Earth Science Systems
ESSENTIAL UNDERGROUND INFORMATION

A Demonstration of the GPR Utility Scanner System

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Introduction

Proper knowledge of subsurface utility location and extent is critical before beginning any construction activity that could disturb or damage these utilities. The ramifications of poor subsurface knowledge includes schedule delays, cost overruns, liability and negligence suits, and risk to public health and safety. These risk factors and problems can be minimized through the use of sub-surface utility location and mapping tools, along with subsurface utility engineering (SUE) practices. The ESS Utility Scanner is a revolutionary new ground penetrating radar (GPR) system that provides comprehensive subsurface mapping capabilities with an ease of use not found in other scanners. This report demonstrates the versatility of the Utility Scanner system

Figure 1. The Utility Scanner system with the scanner (left) and the optional GPS base station (right).

and examines the nature and detail of 3D views, survey reports, and as-built drawings that users can generate. The system not only allows for quick utility mark outs but also supports the work flow for subsurface utility engineering that is becoming standard practice in the industry (ASCE 38-02). The system can be used for planning new construction, process control during construction, and for inspection and acceptance after construction.

The Utility Scanner system is comprised of a survey cart that is used to scan the area of interest and an auxiliary global positioning system (GPS) base station. This equipment is shown in Figure 1 and described below. The real-time kinematic GPS system provides cart positioning with 1 cm accuracy, and enables a real-time steering guidance so that traditional time-consuming survey grid layout is no longer needed. The entire system has been designed for ease of use without troublesome cables or connectors. The scan cart has a set of 750 MHz GPR antennas for high resolution imaging, a 350 MHz set for deeper penetration, and a magnetic power line detector. A tablet computer mounted to the scan cart handle is used to acquire, display, and process the data, and Figure 2 shows a typical cross section displayed during data acquisition. Easy-to-use software on the tablet provides complete data analysis and reporting capabilities so that deliverable results can be produced in the field before leaving the jobsite. The system's streamlined workflow significantly reduces survey execution and reporting time, especially when using SUE practices.

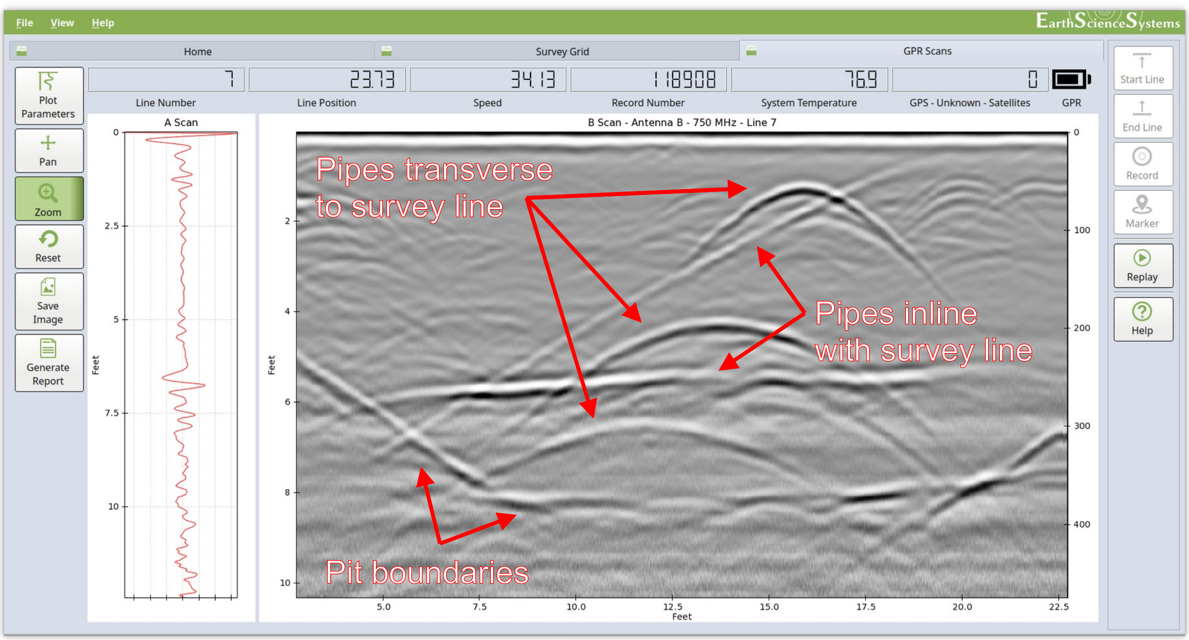


Figure 2. A screen shot of a scan over a utility pit showing characteristic hyperbolic reflections from pipes using the 750 MHz antennas. The sloping side of the pit is visible on the left side of the image, and the bottom of the pit is visible at a depth of about 8 feet.

