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Estimation of Dar-Zarrouk parameters for groundwater exploration in parts of Chopda Taluka, Jalgaon district, Maharashtra (India)

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ABSTRACT

Vertical Electrical Soundings using Schlumberger technique with a maximum current electrode spacing (AB/2) of 150 m were carried out at 34 locations to delineate the ground water potential zones in Chopda taluka of Jalgaon district (Maharashtra), covered by Deccan trap inliers in the center surrounded by alluvium. The results indicate that the study area encompasses a multilayer admixture of pebbles, sand, silt and clay, with resistivity values in the range of 18-25 Ω-m. The area comprised of three types of aquifers which is (i) loose clayey or silt with intercalation of sand (< 10 Ω-m), (ii) clayey-sand layer (10-25 Ω-m), and (iii) compacted clay or pebbles/cobbles and sand (25-50 Ω-m). VES 29 and 15 inliers, are seemingly composed of fractured and weathered basaltic formation. Hard rock is revealed at 12-25 m and exposed at some locations in Chahardi area. Four resistivity profiles revealed a clear picture of the continuity of aquifer and movement of water, while the sounding data provided 2-5 geoelectric layers of different thickness. Dar-Zarrouk parameters i.e., (i) Longitudinal conductance (S) (ii) Longitudinal resistivity (ρl) (iii) Transverse resistance (T) (iv) Transverse resistivity (ρt) and (v) Electrical anisotropy (λ), derived from resistivity data helped in categorizing the study area with respect to protective capacity rating of different aquifers. The S map suggest that about 17 % of the area falls under 'very good' to 'excellent' and protective capacity, while about 50 % falls under 'good' protective capacity rating. A large variation is observed in λ map, ranging from 0.38 to 2.73 over the studied region. This indicates the anisotropic nature of the aquifers in such hard rock terrain. Several lineaments are cris-crossing the study area and the intersection points are considered favorable zone for groundwater exploration.

Key words: Vertical Electrical Sounding, Alluvium, Dar Zarrouk parameters, Longitudinal conductance

INTRODUCTION

Water level depletion is increasing day by day because of fast growing industrialization and increasing agricultural practices. The study area is characterized by different aquifer behaviors due to the complex hydrogeological conditions comprising of trap rock in the middle part.

The electrical resistivity technique has been widely used by many researchers (Gupta et al., 2010, 2015; Patil et al., 2015; Khalil et al., 2015; Srinivasamoorthy et al., 2014; Narayanpethkar et al., 2009; Golekar et al., 2014) for groundwater exploration studies in different parts of India. Deccan traps, consist of multiple layers of solidified lava flows and behave as a multilayered aquifer system and VES is a suitable technique to map the depth distribution of litho units. (Rai et al., 2013). The D-Z parameters of different layers derived from geoelectric parameters have been used for groundwater exploration studies of the aquifers in different parts of the world, such as in Nigeria (Udoinyang et al., 2012; Egbai et al., 2015), Brazil (Antonio Celso de Oliveira Braga et al., 2006) and in India (Mondal et al., 2013; Gupta et al., 2015; Shailaja et al., 2016). Earlier studies (Patil et al., 2015) in Chopda taluka have been carried out using 10 sounding data, while in present study, the sounding was extended further in parts of south and north-east area also. D-Z parameters are calculated to understand the groundwater regime and the aquifer protective capacity of different layers based on the variation of longitudinal conductance (S), longitudinal resistivity (ρl), Transverse resistance (T), Transverse resistivity (ρt), Anisotropy (λ).

STUDY AREA

The study area (figure 1) is in the northern part of Chopda Taluka of Jalgaon district, Maharashtra bounded by latitudes 21°8′N to 21°22′N and longitudes 75°12′ E to 75°22′E. Ratnavati, the main river of Chopda taluka is a tributary of Tapi river. The study area is characterized by semi-arid climatic conditions with annual rainfall of 647.1 mm during 2017. In study area well inventory survey was carried to know the lithology and condition of groundwater. During survey observed static water level of the study area ranges from 14.1m to 20.2m in the month of May-2017. The mean minimum temperature varies from 12^{0}C to 38^{0}C throughout the year and high relative humidity occurs during the rainy season, viz. June to October. The important crops cultivated are Banana, Sugarcane, Cotton and Wheat.

