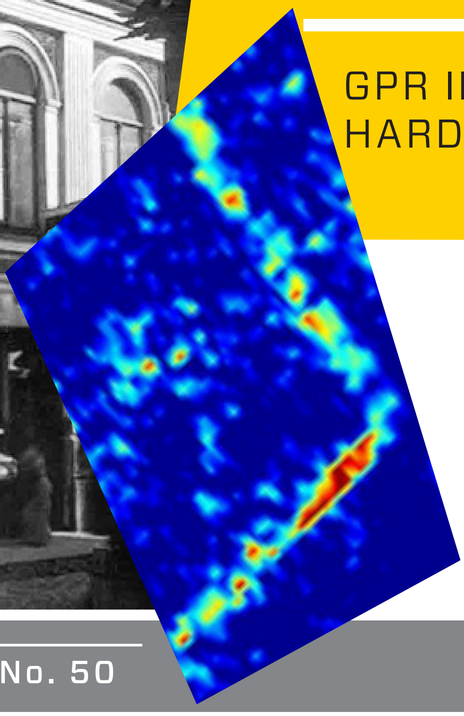

# SUBSURFACE VIEWS

GPR INNOVATIONS
HARDWARE AND SOFTWARE

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## In this issue



## An Ancient Synagogue Lost and Found

Sixty Years after the Great Synagogue and Shulhoyf of Vilna (Vilnius) was razed, a team of international scientists is uncovering precious history with the assistance of pulseEKKO Ground Penetrating Radar (GPR).

The city of Vilnius has been recognized as an important cultural and scientific hub as far back as the mid-1500's. By the end of the 17th century, Vilnius had a reputation unrivalled in Europe for having the largest number of churches of different faiths. One such establishment was the Great Synagogue of Vilna. Over time, the Great Synagogue became surrounded with other buildings within the labyrinth-like Shulhoyf, a complex of twelve synagogues and other communal institutions. As World War II ravaged Europe, the Great Synagogue was looted and burned, leaving the building empty and absent its former glory. In 1957, the Soviet Union, then in control of Lithuania, demolished the structure to provide space for a boulevard, and years later built an elementary school. Researchers believe the Great Synagogue was demolished by imploding it in on itself with nearly all the collapsed structure being left on site.

In 2015 a group of international scientists, headed by Dr. Jon Seligman of Israel Antiquities Authority were commissioned to research, uncover and preserve the remnants of the Great Synagogue of Vilna. After some preliminary excavations, it was decided to use Ground Penetrating Radar (GPR) to scan the site. GPR could provide an economical way to non-destructively scan the area to identify where there was a higher likelihood of finding intact sections of the foundation. Dr. Harry Jol of the Department of Geography and Anthropology from the University of Wisconsin-Eau Claire was chosen to be the GPR project leader due to his extensive experience with the technology.

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The initial work done with a pulseEKKO GPR system took place during the summer of 2015 (Figure 1). Six grids with a line spacing of 0.25m were collected, totaling over 1600 square meters (Figure 2). The 225 MHz antenna provided an excellent view penetrating to over 3 meters into the subsurface (Figure 3) and gave indications of where the ancient complex might be intact. Looking at archaeological GPR data, well-defined circles, squares, and lines in depth slice maps are strong indicators of human interaction with the landscape. It is also important to review cross-section data because features like ancient floors and walls can often be seen more clearly (Figure 4).

In 2016, excavations were conducted based on the information from the pulseEKKO GPR surveys. These excavations allowed for the exact nature of the GPR responses to be determined. Excavation began by removing the top organic fill. Soon after, the top of some walls from a number of individual rooms became visible. Upon further analysis, it was determined that the walls were those of the bath house, a key part of the synagogue complex. (Figure 5 shows a number of the findings.)

