Assessing the Reliability of Vertical Electrical Sounding as an Alternative to Standard Penetration Testing in Inaccessible Terrains

***[1]Abdul A. Koroma., [2]Victor S. Kamara**

[1]Department of Civil Engineering, Faculty of Engineering, Fourah Bay College, Mount Aureol, University of Sierra Leone, Freetown, Sierra Leone

[2]Department of Civil, Mining and Process Engineering, School of Engineering, Namibia University of Science and Technology, Windhoek, Namibia

***Corresponding Author**

DOI: https://doi.org/10.47772/IJRISS.2026.10200217

Received: 12 February 2026; Accepted: 17 February 2026; Published: 02 March 2026

ABSTRACT

Site investigations are crucial for the safe design of foundations. This study evaluates the use of Vertical Electrical Sounding (VES) to determine subsoil stratigraphy in inaccessible areas along a proposed transmission line grid, comparing the results with traditional Standard Penetration Testing (SPT) data. SPT and VES tests were conducted concurrently at three tower locations (TT – Bu – L9, TATA sites) to a non-refusal depth of 15m. Results from both methods correlated well, suggesting that VES is a reliable and efficient tool for geotechnical investigations in challenging terrains, which can improve the safety and cost-effectiveness of infrastructure development.

Keywords: SPT, resistivity, stratigraphy, transmission, VES

INTRODUCTION

Accurate determination of soil layering is paramount for structural safety, yet traditional methods like the Standard Penetration Test (SPT) are often impractical for the remote, challenging locations typical of transmission line routes. This study explores the potential of the non-disruptive geophysical technique, **Vertical Electrical Sounding (VES)**, as a reliable alternative for these hard-to-reach areas. The research analyzes the methodologies, strengths, and limitations of both VES and SPT to characterize soil composition in diverse geological settings, aiming to provide valuable insights for optimizing data collection and enhancing construction project efficiency in inaccessible regions.

Methodology and Field Setup

The study followed a comparative procedure involving:

Data Collection: Performing both VES surveys and SPTs simultaneously at three accessible tower locations.

Analysis and Interpretation: Analyzing SPT data to establish detailed soil profiles, then using specialized software to process VES data into true resistivity profiles.

Comparison and Evaluation: Comparing the resulting soil stratigraphy from both methods to assess the accuracy and consistency of VES relative to SPT findings.

Test Methods

Standard Penetration Test (SPT) (ASTM D5771)

The SPT is an established in-situ testing method for determining soil stratigraphy. In this study, a standardized drilling rig drove a thick-walled sampler in 30 cm increments. The number of blows required for penetration (N-value) was recorded, with higher counts indicating denser soils. Retrieved samples and N-values were used to classify soil layers according to the USCS system (relative density, type, etc.), establishing a depth profile.

Vertical Electrical Sounding (VES) (ASTM D6431)

VES is a geophysical alternative suited for remote sites. It measures the electrical resistivity of the subsurface, as different soil layers possess varying resistivity values. An electric current is injected into the ground, and the resulting voltage difference is measured across varying electrode separations. The Wenner array configuration was used due to space constraints and the need for deeper investigation. Data were processed using inversion modeling software to correlate measured apparent resistivity values with true resistivity profiles and identify different soil layers.

Field Execution

Standard Penetration Tests and Vertical Electrical Sounding were performed concurrently at all three locations (TT – Bu – L9, KPTL, and TATA sites) down to a 15m depth, where no rock was encountered. Quality control measures, including spread resistance tests, ensured proper electrode contact and data consistency.

RESULTS

Table 1 - Summary of Laboratory Results for Soil Samples (BH61, BH2, and BH1)