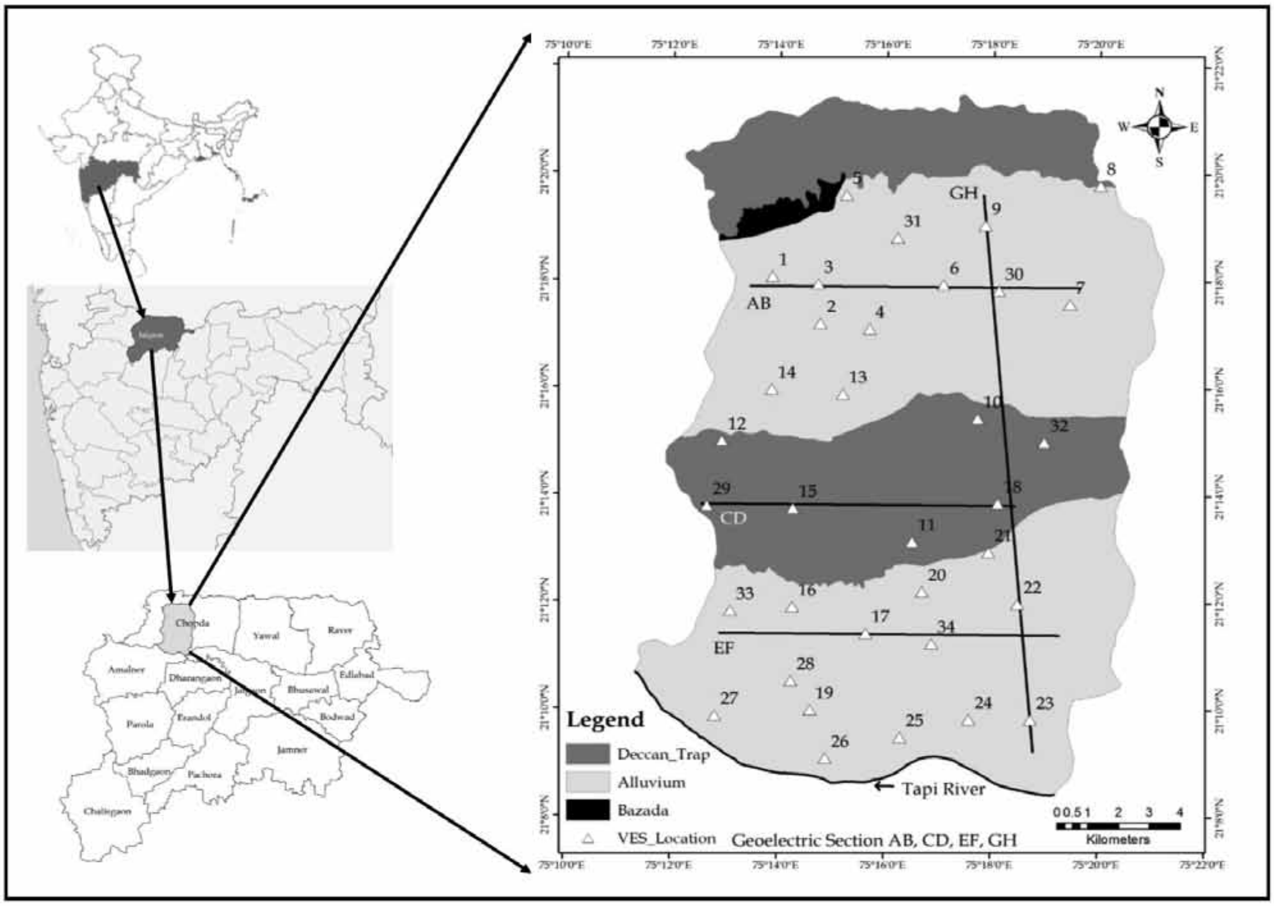

Figure 1. Location and Geological Map of study area.

Table 1. Resistivity values of different rock type in the study area (Source: CGWB website: http:// cgwb.gov.in/CR/ achi_geo_stu. html).

Geological Formation	Resistivity (Ω m)
Alluvium, Black cotton, Bole bed	5-10
Weathered /fractured/vesicular basalt Saturated with Water	20-40
Moderately Weathered/Fractured /Vesicular Basalt with Water	40-70
Massive Basalt	> 70

GEOLOGY OF THE STUDY AREA

The northern part of the study area (figure 1) comprises of Satpuda ranges covered by the Deccan Volcanic Basalts (Upper Cretaceous to lower Eocene age), while the southern part is occupied by thick alluvium (Quaternary age) as seen at gullies and river bank. The different formations in the study area are (CGWB, 2013)

Deccan Traps: The central part of study area covered by Deccan traps formed due to the enormous lava flows which extend over huge areas of western, central and southern India at the end of Mesozoic era. Deccan traps (basaltic flows) consist mainly two units, Aa flow which consists of dark fine to medium grained sparsely porphyritic and Pahoehoe flow – medium grained, sparsely porphyritic. (Deshpande, 1998; GSI, 1984)

Alluvium: Alluvium mainly consists of layers of clay, sand, gravels, and boulders of variable thickness. The sand and gravel occur in one or more beds. The alluvium occupies the southern part of the area under study. The alluvium is clayey and yellowish to light brownish in colour as observed in exposures around Tapi bank (GSI, 1984) it is associated with calcrete nodules.

The topography in combination with type of soil, high run-off, medium to high infiltration, over exploitation of groundwater (particularly for banana crops) resulted in lowering of groundwater resources in the area further accentuated by the unpredictable fluctuations of seasonal rainfall.

Table 2. Dar-Zarrouk parameters in Study area of Chopda Taluka

VES	Name	Total depth		Longitudinal Conductance	Transverse Resistance	Longitudinal Resistivity	Transverse Resistivity	Anisotropy
		H(m)	Error (%)	S	T	ρ_l	ρ_t	λ
1	Chaugaon	38.97	0.795	6.73	292.54	5.79	7.51	1.14
2	Chunchale	35.248	0.794	4.91	400.46	7.18	11.36	1.26
3	Krishnapur	44.2	0.897	9.26	389.54	4.78	8.81	1.36
4	Mamalde	28.36	0.814	26.19	117.57	1.08	4.15	1.96
5	Angurne	62.26	0.797	17.85	419.18	3.49	6.73	1.39
6	Varad 1	35.2	0.804	2.21	635.04	15.95	18.04	1.06
7	Adgaon	102.5	0.748	10.91	1071.21	9.40	10.45	1.05
8	Virwade	37.03	0.681	12.72	311.36	2.91	8.41	1.70
9	Nagalwadi_1	1.673	0.52	0.11	107.96	15.50	64.53	2.04
10	Chopda Urban_1	92.355	0.471	0.95	5658.95	97.03	61.27	0.79
11	Vele	21.7	0.712	2.05	374.71	10.60	17.27	1.28
12	Kazipura	30.829	0.489	0.62	216.05	49.45	7.01	0.38
13	Akkulkhede	37.461	0.549	5.34	297.82	7.02	7.95	1.06
14	Hingone	21.935	0.693	6.68	231.65	3.28	10.56	1.79
15	Chahardi_1	92.97	0.811	2.82	3467.86	32.98	37.30	1.06
16	Chahardi_2	102.1	0.672	17.18	613.87	5.94	6.01	1.01
17	Chahardi_5	34.72	0.674	0.70	2618.41	49.40	75.42	1.24
18	Chopda Gartad Rd	16.49	1.75	8.07	155.67	2.04	9.44	2.15
19	Nimgavan_1	1.21	2.1	0.00	637.67	527.00	527.00	1.00
20	Hol	15.71	0.473	1.58	157.87	9.93	10.05	1.01
21	Gartad	12.16	0.808	2.44	96.10	4.98	7.90	1.26
22	Dhanwadi	5.997	1.65	0.05	5485.25	122.59	914.66	2.73
23	Sanpule	15.2	0.895	3.77	61.26	4.03	4.03	1.00
24	Kurwel	5.685	0.939	2.05	17.10	2.77	3.01	1.04
25	Tavse Bk_1	46.2	0.665	7.01	304.46	6.59	6.59	1.00
26	Khachne	4.198	0.74	1.06	44.90	3.95	10.70	1.65
27	Tandalwadi	33.28	0.524	4.45	250.96	7.47	7.54	1.00
28	Nimgavan_2	7.12	0.6	0.75	87.00	9.51	12.22	1.13
29	Chahardi_3	88.79	0.911	2.71	3234.42	32.82	36.43	1.05
30	Nagalwadi_2	1.448	0.716	0.11	103.90	13.11	71.75	2.34
31	Varad_2	35.2	0.501	1.80	758.08	19.53	21.54	1.05
32	Chopda Urban_2	102.348	0.451	0.92	6082.56	111.79	59.43	0.73
33	Chahardi_4	102.1	0.915	15.39	694.73	6.64	6.80	1.01
34	Tavse Bk_2	11.83	0.861	1.22	116.66	9.73	9.86	1.01

METHODOLOGY

34 vertical electrical soundings (VES) carried out at different locations (figure 1) were interpreted with the help of the interactive semi-automated technique using IPI2WIN software 3.0.1.a7.01.03 (Bobachev, 2003). A few representative sounding curves along with layer parameters are shown in figure 7.

