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Integration of 2D AMT and Subsurface Geoelectric Exploration Techniques for Mapping Deep Confined Fresh Water Aquifer in a Saline Sedimentary Environment in Vridhachalam Taluk, Cuddalore District, Tamilnadu, India

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Abstract:- While the presence or absence of water in the subsurface obviously should have an effect on the electrical properties of the ground, in the exploration process, particularly in relatively unexplored basins, it is not always immediately clear whether groundwater is a low resistivity target relative to background, or a high resistivity target. Correlation with known or suspected geological structure, borehole geophysics, and down-hole lithology is often critical in the proper application of surface geophysics to groundwater exploration. Magneto telluric [MT] is an electromagnetic surface geophysical exploration method, can give a good result with good resolution of data. The constant source audio magneto telluric method [CSAMT] and natural source audio magneto telluric method [NSAMT] which are one among electromagnetic techniques, usually provide better lateral high resolution at shallow and deeper depths than galvanic electrical resistivity methods. This research paper deals with integration of NSAMT- 2D AMT method and subsurface geoelectric exploration- borehole geophysics technique to explore the very deep fresh water aquifer in a saline sedimentary environment for irrigation needs. The research area falls in Vridhachalam taluk & block in Cuddalore district of Tamilnadu, South india. The investigation constraints being complex geological and hydrogeological setup with salinity problem. Added to this a very huge thickness of aquiclude and the aquifers occur @ very deeper depths for which a high financial investment is needed. The problems were overcome by carrying out systematic hydrogeological, geophysical- both electromagnetic and geoelectric explorations and the very deep freshwater confined aquifer could be prospected. A pilot borehole to a depth of 312mbgl was drilled by rotary rig and the borehole was electrically logged. A tube well of 150mm dia was constructed to a depth of 312m, developed and finally completed. The discharge of well is 600 lpm with good potable water which could cater the water needs of entire farm.

Keywords:- *Aquiclude; Confined Aquifer; 2D AMT; Electrical Well Logging; Well Developing*.

I. INTRODUCTION

Geoelectrical methods are most commonly considered to be the basic methods in groundwater investigations, but in case of deeper aquifers the electrical resistivity tomography [ERT] / 1D VES cannot achieve deeper targets and the electrical sounding cannot ensure a complete and dense space coverage. In such a case the use of the magneto telluric [MT] method can provide for great depths of research, as well as a good space sampling. MT techniques can give high resolution at moderate and deeper depths than galvanic electrical resistivity methods, since the depth of investigation of CSAMT and NSAMT is determined by frequency of the signal and background resistivity, rather than dipole size and array geometry, as is the case in the galvanic methods [1]. The magneto telluric (MT) method is a well-established for subsurface imaging technique that is most often used in geothermal, minerals, and hydrocarbon exploration, as well as deep crustal studies. This surface-based method involves measuring the electric field (usually referred to as the E-field) and magnetic field (H-field) components of naturally occurring electromagnetic fields in order to calculate an apparent resistivity value of the subsurface from the ratio of these measurements [2]

II. AREA OF INVESTIGATION

The area confines to Ko.Pavalangudi village of Vridhachalam block & taluk in Cuddalore district of Tamilnadu. The client is an agriculturist, Mr.Jeyaraman with a total extent of agri land of about 100 acres, which is on northeast of Vridhachalam on Vridhachalam-Mangalampettai highway. The area is almost a plain topography with a gentle slope towards east and the altitude is 57 AMSL. The investigation carried out in the land falls on Lat- N 11.61444, Long- E 79.25766.

