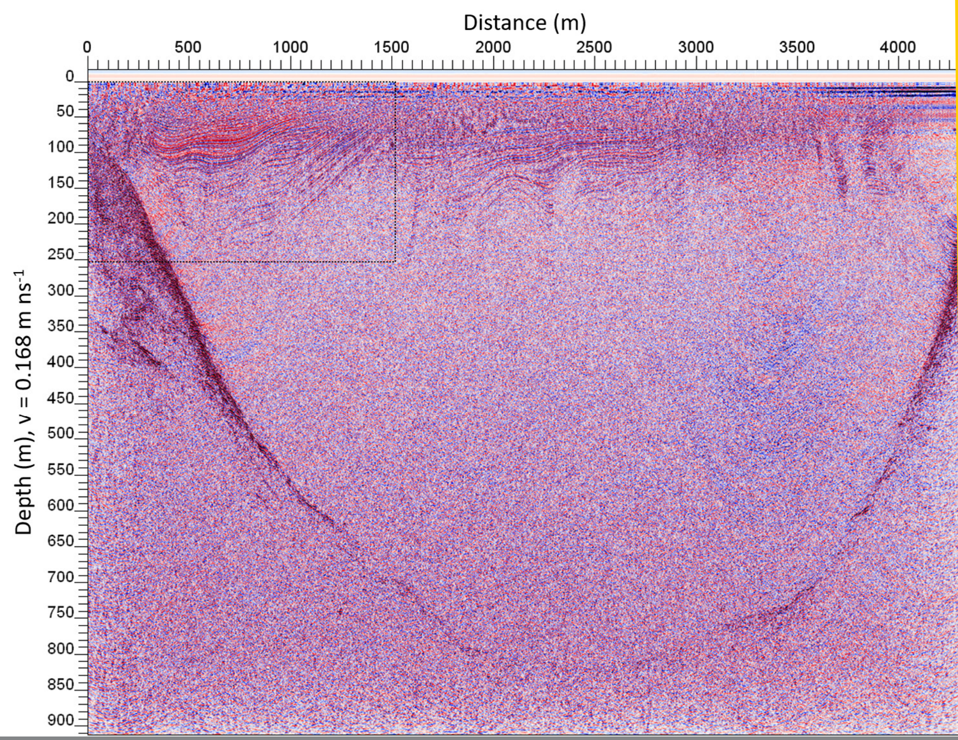



# SUBSURFACE VIEWS

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## In this issue



*Sensors & Software loves to share customer stories in our newsletter! We find that customer stories are always popular with our newsletter readers. This newsletter contains two articles kindly provided to us from customers. The details and descriptions are those of the authors and Sensors & Software has not made any edits except for typographical errors. If you have a GPR topic of interest to share, please contact us and submit your suggestions.*

## Deep GPR survey of the cold ice in Antarctica

***Written by Dr. Mette Kusk-Gillespie***

Although I am now a more seasoned geophysicist, the data I helped collect in 2008 during my PhD studies at the University of Canterbury in New Zealand still holds an honorary place in my office at the Western Norway University of Applied Sciences. It reminds me of three weeks spent on the magnificent Darwin and Hatherton glaciers in Antarctica (**Figure 1**) with a 25 MHz Sensors & Software pulseEKKO® GPR system (**Figure 2**), visualising internal layers in snow, firn and ice, and mapping deep glacier beds.

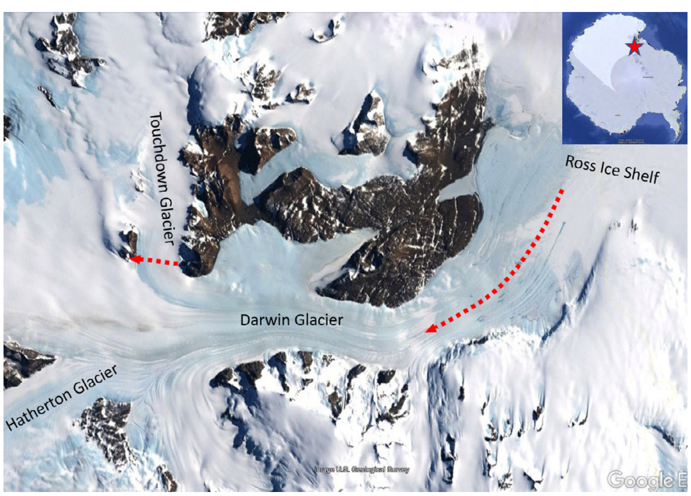


**Figure 1:** GPR survey area in Antarctica, near the Darwin and Hatherton glaciers. The paths of the 4500-meter-long GPR line across the Touchdown Glacier shown in Figure 3 and the 15,000-meter-long-line shown in Figure 4 are indicated.

