INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Deep Fracture Mapping and Groundwater Potential Assessment Using Magneto Telluric (MT) Resistivity Imaging in Kilambakkam Region

***Mohamed Afzal J**

Department of Geology, University of Madras, Guindy Campus, Chennai, India 600025

***Corresponding Author**

DOI : https://doi.org/10.51583/IJLTEMAS.2025.140300070

Received: 19 April 2025; Accepted: 22 April 2025; Published: 24 April 2025

Abstract: Groundwater exploration in hard rock terrains requires advanced geophysical techniques to identify high-yielding aquifers. This study utilizes Magneto telluric (MT) resistivity imaging to delineate subsurface fracture zones and assess groundwater potential in the Kilambakkam region. The resistivity profiles reveal a complex hydrogeological setting characterized by shallow weathered zones (50m-100m depth) with low water yield, deeper fractured aquifers (120m-250m depth) with moderate yield, and deep-seated fault zones (180m-300m depth) exhibiting high groundwater potential. Two primary borewell target zones have been identified based on low resistivity anomalies (1-6 Ωm), indicating significant water-bearing formations. The study emphasizes the importance of integrating geophysical surveys with hydrogeological data to optimize borewell placement and enhance sustainable groundwater extraction. Further validation through vertical electrical sounding (VES) and pumping tests is recommended to ensure long-term aquifer viability.

Keywords: Magneto telluric (MT) Resistivity Imaging, Groundwater Exploration, Fracture Zones, Hard Rock Aquifers, Low Resistivity Anomalies, Hydro geophysics, Fault Zones, Kilambakkam,

I. Introduction

Magnetotelluric (MT) resistivity imaging is a geophysical technique widely used for subsurface characterization, particularly in groundwater exploration, mineral prospecting, and geothermal studies (Vozoff, 1972). The method relies on natural electromagnetic (EM) field variations to map resistivity contrasts at different depths, offering insights into geological formations and hydrogeological structures (Chave & Jones, 2012). Groundwater occurrence in crystalline hard rock terrains, such as Kilambakkam, is largely influenced by the presence of fractures, faults, and weathered zones (Singhal & Gupta, 2010). These structures typically exhibit lower resistivity due to water saturation, making MT an effective tool for delineating potential aquifers. High-resistivity zones correspond to massive rock formations, while low-resistivity anomalies indicate water-bearing fractures and weathered layers (Kumar et al., 2015). In this study, we analyze MT profiles collected from Kilambakkam to identify potential groundwater reservoirs. The interpretation of resistivity variations helps in locating suitable drilling sites, ensuring sustainable water resource management in the region.

Study Area

The study area, Kilambakkam, is located in the southern region of India and is part of the hard rock terrain dominated by crystalline formations. (Fig 1)The geology of the area is primarily composed of charnockite, granite gneisses, and weathered/fractured zones, which significantly influence groundwater occurrence and movement (Sathish et al., 2020). Due to rapid urbanization and increasing water demand, identifying sustainable groundwater resources in this region is crucial. Kilambakkam is characterized by a semi-arid climate with moderate to low annual rainfall, making groundwater the primary water source for both domestic and agricultural needs (CGWB, 2019). The hydrogeology of the region is complex due to the presence of varying resistivity structures, which include low-resistivity zones associated with weathered/fractured formations and high-resistivity zones representing hard rock formations (Ramesh et al., 2017). To effectively identify groundwater potential zones, the magnetotelluric (MT) method was applied across multiple profiles in the region. The analysis of resistivity variations provides a detailed subsurface characterization that aids in mapping aquifer zones and optimizing well locations for sustainable groundwater extraction (Krishnamurthy et al., 2019).

II. Methodology

The ADMT-300S low-frequency magnetotelluric equipment is used to locate quartzite and gneisses, shale, and granite rocks beneath the surface of deeper structural formations, which are plotted on a 2D image (Ravindran, A. A., Kingston, J. V., & Premshiya, K. H. 2020). The natural electromagnetic field's strength correlates to the subterranean creation of the earth's rock and changes in resistivity recorded in the field.