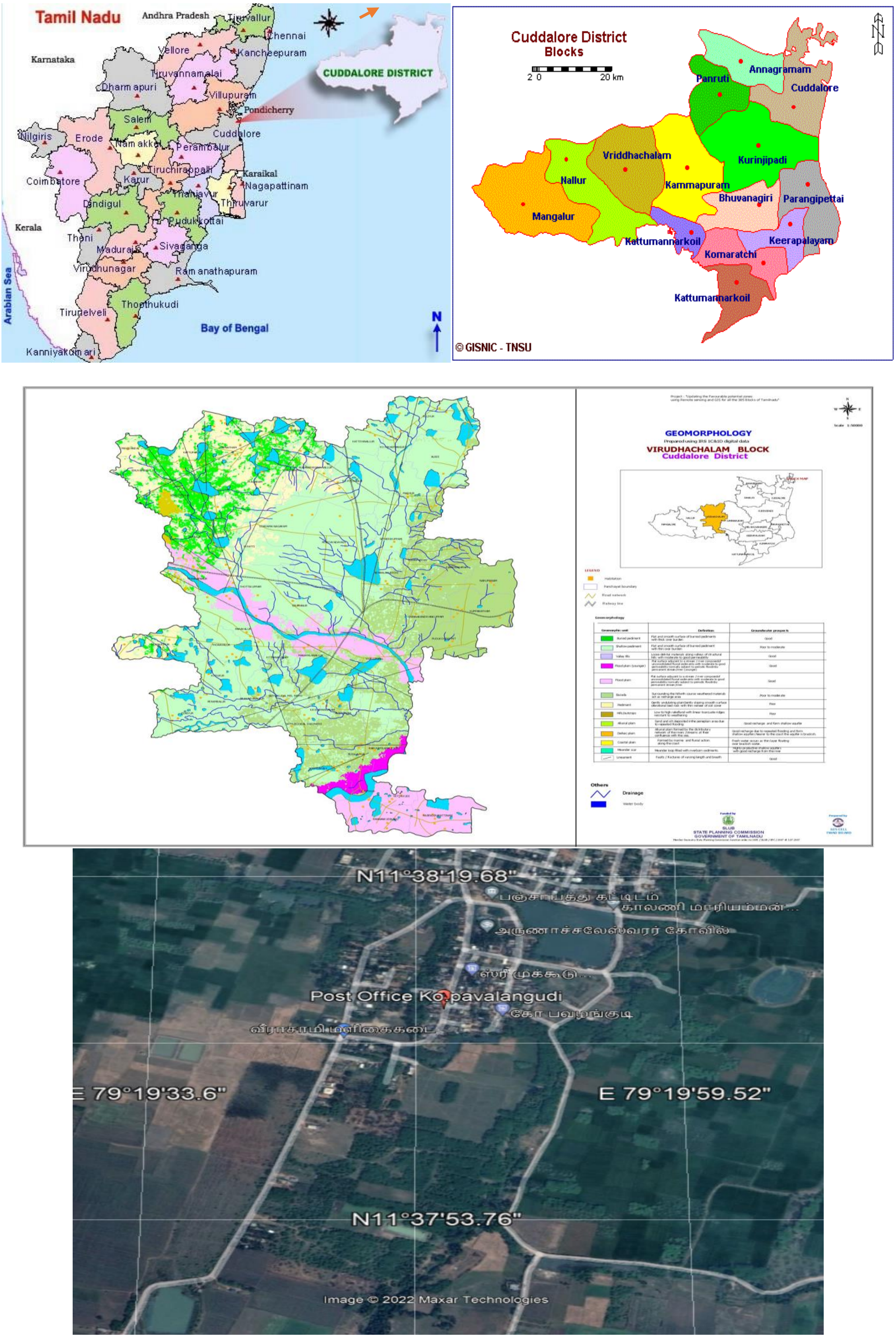

Fig 1,2,3,4. Area of investigation

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A. Gravity of the problem

There has been no permanent water source prior to investigation. The geological and hydrogeological conditions are very complex that the area is an unconsolidated sedimentary terrain with shallow & deep aquifers are brackish/ saline in nature. A very huge thick layer of aquiclude of clay is present [3]. Potential freshwater aquifers occur below 210 mbgl. Exploring the very deep water resources and construction of tube well are problematic. Construction of such very deep tube well incurs much financial commitment.

B. Geological and hydrogeological backgrounds

The area is a sedimentary terrain covered by various geological formations ranging in age from Cretaceous to Recent represented by black clay, calcareous sandstones & marls [Upper Cretaceous] overlain by Gopurapuram formations of Eocene age, essentially argillaceous, comprising silts, clay stones, calcareous sandstones, shale's, black clay & soils [3] [Figs-5, 6 ,7] The area is about 60 to 65 kms from sea coast.

Groundwater occurs in all geological formations both under confined & unconfined conditions. The shallow unconfined aquifers may not be potential to tap for irrigation purposes. The deep confined aquifer occurs 200 meters below ground level. The principal & potential aquifers are sand stones, fine to medium grained sands, pebbles & gravels [Fig-8]. The depth to water level ranges from 20 to 60 mbgl. The area receives maximum rain fall during northeast monsoon period which is the main source for groundwater recharge.

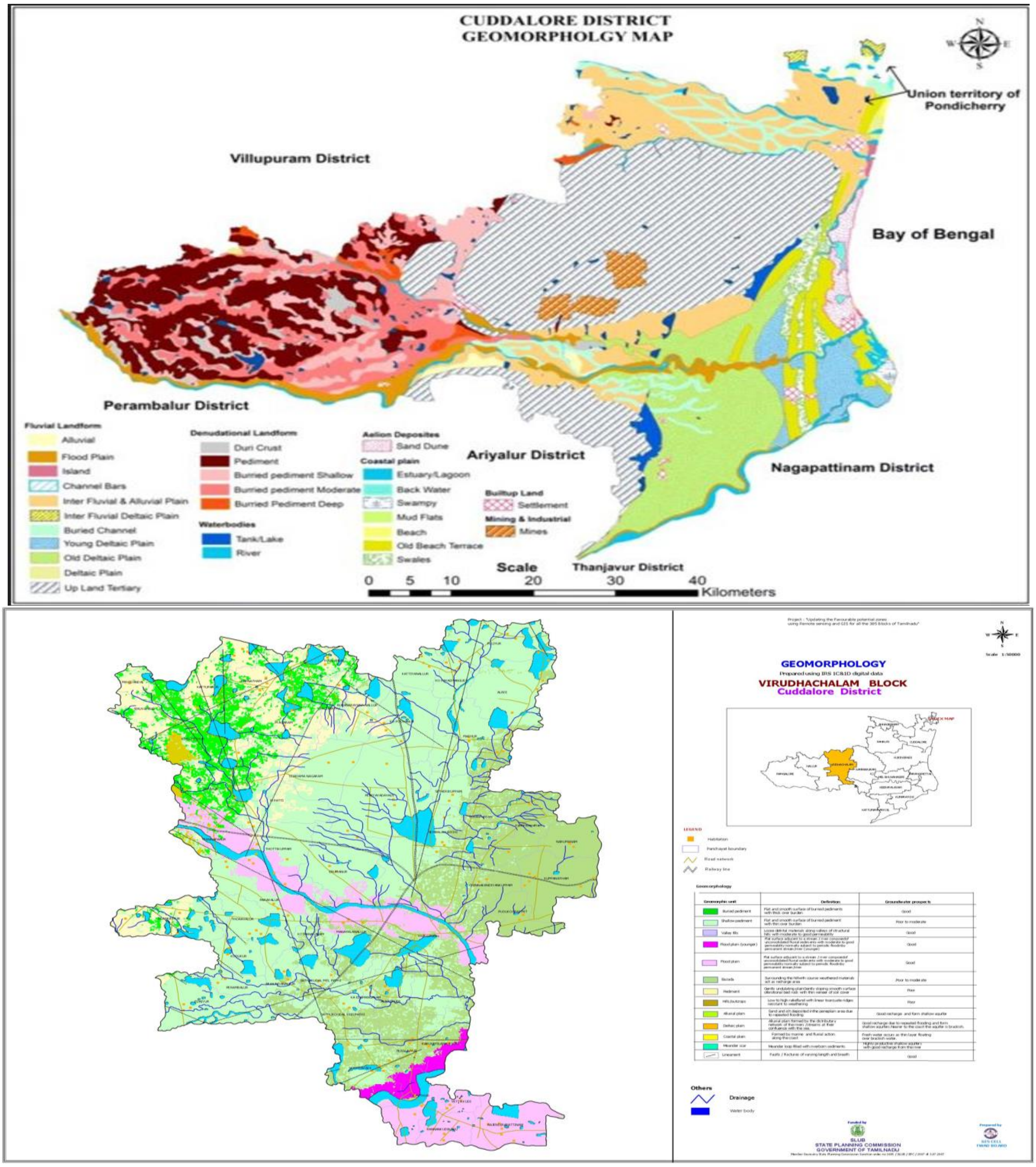
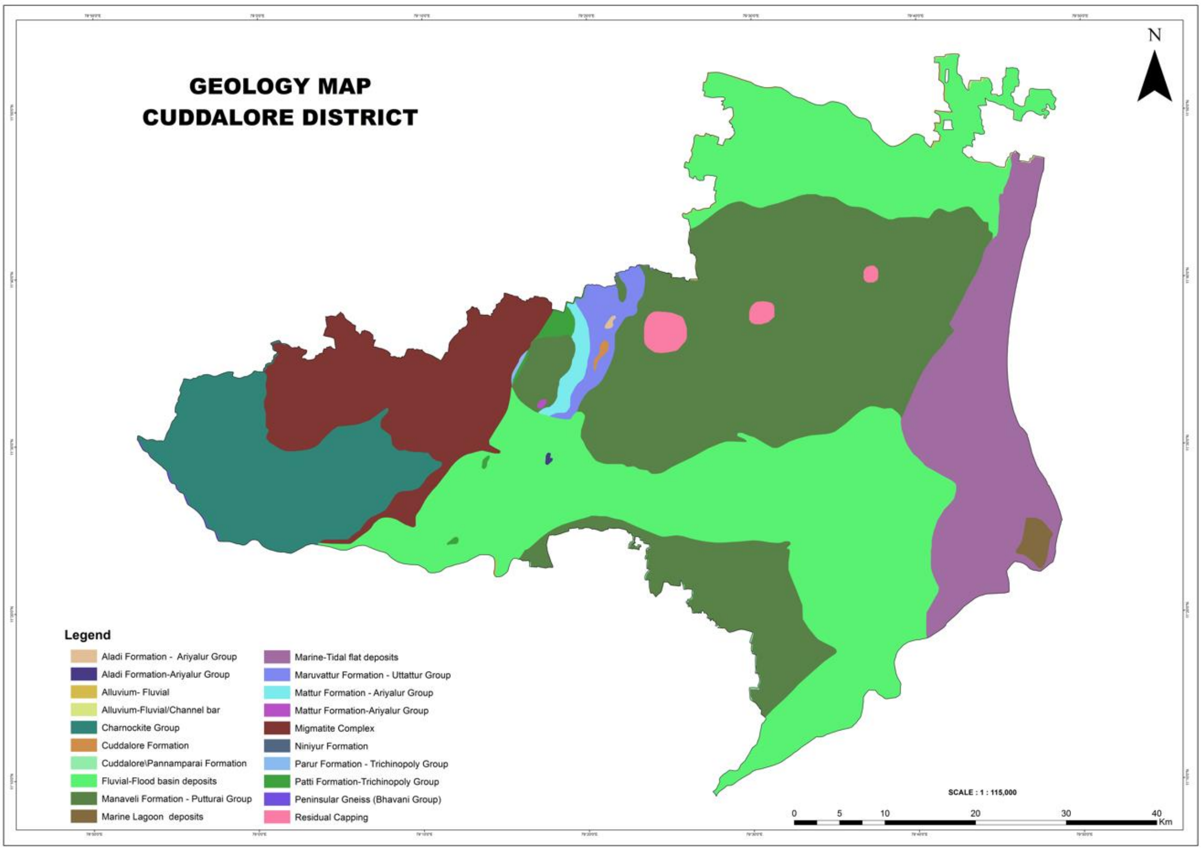