An Example Survey

A survey over a utility convergence point at an industrial site was made using the Utility Scanner system to determine the location of buries pipes in order to plan an excavation for maintenance. The area had been back filled with a sandy soil which allows good penetration of the GPR signal, and the 750 MHz antennas were able to reach the bottom of the pit at a depth of about 8 feet. In general a wide variety of soil types exist with varying penetration depths, and target detectability typically varies from 20 feet in ‘good’ soils to only 3 feet in ‘poor’ soils (i.e., soils with high electrical conductivity). Consult the Appendix for more information. The results shown in figures below are all from the same site.

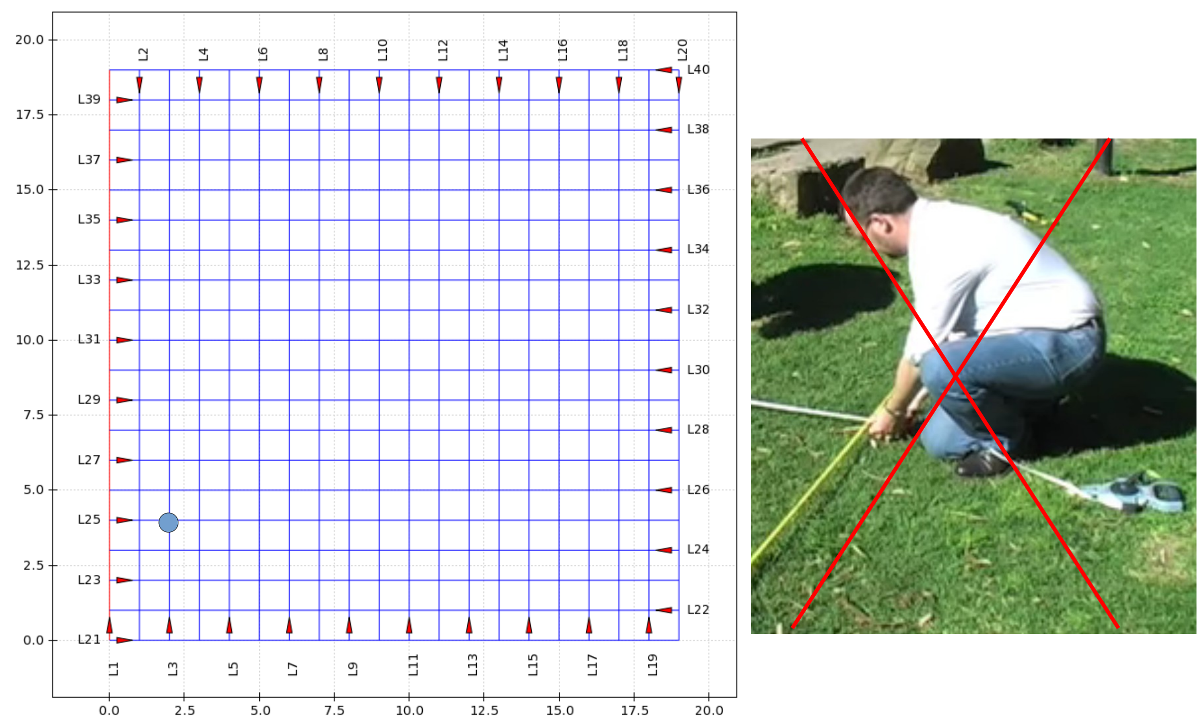


Figure 3. The left panel shows a survey grid layout where the blue dot provides real-time steering guidance (left). With real-time steering guidance the time-consuming process of physically laying out and marking a survey grid is no longer necessary (right).

The surveyed area was a 19 foot square with a set of scan lines in the north-south direction and another in the east-west direction, and it took less than an hour to setup and conduct the survey. Figure 3 shows the scan grid layout where each successive survey line was run in the opposite direction to the previous. After the scan grid was configured in the acquisition program, real-time steering guidance was provided by the GPS. The first line in the survey becomes the baseline, and after traversing the baseline the system displays a moving dot on the grid display showing the cart's current position on the grid which guides the user as the cart is pushed along the survey lines.

The Utility Scanner system can be outfitted with a GPS rover that can be used to survey in surface features such as manholes, valve boxes, posts, etc. and add them to the system database. A smart phone app (see Figure 4) is used in conjunction with the rover so the user can enter a name and description for each surface feature. The system then uses wireless communications to transfer these survey points to the database on the tablet PC for inclusion in reports and CAD drawings. If potholing operations are performed to expose utilities, the GPS rover and smart phone app can be used to log those locations, depths, and other information about the utility. With the ability to import previous as-built drawings, all of the SUE information from surveys (quality levels A – D) can be combined into the same database so that reports and drawings can be easily produced.

Utility locations are typically designated by physically marking the ground surface with spray paint, pin flags or other methods; and this can be done during the GPR survey or after the survey is complete. It is often more accurate and convenient to add the location marks to the ground after all SUE information has been collected, including the GPR survey, any potholing activities, other utility survey results, and the locations of surface features. In this case the smart phone app shows the user's ground position and location of the known utilities in the database. Survey technicians can walk through the site and decide which utilities need to be marked out to provide a clear picture of the entire area. This results in the most accurate designations possible and eliminates spurious markings.

