Earth Science Systems
ESSENTIAL UNDERGROUND INFORMATION

A Demonstration of the GPR Concrete Scanner System

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Introduction

The GPR Concrete Scanner locates objects that are embedded in concrete such as rebar, conduits, post-tension cables, metal and plastic pipes, power lines, and utilities with precision and clarity. It also measures concrete thickness and rebar cover, and can find defects such as voids and honeycombing. The system's software produces simple cross sections, depth slice images, or 3D images of the concrete structure. The system includes a scanner unit with integrated radar, odometer, a power line detector, and a tablet computer (Figure 1). An extension handle is available for scanning hard to reach places. The Concrete Scanner's cable-less design increases reliability and ease of use. The examples that follow demonstrate how the Concrete Scanner system is used to measure cover, rebar location and depth, rebar size, concrete thickness; as well as detect voids and honeycombing.

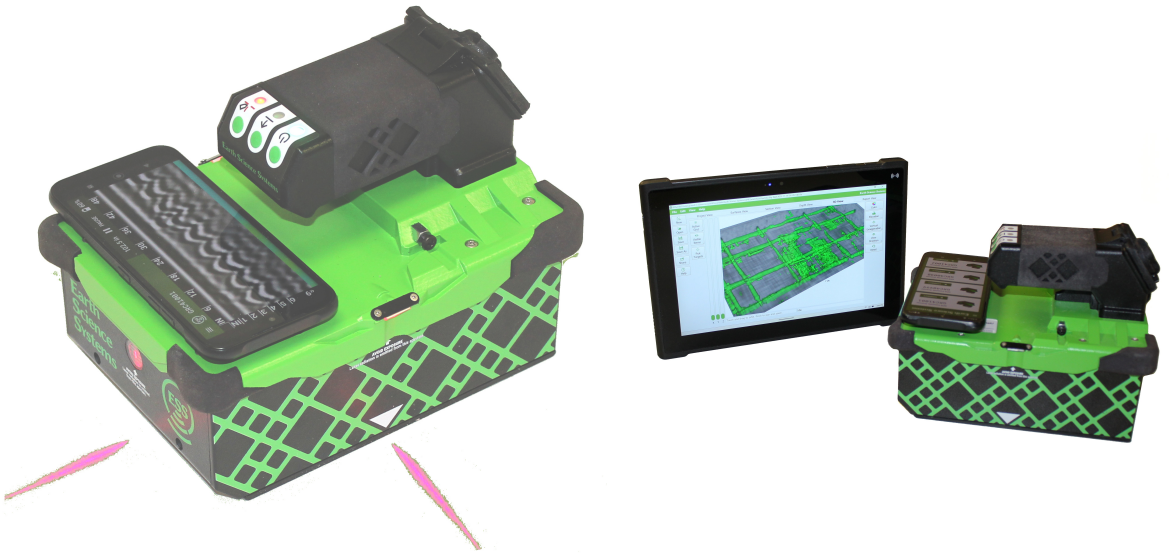


Figure 1. The GPR Concrete Scanner shown with a smart phone (left), and tablet computer (right). The scanner dimensions are 8.7 x 6.2 x 6.5 inches and its weight is 4.9 lbs (22.8 x 15.8 x 16.6 cm, 2.25 kg). The right picture shows the scanner along with the tablet PC.

Simple Markouts and Cross-Sections

This configuration is the easiest to setup and use, and is primarily utilized when determining where to drill or cut. Simple markouts and cross-sections can be created using the Surveyor Mobile app on a smart phone (Android or iOS). In this configuration, the phone is attached to the scanner using a quad-lock as shown in Figure 2. As the scanner is pushed forward, the Surveyor Mobile app displays a cross-section on the phone's screen. The scanner can be moved back and forth along the scan line until the antennas are directly over the rebar target. The rebar location is then marked on the surface using the laser guides. This process is repeated until all targets have been marked and the marked locations joined together as needed. After the scan, the phone can be easily removed from the scanner to view and interpret the data. Depth to targets can be measured using the velocity tool, and the cross-section displayed on the screen can be exported to a PDF file to provide a simple report.

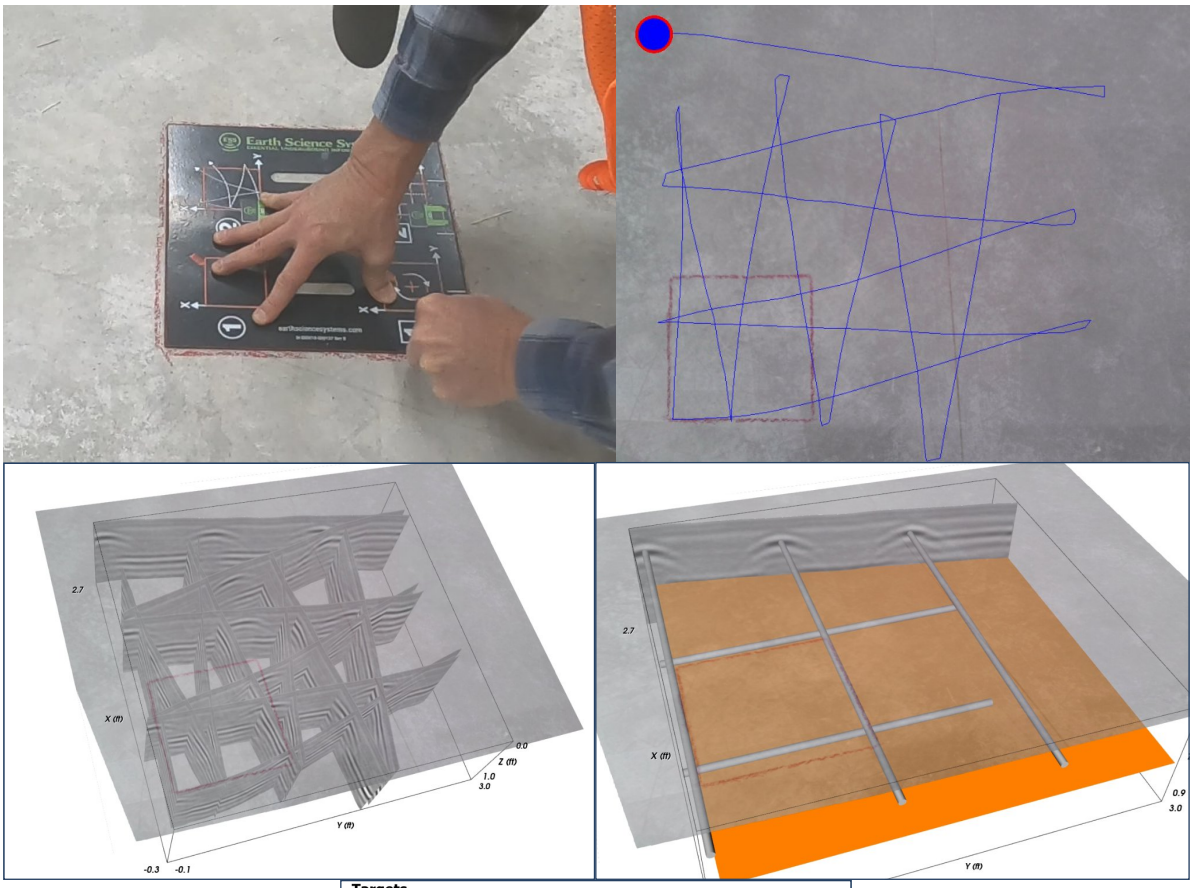
Figure 2. Conducting a simple markout. Surveyor Mobile screen showing the radar image hyperbolic targets (left), marking a target using lasers (center), and connecting the marks (right).

