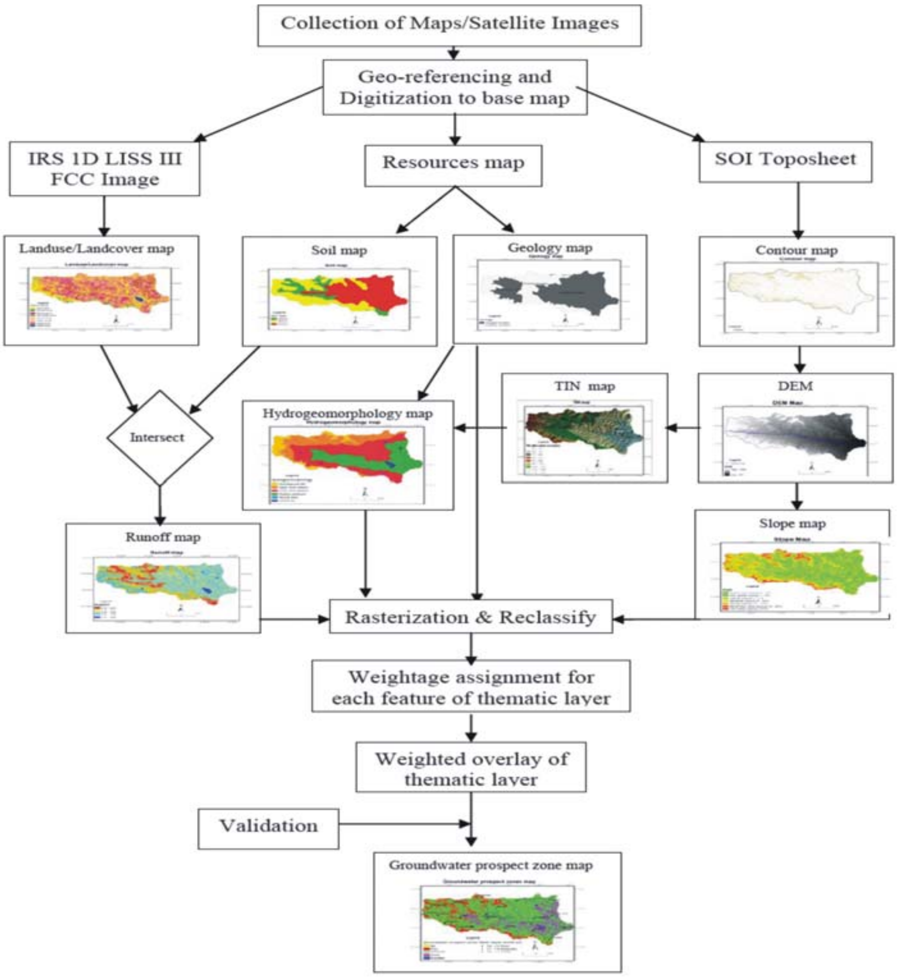

Fig.2 Methodology

SPATIAL DATA
Hydrogeomorphology

As recognised by many (Dinesh Kumar et al. 2007, Vijith and Satheesh, 2007), geomorphology and landforms have a very dominant role in the movement and storage of groundwater in the study area. The geomorphic units identified were in accordance with the widely accepted Geomorphological classification of the region (Thomas, B.C. et. al. 2009). The hydrogeomorphology feature can be extracted from the geomorphology map integrated with TIN of study area with ground truth for various feature. The study mainly shows high elevation area and covered with basalt. The main hydrogeomorphological features were found to be main water body, shallow alluvial plain, shallow pediments, plateau (upper/lower) and denudational hill.

Landuse/Land cover

The Satellite image was classified using supervised algorithm. Eight types of land use patterns were identified in the entire study area, which includes crop land, harvested land, dense forest, open forest, land with or without scrub (dense and open scrub respectively), settlement and waterbodies.

