SUBSURFACE VIEWS

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Depth Slicing without a Grid

Many GPR users dislike setting up survey grids; the complaint is that it takes time and is not easy. Sensors & Software has recommended grid collection for two decades because, simply put, it generates data with reliable area coverage and results in better subsurface imaging, hence making interpretation easier. The most spectacular GPR data is almost always displayed as a depth slice or a 3D voxel cube. But, for many people there is a reluctance to take the time and effort required to set up and collect data in a grid.

The reason that grids are useful is because they ensure full area sampling, provide data with an accurate position and known sensor orientation for every GPR trace collected, allowing systematic data processing that is spatially dependent. Using a grid "forces" the operator to collect data in an organized manner resulting in better depth slices and 3D cubes.

Is there another, perhaps easier, way to collect data over an area and ensure the position of every GPR trace is known? The answer is "Yes". There are many positioning technologies available including laser theodolites, IMUs (Inertial Measurement Units) but the most well-known is probably GPS. GPSs are widely available and are easily added to Sensors & Software GPR systems but, to use GPS for surveying an area with GPR, the GPS must have better accuracy than the GPS in your car or your Smartphone; and that, of course, means a more costly GPS unit.

The most accurate GPS is RTK GPS which stands for "Real Time Kinematic".

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These systems use two GPS receivers: one roving with the GPR system and a second on a fixed base station which communicates with the roving receiver to provide a much higher level of positional accuracy than can be achieved with the roving receiver alone; to less than 0.5 meters in most cases.

RTK GPS is not always necessary. Many moderately-priced differential GPSs which have built-in smoothing algorithms and satellite-based position correction (such as WAAS) that reduce drift and access both GPS (USA) and GLONASS (Russia) satellites. These GPS units can provide the positional accuracy necessary to generate depth slices using GPS. In fact, the data shown in Figure 3 was collected with such a GPS (Topcon SGR-1).

When GPR data is collected with high accuracy positioning, setting up a grid can be avoided. Data is collected over an area in the same way you cut your lawn with a lawnmower; just walk around in some sort of smooth pattern to make sure the whole area has been covered. While the positioning is handled by a system such as GPS, the user must still be diligent to ensure that adequate area coverage is attained.

The EKKO_Project V5 software offers a new feature in the SliceView module: the ability to process line data collected with controlled position into depth slices.

For example, two single "line" data sets were collected over a golf green using two different paths. Line 1 entailed walking back and forth in both the X and Y directions (Figure 1a) and Line 2 followed a spiral path starting in the center and spiralling outward (Figure 1b).

Like SliceView for grid data, SliceView for lines with controlled xy positions has several processes that run automatically before the interpolation and depth slicing step, specifically, Dewow, Background Subtraction Filter, Migration, Envelope and Gain (Figure 2). Advanced users can select the processes to apply to the data. Most of the input parameters for these processes are defaulted but one parameter important for generating the best, most focused depth slices is the GPR velocity at the survey site.

If possible, measure the GPR velocity by finding a hyperbolic reflector in the data and using the hyperbola-fitting function and enter this velocity into the velocity field for the Migration process. If not possible, use the default velocity of 0.10 m/ns.

