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# Characterisation of the Aquifers for Resource Management and Protection

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***Abstract***

*The base line hydrogeological survey for village Vadhane was conducted with a view to demarcate the aquifer boundaries to manage the groundwater resources for the sustainability of drinking water sources. To delineate the aquifer boundary, further, comprehensive geomorphological, geological and geophysical investigations were carried out. The depth to water level and water level fluctuation maps were also used to confirm the boundary and thickness of the aquifer. Vertical electrical soundings (VES) were carried out in the area to understand the subsurface geo-electrical distribution. A grid of 1 km x 1 km was laid down in the study area and ten VES profiles were carried out at the intersection of these grid points. The integrated studies have indicated the fine-grained jointed massive basalt and weathered zeolitic basalt are predominant water bearing formations within the village. The groundwater worthy zone is restricted to the depth of 10-20 m bgl. The hydrogeological inputs were further utilized for management and protection of the resource.*

***Keywords:*** *aquifer characterization, integrated study, resource management.*

## Introduction

The study area covered by hard rock formation faces water scarcity problem for both irrigation and drinking purposes. Occurrence of groundwater in this type of area is unconfined / semi-confined in secondary permeable structures i.e. fractured and weathered horizons (Singhal, 1973; Singhal, 1986; Karanth, 1987; Maggirwar and Umrikar, 2011). Therefore, the characterization and delineation of aquifer becomes important for the management and protection of this precious resource. Delineation of groundwater potential zones and site suitability for artificial recharge structures using Remote Sensing, GPS and GIS techniques are in vogue (Saraf and Choudhary 1998; Haridas et al, 1998; Pradeep, 1998; Javed and Wani, 2009; Maggirwar and Umrikar, 2009). An attempt has been made in present study to delineate the aquifer boundary based on the comprehensive geohydrological, geomorphological, geological and geophysical investigations. The data so generated has been further utilized to demarcate the area of groundwater potential zones and to propose measures for sustainable groundwater management.

## Study area

**Vadhane** is one of the villages of **Baramati** taluka located due southeast of Pune city at a distance of about 65 km. The village falls in Survey of India toposheet no. 47 J/7 (quadrant no. A3). The village is connected by tar road up to Supe and from Supe to Vadhane by metal road (Fig. 1).

The village Vadhane is included in the mini watershed 3/6 of BM 60 watershed (Bhima basin) as per the G.S.D.A. (Groundwater Surveys and Development Agency) nomenclature (Maggirwar, 1990). The study area receives an average annual rainfall of 394.00 mm. The village is included in the eastern portion of the drought prone region of the State i.e. rain shadow zone, which has the lowest, irregular and uncertain rainfall pattern. The maximum temperature during summer goes up to 42°C, while the lowest temperature during winter goes up to 9.5°C

The geographical area of the village is 2041 ha. Out of this, cultivable waste is 225 ha and uncultivable land is 645 ha and land available for cultivation is 844 ha. There is no forest area in this village. Thus, it is seen that the cultivable area is about 41.47 % the total area of the village

## Geomorphology

Geomorphology of the village as ascertained on the basis of 1:50,000 scale morphological maps (MRSAC, Nagpur) and remote sensing study is as described below.

