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Research Article

AQUIFER CHARACTERISTICS STUDIES USING GEOPHYSICAL TECHNIQUES INAYACUT AREA OF BAKKIKAYAM REGULATOR, MALAPPURAM, KERALA

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Abstract: Aquifer characteristics studies was conducted at the ayacut areas of Bakkikayam regulaor situated across the Kadalundi River Pandikasala, Vengara, Malappuram district using earth resistivity techniques. In order to analyze the aquifer characteristics of the study area, Vertical Electrical Sounding (VES) surveys was carried out using Signal Stacking Resistivity Meter (MODEL-SSR-MP-ATS) at 18 locations and were interpreted using IPI2WIN software. From sounding curve interpretation, 2 to 4 subsurface layers were identified within the study area and resulting sounding curves were H, K, A, HK, QH, KH and AK. The presence of three layers substrata was represented by H, K, A and Q sounding curves, while the combination curves such as HK, QH, KH and AK curves represents four layers sub strata. From the VES studies, it could be concluded that, top soil of the study area is either laterite soil or hydromorphic soil of thickness 0.75 to 4 m, followed by laterites with varying hardness to a depth of 4 m to 17 m. Lithomargic clay of thickness less than 2 m is seen below the laterites in some places. These layers are overlying weathered rock of 2 to 14 m thickness followed by hard rock with or without fractures.

Keywords: *Vertical Electrical Sounding, Sounding curve, Wenner Electrode Configuration, IPI2WIN software*

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Introduction

Groundwater is one of the most precious natural resources required for sustainable human living. Geophysical electrical resistivity methods have been extensively used for ground water investigation by many researchers throughout the world, which were developed in early nineties. It is the most suitable method of ground water investigations in most geological formations due to simplicity. Among various geophysical studies, Vertical Electrical Sounding (VES), a depth sounding galvanic method and has proved very useful in ground water studies due to simplicity and reliability of the method.

Materials and Methods

Study area

The study area selected for the study was ayacut area of Bakkikayam Regulator constructed across the Kadalundi River at Pandikasala in Vengara Panchayth of Malappuram District. The study area of about 290 km2 lies between 11º 3' 33" to 11º 4' 1.01" N Latitude and 76º 2' 1.92" to 75º 53' 3.80" E Longitude. Location map of the study area is shown in the [Fig-1]. The ayacut area of the Bakkikayam Regulator is spread through fifteen panchayaths *viz*. Vengara, Kannamangalam, Edarikode, Oorakam, Othukkungal, Parappur, Kottakkal, Perumannaklari and A.R. Nagar panchayths in upstream side and Nannambra, Thennala, Munniyur, Thenhipalam, Peruvallur and Thirurangadi panchayaths in downstream side of the regulator.

Vertical Electrical Sounding (VES)

Vertical Electrical Sounding (VES) was carried out using Signal Stacking Resistivity Meter (MODEL-SSR-MP-ATS). VES survey was carried out in 18 locations using Wenner electrode configuration and the locations are given in [Fig-2]. The Wenner electrode configurations were carried out with current electrode spacing (AB) ranging from 6 to 66 m (AB/2 = 3 to 33 m) and potential electrode spacing (MN) ranging from 2 to 22 m (MN/2 = 1 to 11 m). In order to conduct VES survey, electrodes were placed in a straight line and inter electrodes spacing was increased gradually about a fixed centre, where the instrument is placed. Current (I) was applied to the ground through the current electrode and the potential difference (V) created by applying the current were measured and recorded against the electrode spacing. As the spacing of current electrode increases depth of penetration of current also increases. The apparent resistivity (ρa) can be got from the instrument using the applied value of current (I) and corresponding potential (V) of the electrode configuration. The apparent resistivity value varies with different substrata as it decreases with factures, joints, water content etc of the formation.

