



EKKO_Project

with
Processing,
Bridge Deck Condition &
Pavement Structure Modules

User's Guide

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s u b s u r f a c e i m a g i n g s o l u t i o n s

Sensors & Software Inc.
1040 Stacey Court
Mississauga, ON L4W 2X8 Canada

Tel: (905) 624-8909
Fax: (905) 624-9365

E-mail: sales@senssoft.ca
Website: www.senssoft.ca

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1040 Stacey Court

Mississauga, Ontario

Canada L4W 2X8

Tel: (905) 624-8909

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Table of Contents

1	Introduction.....	1
2	Getting Started.....	3
2.1	Opening a Project.....	3
2.1.1	<i>Open a Recent EKKO_Project File</i>	<i>4</i>
2.1.2	<i>Open an Older EKKO_Project File.....</i>	<i>4</i>
2.2	Creating a New Project	5
2.2.1	<i>Adding a Grid</i>	<i>5</i>
2.2.2	<i>Adding all Lines in Folder.....</i>	<i>5</i>
2.2.3	<i>Adding Line(s).....</i>	<i>5</i>
3	EKKO_Project Interface	7
3.1	Active Window	7
3.2	Project Explorer	9
3.2.1	<i>Data Collections Linesets vs. Grids.....</i>	<i>10</i>
3.2.2	<i>Selecting vs. Checking GPR Lines.....</i>	<i>10</i>
3.2.2.1	Clicking the Item Name	10
3.2.2.2	Clicking the Item Checkbox	10
3.2.3	<i>Associated Data Files.....</i>	<i>11</i>
3.2.3.1	GPS	11
3.2.3.2	Topography	11
3.2.3.3	Interpretations	11
3.2.3.4	Processing.....	11
3.3	Project Explorer Toolbar.....	12
3.3.1	<i>Add a New Lineset.....</i>	<i>12</i>
3.3.2	<i>Add a Grid</i>	<i>12</i>
3.3.3	<i>Add Lines to Lineset</i>	<i>12</i>
3.3.4	<i>Attach a File</i>	<i>12</i>
3.3.5	<i>LineView Module (Optional).....</i>	<i>13</i>
3.3.6	<i>SliceView Module (Optional)</i>	<i>13</i>
3.3.7	<i>Right Click Menu</i>	<i>13</i>
3.4	Line Preview.....	18
3.5	MapView	19

3.5.1	<i>Depth Slices in MapView</i>	21
3.5.2	<i>Displaying Multiple Grids with GPS</i>	22
3.5.3	<i>Repositioning Grids</i>	23
3.5.4	<i>Editing and Merging Multiple Grids</i>	24
3.6	Layer View.....	25
3.7	Properties Tabs	26
3.7.1	<i>Acquisition Tab</i>	26
3.7.2	<i>Attachments Tab</i>	29
3.7.2.1	Attachments Toolbar.....	29
3.7.2.2	Positioning Files	30
3.7.3	<i>Processing Tab</i>	32
3.8	Toolbars.....	33
3.8.1	<i>Standard Toolbar</i>	33
3.8.2	<i>View Control Toolbar</i>	34
3.8.2.1	Scale Lines	36
3.8.2.2	Measure	37
3.8.2.3	Copy View	37
3.8.2.4	Export View to File	37
3.8.2.5	Save View.....	37
3.9	Menu Bar	38
3.10	File Menu	39
3.10.1	<i>New</i>	39
3.10.2	<i>Open</i>	39
3.10.3	<i>Close</i>	40
3.10.4	<i>Save</i>	40
3.10.5	<i>Save As</i>	40
3.10.6	<i>Import GPZ</i>	41
3.10.7	<i>Export</i>	41
3.10.7.1	Lines	42
3.10.7.2	Slices	47
3.10.7.3	Average Trace Amplitude.....	49
3.10.7.4	Average Frequency Spectrum.....	50
3.10.8	<i>Recent Files</i>	51

3.10.9	<i>Exit</i>	51
3.11	<i>Edit Menu</i>	52
3.11.1	<i>Add Grid</i>	52
3.11.2	<i>Add Lineset</i>	52
3.11.3	<i>New Lineset</i>	52
3.11.4	<i>Add Line(s) to Lineset</i>	53
3.11.5	<i>Rename</i>	53
3.11.6	<i>Attach File</i>	53
3.11.7	<i>Remove</i>	53
3.11.8	<i>Cut</i>	54
3.11.9	<i>Copy</i>	54
3.11.10	<i>Paste</i>	54
3.11.11	<i>Delete</i>	55
3.12	<i>View Menu</i>	56
3.12.1	<i>Units</i>	56
3.12.2	<i>Average Trace Amplitude</i>	57
3.12.2.1	<i>Plot</i>	58
3.12.3	<i>Average Frequency Spectrum</i>	59
3.12.3.1	<i>Plot</i>	60
3.12.4	<i>Trace Plot</i>	61
3.12.4.1	<i>Plot</i>	62
3.12.5	<i>Zoom</i>	62
3.12.5.1	<i>Zoom Out</i>	62
3.12.5.2	<i>Zoom In</i>	62
3.12.5.3	<i>Zoom Window</i>	62
3.12.5.4	<i>Fit to Window</i>	62
3.12.6	<i>Pan</i>	63
3.12.7	<i>Use Getting Started dialog</i>	63
3.12.8	<i>Toolbar Text</i>	64
3.12.9	<i>Toolbars and Docking Windows</i>	64
3.12.9.1	<i>Customize</i>	64
3.12.10	<i>Status Bar</i>	70
3.12.11	<i>GPS Format</i>	70

3.12.11.1	Latitude/Longitude.....	70
3.12.11.2	UTM.....	71
3.13	Tools Menu.....	72
3.13.1	<i>LineView</i>	73
3.13.2	<i>SliceView</i>	74
3.13.3	<i>Report</i>	75
3.13.3.1	GPR Summary Report (PDF).....	75
3.13.3.2	Google Earth (KMZ).....	79
3.13.3.3	Project Report (CSV).....	80
3.13.3.4	CAD (DXF).....	82
3.13.3.5	Bridge Deck Condition Report (PDF).....	83
3.13.3.6	Pavement Structure Report (PDF).....	90
3.13.4	<i>Project Position Relationship</i>	94
3.13.4.1	Wizard.....	95
3.13.4.2	Auto (GPS-based).....	102
3.13.4.3	Undefine.....	102
3.13.5	<i>Grid Position Relationship</i>	103
3.13.5.1	Wizard.....	103
3.13.5.2	Auto (GPS-based).....	108
3.13.6	<i>Process</i>	109
3.13.6.1	Input Parameters.....	111
3.13.6.2	Applying Processing.....	111
3.13.6.3	Deleting a Process.....	111
3.13.6.4	Save Recipe.....	112
3.13.6.5	Load Recipe.....	112
3.13.6.6	My Recipe Management.....	113
3.13.7	<i>Undo Process</i>	113
3.13.8	<i>Merge Lines</i>	114
3.13.9	<i>GPS</i>	115
3.13.9.1	Latency.....	115
3.13.9.2	Offset.....	116
3.14	Window Menu.....	118
3.14.1	<i>Open Line Preview</i>	118

3.14.2	<i>Open MapView</i>	118
3.14.3	<i>Tile Horizontally</i>	118
3.14.4	<i>Tile Vertically</i>	118
3.15	Help Menu	119
3.15.1	<i>About EKKO_Project</i>	119
3.15.2	<i>EKKO_Project User's Guide</i>	119
3.15.3	<i>Restore Factory Defaults</i>	119
3.15.4	<i>EKKO_Project and Module Registration</i>	119
3.15.5	<i>Contact Us</i>	119
4	Window Operations	121
4.1	Resizing the EKKO_Project Window	121
4.2	Undocking and Docking Windows	121
4.3	Pinning Windows	122
4.4	Closing a Window	123
4.5	Adding or Removing Buttons from Toolbars	123
4.5.1	<i>Standard Toolbar</i>	123
4.5.2	<i>View Control Toolbar</i>	124
5	Processing Functions	125
5.1	Attributes	125
5.1.1	<i>Envelope</i>	126
5.1.2	<i>Instantaneous Frequency</i>	126
5.1.3	<i>Instantaneous Phase</i>	126
5.2	Filters – 2D	127
5.2.1	<i>Migration</i>	127
5.3	Filters – Spatial	127
5.3.1	<i>Background Average Subtraction</i>	128
5.3.2	<i>Background Subtraction</i>	128
5.3.3	<i>Horizontal</i>	129
5.4	Filters - Time	130
5.4.1	<i>Bandpass Filter</i>	130
5.4.2	<i>DC Removal</i>	131
5.4.3	<i>Dewow</i>	131
5.4.3.1	<i>Dewow Artifacts</i>	133

5.4.4	<i>DynaT</i>	135
5.4.5	<i>Highpass</i>	135
5.4.6	<i>Lowpass</i>	137
5.4.7	<i>Vertical</i>	138
5.5	First Break.....	140
5.5.1	<i>Edit First Break</i>	140
5.5.2	<i>Repick First Break</i>	140
5.6	Gains.....	143
5.6.1	<i>Automatic Gain Control</i>	144
5.6.2	<i>Constant Gain</i>	145
5.6.3	<i>SEC2</i>	146
5.7	Line Editing.....	147
5.7.1	<i>Antenna Separation</i>	147
5.7.2	<i>Crop Data - Horizontal</i>	147
5.7.3	<i>Crop Data - Vertical</i>	147
5.7.4	<i>Pad Data - Horizontal</i>	148
5.7.5	<i>Pad Data - Vertical</i>	148
5.7.6	<i>Reposition Traces</i>	149
5.7.7	<i>Reposition Using GPS</i>	150
5.8	Operations.....	150
5.8.1	<i>Amplitude Spectra</i>	150
5.8.2	<i>Average Trace</i>	151
5.8.3	<i>Delete Traces</i>	152
5.8.4	<i>Flip Polarity</i>	153
5.8.5	<i>Insert Traces</i>	154
5.8.6	<i>Mute</i>	155
5.8.7	<i>Normal Move-out Correction</i>	156
5.8.8	<i>Rectify</i>	157
Appendix A File Formats		159
1.	Interpretation Reports.....	159
2.	Global Positioning Files.....	160
3.	GPS.....	160
4.	GP2.....	161

- 5. SEG-Y 162
- 6. Topography Files..... 164
- Appendix B Calculating GPS Latency 165**
- Appendix C Glossary 173**
- 1. Definitions 173
- 2. Abbreviations 177

1 Introduction

EKKO_Project was designed to simplify the display, editing, processing, and interpretation of Ground Penetrating Radar (GPR) data.

EKKO_Project increases productivity by giving you more time to view and interpret data and less time spent organizing it.

Use EKKO_Project to display project (.gpz) files (compressed files containing GPR linesets and grid data) intuitively in the Project Explorer tree. The Properties pane displays GPR line details such as acquisition parameters and associated files.

The Line Preview window automatically displays the first line in the project with the view settings from the data acquisition software or default view settings. The user can display other lines by clicking on the line name in Project Explorer or using the arrow keys.

The MapView window displays the position of grids in the project space coordinate system. If GPR data was collected with GPS or, if the relationship between the project coordinate system and the global coordinate system (Latitude-Longitude or UTM) is defined by the user, grids and the GPS path of GPR lines are displayed in MapView.

Depth slices processed in the field using the data acquisition software (LMX200) or using the optional SliceView module (see below) are also displayed in the MapView window.

The optional Processing module allows you to edit and process data, including cropping data, time filters, migration and gain. You can then save processing streams as Recipes that you can apply to other GPR projects.

GPR lines are visualized and the view settings edited using the optional LineView module. See the LineView manual for more details.

The optional Interpretation module in LineView is used to create interpretations of Points, Polylines, Boxes, and Annotations, view them in GPR lines, and then output your interpretations as Reports. Point interpretations are displayed in MapView. See the LineView manual for more details.

The optional SliceView module allows you to process and display GPR data collected in a grid as a series of depth slices. Depth slices enhance interpretations at complex sites by providing a powerful way of visualizing the spatial relationships between targets seen in multiple GPR lines. SliceView also allows grid data to be exported in a 3D format. See the SliceView manual for more details.

The optional Bridge Deck Condition Report module allows you to process point interpretations on the rebar in a bridge deck or other concrete structure and output a PDF report with an amplitude map image and statistics about the rebar in the structure.

The optional Pavement Structure Report module allows you to process polyline interpretations on subsurface layers and output a PDF report with cross-sections of and statistics about of the layers.

2 Getting Started

EKKO_Project works with compressed GPR project files called GPZ (GPR Project Zip) files. Each project file contains one or more GPR line data files and may contain information from other related files such as GPS files that were saved as the GPR data was collected.

New generation Sensors & Software GPR devices automatically create Project files however, GPR data collected using older Sensors & Software GPR systems can easily be added to a new EKKO_Project project file following the [Creating a New Project](#) procedure.

2.1 Opening a Project

When you open EKKO_Project, the **Getting Started** dialog box automatically opens to help you open or create a new project based on the data file format you select.

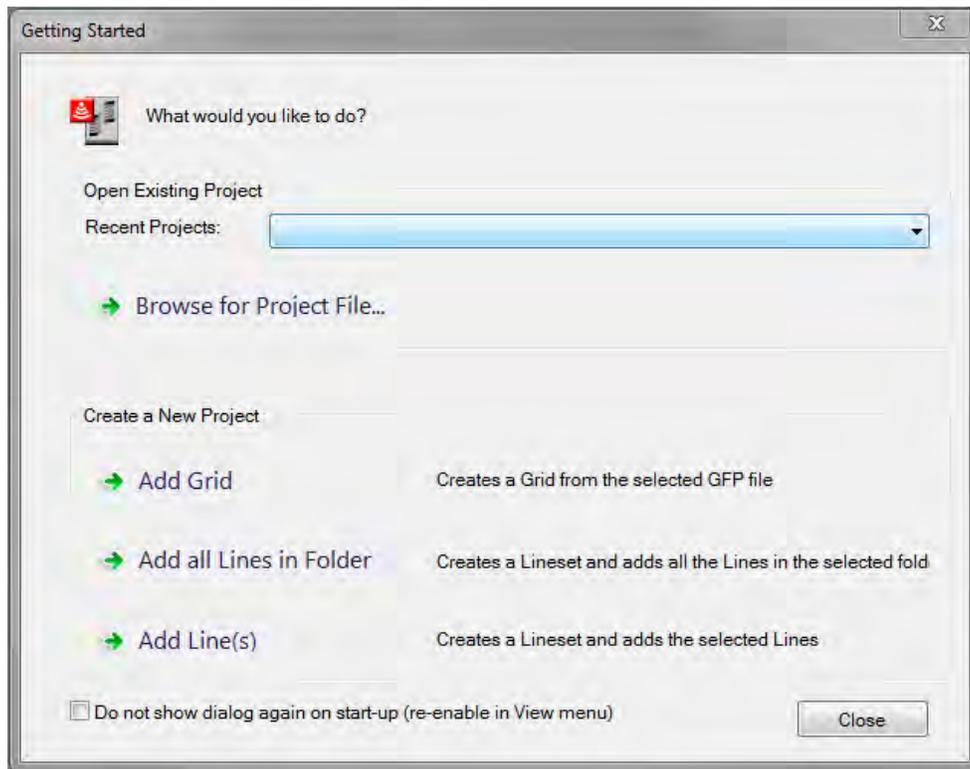


Figure 1: The Getting Started dialog box

2.1.1 Open a Recent EKKO_Project File

1. In the **Getting Started** dialog box **Open Existing Project** pane, click the **Recent Projects** drop-down list.
2. In the drop-down list, click the project file you want to open.



2.1.2 Open an Older EKKO_Project File

1. In the **Getting Started** dialog box **Open Existing Project** pane, click **→ Browse for Project File...**
2. In the **Open** dialog, navigate to the folder and select the project file you want to work in.

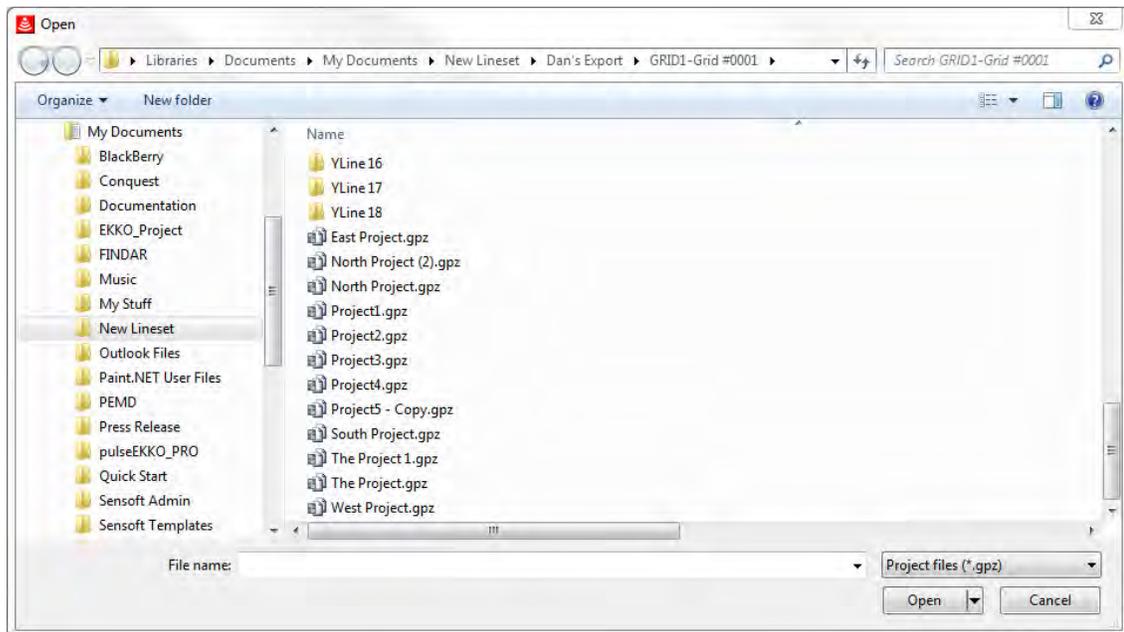


Figure 2: Open Dialog

Only files with a .gpz extension are listed.

3. Select the project you want to work with and then click **Open**.

The project contents are displayed in the [Project Explorer](#) and, if positioning information is available, the GPR lines are displayed in [MapView](#).

2.2 Creating a New Project

To create a new EKKO_Project file, in the **Create a New Project** pane, select one of the following options:

- ➔ Add Grid
- ➔ Add all Lines in Folder
- ➔ Add Line(s)

A project file can contain multiple grids and line sets.

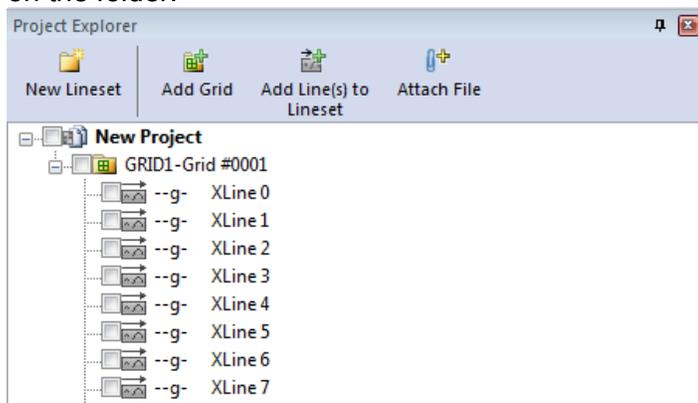
2.2.1 Adding a Grid

1. In the **Getting Started** dialog box **Create a New Project** pane, click ➔ Add Grid.
2. In the **Open** dialog box, navigate to and then select a grid (.gfp) file.

Only files with a .gfp extension are listed. For more details about GFP files, see [Add Grid](#).

3. Click **Open**.

The grid is displayed in the [Project Explorer](#) and indicated with the small green grid on the folder.



2.2.2 Adding all Lines in Folder

1. In the **Getting Started** dialog box [Create a New Project](#) pane, click ➔ Add all Lines in Folder.
2. In the **Select folder to import lines from** dialog box, navigate to and then select a folder containing GPR lines.
3. Click **Select Folder**.

The new project folders will be displayed in the [Project Explorer](#)

2.2.3 Adding Line(s)

1. Click ➔ Add Line(s).
2. In the **Open** dialog box, navigate to and then select one or more GPR (.hd) Lines.

Only GPR files with an .hd extension are listed.

Note: although only .hd files are listed and selected, the folder must also contain the associated .dt1 file(s).

3. Click **Open**. The Line(s) are displayed in the [Project Explorer](#)

3 EKKO_Project Interface

When a project file is open, EKKO_Project is populated with information about the GPR data in the Project file.

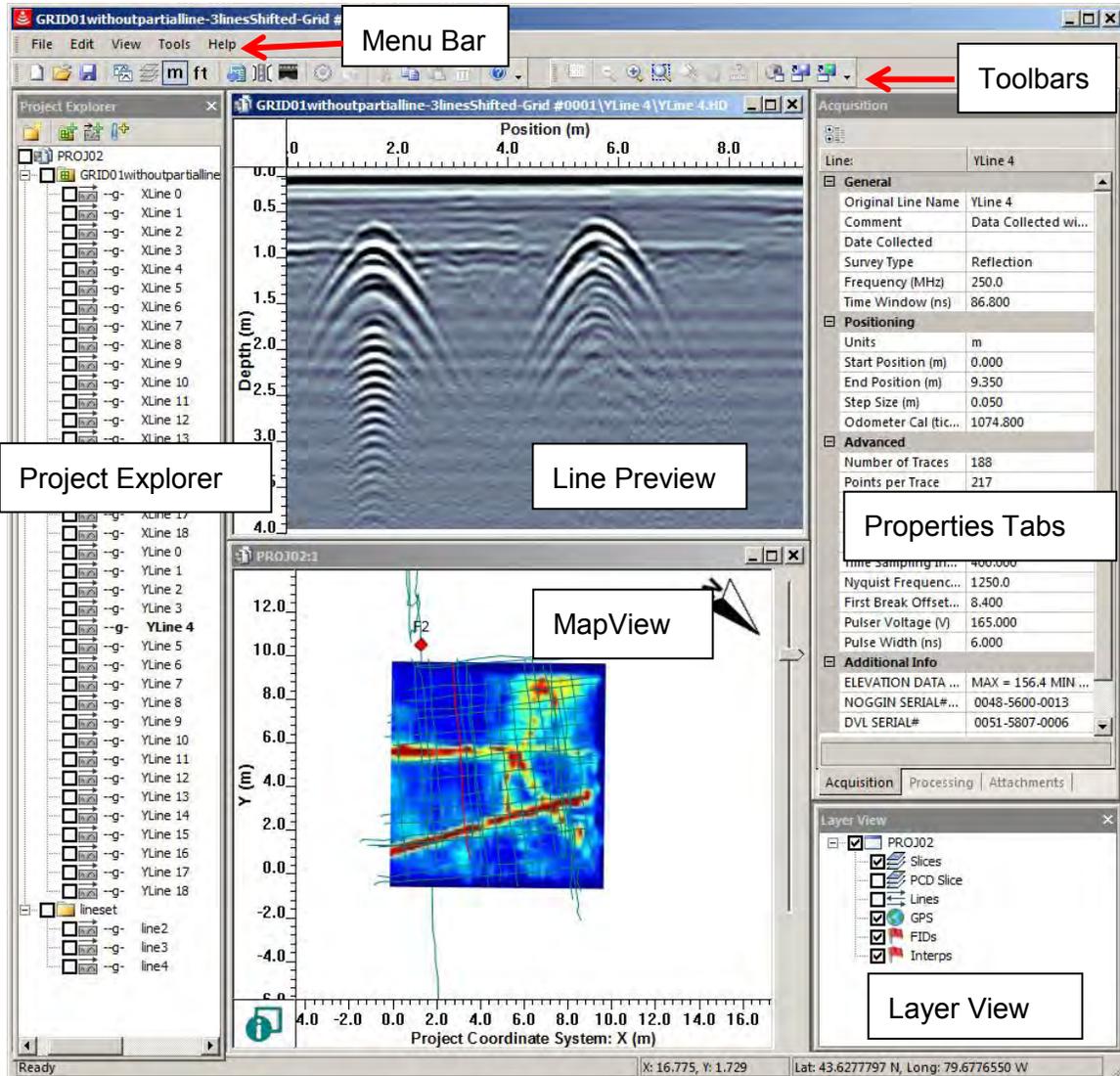


Figure 3: The EKKO_Project interface

The main EKKO_Project window consists of a [Menu Bar](#), [Toolbars](#), [Project Explorer](#), [Line Preview](#), [MapView](#), [Layer View](#), and [Properties tabs](#).

All windows can be moved, resized, and modified. The tabs that make up the Properties window can be separated into individual windows (to learn more, see [Window Operations](#)).

3.1 Active Window

EKKO_Project typically displays several windows at a time including Line Preview, MapView and Project Explorer. Only one window can be active and accept changes at a

time. The active window is the one that was last selected by clicking in it with the mouse cursor and is usually identified by its darker title banner.

To make changes in a particular window, first ensure it is the active window.

Often, trying to edit a window immediately makes it the active window, for example, selecting a GPR line in the Project Explorer by clicking on it or checking a layer in the Layer window.

3.2 Project Explorer

Project, folders, and files are displayed in the Project Explorer which is similar to Windows Explorer. In Project Explorer, grids and linesets are used just like folders in Windows, and GPR lines are similar to files.

To display all GPR Lines associated with a project folder, click the plus sign (+) beside the grid or lineset name

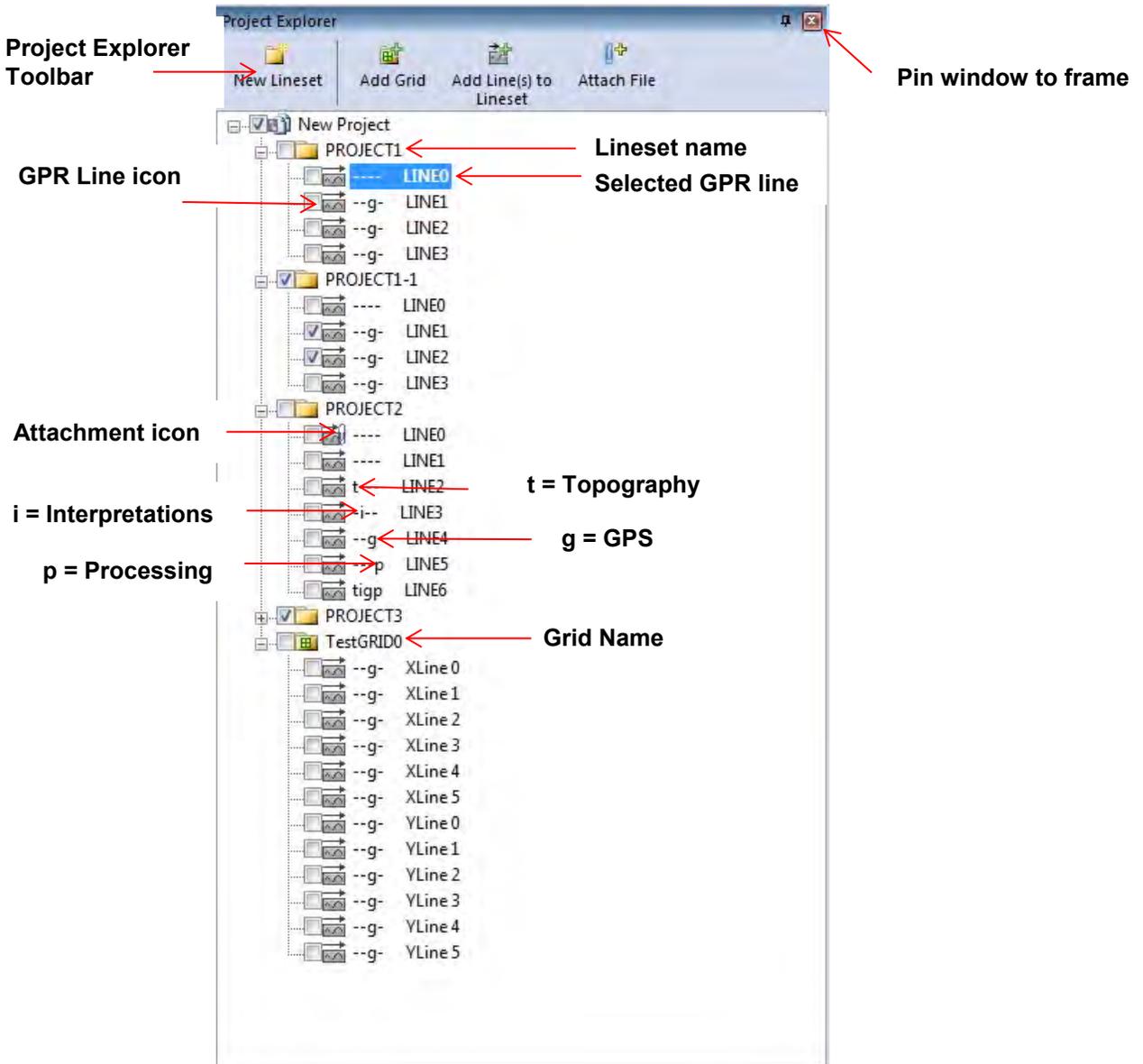


Figure 4: Project Explorer pane displaying open data folders listing the GPR lines.

The names of all the GPR data files in the grid and/or linesets are listed. The line icon () indicates which files are GPR lines. If other files associated with the line (photos, videos, field notes, etc.) have been attached, the line icon displays a paperclip icon

 (to learn more, see [Attach a File](#)).

3.2.1 Data Collections Linesets vs. Grids

Data collections in EKKO_Project are composed of either linesets or grids.

Grids are, by definition, a complete collection of GPR lines related to one another spatially; GPR lines cannot be added or deleted from a grid (this requires a separate utility program called GFP_Edit). However, individual GPR lines in a grid can be copied and added to a lineset.

Linesets are collections of GPR lines that may or may not relate to one another spatially. Linesets can be edited to add or delete GPR lines. GPR lines in linesets can also be cut and/or copied and pasted into other linesets.

3.2.2 Selecting vs. Checking GPR Lines

GPR lines, linesets, grids, and projects can be selected in two different ways:

3.2.2.1 Clicking the Item Name

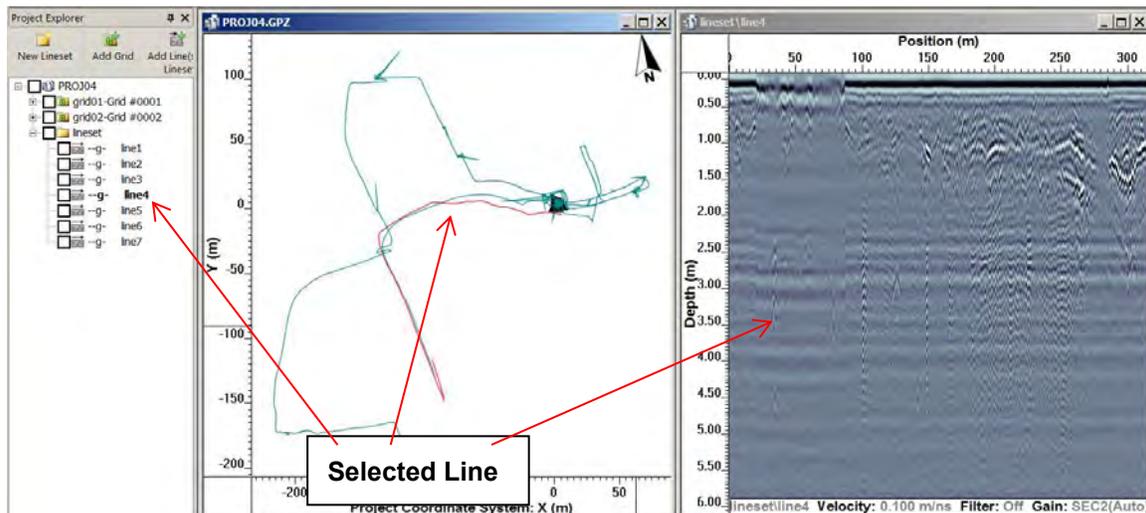
To select the name of a GPR line, lineset, grid, or project, click the item name.

Once an item is selected, it is highlighted blue and you can only apply [Right Click](#) menu operations to the item.



If the item displayed in MapView, it turns red to indicate it has been selected. For example, if a single GPR line collected with GPS is selected, the GPS path in MapView turns red. If a grid is selected, all the grid lines turn red.

When a GPR line is selected in Project Explorer, either a line collected GPS or a grid line, it is displayed in the Line Preview window.



3.2.2.2 Clicking the Item Checkbox

To access copy, cut, paste, delete, and process operations from the Standard Toolbar or the Edit Menu, click the checkbox beside the GPR Line, lineset, grid, or project name.

Note: When a GPR Line is checked, the GPR collection (lineset or grid) and the project name are also checked. This feature enables you to identify when GPR Lines in the collection are checked even if the GPR collection is collapsed (click the minus sign [-]).



3.2.3 Associated Data Files

An icon is displayed next to the line name in [Project Explorer](#) to indicate whether any of the following file types are attached to the GPR line:

3.2.3.1 GPS

If a GPS is connected to the GPR system during data collection, GPS files with the same name as the GPR line are saved to the Project file and/or data folder. When the GPR data is opened in EKKO_Project, GPS positions are automatically integrated with the GPR lines. This is indicated by the letter “g,” see the example in the [Project Explorer](#).

GPS integration means Latitude-Longitude and UTM coordinates are displayed on the Status Bar when viewing the GPR line in [LineView](#) and listed in [Reports](#).

The name of the GPS file is listed under the [Attachments](#) tab.

3.2.3.2 Topography

When a topography (.top) file with elevation information is attached to a GPR line, it is indicated by the letter “t,” see the example in the [Project Explorer](#).

Integrating topography information means that the GPR line can be plotted with an elevation axis in [LineView](#), rather than the default depth axis. Elevations of interpretations and fiducial markers are also listed in [Reports](#).

The topography file name is listed in the [Attachments](#) tab.

Topography files with the same name and in the same folder as the GPR line are automatically attached. Topography files with a different name can be manually attached; see the [Attachments](#) tab.

GPS files also contain elevation information; see [GPS Files](#) for more information about GPS elevations and how EKKO_Project decides whether to use Topography file or GPS file elevations.

3.2.3.3 Interpretations

Interpretations added to the file using the optional Interpretation module in [LineView](#) are identified by the letter “i,” see the example in the [Project Explorer](#). Interpretations are points of interest (points, polylines, boxes, and annotations) added to GPR lines. This is similar to adding a flag/fiducial during data collection.

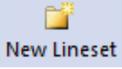
3.2.3.4 Processing

GPR data that has been processed using the optional [Processing](#) module is identified by the letter “p,” see the example in the [Project Explorer](#).

3.3 Project Explorer Toolbar

The [Project Explorer](#) toolbar displays four icons representing features that enable you to add GPR lines to the current project.

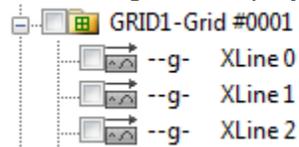
3.3.1 Add a New Lineset

- To add a new lineset folder to the current project file, in the menu bar click  **New Lineset**.
- A  **New Lineset** folder opens in the Project Explorer.
- To rename the new lineset, right-click **New Lineset**.
- In the drop-down list, click **Rename**.

3.3.2 Add a Grid

- To add a grid (.gfp) file to the current project, in the menu bar click  **Add Grid**.
- In the **Open** dialog box, navigate to the folder and click the grid file you want to open.
Only files with a .gfp extension are listed.
- Click **Open**.

The new grid is displayed in the Project Explorer:



3.3.3 Add Lines to Lineset

- To add lines to the selected lineset, in the menu bar, click  **Add Line(s) to Lineset**.
- In the **Open File** dialog box, navigate the file folder and then select one or more GPR (.hd) Lines.

The GPR lines are added to the current Lineset. If the highlighted item is not contained in a lineset, a new lineset will be created in the project.

Note: GPR lines cannot be added to a grid.

- Click **Open**.

The lines are displayed in the Project Explorer:



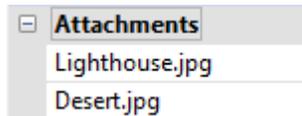
3.3.4 Attach a File

The Attach File feature enables you to attach any file to the selected GPR line, lineset, grid, or project.

Note: any item with the same name as the line is automatically attached when the line is added to the project (for example, a picture of the site could be renamed as LineX0.jpg so it is automatically attached to the project when the LineX0 data is added).

1. To add an attachment to a file, in the menu bar click **Attach File** .
2. In the **Open File** dialog box, navigate to the folder and then select the file you want to attach.
3. Click **Open**.

The files are displayed in the Attachments pane:



Note: if you attach multiple topography (.top) or GPS (.gps or .gp2) files, the last file attached is the one that is used.

3.3.5 LineView Module (Optional)

Double-clicking on a GPR Line name in Project Explorer displays it in the optional LineView module. For more details, see [LineView](#).

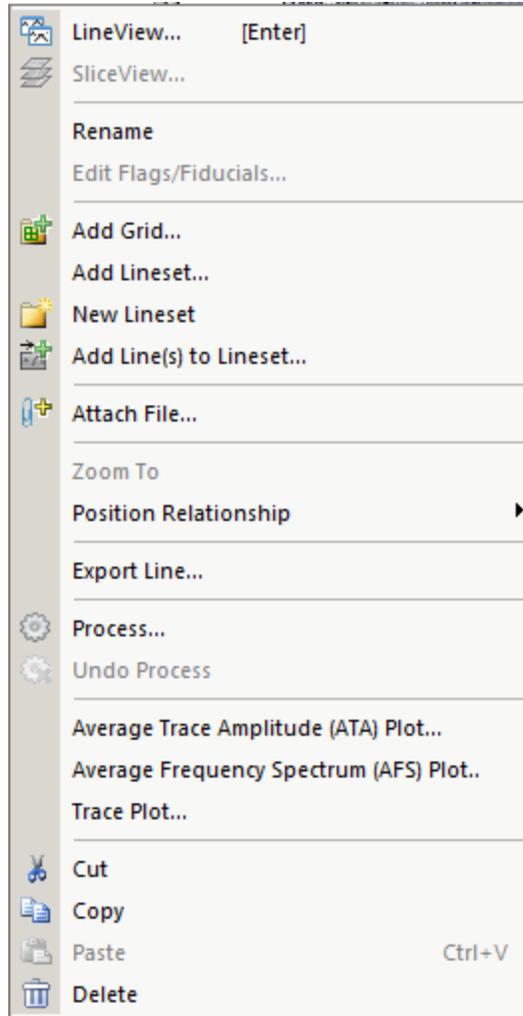
3.3.6 SliceView Module (Optional)

Double-clicking on a GPR grid name in Project Explorer displays it in the optional SliceView module. For more details, see [SliceView](#).

3.3.7 Right Click Menu

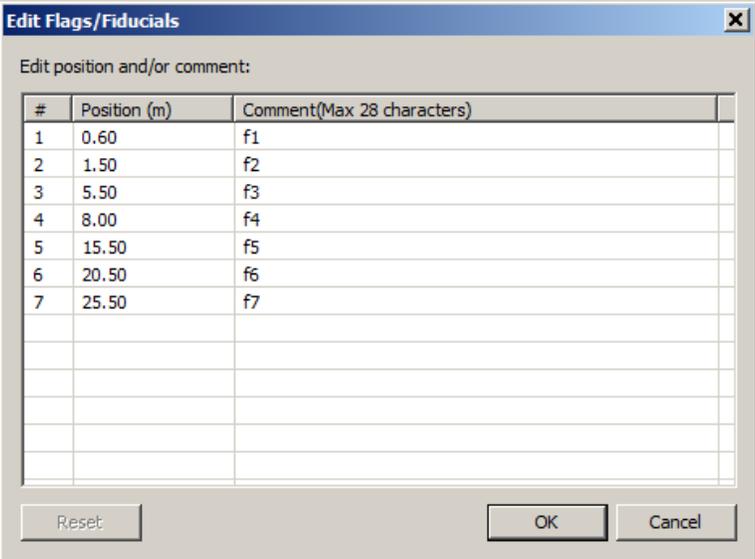
When you right-click a grid, lineset, or GPR line in Project Explorer, a context-sensitive menu opens.

Tools in the right-click menu operate only on the item that was selected. The checked items in the Project Explorer are ignored.



Use the following table as a guide to working with the LineView Right Click menu features:

Field	Description
LineView	Click  LineView to open and display project GPR lines in the optional LineView module. To learn more, see the LineView User's Guide.
SliceView	With a Grid selected in the Project Explorer , click  SliceView to open and display the grid as a series of depth slices in the optional SliceView module. To learn more, see the SliceView User's Guide.
Rename	To change the name of the selected project, grids, or linesets, click Rename . Rename an item when you want to give the data a more descriptive name.

Field	Description
<p>Edit Flags/Fiducials</p>	<p>To edit flags/fiducials added during data collection, click Edit Flags/Fiducials. This opens a dialog listing all the fiducials in the selected GPR line and allows the position and/or the text to be edited.</p>  <p>Note that the all original positions and comments are always available by clicking on the Reset button.</p>
<p>Add Grid</p>	<p>To add a grid to the current project file, click  Add Grid. You can only add files that have a .GFP extension.</p>
<p>Add Lineset</p>	<ol style="list-style-type: none"> To add a lineset to the current project file, click Add Grid To add a grid to the current project file, click Edit > Add Grid. In the Open dialog box, navigate to and then click the grid (.gfp) file you want to add. Click Open. <p>The project file grid name defaults to the same name as the .gfp file. To learn about renaming files, see Rename.</p>
<p>New Lineset</p>	<p>To add a new lineset folder to the current project file, click  New Lineset. A new folder named “New Lineset” appears in the Project Explorer list.</p>
<p>Add Line(s) to Lineset</p>	<p>To add one or more GPR Lines to a Lineset folder, click  Add Line(s) to Lineset.</p>
<p>Attach File</p>	<p>To attach any file to the currently selected GPR data line, lineset, grid, or project, click  Attach File. The file is then displayed in the Attachments tab.</p>

Field	Description
Export Line	<p>Use the Export feature to send linesets, grids, or GPR Lines from a project (GPZ) file to a different folder.</p> <p>Exported files can be GPR data files (DT1 and HD) or other associated files such as GPS and elevation (TOP) files.</p>
Zoom To	<p>Zoom to the currently selected GPR line or grid in MapView. The GPR line or grid must be plotted in MapView so only grid lines or lines with GPS are eligible or this option is greyed out and not accessible.</p>
Position Relationship	<p>Modify the position of the selected grid or the project. If a grid is selected, the grid-to-project position relationship is edited (see Grid Wizard) – useful for moving a grid in the project coordinate system.</p> <p>If the whole project is selected, the project-to-global position relationship is defined or edited (see Project to Global).</p> <p>Note: the position of Linesets, individual GPR lines or individual grid lines cannot be edited with this option; the options are greyed out and not accessible.</p>
Process	<p>To open the Processing dialog box, click  Process.</p> <p>This feature enables you to edit and process selected GPR line using repositioning, temporal and spatial filters, and migration features.</p>
Undo Process	<p>To reset the selected GPR line to its original format before processing was applied, click  Undo Process.</p> <p>Copied GPR lines are reset to the any processing they had at the point they were copied.</p> <p>When processing is undone to an item, the small letter “p” beside the file name indicating that it was a processed file disappears.</p>
Cut	<p>Use the  Cut feature to remove the selected GPR line, lineset or grid from the project.</p> <p>This enables you to remove a GPR line from a lineset and paste it into a different lineset.</p> <p>Note: a GPR line cannot be cut from a grid.</p>
Copy	<p>Use the  Copy feature to:</p> <ul style="list-style-type: none"> • Copy the selected GPR line so it can be pasted into the same or a different lineset in the project • Copy the selected lineset or grid so it can be pasted back into the project <p>Note: You can copy GPR lines from a grid and paste then into a lineset, but you cannot be paste them into a grid.</p>
Paste	<p>Use the  Paste feature to:</p> <ul style="list-style-type: none"> • Paste a copied or cut GPR line into the same or a different lineset in the project • Paste a copied or cut lineset or grid back into the project <p>Note: You can copy GPR lines from a grid and paste them into a lineset, but you cannot paste them into a grid.</p>

Field	Description
Delete	To Delete the selected grid or lineset from a project, click  Delete . You can also delete a GPR line from the Lineset in the project. Note: GPR lines cannot be deleted from a grid. .

3.4 Line Preview

The Line Preview window displays the GPR line currently selected in Project Explorer. When EKKO_Project first opens, Line Preview automatically displays the first GPR line listed in the project.

The user can change the Line Preview display to another GPR line in the project by:

- 1) Clicking on the name in Project Explorer, or
- 2) After clicking in the Project Explorer window to make it the [Active Window](#), using the up and down arrow keys on the keyboard to move to a new GPR line name.

Both options provide fast switching between lines to quickly review all the lines in a project.

Any Flags/Fiducials added to the GPR line during data collection or interpretations added to the GPR line using the optional Interpretation module are visible in the Line Preview plot.

On the bottom of the GPR line is a simple legend listing the file path and line name, the velocity used to calculate the depth axis and the View Settings (gain and filter).

After selecting the Line Preview window, use the zoom options to zoom in, out or to a user-specified zoom window using the buttons on the [View Control Toolbar](#) or the **View > Zoom** menu options.

After zooming in, plot the whole GPR line to the Line Preview window by selecting the **Fit to Window** button on the [View Control Toolbar](#) or the **View > Zoom** menu option.

GPR lines plotted in Line Preview use the View Settings (gain, color table, filter, etc.) from the Digital Video Logger. If these are not available, default settings that include Auto gain, the "Bone" color palette and no background subtraction filter applied.

The View Settings can be changed in Line Preview by plotting the GPR line(s) in the optional LineView module and changing the View Settings there. After exiting LineView, the Line Preview settings for that GPR line are updated.

If LineView module is not enabled, change the View Settings for the GPR line on the DVL and transfer the data, along with the new View Settings, to the PC and open the updated project file in EKKO_Project.

Line Preview will not plot GPR traces in wiggle mode and GPR lines cannot be plotted with an elevation axis with the traces shifted for topography – these advanced display options are available in the LineView module.

If the Line Preview window is closed, open it by selecting **Window > Open Line Preview**.

3.5 MapView

The MapView window shows a plan map image of GPR lines and grids including flags/fiducials, point interpretations and depth slices.

GPR lines are only displayed in MapView if they have some local coordinate (XY) definition (i.e. part of a grid). MapView displays GPR lines in a grid as black lines with arrows. Move the mouse cursor over the MapView image to display the XY coordinates in the Status Bar along the bottom of the EKKO_Project screen.

If a grid or the GPR line was collected using with GPS, the GPS paths are also displayed as dark green lines. Due to the variable accuracy of GPS units, the GPS lines will not typically correspond exactly with the GPR lines.

Move the mouse cursor over MapView image to display the global position in Latitude-Longitude and UTM in the Status Bar along the bottom of the EKKO_Project screen.

The GPS paths will be displayed for any GPR line (part of a grid or not) that has GPS data associated with it.

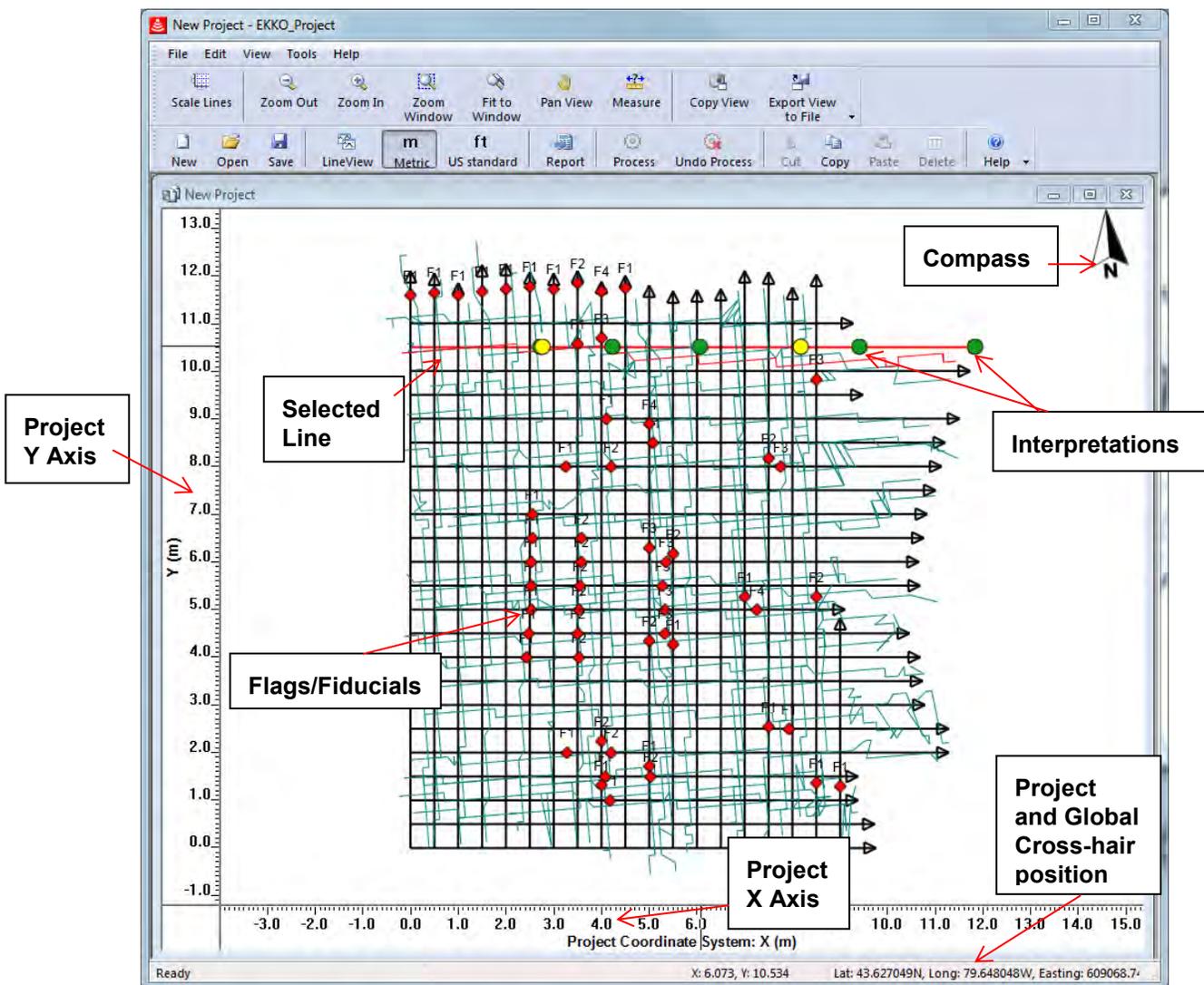


Figure 5: MapView Window

- If the GPR project does not contain any grids and none of the GPR lines were collected with GPS, then the MapView window will remain greyed out as there is nothing to plot.
- When one or more GPR lines are selected in the Project Explorer, they appear in red in MapView. If the file has an associated GPS file, the GPS path also appears in red.
- Flags/Fiducials always appear as red diamonds with text nearby.
- Point interpretations appear in the color and shape they were defined with.
- Depth slices can be plotted in MapView. For more information, see below.