Free-Form Survey Mode

The free-form survey mode is the fastest way to produce a 3D scan. This mode utilizes the Surveyor Pro program on a Windows tablet, the smart phone, and scanner (Figure 1 right). The steps for surveying and reporting are listed below.

- Use fiducial template and mark a red square on the surface area (Figure 3, top left).
- Use Surveyor Pro to take a photo of the red square. The program will automatically make the orthogonal perspective correction and register the image to the survey (Figure 3 top right).
- Place the scanner at the lower left corner of the square and record a free-form survey line by moving the scanner up and down freely in a zigzag pattern over the scan area. The scanner will track your movements. Repeat with a second line moving the scanner in a zigzag pattern left and right. (Figure 3 top right).
- Export the data to ESSential Underground for 3D viewing and analysis (Figure 3 middle right). To finish, pick targets and generate reports (Figure 3, bottom row).

A structural assessment can be made from this survey by observing the targets table created by ESSential Underground. The cover is 0.2 feet (2.4 inches), the rebar diameter is 0.06 feet (0.72 inches or number 6 rebar), and the slab thickness is 0.55 feet (6.6 inches). The rebar diameter is determined by subtracting the depths of the bars that cross in different directions. The nominal rebar spacing was 12 inches. These values can also be assessed by using the cross section view. No voids, honeycoming, or live power lines were detected in this survey. In this example, the cover and thickness conform to the structural design specifications for this floor.



Targets

ID	Type	Description	SUE-QL	Size	Depth	Location X	Location Y
1	Structural	rebar	QL-B	0.05 ft	0.20 ft	2.67	-0.02
	2 points, Odometer positioning				0.20 ft	-0.29	-0.06
2	Structural	rebar	QL-B	0.05 ft	0.21 ft	2.67	1.03
	2 points, Odometer positioning				0.21 ft	-0.26	1.03
3	Structural	rebar	QL-B	0.05 ft	0.21 ft	2.60	2.09
	2 points, Odometer positioning				0.21 ft	-0.29	2.07
4	Structural	rebar	QL-B	0.05 ft	0.26 ft	0.37	-0.11
	2 points, Odometer positioning				0.26 ft	0.39	1.90
5	Structural	rebar	QL-B	0.05 ft	0.27 ft	1.39	-0.09
	2 points, Odometer positioning				0.27 ft	1.42	2.09
6	Telecom	base	QL-B	3.00 ft	0.55 ft	1.22	-0.03
	2 points, Odometer positioning				0.55 ft	1.23	2.98

Figure 3. Start free-form survey by drawing a red marker square (top left). Then run a zigzag scan line moving freely up and down, and repeat with a left and right scan zigzag line (top right). The surface photo and GPR scan data are imported into ESSential Underground (middle left), and then analyzed to show the rebar (gray) and slab base (orange) in a 3D view (middle right). Finally an automatically generated table of target depth from the analysis is shown (bottom).

Guided-Grid Mode

The guided-grid survey mode is another method to quickly produce a 3D scan, and it generally provides more resolution than the free-form survey. This mode also utilizes the Surveyor Pro program on a Windows tablet, the smart phone, and scanner. Because this method provides tracking guidance when traversing the lines, a cumbersome scan mat with printed lines is not needed. The guided-grid mode is used for scan areas up to 3 x 3 feet (one square meter). The steps for surveying and reporting are listed below.

- Use fiducial template and mark a red square on the surface area, and then use a black marker to mark the starting offsets for the scan lines (Figure 4 top left).
- Use Surveyor Pro to take a photo of the red square. The program will automatically make to orthogonal perspective correction and register the image to the survey (Figure 4 top right).
- Place the scanner at the base line at the beginning of line 1 and traverse the survey line. The displays on both the phone and the tablet show the scanner's current position on the scan grid so that the user can traverse the scan line without moving off-course. Repeat this process for the remaining scan lines. (Figure 4 top right).
- Export the data to ESSential Underground for 3D viewing and analysis. Measure depths (Figure 4, bottom left) and pick targets (Figure 4, bottom right).

The depths of subsurface features can be measured by moving the cursor over the cross section view in ESSential Underground and observing the indicated depth ESSential Underground (Figure 4 bottom left). The cover is 0.194 feet (2.32 inches), the rebar diameter is 0.065 feet (0.78 inches or #6 rebar), and the nominal slab thickness is 0.526 feet (6.3 inches). The rebar diameter is determined by subtracting the depths of the bars that cross in different directions. The nominal rebar spacing was 12 inches. No voids, honeycoming, or live power lines were detected in this survey. In this example, the cover and thickness conform to the structural design specifications for this floor.