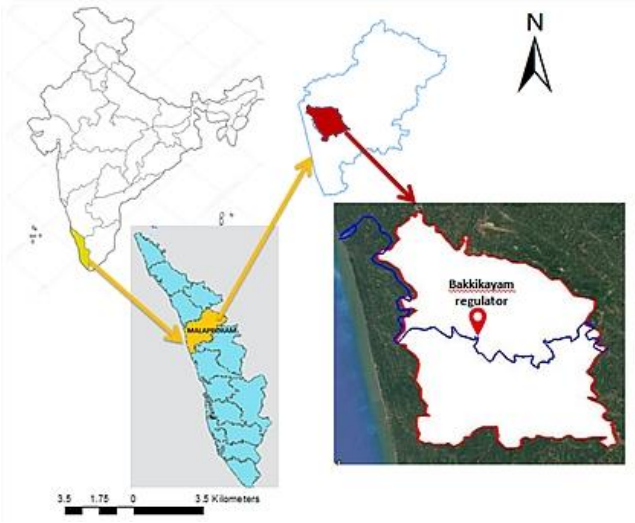

Fig-1 Location map of the study area

Table-1 *Resistivity data interpretation and corresponding thickness*

SN	Locations	ρ1 (ohm-m)	ρ2 (ohm-m)	ρ3 (ohm-m)	ρ4 (ohm-m)	h1 (m)	h2 (m)	h3 (m)	Depth to bed rock(m)
1	Vengara	204	750		-	2.05		-	2.05
2	Vengara	109	46.7		-	2.4		-	2.4
3	Thenjipalam	714	1503	220	-	1	4.49	-	5.49
4	Peruvallur	2314	1243	4.43	229	1.35	5.85	54.7	61.9
5	Moonniyur	270	1396	43.6	4556	1.79	4.38	7.28	13.5
6	A R Nagar	1154	700	115	-	7.05	4.72		11.8
7	Kannamangalam	3762	60.8	1834	-	5.8	8.34	-	14.1
8	Oorakam	1017	3463	261	153484	2.62	2.33	2.68	7.64
9	Parappur	1857	175	3161	76.3	1	0.543	2.11	3.65
10	Othukkungal	511	3049	3.4	-	1.33	3.61		4.93
11	Kottakkal	303	1693	45.8	-	2	3.53	-	5.53
12	Edarikode	530	113	1767	4.94	1.16	1.39	5.43	6.71
13	Perumannaklari	648	7273	383	6274	1	1.15	2.06	6.76
14	Ozhur	195	382	3188	17.5	1.02	2.68	3.17	6.87
15	Tirurangadi	140	56.5	10073	-	1.7	9.75	-	11.4
16	Kuruvapadam	123	382	73148	-	1	13.5	-	14.5
17	Kuruvikundu	1943	1161	4062	726	0.75	4.79	3.89	9.43
18	Kottakkal	897	1744	239	-	2.47	3.95	-	6.42