Soil: Soils is important parameter in this kind of study, the infiltration rate of the soil determines the type of structure to be located and the surface runoff potential also depends on the soil texture of the area. **(Jasrotia, A. S., 2009).** The hydraulic soil group (HSG) of the study area was derived from prevailing National Bureau of Soil Survey (NBSS) soil maps. The soils of the study area fall in B, C and D hydrological soil groups. The B type soil is of loam, C type soil is sandy clay loam and D Fine, Clay type of soil.

Slope

Slope plays a key role in the groundwater occurrence as infiltration is inversely related to slope (Mondal et al. 2009). A break in the slope (i.e. steep slope followed by gentler slope) generally promotes an appreciable groundwater infiltration (Saraf *et al*., 1998). The DEM was generated through 20 m contour lines which were obtained from SOI toposheet (1:50,000). The slope (%) was derived from DEM.

Geology

The major part of watershed is occupied by Basalt belonging to age ranging from late cretaceous to palaeogene and by basalt. The study area is having only two types of lithology mainly Diveghat formation and Purandar Formation

Runoff

The thematic layer of landuse/landcover and soil were crossed. Then run off was calculated for each landuse/land cover-soil texture class using the ArcCN-Runoff tool calculations method (Xiaoyong Zhan et. al. 2009). The runoff is calculated based on the SCS curve number-runoff method. The SCS curve-number method assumes that, for a rainfall storm event, the ratio of actual retention of soil after runoff begins to the potential maximum retention of soil is equal to the ratio of direct runoff to rainfall. (Xiaoyong Zhan et. al., 2009). The runoff is the function of landuse and soil. The above two layer landuse and soil where intersect and according to CN number for each landuse with respect to the soil where calculated for runoff of the area. The runoff map has been classified into on basis runoff into 5 group 0.10in -0.24in low, 0.24in -0.68in low to moderate, 0.68in - 0.97in moderate, 0.97in -1.40 in moderate to high and 1.41in -2.60 in high of study area. This was used for the detection of the groundwater potential zone.Table1 shows the average annual runoff different landuse/landcover and hydraulic soil group.

Table 1. Runoff estimates for different landuse and hydraulic soil group (HSG) using Arc-CN Runoff

ID	Soil type	Class name	CN	Runoff (inch)
1	B	Dense forest	55	0.1
2	B	Dense scrub	58	0.16
3	B	Open forest	58	0.16
4	B	Open scrub	61	0.23
5	B	Settlement	66	0.37
6	B	Agriculture	77	0.8
7	B	Harvested land	77	0.8
8	B	Waterbody	100	2.6
9	C	Dense forest	70	0.5
10	C	Dense scrub	71	0.54
11	C	Open forest	71	0.54
12	C	Open scrub	74	0.67
13	C	Settlement	78	0.85
14	C	Agriculture	83	1.13
15	C	Harvested land	83	1.13
16	C	Waterbody	100	2.6
17	D	Dense forest	77	0.8
18	D	Open forest	78	0.85
19	D	Dense scrub	78	0.85
20	D	Open scrub	80	0.96
21	D	Settlement	83	1.13
22	D	Agriculture	87	1.4
23	D	Harvested land	87	1.4
24	D	Waterbody	100	2.6

Table2. Rank and weightage of different parameters for Groundwater potential zones

Sr no.	Criteria	Classes	Rank	Weights (%)
1	Hydrogeomorphology	Waterbody	5	25
		Alluvial Plain	4	
		pediments shallow	3	
		Plateau (Upper/Lower)	2	
		Denudational Hill	1	
2	Runoff (mm)	1.41-2.6	5	40
		0.97-1.40	4	
		0.96-0.68	3	
		0.67-0.24	2	
		0.10-0.23	1	
3	Slope	0-3%	5	25
		3-5%	5	
		5-10%	4	
		10-15%	3	
		15-35%	2	
		>35%	1	
4	Geology	Purandar Formation	3	10
		Diveghat formation	2	

RESULTS AND DISCUSSIONS

Hydrogeomorphology: The feature identified and rated based on their groundwater potential is, alluvial plain (0.74%) mainly present very small area as the river was not perennial, the soil type is mainly shows was clay, fine. Groundwater prospects in alluvial plains are good. Piedmont zone (30.31%) occurring in the elevation range of about 630 m to 730 m above m.s.l. and characterized by Denudational origin on deccan trap shows moderate groundwater potential. The plateau shows two types based height, upper plateau (21.39%) on basalt rising to heights over 950m from plains and lower plateau (37.78%) on basalt rising to heights from about 730 – 950 m from plains region indicates very little groundwater potential. Denudational hills (8.79%) comprising of massive rocks like basalt of high height shows poor groundwater potential.