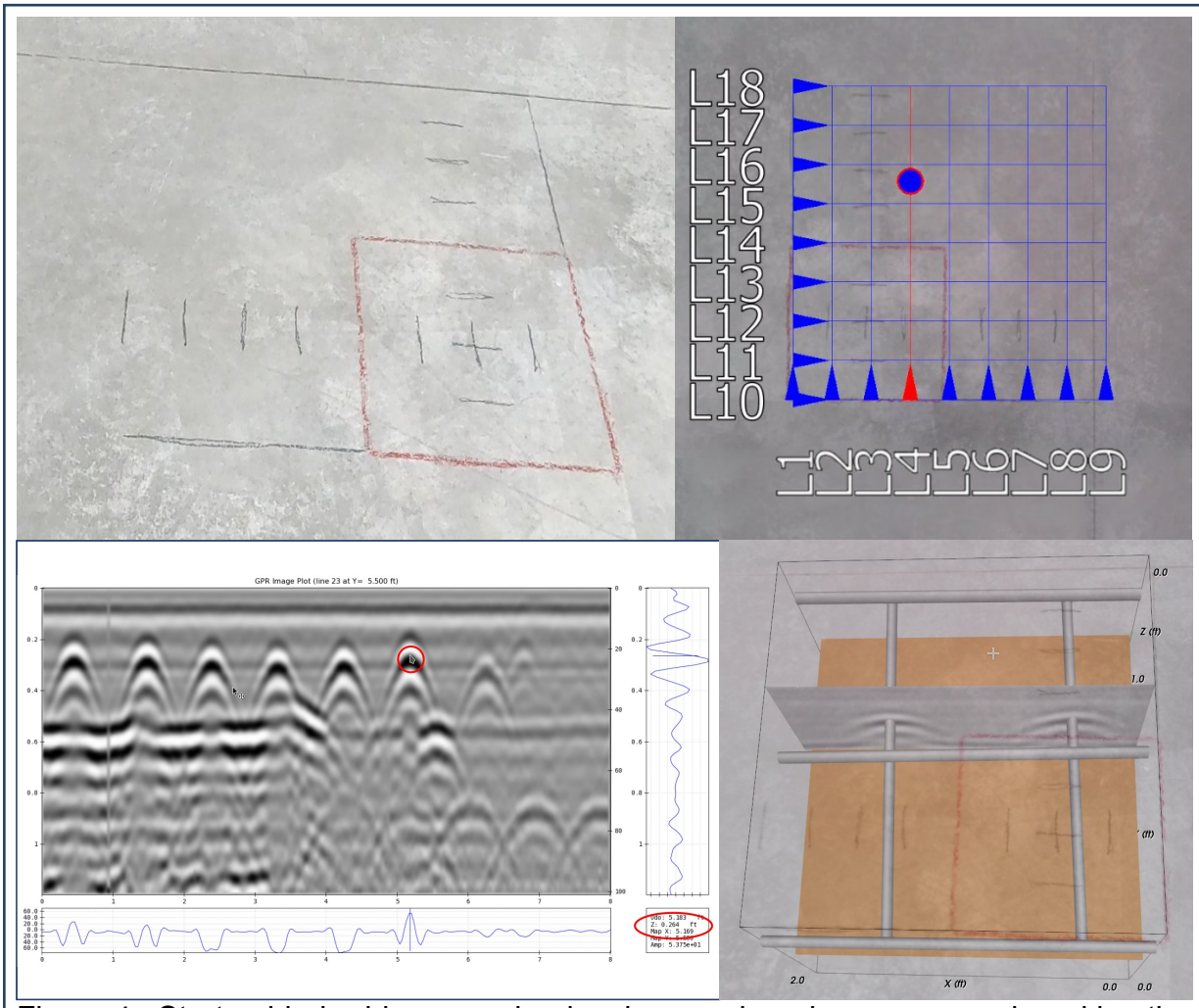


Figure 4. Start guided-grid surveys by drawing a red marker square and marking the starting offsets for the scan lines in black (top right). Place the scanner at the beginning of each line and use the position indicated on the phone or tablet plots to properly traverse each scan line (top right). The cross-section view in ESSential Underground is used to measure the depths of subsurface objects (bottom left), and the transparent surface photo along with selected rebars (gray) and concrete base (orange) are shown in the 3D view (lower right).

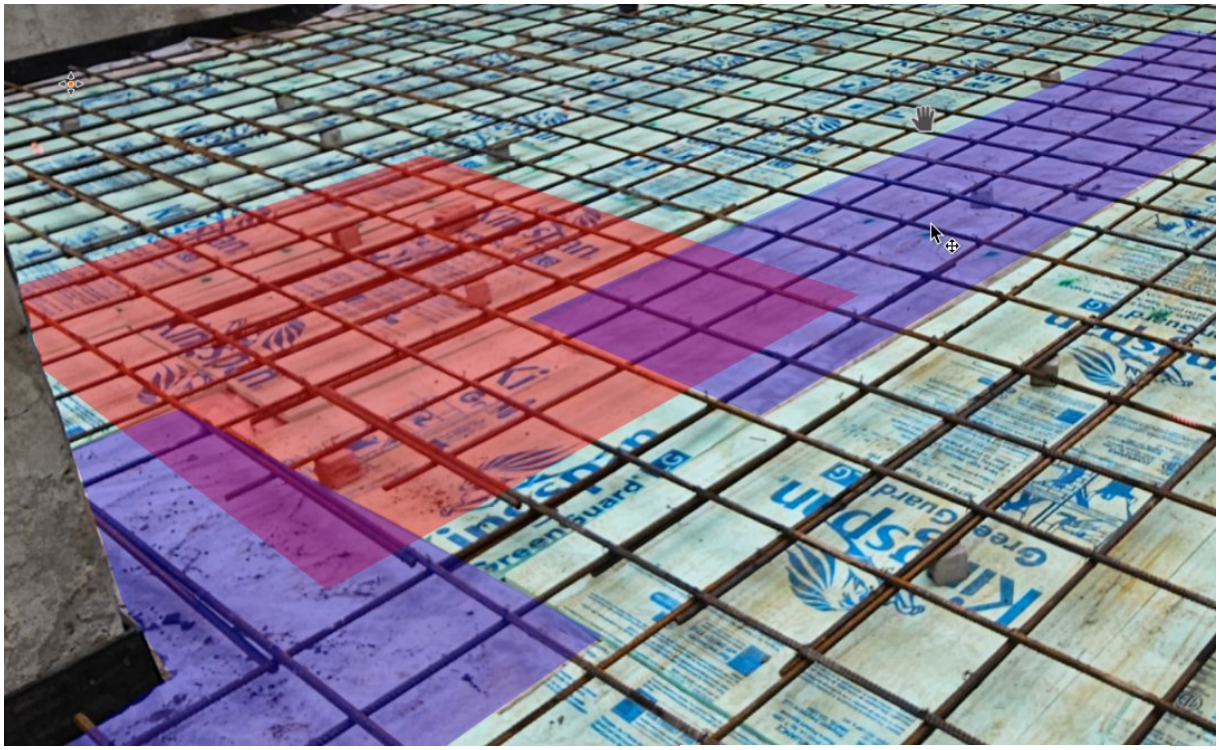
Standard Grid Mode

The standard-grid survey mode produces detailed 3D scans in areas larger than 3 x 3 feet (one square meter). This mode also requires the Surveyor Pro program on a Windows tablet, the smart phone, and scanner. This example is a larger area scan of a concrete floor, whose internal structure before pouring cement is shown in Figure 5 (top). The steps for surveying and reporting are listed below.

- Mark out a crosshatch scan grid using a chalk line or other surface marker (Figure 5 bottom-left). For dense grids, users may chose to only mark every second, third, or fourth scan line to save time.
- Use Surveyor Pro to take a photo of the scan area. In the surface photo dialog, drag the corners of the rectangle so that they correspond to the corners of the survey grid in the photo. The program will then make the orthogonal perspective correction and register the image to the survey (Figure 5 bottom-right).
- Place the scanner at the base line at the beginning of line 1 and traverse the survey line. The displays on both the phone and the tablet show the scanner's current position on the scan grid so that the user can traverse the scan line without drifting off-course. Repeat this process for the remaining scan lines.
- Export the data to ESSential Underground for 3D viewing and analysis, then create isosurface view and pick targets (Figure 6).

Importing the survey data into ESSential Underground and creating the isosurface view shown in the top of Figure 6 can be accomplished in less than a minute. More subtle features in the radar images can be found by examining the cross-section images in the 2D and 3D views, and then creating targets as shown in the bottom of Figure 6. The scan in this example provides the following information.

- The cover, rebar size and spacing, and slab thickness are all easily determined from the targets report or by examining the cross section.
- In addition to the shallow rebar mesh, there are deeper rebars that makeup the footer in the right corner of the 3D image.
- The slab thickness varies by about an inch.
- There is an unknown target shown in blue that is likely an air void (Figure 6 bottom).