**Figure 1:** Data collection with the pulseEKKO system at the school grounds, site of the ancient Synagogue

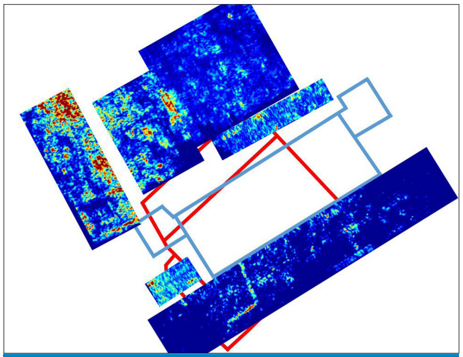

**Figure 2:** Grids superimposed on outlines of the new school and the ancient Synagogue.

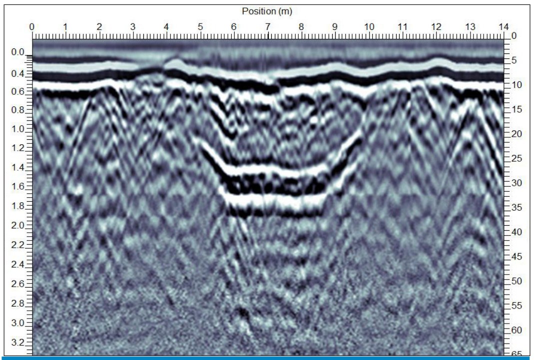


**Figure 3:** Cross-section view of data showing subsurface features.

Due to the success of the GPR surveys, two more grids were surveyed in the summer of 2016. Excavations are planned for the summer of 2017 to further investigate the geophysical findings. pulseEKKO GPR systems are favored by archaeologists for their ability to see deep into the subsurface while giving excellent visualization of ruins, cavities, graves and buried ancient roads. For the Great Synagogue of Vilna, this means that while the structure was flattened, it was not entirely erased and will continue to be a part of Vilnius' great cultural heritage.

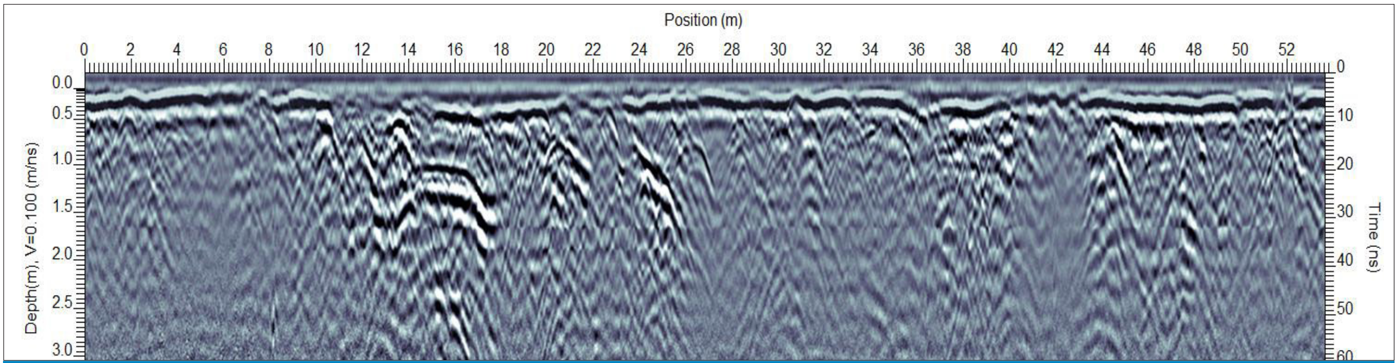


**Figure 4:** Cross-section view of data showing GPR responses that are interpreted as ancient walls and floors.

**Figure 5: Areas that showed promise in the GPR results were excavated in 2016 to show a number of individual rooms. (Source: http://www.seligman.org.il/vilna_synagogue_2016.html)**

Special Thanks to Thomas Wavrin in cooperation with Harry Jol PhD and www.seligman.org.il

# Utility-Locating with GPR? - Get the most out of your data!

GPR is now a complementary tool to EM when locating buried utilities. Unlike active EM methods where an individual utility is excited, GPR sees any buried feature that differs from its surroundings which can result in many targets being observed. This article focuses on getting the most out of your utility data in two common but challenging situations:

**Challenge #1: Too Many Targets:** When there are many buried targets present, sorting out the identity of responses at different depths, oriented in different directions, and separating utilities from other targets (such as rocks, tree roots, etc) can be challenging. Figure 1 shows an example of a complex multi-target GPR cross section.

**Challenge #2: Weak Targets:** Targets of differing composition, at varying depths in differing soil conditions, result in highly variable on GPR reflection response amplitudes. As a result, the sought after buried utility may not be the strongest most prominent response in the GPR cross section. Non-metallic pipes and conduits often produce weak responses since their composition represents a small contrast to the host material properties. In many instances a desired targets may be overlooked if the response is weak as illustrated in Figure 2. Let's look at some strategies to help to get the most from your data in these situations or a combination of these situations.

