SENSORS & SOFTWARE®
from RADIODETECTION

LMX100™

Ground Penetrating Radar

Operation manual

2016-00048-06

SPX

Product Registration

Return this card to register your product, streamline technical support inquiries and receive updates and notifications. You can mail it to Sensors & Software, fax it to +1-905-624-9365, or register your product online at www.sensoft.ca/product-registration.

Name:	Company Name:	
Address:		
City:	State/Province:	Zip Code:
Country:	email:	
Phone:	Fax:	

Component Serial Numbers (refer to packing list or the sticker on the component)

Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Vendor Name:		Date Received:	

End User License Agreement

Please read the End User License Agreement at **https://www.sensoft.ca/producteula/**

Product Warranty and Limited Liability

Please refer to the terms and conditions included as part of your order acknowledgement and/or invoice for full details of the product warranty and limited liability.

Important Safety Information

Use the Display Unit only as specified in these operating instructions, or the protection provided by the unit may be impaired.

The battery charger/AC adapter must only be connected to a power outlet which provides a protective earth (ground).

Connect the AC power cord only to designated power sources as marked on the battery charger/AC adapter.

The battery charger/AC adapter is rated for indoors use only.

Do not replace detachable MAINS supply cords for the battery charger/AC adapter by inadequately RATED cords.

Do not position the Display Unit such that it is difficult to disconnect the 37-pin GPR connector.

The exterior of this product should be cleaned using a damp cloth.

Safety Symbols

Consult this documentation in all cases where this safety symbol appears. This symbol is used to inform you of any potential HAZARD or actions that require your attention.

Do not attempt to open or dismantle any part of this equipment unless directed specifically by this manual. Doing so may render the equipment faulty and may void the manufacturer's warranty.

Use authorized accessories only. Incompatible accessories may damage the equipment or give inaccurate readings.

Follow your company and national safety procedures and or requirements when operating this equipment in any environment or workplace. If you are unsure what policies or procedures apply, contact your company or site's occupational health and safety officer or your local government for more information.

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1. Overview

This manual references embedded software version V1 R6. To see which software version is installed on your system, see the Swipe Down menu in Section 3.4.

The LMX100 Ground Penetrating Radar (GPR) system is optimized for locating buried utilities. With a very simple menu and user-friendly interface, you will be finding targets in minutes.

Features of the LMX100 include:

- High visibility, touch screen display
- UWB (ultra-wide band) Antenna producing highest data quality
- Lightweight fibreglass cart frame
- Built-in Wi-Fi capability
- Integrated GPS receiver for geo-referencing data
- Ability to draw arrows on the screen, to highlight objects
- Easy screen captures of data

This manual describes everything you need to assemble the system, change settings and start scanning. There is also a section that describes the basics of GPR theory and techniques for locating utilities.

Online training videos for the LMX100 can be found on Sensors & Software's website at:

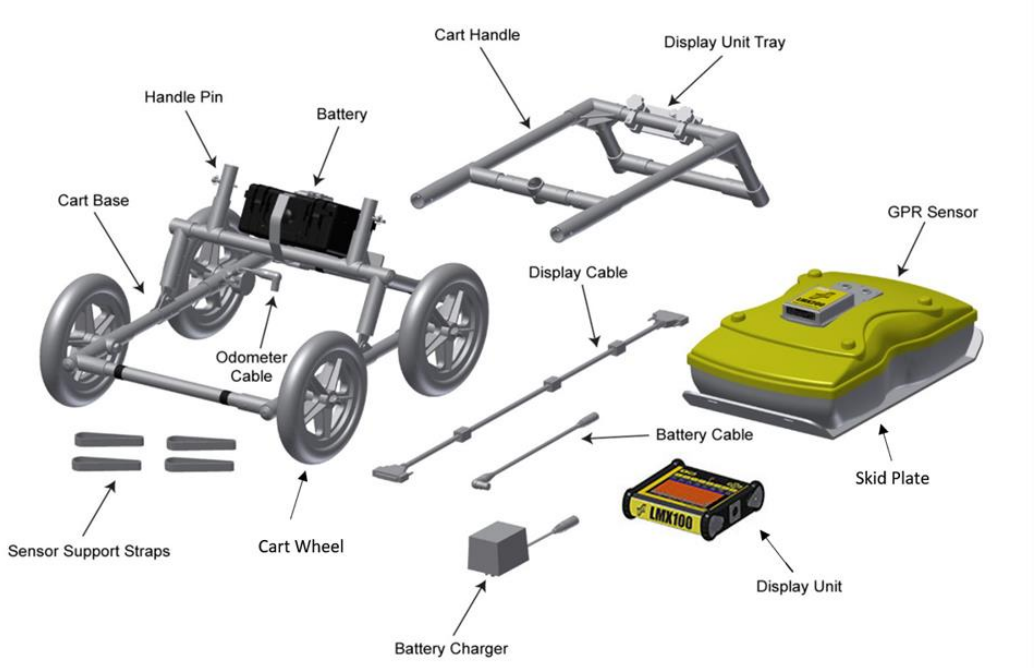
https://www.sensoft.ca/training-events/training/lmx100-training-videos

(note: you will need to setup a login & password to access this)

2. Assembly

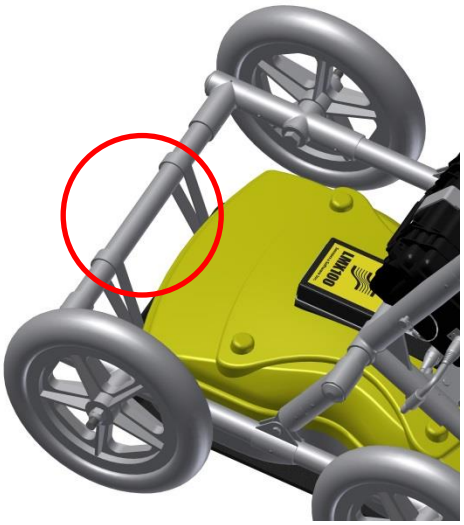
2.1 Out of the box

You will find the following components in your LMX100 box. Some of these may already be assembled.



Attach the Cart Handle to Cart Base using the Handle Pins. Ensure the Display Unit Tray is facing the operator.

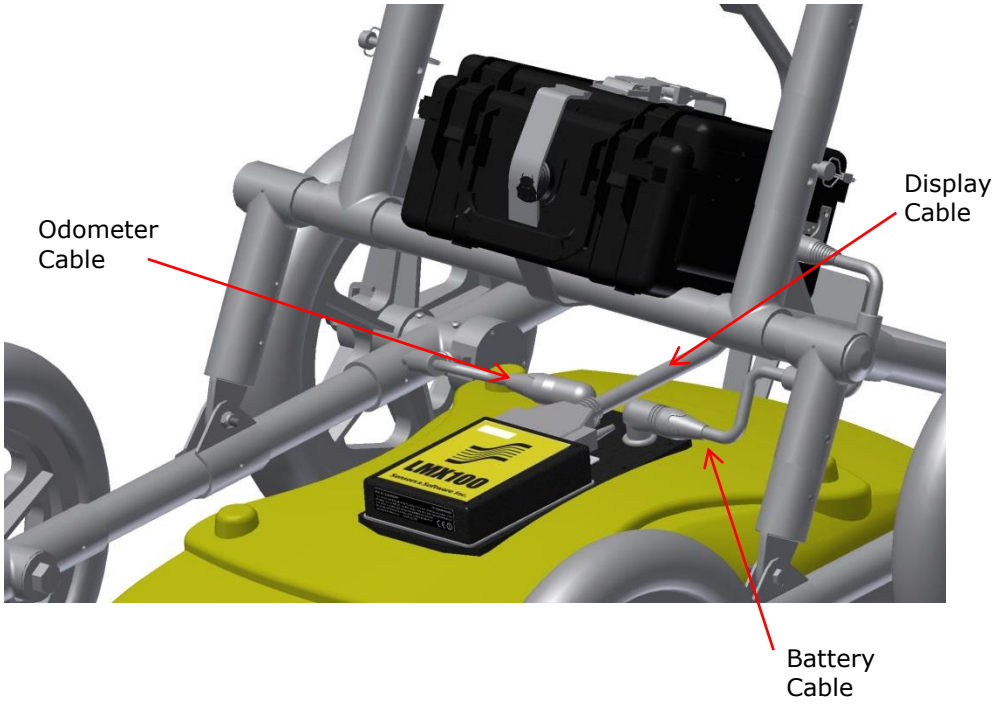
Attach the GPR Sensor to the Cart using the Sensor Support Straps. Ensure the Sensor is oriented the correct way with the connections toward the back of the Cart. Using the Sensor Support Straps, adjust the height of the Sensor so it is 1-2 cm (½ – ¾ inch) above the ground. The best way to get a uniform Sensor height is to place a couple of sheets of thick cardboard, particle board or Styrofoam under the sensor before securing the Sensor Support Straps.



Attach the Display Unit onto the Display Unit Tray on the Cart. The Display unit slides down into the tray, catching on both sides of the mount and is held in place with the pull pin. When a click is heard, the Display Unit is firmly in place. Adjust the angle of the Display Unit by loosening the hand-screws underneath the Display Unit Tray, rotating the Display Unit to the desired angle and tightening the hand-screws. To remove the Display Unit, disconnect all cables, pull out the pull pin and lift the Display Unit up.

Attach the Display Cable to the back of the Display Unit with the jackscrews. Connect the other end of the cable to the Sensor. Ensure the cable is routed as shown below.

Attach the Odometer and Battery Cables. The Odometer Cable connects to the closest receptacle on the Sensor. Attach the Battery Cable to the Sensor and the Battery. The system is now setup and ready to use.



2.2 Fully Assembled

The fully assembled LMX100 will look like the following. Simply reverse directions to disassemble for transport.

3. Getting Started

3.1 Powering Up

When the battery is first plugged in, the LED goes green for 5 seconds then disappears.

To start the system, press the red power button on the display unit. The LED on the front panel will light up red.

Figure 3-1: Display Unit

Once boot up is complete, the colour of the LED will indicate the amount of battery power remaining:

- 20% to 100% = green
- 10% to 20% = orange
- 0% to 10% = red

The first time you turn on the LMX100, you will need to configure the system (Figure 3-1). A series of screen prompts will allow you to setup the language, units, date & time, and some other options. You will have to do this again anytime you update the embedded software (Section 10.6).

Every subsequent time the system boots up, you will see the main screen (Figure 3-2).

Figure 3-2: Main Screen for LMX100

3.2 Shutting down

To power down, press the red power button on the display unit once. A confirmation message will appear, after which you can press **Yes** to proceed. In the rare event that the display unit is unresponsive, a hard shutdown can be done by pressing and holding the red power button until the unit shuts down.

3.3 Interacting with the Display Unit

Data collection is controlled by the Display Unit. The Display Unit has embedded software to set survey parameters and collect, display and store data.

The Display Unit offers touch screen operation, as well as a water-resistant membrane keypad with a number of buttons that can be pressed to perform various tasks. Most operations can be done using either the touch screen or the keypad.

Use the following table as a guide to working with the keypad on the Display Unit:

Item	Description
Menu Buttons	The yellow buttons labelled 1 to 8 correspond to menu choices that appear on the screen.
4-way directional keypad	Controls Up/Down/Left/Right operations in certain menus.

Item	Description
Camera	Saves a screenshot of data.
Asterisk / Special Function	Used for adding Flags during data acquisition

3.4 Swipe Down menu

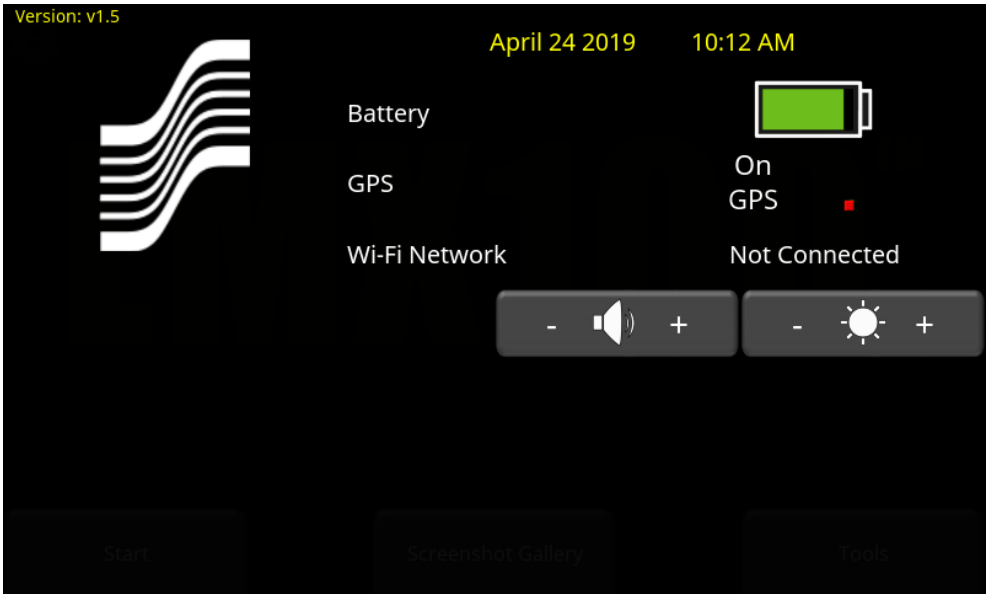


Figure 3-3: Swipe Down Menu

When the Display Unit is powered on, you can “swipe” your finger from the top of the screen towards the bottom, to display a Swipe-Down menu (Figure 3-3) with the following items:

Date and Time: The current date and time (12-hour clock). The time needs to be changed in areas that observe daylight-savings-time.

Battery: The battery icon displays the amount of power remaining in the battery.

GPS: Shows the status of the GPS receiver

Wi-Fi Network: Indicates if the system is connected to a wireless network and, if so, the name of the network. See Section 4.1.6 for details on connecting the system to a wireless network.

Volume: The Volume + and - buttons are used to increase and decrease speaker volume.

Brightness: The Brightness + and - buttons are used to increase and decrease the screen brightness. Increasing the brightness setting may improve the visibility of the screen in bright sunlight. Note, however, that increasing the screen brightness also increases power consumption, thus reducing battery life.

To close the Swipe-Down menu, touch anywhere on the screen below the swipe-down menu.

4. Tools

From the main screen shown, press **Tools** to enter this sub-menu. Here you can set preferences, adjust system settings and perform system tests. You will see the screen shown in Figure 4-1:

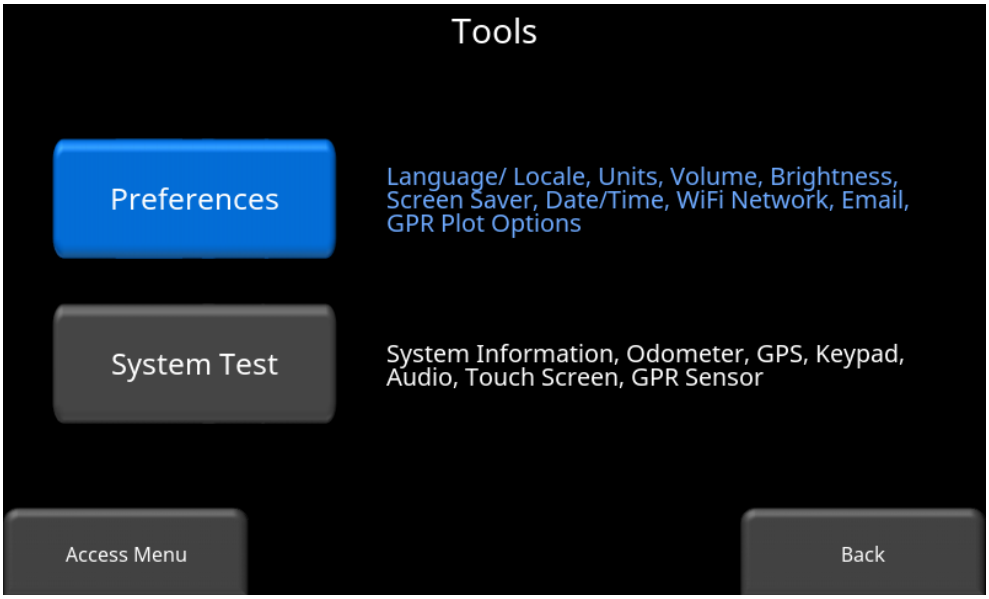


Figure 4-1: Tools menu

4.1 Preferences

Selecting the preferences option will take you to the sub-menu shown in Figure 4-2.

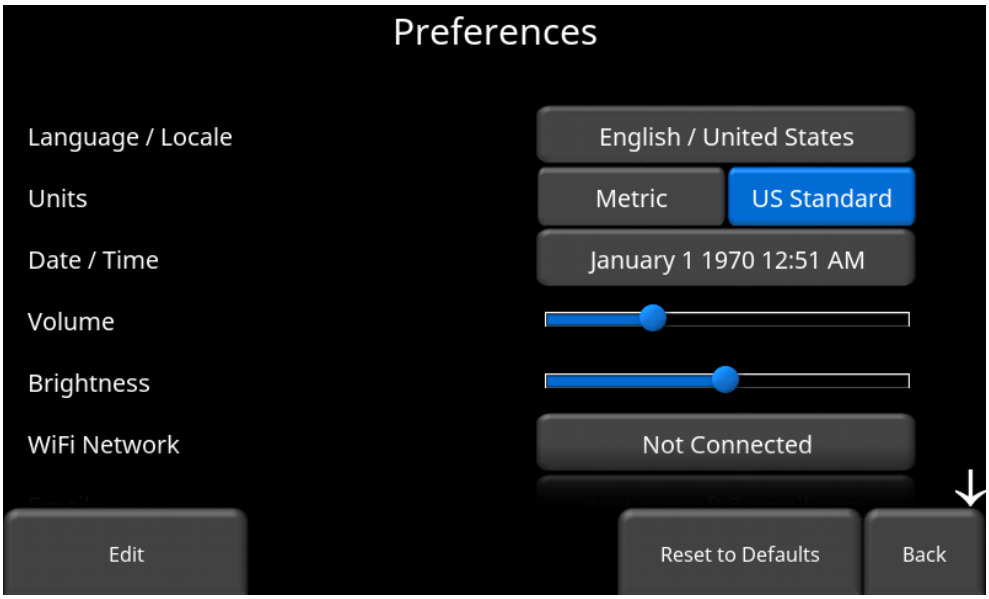


Figure 4-2: Setting Preferences

There are several parameters that can be modified. Touch the screen and swipe up or down to scroll and view additional parameters. To change a value, press the value on right side of the screen. Alternatively, use the up and down arrows on the 4-way keypad to highlight the desired parameter, then press **Edit**. Each parameter is described in detail below.

4.1.1 Language / Locale

Selecting this option will display the screen in Figure 4-3. The current language is displayed; pressing the **+** and **–** buttons on either side of the language will cycle between the languages currently available. Below that, the Country/Region is displayed. Press the **+** and **–** buttons on either side of the displayed Country/Region to alphabetically move to the next or previous country or region.

Alternatively, both Language and Country/Region can be changed by pressing the **+** and **–** buttons on the bottom of the screen. Press **Back** when you are done.

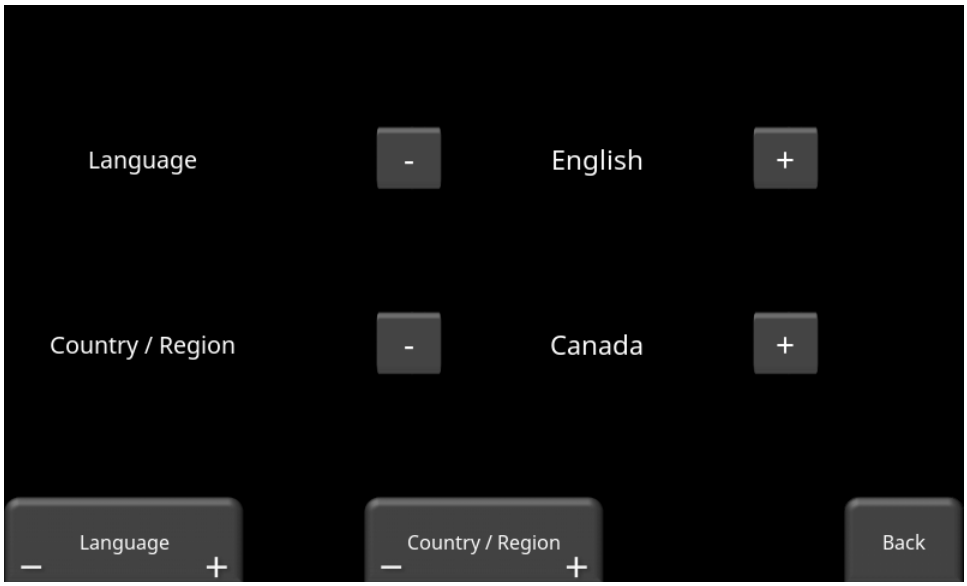


Figure 4-3: Changing Language and Country/Region

4.1.2 Units

Pressing **Units** will cycle between US Standard and Metric Units.

4.1.3 Date/Time

Selecting this option takes you to a screen where the date and time can be set. The time is manually set and will not automatically correct for daylight savings time.

4.1.4 Volume

Scroll bar for adjusting the volume of clicks and beeps heard during operation. This can also be changed by using the Swipe Down menu (Section 3.4) anytime the system is not collecting data.

4.1.5 Brightness

Scroll bar for adjusting the brightness of the screen. Note that increasing the brightness consumes more battery power. This can also be changed by using the Swipe Down menu (Section 3.4) anytime the system is not collecting data.

