SELF-POTENTIAL SURVEYING METHOD IN SEARCH OF BURIED UNDERGROUND PIPE

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ABSTRACT

Investigation into the possible location of underground pipe using the self-potential survey method has been carried out with the aim of maximise the chances of finding the underground structure.

Self-potential surveying technique was used with two approach; roving dipole approach, where one electrode is left in a base position, while the other electrode scouts each survey position, and the leapfrogging approach were potential differences are measured between consecutive sample stations along the line.

Results from the investigation shows that numerous small circular potential anomalies exist around the underground pipe but the only trends that could be correlated across all surveys were the linear E-W trend around 80-85mN and the elongate anomaly in the north of the grid. The linear anomaly may represent the location of the pipe and the northern anomaly may relate to bioelectric activity around tree roots.

Key words: Underground pipe, self-potential, roving, leapfrog

1.0 INTRODUCTION

Delineating and monitoring, leakage from aging or ruptured underground storage tanks is both a common and expensive problem. Over the years the self-potential surveying method is rarely used for detecting underground pipe despite its many superior advantages over other methods. In geophysics, the Electrical surveying methods utilizes two approaches, one using natural currents and the other using artificially generated current. For this study, we employed the self-potential method which measures the potential difference due to the natural currents flowing within the Earth’s surface. The SP method is very simple, cost-effective and less sophisticated compared to other geophysical methods. Well defined sources of the SP are mainly the fluid and heat fluxes, diffusion between regions of different chemical composition, and redox reactions between ore bodies and their surroundings (Fagerlund and Heinson 2003).


The basic principle of the electrical resistivity method is based on Ohm’s law, which states that current (I) passing through any two points in a circuit is directly proportional to the potential difference (dv) and inversely proportional to the resistance (R) between them. The resistance (R) of any medium or conductor depends on the length (l) and cross-section area (A) through which the current is passing. These two relations are expressed in the following equations 1 and 2

\[ I = \frac{dv}{R} \]  
\[ R = \frac{\rho l}{A} \]

where \( \rho \) is the constant of proportionality, known as the resistivity of the medium through which the current is passing

2.0 STUDY AREA

The study area (Agbarho town) is located in Ughelli North Local Government Area of Delta State, Nigeria on longitudes 5° 50’ and 5° 59’E and latitudes 5° 30’ and 5°
35°N. The area covers approximately 700 sq Km and is found to enjoy the Tropical Equatorial climate with an average annual temperature of 30°C and 3130 mm of rainfall, while relative humidity is 80% -90% (Efe, 2007). Three stratigraphic units underlain this area starting with the unconsolidated coastal plain sands (Benin) formation at the top, followed by an intervening unit of sandstone and shale called Agbada formation and bottom unit shale known as the Akata formation, representing continental, paralic and marine depositional environments respectively (Short and Stauble, 1967). Sedimentary rock formations form both the surficial and subsurface geology of the area (Odemerho, 2017). The relief of the area is generally a sloping, gently undulating plain while the survey environment consisted of flat topography with well-draining sand and trees. Figure (2.1) is the layout of the experimental survey showing the location of the underground pipe (blue).

Figure 2.1: Layout for the experimental survey showing the location of the buried pipe underground in (blue) at Agbarho water board. The red dots are current spikes.

3.0 MATERIALS AND METHOD
This investigation was completed at the east side of Agbarho Water board over the approximate location of a buried water pipe draining from the water board into the surrounding environment. In order to cover the area with pipe, a grid was set up consisting of six parallel, 30m lines, oriented north-south that were five meters apart to cover an area approximately 30 by 30m. Stations were set up at two meter intervals along each line and the potential electrodes were summed up to make the measurements. Three different potential arrays were thereafter constructed to complete the measurements. Each of the potential arrays consisted of two porous pot potential electrodes joined in a circuit with a low impedance voltmeter to take the readings. The other array was connected through a long cable so that potentials could be measured relative to only one electrode. The survey parameters were optimised for resolving the water pipe that is predicted to represent a linear anomaly; of a few meters in width crossing one to two meters below the survey area oriented approximately east-west.