III. Results and Discussion

Detailed Analysis of Magnetotelluric (MT) Resistivity Profiles

Color Representation and Resistivity Distribution in Low Resistivity Zones (40-90 Ωm, Blue to Purple) Primarily on the right side and in deeper parts of the section (~200m and below). Geological Implication Likely corresponds to water-saturated zones, clay-

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

rich formations, or fault zones. Possible aquifer presence if linked to porous sedimentary layers. May indicate fluid movement influenced by fractures or faults.

Moderate Resistivity Zones (100-140 Ωm, Green to Yellow) Found throughout the section, transitioning between high and low resistivity zones.Geological Implication: Represents weathered rock layers, fractured bedrock, or semi-saturated formations. Partial saturation suggests groundwater presence but not dominance. Crucial for understanding water recharge areas and hydrogeological connectivity.

High Resistivity Zones (150-175 Ωm, Red to Orange) Found on the left side and in upper sections. Geological Implication Represents compact bedrock, igneous intrusions, or dry formations. Could be granite, basalt, or metamorphic formations with minimal porosity. Acts as water barriers or structural boundaries.

Structural and Fault Identification

Sharp Resistivity Transitions Areas of abrupt resistivity change suggest faults or lithological boundaries Steep gradients between red (high resistivity) and blue (low resistivity) may indicate fault systems. Faults may act as conduits or barriers to fluid movement. Localized Anomalies (Blue Pockets in High-Resistivity Areas) Small blue patches within high-resistivity zones suggest trapped water pockets or localized fractures. Potential groundwater reservoirs or mineralized zones.

Depth-wise Analysis

In 0–100m Depth Mixed resistivity values suggest weathered rock, topsoil, and partially saturated layers. Potential for shallow aquifers connected to deeper conductive zones. In 100–200m Depth More structured resistivity variations indicate fractured formations or lithological transitions. Important for understanding groundwater movement and rock properties. In 200m+ Depth Dominated by blue and purple areas, indicating high conductivity. Suggests deep-seated water-bearing formations or potential mineralized zones. Possible target depth for groundwater exploration.

Comparative Analysis of MT Profiles (Profile 1&2)

High-Resistivity Zones (150-270 Ωm)

First MT Profile Dominated by high resistivity, indicating compact basement rock (igneous/metamorphic formations). Less permeable, acting as barriers to fluid flow. Second MT Profile More fragmented, suggesting lithological variations or partially weathered formations. More favorable for groundwater storage (Table1)(Fig 2).

Low-Resistivity Zones (<100 Ωm)

First MT Profile shows Small, scattered low-resistivity areas indicating localized water-bearing formations. Limited connectivity. Second MT Profile shows Large conductive zones on the right side, extending deeper. Suggests continuous groundwater-bearing formations associated with faults or fractures. (Table1)(Fig 2).

Structural Features (Faults & Fractures)

First MT Profile Shows Some resistivity changes indicate possible faults but not sharply defined. Transitions suggest gradual lithological changes rather than major faulting. Second MT Profile Displays steeper resistivity gradients, indicating clear fault zones. Presence of conductive anomalies near fault lines suggests fluid movement. (Table1)(Fig 2).

IV. Groundwater Potential & Drilling Recommendations

Groundwater Potential Comparison

First MT Profile Shows Moderate potential with small water-bearing zones. Limited connectivity means restricted recharge potential. Second MT Profile Larger, connected conductive zones indicate better groundwater storage and recharge potential. Right side of the profile is a strong drilling target.

Drilling Recommendations

For Groundwater Exploration Second MT Profile Target blue conductive zones on the right (~150-250m depth). First MT Profile Focus on localized blue zones (~100-200m depth), but expect limited yield. (Table1)(Fig 2).

For Stable Bedrock (Construction/Mining): First MT Profile represents Left side dominated by high-resistivity formations (compact basement rock). Second MT Profile: More fractured, requiring additional geotechnical evaluation. (Table1)(Fig 2).