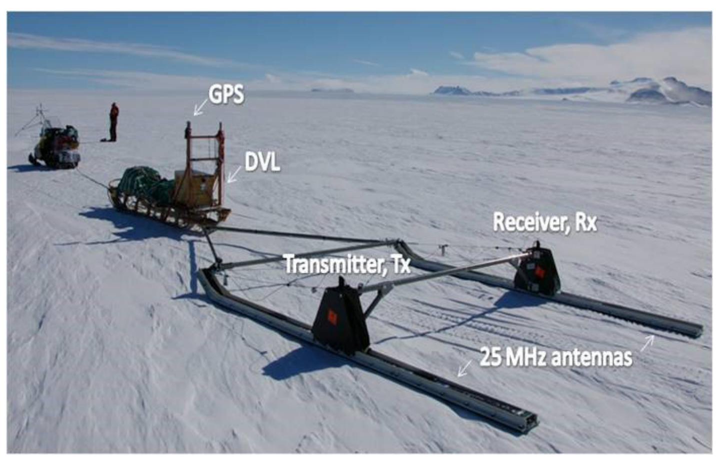


**Figure 2:** 25 MHz pulseEKKO® GPR setup using a custom-made all-plastic sledge developed at the University of Canterbury. We had temperatures below minus 30°C and rattled across large blue ice areas, but the sledge held together. The wooden Nansen sledge was newly restored and made for a fantastic GPR operator sledge.

***continued on page 2***

One of the first GPR profiles we collected during our 2008 Antarctic fieldwork is the 4500-meter-long line shown in Figure 3. The profile crosses the Touchdown Glacier and illustrates well the high degree of detail that can be achieved by a 25 MHz antenna setup. Strong shallow internal layer reflections in snow- and firn-covered glaciers predominantly relate to density differences caused by changing atmospheric conditions during precipitation events. Below a certain depth, firn compresses to form ice with a roughly constant density, and internal layer reflections are instead largely related to layers of volcanic dust originally deposited on the glacier surface. Along the Touchdown Glacier profile, the surface changes from snow-covered conditions to exposed blue ice at the very end of the profile. The profile consequently takes us from a region where annual snow settles and compresses to form firn and eventually ice, to a region where snow and ice is removed from the surface by strong katabatic winds. This change is observed clearly in the data where near-surface internal layers are absent or weaker, near the end of the profile (**Figure 3a**), while the general across-glacier decrease in annual snow accumulation results in the dipping of near-surface layers towards the start of the profile (**Figure 3b**). At depth, layer reflections are largely absent, and the ice appears reflection free. Multiple diffraction hyperbolas within the glacier at the very start of the profile (**Figure 3b**) can be explained by the presence of buried rockfall debris from nearby mountains.

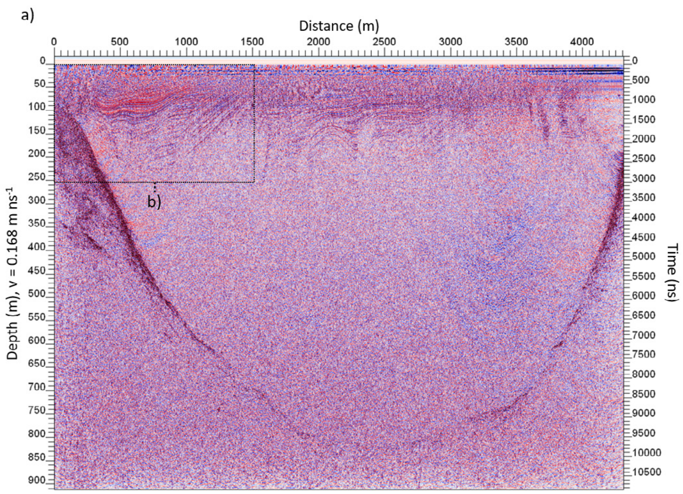


**Figure 3a:** Fully processed profile, collected with a pulseEKKO® GPR system and 25 MHz center frequency antennas, crossing the Touchdown Glacier. The profile was processed in EKKO_View Deluxe (predecessor to EKKO_Project) using filters: 1) rubberbanding to a 2 m step size using GPS data, 2) time zero correction, 3) Dewow, 4) bandpass filter (0/5/40/60 MHz), 5) gain (AGC) and 6) migration.