Three different sets of self-potential measurements over the survey area were taken. The first set of measurement involving roving potentials measures between a far negative electrode twenty meters from the survey area and each station location was measured with a positive electrode. The roving survey is a technique where potential is measured relative to a fixed point so the potential electrode measures absolute potential and only one pot is moved reducing zero errors (Telford, 1976). The potential at each station was measured from north to south, first and last station measurements were repeated after the line was complete to get approximate estimates of drift and random variance. The other two set of experiments measured the potentials between stations two meters apart along the lines from north to south using leapfrog method which measures potential gradient between stations and minimises the zero errors by moving only one pot at a time (Telford, 1976).

The first station on each line was repeated after the line was complete to measure the drift with time. All drift corrections were done separately for each line by applying the linear best fit method to each station on a given line. Variance repeats were taken immediately after the original reading and bias repeats were completed for each line by reversing the direction of the potential electrodes at the first station and repeating the measurement.

4.0 RESULTS
The results were put together by measuring voltage potential through a high impedance multimeter. Drift was corrected using linear best fit correction assuming stations were measured at equal time intervals. Polarity of the leapfrog data potential was reversed for all positive north measurements after the drift correction was done. Random errors (noise) plagued this survey and made the presentation of reliable results difficult. The major source of the random noise includes a) solution in the pots which may change, or the connections can become unstable throughout the day, b) Telluric currents and ionospheric changes which can affect potentials in the ground, c) cultural noise, AC power lines and Agbarho Water Corporation infrastructure are all around and d) contact resistances and soil moisture which can greatly affect the voltage readings. The variance of repeat measurements and
the bias between pots was found to be of equal or greater magnitude to the drift (Table 4.1).

<table>
<thead>
<tr>
<th>Data</th>
<th>Errors</th>
<th>Line 1</th>
<th>Line 2</th>
<th>Line 3</th>
<th>Line 4</th>
<th>Line 5</th>
<th>Line 6</th>
<th>Average mV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. 1</td>
<td>Drift</td>
<td>3.3</td>
<td>2</td>
<td>-0.4</td>
<td>-0.4</td>
<td>-0.5</td>
<td>-1.1</td>
<td>1.28</td>
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<tr>
<td>Exp. 1</td>
<td>Var.</td>
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<td>1.6</td>
<td>1.5</td>
<td>1.9</td>
<td>0.9</td>
<td>-0.1</td>
<td>1.15</td>
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<tr>
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<td>Drift</td>
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<td>-5</td>
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<td>-1.3</td>
<td></td>
<td>0.8</td>
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<tr>
<td>Exp. 3</td>
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<td>-3</td>
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<td>3.7</td>
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<td>0</td>
<td>0.6</td>
<td>-0.7</td>
<td>1.06</td>
</tr>
</tbody>
</table>

**Table 4.1 Variance of repeated measurements**

Average variance was 1.15mV (experiment 1); average drift was 1.28mV (experiment 1), 2.44mV (experiment 2), 2.44mV (experiment 2) and 1.08 mV (experiment 3). The variance measured from first experiment was approximately equal to average drift magnitude implying that linear time related drift is not significant and the majority of the variance is due to random short term variations or coupling issues. The average magnitude of bias from the polarisation of porous pots was 2.9mV (experiment 3) which is a much greater error than the drift (1.08mV). More significant than the magnitude is the random distribution of polarisation bias ranging from -3 millivolts to 4.5mV so there is no constant that can remove bias for all measurements. Drift magnitude was equivalent to random variations and bias was not consistent and had a larger magnitude than the drift or repeat variance. The data was corrected for drift, bias and polarity so that plots could be generated to compare survey methods. The maps (figure 2-4: below) display the final corrected potential data gridded using minimum curvature (0.5m grid cells) for each survey method. The map in figure 5 is the average of the three survey grids calculated using grid math in oasis.
Figure 2: Minimum curvature gridded image of the roving electrode (experiment 1) self-potential survey with survey lines overlayed (white) with evidence of possible anomalies around 80-88mN.