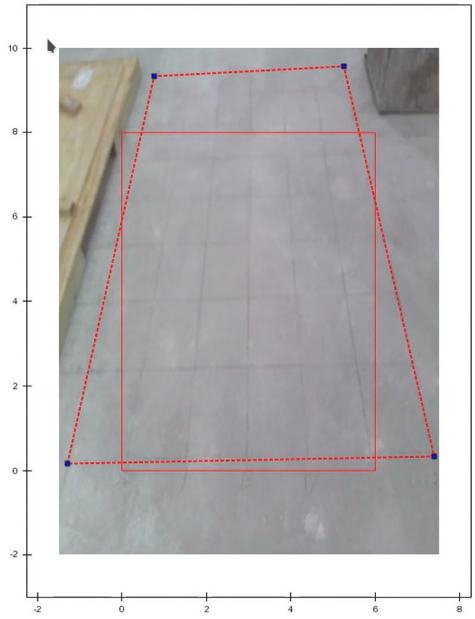


Figure 5. Concrete floor before pouring (top). Red region is the scan area and blue regions are footers. Standard-grid surveys start by marking out the scan grid and taking a photo (bottom-left). Use the software to correct for perspective by dragging the corners of the rectangle to match the corners of the scan grid in the photo (bottom-right).

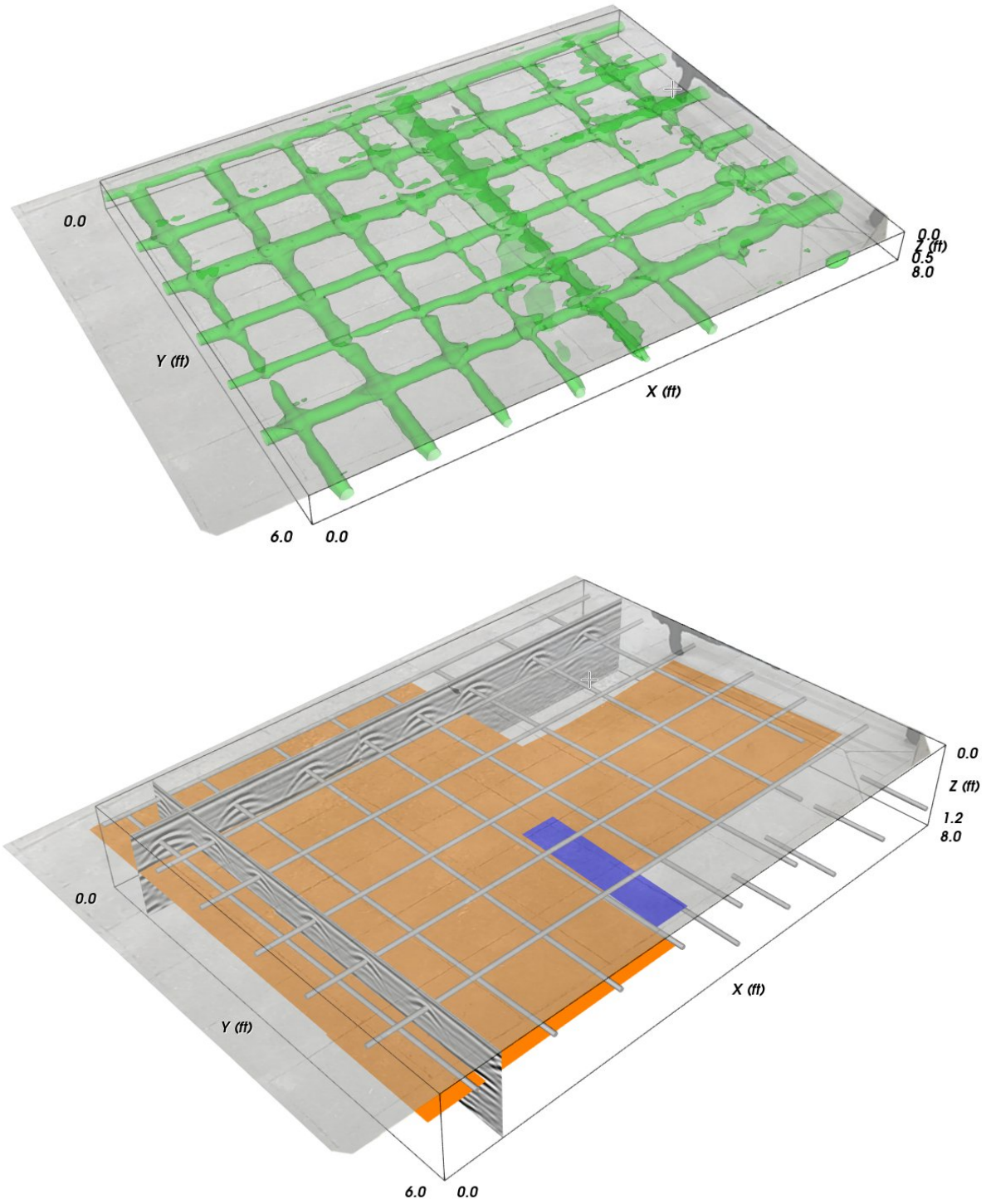


Figure 6. Scan results from a standard-grid survey. Generating isosurface views (top) is quick and easy. More subtle features in the radar images can be found by examining the cross-section images in the 2D and 3D views, and then creating targets (bottom). Rebar is shown in gray, the slab bottom in orange, and the air void in blue.

In another standard-grid example, a test wall (constructed by Olson Engineering, Inc., Wheat Ridge, CO) was surveyed that has known rebar locations and defects. Figure 7 shows the rebar and defect locations, which are listed below.

- Two levels of #4 rebar grids — one shallow and one deep.
- A hollow concrete box was placed in the upper left corner to provide an air void.
- The cardboard form in the top middle of the wall was filled with weak watered down concrete.
- The block in the middle is a honeycomb structure made with coarse aggregate dipped in cement.
- Crack and debonding defects were also built into the test wall for acoustic tests, but are not shown here.

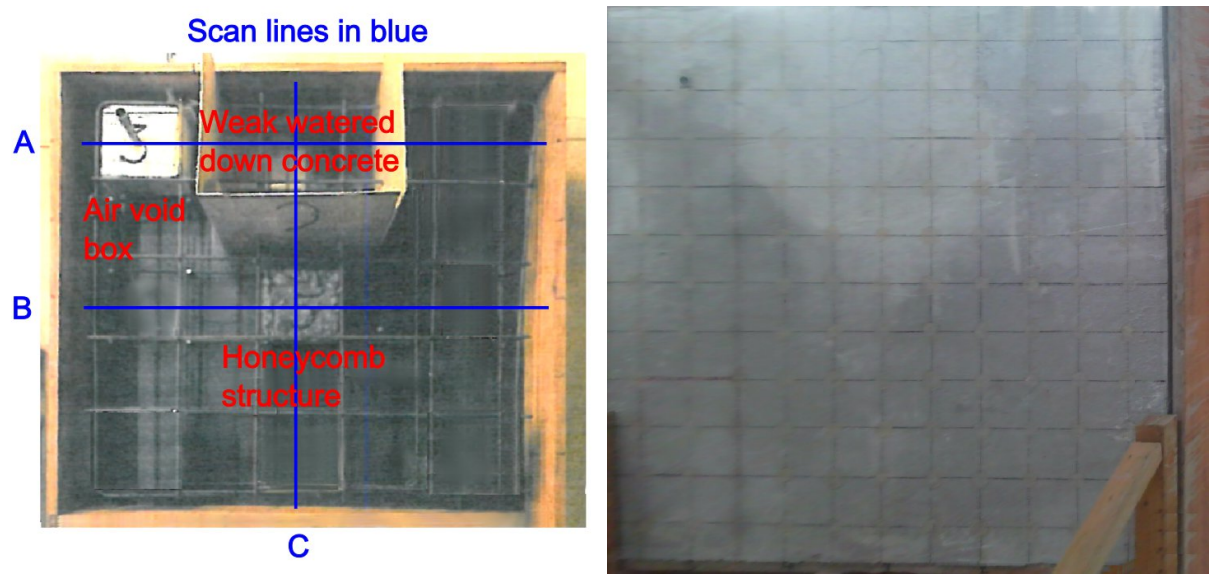


Figure 7. A concrete test wall build by Olson Engineering (Wheat Ridge, CO) with various defects shown before concrete filling (left) and the resulting wall (right).