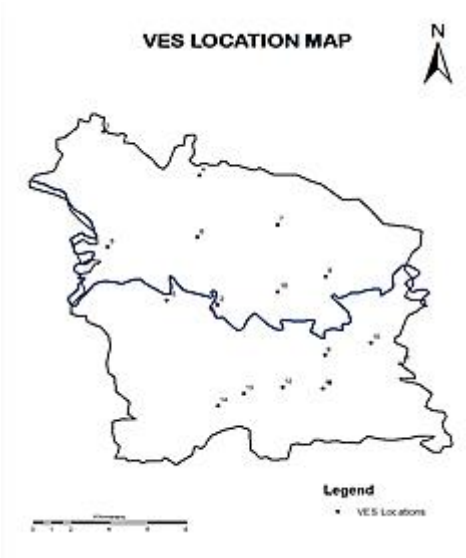

Fig-2 VES location map

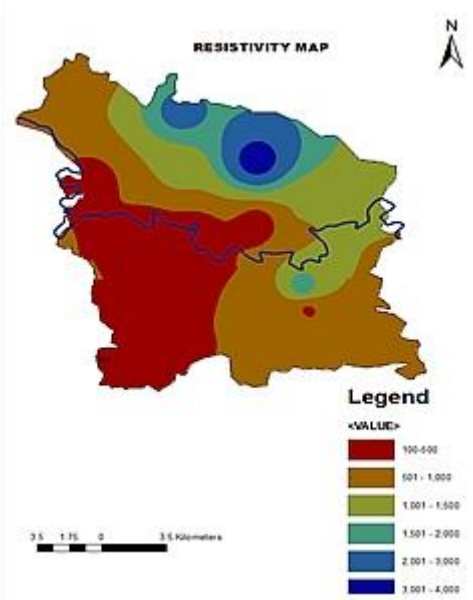

Fig-3 Surface resistivity map

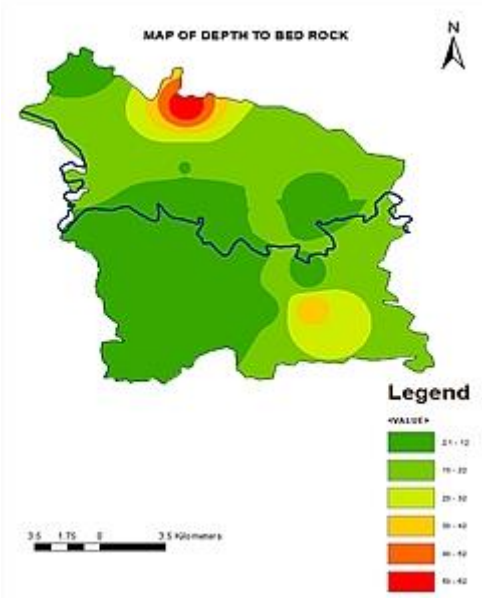

Fig-4 Map of depth to bed rock

Results and Discussions

Interpretation of VES Data

Collected field data from VES survey were interpreted using IPI2WIN software to obtain the resistivity values of different subsurface layers and thickness of each layer are given in [Table-1]. From sounding curve interpretation, 2 to 4 subsurface layers were identified within the study area and resulting sounding curves were H, K, A, HK, QH, KH and AK. The presence of three layers substrata was represented by H, K, A and Q sounding curves, while the combination curves such as HK, QH, KH and AK curves represents four layers sub strata. Among the 18 VES survey, two locations showed two layers substrata, seven locations showed three layers substrata and nine locations showed having four layers sub strata.

Surface resistivity map of the study area was prepared using the first layer resistivity data collected from the interpretation of VES data. The map was prepared in the Arc GIS (10.4) software and shown in the [Fig-3]. From the figure, it could be seen that the major portion of the study area is having the resistivity ranging from 100 to 1000 ohm-m. This showed that the major portion of the study area is covered with lateritic and hypodermic soil which is onpar with the conclusion of Sajeena and Kurien (2015).

The map of depth to bed rock was prepared using Arc GIS (10.4) and shown in the [Fig-4]. From the map it could be revealed that major portion of study area have same depth range of 12 to 22m to the bed rock. Some locations *viz.* Vengara, Nammabra, Tirurangadi and Thennala found to have shallow bed rock of 2-12 m. A small portion of Peruvallur has deep bed rock with 43- 63 m.

H type curve

Soundings from Kannamangalam (VES 7) and Thirurangadi (VES 15) showed 'H' type curve with three layers model (ρ1>ρ2< ρ3) as shown in [Fig-5]. This type of curve represents a high resistivity first layer such as dry top soil and second layer of low resistivity *i.e.*, saturated weathered layer followed by last layer of very high resistivity hard rock. Results of the field study showed that the resistivity of top layer ranged 140 to 3762 ohm-m with thickness ranging from 1.7 m to 5.8 m. This in turn indicates the presence of lateritic formation. The second layer has resistivity ranging from 56.5 to 60.8 ohm-m, indicated the presence of clay or clayey laterite zone of thickness 8.34 m to 9.75 m. The third layer has resistivity ranged from 1834 to 10073 ohm-m indicated the presence of hard laterite and hard rock and this result is in agreement with the lithology data obtained from the Department of Groundwater, Govt. of Kerala.