Based on the three to four layered models, obtained over the 34 locations of the area, four geoelectric sections were drawn (3 in E-W direction and one in N-S) spread over the study area. The resistivity data was compared with the tube well data existing in the study area to aid in recommending sites for drilling. The resistivity ranges (Table 1) were used in the present study area as suggested by Central Ground Water Board (CGWB).

DAR-ZARROUK PARAMETERS (METHODS OF ESTIMATION)

Dar-Zarrouk parameters (D-Z) termed by (Maillet, 1947) play an important role in geoelectrical resistivity soundings. They have been used in computing a distribution of surface potential and the section consists of *n* geoelectric layers with thicknesses h_1, h_2, h_3, …., h_n and resistivity ρ_1, ρ_2, ρ_3, …..ρ_n for a block of unit square area and thickness

$$H = \sum_{i=1}^{n} hi$$

The D-Z parameters, i.e., S, T, ρ_l, ρ_t & λ are defined as following.

A geoelectric unit is characterized by two basic parameters the layer resistivity (ρi) and the layer thickness

Table 3. Longitudinal Conductance/Protective capacity rating (Oladapo and Akintorinwa, 2007).

Longitudinal Conductance (Ω^{-1})	Protective Capacity Rating
>10	Excellent
5 – 10	Very good
0.7 – 4.9	Good
0.2 – 0.69	Moderate
0.1 – 0.19	Weak
<0.1	Poor

(hi) for i th layer (i =1 for the surface layer). Two further electrical parameters can be derived for each layer from the respective resistivity and thickness; these are called the Longitudinal Conductance, Transverse Resistance.

$$S = \sum_{i=1}^{n} \frac{hi}{\rho i} \quad \text{.....................(1) longitudinal conductance}$$

The longitudinal resistivity of the current flowing parallel to the layers is given by,

$$\rho l = \frac{H}{S} \quad \text{.....................(2) longitudinal resistivity}$$

$$T = \sum_{i=1}^{n} hi * \rho i \quad \text{.....................(3) Transverse resistance}$$

This is the "transverse resistance".

The transverse resistivity to the current flowing perpendicular to the layers is given by,

$$\rho t = \frac{T}{H} \quad \text{Where } H = \sum hi$$

H is the depth to the bottom most geoelectric layer.

$$\rho t = \frac{T}{H} \quad \text{.....................(4) Transverse resistivity}$$

The coefficient of pseudo-anisotropy (λ) is given by:

$$\lambda = \sqrt{\frac{\rho t}{\rho l}} \quad \text{.....................(5) Anisotropy}$$

RESULT AND DISCUSSION

Result of DZ Parameter

The results of DZ parameter estimated from the inverted resistivity sounding data and geo electric layer sequence in the study area as are shown in Table 2.

Longitudinal unit conductance (S)

In present study, the longitudinal conductance values were classified according to (Oladapo and Akintorinwa, 2007) into poor, weak, moderate, good, very good and excellent protective capacity zones showed in Table no.3. It can be concluded (Table 2) that VES Station 4,5,7,8,16 and 33 ranging from 10.91 – 26.19 siemens and the thickness (H) of the sounding stations vary between 28 and 102.5 m. The stations with high S values may be due to increase in H values and *vice versa* (Murali and Patangay, 2006). Those VES stations with increase in S values may corresponds to an average increase in the clay content that would result decrease in the transmissivity of the aquifer (Oteri, 1981). The litholog data available at VES 4, suggests layers comprised of a black cotton soil with sand and kankar followed by admixture of pebbles and sand with clay.

The longitudinal conductance value at VES 4 is 26.19 and it falls under excellent protective capacity rating. VES station 1,3,13,14,18 and 25 falls under the very good protective capacity rating which is ranging from 5.34 – 9.26 siemens and the thickness (H) of the sounding stations varies between 16.49 – 44.2 m. VES 18, encompassed overburden of black cotton soil (2 m) with resistivity 47 Ω-m and which may be followed by loose soil (13 m) with resistivity 1.71 Ω-m and further moving with a hard and compact rock. The longitudinal conductance map (figure 2) revealed that 17.65 % area falls under the 'excellent' and 'very good' protective capacity categories of the area and about 50 % of the area falls under 'good' protective capacity and remaining 2.94 %, 5.88 %, 5.88 % area under the moderate, weak and poor protective capacity rating respectively. This study suggests that a major part of the study area can be categorized as relatively good to very good protective capacity ratings.

Longitudinal Resistivity (ρl)

A spatial distribution map of longitudinal resistivity (figure 3) of the study area shows the values ranging between 1.08 – 526.72 Ω-m while 82 % of the study area is covered by values between 1.08 - 34.06 Ω-m. VES station 19, reveals a very high Longitudinal resistivity of 526.72 Ω-m while those at VES station 10, 32, 22 and surrounding part of VES 19 show values ranging between 34.06 - 89.72 Ω-m. In present study, less longitudinal resistivity observed than transverse resistivity which shows different layers present below the earth surface (Flathe, 1955). The different layers of pebbles-sand, pebbles-sand-silt, pebbles-sand-silt-clay bed was seen at litholog at VES Dhanwadi and Mamalde. The overall area can be categorized as low longitudinal resistivity meaning that different layers of pebbles, sand, silt and clay were present in study area.

