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Hydrogeological Studies Using Vertical Electrical Sounding (VES) Method in Uttar Mand Basin, Satara District, Maharashtra (India)

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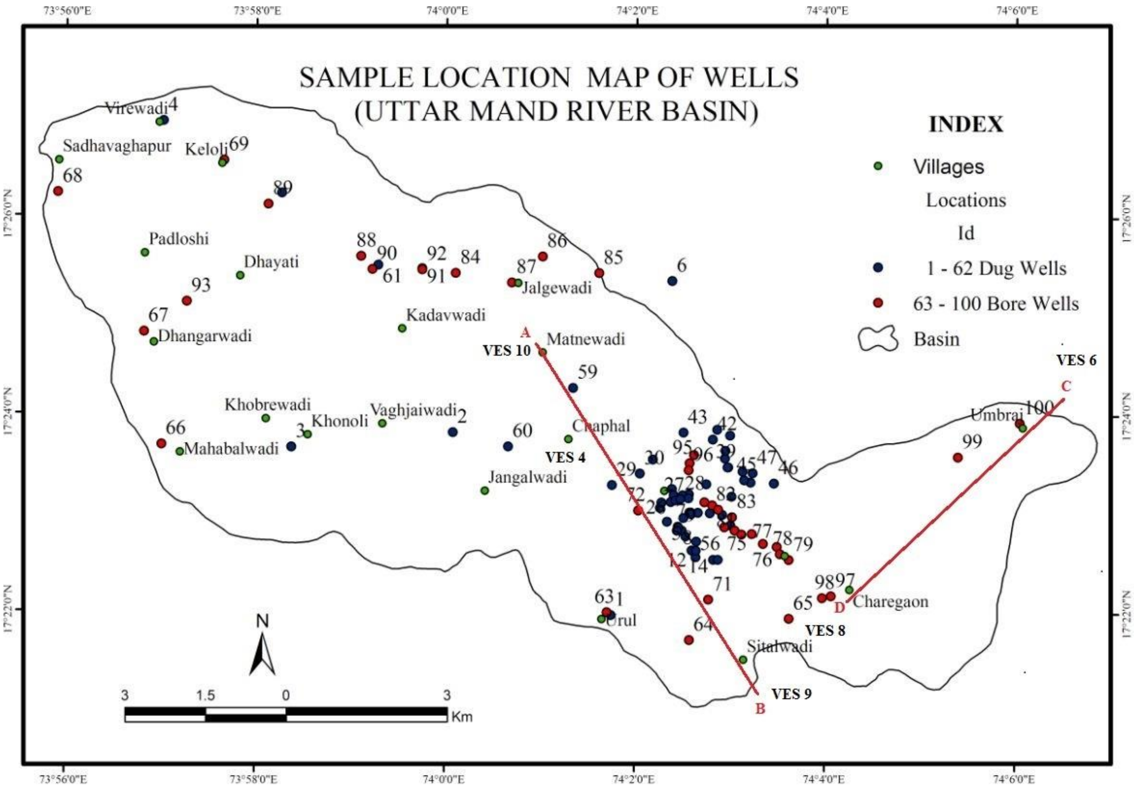
ABSTRACT
Vertical electrical resistivity soundings (VES) were executed in demarcating groundwater potential zones around Uttar Mand River, Satara district. Ten VES using Schlumberger configuration of electrode array have been conducted to find the groundwater potential zones. The field measurements were processed and interpreted by IPI2 win software program. The pseudo and resistivity cross-sections for the study area have been processed. The present study area covers basaltic rock formations of Cretaceous to lower Eocene in age. Interpretations of vertical electrical sounding (VES) using Schlumberger arrangement had been carried out and resistivity results had been compared with the present lithology. Good, average and poor zones were categorized.

KEYWORDS: *Vertical Electrical Sounding, Schulmberger Array, Groundwater, Uttar Mand River Basin.*

INTRODUCTION

The modern civilization is most populous and prospering due to rapid development in the industrial, agricultural and domestic utility, owing to which groundwater exploitation is rigorous due to its everlasting needs. The sources of groundwater appear to be available in weathered and fractured basalt trapped between weathered overburden and hard rock. Thus, exploration and exploitation of groundwater resources demand in-depth knowledge of geology, hydrogeology, and geomorphology of the area.

Generally, 82% of the Maharashtra state in India is covered by the Deccan trap basalt showing uneven distribution of groundwater resources (Kulkarni et al., 2012). The uneven distribution of groundwater resources is largely due to variation in topographic, geomorphologic and local environmental conditions. Deccan trap basalt flows vary in thickness from few meters to hundreds of meters. The field characteristics of basaltic flows greatly influence to their water-bearing capability as a result of variation in their compactness, occurrence of amygdales, vesicles, fractures and joints. If the fractures are saturated with groundwater, a clear difference between the resistivity of fractured rocks and fresh hard rock's would be noticed as fractured rocks exhibit lower resistivity than hard rock's (Karous and Mares, 1988; Yadav and Singh, 2007, Rai et al., 2013). Applications of geophysical methods especially vertical electrical sounding methods have proved as effective tools in the successful assessment of groundwater potential zones (Yadav et al., 2007 and Singh et al., 1997; Srivastava et al., 2012, Gupta et al., 2015). Electrical resistivity method can be effectively utilized in deciphering the depth of occurrence of fractured zones and the locating good groundwater potential well sites (Tarawneh and Janardhana, 2017). Collective analysis and study, in addition to mapping and demarcation of aquifers on small and regional scale help in understanding aquifer characteristics, flow pattern, and correlation of lithology (Srivastava et al., 2012). Earlier researchers proved that vertical electrical sounding is successful method for identification of groundwater potential zones in hard rock terrain (Singhal, 1997; Yadav and Singh, 2007; Rai et al., 2011; Srivastava et al., 2012; Maiti et al., 2012; Kumar et al., 2014; Ratna Kumari et al., 2012; Golekar et al., 2014; Yousuf et al., 2015, Sonar et al., 2019).



