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# Evaluation of Aquifer Parameters in the Bori-Chikli Watershed of Jalgaon District, Maharashtra State, India

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***Abstract***

Groundwater is valuable source of drinking water. Groundwater potential in consolidated and unconsolidated sediments varies due to variation in hydraulic parameters of an aquifer. In present study aquifer parameters were assessed by pumping test. Groundwater occurrence and movement in the area is mainly through the Deccan Basalt and/or alluvium. The Deccan Basalt is hydrogeologically very complex, and it may or may not be useful everywhere to tap groundwater. The fractured and weathered basalt behaves as a good aquifer whereas massive basalt doesn't. In the present study, aquifer parameters like Specific Capacity (C), Coefficient of Transmissivity (T) and Storage Coefficient (S) are calculated by conducting pumping test. Majority of the basaltic areas of the watershed is characterized by good to moderate and moderate to poor groundwater potential. Alluvium is representing excellent to good groundwater potential.

*Keywords:* Pumping Test, Specific Capacity, Coefficient of Transmissivity, Time-draw Down and Theis Recovery Plot

## Introduction

Water is an elixir of life and whole world depends upon groundwater to fulfill the requirement of human being. Groundwater occurrence and movement is mainly controlled by subsurface lithology and geomorphic landforms of the area. Evaluation of aquifer parameters *viz.* Specific Capacity, Coefficient of Transmissivity, Storage Coefficient and Specific yield are utmost important for development and management of groundwater resources. In present study, an attempt has been made to determine the hydraulic properties of basaltic aquiferof Bori- Chikli watershed using pumping test.Copper and Jacob's methods are accurate methodsfor determination of Specific Capacity (C), Coefficient of Transmissivity (T), Storage Coefficient (S) and Specific yield. Several researchers have investigated aquifer parameters by conducting the pumping tests (Theis 1935; Cooper and Jacob 1946; Singhal and Gupta 1999; Singh and Gupta 1986; Singh and Gupta 1991; Hantush and Jacob 1955; Hantush 1960, 1966; Javandel and Witherspoon 1983; Theim 1906; Raj 2001; Kruseman and de Ridder 1970). In present study, pumping tests were carried out at Kunzar and Ranaiche villages. Dug wells penetrating weathered and fractured basalts represented an unconfined aquifer in the area. The main objective of the study is to determine transmissivity 'T' and storage coefficient 'S' of basaltic areas for correlating groundwater level fluctuation and for evaluation of groundwater potential.

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## Study Area

Study area is situated in the western region of Jalgaon district in the state of Maharashtra. It lies between longitude 75°19'10" and 74°55'45" E and latitudes 20°40'05" and 21°11'03" N covering 1438.57 km$^2$ area (Fig. 1). Bori-Chikli watershed is forming a part of Bori River Catchment, Tapti River Basin and Arabian Sea Water Resource Region (AIS and LUS, 1988). Climate of the area is hot and dry during October to June ranging 10°C to 46°C temperature. Mostly rainfall received in monsoon season (June to September) recording 736.75 mm average rainfall. Agriculture is the main practice for survival of human beings. Crops like Cotton, Jowar, Bajara, Maize and grains are prominently harvesting in the area. Geologically, area is occupied by basaltic rocks, dykes and alluvium. Geomorphic landforms like plateau, dissected hills, pediment, pediplain and alluvial plain controls groundwater occurrence and movement in accordance with geology of the area.

## Methodology

In present study, pumping tests were conducted at two large diameter dug wells in basaltic terrain located in Kunzar and Ranaiche villages of the Bori-Chikli watershed. Pumping tests were carried out using 7.5 H.P. pumps to determine aquifer parameters

