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# Integrated Investigation For Artificial Recharge Structures In Rajura And Digargavan Percolation Tanks, Amravati District, Maharashtra

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***Abstract:** In India, percolation tank are known to have the potential to serve as one of the important type of artificial recharge structure. Despite water harvesting measures supported on a massive scale, groundwater levels are declining. New programmes are being implemented to improve artificial percolation whilst the impact of former measures on groundwater recharge is still undefined. Downstream impact of upstream watershed development becomes a key question for future programmes.*

***The present study focuses on integrated geological, geomorphological, hydrogeological and geophysical investigations were carried out at Rajura and Digargavan percolation tanks in Amravati district Maharashtra. Geological studies indicated the usually the structure covers a single flow or sometimes spread over two flows. All the flows are simple AA flow and overlain by thin alluvium. The depth of weathering varies from 3.39 – 4.11.***

***Geomorphological studies have been done on 1:50,000 scale using Survey of India toposheets and linear, aerial and relief aspects have been determined for each basin and interpreted for their controls of percolation tank sites. About 7-15 dug well has been selected around each structure and monitored for studying hydrogeological condition and determining the effective area by groundwater fluctuations. At each structure three vertical electrical sounding with AB/2 = 35 m have been carried out and interpreted by IPI2WIN software for layers and their resistivity. The mean resistivity for first layer at each site has been determined on upstream and downstream side. Ultimately an attempt has been made to integrate the collected data to determine the efficiency of percolation tank in the Deccan trap. It was found that low values of first layer resistivity on the upstream side in collaboration with high weathered zone, high drainage density, high drainage frequency, low length of overland flow and high ground water fluctuation favored the feasibility of percolation tanks in Amravati district, Maharashtra.***

***Keywords:** Integrated Investigations, Artificial recharge, Percolation tanks, Digargavan, Rajura.*



## I. INTRODUCTION

Groundwater has emerged as important resources to meet the water requirement of various sectors. Ground water tables are declining from 4-15 m below ground level in some parts of the state. The occurrence, movement and storage of groundwater within rock aquifers is quite complex and depends on several factors like geological, geomorphological and hydrological conditions. Though there is good rainfall, large amount of it is lost through runoff. The varied hydrogeologic conditions may prevent rapid infiltration into groundwater reservoir. There is thus an imbalance between recharge and groundwater development (Raju K.C.B, 1998) resulting in declining groundwater levels. This over extraction of groundwater resources has affected the agricultural economy and rural development. Realizing this many artificial recharge projects have been undertaken up by central and state groundwater department, in an attempt to recharge the depleted aquifers by spending huge amounts. To make the expenditure viable and have the sustainable development, it is

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essential that the sites and structures should be planned on sound scientific basis.

National Water Policy (2002) has identified conjunctive use of surface and groundwater as one of the thrust areas for sustained management of water resources in the country. In turn with the policy augmenting natural infiltration of rain water/surface water into underground storages by construction of conventional artificial recharge structures (like percolation tanks, kolhapur type weirs, underground bandhara, checkdams etc.) is being undertaken in different parts of the state by investigating mammoth revenues.

Effective groundwater management in any watershed or basin is purely based on the fact that how best one understands the natural environment in which groundwater occur and moves. Diverse physical conditions, including geological settings, geomorphological set up, hydrological and hydrogeological set up and geophysical conditions etc make generalization rather difficult. Such, integrated studies can provide useful information sustainability of artificial recharge structures.

## II. STUDY AREA

With the above aim in mind two percolation tanks, were selected from Amravati taluka, District Amravati, Maharashtra (figure No. 1) to evaluate their efficiencies in different hydrological, geomorphological, geological, hydrogeological and geophysical conditions in the region. Amravati District is situated in the northern part of the State and lies between north latitudes 20$^0$32' and 21$^0$46' and east longitudes 76$^0$37' and 78$^0$27' and falls in Survey of India degree sheets 55 G, 55 H, 55 K and 55 L.