Borehole ID	Depth (m)	Natural Moisture Content (%)	LL (%)	PL (%)	PI (%)	USCS	%Gravel	%Sand	%Clay
BH61	1	18.9	40.0	20.0	20.0	GP-GC	70.0	10.0	20.0
BH61	5	24.6	44.1	20.1	24.0	SC	12.7	64.7	22.6
BH61	9	24.9	40.1	20.0	20.1	SC-SM	9.9	70.1	20.0
BH61	15	32.5	45.0	20.3	24.7	GP-GC	65.1	12.0	22.9
BH2	1	17.5	28.1	20.2	7.9	GP-GC	77.8	9.8	12.4
BH2	4	24.5	31.8	14.6	17.2	SP-SC	10.6	74.1	15.3
BH2	7	25.6	39.8	17.2	22.6	SC-SM	5.5	56.0	38.5
BH2	13	22.1	38.2	20.1	18.1	GP-GC	66.3	11.6	22.1
BH1	1	14.5	25.4	19.2	6.2	GP-GC	70.8	12.3	16.9
BH1	4	25.2	31.3	14.6	16.7	SP-SC	10.4	74.8	14.8
BH1	7	27.7	39.8	19.2	20.6	SC-SM	7.1	58.0	34.9
BH1	15	29.2	39.8	18.9	20.9	GP-GC	73.4	4.5	22.1

Note: LL = Liquid Limit; PL = Plastic Limit; PI = Plasticity Index; USCS = Unified Soil Classification System

Table 2 - Summary of VES Test Results (BH61, BH2, and BH1)

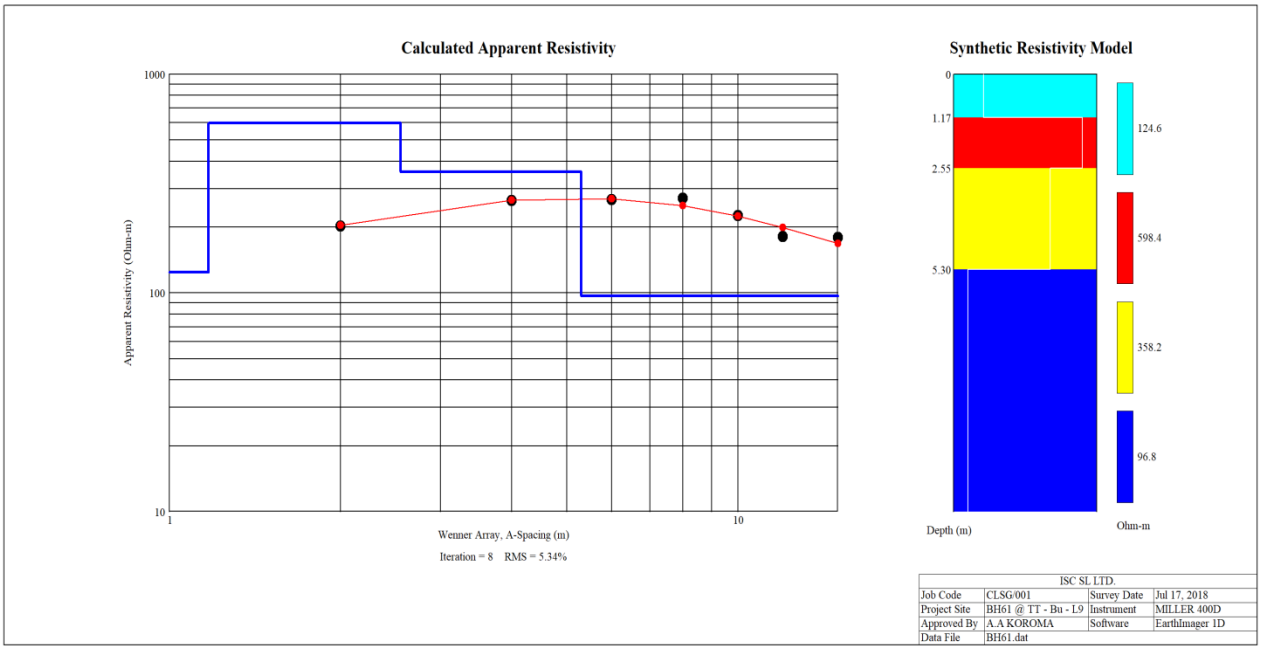
Standard Penetration Test (SPT)