Fig 5 & 6. Geomorphology maps of Cuddalore district & Vridhachalam block



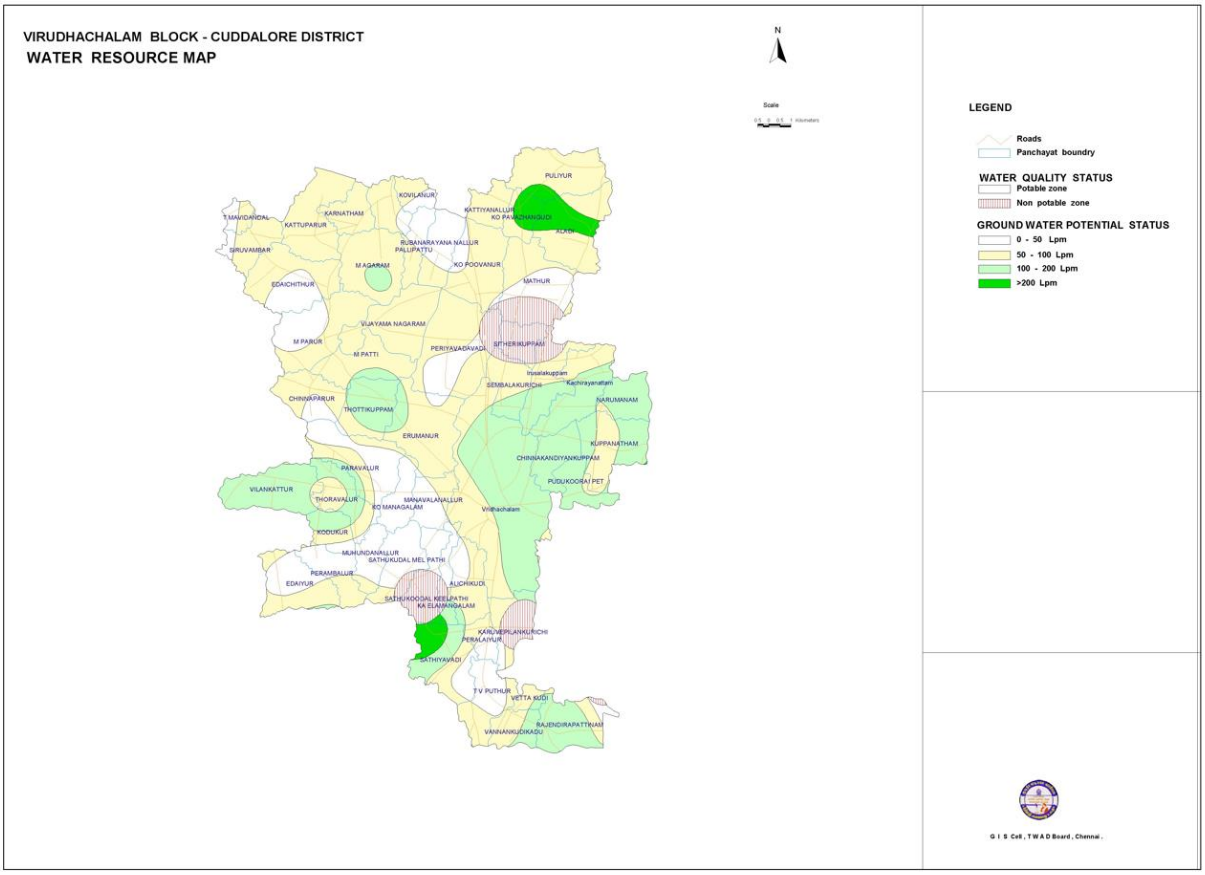


Fig 7 & 8. Geology map cuddalore dist & GW prospects map- vridhachalam block.