Source : Based on 'SOI' Toposheet 47K-3,47G-15

Figure 1: Resistivity survey locations in the study area

The Uttar Mand river basin bounded between latitude 17º 20' 12'' N to 17º 25' 24'' N and longitude 73º 55' 07'' E to 74º 5' 7'' E in Survey of India Toposheet numbers 47 G/15, 47 K/3 and having area of about 109 km2 (Fig. 1). The Uttar Mand River is one of the tributary of the Krishna River. The present study area geologically covers a Deccan Volcanic Basalt of Upper Cretaceous to Lower Eocene age. The soil cover of the study area is fertile and this very useful for agriculture purpose. The climate of the area comes across as an amusing blend of the coastal and inland climate of Maharashtra. The temperature ranged from 10° C and 40° C. The average annual rainfall of the area is 4,800 mm. The Uttar Mand river basin shows well developed dendritic to sub dendritic type drainage pattern (Fig. 2).

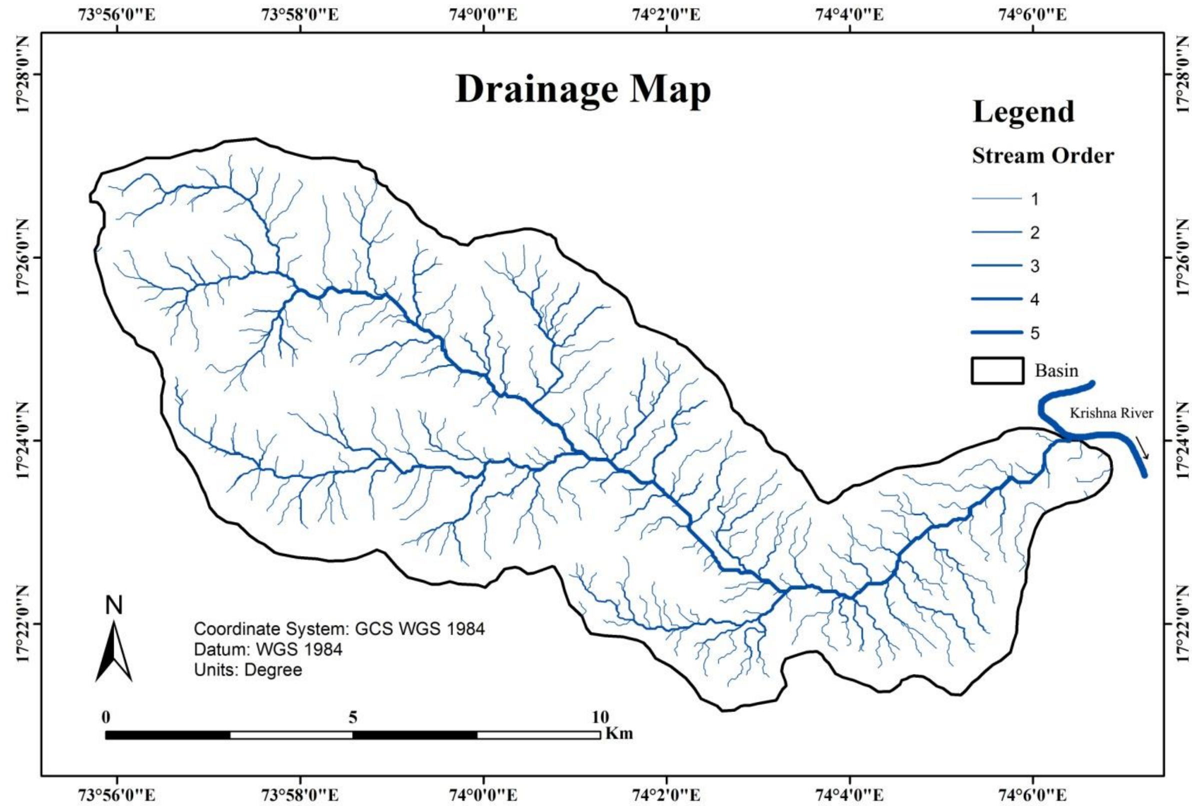


Figure 2: Drainage map of the Study area

METHODOLOGY

Considering heterogeneity in the topographical and geological characters within the study area grid wise localities were selected for carrying out VES soundings. In the resistivity survey, a known electric current is incorporated into the earth through current electrodes and the potential difference measured between potential electrodes (Baride et al., 2017). Current penetrates into the ground with the increase in electrodes spacing. The earth's surface having diverse lithology with depth, apparent resistivity is measured where the pattern of current flow is affected by the density, porosity, and salinity of the bounded fluid in the land (Mohammed et al., 2007; Bashir et al., 2014). Ten (10) Vertical Electrical Sounding (VES) carried out using Schlumberger electrode array (Zhody, 1969 and 1989) along the roads and some farms in the area under study (Figure 1). The resistivity measurements were taken by using SSR-MP-AT resistivity meter. This resistivity meter is hiring from Indian Institute of Geomagnetism, Panvel (IIGM, Mumbai). The well inventory data showed that, groundwater level in study area occur at shallower depth. Hence, the current and potential electrode separation is 1m to 50m from the midpoint. IPI2Win software is user-friendly and easy for interpretation. Since concept of profile interpretation is the foundation of IPI2WIN software, geo-electrical cross-sections along chosen profiles passing through different VES locations were prepared to understand the aquifer geometry (Babachev, 2003). This programme is employed to obtain true resistivity and depth from the apparent resistivity data acquired at each VES station. Apparent resistivity versus electrode separation map had been drawn for obtaining sounding curves.