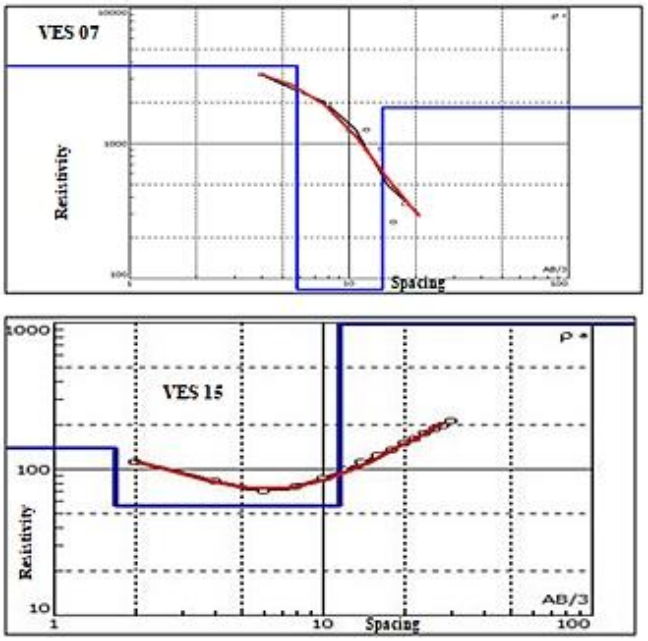

Fig-5 Resistivity sounding curves (H type)

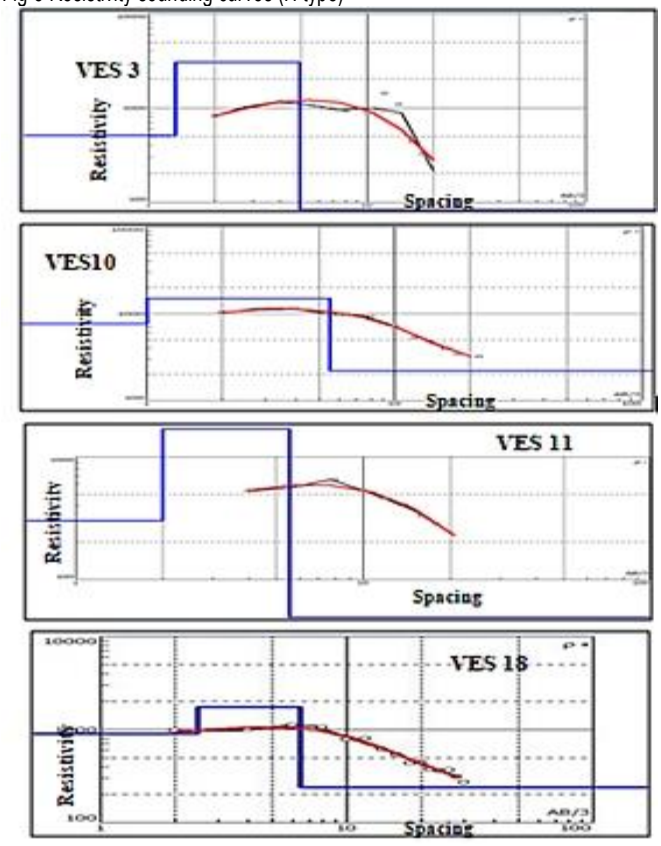

Fig-6 Resistivity sounding curves (K type)

K type curve

Soundings from Thenhipalam (VES 3) and Kottakkal (VES 11, VES 18) revealed three layered model (ρ1<ρ2>ρ3) with 'K' type curve as shown in [Fig-6]. The resistivity of first layer ranged from 303 to 897 ohm-m with a thickness of 2 to 2.4 m. This pin points presence of lateritic/hydomorphic topsoil. The second layer has resistivity range 1693 to 1744 ohm-m which indicate the presence of hard laterite/ gnesis with thickness range of 3.53 m to 3.95 m. Third layer is a low resistivity substratum (45.8-239 ohm-m) such as weathered rock. These results were in agreement with the result reported by Sajeena and Kurien (2015).