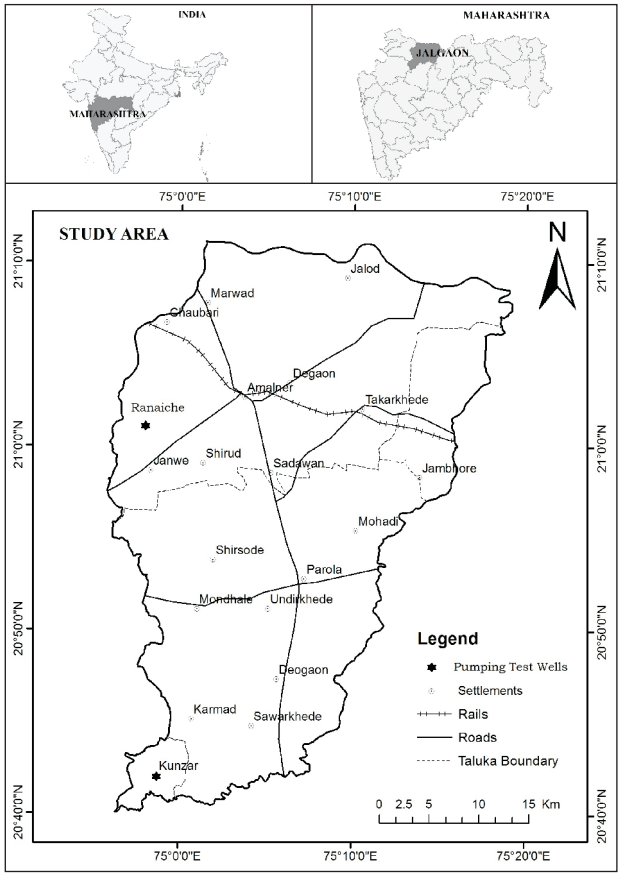


**Fig. 1.** Location map of the Bori-Chikli watershed and wells used for pumping test

viz. Specific Capacity (C), Coefficient of Transmissivity (T) and Storage Coefficient (S). During the testwells are observed for 6 Hrs. and water level, drawdown and well recuperation rate measured at 5 minutes interval.The dischargewas measured by volumetric method and Time- drawdown plot and Theis recovery plot were drawn. Cooper and Jacob's methods were used to calculate Specific Capacity (C), Coefficient of Transmissivity (T) and Storage Coefficient (S) of the aquifer. Aquifer parameters, water level fluctuations and thickness of the aquifer were considered for evaluation of groundwater potential in the study area.

## Geological Setting

On the basis of interpretation of satellite data, field work and existing District Resource Map of Jalgaon district (1: 2,50000 scale) published by Geological Survey of India, the area have been mapped (Fig. 2). Major part of the watershed is covered by basaltic flows of Sahyadri group of Deccan Trap.The lava assemblage of Sahyadri group consists of alternating sequence of 'Pahoehoe' and 'Aa' flows with cumulative exposed thickness varying between 90 and 200 m (GSI, 2009). In study area, Sahyadri Group is represented by Compound Pahoehoe flows and group of compound Pahoehoe flows of Upper Cretaceous to Paleogene age (Shimpi, 2020). These rocks are dark, massive, fine to medium grained and highly jointed (Vertical joints and columnar joints) Basalt. Northern part of the study area is covered by Tapi alluvial plain. The alluvium comprises of beds of clay and silt with lenses of coarse sand, gravels and pebbles. Doleritic dykes trending E-W, N - S and NE – SW directions are crisscrossing in the area (Shimpi, 2020).

## Results and Discussion

### *Hydrogeological Characteristics*

The Deccan Trap Basalt of upper Cretaceous to lower Eocene age and Alluvium of Quaternary agecontrols groundwater movement in Bori- Chikli watershed (Shimpi, 2020). Hydrogeological characteristics of consolidated Deccan basalt is complex, occupied 91 % area of the watershed. Unconsolidated alluvium and murum accounted for 9 % of the study area (Shimpi, 2020). In Deccan basalts groundwater occurs mostly in the upper weathered and fractured parts down to 20 - 25 m depth. 21 $m^3$/day and 337 $m^3$/day are the ranges of yield of dug wells tapping upper phreatic aquifer. Depth of the dug well in this area is in the range of 5 - 15 m bgl and bore wells are in the range of 60 - 150 m depths (Shimpi and Rokade, 2021). Weathered and vesicular basalts yield groundwater in the range of 1.8$m^3$/day to 52 $m^3$/day. Northern part of the watershed is represented by Tapi alluvium, it can be sub-divided into upper younger alluvium and deeper older alluvium attaining depth of 70 - 80 m and 450 m, respectively (CGWB, 2017). In Bori-Chikli watershed, tapping of groundwater from alluvium is through tube wells ranging in 70 - 150 m depths and yielding 20 $m^3$/day to 52 $m^3$/day groundwater. Due to granular zones of sand and gravel alluvium forms potential aquifer in the northern part of the study area.