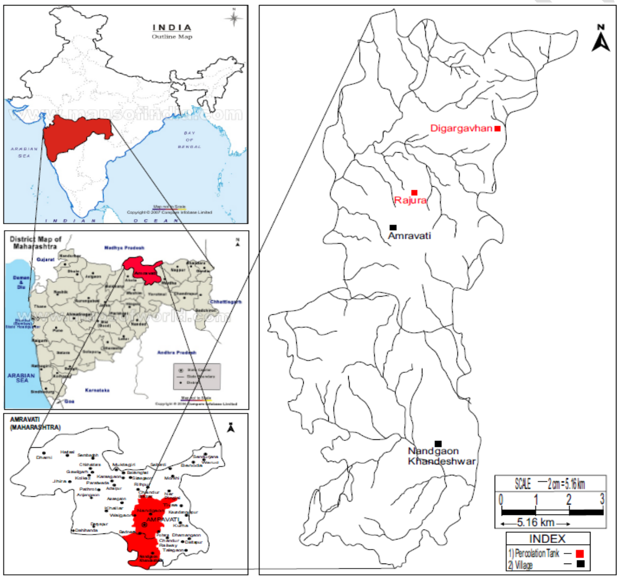


*Figure 1: Location Map of the study area*

## III. GEOLOGICAL SETTING OF THE AREA

To design a system for artificial recharge of groundwater requires permeable soil surface, greater infiltration rates of the soil and good unsaturated zone with adequate permeability. Knowledge of these conditions requires field investigations and hence geology of area where artificial recharge structures need to be constructed.

The study geological set up of Amravati district was undertaken by Geological survey of India in their operation Maharashtra programme, GSI (2001) and the district resource map provided by them.

The main formations in the Amravati Taluka are Archeans, Deccan Traps, Gondwana and Alluvium. Deccan Trap covers 75% of the area while 25% area is covered by Purna alluvium. Most of the area is covered by Deccan trap flows and Alluvium mainly occurring along the river channels and in the Purna river basin (Bhai and Saha (1989). The selected structures occur over Deccan trap formation. The Deccan trap formation consist number of lava flows varying in age from upper Cretaceous to lower Eocene period 65 +/-10 Million years ago.

Based on observation of lithologs and well sections, depth of weathering varies from 2.20 to 10.20 m. Geological studies indicated that usually the structure covers a single flow or sometimes spread over two flows. All the flows are simple AA flow and overlain by thin alluvium. The depth of weathering varies from thin about 0.5 m to 8.5 m. Numbers of field traverses were taken to evaluate the geological conditions at the artificial recharge sites and the geological map of four percolation tanks were slightly modified after GSI (2001) and presented in figure No.2.

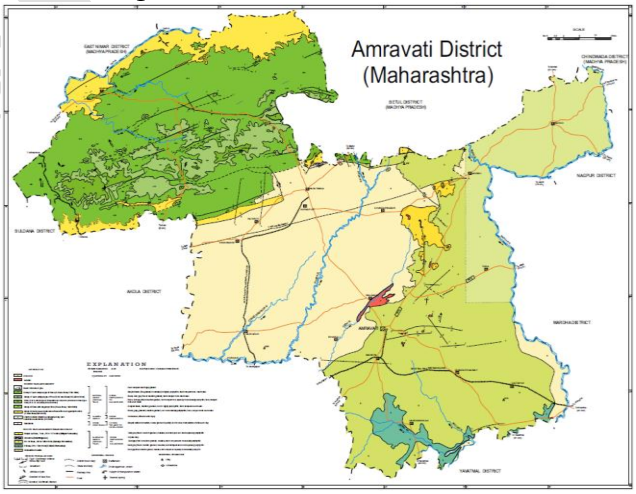


*Figure 2: Geological Map of the Amravati district, Maharashtra (After GSI, 2001)*

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### DIGARGAVAN PERCOLATION TANK

Only one type of 'AA' basalt flows is found in the area. Flow is dark grey, fine grained, non to sparsely porphyritic, shows fragmentary top and gives bouldary appearance. It has limited outcrops and flow was almost horizontal. The depth of weathering is 4.41 m.