A standard-grid survey was conducted and the results are shown in Figure 8. The scan in this example provides the following information.

- The shallow and deep rebar layers can be seen. The cover depth varies from 1.95 to 2.58 inches. The nominal rebar spacing is 12 inches.
- The measured rebar thickness from the cross section is 0.57 inches (#4 rebar).
- The slab thickness is nominally 12.96 inches.
- The radar reflections from the air void and honeycomb regions are indicated in the radar images (see images in next section).
- The weak concrete results in a faster radar wave velocity which makes the slab thickness appear thinner. There are also reflection from the sides of the weak concrete region (see images in next section).

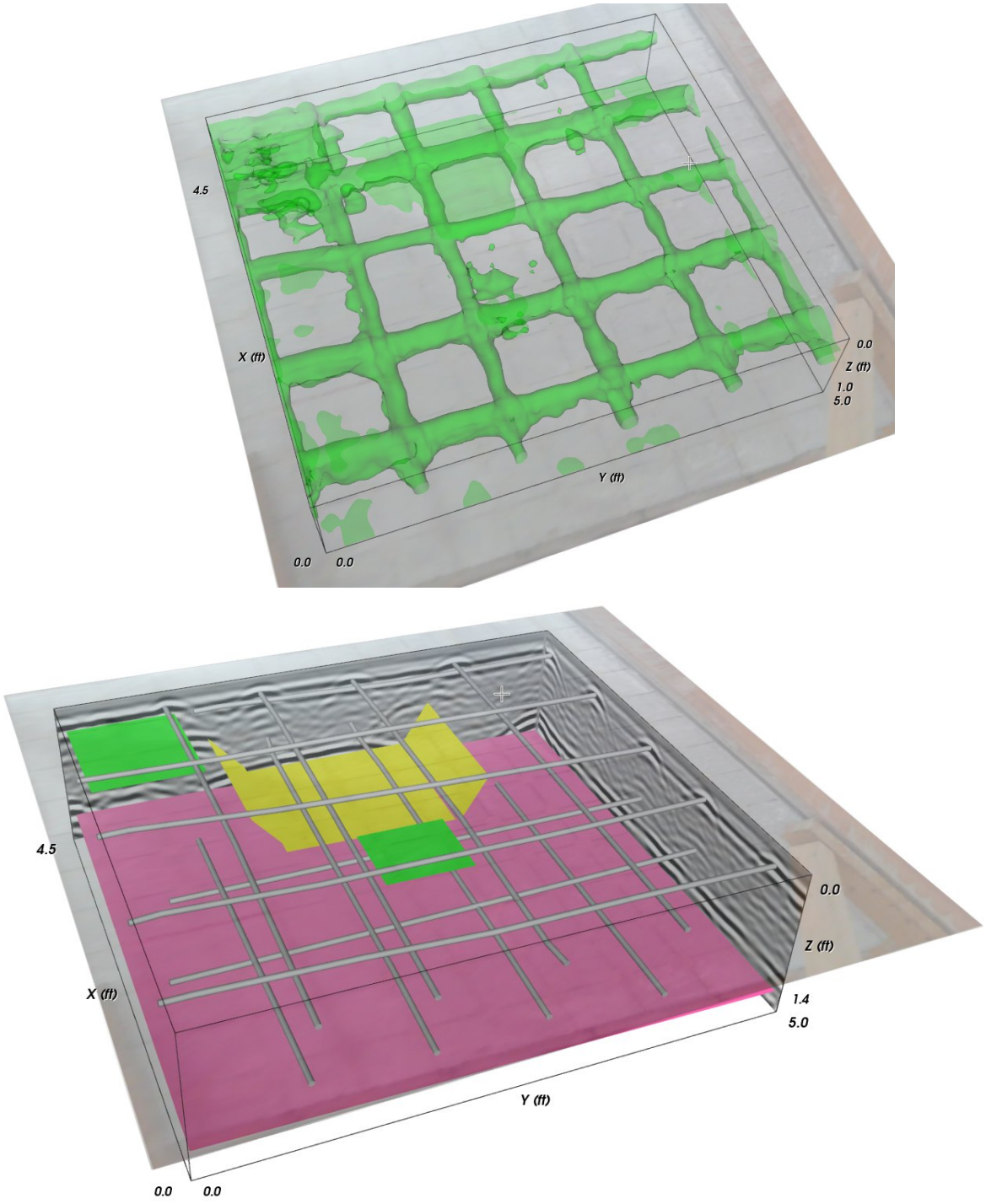


Figure 8. Scan results from the concrete test wall built by Olson Engineering (Wheat Ridge, CO) with the quickly generated isosurface view (top). More subtle features in the radar images can be found by examining the cross-section images in the 2D and 3D views, and then creating targets (bottom). Rebar are shown in gray, the void and honeycomb regions in green, the weak zone in yellow, and the slab bottom in pink.

Structural Analysis and Defects

The Concrete Scanner provides valuable information for conducting structural analysis and finding defects. The structural analysis begins by measuring the depth to rebar, the spacing between rebar, and the thickness of the slab (see Figure 9). From those measurements, rebar diameter and cover can be determined (as discussed in the previous examples).