### *Depth of Weathering*

Depth of weathering plays pivotal role in an occurrence and movement of the groundwater (Rokade *et al.*, 2007). In present study, depth of weathering measured from the dug wells, road

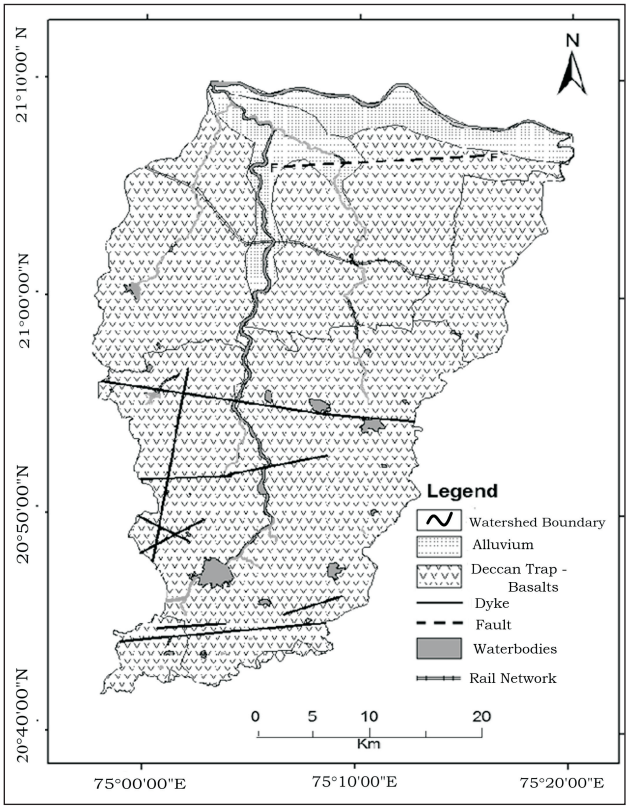


**Fig. 2.** Geological map of the Bori-Chikli watershed

**Table 1:** Description of the calculated aquifer parameters of the pumping test

| Well No. | Village | Geological Formation | Specific Capacity ($C = 303*A/t_1$ x log S1/S2) | Coefficient of Transmissivity ($T = 2.303$ x $Q/4*3.14$ x $\Delta s$) | Storage Coefficient ($S = 2.25$ x T x $t_o / R^2*6.96/10^{-4}$) | Specific yield (S*100) |
|---|---|---|---|---|---|---|
| 1 | Ranaiche, Amalner Taluka | Moderately weathered and Jointed Basalt | 313.36 ltrs/min/ meter of draw down | T = 141.817 sq. m/day | S = 0.074 | 7.40 % |
| 2 | Kunzar, Chalisgaon Taluka | Moderately weathered and Jointed Basalt | 558.43 ltrs/min/ meter of draw down | T = 108.568 sq. m/day | S=0.081 | 8.10 % |

cuttings and in river courses. In study area, depth of weathering is in the range few centimeters to 10 m (Shimpi, 2020). It is classified as shallow depth of weathering (0 - 2 m), moderate depth of weathering (2.1 - 5 m), deep depth of weathering (5.1 - 10 m) and very deep depth of weathering (More than 10 m) (Rokade, 2007). About 28 % of the watershed area is covered with very deep depth of weatheringand 25% area of the watershed is covered by shallow depth of weathering and remaining 47 % area of the watershed is represented by moderate and deep depth of weathering**.**Deep to very deep depth of weathering were reported in northern part of the area. Southern and western part of Parola and Amalner Tehsil are representing moderate depth ofweathered section.Shallow weathered sections are observed in western and eastern part of the study area.