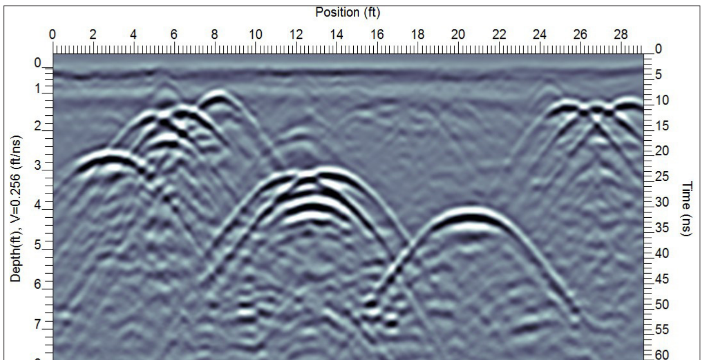


**Figure 1:** Multiple targets create numerous hyperbolic responses making GPR data challenging to interpret.

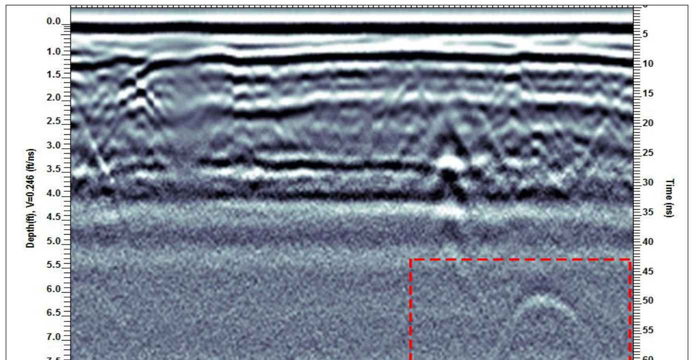


**Figure 2:** A weak response from a deeply buried utility (boxed in the above cross-section) can often be missed if only strong responses are noted.

**Interpretations & MapView** When locating utilities, existing plan map records often provide initial guidance as to what to expect on site . Further, standard practice requires creation of site sketch maps of observed features and targets prior to leaving the locate area MapView is an integrated display feature that enables GPR data to be viewed in a similar manner on site. During data collection, the operator simply adds color-coded dots (interpretations) on all responses (normally each hyperbola) by touching the screen at the top of the hyperbola (Figure 3). Little discrimination is needed in this first step, every potential target can be marked. Attention should be given to the pattern, direction and spacing of the GPR data collection path to ensure that the area is properly covered.

At any time during data collection, selecting MapView will show the entire area surveyed with all the interpretations clearly marked on the screen. Since buried utilities are normally long linear features, examining MapView for sequences of linear dots is a powerful methods for differentiating utilities from localized soil features. In the example below in Figure 3, the operator decided to mark the deepest response blue, the middle depth target response pink, and shallow targets yellow. When displayed in MapView, the blue and the pink interpretations clearly form lines suggesting that these are indeed the sought after utilities(Figure 4). The yellow interpretations appear to be single point targets.

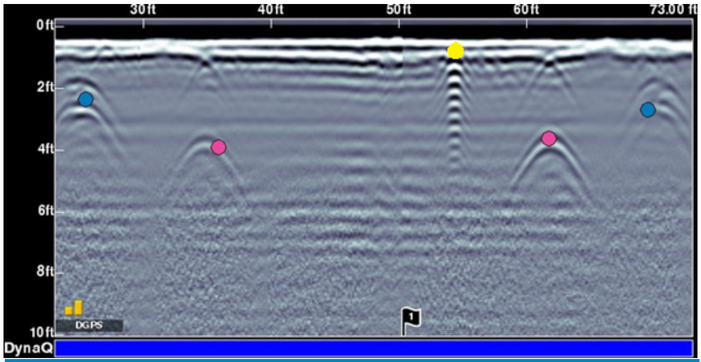


**Figure 3:** User marks interpretations on the screen while collecting data. (Pink – deep response, Blue - medium, Yellow - shallow)