A type curve

Soungings of Vengara (VES 1) and Kuruvapadam(VES 16) were morphologically defined by three layer model with the resistivity sequence of ρ1<ρ2<ρ3 as shown in [Fig-7]. This type of curve implies the soil having a low resistivity top layer and a high resistivity third layer showing a steady increase in the resistivity with increase in the depth. The first layer has a resistivity range of 123 – 230 ohm-m of thickness 1 to 2.5 m. this result indicated that this area is suitable for open wells and is correlated with the lithology of Department of Groundwater, Govt. of Kerala.

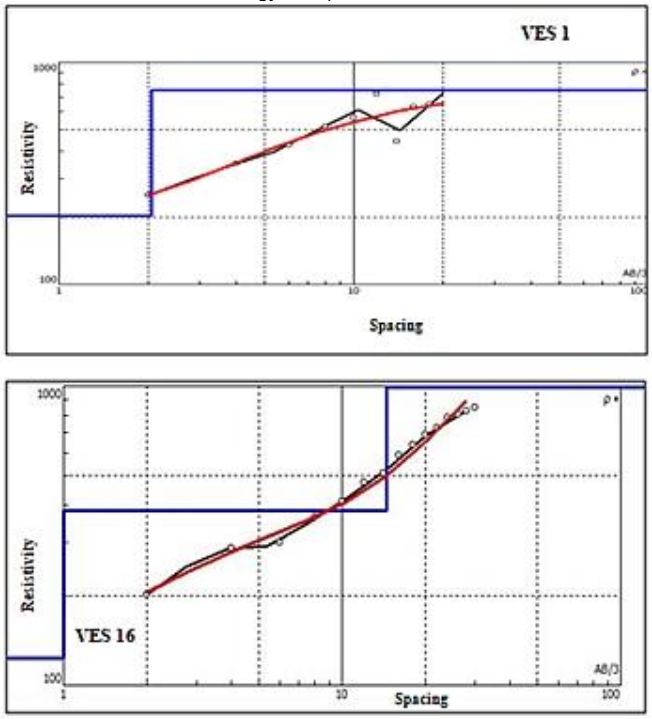

Fig-7 Resistivity sounding curves (A type)

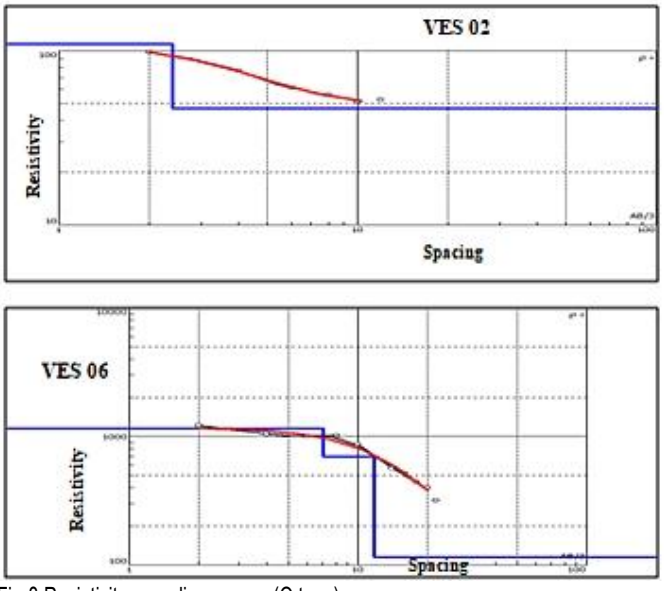

Fig-8 Resistivity sounding curves (Q type)

Q type curve

Soundings from Vengara (VES 2) and A. R. Nagar (VES 6) could be explained by the three layers model with steady decrease in the soil resistivity (ρ1>ρ2>ρ3) which indicates the top soil is a high resistivity soil and the substrata followed a low resistivity pattern. In the present study, at Vengara (VES 2) Q type of curve is obtained as it is near to the river.