Figure 3: Minimum curvature gridded image of the dipole survey from experiment 2 over the areas with self-potential lines overlayed (white).
Figure 4: Minimum curvature gridded image of the dipole survey from the third experiment over the area with self-potential lines (overlayed)

Figure 5: Minimum curvature average of the three corrected self-potential surveys. The potential anomalies that are present across the three surveys are; the negative point anomaly centred at 120E, 80N (local grid), the positive linear anomaly that crosses approximately E-W between 80-90N and an elongate linear E-W trending feature in the north of the grid.
5.0 DISCUSSION OF RESULTS

The overall aim of this investigation was to interpret real SP anomalies in the ground and separate them from the unwanted signals in the data. The survey environment consisted of flat topography with well-draining sands, few trees and a buried pipe. From the investigation of the sample errors we identified significant short term variations in the voltage present in all the survey methods. These are significant in magnitude and may be sourced from telluric noise, equipment errors, measurement or coupling errors or changeable potentials within the ground. It is practically difficult to separate and remove these effects individually but by summing the grids and correlating between surveys (Figure 5), the effects are substantially reduced. The potential anomalies that are present across the three surveys are; the negative point anomaly centred at 120E, 80N (local grid), the positive linear anomaly that crosses approximately E-W between 80-90N and an elongate linear E-W trending feature in the north of the grid (Figures 2-5). There are also numerous other circular and minor linear anomalies that cannot be convincingly correlated between the various grids.

Interpretation of self-potential anomalies requires us to define the possible sources of self-potential in the survey area. Generally the self-potential sources in the ground are produced by; thermoelectric, electrokinetic and electrochemical processes that occur in nature. Thermoelectric potentials are sourced from thermal gradients in the semiconductors in the ground. The location of the survey is not likely to have much of a thermal gradient so we can assume thermoelectric effects are negligible. Self-potential anomalies in this area are likely to be produced by electrochemical and electrokinetic processes occurring within the ground (Corwin and Hoover 1979). Electrokinetic potentials occur via the movement of material in differing phase. In nature this is commonly from water based solution flowing through solid sediments. Electrochemical effects occur anywhere there is a concentration gradient of chemicals with electrical bias. In nature this commonly occurs through; ionic concentration gradients, the reduction - oxidation zone, the concentration of hydrogen ions in areas with acidic gradients, bioelectric processes that concentrate ionic salts or anywhere metallic materials are in solution (Telford 1976).

The survey area was expected to contain a water pipe and a large tree was present near the NW corner of the survey. The pipe may produce an electrokinetic and/or electrochemical potential anomaly. The electrokinetic effect may be produced by the flow of water through the pipe creating a weak electric field via varying ionic concentration in the solution or the streaming potential of the flow. The pipe may also create electrochemical self-potential through the redox oxidation of any metal in the pipe and the contact of the metal with any ionic solution in the pipe. The measured potential will be the combined effects of these potentials and other potentials from around the pipe. Due to these combined effects it is difficult to predict the exact shape or polarity of the anomaly other than a linear trend of potentials correlating to the pipes location. We do general see an E-W trend between 80-90mN (local) in all the surveys, however this is not definitive enough to be confident it actually represents the pipe.

The large tree in the NW of the survey should produce a consistent negative gradient of potentials toward the tree. In this area we see a mix of point anomalies and an elongate negative anomaly in the north that cannot be correlated with the tree. The point anomaly at 120E, 80N on all grids (Figure 2-5) probably represents a circular feature of minimum size. We can estimate depth to the circular anomaly using the half width at half height method that gives us a depth estimate of 2m for this anomaly (Telford 1976). The interpretation of SP data requires a higher sensitivity survey that may be achieved in future surveys by continuously monitoring noise and using more accurate potential electrodes.

6.0 CONCLUSIONS:

Three Self Potential electrical surveys were conducted over an area known to contain a water pipe. High sensitivity was desired to detect passive source anomalies of only tens of milli- volts but the survey was strongly influenced by noise up to five millivolts. There were numerous small circular potential anomalies but the only trends that could be correlated across all surveys were the linear E-W trend around 80-85mN and the elongate anomaly in the north of the grid. The linear anomaly may represent the location of the pipe and the northern anomaly may relate to bioelectric activity around tree roots.

REFERENCES