4.1.6 Wi-Fi Network

Connecting to a wireless network allows you to send a mini-report to someone by email. This connection can be through a standard Wi-Fi network or through a hotspot on your mobile device while in the field.

Note that LMX100 CANNOT connect to Public Hotspots (typically restaurants, hotels and airports) that require a web-based login and acceptance of their Terms & Conditions. It also CANNOT connect to unsecured networks (networks that do not require a password).

If you are already connected to a Wi-Fi network, the name of the network is listed beside the Wi-Fi Network field. Selecting **Wi-Fi Settings** takes you to a sub-menu (Figure 4-4) for connecting and configuring Wi-Fi settings.

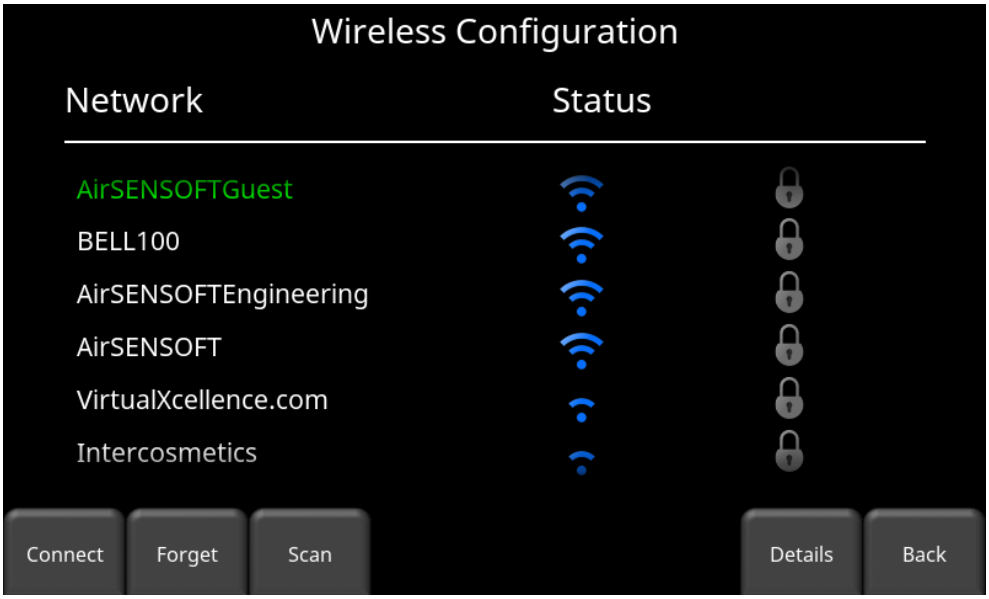


Figure 4-4: Configuring Wireless settings and Email address

Use the up and down arrows on the 4-way directional keypad or touchscreen to select the network. The color of the Network Name indicates the status:

- Green = Connected
- Yellow = Not currently connected but remembered from before when you previously connected and entered a password.
- White = Not connected

- **Connect** – Select the desired network and press **Connect**.
  If the connection is successful (this can take a minute or so) a screen appears asking for the password for that network. If the network name is yellow (from a previous connection to this network), it will not ask for a password because it is a remembered network. Once it connects the Network Name will turn green.
- **Forget –** Use the **Forget** button to remove the password for connected or remembered networks (text in green or yellow). Once the 'forget' button is pressed on a selected network it will remove the password and the Network Name will turn white. You will also be disconnected if you are currently connected to that network.
- **Scan –** Scans for any available networks in the area and displays them in order of strength of signal. You may need to press this button a second time if you don't see the network you are looking for.
- **Details –** Pressing this button displays the security settings and device addresses related to the selected network.
- **Back –** Press this button to return to the System Settings screen.

4.1.7 Email

Press **Email** to arrive at a sub-menu where you can setup and configure a sending email address. Ensure that this email address already exists. This is the sending account where messages will originate from. All mini-reports received by the recipient will appear to come from this account.

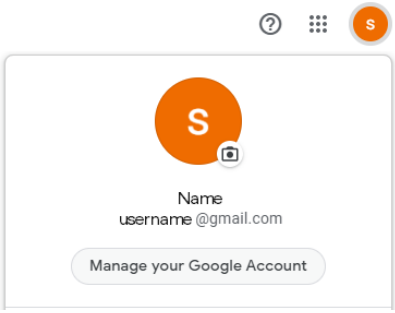
Using GMAIL

Using a Gmail address on the Display Unit requires "app specific password". An app specific password is a 16 character randomly generated passcode that allows access to a portion of the overall Google account. These passwords can be deleted at any time if the user feels it has been compromised. Note that 2 factor authentication is required for the use of app specific passwords.

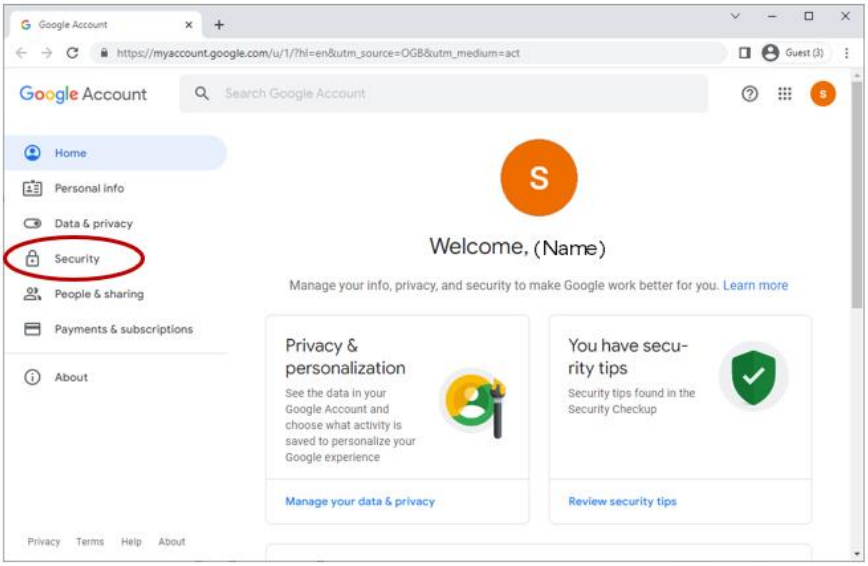
The following procedure details the steps required to enable and generate an app specific password:

1) Log into Google account on a desktop computer.

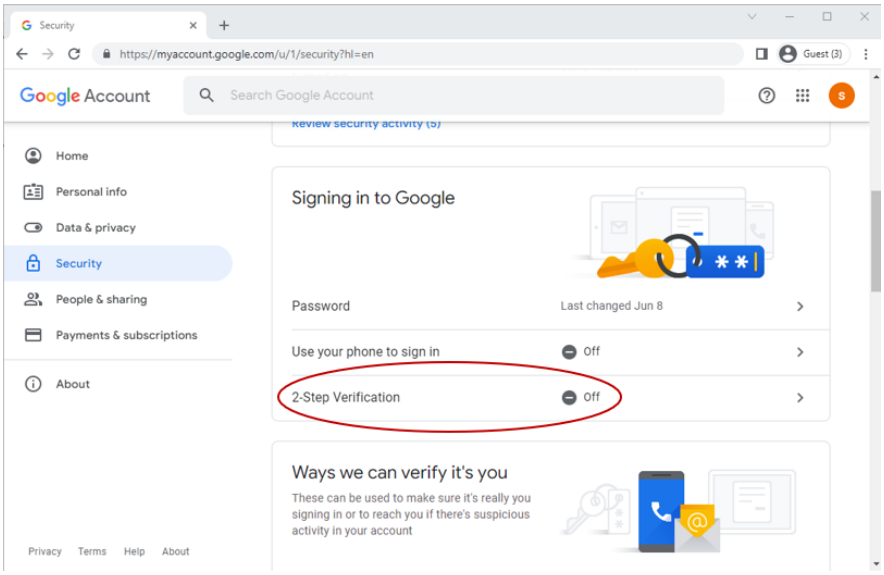
2) Click on the top right account icon and select **Manage your Google Account**



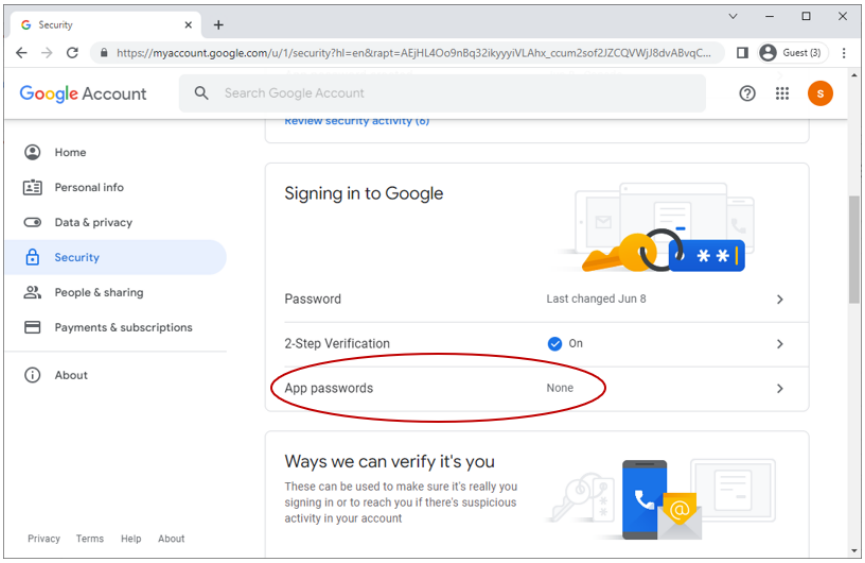
3) Select **Security** from the left menu



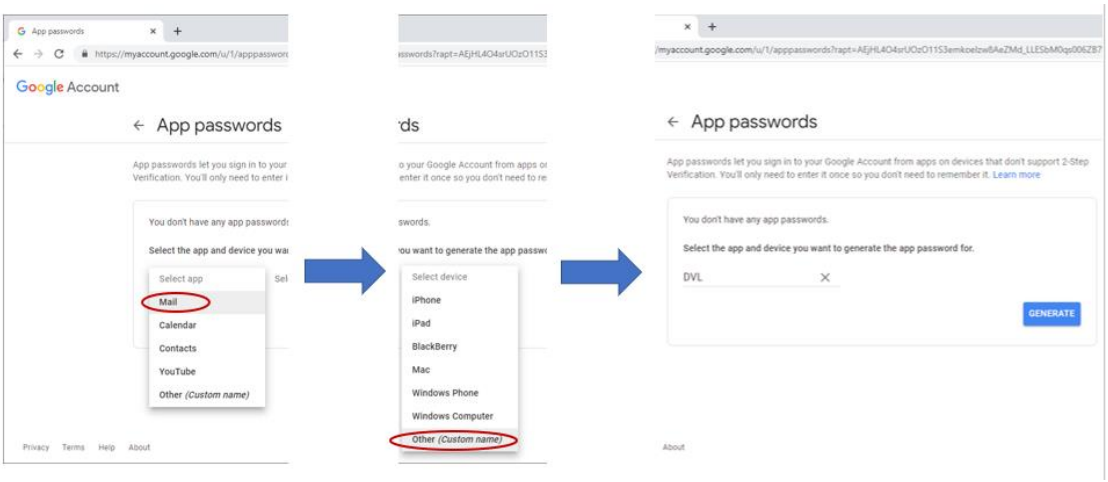
4) Scroll down to the **Signing into Google** section and turn on **2-Step Verification** (if it is not already enabled). Follow the onscreen instructions to add/verify your phone number



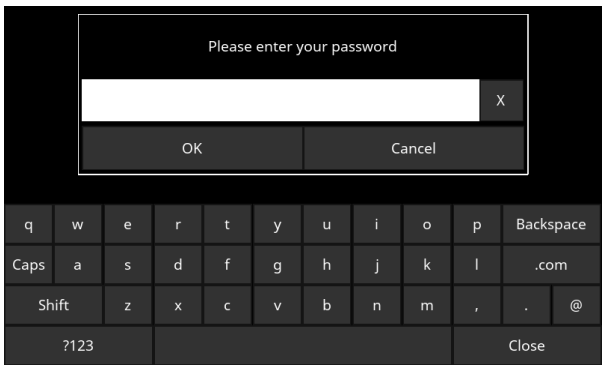
5) Return to the Security menu and you should now find the **App passwords** option under **Signing into Google**. Click on **App passwords**.



6) Under “Select app” choose **Mail**, and under “Select device” choose **Other** and enter an appropriate name (i.e., DVL). Click **Generate**.



7) Use the generated 16-character password when configuring your Gmail account on the DVL:



Once you have made the changes in your Google account, continue below (Figure 4-5):

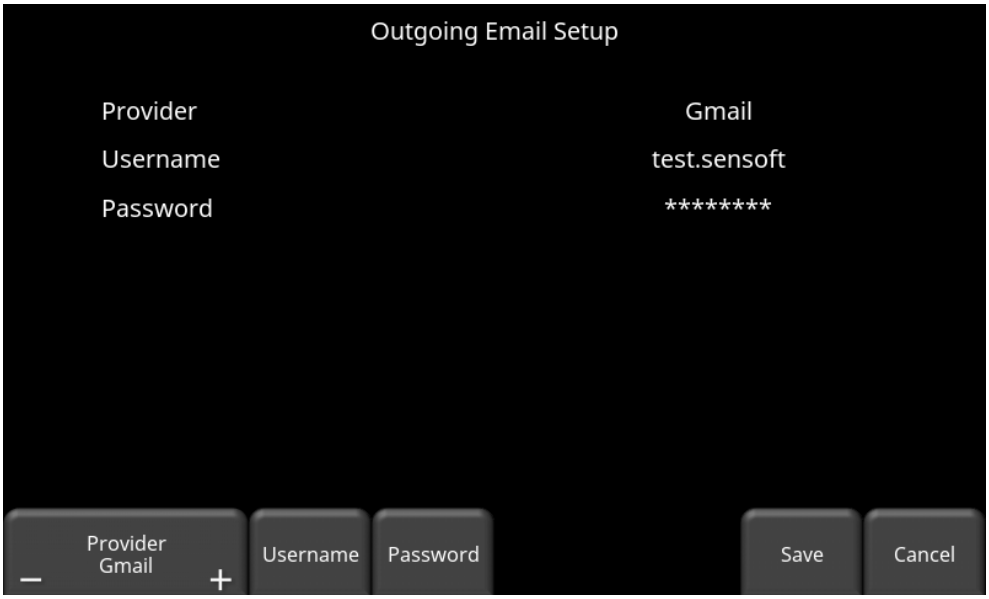


Figure 4-5: Using GMAIL as email provider

- Press **Username** to display a keyboard where you can enter your GMAIL username only; you do **not** need to enter @gmail.com. Then press OK when done (Figure 4-6a)
- Press **Password** to display a keyboard where you can enter your GMAIL password. Then press OK when done (Figure 4-6b)
- Press **Save** when both Username and Password have been entered.

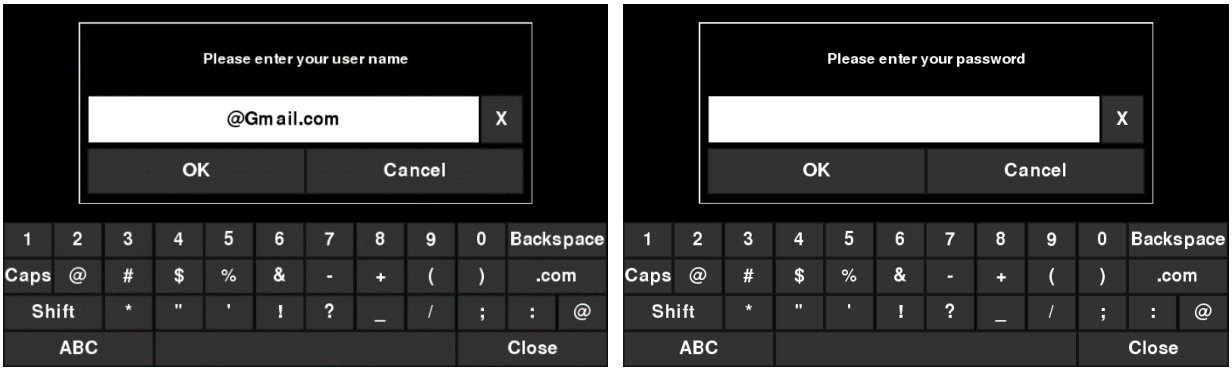


Figure 4-6: Entering email address (a) and password (b) for GMAIL

If there are no warning messages, the email address is setup properly and you are ready to email mini-reports from the field. If this does not work, see the Failed Setup section below

Using Another Provider

To use another email provider, press the **+** and **–** buttons under **Provider** until it says **Custom.** This will display the screen shown in Figure 4-7 allowing you to setup and configure a different email provider:

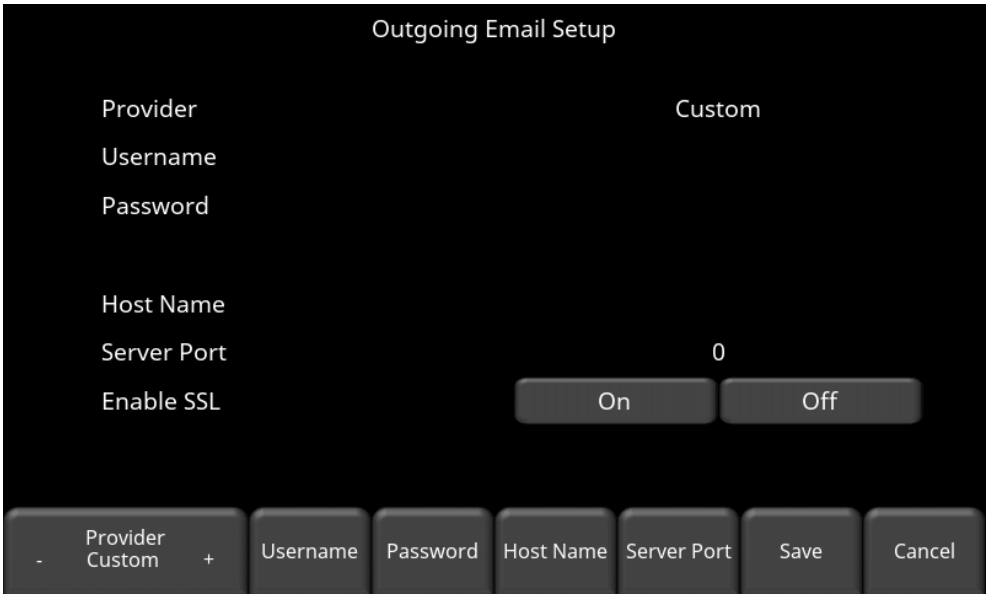


Figure 4-7: Entering email address and password for another email provider

- Press **Username** to display a keyboard where you can enter the complete email address, then press OK when done.
- Press **Password** to display a keyboard where you can enter the password, then press OK when done.
- Press **Host Name** to display a keyboard where you can enter the name of the server address handling the outgoing mail. See chart below for some common email providers. If your provider is not listed, it can usually be found by searching online for "SMTP host name <provider>", where provider is the host name e.g. Yahoo or AOL. Press OK when done.
- Press **Server Port** to display a keyboard where you can enter the port number used by the email server. Searching online for host name will usually provide the port number for that email provider. In most cases, it's usually 465 (if SSL is enabled, see next bullet point), or 587. See chart below for some examples. Press OK when done.
- Enable SSL – you can select **On** or **Off** on the display. SSL provides encryption security. Some email providers require this set to ON. This will usually be indicated on the same online search page that was used above. See the chart below for examples.
- Press **Save** when all the information is entered and correct.

Below is the chart for some common email providers:

Provider	Host name	Server Port	Enable SSL
Yahoo	smtp.mail.yahoo.com	465	On
Hotmail/Outlook	smtp.live.com	587	Off
iCloud	smtp.mail.me.com	587	Off
163.com	smtp.163.com	465	On
Yandex	smtp.yandex.com	465	On

If there are no warning messages, the email address is setup properly and you are ready to email mini-reports from the field.

Failed Setup

If setup failed, possible reasons include:

1. No-Wi-Fi connectivity
2. Email address or password was entered incorrectly – try re-entering these fields.
3. Hostname, port or SSL setting are incorrect
4. Your email security settings **may need** to be adjusted to a more permissive setting, which may require you to login to your email account from a PC or mobile device.

4.1.8 Screen Saver

A screen saver can be setup to turn off the Display Unit screen after a period of inactivity to save power. The Screen Saver can be set to turn the screen off after 1 minute, 5 minutes or never (OFF setting). Pressing this button cycles between those three options. When the screensaver is activated and the screen shuts off, touch anywhere on the screen to turn it back on again.

4.1.9 GPR Plot Options

Selecting this option will display the screen in Figure 4-8.

Figure 4-8: GPR Line Plot Options

- **Auto-Hide Buttons** - If this is set to ON, then in Line Scan mode, the buttons at the bottom of the screen disappear shortly after data collection begins, effectively enlarging the area for data display. The buttons will re-appear after a couple of seconds whenever the sensor stops moving forward, is in back-up mode or any button is pressed on the keypad.

4.1.10 Reset to Defaults

Selecting this option at the bottom of the screen will reset all settings & preferences back to the default settings (Figure 4-9). Pressing this will ask you to confirm the Reset to Defaults. If **Yes** is selected, the next screen will ask if you would like to remove all saved wireless networks and emails addresses. Note that any saved screenshots will still remain on the system.