The first layer is having the resistivity 109 ohm-m followed by a layer of resistivity 46.7 ohm-m. This indicated that the top soil is riverine alluvium underlying by clay layer. Whereas at A.R. Nagar (VES 6), the top layer having resistivity 1154 ohm-m, and decreasing towards the bedrock. This indicated the presence of hard laterite layer at the top and its hardness decreases towards the bottom. Soundings are as shown in [Fig-8].

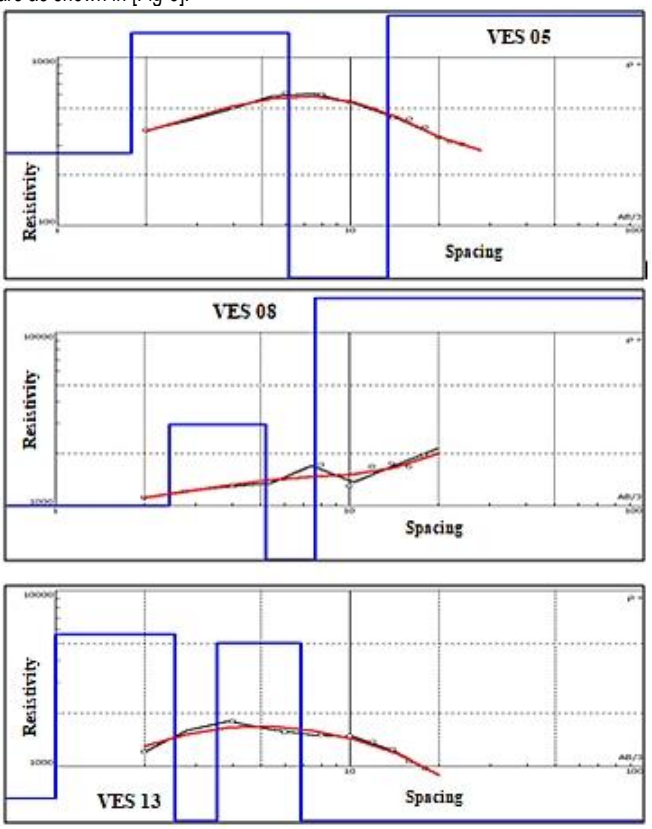

Fig-9 Resistivity sounding curves (KH type)

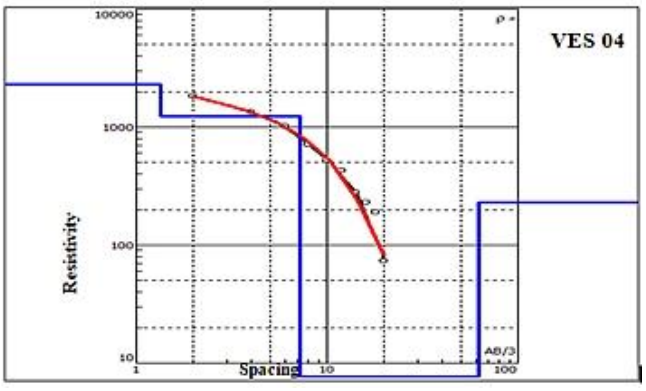

Fig-10 Resistivity sounding curves (QH type)

KH type curve

Soundings from Munniyur (VES 5), Oorakam (VES 8), Perumannaklari (VES 13) revealed four layers model with a resistivity sequence of ρ1<ρ2>ρ3<ρ4 (KH type curve) as shown in [Fig-9]. The third layer with low resistivity of 43 to 252 ohm-m and thickness of 2.06 to 7.26 m, indicated the presence of weathered zone. This area is more suitable for open wells.