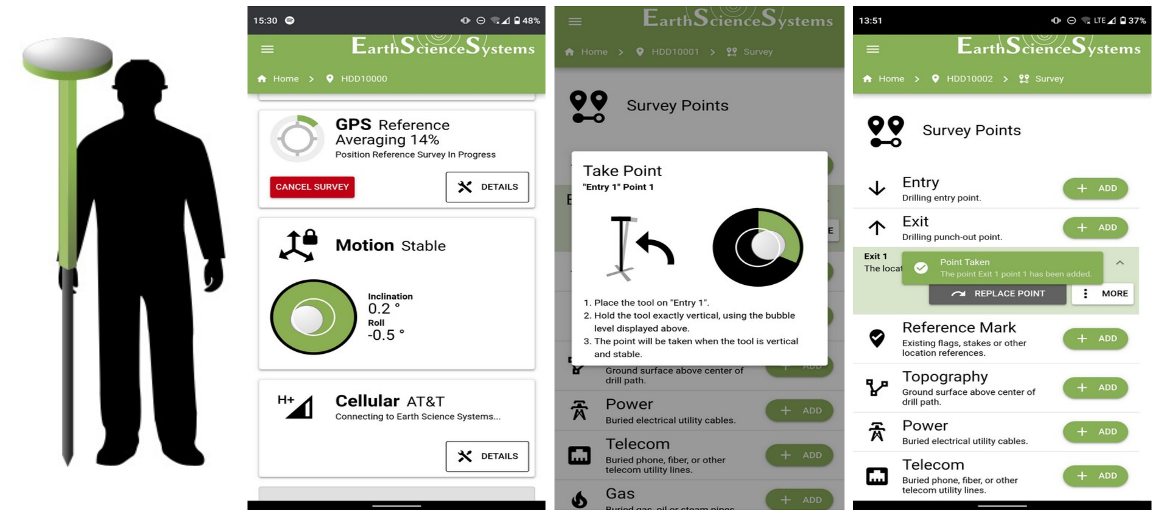


Figure 4. GPS rover and smart phone app screens.

After conducting the survey, the data was imported into the processing and reporting application (i.e., ESSentialUnderground) where users can view cross sections, depth slices, or 3D views of the subsurface scan data. Although the program provides many data processing and enhancement functions, in many cases very little processing is needed. The processing steps used for this survey are typical and are outlined below.

1. Calibrate depth using interactive hyperbolic curve fitting
2. Subtract background response (optional)
3. Adjust color scale
4. Pick targets
5. Generate reports

The cross-section and depth-slice views provided by ESSentialUnderground give users the ability to virtually fly-through the subsurface in the horizontal or vertical directions (see Figures 5 and 6). Subsurface targets such as rocks, pipes, and layered interfaces can be delineated by users in cross-section or depth-slice views, which are then displayed as iso-surfaces in the 3D view. These targets can be labeled and color coded according to the utility type if it is known. The 3D view also provides fly-through capabilities (see Figures 7 and 8), as well as visualization of targets and surface images such as a Google Maps overlay or a power line detector heat map.