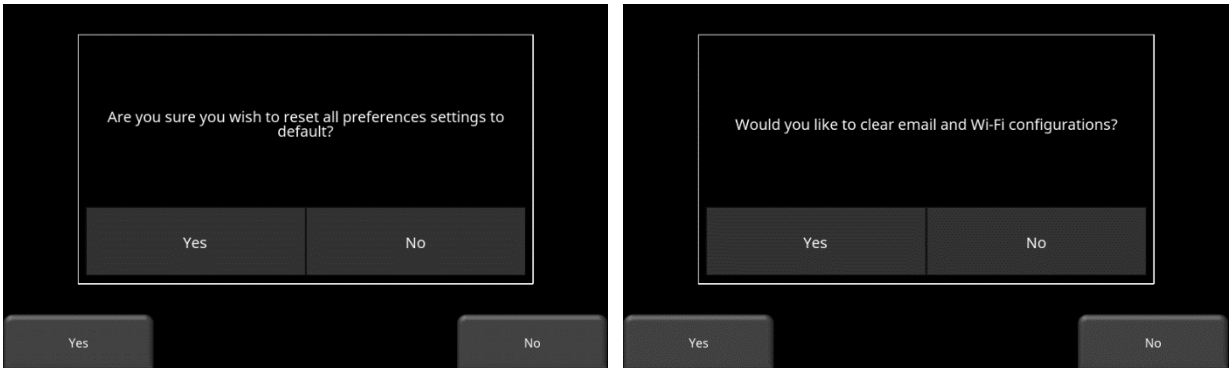


Figure 4-9: Reset to Defaults, a) Image on left is the first confirmation screen. b) If you press Yes, you will see the second confirmation screen on the right asking about deleting emails and Wi-Fi settings.

4.2 System Test

The system test sub-menu (Figure 4-10) allows the user to perform certain tests to ensure proper operation of the system. Select the component to test then press **Start**. After completing a test there is an indication of whether the system passed or failed the test. Each test is described below in more detail.

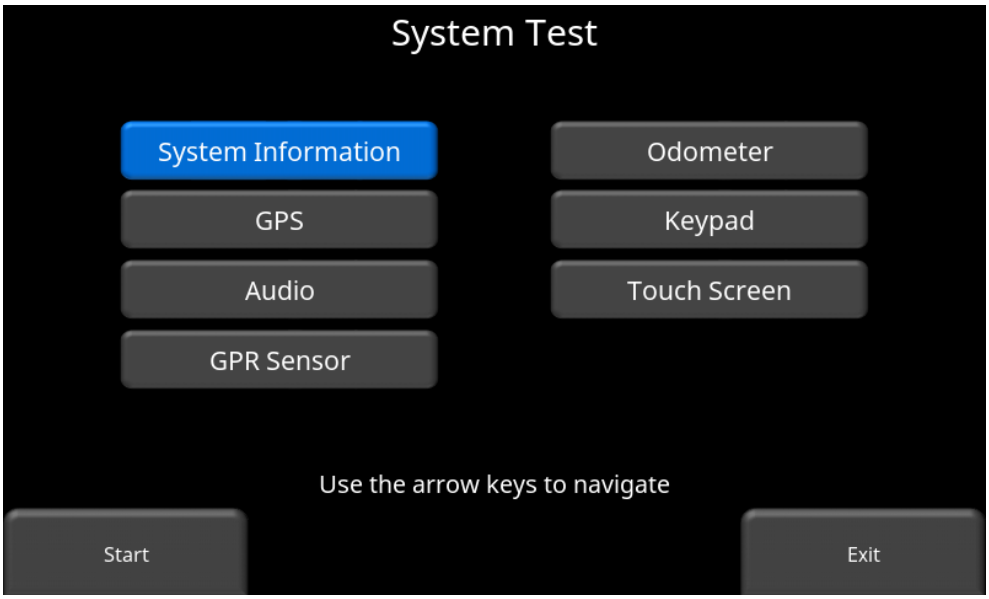


Figure 4-10: System Test menu

4.2.1 System Information

System Information is the only option in System Test which is not actually a test. Here information such as the version, serial numbers, temperature and battery power are displayed. (Figure 4-11). There are two options at the bottom of this screen:

- **Export** - If a USB key is currently inserted, pressing Export will just export the System Log and Summary Files

Figure 4-11: System Information

- **Anonymous Usage Statistics** - When this is set to ON and the user is connected to a wireless network, any system malfunctions will trigger an automatic notification to Sensors & Software. This is to help with gathering information about any system irregularities. As the name suggests, the notification is completely anonymous and no personal information is sent.

4.2.2 Keypad Test

The keypad test ensures that all buttons on the membrane keypad are working. Press **Start** to begin the test which requires the user to press each button once, within a 20 second timeframe (Figure 4-12).

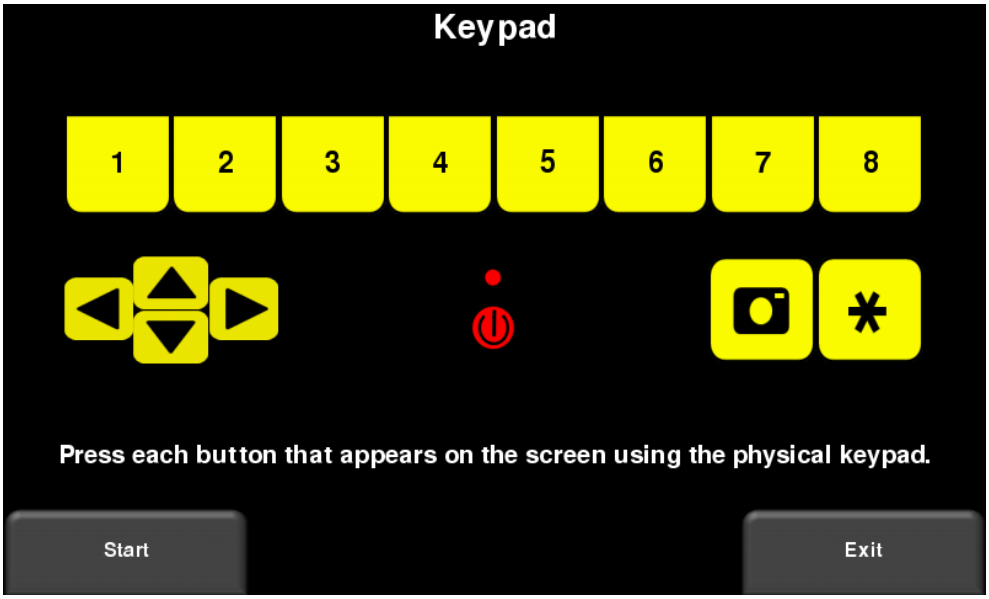


Figure 4-12: Keypad Test

Once that is complete, a short LED test will ensue, which checks the proper operation of the LED.

4.2.3 Audio

This test ensures that the speaking is operating properly (Figure 4-13). After starting the test, you should hear a sound with an increasing pitch.

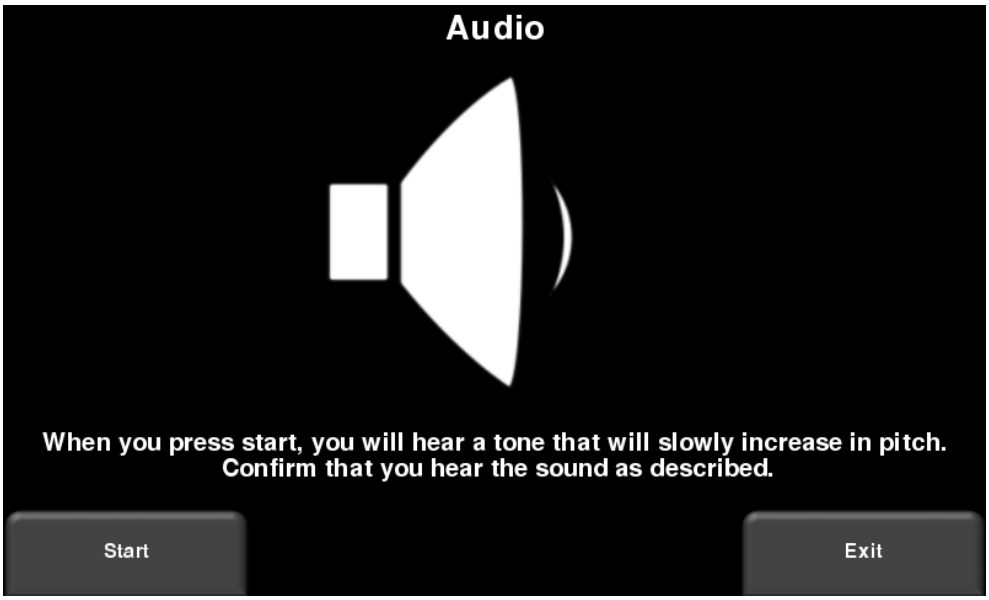


Figure 4-13: Audio Test

4.2.4 Touch Screen

The test checks proper operation of the touch screen (Figure 4-14). It allows you to test the screen (by pressing **Test**) or perform a quick calibration followed by a test (by pressing **Calibrate**). Both involve touching targets on the screen in the allotted time.

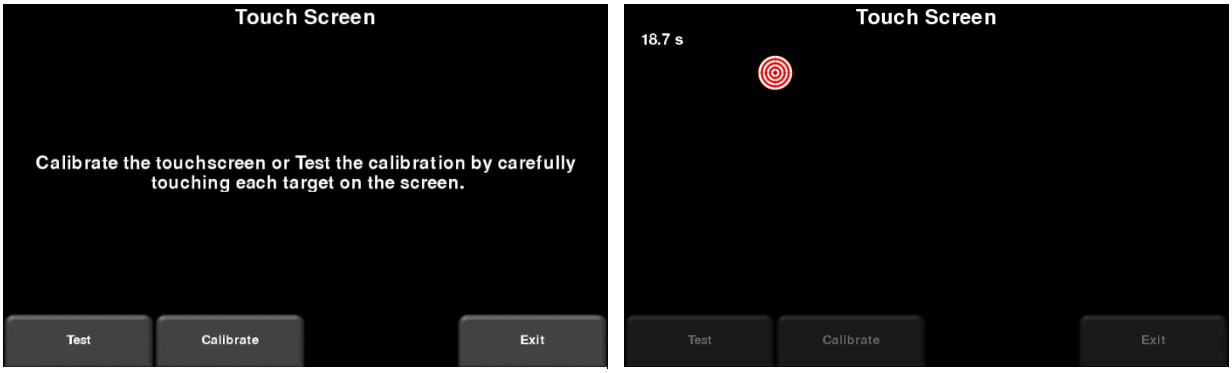


Figure 4-14: Touch Screen test on the left, Touch Screen calibration on the right

4.2.5 Sensor Test

This test checks proper operation of the GPR sensor, including the amplitude of the pulse. Once the cart is tipped backwards and start is pressed, it will conduct the test (Figure 4-15). If there are any irregularities, the test will indicate failure. However, if the test passes, it doesn't mean the system is working perfectly. A test line should be setup as a baseline, and results compared to the test line to validate proper performance and operation (Section 9.6)

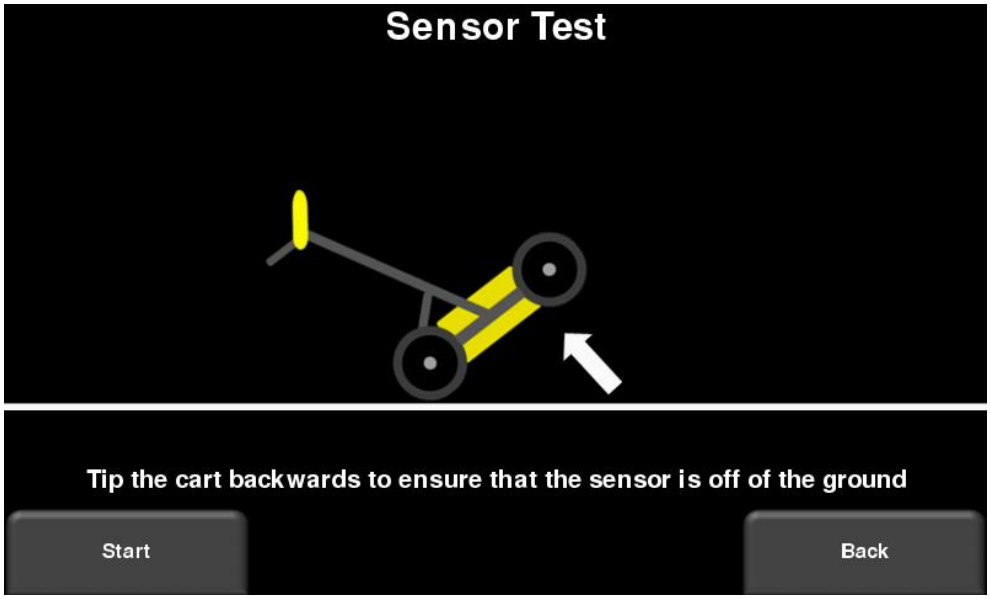


Figure 4-15: Sensor Test

4.2.6 Odometer Calibration

This test ensures that the odometer is measuring distance accurately. Even though the odometer is calibrated in the factory, you must calibrate it periodically to ensure accuracy. This is particularly important as the calibration can change with different surface materials.

When selecting this option, you will see the screen in Figure 4-16. The following options exist:

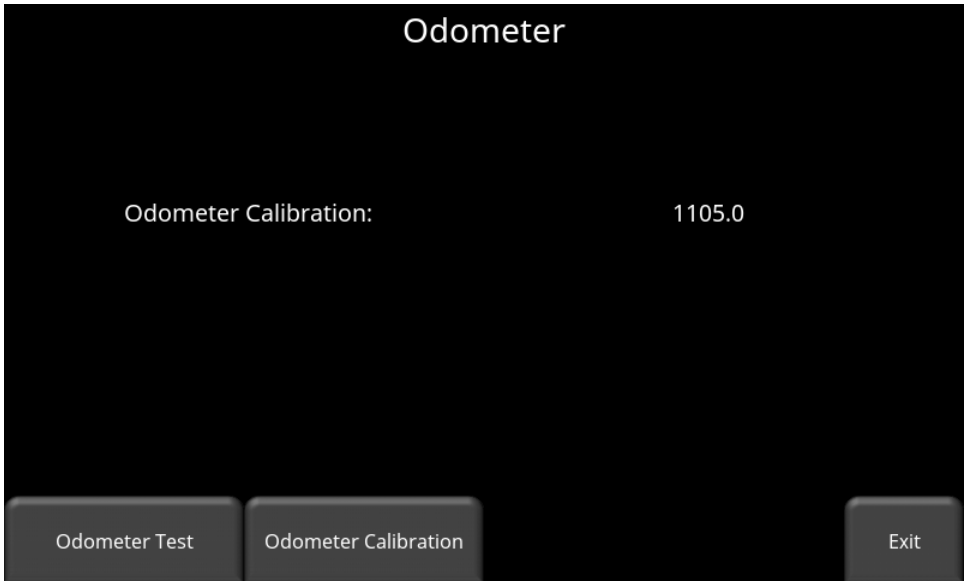


Figure 4-16: Screen displaying current odometer calibration

- **Odometer Test** – This test verifies the odometer is calibrated properly. It involves moving the system a set distance (5m or 10', depending on units used), and comparing the value obtained to a known value. The screen in Figure 4-17 will be displayed once Odometer Test is pressed. Press **Start** to begin and then press **Finish** when you've moved that distance. It will display a pass or fail, along with a percentage difference from the known value (Figure 4-18).

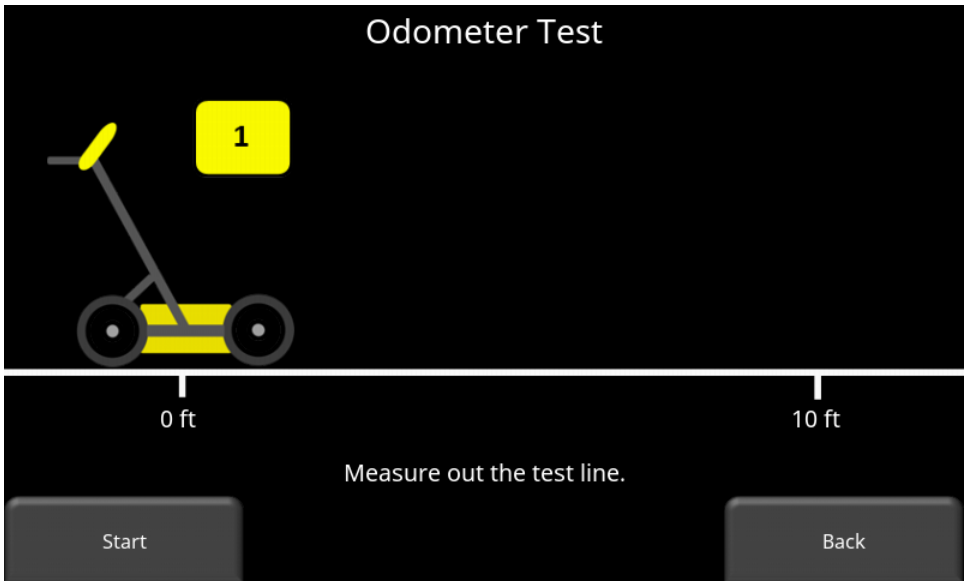


Figure 4-17: Doing an odometer test

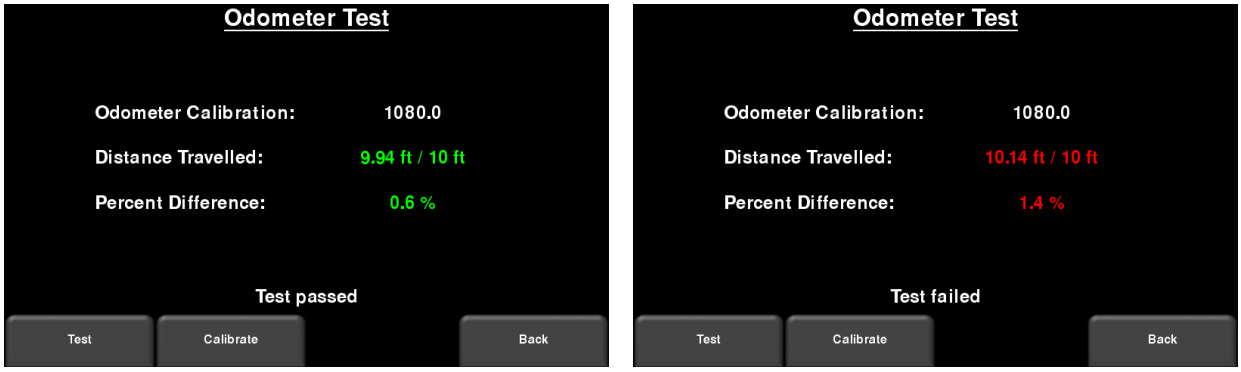


Figure 4-18: Odometer Test passed on left, failed on the right

- **Odometer Calibration** - This option actually calibrates the odometer (Figure 4-19). Choose a set distance from the screen or select Custom. Then press **Start** and move the system that exact distance, using a measuring tape or other known distance indicator. Press **Finish** when you have travelled that distance

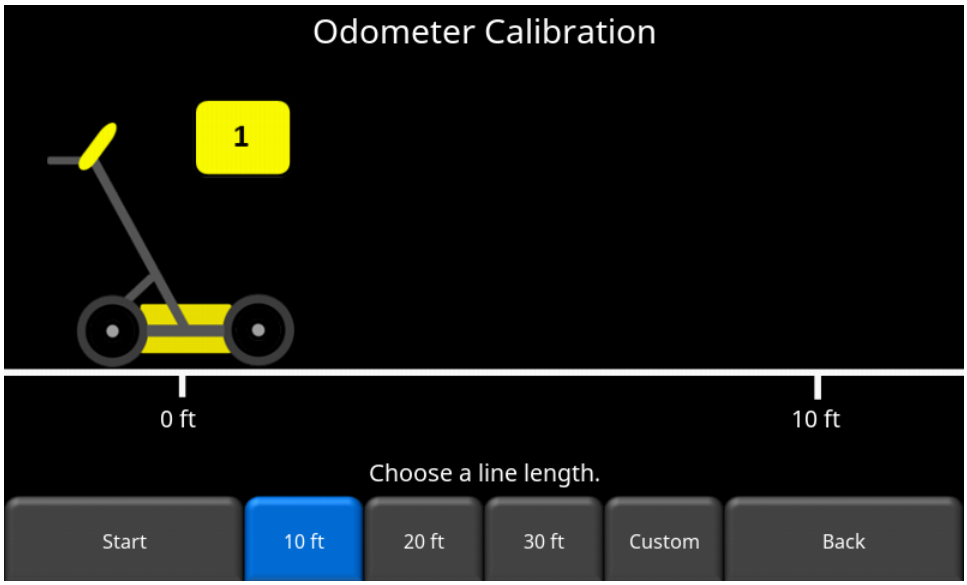


Figure 4-19: Odometer Calibration – select a distance and then press Start

Upon completion, it displays the screen in Figure 4-20 (left image). You can either accept the new value by pressing Accept or revert back to the previous value by pressing Reject. If the new value is significantly out of range, the test will fail Figure 4-20 (right image).

The odometer calibration value is stored in the Display Unit. If the Display Unit is changed, or swapped out, you will need to run the Odometer Calibration test again.