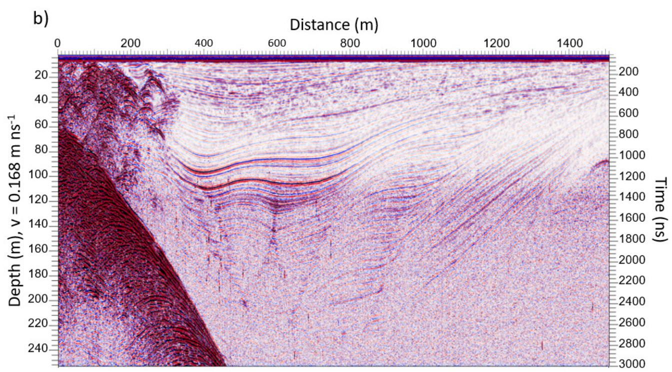


**Figure 3b:** Zoom in on the data in the black rectangle box in a) showing near-surface details. This profile was not migrated.

While we did not observe this in the DVL display during data collection, the fully processed profile shows that the Touchdown Glacier is more than 850 m deep in the central parts of the radargram (**Figure 3a**). The apparent lack of basal reflections below 400 m of ice during data collection led to my most memorable interaction with any customer support, and I have had many! You rarely get a second chance at data collection in Antarctica, and we wanted to make sure the extensive rattling of the antennas while driving for long periods on blue ice was not affecting the data collection. I therefore contacted Sensors & Software via a poor satellite phone connection and set out to explain the situation to them. After initially being told to send the GPR to the nearest distributor for a check-up, I got in contact with an extremely resourceful technician. Following his advice, all antenna connections were successfully cleaned and improved using a toolset of whisky, cotton sticks, chocolate foil wrappings and silver duct tape!

Maybe it was because of these improvements that we managed to penetrate to an astonishing ice thickness of 1125 m on one of our last days in the field. This is the profile which is hanging on my office door, and it was collected travelling up glacier from where the ice flows into the floating Ross Ice Shelf (**Figure 4**). It is a fascinating profile which images the basal condition of grounding zones at an extraordinary level of detail. The dielectric contrast between ice and saltwater makes for a very strong basal reflection at the start of the profile, and the floating ice base is characterised by smooth near-horizontal steps that increase in depth towards the grounding line. Near the grounding line, the increased abundance of diffraction hyperbolas illustrates the presence of basal crevasses as the ice flexes in response to tidal changes. The ice base reflection is eventually obscured by the hyperbolas only to reappear at the end of the profile as a weak reflection at about 1125 m below the glacier surface. At this location we believe the glacier is grounded and resting on bedrock.

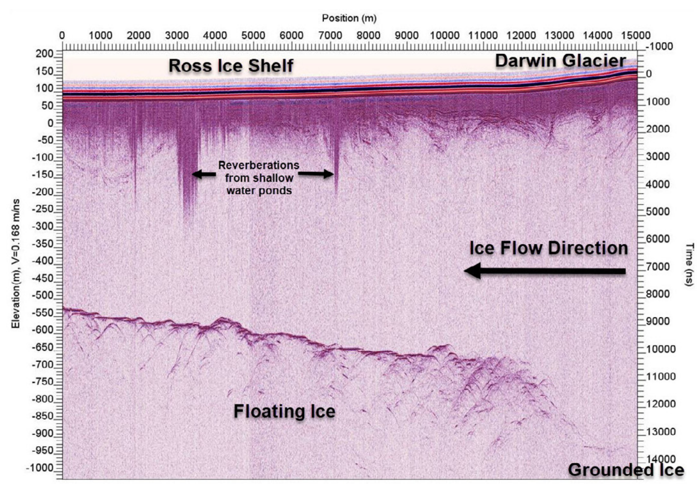


**Figure 4:** Centreline profile (see path on Figure 1) illustrating the change from floating to grounded ice conditions as we travelled from the Ross Ice Shelf and onto the Darwin Glacier outlet. The profile was processed in EKKO_View Deluxe using filters: 1) rubberbanding to a 2 m step size using GPS data, 2) time zero correction, 3) Dewow, 4) bandpass filter (0/5/40/60 MHz), 5) gain (AGC) and 6) Elevation correction.