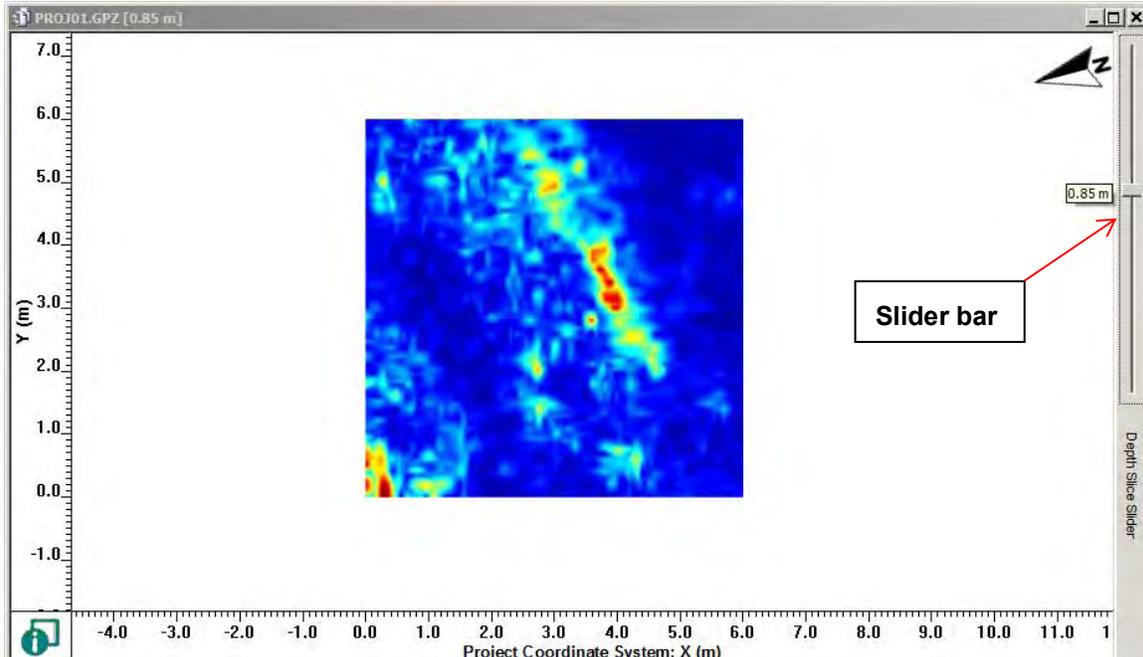
A compass icon  pointing to geographic North is displayed if the World-Project relationship is defined. This relationship is calculated automatically if the GPR data were collected with GPS. If this relationship is not defined, the Status Bar displays “GPS relationship not defined”.

Use the following table as a guide to working with MapView:

Item	Description
Cross-hair position	As you move the cursor over an area in the Grid Map, the position of the mouse cross-hair is displayed in XY coordinates and GPS (if present) at the bottom right of the screen.
Flags/Fiducials	Flags/Fiducials are markers added during data collection at specific trace positions along the line. Flags/Fiducials can be repositioned and the labels edited (see Right Click Menu).
Interpretations	Interpretations added to the file using the optional Interpretation module in LineView. Interpretations represent points of interest (points, polylines, boxes, and annotations) added to the line. To learn more, see Interpretations , Only point interpretations are displayed in MapView.
Field Interpretations	Some GPR systems such as the LMX200 have the capability of adding point interpretations in the field. These are just like the interpretations added with the Interpretation module and are displayed in MapView.
Selected Line	The line selected in the Project Explorer is highlighted red in the plan Map. The details of the selected line are displayed in the Properties Pane .

3.5.1 Depth Slices in MapView

Depth slices from grid data, generated with the optional SliceView module or, for some GPR systems (for example, the LMX200), in the field with the data acquisition program are displayed in MapView.



Depth Slice at 85 cm displayed in MapView.

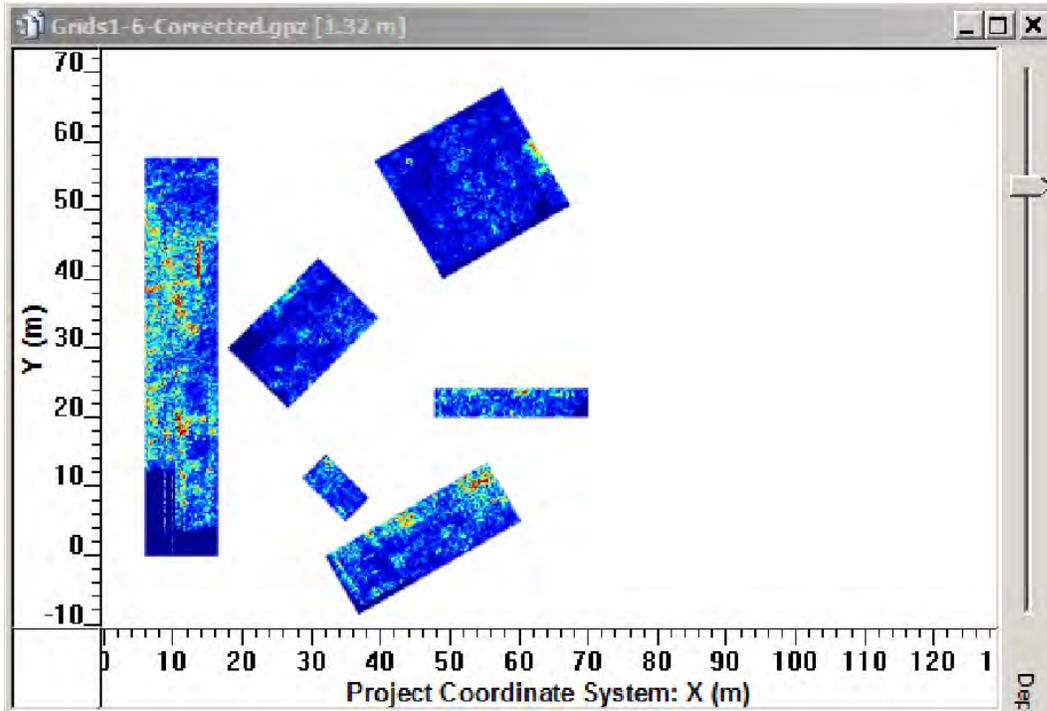
Use the depth slice slider bar to scroll through the depth slices. You can also use the mouse-wheel to smoothly scroll through the depth slices, after selecting the MapView window to make it the [Active Window](#).

The current slice depth is displayed next to the slider bar and in the window title.

For multiple grids, slice through all of them simultaneously, even if:

- they are at different angles to one another,
- they were collected with different GPR systems with different center antenna frequencies
- they were collected with different depth slice processing (slice thickness, amplitude equalization gain, background subtraction filter, resolution, etc.).

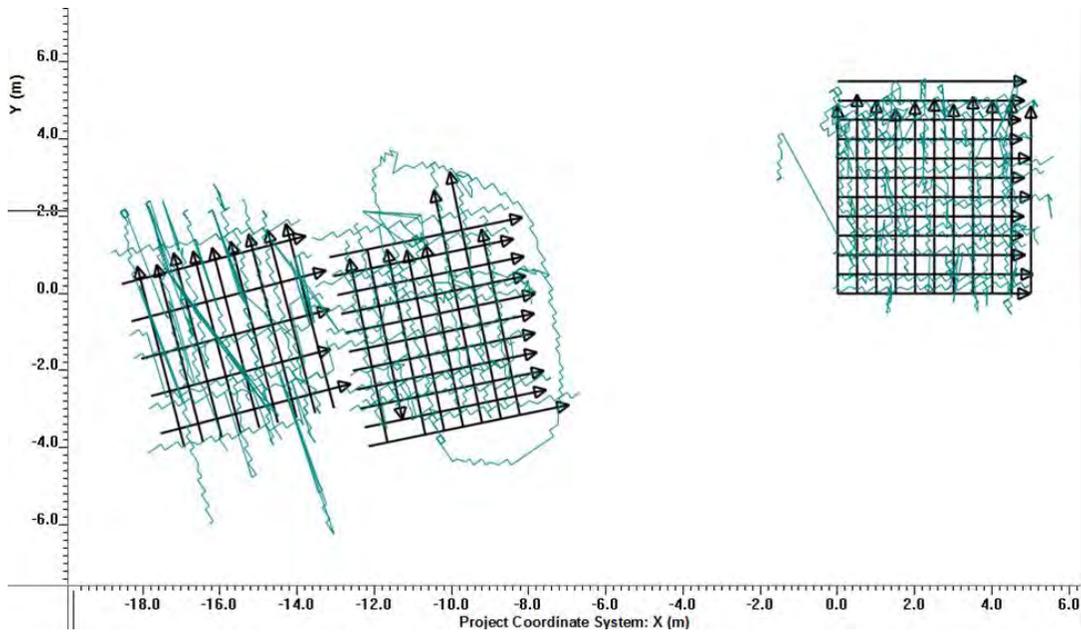
For example, if depth slices were processed using a different slice thickness value, the depth slices shown in MapView are the depth slices closest to the current depth value.



3.5.2 Displaying Multiple Grids with GPS

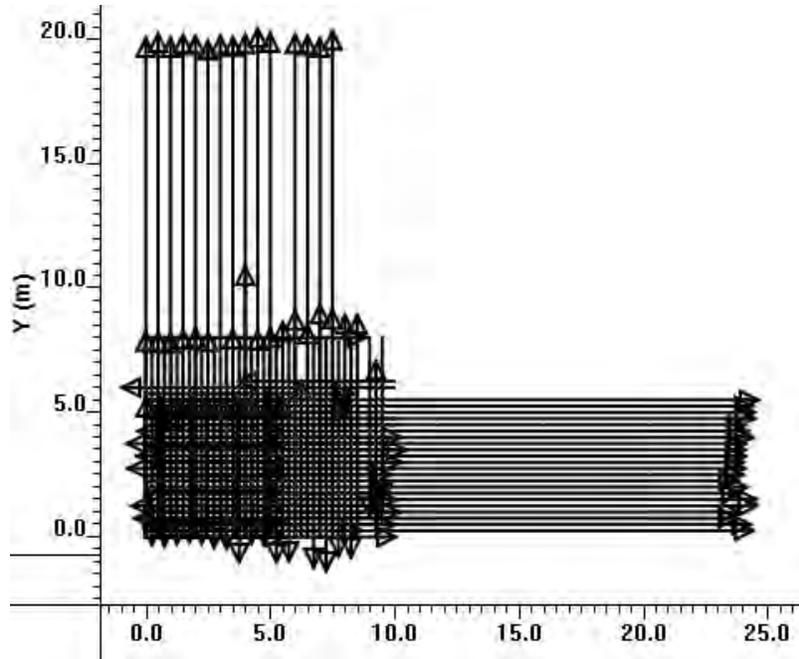
Many GPR surveys are made up of multiple grids. EKKO_Project can display more than one grid to confirm targets within the grids.

Multiple grids collected using GPS are automatically arranged within the MapView window.



3.5.3 Repositioning Grids

Multiple grids collected without GPS all have their X=0, Y=0 corner corresponding with the X=0, Y=0 of the Project coordinate system, thus all the grids are “stacked” at that position.

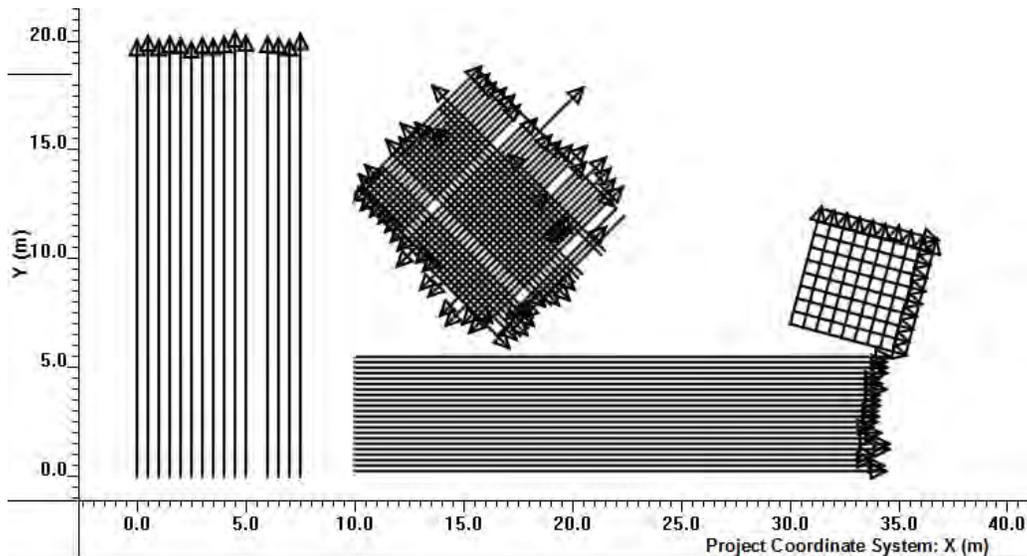


To move a grid within the project coordinate system, select the grid in Project Explorer and then:

- 1) right-click to open the menu and select **Position Relationship > Wizard** or,
- 2) select **Tools > Grid Position Relationship > Wizard**

and follow the directions (see [Grid Position Wizard](#)).

For example, the image below shows grids after each one was repositioned within the Project coordinate system.



3.5.4 Editing and Merging Multiple Grids

Use the GFP_Edit utility program to edit grids or merge multiple grids to create one large grid.

The key advantage of using GFP_Edit to merge multiple grids together is that then all grid data are processed together in SliceView, so filters such as Background Subtraction use all the data in their calculations.

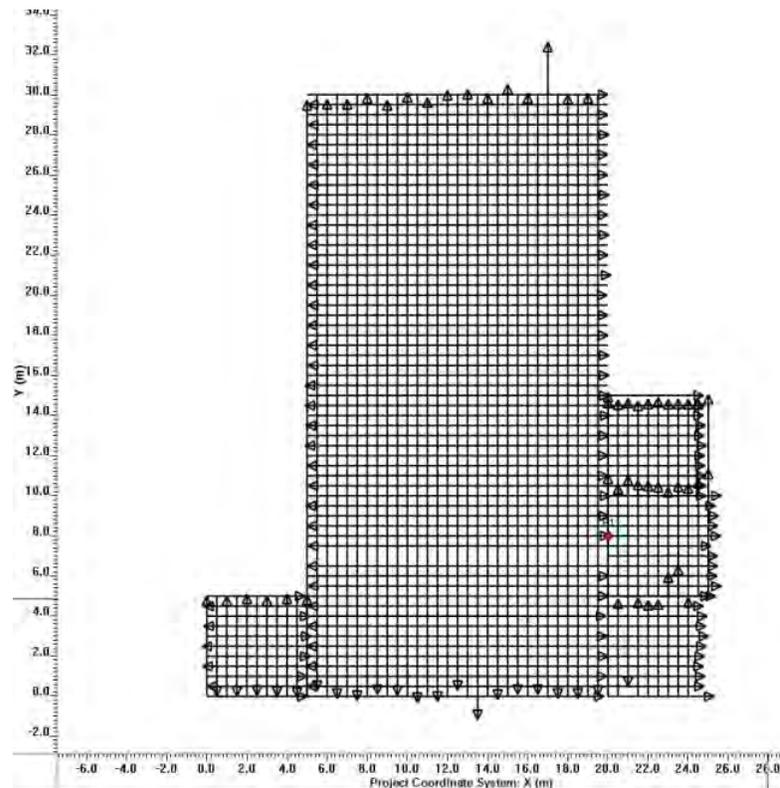
Merging grids in GFP_Edit requires the grid lines for all grids to be parallel or orthogonal (90 degrees) to one another. You cannot merge grids if grid lines are oriented at other angles, for example, 45 degrees.

As well, all the grids being merged together must have consistent settings such as antenna frequency, temporal sampling interval, antenna separation, etc. If any key settings differ between grids, they cannot be merged together. In this case where there are differences, it is better to plot the grids separately as shown in the sections above.

The GFP_Edit program does NOT read project (.gpz) files so, to use GFP_Edit to work with grids inside a project file, all the grid lines must first be exported into "Line Data" format (see [Line Data](#)).

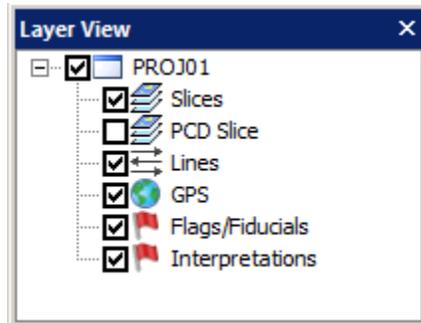
Once grid editing and/or merging are complete in GFP_Edit, open the new grid in EKKO_Project by importing the new grid (.gfp) file ([Add a Grid](#)).

To learn more, see the GFP_Edit User's Guide.



3.6 Layer View

The Layer View window allows the user to specify which items to display in MapView and Line Preview windows.



All instances of unchecked items are removed from MapView and Line Preview; it is not possible to specify particular items to remove, for example, GPS for a single line.

Layer	Description
Slice	Plot depth slices in the MapView window. Depth slices generated with the optional SliceView module or, for some GPR systems, in the field with the data acquisition program. For example the LMX200 generates depth slices in the field. For Conquest users, the PDC image is always plotted on top of depth slices so ensure it is not selected when viewing depth slices.
PCD Slice	Plot Power Cable Detector (PCD) image in the MapView window. Only available for grid data collected with a Conquest GPR system. The PDC image is always plotted on top of depth slices so ensure it is not selected when viewing depth slices.
Lines	Plot GPR grid lines in the MapView window. Grid lines plot on top of depth slices so turning the grid lines off makes the depth slices more visible.
GPS	GPS paths for lines and grids collected with a GPS in the MapView window.
Flags/Fiducials	Markers added to GPR lines in the field during data collection. When selected, Flags/Fiducials are displayed in both the Line Preview and MapView windows. Flags/Fiducials are indicated by a red diamond icon and a label such as F1, F2 etc. Flags/Fiducials can be repositioned and the labels edited (see Right Click Menu).

Interpretations

Interpretations added to GPR lines in the project using the optional Interpretation module in LineView.

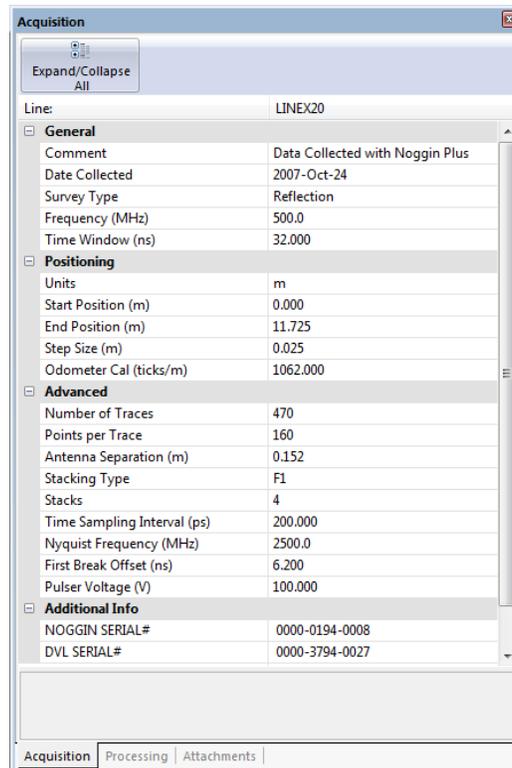
Interpretations are points of interest (points, polylines, boxes, and annotations) added to GPR lines.

Some GPR systems such as the LMX200 have the capability of adding point interpretations in the field. These are just like the interpretations added with the Interpretation module.

All interpretations are displayed in Line Preview but only point interpretations are displayed in MapView.

3.7 Properties Tabs

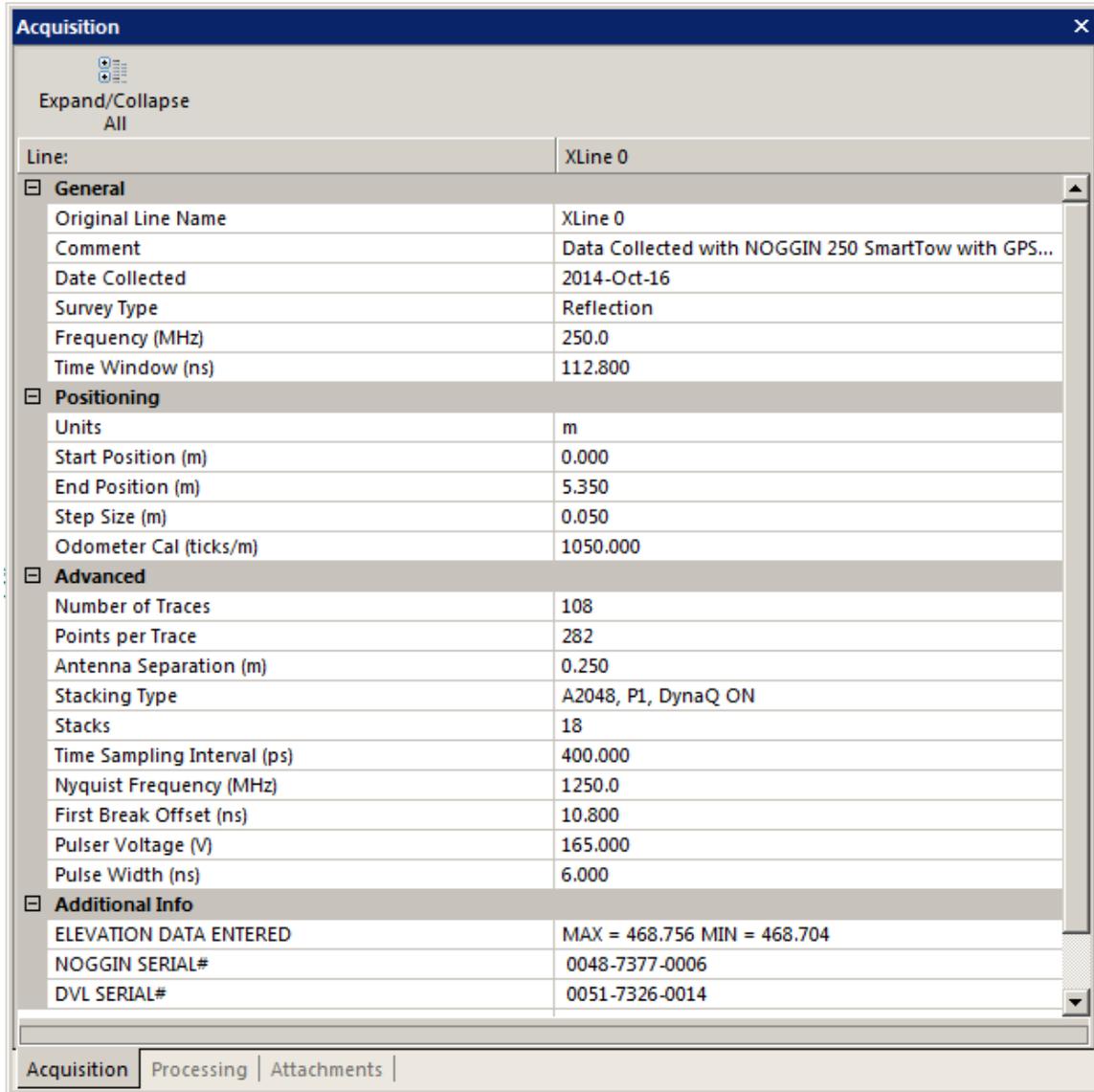
The Properties pane is a series of tabs that display information about the selected GPR line. The Properties pane can usually be found on the right side of the EKKO_Project screen; the tabs are displayed at the bottom of the pane.



3.7.1 Acquisition Tab

The Acquisition tab displays information about how the GPR line was acquired. It lists the survey parameters under four headings: General, Positioning, Advanced, and Additional Info. You may need to click the plus (+) sign to view the details under a heading.

To quickly open or close all the headings, click



Use the following tables to guide you through working with the Acquisition tab.

The **General** pane displays the following basic survey parameters:

Field	Description
Original Line Name	The name of the GPR line when first opened in EKKO_Project.
Comment	Comment about the system used to acquire the data.
Date Collected	The collection date.
Survey Type	GPR survey type: reflection, CMP/WARR, or transillumination.
Frequency (MHz)	The antenna center frequency
Time Window (ns)	The length of the time window in nanoseconds (ns).

The **Positioning** pane displays the following parameters related to the positioning of the GPR line:

Field	Description
Units	Meters or feet
Start Position	The initial position of the GPR system along the line, generally will be zero, but could be different if an offset was used, or if the line was collected as part of a forward/reverse grid.
End Position	The ending position of the GPR system along the line
Step Size	The distance interval along the surface between GPR data traces
Odometer Cal.	The calibration value of the odometer wheel (if applicable)

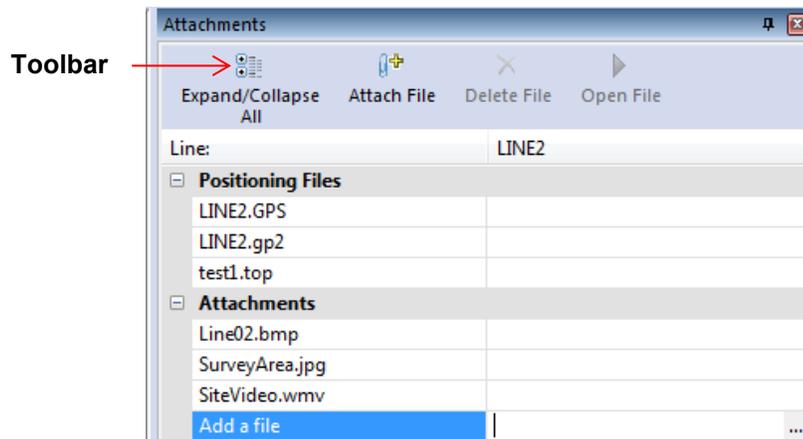
The **Advanced** pane displays the following advanced survey parameters:

Field	Description
Number of Traces	Total number of traces
Points per Trace	The number of sample points per trace
Antenna Separation	Spacing between transmitting and receiving antennas
Stacking Type	<ul style="list-style-type: none"> • DynaQ ON: indicates automatic stacking • P: number of point stacks • S: number of trace stacks • A: maximum number of stacks
Stacks	Number of repeated measurements averaged to get resulting measurements
Time Sample Interval (ps)	The time period in picoseconds at which the GPR signal is sampled. Often set automatically by the system based on GPR frequency.
First Break Offset (ns)	The number of nanoseconds from the start of the trace to the first break
Transmitter Voltage	The voltage of the transmitter
Pulse Width (ns)	The width of the GPR pulse in nanoseconds. Varies with antenna center frequency.
GPS Latency (s)	The GPS latency in seconds (only listed if a non-zero value applied)
GPS X Offset	X direction offset between GPR and GPS (only listed if non-zero value applied)
GPS Y Offset	Y direction offset between GPR and GPS (only listed if non-zero value applied)
GPS Z Offset	Z direction offset between GPR and GPS (only listed if non-zero value applied)

The **Additional Information** pane may include the serial numbers of the GPR system and the Digital Video Logger (DVL), as well as any processing done prior to importing the data.

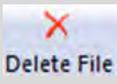
3.7.2 Attachments Tab

The Attachment tab lists all files attached to the current GPR line, project, grid, or lineset such as GPS files, topography files, photos of the line location, documents, videos of the area, or voice recordings of information relevant to the GPR line.



3.7.2.1 Attachments Toolbar

Use the following table as a guide to working with the Attachments pane toolbar:

Item	Description
	Click to display or hide the list of attached files.
	This feature enables you to attach a file to the GPR line. <ol style="list-style-type: none"> 1 Click Attach File. 2 In the Attach File(s) dialog box, navigate to and select the file you want to attach. 3 Click Open.
	<ol style="list-style-type: none"> 1 In the Attachments tab, select the item you want to delete. 2 Click Delete File. 3 In the message box, click Yes. <p>Note: Positioning files (GPS, Topography) cannot be deleted.</p>
	<ol style="list-style-type: none"> 1 In the Attachments tab, select the item you want to open. 2 Click Open. <p>Note: if there is no application associated with the selected file type, Windows will prompt you to select one from a list.</p>

3.7.2.2 Positioning Files

GPS and Topography files are special files called “Positioning Files”; they are always listed first in the Attachments list. When attached, either automatically or manually, they cannot be deleted, only replaced by another GPS or topography file.

If another GPS or topography file is attached, the user is prompted whether or not to replace the current file. If they answer “Yes”, the new file is added to the list and the old GPS or topography file is appended with the extension .BAK and kept as an attachment for record-keeping but is not used for positioning.

GPS and topography files both contain elevation information but the topography file takes precedence. Therefore, if both a GPS and topography file are attached, the topography file elevations are used when plotting the data.

The GPS and topography file names must always match the name of the GPR line. If a GPS or topography file with a different name is manually attached to a GPR line, the name is changed to match the name of the GPR line. Further, these attached files will be automatically renamed when the GPR line name is changed. Other attachments do not follow this requirement.

3.7.2.2.1 GPS Files

Attaching a GPS file adds Latitude, Longitude, UTM coordinates, and GPS elevation to every trace in the GPR line.

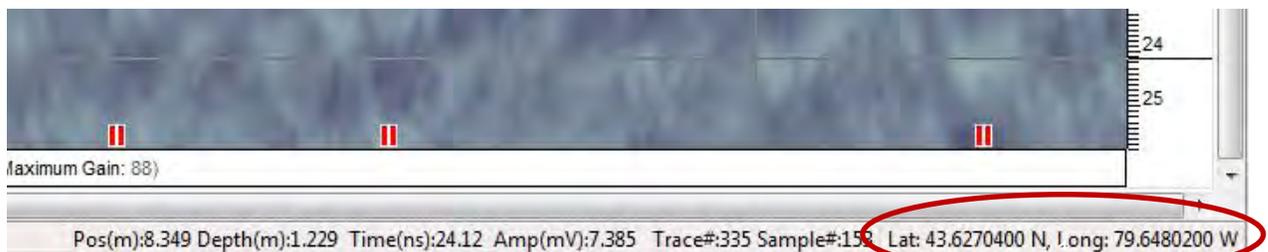
A GPS file is created by attaching a GPS system to the GPR system during data collection. GPS files contain lines of standard GPS positional output text (called NMEA strings) and the associated GPR trace number. When the GPS (or GP2) file is attached to a GPR line, latitude, longitude, and GPS elevations for every GPR trace are calculated and saved into the GPR line.

Some later GPR systems also save GP2 files, which contain GPS data in a different format than the GPS file.

Note: EKKO_Project automatically creates a GP2 file if one doesn't already exist.

GPS and GP2 files formats are defined in [Appendix B – File Formats](#).

When GPS information is available, GPR lines plotted in LineView display the GPS position of the current mouse cursor location on the status bar along the bottom of the screen.



When a GPS file is created with the same name as a GPR line in the project folder, the GPS file is automatically attached to the GPR line. GPS files, even those with different

names, can also be attached manually. In this case the GPS file is copied, renamed to the same name as the GPR line and attached.

A GPR line with integrated GPS is indicated by a small letter “g” beside the GPR line name in [Project Explorer](#).

3.7.2.2.2 GPS Elevations

GPS data contains an elevation value that is integrated with the GPR line. However, be aware that if you are using a lower-end GPS system the elevation data may not be very accurate; plotting the GPR line with an elevation axis in LineView usually provides poor results with large vertical shifts in the data image. High-end GPS systems can provide accurate elevation values that work well when the GPR line is plotted with an elevation axis in LineView.

3.7.2.2.3 Topography Files

A topography file is a text file containing GPR line positions and the elevations at those positions. When a topography file is attached to a GPR line, elevations for every GPR trace are saved into the elevation field of the GPR trace header.

When elevation information is available, GPR lines can be plotted in LineView with an elevation axis. This type of display can be invaluable for understanding the proper spatial positioning of GPR reflections.

- Each line of text must contain a pair of numbers representing position and elevation.

Topography file example:

0.0	935.8
10.1	933.9
22.7	930.3
30.5	932.7
34.6	936.5

The Topography file format is defined in [Appendix B – File Formats](#).

Note: Topographic files (.top) are stored in the same units that the data was collected in (meters or feet); however, the file could be viewed in a different unit. The units used during collection are displayed in the [Acquisition tab Positioning Pane](#).

When a topography (.top) file is available with the same name as a GPR line in the folder, it is automatically attached to the GPR line. Topography files, even those with different names, can also be attached manually. In this case the topography file is copied, renamed to the same name as the GPR line and attached.

A GPR line with integrated topography is indicated by a small letter “t” beside the GPR line name in [Project Explorer](#).

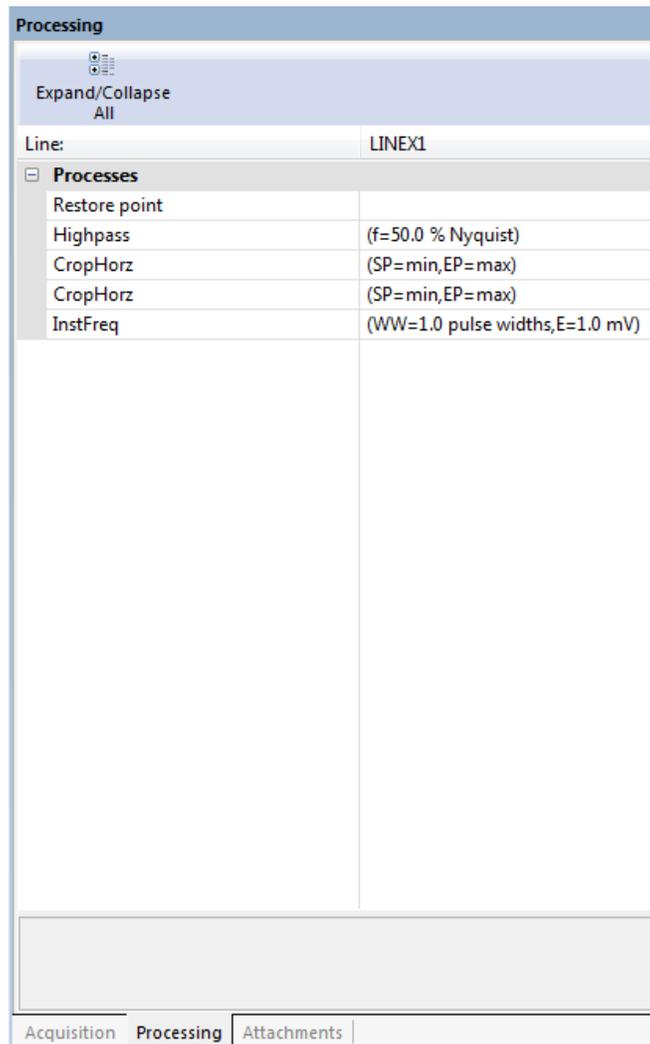
If a topography file is attached *after* a GPS file is attached, the user is prompted to confirm whether or not they would like to replace the GPS elevations with the elevations from the topography file. If the answer is “Yes”, the topography file is attached. If the

answer is “No”, the topography file is not attached. In other words, if a Topography file has been attached, it is used for elevations.

3.7.3 Processing Tab

If GPR lines have been processed using the optional [Processing](#) module, the processing details, including the name of the processes, the order the processes were applied, and the details of the process parameters are listed in the Processes tab.

Only processed GPR lines are identified by a small letter “p” in the Project Explorer will list processing information in the Processes tab. However, GPR Lines that have been processed and then copied into a lineset will be listed but will not be identified by the letter “p.” To learn more, see [Processing Functions](#).



The screenshot shows the 'Processing' tab in the software interface. The tab is titled 'Processing' and has a sub-header 'Expand/Collapse All'. Below this, the 'Line:' is identified as 'LINEX1'. The 'Processes' section is expanded, showing a table of processing parameters:

Processes	
Restore point	
Highpass	(f=50.0 % Nyquist)
CropHorz	(SP= min,EP= max)
CropHorz	(SP= min,EP= max)
InstFreq	(WW=1.0 pulse widths,E=1.0 mV)

At the bottom of the interface, there are three tabs: 'Acquisition', 'Processing' (which is selected), and 'Attachments'.

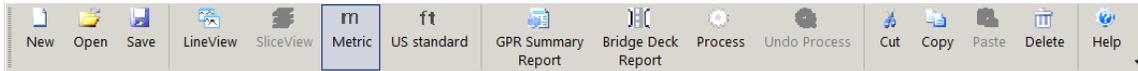
Note: Distance units (m/ft.) listed in the processes tab are always displayed in the format the GPR line was collected in, even if the [Units](#) have been changed in EKKO_Project.

3.8 Toolbars

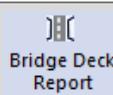
To manage how toolbars are displayed in EKKO_Project, in the menu bar, click the [View](#) Menu.

3.8.1 Standard Toolbar

The EKKO_Project Standard toolbar displays icons or text that represents features that allow you to work with GPR data.



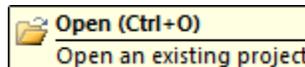
Use the following table as guide to working with the Standard Toolbar:

Field	Description
New	Click  New to create a New project.
Open	Click  Open to Open an existing project.
Save	Click  Save to Save the current project
LineView	Select an item(s) in Project Explorer and then click  LineView to display the items in LineView .
SliceView	Select a grid in Project Explorer and then click  SliceView to display the grid as depth slices in SliceView .
Metric	Click  Metric to change units to Metric.
US Standard	Click  US standard to change units to US Standard (feet).
GPR Summary Report	Click  GPR Summary Report to generate a GPR Summary Report .
Bridge Deck Report	Click  Bridge Deck Report to generate a Bridge Deck Condition Report .
Pavement Report	Click  Pavement Report to generate a Pavement Structure Report .
Process	Click  Process to open the Processing dialog box
Undo Process	Click  Undo Process to Undo Processing applied to checked GPR lines.

Field	Description
Cut	 <p>Click Cut to Cut the selected or checked item(s) and place them on the clipboard.</p> <p>This enables you to remove a GPR line from a lineset and paste it into a different lineset.</p> <p>Note: a GPR line cannot be cut from a grid.</p>
Copy	 <p>Click Copy to Copy the selected or checked GPR line(s), lineset, or grid, and place them on the clipboard.</p>
Paste	 <p>Click Paste to Paste the cut or copied GPR line(s), lineset, or grid from the clipboard into the project.</p>
Delete	 <p>Click Delete to Delete the selected GPR line, lineset, or grid from the project.</p>
Help	 <p>Click Help to display the this manual.</p>
Add or Remove Buttons	<p>Click the drop-down arrow beside the Help icon to add or remove buttons from the Standard toolbar.</p> <p>To learn more, see Add or Remove Buttons.</p>

To display a brief description of the icon's function, hold your mouse cursor over the icon on the toolbar.

If a keyboard shortcut is associated with the toolbar item, it is displayed with the tool tip



A description also appears on the Status Bar at the bottom of the screen:

Open an existing project

3.8.2 View Control Toolbar

The EKKO_Project **View Control** toolbar allows you to manage how to display images in [MapView](#) and [Line Preview](#).



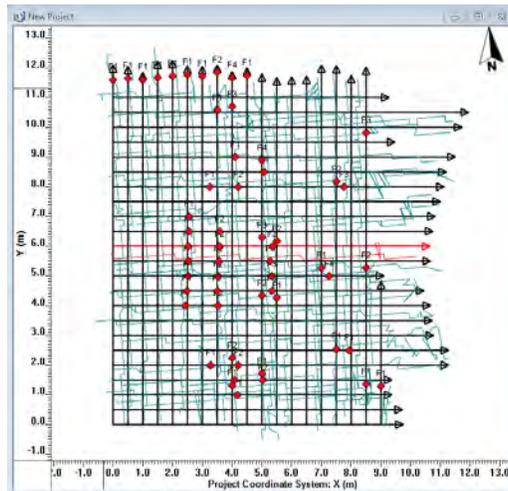
Use the following table as a guide to working with the View Control toolbar:

Field	Description
Scale Lines	 <p>Click Scale Lines to show or hide Scale Lines in MapView. Not available for Line Preview.</p>
Zoom Out	 <p>Click Zoom Out to display more of the MapView image. For Line Preview, Zoom out shows more horizontal data in the window. To learn more, see Zoom Out.</p>
Zoom In	 <p>Click Zoom In to magnify the MapView image. For Line Preview, Zoom in shows less horizontal data in the window. To learn more, see Zoom In.</p>
Zoom Window	 <p>Click Zoom Window to magnify a selected area within MapView or Line Preview. To learn more, see Zoom Window.</p>
Fit to Window	 <p>Click Fit to Window to automatically zoom to fit all data in the MapView or Line Preview windows. To learn more, click Fit to Window.</p>
Pan View	 <p>Click Pan View to pan the Display area (drag and drop) in MapView. Not available for Line Preview. To learn more, see Pan View.</p>
Measure	 <p>Click Measure to measure distance in the MapView window Not available for Line Preview. To learn more, click Measure.</p>
Copy View	 <p>Click Copy View to copy the active view to clipboard To learn more, click Copy View.</p>
Export View	 <p>Click Export View to export the active view as a graphics image file (jpg, bmp, png etc.) To learn more, see Export View to File.</p>

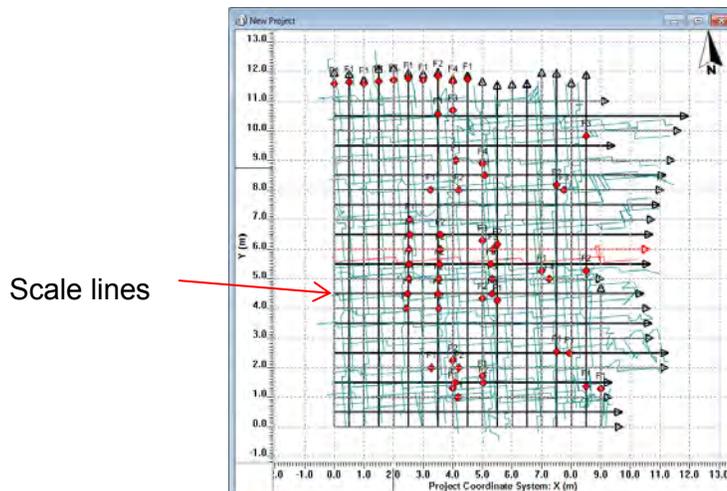
Field	Description
<p>Save View</p>	 <p>Click Save View to save the Active Window as an image file and attach it to the project file. When the GPR Summary Report is selected, the user can select from the images attached to project to appear in the report. To learn more, see GPR Summary Report.</p>
<p>Add or Remove Button</p>	<p>Click the drop-down arrow beside the Export View to File icon add or remove buttons from the View Control toolbar. To learn more, see Add or Remove Buttons.</p>

3.8.2.1 Scale Lines

Scale lines are dashed lines that correspond to the X and Y axes label increment. They can assist in determining an accurate XY position within the project data.



To display a axes scale lines in MapView, in the View Control toolbar, click **Scale Lines**.



3.8.2.2 Measure



To measure distance within the MapView, click **Measure**.

Click and drag the ruler icon () to span two points within the MapView that you want to measure.

The measured distance is displayed in the status bar:

Distance(m): 6.006 (6.006,0.018)

The first value indicates the straight line distance between the two points. The values displayed in brackets represent the distance along the X-axis and Y-axis respectively.

3.8.2.3 Copy View



To copy the MapView image to the clipboard, click **Copy View**.

This feature enables you to copy and paste the image to a document or image editor.

3.8.2.4 Export View to File



1. To export the MapView image to a file, click **Export View to File**.
2. In the **Save As** dialog box, navigate to, and select the folder you want to save this image in.
3. Use the **Save as Type** dropdown to select the file format (jpg, bmp, gif, png or tiff)
4. Click **Save**.

3.8.2.5 Save View

To save the active window (Line Preview or SliceView window) as an image file and



attach it to the project file, click **Save View**.

The Save View button opens a dialog for naming the image. The default name is based on what window is being saved (Line Preview, MapView, LineView or SliceView).

For MapView images, the default image name will include:

- the depth of the slice being shown, if Slices are turned on.
- PCD, if PCD is turned on.

When the [GPR Summary Report](#) is selected, the user can select from the images attached to project to appear in the report.

To see a list of the images currently saved and available for the GPR Summary Report, select the project item in [Project Explorer](#) and then open the [Attachments Tab](#).

3.9 Menu Bar

The EKKO_Project menu bar displays a number of options that allow you to create, save, manipulate, and export GPR data.

File Edit View Tools Window Help

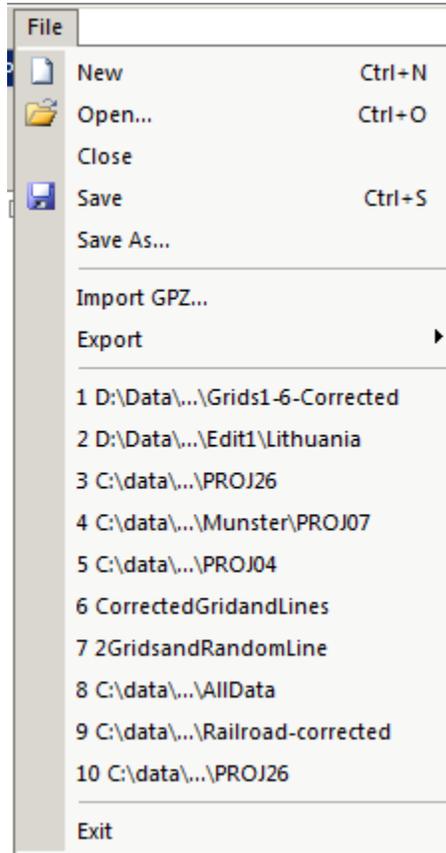
Use the following table as a guide to working with the EKKO_Project menu bar:

Field	Description
File	Create a New project, or Open, Close, Save, Report, Export, or Exit existing projects. To learn more, see the File menu.
Edit	Update your project - add lines, linesets, or grids, rename files, or attach files. To learn more, see the Edit menu.
View	Display units in meters or feet, view data in Average Amplitude Spectrum, Average Trace Amplitude, or Trace Plot graphs, or define how the toolbars are displayed. To learn more, see the View menu.
Tools	Access LineView, SliceView (optional), modify Project or Grid Position Relationships, Processing (optional) and GPS routines. To learn more, see the Tools menu.
Window	To open the Line Preview or MapView windows or tile the Line Preview and MapView windows horizontally or vertically. To learn more, see the Window menu.
Help	Display information about EKKO_Project, a PDF version of this manual, the About dialog, and the EKKO_Project Registration. See Help .

3.10 File Menu

Use the File menu to create a [New](#) project, [Open](#), or [Save](#) files, create [Reports](#), [Export](#) lines, or **Exit** the EKKO_Project.

To open the file menu drop-down list, click **File**:



The following sections describe the File menu features:

3.10.1 New

1. To create a new project file, In the EKKO_Project menu bar, click **File > New**.



Alternatively, in the [Standard Toolbar](#), click **New**.

2. In the **Getting Started** dialog box (**Figure 1**), in the **Create a New Project** pane select one of the three data type options to add GPR data to a new project file:

- [Add Grid](#)
- [Add all Lines in Folder](#)
- [Add Line\(s\)](#)

Note: Project files can contain multiple grids and linesets.

To learn how to add more data to the current project file, see the [Edit](#) menu.

3.10.2 Open

1. To open an existing project (.gpz) file in EKKO_Project, click **File > Open**.



Alternatively, in the [Standard Toolbar](#), click **Open**.

2. In the **Open** dialog ([Figure 2](#)), navigate to and then select the project you want to open.
3. Click **Open**.

3.10.3 Close

1. To close the current project click **File > Close**
2. In the message box, to close the project and save your changes, click **Yes**.

To close the project without saving your changes, click **No**.

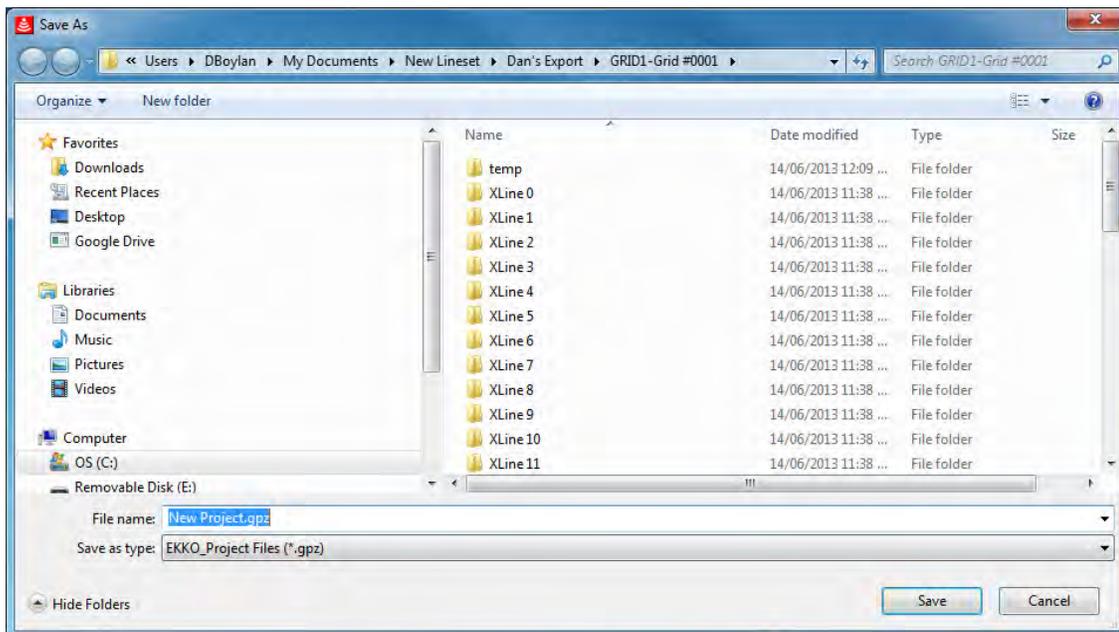


Figure 6: Save As dialog box

3. In the **Save As** dialog box, navigate to the folder you want to save the project to.
4. Click **Save**.

3.10.4 Save

1. To save the current project to a .gpz file, click **File > Save**.



Alternatively, in the [Standard Toolbar](#), click **Save**.

2. In the **Save As** dialog box, navigate to the folder you want to save the project to.
3. Click **Save**.

When a new project is saved, the .dt1, .hd, and all other ancillary files such as GPS and topographic files are saved to a compressed .gpz project file.

3.10.5 Save As

1. To save the current project to a different folder and/or name, click **File > Save As**.

2. In the **Save As** dialog box, navigate to the folder you want to the project to.
To save the project with a different file name, in the **File name** field enter the new project name.
3. Click **Save**.

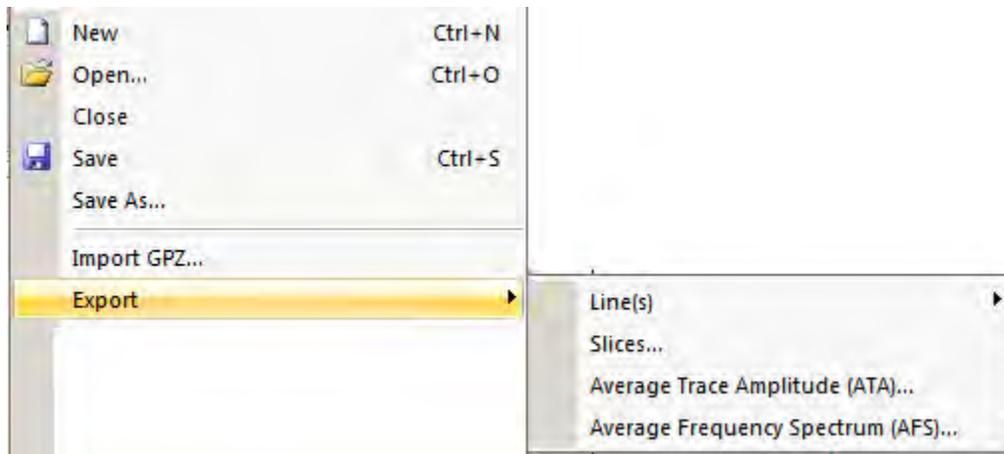
3.10.6 Import GPZ

1. To merge the data from an existing project (GPZ) file with the current project in EKKO_Project (if a project file is already open), click **File > Import GPZ**.
2. In the **Open** dialog ([Figure 2](#)), navigate to and then select one or more projects (GPZ files) you want to import and merge into the current project.
3. Click **Open**.
4. Data folders and grids in the imported project files are added to the current project file.
5. **Note that no interpretations are imported from the project file into the current project.** It is best to import and merge all the project files before adding interpretations or processing data.