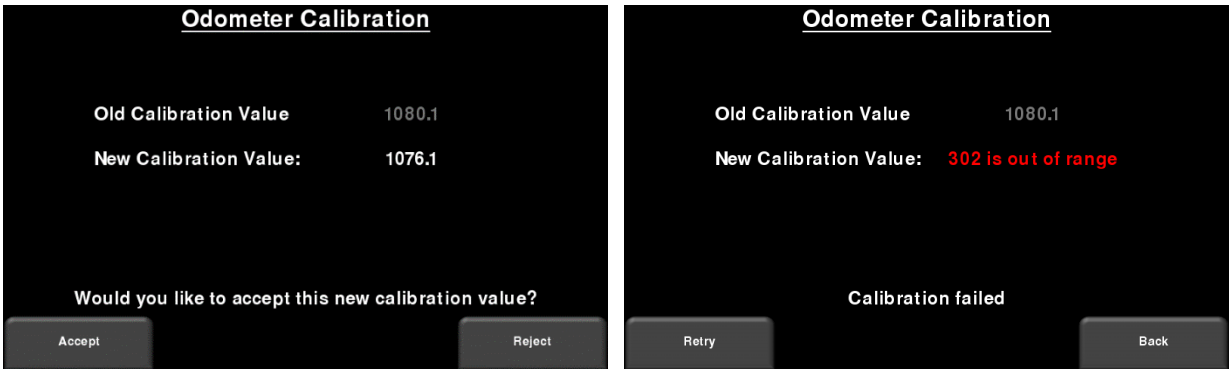


Figure 4-20: Results of successful Odometer Calibration (Left). Image on Right shows a failure, as calibration is out of range

4.2.7 GPS

The internal GPS can be used to geo-reference screenshots, so they can be positioned on Google Earth™ for example. The GPS test will ensure that the system is communicating properly with the GPS and receiving data (Figure 4-21). It doesn't mean you are actually seeing satellites; the GPS test can still pass indoors with zero satellites visible.

Figure 4-21: GPS Test

The basic position and time information is displayed on the screen. On the screen, the Fix Type notes if there are any corrections being applied, such as DGPS. When first going outside, give it a few minutes to track, or lock onto satellites.

Pressing **Strings** will display the raw data strings that are outputted by the GPS (Figure 4-22) as they scroll down the screen. The user may select this option to verify the GPS is outputting the proper NMEA string format.

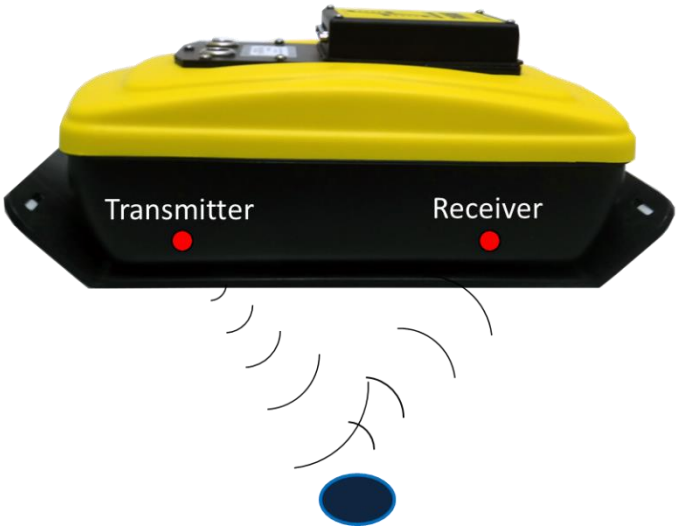
Figure 4-22: GPS Strings

Pressing **Clear** will clear the strings. Pressing **Info** will return to the main GPS test menu.

5 GPR Concepts

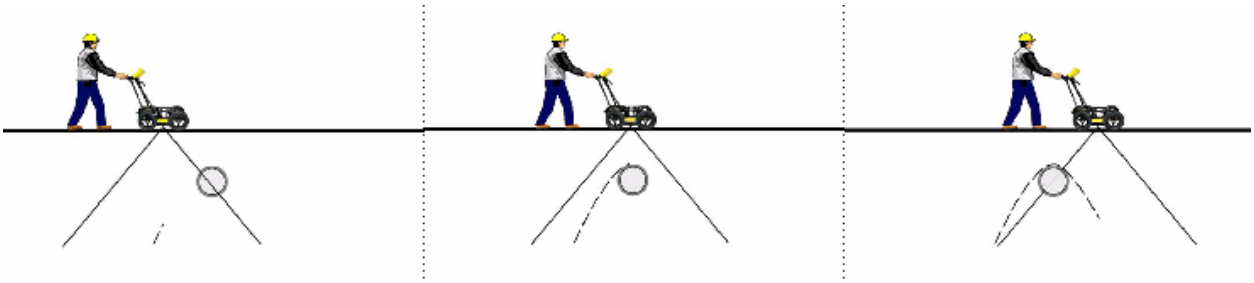
5.1 Theory

Ground penetrating radar (GPR) technology uses radio waves to image objects in the subsurface. The subsurface may consist of soil, rock, asphalt and other materials. GPR systems emit high frequency radio wave pulses and detect the echoes that return from objects within the subsurface. Echoes are produced when the target material is different from the host material (e.g. PVC pipe in gravel)

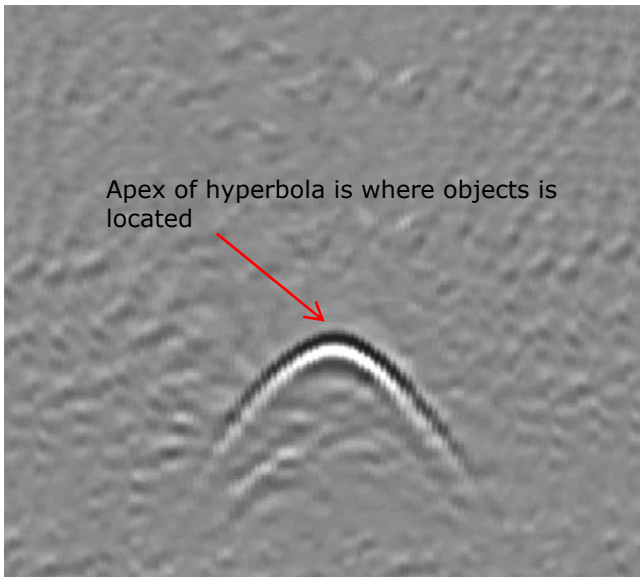


5.2 Hyperbolas

The GPR display shows signal amplitude versus depth (time) and sensor position along a line. Since radar energy radiates in a 3D cone shape rather than a thin beam, a ***hyperbola*** (or inverted U) is the GPR response from a small point target like a pipe, rock, or a tree root. The radar wave hits the object before and after going over it and forms a hyperbolic reflection that can appear on the record even though the object is not directly below the radar:



Hyperbolas are best viewed when subsurface targets are crossed perpendicularly (at a 90-degree angle). The actual position of the object is located at the apex of the hyperbola.



5.3 Calculating Depth

Ground penetrating radar records the time it takes a radio wave to travel to a target and back; it does not measure the depth to that target directly. Depth to target is calculated based on the velocity with which the wave travels to the target and back.

To calculate depth:

$$D = V\ x\ T/2$$

$$Where\ D\ is\ Depth$$

$$V\ is\ Velocity$$

$$T\ is\ the\ Two-way\ travel\ time$$

For the LMX100, velocity is indicated by the Soil Calibration Value, known as Soil Cal. Once the Soil Cal values are set, the measured depths will be determined accurately (Section 6.2.4)

5.4 Soil Calibration Values

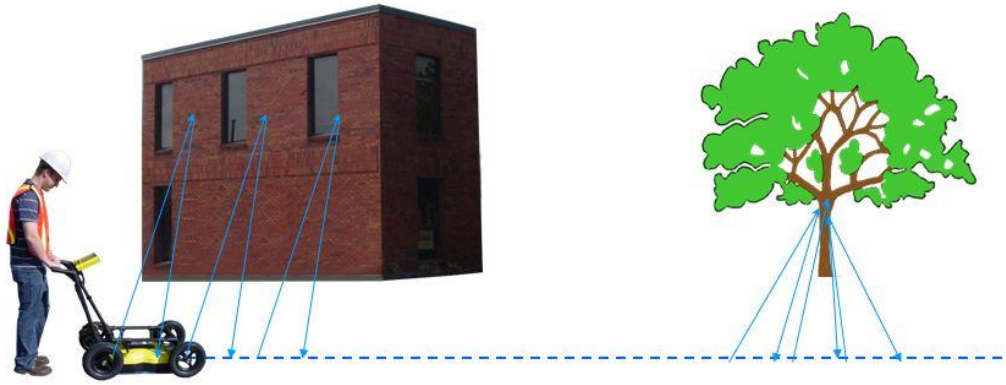
Below is a table of common subsurface materials and their corresponding Soil Cal. This is only a guideline and there is some variation based on the fact that there can be a mixture of different materials in the subsurface. By far, the soil water content has the biggest influence on Soil Cal values.

Material	Soil Cal
Air	300
Ice	160
Dry Soil	140
Dry Rock	120
Soil	100
Wet Rock	100
Concrete	100
Pavement	100
Wet Soil	65
Water	33

5.5 Air Waves

Some hyperbolas are caused by air wave reflections from objects above ground, such as posts, fences, overhead wires, and trees.

The following image displays how air wave reflections affect data:



An important part of understanding the data image is learning to recognize these unwanted "air" targets and distinguish them from the targets in the ground. Good field notes are indispensable for helping identify unwanted events on the data.

The best way to identify air reflections is the target hyperbola method. Hyperbolas from above ground objects are wider than objects in the ground and will have a Soil Cal at, or close to, 300.

To learn more, see Soil Cal (Section 6.2.4).

6 Data Collection

GPR data is collected along a straight line and allows the operator to view it as a cross-section image. The operator can locate a feature and easily back-up and mark the location of that object on the ground. The operator can identify the alignment of subsurface features, check for linearity and acquire accurate depth measurements.

From the main screen, press the **Start** button; you will see the screen shown in Figure 6-1.

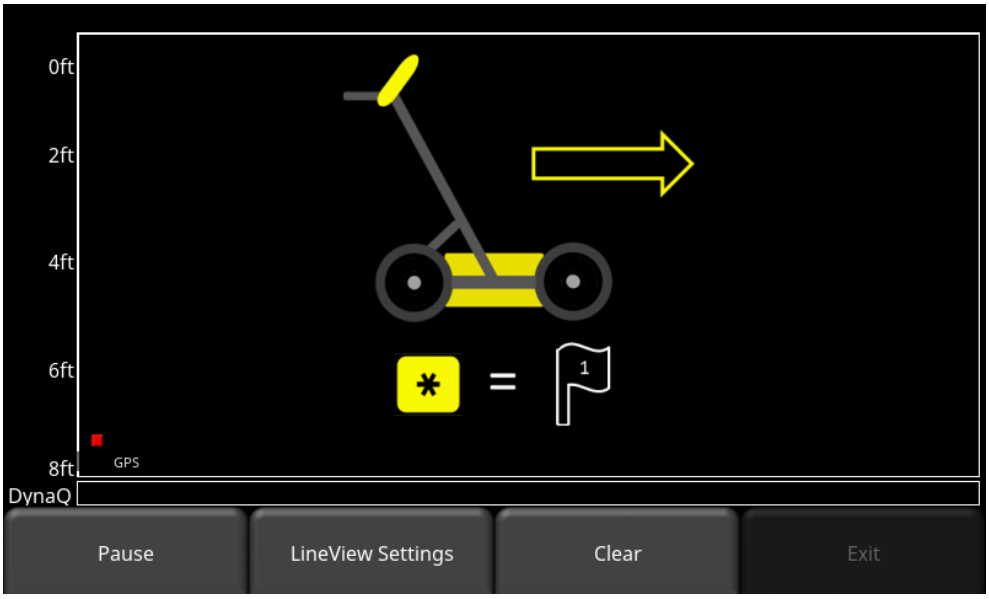


Figure 6-1: Data Collection screen

The GPS Status Indicator (lower left in Figure 6-1) shows the quality of the GPS signal, which is based on the number of satellites that it sees. The chart below explains what the colours and bars mean:

Indicator Color	# of bars	# of Satellites
Red	1	4
Orange	2	5
Green	3	6,7
Green	4	8,9
Green	5	10+

6.1 Acquiring Data

The system is ready to collect data as soon as you see this screen. As the system is pushed along a straight line, the collected GPR data scrolls onto the screen from the right and moves to the left (Figure 6-2).

The depth scale along the side of the GPR Line image and the position scale along the top of the image are set to Metric or US Standard units based on the setting in the Preferences menu.

If Auto-Hide Buttons is set to ON (Section 4.1.9), the menu at the bottom of the screen disappears as soon as you start collecting new data, thereby maximizing the data display area. When the user stops, backs up or presses a button on the keypad the menu reappears.

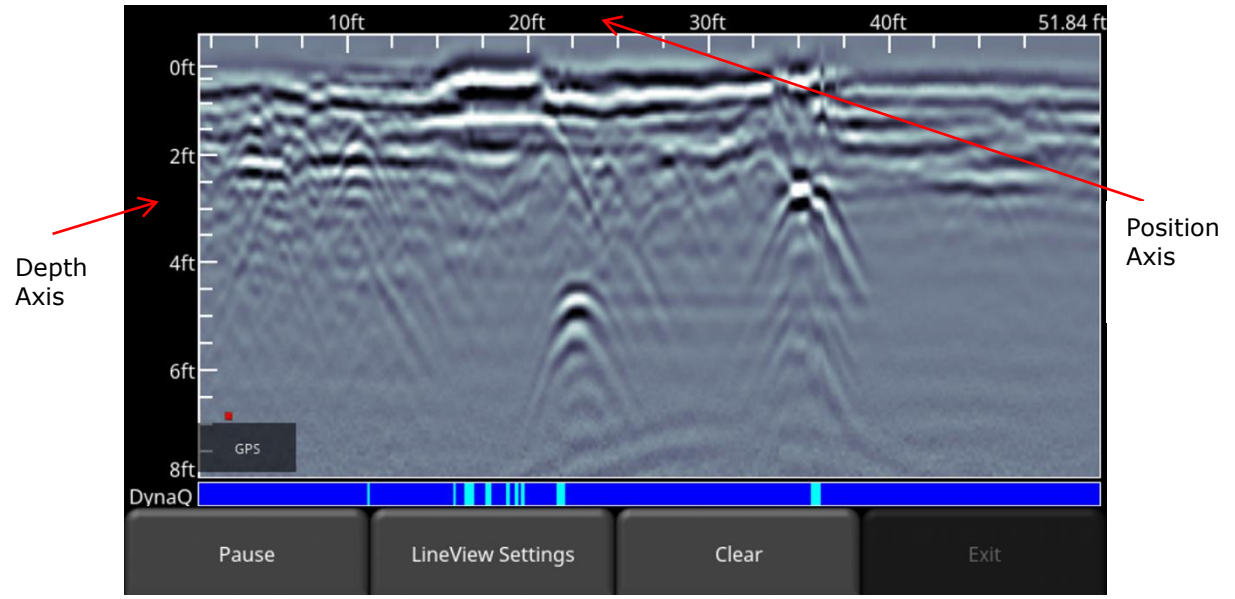


Figure 6-2: Data collection screen showing axis labels

6.1.1 DynaQ

DynaQ is an advanced patented technology that adjusts data quality as the system movement speed varies. In most situations, moving the system at a comfortable walking speed generates data of good quality. In situations where target resolution or maximum penetration depth is critical, moving slower increases data quality.

As the Line Scan data scrolls on the screen, the DynaQ Index Bar is displayed along the bottom of the screen (Figure 6-2). The color of the bar indicates the quality of the data at that point along the line:

White	= No Data (too fast!)
Yellow	= Moderate quality
Light blue	= Better quality
Dark Blue	= Highest quality

In general, avoid collecting data at extremely high speeds.

6.1.2 Back-Up Indicator

Data collection mode incorporates a back-up feature to enable you to accurately locate targets and mark them on the ground. After acquiring some data on the screen, pull the system backwards (Figure 6-3a).

During back-up mode, there will be two indicators:

- **Position Indicator**: The red vertical line corresponds to the location at the center of the GPR sensor. As you pull the cart backwards, the Position Indicator moves to mark the current location of the cart in the image and a box appears at the bottom of the screen with the current position, relative to the start of the line, listed as the top number.

- **Depth Indicator**: A short red horizontal line corresponds to the current depth value, as shown in the lower number in the box at the bottom of the screen. To determine the depth of an object, move the indicator up or down by dragging the horizontal line to the desired location (Figure 6-3b). Alternatively, you can also use the **Up** and **Down** arrows on the 4-way directional keypad. Note: make sure you have done a Soil Calibration to ensure depth accuracy (Section 6.2.4).

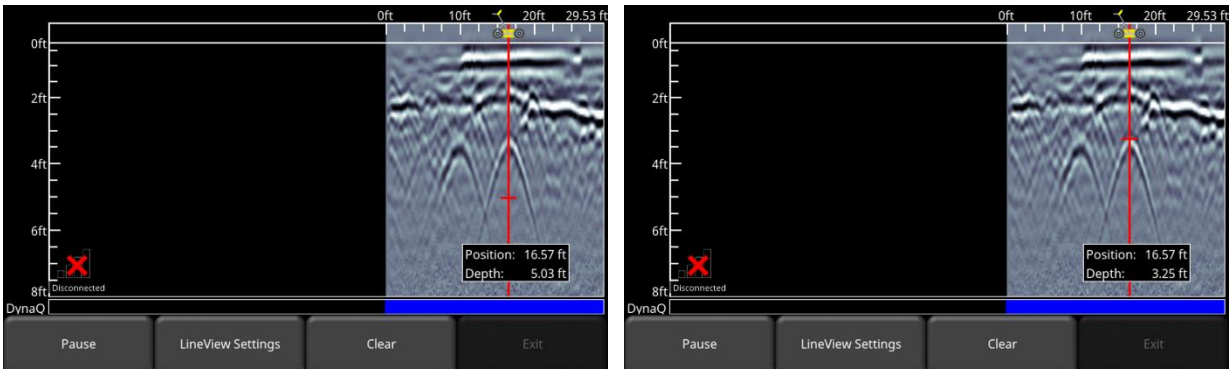


Figure 6-3: a) Back-up Indicator, b) Moving the Depth Indicator to the top of the hyperbola

To locate a feature, simply roll the system back along the same path until the red vertical line is exactly over the response (usually a hyperbola). You can mark the location of the object on the surface and continue data collection. Once you reach the point where you initially started backing-up, the system will continue acquiring new data.

You can also obtain depth and position information anywhere on the Line Scan by touching the screen, holding for a second, then releasing. A cross-hair appears where you touched the screen, with a box displaying the position and depth (Figure 6-4). To get the position and depth information about a different point on the screen, simply drag the box or cross-hair to the desired position.

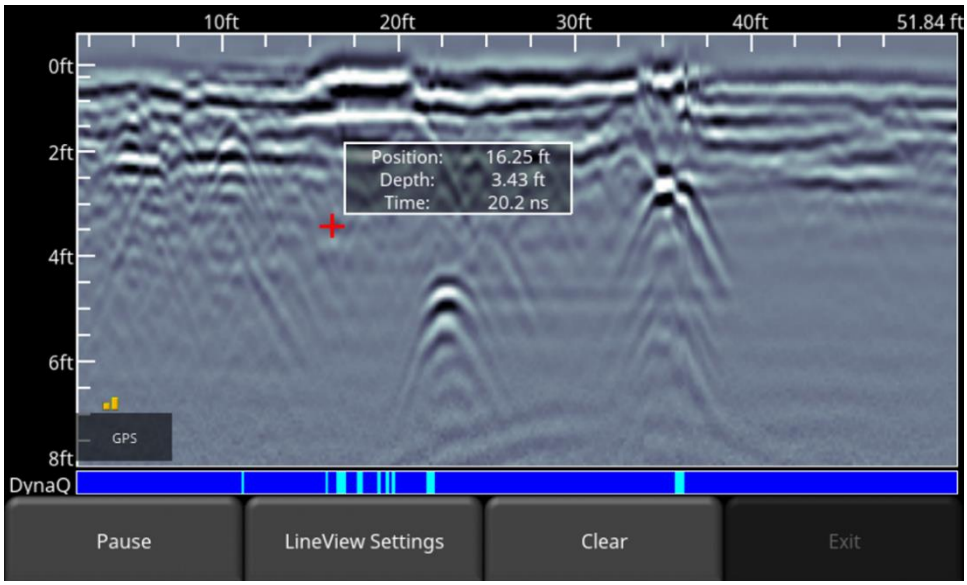


Figure 6-4: Touch screen to get depth and horizontal position at any point

6.1.3 Pause

The Pause button allows you to temporarily stop data collection and resume again, without clearing the data from the screen. This might be useful if you want to collect a series of parallel lines over a target and show all the passes on the screen for comparison.

Once you collect some data, press **Pause.** You can now move the LMX100 without data scrolling on the screen. When you are ready to resume collecting data, press **Resume**. You will see a thick, red vertical line, corresponding to when you hit the Pause button and then restarted.

While in Pause mode, press the **Exit** button to exit data collection and return to the main menu.