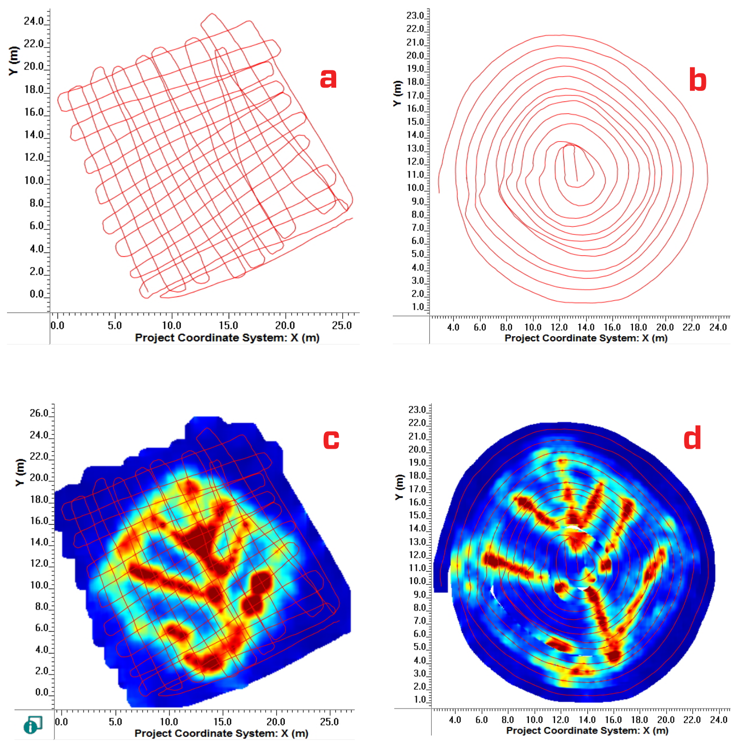

Figure 1: X - Y path (a) with depth slice (c). Spiral path (b) with depth slice (d)

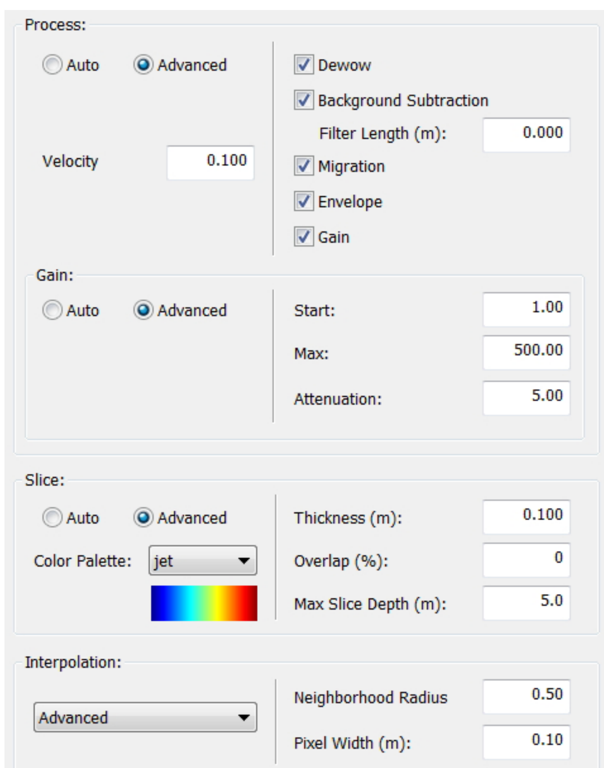

Figure 2: GPS-based depth slicing parameters

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Another parameter important for the depth slice processing is the interpolation distance. Generally, this is set to a value equal to the average distance between adjacent passes across the survey area.

Just like GPR gridded data collection, the tighter the distance between adjacent passes, the better the final images. The average distance between passes in Figure 1 is about 1 meter. The depth slices generated from the data paths in Figure 1 are displayed in Figure 1c and 1d. These show the dendritic pattern of the draining pipes under the golf green.

Depth slicing line data collected with GPS will be popular with those who dislike creating grids. As the cost of accurate positional technologies such as RTK GPS and laser theodolites come down in price, more extensive use of gridless data collection will occur. Simplifying GPR data collection for our customers means they get the most from the time they spent in the field and ultimately provide more economic solutions to subsurface challenges. We anticipate seeing many more surveys like the one shown in Figure 3.

For more information about the EKKO_Project V5 software, contact our Sales Department at sales@sensoft.ca.

Golf green GPR data courtesy of Barry Allred, USDA.