3.10.7 Export

Select **Export** to extract data files from a project and save them as GPR [Line\(s\)](#), [Slices](#), [Average Trace Amplitude](#) (ATA) plots, or [Average Frequency Spectrum](#) (AFS) plots.

1. To export data files, click **Export**.

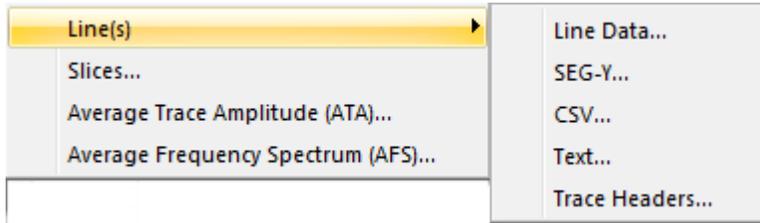


2. In the drop-down list, click the format you want to save the file as.

3.10.7.1 Lines

Select **Line(s)** to extract data from a project file and save them to a separate folder as Line Data, CSV, or Text.

1. Click the **Line(s)** drop-down list to select the format you want to export line data to:



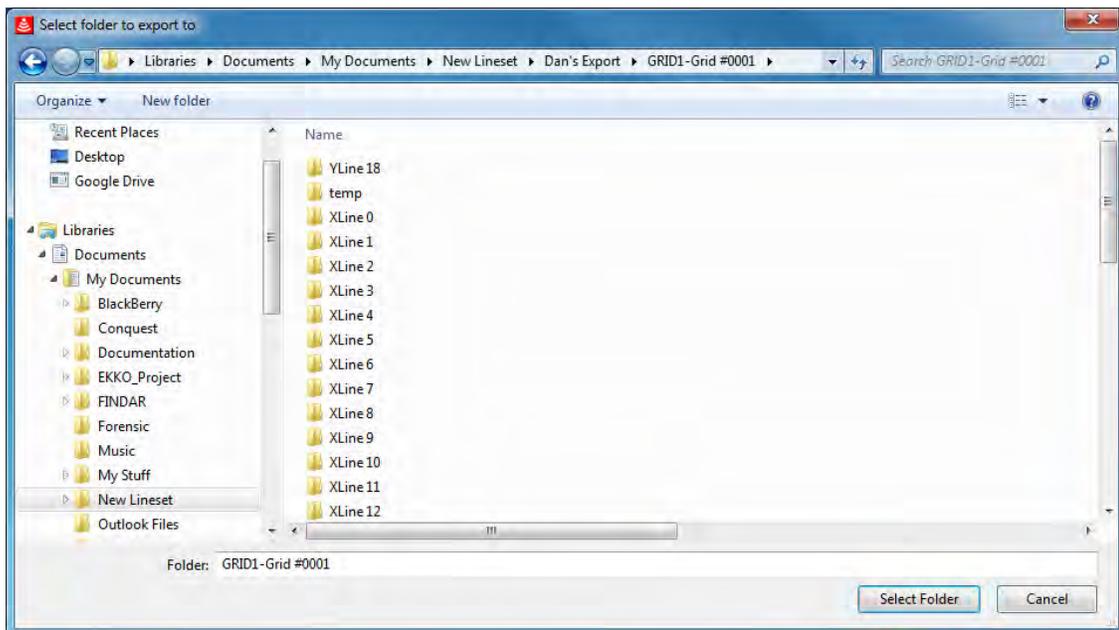
2. In the drop-down list, click the format you want to save the file in:

- Line Data
- SEG-Y
- CSV
- Text
- Trace Headers

3.10.7.1.1 Line Data

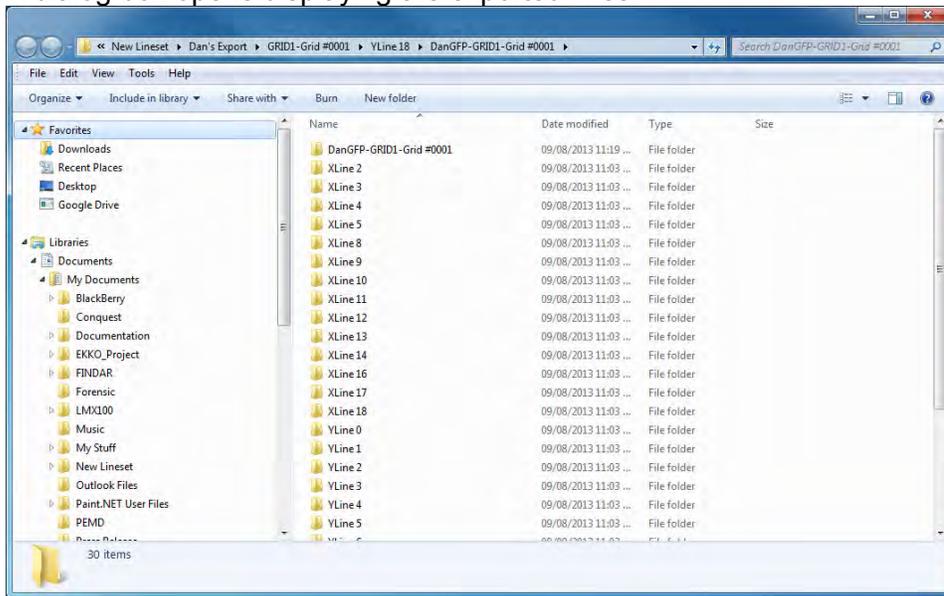
Select **Line Data** to export selected GPR lines (.dt1 or .hd) and any files attached to that data (such as GPS, topography, photos, etc.).

1. To export GPR lines from the project (.gpz) file to a different folder location click **File > Export > Line(s) >Line Data**.



2. In the **Select folder to export** to dialog box, navigate to and then select the folder you want to export the files to.
3. Click **Select Folder**.

A dialog box opens displaying the exported lines.



Note: Interpretations are not saved when GPR lines are exported.

3.10.7.1.2 SEG-Y

Select **SEG-Y** to export GPR lines to a SEG-Y, a format commonly used for seismic data. Selected GPR lines are converted to a file with the same name as the original file(s) appended with a .sgy extension,

1. Click **File > Export > Line(s) > SEG-Y**.
2. In the **Select folder to export to** dialog box, navigate to and select the folder you want to export the file to.
3. Click **Select Folder**.

A dialog box opens to display the folder that the .sgy lines were saved to.

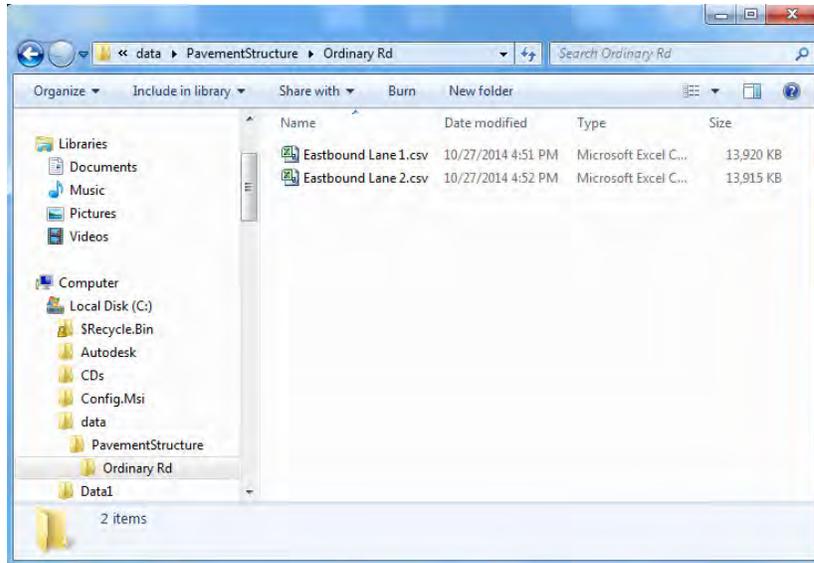
The SEG-Y format is defined in [Appendix B – File Formats](#).

3.10.7.1.3 CSV

Select **CSV** to export GPR lines to a comma separated value (CSV) file. This feature converts selected GPR lines to a single file with the same name as the original file(s) appended with a .csv extension,

4. Click **File > Export > Line(s) > CSV**.
5. In the **Select folder to export to** dialog box, navigate to and select the folder you want to export the file to.
6. Click **Select Folder**.

A dialog box opens to display the folder that the .csv lines were saved to.



- To open a .csv file, navigate to the folder you saved the lines in and then click the .csv file.

The CSV files can be read by spreadsheet software such as Microsoft Excel and GIS packages.

The new file lists the data in a table that displays point amplitudes from each trace in separate columns with trace numbers and position values at the top of each column and point numbers and time values at the beginning of each row.

	TRACE	1	2	3	4	5	6	7	8	9	10
	Position (m)	1	1.05	1.1	1.15	1.2	1.25	1.3	1.35	1.4	1.45
Point	Time (ns)										
1	-11.2179	-63	-39	-67	-59	-35	-64	-67	-70	-64	-70
2	-10.4167	-58	-63	-63	-63	-43	-71	-75	-79	-68	-76
3	-9.61538	-66	-67	-59	-54	-55	-75	-82	-64	-87	-79
4	-8.8141	-54	-67	-63	-63	-62	-71	-84	-51	-76	-52
5	-8.01282	-68	-76	-59	-62	-82	-71	-62	-79	-68	-72
6	-7.21154	-48	-68	-78	-80	-79	-85	-88	-79	-90	-75
7	-6.41026	-58	-71	-92	-88	-72	-89	-94	-74	-81	-60
8	-5.60897	-72	-72	-86	-90	-63	-74	-67	-79	-84	-79
9	-4.80769	-87	-95	-82	-86	-67	-79	-94	-81	-108	-81
10	-4.00641	-80	-89	-89	-90	-90	-104	-106	-74	-84	-89
11	-3.20513	-95	-67	-74	-85	-100	-103	-80	-96	-114	-87
12	-2.40385	-84	-78	-92	-95	-62	-71	-100	-95	-92	-94
13	-1.60256	-79	-64	-79	-79	-79	-90	-74	-87	-98	-95
14	-0.801282	-96	-78	-80	-71	-68	-67	-85	-96	-72	-81
15	0	-72	-85	-88	-81	-75	-85	-84	-72	-78	-76
16	0.801282	-95	-64	-89	-104	-89	-82	-93	-105	-86	-105
17	1.60256	-168	-162	-177	-181	-170	-170	-174	-190	-134	-160
18	2.40385	-319	-188	-257	-296	-390	-259	-372	-334	-254	-225
19	3.20513	-550	-654	-595	-531	-765	-582	-750	-606	-602	-591
20	4.00641	-977	-1039	-633	-829	-1041	-1116	-1139	-964	-962	-781
21	4.80769	-95	247	-633	-488	1336	413	-1095	-809	-390	-592
22	5.60897	3171	5875	5931	2228	6845	3724	3889	4820	5397	4700
23	6.41026	14598	18501	16181	13723	16706	16393	16985	16911	14282	15368
24	7.21154	28652	28583	28015	28171	30727	27429	28763	28139	28666	24952
25	8.01282	32527	32556	32752	32752	32752	32387	32561	32535	32752	32505
26	8.8141	32752	32752	32752	32752	32752	32752	32752	32752	32752	32752
27	9.61538	32752	32752	32752	32752	32752	32752	32752	32752	32752	32752
28	10.4167	32752	32752	32752	32752	32752	32752	32752	32752	32752	32752
29	11.2179	32752	32752	32752	32752	32752	32752	32752	32752	32752	32752
30	12.0192	32752	32572	32603	32752	32573	32752	32094	32752	32752	32752
31	12.8205	31422	32285	31184	31625	29620	32012	30352	32440	31116	32359
32	13.6218	25666	17666	13981	22071	15361	15412	21748	24947	17647	26989
33	14.4231	592	-20493	-15565	-4700	-9915	-11535	-3172	-11154	-10237	-2856

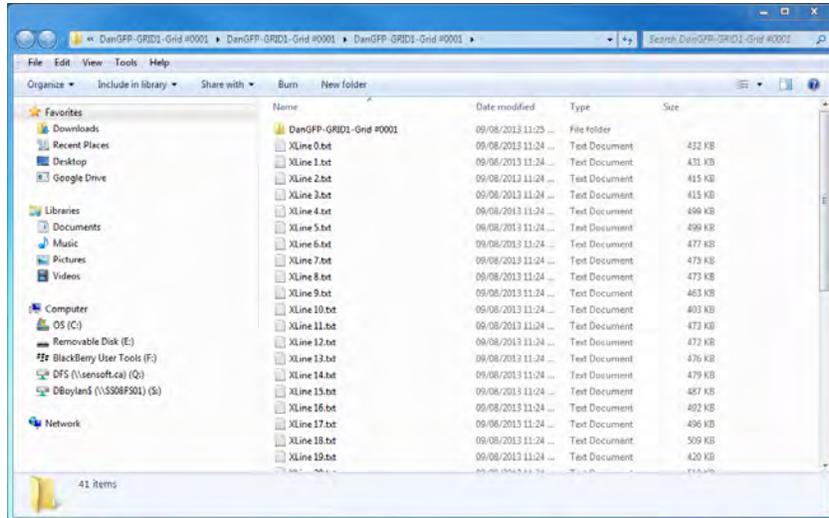
Amplitude values are expressed as 2-byte integers ranging from -32767 to +32767 and can be converted to millivolts by multiplying by $50/32767 = 0.0015259$.

3.10.7.1.4 Text

Select **Text** to export GPR lines to a text file. This feature converts GPR lines to a single text file with the same name as the original file(s) appended with a .txt extension.

1. Click **File > Export > Line(s) > Text**
2. In the **Select folder to export to** dialog box, navigate to and select the folder you want to export the file to.
3. Click **Select Folder**.

A dialog box opens to display the folder that the .txt lines were saved to.



4. To open a .txt file, navigate to the folder you saved the lines in and then click the .txt file.

This format can be read by spreadsheet software, Microsoft Notepad, and WordPad. The text file lists data in a table that displays point amplitudes from each trace in separate columns with position values at the top of each column and time values at the beginning of each row.

	-999	0.000	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500
-6.00	-66	-58	-55	-55	-58	-58	-55	-55	-55	-55	-55	-58
-5.60	-67	-59	-62	-62	-59	-55	-59	-59	-59	-63	-59	-55
-5.20	-79	-62	-59	-59	-63	-63	-59	-58	-63	-63	-63	-59
-4.80	-74	-59	-55	-63	-58	-59	-59	-59	-55	-62	-62	-59
-4.40	-74	-55	-55	-55	-54	-55	-55	-55	-55	-55	-55	-54
-4.00	-46	-55	-51	-55	-55	-51	-51	-54	-50	-54	-58	-58
-3.60	-62	-58	-55	-55	-51	-55	-55	-51	-59	-58	-58	-58
-3.20	-55	-59	-58	-58	-63	-55	-62	-59	-55	-55	-58	-58
-2.80	-79	-63	-63	-55	-59	-63	-59	-59	-59	-58	-59	-63
-2.40	-59	-62	-59	-58	-59	-63	-62	-59	-59	-59	-62	-63
-2.00	-63	-59	-59	-59	-59	-58	-54	-63	-62	-59	-59	-59
-1.60	-54	-59	-59	-63	-55	-58	-58	-55	-59	-59	-55	-55
-1.20	-51	-59	-59	-62	-63	-58	-59	-38	-59	-63	-59	-59
-0.80	-63	-59	-59	-62	-59	-59	-59	-59	-55	-63	-59	-59
-0.40	-50	-50	-43	-43	-43	-47	-42	-37	-39	-47	-47	-47
0.00	103	81	88	92	88	95	88	92	95	85	86	86
0.40	1297	924	919	936	957	962	983	924	947	977	949	949
0.80	2930	2925	2996	2981	3040	2987	3016	3007	3143	3054	3032	3032
1.20	6403	5963	5941	6171	6012	6089	6139	6143	6101	6282	6110	6110
1.60	11010	10621	10735	10801	10847	10908	10991	11032	11054	11064	11171	11171
2.00	13821	13680	13728	13805	13925	14067	14182	14230	14207	14194	14082	14082
2.40	9461	9567	9622	9763	9789	9769	10223	10136	9657	9888	9514	9514
2.80	-1049	-646	-631	-375	-381	-509	12	-159	-737	-528	-1041	-1041
3.20	-11975	-11743	-11597	-11441	-11389	-11389	-11300	-11456	-11995	-11679	-12070	-12070
3.60	-18546	-18382	-18097	-18019	-18034	-18087	-18062	-18177	-18515	-18423	-18604	-18604
4.00	-20711	-19783	-21380	-21564	-21599	-21806	-21542	-21341	-21067	-20811	-20946	-20946
4.40	-10897	-8028	-11225	-11871	-11861	-11878	-11228	-10010	-9249	-9173	-8908	-8908
4.80	1954	3287	-582	-928	-1203	-847	261	1873	2826	3102	3662	3662
5.20	4421	4802	4534	4351	4148	4198	4886	5515	6001	6491	6653	6653
5.60	23	-519	3027	3671	3338	2754	1909	1433	995	865	806	806
6.00	-409	-587	2961	4116	4575	4169	2652	673	-791	-1628	-1595	-1595
6.40	3433	3683	4220	5010	5587	5731	4696	2703	1571	1690	2084	2084
6.80	5574	6318	4986	4927	4682	4655	4733	4947	5370	6081	6864	6864
7.20	7174	7257	5710	5070	4597	4258	5476	7618	8990	9536	10200	10200
7.60	7208	6608	5857	5593	5516	5487	6606	8041	9240	9608	9141	9141
8.00	4944	4515	5640	5711	5718	6035	6064	5929	6016	5543	3970	3970
8.40	3870	3032	4365	4357	4802	5295	4466	3140	2098	673	-1108	-1108
8.80	2184	1172	1402	1315	2339	2867	1925	167	-1791	-3340	-4292	-4292
9.20	-248	-1638	-2169	-2379	-1933	-1715	-2226	-3652	-5035	-5664	-5210	-5210
9.60	-3282	-4055	-4381	-5059	-5432	-5511	-4921	-4454	-4772	-4689	-3349	-3349
10.00	-2993	-3757	-3809	-4423	-5006	-4805	-3338	-1760	-1049	-660	103	103
10.40	-1648	-2068	-1908	-2283	-2774	-2292	-936	495	1576	2124	2099	2099
10.80	-407	-610	-331	-441	-721	-657	-316	555	1586	2098	1638	1638
11.20	206	42	422	509	426	-321	-1195	-821	280	847	551	551

The first value in this file is a placeholder and is always set to -999.

Amplitude values are expressed as 2-byte integers ranging from -32767 to +32767 and can be converted to millivolts by multiplying by $50/32767 = 0.0015259$.

3.10.7.1.5 Trace Headers

Every time a GPR data trace is collected, as well as saving the trace amplitude information, other parameters associated with that trace are saved to the “trace header” in the data file.

The trace header consists of 25 floating point numbers. Parameters such as the trace number, trace position, elevation data, Transmitter X, Y and Z positions, Receiver X, Y and Z positions, GPS X, Y and Z positions and the time of day in seconds past midnight when the trace data were collected, are saved to the trace header.

Exporting the trace headers allows the user to see the values of these parameters from every trace header in the GPR line.

Select **Trace Headers** to export the GPR tracer header information to a CSV. The selected GPR lines are converted to a file with the same name as the original file(s) appended with a .csv extension,

1. Click **File > Export > Line(s) > Trace Headers**.
2. In the **Select folder to export** to dialog box, navigate to and select the folder you want to export the file to.
3. Click **Select Folder**.

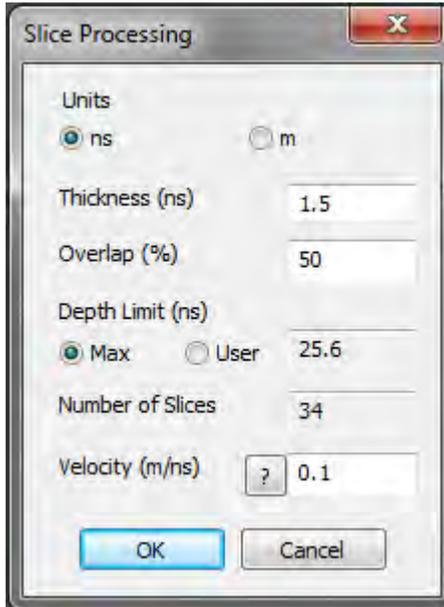
A dialog box opens to display the folder that the .csv lines were saved to. The CSV file format allows the trace header information to be exported to programs like Microsoft Excel.

Trace Number	Position	Number of points per trace	Elevation data	Total odometer ticks	# bytes/point	Time Window	# of stacks	GPS X Position	GPS Y Position	GPS Z Position	Receiver X Position	Receiver Y Position	Receiver Z Position	Transmitter X Position	Transmitter Y Position	Transmitter Z Position	Timezero adjustment	Zero Trace Flag	Time of Day	Comment flag
1	0	100	0	0	2	10	1	-79.734419	43.6333983	0	0	0	0	0	0	0	0	0x0	0	0
2	0.03	100	0	19	2	10	1	-79.7344193	43.6333982	0	0	0	0	0	0	0	0	0x0	0	0
3	0.06	100	0	38	2	10	1	-79.7344197	43.633398	0	0	0	0	0	0	0	0	0x0	0	0
4	0.09	100	0	57	2	10	1	-79.73442	43.6333979	0	0	0	0	0	0	0	0	0x0	0	0
5	0.12	100	0	76	2	10	1	-79.7344203	43.6333978	0	0	0	0	0	0	0	0	0x0	0	0
6	0.15	100	0	94	2	10	1	-79.7344206	43.6333976	0	0	0	0	0	0	0	0	0x0	0	0
7	0.18	100	0	113	2	10	1	-79.734421	43.6333975	0	0	0	0	0	0	0	0	0x0	0	0
8	0.21	100	0	132	2	10	1	-79.7344213	43.6333973	0	0	0	0	0	0	0	0	0x0	0	0
9	0.24	100	0	151	2	10	1	-79.7344216	43.6333972	0	0	0	0	0	0	0	0	0x0	0	0
10	0.27	100	0	170	2	10	1	-79.7344219	43.6333971	0	0	0	0	0	0	0	0	0x0	0	0
11	0.3	100	0	189	2	10	1	-79.7344223	43.6333969	0	0	0	0	0	0	0	0	0x0	0	0
12	0.33	100	0	208	2	10	1	-79.7344226	43.6333968	0	0	0	0	0	0	0	0	0x0	0	0
13	0.36	100	0	227	2	10	1	-79.7344229	43.6333966	0	0	0	0	0	0	0	0	0x0	0	0
14	0.39	100	0	246	2	10	1	-79.7344232	43.6333965	0	0	0	0	0	0	0	0	0x0	0	0
15	0.42	100	0	265	2	10	1	-79.7344236	43.6333964	0	0	0	0	0	0	0	0	0x0	0	0
16	0.45	100	0	283	2	10	1	-79.7344239	43.6333962	0	0	0	0	0	0	0	0	0x0	0	0
17	0.48	100	0	302	2	10	1	-79.7344242	43.6333961	0	0	0	0	0	0	0	0	0x0	0	0
18	0.51	100	0	321	2	10	1	-79.7344245	43.633396	0	0	0	0	0	0	0	0	0x0	0	0
19	0.54	100	0	340	2	10	1	-79.7344249	43.6333958	0	0	0	0	0	0	0	0	0x0	0	0
20	0.57	100	0	359	2	10	1	-79.7344252	43.6333957	0	0	0	0	0	0	0	0	0x0	0	0
21	0.6	100	0	378	2	10	1	-79.7344255	43.6333955	0	0	0	0	0	0	0	0	0x0	0	0
22	0.63	100	0	397	2	10	1	-79.7344258	43.6333954	0	0	0	0	0	0	0	0	0x0	0	0

3.10.7.2 Slices

Use the Slices feature to export Average Trace Amplitudes for one or more intervals from all the traces in the selected lines to a comma separated (.csv) file. Slices are compatible with 2D plotting software applications such as Golden Software's Surfer.

1. To export depth slice information from the project (gpz) file, click **File > Export > Slice**.



The **Slice Processing** dialog box is automatically populated with default data.

2. Use the following table as a guide to working with the Slice Processing dialog box:

Field	Description
Units	Select an option to generate slices based on time (ns) or depth (m or ft.).
Thickness	Enter the thickness for each slice, in terms of time (ns) or depth (m or ft.).
Overlap	Enter the overlap percentage between slices. Overlap represents the amount that each slice overlaps the previous slice as a percentage of the slice thickness.
Depth Limit Max/User	The maximum depth (or time) that slices will be generated: <ul style="list-style-type: none"> • Select Max to generate slices up to the maximum line depth • Select User to generate slices up to the user defined depth
Number of Slices	The number of slices in the slice export dialog is an estimate. For large antenna separations and low signal velocities the number of slices exported in depth mode may be fewer since the slicer uses individual depth for each line as shown in LineView depth axis at the selected velocity.

Field	Description
Velocity	Enter the signal velocity for generating depth slices. Click  to learn more about signal velocity

3. Click **OK**.
4. In the **Select folder to export to** dialog box, navigate to and then select the folder you want to save the slices to.
5. Click **Select Folder**.

Windows Explorer opens to display where you saved the slices.

6. Double-click a .csv file to display the results:

X(m)	Y(m)	Longitude	Latitude	GPS- Easting (Z=33U)	GPS- Northing (Z=33U)	Amplitude (mV)	Elevation(m)
0	0	178.0216	48.40248	575612.5	5361540	10.68167	182.21
0.02	0	178.0216	48.40248	575612.5	5361540	11.02386	182.22
0.04	0	178.0216	48.40248	575612.5	5361540	11.57758	182.23
0.06	0	178.0216	48.40248	575612.5	5361540	10.57218	182.24
0.08	0	178.0216	48.40248	575612.5	5361540	10.83922	182.25
0.1	0	178.0216	48.40248	575612.5	5361540	10.10773	182.26
0.12	0	178.0216	48.40248	575612.5	5361540	9.425069	182.27
0.14	0	178.0216	48.40248	575612.5	5361540	9.862819	182.28
0.16	0	178.0216	48.40248	575612.5	5361540	10.61968	182.29

3.10.7.3 Average Trace Amplitude

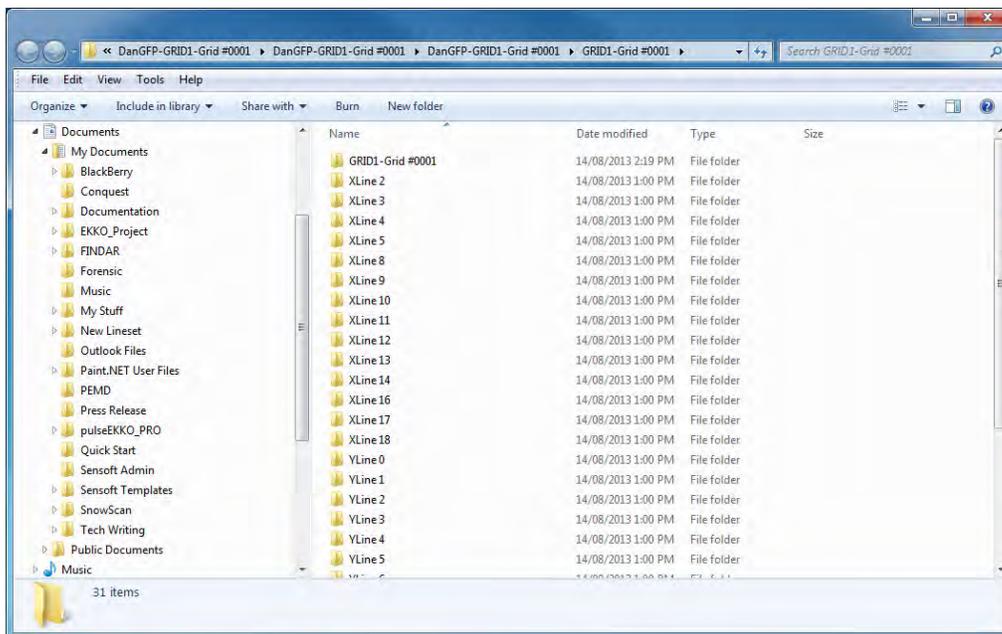
Select **Average Trace Amplitude (ATA)** plot to display the average rectified signal amplitudes (in microvolts) for one or more GPR lines. To learn more, see [Average Trace Amplitude Plot](#).

Use ATA to display how rapidly the signal amplitude decays into the background, giving you an idea of the maximum penetration of the GPR system.

The following procedure describes how to export the average rectified trace amplitudes for all the traces in the selected GPR line(s) to comma separated value (.csv) files:

1. Click **File > Export > Average Trace Amplitude (ATA)**.
2. In the **Select target folder for the ATA report** dialog box, navigate to and then select a target folder.
3. Click **Select Folder**

A dialog box opens to display the folder containing the reports in Windows Explorer.



3.10.7.4 Average Frequency Spectrum

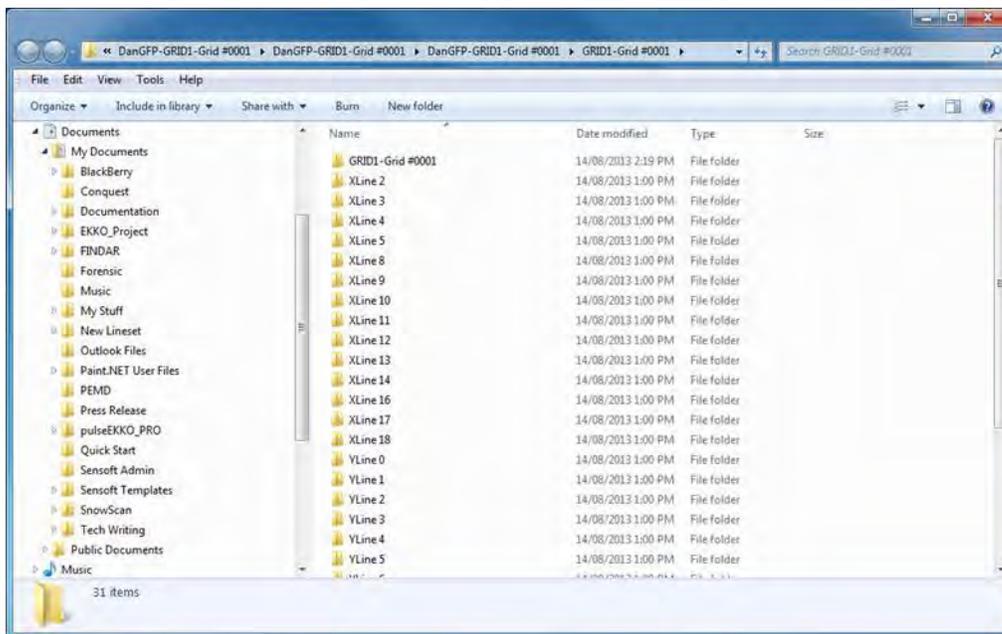
Select **Average Frequency Spectrum (AFS)** to display the average frequency spectrum of the selected GPR line(s). To learn more, see [Average Frequency Spectrum](#).

Use AFS to determine the frequency content of a GPR line in order to decide if filtering is required to remove unwanted frequencies such as high frequency noise. If required, lowpass, highpass or bandpass filtering can be applied (to learn more, see [Filtering](#)).

The following procedure describes how to export the average frequency spectrum for all the traces in the selected GPR line(s) to comma separated (.csv) files:

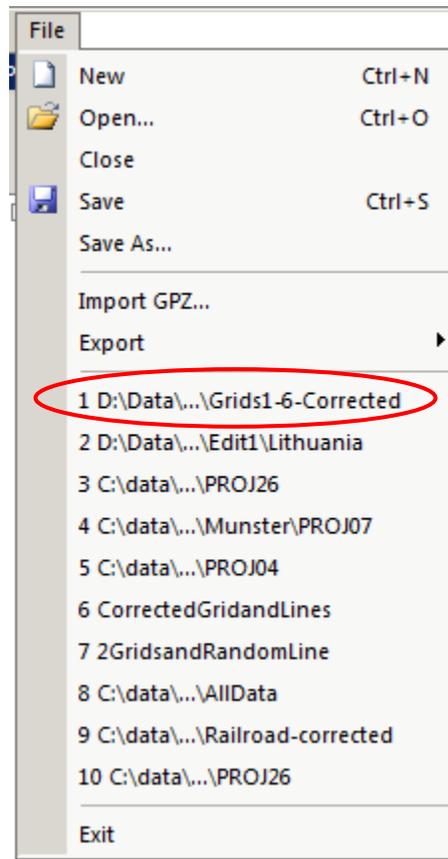
1. Click **File > Export > Average Frequency Spectrum (AFS)**.
2. In the **Select target folder for the AFS report** dialog box, navigate to and then select a target folder.
3. Click **Select Folder**

A dialog box opens to display the folder containing the reports in Windows Explorer.



3.10.8 Recent Files

1. To re-open a project (.gpz) file that you recently worked with, click **File**.



2. In the drop-down list, click one of the projects listed in the recent files area.

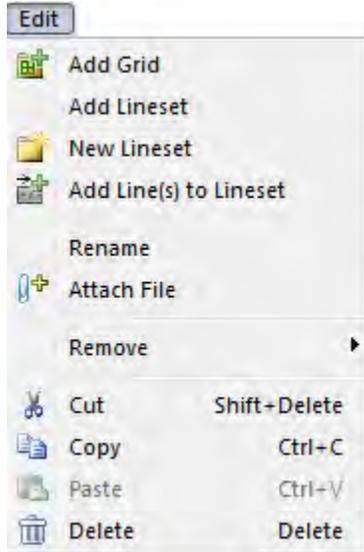
3.10.9 Exit

1. Click **File > Exit** to close all windows that are open as part of the current EKKO_Project session and exit the application.
2. In the message box, click **Yes** to save the project file.

3.11 Edit Menu

The EKKO_Project menu bar Edit menu contains many features that allow you to add and update GPR project files.

To open the edit menu drop-down list, click **Edit**:



The following sections describe the Edit menu features:

3.11.1 Add Grid

1. To add a grid to the current project file, click **Edit > Add Grid**.
2. In the **Open** dialog box, navigate to and then click the grid file you want to add.
3. Click **Open**.

The project file grid name defaults to the same name as the .gfp file.

3.11.2 Add Lineset

A Lineset represents a number of GPR lines grouped into a single folder. Select **Add Lineset** to create and then populate a lineset folder.

1. Click **Edit > Add Lineset**.
1. In the **Select folder to import Lines From** dialog box, navigate to and then select the folder you want to add.
2. Click **Select Folder**.

The lineset and lines are displayed in [Project Explorer](#).

3.11.3 New Lineset

Select **New Lineset** to create a New Lineset folder in the current project file.

1. Click **Edit > New Lineset**.

The lineset name appears in the [Project Explorer](#) window.



3.11.4 Add Line(s) to Lineset

Select **Add Line(s) to Lineset** to add lines to a Lineset in a project.

1. Click **Edit > Add Lines to Lineset**.
2. In the **Open** dialog, navigate to and then select one or more GPR (.hd) lines.
3. Click **Open**.

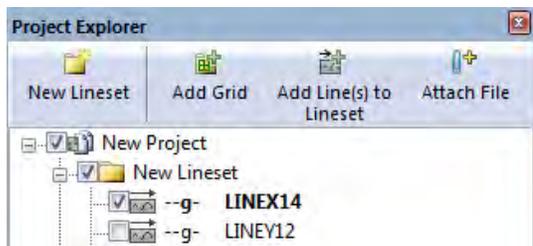
The data files are added to the Lineset and are displayed in the [Project Explorer](#).

3.11.5 Rename

Select **Rename** to change the name of the project, grid, lineset, or GPR line in a lineset.

Note: A GPR line name in a grid cannot be renamed.

1. To rename an item, in Project Explorer, select the item you want to rename.



2. In the menu bar, click **Edit > Rename**.



A box appears around the item name signifying that the name is now editable.

3. Type the new item name and then press **Enter**.

Note: Certain characters, such as periods and slashes are not valid in names. If you enter one of these characters it will be automatically replaced with an underscore.

3.11.6 Attach File

Select **Attach File** to attach GPS files, topography files, photos of the line location, videos of the area, or voice recordings of information relevant to the GPR project, grid, lineset, or line.

1. To attach a file to the selected GPR data line, lineset, grid, or project, click **Edit > Attach File**.
2. In the **Attach Files** dialog box, to navigate to and then select the file you want to attach.

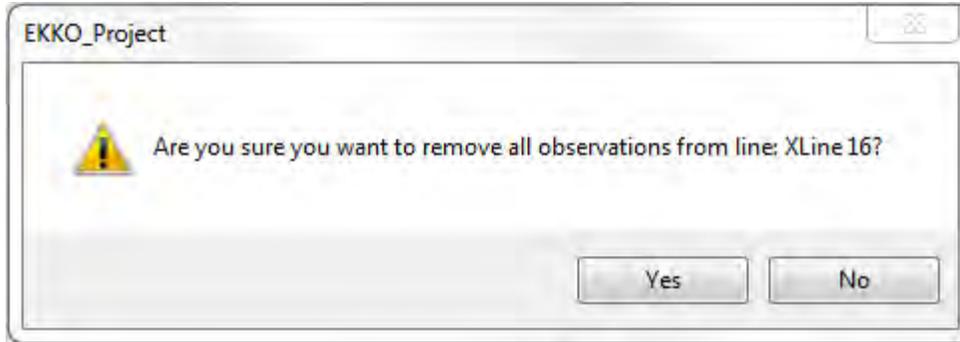
The file is listed in the Attachments tab. To learn more, see [Attachments Tab](#).

3.11.7 Remove

Use **Remove > Interpretation Observations** to remove interpretations from MapView. For example, since interpretations are included when a GPR line is copied, you may want to remove interpretations from the copied line.

1. To remove interpretations from GPR line, lineset, or grid, click **Edit > Remove > Interpretation Observations**.





2. To remove the observation, in the message box, click **Yes**.

3.11.8 Cut

To remove the selected GPR line, lineset or grid from the project, click **Edit > Cut**.

This enables you to remove a GPR line from a lineset and paste it into a different lineset.

Note: a GPR line cannot be cut from a grid.

3.11.9 Copy

To copy an item, click **Edit > Copy**.

Use the **Copy** feature to:

- Copy a GPR line, lineset, or grid and display it in [LineView](#) or [Process](#) the item differently than the original.
- Copy and then paste the selected lineset or grid back into the project.

Note: GPR lines in a grid can be copied, but they must be pasted into a lineset; they cannot be pasted into a grid.

3.11.10 Paste

Select **Paste** to add a GPR line from one lineset to a different lineset.

To paste an item, click **Edit > Paste**

Use the **Paste** feature to:

- Paste a copy of a GPR line, lineset, or grid into [LineView](#), or [Process](#) the item differently than the original.
- Paste a copied or cut lineset or grid back into the project.

Note: copied GPR lines must be pasted into a lineset; they cannot be pasted into a grid.

3.11.11 Delete

To remove a grid or lineset from a project, or delete a GPR line from the lineset in the project, click **Edit > Delete**.

Note: GPR lines cannot be deleted from a grid.

To delete a line or lines from a grid, use the GFP_Edit utility program that accompanies SliceView.

Caution: Removing a GPR line from the project file may result in the total loss of the GPR data line, interpretations, and associated files (.gps, .top, and .ini) unless a separate copy of the original data files exists.

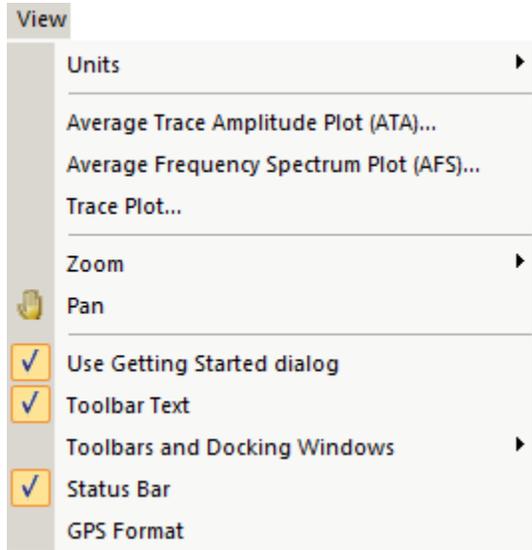
The original data files may exist if the GPR lines were added to the project file rather than being embedded in the project (.gpz) file.

If the project (.gpz) file was generated by the Sensors & Software GPR system, a copy of the GPR line(s) can be made clicking **File > Export > Lines**; this saves the original .dt1 and .hd files, and not the interpretations.

3.12 View Menu

The EKKO_Project View menu contains many features that allow you to change the way information is displayed in EKKO_Project.

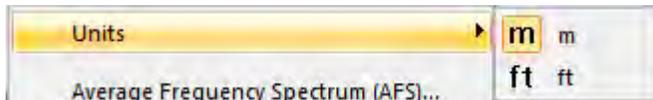
To open the view menu, click **View**:



The following sections describe how to work with the View menu features:

3.12.1 Units

1. To display units of measurement in EKKO_Project in meters or feet, click **Units**.
2. In the drop-down list, click **m** (metric) or **ft.** (US standard).



Changes in units of measurement affects the following EKKO_Project features:

- [Line Preview](#)
- [MapView](#)
- [LineView](#)
- [Reports](#) (including Bridge Deck Condition and Pavement Structure Reports)
- [Processing](#)

3.12.2 Average Trace Amplitude

Average Trace Amplitude (ATA) plots display the average signal amplitudes (in microvolts) for one or more selected GPR lines. Data is Dewowed before being displayed (to learn more, see [Dewow](#)).

ATA plots enable you to display how quickly signal amplitude decays to the background noise level, providing an indication of the maximum penetration in the survey area.

1. To display all the currently checked GPR lines in an Average Trace Amplitude (ATA) plot, click **View > Average Trace Amplitude Plot (ATA)**.

The ATA plot is greyed out if no lines are selected.

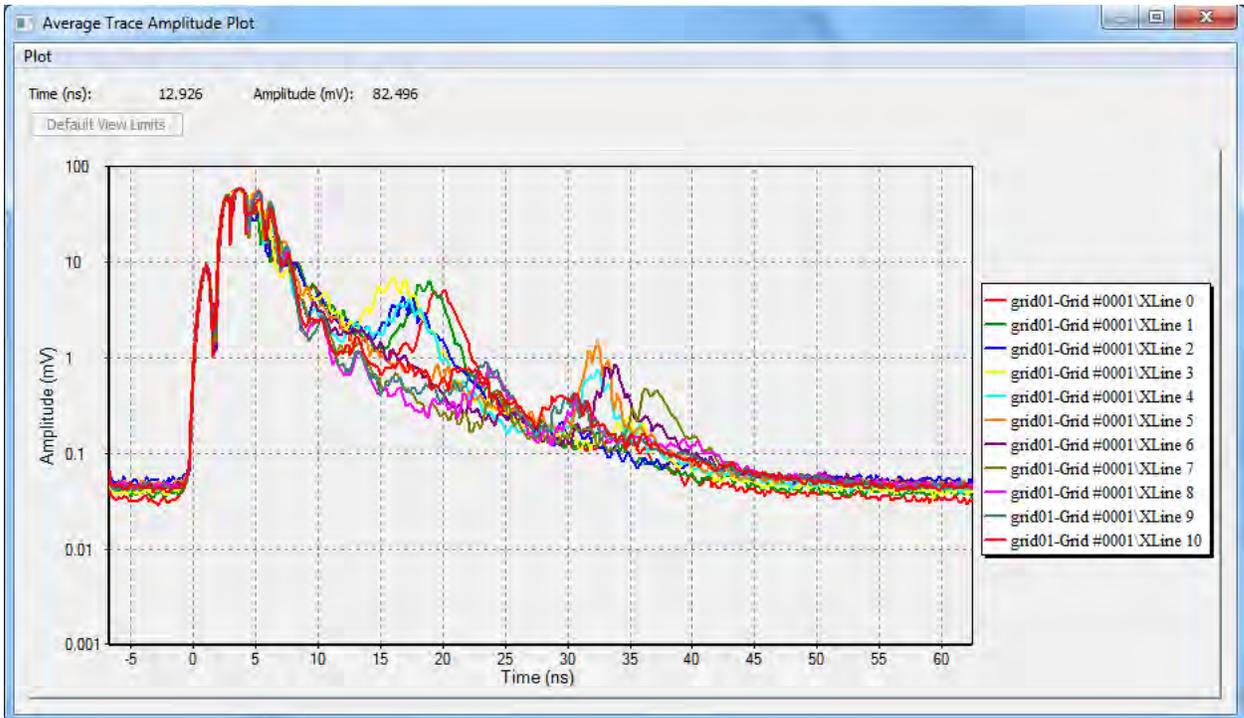


Figure 7: Average Trace Amplitude Plot

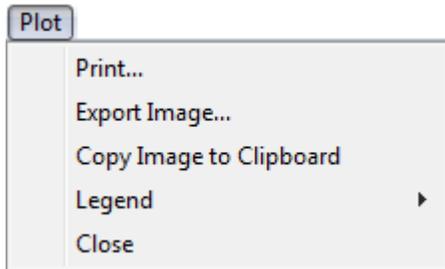
2. Use the following table as a guide to working with the Average Trace Amplitude Plot:

Item	Description
Resize Window	Drag and drop a corner or edge of the window to resize it. The Window can also be maximized using the Maximize button in the top right.
Pan View	Hold the right-click button and drag the mouse in the direction you want to move the image.
Default View Limits	Click Default View Limits to return to the original plot display.
Zoom	<ol style="list-style-type: none"> 1 Left-click the image to define the top left corner of the zoom box 2 Hold the left-click button and drag the mouse to the bottom right corner of the zoom box. 3 Release the mouse button and the image zooms to the box

Item	Description
Amplitude (mV)	<p>The GPR signal amplitude in millivolts (mV).</p> <p>Move the cursor along the time axis to display the time and GPR signal amplitude.</p> <p>The signal amplitude typically starts at the background noise level on the left. At zero time, a strong amplitude signal occurs when the GPR system fires its transmitter. At later times, the GPR signal slowly decays back to the background noise level (providing the recording time window is long enough). The slope the signal level drops depends on the material being surveyed.</p>
Time (ns)	<p>The time in nanoseconds from the start of the recording window. Time before zero time is displayed as a negative value.</p> <p>The time at which the signal level drops back to the background noise level is the maximum penetration time. This can be converted to the average maximum depth of penetration if a radar velocity for the material is known.</p>

3.12.2.1 Plot

1. Click **Plot** to display the ATA plot options drop-down list.



2. Use the following table as a guide to working with the Plot drop-down features:

Item	Description
Print	To print the ATA plot, click Print .
Export Image	<ol style="list-style-type: none"> 1 To send the ATA plot as an image, click Export Image. 2 In the Save As dialog box, navigate to the folder you want to send this image to. 3 Click Save.
Copy Image to Clipboard	To copy an ATA plot image to paste to a document, click Copy Image to Clipboard .
Legend	<ol style="list-style-type: none"> 1 To define where on the ATA plot the legend is click Legend. 2 In the drop-down list click Top, Bottom, Left, Right, or Hide.
Close	To close the ATA plot, click Close .

3. To export the data used to create the plot, click **File > Export. > Average Trace Amplitude**.

3.12.3 Average Frequency Spectrum

Average Frequency Spectrum (AFS) plots display the average frequency spectrum of the selected GPR line(s). Data is dewowed before being displayed (to learn more, see [Dewow](#)).

Select AFS to determine the frequency content of a GPR line to decide if filtering is required to remove unwanted frequencies like high frequency noise. If so, lowpass, highpass, or bandpass filtering can be applied (to learn more, see [Filtering](#)).

1. To display all the currently checked GPR lines in an Average Amplitude Spectrum (AFS) plot, click **View > Average Frequency Spectrum Plot (AFS)**.

The AFS plot is greyed out if no lines are selected.

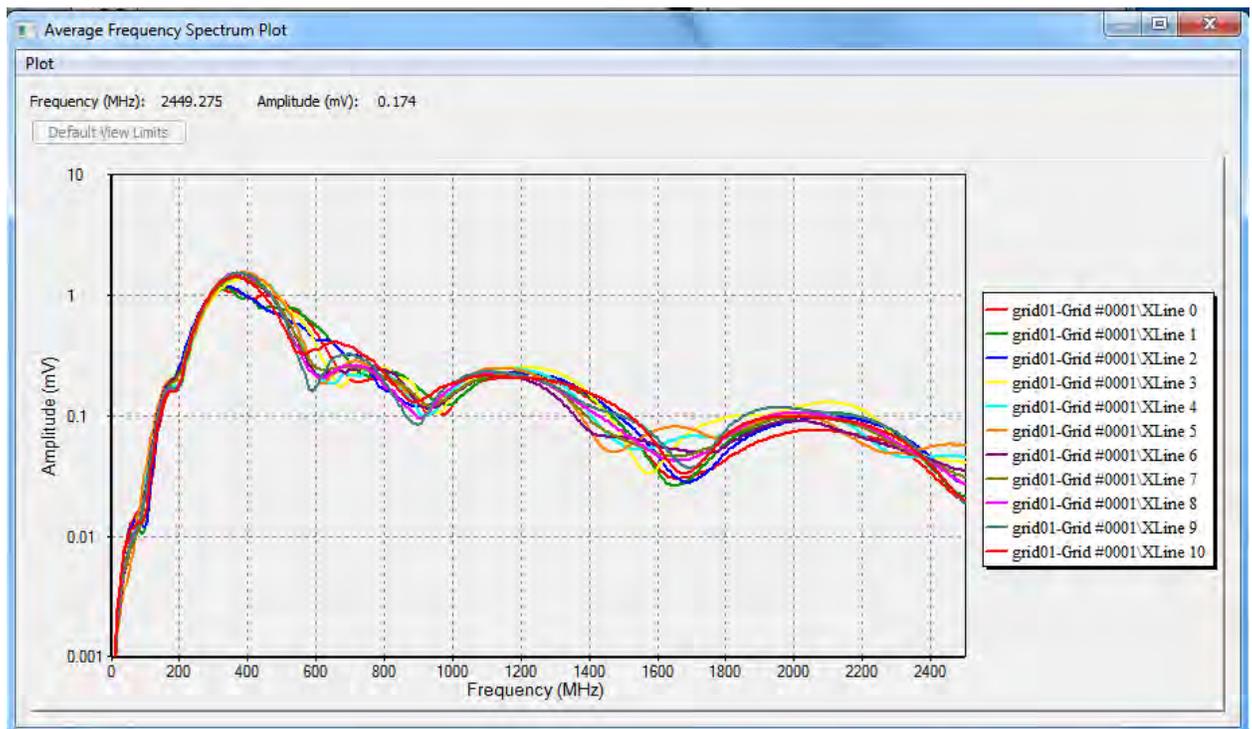


Figure 8: Average Frequency Spectrum Plot

2. Use the following table as a guide to working with the Average Frequency Spectrum Plot:

Item	Description
Resize Window	Drag and drop a corner or edge of the window to resize it. The Window can also be maximized using the Maximize button in the top right.
Default View Limits	Click Default View Limits to return to the original plot display.
Zoom	<ol style="list-style-type: none"> 1 Left-click the image to define the top left corner of the zoom box 2 Hold the left-click button and drag the mouse to the bottom right corner of the zoom box. 3 Release the mouse button and the image zooms to the box

Item	Description
Amplitude (mV)	<p>The GPR signal amplitude in millivolts (mV).</p> <p>Move the mouse cursor along the frequency axis to display the frequency and amplitude.</p> <p>The signal amplitude typically starts at the background noise level on the left.</p>
Frequency (MHz)	<p>The Frequency in MHz.</p> <p>The displayed frequency range defaults to zero to the Nyquist frequency (calculated from the temporal sampling interval for the GPR line).</p>

Note: Sensors & Software antennas center frequency is measured in air. For example, 100 MHz antennas produce a center frequency of about 100 MHz when data is collected in air. The center frequency of data from antennas placed on the ground will be lower in frequency than the stated frequency of the antenna. For example, the center frequency of data collected with 100 MHz antennas is often 60 to 70 MHz.