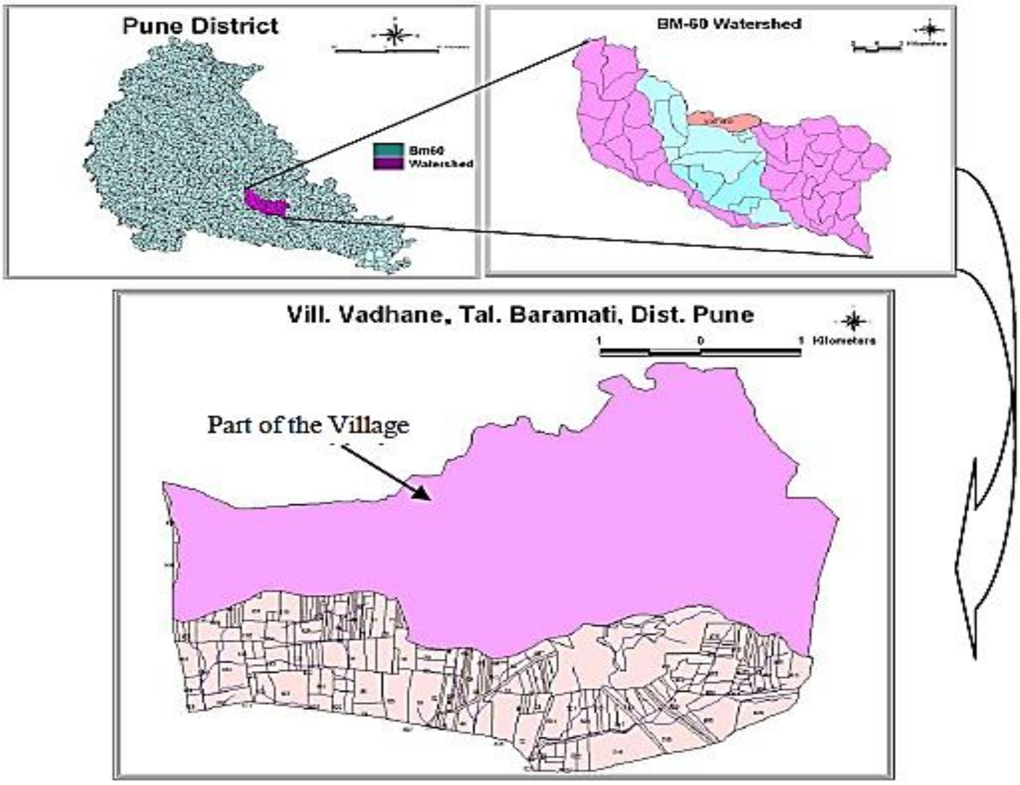


**Fig. 1:** Location map of Vadhane village.

The northeastern portion is categorised as HDP-A (with exposed rock and negligible soil cover) and is not favourable from groundwater point of view. The Central portion represents MDP-A, (moderately dissected plateau with exposed rock and thin soil cover) which is not favourable from groundwater point of view. The western portion is categorised as MDP-B, (moderately dissected plateau with moderate soil cover) which is poorly favorable from groundwater point of view (Fig. 2).

The rest of the area is categorized as MDP-C (moderately dissected plateau with thick soil cover and thick weathered zone) which is moderately favourable mostly along Nalla banks.

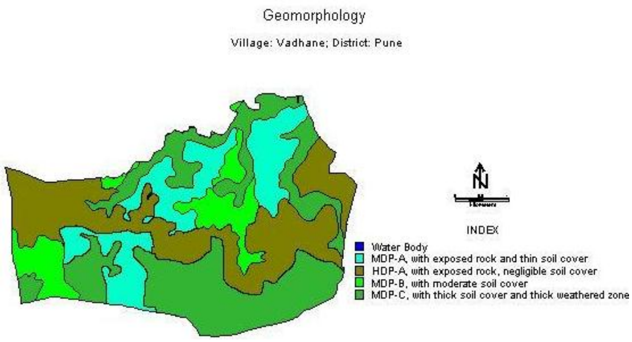


**Fig. 2:** Geomorphological map of Vadhane village.

**Geology:** The traverses in the area supported by the study of surface exposures and the well sections indicate that the village area is occupied by multi-layered thin laminated lava flows of Deccan Traps which belong to Upper Cretaceous to Lower Eocene age. In the village different flows have been demarcated with respect to elevation (Table - 1).

**Table 1:** Elevation, thickness and type of flow unit in the study area

| Altitude Range (m) | Thickness (m) | Type of Flow Unit |
|---|---|---|
| >700 | - | Massive Basalt |
| 700 – 690 | 10 | Zeolitic Basalt |
| 690 – 660 | 30 | Massive Basalt |
| 660 – 655 | 5 | Zeolitic Basalt |
| 655 – 640 | 5 | Massive Basalt |
| 640 – 620 | 20 | Zeolitic Basalt |
| < 620 | - | Massive Basalt |

## Methodology

The base line hydrogeological survey for village **Vadhane** was conducted with a view to demarcate the aquifer boundaries, for managing the groundwater resources for the long-term sustainability of drinking water sources. Conducting field surveys by collecting data to produce hydrogeological maps, which were used to locate potential groundwater zones and evaluate aquifer related controls. Aquifer characteristics were computed by conducting hydrogeological survey and geo-physical surveys along with other tools like aquifer performance tests.

The physiography, geomorphology, hydrogeology, surface water availability, hydrometeorology and conventional practices for additional recharge have been given due consideration in identifying the areas for additional recharge to groundwater.

There are 149 wells existing in the village, out of them, 148 are irrigation wells and one well is used for domestic water supply. The average well density of this village is 13.69 wells / km2. In all fourteen bore wells have been drilled for the purpose of drinking water supply, out of these, eleven bore wells have proved to be successful with yield range of 300 to 7770 lph (liters per hour). Besides, 46 private irrigation bore wells also exist. One observation well has been established in the village to monitor the water level conditions. This observation well is being monitored since year 2000.