QH type curve

Soundings of Peruvallur (VES 4) showed QH type curve representing four layered model which can be morphologically explained by resistivity sequence ρ1>ρ2>ρ3<ρ4. This type curve indicated the lateritic soil/ moderate laterite followed by weathered rock/clay with a thickness of 5.85 m. The fourth layer has high resistivity 229 ohm-m. indicated the presence confining layer. Soundings are shown in [Fig-10].

HK type curve

Soundings obtained from Vengara (VES 1, VES 2), Kuruvikundu Othukkungal (VES 17) could be explained with a four layers model with a resistivity sequence of ρ1>ρ2<ρ3>ρ4, 'HK' type curve.

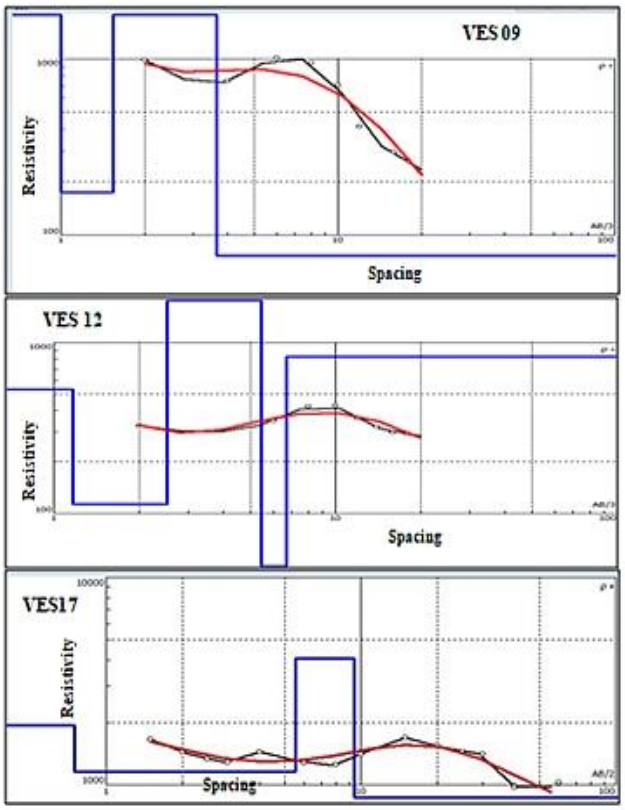

Fig-11 Resistivity sounding curves (HK type)

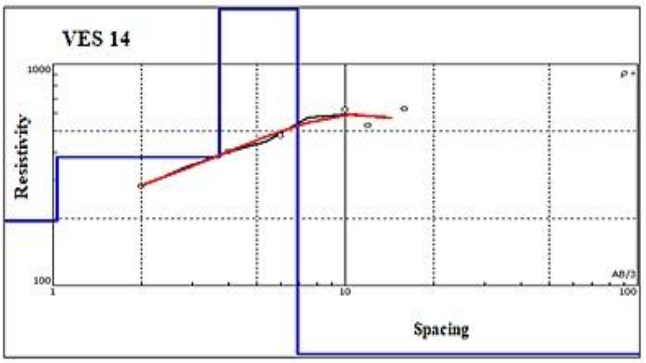

Fig-12 Resistivity sounding curves (AK type)

This showed the probability of existence of a weathered rock as second layer which can act as better conduits for groundwater movement down to deep aquifers. The third layer shows a sudden raise in resistivity value with the indication of the absence or lack of fractured rock layers. Fourth layer is indicating slight reduction in the resistivity value due to the presence of interconnected fractures which can be used for moderate groundwater supply. Soundings are shown in [Fig-11].

AK type curve

Soundings of Ozhur (VES 14) showed a four layers model having a resistivity sequence of ρ1<ρ2<ρ3>ρ4 with 'AK' type curve as shown in [Fig-12]. The first and second layers have a resistivity of 195 and 382 ohm-m respectively.

The third layer exhibits a high resistivity of 3188 ohm-m with a thickness of 2.68 m. The fourth layer is a low resistivity layer (17.50Ohm-m).