- To export the data used to create the plot, click **File > Export. > Average Frequency Spectrumm.**

3.12.3.1 Plot

Click **Plot** to display the AFS plot options drop-down list.

To learn about the Average Frequency Spectrum Plot feature, click [Plot](#).

3.12.4 Trace Plot

View Traces to display subtle features in the data file, or view the effect of different editing and processing types on individual traces. Only a single line can be loaded into the trace plot at a time. Data is dewowed before being displayed (to learn more, see [Dewow](#)).

Viewing traces can also help you determine if the first break offset needs to be edited. Normally the first break should occur at the first large deflection in the signal. If not, time scales and depth scales on section plots will be inaccurate. .

1. To display all the currently checked GPR lines in a Trace plot, click **View > Trace Plot**.

The Trace plot is greyed out if no GPR lines are selected.

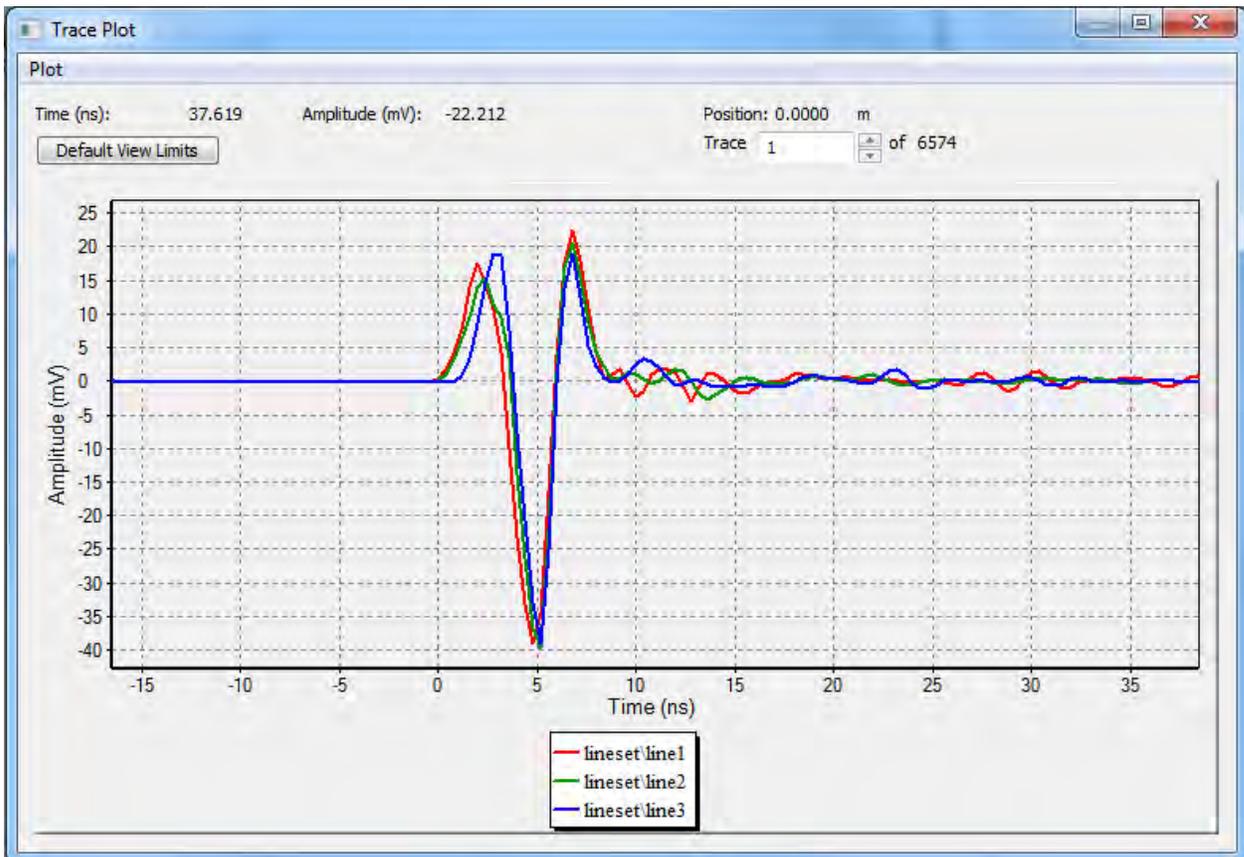


Figure 9: View Traces Plot

2. Use the following table as a guide to working with the Trace Plot:

Item	Description
Resize Window	Drag and drop a corner or edge of the window to resize it. The Window can also be maximized using the Maximize button in the top right.
Default View Limits	Click Default View Limits to return to the original plot display.

Item	Description
Zoom	<ol style="list-style-type: none"> 1 Left-click the image to define the top left corner of the zoom box 2 Hold the left-click button and drag the mouse to the bottom right corner of the zoom box. 3 Release the mouse and the mage zooms to the box
Amplitude (mV)	<p>The GPR signal amplitude in millivolts (mV)</p> <p>Move the cursor along the time axis to display the time and GPR signal amplitude.</p> <p>The signal amplitude typically starts at the background noise level on the left. At zero time, a strong amplitude signal occurs when the GPR system fires its transmitter. The GPR signal slowly decays back to the background noise level, providing the recording time window is long enough.</p>
Time (ns)	<p>The time in nanoseconds from the start of the recording window. Time before zero time is displayed as a negative value.</p>
Trace	<p>The displayed trace.</p> <p>Click the up and down arrows to display other traces.</p>
Position	<p>The position of the displayed trace on the GPR line. The position is based on the trace number and the step size</p>

3.12.4.1 Plot

Click Plot to display the View Traces plot options drop-down list.

To learn about the View Traces Plot feature, click [Plot](#).

3.12.5 Zoom

3.12.5.1 Zoom Out

To decrease the magnification of the MapView image, click **View > Zoom > Out**.

3.12.5.2 Zoom In

To increase the magnification of the MapView image, click **View > Zoom > In**.

When you zoom in to display a portion of the project data, an icon appears in the lower left corner of MapView to indicate that data exists outside the current view (see [Pan](#)).

3.12.5.3 Zoom Window

To magnify a selected area of MapView, click **View > Zoom > Zoom Window** and then click and drag a rectangle in the area of interest.

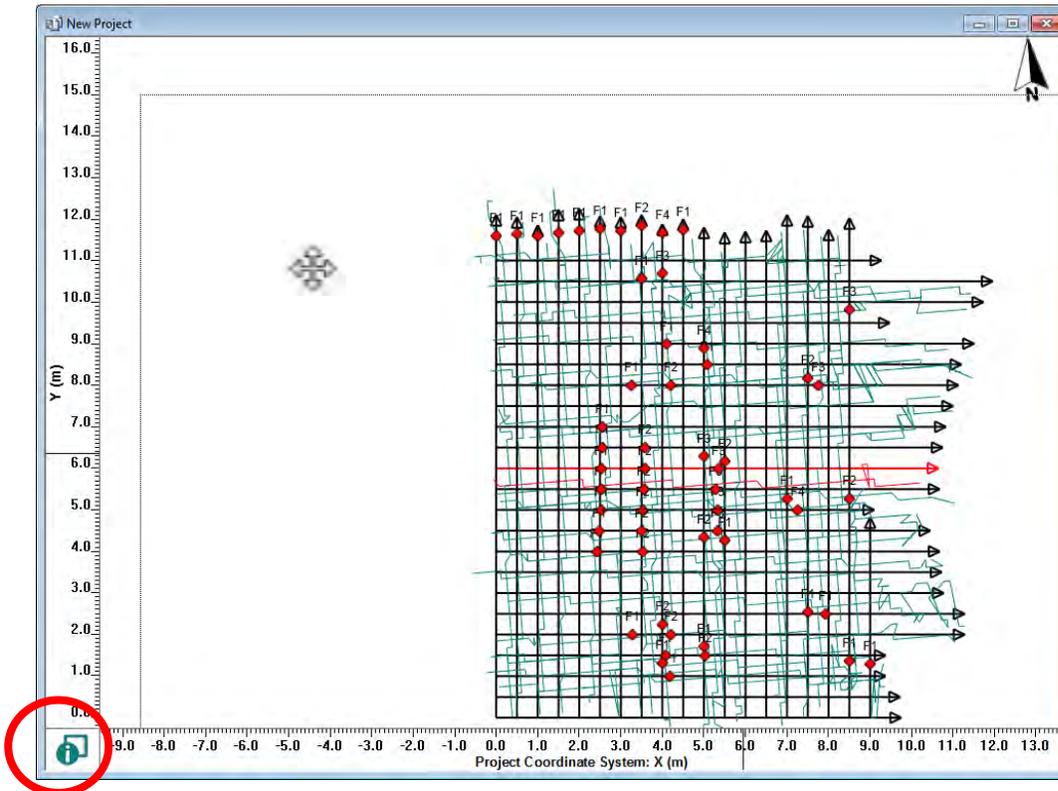
3.12.5.4 Fit to Window

To adjust the zoom to fit all the data in the MapView click **View > Zoom > Fit to Window**.

3.12.6 Pan

To reposition the MapView, click **View** > **Pan**.

Click and drag the cursor () to move the MapView within the Display pane. Panning does not change the location or magnification of objects on your drawing; it changes only the view.



Panning or zooming images within MapView prompts the following icons to be displayed:



Indicates that some of the data is outside the current window.



Indicates that all of the data is outside the current window. Click **View** > **Zoom** > **Fit to Window** to see all the data in the project in the MapView window.

3.12.7 Use Getting Started dialog

When a new project is created, the Getting Started dialog ([Figure 1](#)) automatically opens to guide you through creating a project file.

To disable this feature, click **View** and then uncheck **Use Getting Started dialog**.

3.12.8 Toolbar Text

EKKO_Project enables you to display/hide the text that appears below each toolbar icon.

Select **View > Toolbar Text** to display text below each icon:



To display the toolbar icons without text, reducing the size of the toolbar, select **View** and then uncheck **Toolbar Text**.



3.12.9 Toolbars and Docking Windows

Select **View > Toolbars and Docking Windows** to view or hide the following features:



- [Standard Toolbar](#)
- [Project Explorer](#)
- [Acquisition Tab](#)
- [Attachments Tab](#)
- [Processing Tab](#)

3.12.9.1 Customize

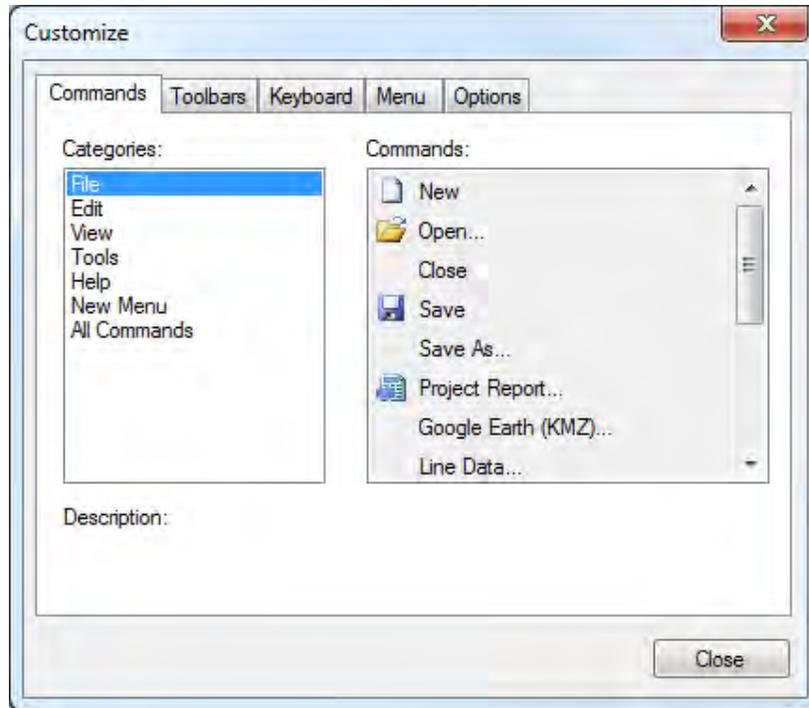
Customize is standard Microsoft functionality; for more details see Microsoft documentation.

To modify the Commands, Toolbars, Keyboard, Menus, and other Options in EKKO_Project, click **View > Toolbars and Docking Windows > Customize**.

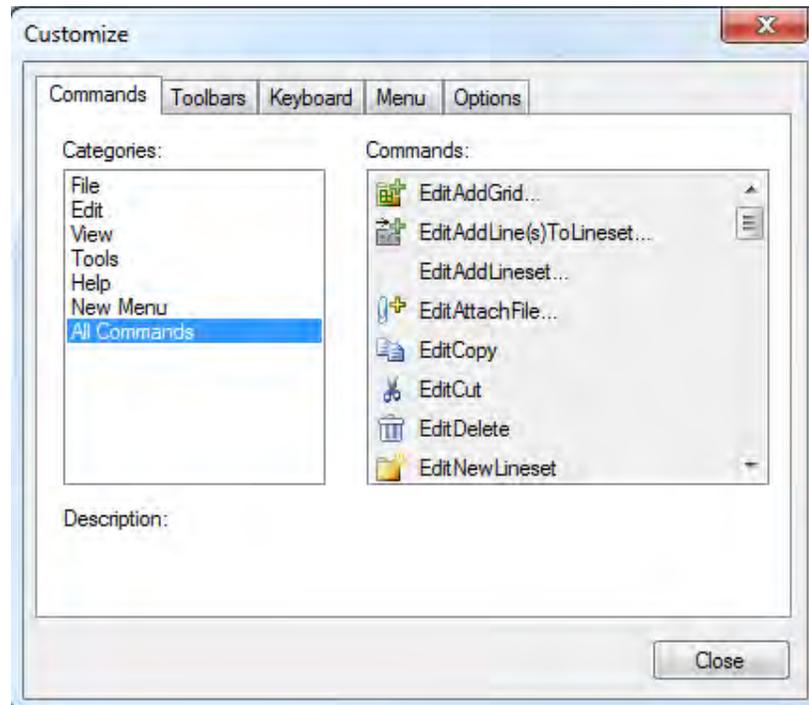
3.12.9.1.1 The Commands Tab

Use the Commands tab to display all commands available to add to a toolbar.

1. The Commands tab lets you see all the commands available to add to a custom or existing toolbar. To determine which commands will be displayed in the menu bar, click the item in the **Categories** pane.



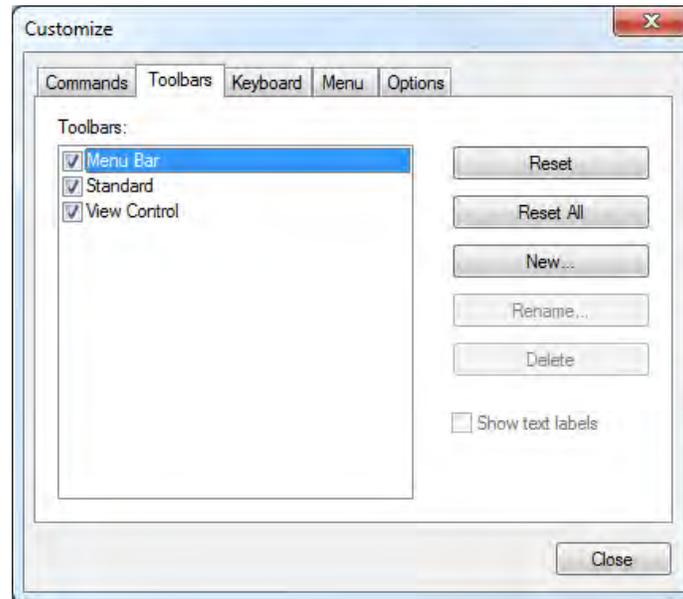
2. To display a description of the command, click a menu item in the **Commands** pane.



3. To exit the Customize window, click **Close** or click another tab to view more information.

3.12.9.1.2 Toolbars Tab

1. To display the available Toolbar options, click the **Toolbars** tab.

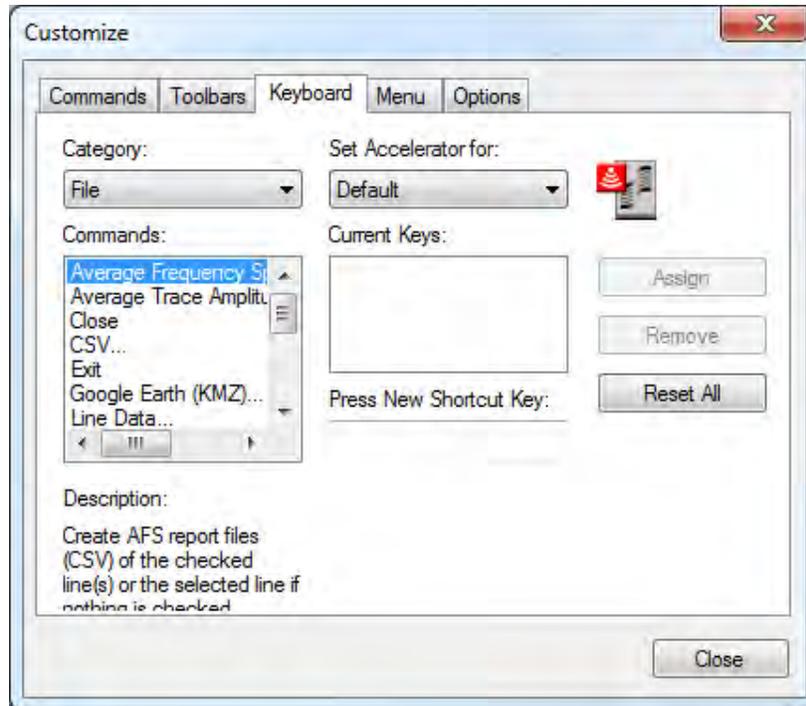


2. Use the following table as a guide to working in the Toolbars tab:

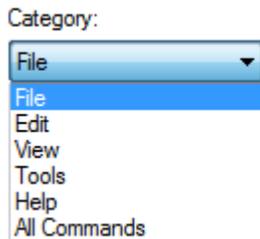
Field	Description
Toolbars	The Toolbars field displays the available menu bars. To display or hide a toolbar in EKKO_Project, select/deselect the checkbox next to the toolbar name.
Reset	In the Toolbars field, select the menu bar(s) that you want to return to the default setting and then click Reset .
Reset All	To return all toolbars to their default view, click Reset All .
New	<ol style="list-style-type: none"> 1 To add a new toolbar to EKKO_Project, click New. 2 In the Toolbar Name field, type the name of the new toolbar. The new toolbar is displayed in the Toolbars field.
Rename	To Rename a toolbar that you have added to EKKO_Project: <ol style="list-style-type: none"> 1 In the Toolbars pane, select the toolbar you want to rename. 2 Click Rename. 3 In the Toolbar Name dialog box, type the new toolbar name. 4 Click OK.
Delete	To Delete a toolbar that you have added to EKKO_Project: <ol style="list-style-type: none"> 1 In the Toolbars pane, select the toolbar you want to rename. 2 Click Delete. 3 In the confirmation dialog box, click Yes.
Show text labels	To display text descriptions with the toolbar icons, click the Show text labels checkbox

3.12.9.1.3 Keyboard

To manage how your keyboard interacts with EKKO_Project, click the **Keyboard** tab. Use the Keyboard tab to assign keyboard shortcuts to any feature in the **File**, **Edit**, **View**, **Tools**, **Help**, or **All Commands**.



1. To create a new keyboard shortcut, in the **Category** drop-down list, click one of the following options:



2. In the **Commands** pane, click the command that you want to apply a hotkey shortcut to.

A brief description of the command is displayed in the **Description** area. Any existing shortcuts associated with the selected command are displayed in the **Current Keys** pane.

Current Keys:

Ctrl+N

3. In the **Set Accelerator for** drop-down list, click an option.
4. To create a new hotkey shortcut, select the **Press New Shortcut Key** field and then press a shortcut combination on your keyboard.

The shortcut is displayed in the **Press New Shortcut Key** field.

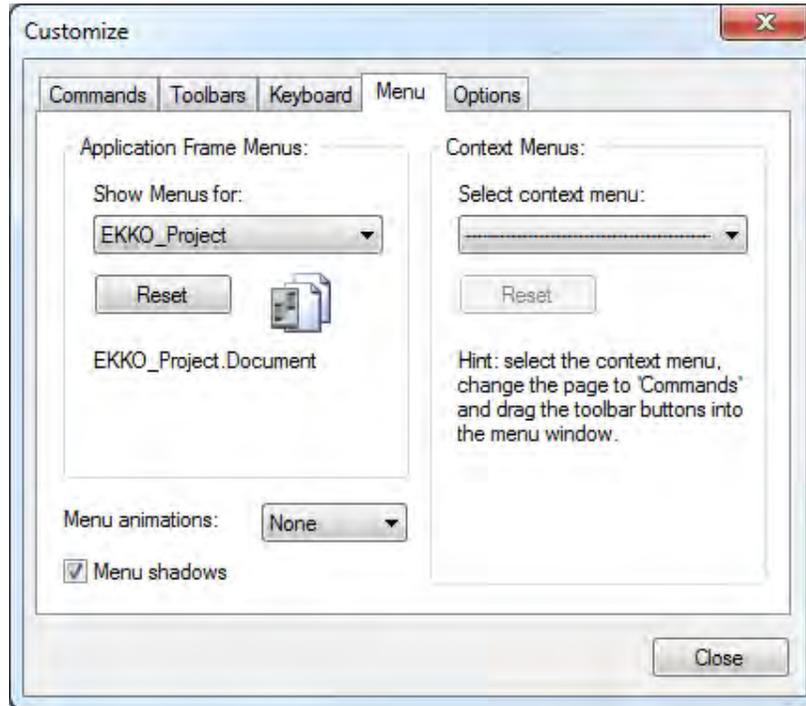
- Click **Assign** to assign the shortcut to the selected command.

Press **Remove** to remove a shortcut from a command.

Press **Reset All** to remove all shortcuts.

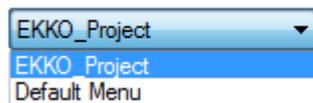
3.12.9.1.4 Menu

- To change the items displayed in the menu bar, click the **Menu** tab.



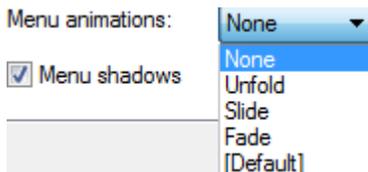
- In the **Application Frame Menus** pane, click the **Show Menus for** drop-down list.
- Click one of the following options:

Show Menus for:



Click **Reset** to abandon your changes.

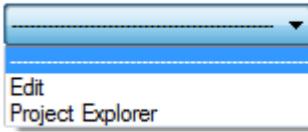
- To apply animations to the menu, click the **Menu animations** drop-down list and select one of the following options:



- To apply shadows to the menu items, select the **Menu shadows** option.

- To allow context menus to be displayed, in the Context Menu pane, click the **Select context menu** drop-down list to select one of the following:

Select context menu:

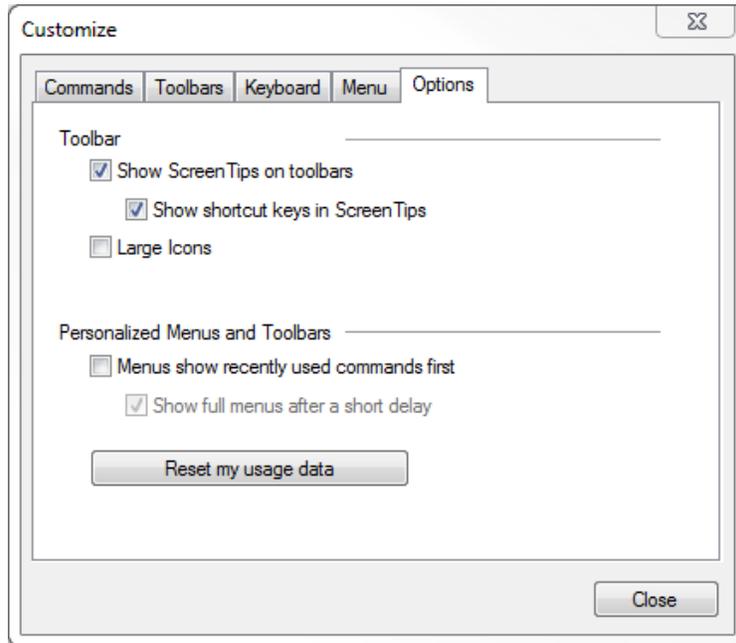


Click **Reset** to abandon all your changes.

- Click **Close** to close the window.

3.12.9.1.5 Options

- To define your toolbar and menu options, click the **Options** tab.



- Use the following table as a guide to working with the **Options** tab:

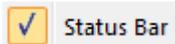
Field	Description
Toolbar	
Show Screen Tips on toolbars	Select this option to display text screen tips when you hold your mouse over the toolbar icon.
Show shortcut keys in Screen Tips	Select this option to display text keyboard shortcuts when you hold your mouse over the toolbar icon.
Large Icons	Select this option to display the large toolbar icons.
Personalized Menus and Toolbars	
Menus show recently used commands first	Select this option to place the commands you most recently used at the top of the drop-down list. Click the arrow (>) to display other menu options,

Field	Description
Show full menus after a short delay	Select this option to first display only the most recent commands and then display the full menu after a few seconds.
Reset my usage data	Select this option to reset the recently used order.

3. Click **Close** to close the window.

3.12.10 Status Bar

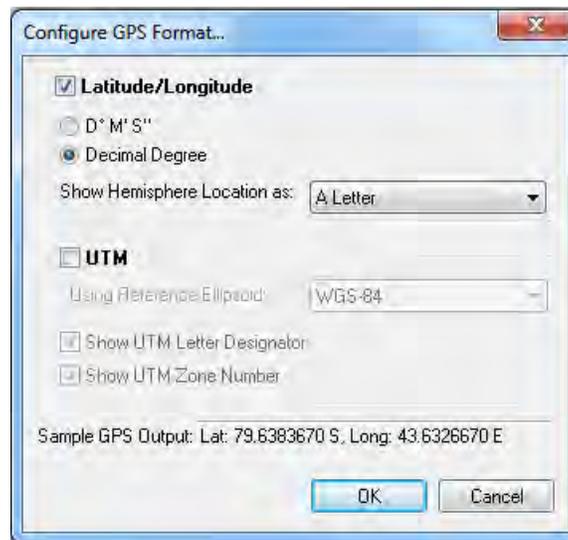
To display information in the Status Bar at the bottom of the EKKO_Project window, in the menu bar, click **View > Status Bar**.



To not display information in the status bar, de-select the Status Bar option.

3.12.11 GPS Format

To modify the format of the GPS information in the Status Bar at the bottom of the EKKO_Project window, in the menu bar click **View > GPS Format**.



3.12.11.1 Latitude/Longitude

If Latitude/Longitude is selected with the checkbox, the display options are:

- 1) **Degrees Minutes Seconds**
- 2) **Decimal Degrees**

The options for the Hemisphere are:

- 1) **Do not show**

- 2) Show as a **Positive** (+) or **Negative** (-) sign. A plus (+) sign if Latitude is in the Northern hemisphere or Longitude is in the Eastern Hemisphere and a minus (-) sign if Latitude is in the Southern hemisphere or Longitude is in the Western Hemisphere.
- 3) **Letter**: For latitude, "N" for North or "S" for South. For Longitude, "E" for East or "W" for West.
- 4) **Word**: For latitude, "North" or "South". For Longitude, "East" or "West".

A sample of the current GPS output is shown at the bottom of the dialog box.

3.12.11.2 UTM

If UTM is selected with the checkbox, the Reference Ellipsoid can be selected from the drop-down list. The default is WGS-84.

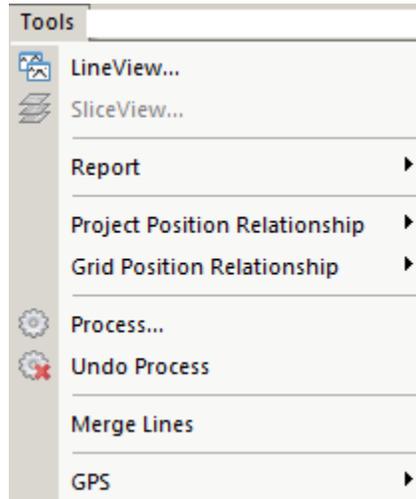
To display the UTM Zone Number and/or the UTM Letter Designator, select those options.

A sample of the current GPS output is shown at the bottom of the dialog box.

3.13 Tools Menu

The EKKO_Project Tools menu contains many features that allow you work in [LineView](#), and the optional [SliceView](#) and [Process](#) views within EKKO_Project. The Tools menu is also used to produce various reports using the GPR data and images in the project.

To open the tools menu drop-down list, click **Tools**:

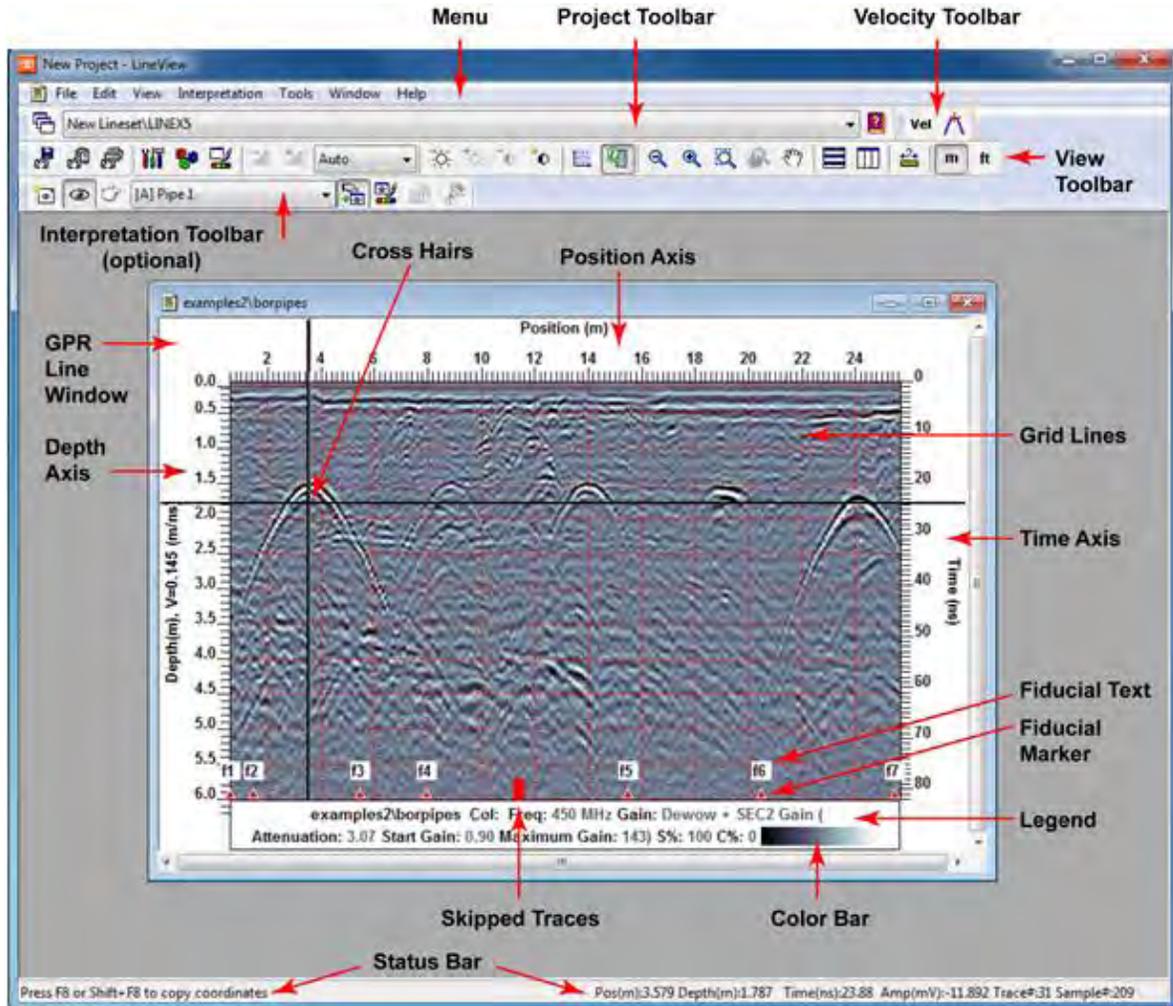


The following sections describe how to work with the Tool menu features:

3.13.1 LineView

LineView displays cross-sectional views of GPR lines; you can change the display settings such as color table, gain, and axes.

1. To display a GPR Line name in the LineView module, in [Project Explorer](#), select a line. 
2. Click **Tools > LineView**.



If the optional Interpretation module is enabled, use LineView to add interpretations such as Points, Polylines, Boxes, and Annotations to the GPR Line which can be listed in the [Project Report \(CSV\)](#).

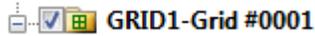
Only the selected GPR Line or those checked in to Project Explorer are displayed in LineView, however all GPR Lines in the project can be displayed using the LineView toolbar Project List drop-down.

To learn more about using LineView to display GPR lines and add Interpretations, see the LineView User's Guide.

3.13.2 SliceView

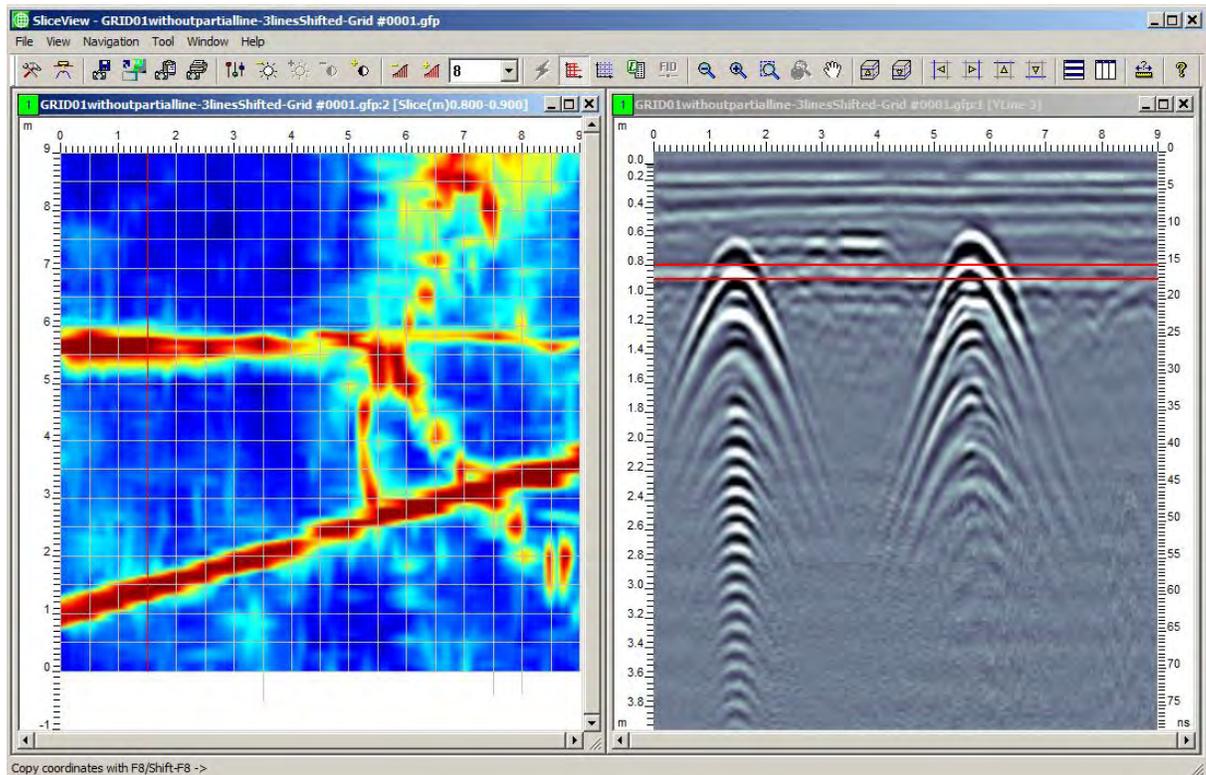
Use the optional SliceView module to generate depth slices with highly detailed subsurface information for GPR data collected in a grid. Viewing data as a series of depth slices enhances GPR data interpretation.

1. To display a grid in SliceView, in Project Explorer, select a grid.



2. Click **Tools > SliceView**.

The following grid image displays the relationship between depth slice images and X and Y GPR line images.



When GPR responses are displayed as depth slices, you can see the spatial correlation of targets, making interpretation easier as you can differentiate real targets from targets of no interest. For example, responses from utilities tend to produce linear targets while local targets, such as rocks, appear as point targets. This type of display can greatly enhance the interpretation of large data volumes.

SliceView is designed to process GPR grid data to enhance targets and create depth slices.

Use SliceView to:

- Analyze grid data by viewing depth slices at increasing depths
- Reprocess grid data using different velocities
- Save depth slices as images
- Display depth slices generated from grid data collected with a GPS on Google Earth.

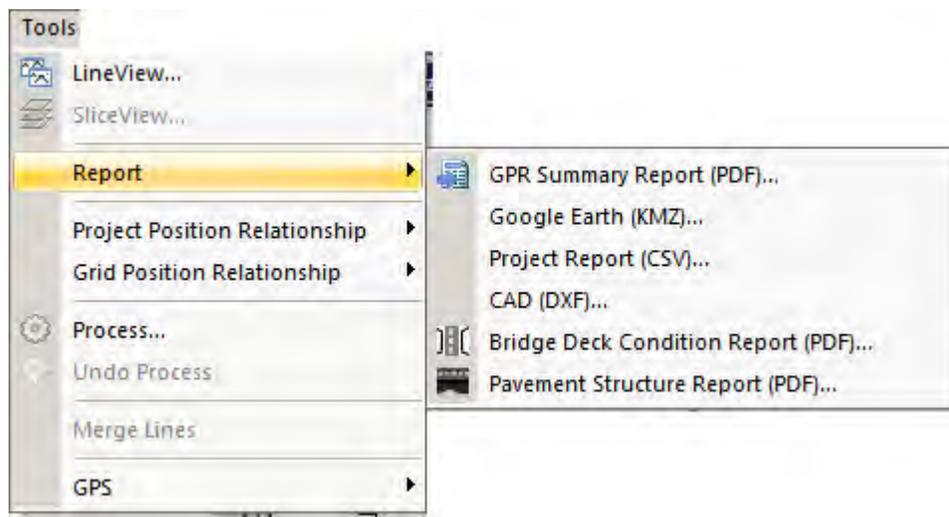
- Export grid data to 3D data files and 3D visualization software (available from [Sensors & Software](#))

To learn more about using SliceView to display depth slices, see the SliceView User's Guide.

3.13.3 Report

EKKO_Project can generate several reports from data at fiducial markers and interpretations added to the project data. Reports are output in several formats including Adobe Acrobat (.pdf), Google Earth (.kmz), Comma Separated Values (.csv), and AutoCAD (.dxf) files.

1. Click **Tools > Report**.



2. In the drop-down list, select a report format:

- [GPR Summary Report \(PDF\)](#)
- [Google Earth \(KMZ\)](#)
- [Project Report \(CSV\)](#)
- [CAD \(DXF\)](#)
- [Bridge Deck Condition Report \(PDF\)](#)
- [Pavement Structure Report \(PDF\)](#)

3.13.3.1 GPR Summary Report (PDF)

The GPR Summary Report allows users to take data images saved of EKKO_Project windows and their own photographs and images attached to the project, add text and include them in a PDF report.

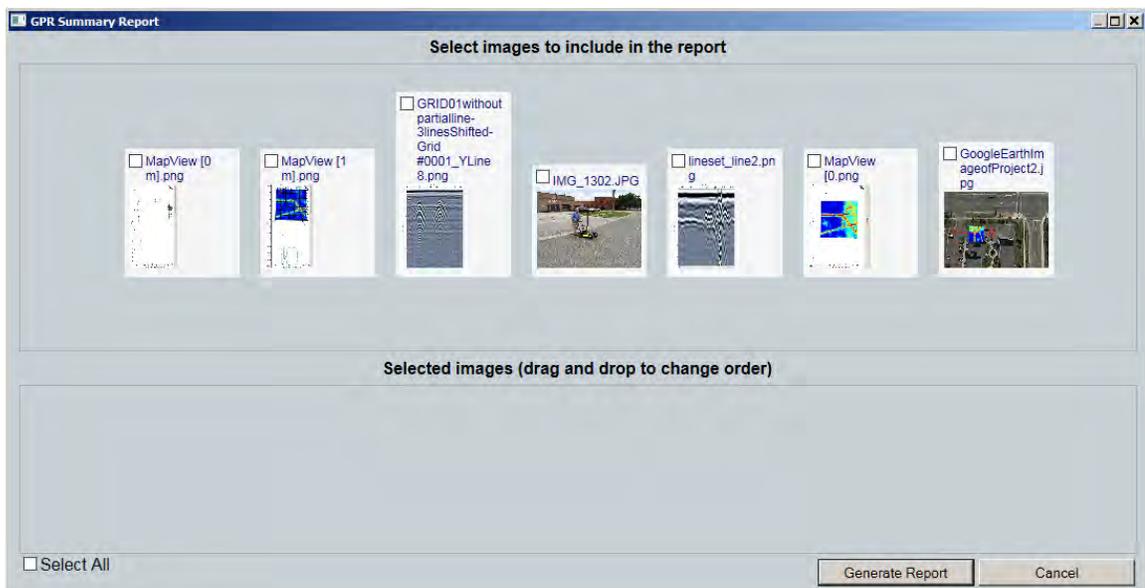
Images saved from EKKO_Project windows include the Line Preview and MapView windows (see [Save View](#)) as well as images of windows from the optional LineView and SliceView modules.

As well, for some newer GPR systems, such as the LMX200 Enhanced, screen captures saved in the field (by pressing the camera button) are also saved in the project file and are available for inclusion in the GPR Summary Report.

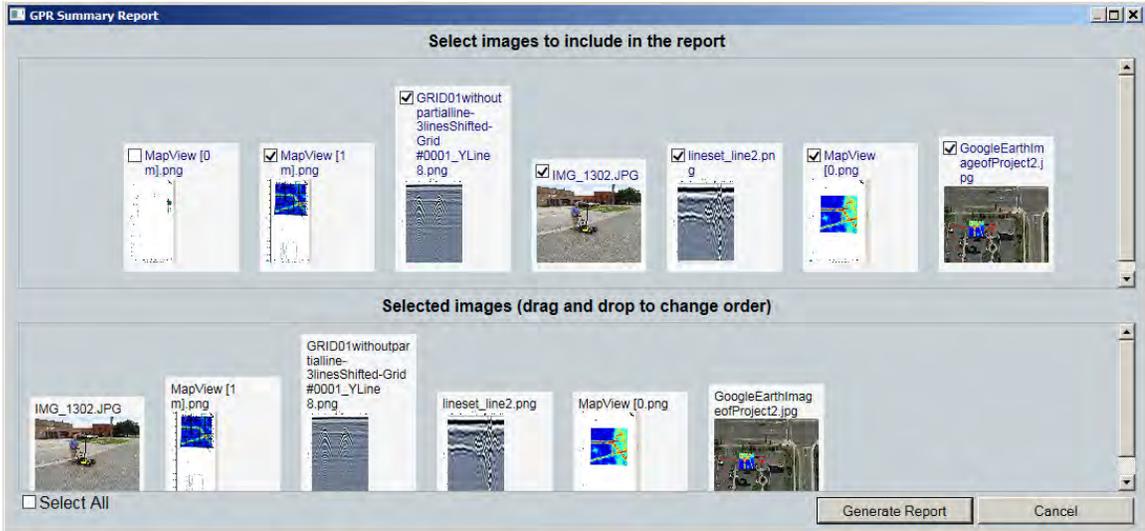
To see a list of window images currently saved and available for the GPR Summary Report, select the project item in [Project Explorer](#) and then open the [Attachments Tab](#).

Photographs and other images attached to the project file, grid folder, lineset folder or individual GPR line in the project are available to include in the report. For details on attaching a file, see [Attachments Tab](#).

1. To generate a GPR Summary Report (pdf) click **Tools > Report > GPR Summary Report**.
2. A dialog opens, displaying all the data images available to include in the report. Click on the images to include or click on the Select All checkbox in the bottom left corner to quickly include all the images.



3. Once the desired images are selected, they appear in the bottom of the dialog. Change the order of the images by dragging and dropping them in the desired order for the report.



4. Select **Generate Report** button. A preview of the report appears.



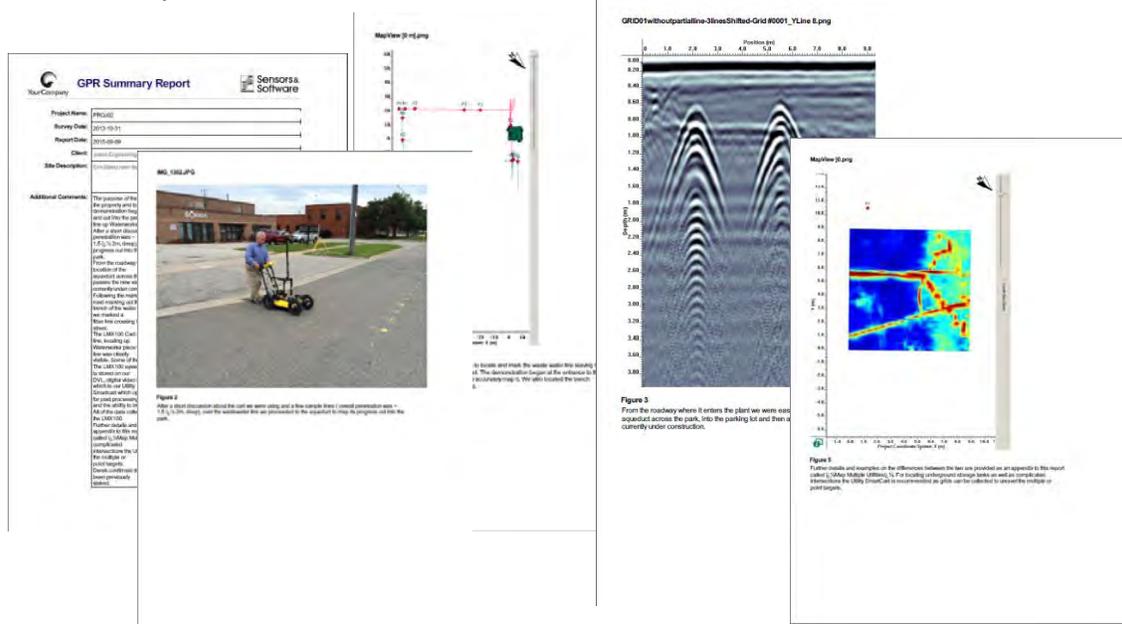
- The Report preview is editable, with many of the fields filled in automatically. Users can modify titles and comments for each image. Note that all text entered into the text boxes here is lost when you leave this dialog by pressing **Save** or **Exit**.
- If you want to make changes to the images in the report, select the **Back** button to move back to the previous screen. Text entered into text boxes before pressing **Back** is saved.
- The user can add their own logo to the top left-hand corner of the report by clicking on the “click here to add logo” link, and selecting an image file.



The logo image is automatically remembered for that installation of EKKO_Project, so the logo file only has to be selected once.

To clear the current logo image, select the **Clear Logo** button.

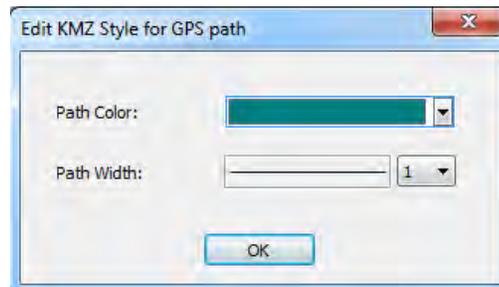
- When the editing of the report is complete, save the report as a PDF document by clicking the **Save** button. Providing the computer has PDF reader software installed (it may be necessary to install Adobe Acrobat Reader from www.adobe.com), the PDF file opens.



3.13.3.2 Google Earth (KMZ)

Projects containing GPR lines and grids collected using GPS can be written to a Google Earth (.kmz) report file and displayed in Google Earth. The path of the GPR lines, any fiducial markers added during data collection, and post-processing interpretations (using the Interpretations Module in [LineView](#)) are displayed on Google Earth. To enable or disable these items, select the corresponding check-box in the Google Earth Places window.

9. To generate a Google Earth (.kmz) report file for GPR lines in the project (.gpz) file with GPS, click **Tools > Report > Google Earth**.
10. A dialog opens to define the color and thickness of the GPS path when plotted on Google Earth:



Use the dropdowns to select a new color or width.

11. In the **Save As** folder, navigate to the folder you want to save the file to.
12. Click **Save**.

Google Earth opens to display a satellite image of the data collection site.

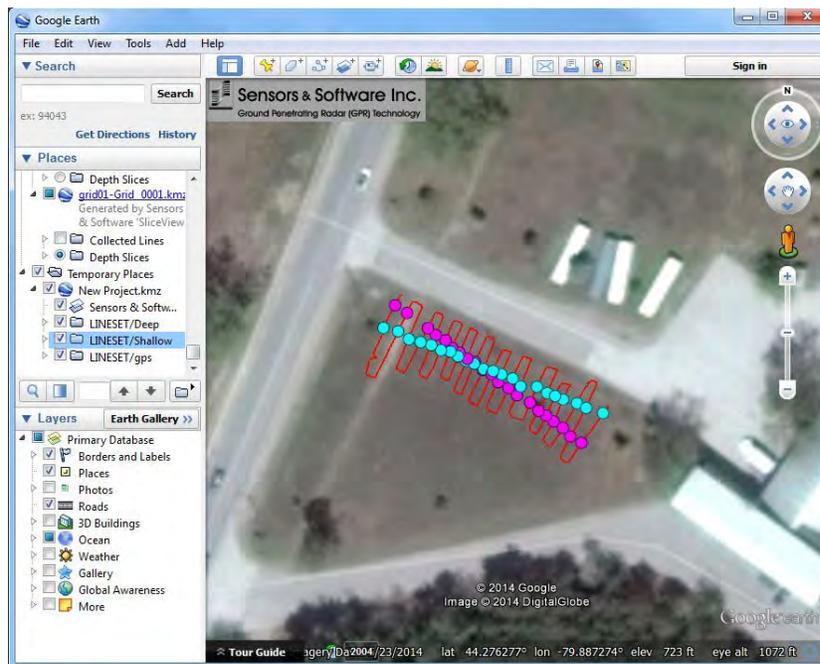


Figure 10: Google Earth image of the data collection site with the GPR line survey path in red and utility point interpretations as pink and light blue dots.