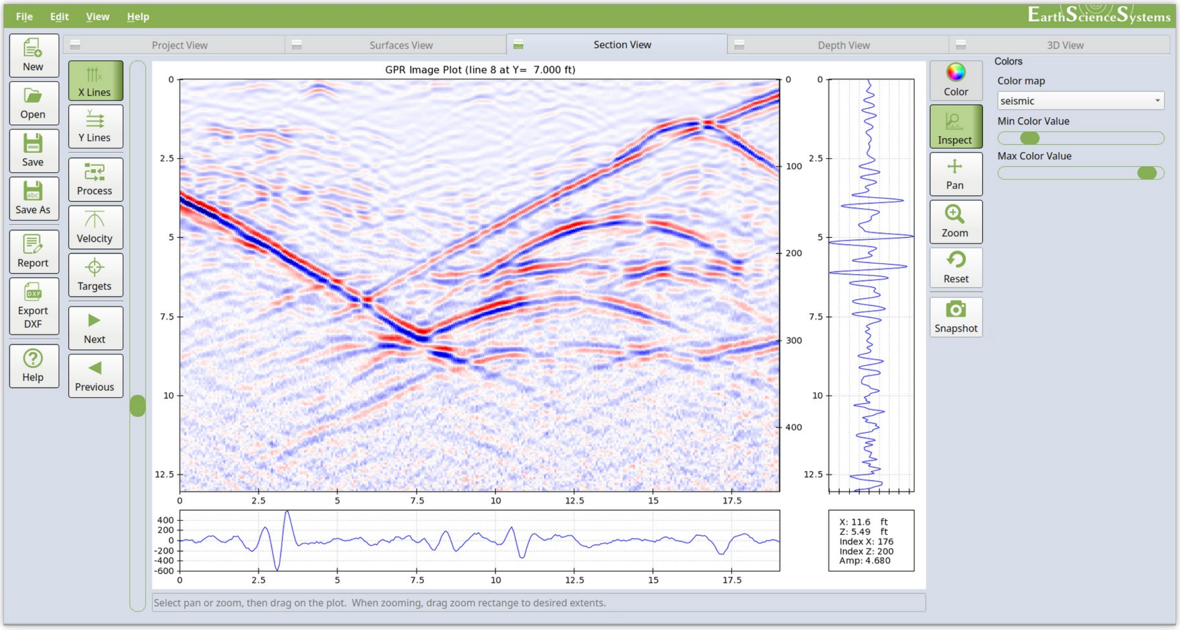


Figure 5. A cross section image from the 750 MHz antennas.

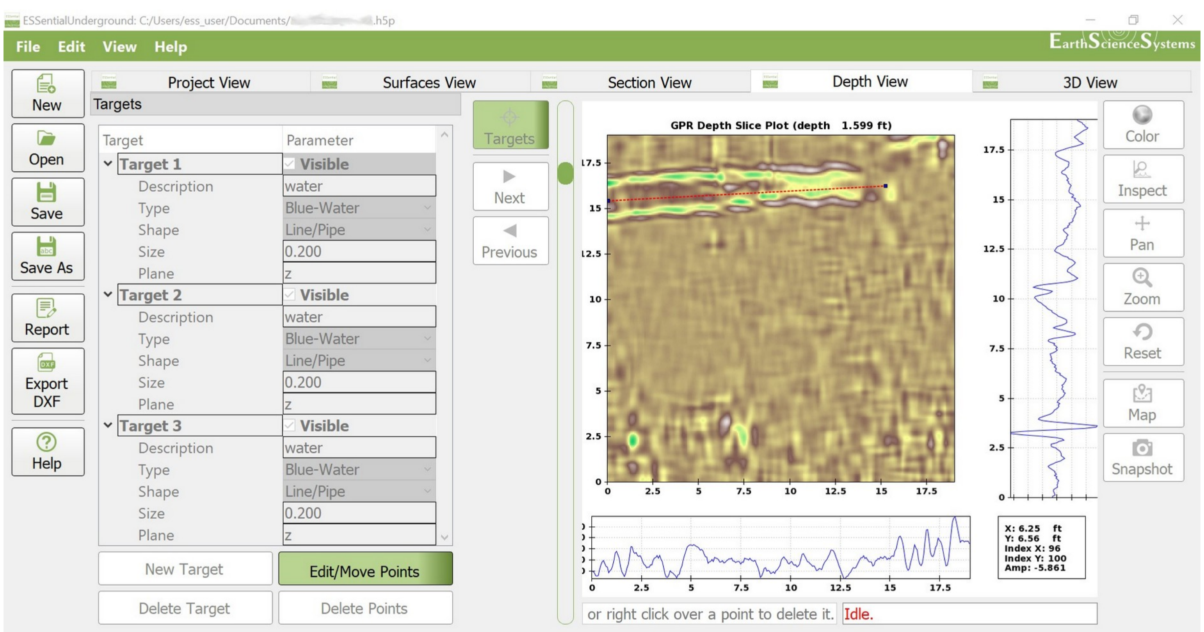


Figure 6. Depth slice view and interactive target picking (red dotted line).