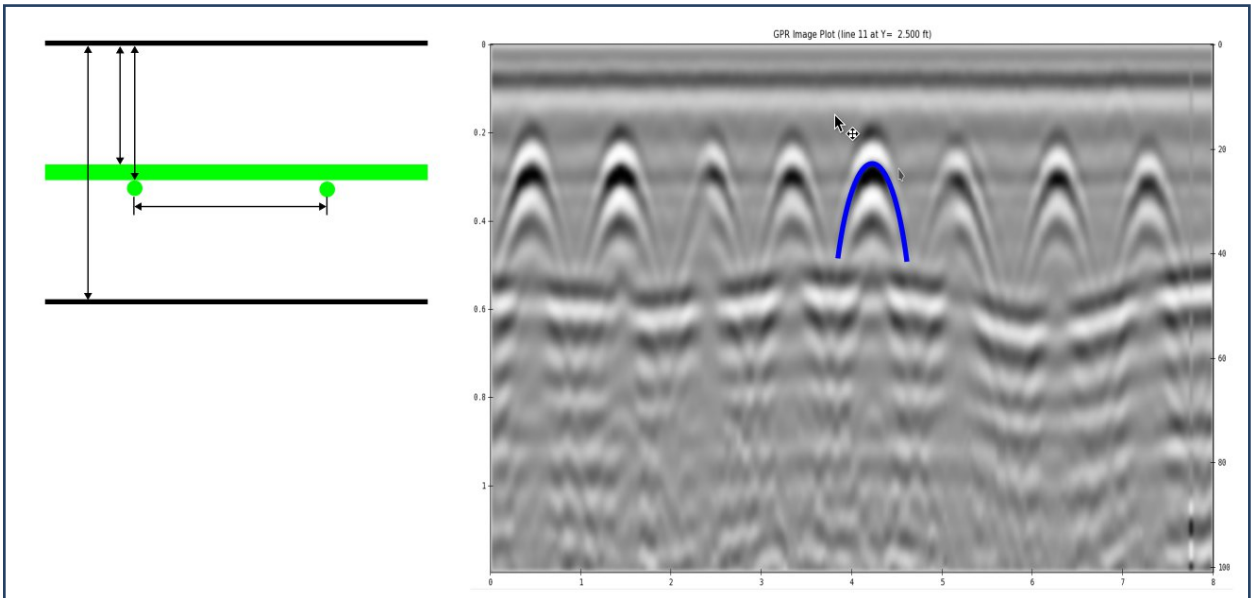
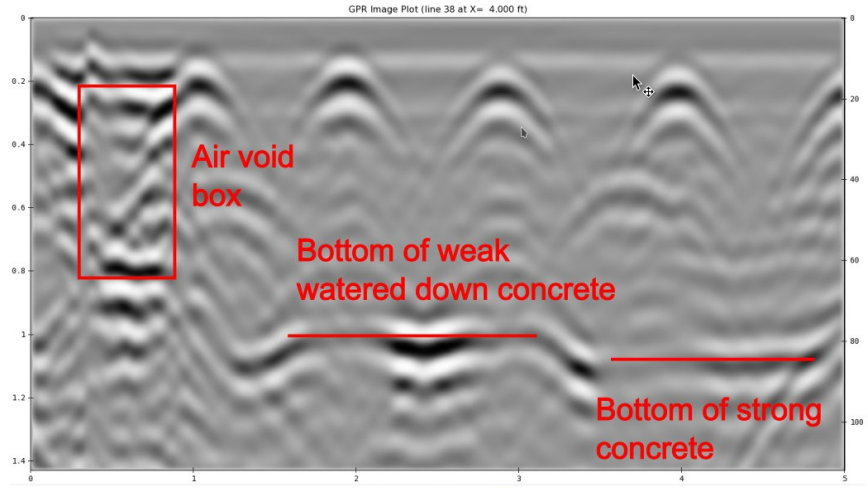
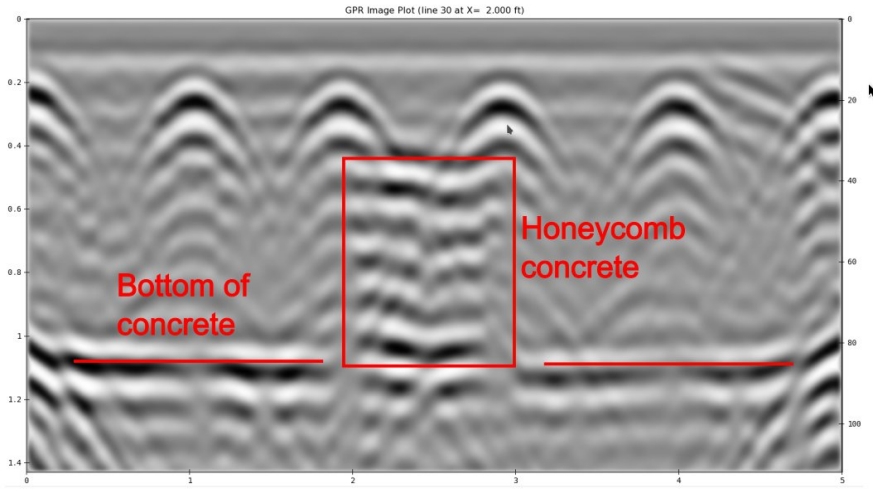


Figure 9. Measuring the depth of subsurface objects to perform a structural analysis.

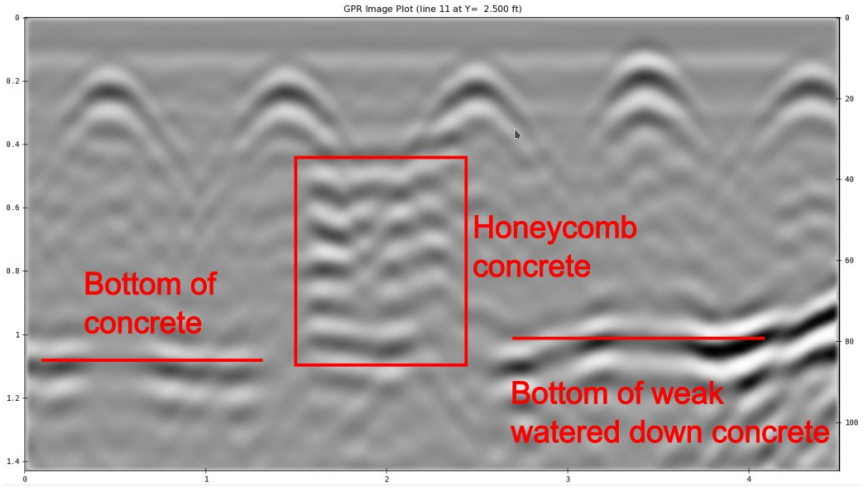
Structural defects can also be detected as shown in Figure 10. The three panels in this figure correspond to scan lines A, B, and C as shown in Figure 7. Scan line A shows reflections from the air void. Note the reversal of the color sequence in reflections from voids where the center band is white rather than black. Scan lines B and C show the response from inhomogeneous concrete caused by honeycombing. This causes a random chaotic reflections, whereas uniform concrete would not cause reflections. The final defect is from weak concrete that had too much water when poured, which results in more air in the concrete. This reduces its dielectric constant and causes the thickness of the slab to appear thinner than the surrounding more dense concrete, which can be seen in scan lines A and C.



Scan line A



Scan line B



Scan line C

Figure 10. GPR response to various defects in a concrete wall (see text).

Power Line Indicator

The Concrete Scanner can detect live power lines under load. The color bar under the GPR B-scan indicates live power lines in the vicinity. Cool colors range from blue (no power detected) to green, yellow (power possible), red (power detected), and pink (strong power detected). This color bar is present in both Surveyor Mobile and Surveyor Pro (see Figure 11).