For Mineralization Exploration: Low-resistivity zones could indicate sulfide mineralization. Second MT Profile's deep blue areas are promising for further geophysical testing. The Second MT Profile is more favorable for groundwater exploration, with larger and better-connected conductive zones. The First MT Profile shows more compact, resistive formations, making it suitable for geological stability but less ideal for water storage. Structural features (faults/fractures) are more pronounced in the Second Profile, suggesting better pathways for fluid movement.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Resistivity Variations and Subsurface Lithology

The results of the Magnetotelluric (MT) survey across Kilambakkam reveal significant resistivity variations corresponding to different lithological units. High resistivity zones (above 150 Ωm) are observed at shallow depths, indicating the presence of massive crystalline rocks such as charnockite and granite gneiss (Sathish et al., 2020). In contrast, low resistivity zones (below 60 Ωm) correspond to weathered/fractured rock formations and potential groundwater-bearing zones (Krishnamurthy et al., 2019).

The presence of alternating resistivity layers suggests a heterogeneous subsurface with varying degrees of weathering and fracturing. The deeper conductive anomalies (below 50 Ωm) are indicative of saturated fracture zones, which are significant for groundwater potential evaluation (Ramesh et al., 2017).

Identification of Potential Groundwater Zones

Based on the MT profiles, potential groundwater zones are identified in areas where resistivity values range between 30–100 Ωm, signifying weathered and fractured formations. These zones are primarily located between 100–250 meters depth, where deep-seated fractures may act as confined aquifers (CGWB, 2019). The resistivity contrast in these zones suggests that they are hydraulically connected to deeper aquifers, supporting sustainable groundwater extraction(fig 2,3,4 &5).

The variation in resistivity values indicates a transition from shallow weathered zones to deeper fractured aquifers, which is consistent with previous studies on hard rock hydrogeology in Tamil Nadu (Sathish et al., 2020). The integration of geophysical data with hydrogeological knowledge provides a reliable approach for delineating water-bearing formations (Krishnamurthy et al., 2019).

Implications for Groundwater Management

The study highlights the importance of using geophysical methods like MT to map groundwater resources in hard rock terrains. The findings emphasize the need for sustainable groundwater extraction, as overexploitation of these fractured aquifers can lead to reduced recharge potential and groundwater depletion (Ramesh et al., 2017).

To optimize groundwater utilization, it is recommended that future borewell sites be selected based on the identified low-resistivity zones. Additionally, long-term monitoring of groundwater levels and recharge rates should be conducted to ensure sustainable water management in Kilambakkam (CGWB, 2019).

Analysis of the MT Profile and Water Zones (Profile 5)

Identified Low-Resistivity Zones (Potential Water-Bearing Areas)

The resistivity profile highlights significant low-resistivity anomalies (1-6 Ωm), which indicate:Shallow aquifer possibilities (weathered zone). Deep fracture-controlled aquifers in the hard rock system. (Table 2)(Fig4)

Recommended Borewell Drilling Targets

Central Fractured Zone (~120m - 250m depth, 60m-100m horizontal distance) High groundwater storage probability. Fractures act as conduits for groundwater flow. Recharge is likely from rainfall infiltration. Recommended drilling depth: 250m-300m.Deep-Seated Fault Zones (~180m - 300m depth, 0-40m & 120-150m) Highly fractured, deep groundwater pockets. Suitable for long-term groundwater extraction. Recommended drilling depth: 280m-320m.The central fracture zone (~120m-250m depth) and deep tectonic zones (~180m-300m depth) exhibit high water potential. Drilling in these areas is recommended for sustained groundwater availability. (Table 2& fig 4) The local geology supports groundwater storage in fractured rock systems, making these zones viable for future groundwater exploration.

Borewell Placement & Geological Mapping Strategy

Borewell Site Selection

Based on the resistivity results, two primary drilling targets are identified for maximum groundwater yield:

Borewell Drilling Recommendations

Depth of Drilling Minimum Depth: 250m (to tap into deep aquifers). Maximum Depth: 300m - 320m (if additional fractures are encountered). Expected Water Yield Shallow weathered zones (~50m-100m depth): Low yield (~0.5 - 2 LPS) Fractured rock aquifer (~120m-250m depth): Moderate to high yield (~3 - 5 LPS). Deep fault zone (~180m-300m depth): High yield (~5 - 7+ LPS). (Table 3& Fig 3) This study provides a scientific approach to groundwater exploration, ensuring sustainable water resource management for the Kilambakkam region. Further geophysical and hydrogeological studies may enhance the accuracy of groundwater predictions.