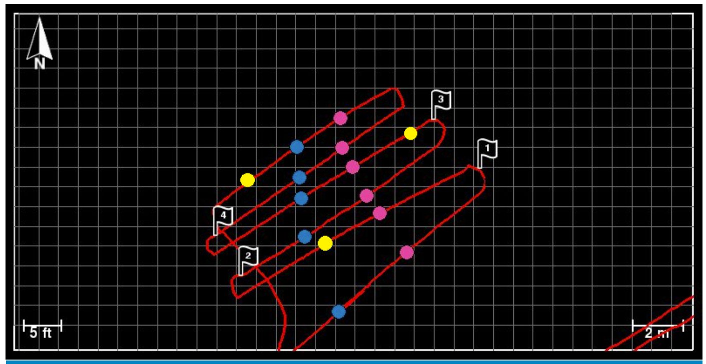


**Figure 4:** MapView showing linear utilites (blue and pink) and point targets (yellow).

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**Depth Slicing** produces a 2D map image of GPR data at varying depths based on signal amplitude. When locating in an area with many utilities, depth slicing is a powerful way of looking for linear subsurface objects likely to be utilities. Sensors & Software GPR systems guide the user through setup, grid data collection, data processing and display depth slices right in the field (Figure 5). If your GPR has an accurate GPS (< 1m) attached and you are working in an open area with lots of sky visible, you can also generate a depth slice from line collection using the GPS for positioning the GPR data. Cover the area by walking back and forth with the GPR system to collect closely spaced lines. The data is then processed into depth slices using the new SliceView-Lines capability of the EKKO_Project V5 PC software (Figure 6). Depth slicing aids significantly with Challenge #1, as it helps to visualize the targets and highlight linear features like utilities.

**Figure 5:** Collecting a grid allows data to be processed into depth slices to reveal utilities at different depths. This helps in mapping utilities at complex sites.

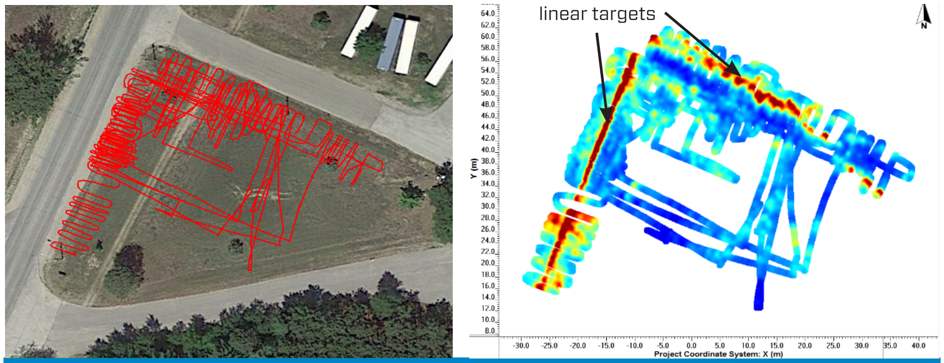


**Figure 6:** Collecting GPR data in a pseudo-grid, using an accurate GPS for positioning (left) is another way to generate depth slices that reveal utilities at different depths (right).

**Interpretations overlaid on Depth Slices:** Depth slicing is complimentary to MapViews of user selected targets. MapView allows the operator to use experience and knowledge to highlight even weak responses that may not be strongly presented in a depth slice. Combining both approaches is definitely beneficial in complex areas. In the situation where target responses in the GPR cross section are visible to the eye but too weak to appear in a depth slice (such as depicted in Figure 7, red dot), it is possible to map the weak hyperbolas by adding user selected point interpretations to the weak responsess directly in the field or in EKKO_Project PC software. There are different ways to choose what color of interpretation to put on a hyperbola. For example a user could choose to color an interpretation based on the utility marking color code, for example using blue to mark a target believed to be potable water. Another option would be to mark based on depth of the utility; shallow green, medium depth red, deep blue (figure 8, left). One could also mark based on how strong the hyperbolic response is. The options are endless; however, the user must choose a convention for the project and stick with it for this method to be effective.