RESULT AND DISCUSSION

Vertical Electrical Sounding

The litho types and thickness of the individual layers from the vertical electrical sounding locations were anticipated by referring litho unit suggested by the earlier researcher foe basaltic rocks (Zambre and Thigale 1980). Because of this litho units are similar as geological formation presence in the present study area. These referring tables are depicted in Table 1. Comprehensive geophysical field results obtained from VES were presented in Table 2. Resistivity value and thickness of each layer were illustrated in this table. The obtained VES curves have been showed in Fig. 3 to Fig. 12. In the study area 3 to 4 layer model is obtained.

The top most layer were consisting of black cotton soil, red lateritic soil and calcareous soil or highly weathered basalt having a thickness 0.5 m - 1.6 m and resistivity is 59.4 - 559 Ωm. In some occasion black cotton soil may show higher resistivity due to the impervious nature (Zambre and Thigale, 1980; Golekar et al., 2016). The second stratum consists of fractured basalt having a thickness of 0.8 m - 4.9 m and resistivity ranged from 43.2 - 1422 Ωm. The third stratum is made up of highly weathered or fractured basalt having thickness of 0.1 - 19.8 m and resistivity ranges from 58.5 - 2807 Ωm except for VES station 1 and 7. The high value of resistivity at VES station 1 and at VES 7 may be due to the presence massive or hard rock which was seen in the actual field works. The fourth stratum was comprised of calcareous buff white soil with highly weathered or sometimes fresh basalt having a thickness of 0.3 m - 35 m and resistivity ranges from 4.43 - 15277 Ωm. In the present study based on field observations and obtained data of resistivity, suggesting feasible zones for exploration of groundwater whereas resistivity ranged from 43.2-106 Ω.m only exceptional case is black cotton soil it show sometimes this range of resistivity due to the impervious nature. All the feasible zones for exploration of groundwater in the study area were depicted in Table 2.

Table 1: Ranges of resistivity values of different Litho unit in Basaltic rocks (Zambre and Thigale, 1980)

Sr. No.	**Range of resistivity (Ohm-m)**	**Litho unit**
1	4 – 6	Black cotton soil with sand
2	6 -10	Black cotton soil with calcified soil / murum
3	10 – 12	Black cotton soil / murum
4	12 – 26	Black cotton soil with Murum
5	26 – 60	Highly weathered and fractured basalt
6	60 – 100	Highly fractured basalt
7	100 - 250	Weakly fractured basalts
8	>250	Hard compact Basalts

Table 2: Ranges of the resistivity values and thickness for all the layers

VES No.	Location	Latitude	Longitude	Resistivity (in Ω .m)				Thickness (in meter)				Favorable zone (m)	Category of groundwater potential
				p1	p2	p3	p4	h1	h2	h3	h4		
VES 1	BOLEWADI	17˚ 21' 41'' N	74 ˚03' 42 '' E	412	405	436	4287	0.6	1.6	0.1	1	-	Poor
VES 2	SANGARWADI	17˚ 21' 42'' N	74 ˚ 02' 09'' E	559	1267	58.5	5438	0.7	1.1	0.2	1.1	1.8 to 2.0 m	Medium
VES 3	KOUTEKARWADI	17° 25' 15'' N	73° 59' 48'' E	526	1207	59.3	5625	0.6	1.3	0.2	1.1	1.9 to 2.1 m	Medium
VES 4	CHAPHAL	17° 24' 09'' N	74° 01' 00'' E	526	1129	61.3	5104	0.65	1.5	0.26	1.1	2.1 to 2.4 m	Medium
VES 5	MAJGAON	17° 22' 54'' N	74° 02' 56'' E	506	1056	64.1	4888	0.56	1.68	0.26	1.17	2.2 to 2.5 m	Medium
VES 6	UMBRAJ	17° 22' 03'' N	74° 02' 56'' E	306	945	206	8871	1.6	1.95	5.1	9.7	-	Poor
VES 7	BHAWANWADI	17° 23' 03'' N	74° 05' 24'' E	279	446	2807	4.43	1.1	4.9	15.1	-	-	Poor
VES 8	CHAREGAO	17° 22' 59'' N	74° 04' 35'' E	111	43.2	75.5	15277	0.5	1.85	3.38	0.331	0.5 to 3.8 m	Good
VES 9	SITALWADI	17° 21' 42'' N	74° 03'14'' E	59.4	99.9	66	-	0.5	0.893	19.8	-	1.3 to 21.1 m	Good
VES 10	MATNEWADI	17° 25' 18'' N	74° 00'59'' E	300	1422	106	771	1.56	1.02	0.814	35	2.5 to 3.3 m	Medium