III. ELECTROMAGNETIC EXPLORATION TECHNIQUES

A. Two dimensional audio magneto telluric imaging [2D AMT]

Electromagnetic (EM) induction technique is one of the most important geophysical techniques in understanding the subsurface structure. The theory of magnetotelluric (MT) method, the main branch of the EM technique, was introduced during 50's by Tickonov (1950) and Cagniard (1953) with the natural variation of electromagnetic fields, as its source [5] Magneto telluric (MT)technique is an electromagnetic geophysical method for inferring the earth's subsurface electrical conductivity from measurements of natural geomagnetic and geoelectric field variation at the Earth's surface. Electromagnetic (EM) theory is originated from four fundamental equations proposed by James Clerk Maxwell. Magneto telluric method depends mainly on the electrical resistivity parameter of the earth [5]. CSAMT is a commonly used electromagnetic sounding technique used for shallow subsurface geophyical surveys at depths up to three kilometers beneath the surface. This method is similar to natural-source magnetotellurics (MT) and audio-frequency magnetotellurics (AMT) with the key difference being the use of an artificial signal source. Natural electric currents cause detectable potential (voltage) differences that can be detected on the earth's surface [4]. Currents can result from chemical reactions around natural conductors (e.g. metals), moving fluids, diffusion-adsorption processes, localized heating, and chemical gradients in the subsurface. . Depth of investigation depends on the transmitted frequency and resistivity of the subsurface [6] In general, the lower the frequency and the higher the ground resistivity, the greater the depth of the data more [6]. Vertical resolution of MT mainly depends on the frequency being measured, as lower frequencies have greater depths of penetration. Magnetic fields in the frequency range of 1 Hz to approximately 20 kHz are part of the audiomagnetotellurics (AMT) range.

B. PQWT geophysical prospecting instrument

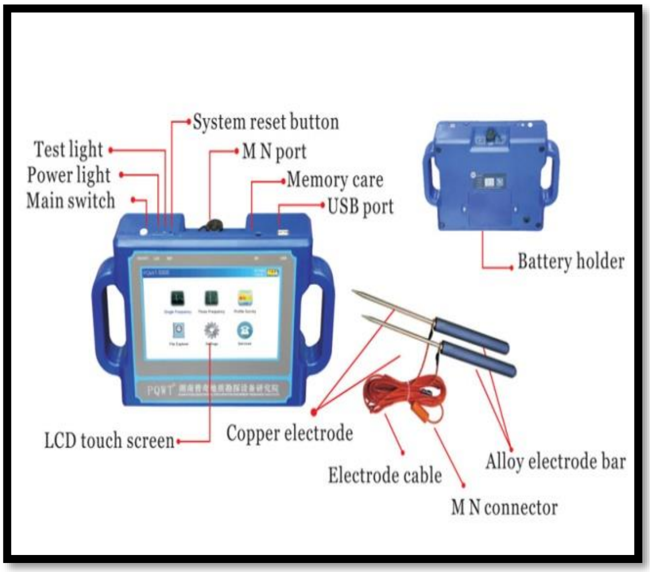
This equipment works on the principle of Audio Magneto Telluric [AMT} method. The prospecting technique is based on natural electrical field source which is influenced by resistivity contrast of underground rock, minerals and ground water [7]. Without heavy power supply, it uses low frequency signals in earth natural electric field as signal source. Equipment is automatically controlled by micro PC with a high resolution of measuring accuracy of 0.001 mili volt. Since it uses natural electric field source without any external source of heavy batteries, it is handy, tiny & portable [Figures-9,10 & 11]. Prospecting & profiling can be done more rapidly than conventional resistivity survey, which is time consuming & laborious. It has built in software to digitally process the data & 2D profile is directly displayed on the system. The data & 2D profiles are stored in the system and could be imported directly to computers. There are different models with different depth of investigation ranges.

C. Pqwt Tc-500 Model

This model [Figures-7, 8 & 9] is capable of investigating up to a depth of 500 meters below ground level [MBGL]. There are 3 main options of methods of frequency of profiling. 1. Single frequency, 2. Three frequency & 3.Multi frequency. In this research, multi frequency profiling is adopted where in data sets for 56 frequencies are recorded & stored as csv file format in Excel. For correlation purposes, profiling was carried out near existing bore wells i.e., both yielding and unyielding.

IV. ELECROMAGNETIC-2D AUDIO MANETO TELLURIC IMAGING

A. PQWT TC-500 WATER DETECTOR



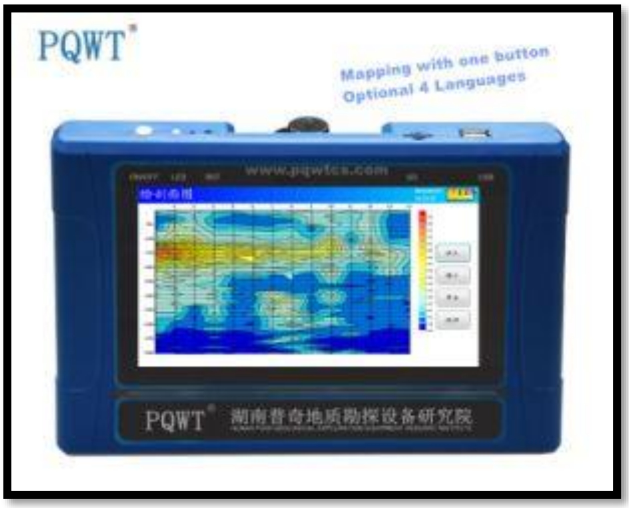


Fig 3. 9, 10 & 11

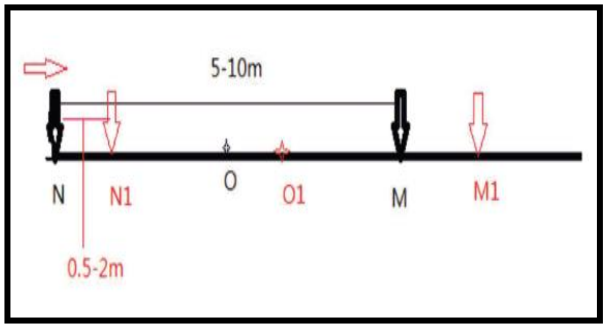


Fig 12. PQWT profiling field layout- 0: center point of observation, M & N-electrodes

In the area of investigation one multi frequency profiling was carried out with M-N electrodes spacing-10m and dot pint spacing 01m with 15 observation points [Fig-13, 14]. One 1D VES has also been conducted @ the point-05 using IGIS, SSR-MP-AT-S model employing Schlumberger array [Fig-17].