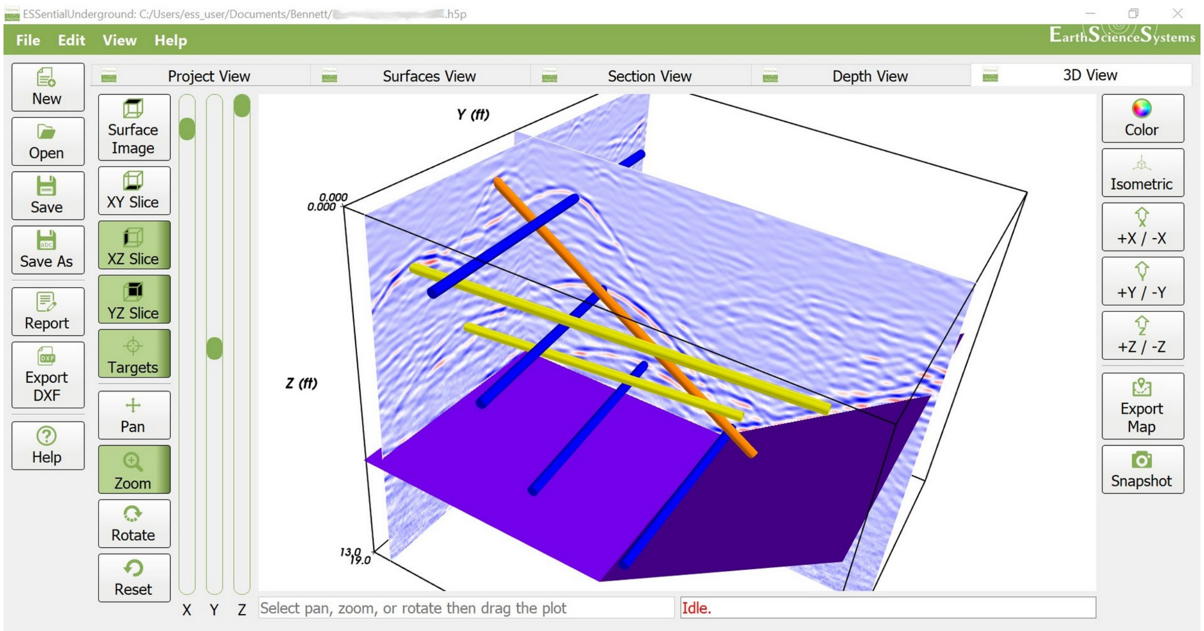


Figure 7. 3D view showing GPR data as cross-sections and targets as iso-surfaces (pipes and pit bottom).

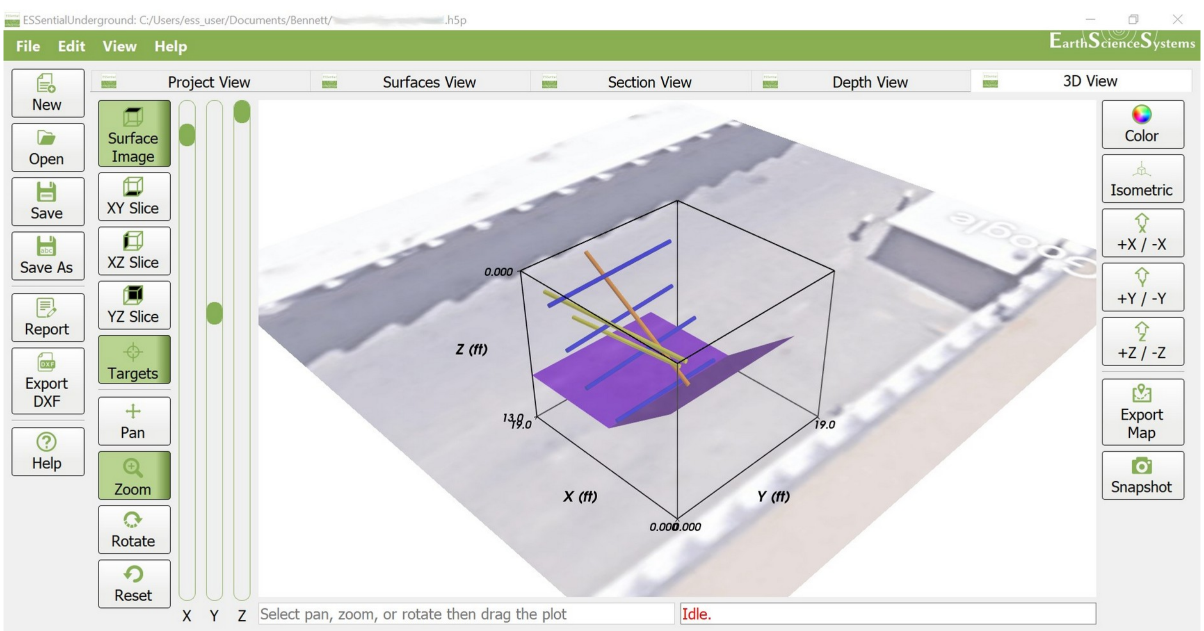
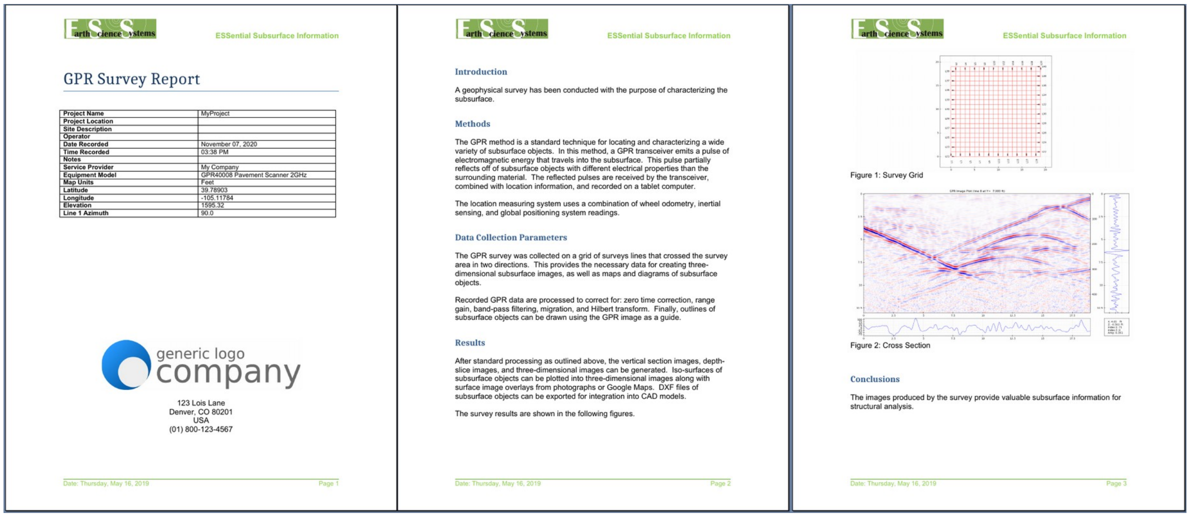