3.13.3.3 Project Report (CSV)

Fiducial markers are added to the data during data collection and [Interpretations](#) are added during post-processing using the optional Interpretation module in LineView.

Exporting the fiducial markers and interpretations to spreadsheet-type files (.csv) allows you to transfer the information to third-party software applications such as Excel and Geographical Information Systems (GIS).

Before adding interpretations, decide whether to plot data with a depth axis or an elevation axis.

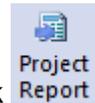
To include observation values in the report by elevation rather than depth, add the Interpretations **after** one of the following:

- the GPR line has topographic data added that will not be changed
- the GPR line is plotted with an elevation axis using a velocity value that will not be changed

Note: Changing either of these conditions after adding interpretations shifts the vertical positions of the interpretations and is not recommended.

Changing the depth or elevation axis velocity in LineView changes the depth and elevation values.

1. To generate a Project Report, click **Tools > Report > Project Report**.



Alternatively, from the [Standard Toolbar](#), click

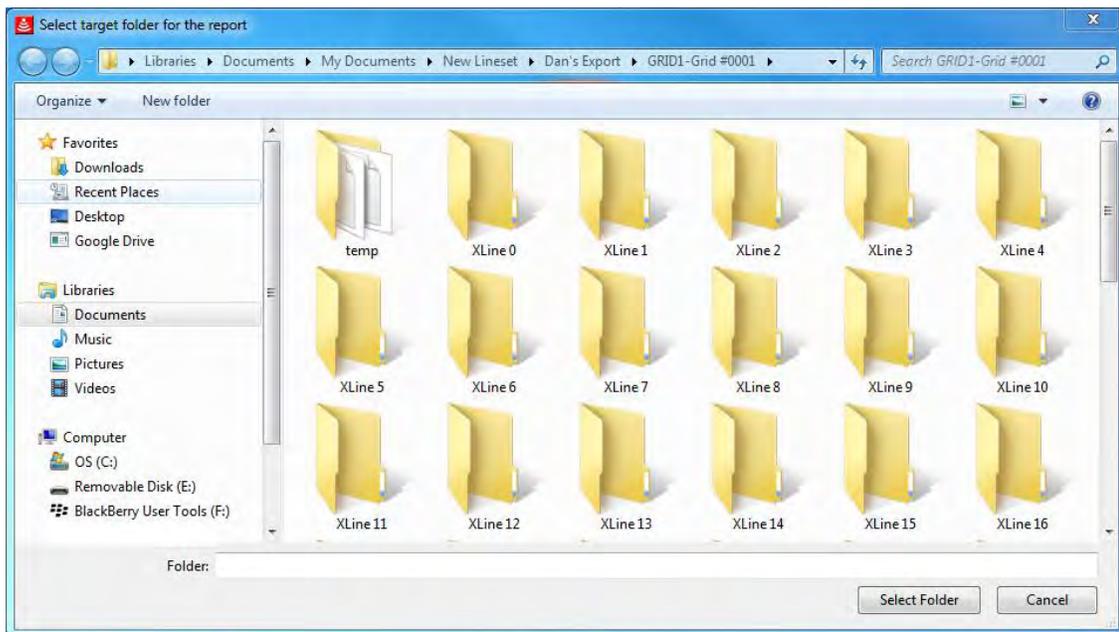
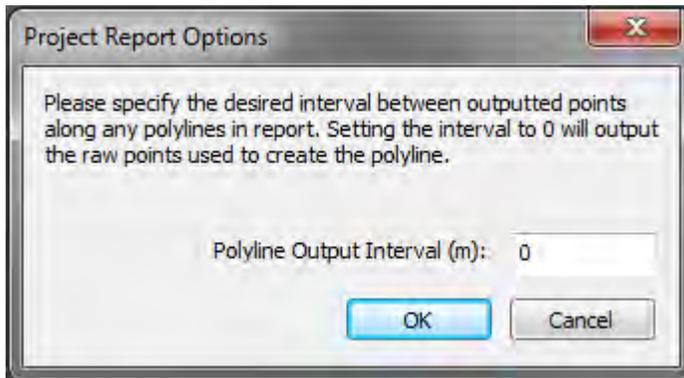


Figure 11: Select target folder for export

2. In the **Select target folder for the report** dialog box, navigate to and then click the folder to save the report files to

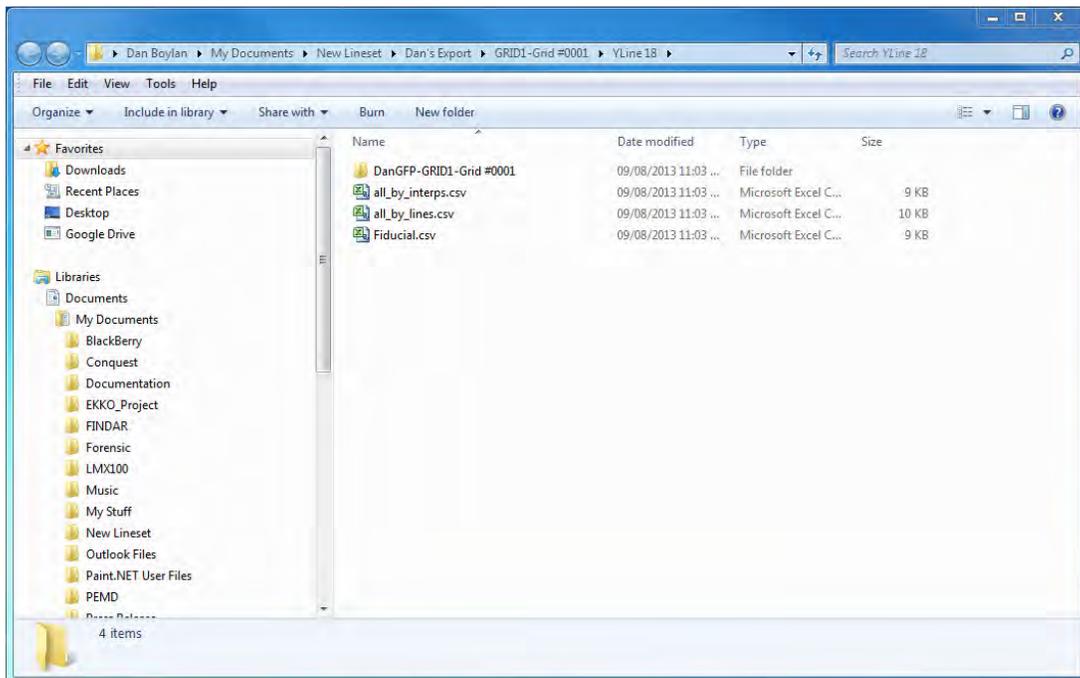
3. Click **Select Folder**.
4. In the **Report** dialog box, enter the Polyline Output Interval (the horizontal distance between points on any polylines in the project).



The Project Report Options dialog box opens whether polyline interpretations were added or not, if you do not have any polyline interpretations click OK to ignore the dialog.

5. Click **OK**.

A dialog box opens to display the folder that the .csv lines were saved to.



The types of .csv files generated are:

- .csv files for each interpretation
- .csv files for each GPR line
- A .csv file containing all interpretations sorted by interpretations
- A .csv file containing all interpretations sorted by GPR line
- A .csv file for all fiducial markers

Name	Description	Count													
Annotation1		1													
Box1		1													
Alrwave		1													
Pipe1		2													
Shallow Metal		1													
Horizon1		2													
Fiducial		5													
Tool	Interpretation	GPR Line	Position(m) X(m)	Y(m)	Depth(m)	Time(ns)	Elevation(m)	Amplitude(mV)	Velocity(m/ns)	GPS Easting (17T)	GPS-Northing (17T)	Latitude	Longitude	GPS Elevation	Comment
Annotation	Annotation1	PROJECT0\LINE00	26.057	26.057	0	1.679	88.77	111.137	-0.017	0.085	609817.58	4821949.53	43.6224321	-79.6386439	112.82 Air wave from overhead power line
Box	Box1	PROJECT0\LINE00	12.113	12.113	0	0.223	5.19	112.877	16.242	0.085	609807.88	4831939.71	43.6323453	-79.6347686	113.1
Box	Box1	PROJECT0\LINE00	18.354	18.354	0	0.708	16.04	112.294	0.092	0.085	609812.11	4831944.11	43.6323841	-79.6347128	113
Point	Alrwave	PROJECT0\LINE00	25.607	25.607	0	1.665	38.46	111.219	-0.005	0.085	609817.27	4831949.21	43.6324293	-79.6386479	112.88
Point	Pipe1	PROJECT0\LINE00	27.407	27.407	0	0.649	14.71	111.951	-2.905	0.085	609818.54	4831950.48	43.6324406	-79.6386318	112.6
Point	Pipe1	PROJECT0\LINE00	39.214	39.214	0	0.669	15.18	112.231	4.81	0.085	609826.93	4821958.79	43.6325141	-79.6385262	112.9
Point	Shallow Metal	PROJECT0\LINE00	82.451	82.451	0	0.239	5.51	113.061	4.595	0.085	609857.64	4831989.22	43.6327835	-79.6381394	113.3
Polyline	Horizon1	PROJECT0\LINE00	23.808	23.808	0	0.522	11.8	112.478	3.638	0.085	609815.99	4831947.95	43.6324181	-79.638664	113
Polyline	Horizon1	PROJECT0\LINE00	24.427	24.427	0	0.501	11.33	112.499	6.72	0.085	609816.43	4831948.38	43.632422	-79.6386685	113
Polyline	Horizon1	PROJECT0\LINE00	24.933	24.933	0	0.47	10.82	112.514	6.632	0.085	609816.79	4831948.74	43.6324251	-79.638654	112.98
Polyline	Horizon1	PROJECT0\LINE00	26.001	26.001	0	0.536	12.11	112.287	2.828	0.085	609817.54	4831949.49	43.6324318	-79.6386444	112.82
Polyline	Horizon1	PROJECT0\LINE00	26.451	26.451	0	0.495	11.17	112.305	1.806	0.085	609817.86	4831949.81	43.6324346	-79.6386404	112.8
Fiducial	Fiducial	PROJECT0\LINE00	15.4	15.4	0	0	N/A	N/A	N/A	0.085	609810.01	4821942.03	43.6323657	-79.6387392	113 F1
Fiducial	Fiducial	PROJECT0\LINE00	21.4	21.4	0	0	N/A	N/A	N/A	0.085	609814.28	4831946.25	43.6324031	-79.6386856	113 F2
Fiducial	Fiducial	PROJECT0\LINE00	27.4	27.4	0	0	N/A	N/A	N/A	0.085	609818.54	4831950.47	43.6324405	-79.6386319	112.6 F3
Fiducial	Fiducial	PROJECT0\LINE00	39.25	39.25	0	0	N/A	N/A	N/A	0.085	609826.96	4831958.81	43.6325143	-79.6385259	112.9 F4
Fiducial	Fiducial	PROJECT0\LINE00	82.4	82.4	0	0	N/A	N/A	N/A	0.085	609857.61	4831989.19	43.6327832	-79.6381398	113.3 F5

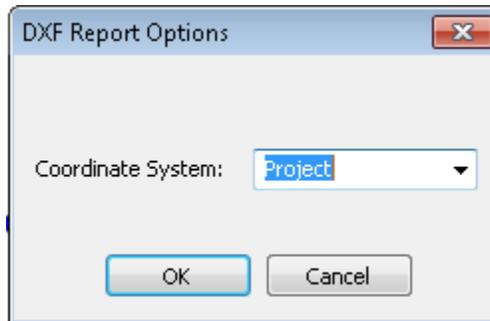
Figure 12: Example of Project Report

3.13.3.4 CAD (DXF)

Projects can be written to a CAD report (dxf) file. The path of the GPR grid lines, the GPS path for GPR lines collected with GPS, fiducial markers added during data collection, and post-processing point interpretations (using the Interpretation Module) are saved as layers in the DXF file.

Exporting this information to a .dxf file allows you to transfer the information to third-party CAD programs. The Voxler software, if available, reads .dxf files. If necessary, free CAD (.dxf) file viewers can be found on-line.

1. To generate a CAD (dxf) report file, **click Tools > Report > CAD (DXF)**.
2. Use the dropdown box in the dialog box to select the coordinate system to save with the DXF file:



The options are Project (Local X, Y), or, if a local-global coordinate relationship has been established (usually by GPS data), UTM and Latitude-Longitude options are also available.

UTM is usually selected to open the GPR report in AutoCAD programs while Latitude-Longitude is the choice for GIS programs. When UTM or Latitude-Longitude is selected, a projection file (.prj) is generated that lists the projection details. It is important to keep this file with the .dxf file when importing the data into third-party programs such as ArcGIS.

The projection file always uses the WGS84 reference ellipsoid for UTM and latitude/longitude outputs.

3. In the **Save As** folder, navigate to the folder you want to save the file to.
4. Click **Save**.

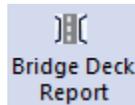
3.13.3.5 Bridge Deck Condition Report (PDF)

If the optional Bridge Deck Condition Report module is enabled, projects containing GPR lines collected using GPS or grids where point interpretations have been added to rebar responses are processed to generate a Bridge Deck Condition Report.

The report requires positioning information so it will only run if the GPR lines were collected in a grid or with GPS.

Select the GPR lines to include in the report in Project Explorer. If no GPR lines are selected, all the lines in the project with point interpretations are included in the report.

Select **Tools > Report > Bridge Deck Condition Report** or select the Bridge Deck Report button from the Toolbar:



The Bridge Deck Condition dialog opens:

A screenshot of the "Bridge Deck Condition Report" dialog box. The dialog has a title bar with the text "Bridge Deck Condition Report" and a close button (X). The main area contains several settings: "Velocity" with radio buttons for "Local" (selected), "Average", and "Manual" (with a text input field and "m/ns" label); "Interpretation:" with a dropdown menu showing "Rebar"; "Processing type:" with a dropdown menu showing "ASTM_D6087_08"; "Interpolation Limit" with radio buttons for "Auto" (selected) and "Manual" (with a text input field and "m" label). At the bottom, there are three buttons: "Generate Report" (highlighted with a blue border), "Export CSV", and "Cancel".

An error message "There is insufficient data to generate the bridge deck condition report" usually means that there are too few picked points in the data or they are too widely scattered to generate an amplitude map image and good statistics.

Field	Description
Velocity	<p>Velocity used to migrate the rebar hyperbolas to point responses for amplitude analysis. Also used to calculate rebar depths.</p> <p>Local uses the GPR line velocities set in LineView (if not set in LineView, default is 0.10 m/ns or 0.328 ft/ns).</p> <p>Average uses the average velocity of all the GPR line velocities set in LineView.</p> <p>Manual uses a velocity entered by the user for all GPR lines.</p>
Interpolation Limit	<p>The Bridge Deck Condition Report generates an amplitude map image by interpolating data into the gaps between GPR lines. As the GPR line separation increases, interpolating data into the gap is less desirable as artifacts may be created in the image.</p> <p>If set to Auto, the value is calculated based on the average rebar spacing in the data set to provide a “solid” map image with few or minimal gaps.</p> <p>Manual uses an interpolation limit value input by the user.</p> <p>The interpolated Limit calculated by Auto is listed in the report. The user can regenerate the report using a Manual interpolation limit, if desired.</p>
Interpretation	<p>Select the name of the Point Interpretation to process for the report. The dropdown lists all the “Point” interpretation names added to GPR lines in the project (or selected lines). Only one interpretation is used to generate the report.</p>
Processing Type	<p>Absolute Amplitude produces a map image plotted in signal amplitude values of millivolts (mV). Higher values indicate higher GPR signal amplitudes.</p> <p>ASTM D6087-8 produces a map image plotted in signal amplitude values of decibels (dB) based on the processing outlined in ASTM D6087-8 –“<i>Standard Test Method for Evaluating Asphalt-Covered Concrete Bridge Decks Using Ground Penetrating Radar</i>”. Higher values indicate higher GPR signal attenuation. The reference amplitude is the median of the top 10% of the picked rebar.</p>
Generate Report	<p>Select to generate the Bridge Deck Condition Report.</p>

Field	Description																																																																																																																
Export CSV	Export the calculated amplitude value (in mV or dB), Latitude-Longitude and UTM coordinates for each picked rebar to a .csv file. This allows the user to import the data into a third-party software for interpolation, image generation and/or further analysis.																																																																																																																
	<table border="1"> <thead> <tr> <th>X(m)</th> <th>Y(m)</th> <th>Amplitude(mV)</th> <th>GPS Latitude</th> <th>GPS Longitude</th> <th>UTM Easting (17T)</th> <th>UTM Northing (17T)</th> </tr> </thead> <tbody> <tr><td>32.995</td><td>9.298</td><td>3.534</td><td>43.6236586</td><td>-79.6589786</td><td>608192.956</td><td>4830948</td></tr> <tr><td>32.659</td><td>9.654</td><td>3.703</td><td>43.6236619</td><td>-79.6589827</td><td>608192.62</td><td>4830949</td></tr> <tr><td>32.337</td><td>9.994</td><td>3.467</td><td>43.623665</td><td>-79.6589866</td><td>608192.298</td><td>4830949</td></tr> <tr><td>32.015</td><td>10.335</td><td>3.285</td><td>43.6236681</td><td>-79.6589905</td><td>608191.975</td><td>4830949</td></tr> <tr><td>31.678</td><td>10.691</td><td>2.904</td><td>43.6236713</td><td>-79.6589946</td><td>608191.639</td><td>4830950</td></tr> <tr><td>31.324</td><td>11.07</td><td>2.608</td><td>43.6236748</td><td>-79.6589989</td><td>608191.285</td><td>4830950</td></tr> <tr><td>30.984</td><td>11.435</td><td>2.383</td><td>43.6236781</td><td>-79.6590031</td><td>608190.945</td><td>4830951</td></tr> <tr><td>30.675</td><td>11.767</td><td>1.691</td><td>43.6236812</td><td>-79.6590068</td><td>608190.636</td><td>4830951</td></tr> <tr><td>30.369</td><td>12.096</td><td>1.518</td><td>43.6236842</td><td>-79.6590106</td><td>608190.33</td><td>4830951</td></tr> <tr><td>30.058</td><td>12.432</td><td>1.532</td><td>43.6236872</td><td>-79.6590143</td><td>608190.019</td><td>4830952</td></tr> <tr><td>29.727</td><td>12.789</td><td>1.793</td><td>43.6236905</td><td>-79.6590184</td><td>608189.688</td><td>4830952</td></tr> <tr><td>29.437</td><td>13.102</td><td>0.803</td><td>43.6236934</td><td>-79.6590219</td><td>608189.398</td><td>4830952</td></tr> <tr><td>29.076</td><td>13.496</td><td>2.15</td><td>43.623697</td><td>-79.6590263</td><td>608189.036</td><td>4830953</td></tr> <tr><td>28.714</td><td>13.891</td><td>2.835</td><td>43.6237006</td><td>-79.6590307</td><td>608188.675</td><td>4830953</td></tr> <tr><td>28.415</td><td>14.215</td><td>1.944</td><td>43.6237035</td><td>-79.6590343</td><td>608188.376</td><td>4830953</td></tr> </tbody> </table>	X(m)	Y(m)	Amplitude(mV)	GPS Latitude	GPS Longitude	UTM Easting (17T)	UTM Northing (17T)	32.995	9.298	3.534	43.6236586	-79.6589786	608192.956	4830948	32.659	9.654	3.703	43.6236619	-79.6589827	608192.62	4830949	32.337	9.994	3.467	43.623665	-79.6589866	608192.298	4830949	32.015	10.335	3.285	43.6236681	-79.6589905	608191.975	4830949	31.678	10.691	2.904	43.6236713	-79.6589946	608191.639	4830950	31.324	11.07	2.608	43.6236748	-79.6589989	608191.285	4830950	30.984	11.435	2.383	43.6236781	-79.6590031	608190.945	4830951	30.675	11.767	1.691	43.6236812	-79.6590068	608190.636	4830951	30.369	12.096	1.518	43.6236842	-79.6590106	608190.33	4830951	30.058	12.432	1.532	43.6236872	-79.6590143	608190.019	4830952	29.727	12.789	1.793	43.6236905	-79.6590184	608189.688	4830952	29.437	13.102	0.803	43.6236934	-79.6590219	608189.398	4830952	29.076	13.496	2.15	43.623697	-79.6590263	608189.036	4830953	28.714	13.891	2.835	43.6237006	-79.6590307	608188.675	4830953	28.415	14.215	1.944	43.6237035	-79.6590343	608188.376	4830953
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After generating a report, a preview is displayed. There are several fields in the report that are auto-filled with known information or the user can add information. There are also options to modify the amplitude image map. The Bridge Deck Analysis Report includes:

1. Bridge deck name and description including:
 - a. number of lanes
 - b. surface material
 - c. surface condition
 - d. expansion joints
 - e. divided center median
 - f. additional information
2. Bridge deck location description (user input) and the GPS coordinates of the center of the bridge deck
3. GPR survey details including:
 - a. type of GPS
 - b. GPR system
 - c. GPR system configuration
4. Processing Summary listing:
 - a. Processing Type (Absolute Amplitude or ASTM D6087-8)
 - b. GPR Velocity
 - c. Analysis Date
 - d. Total number of rebar responses picked and processed to generate the amplitude image

- e. Interpolation Type (Auto or Manual with value listed)
5. Bridge deck rebar amplitude image:
 - a. With user-selectable Color Palette
 - b. Export to .png, .bmp or .jpg graphic file formats
 - c. Amplitude range plotted can be set to Automatic (full range) or Manual (user sets the range)
 6. Statistical summary of the rebar measurements including:
 - a. Minimum, maximum and average amplitude
 - b. Minimum, maximum and average rebar depth
 - c. Minimum, maximum and average rebar spacing



Bridge Deck Condition Report

Exit

Save

Export Image

Export to Google Earth

Bridge Deck Name:

Main Street Bridge

Bridge Deck Description

of Lanes: 6
 Surface Material: Asphalt
 Surface Condition: Fair
 Expansion Joints: Yes, 2
 Divided Center Median: Yes
 Additional Information: Dry and Sunny, 20 C

Color Palette: jet reversed
 Range: Automatic
 Min: 0.049 mV
 Max: 5 mV
 OK

Location Description

Town of Smithville

GPR Survey:

GPS System: TopCon SGR-1
 GPR System: NOGGIN
 System Configuration: SmartChariot

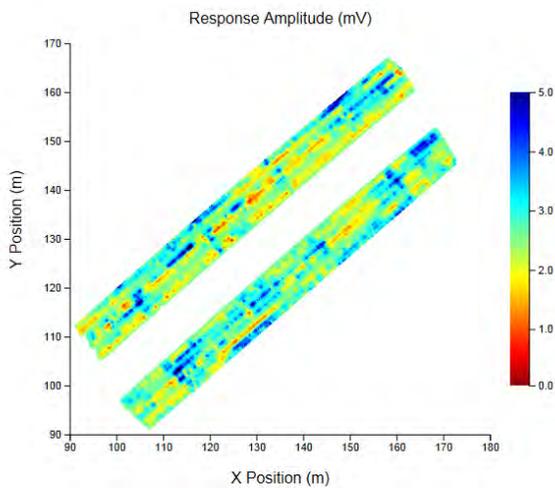
GPS Location(Center of bridge deck):

Easting: 601907
 Northing: 4831788
 Zone: 17T

Processing Summary:

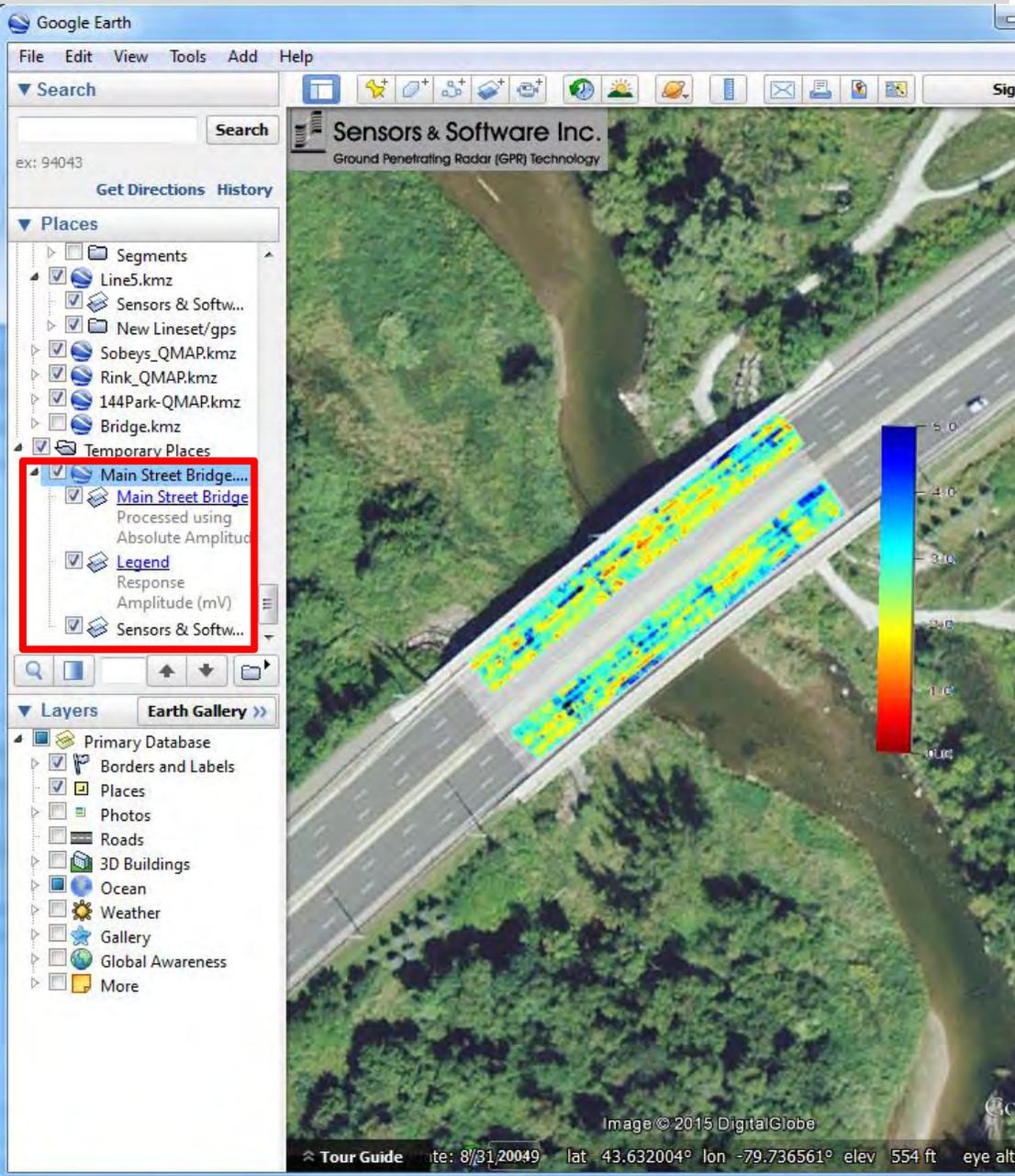
Processing Type: Absolute Amplitude
 GPR Signal Processing Velocity: Local (0.083 - 0.100 m/ns)
 Analysis Date: Friday, April 10, 2015
 Number of measurements: 5480
 Interpolation Type: Auto (1.021 m)

Bridge Deck Amplitude Image:



Statistical Summary:

	GPR Amplitude (mV)	Reinforcement Depth (m)	Reinforcement Spacing (m)
Minimum	0.049	0.120	0.147
Maximum	7.923	0.206	2.010
Average	2.634	0.164	0.255

Field	Description
Save	Save the current report to an Adobe Acrobat PDF file.
Export Image	Export Response Amplitude map image to .png, .bmp or .jpg graphic file formats
Export to Google Earth	<p>Export Response Amplitude map image to a .kmz file format so the image can be displayed in Google Earth at the survey location. The image elements can be modified in Google Earth using the checkboxes and other options under Places > temporary Places.</p> 
Color Palette	Select a color map from the dropdown list to display the response amplitude image in various colors.

Field	Description
Color Palette Range	The range of amplitude values to display in the map image. Automatic uses the full range of calculated of response amplitudes in the data set. Manual uses the range set by the user. Changing the range is often used to emphasize high or low amplitude areas of the map or if you want to compare maps from more than one bridge deck using the same range.

3.13.3.6 Pavement Structure Report (PDF)

If the optional Pavement Structure Report module is enabled, Projects containing GPR lines where polyline interpretations have been added are processed to generate a Pavement Structure Report.

The report requires:

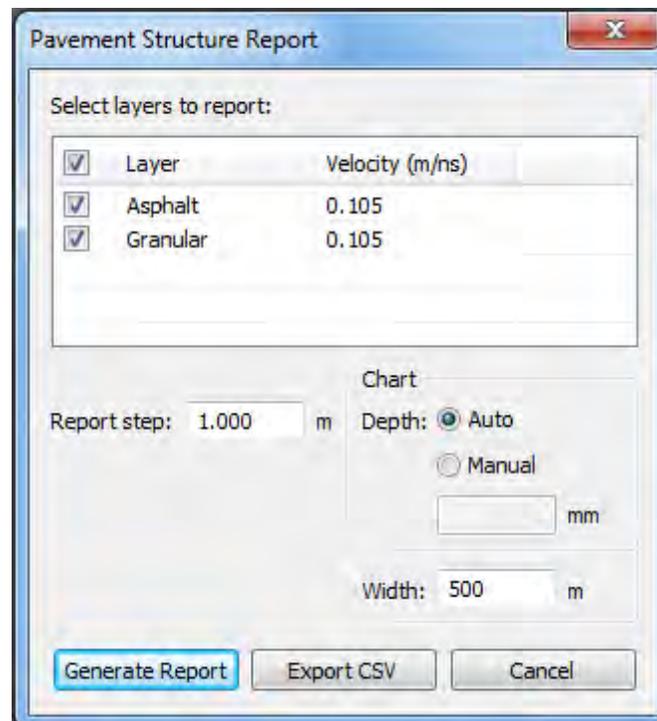
- The polylines placed in the GPR lines must not change order (shallow to deep)
- The report will not plot the thickness of layers under areas where portions of the shallower layers have not been picked

Select the GPR lines to include in the report in Project Explorer. If no GPR lines are selected, all the lines in the project with polyline interpretations are included in the report.

Select **Tools > Report > Pavement Structure Report** or select the Pavement Structure Report button from the Toolbar:



The Pavement Structure dialog opens:



Field	Description																																																																																																																																																									
Layers to Report	<p>The dialog lists the names of all the polyline interpretations added to the GPR line(s). The default is to include all layers in the report but the user can uncheck any layers to ignore.</p> <p>Each layer has a velocity value. This is the average velocity from the surface to the bottom of the layer.</p> <p>An error message is generated if a velocity is used that is impossible, that is, it causes layers to switch the order they appear from shallow to deep.</p>																																																																																																																																																									
Report Step	<p>The distance between reported depth measurements along the GPR line. The smaller this value, the more detail there is in the charts in the report.</p>																																																																																																																																																									
Chart Depth	<p>The total depth to plot in the chart.</p> <p>Auto sets the maximum depth in the chart to the deepest point of the deepest layer.</p> <p>Manual allows the user to set the maximum value to plot. A manual value is often used so all GPR line structure charts are plotted to the same depth for easier comparison.</p>																																																																																																																																																									
Chart Width	<p>The total horizontal distance depicted in each Pavement Structure chart. Setting this distance allows all the data to be displayed on one chart or broken up into several charts with the specified width.</p> <p>Defaults to 500 meters or 1000 feet.</p>																																																																																																																																																									
Generate Report	<p>Select to generate the Pavement Structure Report.</p>																																																																																																																																																									
Export CSV	<p>Export the pavement layer depths to a .csv file. One csv file is created for each GPR line. This allows the user to import the data into third-party software for image generation and further analysis.</p> <p>If the thickness of a layer cannot be determined because the layers above were not picked, then those cells are blank.</p> <table border="1"> <thead> <tr> <th>Position(m)</th> <th>Asphalt1(m)</th> <th>Layer2(m)</th> <th>Layer3(m)</th> <th>Layer4(m)</th> <th>Latitude</th> <th>Longitude</th> <th>UTM Easting (10S)</th> <th>UTM Northing (10S)</th> </tr> </thead> <tbody> <tr><td>0</td><td>0.18</td><td></td><td></td><td></td><td>37.4957</td><td>-122.3101</td><td>560988.261</td><td>4150084.267</td></tr> <tr><td>1</td><td>0.181</td><td>0.202</td><td>0.31</td><td>0.287</td><td>37.4957</td><td>-122.3101</td><td>560987.151</td><td>4150084.654</td></tr> <tr><td>2</td><td>0.183</td><td>0.204</td><td>0.296</td><td>0.297</td><td>37.4957</td><td>-122.3101</td><td>560986.115</td><td>4150085.017</td></tr> <tr><td>3</td><td>0.185</td><td>0.205</td><td>0.294</td><td>0.296</td><td>37.4957</td><td>-122.3101</td><td>560984.968</td><td>4150085.411</td></tr> <tr><td>4</td><td>0.187</td><td>0.203</td><td>0.311</td><td>0.283</td><td>37.4957</td><td>-122.3101</td><td>560983.945</td><td>4150085.764</td></tr> <tr><td>5</td><td>0.186</td><td>0.204</td><td>0.322</td><td>0.278</td><td>37.4957</td><td>-122.3101</td><td>560982.807</td><td>4150086.152</td></tr> <tr><td>6</td><td>0.185</td><td>0.203</td><td>0.337</td><td>0.267</td><td>37.4957</td><td>-122.3101</td><td>560981.681</td><td>4150086.537</td></tr> <tr><td>7</td><td>0.184</td><td>0.2</td><td>0.353</td><td>0.259</td><td>37.4957</td><td>-122.3101</td><td>560980.602</td><td>4150086.905</td></tr> <tr><td>8</td><td>0.184</td><td>0.198</td><td>0.356</td><td>0.266</td><td>37.4957</td><td>-122.3102</td><td>560979.555</td><td>4150087.28</td></tr> <tr><td>9</td><td>0.183</td><td>0.196</td><td>0.353</td><td>0.267</td><td>37.4957</td><td>-122.3102</td><td>560978.411</td><td>4150087.67</td></tr> <tr><td>10</td><td>0.18</td><td>0.196</td><td>0.345</td><td>0.267</td><td>37.4957</td><td>-122.3102</td><td>560977.38</td><td>4150088.036</td></tr> <tr><td>11</td><td>0.175</td><td>0.199</td><td>0.336</td><td>0.27</td><td>37.4957</td><td>-122.3102</td><td>560976.298</td><td>4150088.419</td></tr> <tr><td>12</td><td>0.17</td><td>0.206</td><td>0.345</td><td>0.262</td><td>37.4957</td><td>-122.3102</td><td>560975.244</td><td>4150088.785</td></tr> <tr><td>13</td><td>0.175</td><td>0.204</td><td>0.356</td><td>0.252</td><td>37.4957</td><td>-122.3102</td><td>560974.079</td><td>4150089.203</td></tr> <tr><td>14</td><td>0.184</td><td>0.196</td><td>0.368</td><td>0.243</td><td>37.4957</td><td>-122.3102</td><td>560972.994</td><td>4150089.591</td></tr> <tr><td>15</td><td>0.184</td><td>0.199</td><td>0.376</td><td>0.237</td><td>37.4957</td><td>-122.3102</td><td>560971.927</td><td>4150089.979</td></tr> </tbody> </table>	Position(m)	Asphalt1(m)	Layer2(m)	Layer3(m)	Layer4(m)	Latitude	Longitude	UTM Easting (10S)	UTM Northing (10S)	0	0.18				37.4957	-122.3101	560988.261	4150084.267	1	0.181	0.202	0.31	0.287	37.4957	-122.3101	560987.151	4150084.654	2	0.183	0.204	0.296	0.297	37.4957	-122.3101	560986.115	4150085.017	3	0.185	0.205	0.294	0.296	37.4957	-122.3101	560984.968	4150085.411	4	0.187	0.203	0.311	0.283	37.4957	-122.3101	560983.945	4150085.764	5	0.186	0.204	0.322	0.278	37.4957	-122.3101	560982.807	4150086.152	6	0.185	0.203	0.337	0.267	37.4957	-122.3101	560981.681	4150086.537	7	0.184	0.2	0.353	0.259	37.4957	-122.3101	560980.602	4150086.905	8	0.184	0.198	0.356	0.266	37.4957	-122.3102	560979.555	4150087.28	9	0.183	0.196	0.353	0.267	37.4957	-122.3102	560978.411	4150087.67	10	0.18	0.196	0.345	0.267	37.4957	-122.3102	560977.38	4150088.036	11	0.175	0.199	0.336	0.27	37.4957	-122.3102	560976.298	4150088.419	12	0.17	0.206	0.345	0.262	37.4957	-122.3102	560975.244	4150088.785	13	0.175	0.204	0.356	0.252	37.4957	-122.3102	560974.079	4150089.203	14	0.184	0.196	0.368	0.243	37.4957	-122.3102	560972.994	4150089.591	15	0.184	0.199	0.376	0.237	37.4957	-122.3102	560971.927	4150089.979
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After generating a report, a preview is displayed. There are several fields the user can add information and options to modify the amplitude image map. The Pavement Structure Report includes:

1. Road name and description including:
 - a. number of lanes
 - b. surface material
 - c. surface condition
 - d. additional information
2. GPR survey details including:
 - a. GPR system
 - b. GPR system configuration
 - c. type of GPS
3. Overall Pavement Structure Summary listing:
 - a. Layer Names
 - b. GPR Velocities
 - c. Minimum, maximum and average layer thicknesses for all GPR lines included in the report.
4. Individual GPR line pavement structure report
 - a. Layer Names
 - b. GPR Velocities
 - c. Minimum, maximum and average layer thicknesses for that particular GPR line.

Sensors & Software

GPR Pavement Structure Report

Road Name:

Road Description

Number of Lanes:
 Surface Material:
 Surface Condition:
 Additional Information:

GPR Survey

GPR System:
 System Configuration:
 GPS System:

Pavement Structure Summary:

Layer	Signal Velocity (m/ns)	Thickness (mm)		
		Minimum	Maximum	Average
Asphalt	0.105	133	250	185
Granular	0.105	169	309	236

Line Name: Ordinary Rd - Eastbound Lane 1

Layer	Minimum	Thickness (mm)		Average
		Maximum	Average	
Asphalt	133	240	188	
Granular	170	289	233	

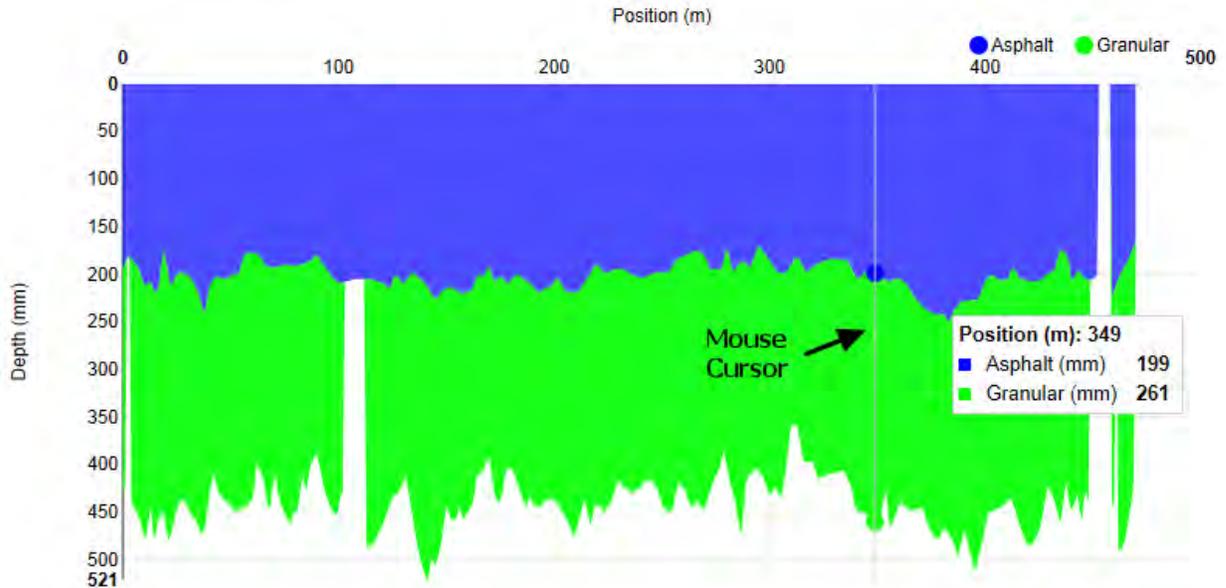
Ordinary Rd - Eastbound Lane 1 - Profile 1 of 1

Line Name: Ordinary Rd - Eastbound Lane 2

Layer	Minimum	Thickness (mm)		Average
		Maximum	Average	
Asphalt	170	250	202	
Granular	169	309	240	

Ordinary Rd - Eastbound Lane 2 - Profile 1 of 1

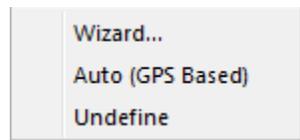
Field	Description
Save	Save the current report to an Adobe Acrobat PDF file.
Interactive Chart	Charts of layer thicknesses are interactive. Place the mouse cursor anywhere on the chart to display the position along the line and depth of each layer at that position.



3.13.4 Project Position Relationship

The Project Position Relationship defines the relationship between the project coordinates and a global coordinate system.

The Project Position Relationship menu has 3 options:



This menu is also available in the Project Explorer [Right Click](#) menu.

The **Wizard** takes the user step by step through manually adding global coordinates to a GPR project data.

Note: The position of Linesets, individual GPR lines or grid lines within the project cannot be modified by this Wizard.

Auto (GPS based) defines the project-to-global relationship using the GPS files generated during data collection or manually created and attached.

Undefine removes any previously-defined project-to-global relationship.

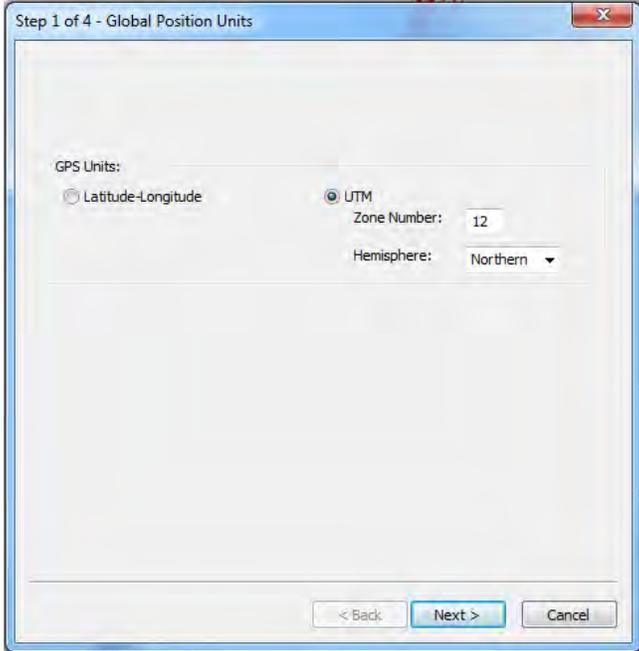
3.13.4.1 Wizard

Use the Wizard option to manually define the relationship between the project (X, Y) coordinates and the global coordinates (Latitude-Longitude or UTM) of the GPR project data.

Use the Wizard if:

- GPS data were not collected for a GPR data grid but one or two GPS positions in the grid area are known; GPS positions for the entire grid can be calculated.
- The automatic positioning of the grid using GPS files generated during data collection does not provide an accurate fit to the GPR data grid so you would like to manually enter GPS positions reference points to provide better positioning of the grid.

Step 1- Global Position Units



Global Position Units are defined as Latitude-Longitude or UTM (Universal Transverse Mercator).

1. Select **Latitude-Longitude** or **UTM**. UTM is the default.
2. If UTM is selected, update the **Zone Number** field.
3. If UTM is selected, in the **Hemisphere** drop-down list, click **Northern** or **Southern**.
4. Select **Next**.

Step 2 – Project to Global Transformation – Primary Point

Define a primary X, Y position in the Project coordinate system with a known global position in UTM or Latitude-Longitude.

Step 2 of 4 - Project to Global Transformation - Primary Point

For the primary point, please enter the coordinate relationship between the project and the world.

The primary point acts as the anchor for the project and any subsequent rotation of the project will happen around this point. The point is a 1:1 mapping between the local coordinate system of the project and the global coordinate system.

Primary Point

Project (ft)

X: 0

Y: 0

Global (m)

East: 400567.058

North: 3701368.032

< Back Next > Cancel

Step 2 of 4 - Project to Global Transformation - Primary Point

For the primary point, please enter the coordinate relationship between the project and the world.

The primary point acts as the anchor for the project and any subsequent rotation of the project will happen around this point. The point is a 1:1 mapping between the local coordinate system of the project and the global coordinate system.

Primary Point

Project (ft)

X: 3,000

Y: 0,000

Global (deg)

Long: -112.069816191

Lat: 33.44711875533

< Back Next > Cancel

1. In the Primary Point fields, enter the project X, Y coordinates for the point where the global position is known.

The first time you select this option, the Project X, Y position defaults to the center of all the GPR grid data; this could be the center of one grid or several grids. If the user manually defines the project X, Y position, the wizard remembers these values the next time the Wizard is run. Any X, Y point in the project coordinate system can be entered; X=0, Y=0 is popular.

2. In the **Global East** or **Long** field enter the **Easting** or **Longitude** Global coordinates.

In the **Global North** or **Lat** field enter the **Northing** or **Latitude** Global coordinates.

UTM Northing and Easting values are always entered in meters and can be positive or negative.

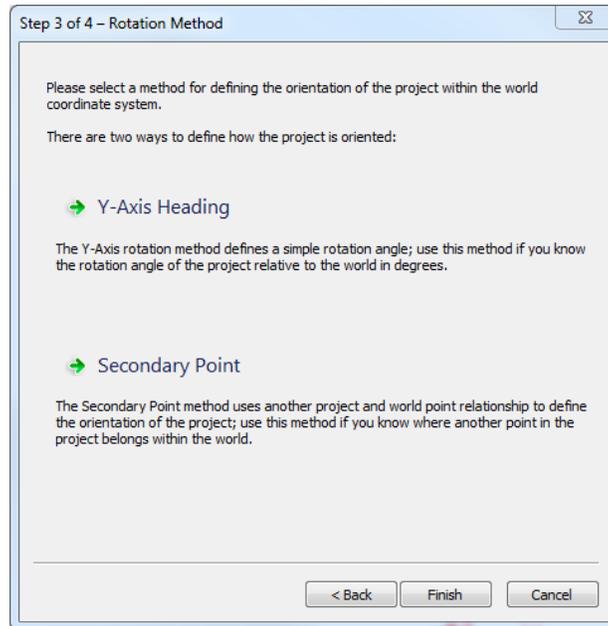
For example, the UTM values above position the X=0, Y=0 project coordinate point at Easting = 400567.058 meters and Northing = 3701368.032 in Zone 12 in the Northern hemisphere.

Latitude and Longitude values are always entered in decimal degrees. Latitudes north of the Equator are positive (+) values and south are negative (-) values. Longitudes east of the Prime Meridian (Greenwich) are positive (+) and west are negative (-).

Step 3 – Rotation Method

The orientation of the project-to-global coordinate relationship can be set in two ways:

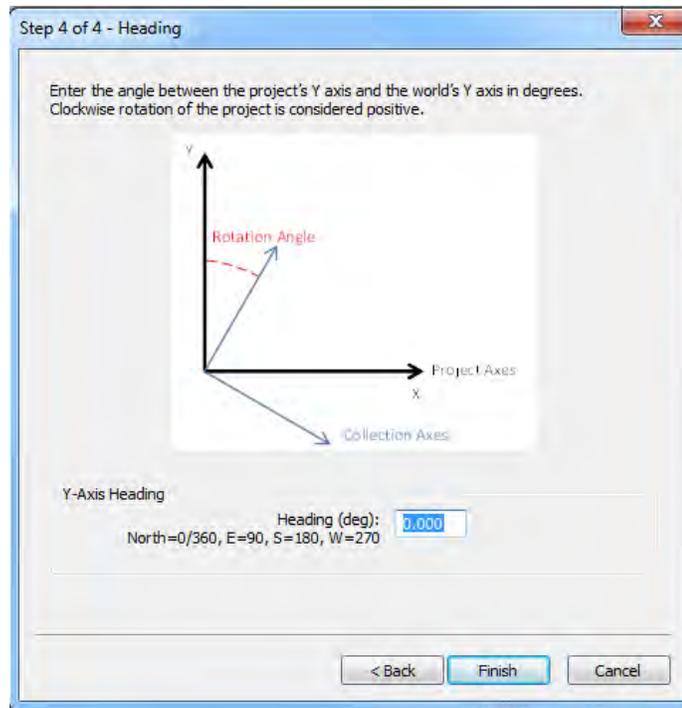
1. Rotating using a Y-Axis heading, or
2. Defining the global position of a second point in the project.



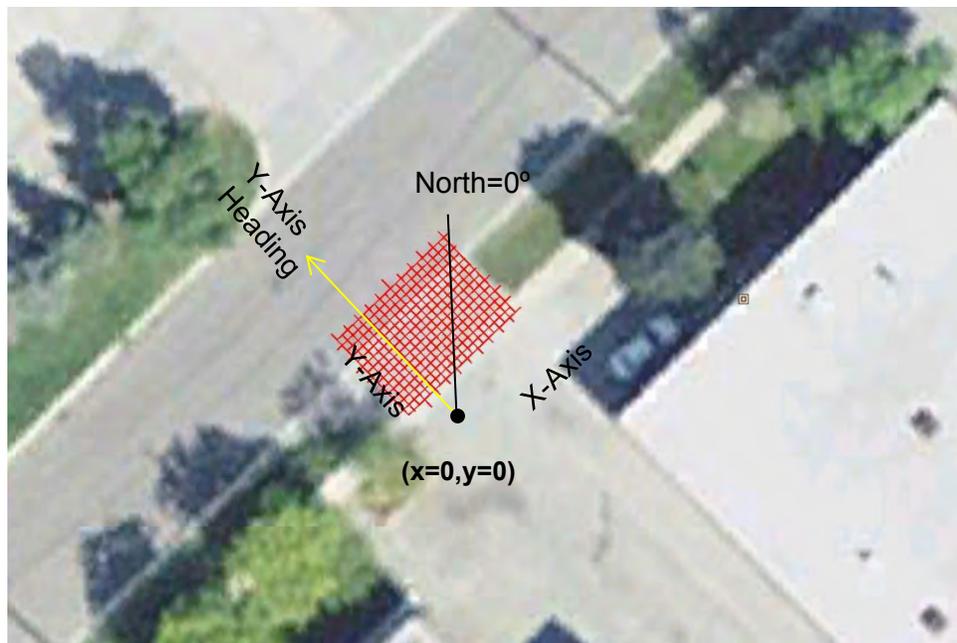
Note: if you are simply moving the Primary Point to a new location and not changing the orientation, select the **Finish** but before selecting either of the rotation methods listed.