V. Conclusion

The comparative analysis of the two Magnetotelluric (MT) profiles has provided significant insights into subsurface resistivity variations, structural geology, and groundwater potential. The key findings are summarized as follow Resistivity Variation & Geological Interpretation the MT Profile shows a higher dominance of resistive formations (77–269 Ωm), indicating compact

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

bedrock with limited fluid presence. The MT Profile has a broader range (40–175 Ωm) with more prominent low-resistivity zones, suggesting potential groundwater-bearing formations. The Second MT Profile is more favorable for groundwater exploration due to its well-connected, larger conductive zones, particularly on the right side of the profile at depths of 150–250m.The First MT Profile has fewer conductive zones, suggesting localized water-bearing formations with limited connectivity and recharge potential. The Second MT Profile shows steeper resistivity transitions, indicating well-defined fault structures that may enhance groundwater movement. The First MT Profile displays more gradual resistivity transitions, suggesting lithological variations rather than distinct fault zones. Implications for Drilling & Exploration If targeting groundwater, the Second MT Profile offers more promising drilling locations within its deep conductive zones (~150-250m). If seeking stable bedrock for construction or mining, the First MT Profile's high-resistivity formations are more suitable. Potential mineralization zones could be present in the low-resistivity regions of the Second MT Profile, requiring further geophysical assessment.

Final Recommendations:

Further field validation through borehole drilling, hydrogeological testing, and geotechnical studies is advised to confirm groundwater yield and rock integrity. Additional geophysical surveys (e.g., seismic or borehole logging) could enhance structural interpretation and resource evaluation. Overall, the study confirms the hydrogeological significance of conductive zones in the Second MT Profile and highlights structural complexities influencing subsurface fluid movement. The insights gained will help guide groundwater development, construction planning, and resource exploration efforts.

References

1. Chave, A. D., & Jones, A. G. (2012). The Magnetotelluric Method: Theory and Practice. Cambridge University Press.
2. Kumar, D., Singh, V. S., & Mohan, S. (2015). Identification of groundwater potential zones using resistivity imaging and GIS techniques. Journal of Hydrology, 529, 1242-1253.
3. Singhal, B. B. S., & Gupta, R. P. (2010). Applied Hydrogeology of Fractured Rocks. Springer Science & Business Media.
4. Vozoff, K. (1972). The magnetotelluric method in the exploration of sedimentary basins. Geophysics, 37(1), 98-141.
5. CGWB (2019). Groundwater Resources and Development Prospects in Tamil Nadu. Central Ground Water Board, India.
6. Krishnamurthy, N. S., Kumar, D., & Singh, V. S. (2019). Identification of groundwater potential zones in crystalline terrain using geophysical methods. Journal of Environmental Geology, 78(5), 245-256.
7. Ramesh, S., Rajendran, K., & Kumaravel, P. (2017). Hydrogeophysical investigation in hard rock terrain using resistivity techniques. Hydrogeology Journal, 25(3), 561-576.
8. Sathish, R., Prabhakar, K., & Balasubramanian, A. (2020). Geoelectrical characterization of groundwater in fractured rock aquifers of Tamil Nadu. Geophysical Journal International, 221(2), 1005-1018.
9. Ravindran, A. A., Kingston, J. V., & Premshiya, K. H. (2020). Mitigation Dredging in SeabedGeotechnical Engineering Study Using Marine 2D ERI and Textural Characteristics in ThengapattanamHarbour, South India. Geotechnical and Geological Engineering, 1-11. https://doi.org/10.1007/s10706-020-01530-z(01