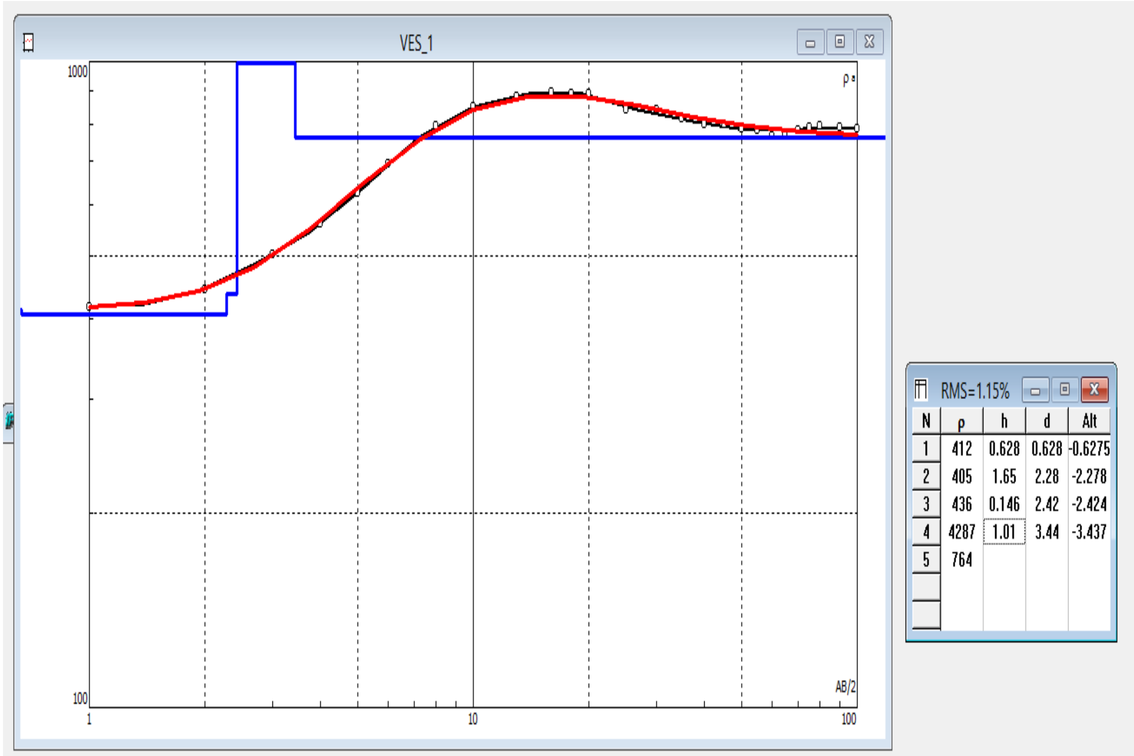


Figure 3: Curves at VES 1

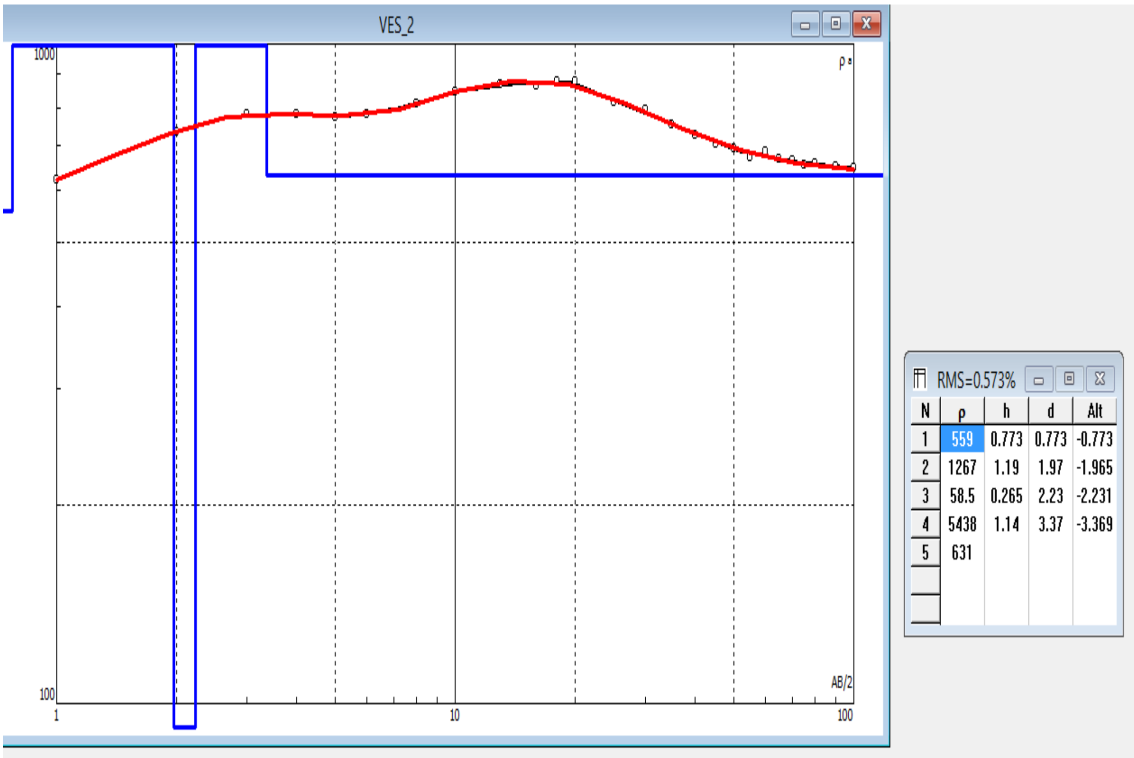


Figure 4: Curves at VES 2

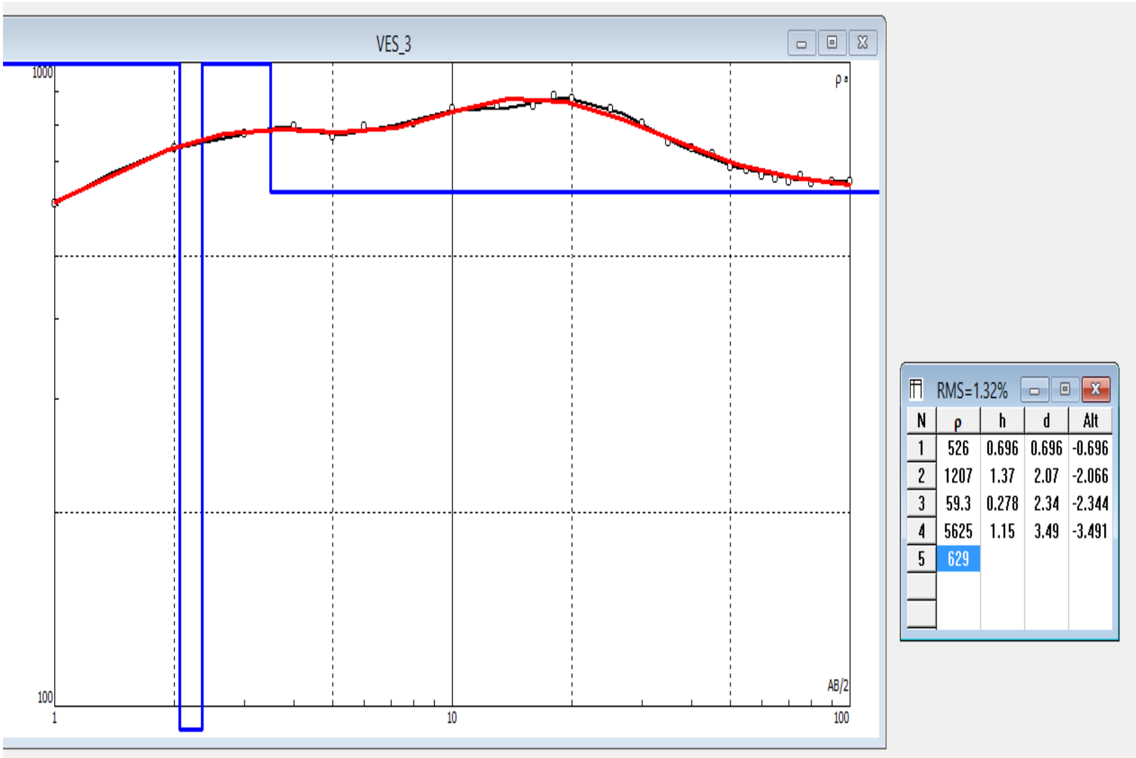


Figure 5: Curves at VES 3

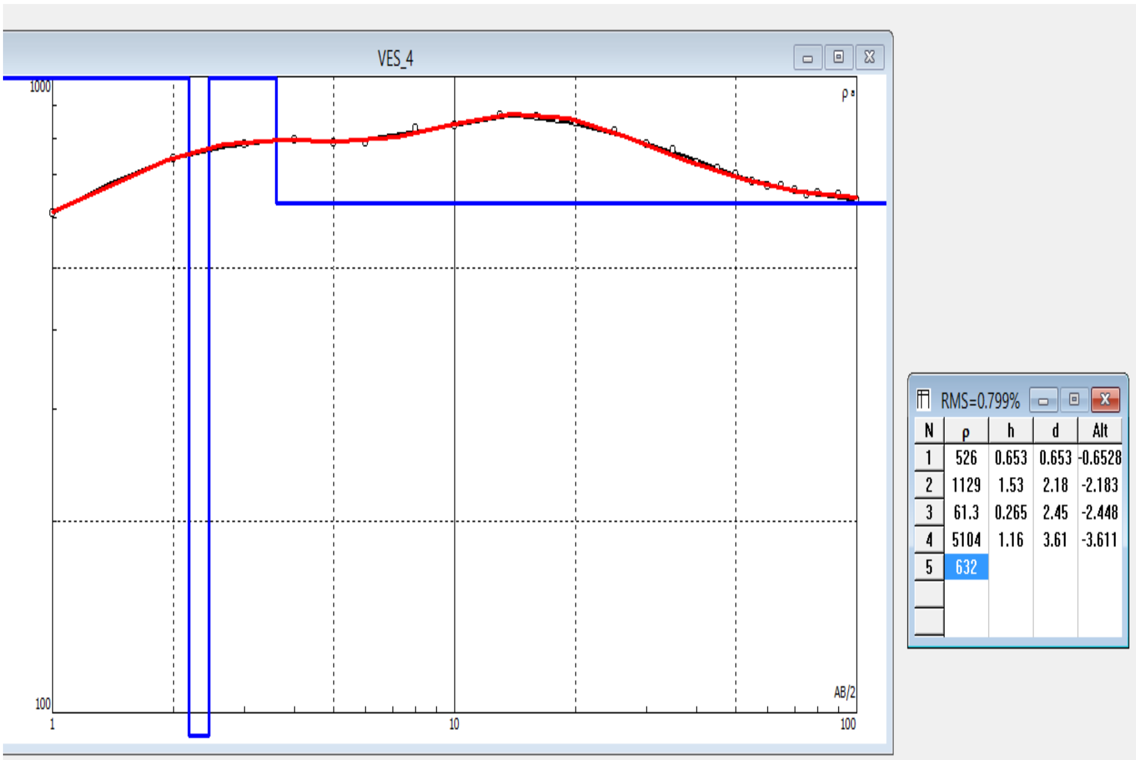


Figure 6: Curves at VES 4

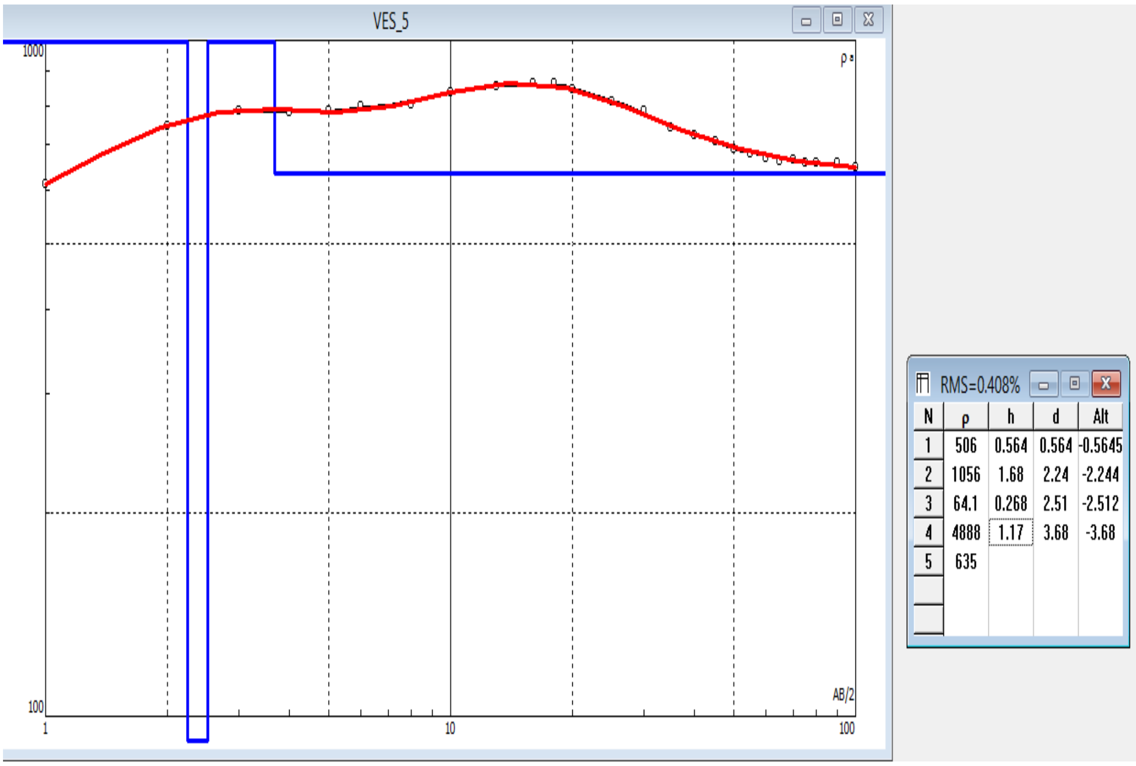


