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UNDERGROUND UTILITY SURVEY OF PART OF AN INDUSTRIAL AREA, PORT HARCORT, NIGERIA

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Abstract

This project is termed 'Underground utility survey of part of an Industrial Area Port Harcourt, Nigeria '. The accurate location of underground utilities at a construction site can prevent any damage to the utilities during excavation works. The means of fixing the damage utilities can be very costly and will reduced the expected profit of the construction works. Therefore underground utility detection using Ground Penetrating Radar (GPR) is important in providing accurate information of the utilities within the project site. In this study a USS RADAR-3000 GROUND PENETRATING RADAR equipment was used to detect underground utility, with a 400 MHz ability which can reach up to 6m and 60m depth depending on the purpose and mode of operation. Based on the results obtained the GPR equipment is capable of detecting underground utilities such as pipe, cable, shaft, etc. The detected utilities are then shown in the 2-D and 3-D drawing for better visualization and identification. The project entails reconnaissance, Scanning, Using GPR (GROUND PENETRATING RADAR) and DGPS (Differential Global Positioning System) for positioning of the buried utility. Both equipment was used simultaneously, the plan was produced using ArcGIS 10.5 and Auto-Cad civil 3D. Data downloading for both GPR and DGPS was done using Radan software and windows mobile software.

The results of this study demonstrates the effectiveness of GPR for underground utility mapping. GPR is a quick and easy way to map the location of underground utilities, and it can help to prevent costly and dangerous accidents during excavation.

Keywords: Utility Survey, Ground Penetration Radar, GPS.

1. Introduction

Since the advent of civilization, mankind has interacted more with the near-surface part of the Earth's crust than the other deeper layers (Akindulureni et., al,. Therefore, an understanding of the dynamics of this part of the Earth is paramount; industrialization has caused rapid growth, leading to the expansion of man's habitat through the construction of roads, bridges, high-rise buildings, layouts and so on. One of the priority considerations is the design of the foundation for civil engineering structures; therefore, a pre-construction investigation of the proposed site is required in order to ascertain the fitness of the host earth material. This therefore calls for a better understanding of the subsurface geometry and the structural setting in situ.

With the rapid urbanization, industries have started relying on more complex and larger utility networks underground. You'll be surprised to know that utility surveying has been with us since the beginning of the 20th century. From underground utility locating and mapping, GPR to buried utility detection, utility surveying has become an essential step to identify, and map buried infrastructure. (Hussin, Ahamad, & Alhasanat , 2011).

In the early years, people used electromagnetic locator - the very first tool to detect utility maze of pipes and cables underneath the ground. Since its first investigation, the EM field detection theory hasn't been changed. Found in the 1970s, electromagnetic (EM) locator has evolved drastically. Earlier, it used to be a needle-based analogue display whereas, with the advancement in technologies, modern EM locators come with digital display and are more efficient, compact and user-friendly. It now also provides important data like direction, current and strength of the signal.

In the early days of utility location services, surveying was done with the help of the only EM locator available in the market and

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few handy tools. Fiber optics weren't so much popular and thus locators were only locating metallic utilities. Similarly, GPS technology wasn't used widely as it was expensive. Earlier, utility location services provider has simple rules, lift and trace every possible thing to get the required data and leave no room for errors. These still remain the key points of performing any underground utility locating survey. Over the years, the locator has changed while the theory and the methodology remain the same.

Ground Penetrating Radar (GPR) is a real-time NDT technique that uses high frequency radio waves, yielding data with very high resolution in a short amount of time. This technique uses electromagnetic waves that travel at a specific velocity determined by the permittivity of the material. GPR can be used in a variety of different media including rock, soil, ice, fresh water, pavements and structures Adepelumi & Fayemi. (2012). It incorporates the geophysical method that uses radar pulses to image the subsurface. This non-destructive method uses electromagnetic radiation within the frequencies of the radio spectrum, and detects the reflected signals from subsurface structures. It can detect objects, changes in material, voids and cracks. GPR Radar measures the depth in terms of the time it takes for a signal to return after emission. The depth in cm or m, depends on soil conditions and how fast the electromagnetic waves can travel through the ground Jeong & Abraham (2004).

GPR which is widely used to detect underground infrastructures, such as underground utilities, consists of an electromagnetic transmitter and receiver. This technology has been used primarily for detecting structural defects, such as voids and cavities in pavement. The principle of detection is the electromagnetic wave which is radiated from a transmitting antenna, and travels through the material at a velocity which is determined primarily by the permittivity of the material. The wave spreads out and travels downwards until it hits an object which has different electrical properties from the surrounding medium, is scattered from the object, and is detected by a receiving antenna. A straight line drawn from the transmitter to the edge of the wave front is called a ray. Rays are used to show the direction of travel of the wave front in any direction away from the transmitting antenna. If the wave hits a buried object, then part of the wave energy is reflected back to the surface, while part of its energy continues to travel downward. The wave that is reflected back to the surface is captured by a receiving antenna, and recorded in a digital storage device for interpretation. GPR waves can reach depths up to 30 meters in low conductivity materials such as dry sand or granite.

The depth of the penetration is also determined by the GPR Antenna used. Antennas with low frequencies obtain subsurface reflections from deeper depths. These low frequency antennas are used to investigate the geology of a site such as for locating sink-holes or fractures and to locate large and deep buried objects. Antennas with higher frequencies obtain reflections from shallow depths and have high resolution. These high frequency antennas are used to investigate surface soils and to locate small, large or shallow buried objects such as utilities and also rebars in concrete. Utility mapping is done to portray the location of the underground utilities obtained from the GPR survey. In order to place such information in the right context and to understand their mutual relationship over a larger area, it is necessary to map their distribution in the terrain(Annan, 2001).