*continued on page 3*

Increased basal melting by relatively warm ocean waters and a downstream widening of the valley shape explains the dramatic 250 m ice thickness change which occurs in the region obscured by diffraction hyperbolas. Nearer the glacier surface the radargram is characterised by undulating internal layer reflections and large cone-shaped zones of high reflectivity extending from the glacier surface to an apparent depth of up to 400 m. These zones relate to reverberation of the GPR signal in shallow sub-surface water ponds that sometimes develop in blue ice areas. We had the misfortune of verifying this, as one of the snow scooters broke through the surface ice layer. It sounds more dramatic than it was, and as a geophysicist I highly appreciate the effort, although unintentional, to supplement GPR datasets with direct observations!

I have very fond memories of this field work in Antarctica as I now spend most of my time working on equally beautiful but "warm" Norwegian glaciers, where scattering of the GPR signal by internal water bodies significantly limits the level of detail and the GPR penetration depth. For example, on a recent fieldtrip to Jostedalsbreen Glacier, the 25 MHz GPR setup gave us a penetration depth generally well below 200 m. While GPR is still the preferred method for mapping warm glaciers, the data shown here clearly indicates that cold glaciers are really the ideal medium for GPR surveys.

*For more information about the survey and the results, see the following publication:*

*Gillespie M.K., Lawson W., Rack W., Anderson B., Blankenship D.D., Young D.A. and Holt J.W. (2017), Geometry and ice dynamics of the Darwin–Hatherton glacial system, Transantarctic Mountains, Journal of Glaciology, 63, 959-972.*

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## Forensic use of ground penetrating radar: Teaching

***Written by PhD. Lerah Sutton, PhD***

Welcome back, readers, to the next segment of the forensic use of ground penetrating radar! In our last segment (https://www.sensoft.ca/blog/forensic-use-of-ground-penetrating-radar-casework/), we explained how GPR can be a powerful tool for investigators to use as a sort of "presumptive test" when attempting to locate a clandestine grave or other item buried beneath the soil surface. However, for this tool to be effective within an investigation, the investigator must first understand how to use it and in what circumstances it can and should be used. When approaching the concept of teaching any subject – particularly something as specialized as GPR – it's important to first understand that not everyone learns the same way; some people learn best by seeing/hearing (such as reading an article or watching a lecture/webinar) and some people learn by doing (such as workshops or hands-on demonstrations). That is why it is so critical to take a well-rounded approach to teaching the techniques and applications of GPR within the forensic sciences.

With the advancement of technology, much of the traditional lecture-based format of education has transitioned to an online, distance education format either in the form of live webinars that utilize real-time instructors or text-based, self-paced training courses. The resources available to help teach investigators the best way to use and apply GPR to medicolegal death investigations are available in various formats. A great example are the webinars (https://www.sensoft.ca/georadar/webinars/) and SensoftU online courses offered by Sensors & Software which are hosted live and available on-demand (http://www.SensoftU.com). These trainings use a combination of auditory and visual education, including filmed demonstrations of the GPR principles and practices they are teaching and offer easy access to various GPR data interpretation and processing topics. Other online-learning platforms present the concepts of GPR application to death scenes in a more traditional academic setting including the UF Master's Degree in Forensic Medicine which discusses concepts of clandestine grave detection based on geophysics within a graduate-level course.

However, even once theoretical concepts are presented in a lecture-based format, it is very helpful to be able to apply the concepts to a hands-on practical demonstration. This is why field demonstrations, and in-person workshops are a crucial component of providing a comprehensive learning environment to ensure that investigators understand all aspects of the technology they're using. Simulating an actual field investigation where instructors bury items of evidence (for e.g., skeletal material, evidentiary items, and/or animal carcasses) in mock clandestine graves for students to locate using GPR, provides a real-world scenario in a controlled, instructor-guided learning environment (**Figure 1**). There is a great deal of planning and logistics to setup these field sites including burying skeletal materials and evidentiary items. The purpose of these scenarios is to simulate the types of actual cases investigators may encounter, so the mock gravesites are dug at relatively shallow depths, usually 2-4 feet. The carcasses or skeletal materials are sometimes wrapped in tarps, plastic sheeting, or other material to simulate body concealment methods.