### *Evaluation of Aquifer Parameter*

The hydrogeological system of the area is determined by its hydraulic parameters and aquifer recharge and discharge. The hydraulic parameters *i.e.* specific yield, transmissivity and storage coefficient are evaluated by pumping test. In evaluation of the hydrogeological parameters of an aquifer, the storativity and transmissivity are the most important parameters for quantitative understanding of the problems in hydrogeological regime. In the study area, pumping tests werecarried out at Kunzar and Ranaiche villages to determine the aquifer parameters. The dug wells used for pumping test are primarily used for irrigation purpose. The depth of both the dug wells are in the depth - range of 10 m to 20 m. Diameter of the dug-wells are in the range of 4.0 m to 8.0 m. The various aquifer parameters were calculated from the obtained data using the Cooper and Jacob's method. Calculated aquifer parameters are as given in the Table 1.

Specific capacity is the wells capacity evaluated by taking the ratio of discharge rate to the water level drawdown. In study area, Specific capacity of the aquifer at Ranaiche village is 313.36 ltrs/min/ meter whereas at Kunzar, it is calculated 558.43 ltrs/min/ meter.

The coefficient of transmissivity of the aquifer can be determined from a pumping test using the levels of drawdown over time pumped. In study area, Coefficient of transmissivity of the aquifer at Ranaiche and Kunzar are calculated 141.817 sq. m/day, 108.568 sq. m/day, respectively.

The storage coefficient or storativity of the aquifer is mainly depends upon its unconfined or confined nature. It is the measure of the waterreleased with respect to change in the water level. In study area, storage coefficient value of 0.074 and 0.081 are calculated for aquifer at Ranaiche and Kunzar villages, respectively. These values indicate that the basaltic aquifer is of unconfined nature (Shimpi, 2020).

Specific yield is the ratio expressed as percentage of the volume of water can be drawn out of saturated aquifer. Specific yields at Ranaiche and Kunzar villages are 7.40 % and 8.10 %, respectively. Time recovery plots of both pumping wells are shown in Fig. 3.

### *Thickness of the Aquifer*

Aquifer thickness in the Bori- Chikli watershed is evaluated by plotting an estimated thickness of unconsolidated sediments and thickness of weathered and fractured Deccan basalt. Thickness of these litho-units are estimated from Vertical Electrical Sounding (VES) data. In Bori- Chikli watershed, maximum aquifer thickness is obtained in the area covered by alluvium (Shimpi, 2020). The range of aquifer thickness in alluvium area is 2 m to 20 m, whereas in case of basalt the range is 2 m to 7 m. In villages like Lon Bk., Nagao Bk., Gadkhamb, Taskhede, Holpimpri, Ratnapimpri, Dangar, Janave and Pimpalkotha weathered and fractured basalt of thickness ranging 2 m to 7 m behaves good aquifer. Hydrogeological Fence diagram the study area is as shown in Fig. 4.