The underground utility information of SPDC Industrial Area in Port Harcourt is needed for the construction of a central sewage system. Since waste water or sewage generated are often discharged into septic tanks, soak-aways within the study. These systems become problematic as soils become saturated with pollutants and effluents with very high suspended and dissolved solids causing environmental pollution within the study and even groundwater pollution in some cases. This gave rise to plan to construct a central sewage system within the study area to mitigate this problem and to construct this system successfully an underground utility survey is needed within the study area as presence of other utilities such as gas line, power line etc.. This information will aid the construction engineers for the design and construction of these system.

2. Study Area

The project is located at SSPDC Industrial Area, Part of Port Harcourt in Rivers State, Nigeria. The site for this project falls approximately between the geographical location of latitude 04º 50’ 05º.28’’N to 04º 49’ 13.44’’N and longitude 07º01’ 24.96’’E to 07º 02’16.08’’E.

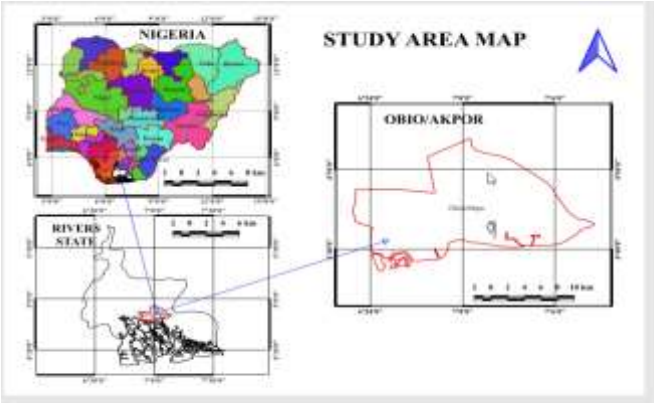

Figure 1.1: Map of Nigeria and Map of Rivers State showing verged Obio/Akpor Local Government Area. Source: Author:,2022.

Figure 1.2: Map of SPDC Industrial Area of the study. Source: SPDC Geomatics department, 2022.

2.1 Development Of Ground Penetrating Radar

The rapid development of electromagnetic technology in the last few years has achieved a new method for exploration geophysics science, which is GPR. In this technology, the electromagnetic pulse is transmitted into the ground and recorded by antenna in the

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surface. The GPR method is intensively used on the land in mapping of underground structure, and searching of archaeological objects, pipes, cable, mineral substance, either underground or below sea level (Witten Technologies Inc. (2001).

Beneath the surface of urban region and big cities all over the world lies a wide complex network of cables and pipelines which provide the vital utility services that reinforce modern civilized life. An extraordinary call for utility services within the urban region leads to bury an accumulative digit of utility pipelines such as; telecommunication lines, fibre optics, water and gas pipelines electrical cables. Today many of underground utilities have reached its ending practical life which makes it necessary to be replaced or repaired. While new utilities are awaiting installation due to urban development and the advancement of human life style such as; advanced communication technologies. Then an accurate data and info of these utilities is needed for engineers, surveyors, utility owners, or contractors, generally as reference for the excavation work.

Many have not realized the significance of the underground utility detection which is vital before starting any excavation works. A misfortune could take place if the work is ongoing before the underground utilities are located. Basically, underground utility detection is the procedure of recognizing, isolating and labelling the public and private subsurface utility lines which are hidden beneath the ground surface. These lines comprise of electricity distribution cable, telephones, fibre optics and communication lines, water and waste water conduits and major oil and gas pipeline, mass transit, road tunnels and rail etc.. (Dharam, Ranjit, Mohamed, March 2020).

Table 1: Wave velocities and dielectric constants of subsurface medium

Medium	Velocity(m/ns)	Dielectric Constant
Air	0.3	1
Water	0.033	81
Rocks	0.15–0.087	4–12
Sanddry	0.15–0.12	3–5
Sandwet	0.055	20–30
Clay dry	0.11–0.09	2–6
Claywet	0.052	15–40
Concrete	0.10–0.087	9–12

Source: International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8 Issue-6, March 2020

An electromagnetic technology is used in GPR system to detect lines among subsurface mediums with differing dielectric constants (Table 1). GPR system comprise of antenna that houses the receiver and transmitter with a recorder that reproduce the received signal data in form of a graphic display.

The instrument employs two antennas offering different detection frequencies. The 700 MHz antenna detects objects with very high resolution but with a smaller depth range. On the other hand, the antenna with a lower frequency (250 MHz) has a lower resolution, but at the same time, it offers a more extensive depth range. Therefore, one can read the resolution and depth information from a given frequency. The resolution of GPR measurements is called the instrumental ability to determine a minimum distance at which two identical targets can be recognized as separate objects. One can distinguish vertical and horizontal resolutions—the increment values of changing antenna frequency and the dielectric constant of the medium. The vertical and horizontal resolution of the GPR method can be calculated from equations (1) and (2), respectively. : (Karsznia, Onyszko & Borkowska, 2021).

$$\Delta d \cong \frac{c}{4f.\sqrt{er}} \qquad (1)$$

$$\Delta a \cong \frac{d-c}{2f.\sqrt{er}} \qquad (2)$$

where:

C—velocity of propagation of an electromagnetic wave,
F —antenna frequency,
Δd—vertical resolution of the GPR method,
Δa—horizontal resolution of the GPR method,
εr —relative dielectric permittivity,

Therefore reliable and accurate information on underground assets is of vital importance for the planning and management of land and the space below its surface. Underground utilities typically reside in the shallow part of such space. They are just one of its many competing uses, which include building basements and interlinking pedestrian corridors, piles, transportation infrastructure, and more (Chandran, 2019).