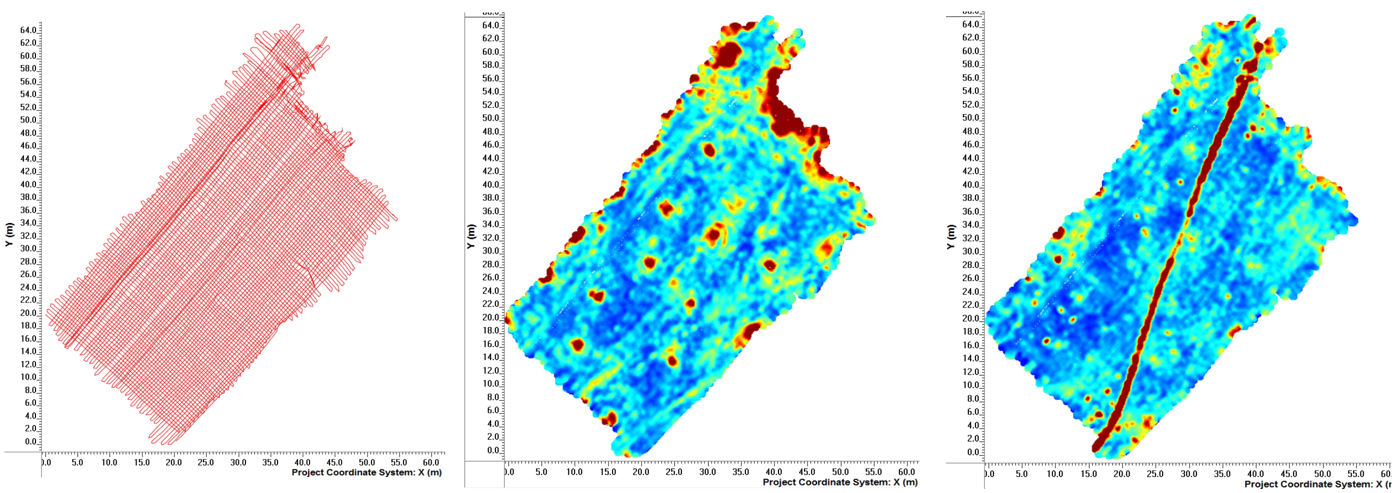

Figure 3: Area approximately 30 x 60 meters (1,800 m^2 or 20,000 square feet) surveyed without a grid using GPS for positioning. Two depth slices show the major targets detected in the area. A total of about 7000 line meters were collected in 5 hours

Measuring GPR Velocity for Water Content Estimation

The GPR wave velocity provides direct and indirect benefits. First, knowing velocity is essential for the calculation of the depth of an object that appears in a GPR data section. Second, less commonly known, GPR velocity can be used to infer another physical property when an empirical relationship between velocity and the other physical property has been developed. For example, GPR velocity is often used to measure water content of materials; critical information for many industries such as agriculture and logging.

In principle, measuring the GPR velocity of a sample of material is relatively simple. First, ensure that the bottom of the sample is resting on a material with quite different electrical properties than the sample; a metal plate works well.

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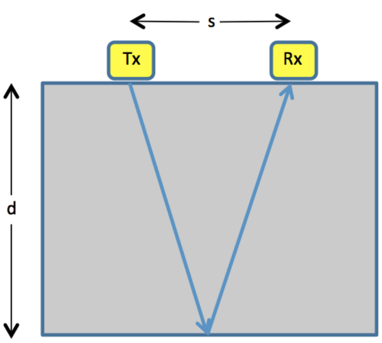
Second, good coupling between the GPR antennas and the sample is desired so creating a flat surface on the sample is optimal. With the GPR antennas in the middle of the sample collect a few GPR traces and average them to a single trace. Measure the arrival time (t) of the reflection event from the bottom of the sample. Using the known receiver/transmitter separation (s), and the speed of light in a vacuum (c) and the sample thickness (d) compute the velocity using equation in Figure 1.

There are a number of issues that need to be considered to get reliable results. Samples need to be sufficiently large to ensure that the measured travel time provides an accurate velocity and that there is no impact from the finite sample size on the measured travel time (Discussed in Redman et al 2016).



$$v = 2\frac{\sqrt{d^2 + \frac{s^2}{4}}}{t + \frac{s}{c}}$$

Figure 1: Computing velocity from a two way travel time (t) to bottom of a sample where c is speed of light in a vacuum.

In general if the size of the face of the sample on which the GPR sits (diameter or width) is more than twice the antenna spacing, the impact on travel time is small. The amplitude of the reflected event is much more sensitive to sample size; the reflection from the bottom of the sample may be difficult to identify due to clutter or because it is of low amplitude. The following example illustrates a simple method to provide a more clearly identifiable reflection event.

A pulseEKKO PRO TR1000 GPR was used to acquire data on a sample of wood chips (Figure 2). Traces were acquired on the wood chips with a metal plate on the bottom of the container and then with the container directly on the plastic box (essentially air). The traces were averaged and a difference trace created.

Figure 2: Equipment setup to acquire data on wood chips.

In Figure 3, the reflection events from the bottom of the sample can be seen in the left plot for both cases but determining the exact time of the bottom reflection is difficult. The difference between the two traces (Figure 3, right) shows a clearly identifiable reflection event. This approach dramatically improves the ability to see the desired reflection and provides better accuracy in determining the arrival time and consequently the measured velocity.