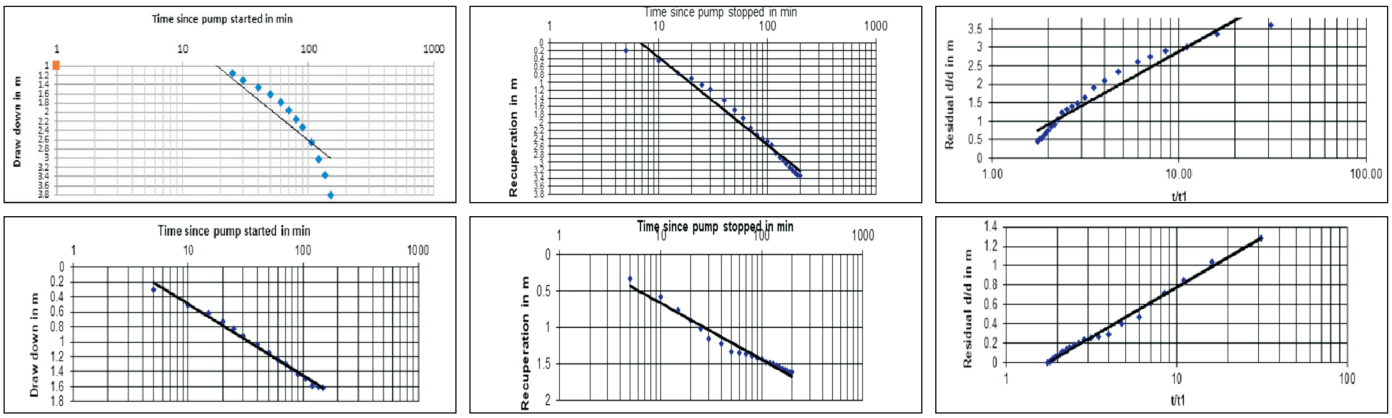


**Fig. 3.** Plots of pumping tests carried out at Ranaiche and Kunzar villages, a. Time-draw down plot of well No. 1.at Ranaiche –Tal-Amalner (Bori-Chikli Watershed), b. Time-draw down plot of well No. 2.at Kunzar, c. Time Recovery plot of well No. 1.at Ranaiche –Tal-Amalner (Bori-Chikli Watershed), d. Time Recovery plot of well No. 2.at Kunzar, e. Theis Recovery plot of well No. 1.at Ranaiche –Tal-Amalner (Bori-Chikli Watershed), f. Theis Recovery plot of well No. 2. at Kunzar

*Groundwater-Level Fluctuation*

In the Bori-Chikli watershed, water-levels were monitored for consecutive three hydrologic years 2014, 2015 and 2016. Groundwater level fluctuations are observed in the range of 1 m to 10 m. In study area, minimum 1 m - 2.5 m water level fluctuations are observed in alluvium areas. In thick alluvium areas, more groundwater exploitation is resulting water level fluctuating in between 10 m to 13 m.In agricultural rich areas groundwater level fluctuation range 7.5 m to 10 m is observed in Shirud, Jirali, Jamade, Karadi, Udanidigar, Shirasmani, Khedi-Dhok, Amalner, Nimbhora, Rotwad, Higaon, Savkhede and Dhavade villages. At some places of alluvium belt groundwater level fluctuation reached up to 30 m. In weathered basaltic areas, 2.5 m to 7.5 m of water level fluctuations are reported at Lon Bk., Nagao Bk., Gadkhamb, Taskhede, Holpimpri, Ratnapimpri, Dangar, Janave, Pimpalkotha, Soke, Bole, Sabgavhan and Hirapur villages. In massive basaltic areas, fluctuations are more than 13 m. Spatial distribution of groundwater fluctuation and groundwater flow directions observed in the study area is given in Fig. 4.

*Groundwater Potential*

Groundwater potential of the area depends upon the degree and depth of weathering, behavior of fractured and jointed basalts and inter-connectivity between cavities of the basaltic rocks (Rokade, 2019). In present research, groundwater potential map is generated by considering aquifer thickness, aquifer resistivity and groundwater level fluctuations in addition to geology of the area. In Bori-Chikli watershed, groundwater potential zones are classified as Excellent, Very Good to Good, Very Good, Good, Moderate, Moderate to Poor, Poor and Poor to Nil. In each zone, the prospect of