***continued on page 4***

**Figure 1:** Hands-on practical demonstration of use of GPR for forensic investigations.

In a real-world setting, GPR is typically used to locate potential clandestine gravesites using the "pseudo-grid" method first, rather than a complete grid data collection, which is very time consuming. The reason for this is that GPR can be used more as a sort of presumptive test to identify possible clandestine gravesites to flag areas of interest for further investigation with a more detailed grid survey. In addition to GPR, other field techniques are used such as probing and coring to help identify a suspected gravesite (**Figure 2**). Within the lecture portion, the specific techniques involved in systematically excavating a gravesite are taught, which are then put into practice at the field site. Students are expected to set up a grid around the suspected grave area. The considerations for determining the grid size and placement are scene dependent. That is, they must consider the size of the suspected grave along with any items of evidence that may be present on the surface to ensure their grave encompasses all relevant items that must be included in the mapping, measuring, and excavation process.

**Figure 2:** Viewing the GPR data to pinpoint areas of interest after an initial reconnaissance survey and probing the potential gravesite.

Up to this point, the investigation process is driven by the data students are collecting. They will explain to the instructors why they feel they have correctly identified their gravesite based on their GPR use, taphonomic clues, surface evidence, and any other relevant factors. Often, students will learn that not all grave-like anomalies are forensically significant and to only focus time and effort on excavating areas of interest to their investigation (**Figure 3**).

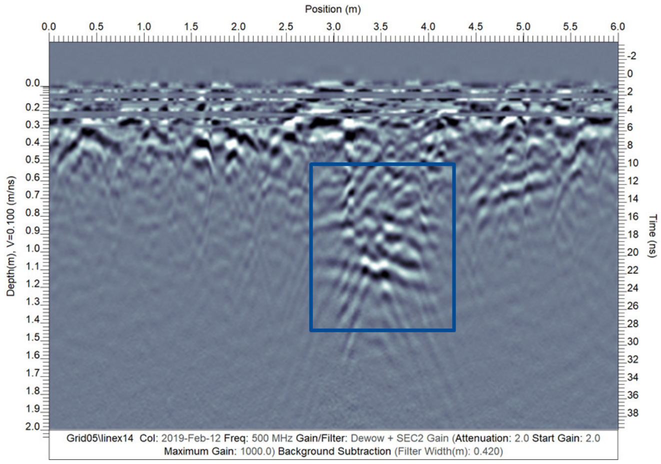



**Figure 3:** An example of a disturbance at depth in a GPR data cross section (blue rectangle) caused by a buried body that students are trained to recognize during valuable in-field learning experiences.

This practice environment is critical because the instructors know exactly where the gravesites are and can explain to students the differences between the actual gravesites and non-gravesite anomalies so that students can better understand the nuanced differences.

**Figure 4:** Students doing a detailed grid survey over a suspected gravesite to simulate a forensic investigation environment.

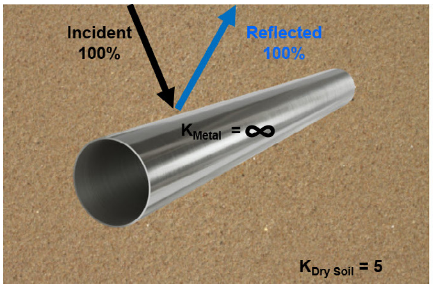
Once students have identified their gravesite using GPR (**Figure 4**), they excavate their potential gravesites to develop tangible associations between what was shown on the GPR screen and what was found within the suspected grave. It's much better for students to discover they're making mistakes and learn to correct them in this environment, rather than on an actual death investigation scene. Providing the opportunity for students to apply what they've learned in a lecture-based format, in a hands-on scenario is one of the best methods to bring theoretical concepts into practice.

*Story courtesy of PhD. Lerah Sutton, PhD*
*Director – Forensic Medicine Educational Program*
*Assistant Director – Maples Center for Forensic Medicine*
*University of Florida College of Medicine*

# TIPS: Beware of the (GPR) shadow!

One of the first lessons GPR practitioners learn about GPR is that radio signals cannot penetrate through metal objects. In this TIPS article, we show a few examples of this phenomenon and how it affects GPR data interpretation.