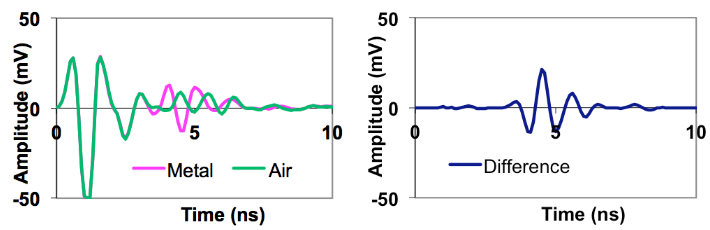


Figure 3: Traces collected with metal plate and air at bottom of wood chip sample container on left and the difference between two traces on right.

Measuring velocity in a sample enables estimation of a related property of the sample such as the water content. In this case, you need to measure velocity of samples where the water content is known from another reliable methodology (e.g. weighing sample wet and after drying).

Then determine an empirical relationship between the GPR measured velocity and the known water content. Often, velocity is translated into relative dielectric permittivity, a more basic material property: $Kr=(c/v)^2$ where c is the speed of light. Empirical relationships already exist for some materials such as soils, where the Topp relationship is commonly used to infer water content.

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An example of this methodology applied to wood chip samples with varying water content is shown in Figure 4.

In summary, GPR velocity can provide an indirect and fast measurement of physical properties of samples. This same methodology can be used to monitor changes in a physical property of a sample (such as water content) over time. Contact us for references to the papers cited in this story.

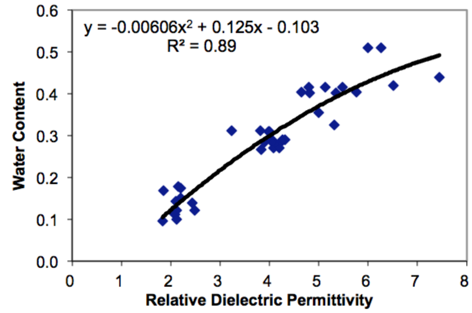

Figure 4: Gravimetric water content derived from drying wood chips plotted versus GPR dielectric permittivity (derived from measured travel time to the bottom of sample container).

The Advantage of Conquest Depth Slices

The goal of using GPR in concrete structure assessment is to define the internal structure prior to cutting and coring. Knowing what's there prevents structural damage and improves safety. Conquest users face the operational challenge of how to most cost effectively achieve this goal which usually takes the form of accurately marking the location of embedded structures. Conquest provides users with two modes of operation to achieve this goal – line scanning and grid scanning.

A single line scan essentially provides a cross section through the concrete scanned (line scanning); often this approach may provide a satisfactory answer when the structural conditions are simple. Complicated concrete structures are often very difficult to understand and best addressed by developing a full three dimensional understanding of embedded elements by collecting data on a regular grid of lines (grid scanning). Hence the question, what survey mode should be used?

Cost is often related directly to the time spent on a site. Simple line scans can be quick and hence less costly. Grid scans take a little more time but provide a much more comprehensive understanding of conditions. The cost benefit must be weighed against the risk factor in being wrong about site conditions. Risk comes in various forms such as costly damage repairs, workplace injuries and business reputation.

A recent Conquest training session in Richmond Hill, ON, entailed scanning an elevated concrete slab in an industrial warehouse. This site illustrates the trade-offs between line scanning and grid scanning. A simple line scan shown in Figure 1 indicates irregular rebar conditions on the right accompanied by a PCD (Power Cable Detector) response.

The PCD response indicates that there is electrical current in this area likely associate with an embedded power cable. The single line indicates the potential of a problem area but how best to avoid damage when cutting and coring is unresolved.

By carrying out a grid scan, depth slice images at several depths can be generated such as those shown in Figure 2 and 3. From the plan views, it is clear that there are features running obliquely to the regular rebar structure. These features are inferred to be electrical conduits (conduits commonly appear as irregular features within a normal rebar structure).

The data suggest there are 4 conduits present (labelled 1, 2, 3, and 4); conduit 1 is at a shallower depth than the other three. Conduits labelled "1", "2" and "3" in Figure 3 appear to run at 45 degrees to the rebar grid and then turn parallel in the upper right of the area scanned. Conduit "4" runs from top to bottom at the right but does not align with the rebar.