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Fig :1 Study Area Map

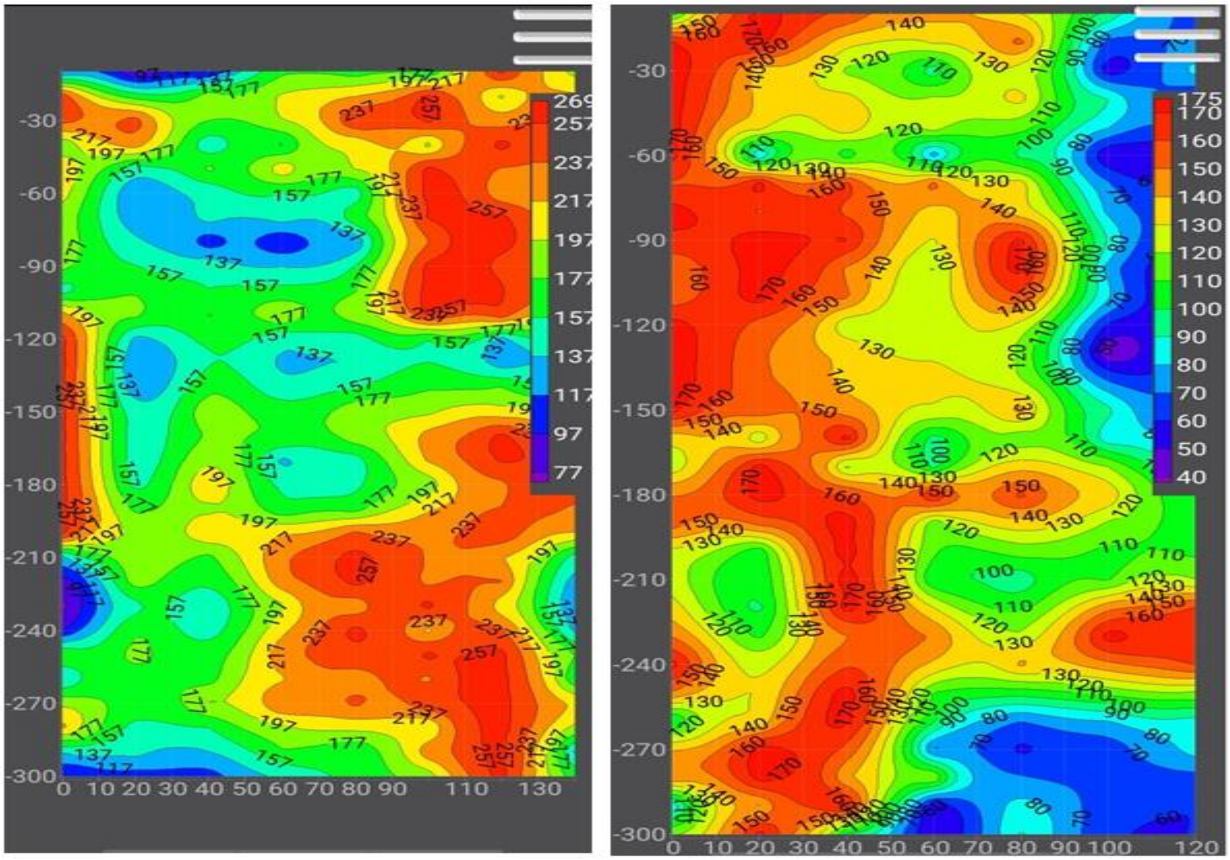

Fig:2 Magneto telluric profile 1&2 in the study Area

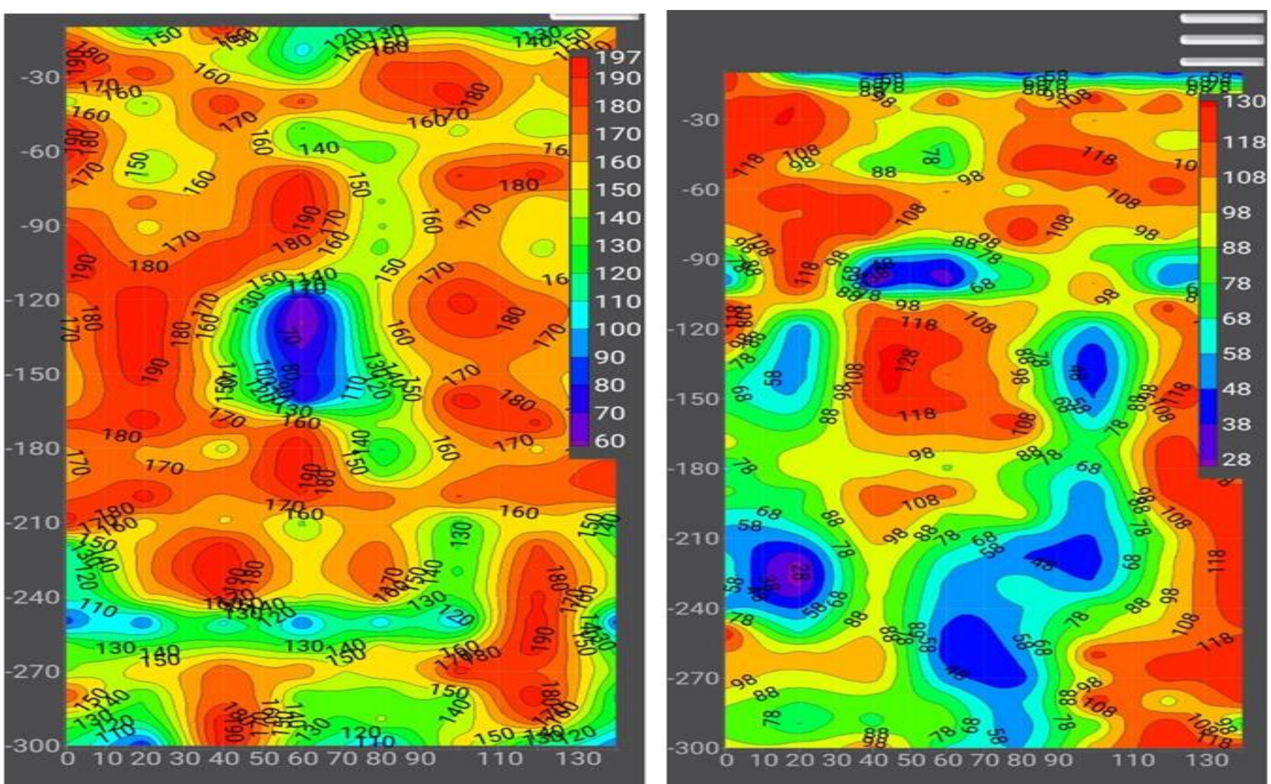