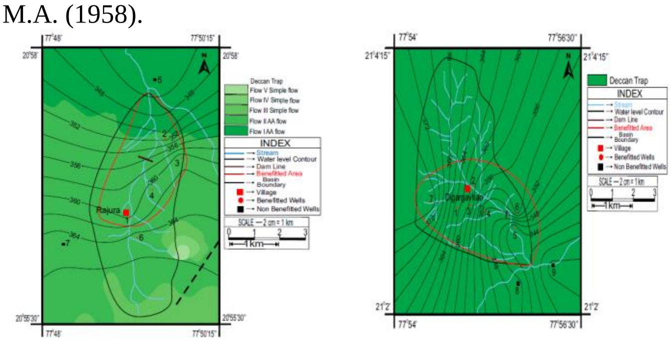
RAJURA PERCOLATION TANK

Five Deccan trap basalt flows were found in the area. All the flows are simple aa type. Flow I is dark grey, fine grained, non to sparsely porphyritic, shows up to 10 m fragmentary top and gives boulder appearance. Flow II is dark grey, fine grained, non-porphyritic to sparsely porphyritic and shows fragmentary top. Flow III is dark grey, fine grained, sparsely porphyritic shows fragmentary and vesicular top. It shows variation in characters, from simple to AA type. Flow IV is dark grey, fine to medium grained, highly porphyritic, show vesicular top, breaks into small rounded pieces and serves as Marker flow. Thin bands (0.30 m to 0.70 m) of red bole are well developed at the contacts of flow nos. I, II, III and IV. Flow V is dark grey, fine grained, non-porphyritic. Flow I and II are almost horizontal and flow III, IV, V show a very gentle gradient towards east. The depth of weathering is 3.39 m.

## IV. GEOMORPHOLOGICAL AND MORPHOMETRIC ANALYSIS

Geomorphological studies throw light on the lithology, structure, relative infiltration, runoff erosional aspects and on the stage of maturity of the basin. A strong mutual relationship exists between morphologic variables and hydrologic characteristics and can be applied to both surface and groundwater regimes.

Morphometry incorporates quantitative study of the area, altitude, volume, slope of the land and drainage basin characteristics of the area concerned (Savindra Singh, 1972). Morphometric studies in the field of hydrology were first initiated by Horton (1945) and Strahler (1957). Their studies on the geo-hydrological behavior of drainage basin and the prevailing climate, over geomorphology, structural aspects of the catchment and their relationship between drainage parameters and other factors were well recognized by many workers like Horton R.E. (1945), Strahler A.N. (1957), Melton M.A. (1958).



Rajura Percolation tank    Digargavhan Percolation tank

*Figure 3: Geological Map of Percolation tanks with geology, drainage, observation wells, water level contours and benefitted area*

Drainage map has been prepared from Survey of India toposheets on 1:50,000 scale for all the percolation tanks (Figure No.3) and used for morphometric analysis. Morphometric study includes the analysis of linear, aerial, and relief aspects of basin Table No. 1.

The linear aspects include stream order, stream number, stream lengths, bifurcation ratio, length of overland flow, constant of channel maintenance etc. and the observations presented in Stream ordering and numbering has been carried out based on the method proposed by Strahler (1969). The percolation tank of Rajura and Digargavan are situated on third order stream. The total stream length varies from 10.45 km and 24.43 km respectively. The mean stream length for percolation tanks Rajura and Digargavan located on third order streams was found to be 0.75 and 0.7 respectively. The length ratio of Rajura is found to be1.45 and that of Digargavan it is 2.24. The bifurcation ratio Digargavan is 5.4 indicating presence of structural control. Rajura have avg. bifurcation ratio of 3.75 indicating general absence of significant structural control on the development of the drainage. For Digargavan Length of overland flow is 0.17 while Rajura it is 0.25.Digargavan has high value of constant of channel maintenance than Rajura.

| Sr. No. | Geomorphological Parameters | Artificial recharge structures | |
|---|---|---|---|
| | | Digargavan P.T | Rajura P.T |
| 1 | Order of stream | 3.00 | 3.00 |
| 2 | Number of streams | 35 | 14 |
| 3 | Length of streams (km) | 24.43 | 10.45 |
| 4 | Avg. Bifurcation ratio | 5.4 | 3.75 |
| 5 | Length of overland flow | 0.17 | 0.25 |
| 6 | Constant of channel maintenance | 0.35 | 0.5 |
| 7 | Total area (sq.km) | 8.50 | 5.22 |
| 8 | Mean area | 0.24 | 0.37 |
| 9 | Drainage frequency | 4.12 | 2.68 |
| 10 | Drainage density | 2.87 | 2 |
| 11 | Form factor | 0.76 | 0.24 |
| 12 | Texture ratio | 3.41 | 1.1 |
| 13 | Infiltration Number | 11.83 | 5.37 |
| 14 | Relief Ratio | 13.43 | 24.95 |
| 15 | Ruggedness Number | 129.15 | 232 |
| 16 | Hypsometric Integral (%) | 66.75 | 21 |