Landuse/Landcover: The study area mainly comprises of semi arid region shows eight type of landuse (Fig.2) mainly crop land (30.84%) as the image from October it will shows good water potential, fallow land (11.01%), open forest (1.57%), dense forest (1.18%), land with scrub (dense scrub)(24.91%), land without scrub (open scrub) (28.53%), Waterbody (1.26%) and settlement (0.69%). This layer along with soil were used for runoff layer of study area.

Slope: The study area show low slope (0–5%) 70.57% of study area, indicate presence of good groundwater potential. Medium slope (5–15%) 22.53% of study area indicate moderate groundwater potential, moderate to high slope (15-35%) 5.33% of study area indicates low groundwater potential. High slope (>35%) 1.58% of study area indicates presence of poor groundwater potential. (modified from Jha et. al. 2007, Todd, 1980; Todd and Mays, 2005) . Major area of study was having low slope indicates high groundwater potential but may affected by underlying litology as well as hydrogeomorphology feature.

Soil: The soils in the study area can be grouped under three hydraulic soil groups, i.e. groups B, C and D. Soil groups B is very shallow, somewhat excessively drained loamy, calcareous soils on very gently sloping plains with moderately deep, well drained clayey calcareous soils with moderate erosion (9.18%) of study area and C is very shallow, excessively drained, loamy soils on moderately steeply sloping highly dissected hill ranges with escarpments and narrow valleys with very severe erosions (15%) of study area were confined to be from denudational hills and upper plateau. Soil group D is shallow, well drained, clayey moderately calcareous soils on gently sloping lands with moderate erosion and moderate stoniness; associated with slightly deep, well drained, fine, moderately calcareous soils with moderate erosions and moderate salinity. (75.82%) confined to pediment and barren uplands origin. This is along with landuse used for runoff map generation.