2.2 Importance Of Underground Utility Survey.

The presence, layout, and organisation of underground utilities directly affect the value that the land can continuously deliver. It may limit the potential for future development and use or the capacity to host new infrastructure and may present significant obstacles, risks, and nuisances for owners, developers, engineers, and users of the land. It is reasonable to expect that the need for reliable information on underground utilities will become increasingly relevant as cities over the world continue to grow, densify, and change. Vertical and in particular underground development is a way to deal with the limited availability of land above ground. Furthermore, ongoing developments such as the introduction of new services such as 5G (Mims, 2019) and district cooling or heating systems (Bradley, 2020; Wee, 2017), the transition to non-fossil energy sources, and the need to replace existing ageing utility infrastructure will only increase the pressure on an often already congested under- ground space.

Some cities have responded to these challenges. The City of Helsinki released its first Underground Master Plan in 2011 (City of Helsinki, 2011) . The Municipality of Rotterdam has adopted an asset management strategy for the management of underground space and infrastructure. It has a specialized unit coordinating utility developments and the collection of survey data (Rotterdam, 2019).

In Japan, the Road Administration Information Centre coordinates all utility works that occur on roads in metropolitan areas and, to support that, maintains a centralized dataset of all road and utility information (Zeiss, 2019). For the city-state of Singapore, “going underground” is one of its strategies to deal with limited land availability. The Master Plan 2019 (Urban Redevelopment Authority of Singapore, 2019a) highlighted underground space use as a means to create space for growing needs. The Urban Redevelopment Authority of Singapore (URA) furthermore mentions that planning the underground space upfront in 3D based

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on BIM and GIS data and the mapping and dissemination of data on shallow utility lines are required to safeguard underground space for future uses and to eliminate uncertainty and risk during the planning process (Urban Redevelopment Authority of Singapore, 2019b). Besides master planning, reliable information on underground utilities is expected to continuously provide value throughout the life cycle of land assets and management.

In Nigeria the lack of pre-construction under-ground utility investigations, which assist engineers in obtaining as-built sub-surface information has led to building collapse and structural failures. . A number of factors such as subsurface geological material, inadequate information about the soil, poor foundation design and poor building materials have also attributed to this failure (Fatoba et al., 2013). This has led to the loss of life and lots of goods and properties worth millions aside from the cost of rehabilitation or complete redesign and reconstruction at much higher cost.

Recently, the collapse of civil engineering structures has increased greatly for reasons associated with lack of information about subsurface geological and utility data. As a result, the need for subsurface investigation has become very crucial so as to prevent loss of lives and valuable properties that consistently occur with such a failure. Foundation assessment of a new site is required so as to provide subsurface and aerial information that normally assist civil engineers, builders and town planners in the design and citing of foundations of civil engineering structures (Omoyoloye et. al., 2008).

Currently in Nigeria the management and maintenance of underground utilities are non-existence. As more currently there is a water project going on within the city of Port Harcourt without any information taken about the buried utilities, such as the location and size of the facility. This will affect future construction because of the absence of the underground -utility data.

3. Data Acquisition

Data acquisition involves the deployment of personnel and equipment to the site to acquire the necessary data from the study area.Two equipment's were deployed to accomplish this task,they are GNSS RTK, AND GPR (ground penetrating radar).

The operation centres on using a GPR in conjunction with CHC GPS receiver set on real time kinematic mode (RTK mode).

3.1. Field Operations.

Ground penetrating radar (GPR) is a geophysical survey method which uses high-frequency-pulsed electromagnetic (EM) waves to acquire subsurface information. It is used to investigate the subsurface without drilling, probing or digging. Basic GPR survey equipment consists of a transmitting and receiving antennae, a radar control unit and a data storage and display device. Energy is radiated into the ground from a transmitting antenna. As the wave spreads out and travels downward at both sides, if it encounters a buried object or boundary with different electromagnetic properties, then part of the wave energy is reflected or scattered back towards the surface. The receiving antenna at the surface records the strength (amplitude) of the reflected signal with time. The amplitude of the EM energy reflected from any boundary depends on the change in material properties (dielectric constant, magnetic permeability and electrical conductivity) at the boundary. The reflected signals are recorded over a selected time range for a fixed antenna position to produce a scan or trace of radar data. Scans obtained as the antennae are moved over a surface are placed side by side to produce a radar profile or radar-gram.

However there are three main approaches to surveying with GPR the selection of which depends on the desired results and whether real time results are required or if post processing is desired.

First the site was examined for clues such as manholes, manifold, valves etc., this is always a good starting point for location in GPR investigation survey. In this instance the gas manifold was identified and the cart was moved perpendicular to the object until the pipe was detected and shown on the screen once these points are identified they are either marked on the ground and the GPS coordinates is then logged. This process is repeated until the entire line is traced to the SUB-STATIONS. This techniques was used to trace all other utilities starting from the source to the end point.. During this operation each, facility was probed separately and given a unique ID also the attribute data of the facility was collected and stored. The utility within the Built-up area were traced from source to the end users point in a grid pattern. This method is adopted so as to have the exact position of buried facility within the area of interest.