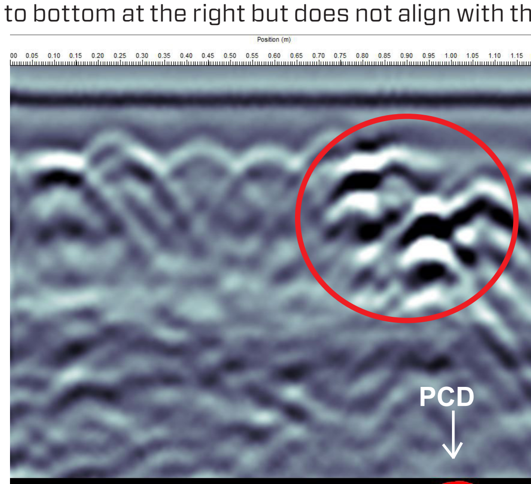

Figure 1: Line Scan showing anomalies and a PCD spike.

Figure 4 displays the plan view of the PCD response; strong fields are associated with conduits "2" and "3", indicating that electrical current carrying wires are present.

Comparing the single line scan information to the rich detail obtained with the grid scan demonstrates the benefit of the more comprehensive grid scanning approach. Given that the time on site is only about 10 minutes different from start to finish, the risk mitigation values is fairly clear.

We regularly discuss these operational decision issues with our customers so we can learn what is best to recommend to others. We observe that the most successful are extremely concerned about delivering value to their customers As they have evolved their business they have learned that the risk reduction from a few extra minutes using grid scanning to generate depth slices is well worth while. From more than 25 years of delivering GPR for concrete imaging, we strongly recommend taking the time to do grid scanning and to use line scanning as a quick reconnaissance approach to establish optimal grid orientation.

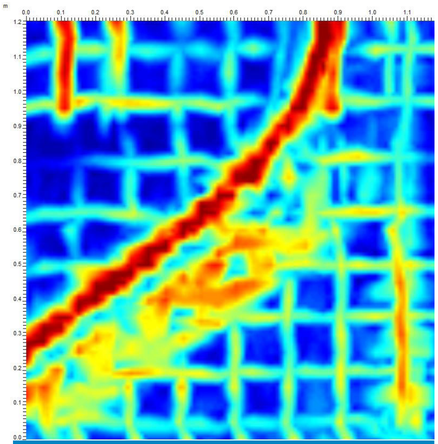

Figure 2: 120-150 mm depth slice

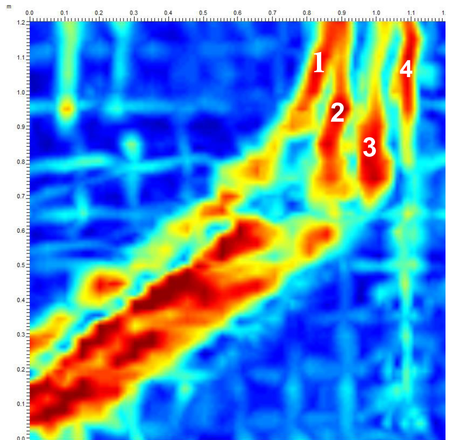

Figure 3: 150-180 mm depth slice

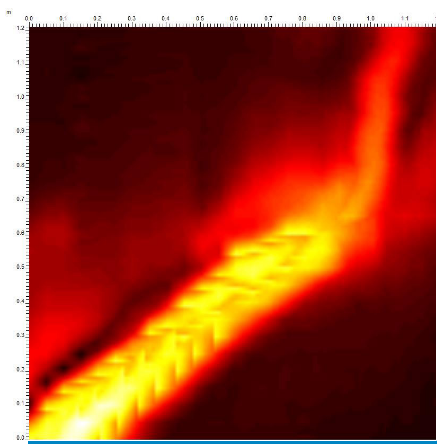

Figure 4: PCD Response

Courses

Subsurface Imaging with GPR course - March 6, 2017, Mississauga, ON, Canada

Concrete Scanning with GPR course - March 7, 2017, Mississauga, ON, Canada

3 Day GPR course - May 31 - June 2, 2017, Mississauga, ON, Canada

Upcoming Tradeshows

CONEXPO-CON/AGG
March 7-11, 2017, Las Vegas, NV, USA

CGA Excavation Safatey 811
March 14-16, 2017, Orlando, FL, USA

Environmental and Engineering Geophysical Society (SAGEEP)
March 19-23, 2017, Denver, CO, USA

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