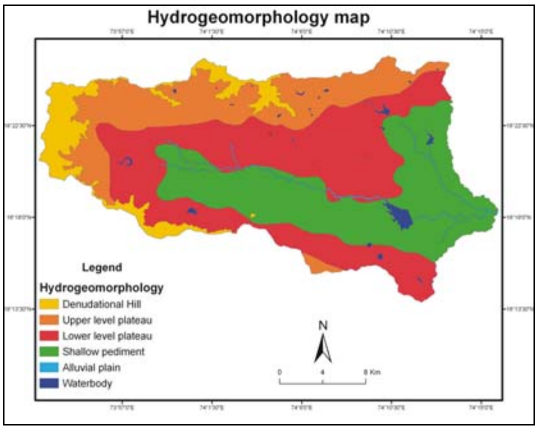

Fig 1. Hydrogeomorphology map of study area

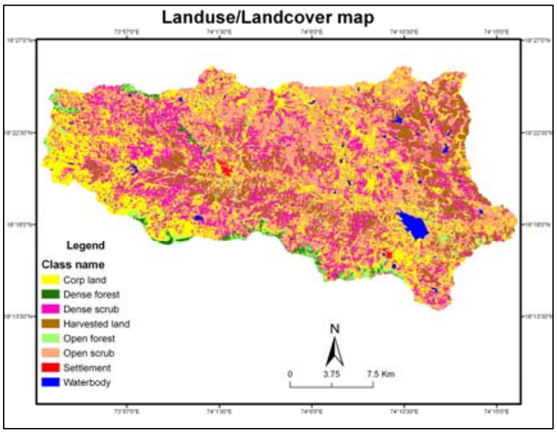

Fig 2. Landuse/Landcover map of study area

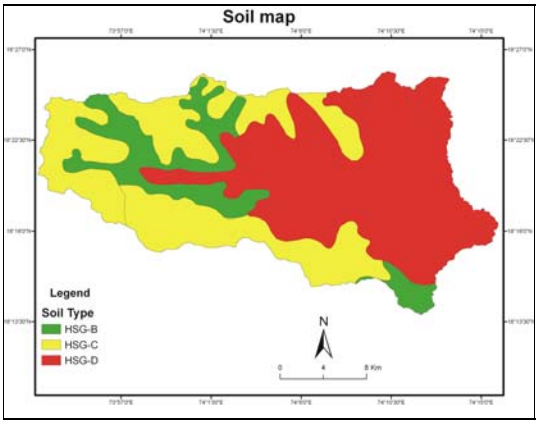

Fig3. Soil map of study area

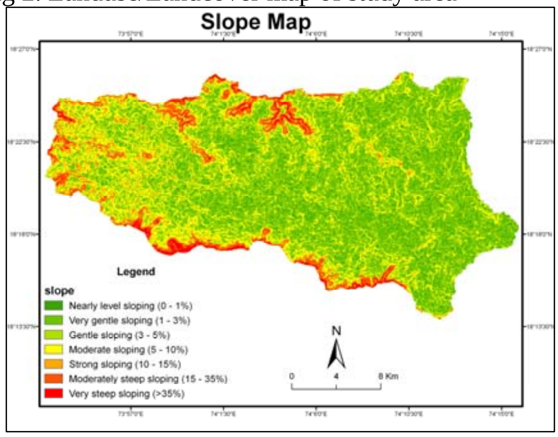

Fig 4.Slope map of study area

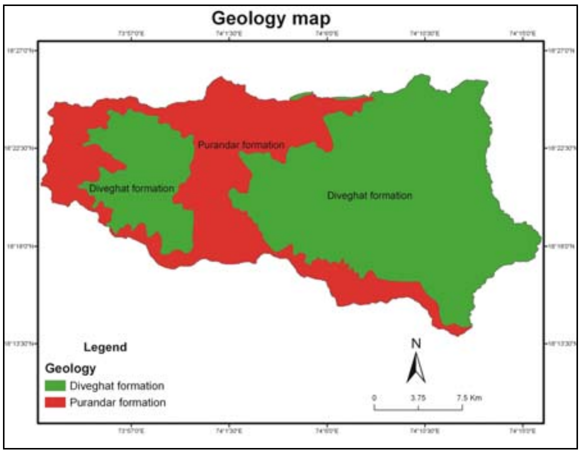

Fig. 5 Geology map of study area

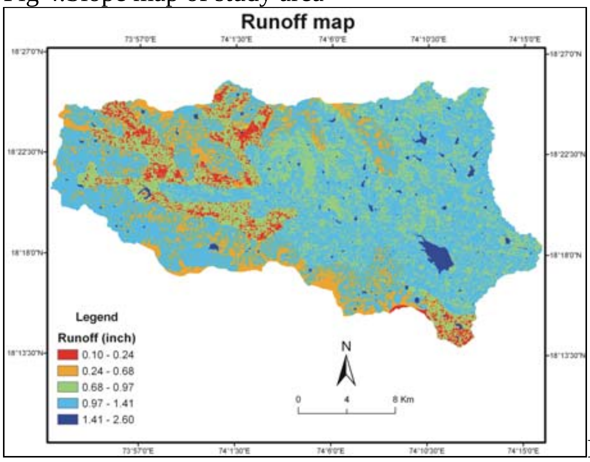

Fig.

Fig. 6 Runoff map of study area

Geology

The study area belonging only two types of lithology mainly 10 - 15 "aa" and simple basaltic lava flows (50-350 m) having characteristics dark grey, fine to medium grained, hard and compact, sparsely to highly porphytic belong to Diveghat formation 65.76% of study area shows poor groundwater potential. Other one having lithology 10 - 16 "aa" and simple basaltic lava flows (50- 350 m) having characteristics Dark grey, fine to medium grained, hard, compact and porphyritic in nature belong Purandar Formation 34.24% of study area shows moderate groundwater potential.