We captured gas line, hydrant line, High voltage (HV) lines, Telecom lines, Low voltage (LV) lines etc. alongside the features such as; buildings and other details adjacent to the utilities. The pictures below shows an example of a buried gas line.

Figure 3.1 Sight of probed disuse 5.5”Apara gas pipe (left) and life 6” gas pipe (right)

Source: Arthur, September 2022.

4.1 Data Analysis And Result

In the determination of the spatial positioning of the underground features. The GPR equipment was attached with a CHC GPS receiver on RTK mode was used to scan over the study area and the GPR equipment radiates pulse of electromagnetic rays into the ground and recorded the position of the point on the surface antenna. The figure in 4.1 shows the images of the underground feature.

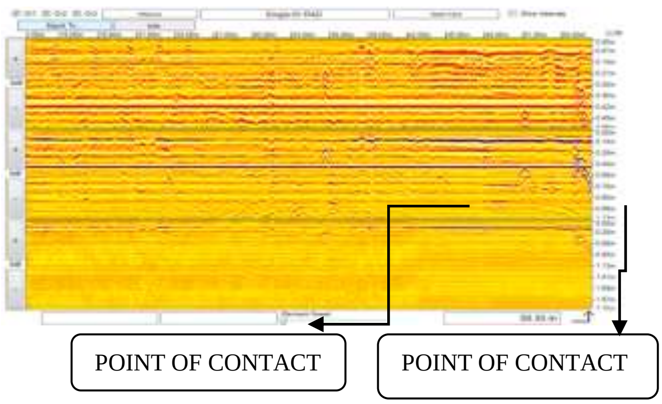

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Figure 4.1: Image of the GPR showing the traced gas line. Source:Arthur, September 2022.

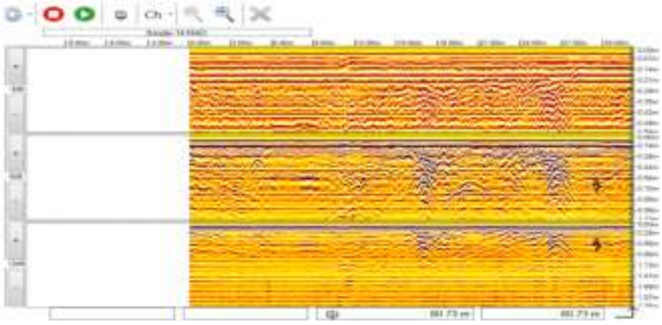

Figure 4.2 .Image of the GPR showing the traced gas line. Source: Arthur , September 2022.

4.2 Identification of Gas line pipeline supplying manifold and distribution network.

The manifold of the Gas line was identified and the point of entry of the Gas line was identified.

The GPR system was then used to trace as shown in the figure 4.3 below.

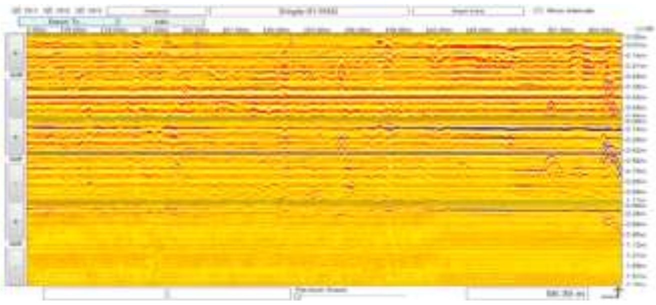

Figure 4.3 .Image of the GPR showing the traced gas line
Source: Arthur , September 2022

4.1 Query And Presentation Of Analysis.

This is one of the unique features of GIS .It is used in the processing and manipulation of data to generate information necessary for decision making during construction phase. utility network plan was produced with ArcGIS 10.5 software on a scale of 1:5000 as well as the ARCGIS 3D drawing This will enable every user to carry out spatial analysis on each feature, such as gas line, telecoms line, hydrant line, etc. through their attributes. The Gas pipelines and other Utilities profiling, on the other hand, were plotted in AutoCAD Land Dev. Civil 3D 2018 on a scale Horizontal of 1: 2500 and Vertical scale of 1:250.

4.1.1 Query Of Results.

This is a common features in GIS .It is basically used in the processing and manipulation of data to generate accurate information necessary for decision making. These information generated are used to answer questions in GIS such as where is what, what is where, etc. In this study the question is 'what is where. There two types of query namely single query and multiple query.

4.3.2 Single criterion analysis.

Single criterion analysis refers to the situation where a single condition is used to query a database.

4.3.3 Multiple criterion analysis.

Multiple criterion analysis refers to the situation where a single condition is used to query a database.

Query 1: (Single Criteria) To Show The Ground Level gas Line That Are Less Than Or Equal To 16.834 m Relative to a Datum Within The Study Area.

4.4 Determination of the depth analysis of the ground features.

This was achieved using the imported GPR and GPS data into ArcGIS 10.2 and analysed the results as shown below.