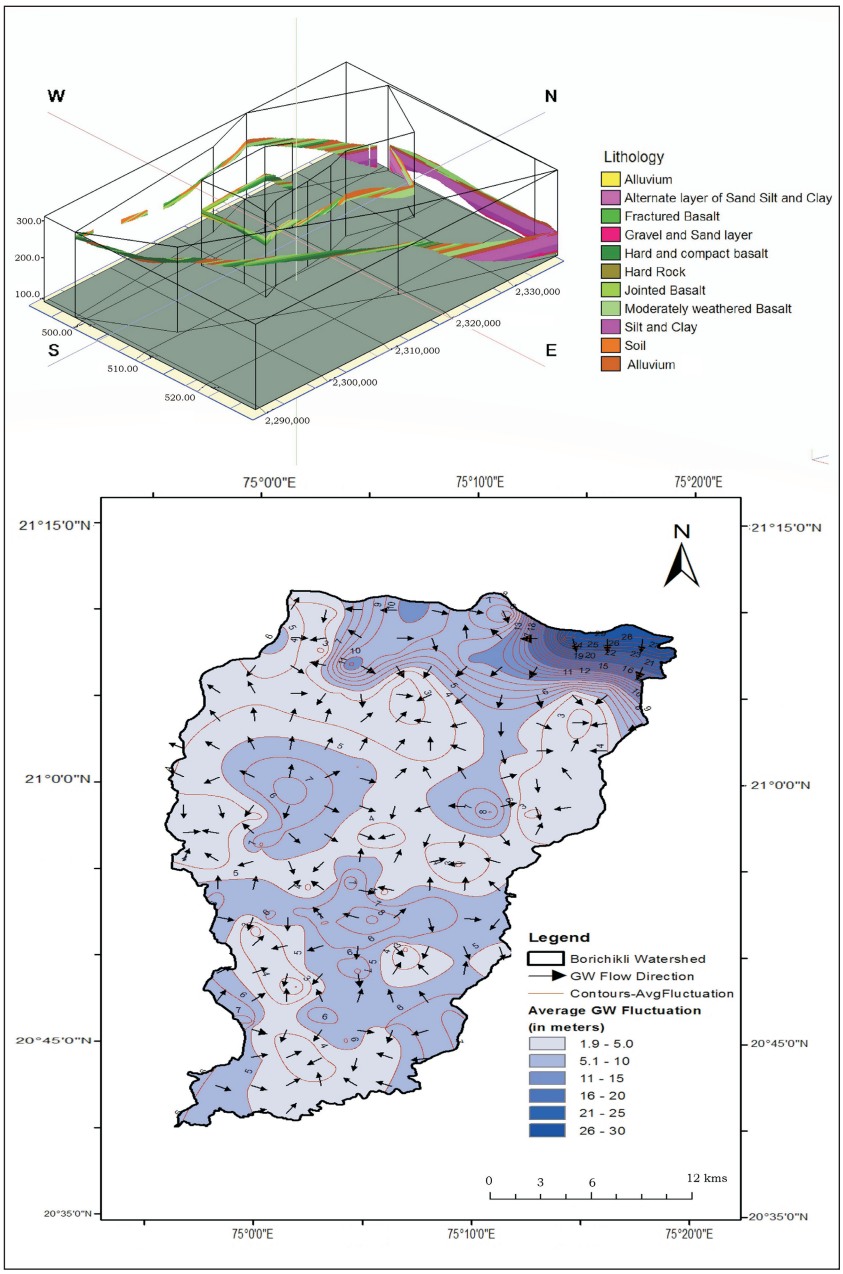


**Fig. 4.** Hydrogeological Fence diagram and groundwater fluctuation and flow directions observed in the area

groundwater has relation to its lithology and its hydrogeological characteristics, aquifer thickness and groundwater level fluctuation. Maximum area of the Bori-Chikli watershed characterized by moderate and good groundwater potential zones, followed by very good and excellent potential.Massive basaltic areas are represented by moderate to poor, Poor and Poor to Nil.Excellent, very good to good and good groundwater potential zonesare characterized by low groundwater level fluctuation with aquifer thickness of 8 m to 20 m. Tapti River alluvium is characterized by good to excellent groundwater potential and low water level fluctuation in undeveloped areas. Unfractured massive basalt having low aquifer thickness show more water level fluctuation designating poor groundwater potential zone.

## Conclusions

Aquifer parameters controlling groundwater flow needs to estimate for effective groundwater development and management. Pumping test proved to be best tool for accurate estimation of aquifer parameters such as specific capacity, Coefficient of Transmissivity (T), storage coefficient (S) and Specific yield of the aquifer. In Bori – Chikli watershed, basalts of Sahyadri group exhibits different hydrogeological behavior. In this area, specific capacityof the basalt is in the range of 558.43 ltrs/min/ meter to 313.36 ltrs/min/ meter. Coefficient of Transmissivity of the basalt is in the range of 108.568 $m^2$/day to 141.817 $m^2$/day and storage coefficient of the basalt is ranging from 0.074 to 0.081. Specific yield of the basaltic aquifer is in the range of 7.40 % to 8.10 %. Theis and Cooper-Jacob methods proved to be most useful for estimation of Transmissivity and storage coefficient.

## Authors' Contributions

**V. M. Rokade**: Conceptualization and Design, Analysis and Interpretation, Writing- Original Draft, Reviewing and Editing. **Sujit S. Shimpi**: Data collection, Analysis and Interpretation, , Writing- Original Draft, Reviewing and Editing.

## Conflict of Interest

Authors declare no conflict of interest.

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