Runoff

The calculation of average annual runoff for different landuse and soil class from the study area is given in **Table 1.** The runoff value which was calculated from the ArcCN-Runoff was put in the GIS environment to generate the runoff map (Fig. 7). The runoff map has been classified into on basis runoff into 5 group low (4.90%), low to moderate (13.18%), moderate (26.06%), moderate to high (54.15%) and high (1.69%) of study area. More than half of the area i.e. 52.87% is dominated by low runoff potential zones, where as high runoff potential zone covers an area of 20.57% and the suitable zone for selecting rainwater harvesting structure i.e. moderate runoff potential zone covers an area of 26.56% of upper Karha watershed.

Delineation of groundwater prospect zones

All the thematic maps were converted into grid (raster format) and superimposed by weighted overlay method (rank and weightage wise thematic maps). The analysis shows that the groundwater prospect zones in-terms of Excellent, Good, moderate, Poor; nil zones 0.40 %, 20.19%, 64.11 %, 14.93% and 0.36% of study area respectively.

Table 3. Predictable potentiality and the identified existing physical and natural earth features study area.

Predictable Potentiality	Hydrogeomorphology	Runoff	Slope	Geology
Excellent	Alluvial Plain	High	0-5%	Purandar
Good	Piedmont zone	Moderate to high	5-10%	Purandar
Moderate	Plateau (Upper/Lower)	Moderate	10-15%	Diveghat
Poor	Upper Plateau, Denudation Hill	Low to moderate	15-35%	Diveghat
Nil	Denudation Hill	low	>35%	Diveghat

The categories mainly excellent and nil will present for water and near places and rocky surface with steep slope respectively so we are not collected sample from that. We collected the 23 samples of dug well water table for post monsoon 2006 was collected for mainly for good, Moderate and poor zone. The wells were located in the field using a Garmin handheld GPS. The average depth of well water was collected from the GSDA, Department of Ground Water catalogues. Well water depth will be ranging from 0.8 to 8.0 meter. Which will be further classified into 0.8-3.2m, 3.2-5.6m, 5.6-8.0m for good, moderate, poor zone and overlaid on groundwater potential map for cross referencing. This shows positive correlation between map and well depth.