*Table 1: Salient features of Morphometric analysis of Percolation tanks, in Amravati district*

Aerial aspects include study of basin area, mean area, drainage frequency, drainage density, form factor, texture ratio and infiltration number etc. Total area of stream at Rajura and Digargawan located on third order ranged from 5.22 sq.km to 8.50 sq.km. Drainage density of stream at Rajura and Digargawan located on third order had 2.87 and 2.0 respectively Drainage frequency of stream at Rajura was 2.68 and at Digargawan it was 4.12. Basin of Digargavan have relatively high stream frequency value indicating less permeable rocks which facilitates greater runoff, less infiltration and steep slopes as compared to Rajura. Form factor of stream at Rajura and Digargawan was found to be 0.24 and 0.76 respectively. The values of form factor indicate Digargavan is more or less in circular shape while Rajura have elongated shape. Infiltration number of Rajura and Digargawan were 5.37 and 11.83 respectively.

Relief aspects includes relief ratio, ruggdness number slope and hypsometric analysis i.e. area and altitude analyses etc. Relief ratios and Ruggdness number of stream at Rajura was 24.95 and 232.0 respectively. For Digargawan it was 13.43 and 129.15 respectively. Hypsometric integral of stream at Rajura and Digargawan located on third order had 21 and 67.75 respectively.

## V. HYDROLOGICAL AND HYDROGEOLOGIC STUDIES

Hydrologic and Hydrogeological studies integrate a variety of hydraulic and geological data, in the delineation, evaluation and management of groundwater. Rainfall data for 10 years has been collected from agriculture department, Government of Maharashtra and trend analysis of rainfall of both percolation tanks has been determined and presented in fig. no.4 and table no.2. Typically 7-8 observation wells has been selected on the downstream and upstream side of the percolation tanks and monitored for monthly groundwater levels along with tank water level. Hydrograph has been plotted (fig. no. 5) and correlation coefficients determined. With cutoff value of 0.60 for each structure wells directly depended were determined. Based on the benefitted wells area benefited were determined and its average fluctuations determined and presented in table no 2.

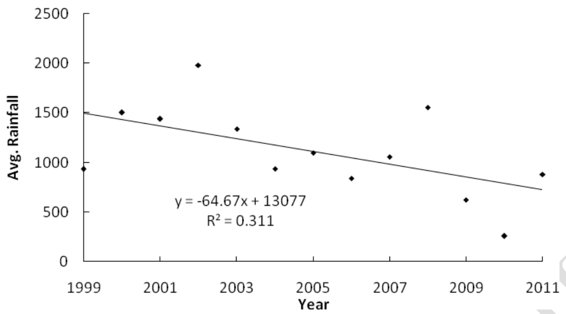


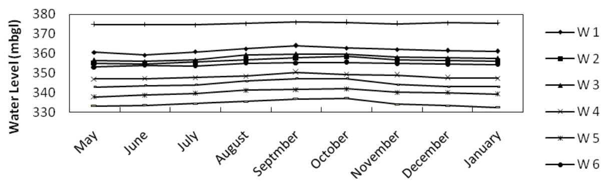

*Figure 4: Long term trend analysis for rainfall data (1999-2011) For Rajura and Digargavhan Percolation tanks*

| Sr. No. | Hydrological and Hydro geological parameters | Percolation Tank | |
|---|---|---|---|
| | | Digargavan | Rajura |
| 1 | Aquifer | Deccan trap | Deccan trap |
| 2 | Thickness of weathered zone (m) | 4.41 | 4.51 |
| 3 | Zone of aeration | 3.64 | 1.04 |
| 4 | Decline in Water level (Rain fall) | y = -64.67x + 13077 $R^2$ = 0.31 | y = -64.67x + 13077 $R^2$ = 0.31 |
| 5 | Average rainfall | 1090.55 | 1090.55 |
| 6 | Avg. fluctuation in the total area | 2.93 | 3.61 |
| 7 | Avg. Fluctuation in Structure | 2.62 | 4.33 |
| 8 | Area benefitted | 3.48 | 3.17 |
| 9 | Avg. fluctuation in the benefitted area | 2.62 | 4.33 |
| 10 | Specific Yield | 0.03 | 0.03 |
| 11 | Groundwater added (tcm) | 0.274 | 0.412 |

