## Ground Penetrating Radar

Ground penetrating radar reflection profiles are created by the reflection of radar energy from interfaces that are created by differences in the dielectric constant between two types of material (e.g. rock and air), or differences in water saturation levels within similar materials. The larger the differences in dielectric between materials, the brighter the radar reflection return will be. These reflection profiles are interpreted based on knowledge of the local geology, amount of recent rainfall in the area of interest, and other factors specific to the study. Depth of investigation and resolution are determined by several factors including, but not limited to, the center frequency of the antenna, soil moisture, and rock type.

A two-dimensional radar reflection profile can provide information on the subsurface as a vertical "slice" between 2 to 5 meters deep based on the soil type and moisture content. A three-dimensional survey can provide a map view at selected depths between the surface and depth of penetration of the radar signal and a three-dimensional rendering of reflection intensity (an isosurface) of the subsurface.

A Geological Survey Systems Incorporated (GSSi), D350HS 350 MHz, hyperstacking antenna and SIR-4000 control unit attached to a four-wheel cart will be used to image the top two to three meters of the subsurface. An integrated Juniper Systems Geode sub-meter global positioning system is used to georeference the radar profiles collected. Radar controller settings and an odometer calibration for the GPR are typically determined during an onsite initialization and recorded for the report prior to collecting the radar reflection profiles. The software used for post data processing is RADAN-7.

## Workflow and Description of Work

**Field Preparation:** Field prep consists of analysis of satellite imagery to determine grid layout and expected obstacles, survey planning, GPS data upload, and inventory and packing of equipment for transport. This process takes approximately 1 day.

**Day of Arrival:** The first day of the project will be a travel day and, if time permits, ground truth of the satellite photos, area ground level photographs, and grid survey and set-up. Otherwise these activities will be completed the morning of the following day.

**2D Surveys** (**Figure 1**): On average, up to thirty 50-meter long reflection profiles can be collected per day. These reflection profiles are typically used for utility locating and marking in the field, location of areas of interest for further study by 3D surveys, and other projects where a plan-view map of the area of interest is not needed. 2D surveys do not typically need a lot of set up time and can usually be done "on the fly".

**3D Surveys** (**Figure 2**): A maximum of a half-an acre can be surveyed per day under ideal conditions (perfectly flat, no vegetation, obstacles, or debris, square or rectangular area). 3D GPR surveys consist of orthogonal grids up to 50 X 50 meters with each line separated by between 0.25 and 1 meter, depending on the resolution required by the client. The grids, as much as possible based on the size and

site conditions, are oriented north – south with an "origin" at the southwest corner. These surveys are typically used to map out archaeological sites, produce utilities maps, and other projects where a map view and depth to target are required. 3D surveys will often need to be pre-planned prior to getting to the field. Dimensions of the survey, number of grid lines, and obstacles within the survey area all determine the amount of time the survey will take, which needs to be planned for. Upon arrival at the project site, after any safety and site briefs, a site inspection will occur which included photographs and notes of the obstacles in the area, which are needed during the interpretation phase. Once this is complete, the survey grid will be set up, the radar will be calibrated for the site conditions, and the survey will commence. The survey itself isn't much different than mowing the lawn and may even look as if that's what we're doing as we follow the grid lines first in a west – east direction, then in a south – north direction. Once the survey is complete, the data is downloaded to a USB stick for later data processing and interpretation.

**Final Day:** The last day of the survey is typically used for clean-up of the area if required, gear stowage, and travel.

**Interpretation and Report:** Upon return to the office, the data is downloaded from the field computer and uploaded to the data processing program. Data processing for 2D lines takes approximately an hour per line and for a 3D grid can take approximately two to four hours depending on the grid size and any complicating factors such as an obstacle that had to be avoided within the survey grid. Interpretation can take up to three full days depending on the complexity of the area and the amount of data collected. Once an interpretation is completed, a report of the study is written which includes an executive summary, description of the study area, description of the survey, results, photos, maps, cross-sections, and recommendations. The report generally takes a day to two days and will be provided to the customer in either a .doc or .pdf format, whichever is preferred, within 10 business days of the completion of the field work. An example report is available on request.

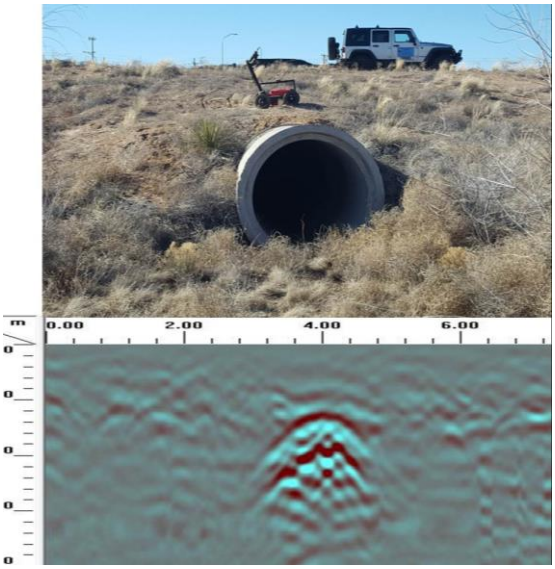


**Figure 1: 2D Survey Example.**

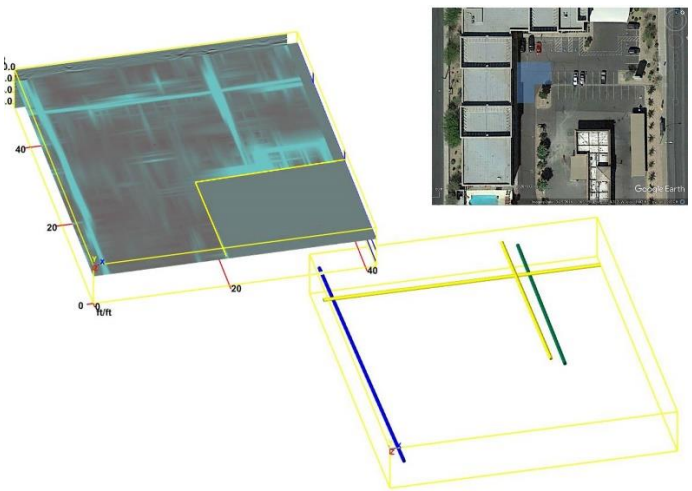


**Figure 2: 3D Survey Example.**