Figure 7: Curves at VES 5

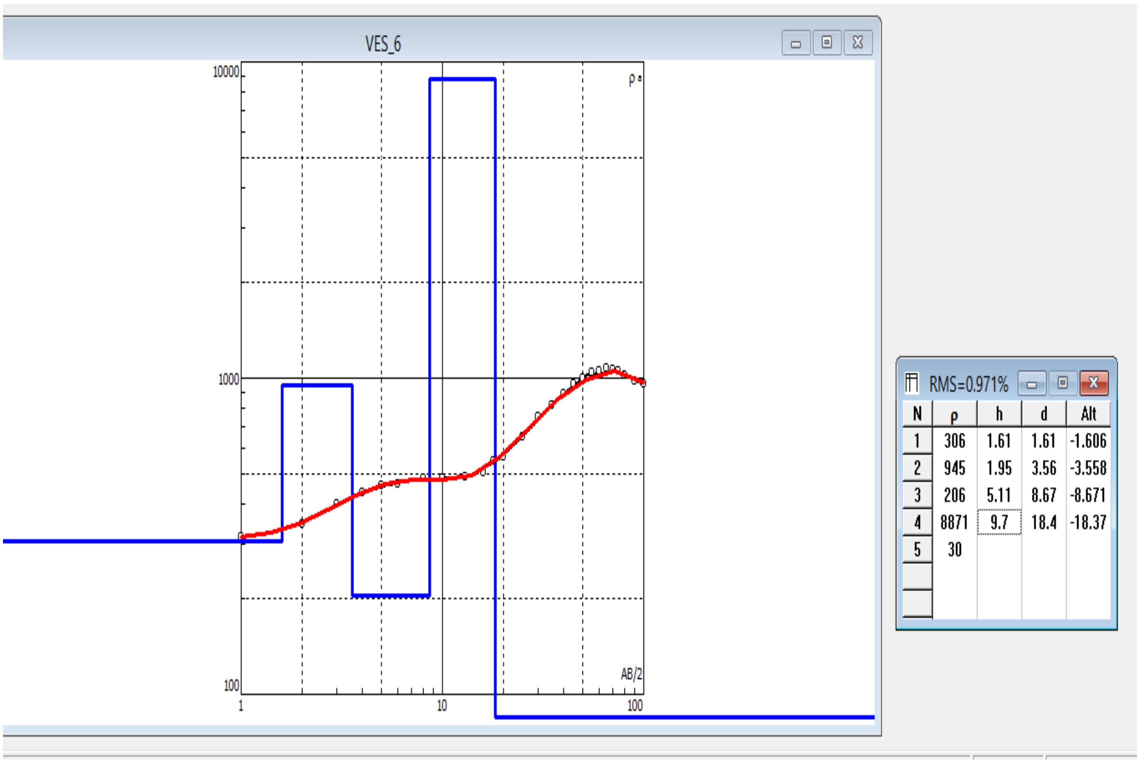


Figure 8: Curves at VES 6

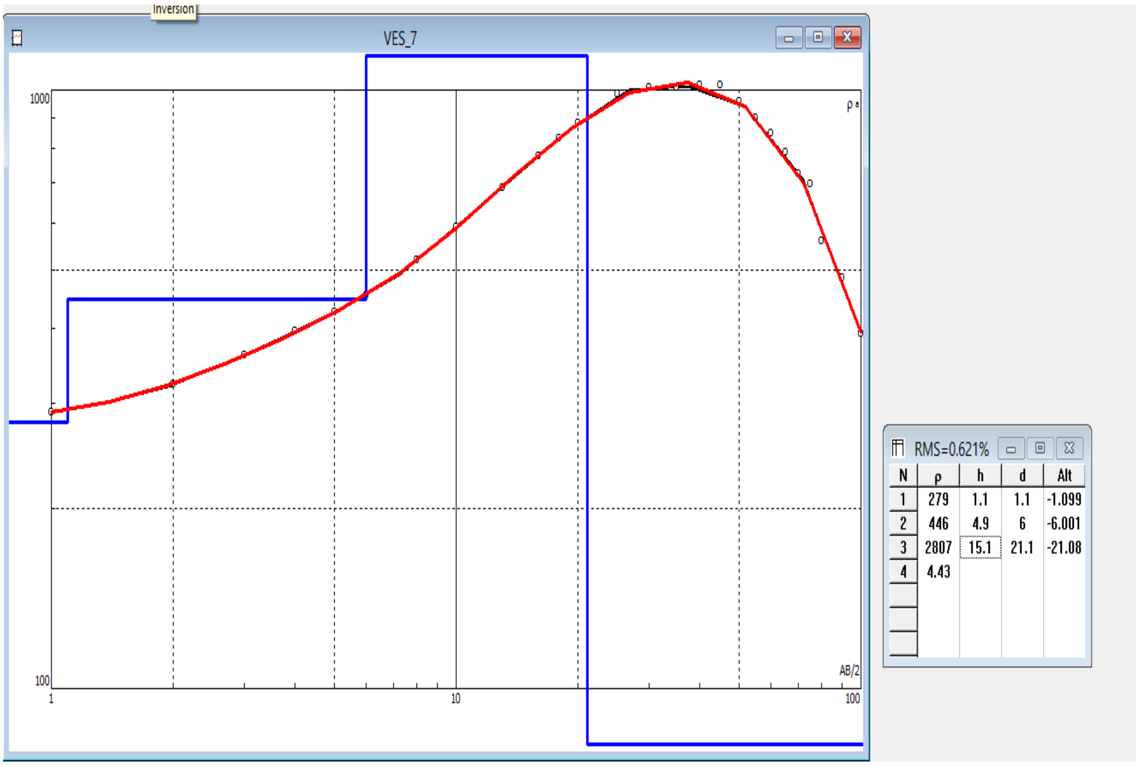


Figure 9: Curves at VES 7

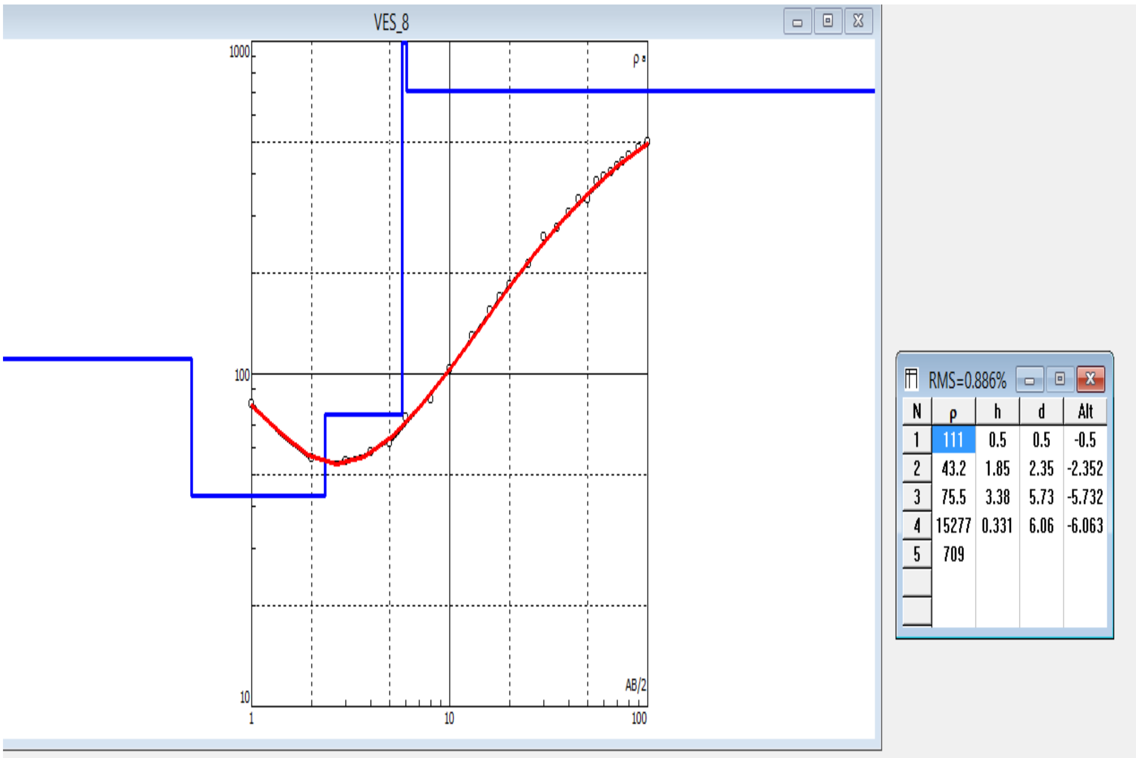


Figure 10: Curves at VES 8

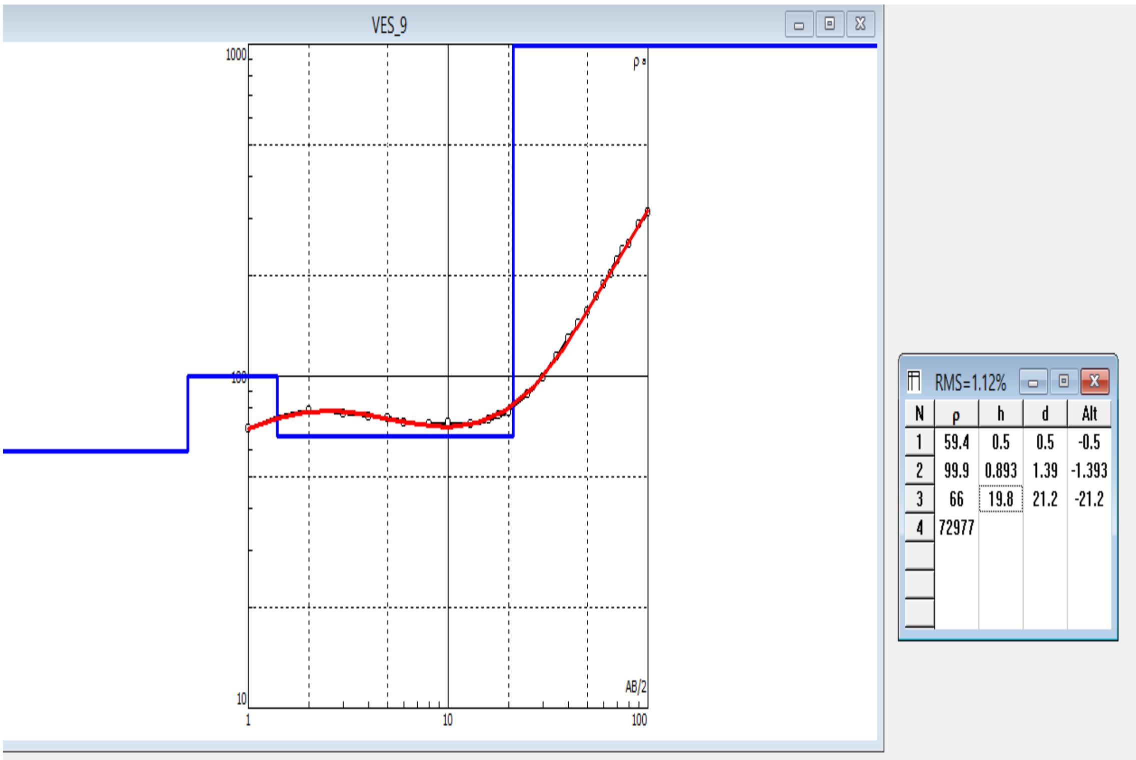


Figure 11: Curves at VES 9