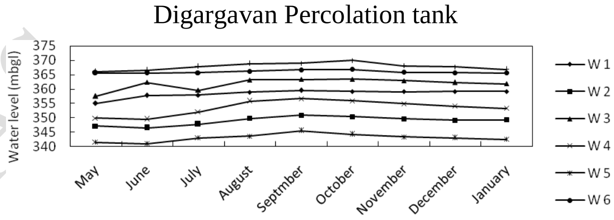
*Table 2: Salient features of Hydrological and Hydrogeological analysis of various Percolation tanks, in Amravati district, Maharashtra*

In Deccan basalt aquifers, hydrogeological map represents the mapping of the physical state of ground waters within their geological framework and includes the lithological boundaries between basalt flows, fracture zones and the weathered zone dispositions, Kulkarni and Deolankar, 1989. The hydrogeological study requires the study of water level, its long term behavior and evaluation of aquifer parameters, to understand the water yielding capacity of the formation (Todd, 1980, Karanth, 1999). Groundwater occurrence and its movement, and hydrodynamic condition in the basin with the relative transmissivity and storage behavior of different litho units can be very well assessed through hydro geological investigations.

Ground water in Deccan Trap Basalt occurs mostly in the upper weathered and fractured parts down to 15-20m depth. Based on the groundwater levels observed during monthly monitoring groundwater level contours had been superimposed on geological map (figure no. 3). The upper weathered and fractured parts form phreatic aquifer and ground water occurs under water table (unconfined) conditions. At deeper levels, the ground water occurs under semi-confined conditions. At places potential zones are encountered at deeper levels in the form of fractures and inter-flow zones.




Digargavan Percolation tank




Rajura Percolation tank

*Figure 5: Hydrographs of Observation wells at different percolation tanks in Amravati District, Maharashtra*

## VI. GEOPHYSICAL STUDIES

Application of the geoelectrical method has led researchers to develop surface resistivity techniques for making quantitative estimates of the water transmitting properties of aquifers, Roy and Apparo, 1971, Zohdy et al., 1974, Griffith 1976; Zhdanov and Keller, 1994, Louis et al. 2004. Number of researchers successfully used the electrical resistivity methods for groundwater prospecting in various terrains Prakash et al. 1993, Ballukraya, 2001, Rai et al. 2005, Idornigie et al. 2006, Das et al. 2007, Bhoyar C.P, 2008, Khadse S.P and Ingle S.D., 2011 and brought out the relationship between electrical and hydraulic properties of the aquifer.

Geophysical approach has been used for artificial recharge of groundwater by Jupp and Vozoff 1975, Koefoed 1979, Khadse S.P, 2003, Rubin and Hubbard 2005, Ekwe et al., 2006, Enikanselu, 2008, Armada et al.,2009, Sikandar et al., 2010, Hodlur et al., 2010, Tizro et al., 2010, Abdullahi et al., 2011and George et al., 2011.

The electrical resistivity method can be employed to estimate the thickness of overburden and also the thickness of weathered/fractured zones with reasonable accuracy. They can be used in identification of aquifer zones, their depth from the surface, lateral extent and thickness etc by the resistivity method.

| S. No. | VES No. | Curve type | Resistivity in Ohm.m | | | | | Thickness in m. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\rho_1$ | $\rho_2$ | $\rho_3$ | $\rho_4$ | $\rho_5$ | $h_1$ | $h_2$ | $h_3$ | $h_4$ |
| 1 | Rajura 1 DS | AK type | 40.95 | 81.27 | 132.3 | 18.67 | | 1.53 | 1.29 | 4.21 | |
| 2 | Rajura 2 US | KHK Type | 46.5 | 74.9 | 43.2 | 1055 | 59.8 | 0.6 | 0.79 | 1.85 | 4.29 |
| 3 | Rajura 3 US | HK Type | 57.6 | 13.6 | 3522 | 9.8 | | 0.635 | 0.879 | 3.65 | |
| 4 | Digargavhan 1 US | AK Type | 14.4 | 18.9 | 1993 | 1.71 | | 0.72 | 0.61 | 1.99 | |
| 5 | Digargavhan 2 DS | AHK Type | 51.5 | 29.2 | 16.6 | 1303 | 29.5 | 0.52 | 0.76 | 1.57 | 2.67 |
| 6 | Digargavhan 3 US | AKH Type | 9.6 | 12.4 | 47 | 8.18 | 69.5 | 0.6 | 0.79 | 1.85 | 4.29 |