4.4.1 Identigfiction Of Gas Line:

Syntax:Ave_Depht<=16.834m

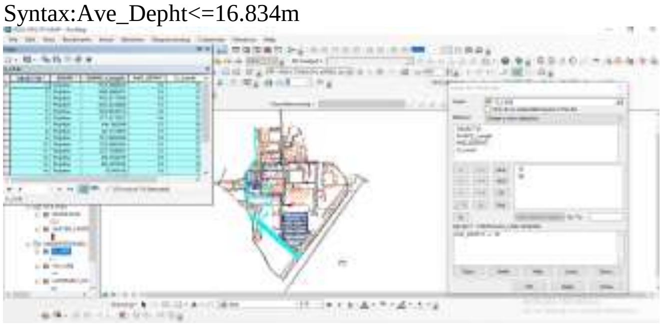

Figure 4.4: Query showing the depth of the gas-line that are less than or equal to 16.834m relative to a datum.

Syntax:Ave_Gas_Depht >= 15.971m

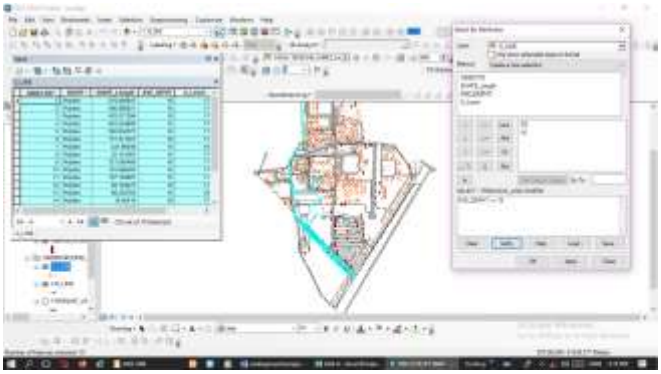

Figure 4.5: Query showing the depth of the gas-line that is grater than or equal 15.971m relative to a datum.

From the analysis it can be deduced that the difference between lowest average depth and the ground level is 0.863m.

4.4 Determination of High Voltage Line:

Syntax:Ave_Gl_Depht<=16.340m

Figure 4.6 Query showing the Ground level depth of the High Voltage-line that are less than or equal 16.340m relative to a datum.

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Syntax:Ave_Hv_z =< 15.684m

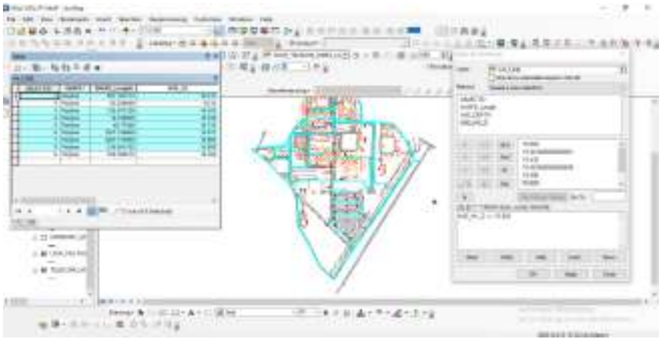

Figure 4.7 Query showing the depth of the High Voltage-line that are grater than or equal 15.648m relative to a datum.

From the analysis it can be deduced that the difference between lowest average depth and the ground level of the High Voltage line is 0.692m.

4.6 Determination Of Hydrant Line:

Syntax:Ave_Gl_Hydrant Line<=16.681m

Figure 4.8: Query showing the depth of the HYDRANT-line that are less than or equal 16.681m relative to a datum.

Ave_Hydrant_Depth <= 16.440m

FIGURE 4.9 Query showing the depth of the HYDRANT-line that are greater than or equal 16.440m relative to a datum

From the analysis it can be deduced that the difference between lowest average depth and the ground level of the Hydrant line is 0.241m.

LOW VOLTAGE LINE

SYNTAX:AVE_LV_LINE <= 16.826

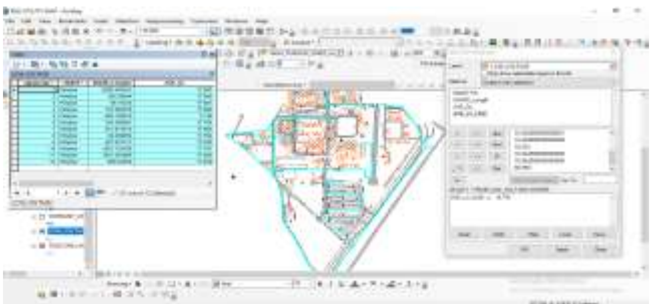

FIGURE 4.10 Query showing the ground level of the Low Voltage-line that are less than or equal 16.826m relative to a datum

SYNTAX:AVE_GL_LV <= 17.498

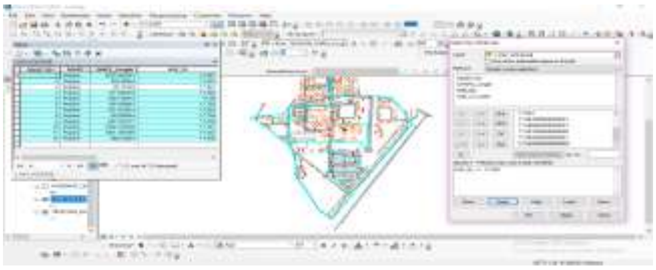

FIGURE 4.11 Query showing the depth of the Low Voltage-line that are greater than or equal 16.862m relative to a datum.

From the analysis it can be deduced that the difference between average low voltage lines with the average ground level is 0.636m.

From the chart above it can be deduced that the lowest of all the underground utility is the telecommunication line however there are some areas where it protrudes or visible from the ground level as shown in the auto Cad drawing.

The gas line is also laid below the ground surface but at the point where it connects to the manifold is above the ground level.