**Hydrogeology**

The analysis of data collected reveals that the depth of the wells varies from 8.40 to 19.20 m bgl and the diameter varies from 6 to 10 m. It is observed that the depth of water level in the post monsoon period i.e. Oct/Nov vary from 2.00 to 15.50 m. bgl, while in the pre monsoon period i.e. May, it is deeper and varies from 4.00 to 19.10 m bgl. Similarly, by using the data, water table maps for the post monsoon and pre monsoon are prepared (Fig. 3 and 4). The general groundwater movement is towards southeast. There is convergence of flow lines in the south-eastern part indicating good groundwater potential. The area in the north and northwest part, however, shows divergence of flow lines indicating poor groundwater potential. The groundwater worthy zone is restricted to the depth of 10-20 m bgl. Groundwater occurs under water table condition (unconfined) within this zone. The depth to water level maps show that the area with water levels in the range of 10 to 16 m bgl in pre monsoon and that in the range of 8 to 14 m bgl in post monsoon represents the groundwater potential zone.

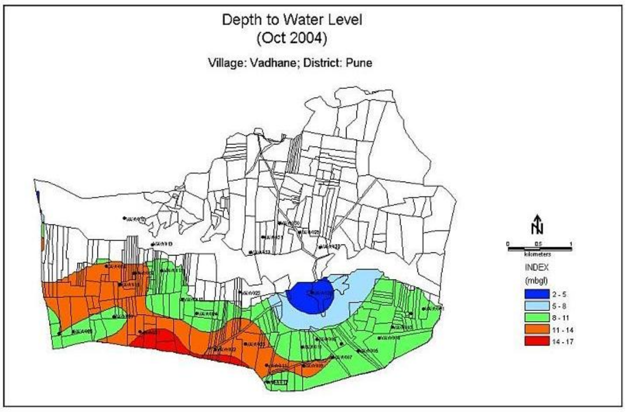


**Fig. 3**: Depth to water level for Post monsoon period.

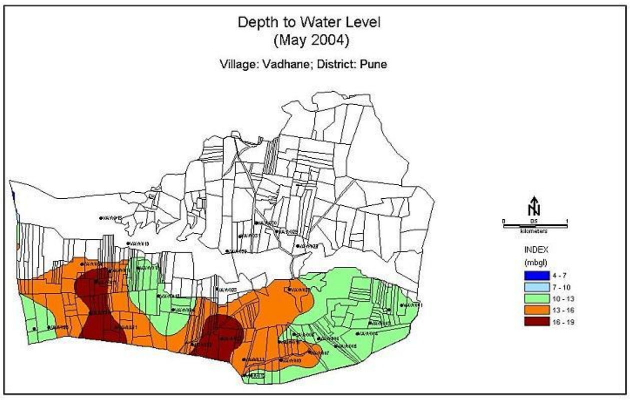


**Fig. 4**: Depth to water level for Pre monsoon period.

The water level fluctuation map drawn for the village is shown in the figure 5. The annual groundwater fluctuation ranges between 2 to 11.50 m indicating moderate areal extent and moderate groundwater potential in the aquifer.

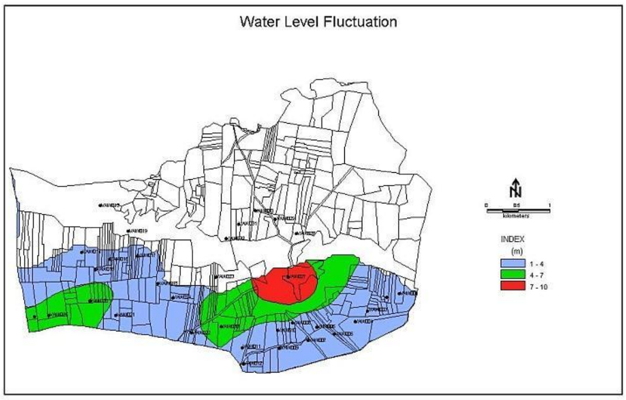


**Fig. 5**: Water level fluctuation map of Village Vadhane.

The fine-grained jointed massive basalt and weathered zeolitic basalt are predominant water bearing formations within the village. The weathered thickness is more along the local stream in the village. The wells which are fully penetrating weathered layer are yielding groundwater at the rate of 10 to 96 kilolitres per day during winter and the yield reduces to almost nil during summer. The water bearing formation in the area yields groundwater only up to January i.e. rabbi season. Hence the irrigation wells are seasonal. Due to high density of wells (13.69/km) tapping this aquifer, it has started showing the signatures of over development by way of depletion in water levels, reduction in annual yield and water availability period.