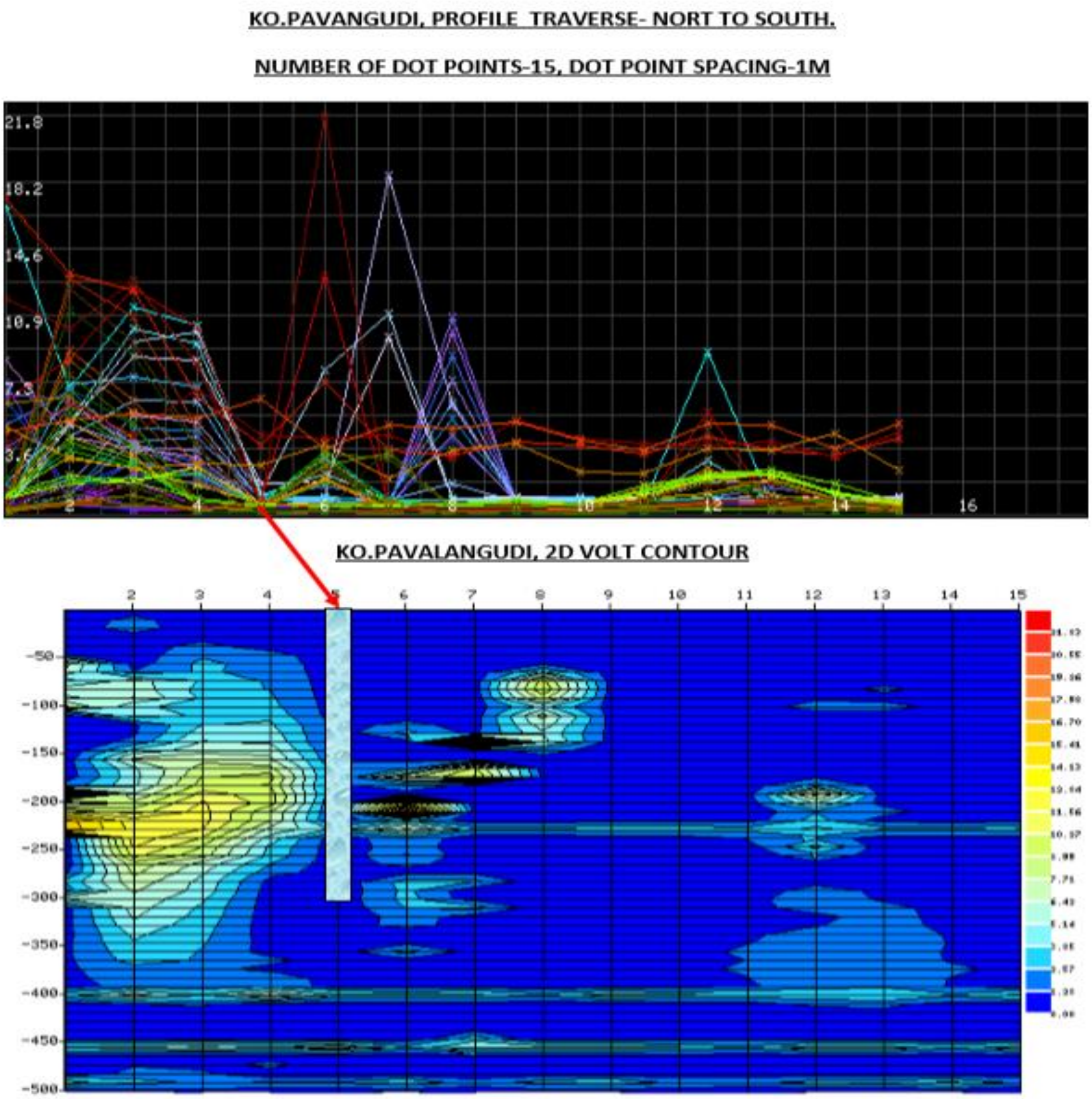


Fig 13 & 14-2D AMT profiles

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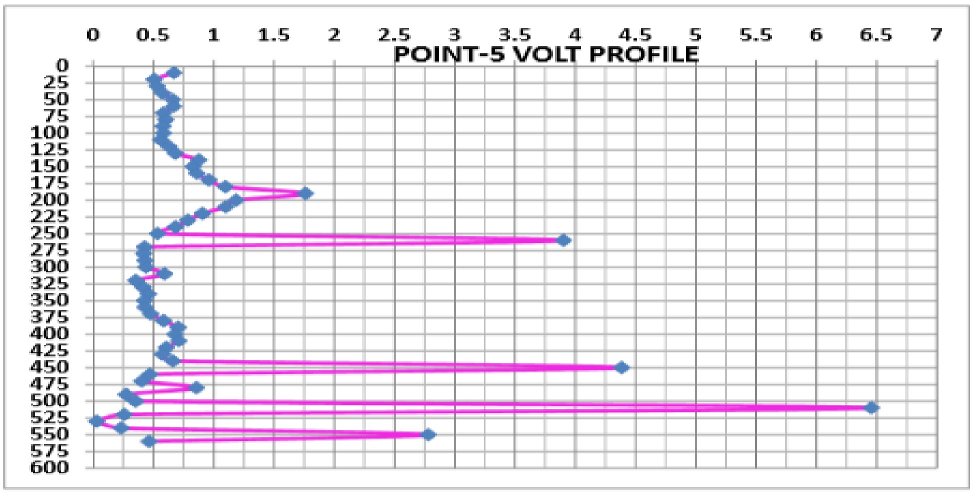
KO.PAVALANGUDI, POINT-5 VOLT PROFILES