Figure 8. 3D view with Google Maps overlay showing survey location between two buildings. The overlay transparency is set so that subsurface targets are visible.



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GPR Survey Report

Project Name	MyProject
Project Location	
Site Description	
Operator	
Date Recorded	November 07, 2020
Time Recorded	03:38 PM
Notes	
Service Provider	My Company
Equipment Model	GPR40008 Pavement Scanner 2GHz
Map Units	Feet
Latitude	39.78903
Longitude	-105.11784
Elevation	1595.32
Line 1 Azimuth	90.0

generic logo company

123 Lois Lane
Denver, CO 80201
USA
(01) 800-123-4567

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Introduction

A geophysical survey has been conducted with the purpose of characterizing the subsurface.

Methods

The GPR method is a standard technique for locating and characterizing a wide variety of subsurface objects. In this method, a GPR transceiver emits a pulse of electromagnetic energy that travels into the subsurface. This pulse partially reflects off of subsurface objects with different electrical properties than the surrounding material. The reflected pulses are received by the transceiver, combined with location information, and recorded on a tablet computer.

The location measuring system uses a combination of wheel odometry, inertial sensing, and global positioning system readings.

Data Collection Parameters

The GPR survey was collected on a grid of surveys lines that crossed the survey area in two directions. This provides the necessary data for creating three-dimensional subsurface images, as well as maps and diagrams of subsurface objects.

Recorded GPR data are processed to correct for: zero time correction, range gain, band-pass filtering, migration, and Hilbert transform. Finally, outlines of subsurface objects can be drawn using the GPR image as a guide.

Results

After standard processing as outlined above, the vertical section images, depth-slice images, and three-dimensional images can be generated. Iso-surfaces of subsurface objects can be plotted into three-dimensional images along with surface image overlays from photographs or Google Maps. DXF files of subsurface objects can be exported for integration into CAD models.

The survey results are shown in the following figures.

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Figure 1: Survey Grid

Figure 2: Cross Section

Conclusions

The images produced by the survey provide valuable subsurface information for structural analysis.

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Figure 9. An example report.

ESSentialUnderground has extensive report generation capabilities so that deliverables can be generated on-site without the need to return to the office to conduct data processing tasks. Report generation starts with a template Microsoft Word document that contains company logos and boilerplate report text. Then users use ESSentialUnderground to extract the views of the data and insert them to the report as desired. Finally the document can be edited with a word processor to provide final narratives and explanations (see Figure 9). ESS provides LibreOffice on the tablet PC for this task, but users are free to use their preferred office suite.

Table 1. The Four Quality Levels of Subsurface Utility Engineering.

Quality Level D	Information derived from existing records or oral recollections.
Quality Level C	Information obtained by surveying and plotting visible above-ground utility features and by using professional judgment in correlating this information to Quality Level D.
Quality Level B	Information obtained through the application of appropriate surface geophysical methods to determine the existence and approximate horizontal position of subsurface utilities.
Quality Level A	Precise horizontal and vertical location of utilities obtained by the actual exposure and subsequent measurement of subsurface utilities, usually at a specific point.

Practitioners of subsurface utility engineering (SUE) will start with an as-built CAD drawing to achieve Quality Level D (see Table 1). Then to arrive at Quality Level C, above ground surface features can be surveyed in using the GPS rover and added to the database on the tablet PC. Next the targets delineated by geophysical survey data along with the above ground features can be exported as a DXF file and added to the as-built drawing. If locations from potholing or other sensors were recorded by the GPS rover, this information can also be exported as a DXF layer. At this point all information from SUE Quality Level D through A are all available in the database, and can be viewed using ESSsentialUnderground, or combined in a CAD drawing to provide an updated as-built drawing. An example is shown below in Figure 10. The line colors and labels that were specified when picking the targets are used when creating the DXF file. ESS provides LibreCAD on the tablet PC for editing DXF files, but users are free to use their preferred CAD suite.

The tablet PC contains all software needed to generate reports and drawings; and these deliverables can be shared with engineers, managers, and owners using the cellular data link in the tablet PC. If the SUE engineer is in the office, the field technicians can send data, reports, and drawings to the engineer for final inspection and approval. This capability helps keeps the project moving forward by reducing the turnaround time for SUE surveying and reporting.