**Table 2:** Average aquifer parameter values of the dug wells in the study area.

| S. No. | Aquifer type | Specific yield | Transmissibility m2 /day | Specific Capacity lpm/m | Hydraulic Conductivity m/day |
|---|---|---|---|---|---|
| 1 | Jointed Massive basalt | 2.30% | 34.68 | 108.85 | 1.96 |

An aquifer performance test (APT) was conducted on 9 dug wells. The contributing aquifer to the wells is jointed massive basalt. The following parameters were worked out and averaged from the pump test data by using the Theis and Jacob formula (Table 2).

**Geophysical Investigation**

The vertical electrical soundings (VES) were carried out in the area to understand the subsurface geo-electrical layer distribution. A grid of 1 km x 1 km was laid down in the village area and VES were carried out at the intersection of these grid points. Schlumberger electrode array with a maximum half current electrode separation of 120 to 200 m (AB/2) was used in carrying out vertical electrical soundings. The instrument for the collection of data used is SAS 300 Terrameter (make of ABEM, Sweden).

**Table 3:** Interpretation of sounding data

| VES no. | True resistivity in Ohm.m | Depth in m | Lithology |
|---|---|---|---|
| F6 | 13 | 1.1 | Top soil |
| | 130 | 45.1 | Massive basalt |
| | 24 | | Jointed/Fractured/weathered basalt |
| G7 | 62 | 2.1 | Top soil |
| | 217 | 27.3 | Massive basalt |
| | 34 | | Jointed/Fractured/weathered basalt |
| H8 | 85 | 1.3 | Top soil |
| | 126 | 23.4 | Massive basalt |
| | 30 | | Jointed/Fractured/weathered basalt |

The sounding data is interpreted by partial curve matching technique, using Orellana and Mooney standard graphs for Schlumberger sounding data. The raw data is used in preparing the iso-resistivity maps using the values of particular separation, which gives the variation of resistivity values within the area, in terms high and low resistivity zones. The interpreted results show the true resistivity values and its thickness. The results are further utilized for preparing geo-electric section, which gives the idea of subsurface formations. In all ten vertical electrical soundings (VES) were carried out in the area. VES taken at grid points $F_6$, $F_7$, $G_4$, $H_8$, $G_8$, $H_9$, $G_9$, $J_{10}$, $I_{10}$, & $H_{10}$ fall in this village. Obtained field VES curves are mostly of KH Type. The top layer is having a thickness of 1.0 to 2.0 m followed by high resistivity value layer in the range of 126 to 217 ohm-m, which is compact massive basalt having thickness of 23 to 45 m. The thickness of this compact massive basalt decreases from NW to SE of the village, maximum being 45 m on NW side of the village. The third layer in the area is having resistivity range of the order of 24-30 m which could be jointed / fractured massive basalt (Table 3).

**Discussion**

The data generated through all the above tools has been edited, validated with the help of GWDES, GEMS. MapInfo Professional ver. 6.0,GIS software for integrated analysis. On the basis of the integrated analysis final maps and reports have been generated. Thus the area of the aquifer so derived in the village is 291.30 ha (Fig. 6).

Though the area of aquifer (groundwater potential zone) is 291.30 ha, there are a number of wells outside this area. These wells are very low yielding and do not have any direct relation with the groundwater potential zone. In the area outside the groundwater potential zone, though the aquifer exists, it has very low potential.

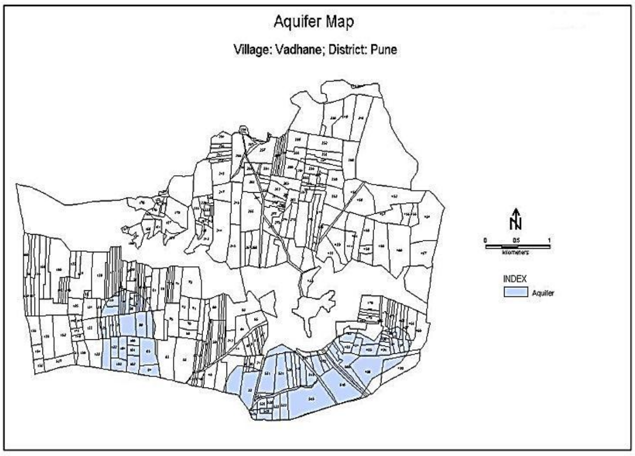


**Fig. 6:** Aquifer map of Village Vadhane

**Management Strategies**

**Surface water: Supply and Demand Side Management**

From the point of artificial and conventional water conservation, it is important to know about the availability of surface water. The surface water includes both, water available due to run off and water stored in water conservation structures.