4.3 Mapping Of The Underground Facility/Features.

The identified underground facilities were analysed and plotted using the ArcGIS10.2 mapping software and the results are attached in the appendix of the report.

5.0 Summary, Conclusion And Recommendations

This study was carried out to determine the underground utilities within the study area and produced a map depicting the position, depth and size of the underground facilities in focus. The plan showing the underground utilities and facilities was produced with appropriate colour code.

It can be concluded that US RADAR GPR equipment with a 400 MHz shielded antenna is capable of detecting underground utilities. The technique used is efficient and non-destructive for locating underground utilities in construction sites. It is advisable to perform an underground utility detection before carrying out any excavation works in order to avoid damage to the utilities which can be quite expensive to fix. As a damage water pipe or electric cable can be

Presently in Nigeria there are no laws mandating a licensed surveyor to be involved in the planning and execution of a underground utility survey. Introduction of this law will give credence to underground utility mapping with the proposition that all newly laid utility data must be surveyed by a qualified land surveyor and an as-built plan drawn and the plan with its digital data submitted to the Ministry of survey.

This will to ensure that the location of the underground utilities being mapped are accurate and reliably acquired.

5.1 Recommendations

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As a matter of fact, underground survey should be encourage within the city as they form the foundation within which modern cities are built.

Also, there should be awareness on the importance of the underground utility survey, especially during road construction going within our city. Presently in Nigeria there are no laws mandating a licensed surveyor to be involved in the planning and execution of a underground utility survey. Introduction of this law will give credence to underground utility mapping with the proposition that all newly laid utility data must be surveyed by a qualified land surveyor and an as-built plan drawn and the plan with its digital data submitted to the Ministry of lands and to the office of the Surveyor General of the state.

APPENDIX I

COORDINATE LISTING OF UNDERGROUND TELECOM LINES

DESCRIPTION	EASTINGS (m)	NORTHINGS (m)	DEPTH (m)
TL	507501.1	91756.47	16.278
TL1	507499.5	91754.3	15.853
TL	507498.1	91755.1	15.824
TL2	507458.9	91755.32	15.015
TL G	507464.2	91696.62	15.735
TL G	507464	91718.45	15.518
TL G	507464.6	91731.05	16.403
IV D2.1 1.4	507443.6	91624.92	15.46
TL	507458	91624.65	16.156
TL	507458	91625.84	16.211
TL	507458.2	91631.14	16.28
TL	507464.8	91631.11	16.097
TL	507466.3	91634.14	15.866
TL	507509.5	91635.54	15.777
TL	507547.4	91636.5	15.948
TL	507547.4	91636.5	15.866
TL	507549.5	91648.71	16.023
TL	507406.2	91731.05	16.081
TL1	507396.9	91731.32	16.136
TL2 0.4	507345.7	91668.48	16.272
TL2 0.3	507346	91662.93	16.293
TL2 0.4	507357.3	91663.25	16.126
TL2 0.4	507371.2	91662.26	16.236
TL2 0.35	507371.4	91659.42	16.392
TL23M1	507371	91631.9	15.731
TL23M	507376.8	91631.65	15.713
TL2 3M	507372.6	91659.49	15.809
TL2 3M	507372.6	91644.48	15.898
TL2 3M	507374.4	91643.68	15.89
TL2 3M	507377.3	91643.61	15.973
TL 1	507402.9	91622.58	16.824
TL 2	507403.1	91608.11	16.359
TL 3	507419.3	91608.11	15.994
TL4	507458.3	91607.97	15.601
TL G0.65	507408.2	91729.14	16.06
TL G0.7	507403.6	91729.28	16.142
TL G5	507402.6	91676.46	15.704
TL G5 0.5	507402.8	91675.53	15.677
TL G1	507433.5	91673.8	16.071
TL G2	507433.4	91669.32	16.177
TL	507151.9	91612.95	15.23
TL4	507180.4	91614.6	15.408
TH3	507250.1	91613.36	16.781
TL1 0.4	507334.2	91612.01	17.308
TL1	507334.3	91737.39	16.114
TL2	507339.6	91737.56	15.882
TL3	507357.3	91783.16	15.372
TL4	507441.9	91783.18	15.86
TL5	507443	91783.18	15.879
TL6	507445	91814.63	15.919
TL7	507454.9	91814.95	16.281
TL1	507422.5	91734.69	15.743
TL2	507423.7	91782.04	15.87
TL1	507457.4	91813.83	16.131
TL2	507458.9	91755.32	15.015
TL3	507459	91706.36	15.514
TL4	507458.6	91672.54	16.455
TL5	507458	91624.65	16.156
TL6	507458.3	91607.97	15.601
TL7	507459.2	91574.25	15.759
TL8	507460.5	91552.28	15.909
TL9	507530.3	91551.72	15.909
TL10	507644.4	91553.43	15.825
TL1	507647.7	91869.93	15.315
TL2	507653.9	91875.84	14.886
TL3	507714.3	91875.55	14.807
TL4	507748.8	91875.65	14.614

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TL5	507760.1	91875.91	14.596
TL6	507816	91875.52	13.521
TH3	507250.1	91613.36	16.781
TH4	507250.1	91627.63	17.083