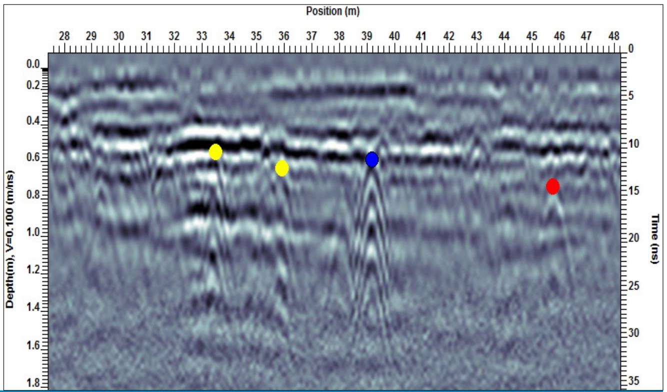


**Figure 7:** Add point interpretations to the GPR lines. Once displayed in MapView, linear utility features are revealed.

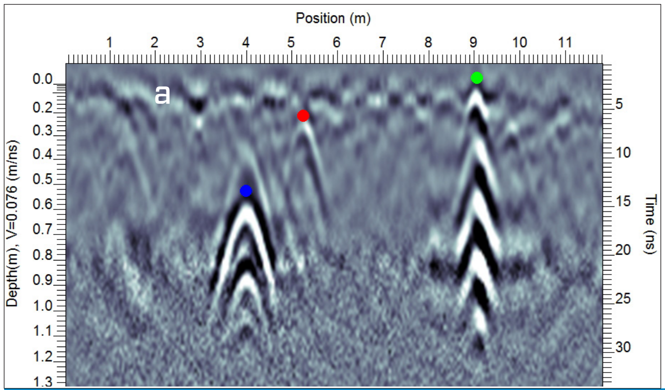


**Figure 8:** Add point interpretations to interesting features like ringing metal responses (green dot)

After adding the point interpretations, display MapView in the EKKO_Project PC software and look at the patterns the interpretations make (Figures 9 and 10). Some point interpretations will line up, indicating a linear object, probably a utility. Some interpretations will not line up with any others; these are from point targets and are usually not of interest to utility locators. Adding interpretations and superimposing them on your depth slices is the best way to confirm that the strong linear features that appear in the depth slices really are a result of strong hyperbolas (Figure 9) and, more importantly, to detect utilities from weak hyperbolas that do not appear clearly in depth slices (Figure 10).Depth slices and interpretations are two key methods to help unravel complex sites and reveal weak responses from utilities that are often missed. Safety and damage prevention is of utmost importance to everyone; use all the weapons in your arsenal to resolve the challenging utility locating problems you face.

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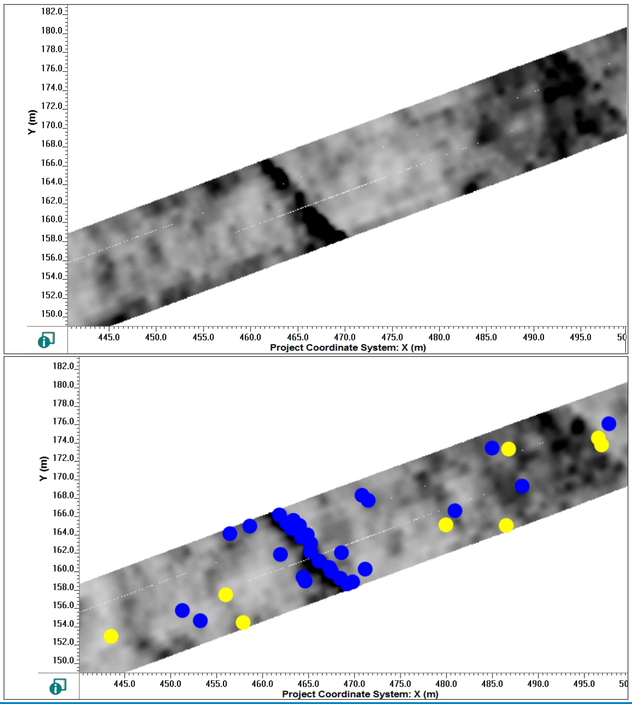


**Figure 9:** Depth slice showing the strong linear response from a utility (top) is confirmed after adding interpretations (bottom).