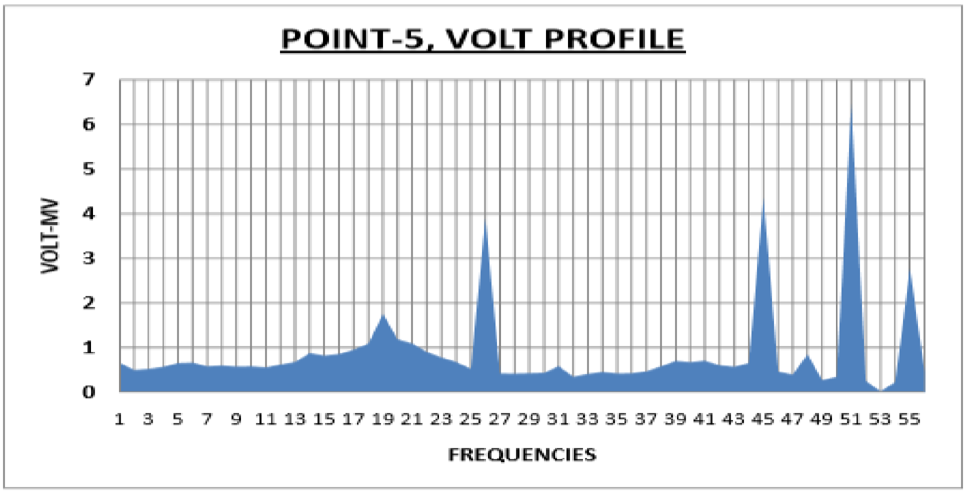


Fig 15 & 16-Point-05 millivolt profiles

KO.PAVALANGUDI, VES CURVE

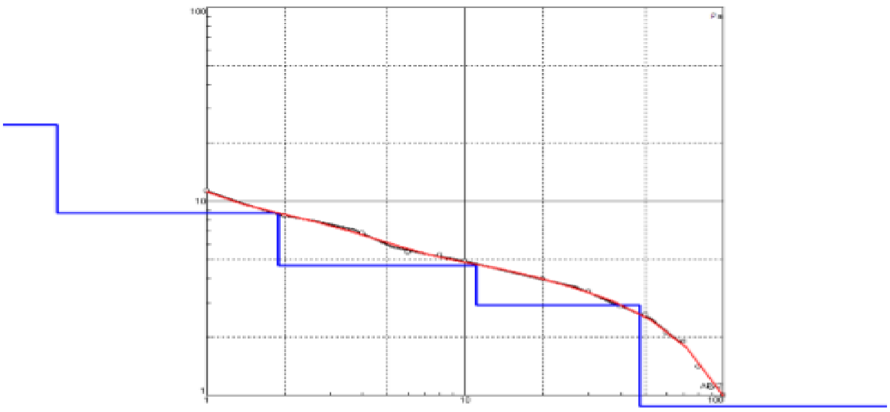


Fig 17- VES curve

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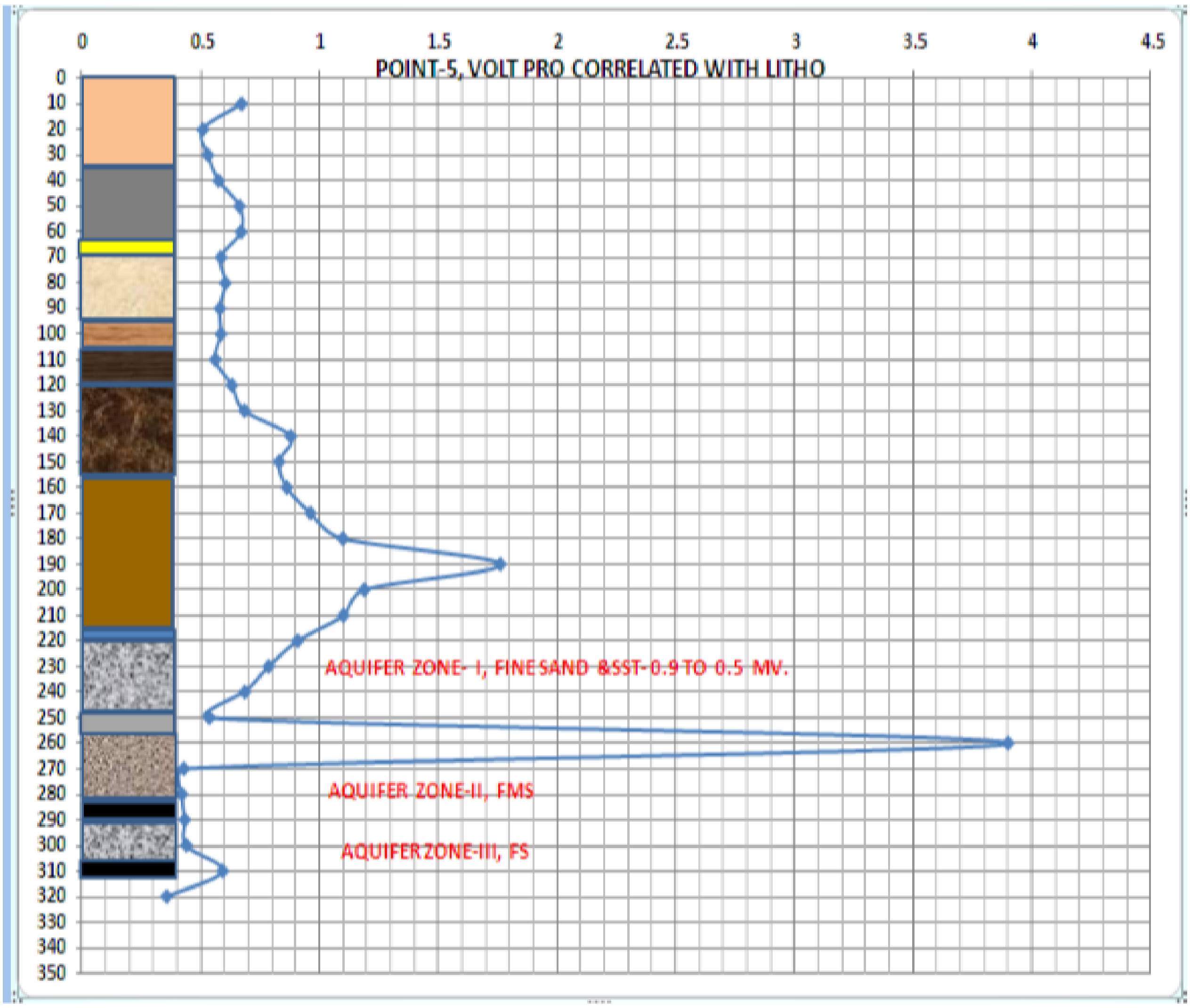
B. Subsurface geoelectric investigation- Electrical well logging