*Table 3: IPI2WIN Interpreted geophysical structures at percolation tanks in Amravati District, Maharashtra*

| Geophysical parameters | Percolation Tank | |
|---|---|---|
| | Rajura | Digargavan |
| Average resistivity of 1$^{st}$ layer | 48.35 | 25.17 |
| Thickness of 1$^{st}$ layer | 0.92 | 0.95 |

*Table 4: Salient features of geophysical parameters of various Percolation tanks, in Amravati district, Maharashtra*

Six vertical electrical soundings (VES) using Schlumberger electrode configuration were conducted at the selected percolation tanks with a maximum current electrode spacing of 35 meters. The resistivity meter ANVIC CRM-500 was used for this survey work. At each location three VES were taken, two on upstream and one on downstream side so that the correlation can be made in terms of thickness, depth, and water bearing and transmitting capacity of the aquifers. The VES data curve was visually interpreted using curve matching technique of Orellana and Mooney,1966 and later by computer aided software program of Zohdy, 1974, and IPI2WIN software, Bobachev, 2003. While interpreting the sounding curve information from observation wells was incorporated. The average apparent resistivity's and true resistivities were determined and layered model developed for each artificial recharge structure. The values of resistance and apparent resistivity observed at different structures are presented in the table no. 3.

Four types of curve are obtained in percolation tanks, 'HK' type, 'AK' type, 'KHK' type, 'AKH' type. The resistivity for first, second, third and fourth layer ranges between 1.71 to 3522 ohm-m. This indicated that low resistivity first and second layer are more favorable for percolation tanks. The average resistivity of first layer and thickness of first layer have been presented in the table no. 4.

## VII. SUMMARY AND CONCLUSION

Integrated geological, geomorphological, hydrological and hydrogeological, geophysical studies of the four percolation tanks in the deccan trap area was found to be very useful for determining the efficiencies of the percolation tanks.

Geological studies indicated the usually the structure covers a single flow or sometimes spread over two flows. All the flows are simple AA flow and overlain by thin alluvium. The depth of weathering varies from thin about 3.39 – 4.11. Percolation tank located on the inter flow zone or those having catchment area in the interflow zone where more efficiency as compared those on highly weathered rock. The efficiency of structure located on simple AA flow depends on extent of weathering and fracturing.

Geomorphological studies carried on linear, aerial and relief aspects have indicated that drainage density, drainage frequency, length of overland flows, bifurcation ratios, hypsometric integral are the controlling parameters in location of percolation tanks. The percolation tank located on third order basin where more effective as those located on second order. Low drainage density indicated a poor condition as compared to those with moderate drainage density. They have their controls on the efficiencies of percolation tank sites.

Hydrogeological condition in the basin indicated that all the structures unconfined groundwater situation. Based on the correlation coefficient effective are of percolation tanks and the mean fluctuation determined. The average fluctuation varies from 2.93 to 3.61 m in catchment area but in benefited area it varies from 2.62 to 4.33 m. The zone of benefit in case of percolation tank varies from 3.17 to 3.48 sq. km.

Geophysical resistivity investigation indicated that better efficiencies can be achieved if the first geoelectrical resistivity lies below 25 ohm-met and have a thickness of above 0.5 met. Geophysical investigation indicated percolation tanks should not be constructed if the first layer resistivity is above 50 ohm/m and thickness is at least 1.0 met.

Ultimately an integrated studies indicated that presence of interflow zones, low values of first layer resistivity on the upstream side in collaboration with high weathered zone, high drainage density, high drainage frequency, low length of overland flow and high ground water fluctuation favored the feasibility of percolation tanks in the Deccan trap of Amravati district, Maharashtra.



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