COORDINATE LISTING OF UNDERGROUND LOW VOLTAGE LINE

I1	507216.3	91671.5	16.358
I2	507229.2	91674.23	16.476
I4	507261.1	91676.93	17.198
I3	507264.2	91676.66	17.28
0.6	507337.3	91460.54	18.106
lv0.5	507337.4	91448.66	17.869
lv	507337.4	91446.13	17.974
lv0.5	507338.7	91429.2	17.975
lv	507344.9	91409.79	17.961
lv	507376	91351.16	17.499
lv0.0.8	507378.6	91336.34	17.212
lv0.9	507389.6	91338.3	17.108
lv1.00	507411.2	91295.04	17.203
lv0.7	507412	91275.6	17.078
lv0.7	507413.2	91253.57	17.63
lv	507414.4	91232.45	18.003
lv0.5	507726.7	90881.83	16.584
lv0.4	507691.1	90824.74	17.097
lv0.4	507691.1	90824.74	17.097
lv0.6	507655.1	90768.64	17.194
lv0.7	507632.3	90733.86	17.513
lv0.6	507592.3	90775.1	17.187
lv0.6	507569.1	90799.39	16.938
lv0.9	507545.1	90823.08	16.729
lv	507536.7	90832.83	16.792
lv0.8	507528.4	90849.97	16.781
lv0.7	507514.1	90881.12	16.502
lv0.7	507486.6	90941.73	16.668
lv0.8	507473.2	90971.8	17.05
lv	507457.5	91001.46	17.287
lv0.8	507440.6	91031.85	17.617
lv	507424.4	91061.14	17.59
lv0.8	507407.2	91091.85	18.016
lv0.5	507391.1	91120.78	17.977

lv	507384.4	91158.98	18.033
lv	507386.7	91130.36	18.145
lv0.6	507383.6	91190.53	18.308
lv	507382.9	91227.04	18.231
lv0.45	507382.1	91253.73	18.163
lv0.5	507382	91279.58	18.222
lv	507377.2	91304.05	17.774
lv0.7	507371.6	91320.52	17.474
lv0.0.8	507378.6	91336.34	17.212
lv	507376	91351.16	17.499
lv0.6	507352.5	91398.03	17.373
lv	507344.9	91409.79	17.961
lv0.5	507338.7	91429.2	17.975
lv	507337.4	91446.13	17.974
lv0.5	507337.4	91448.66	17.869
lv0.6	507337.3	91460.54	18.106
lv0.5 ep	507630.9	91195.38	16.557
lv0.5	507687	91195.32	16.721
lv0.55	507740.7	91195.17	16.574
lv0.65	507784.8	91195.08	16.3
lv0.7	507831.5	91194.56	16.25
EP0.4	507631	91301.34	16.429
LV.0.7	507677.5	91301.34	16.443
EP	507723.8	91301.5	16.324
LV0.6	507765.9	91301.16	16.089
lv0.62	507816.1	91301.23	15.92
LV0.8	507816.1	91299.09	15.998
LV0.7	507828.6	91298.25	15.891
LV0.6	507833	91298.29	15.868
LV1.00	507597	91171.03	16.739
LV1.2	507619.3	91158.47	16.367
LV0.0.4	507624.3	91139.97	16.162
LV0.0.5	507629.1	91133.12	16.112
LV0.0.4	507655.5	91104.37	15.974
LV0.0.5	507673.6	91085.99	16.072
LV0.0.4	507696.7	91064.48	16.236
LV0.0.4	507721.1	91041.42	16.348
LV0.5	507721.1	91041.37	16.354
LV0.4	507744.1	91017.18	16.217
LV0.3	507772.3	90988.74	16.498

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LV0.4	507784.1	90973.3	16.293
lv0.66	507801.7	91001.88	16.461
lv0.75	507853.4	91085.81	16.119
lv0.7	507874.1	91113.83	15.77
lv0.68	507944.4	91224.66	14.736
HV0.7	507978.7	91276.83	14.541
HV0.7	507995.8	91303.87	14.755
HV0.65	508012.4	91330.39	14.257
HV0.5	508028.7	91356.28	14.435
LV0.5	508046.1	91383.35	14.237
LV0.7	508062.8	91410.53	14.227
LV0.8	508079.2	91436.43	14.464
LV0.7	508097.5	91466.47	14.653
LV0.7	508114.3	91493.42	14.532
LV0.8	508132.1	91522.27	14.629
LV0.8	508150.9	91552.12	14.728
LV0.7	508166.8	91580.7	14.633
LV0.7	508180.4	91599.41	14.704
EP0.1	507584.4	91786.81	16.666
EP0.25	507563.8	91786.33	16.381
EP0.2	507543.7	91786.14	16.312
EPL0.2	507533.2	91786.41	16.126
EPL0.26	507532	91787.04	16.366
EP	507499.2	91787.11	16.492
EP0.3	507465.5	91787.67	16.559
EP	507466.3	91708.62	16.842
EP1	507465.2	91743.59	16.615
EP2L	507464.6	91766.42	16.438
EP3	507465.6	91783.11	16.567
TL G0.65	507408.2	91729.14	16.71
TL G0.7	507403.6	91729.28	16.842
TL G5	507402.6	91676.46	16.204
TL G5 0.5	507402.8	91675.53	16.177
TL G1	507433.5	91673.8	16.471
TL G2	507433.4	91669.32	16.477