Resistivity and Psuedo sections

The resistivity and pseudo cross section along two cross sections *viz*., AA' and BB' were prepared using true and apparent resistivity values and given in [Fig-13]. AA' represents the cross section along the VES locations *viz* A. R. Nagar and Ozhur while BB' represents cross section along the VES locations *viz*. Oorakam, Parappur and Kottakkal.

The section AA' was plotted with the soundings VES 6 and VES 14 in North South direction. A high resistivity layer was observed in A.R. Nagar (VES 6) and the resistivity is decreasing towards Ozhur (VES 14). Similarly, the resistivity decreases towards the bottom from 1679 - 178 ohm-m at A. R. Nagar and 1188 – 420 ohm-m at Ozhur. This indicated that hard laterite at top layers, and gradually decreasing the hardness of laterite.

The section BB' was plotted with the soundings VES 8, VES 9 and VES 11 in North South direction. A medium resistivity layers ranging from 1103 – 529 ohm-m was observed throughout the cross section indicated the presence of laterite or hypodermic soil at a depth of 4.68 – 8.58 m.) A patch of very low resistivity zone was observed at a depth of 11 m from Parappur (VES 9) to Kottakkal (VES 11) indicated the presence of either lithomargic clay or weathered rock.

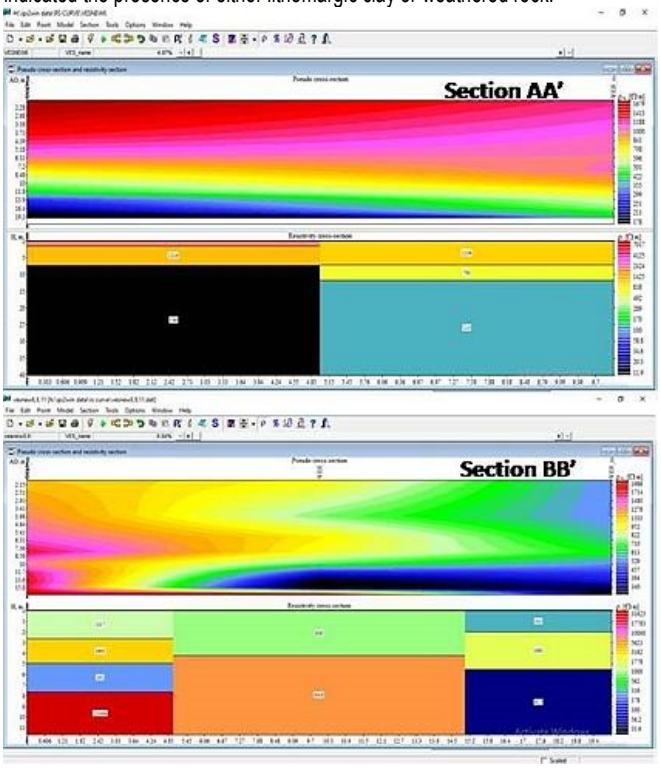

Fig-13 Pseudo and Resistivity cross sections of two sections AA' and BB'.

Summary

From VES data interpretation using IPI2WIN software, it could be concluded that most part of the study area showed H, KH and HK type curve indicating the presence of good to moderate quality ground water. From this study, it could be concluded that, top soil of the study area is either laterite soil or hydromorphic soil of thickness 0.75 to 4 m, followed by laterites with varying hardness to a depth of 4 m to 17 m. Lithomargic clay of thickness less than 2 m is seen below the laterites in some places. These layers are overlying weathered rock of 2 to 14 m thickness followed by hard rock with or without fractures.

Application of research: This research helped to study the groundwater level of the study area and its variations. This study also revealed the different subsurface formations in the study area and this will help to identify the groundwater potential area and appropriate site-specific groundwater recharge measures

Research Category: Soil and Water Conservation Engineering

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Research project name or number: M. Tech

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Ayacut area of Bakkikayam Regulator, Vengara, Malappuram Dt, Kerala

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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