Based on the hydro geological conditions, 1D VES & 2D AMT surveys, pilot borewell has been drilled employing rotary rig to a depth of 311m. The primary purpose of geophysical logging is the identification of formations traversed by a bore hole and the salinity of the fluids which some of these formation contains. Well logging detects the permeable beds and thickness of aquifers, is there by very useful tool for the successful well design and construction [8]. There are number of logs like electric logs, radiation logs, acoustic logs, mechanical logs and temperature logs. But in ground water geophysics, the most widely used geophysical logs are SP, Point resistance and normal resistivity logs which is otherwise called as electrical logging. The continuous recording of electrical resistance or resistivity and SP of the formations penetrated by a drill hole is known as electrical logging. A constant current is sent into the bore hole through an electrode placed inside the bore hole. The response of the formations in the form of resistance offered to the electric conduction is measured in two modes either the resistance or apparent resistivity. The potential difference between bore hole electrode and a reference electrode at the surface is recorded [8]. Normal resistivity logs are four electrode system widely used in ground water hydrology which measures the apparent resistivity. There are two types of normal resistivity logs, short normal [SN 16''] and the other long normal [LN 64'']. The normal resistivity logs clearly distinguish the clay, saline and fresh water zones. SP measurements are useful in deciphering the saline and clay predominant zones. The pilot bore hole has been electrically logged using portable spot logger and both DC and microprocessor based signal stacking digital resistivity meters. SP and resistivity measurements have been recorded for every 2 meter [Figs-19, 20, 21].

POINT-5 VOLT PROFILE CORRELATED WITH LIHOLOG



TUBE WELL DEPTH- 311M, YIELD: 600 LPM.

Fig 18- P5 mv profile correlation with lihology.

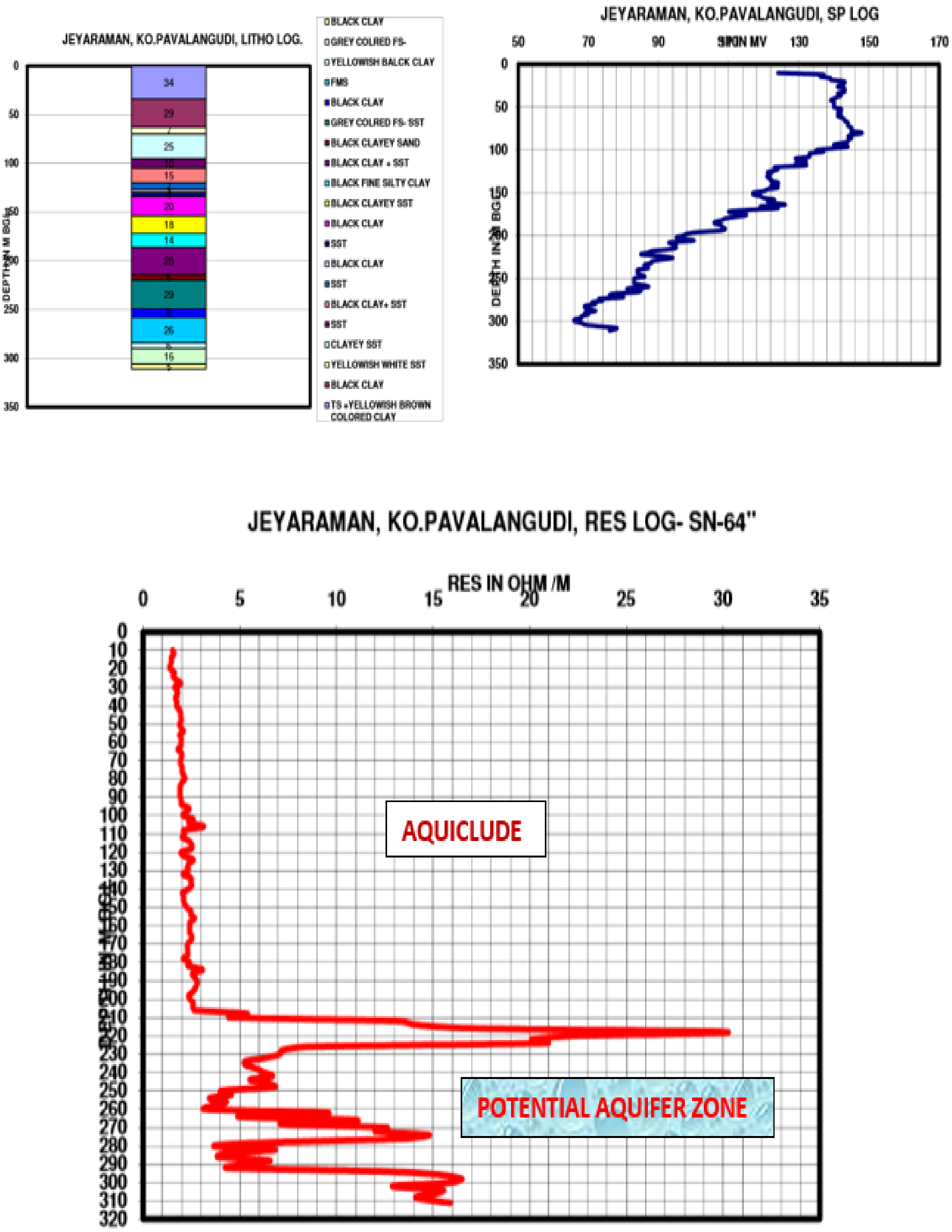


Fig 19, 20 & 21 Liholog, electro logs-SP profile & Ln-64''