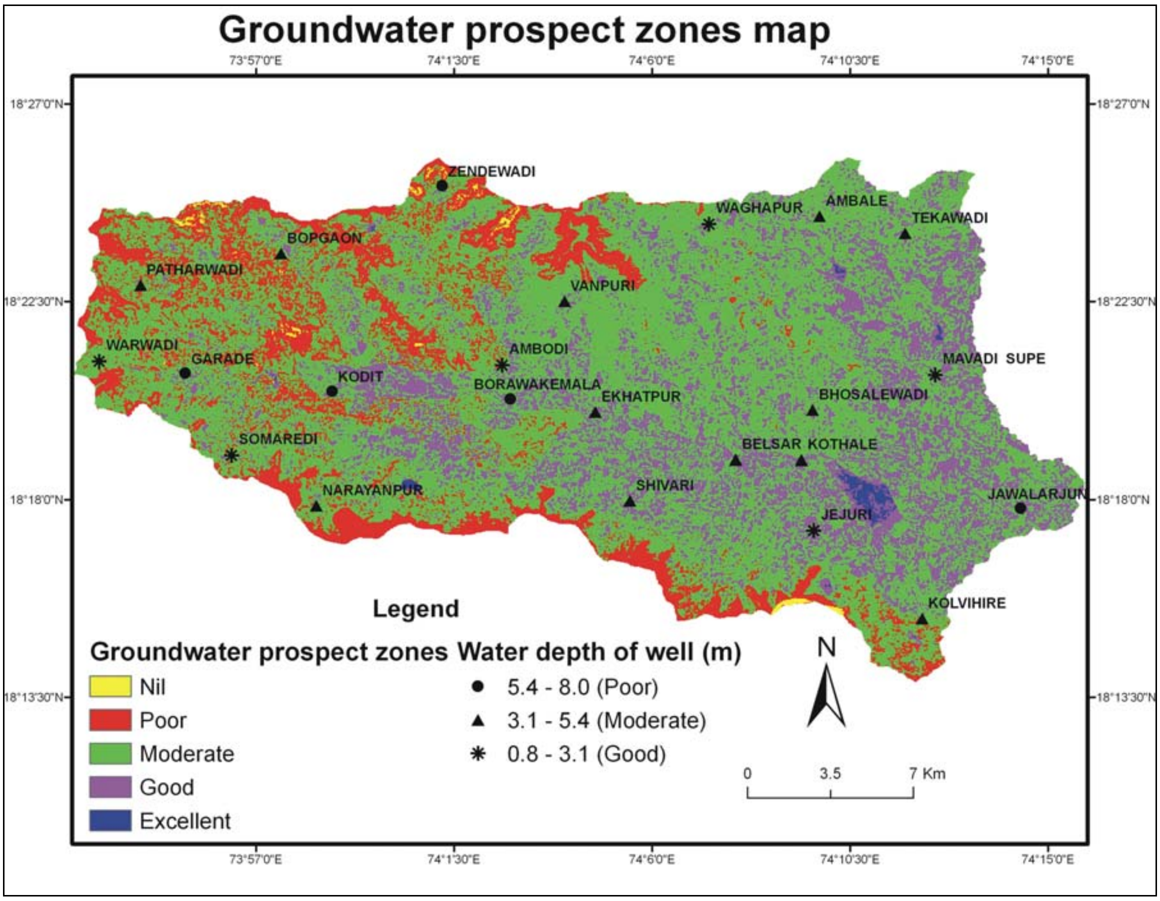

Fig. 8 Groundwater prospect zone map of study area

Table 4. Groundwater prospect zones overlain by the water wells

ID	X	Y	Sampling site	Water level (m)
1	74.16121	18.28812	JEJURI	0.8
2	73.94061	18.31653	SOMARDI	1.7
3	74.12153	18.40436	WAGHAPUR	2.3
4	74.04311	18.35081	AMBODI	2.5
5	73.89053	18.35228	WARWADI	2.9
6	74.20722	18.34706	MAVADI SUPE	3.1
7	74.20225	18.25486	KOLVIHIRE	3.5
8	74.13172	18.31508	BELSARE	3.6
9	74.06681	18.37508	VANPURI	3.9
10	74.16083	18.33381	BHOSALEWADI	3.95
11	73.97283	18.29772	NARAYANPUR	4.1
12	73.95944	18.39328	BOPGAON	4.25
13	74.15658	18.31492	KOTHALE	4.8
14	74.16342	18.40733	AMBALE	4.9
15	74.0785	18.33297	EKHATPUR	5.0
16	74.19589	18.40094	TEKAWADI	5.2
17	74.09161	18.29958	SHIVARI	5.3
18	73.90628	18.38122	PATHARWADI	5.4
19	73.92319	18.34767	GARADE	6.2
20	73.97883	18.34086	KODIT	7.3
21	74.23964	18.29661	JAWALARJUN	7.7
22	74.02056	18.41883	ZENDEWADI	7.8
23	74.04628	18.33794	BORAWAKEMALA	8.0

An uncertainty analysis of the parameters in light of the model results is also lacking in the study. Such an analysis was beyond the scope of this study as most of the data (excluding the landuse map) were available from secondary sources that do not describe the variability of the parameters. Provided the variability of the parameters, a First-Order Second Moment Method (Ang and Tang, 1984) could be adopted for the uncertainty analysis.

CONCLUSIONS

The occurrence and movement of groundwater in this zone is controlled by many factors such as rock types, landforms, geological structures, soil, land use, rainfall etc. Remote sensing based groundwater prospect zone map serves as a base for further exploration using hydro geological and geophysical methods to locate well sites. Groundwater withdrawal is increasing year after year due to very erratic rainfall and insufficient surface water bodies resulting, in the drying-up of dug and bore wells. To understand the groundwater regime, well inventory data have been collected. Groundwater potential and water table fluctuation are in agreement with the denudational and fluvial landforms. Keeping this in view, a proper groundwater management should be adopted to utilize groundwater in a sustainable manner.

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