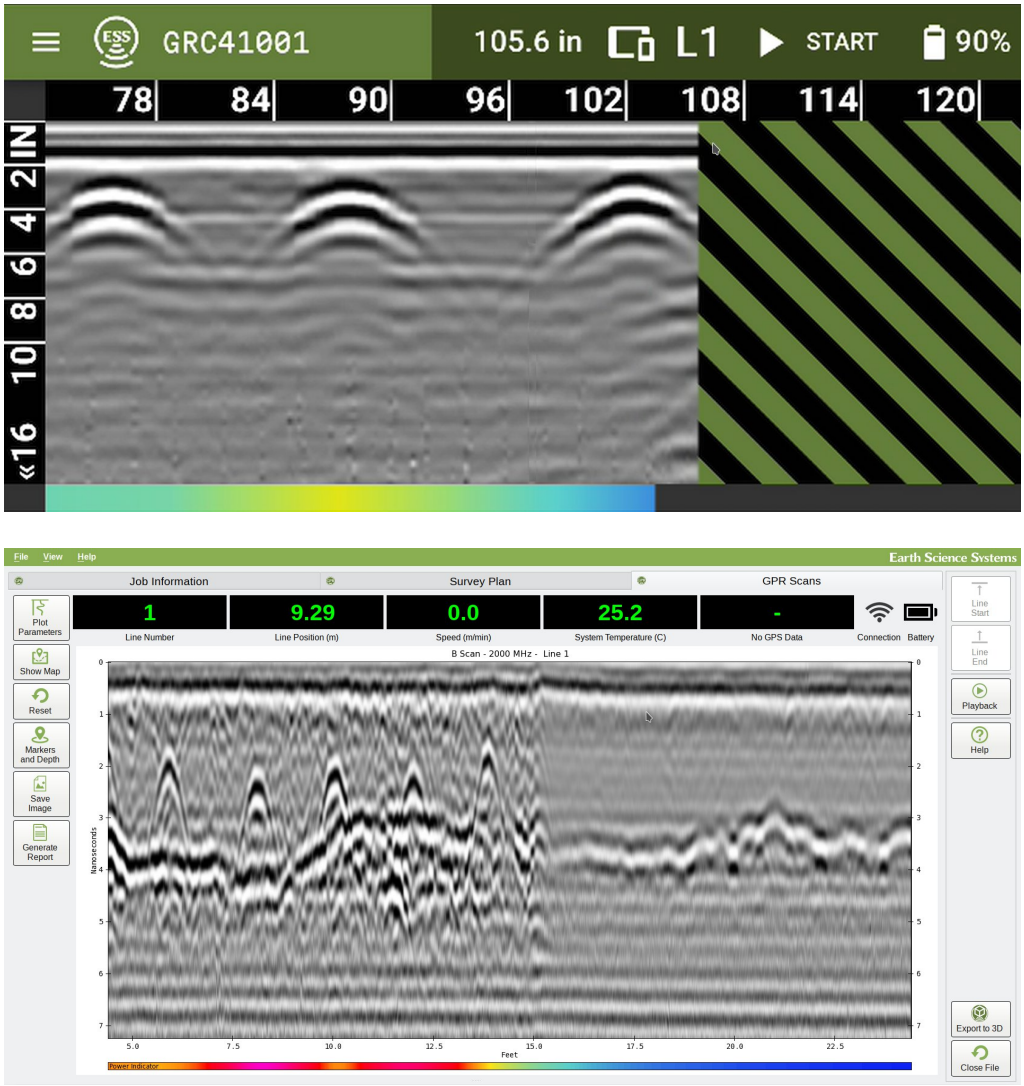


Figure 11. Color bar under B-scan indicating power in the vicinity. Surveyor Mobile (top) and Surveyor Pro (bottom).

Accessories

The Concrete Scanner ships with a snap-on wheel truck that makes surveying over larger areas easier. An optional extension handle makes floor surveys effortless and enables scanning in hard to reach areas. Figure 12 shows how the wheel truck and extension handle can be used for floor and wall surveys.

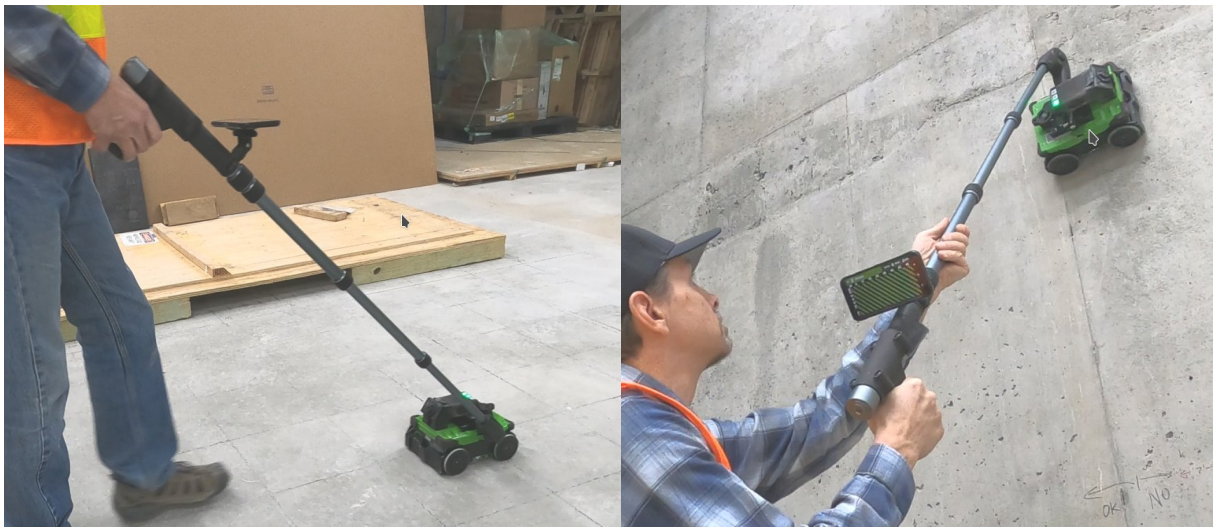
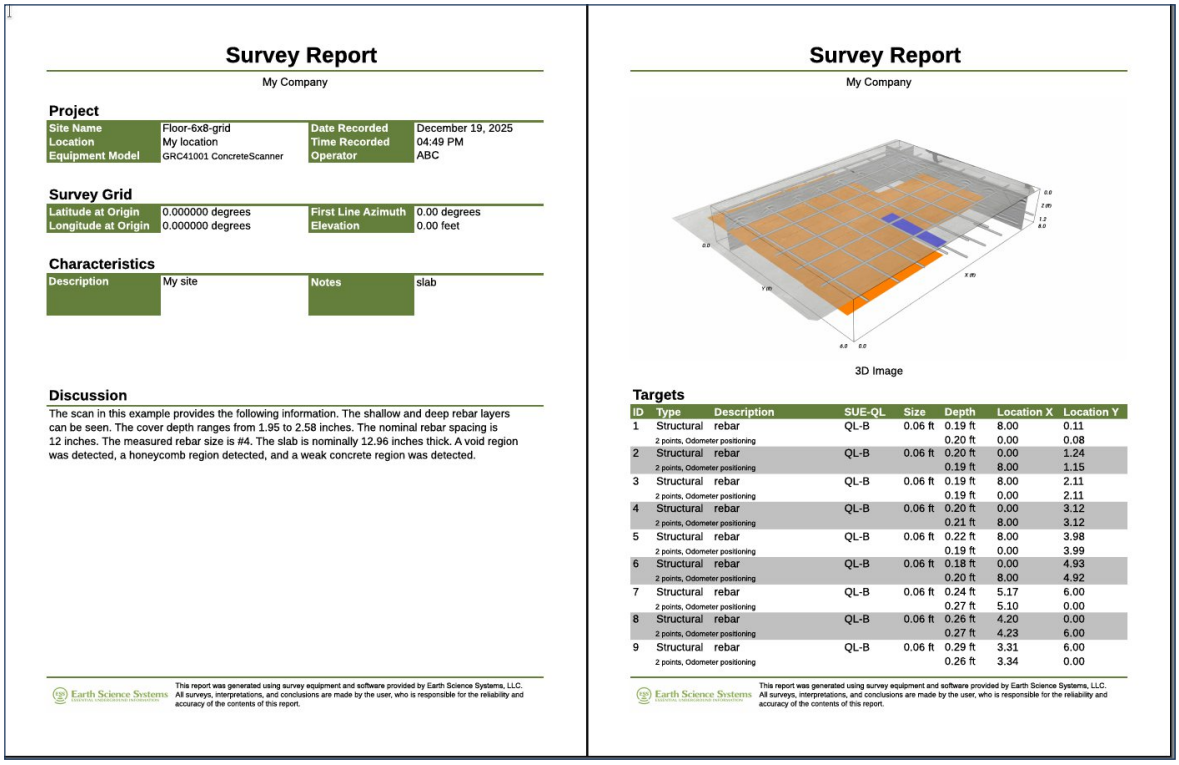