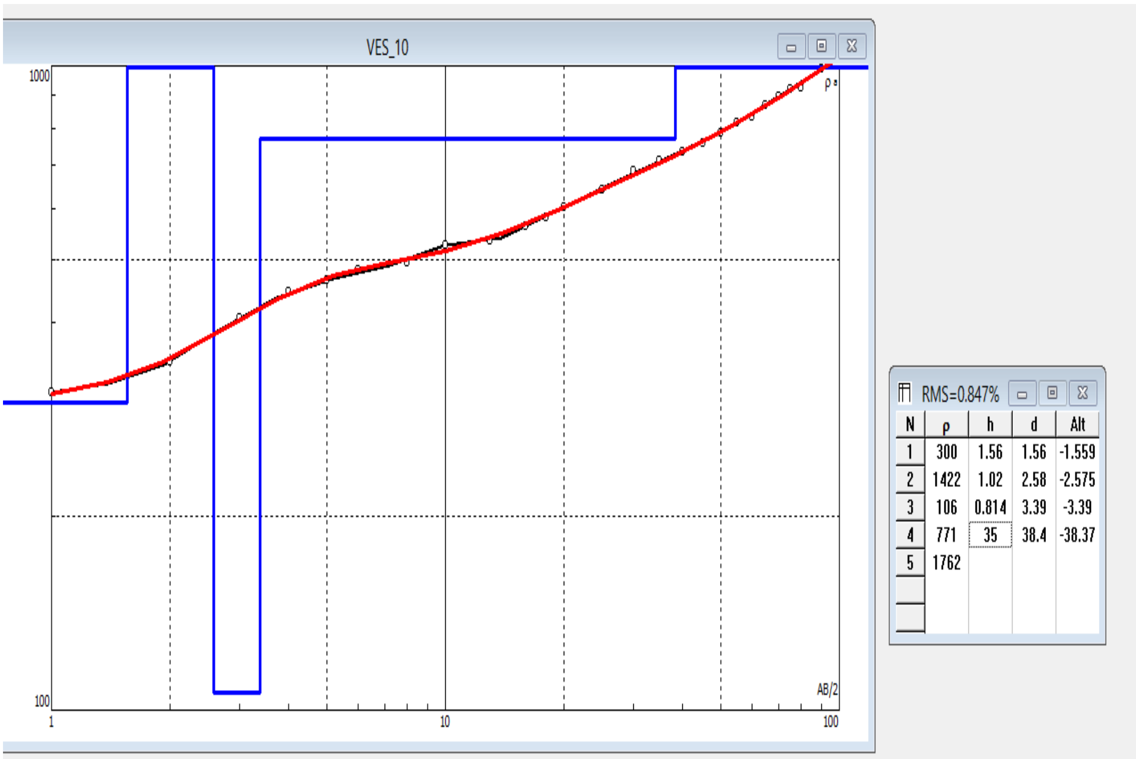


Figure 12: VES 10 Curves

CONCLUSION

The interpreted results of vertical electrical sounding cross sections were correlated with geological features exposed in the surrounding areas of sounding stations. Based on field observations, it is suggested to associate 43.2-106 Ω.m zones with the weathered and fractured zone which is feasible for exploration of groundwater. These feasible groundwater zones occur in VES station 2, 3, 4, 5, 8, 9 and 10 at 1.8 to 2.0 m, 1.9 to 2.1 m, 2.1 to 2.4 m, 0.5 to 3.8 m, 1.3 to 21.1 m and 2.5 to 3.3 m, respectively below the ground level. The ranges of resistivity values were occurs ranged from 43.2-106 Ω.m where is good groundwater potential. The good groundwater potential zones were occurred at VES 8 and 9 (CHAREGAO and SITALWADI) whereas at VES 1, 6 and 7 (BOLEWADI, UMBRAJ and BHAWANWADI) were poor groundwater potential zones.

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