Borehole log - BH61 at TT – Bu – L9

BH NO.	DEPTH (m)	LEGEND	SOIL DESCRIPTION	USCS	MOISTURE CONTENT (%)	FIELD N - VALUE
BH 61	0.0-0.2		Dark organic material	-	-	-
	0.2-1.0		Reddish brown poorly graded gravel with clay and sand.	GP-GC	18.9	16
	1.0-2.0		Reddish brown poorly graded sand with clay and gravel	SP-SC	20.2	23
	2.0-3.0		Reddish brown poorly graded sand with clay and gravel	SP-SC	21	20
	3.0-4.0		Reddish brown poorly graded sand with clay and gravel	SP-SC	23	23
	4.0-5.0		Reddish brown clayey sand with gavel.	SC	24.6	27
	5.0-7.0		Reddish brown Silty clayey sand with gravel	SC-SM	25	30
	7.0-9.0		Reddish brown Silty clayey sand with gravel	SC-SM	24.9	28
	9.0-11.0	▽	Reddish brown poorly graded gravel with clay and sand.	GP-GC	30.5	28
	11.0-13.0		Reddish brown poorly graded gravel with clay and sand.	GP-GC	31.7	36
	13.0-15.0		Reddish brown poorly graded gravel with clay and sand.	GP-GC	32.5	18

Note: VES = Vertical Electrical Sounding; ABC = Allowable Bearing Capacity; IUW = In-situ Unit Weight; PIF = Angle of Internal Friction; AOR = Angle of Repose.

VES Mode



Interpretation of VES test results

During SPT sampling, different soil material was encountered throughout the investigated depth of 15m. No SPT refusal was encountered. These layers of soil were seen to contain different percentages of gravel, sand and fines as presented above.

In order to validate the presence of soil layers with no refusal (bedrock, boulder or the like), VES testing was carried out from the ground surface down to 15m. Resistivity model was developed. This model is stratified with different resistivity values, indicating different soil types. These values were correlated with typical soil resistivity values attached herein. These resistivity values fall on different range of sand, clay and gravel with no bedrock, indicating the presence of variable quantity of fines. From the outcome of both tests, the materials encountered do correlate well and as such present a consistent lithology at the location investigated.

VES LOG

Depth (m)		**Legend**	**Material Type**
From	***To***		
0.0	15.0		Soil

Comparison between VES and SPT logs

For ease of comparison of the lithology of this location, logs of VES and SPT are combined and presented below.

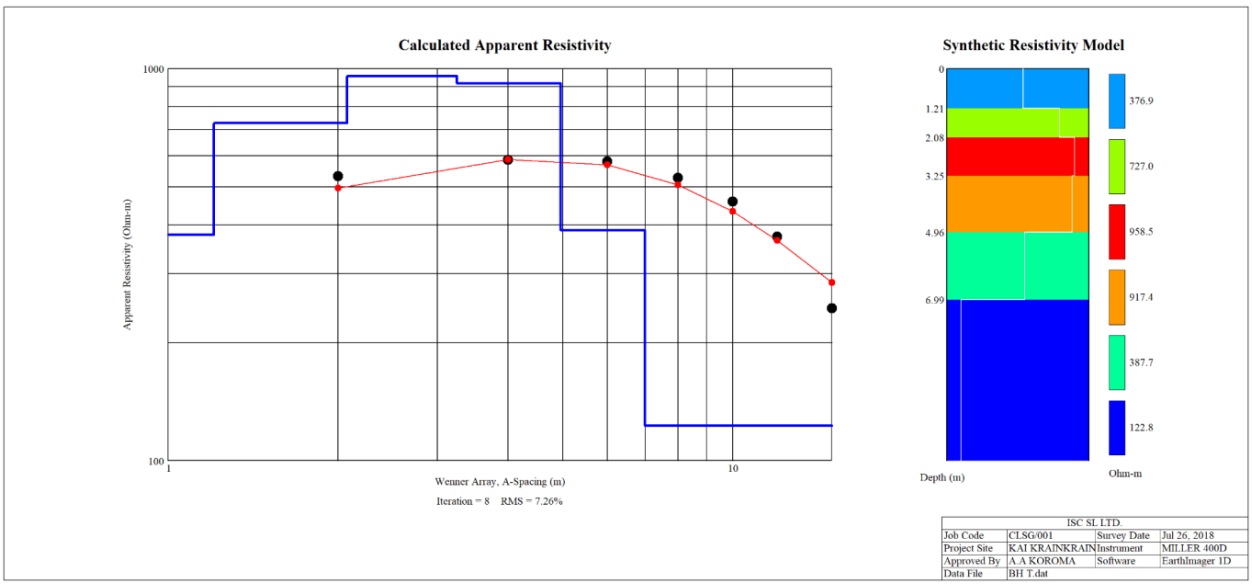
Depth (m)		**SPT Log**	**VES Log**	**Material Type**
From	***To***			
0.0	15.0			Soil