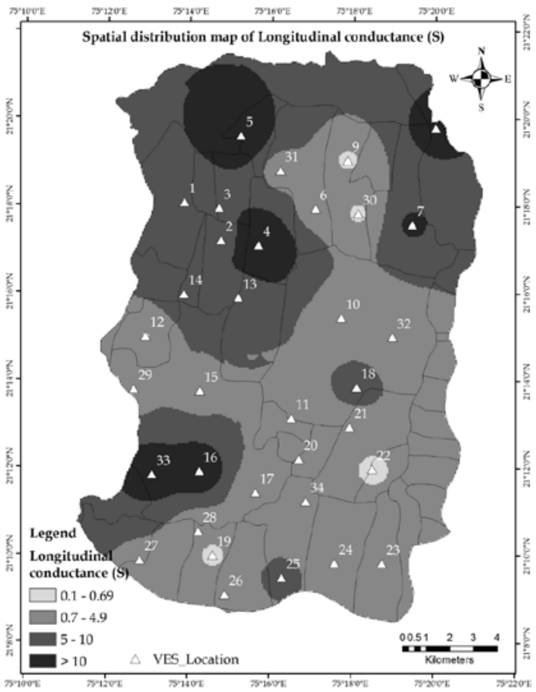

Figure 2. Spatial Distribution of Longitudinal Conductance.

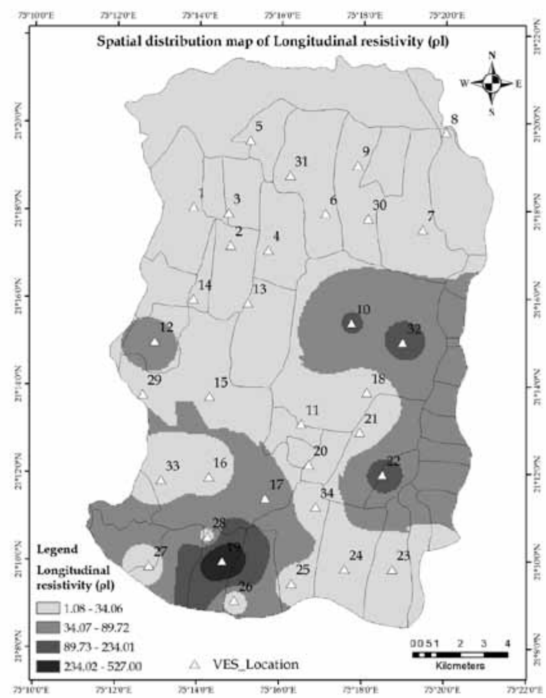

Figure 3. Spatial Distribution of Longitudinal Resistivity.

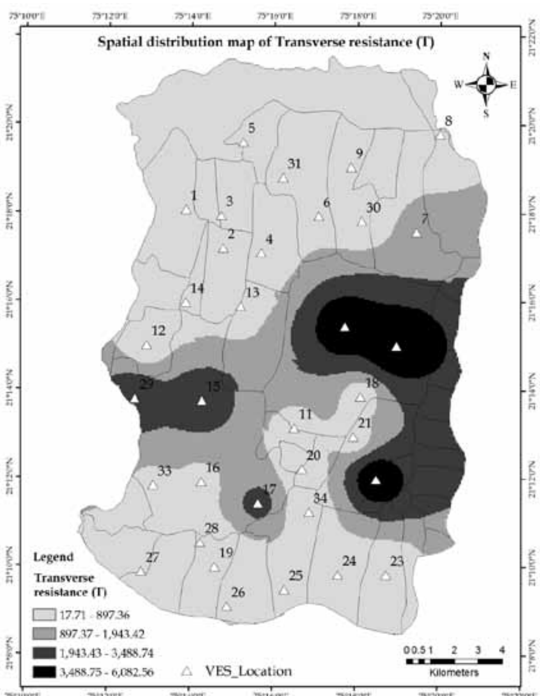

Figure 4. Spatial Distribution of Transverse Resistance.

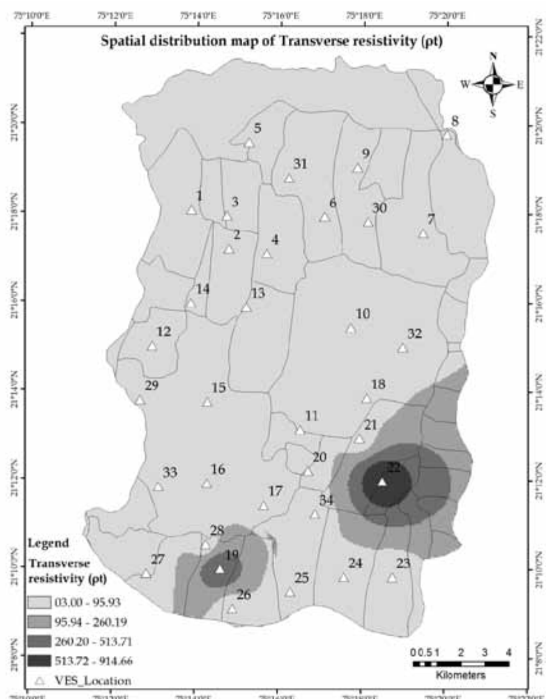

Figure 5. Spatial Distribution of Transverse Resistivity

Transverse Resistance (T)

Figure 4, illustrates that, 79.42 % of the area shows transverse resistance values below 897.36 Ω-m^2 with a minimum of 17.10 Ω-m^2 at VES 24. The North, North-Western, some central and Southern part are mostly covered by T value (<897.36 Ω-m^2). Three VES station, 29, 15 and 17 show values ranging between a 1943.42-3488.74 Ω-m^2 which is 8.82 % of the area. High T Value indicates high transmissivity of aquifers suggesting porous medium for water movement. The highest T value at VES 32 and 10, is a 6082.56 Ω-m^2 which is a good aquifer and it ranges in a map between 3488.74-6082.56 Ω-m^2. VES stations 7,10,15,17,22,29,32 with above T values (1000 Ω-m^2) have