Step 4a – Y-Axis Heading

Enter the Y-Axis Heading in degrees from 0 (zero) to 360 degrees. Angles are defined positive in the clockwise direction, for example, East is 90, South is 180, and West is 270 degrees.



If the project-to-global coordinate relationship is acceptable, click **Finish** to save the new settings and exit the dialog.



Step 4b – Secondary Point

Define a secondary X, Y position in the Project coordinate system with a known global position in UTM or Latitude-Longitude.

Step 4 of 4 – Project to Global Transformation – Secondary Point

For the secondary point, please enter the coordinate relationship between the project and the world.

Define the orientation by entering the location of a second point from the project within the world.

The secondary point is used to calculate the rotation angle.

Click Finish to apply the transformation.

Secondary Point

Project (ft)		Global (m)	
X:	0.000	East:	400570.150
Y:	0.000	North:	3701376.755

< Back Next > Cancel

1. In the Secondary Point fields, enter the project X, Y coordinates for a second point where the global position is known.

The first time you select this option, the Project position defaults to X=0, Y=0 but any X, Y point in the project coordinate system can be entered.

2. In the **Global East** or **Long** field enter the **Easting** or **Longitude** Global coordinates.

In the **Global North** or **Lat** field enter the **Northing** or **Latitude** Global coordinates.

UTM Northing and Easting values are always entered in meters and can be positive or negative.

For example, the UTM values above position the X=0, Y=0 project coordinate point at Easting = 400570.150 meters and Northing = 3701376.755 in Zone 12 in the Northern hemisphere.



Latitude and Longitude values are always entered in decimal degrees. Latitudes north of the Equator are positive (+) values and south are negative (-) values. Longitudes east of the Prime Meridian (Greenwich) are positive (+) and west are negative (-).

Note: The Primary and Secondary points are used to determine the heading only; the GPR data does not expand or contract to fit the data from the project coordinates to the global coordinates. The Primary Point, the heading from Primary to Secondary Point and the local positioning method used for the survey, typically an odometer, are used to position the grid in global coordinates.

The Secondary point method is commonly used when GPS positions using a handheld GPS for two corners of the grid are collected out in the field.

Using GPS Positions from Third-Party Sources

Google Earth is a third-party source to obtain Global positions for the Primary and/or Secondary Points in the area of your grid. Find the location of the GPR grid in Google Earth and then use the mouse cursor to find the GPS position for a particular point near or within the grid. As the mouse cursor is moved around on the image, the global position is listed on bottom edge.

To obtain better accuracy for points, use the **Ruler** option in Google Earth to change the mouse cursor from the default hand to cross-hairs.

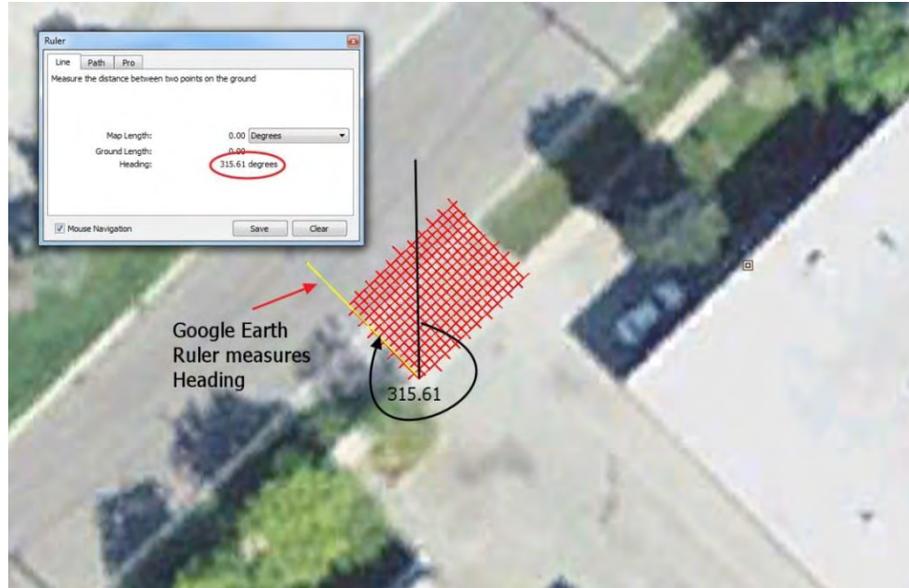


Global positions are entered as UTM or Latitude-Longitude in decimal degrees. Google Earth usually displays in degrees-minutes-seconds but you can change the Google Earth display to decimal degrees or UTM under **Tools > Options > 3D View Tab > Show Lat/Long**.

Extracting global positions from Google Earth is useful when a GPR grid was collected along a visible feature such as the edge of a sidewalk, building or road.

Note: while this method ensures the data align with features visible in Google Earth, the absolute accuracy of the GPS coordinates are only as good as the Google Earth imagery placement, which can be several meters in some places.

The Google Earth Ruler can also be used to help determine the Y Axis Heading. If the Ruler function is set to degrees, it displays the Heading in degrees that the Heading dialog requires.



3.13.4.2 Auto (GPS-based)

Auto calculates the Project-to-Global coordinate relationship using GPS files in the project file.

The Auto menu option is most commonly used to restore the original Project-to-Global relationship after altering it using the Wizard.

Note: it is not recommended to have data in a project widely separated in space. A warning is displayed if GPS files from different UTM zones are found because the positional accuracy decreases with increasing separation.

Grids

If a grid of GPR lines were collected with GPS, the Project-to-Global coordinate relationship is calculated by finding the “best fit” between the known positions of the grid lines and the GPS positions for those lines. This calculation was automatically done when the project was opened or the grid was imported into EKKO_Project.

The best-fit calculation minimizes the error between the grid lines and GPS but depending on the GPS accuracy and the correlation with the grid lines, a manual adjustment may be necessary in some cases. Use the Wizard option to do this.

GPR Lines

When individual GPR lines in a Lineset are collected with GPS, the raw GPS positions are used to calculate the Project-to-Global coordinate relationship.

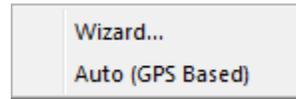
3.13.4.3 Undefine

Undefine removes any previously-defined Project-to-Global coordinate relationship. When the Project-to-Global relationship is undefined, GPS coordinates are not displayed on the MapView Status Bar and you cannot generate Google Earth (KMZ) export slice images to KMZ files for display in Google Earth (to learn more, see the SliceView User's Guide).

3.13.5 Grid Position Relationship

The Grid Position Relationship defines the relationship between the project coordinates and grids in the project.

The Project Position Relationship menu has 2 options:



This menu is also available in the Project Explorer [Right Click](#) menu.

The **Wizard** takes the user step by step through manually defining the relationship between the project coordinate and the grid coordinate systems.

Note: The position of Linesets, individual GPR lines or grid lines within the project cannot be modified by this Wizard.

Auto (GPS based) defines the grid-to-project relationship using the GPS files generated during data collection or manually created and attached. It is not accessible if there is no Project-to-Global relationship defined.

3.13.5.1 Wizard

Use the Wizard option to manually position a grid in the project coordinate system.

Step 1 – Primary Point

Define a primary X, Y position in the grid coordinate system to define in the Project coordinate system.

Step 1 of 3 - GRID0-Grid #0000 - Primary Point

For the primary point, please enter the coordinate relationship between the grid and the project.

The primary point acts as the anchor for the grid and any subsequent rotation of the grid will happen around this point.
The point is a 1:1 mapping between the local coordinate system of the grid and the project coordinate system.

Primary Point

Grid (m)		Project (m)	
X:	0	X:	10,000
Y:	0	Y:	10,000

< Back Next > Cancel

1. In the Primary Point fields, enter the project **X**, **Y** coordinates for the grid point. Select a grid point with the realization that any possible rotation of the grid is about this point.

The Project position defaults to the XY position of the center of the grid if a Project-to-Global relationship has been defined by GPS files; otherwise, it defaults to X=0, Y=0. Any X, Y point in the grid coordinate system can be entered.

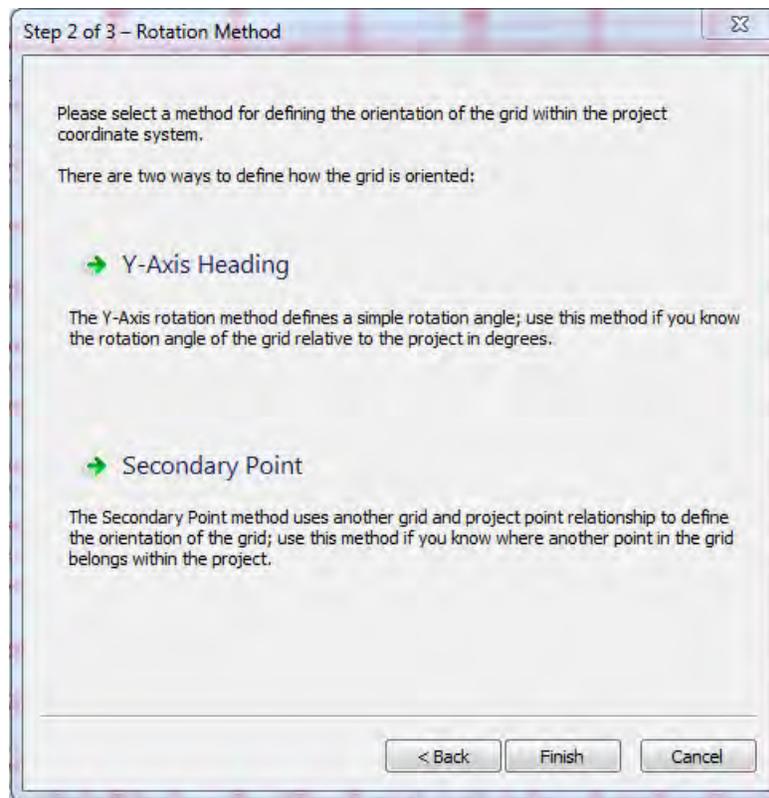
2. In the Project Points field, enter the project X, Y coordinates for the primary point.

For example, the values above position the X=0, Y=0 grid coordinate point at project coordinate X=10, Y=10.

Step 2 – Rotation Method

The orientation of the grid can be set in two ways:

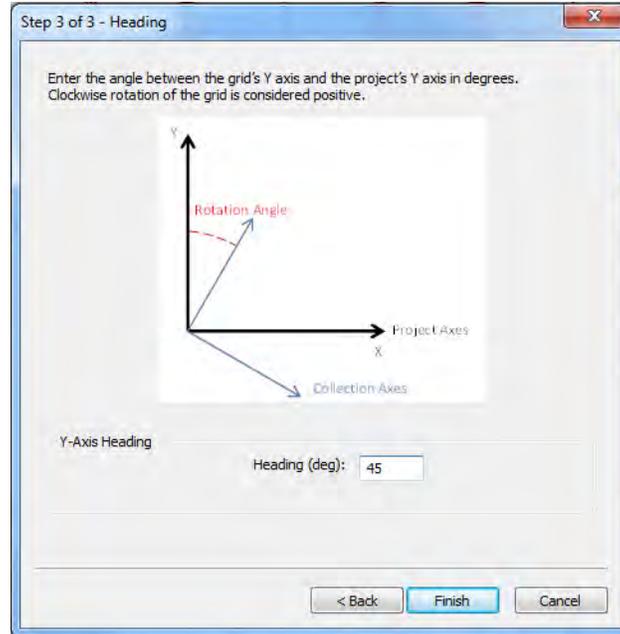
1. Rotating using a Y-Axis heading, or
2. Defining the project position of a second point in the grid.



Note: if you are simply moving the Primary Point to a new location and not changing the orientation, select the **Finish** but before selecting either of the rotation methods listed.

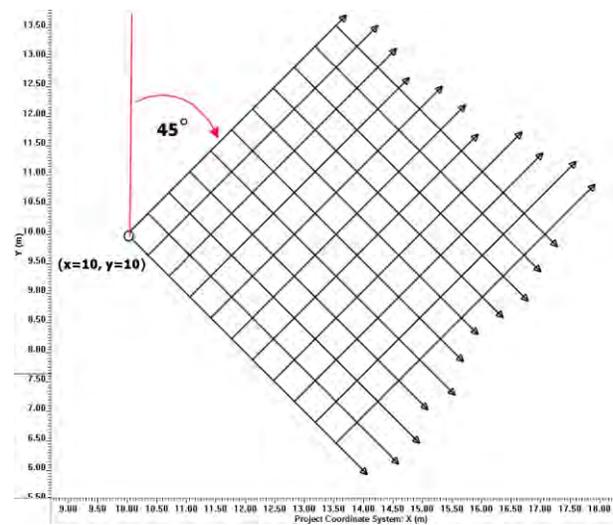
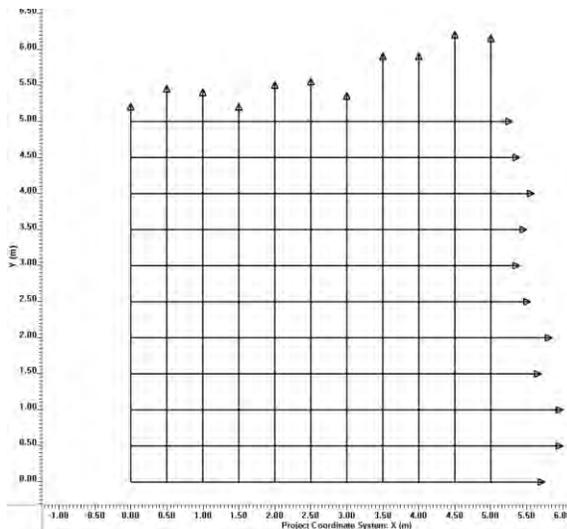
Step 3a – Y-Axis Heading

Enter the Y-Axis Heading in degrees from 0 (zero) to 360 degrees. Angles are defined positive in the clockwise direction, for example, East is 90, South is 180, and West is 270 degrees.



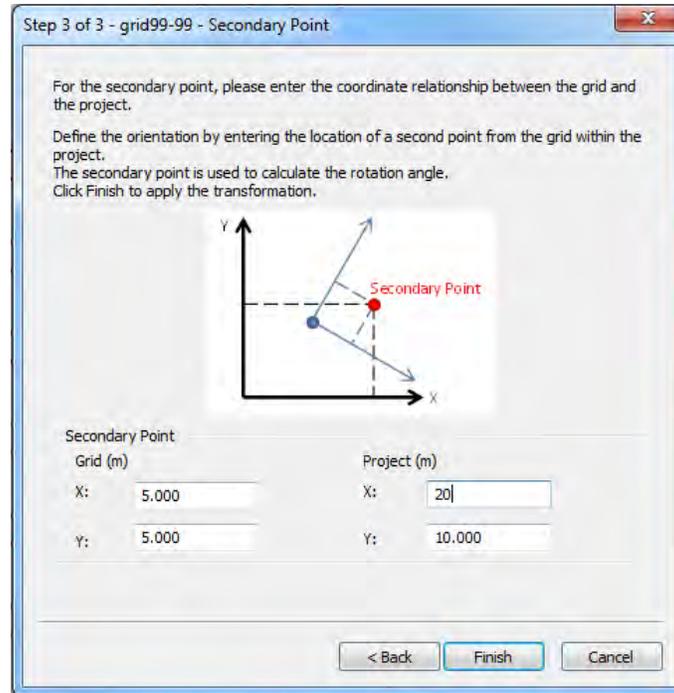
Enter the rotation angle and click **Finish** to save the new settings and exit the dialog.

For example, the two steps above moves the $x=0, y=0$ point of the grid to project position $x=10, y=10$ and the grid is rotated 45 degrees clockwise around the $x=10, y=10$ point.



Step 3b – Secondary Point

Another way of rotating the grid is by defining the project position of a second point in the grid. .



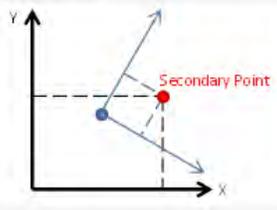
Step 3 of 3 - grid99-99 - Secondary Point

For the secondary point, please enter the coordinate relationship between the grid and the project.

Define the orientation by entering the location of a second point from the grid within the project.

The secondary point is used to calculate the rotation angle.

Click Finish to apply the transformation.



Secondary Point

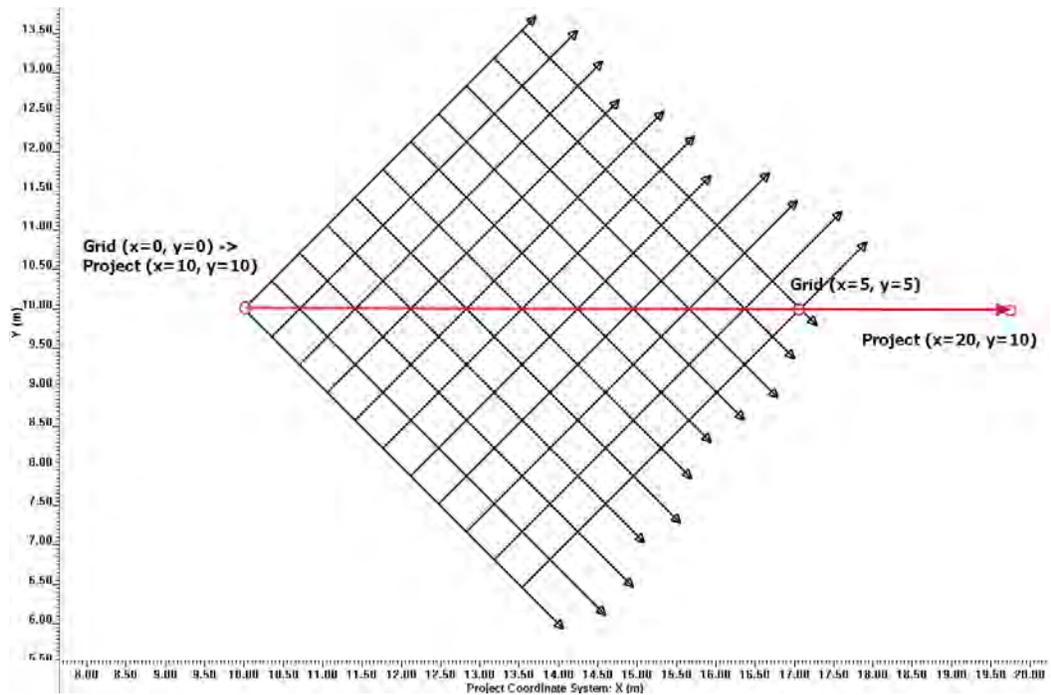
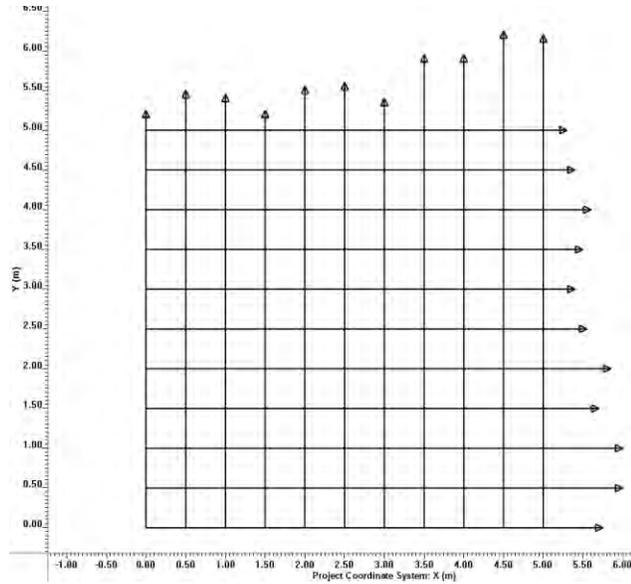
Grid (m)		Project (m)	
X:	5.000	X:	20
Y:	5.000	Y:	10.000

< Back Finish Cancel

1. In the Secondary Point fields, enter the project **X**, **Y** coordinates for the grid point. Select a point with the realization that the grid will rotate based on the direction from the first point to the second point. Any X, Y point in the grid coordinate system can be entered.
2. In the Project Points field, enter the project X, Y coordinates for the secondary point.

Click **Finish** to save the new settings and exit the dialog.

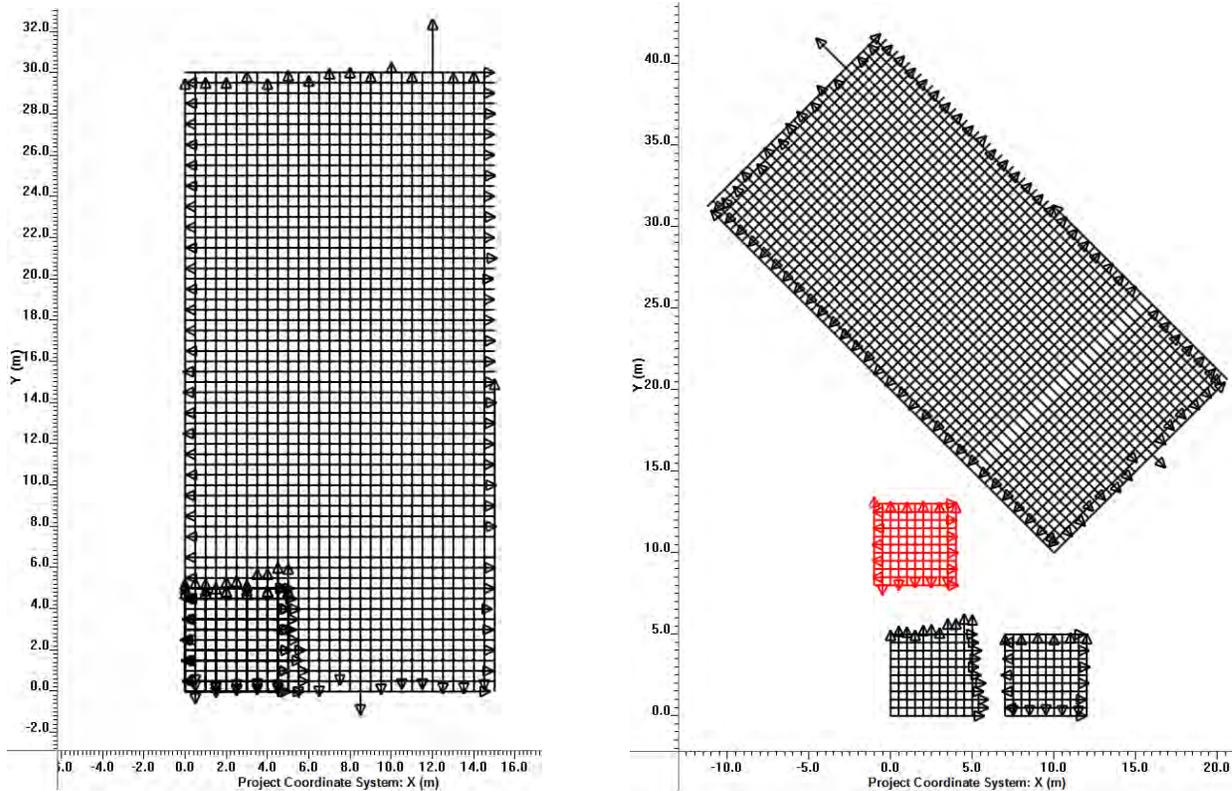
For example, the two steps above moves the $x=0, y=0$ point of the grid to project position $x=10, y=10$ and the grid is rotated based on secondary grid point $x=5, y=5$ moving in the direction of project position $x=20, y=10$.



Note: The Primary and Secondary points are used to determine the heading only; the GPR grid does not expand or contract to fit the data from the grid coordinates to the project coordinates. The Primary Point, the heading from Primary to Secondary Point and the local positioning method used for the survey, typically an odometer, are used to position the grid in project coordinates.

Positioning Multiple Grids

The grid positioning methods shown above can be used to place more than one grid into the correct spatial location in the project space.



3.13.5.2 Auto (GPS-based)

Auto calculates the Grid-to- Project coordinate relationship using GPS files in the project file.

The Auto menu option is most commonly used to restore the original Grid-to- Project relationship after altering it using the Wizard.

Auto is only accessible if a Project-to-Global relationship has been defined by GPS files.

Note: it is not recommended to have data in a project widely separated in space. A warning is displayed if GPS files from different UTM zones are found because the positional accuracy decreases with increasing separation.

Grids

If a grid of GPR lines were collected with GPS, the Grid-to- Project coordinate relationship is calculated by finding the “best fit” between the known positions of the grid lines and the GPS positions for those lines. This calculation was automatically done when the project was opened or the grid was imported into EKKO_Project.

The best-fit calculation minimizes the error between the grid lines and GPS but depending on the GPS accuracy and the correlation with the grid lines, a manual adjustment may be necessary in some cases. Use the Grid Position Relationship Wizard option to do this.

3.13.6 Process

Use the optional Processing module to edit and process GPR lines using various functions including repositioning, temporal and spatial filters, and migration.

Processing is applied to any checked GPR lines. If no GPR lines are checked, processing is applied to the selected GPR line.

Note: Selecting (not checking) a GPR line and then using the Project Explorer right-click menu for processing only processes the selected line regardless of whether any other lines are checked.

It is a best practice to make a copy of the GPR Lineset, grid or lines and then apply the processing to the copy of the GPR lines. While processing can always be undone, this is a good way to plot both the original data and the processed data to compare the effects of the processing.

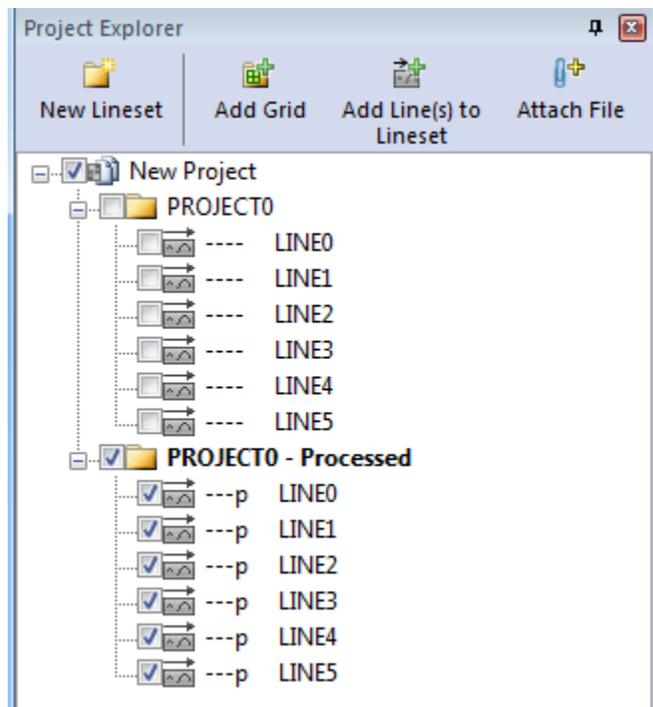


Figure 13: Files to be processed must be checked before selecting Process.

1. To open the Processing window, click **Tools > Process**:

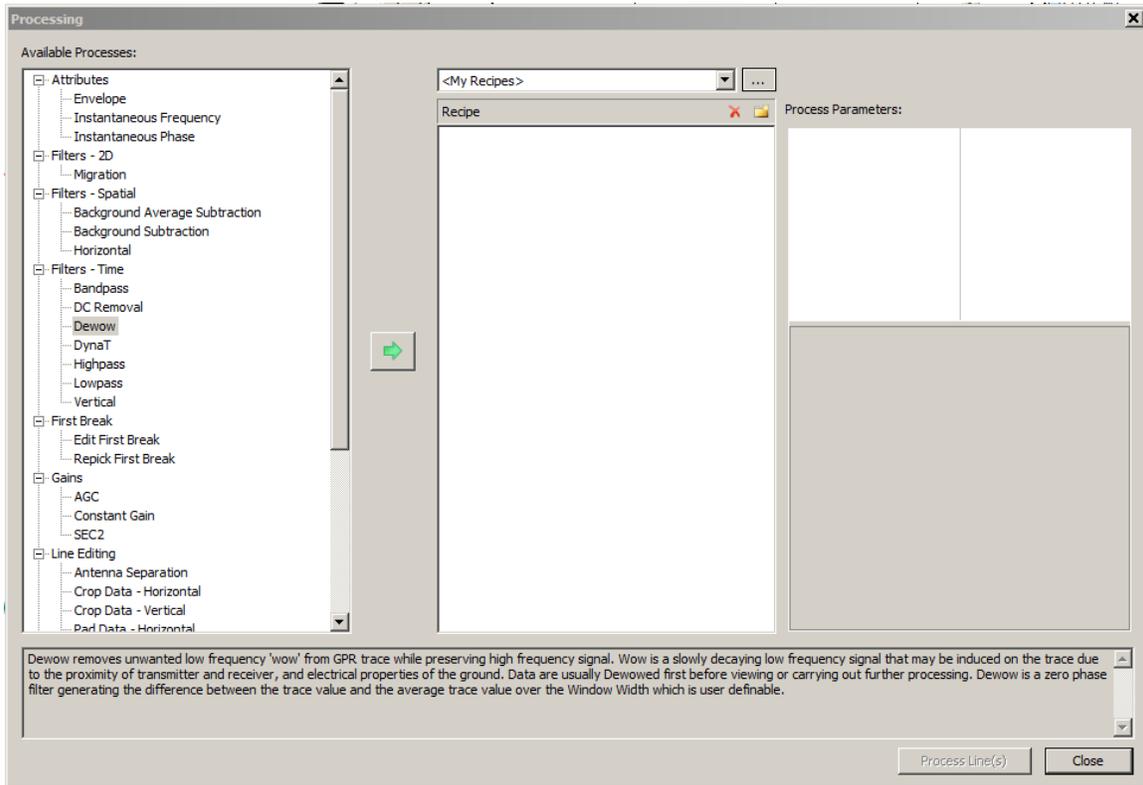


Figure 14: The Processing dialog lists available processing for GPR lines.

The **Available Processes** pane lists all processes that you can add to your [Recipe](#).

2. To add a process to your recipe, in the **Available Process** pane, select the process. To expand the processes list, click the **+** sign.

3. Click the selection arrow .

When a process is selected, a description is displayed on the bottom of the dialog. Detailed descriptions of every process are provided in [Processing Functions](#).

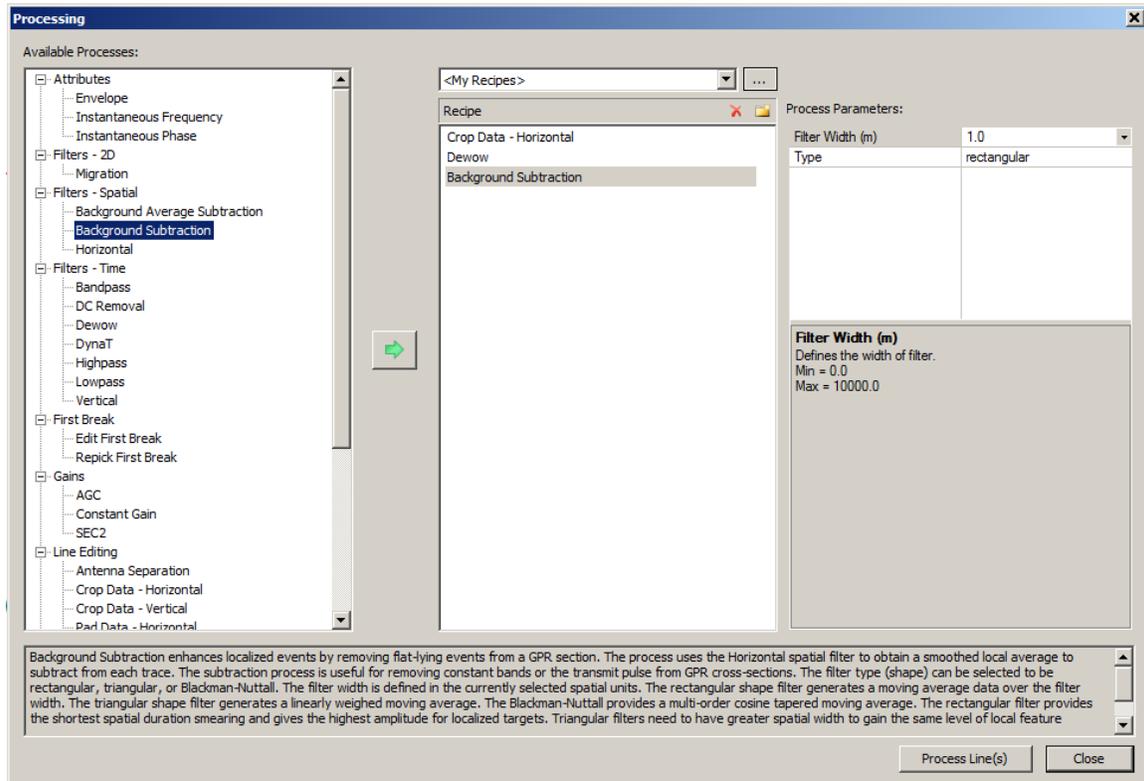


Figure 15: Processes added to the Recipes pane.

- Repeat step 3 until you have added all the processes you want to add to your recipe.

3.13.6.1 Input Parameters

Most processes require one or more input parameters. When a process is selected in the Recipe pane, the parameters are listed in the Process Parameters pane.

- To modify a process value, click the drop-down arrow.
- Click a value.

For most numerical parameters, a new value can be entered by clicking the current value and then entering the new value.

3.13.6.2 Applying Processing

Once you have completed processing, click **Process Line(s)** to apply the processing to the selected GPR line(s).

The list of GPR lines is updated in Project Explorer to display the GPR lines that have been processed (indicated by a small letter “p” beside the file - [Figure 4](#)).

3.13.6.3 Deleting a Process

- To delete a process, from the Recipes pane click the process you want to remove.
- Click the **Delete** .

3.13.6.4 Save Recipe

A Recipe is a set of processing operations that can be saved and used again on other projects. Creating Recipes allows you to reuse common processes or compare different data sets using the same processing.

1. To save the selected processes to your Recipes, in the Recipes pane, click Add **Recipe to my Recipes** 
2. In the **Create New Recipe** dialog box, enter a name for the recipe.



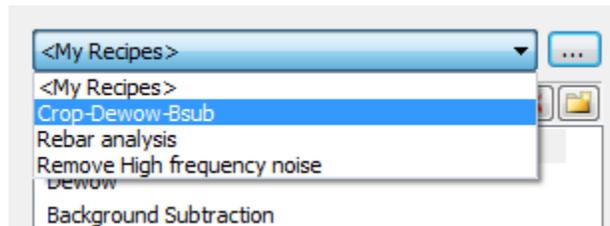
3. Click **OK**.

Once saved, the recipe is available in the **My Recipes** drop-down.

Any recipe can be edited, saved, and renamed as another recipe.

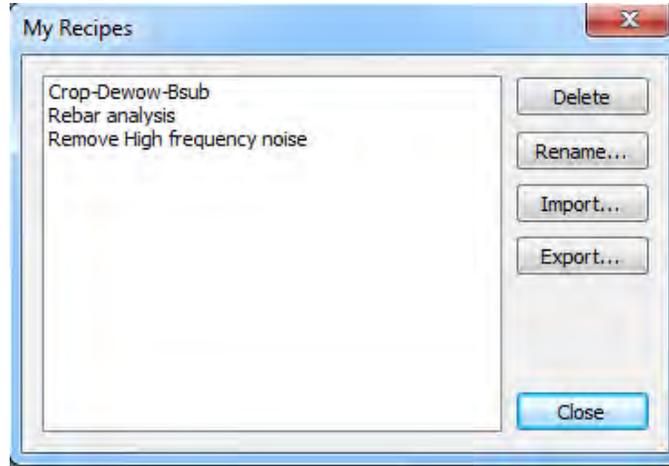
3.13.6.5 Load Recipe

Once a recipe has been saved, you can access it by clicking the My Recipes drop-down list above the Recipe pane.



3.13.6.6 My Recipe Management

- To open your recipe list, in the Processing window, click the ellipsis icon  beside the My Recipes drop-down.



- Use the following table as a guide to working with the My Recipes dialog box.

Field	Description
Delete	<ol style="list-style-type: none"> In the text area, select the recipe you want to remove. Click Delete. In the confirmation dialog box, click Yes.
Rename	<ol style="list-style-type: none"> To change the name of a recipe, click the recipe name. Click Rename. In the Rename Recipe dialog box, type the new recipe name. Click OK.
Import	<ol style="list-style-type: none"> To bring a recipe file in to your recipe file, click Import. In the Open dialog navigate to, and then select the file you want to import. Click Open.
Export	<ol style="list-style-type: none"> To send a recipe to another EKKO_Project user, select the recipe. Click Export. In the Save As dialog box, save the file.

Note: Imported and exported recipes are saved as a .json files.

3.13.7 Undo Process

- To undo processing click **Tools > Undo Process**.

This resets processed GPR lines to their original state before processing was applied to them or to their processing state when they were copied.

When a line is copied, its current processing is permanent and cannot be undone.

- In the confirmation dialog box, click **Yes** to undo the processing.

Otherwise, click **No**.

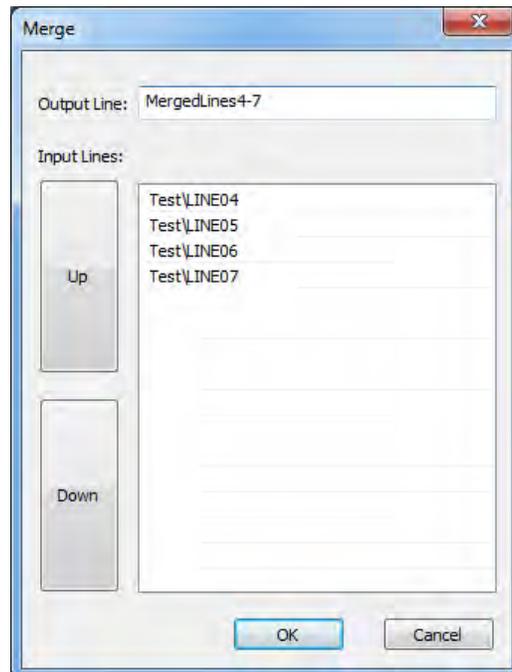
3.13.8 Merge Lines

Sometimes during data acquisition, a long, continuous GPR survey line is broken up into two or more pieces and saved as separate lines. Merge Lines is used to combine the data from two or more GPR lines into a single, separate line.

In Project Explorer, check the GPR lines to be merged and then select **Tools > Merge Lines**.

A dialog allows the merge order of the lines to be changed by selecting the line name and pressing the Up or Down buttons to move the line in the list.

The name of the merged line defaults but can be edited.



Press OK to create the new merged line. If all the lines came from the same folder, the new, merged line is saved to that folder. If the lines came from different folders, the new, merged line is saved in a new lineset folder.

If the merged line name conflicts with a line name already in the project, the new line is automatically appended with (2), (3) etc.

Some of the restrictions/features of Merge Lines are:

1. Lines cannot be merged together if any of the following survey parameters differ:
 - a. Survey Type
 - b. Frequency
 - c. Time Sampling Interval
 - d. Step Size
 - e. Antenna Separation

2. If the lines differ in Time Window length the merges the lines using the longest time window, padding data onto the bottom of lines with shorter time windows so no data is ever lost.
3. If lines have a different First Break point number the largest first break point number from all the lines is used and other lines are padded at the top so that no data is lost during the merge operation.
4. Traces are not shifted for differences in the First Break values between lines. It is best to run the [Repick First Break](#) routine for each line before merging or on the merged line so the first break is consistent for the new merged line.
5. The Start Position of the new merged line is the same as the Start Position of the first line in the merge list.
6. The number of Stacks of the new merged line is the same as the number of Stacks of the first line in the merge list.
7. Lines with interpretations can be merged.

A list of lines used to create a merged line can be seen by selecting the line in the **Project Explorer**, and then selecting the **Acquisition tab** and expanding **Additional Info**.

3.13.9 GPS

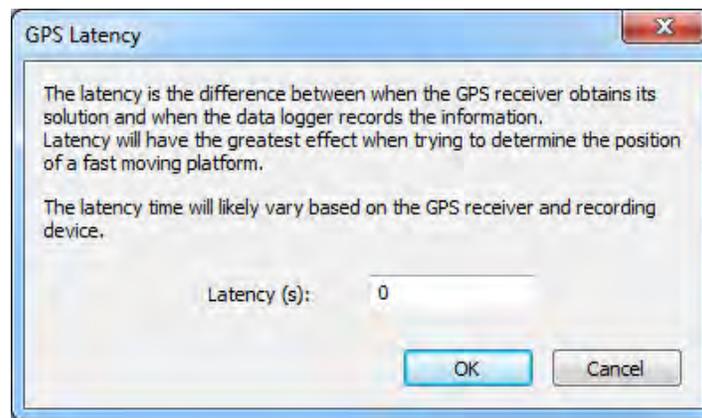
The Survey Line offset and Latency time are used to determine which part of the recorded GPR section correlates to a given GPS position.

3.13.9.1 Latency

The GPS latency time is the time difference between when the GPS receiver obtains its position and when it logged by the DVL. If GPS latency time is not corrected for, the GPS position of targets and features of interest in the GPR line is less accurate.

GPS latency is not a large problem when GPR data are collected on slow-moving platforms such as the SmartCart or SmartTow; it has the largest effect when trying to determine the true position of a fast-moving platform such as the SmartChariot.

For example at 25 kph, you are moving 6.94m per second. If the GPS has 1.00 second latency, your data position would be off by 6.94m. Further, if you also collect data in opposite direction (i.e. north and south adjacent lanes) the positional offset on a linear target such as a buried utility that spans both lanes would be off by $6.94 \times 2 =$ almost 14m.

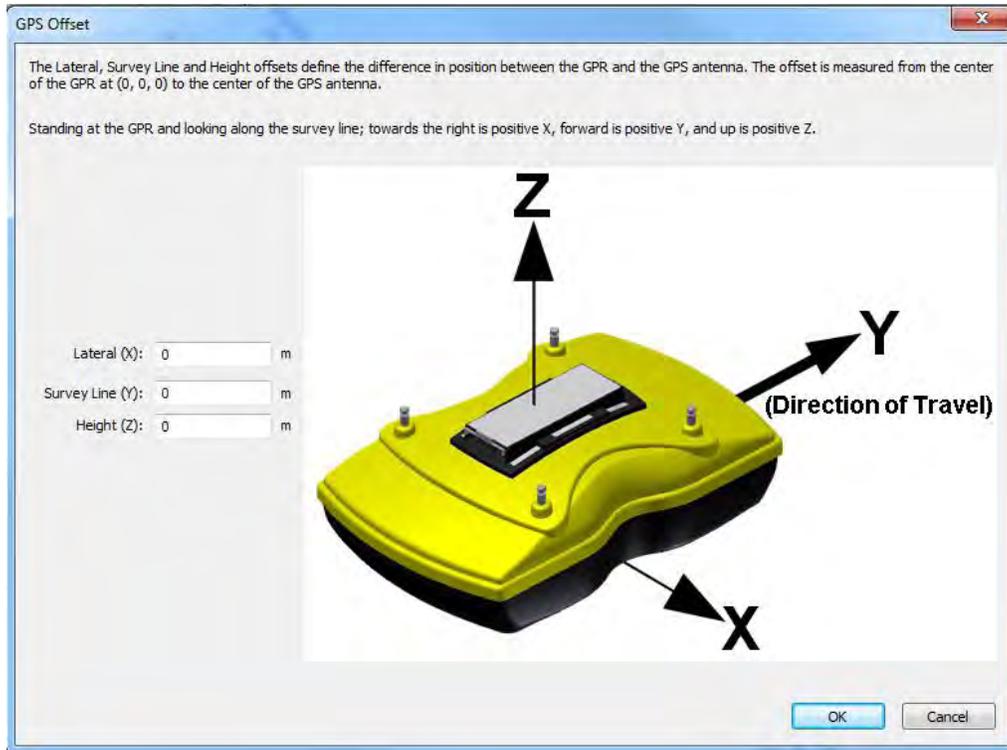


The latency time will vary by GPS, and data logger hardware/software and can be calculated and input in this dialog.

See Appendix C: GPS Latency Procedure for calculating the GPS latency time for your system.

3.13.9.2 Offset

Offset defines the X, Y and Z offset distances between the center of the GPR system (or antennas, if using a low frequency) and the GPS. These distances are necessary to correct the position of the GPS if it is offset from the GPR.



This option displays a diagram that defines the co-ordinate system for the GPS X, Y and Z offset values.

Lateral (X)

X (or Lateral) is the distance, left or right of the survey line direction, from the GPR to the GPS Antenna. Looking in the survey line direction, the distance is positive if the GPS receiver is to the right of the GPR and negative if it is to the left of the GPR.

Survey Line (Y)

Y (or Survey Line) is the distance from the GPR to the GPS receiver in the survey line direction. The distance is positive if the GPS receiver is ahead of the GPR and negative if it is behind the GPR.

Height (Z)

Z (or Height) is the height of the GPS receiver above the GPR.

Example

When a GPR system collects data using a SmartChariot, the GPS is offset +0.50 meters in the Survey Line (Y) direction and +0.50 meters in height (Z).



3.14 Window Menu

To open the Window menu drop-down list, click **Window**:

3.14.1 Open Line Preview

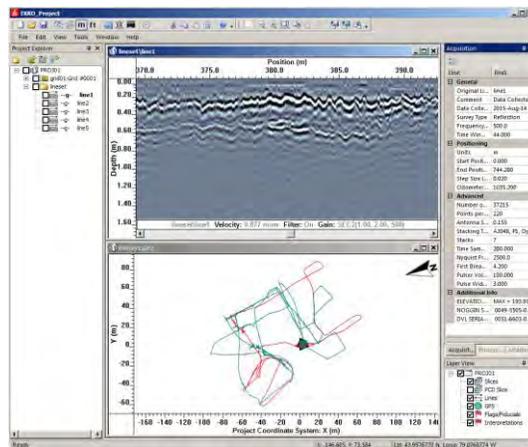
If the Line Preview window was closed, it can be opened by selecting **Window > Open Line Preview**.

3.14.2 Open MapView

If the MapView window was closed, it can be opened by selecting **Window > Open MapView**.

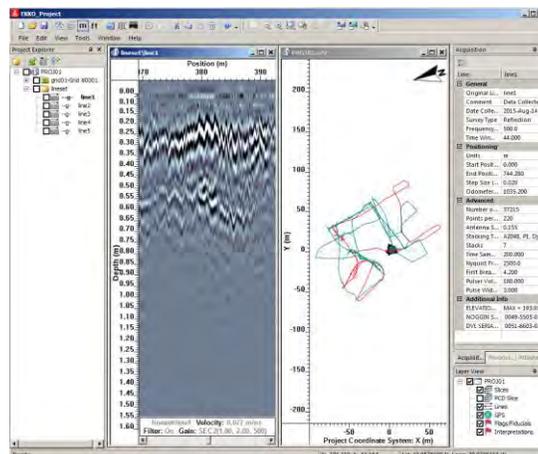
3.14.3 Tile Horizontally

Selecting **Window > Tile Horizontally** will arrange the Line Preview and MapView windows so they are tiled horizontally in the space between the other windows open on the screen.



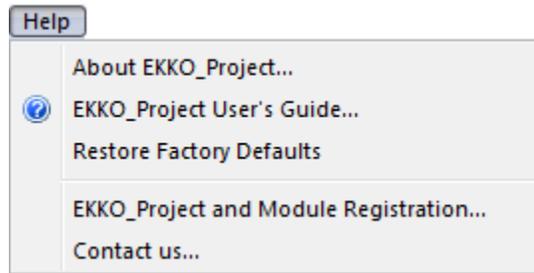
3.14.4 Tile Vertically

Selecting **Window > Tile Vertically** will arrange the Line Preview and MapView windows so they are tiled vertically in the space between the other windows open on the screen.



3.15 Help Menu

To open the Help menu drop-down list, click **Help**:



3.15.1 About EKKO_Project

This option displays the EKKO_Project version number, a description, and ownership information.

3.15.2 EKKO_Project User's Guide

Select this option to open this document in PDF.

Adobe Acrobat Reader must be installed on your PC to open this document. If not, you can download it from Adobe.

3.15.3 Restore Factory Defaults

Click **Restore Factory Defaults** to reset all the windows, dockable windows, menus, and toolbars to their default values.

Note: Restoring automatically closes EKKO_Project, so you must save your project first, and then re-open EP for the restoration to take effect

3.15.4 EKKO_Project and Module Registration

The Product Registration dialog allows you to enter a License Key, request a License Key, request a trial License Key or transfer a License to a different computer.

For more details see the **System Documentation and Software Installation** document.

3.15.5 Contact Us

Displays contact information for Sensors & Software including mailing address, email addresses, website, and phone and fax numbers.

4 Window Operations

EKKO_Project can display multiple panes on the main screen, but only one pane can be active and accept changes at one time.

4.1 Resizing the EKKO_Project Window

If an EKKO_Project pane is not maximized (full screen), you can resize it by clicking and dragging any frame or corner to the size you require.

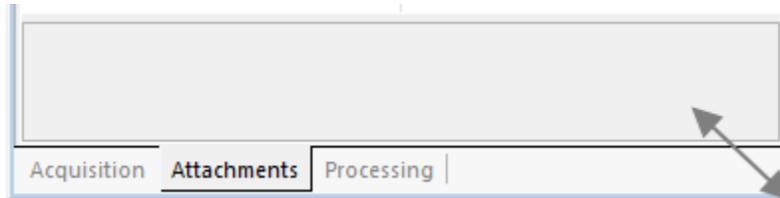


Figure 16: Click and drag a Project Explorer or Properties window to change its dimensions.

Note: As the size of the window changes, the information in the window will distort to fit the window size. If the window is made too small, the pane may close completely; click and drag the frame to re-open it.

4.2 Undocking and Docking Windows

1. To undock the [Project Explorer](#) and [Properties](#) panes from the edge of the screen, click and drag the window's title banner.
2. Drop the window at any location, or dock it on any edge of EKKO_Project.



Arrow icons () appear on the screen to indicate where (top, bottom, left, or right edge) the pane can be docked.

3. Drag the title banner to the icon and drop the window to dock it in the indicated position.

Note: It is a best practice to dock windows.

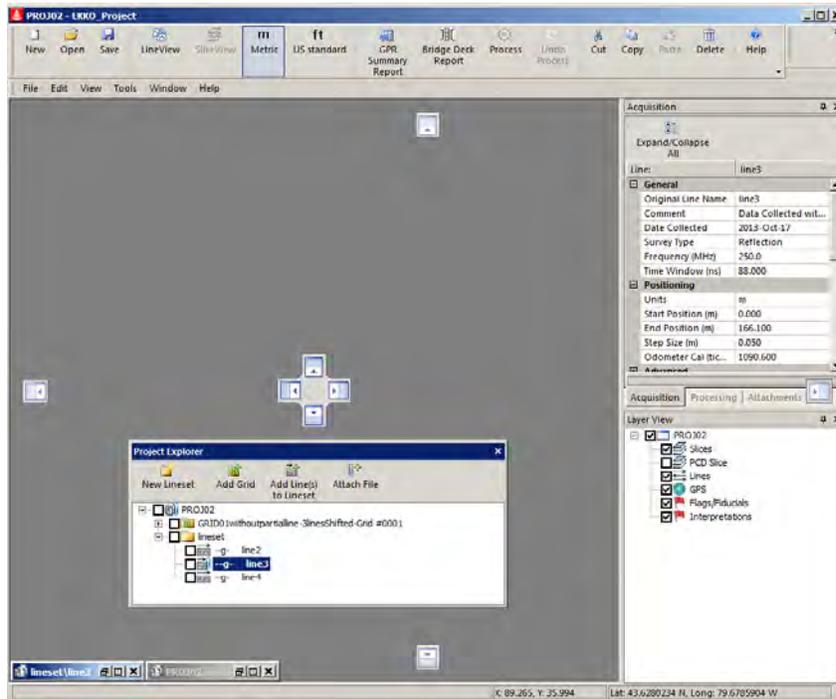


Figure 17: Example of moving the Project Explorer. Note the docking arrows.