Metal objects provide a reflectivity of 100% (**Figure 1**). The equation for calculating reflectivity is shown alongside, using a dielectric permittivity value of K1=5 for dry soil.




$$R_{metal} = \frac{\sqrt{K_1} - \sqrt{K_2}}{\sqrt{K_1} + \sqrt{K_2}}$$

$$R_{metal} = \frac{\sqrt{5} - \sqrt{\infty}}{\sqrt{5} + \sqrt{\infty}}$$

$$R_{metal} = -100\%$$

**Figure 1:** Using the equation for reflectivity (R) and dielectric permittivity values for metal mean that $K_2 = \infty$ and non-metal ($K_1 = 5$), the reflectivity of metal is 100%. In fact, it is always 100% for a buried metal object, no matter the what the host material is.

This means that all the GPR signal that hits a metal object reflects from it, and no signal transmits through it and continues deeper. This results in a "shadow zone" of no signals under metal objects (**Figure 2**). For small targets energy can be diffracted and scattered so can appear under the metal target.

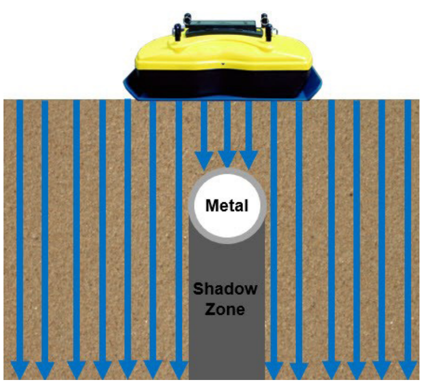
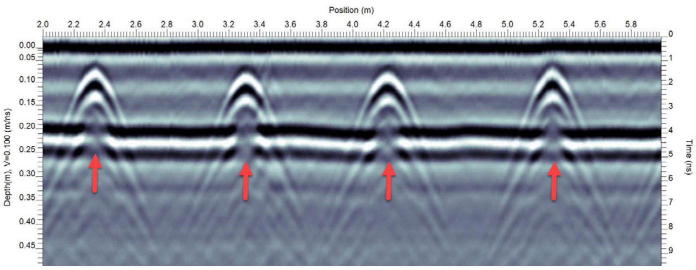
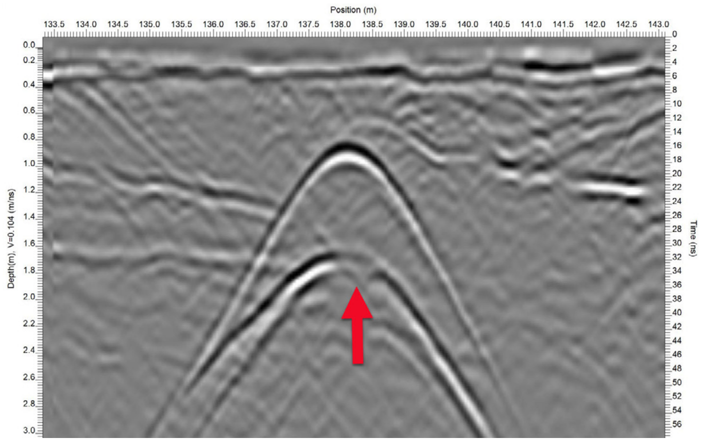



**Figure 2:** When a GPR system travels over a metal object, all the signals reflect from the metal object, resulting in a shadow zone, free from GPR reflections, underneath.

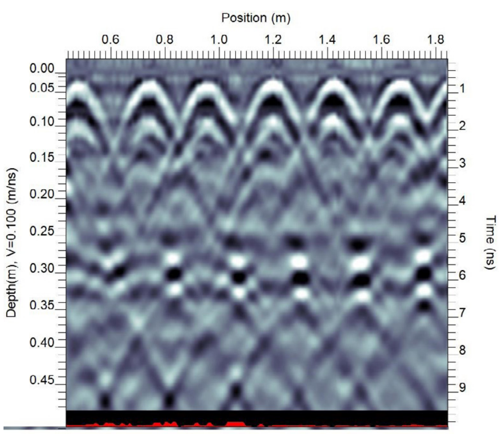
**Example 1**: One of the most common places to see the shadow zone under a metal object is under rebar in concrete. In this suspended slab example, the strong, horizontal reflector from the bottom of concrete (at ~0.2 m depth) is interrupted with shadow zones directly under each rebar. Since these are small interruptions, we can still easily see the strong flat-lying reflection from the bottom of concrete.