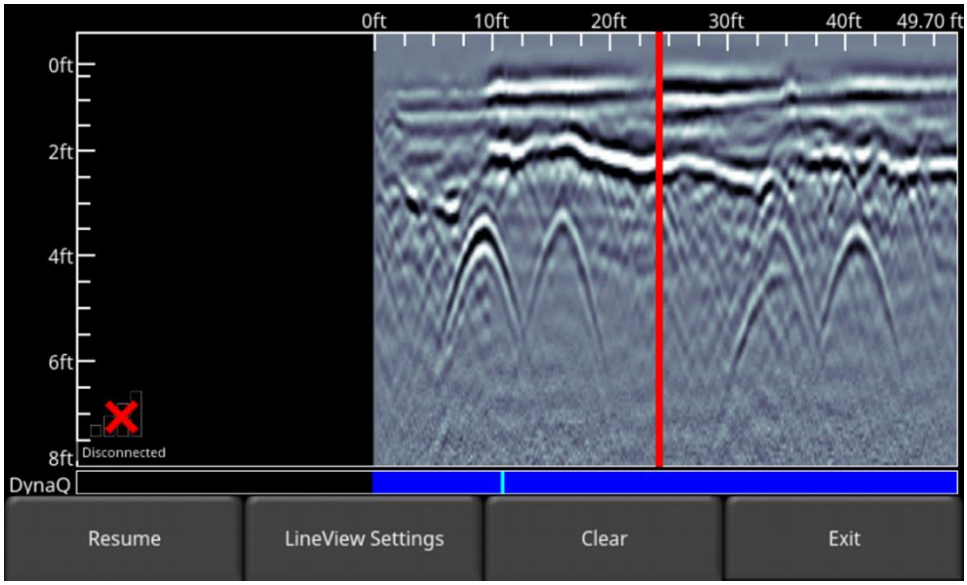


Figure 6-5: Pressing Pause and resuming data collection

6.1.4 Clear

Pressing the Clear button will clear all data that was collected. Continue to push the system to acquire new data. If you were in Pause mode, press Resume to continue collecting data

6.1.5 Drawing arrows

Arrows can be drawn on the screen to highlight features. Touch the screen where you want the head of the arrow to appear, and then swipe away in the direction of the shaft. Alternatively, if you just tap the screen, it will insert a vertical arrow pointing up at that position. In the example in Figure 6-6, the user touched near the hyperbolas, then swept their finger towards the top to create the arrows. Touch any arrow to remove it.

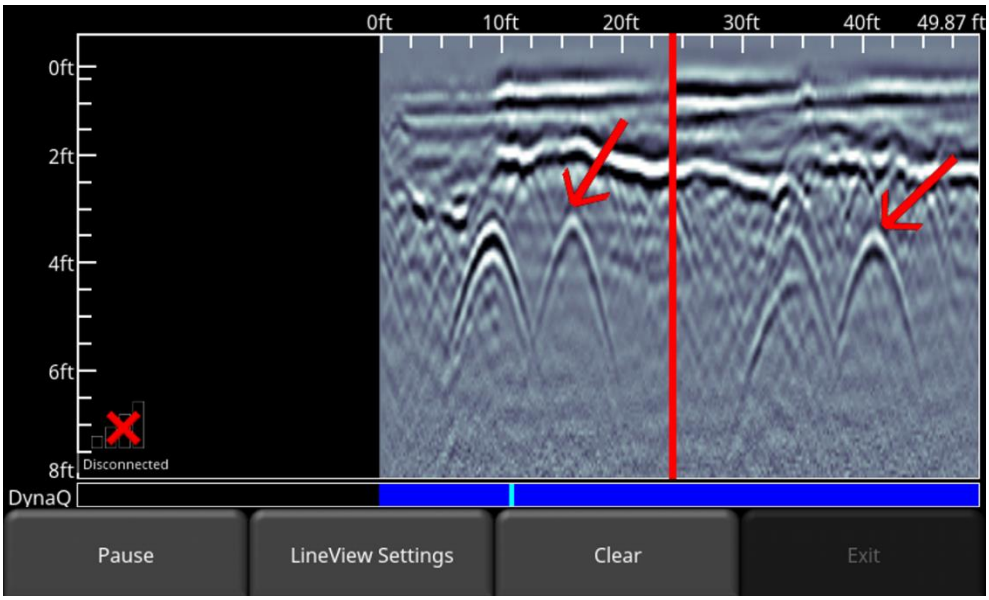


Figure 6-6: Drawing arrows on the screen to highlight features

6.1.6 Flags

Flags are often inserted to mark noteworthy surface features, such as poles, sidewalks, changes in terrain etc. These markers may help you correlate subsurface targets with above ground features.

Pressing the **asterisk (*)** button on the keypad will insert a flag at your current position, either during forward data acquisition or when backed-up. Flags are sequentially numbered (Figure 6-7).

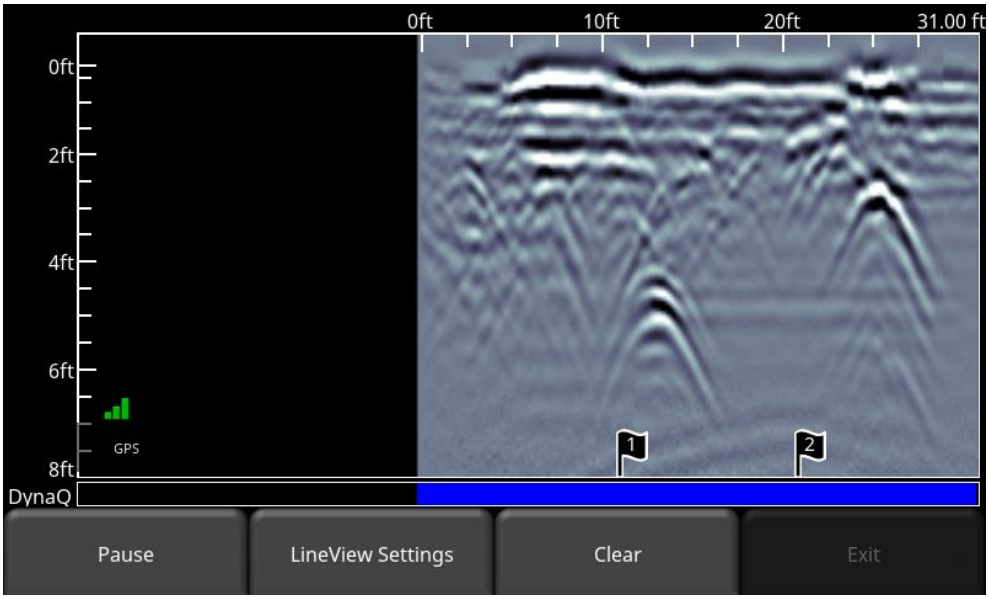


Figure 6-7: Inserting Flags

6.2 LineView Settings

Pressing the **LineView Settings** button will change the menu at the bottom of the screen, so the user can adjust the way data is viewed on the screen (Figure 6-8). This can be useful for optimizing the appearance of different features.

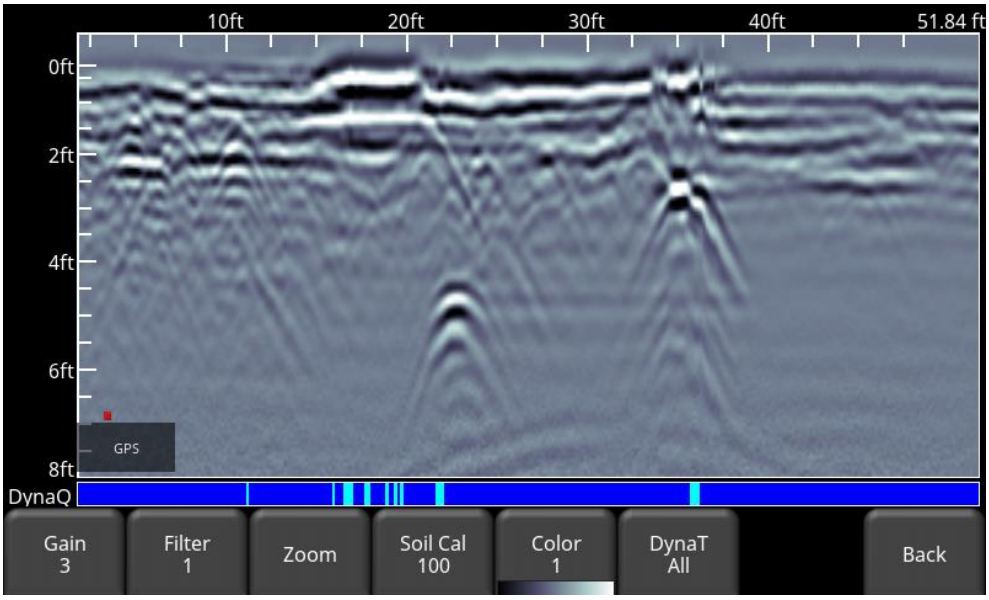


Figure 6-8: Pressing LineView Settings changes the bottom menu on the screen

6.2.1 Gain

Since the material being scanned absorbs the GPR signal, deeper targets return weaker signals. Gain acts like an audio volume control, amplifying signals and making deeper targets appear stronger in the image. Gain values vary from 1 to 9 where 1 means a minimal amplification has been applied and 9 means that maximum amplification has been applied. Pressing this button increments the gain; once you reach 9 it cycles back to 1. Avoid over-gaining the data as it can make interpretation difficult (Figure 6-9). In general, soils that are more electrically conductive (e.g. clays) will require a higher gain compared to soils that are less electrically conductive (e.g. sand).

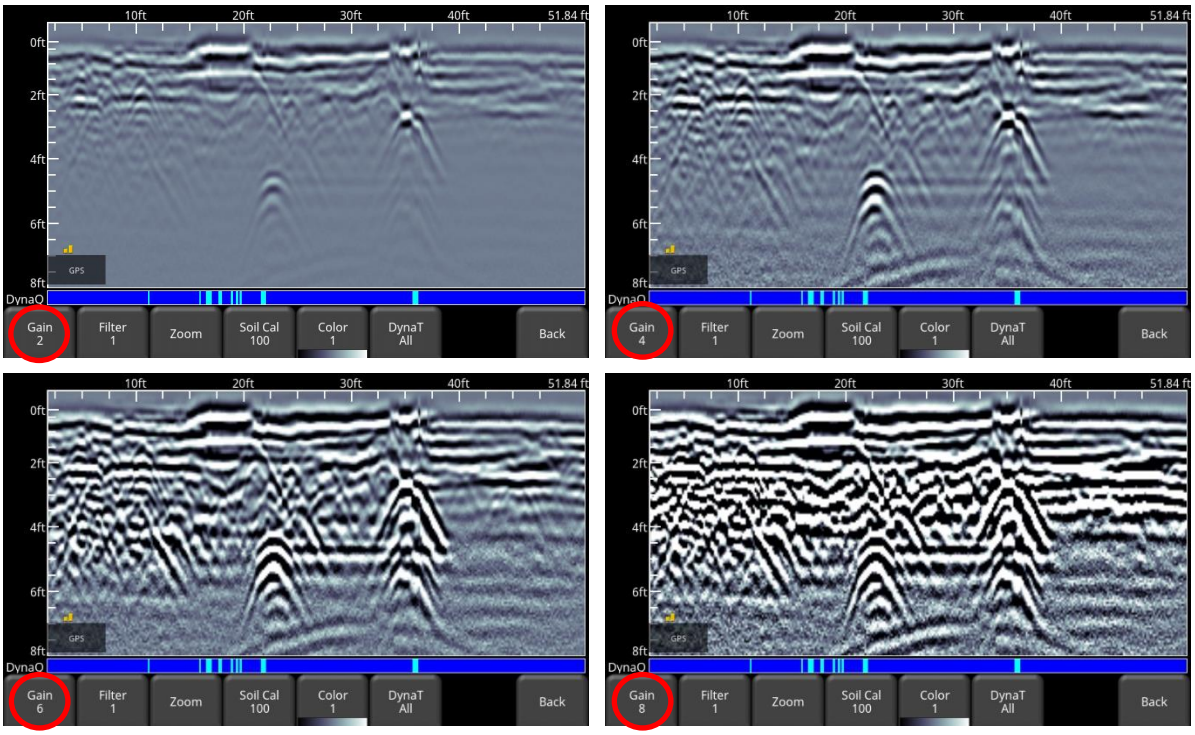


Figure 6-9: Varying the Gain

6.2.2 Filter

The Filter is a background subtraction filter used for removing flat-lying responses in the data. Filtering helps identify shallow targets that might be masked by the strong signals at the top of the image, as well as possibly enhancing the visibility of hyperbolas further down in the data. However, it will also filter out other flat-lying responses, such as soil boundaries, so be careful when using this option if your target is flat.

It works by applying a running-average background subtraction to the data set, defined by the filter width or a window. This window “moves” across the data and the result is subtracted for every trace in the data set. The Filter is variable and pressing this button cycles between **OFF** and values **1** to **5.** Variable filter lengths are shown in Figure 6-10**.**

The lower the number, the longer the filter width, and the more “relaxed” the filter. Only the longer flat-lying features get removed.

The higher the number, the shorter the filter width, and the more “aggressive” the filter. This results in the removal of long and short flat-lying features.

Pressing **OFF** turns the filter off completely.

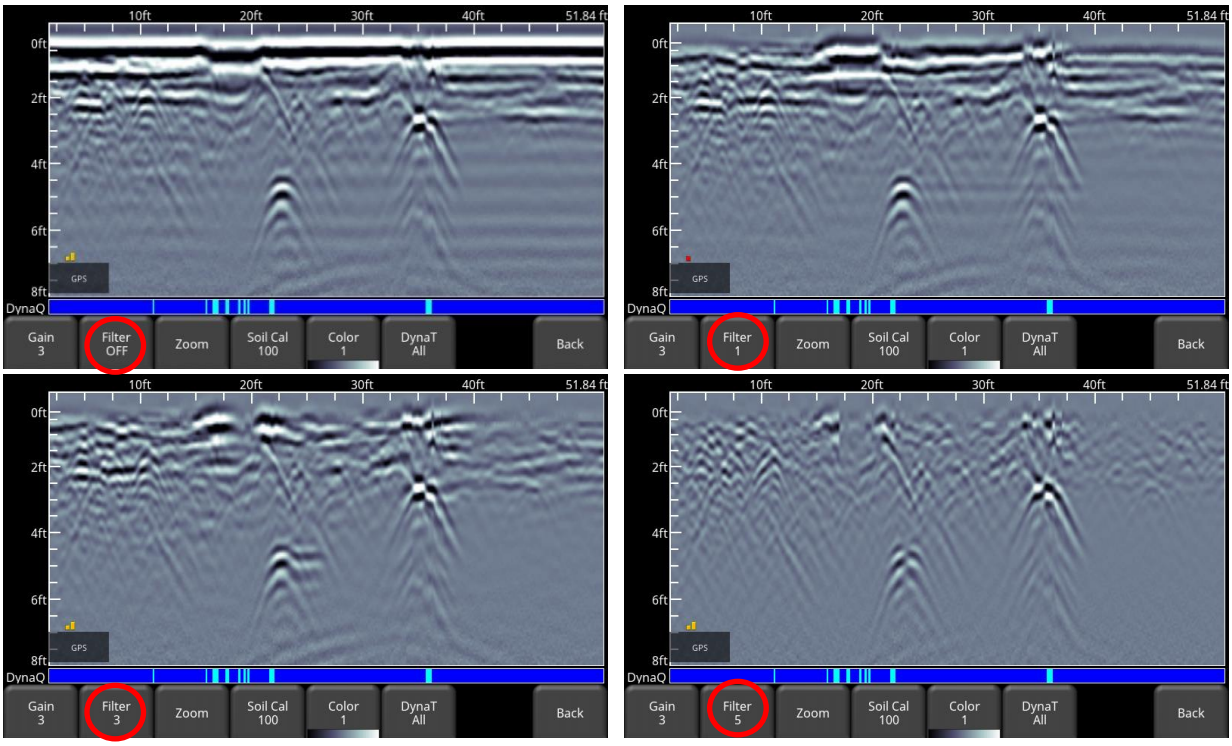


Figure 6-10: Showing variable filter lengths, including Filter Off

6.2.3 Zoom

This button controls the horizontal and vertical scaling of the displayed GPR data. Pressing the **Zoom** button changes the buttons on the bottom menu, which are explained below:

- **Depth** – Pressing **+** and **-** under the **Depth** button allows you to change the display depth of the data. This is commonly referred to as the depth window. The pre-set values range from 1m to 8m (4’ to 30’), see Figure 6-11.

  If the data was collected with a shallower depth, the depth setting can still be increased after the fact, when reviewing the data. In general, it’s a good idea to set your displayed depth to 1.5 - 2 times the depth you expect the deepest target to be.

- **Position** – Pressing **+** and **-** under the **Position** button allows you to change the length of data displayed on a single screen. This is also known as horizontal scaling. The pre-set values range from 10m to 30m (25’ to 100’), see Figure 6-12.
  One reason for setting this to 30m would be to fit more data on the screen and look for consistency among hyperbolas that were crossed.

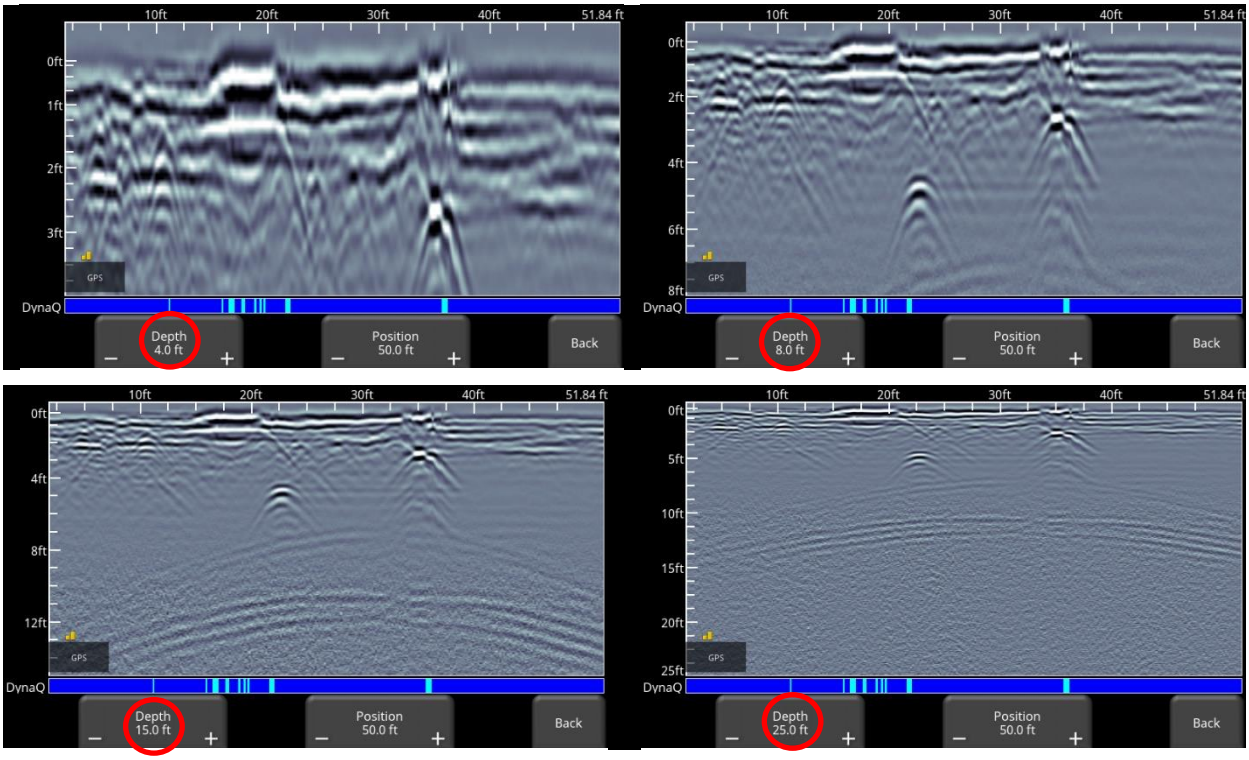


Figure 6-11: Varying displayed depth

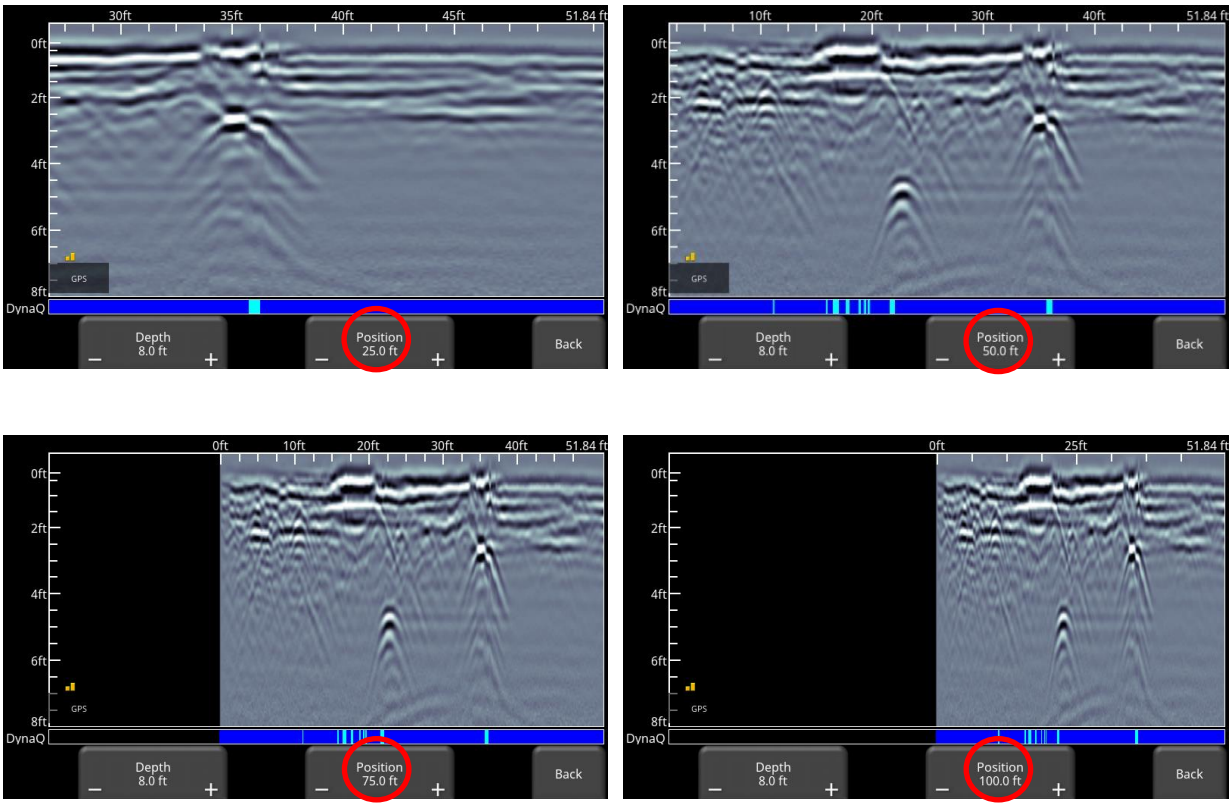


Figure 6-12: Varying position, or horizontal scaling

6.2.4 Soil Cal

The Soil Cal (also known as velocity) is a parameter used to ensure that measured depths are accurate. The best way to ensure this is by using the hyperbola-fitting method, since it is based on data collected in the area.