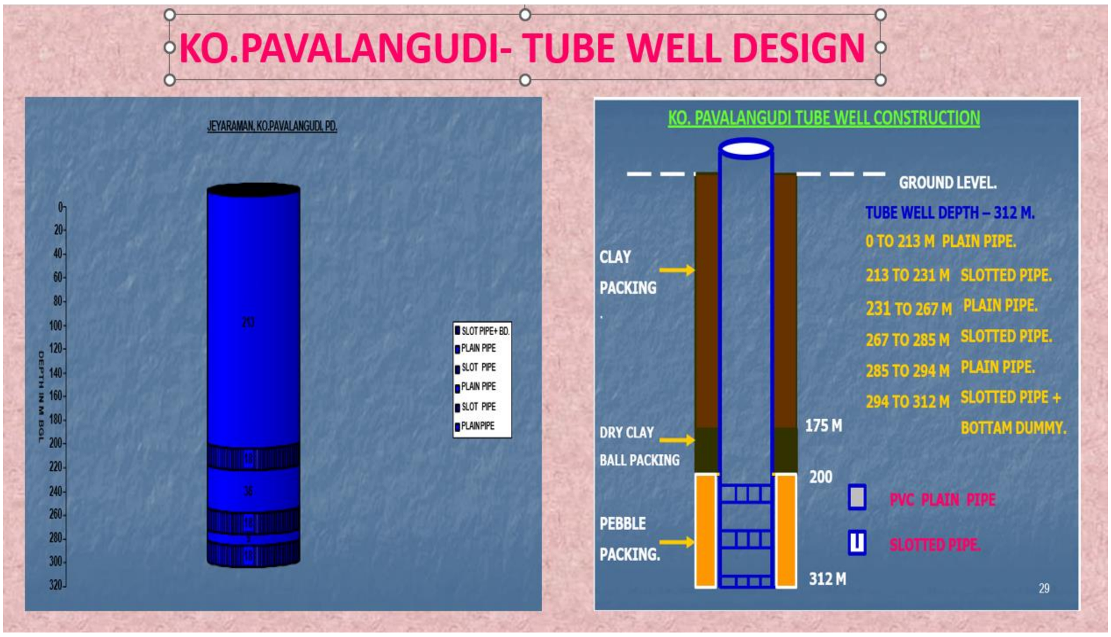


Fig *22 Tube well design & construction.*

V. RESULTS AND DISCUSSIONS

The 2D AMT profiles [Figures-13 & 14] show 15 observation points with 1m dot point spacing and exhibit a prominent low millivolt profile @ point-05. The maximum mv value recorded is 18.2mv. The point no-5 mv profile reflects 3 high anomaly peaks @ 200, 250 & 300m depths with a maximum mv value of 1.75@ 200m & 4mv @ 250 indicating aquifer zones. The profile [Figs-15 & 16] crystal clearly shows a high peak @ 260m with 3.9mv value where the corresponding litho unit is sand which being the potential confined aquifer. In the litholog [Fig-19] three sand aquifer zones are observed @ 220-250m with 30m thickness, followed by 260-280m with 20m thickness & 290-310m depth with 20m thickness which are the productive multi layered potential aquifer zones. In the electrologs [Fig-21] LN-64'' profile 3 prominent high resistivity anomalies are noticed with a resistivity range of 15-30ohm.m below 200m depth, indicating good potential fresh water sand aquifers. The tubewell design & construction [Fig-22] shows that slotted pipe [screens] are provided @ the depths of 213-231m, 267-285, & 294-312m with dry clay ball packing up to 200m to arrest the saline water and from 200-312m pebble packing.

Finally the tube well was developed and completed. The yield of the well is reported as 600 lpm with good potable water.

VI. SUMMARY AND CONCLUSION

The research area falls in Vridhachalam taluk & block in Cuddalore district of Tamilnadu, South india. The investigation constraints being complex geological and hydrogeological setup with salinity problem. The problems were overcome by carrying out systematic hydrogeological, integrated geophysical- both electromagnetic and geoelectric explorations. 2D AMT imaging, 1D VES and subsurface geoelectrical- electrical well logging have been done combinedly one by one to detect the very deep fresh water potential aquifers. Since integrated approach was employed, a fruitful encouraging result could be achieved with copious discharge of 600 lpm of potable water. Thus the integrated geophysical investigations has been found to be very successful to solve such hydrogeological problems.

REFERENCES

[1]. Abdullah Abderahman- B.Sc. research Essay- magneto telluric deep into groundwater exploration- Helwan University Faculty of Science Geology Department, 2019.
[2]. Agro Engineering, Inc- Project report- Comparison of Electromagnetic and Natural Potential Geophysical Investigations near the Emperious Tailings Pile Creede, Colorado, Jan26, 2004.
[3]. Badrinarayanan T.S- Deep tube well construction, power point presentation, India water portal, 2010-
[4]. Harinarayana T- NGRI, Hyderabad- Applications of Magnetotelluric Studies in India- *Memoir geological society of India* No.68, 2008, pp.337-356.
[5]. Katherine E. Anderson Russell D & etal- Project report- Controlled source audio magneto- telluric (csamt) geophysical investigation of the middle san pedro river basin, southeastern Arizona, Geophysics field camp 2008, May 14, 2008-Published by *LASI Laboratory for Advanced Surface Imaging*, The University of Arizona (Tucson, AZ).
[6]. Norman R. Carlson*, Zonge International, Inc., Charles F. Feast, Feast Geosciences, LLC., Greg L. Bushner, Vidler Water Company, Ryan Hoerth, Vidler Water Company- The Use of CSAMT and NSAMT in siting groundwater production wells: two case histories- Presented at the International Workshop on Gravity, Electrical and Magnetic Methods and Their Applications October 10-13, 2011, Beijing, China. *Operation manual* TC-500-www.pqwtcs.com

[7]. Ponnambalam A, Badrinarayanan T.S- exploring the deep confined aquifers by electrical well logging techniques- a case study from T.Cholankuruchi of Udayarpalayam taluk, Ariyalur distrct, Tamilnadu - Proceedings of the National seminar spatial modelling and soft computing in water resources management SSWRM 2008, March 14 – 15, 2008, Department of Civil Engineering Faculty of Engineering and Technology Annamalai University, Annamalainagar – 608002, India.
[8]. Ramanuja Chary K.R, Gangadhara Rao T- A Monograph on ground water exploration by resistivity, SP and well logging techniques- 2005, *IGIS P Ltd*, Hyderabad, India.