Figure 12. Using the wheel truck and extension handle for a floor survey (left) and a wall survey (right).

The ESSential Underground software provides advanced data processing and interactive 3D views. After interpreting the data, reports can be generated with a few button taps, and these reports and 3D views can be published to the cloud for viewing by team members and clients. Users can share their results with anyone with access to the web, no matter if it is a phone in the field or a computer in the office. An example is shown in Figure 13.



Survey Report

My Company

Project

Site Name	Floor-6x8-grid	Date Recorded	December 19, 2025
Location	My location	Time Recorded	04:49 PM
Equipment Model	GRC41001 ConcreteScanner	Operator	ABC

Survey Grid

Latitude at Origin	0.000000 degrees	First Line Azimuth	0.00 degrees
Longitude at Origin	0.000000 degrees	Elevation	0.00 feet

Characteristics

Description	My site	Notes	slab

Discussion

The scan in this example provides the following information. The shallow and deep rebar layers can be seen. The cover depth ranges from 1.95 to 2.58 inches. The nominal rebar spacing is 12 inches. The measured rebar size is #4. The slab is nominally 12.96 inches thick. A void region was detected, a honeycomb region detected, and a weak concrete region was detected.

Survey Report

My Company

3D Image

Targets

ID	Type	Description	SUE-QL	Size	Depth	Location X	Location Y
1	Structural	rebar	QL-B	0.06 ft	0.19 ft	8.00	0.11
	2 points, Odometer positioning				0.20 ft	0.00	0.08
2	Structural	rebar	QL-B	0.06 ft	0.20 ft	0.00	1.24
	2 points, Odometer positioning				0.19 ft	8.00	1.15
3	Structural	rebar	QL-B	0.06 ft	0.19 ft	8.00	2.11
	2 points, Odometer positioning				0.19 ft	0.00	2.11
4	Structural	rebar	QL-B	0.06 ft	0.20 ft	0.00	3.12
	2 points, Odometer positioning				0.21 ft	8.00	3.12
5	Structural	rebar	QL-B	0.06 ft	0.22 ft	8.00	3.98
	2 points, Odometer positioning				0.19 ft	0.00	3.99
6	Structural	rebar	QL-B	0.06 ft	0.18 ft	0.00	4.93
	2 points, Odometer positioning				0.20 ft	8.00	4.92
7	Structural	rebar	QL-B	0.06 ft	0.24 ft	5.17	6.00
	2 points, Odometer positioning				0.27 ft	5.10	0.00
8	Structural	rebar	QL-B	0.06 ft	0.26 ft	4.20	0.00
	2 points, Odometer positioning				0.27 ft	4.23	6.00
9	Structural	rebar	QL-B	0.06 ft	0.29 ft	3.31	6.00
	2 points, Odometer positioning				0.26 ft	3.34	0.00

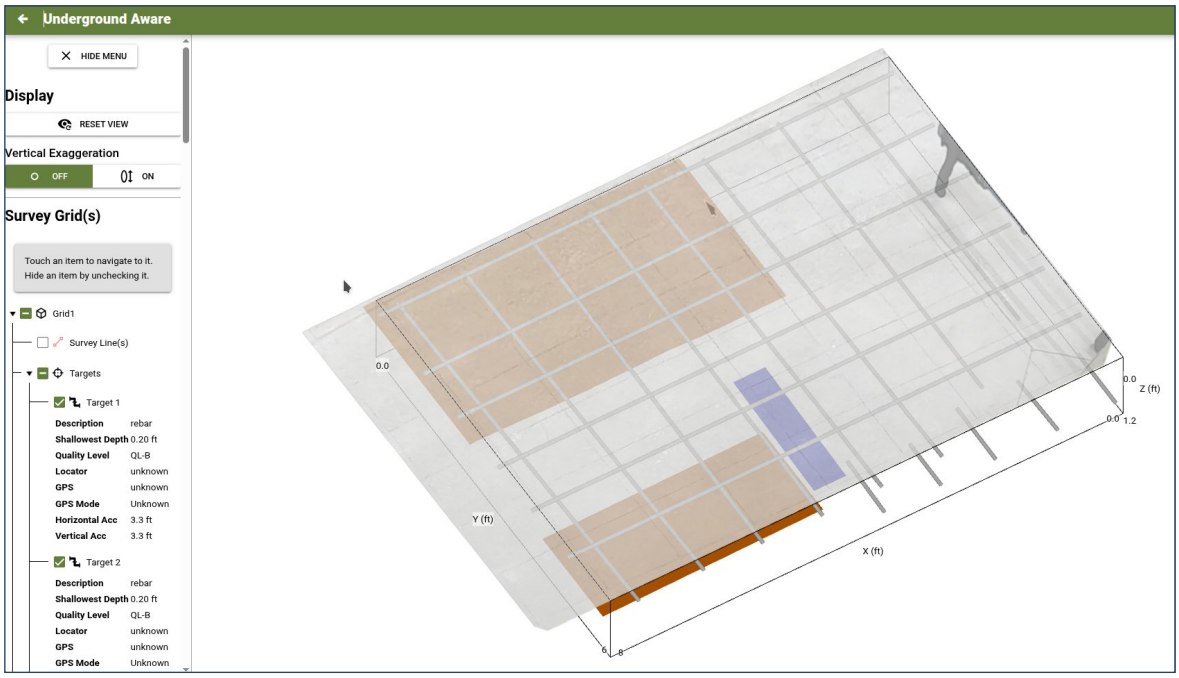


Figure 13. Survey results shared in the cloud. Excerpt of an fast report created by ESSential Underground (top). A shared interactive 3D view using Underground Aware (bottom). Users can share results to anyone with a web browser, on a smart phone or a computer.