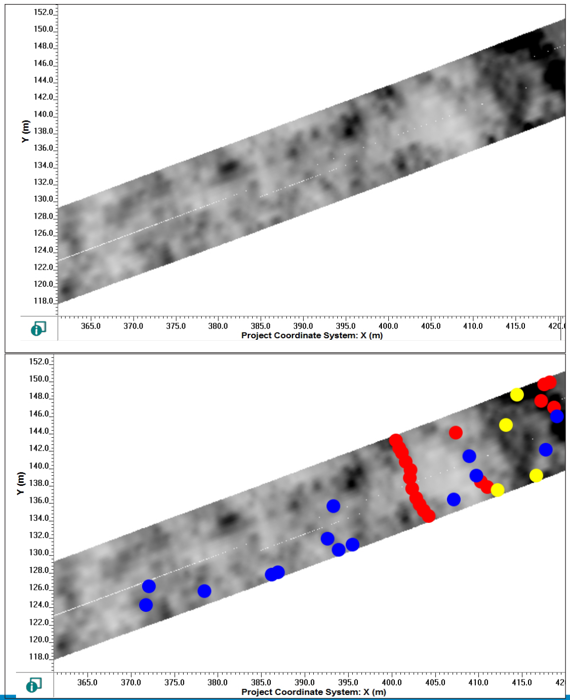


**Figure 10:** Depth slice (top) does not show any obvious linear utilities but after adding interpretations to all hyperbolas, including very weak ones, the interpretations reveal a utility that could easily have been missed (bottom).

# **TIPS:** Using GPS elevation with GPR

When we think about GPS, we usually only think about our lateral position on the Earth, or, in other words, our XY position. But GPS also provides Z, your elevation. If you are collecting GPR data with GPS, the elevation is pretty much free information. When GPR data with GPS files are opened in the EKKO_Project software, the software automatically adds GPS position values for every GPR trace collected, including the elevation.

GPR lines are typically plotted with a depth axis but when elevation information is available, the data can be plotted with an elevation axis simply by switching the vertical axis from depth to elevation in the LineView Module> View Settings > Axes menu option ( Figure 1):

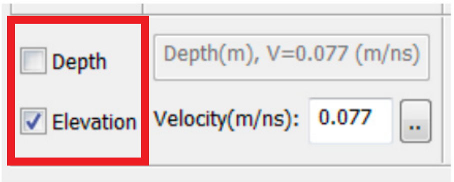


**Figure 1**

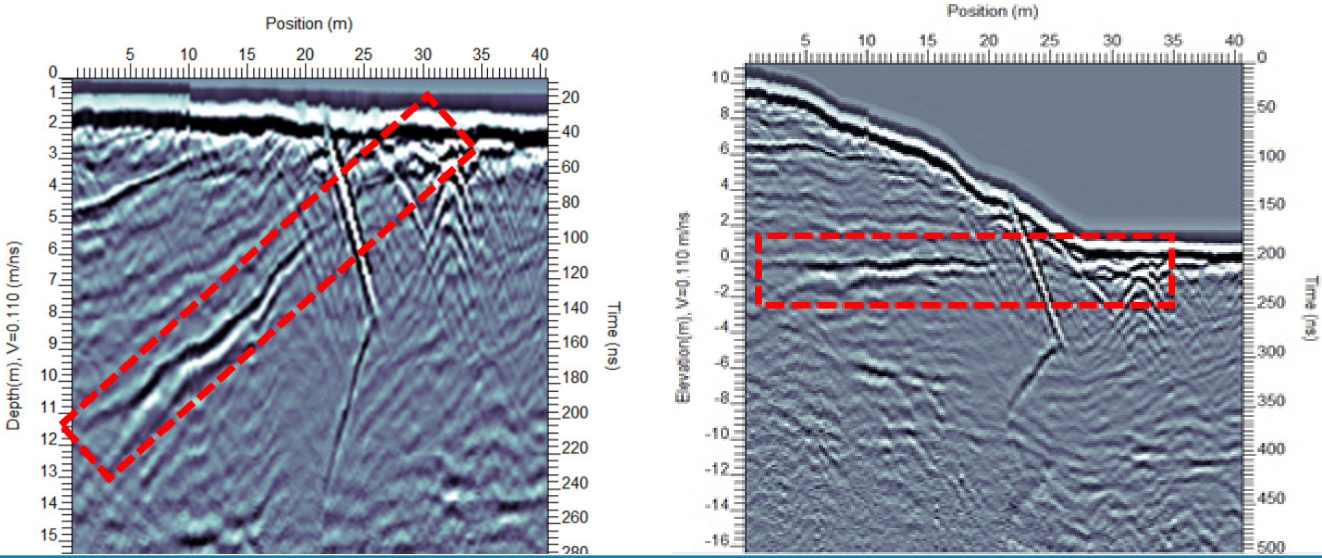


**Figure 2:** GPR line plotted with the vertical axis in depth (left) and elevation (right) shows that the sloping reflector in the depth plot (red dashed box) is flat-lying in the elevation plot.