Fig :3 Magnetotelluric Profile 3&4 in the study area.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

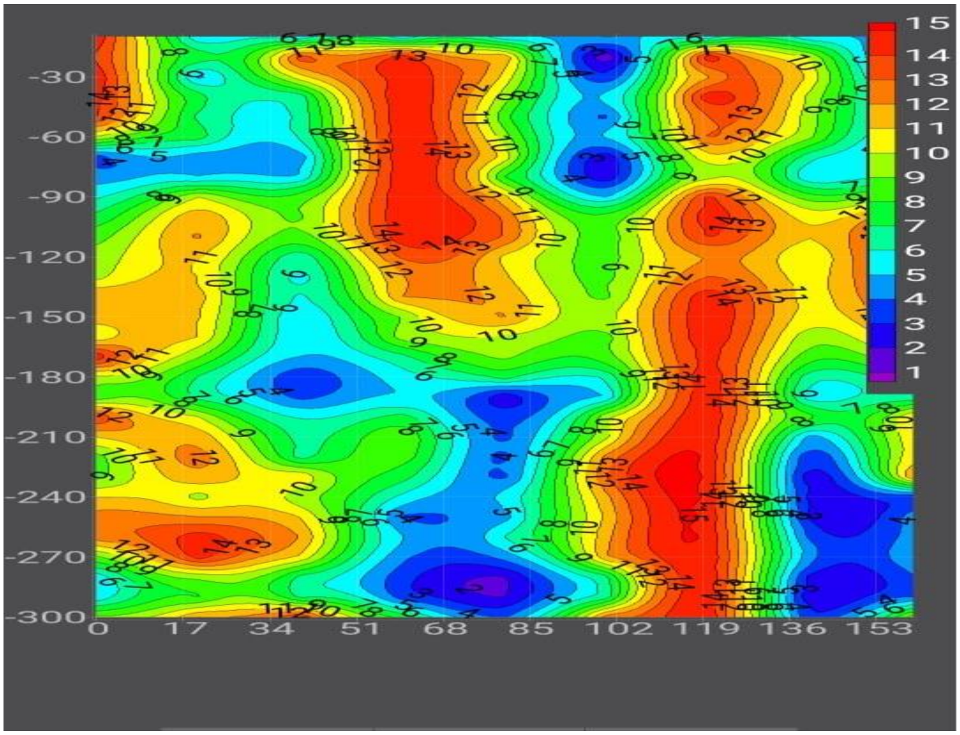

Fig :4Magnetotelluric Profile 5 in the study area.