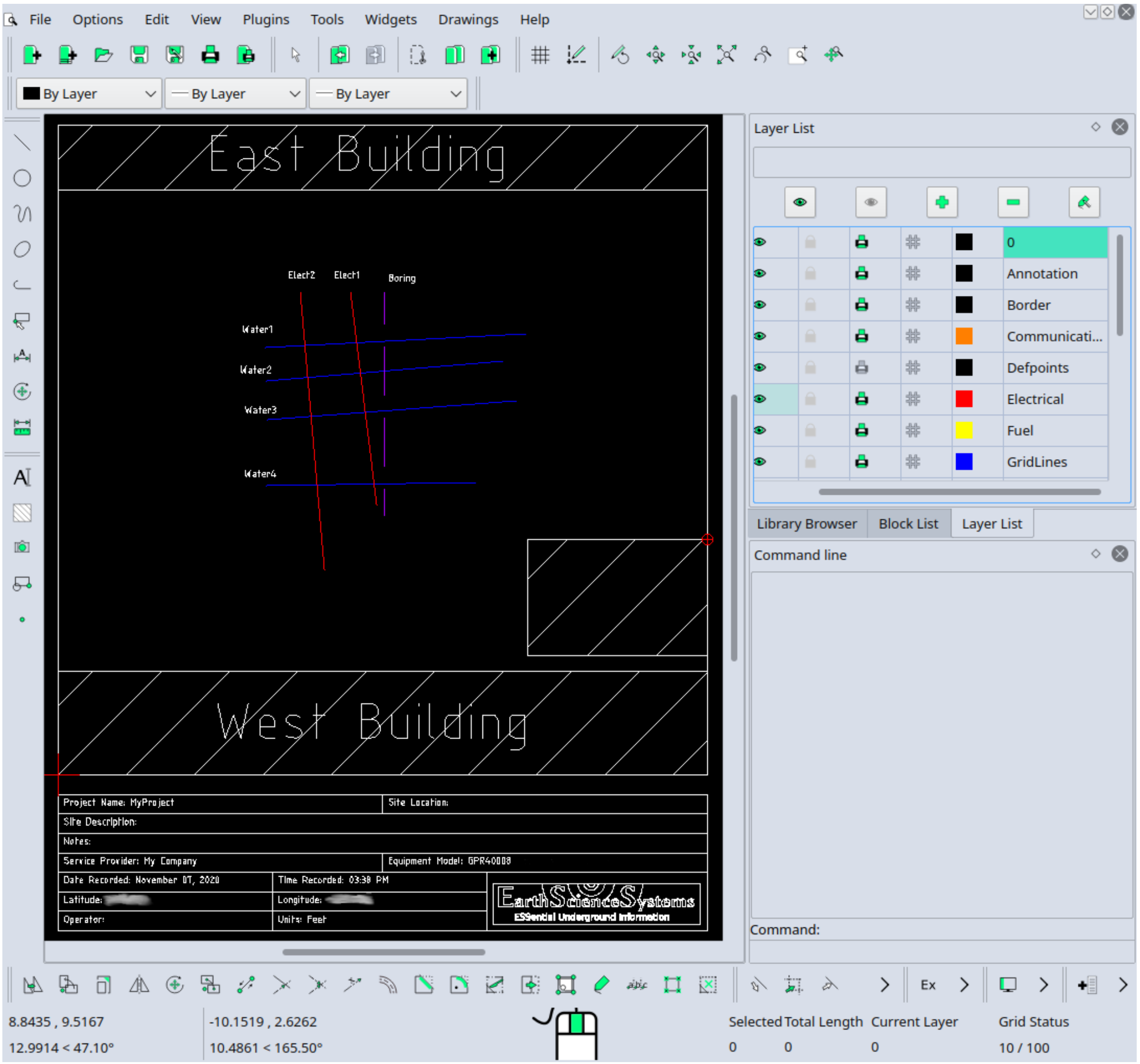

Figure 10. An example DXF output.

Discussion and Conclusions

This paper has provided an overview the capabilities of the Utility Scanner system and the features that streamline workflow to save time and money. With no cables or cart assembly required, surveys can be conducted quickly and efficiently. The real-time steering guidance system enables surveying on a grid without the time consuming processes of marking a survey grid on the ground.

With the Utility Scanner system technicians and engineers can quickly conduct accurate utility markouts and/or provide the crucial deliverable reports and CAD drawings that are needed to keep projects on time and on budget. The ESSentialUnderground application enables users to conduct a thorough analysis of the survey data in either the field or the office. The application helps create written reports with images and figures generated from the survey data that depict depth slices, cross sections, surface overlays, and 3D plotting. The system supports the workflow of subsurface utility engineering, and provides a database for recording all SUE information from quality level D – A. Reports and CAD drawings can be generated according to SUE recommendations. A cellular data link allows users to share data, reports, and CAD drawings with project managers and owners while on-site using the cellular data link in the tablet PC.