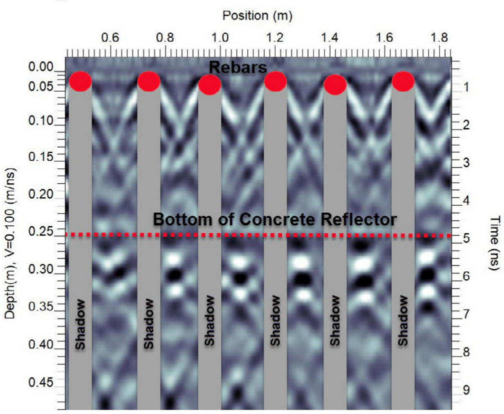



**Example 2**: When a deeper, large diameter, metal utility crosses or runs parallel to a metal shallower utility, it is sometimes possible to see the shadow of the shallower utility at the top of the hyperbolic response from the deeper utility. This provides confirmation that the two hyperbolic responses are from two separate objects and not the top and bottom reflections from a non-metallic utility (see [TIPS: Determining pipe diameter from GPR data](#)).




**Example 3**: This concrete image is like Example 1 except the spacing between the rebars is significantly less. This results in a series of very short, flat reflections from the bottom of concrete interface that is only visible between each pair of rebars. Since the bottom of concrete reflector is so discontinuous with large gaps in it, it is easy to miss it and not interpret it; meaning that estimating the slab thickness, which could be important information for your client, is not included in your project report.

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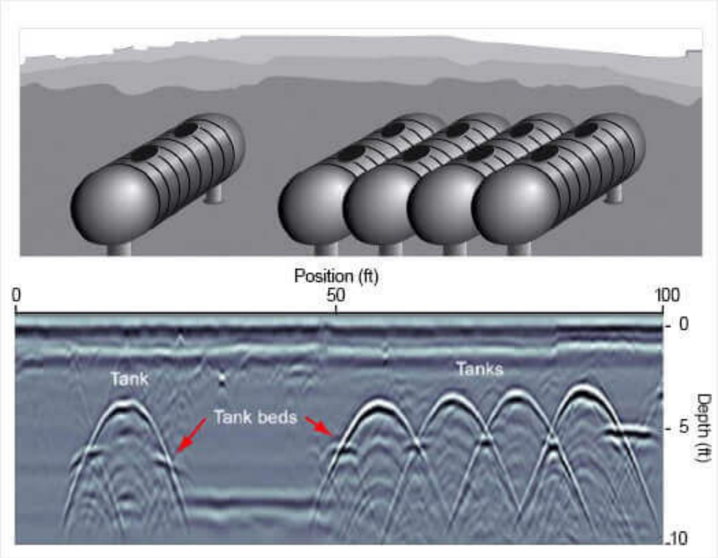
**Example 4**: This example is like Example 3 but on a much larger scale. The responses between the metal tanks shows a series of short, flat reflectors that could be interpreted as the bed of material that the tanks were placed on. If this reflector is recognized, and the interpretation that it is, in fact, the tanks bed, this additional information provides a way to estimate the diameter of the tanks.




These examples are simple situations where the shadow zone is easy to see and explain but other situations may not be as simple to understand. The problem is complex and depends on many factors including the size and depth of the metal object and the antenna center frequency target.

## Current Events

**CGA Conference & Expo 2021** - October 12-15, 2021, Orlando, Florida, USA

The 2021 CGA Conference & Expo is the premier event for damage prevention stakeholders to assemble to share knowledge, data and technology.

Radiodetection, Schonstedt and Sensors & Software will be exhibiting our products at CGA.

Come visit us at booth #101
**Register to attend**

## Upcoming Courses & Webinars

**Virtual Course - GPR: Principles & Practice** - October 20-21, 2021, online 9am to 1pm ET (UTC -5) (both days)

Attend this online, live instructor led GPR course. Using slides, videos and interactions, participants will learn all aspects of GPR from theory and instrumentation to survey techniques and data interpretation.

**Click here** to learn more about the course and Register.

## On-Demand Training

Pre-recorded webinars and EKKO_Project tutorial webinars are at: www.sensoft.ca/georadar/webinars

Interactive courses are available via our online learning platform: www.SensoftU.com

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