BH2 at KAI KRAINKRAIN

SPT Borehole log

BH NO.	DEPTH(m)	LEGEND	SOIL DESCRIPTION	USCS	MOISTURE CONTENT (%)	FIELD N - VALUE
BH 2	0.0-0.2		Dark organic material	-	--	-
	0.2-1.0		Brown poorly graded gravel with clay and sand.	GP-GC	17.5	17
	1.0-2.0		Brown poorly graded sand with clay and gravel	SP-SC	19.8	15
	2.0-3.0		Brown poorly graded sand with clay and gravel	SP-SC	22.1	27
	3.0-4.0		Brown poorly graded sand with clay and gravel	SP-SC	24.5	25
	4.0-5.0		Brown silty clayey sand with gravel	SC-SM	26.4	39
	5.0-7.0		Brown silty clayey sand with gravel	SC-SM	25.6	46
	7.0-9.0		Brown poorly graded gravel with clay and sand.	GP-GC	24.5	43
	9.0-11.0		Brown poorly graded gravel with clay and sand.	GP-GC	22.5	39
	11.0-13.0		Brown poorly graded gravel with clay and sand.	GP-GC	22.1	19
	13.0-15.0	▽	Brown poorly graded gravel with clay and sand.	GP-GC	24.3	21

VES Model



Interpretation of VES test results

During SPT sampling, different soil material was encountered throughout the investigated depth of 15m. No SPT refusal was encountered. These layers of soil encountered were seen to contain different percentages of gravel, sand and fines as presented above.

In order to validate the presence of soil layers with no refusal (bedrock, boulder or the like), VES testing was carried out from the ground surface down to 15m. Resistivity model was developed. This model is stratified with different resistivity values, indicating different soil types. These values were correlated with typical soil resistivity values attached herein. These resistivity values fall on different range of sand, clay and gravel with no bedrock, indicating the presence of variable quantity of fines. From the outcome of both tests, the materials encountered do correlate well and as such present a consistent lithology at the location investigated.

VES LOG

Depth (m)		**Legend**	**Material Type**
From	***To***		
0.0	15.0		Soil

Comparison between VES and SPT logs

For ease of comparison of the lithology of this location, logs of VES and SPT are combined and presented below.

Depth (m)		**SPT Log**	**VES Log**	**Material Type**
From	***To***			
0.0	15.0			Soil