Crossing linear targets like pipes or cables at a 90-degree angle produces a hyperbola suitable for soil calibration. The Soil Cal value obtained will be used to compute a depth estimate of a target. These depths will be *incorrect* if the soil type is calibrated on a target hyperbola produced at an oblique angle, rather than 90 degrees.

Once you have a hyperbola on the screen from a subsurface target, press **Soil Cal**. The menu at the bottom of the screen will change, giving you the option of specifying a Soil Type or adjusting the Soil Cal using the hyperbola-fitting method (Figure 6-13). These options are explained below:

- **Soil Types** – If there are no targets to calibrate to, and you know the type of soil, press this button to vary between the following mediums, with the pre-set Soil Cal value shown in brackets:
    - very wet soil (60)
    - wet soil (80)
    - moist soil (100)
    - dry soil (120)
    - very dry soil (150)
    - air (300) – note that you can't "apply" and accept this value. This is only to fit the hyperbola to determine if it is an air wave (Section 5.5)
- **Soil Cal** – allows you to use hyperbola-fitting to determine a more accurate Soil Cal. The options are slightly different, depending on whether or not you are in backup mode.

  If the back-up indicator is on screen, it is presumed you have backed up the LMX100 and you're right over the hyperbola. Move the horizontal line to the align with the top of the hyperbola by touching and dragging it. Pressing Soil Cal will display a hyperbola that is locked to the position where the back-up indicator meets the horizontal line (Figure 6-13).

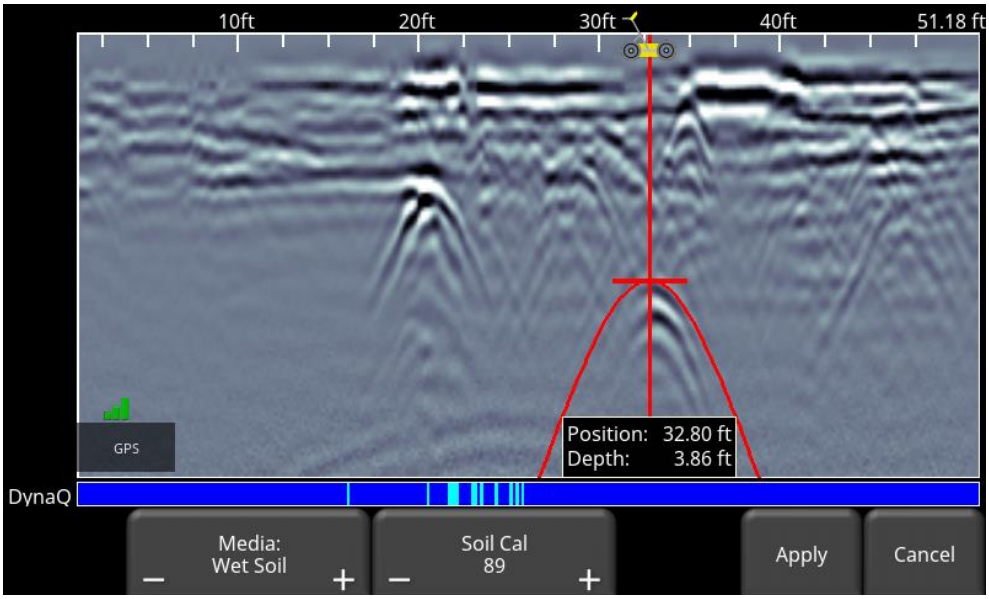


Figure 6-13: Adjusting Soil Cal while in backup mode

On the other hand, if you press Soil Cal while you are collecting data or have pressed Pause, you will see a red hyperbola in the middle of the screen. Drag the hyperbola such that the cross hairs are at the top of a real hyperbola from the ground (Figure 6-14). You can use the 4-way keypad arrows to fine tune the movements.

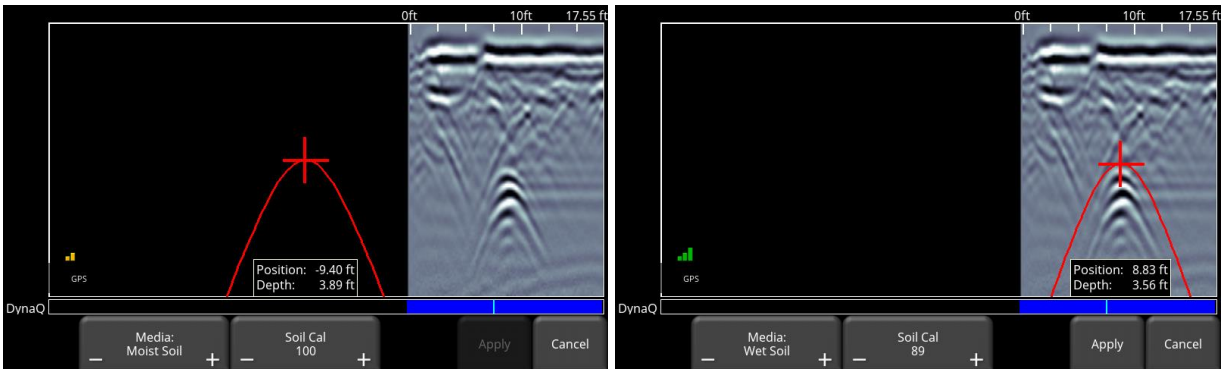


Figure 6-14: Pressing Soil Cal display red hyperbola (Left). Then move the hyperbola so that it lies over a hyperbola from the ground and adjust the shape (Right)

For either scenario above, once the red hyperbola is properly positioned, you can now use the **+** and **–** buttons on the **Soil Cal** button to widen or tighten the shape. Once the shape is matched (Figure 6-13 and right image of Figure 6-14), you now have the correct Soil Cal and the measured depths will be most accurate. Press **Apply** to use this value.

If you get a Soil Cal near 300, this could be an Air Wave (Section 5.5), and you should calibrate to a different hyperbolic response.

6.2.5 Color

Pressing this changes the color palette for the GPR Lines. There are 9 different color palette options. Pressing this button increments the color number and re-displays the image; once you reach 9 it cycles back to 1. A few sample color palettes are shown in Figure 6-15.

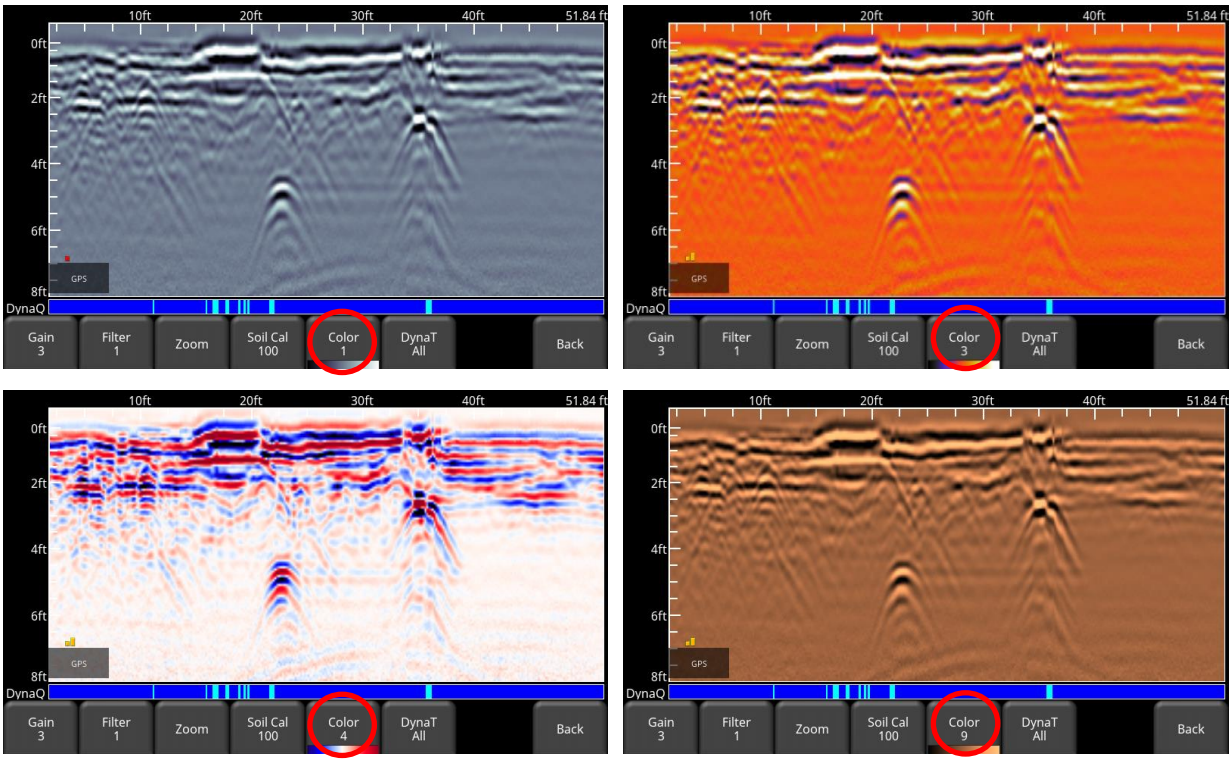


Figure 6-15: Changing Color palettes

6.2.6 DynaT

DynaT is a feature that can selectively enhance small, medium or large size targets for easier viewing and detection. Pressing **DynaT** cycles between options: **All**, **Small**, **Medium** and **Large** (Figure 6-16). Each option allows the user to enhance part of the ultra-wide band (UWB) spectrum to focus on those desired features.

Selecting **Small** will show more of the smaller hyperbolas and more detail, whereas **Large** will focus more on the larger targets with better depth penetration. Selecting **All** will show a combination of small, medium and large targets

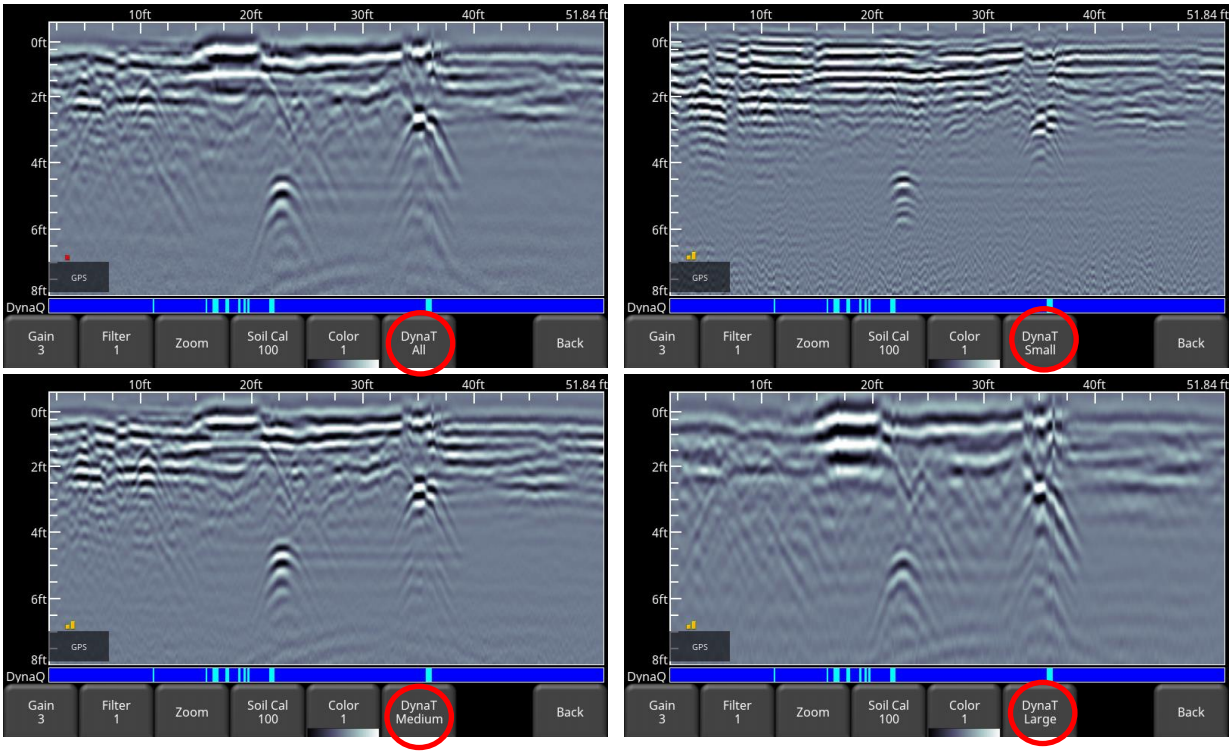


Figure 6-16: DynaT settings: a) Top left shows All b) Top right set to Small targets c) Bottom left set to Medium targets d) Bottom right set to Large targets

6.3 Saving images as screenshots

Pressing the Camera button will take a screenshot of whatever is on the screen and save this as a .JPG file. See Section 7 for more details on screenshots and emailing mini-reports

7 Screenshots & Mini-Reports

7.1 Capturing Screens

If you would like to save an image of the current screen press the **Camera** button on the Display Unit. This saves the screen as a Screenshot image (.JPG), which can be viewed in any third-party viewing software.

If you are not connected to a Wi-Fi network or do not have a sending email address configured, a message appears confirming the filename of the saved image (Figure 7-1).

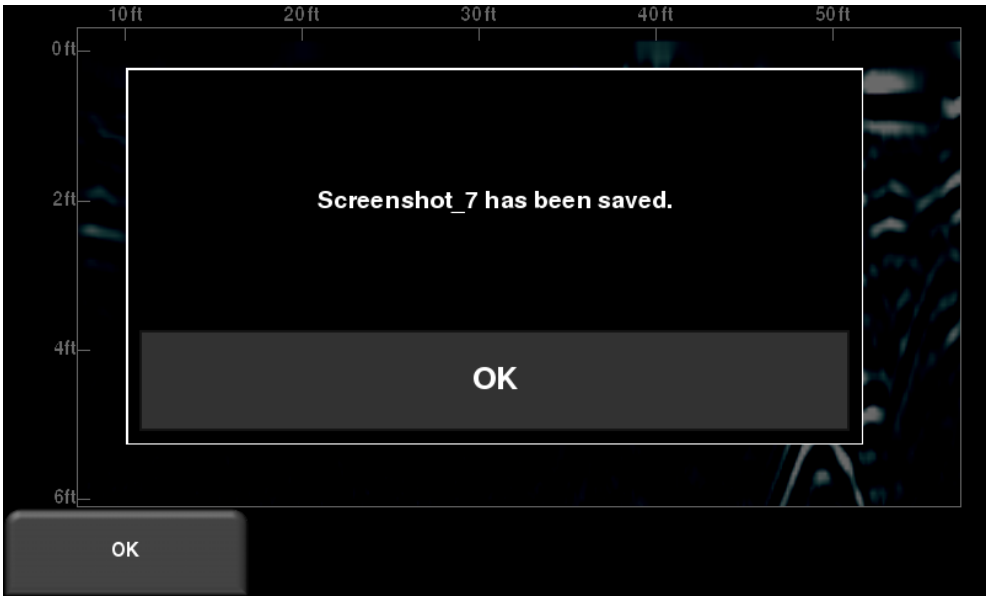


Figure 7-1: Message displayed after pressing the camera button on the Display Unit to capture the screen (no Wi-Fi present).

If you are connected to a wireless network and have a sending email address configured, the user will see the message in Figure 7-2, asking if you would like to email the screenshot and prompts you to enter the email address. The email address defaults to the last one entered. Tapping on the address box brings up an on-screen keyboard and allows you to enter a new email address. Pressing the "**…**" button to the left of the email address displays the last 5 email addresses used, allowing the user to easily select a recent email address, rather than re-entering it.

Screenshots can always be emailed at a later time from the Screenshot Gallery (Section 7.2)

Figure 7-2: Message after pressing the Camera button on the Display Unit to capture the screen with Wi-Fi enabled and a connection to a wireless network. The user can enter an email address to send the mini-report to.

7.2 Screenshot Gallery

The screenshot gallery allows you to manage all screenshots saved on your LMX100. If you have at least one screenshot saved, you will be able to enter the gallery; otherwise the Screenshot Gallery button will be greyed out.

Press **Screenshot Gallery** from the main screen, you will see the image in Figure 7-3.

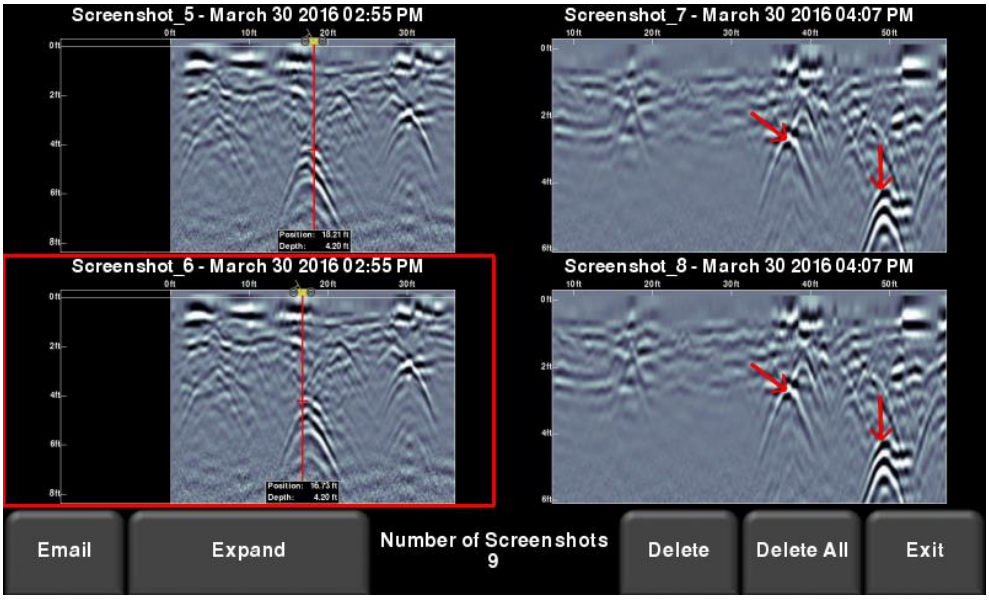


Figure 7-3: Screenshot Gallery – Tiled View

The number of total screenshots is shown in the bottom middle of the screen.

If you have more than four screenshots saved, you can view the others by either swiping on the screen (right and left), or using the 4-way directional arrows. To select a particular screenshot, touch the screen directly, or use the 4-way directional arrows. From here you have the option to:

- **Email** – Pressing this will allow you to email the screenshot as a mini-report, provided you're connected to a Wi-Fi network and have a sending email address saved on the system. You will see the same email prompts as shown in Section 7.1.
- **Expand** – This will enlarge the selected screenshot to full screen (Figure 7-4)

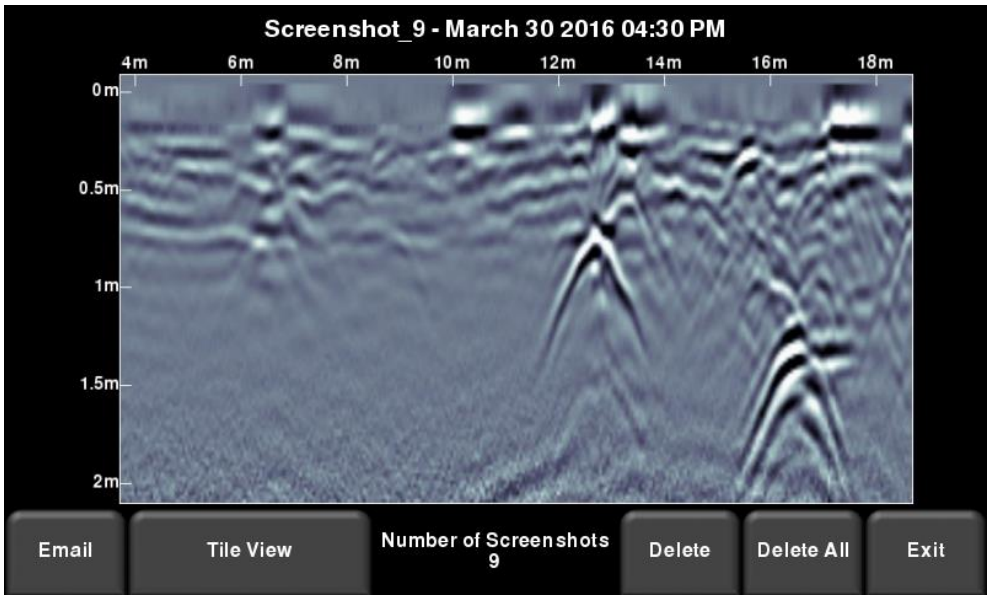


Figure 7-4: Screenshot Gallery – Expanded View

Press **Tile View** to return to the view showing four per page.