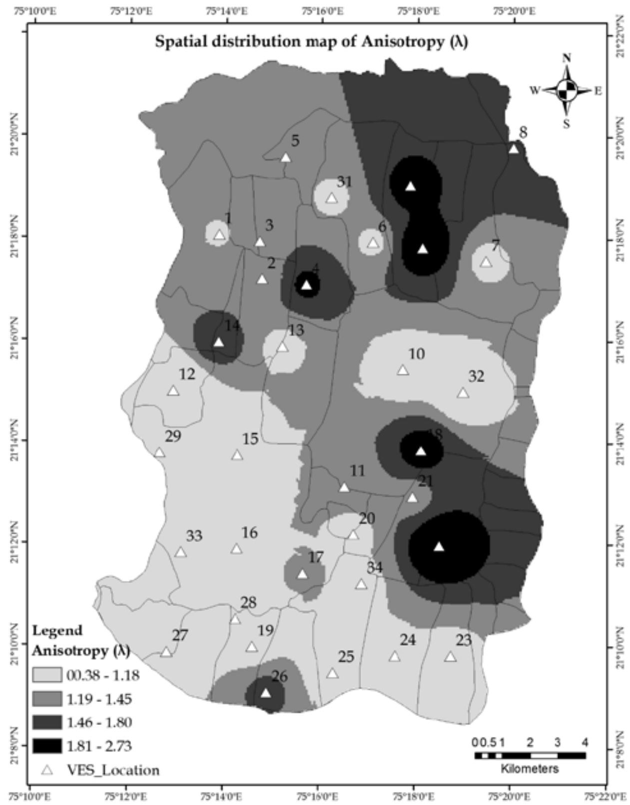

Figure 6. Spatial Distribution of Anisotropy.

a moderately high transmissivity which may be due to high clay content with pebbles-sand and silt bed in alluvial basaltic formations, as a result, fractured or exposure of basaltic rock on surface at some places in Chahardi area. The northern, north-western and south-west part of the study area reflects a high longitudinal conductance values (figure 2) which indicates high clay content resulted in less transmissivity of the area.

Transverse resistivity (ρt)

Figure 5, depicts the spatial distribution map of transverse resistivity (ρt) showing 94 % area with low resistivity ranging from 3.09 Ω-m - 95.93 Ω-m while the eastern part of study area shows very high values between 914.66 Ω-m at VES station 22 and 527 Ω-m at VES 19 respectively. At VES station 22 highest value observed which is due to may be clay with siliceous material is present at 6 m. There is not much effect of any layer in the transverse resistivity.

Anisotropy (λ)

The anisotropy map (figure 6) shows 61.76 % of the area ranges between 0.38 to 1.18 with the low anisotropy at South-western and some central part of VES 10, 32, 7, 6, 31, 1, and 13 The average of Electrical anisotropy for the entire study area is 1.29. VES station 5,3,2,11,21 and 17 ranges in between 1.18-1.45 which is cover a 17.64 % the area. The higher values (2.04, 2.34, 1.96, 2.15, 2.73) observed at VES station 9, 30, 4, 18 and 22 corresponds to hardness and compaction of rocks as suggested by (Keller and Frischknecht, 1966). A large variation is observed in λ map, ranging from 0.38 to 2.73 in the study area which indicates the anisotropic nature of the aquifers in such hard rock terrain. In present study area, high anisotropy (1.80-2.73) value inferred that presence of lineaments or fractures. The lineaments are crossing over each other and these points are good for exploration of groundwater.

RESULT OF VES DATA

The 2D geoelectrical section over four selected profiles in the study region (figure 1) provided the aquifer geometry in the study area. The pseudo cross section was generated by using IPI2WIN Software. With the help of resistivity data obtained in the present study it is compared with the exposed lithology in the dugwell (VES 4 and 22) and it facilitates to classify the area into different alluvial formation. Where the resistivity value is less than 10 Ω m, they are loose clayey/silty layer with intercalation of sand. The part having resistivity ranges between 10-25 Ω m are exhibiting clayey sand layer; area with compacted clay or with pebbles/cobbles and sand having a resistivity ranges 25-50 Ω m.