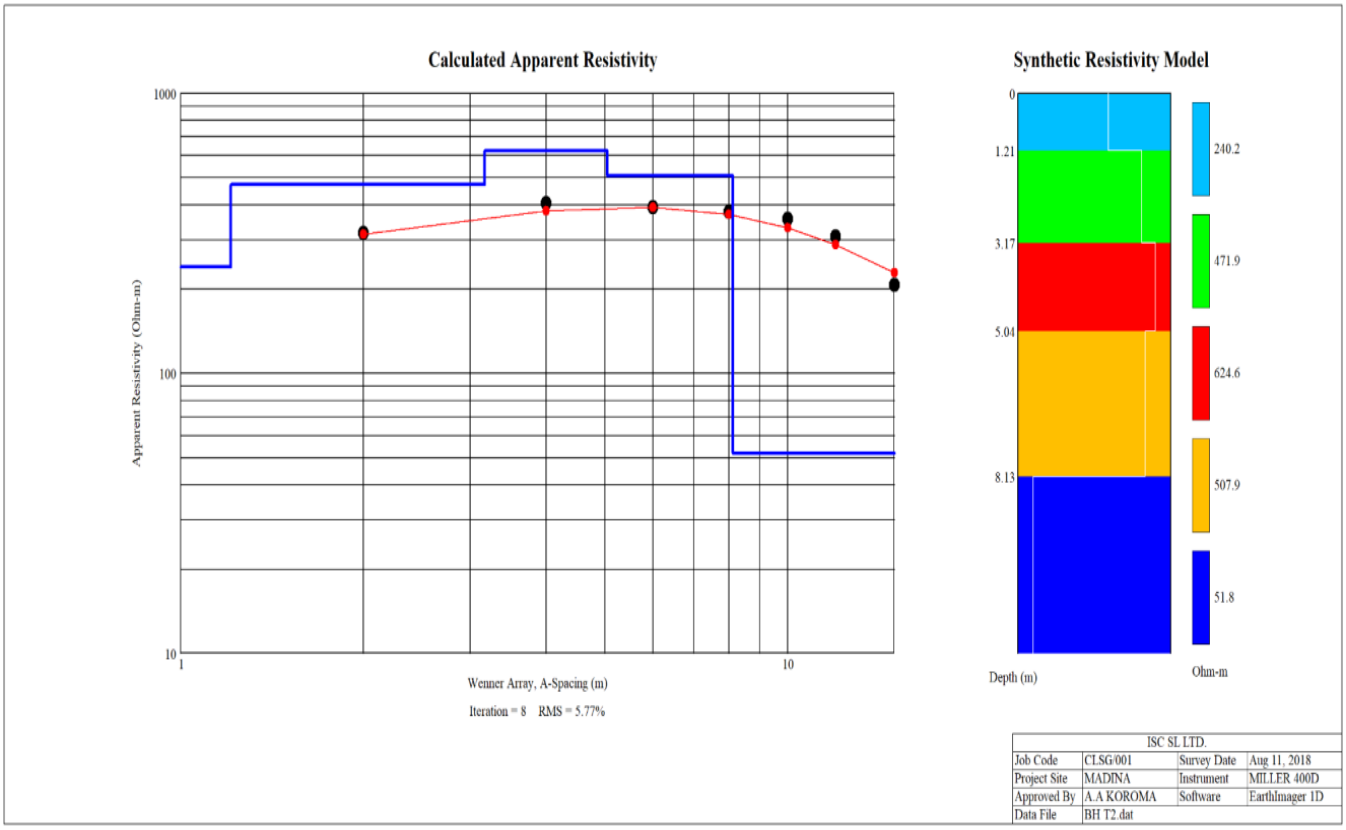
BH1 at KAMASAPAY

SPT Borehole Log

BH NO.	**DEPTH(m)**	**LEGEND**	**SOIL DESCRIPTION**	**USCS**	**MOISTURE CONTENT (%)**	**FIELD N - VALUE**
BH 1	0.0-0.2		Dark organic material	-	--	-
	0.2-1.0		Brown poorly graded gravel with clay and sand.	GP-GC	14.5	13
	1.0-2.0		Brown poorly graded sand with clay and gravel	SP-SC	20.1	18
	2.0-3.0		Brown poorly graded sand with clay and gravel	SP-SC	21.5	19
	3.0-4.0		Brown poorly graded sand with clay and gravel	SP-SC	25.2	23
	4.0-5.0		Brown silty clayey sand with gravel	SC-SM	27.1	26

	5.0-7.0		Brown silty clayey sand with gravel	SC-SM	27.7	31
	7.0-9.0		Brown poorly graded gravel with clay and sand.	GP-GC	22.5	32
	9.0-11.0		Brown poorly graded gravel with clay and sand.	GP-GC	24.5	36
	11.0-13.0		Brown poorly graded gravel with clay and sand.	GP-GC	26.1	23
	13.0-15.0	▽	Brown poorly graded gravel with clay and sand.	GP-GC	29.2	24

VES Model



Interpretation and Discussion of Results

Throughout the 15m investigated depth, SPT sampling encountered varying soil materials with no refusal (i.e., no bedrock or boulders were found). These samples contained different percentages of gravel, sand, and fines. Concurrent VES testing validated the absence of refusal layers by producing a stratified resistivity model, where different resistivity values correlated well with typical ranges for sand, clay, and gravel. The lithology findings from both methods demonstrated a high level of consistency across all investigated locations.