- **Delete** – This will delete the selected screenshot. A confirmation message will appear asking if you want to proceed with this.
- **Delete All –** This will delete ALL screenshots. A confirmation message will appear asking if you want to proceed with this.
- **Exit –** this will return you to the main screen. The next time you enter Screenshot Gallery it will show the same view that you left with, Tiled or Expanded.

7.3 Using the Hotspot on your Smartphone

If a Wi-Fi signal in unavailable, you may be able to use your Smartphone as a Wi-Fi access point, by creating a Personal Hotspot. If you are experiencing difficulty connecting to a cell phone Personal Hotspot, ensure that the phone is in discovery mode while connecting. On iPhone (iOS 9.0), for example, this involves going to **Settings - Personal Hotspot** (Figure 7-5). Ensure that the Personal Hotspot setting is turned on and wait on this screen until the LMX100 connection has been established. Once you have received confirmation on the Display Unit, the cell phone can resume normal use.

Figure 7-5: Setting Personal Hotspot on an iPhone (iOS 9.0)

Note that when setting up a Personal Hotspot, you may be disconnected from any Wi-Fi networks. Vice-versa, if you have a Personal Hotspot setup, attempting to connect to a Wi-Fi network may disconnect your personal hotspot.

7.4 Mini-Reports

When a screenshot is emailed, it is sent as part of a mini-report. This mini-report also contains a table with information about the collected data including the settings used, date & time (Figure 7-6)

LMX100™ Mini Report

Screen Capture Number	5
Screen Name	Line Scan
Date Collected	April 25 2019 7:31 AM
Depth	8.0 ft
Line Color Palette	1
Filter	ON (1)
Gain Level	4
Soil Cal	Moist Soil (100)
DynaT	All

Sensors & Software

Your screen capture is attached to this email.

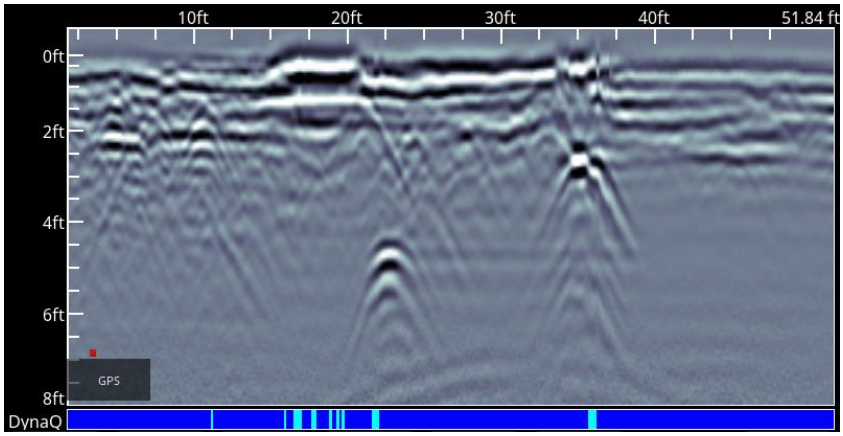


Figure 7-6: Example of a Mini-Report

8 Transferring Data to a PC

Screenshots can be exported to a PC by inserting a USB drive into the USB port (Figure 8-1).

Figure 8-1: Insert a USB memory stick into the USB port on the Display Unit to export data.

Once the USB drive is recognized, a message will appear telling you that a drive has been inserted and if you wish to export your data to it (Figure 8-2). Click **Yes**.

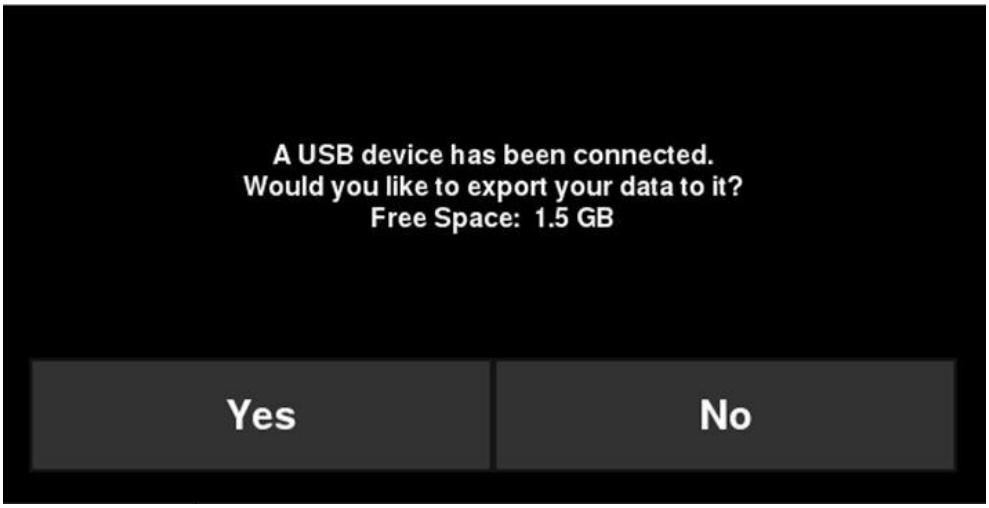


Figure 8-2: When a USB drive is connected to the Display Unit, a message window opens asking if you would like to export all your data to it.

8.1 Formatting USB Sticks

There may be times when a USB stick is not recognized by the LMX100. In this case, you may need to format the USB stick. Ensure that it's formatted as FAT/FAT32 (NTFS will not work). Also ensure that there are no hidden or write-protected partitions on the USB drive.

If the problem persists after formatting, try another USB stick.

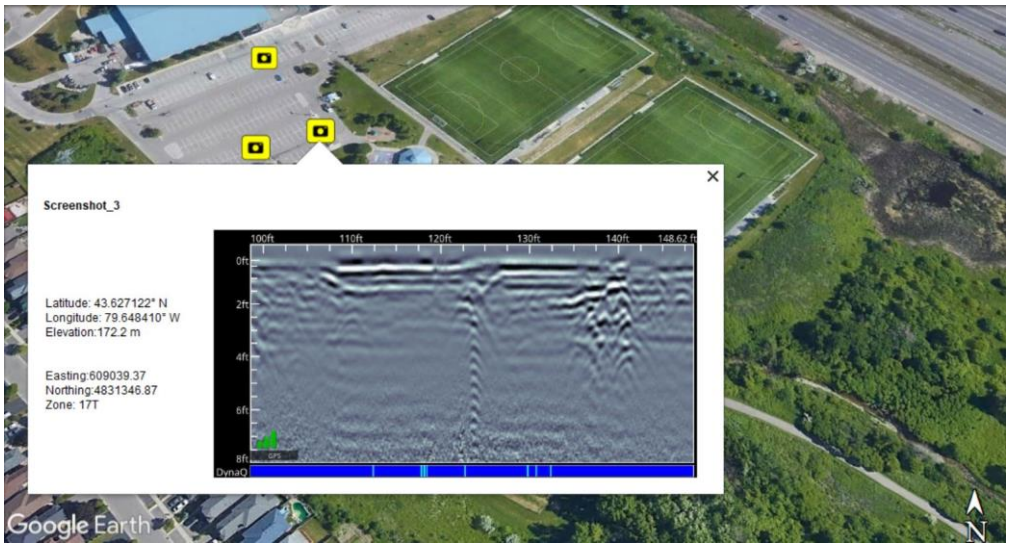
8.2 Directory Structure

The directory structure on the USB drive can be viewed on your PC, and will look as follows:

- GPR Data
  - LMX100
    - Export01
      - Screenshots
        - All Screenshots as .JPG files
      - System Info
        - APP.LOG
        - System Summary.pdf
      - LMX100.kmz
    - ExportXX

Each successive export of data will create a new directory called ExportXX, where XX is incremented by 1 from the previous directory.

All screenshots are saved as .JPG files in the Screenshots folder. If the GPS was available during screen capture, those screenshots are geo-tagged and a .kmz file is generated (otherwise the .kmz file is not created). This file can easily be opened in Google Earth™ and shows you the geographic position of those screenshots.



The System Info folder contains an APP.LOG file and a system summary diagnostic report. The APP.LOG file contains important information about system operation and may be requested by Sensors & Software to help troubleshoot any issues. The System Summary report is a PDF file, which lists system usage information, serial numbers and when system tests were done and their pass/fail status. An example file is shown below:

LMX100™

System Usage Summary
April 30 2019

Usage Statistics

Data Exports	3
Average Line Length	0.0 m / 0.0 ft
Average Line Collection Time	1 minutes 4 seconds
Total Line Collected	0.0 m / 0.0 ft
Screenshots Saved	1
Wi-Fi Reports Sent	0
System Power Cycles	7
Operation Time	21 minutes

System Information

Display Unit (DVL) Serial Number	0084-6319-2014
GPR Sensor Serial Number	0048-9935-0016
Application Version	v1.6.808 (2016-00032-05)
OS Version	2.08.512 (2017-00041-08)
GPR Firmware Version	3.028 (2014-00092-03)
Hardware ID	5410EC6BE99E

System Tests

Odometer Test	30 April 2019	Passed 1101.0 t/m
GPS Test	30 April 2019	Passed - Internal
Keypad Test	30 April 2019	Passed
Audio Test	30 April 2019	Passed
Touch Screen Test	30 April 2019	Passed
GPR Sensor Test	30 April 2019	Passed

9 Troubleshooting

The LMX100 system is designed to minimize user problems; however, all electronic devices are subject to possible failure. The following are troubleshooting hints which can be referred to if your system fails to operate.

9.1 Power Supply

The most common problem that can occur while trying to run the system is insufficient power. The battery may be dead, have a low voltage or the fuse may be blown.

Once boot up is complete, the colour of the LED will indicate the amount of battery power remaining:

- 100% to 20% = green
- 20% to 10% = orange
- 10% to 0% = red

You can check the battery voltage with a voltmeter. Try to do this while the battery is still attached to the Cart to get a true measure of the voltage while under load (it will be necessary to open the Cart battery case and connect the voltmeter to the positive and negative battery terminals). A fully charged battery will show a voltage of 13.8V, whereas a voltage of 10.5V or lower will not power the system. If the battery has a low voltage or seems dead, try using another battery (if available), or give the battery a good 12-14 hour charge and try running the system again.

If the battery does not charge up to 12 Volts or more, it should be replaced.

Batteries are fused to protect the system. Open the battery case and check that the 10 Amp fuse is OK. If necessary, replace it with one of the spare fuses available inside the battery case.

If the battery seems OK but the system still does not power up, check the battery cable connections and inspect the battery cable for damage.

9.2 System Communications

If the battery is OK and the Display Unit turns on but the GPR sensor does not scan, there may be a communication failure between the Display Unit and the GPR sensor. If an error occurs, an error message will appear. Power Off the system and disconnect the battery.

Make sure the display cable is not damaged, all pins are straight, and there is no dirt or debris in the connector. Ensure that the cable connections are tightly secured. Sometimes vibrations cause the cable connections to slightly loosen and break contact leading to errors. Disconnecting the cable and reconnecting it may provide a better contact and solve the problem. Plug in the battery, turn on the system and try scanning again.

If the Battery, Battery Cable and Display Cable are OK, the problem is either a failure of the Display Unit or the GPR sensor. These units have no user-serviceable parts so they will have to be returned to the vendor for inspection and repair.

9.3 System Overheating

The GPR system is designed to operate to a maximum *internal* temperature of 70 ^{o}C or 158 ^{o}F. In situations of high ambient temperatures or long exposure to direct sun, this maximum internal temperature may be exceeded and cause the system to fail.

If you suspect that the GPR sensor is overheating, shut it off and give it a chance to cool down in a shady location before trying to run it again.

If the situation is such that the high temperatures or direct sun cannot be avoided, it may be a good idea to put some sort of shade over the GPR sensor.

9.4 Display Unit Problem

If the Display Unit does not power up, check the battery power and all cable connections. If that doesn't work, contact the manufacturer.

9.5 Wobbly Wheels

If, over time, a wheel becomes wobbly, the wheel nut will need to be manually tightened.

For the rear right wheel only (which is connected to the direct drive odometer), insert a large slotted screwdriver into the end of the axle (there's already a slot there for it) and use a large wrench to slightly tighten the wheel nut. The nut only has to be turned slightly, 1/8th -1/16th of a turn is usually enough. Spin the wheel to make sure it's still free and not too tight.

9.6 Creating a Test Line for Data Quality

After receiving the system and getting comfortable with its operation, one of the best ways of detecting any problems is to collect a line of data at a convenient, easily accessible location. The line does not have to be too long but one screen is a good guide. This data line should be saved electronically and perhaps plotted out on paper and dated. If there is a suspected problem with the system, this test line could be collected and compared with earlier tests. When comparing data, take into account weather and environmental conditions, which could skew the comparisons slightly.

9.7 Contacting the Vendor for Service

When returning the system to the Vendor, have the following information available:

1. GPR sensor Serial Number displayed at the top of the **System Settings Screen**.
2. A brief description of when the error is happening and the operating conditions (temperature, humidity, sunshine, system settings, etc.).
3. Include photos and/or videos to document the occurrence of error messages.
4. APP.LOG file – this is downloaded to your computer during data export

10 Care & Maintenance

10.1 Battery Care

The LMX100 uses a 9-Amp-hour, 12-Volt sealed lead acid battery. It is fused with a 10 Amp fuse to protect it from short circuit damage.

The battery unit should run the LMX100 continuously for 6 hours before recharging is necessary. If long days of data surveying are typical, a second battery unit may be useful.

The battery is strapped onto the cart base and is normally recharged without removing it from the cart. However, the battery can be easily removed for maintenance or for recharging, if required.

If batteries are maintained in a charged condition, they will give long life and reliable service. Improper use and lack of maintenance will greatly reduce their life.

Sealed lead acid batteries should **NEVER** be left in a discharged condition for any period of time. Charge the batteries as soon as possible after use.

Charge the battery at room temperature whenever possible.

The LMX100 has a voltage monitoring circuit that will turn off the unit when the input voltage drops below 10.5 volts.

If a battery has been deeply discharged or left in a discharged condition for some period of time it may not accept charge immediately when it is connected to the charger (the fast charge light will not illuminate). If the fast charge light does not come on within 6 hours the battery should be considered damaged and should be discarded.

Do not assume that a battery that is still charging after 8 hours is nearing the end of its charge cycle. Typical charging time for an empty battery is 12-14 hours from the start of fast charge.

Ensure that the batteries are fully charged before storing. If practical, store the batteries in a cool place, 10^{o}C, but make sure the temperature is not likely to drop below -30^{o}C or the electrolyte may freeze and possibly split the case.

10.2 Cable Care

With the use of this product in rough, dusty and outdoor environments, users can minimize potential downtime if they care for cables and treat connectors with respect.

1) The cable connectors as well as the connectors on the GPR Sensor and Display Unit need to stay clean and free of dust and moisture. Use a brush or air spray to clean dust, lint and other foreign particles from these connectors.

2) The power and odometer receptacles on the top of the LMX100 are watertight, but do not allow water to get into the receptacle by connecting the battery and odometer cables in the rain

3) After working in rainy conditions, disconnect the cables and check for water in the receptacles. Remove the water or allow to air dry, if necessary. Never allow the system to sit in rainy conditions for long periods of time.

4) When the system is not being used, make sure the connections are protected to prevent dust and moisture from collecting inside. If the connectors are exposed, cover them with some sort of dust cap.

5) Cables and connectors are not designed to suspend or tow or otherwise carry the weight of systems. They are part of the electronic circuit and should be treated accordingly. When not in use they should be placed in their storage box.

10.3 Skid Pads

The bottom of the GPR Sensor is covered with one large wear-resistant skid pad. The skid pad is designed to take the majority of the abrasive wear. If the pad wears down enough, the less-resistant plastic housing may start to wear. If this occurs, it is best to replace the skid pad. It is easily removed with a screwdriver and a new one can be purchased from the vendor.

10.4 Odometer

The odometer should be periodically calibrated (refer to Section 4.2.6) to ensure accuracy.

10.5 Storage Cases

Equipment that is transported and stored loosely is more susceptible to damage. All equipment should be stored in its shipping case or a storage box. Sensors & Software has optional shipping cases available for all LMX100 systems.

10.6 Upgrading Embedded Software on Display Unit

From time to time, Sensors & Software may release new software for the Display Unit. The instructions below describe how to update this software. Please note that this procedure will **erase all GPR data** from the system, so export any valuable data before continuing.

1 Download

the zip file provided by Sensors & Software into a folder on your PC.

2 Insert

a clean USB stick into your PC.

3 Unzip

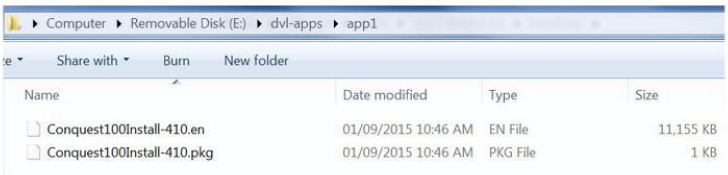
the file by double clicking the file in Windows Explorer.

4 Copy

the unzipped folder to the root of the USB key. The resulting folder structure on the USB key should be:

dvl-apps
app1
PACKAGE_NAME.en
PACKAGE_NAME.pkg

where PACKAGE_NAME is the name of the item to be installed.
An example of the Conquest 100 installation files are shown below:



5 Turn off

the Display Unit. Remove the USB stick from your PC and insert it into the USB port on the side of the Display Unit.

6 Turn On

the Display Unit. You will see a list on the screen showing all software installations. The USB key may hold one or more packages which are displayed as numbered items:

Select app to run:
1. PACKAGE_NAME

7 Select

the package to run by pressing the associated numbered key on the Display Unit. The selected software will now be installed. The process may require multiple reboot cycles initiated by the system. When complete, the system will shut down, and the red light on the front of the Display Unit will turn off.

8 Remove

the USB stick from the Display Unit.

9 Turn On

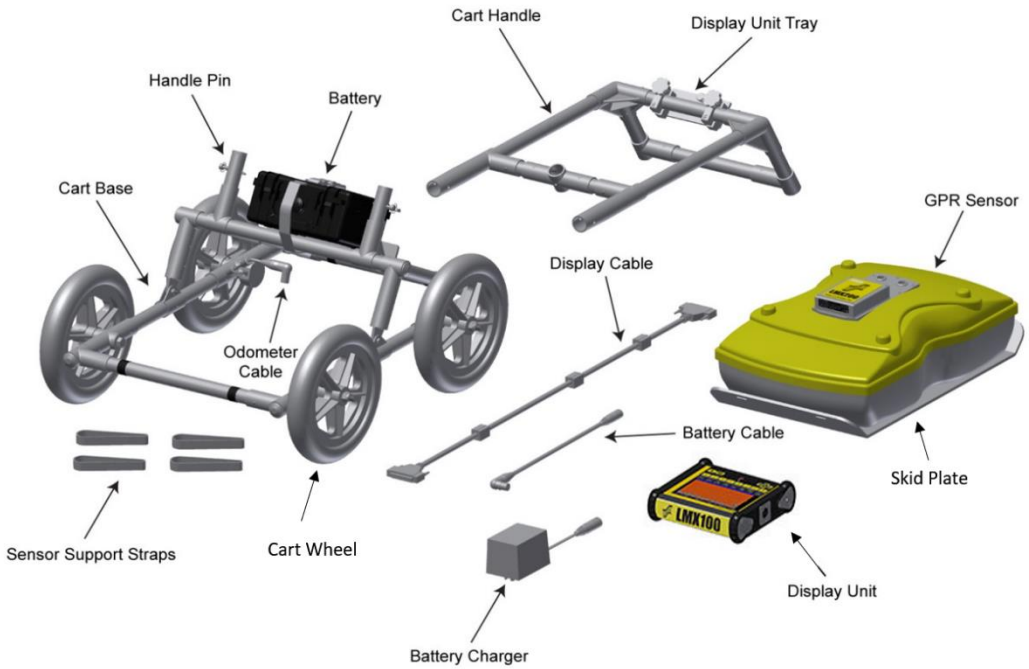
the Display Unit and access the System Info screen to verify the newly installed version number.