**Runoff availability**

In the Deccan Trap basalt hard rock, relation between rainfall and runoff is established using Stranger's formula. Surface runoff in the village is estimated as mentioned below. The village area is divided into good catchments, average catchments and the bad catchments on the basis of geomorphology. The statistics are as below.

The runoff available in the area is 25.585 ham, whereas the storage capacity of the existing water conservation structures is 21.50 ham (Table 4).

**Table4:** Statistical information of surface water for village Vadhane

| S. No. | Subject | Details |
|---|---|---|
| 1 | Total area of the village | 851* ha |
| 2 | IMD normal annual rainfall | 394 mm. |
| 3 | Average of last 2 years actual rainfall (Chandgudewadi HMS) | 423.00 mm. |
| 4 | Runoff yield for good catchment area | 2.640 ham |
| 5 | Runoff yield for average catchment area | 18.975 ham |
| 6 | Runoff yield for bad catchment area | 3.960 ham |
| 7 | Total runoff yield | 25.585 ham |
| 8 | Storage capacity of existing surface water bodies | 21.50 ham |
| 9 | Balance runoff available for additional WCS | 1.085 ham |

***** Referred only to the area within the aquifer of the village.

### Aquifer based groundwater account

With a view to check the balance between annual groundwater recharge and withdrawal status in the aquifer water account has been attempted:

Total rainwater available = Area of village X Rainfall
= 2041 X 0.422 = **861.302 ham.**
Availability of groundwater = Area of village X Rainfall X infiltration factor
= 2041 H X 0.394 m X 0.13 = 104.54 **ham**
Capacity of surface water bodies= 24.50 ham
Total availability of GW + SW= 104.54 + 6.12 ham = **110.66 ham**
Short fall = Total requirement – Total Availability
= 182.462 – 110.66 ham= **71.80** ham

The projected requirement for drinking water after 10 years is **2.632 h**am and after 20 years **3.430** ham. From the above account, it seems that unless preventive measures are adopted, the study area is likely to be overexploited within a short period. With a view to keep the groundwater conditions of this aquifer healthy and to keep the groundwater withdrawals within the safe limits of annual recharge, following interventions have been recommended.

### Water conservation activity

The existence of substantial thickness of weathered zones indicates that the village is suitable to undertake WCS. Amongst the different WCS constructed in the village, the nalla bunding structures have proved to provide maximum benefits. These structures should be desilted to get maximum benefit. The northwest and hilly part of the village being at higher altitude with moderate slope, the erosion is more. Hence to reduce the soil erosion construction of CCT is very much necessary.

### Conclusions

On the basis of hydrogeological, geophysical surveys and geo-chemical studies the following conclusions are made.

- The entire village is covered by basaltic lava flows of varying thickness.
- The aquifer is jointed, fractured massive basalt and the vesicular zeolitic basalt.
- The groundwater flow is towards southeast.
- The water table follows the topography.
- The depth of the irrigation wells varies from 8.4 m bgl to as deep as 19.20 m bgl and the diameter from 5 m to 15 m. The groundwater potential is low.
- As per the village water account there is shortfall of 71.80 ham mainly due to excessive withdrawal of groundwater.

### Recommendations

The multidisciplinary surveys undertaken in the village have given much needed technical input to plan optimum management of water resources in the village. The following recommendations are made.

In order to meet the shortfall or to maintain groundwater level within the safe limit during hydrological cycle and sustainability for years together involvement of the community should be sought, both in supply side and demand side management interventions. Some suitable observation well and rain gauge station may be installed and data to be generated involving village youth for this purpose. Following are some of the recommendation for village Vadhane.

- Additional irrigation bore wells should not be constructed.
- Change in cropping pattern – Low water requirement crops, etc. should be encouraged, mindsets of the people need be oriented in this regard, in consultation with agriculture expert.
- Change in irrigation system – Drip and sprinkler irrigation system in the area need to be encouraged. It is suggested to adopt drip irrigation in place of conventional flood irrigation system, to save water. Also watering to crops should be in the early morning to avoid evaporation losses.
- It is recommended that CCT should be undertaken in the high ground to the north and northwest.
- Dug well / borewell recharging in rainy season is recommended in one hand.
- All the percolation tanks and Nalla bundings in the village should be desilted.
- Water Conservation Activity from ridge to valley has to be implemented.

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