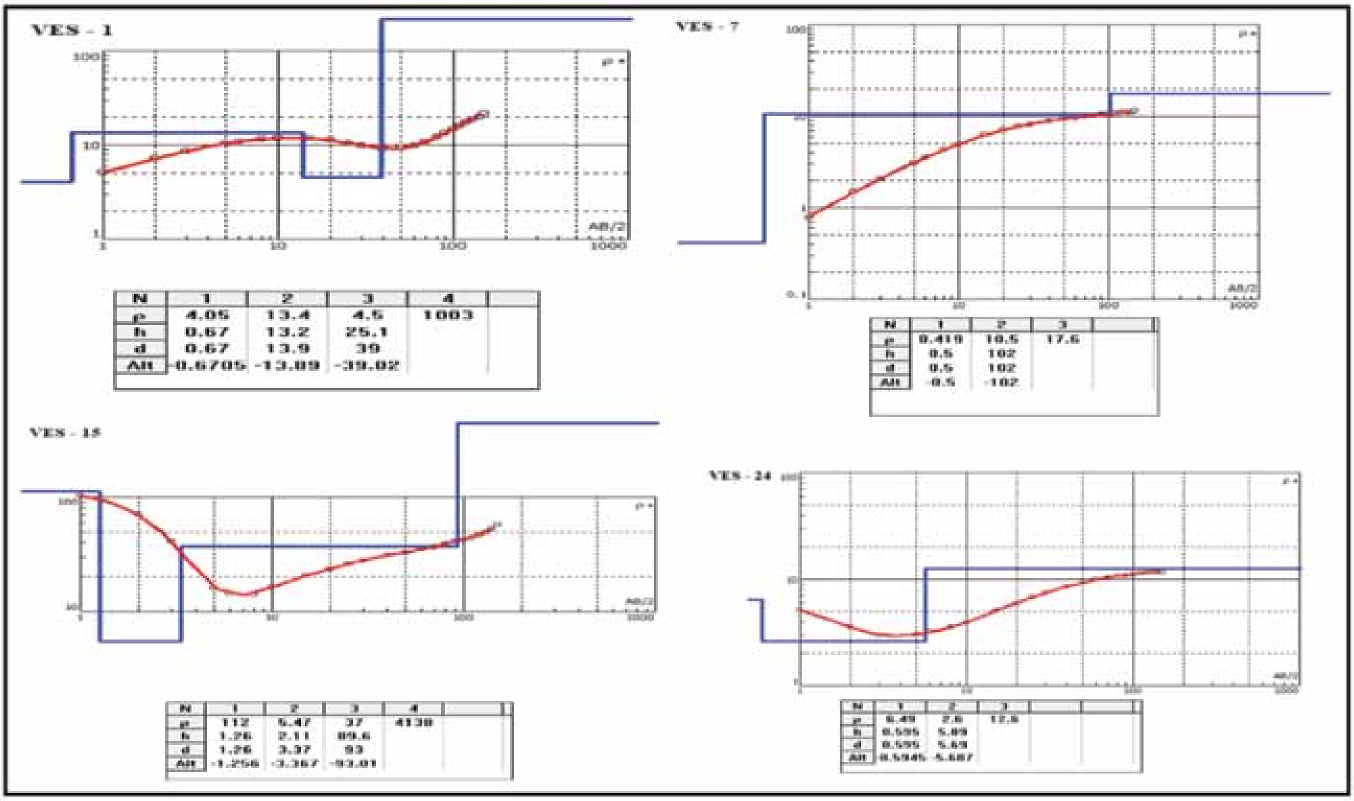

Figure 7. Resistivity curves and tables showing thickness.

Profile – AB

E-W trending profile AB comprises of VES station 1,14,3,2,5,13,4,31,6 and 30 located in alluvium formations. From the section (figure 8), a zone having a resistivity below 10 Ω-m is seen at shallow (10 m) as well as deeper level up to depth of investigation at VES 13 and 4 corresponds to loose clayey/silty layer with intercalation of sand layer. A litholog at VES 4, a layer with mixing of sand, black cotton soil admixture with kankar further below a loose sand with different sizes of pebbles, and compacted sand with gravel present up to 28 m. Below 28 m layers of sand and pebbles were observed up to 49 m fine to coarse sand with calcareous kankar. The lithological cross-section of bore hole at VES 4 (figure 12 B) suggests that, the aquifer zone lies at depths of about 49 m. The longitudinal conductance at VES 4 is 26.19 and falls under the category of excellent protective capacity rating. The resistive (< 10 Ω-m) feature was observed at VES 1,14,3,2, and 5 at deeper level (20 – 120 m) which may show a loose clayey/silty layer with intercalation of sand or clayey-sand layer. VES 31 and 6 are characterized by resistivity (> 26 Ω-m) feature which could be due to compacted clay with pebble up to 10 m. Further east of the profile, low resistivity feature (< 10 Ω-m) was identified with a thickness of about 30 to 35 m at deeper level of VES 30. By observing profile most of the area comprises of the < 25 Ω-m up to a shallow aquifer 25-30 m, which shows a clay/silty or sand layer. VES 7, it can be concluded (figure.7) that top layer (about 1 m) consisted of a loose soil with resistivity 0.41 Ω-m further it moves, 102 m thickness with 10.5 Ω-m resistivity may comprised of a clayey sand layer. VES site 14, 13 and 4 may form a good potential zones are over this profile.

Profile - CD

The profile CD (figure 9) passes through the VES stations 12,29,15,11 and 18 located in the basaltic formations. This cross section reveals that top (2-3 m) layer of profile comprised resistive layer (> 50 Ω-m) indicating hard weathered material which is a spread at VES 29 and 15, further below a (10-30 Ω-m) resistivity may comprised of a fractured or less weathered basaltic formation which is a good potential zone for exploration of water and at basement a hard compact rock may present at the depth of 50m with resistivity > 50 Ω-m. At VES 11 and 18, a low resistive (7-20 Ω-m) feature was observed at the depth of 6 m and 15 m respectively which may give an enough groundwater.

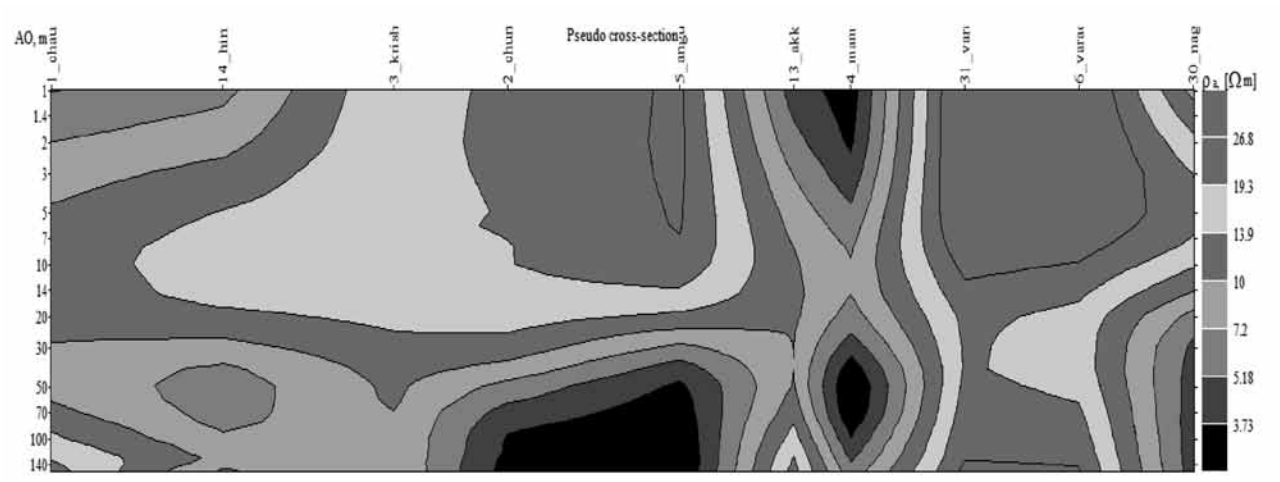

Figure 8. Profile AB Resistivity pseudo cross section.