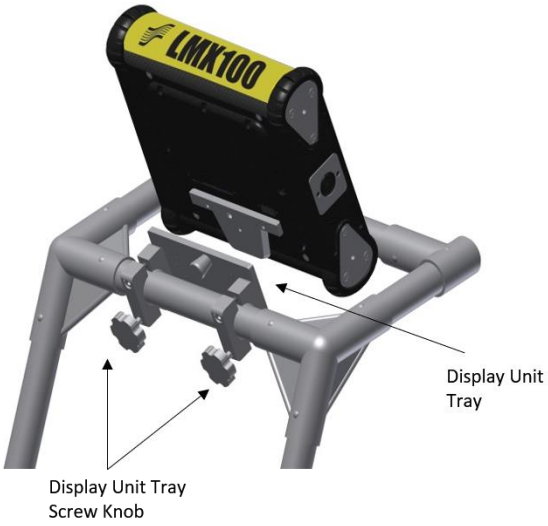
11 Parts List & Accessories

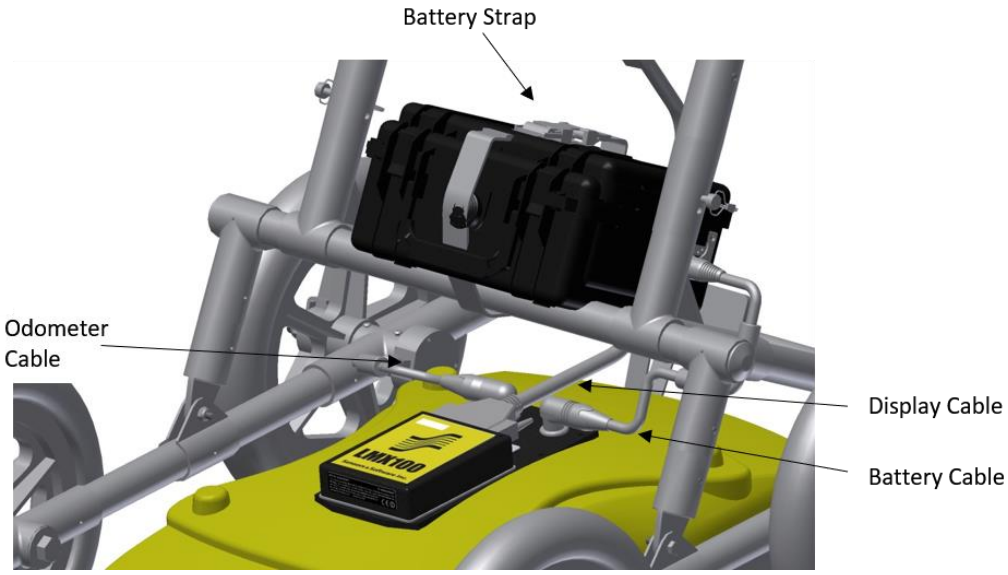
11.1 Spare Parts

The following is a list of spare parts available for purchase, with labelled diagram below that:

122-10-2377	Cart Wheel
100-55-0023	Battery with Case
100-53-0098	Display Unit Tray
100-52-0108	Display Cable
126-77-1450	Skid Plate
126-77-2010	Battery Cable
100-55-0027	Battery Charger
100-22-0084	GPR Sensor
100-22-0085	Display Unit
126-85-0670	Cart Handle
126-81-1600	Cart Base
100-54-0154	Spare Parts Kit consisting of: • Locking Pins (1) • Display Unit Tray Knob Screw (1) • Socket Cap screw (1) • Sensor Support Straps (4) • Standoff (2) • Cable to Display Unit screws (2)




LMX100
Display Unit
Tray
Display Unit Tray
Screw Knob


Battery Strap
Odometer
Cable
Display Cable
Battery Cable
LMX100

11.2 Accessories

The following accessories are available for purchase

100-60-0058 LMX® Series ATA Shipping Case (with DVL Bag)

100-55-0023 Spare Battery

100-55-0027 Spare Battery Charger

100-60-0066 Deluxe Display Unit Carrying Case

12 Technical Specifications

Specifications	Values
GPR Sensor size	630 x 410 x 230 mm (25 x 16 x 9 in)
GPR Sensor weight	5 kg (11 lbs)
Display Unit weight	2.83 kg (6.24 lbs)
Display Unit screen	8.0" high-visibility, sunlight-readable diagonal LCD display with touch screen Adjustable backlighting 1500 NIT and 800:1 contrast ratio
Battery weight	3.6 kg (7.9 lbs)
Total system weight	22 kg (48 lbs)
Wireless	Integrated modules: Wi-Fi (IEEE 802.11 b,g,n) GPS/GLONASS
Audio	Built-in speaker - 85dBA speaker w/volume control
Battery	Lead acid gel cell Battery Life: 4-6 hours Battery Capacity:9.0 Ah
Charger	Built-in charger with status indicator Universal AC mains charger input: 100-240V ~, 1.5A, 50/60Hz Output: 12 Volts @ 3 Amps
DVL-500N Display Unit Input	11-18V ⎓ , 4A maximum
Display Unit Power Consumption*	1.5A @ 12V
Temperature & Environmental	Ruggedized, environmentally sealed unit and connections. Ingress protection (IP) rating: DVL-500 Display Unit is rated to IP65 under IEC 60529 Relative Humidity operation (non-condensing): 10 – 90% GPR Sensor and DVL-500 operating temperature range: -40 to 50°C Do not use touch screen below -20°C. Use battery charger between 0 and 30°C.
Regulatory Specifications	EMC: FCC, CE, IC, ACA, RSM Safety: TUV

Appendix A: Health & Safety Certification

Radio frequency electromagnetic fields may pose a health hazard when the fields are intense. Normal fields have been studied extensively over the past 30 years with no conclusive epidemiology relating electromagnetic fields to health problems. Detailed discussions on the subject are contained in the references at the end of this Appendix.

The USA Federal Communication Commission (FCC) and Occupational Safety and Health Administration (OSHA) both specify acceptable levels for electromagnetic fields. Similar power levels are mandated by corresponding agencies in other countries. Maximum permissible exposures and time duration specified by the FCC and OSHA vary with excitation frequency. The lowest threshold plane wave equivalent power cited is 0.2 mW/cm^2 for the general population over the 30 to 300 MHz frequency band. All other applications and frequencies have higher tolerances as shown in graphically in Figure B-1.

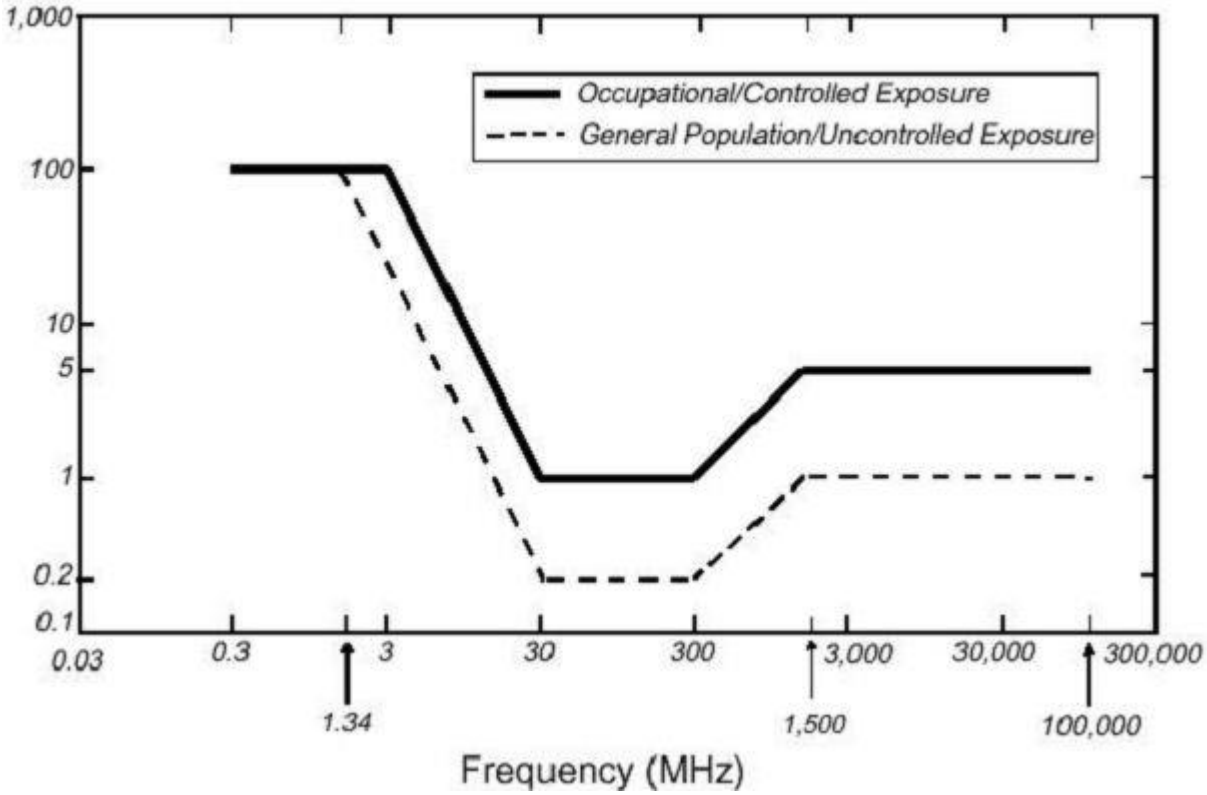


Figure B-12: FCC limits for maximum permissible exposure (MPE) plane-wave equivalent power density mW/cm^2.

All Sensors & Software Inc. GPR products are normally operated at least 1 m from the user and as such are classified as “mobile” devices according to the FCC. Typical power density levels at a distance of 1 m or greater from any Sensors & Software Inc. products are less than 10^{-3} mW/cm^2 which is 200 to 10,000 times lower than mandated limits. As such, Sensors & Software Inc. products pose no health and safety risk when operated in the normal manner of intended use.

References

1. Questions and answers about biological effects and potential hazards of radio-frequency electromagnetic field.

   USA Federal Communications Commission, Office of Engineering &

   Technology OET Bulletin 56
   (Contains many references and web sites)

2. Evaluation Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields.

   USA Federal Communications Commission, Office of Engineering &

   Technology OET Bulletin 56
   (Contains many references and web sites)

3. USA Occupational Safety and Health Administration regulations paragraph 1910.67 and 1910.263

Appendix B: GPR Emissions, Interference and Regulations

All governments have regulations on the level of electromagnetic emissions that an electronic apparatus can emit. The objective is to assure that one apparatus or device does not interfere with any other apparatus or device in such a way as to make the other apparatus non-functional.
The manufacturer tests their GPR products using independent professional testing houses and comply with latest regulations of the USA, Canada, European Community, and other major jurisdictions on the matter of emissions.
Electronic devices have not always been designed for proper immunity. If a GPR instrument is placed in close proximity to an electronic device, interference may occur. While there have been no substantiated reports of interference to date, if any unusual behavior is observed on nearby devices, test if the disturbance starts and stops when the GPR instrument is turned on and off. If interference is confirmed, stop using the GPR.
Where specific jurisdictions have specific GPR guidelines, these are described below.

B-1 FCC Regulations

This device complies with Part 15 of the USA Federal Communications Commission (FCC) Rules. Operation in the USA is subject to the following two conditions:
this device may not cause harmful interference and

this device must accept any interference received, including interference that may cause undesired operation.

Part 15 – User Information

This equipment has been tested and found to comply with the limits for a Class A digital device, where applicable, and for an ultra-wide bandwidth (UWB) device where applicable, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his/her own expense.

WARNING

Changes or Modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.
Certification of this equipment has been carried out using approved cables and peripheral devices. The use of non-approved or modified cables and peripheral devices constitutes a Change or Modification outlined in the warning above.

Operating Restrictions

Operation of this device is limited to purposes associated with law enforcement, firefighting, emergency rescue, scientific research, commercial mining, or construction. Parties operating this equipment must be eligible for licensing under the provisions of Part 90 of this chapter.

FCC Interpretation of Operation Restrictions issued July 12, 2002
(FCC Order DA02-1658, paragraph 9)

The regulations contain restrictions on the parties that are eligible to operate imaging systems (See 47 C.F.R. 5.509(b), 15.511(b), and 15.513(b)). Under the new regulations, GPRs and wall imaging systems may be used only by law enforcement, fire and emergency rescue organizations, by scientific research institutes, by commercial mining companies, and by construction companies. Since the adoption of the *Order*, we have received several inquiries from the operators of GPRs and wall imaging systems noting that these devices often are not operated by the users listed in the regulations but are operated under contract by personnel specifically trained in the operation of these devices. We do not believe that the recent adoption of the UWB rules should disrupt the critical safety services that can be performed effectively only through the use of GPRs and wall imaging systems. We viewed these operating restrictions in the broadest of terms. For example, we believe that the limitation on the use of GPRs and wall imaging systems by construction companies encompasses the inspection of buildings, roadways, bridges and runways even if the inspection finds no damage to the structure and construction does not actually result from the inspection; the intended purpose of the operation of the UWB device is to determine if construction is required. We also believe that the GPRs and wall imaging systems may be operated for one of the purposes described in the regulations but need not be operated directly by one of the described parties. For example, a GPR may be operated by a private company investigating forensic evidence for a local police department.

FCC Permitted Mode of Usage

The GPR antenna must be kept on the surface to be in compliance with FCC regulations. Use of the antenna is not permitted if it is lifted off the surface. Use as a through-the-wall imaging device is prohibited.

GPR Use Coordination

FCC regulation 15.525(c) (updated in February 2007) requires users of GPR equipment to coordinate the use of their GPR equipment as described below:

TITLE 47--TELECOMMUNICATION
CHAPTER I--FEDERAL COMMUNICATIONS COMMISSION
PART 15_RADIO FREQUENCY DEVICES
Subpart F_Ultra-Wideband Operation Sec.
15.525 Coordination requirements.

(a) UWB imaging systems require coordination through the FCC before the equipment may be used. The operator shall comply with any constraints on equipment usage resulting from this coordination.

(b) The users of UWB imaging devices shall supply operational areas to the FCC Office of Engineering and Technology, which shall coordinate this information with the Federal Government through the National Telecommunications and Information Administration. The information provided by the UWB operator shall include the name, address and other pertinent contact information of the user, the desired geographical area(s) of operation, and the FCC ID number and other nomenclature of the UWB device. If the imaging device is intended to be used for mobile applications, the geographical area(s) of operation may be the state(s) or county(ies) in which the equipment will be operated. The operator of an imaging system used for fixed operation shall supply a specific geographical location or the address at which the equipment will be operated. This material shall be submitted to:
Frequency Coordination Branch, OET

Federal Communications Commission
445 12th Street, SW, Washington, D.C.
20554
Attn: UWB Coordination
(**Sensors & Software Inc. Note**: The form given on the following page is a suggested format for performing the coordination.)

(c) The manufacturers, or their authorized sales agents, must inform purchasers and users of their systems of the requirement to undertake detailed coordination of operational areas with the FCC prior to the equipment being operated.

(d) Users of authorized, coordinated UWB systems may transfer them to other qualified users and to different locations upon coordination of change of ownership or location to the FCC and coordination with existing authorized operations.

(e) The FCC/NTIA coordination report shall identify those geographical areas within which the operation of an imaging system requires additional coordination or within which the operation of an imaging system is prohibited. If additional coordination is required for operation within specific geographical areas, a local coordination contact will be provided. Except for operation within these designated areas, once the information requested on the UWB imaging system is submitted to the FCC no additional coordination with the FCC is required provided the reported areas of operation do not change. If the area of operation changes, updated information shall be submitted to the FCC following the procedure in paragraph (b) of this section.

(f) The coordination of routine UWB operations shall not take longer than 15 business days from the receipt of the coordination request by NTIA. Special temporary operations may be handled with an expedited turn-around time when circumstances warrant. The operation of UWB systems in emergency situations involving the safety of life or property may occur without coordination provided a notification procedure, similar to that contained in Sec. 2.405(a) through (e) of this chapter, is followed by the UWB equipment user.[67 FR 34856, May 16, 2002, as amended at 68 FR 19751, Apr. 22, 2003]

Effective Date Note: At 68 FR 19751, Apr. 22, 2003, Sec. 15.525 was amended by revising [[Page 925]] paragraphs (b) and (e). This amendment contains information collection and recordkeeping requirements and will not become effective until approval has been given by the Office of Management and Budget.

FCC GROUND PENETRATING RADAR COORDINATION NOTICE
NAME:
ADDRESS:
CONTACT INFORMATION [CONTACT NAME AND PHONE NUMBER]:
AREA OF OPERATION [COUNTIES, STATES OR LARGER AREAS]:
FCC ID: QJQ-NG250
EQUIPMENT NOMENCLATURE: NG250

Send the information to:
Frequency Coordination Branch., OET
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554
ATTN: UWB Coordination
Fax: 202-418-1944

INFORMATION PROVIDED IS DEEMED CONFIDENTIAL

B-2 ETSI Regulations for the EC (European Community)

In the European Community (EC), GPR instruments must conform to ETSI (European Technical Standards Institute) standard EN 302 066-1 v1.2.1. Details on individual country requirements for licensing are coordinated with this standard. For more information, contact Sensors & Software's technical staff.

All Sensors & Software ground penetrating radar (GPR) products offered for sale in European Community countries or countries adhering to ETSI standards are tested to comply with EN 302 066 v1.2.1.

For those who wish to get more detailed information, they should acquire copies of the following documents available from ETSI.

ETSI EN 302 066-1 V1.2.1 (February 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground and Wall- Probing Radar applications (GPR/WPR) imaging systems; Part 1: Technical characteristics and test methods

ETSI EN 302 066-2 V1.2.1 (February 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground and Wall- Probing Radar applications (GPR/WPR) imaging systems; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive

ETSI TR 101 994-2 V1.1.2 (March 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 2: Ground- and Wall- Probing Radar applications; System Reference Document

B-3a Industry Canada Regulations - English

Industry Canada published it regulations for ground penetrating radar (GPR) on Mar 29 2009 as part of the RSS-220 titled 'Devices Using Ultra-Wideband (UWB) Technology'.
Industry Canada has made a unique exception for GPR by not requiring user licensing. The user does have to comply with the following directives:
This Ground Penetrating Radar Device shall be operated only when in contact with or within 1 m of the ground.
This Ground Penetrating Radar Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.
Should the ground penetrating radar be used in a wall-penetrating mode then the following restriction should be noted by the user:
This In-wall Radar Imaging Device shall be operated where the device is directed at the wall and in contact with or within 20 cm of the wall surface.
This In-wall Radar Imaging Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.
Since operation of GPR is on a license-exempt basis, the user must accept the following:
Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

B-3b Règlement d'Industrie Canada - Français

Industrie Canada a publié des règlements pour les appareils géoradar (GPR) le 29 mars 2009, dans le cadre du RSS-220 intitulé "Dispositifs utilisant la bande ultra-large (UWB)".
Industrie Canada a faite une exception unique pour GPR en n'exigeant pas de licence par utilisateur. L'utilisateur doit se conformer aux directives suivantes:
Ce géoradar périphérique doit être utilisé que lorsqu'il est en contact avec ou moins de 1 m du sol.
Ce géoradar périphérique doit être utilisé que par les organisations d'application de la loi, les instituts de recherche scientifique, des sociétés minières commerciales, entreprises de construction et de secours d'urgence ou des organisations de lutte contre les incendies.
Si le géoradar est utilisé dans un mode de pénétration au mur, la restriction suivante est à noter par l'utilisateur:
Ce dispositif d'imagerie radar doit être utilisé lorsque l'appareil est orienté vers le mur et en contact avec ou dans les 20 cm de la surface du mur.
Ce dispositif d'imagerie radar doit être utilisé que par les organisations d'application de la loi, les instituts de recherche scientifique, des sociétés minières commerciales, entreprises de construction et de secours d'urgence ou des organisations de lutte contre les incendies.
Parce que l'exploitation de GPR est sur une base exempte de licence, l'utilisateur doit accepter le texte suivant:
La fonctionnement est soumis aux deux conditions suivantes: (1) cet appareil ne peut pas provoquer d'interférences et (2) cet appareil doit accepter toute interférence, y compris les interférences qui peuvent causer un mauvais fonctionnement du dispositive

Appendix C: Instrument Interference

Immunity regulations place the onus on instrument/apparatus/device manufacturers to assure that extraneous interference will not unduly cause an instrument/apparatus/device to stop functioning or to function in a faulty manner.
Based on independent testing house measurements, Sensors & Software Inc. systems comply with such regulations in Canada, USA, European Community and most other jurisdictions. GPR devices can sense electromagnetic fields. External sources of electromagnetic fields such as TV stations, radio stations and cell phones, can cause signals detectable by a GPR which may degrade the quality of the data that a GPR device records and displays.
Such interference is unavoidable but sensible survey practice and operation by an experienced GPR practitioner can minimize such problems. In some geographic areas emissions from external sources may be so large as to preclude useful measurements. Such conditions are readily recognized and accepted by the professional geophysical community as a fundamental limitation of geophysical survey practice. Such interference being present in the GPR recordings is not considered as an equipment fault or as a failure to comply with immunity regulations.

Appendix D: Safety around Explosive Devices

Concerns are expressed from time to time on the hazard of GPR products being used near blasting caps and unexploded ordnance (UXO). Experience with blasting caps indicates that the power of Sensors & Software Inc.'s GPR products is not sufficient to trigger blasting caps. Based on a conservative independent testing house analysis, we recommend keeping the GPR transmitters at least 5 feet (2m) from blasting cap leads as a precaution. Some customers do experimental trials with their particular blasting devices to confirm with safety. We strongly recommend that GPR users routinely working with explosive devices develop a systematic safety methodology in their work areas.

The UXO issue is more complex and standards on fuses do not exist for obvious reasons. To date, no problems have been reported with any geophysical instrument used for UXO. Since proximity and vibration are also critical for UXO, the best advice is to be cautious and understand the risks.

Appendix E: Wi-Fi Module

FCC Notice:
NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his/her own expense.

Industry Canada Notice:
This device complies with Industry Canada's license-exempt RSSs. Operation is subject to the following two conditions:
(1) This device may not cause interference; and
(2) This device must accept any interference, including interference that may cause undesired operation of the device.

Appendix F: Calibration

This Ground Penetrating Radar (GPR) system has been manufactured according to Sensors & Software's strict quality standards. All components used in the manufacture of this product are obtained from qualified vendors.

This product has been through a stringent set of tests to ensure all quality requirements are met which includes final system calibration and configuration.

This system is equipped with built-in diagnostic tests. By running the tests and getting a passing result, you can be confident that the system is operating within specification. No further user calibration is required.

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from RADIODETECTION

SPX

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2016-00048-06