Appendix

GPR scanners send electromagnetic waves into the ground and detect waves that have reflected off of subsurface objects. The ability of GPR to detect a subsurface object depends on several factors, including electrical contrast, size, depth, antenna frequency, and soil type. Objects with electrical properties that contrast with the surrounding soil are easier to detect, with metal pipes creating a brighter reflection than plastic pipes. Large targets are also easier to detect, and pipes with a diameter twenty times less than their depth can be difficult to detect. Lower frequency antennas can detect deeper targets but with less resolution than high frequency antennas. The 350 MHz antennas can detect objects to a depth of about 20 feet (7 meters) in 'good' soil conditions while the 750 MHz can reach depths of about 10 feet (3 meters). Soils with electrical conductivity greater than 30 mS/m are considered 'good' soils while soils with conductivity is less than 10 S/m are considered 'poor'. In 'poor' soils the investigation depth of GPR can be reduced by a factor of 5-8. The NRCS has compiled a series of maps that indicate the suitability of soils for the use of GPR , and Figure A1 shows the suitability for the conterminous United States.

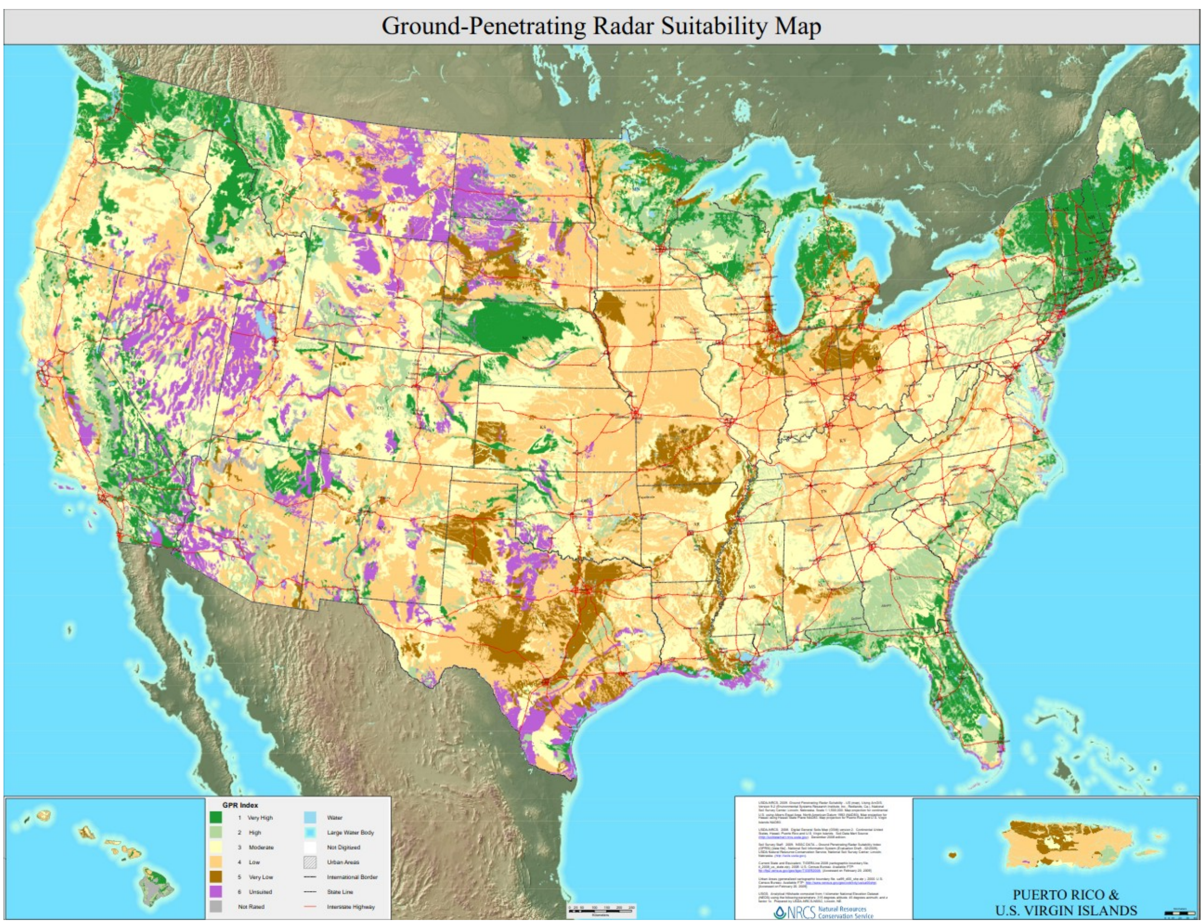

Figure A1. GPR suitability map from NRCS.

References

ASCE standard, CI/ASCE 38-02, Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data, American Society of Civil Engineers, http://ascelibrary.org/action/showPublications?pubType=standards&category=40116359&expand=40116359.

U.S. Department of Agriculture's Natural Resource Conservation Service, 2009, Ground-Penetrating Radar Soil Suitability Maps, https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053622.