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Plotting data with elevation can assist with data interpretation. For example, the left side of Figure 2 shows a GPR line with a boundary that appears to be dipping at an angle from the surface. After switching to an elevation axis, we see that the dipping boundary is actually flat and it is the surface that is sloping.

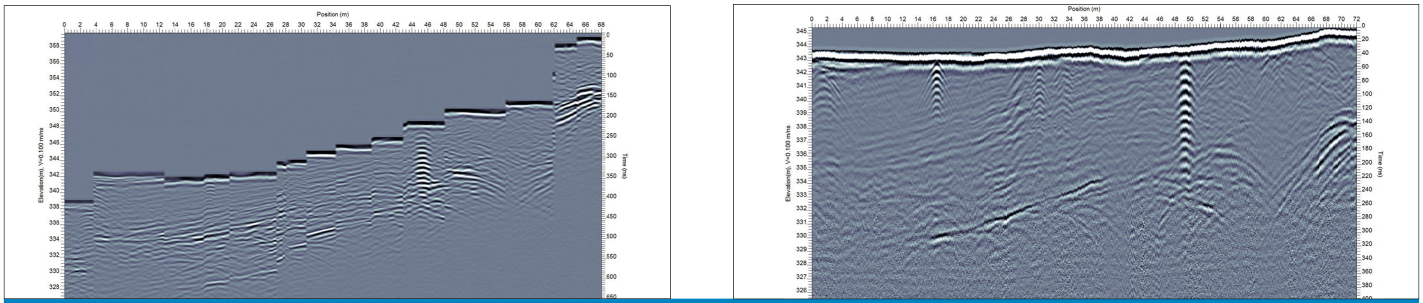
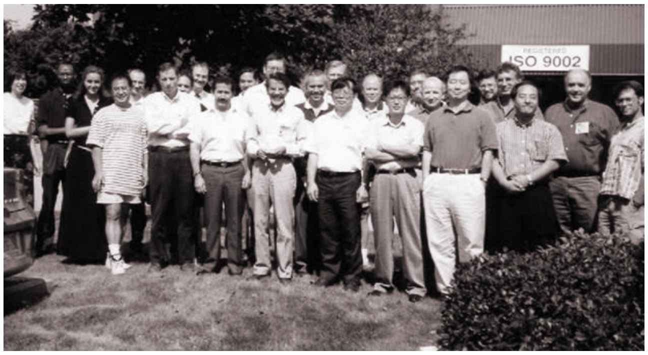


**Figure 3:** GPR lines plotted with elevation values from a higher performance GPS (right) compared with a more rudimentary GPS device (left).

Like most things in life, you need to be careful of the quality of free things. In general, the GPS Z value is less accurate than the XY positions. Historically the error in Z is often 4 to 5 times larger than the error in XY values. To get an accurate elevation value, you generally need a more advanced GPS unit. Figure 3 shows the results of elevation corrections of GPR data collected with GPSs of different accuracies. As the plots in Figure 3 show, it is important to ensure the accuracy of the GPS positioning is sufficient for your survey requirements. Elevation information, when accurate, helps with data interpretation reducing topographic data distortions and by providing better lateral spatial positioning of the targets. Best of all, this capability in the EKKO_Project software is available with no extra effort.

## Celebrating our 20th anniversary teaching the 3-Day GPR course.




**July 1998**

**June 2017**

Sensors & Software is proud to celebrate our 20th anniversary teaching the 3-Day GPR course. The course covered the basic principles of GPR instrumentation, survey design, data processing, analysis, and interpretation. We look forward to welcoming you to one of our many courses.

## Upcoming Courses

Subsurface Imaging with GPR course - September 11, 2017. Mississauga, ON, Canada

Concrete Scanning with GPR course - September 12, 2017. Mississauga, ON, Canada

## Upcoming Tradeshows

International Construction & Utility Equipment Exposition (ICUEE)
October 3-5, 2017, Louisville, KY, USA

Geological Society of America (GSA)
October 22-25, 2017, Denver, Colorado, USA

American Geophysical Union (AGU)
December 11-15, 2017, New Orleans, LA, USA

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