4.3 Pinning Windows

To pin a docked Project Explorer or Properties pane to the side of EKKO_Project, in the pane's title bar, click the **Pin** icon (📌).

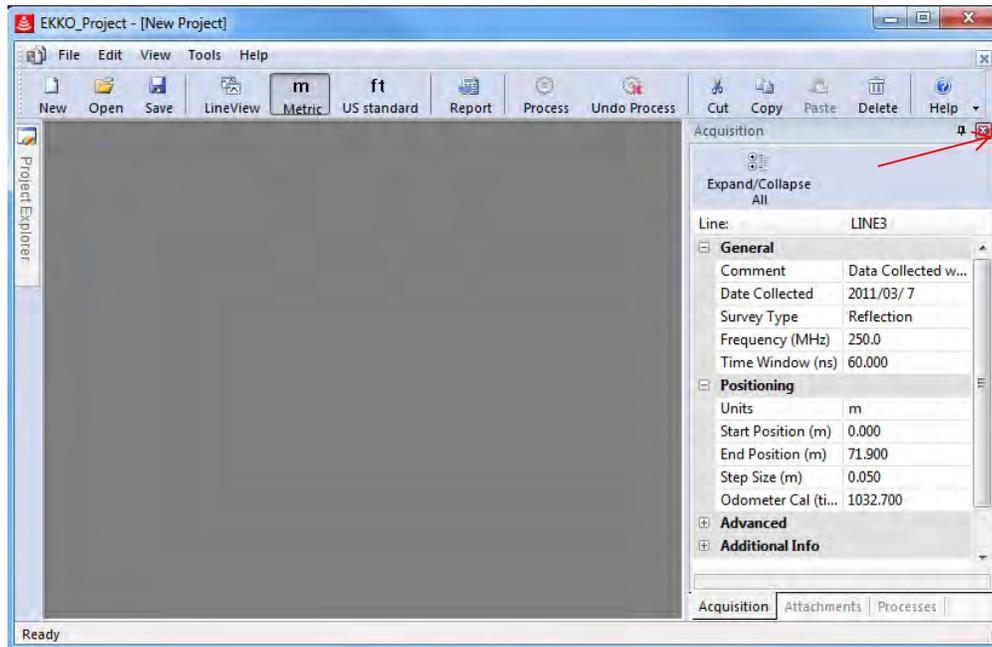


Figure 18: Example of pinning a window

- To expand these panes to their original size, click the pane and then click the pin icon to pin the window back into position.

4.4 Closing a Window

- To close a window, press close (☒)
- To reopen a closed window, in the menu bar, click **View** > [Toolbars and Docking Windows](#)

4.5 Adding or Removing Buttons from Toolbars

Use the Add and Remove buttons to edit the toolbars.

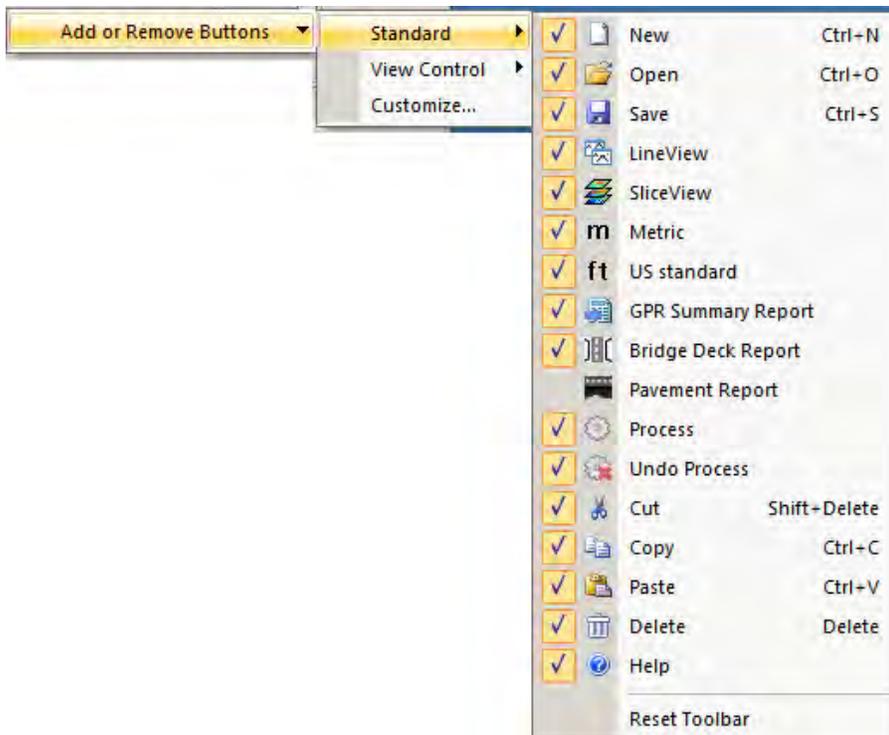
4.5.1 Standard Toolbar

- To manage what appears in the Standard toolbar, click the drop-down arrow beside

the Help icon  Help ▾.



- Click **Add or Remove Buttons > Standard**.



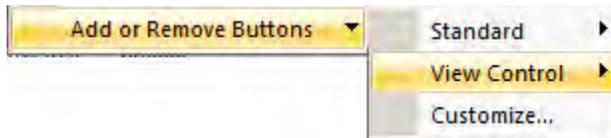
- To display an icon in the **Standard** toolbar, click beside the button to display checkmark icon.

- To restore the Standard toolbar to the factory default settings, click **Reset Toolbar**.
- To tailor the Standard toolbar to better suit your need, click **Customize > Toolbars** tab.

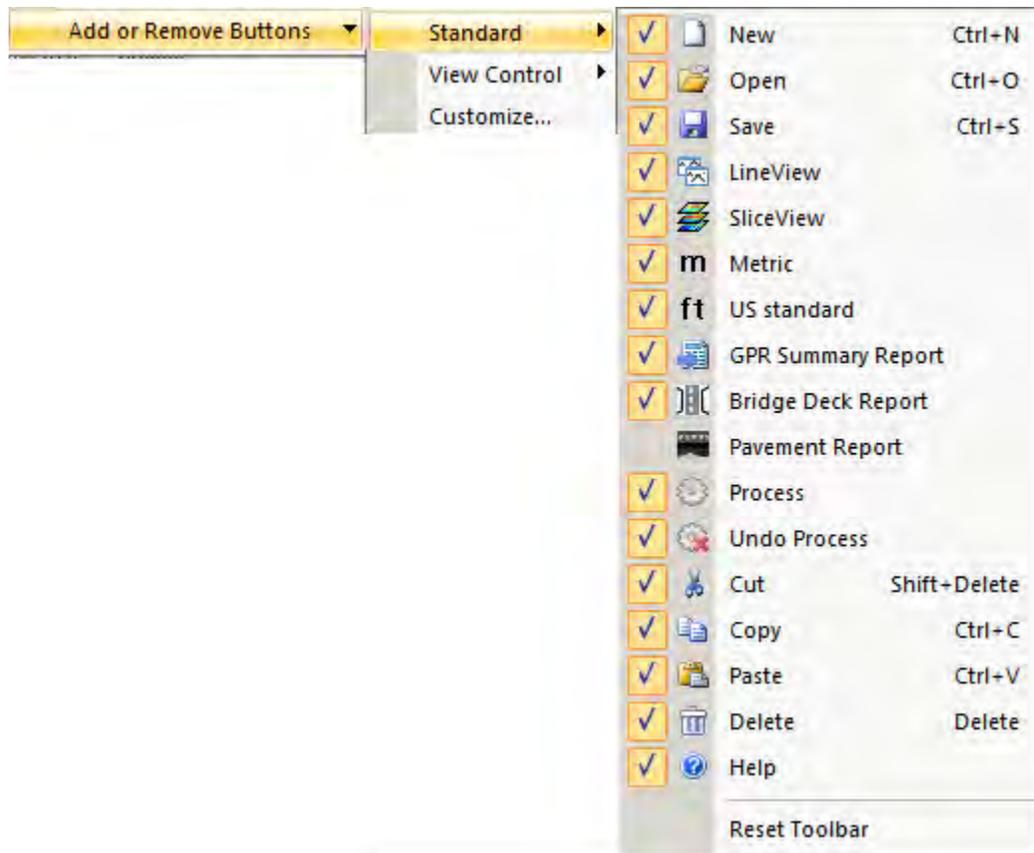
4.5.2 View Control Toolbar

1. To manage what appears in the View Control toolbar, click the drop-down arrow

beside the **Export View to File** icon .



2. Click **Add or Remove Buttons > View Control**.



3. To display an icon in the View Control toolbar, click beside the button to display checkmark icon.
 - To restore the View Control toolbar to the factory default settings, click **Reset Toolbar**.
 - To tailor the View Control toolbar to better suit your need, click **Customize >> Toolbars** tab.

5 Processing Functions

This section lists the details of the processing functions available in the optional [Processing](#) module.

5.1 Attributes

Note: If you are unfamiliar with Attributes, you should refer to an outside reference as only a brief overview is given in this document. For example, Yilmaz, O., 1987, "Seismic Data Processing; Investigations in Geophysics No. 2: Society of Exploration Geophysicists."

While we normally only plot and interpret the real part of a complex-valued signal, the imaginary (or quadrature) component can be used to reveal some useful information about the signal. These attributes, usually called 'instantaneous attributes', include instantaneous amplitude (or trace envelope), instantaneous phase, and instantaneous frequency.

If a complex trace is given by:

$$z(t) = x(t) + iy(t)$$

where $x(t)$ is the real component of the trace

and $y(t)$ the imaginary component of the trace

Instantaneous Amplitude (or Trace Envelope) is given by:

$$e(t) = (x^2(t) + y^2(t))^{1/2}$$

Instantaneous Phase is given by:

$$\phi(t) = \text{atan}\left(\frac{y(t)}{x(t)}\right)$$

Since Instantaneous Frequency is the derivative of Instantaneous Phase, it is given by:

$$\omega(t) = \left(\frac{1}{2\pi}\right) \frac{d\phi}{dt} = \left(\frac{1}{2\pi}\right) \cdot \frac{y'(t)x(t) - y(t)x'(t)}{x^2(t) + y^2(t) + \varepsilon}$$

where $x'(t)$ And $y'(t)$ are calculated using central differences:

$$x'(t) = \frac{x_{i+1} - x_{i-1}}{2\Delta t} \text{ and } y'(t) = \frac{y_{i+1} - y_{i-1}}{2\Delta t}$$

and ε is a constant value (defined as 1) to increase the stability of the function by preventing division by zero.

Since these attributes can only be calculated using the imaginary component of the complex trace, it is necessary that it be obtained before processing the data. This is done automatically in the Envelope, Instantaneous Phase, and Instantaneous Frequency routines using the Hilbert Transform

method. Basically, this method uses a time convolution approach to find the imaginary part of the trace.

5.1.1 Envelope

The basic idea behind enveloping a trace is to convert the trace from a wavelet with both positive and negative components to a monopulse wavelet with all positives. The process removes the oscillatory nature of the radar wavelet and shows the data in its true resolution. This process can also simplify the display of a radar section making it, perhaps, easier to interpret.

The mathematical definition of instantaneous amplitude is shown above. The instantaneous amplitude outlines the envelope of the trace. It is independent of phase, that is, it may have its maximum at points other than the peaks and troughs of the real trace, especially where an event is the composite of several reflections. While it is often referred to as reflection strength, some believe that this term places a dubious interpretational assumption on the true meaning of instantaneous amplitude. They suggest that the envelope of a trace is simply an interpretational tool that describes waveform shape. Interpretation is aided by comparing the constancy of reflection character.

Envelope Parameters

Window Width Is the width of the filter in pulse widths.
The default value is 1.0 pulse widths.

5.1.2 Instantaneous Frequency

The mathematical definition of instantaneous frequency is shown above; it is used as a correlation tool. The frequency character of an event will change as the lithology changes, the thickness changes or at interfaces such as gradational boundaries, pinch-outs and the water table.

Instantaneous Frequency Parameters

Window Width The width of the filter in pulse widths.
The default value is 1.0 pulse widths

Epsilon Enhances the stability of the result for small signals
The default value is 1.0 millivolt

5.1.3 Instantaneous Phase

The mathematical definition of instantaneous phase is shown above. It is used to emphasize the continuity of events. Since phase is independent of the trace envelope, it can often make weak coherent events more prominent, even events that interfere with one another. Instantaneous phase is always measured between $-\pi$ and $+\pi$ and therefore data tends to have a saw-tooth appearance.

The instantaneous phase is multiplied by amplitude/epsilon if amplitude \leq epsilon. This drives the instantaneous phase towards zero for amplitudes smaller than epsilon.

If the amplitudes have a DC offset that place it near a zero imaginary component and a slightly negative real component, $\pm\pi$ phase cross over can occur and data will appear

noisy. Removing DC bias using DEWOW is recommended so that epsilon will remove this problem.

Instantaneous Phase Parameters

Window Width The width of the filter in pulse widths.
The default value is 1.0 pulse widths

Epsilon Enhances the stability of the result for small signals
The default value is 1.0 millivolt

5.2 Filters – 2D

5.2.1 Migration

The migration process applies a synthetic aperture image reconstruction process to the GPR line. It uses a 2D FFT Stolt migration operator to migrate a common offset GPR section.

The process collapses GPR hyperbolic responses from point-like targets back into a point. Hyperbolic shape is dictated by the ground velocity so migration requires the input velocity to be as accurate as possible. If the velocity is too low, the data will be under-migrated with the hyperbola not fully collapsed.

If the velocity is too high, the data will be over-migrated with hyperbolas inverted into smile shapes. The optimal velocity can be determined by experimentation or measured using the Hyperbola Velocity Calibration tool in LineView.

Migration Parameters

Velocity Radar velocity to use in the synthetic aperture process.
Must be 0.01 to 0.30 meters/nanosecond or 0.03 to 0.98 feet/nanosecond.
Typical velocities of ground materials are 0.06 to 0.15 m/ns (0.20 to 0.49 ft/ns).
The default value is 0.1 m/ns (0.328 ft/ns).

The migration process will fail if the First Break Offset time is negative (to learn more, see the [Acquisitions tab](#)).

5.3 Filters – Spatial

Spatial filters act on radar data in the spatial (or position) direction. These filters use adjacent traces during the filtering procedure. They alter the shape of the trace through various mathematical manipulations designed to enhance or eliminate certain features.

5.3.1 Background Average Subtraction

Background Average Subtraction is used to subtract the average trace of the entire GPR line from every trace in the line.

This process has the effect of enhancing dipping events (like hyperbolas from point targets) and removing horizontal responses common to all traces in the line. It is commonly used to remove the direct air and direct ground waves (also known as the transmit pulse) visible at the top of the line. It will also remove horizontal bands in the data present throughout the length of the line.

The average trace is calculated by adding all the traces in the line together and dividing by the total number of traces. This average trace is then subtracted from each trace in the line.

Background Average Subtraction is similar to the Background Subtraction routine below, but, because it averages over the full width of the GPR line, rather than a shorter length typically used with that routine, it tends to be less severe in its removal of horizontal events. The more traces used in the Background Subtraction Filter Width parameter, the more localized horizontal features remain in the data.

Background Average Subtraction Parameters

There are no input parameters necessary to run this process.

5.3.2 Background Subtraction

Background Subtraction is used to apply a running-average background subtraction to the data set.

This process has the effect of enhancing dipping events (like hyperbolas from point targets) and suppressing or completely removing horizontal responses. This can be very useful for removing localized flat-lying events.

A window of traces with a width defined by the **Filter Width** parameter is averaged with a weighted average (see below) and the result is subtracted from the trace in the center of the window. The window moves along one trace and the process is repeated.

To illustrate the processing, consider the case of a GPR line collected with a step size of 0.1 meters. If a Filter Width of 0.5 meters is chosen, the operation works on a window of 5 traces at a time. When the routine processes trace number 9, it reads traces 7, 8, 9, 10, and 11, finds the average of the five traces, subtracts that average trace from the original trace 9 and saves the resultant in place of trace 9. It then moves over one trace to trace 10, averages traces 8, 9, 10, 11 and 12, subtracts the average trace from the original trace 10 and saves the resultant as trace 10, and so on.

The more traces used in the background subtraction process, the more flat-lying reflections will remain in the data. For example, setting the Filter Width to 2 meters removes any local flat-lying reflections 2 meters long or longer. Flat-lying reflectors less than 2 meters long will remain in the data line, although their amplitudes may be reduced.

To remove all flat-lying events from data, set the Filter Width to a distance equal to two times the step size.

Choosing a Filter Width as large as or larger than the line will remove the average trace. Signal from line data, similar to the Background Average Subtraction process described

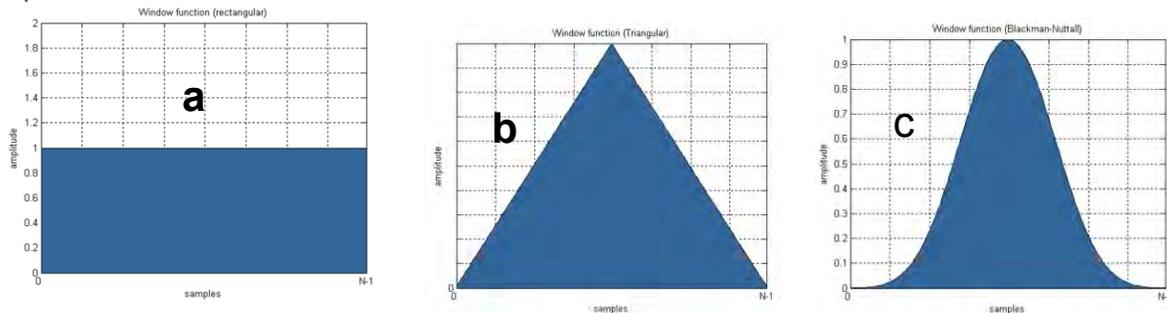


Figure 19: Filter types for the Background Subtraction Filter. (a) Rectangular, (b) Triangular (c) Blackman-Nuttall

The **Filter Type** dictates the weighting the traces on the edges of the Filter Width have on the calculation of the average trace.

- **Rectangular** filter type uses equal weighting to all traces
- **Triangular** filter type applies more weight to the trace in the center of the window and linearly less to the traces moving out from the center to the edges of the window
- **Blackman-Nuttall** filter type applies more weight to the trace in the center of the window and less to the traces on the edges of the window but uses a shape similar to a Gaussian curve ([Figure 19](#))

Background Subtraction Parameters

Filter Width	<p>The width of the running-average window added together in the spatial trace-differencing filter.</p> <p>If the filter width is greater than the length of the GPR line, a filter width equal to the length of the line is used.</p> <p>The default value is 1 meter.</p>
Type	<p>The shape of the filter used to calculate the running-average trace.</p> <p>Options are Rectangular, Triangular or Blackman-Nuttall.</p> <p>The default is rectangular.</p>

5.3.3 Horizontal

Horizontal applies a running average filter horizontally along a GPR line. It replaces each trace with an average trace produced by averaging adjacent traces together. Its primary purpose is to emphasize flat-lying or slowly dipping reflectors while suppressing rapidly changing ones (i.e. hyperbolic tails or random noise).

A window of traces with a width defined by the **Filter Width** parameter is averaged and the resultant replaces the trace in the center of the window. The window moves along one trace and the process is repeated.

To illustrate the processing, consider the case of a GPR line collected with a step size of 0.1 meters. If a Filter Width of 0.3 meters is chosen, the operation works on window of 3

traces at a time. When the routine processes trace number 5, it reads traces 4, 5, and 6, finds the average of the three traces and uses the average trace in place of trace 5. It then does the same thing with trace 6, and so on. If the number of traces to average is even, then the extra trace is taken from the 'left' side, i.e. from the lower trace number.

5.4 Filters - Time

5.4.1 Bandpass Filter

Bandpass filtering is used when the GPR signal is contained in a defined band of frequencies and there is "noise" energy in the remainder of the spectrum. By bandpass filtering, the desired signals can be enhanced at the expense of the out-of-band noise. Bandpass is designed around the use of Fourier transform filtering concepts.

The use of Fourier transform-based filtering is quite common in the geophysical realm and many texts and papers describe the concepts very well. The following briefly outlines the processing, how it is implemented, and the side effects that improper application of the filter may induce.

Each GPR trace is a time series which can be viewed as being composed of a superposition of sinusoidal signals. With a Fourier transform based filter, a GPR trace is decomposed into its spectral (sinusoidal) components through a Fourier transformation algorithm, the spectral amplitudes multiplied by the filter transfer function, and the resultant spectrum is inverse Fourier transformed to create the filtered GPR trace.

Filtering is restricted to zero phase bandpass filtering. To describe the transfer function of a bandpass filter one has to define its lower and upper cut-off frequencies. In addition, the sharpness of the cut-off at either end of the pass band must be quantified.

The transfer function of the filter is characterized by four frequencies, $fc1$, $fp1$, $fp2$, and $fc2$. The filter has zero amplitude at all frequencies below $fc1$ and above $fc2$. In the pass band between frequencies $fp1$ and $fp2$, the filter has unit amplitude. Between $fc1$ and $fp1$ and $fp2$ and $fc2$, the transition from zero amplitude to unit amplitude is a cosine curve that gives a smooth transition.

The most efficient way of Fourier transformation is to exploit the Fast Fourier Transform (commonly referred to as the FFT) algorithm. The FFT algorithm is based on the assumption that the times series being processed is one cycle of an infinitely recurring signal. While this is not strictly true, by extending a finite time series with zeros and tacitly assuming periodicity, one can use the FFT algorithm with impunity to carry out a periodic convolution operations. Bandpass uses this approach.

Bandpass Filter Parameters

The parameters needed for this application are:

- fc1** Lower cut-off frequency.
Frequencies below this value are completely removed from the GPR line.
- fp1** Lower pass band frequency.
Frequencies below this value taper to zero at the $fc1$ frequency.
Frequencies above this value to the $fp2$ value are retained in the GPR

line.

fp2 Upper pass band frequency.

Frequencies below this value to the fp1 value are retained in the GPR line.

Frequencies above this value taper to zero at the fc2 frequency.

fc2 Upper cut-off frequency.

Frequencies above this value are completely removed from the GPR line.

- Frequencies must be ascending order and it is suggested that the slope of the high frequency side be less steep than the slope of the low frequency side to minimize filter artifacts on the data.
- All frequencies are entered as a percentage of the antenna center frequency.
- Default frequencies are 40%, 80%, 120% and 160% of the antenna center frequency.

[Average Frequency Spectrum](#) plots can be used to help determine filter parameters.

5.4.2 DC Removal

While the Dewow process below automatically removes any low frequency "wow" from the data, sometimes it may be desirable to perform a DC removal on the data in addition to, or instead of DEWOW. For example, tests have shown that a DC removal applied to high frequency radar data (> 200 MHz) rather than a Dewow correction may be more effective in reducing correction artifacts.

DC Removal is used to remove a DC level from all the traces in the GPR data line(s). The DC level to be removed can be manually input by the user or automatically calculated by the program.

With an input DC level, the value is subtracted from all the points in all the traces in the data set.

If DC_SHIFT calculates the DC level to be removed, it calculates a new DC level for each trace in the GPR line. This is done by taking all points in each trace and calculating a DC level for that trace. This value is then subtracted from each point in the trace. This process is repeated for each trace in the data set. Typically, traces will have approximately the same DC shift in a given GPR line.

5.4.3 Dewow

In most cases when processing GPR data, it is recommended that Dewow be applied to the GPR line before any other processing steps.

Depending on the proximity of the GPR transmitter and receiver as well as the electrical properties of the ground, the transmit signal may induce a slowly decaying low frequency "wow" on the trace which is superimposed on the high frequency reflections.

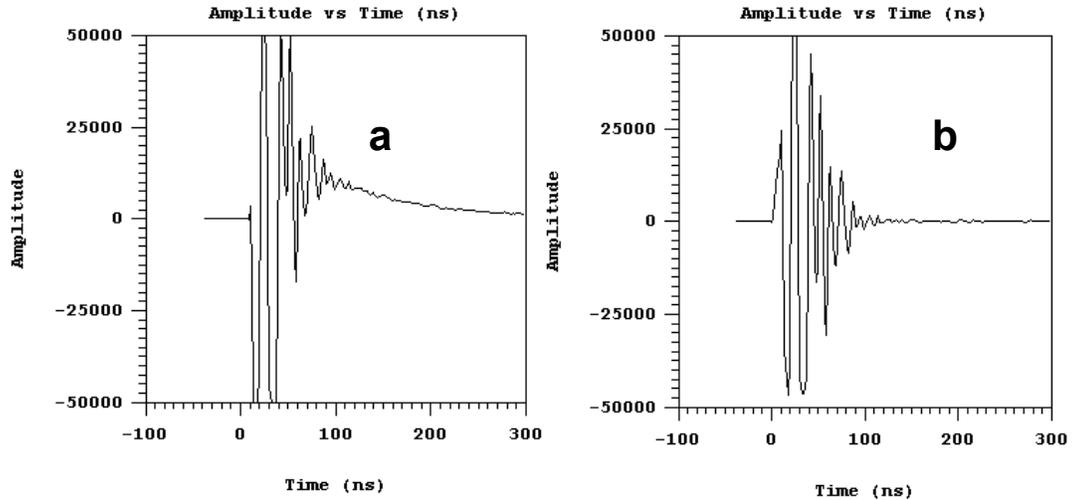


Figure 20: (a) Raw GPR trace with WOW. (b) GPR Trace with WOW removed using DEWOW.

All GPR data contains a low frequency component. The magnitude of the low frequency component and how it manifests itself in the data depends on the ground conditions around the antennas and the distance between the transmitter and receiver. In general, the low frequency component of the GPR signal does not propagate but diffuses into the ground. In other words, the lower end of the spectrum sees an inductive (eddy current) type response as opposed to a propagating (displacement current) type response.

The result is that the large transmit pulse emitted by the radar can be followed by a slowly decaying transient, commonly called “wow”.

With this wow usually present, it is common practice that GPR data be high pass (Dewow) filtered. In fact, LineView and other GPR line display software automatically applies Dewow before plotting the data. Users are often unaware of the wow or low frequency component in the data. The raw data, however, always retains this information.

Dewow is designed to remove this unwanted low frequency while preserving the high frequency signal. The removal of this wow in the data is also called the "signal saturation correction".

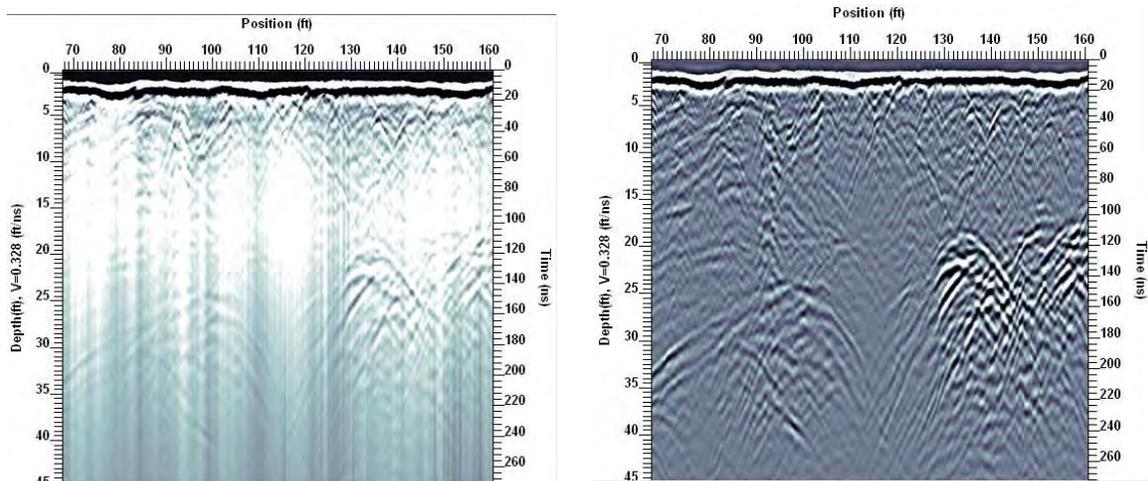


Figure 21: (Left) Raw GPR line with WOW. (Right) GPR line with WOW removed using DEWOW.

The wow is removed from the data by applying a running average filter down each trace. A window with a width of 1.33 pulse widths at the nominal frequency is set on the trace. The average value of all the points in this window is calculated and subtracted from the central point. The window is then moved along the trace by one point and the process is repeated.

5.4.3.1 Dewow Artifacts

While any filter produces unwanted artifacts in the data to which it is applied, Dewow is a good compromise filter.

The Dewow filter can induce two types of artifacts into the plotted data sections. The first is a pre-cursor to the onset of a pulse (**Figure 22: DEWOW artifacts: signal pre-cursor.**[Figure 22](#)). When the original data are high pass filtered the wavelet is stretched in time with additional oscillations occurring before and after the original pulse. This is what gives rise to a pre-cursor in the data before the first break on plotted GPR lines.

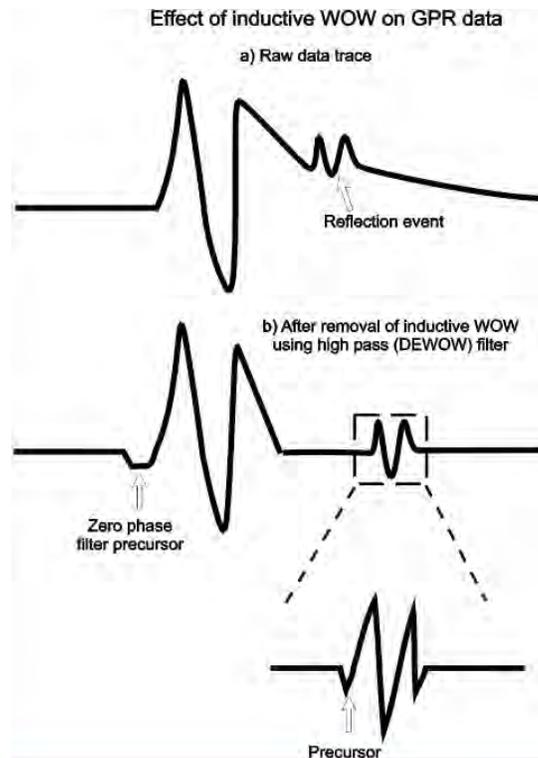


Figure 22: DEWOW artifacts: signal pre-cursor.

The second artifact is caused by electronic clipping. The basic concept is depicted in [Figure 23](#).

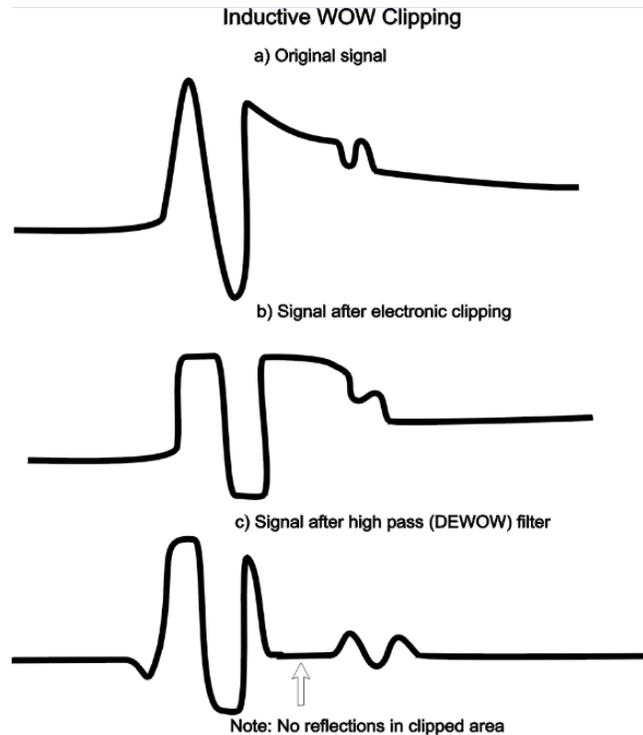


Figure 23: DEWOW artifacts: electronic clipping

The original signal which is acquired by the antenna and presented to the receiver electronics looks like that sketched in [Figure 23 a](#). The radar electronics clip any signals above the 50 millivolt level. [Figure 23 b](#) shows the type of result that will be measured if clipping occurs in the signal pre-conditioning circuitry. When these data are finally high pass filtered, a blank zone in the area where the original signal had a large wow above the clipping level of the electronics can appear. This results in a blank section on the record with no reflections visible ([Figure 23 c](#)). The user must be aware that this can occur in some geologic settings and the antenna spacing should be increased to reduce the wow signal amplitude below the clipping level of the receiver electronics.

Dewow Parameter

Window Width is the width of the filter in pulse widths
The default value is 1.33 pulse widths.

5.4.4

5.4.5 DynaT

Dynamic Target enhancement (DynaT) allows users to preferentially enhance the response from targets of different sizes – small, medium and large. GPR users usually use signal amplitude to discern targets and small targets can be difficult to see in GPR data because they always produce smaller amplitude responses than larger targets.

The DynaT process exploits the fact that the frequency content of the returned signal varies with target size. The rate of change of signal amplitude with size varies especially strongly for small targets. Using the ultra-wideband frequency content inherent in the GPR signals generated by Sensors & Software GPR systems, DynaT differentiates the frequency-dependent GPR target responses to enhance the amplitude of targets based on relative size.

DynaT is optimized for GPR data with a 250 MHz center frequency. The GPR lines to be processed with DynaT must be 250 MHz data.

DynaT Parameter

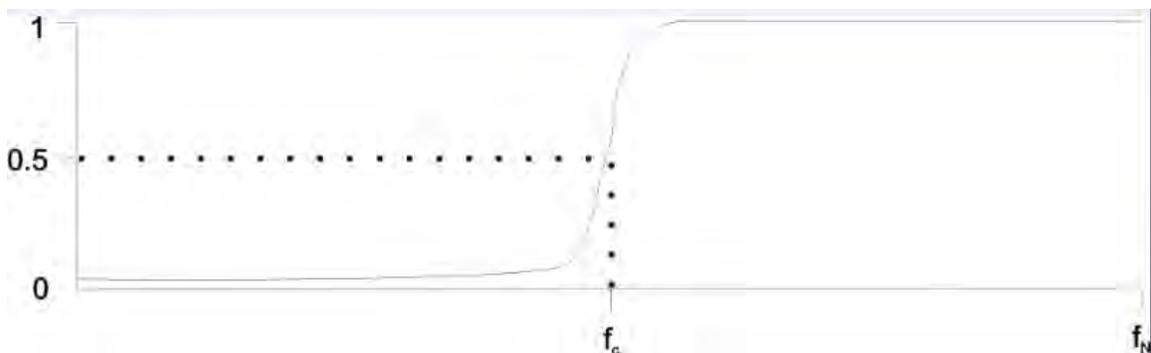
Target Size	The relative size of the target to enhance – Small, Medium or Large
	The default value is Medium.

5.4.6 Highpass

The highpass temporal filter removes frequencies below a cut-off frequency. It is useful for removing low frequency content in the GPR data; it is sometimes used instead of the [Dewow](#) filter.

High Pass is a recursive filter designed for filtering of a GPR line in the time domain. It is an infinite impulse response zero phase filter.

The typical frequency domain characteristics of the filter are as shown below.



The filter requires the input of the cut off frequency. Frequencies between 10% and 90% in 10% increments of the Nyquist frequency can be input.

The **Nyquist frequency** is determined from the **Time Sampling Interval** for the GPR line; these values are listed in the **Advanced** category of the [Acquisition tab](#).

$$f_{Nyquist} = 1/(2 * \text{time sampling Interval} \times 10^{-6})$$

Where:

the Nyquist frequency is in MHz and
The time sampling interval is in picoseconds (ps)

If the default temporal sampling intervals are used when collecting data, the Nyquist frequencies for each antenna frequency are listed in the following table:

Antenna Frequency (MHz)	Temporal Sampling Interval (ns)	Nyquist Frequency (MHz)
12.5	6400	78
25	3200	156
50	1600	313
100	800	625
200	400	1250
250	400	1250
500	200	2500
1000	100	5000

Highpass Parameter

Cut-off Frequency Percent The cutoff frequency is a percentage of the Nyquist frequency in 10% increments from 10%-90%.

Frequency above which data is preserved and below which data is removed.

For example, if the Nyquist frequency is 625 MHz, the possible cutoff frequencies are:

- 10% = 62.5 MHz
- 20% = 125 MHz
- 30% = 187.5 MHz
- 40% = 250 MHz
- 50% = 312.5 MHz
- 60% = 375 MHz
- 70% = 437.5 MHz
- 80% = 500 MHz
- 90% = 562.5 MHz

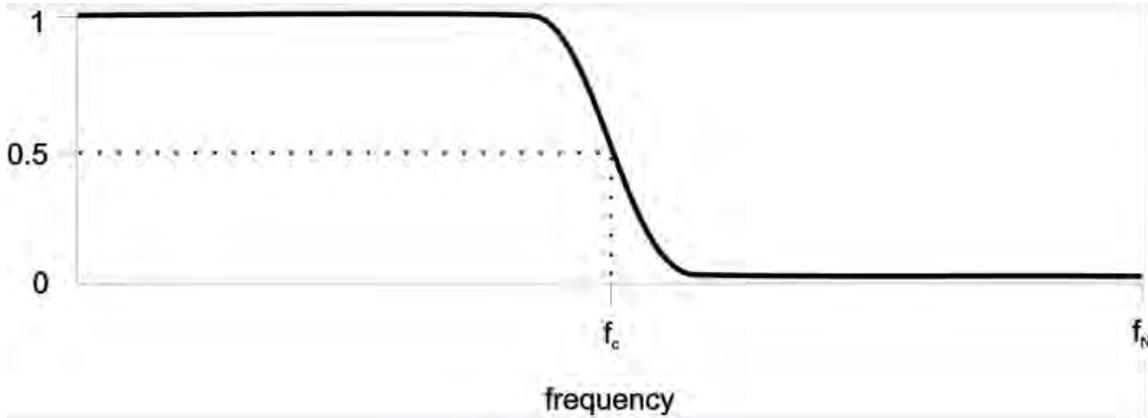
Note: The Average Frequency Spectrum plot extends from 0MHz up to the Nyquist frequency.

5.4.7 Lowpass

The low pass filter removes frequencies above a cut-off frequency. It is useful for removing high frequency noise in the GPR data.

Low pass is a recursive filter designed for filtering of a GPR line in the time domain. It is an infinite impulse response zero phase filter.

The typical frequency domain characteristics of the filter are as shown below.



The filter requires the input of the cut off frequency. Frequencies between 10% and 90% in 10% increments of the Nyquist frequency can be input.

The **Nyquist frequency** is determined from the **Time Sampling Interval** for the GPR line; these values are listed in the **Advanced** category of the [Acquisition tab](#).

$$FN_{\text{Nyquist}} = 1/(2 * \text{time sampling Interval} \times 10^{-6})$$

Where:

- the Nyquist frequency is in MHz and
- The time sampling interval is in picoseconds (ps)

If the default temporal sampling intervals are used when collecting data, the Nyquist frequencies for each antenna frequency are listed in the following table:

Antenna Frequency (MHz)	Temporal Sampling Interval (ns)	Nyquist Frequency (MHz)
12.5	6400	78
25	3200	156
50	1600	313
100	800	625
200	400	1250
250	400	1250
500	200	2500
1000	100	5000

Low Pass Parameters

Cut-off Frequency Percent The cutoff frequency is a percentage of the Nyquist frequency in 10% increments from 10%-90%.

Frequency above which data is preserved and below which data is removed.

For example, if the Nyquist frequency is 625 MHz, the possible cutoff frequencies are:

10% = 62.5 MHz
 20% = 125 MHz
 30% = 187.5 MHz
 40% = 250 MHz
 50% = 312.5 MHz
 60% = 375 MHz
 70% = 437.5 MHz
 80% = 500 MHz
 90% = 562.5 MHz

5.4.8 Vertical

The Vertical Filter is used to apply a running average filter vertically (down the trace) on a GPR line. The signal is averaged by replacing the data value at a given point by the average data value over a window centered about that point. Its primary purpose is to reduce random or high frequency noise by acting as a low pass temporal filter.

A window of pulse widths defined by the **Filter Width** parameter is averaged and the resultant replaces the trace in the center of the window. The window moves along one trace and the process is repeated.

To illustrate the processing, consider the case of a GPR line collected with an antenna frequency of 100 MHz and a time sampling interval of 800 picoseconds:

$$\begin{aligned} \text{Pulse width} &= 1500 / (\text{frequency} * (\text{time sampling interval}/1000)) \\ &= 18 \text{ points.} \end{aligned}$$

If a Filter Width of 0.2 pulse widths is chosen, the operation works on a window of 3 sample points at a time. When the routine processes point number 5, it reads points 4, 5, and 6, finds the average of the three points and uses the average value in place of point 5. It then does the same thing with point 6, and so on. If the number of points to average is even, then the extra trace is taken from the left' side, i.e. from the lower trace number.

The more pulse widths (points) used in the Vertical filter, the more high-frequency data will be removed from the data. Typical values for the number of pulse widths in the filter are 0.1 to 1.

Antenna Frequency (MHz)	Temporal Sampling Interval (ns)	Pulse width (pts)
12.5	6400	18
25	3200	18
50	1600	18
100	800	18

200	400	18
250	400	15
500	200	15
1000	100	15

The following example calculates how to determine how many pulse widths to use in the averaging window.

To filter high frequency noise that's affecting your data:

1. Estimate the length (in nanoseconds) of the noise from a plot of the GPR line ([Trace Plot](#) and [Average Trace Amplitude](#) can be helpful).
2. Select a typical noise cycle from the section and then measure the peak-to-peak or trough-to-trough time length.
3. Divide this number by the time sampling interval in nanoseconds.

The Time Sampling Interval for the GPR line is listed in picoseconds in the [Acquisition tab's Advanced](#) category.

4. Divide by 1000 to calculate it in nanoseconds.

The result is the length of the noise cycle in points (round up to the nearest whole number if necessary).

5. Divide the number of points in the noise by the number of points in the pulse width for the antenna frequency you are using (see table above).
6. To filter out this noise, use a Filter Width equal to or greater than this number.

Vertical Parameters

Filter Width

The width of the running-average window added together in the spatial trace-differencing filter.

If the filter width is greater than the length of the GPR line, a filter width equal to the length of the line is used.

The default value is 1 meter.

Type

The shape of the filter used to calculate the running-average trace.

Options are Rectangular, Triangular or Blackman-Nuttall.

The default is rectangular.

5.5 First Break

5.5.1 Edit First Break

Rather than using Repick First Break to determine the **First Break Offset** (listed in the **Advanced** category of the GPR line [Acquisition tab](#)), it is sometimes desirable to calculate or estimate the first break manually and edit the GPR line. This is what the Edit First Break routine is for.

The first break is edited in a time value in nanoseconds.

One way to calculate the first break offset time is to plot the GPR Line in [LineView](#). Set the time limit to Minimum to estimate the number of nanoseconds from the top of the GPR line to the first break.

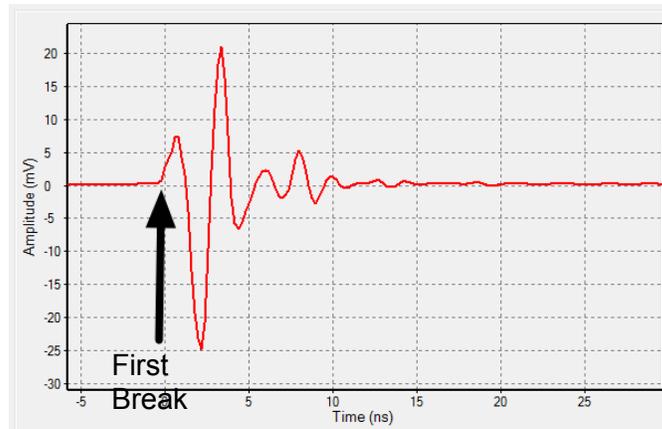
Edit First Break Parameters

First Break Offset The time of the first break on the trace.

5.5.2 Repick First Break

Repick First Break is used to re-pick the first break offset for the GPR line (listed in the **Advanced** category of the GPR line [Acquisition Tab](#)).

When data are collected, the first trace collected is searched to find the first break. This is the first large deflection (either a positive peak or a negative trough) in the trace and indicates the arrival of the direct air wave to the receiver.



Sometimes the automatic first break search fails and the first break is set to the wrong value. The Repick First Break routine uses a relative or absolute threshold value to re-pick the first break for the GPR line.

The relative threshold value is a percentage (0.0 to 100%) of the peak amplitude value in the trace.

The absolute threshold is a signal amplitude value in millivolts from -50 to +50.

The first point in the trace to exceed the threshold value is the first break offset time. This time value can be a decimal number between two points with values on either side of the threshold.

The default value is 5% or 5 mV. Typical percentages required to get a good first break

are 5% to 10% or 5 to 10 mV, but if the data are particularly noisy, a higher threshold may be required.

It is recommended that Repick First break be applied to GPR lines that have not been [Dewowed](#) because the Dewow process introduces a pre-cursor to the data that can affect the Re-pick process.

Transition defines the first break: a positive deflection, a negative deflection or the first deflection either **positive** or **negative**. The default is **both** which means the first positive or negative deflection that exceeds the threshold is the first break.

When determining a threshold value to input, it is a good idea to plot the data in [LineView](#) or Trace Plot and see whether the first major deflection is positive or negative. If the first deflection is positive, use a positive transition. If the first deflection is negative, use a negative transition. Repick First Break searches the input traces and records the first point to exceed the threshold value.

Shift Traces determines if the traces are physically shifted to align with one another. If Shift Traces is set to No, Repick First Break calculates the first break offset time for each trace and sets the first break offset to the median value.

If Shift Traces is Yes, each trace is shifted up or down in time to align with the trace with the smallest first break offset.

Repick First Break may not always give a good pick for the first break. To check the pick, plot the traces in [LineView](#) or Trace Plot and see where the first break is placed on the GPR line. If not, try another threshold value and see if the pick can be improved. The threshold needs to be large enough so that the transmit pulse (which should be a higher amplitude than anything before it) is the point that gets picked.

Usually the first break point on each trace lines up horizontally. However, if data are collected before the radar system has warmed up properly or if the fiber optic cables (on some Sensors & Software GPR systems) are damaged, the first break point may drift up and down from trace to trace. When this problem is visible in the data, the Shift Traces option can be used to horizontally align all the traces at the threshold value.

It is especially important to set Shift Traces to Yes if further data processing on the GPR line is required. Many processes like any of the Spatial Filters or the 2D filters use calculations on amplitude values in adjacent traces. If there is much drift in the data, these processes may not work as well.

Repick First Break Parameters

Method	Select the Method used to Repick the First Break: Absolute or Relative.
Relative Threshold (% of Peak)	Percentage of the peak GPR signal amplitude in the trace that defines the first break. Values are 0% to +100%. Default is 5%
AbsoluteThreshold (mV)	Signal amplitude in millivolts in the trace that defines the first break. Values are -50 to +50 mV. Default is 5 mV

Transition

The trace deflection direction to pick the first break point on.

Options are Positive, to pick the threshold on the first positive part of the trace that exceeds the threshold, Negative, to pick the threshold on the first negative part of the trace that exceeds the threshold or Both (first positive or negative, whichever occurs first in the GPR trace that exceeds the threshold).

Default is Both.

Shift Traces

Option to permanently shift the re-picked traces so they align horizontally to the threshold value. Options are Yes to shift traces or No to just re-pick the first break but not to align the traces.

Default is Yes.

5.6 Gains

Since the radar signal strength normally decreases with increasing time, it is usually necessary to apply some sort of gain function to boost the weaker signals at later times.

The raw, ungained data shows little signal except for the strong near-surface reflectors ([Figure 24](#)). No gain may be useful in areas where the radar signal is very strong or in areas where the targets are very shallow.

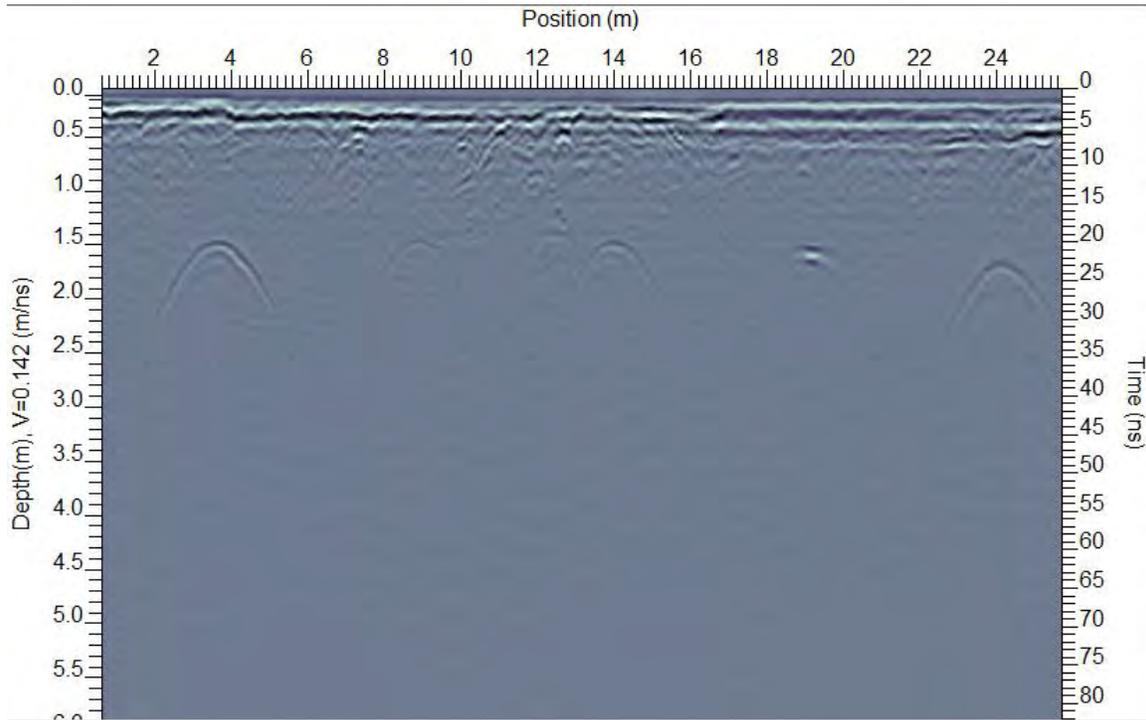


Figure 24: GPR line with no gain applied.

None of the gain functions are permitted to boost a data point value to greater than + or - 50 mV. Values where this occurs are trapped and forced to 50 or -50 mV.

5.6.1 Automatic Gain Control

The Automatic Gain Control (AGC) gain attempts to equalize the amplitudes of all GPR signals by applying a gain which is inversely proportional to the signal strength ([Figure 25](#)). This type of gain is most useful for defining continuity of reflecting events. AGC does not preserve relative amplitude information, so once AGC has been applied to the data, you can no longer make reliable deductions concerning the strength of any particular reflector relative to other reflectors.