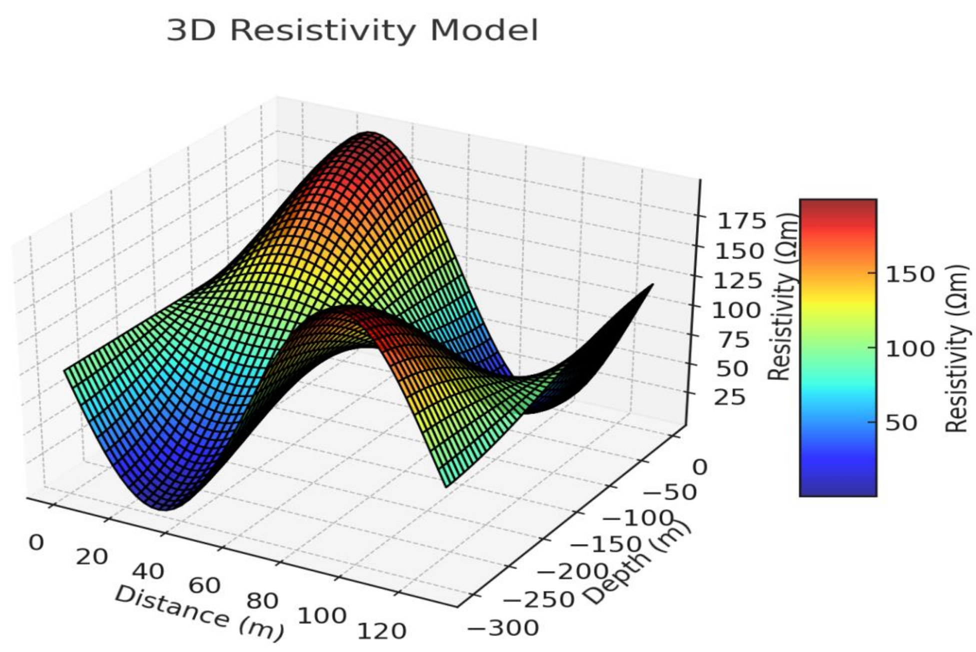

Fig:5 3D Resistivity Model profile

Table :1 Comparison analysis of MT Profile 1&2

Feature	**First MT Profile**	**Second MT Profile**
Resistivity Range	**77–269 Ωm**	**40–175 Ωm**
High-Resistivity Zones (Red/Orange)	**More widespread**	**Present but fragmented**
Low-Resistivity Zones (Blue/Purple)	**Scattered, smaller pockets**	**Larger conductive zones, especially on the right side**

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Fault/Structural Zones	**Some steep transitions**	**More defined transitions suggesting clearer fault presence**
Depth Range	**0–300m**	**0–300m**

Table :2 Identified Low-Resistivity Zones (Potential Water-Bearing Areas)

Depth Range	**Horizontal Distance**	**Resistivity (Ωm)**	**Interpretation**	**Water Potential**
~60m - 120m	50m - 90m	5-10 Ωm	Possible shallow perched aquifer (weathered zone).	Moderate
~120m - 250m	60m - 100m	2-6 Ωm	Fractured rock aquifer with groundwater.	High
~180m - 300m	Left (0-40m) & Right (120-150m)	1-5 Ωm	Deep tectonic fault-controlled aquifer.	High

Table :3 Borewell Site Selection of Profile 5

Location	**Depth Range (m)**	**Resistivity (Ωm)**	**Water Potential**	**Geological Interpretation**
Zone A (Central Fractured Zone)	120m - 250m	2-6 Ωm	High	Fractured rock aquifer – major water-bearing zone.
Zone B (Deep Seated Fault Zone)	180m - 300m	1-5 Ωm	Very High	Deep fault-controlled aquifer with high recharge capacity.