Based on the combined results, the SPT provided specific data on soil composition, moisture content, and penetration resistance (N-values), while VES offered insights into subsurface conditions via electrical resistivity. Although both methods characterize subsurface conditions, VES provides valuable complementary information on resistivity variations within the soil profile. The strong correlation between the SPT borehole logs and the VES resistivity models confirms that both methods yield consistent results regarding soil types, layer continuity, and material presence

VES LOG

Depth (m)		Legend	Material Type
From	***To***		
0.0	15.0		Soil

Comparison between VES and SPT logs

For ease of comparison of the lithology of this location, logs of VES and SPT are combined and presented below.

Depth (m)		SPT Log	VES Log	Material Type
From	***To***			
0.0	15.0			Soil

CONCLUSION

The study leads to the following conclusions:

- Both SPT and VES methods accurately determined the presence of different soil materials and displayed consistent lithology and soil stratigraphy within the 15m depth investigated
- Results from both methods align well in identifying soil types and lithological characteristics, providing a reliable representation of subsurface conditions for geotechnical assessments.
- Atterberg limit tests identified high plasticity soils at deeper levels (14–15m), which corresponded to lower resistivity values observed in the VES results

RECOMMENDATION

The following recommendations are made for future geotechnical investigations:

- Integrate further investigations, such as Cone Penetration Testing (CPT**)** or seismic surveys, to complement existing data and enhance understanding beyond the 15m depth
- Ensure rigorous quality control measures, including equipment calibration and standardized procedures, during all testing phases to maintain data accuracy.
- Conduct cross-validation studies using independent investigations to verify result consistency.
- Integrate all obtained data into a comprehensive subsurface model for improved foundation design and construction planning.

REFERENCES

1. Alile, O. M., Amadasun, C. V. O., and Evbuomwan, A. I. (2008). “Application of vertical electrical sounding method to decipher the existing subsurface stratification and groundwater occurrence status in a location in Edo North of Nigeria.” J. Appl. Sci. Environ. Manage., 12(3), 67–72.
2. Ampadu, S. I. K., Ayeh, F. F. J., and Boadu, F. (2018). “Deriving SPT N-values from DCP test results: The case of foundation design in a tropical environment.” Geotech. Geol. Eng., 36(4), 2517–2531. doi.org

3. Ahmeti, M., and Ahmeti, H. (2024). "Field tests of soil properties under water tanks." Open Civ. Eng. J., 18, e18741495261102. doi.org
4. Bosch, D. R., and Sotelo, R. R. (2015). "Determination of stratigraphy—Soil types—Using Cone Penetration Test in sedimentary deposits in north-east of Argentina." J. Geosci. Environ. Prot., 3(6), 134–139. doi.org
5. Omosanya, K. (2014). "A review of stratigraphic surfaces generated from multiple electrical sounding and profiling." Geofizika, 31(1), 49–63.
6. Osman, M. O., and Osman, A. K. (2016). "Evaluation of Cone Penetration Test (Cpt) classification methods for some local soils." www.researchgate.net (Accessed Jan. 26, 2026).
7. Sarker, D., and Abedin, M. Z. (2015). "Applicability of standard penetration test in Bangladesh and graphical representation of SPT-N value." https://www.researchgate.net/publication/280572148_Applicability_of_Standard_Penetration_Test_in_Bangladesh_and_Graphical_Representation_of_SPT-N_Value (Accessed Jan. 26, 2026).
8. Thabit, J. M., Al-Banna, A. S., and Al-Awsi, M. D. (2015). "Using vertical electrical sounding in building sites investigation; A case study in south of Baghdad, Iraq." Iraqi Bull. Geol. Mining, 11(2), 1–12.
9. van Overmeeren, R. A., and Ritsema, I. L. (1988). "Continuous vertical electrical sounding." First Break, 6(10), 313–324. https://doi.org/10.3997/1365-2397.1988017
10. Villalobos-Aragón, A., Espejel-García, V. V., Espejel-García, D., and Rivas-Lobera, L. (2019). "Shallow subsurface stratigraphy inferred from the use of vertical electrical soundings (VES) survey in central Chihuahua, Mexico." Open J. Geol., 9(1), 1–11. doi.org
11. Yusof, N. Q. A. M., and Zabidi, H. (2018). "Reliability of using standard penetration test (SPT) in predicting properties of soil." IOP Conf. Series: J. Phys.: Conf. Series, 1082, 012094. doi.org