COORDINATE LISTING OF UNDERGROUND HIGH VOLTAGE LINE

DEST	E	N	Z
HV1	507412.7	91889.18	14.209
HV2	507411.2	91888.51	14.232
HV3	507406.7	91886.91	14.623
HV4	507408.6	91887.94	14.655
HV5	507410.1	91888.41	14.577
HV6	507411.2	91888.51	14.292
HV7	507404.7	91885.71	14.692
HV8	507401	91885	14.721
HV9	507391.7	91881.28	15.384
HV10	507389.8	91880.96	15.431
HV11	507387.4	91879.07	15.252
HV12	507368.5	91843.72	15.247
HV13	507344.1	91797.56	15.796
HV14	507342.4	91794.54	15.841
HV15	507320.7	91746.28	16.447
HV16	507305.9	91714.03	16.359
HV17	507298.3	91700.89	16.467
HV18	507292.7	91698.13	16.632
HV19	507281.3	91697.98	16.566
HV20	507260.5	91698.25	16.409
HV21	507241.7	91692.34	15.727
HV22	507235.6	91687.97	15.656
HV23	507233.2	91676.22	15.77
HV24	507231.9	91640.99	16.544
HV25	507221.7	91625.7	16.604
HV	507404.7	91846	16.467
HV56 8GL	507426	91847.74	16.503

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HVA	507447.5	91848.1	16.412
HVA1	507447.7	91865.86	16.395
HVA2	507448.3	91870.6	16.339
HVA3	507448.8	91876.83	16.278
HVA4 4M	507450.9	91897.17	16.2
HVA5	507458.8	91907.77	16.131
HV5	507397.9	91849.32	16.51
HV3 1	507402	91847.7	16.236
HV3 0.35	507396	91833.3	16.805
HV2 0.6	507374.2	91801.25	16.678
HV1 0.4	507371.8	91792.53	16.143
HV6 0.3	507338.3	91725.43	16.92
HV6 0.4	507342.5	91713.78	16.771
HV8 0.4	507336.6	91613.84	16.764
HV9 0.5	507301.6	91613.29	17.586
HV10 0.6	507253.6	91613.23	17.504
HV11 0.	507252.9	91601.91	17.28
HV13 0.75	507215.2	91602.62	16.8
HV14 0.6	507213.8	91610.08	16.913
HV14 0.6	507211.8	91617.06	16.718
HV20	507683.7	91870.99	14.535
HV0.7	507747.4	91872.61	14.923
HV0.6	507790.8	91872.15	14.704
HV1.3	507801	91887.01	14.893
HV1.2	507826.8	91887.8	14.34
HV0.75	507824	91939.81	14.631
HV1.3	507820.3	91997.3	14.716

HV1.09	507819.7	92019.24	15.314
HV0.8	507810.1	92019.09	15.079
HV0.9	507809.7	92020.58	14.957
HV1.1	507773	92020.3	14.929
HV	507772.9	92017.5	14.957
HV0.44	507601.6	91665.6	16.649
HV0.42	507600.4	91665.57	16.74
HV0.47	507591.4	91670.5	16.667
HV0.53	507577	91667.54	16.365
HV0.5	507571.8	91668.95	16.372
HV0.56	507569.5	91651.12	16.762
HV0.6	507564.3	91651.19	16.669
HV0.5	507555	91651.38	16.892
HV0.10	507551.4	91651.35	16.669
HV0.9	507539.4	91650.76	16.762
HV0.6	507530.4	91634.96	16.393
HV0.5	507536.5	91639.95	16.502
HV0.E	507536.6	91640.58	16.214
HV1	507463.9	91632.35	16.386
HV2	507460	91632.28	16.874
HV3	507459.8	91602.43	16.98
HV 0.	507457.8	91602.44	16.977
HV 0.66	507448	91602.33	16.842
HV1 0.7	507388.9	91604.35	16.726
HV1 0.7	507344.9	91605.97	16.7
HV0.4	507337.6	91610.47	16.82
HV0.42	507337.7	91619.38	16.86

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HV1	507463.9	91632.35	16.386
HV2	507460	91632.28	16.874
HV3	507459.8	91602.43	16.98
HV EXP	507459.9	91605.45	16.428
HV0.9	507458.7	91551.01	16.684
HV0.9	507411.3	91550.36	16.597
HV0.9	507337.2	91550.21	17.594
HV0.4	507337.6	91610.47	16.82
HV0.42	507337.7	91619.38	16.86
HV0.4BM	507558.2	91650.93	16.435
HV0.4BM1	507534.3	91651.02	16.007
HVLV0.7	507472.4	91651.8	16.531
HVLV1.1M	507443.9	91650.36	16.751
33KV1.4	508179.6	91599.2	14.711
33KV1.3	508173.2	91588.89	14.668
33KV1.2	508140.2	91537.41	14.771
33KV1.2	508116.3	91498.87	14.608
33KV1.5	508091.8	91458.76	14.775
33KV1.3	508065	91416.05	14.441
33KV1.3	508037.7	91372.63	14.375
33KV1.5	508011.4	91331.42	14.393
33KV EX	507993.5	91301.56	14.442
33KV EX1	507991.3	91298.06	14.537
33KV EX2	507988	91292.84	14.409
33KV1.9	507926.3	91196.8	15.082
33KV1.3	507892	91142.21	15.438
33KV1.00	507854	91086.53	15.77
33KV1.2	507819.7	91032.31	16.119
33KV	507796.8	90995.24	16.461
33KV1.5	507786.6	90984.28	16.364
33KV1.00	507762.4	90960.97	16.7
33KV	507757.4	90957.84	16.1
33KV1.8	507753.7	90952.13	16.505
33KV1.4	507750.9	90943.04	16.749
33KV1.5	507750.1	90935.71	16.631
33KV0.8	507748.3	90912.71	16.903

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