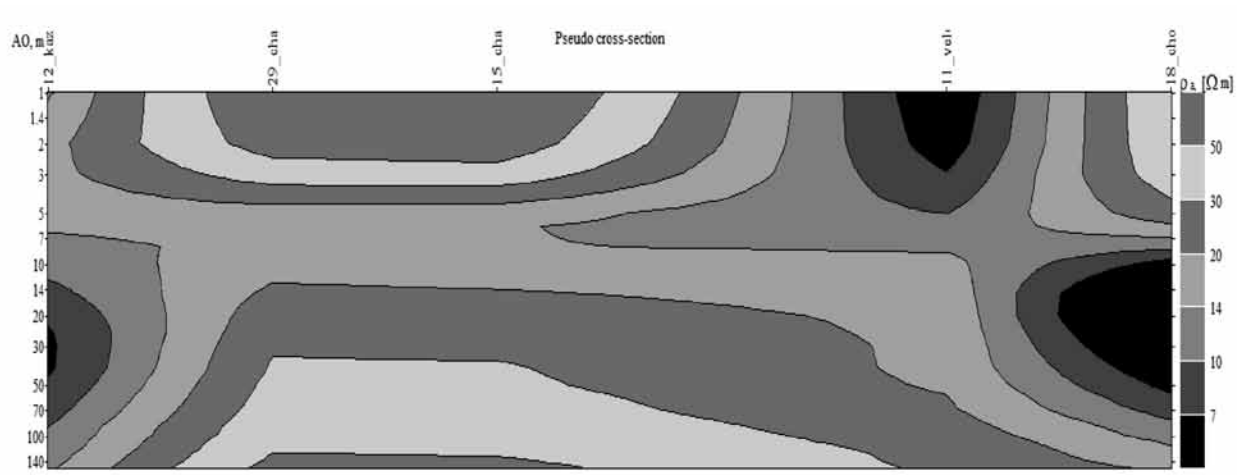

Figure 9. Profile CD Resistivity pseudo cross section.

Profile - EF

E-W trending Profile EF (figure 10) passes through VES stations 33,27,16,28,19,26,17,25,20 and 34. The entire shallow as well as deep sections of VES 33,27 and 16 show a resistivity (< 10 Ω-m) layer which could be a clayey with intercalation of sand layer. VES 28,19 and 26, with a resistivity 28-31 Ω-m may comprised of admixture of clay, sand and pebbles up to 5-6 m, further below a resistive (< 10 Ω-m) feature was observed which might be a clayey with intercalation of sand layer up to depth of investigation. VES 17, shows a resistivity (28-31 Ω-m) throughout depth of investigation which may covered admixture of clay, sand and pebbles. VES 25, 20 and 34 which may have comprised of a clayey with intercalation of sand layer with resistivity < 10 Ω-m up to depth of investigation. VES 24, (figure 7) encompasses of a < 10 Ω-m which may be a clayey with intercalation of sand layer throughout the depth of investigation.

The entire profile suggested that, most of the area covered by clayey sand layer at deeper (from 30 m) section and presence of admixture clay, sand and pebbles which might be porous and permeable in nature to percolate water while clayey-sand layer is less permeable. VES 19, 27,28,26,25 and 34 are the good source for extraction of water from this profile.

Profile - GH

N-S trending profile GH (figure 11) comprises of VES station 8,9,30,10,32,18,21,22 and 23. The deep layer (from 15 m) of the VES 8, 9 and 30 is of resistivity < 10 Ω-m feature, it may have consisted of clayey or silty layer with intercalation of sand. At VES 30 a shallow zone (up to 15 m) with resistivity (26 Ω-m) having compacted clay with pebbles. VES 10 and 32 comprised of a high resistive feature 37 Ω-m which may be fractured basalt at deeper section (below 50-55m), VES 18 shows a resistivity ranges

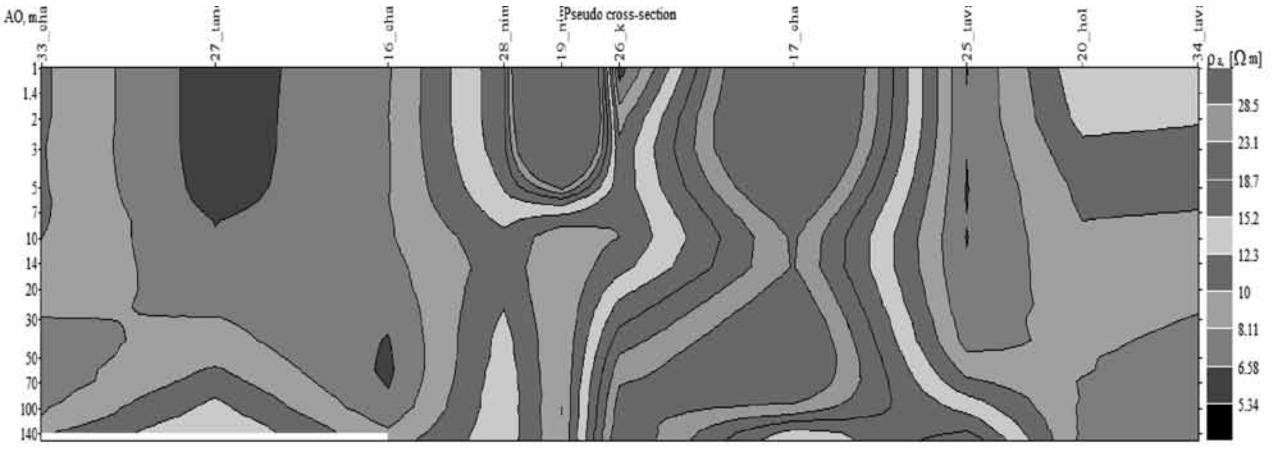

Figure 10. Profile EF Resistivity pseudo cross section.

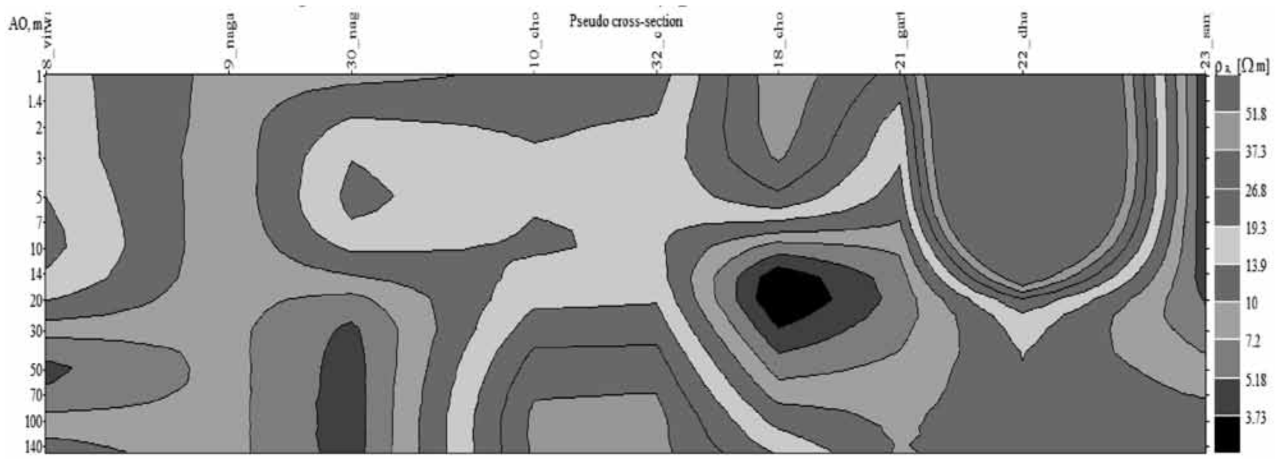

Figure 11. Profile GH Resistivity pseudo cross section.

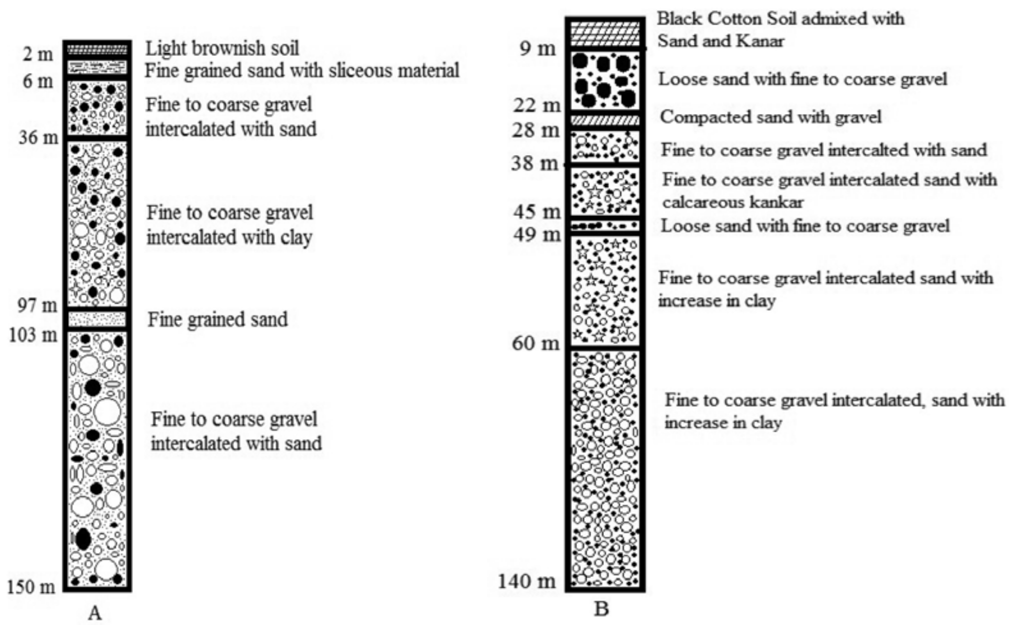

Figure 12. Borehole litholog from the study area showing the major lithological distribution (A-Dhanwadi, B-Mamadle)

26-51 Ω-m which may be a highly fractured basalt at 5-7 m. VES 21 may have alternate layers of clayey-sand layer or intercalation of pebbles in clay/sand layer with > 10 Ω-m resistivity. The borehole lithological cross section at VES 22 is shown in figure 12 A. The litholog suggest that aquifer zone lies at depth 36 m. At VES 22 having a resistivity (> 51 Ω-m) up to 7 m which might be due to contains of clayey-sand layer with siliceous material further it continues with intercalation of pebbles in clay/sand layer. VES 23 comprised of a resistive (< 10 Ω-m) feature, indicating a loose clayey/Silty layer with intercalation of sand. This N-S Profile encompasses with lithological unit i.e loose Clayey/Silt with intercalation of sand, clayey sand layer, compacted clay with pebbles and fractured/weathered basalt.

CONCLUSION

The geophysical survey was carried out in Chopda tehsil of Jalgaon district to identify probable aquifer zones with the help of schlumberger electrical sounding, DZ parameter and borehole lithology. In present study, geologically it is comprising of basaltic and alluvium formation. From resistivity survey, it can be concluded that, the central portion of the study area signifies presence of a basaltic, fractured and weathered part of the area and northern and southern part comprised of alluvium which is of a clay, sand and pebbles. The result of sounding, Dar-Zarrouk parameters and lithology will suggest a probable site 14, 13, 4, 30, 29, 15, 12, 19, 27, 28, 26, 25, 34, 9 and 23 for the exploration of groundwater. The north-western-central part of the area has high ground water potential which is presence of a Bazada zone.

In Earlier research (Patil et al 2015), concluded that VES 15 signifies the presence of fractured or weathered rock at 3-15 m which is a good potential zone for exploration of water. VES 11 (S = 0.71) and 13 (S = 0.54) have comprised a layer of loose clayey/silty layer with intercalation of sand which indicates a low S value in present study. The earlier work of sounding has supported by DZ parameters in present study area.

The vertical electrical sounding data helps to identifies three types of aquifers present in the study area. The first type of aquifers has a resistivity less than 10 Ω-m which comprised of a loose clayey or silt with intercalation of sand, this type of aquifer has a high clay content which is generally characterized by a low resistivity values and have a low permeability, whereas second type has a resistivity 10-25 Ω-m which is a consisted of clayey-sand layer. The third aquifer ranging from 25-50 Ω-m which is of a compacted clay or with pebbles/cobbles and sand.

The estimation of D-Z parameter will use full to understand distribution of groundwater and sub-surface litholog and to identify a potential aquifer zone. The longitudinal conductance map suggests 17 % of the area falls under the category of very good and excellent protective capacity rating which suggest a high transmissivity in north-western-central part of the area which forms the potential aquifers. Longitudinal resistivity shows a different layer present in terms of the loose clayey/silt with mixing of clay, clayey-sand, compacted clay with pebbles/cobbles. A large variation of anisotropy will help in to identify that some lineaments or fractures present in the area. The spatial distribution map of D-Z Parameter S, ρl, T, ρt and λ shows a variation in basaltic and alluvium formation with respect to aquifers which is helpful for analyzing the different geological formation or structure of the study area.

The combine result of litholog, sounding data, D-Z parameters signify the various effective result to find out most suitable site for groundwater exploration. This study is beneficial to the farming community for exploration and management of ground water.

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Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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