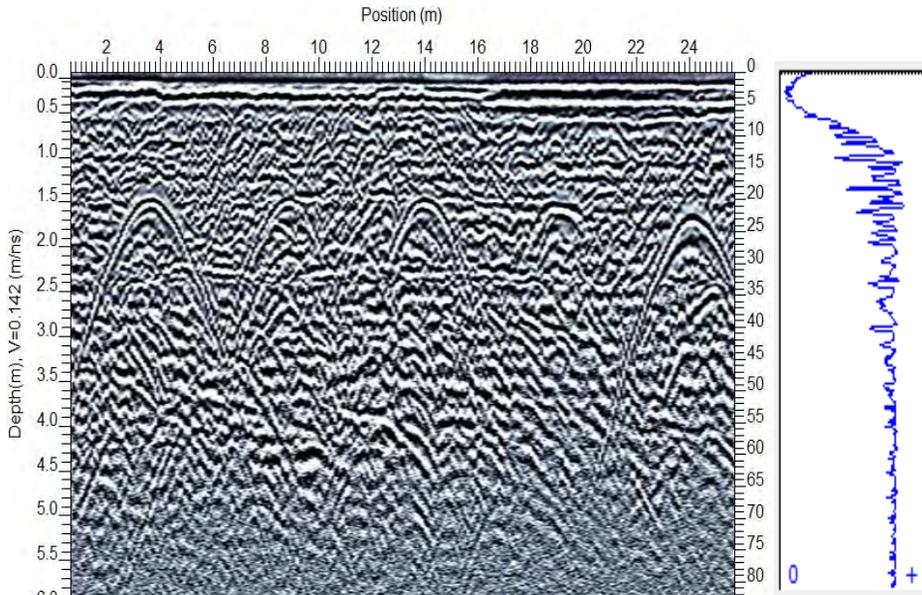


Figure 25: GPR line with AGC gain applied with the AGC gain function on the right. AGC applies a gain inverse to the signal strength. The gain function varies for each trace.

Since the AGC gain is inversely proportional to the signal strength, very small signals can produce very large gains. To avoid this, a gain-limiting scheme called Maximum Gain is applied.

AGC Parameters

Window Width:

To calculate the gain to be applied at each point in the trace, AGC locates the average signal level over a window of width given by Window Width and centered about the point. The Window Width is specified in units of pulse width based on the antenna center frequency. In the case of data collected at 100 MHz with a sampling interval of 800 ps, and a window width of 1.5 pulse widths, 27 points would be used to compute the average signal strength.

The default of 1.5 is adequate in most cases.

Maximum Gain:

A number between 1 and 32767 can be used to determine the maximum gain that can be applied to any data point. If the calculated gain value for any point along the trace exceeds the Maximum Gain value, the Maximum gain value is applied to the data instead. This maximum gain is fixed for the whole data set.

A typical value would be 50 - 2000 depending on the noise and average signal levels.

5.6.2 Constant Gain

This routine will apply a constant gain factor to the GPR Line. Only one parameter is needed, namely the constant factor to multiply all data points by. Thus if the user enters the number 10, all data points will be multiplied by a factor of 10. This will gain strong signals and weak signals equally and result in the clipping of strong signals.

The advantages of a constant gain are:

- It is easy to understand how the amplification works and,
- There is only has one parameter to adjust.

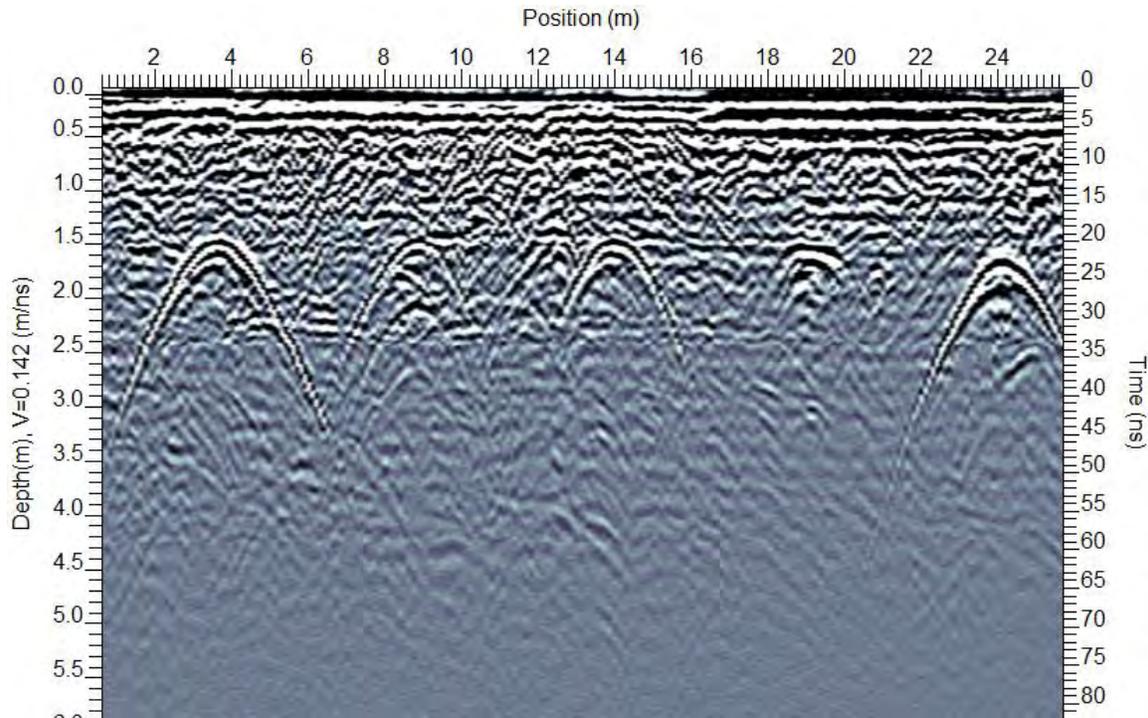


Figure 26: GPR line with a constant gain of 100 applied.

The disadvantage of a constant gain is that it tends to over-gain the strong signals at the beginning of the trace ([Figure 26](#)).

Constant Gain Parameter

Gain:

- The constant gain factor that the data set will be multiplied by.
- The default value is 100 and typical values for the Constant gain are in the range from 2 to 1000

5.6.3 SEC2

The SEC2 (Spreading & Exponential Calibrated Compensation) gain is a composite of a linear time gain and an exponential time gain. This gain attempts to compensate for the spherical spreading losses and the exponential ohmic dissipation of energy in the GPR Line. Since GPR data is attenuated exponentially and the SEC2 is an exponential gain, it tends to be the gain closest to physical reality. Therefore, unlike the AGC gain, after an SEC2 gain is applied to a GPR Line, reflections can be compared for relative signal strength. SEC2 is the preferred gain for GPR data (after applying dewow).

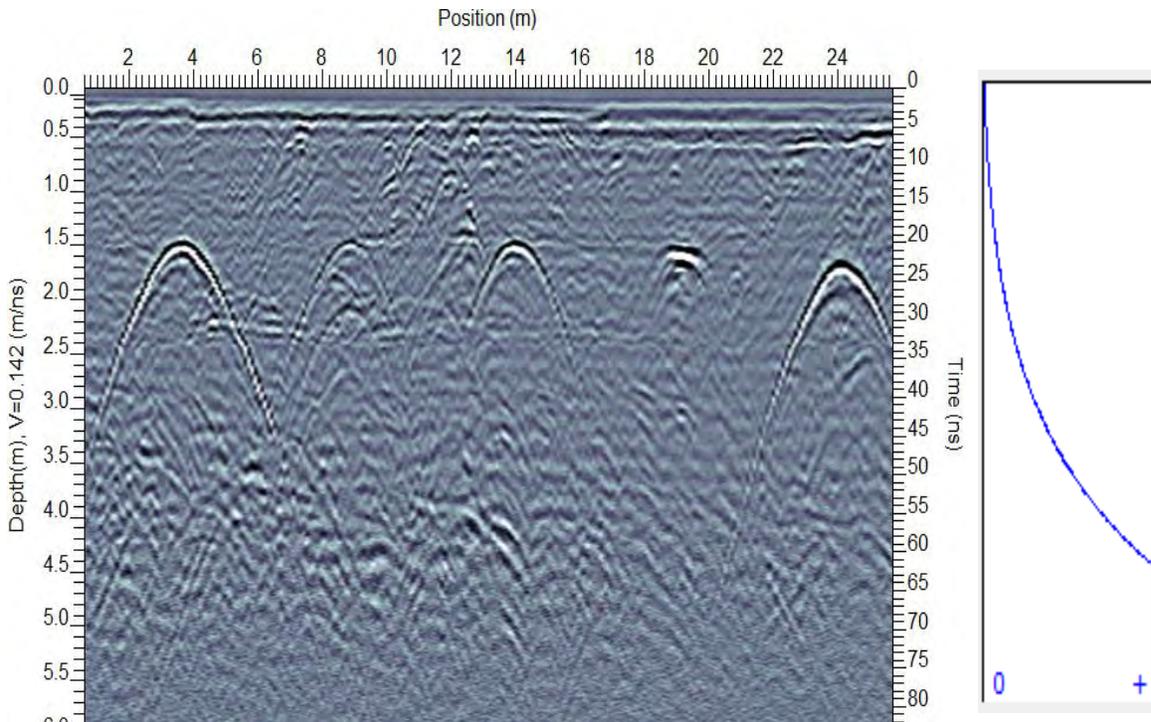


Figure 27: GPR line with an SEC2 gain applied and the SEC2 gain function on the right. This type of gain is the closest to physical reality because it compensates for the attenuation of the signal with depth.

This gain is essentially an exponential function. This exponential function could, in fact, go to infinity. Therefore, as with the AGC gain some gain limiting factor must be applied so a Maximum Gain value is used.

SEC2 Parameters

Attenuation

This quantity represents the radar wave attenuation given in decibels/meter.

The higher the attenuation value, the faster the exponential function rises the more gain applied at earlier times on the GPR Line. Data collected on low attenuation materials like sand and hard rock may only require an attenuation of 0 to perhaps 5. Data collected on high attenuation materials like silts, clay and concrete may require an attenuation of 10 perhaps as high as 40 or 50.

Typical value: 0.5 to 5.

Start Value

This is a constant value (or DC) added to the exponential function. The SEC2 gain rises from this value; normally it will be 1 but for those data sets where more gain is required at early times, this value can be increased accordingly.

Typical value: 0 to 10

Maximum Gain

This is a number between 1 and 32767 which determines the maximum gain that can be applied to any data point. When the exponential gain function exceeds the Maximum gain value, the function levels off at the Maximum Gain value. All points in the GPR trace later in time are gained by the Maximum Gain value. This maximum gain is fixed for the whole data set.

Typical value: 50 to 2000.

5.7 Line Editing

5.7.1 Antenna Separation

This is the distance between the transmitting and receiving antennas. For reflection data this distance is normally kept fixed for every trace collected. Appropriate values of antenna separation for each antenna frequency are given on the table in the data acquisition program.

This option is available for editing the antenna separation saved in the data file. It is important that the correct antenna separation be entered since this value is used in the computation of the depth axis.

This parameter has no meaning for any mode of operation where the antenna separation changes (as in a CMP/WARR profile).

5.7.2 Crop Data - Horizontal

Sometimes a GPR Line is too long and needs to be cropped. For example, the ends of a line may contain poor or uninteresting traces.

Crop Data - Horizontal is used to delete data outside the input minimum and maximum position.

Crop Data - Horizontal Parameters

Minimum, Maximum Positions

Minimum and Maximum positions of traces are used to retain in the cropped GPR Line. The Minimum position must be less than the Maximum position. The default values are the current start and end positions.

5.7.3 Crop Data - Vertical

Sometimes a GPR Line contains too much data in time. For example, if the chosen time window was too long, the data of interest might occur at early times and the later times on the GPR line may contain poor, noisy or otherwise useless data.

Crop Data – Vertical is used to delete data outside the input minimum and maximum time range.

Crop Data - Vertical Parameters

Minimum, Maximum Times

Minimum and maximum times (in nanoseconds) are used to retain in the cropped GPR Line. The minimum time must be less than the maximum time. Times can be positive or negative (data before the first break). If the Start Time is positive, the first break offset is removed and is recorded in the [Acquisition Tab](#) as a negative time.

5.7.4 Pad Data - Horizontal

Sometimes a GPR Line needs to be padded out so two or more lines have exactly the same start and end positions or number of traces.

Pad Data - Horizontal is used to add data traces from the input minimum position to the current start position and add data from the current end position to the input maximum position.

Data traces added to the GPR line have zero (0) amplitude values.

Pad Data - Horizontal Parameters

Minimum, Maximum Positions

Minimum and Maximum positions of the padded GPR Line; the Minimum position must be less than the maximum position.

5.7.5 Pad Data - Vertical

Sometimes a GPR Line needs to be padded out so two or more lines have exactly the same minimum and maximum times.

Pad Data - Vertical is used to add data to the top and bottom of a GPR Line; from the input minimum time to the current start time and/or add data from the current end time to the input maximum time.

Sample points added to the top of the GPR line have the same amplitude value as the first sample point while sample points added to the bottom of a GPR Line have the same amplitude value as the last sample point.

Pad Data - Vertical Parameters

Minimum, Maximum Times

When using minimum and maximum times (in nanoseconds) in the padded GPR Line, Minimum Time must be smaller than the Maximum Time. To pad the GPR Line on the top, the input Minimum Time must be less than the current Start Time. To pad the GPR Line on the bottom, the input Maximum Time must be greater than the current End Time.

Times can be positive or negative (data before the first break).

5.7.6 Reposition Traces

Before a GPR Line is collected, the Start Position and Step Size are defined. These two parameters are used to calculate the position of each trace and the end position of the GPR Line. Often, for a variety of reasons, it is necessary or desirable to change the trace positions after the survey was run.

For example, a survey run at a step size of 0.5 meters between two survey stakes 100 meters apart should produce 201 traces. However, if the step between traces was estimated during the survey, the 100 meter stake will likely be encountered before or after the 201st trace is collected. This means that over the course of the survey the actual step size was not exactly 0.50 meters, but more like 0.54 or 0.45 meters. Reposition is used to correct the step size so the GPR Line is the proper length.

Other examples where Reposition Traces may be useful are:

- The wrong start position was input so all the traces are in the wrong position.
- The wrong step size was input or the odometer calibration was incorrect so all the traces are in the wrong position.

Reposition would be used in these situations to adjust the trace positions to their actual position on the GPR line.

Reposition can be used to adjust the trace positions in four different ways (the Reposition using option determines which):

- **Input a new Start Position:** The Step Size and Length stay the same and the End Position is adjusted.
- **Input a new End Position:** The Step Size and Length stay the same and the Start Position is adjusted.
- **Input a new Step Size:** The Start Position stays the same and the Length and End Position are adjusted.
- **Input a new GPR line Length:** The Start Position stays the same and Step Size and End Position are adjusted.

Reposition Parameters

The parameters needed for this application are:

- **Start Position:** The Start Position (in meters or feet) of the GPR line.
- **End Position:** The End Position (in meters or feet) of the GPR line.
- **Length:** The length (in meters or feet) of the GPR line.
- **Step size:** The distance between traces (in meters or feet) in the GPR line.

Note: Only one parameter can be changed with each call to this routine so in some situations it may be necessary to call the routine more than once to modify the trace positions the way you want.

Example 1

A data file was collected from Start Position of 0.0 and an End Position of 100.0 with a step size of 0.5. An error was made in that the Start Position should be 10.0. To correct this, set the Start Position to 10.0. This will adjust all the trace positions with respect to the new Start Position. The End Position will change to 110.0.

Example 2

A data file was collected from Start Position of 0.0 and an End Position of 100.0 with a Step size of 0.5. An error was made in that the End Position should be 120.0. To correct this, set the Length to 120.0. A new Step size will be calculated to allow the traces to fit within the set Start (0.0) and end positions (120.0). For example, if the data file contains 201 traces, the new calculated Step size is $120.0/(201-1) = 0.6$ meters.

Example 3

A data file was collected from Start Position of 0.0 and an End Position of 100.0 with a Step size of 0.5. An error was made in that the Start Position should be 10 and the step size should be 0.25. To correct this, call the routine first and set the Start Position to 10.0. Then call the routine a second time with the Step size set to 0.25. The two calls will result in a final GPR line that starts at 10.0 and has a step size of 0.25.

5.7.7 Reposition Using GPS

If a GPR line was collected with GPS, every trace has a GPS position saved with it.

Reposition with GPS uses the GPS positions to reposition each trace in the GPR line. First, using all the GPS positions collected along the GPR line, it calculates the total path length for the GPR line. Then it divides the distance by the number of traces to compute a new average step size. The trace number and average step size are then used to calculate a new position for each trace in the GPR line.

This routine is very useful for data collected in Free Run mode with GPS because lines collected in Free Run use an estimated step size so the length of the line in the Acquisition Tab is usually not very accurate. Using GPS provides a good estimate of the actual length of the line.

5.8 Operations

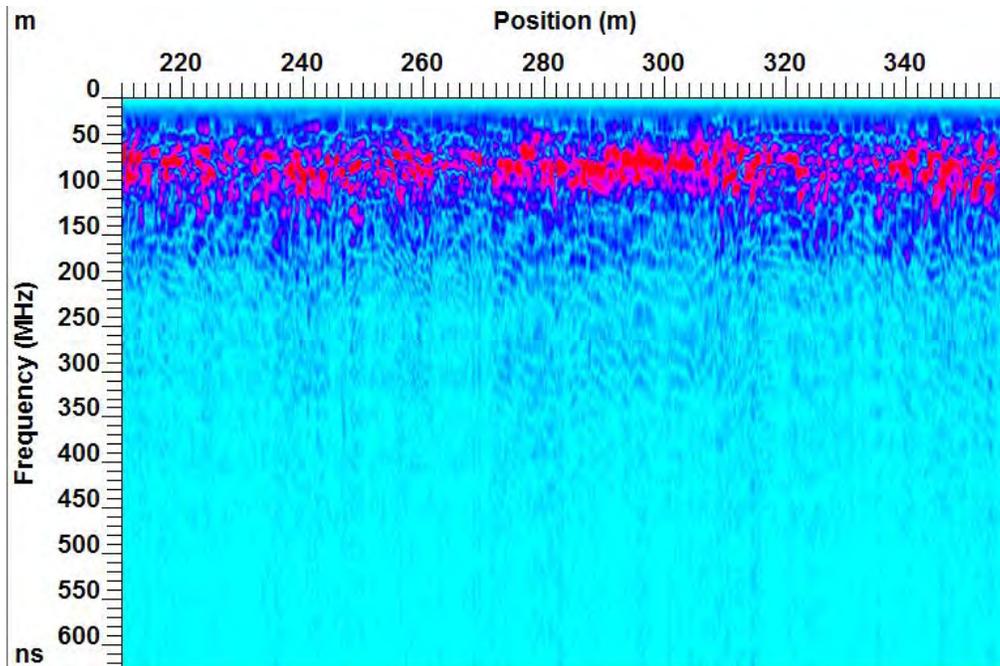
5.8.1 Amplitude Spectra

Amplitude Spectra uses the Fourier Transform to calculate the amplitude spectrum of each trace in the GPR line.

The amplitude spectrum is a plot of amplitude versus frequency and consequently reveals the frequency composition of the trace. This can be extremely useful information in determining which filter or processing technique would be the most effective in eliminating noise or emphasizing the desired signal.

Probably the most popular processing stream using Amplitude Spectra is used by the [Average Frequency Spectrum](#) (AFS) routine. Amplitude Spectra is run on the radar profile to calculate the amplitude spectrum of each trace. Then the average amplitude spectrum is calculated and displayed. This can be used to decide an appropriate filter to apply to the profile data.

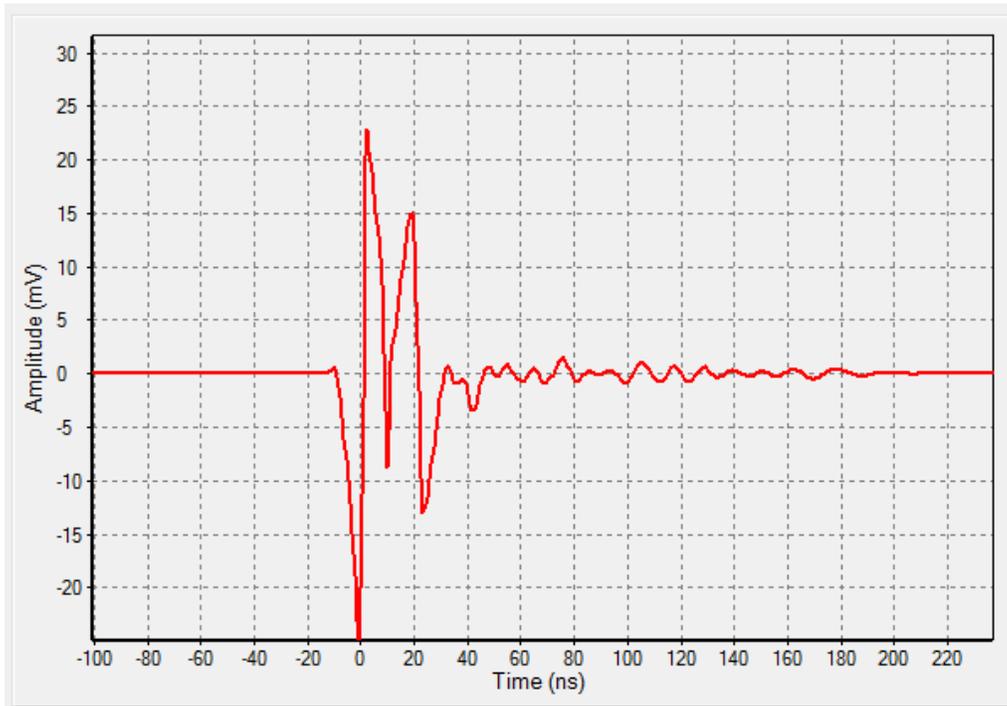
It is also possible to plot an amplitude spectrum section like a GPR line in LineView to see how the frequency content varies over the survey line. Note: when plotting amplitude spectra data in LineView, the frequency is plotted along the Time Axis where 1 ns = 1 MHz. The title of the "Time" axis can be edited to plot "Frequency (MHz)".



The plot above displays amplitude spectra data for 100 MHz geological data.

5.8.2 Average Trace

Average trace uses all the traces in the GPR line and calculates the average trace. The resulting GPR line only contains one trace so it is difficult to plot with [LineView](#) but can be plotted using the Trace Plot.



The average trace shows signals that are common to all or many traces; for example, horizontal signals such as the direct air wave, direct ground wave, banding and reverberations as well as flat reflectors.

5.8.3 Delete Traces

Occasionally, extra traces are recorded in a profile that later need to be deleted. Delete Traces allows the user to delete a trace at a specific position or many traces in a range of positions.

After the deletion of the traces, the traces are renumbered and repositioned so the total length of the line is correct.

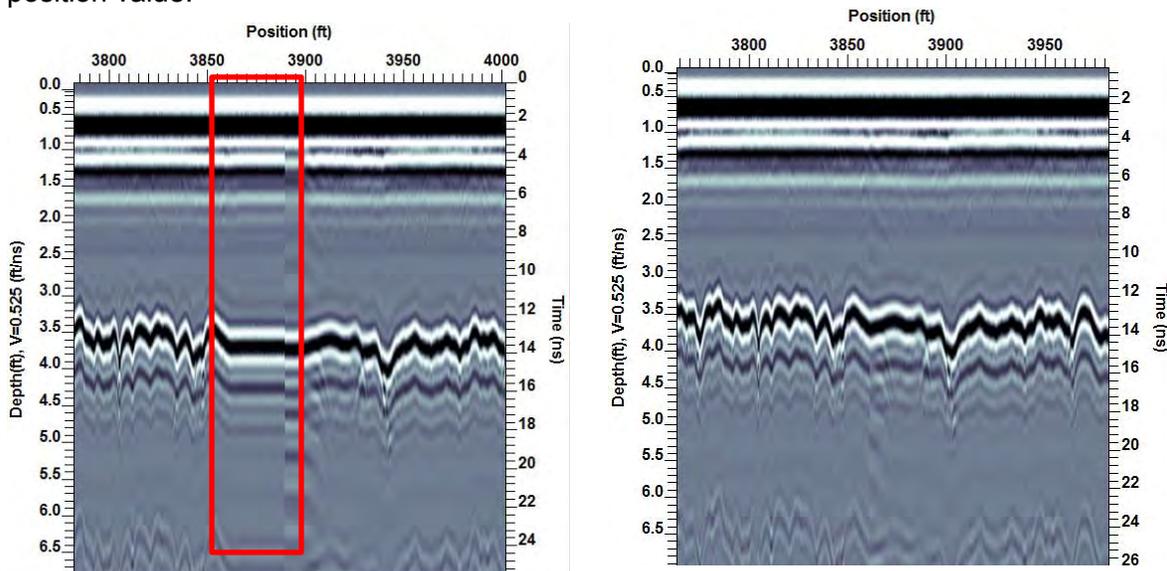
Any interpretations attached to traces that are deleted are permanently removed and **cannot** be recovered using Undo Process. It is advised that processing routines such as Delete Traces are applied before adding interpretation.

Delete Traces Parameters

Minimum Position	Position where first trace is deleted from the GPR line.
Maximum Position	Position where the last trace is deleted from the GPR line.

To delete one trace at one position: make that position **both** the Minimum and Maximum Positions.

Position ranges are independent of the sign of the step size. For example, if step size is negative, the position range still goes from the minimum position value to the maximum position value.



The most common usage of Delete Traces is to remove traces collected while the GPR was stationary in Free Run mode.

5.8.4 Flip Polarity

Sensors & Software pulseEKKO GPR systems have independent transmitters, receivers and antennas that can be put in any orientation relative to one another. While collected data along a profile line, it is important to keep the relative transmitter and receiver orientation the same, especially after any interruption in data collection to change batteries, etc.

One way to control polarity is to always have the Sensors & Software or pulseEKKO name on the electronic units pointed in the direction of antenna movement.

If the transmitter or receiver is rotated 180 degrees and changes the relative orientation, the signal polarity will reverse. If this happens in the middle of a survey line, negative signals (troughs) will change to positive signals (peaks) and vice-versa. If this occurs, the Flip Polarity routine is used to reverse the polarity of all or part of a GPR line.

Flip Polarity is also useful when one wants to merge two profile lines but they have different signal polarities. Simply reverse the polarity of one of the profile lines and then use the Merge Lines tool.

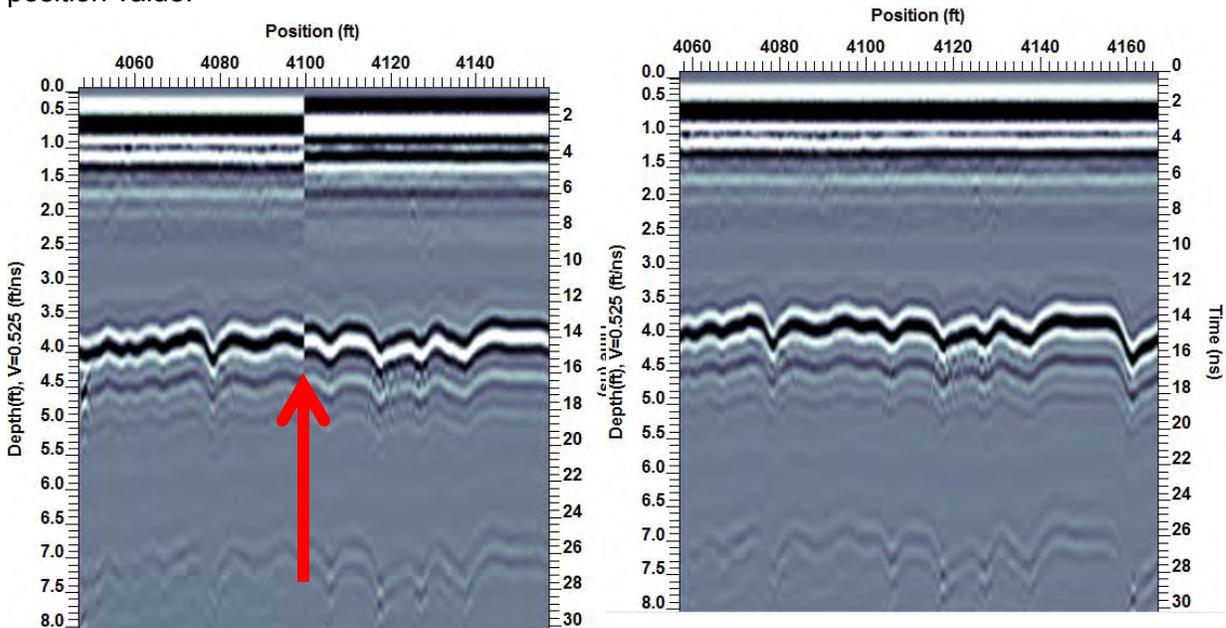
Flip Polarity Parameters

Minimum Position Position of the first trace in the GPR line where polarity is flipped.

Maximum Position Position of the last trace in the GPR line where polarity is flipped.

To flip the polarity of one trace at one position make that position both the Minimum and Maximum Position.

Position ranges are independent of the sign of the step size. For example, if step size is negative, the position range still goes from the minimum position value to the maximum position value.



The images above show a GPR line where the polarity changes in the middle of the line (left) and is corrected on the right.

5.8.5 Insert Traces

The purpose of Insert Traces is to allow blank traces to be inserted at locations which, for one reason or another, had to be skipped while collecting data out in the field. Adding blank traces where necessary makes the GPR line the proper length. After inserting blank traces, the traces are renumbered and repositioned so the total length of the line is correct.

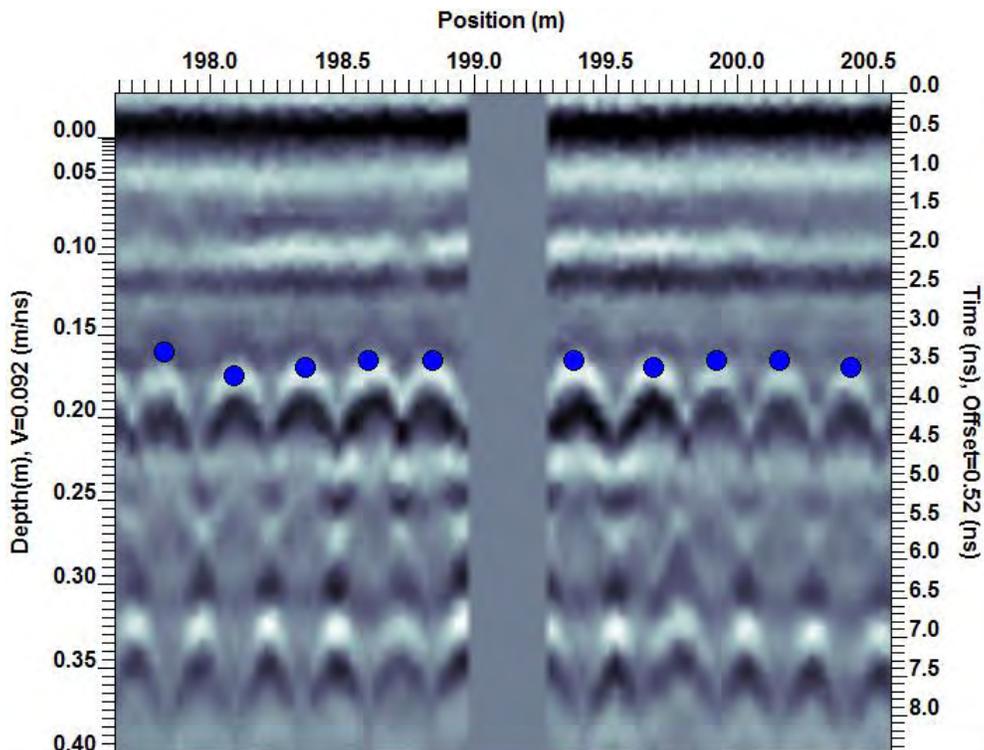
Note that no matter where and how many blank traces are inserted, the start position of the GPR line is preserved; inserting traces only causes the end position to change.

Insert Traces Parameters

Minimum Position The position at which to add blank traces in the GPR line.

Number of Traces The number of blank traces to add at the corresponding position.

Traces are always added in the direction of increasing position; there is always at least one real GPR trace BEFORE the blank traces.



A GPR line with 10 blank traces inserted in the middle is shown above.

5.8.6 Mute

Occasionally, a GPR line contains areas of poor data such as noise, a ringing metal response or a system glitch that draws the eye away from the more important data. Mute Data is used to mute (zero) a rectangle of data within a GPR line.

Mute Parameters

Minimum Position Position of the first trace in the GPR line to mute.

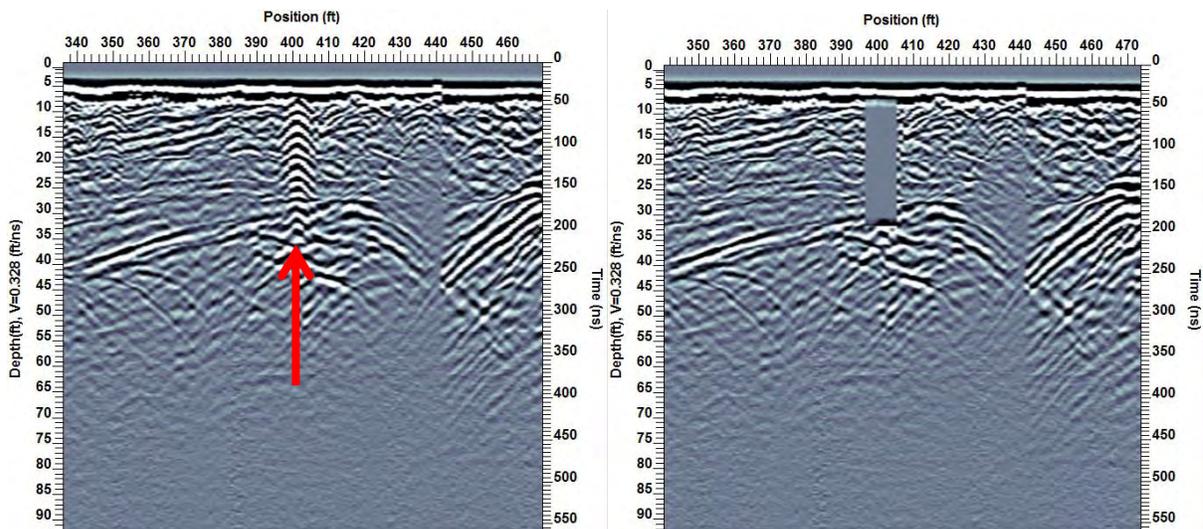
Maximum Position Position of the last trace in the GPR line to mute.

Position ranges are independent of the sign of the step size. For example, if step size is negative, the position range still goes from the minimum position value to the maximum position value.

Minimum Time First time in the GPR line to mute.

Maximum Time Last time in the GPR line to mute.

Minimum time must be less than Maximum Time.



The images above show how the strong ringing from a piece of metal debris (left) was muted out (right).

5.8.7 Normal Move-out Correction

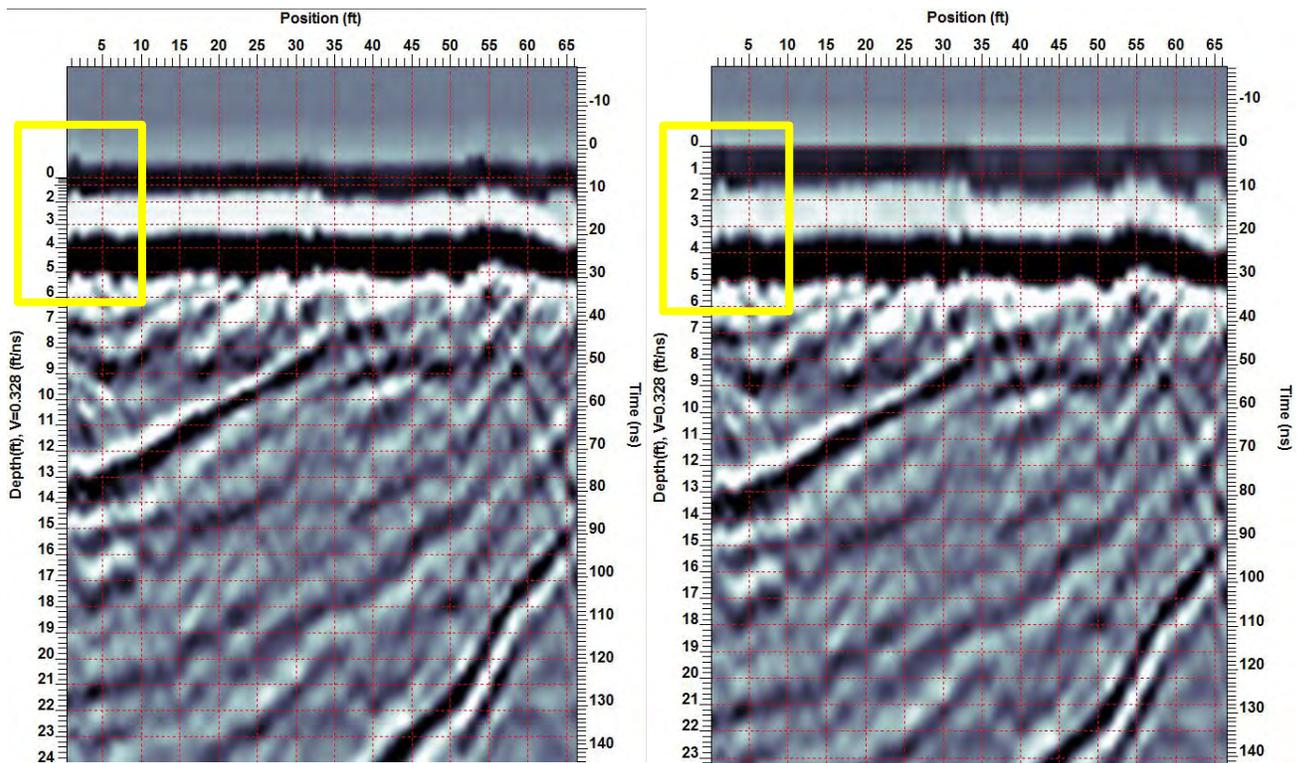
The finite separation between the GPR transmitter and receiver results in the top of the depth scale looking non-linear compared to the rest of the scale. This is because, especially at shallow depths, the depth to a reflector is not equal to half the signal path length.

The Normal Move-Out Correction convert a finite offset GPR line to a zero offset (transmitter and receiver coincident) by correcting for normal move-out using the input velocity.

This process stretches the signals at the top of the section so the depth scale and time start at the same point.

Normal Move-out Parameter

Velocity The average subsurface velocity in meters/nanosecond to use to correct the signal for the normal move-out.



The images above show the effect of applying the Normal Move-out Correction to 100 MHz geological data.

5.8.8 Rectify

Rectify goes through the GPR line and outputs the rectified version of each trace (i.e. the absolute value of each point in the trace).

The Rectify utility is very useful when one wants to look at the L1-norm of a data set. By rectifying a data file and then averaging all the traces together one can obtain a very useful estimate of amplitude fall-off versus time.

Rectifying a trace converts the trace from a wavelet with both positive and negative components to a wavelet with all positives.

L1 norm (rectify equation):

$$X_{\text{Rectify}} = \frac{\sum_{i=N}^M |x_i|}{N - M + 1}$$

At a single time or depth value the amplitude value will be the same amplitude as the raw value but always positive. When amplitude values are averaged over a time or depth range this will give the average, absolute value.

Rectify Variables: There are no input parameters required for this application.

Appendix A File Formats

1. Interpretation Reports

The following information is written to the Interpretation Report:

- Header: lists the Interpretation Names and count of observations for each interpretation
- Drawing Tool
- Interpretation Name
- GPR Line Name
- Position along Line (m or ft.)
- X Position (m or ft.)
- Y Position (if grid data)
- Depth (m or ft.)
- Time (ns)
- Elevation (if available, m or ft.)
- Signal Amplitude (millivolts)
- Velocity (ft/ns or m/ns): Velocity is used to calculate depth and elevation.
- UTM Easting with Zone
- UTM Northing with Zone
- Latitude (degrees and decimal degrees; + = North, - = South)
- Longitude (degrees and decimal degrees; + = East, - = West)
- GPS Elevation of the GPS receiver
- Comments

Name	Description	Count														
Annotation1		1														
Box1		1														
Airwave		1														
Pipe1		2														
Shallow Metal		1														
Horizon1		2														
Fiducial		5														
Tool	Interpretation	GPR Line	Position(m) X(m)	Y(m)	Depth(m)	Time(ns)	Elevation(m)	Amplitude(mV)	Velocity(m/ns)	GPS Easting (17T)	GPS Northing (17T)	Latitude	Longitude	GPS Elevation	Comment	
Annotation	Annotation1	PROJECT0\LINE00	26.057	26.057	0	1.679	38.77	111.137	-0.017	0.085	609817.58	4831949.53	43.6324321	-79.6386439	112.82 Air wave from overhead power line	
Box	Box1	PROJECT0\LINE00	12.113	12.113	0	0.223	5.19	112.877	16.242	0.085	609807.68	4831939.71	43.6323453	-79.6387686	113.1	
Box	Box1	PROJECT0\LINE00	18.354	18.354	0	0.706	16.04	112.294	0.092	0.085	609812.11	4831944.11	43.6323841	-79.6387128	113	
Point	Airwave	PROJECT0\LINE00	25.607	25.607	0	1.665	38.46	111.219	-0.005	0.085	609817.27	4831949.21	43.6324293	-79.6386479	112.88	
Point	Pipe1	PROJECT0\LINE00	27.407	27.407	0	0.649	14.71	111.951	-2.905	0.085	609818.54	4831950.48	43.6324406	-79.6386318	112.6	
Point	Pipe1	PROJECT0\LINE00	39.214	39.214	0	0.669	15.18	112.231	4.84	0.085	609826.93	4831958.79	43.6325141	-79.6385262	112.9	
Point	Shallow Metal	PROJECT0\LINE00	82.451	82.451	0	0.239	5.51	113.061	4.595	0.085	609857.64	4831989.22	43.6327835	-79.6381394	113.3	
Polyline	Horizon1	PROJECT0\LINE00	23.808	23.808	0	0.522	11.8	112.478	3.638	0.085	609815.99	4831947.95	43.6324181	-79.6386664	113	
Polyline	Horizon1	PROJECT0\LINE00	24.427	24.427	0	0.501	11.33	112.499	6.72	0.085	609816.43	4831948.38	43.6324222	-79.6386085	113	
Polyline	Horizon1	PROJECT0\LINE00	24.933	24.933	0	0.47	10.62	112.514	6.632	0.085	609816.79	4831948.74	43.6324251	-79.6386654	112.98	
Polyline	Horizon1	PROJECT0\LINE00	26.001	26.001	0	0.536	12.11	112.287	2.828	0.085	609817.54	4831949.49	43.6324318	-79.6386444	112.82	
Polyline	Horizon1	PROJECT0\LINE00	26.451	26.451	0	0.495	11.17	112.305	1.306	0.085	609817.86	4831949.81	43.6324346	-79.6386404	112.8	
Fiducial	Fiducial	PROJECT0\LINE00	15.4	15.4	0	0	N/A	N/A	N/A	0.085	609810.01	4831942.03	43.6323657	-79.6387392	113 F1	
Fiducial	Fiducial	PROJECT0\LINE00	21.4	21.4	0	0	N/A	N/A	N/A	0.085	609814.28	4831946.25	43.6324031	-79.6386856	113 F2	
Fiducial	Fiducial	PROJECT0\LINE00	27.4	27.4	0	0	N/A	N/A	N/A	0.085	609818.54	4831950.47	43.6324405	-79.6386319	112.6 F3	
Fiducial	Fiducial	PROJECT0\LINE00	39.25	39.25	0	0	N/A	N/A	N/A	0.085	609826.96	4831958.81	43.6325143	-79.6385259	112.9 F4	
Fiducial	Fiducial	PROJECT0\LINE00	82.4	82.4	0	0	N/A	N/A	N/A	0.085	609857.61	4831989.19	43.6327832	-79.6381398	113.3 F5	

In a box interpretation, the positions of the upper-left and bottom-right corners are listed.

2. Global Positioning Files

The Global Positioning System (GPS) uses special satellites around the Earth to determine the position of a GPS receiver located at any position on the surface of the Earth. GPS receivers can be purchased from a number of manufacturers.

Sensors & Software GPR systems have a serial port for attaching a GPS receiver to record the position of the GPR unit. This port will accommodate any GPS receiver that has a standard serial port output.

The GPS receiver sends one or more types of data strings to the GPR. These strings, called NMEA-0183 strings, contain positional and other information in specific formats. Each type of string is specified by a 5-character prefix. There are numerous NMEA strings but to integrate the GPS data into the GPR data, the GPS receiver must be sending the GPGGA string. This may require reprogramming the GPS receiver; most systems come with PC-based utility software.

3. GPS

The .GPS file format consists of a line listing the GPR trace number and the position based on the odometer and the step size, followed by one or more NMEA strings. The GPGGA string must be included in this list.

Depending on the version of the embedded data acquisition software, the trace number lines may have every trace, every nth trace or a somewhat random interval between trace numbers.

Trace #2 at position 0.050000

```
$GPGGA,185721.00,4337.9926,N,07938.2533,W,2,09,1.2,110.2,M,-35.1,M,,138*68
```

```
$GPGSA,A,3,15,05,18,21,26,29,51,02,08,,,,,2.3,1.2,1.9*32
```

```
$GPVTG,0.0,T,,0.0,N,0.0,K*2D
```

Trace #3 at position 0.100000

```
$GPGGA,185731.00,4337.9926,N,07938.2534,W,2,09,1.2,110.3,M,-35.1,M,,138*6F
```

```
$GPGSA,A,3,26,18,05,21,15,29,08,02,51,,,,,2.3,1.2,1.9*32
```

```
$GPVTG,0.0,T,,0.0,N,0.0,K*2D
```

Trace #4 at position 0.150000

```
$GPGGA,185732.00,4337.9926,N,07938.2534,W,2,09,1.2,110.4,M,-35.1,M,,138*6B
```

```
$GPGSA,A,3,21,15,26,29,18,05,51,02,08,,,,,2.3,1.2,1.9*32
```

```
$GPVTG,0.0,T,,0.0,N,0.0,K*2D
```

Trace #5 at position 0.200000

```
$GPGGA,185733.00,4337.9926,N,07938.2534,W,2,09,1.2,110.4,M,-35.1,M,,138*6A
```

```
$GPGSA,A,3,21,51,26,29,15,18,05,02,08,,,,,2.3,1.2,1.9*32
```

```
$GPVTG,0.0,T,,0.0,N,0.0,K*2D
```

Trace #8 at position 0.350000

```
$GPGGA,185734.00,4337.9926,N,07938.2534,W,2,09,1.2,110.4,M,-35.1,M,1,138*5C
```

```
$GPGSA,A,3,21,15,26,29,51,18,05,02,08,,,,,2.3,1.2,1.9*32
```

```
$GPVTG,0.0,T,,0.0,N,0.0,K*2D
```

Trace #12 at position 0.550000

4. GP2

The .GP2 file format consists of 5 header lines, then a line that defines the parameters listed on each line for the rest of the file:

Trace number

Number of odometer ticks

GPR line position (based on odometer ticks, odometer calibration value and step size)

Time elapsed in seconds since the start of the data collection

GPS NMEA string in quotes

Any NMEA strings output by the GPS receiver are listed. The GPGGA string is required to be in the list.

```
;GPS@@@
;Ver=1.1.0
;DIP=2009-00152-00
;Date=2012-Jan-09 13:56:16.0
;-----
traces,odo_tick,pos(m),time_elapsed(s),GPS
1,0,0.000,0.00,"$GPGGA,185713.00,4337.9926,N,07938.2533,W,2,09,1.2,110.2,M,-
35.1,M,,138*69"
1,0,0.000,0.00,"$GPGSA,A,3,15,21,29,51,26,18,08,02,05,,,,2.3,1.2,1.9*32"
1,0,0.000,0.00,"$GPVTG,0.0,T,,0.0,N,0.0,K*2D"
1,1,0.001,0.60,"$GPGGA,185714.00,4337.9926,N,07938.2533,W,2,09,1.2,110.2,M,-
35.1,M,,138*6E"
1,1,0.001,0.60,"$GPGSA,A,3,15,29,21,26,18,05,08,02,51,,,,2.3,1.2,1.9*32"
1,1,0.001,0.60,"$GPVTG,0.0,T,,0.0,N,0.0,K*2D"
1,3,0.003,1.59,"$GPGGA,185715.00,4337.9926,N,07938.2533,W,2,09,1.2,110.2,M,-
35.1,M,,138*6F"
1,3,0.003,1.59,"$GPGSA,A,3,18,21,05,26,29,15,08,02,51,,,,2.3,1.2,1.9*32"
1,3,0.003,1.59,"$GPVTG,0.0,T,,0.0,N,0.0,K*2D"
1,2,0.002,2.58,"$GPGGA,185716.00,4337.9926,N,07938.2533,W,2,09,1.2,110.2,M,-
35.1,M,1,138*5D"
1,2,0.002,2.58,"$GPGSA,A,3,05,21,15,18,26,29,08,02,51,,,,2.3,1.2,1.9*32"
1,2,0.002,2.58,"$GPVTG,0.0,T,,0.0,N,0.0,K*2D"
1,3,0.003,3.63,"$GPGGA,185717.00,4337.9926,N,07938.2533,W,2,09,1.2,110.2,M,-
35.1,M,2,138*5F"
1,3,0.003,3.63,"$GPGSA,A,3,21,26,15,29,18,05,08,02,51,,,,2.3,1.2,1.9*32"
1,3,0.003,3.63,"$GPVTG,0.0,T,,0.0,N,0.0,K*2D"
1,5,0.005,4.61,"$GPGGA,185718.00,4337.9926,N,07938.2533,W,2,09,1.2,110.2,M,-
35.1,M,3,138*51"
1,5,0.005,4.61,"$GPGSA,A,3,18,21,26,29,05,15,08,02,51,,,,2.3,1.2,1.9*32"
1,5,0.005,4.61,"$GPVTG,0.0,T,,0.0,N,0.0,K*2D"
1,6,0.006,5.60,"$GPGGA,185719.00,4337.9926,N,07938.2533,W,2,09,1.2,110.2,M,-
35.1,M,,138*63"
1,6,0.006,5.60,"$GPGSA,A,3,21,18,15,05,29,26,08,02,51,,,,2.3,1.2,1.9*32"
1,6,0.006,5.60,"$GPVTG,0.0,T,,0.0,N,0.0,K*2D"
1,10,0.009,6.59,"$GPGGA,185720.00,4337.9926,N,07938.2533,W,2,09,1.2,110.2,M,-
35.1,M,,138*69"
1,10,0.009,6.59,"$GPGSA,A,3,18,21,15,05,26,29,08,02,51,,,,2.3,1.2,1.9*32"
1,10,0.009,6.59,"$GPVTG,0.0,T,,0.0,N,0.0,K*2D"
1,20,0.019,7.58,"$GPGGA,185721.00,4337.9926,N,07938.2533,W,2,09,1.2,110.2,M,-
35.1,M,,138*68"
```

```
1,20,0.019,7.58,"$GPGSA,A,3,15,05,18,21,26,29,51,02,08,,,,,2.3,1.2,1.9*32"
1,20,0.019,7.58,"$GPVTG,0.0,T,,,0.0,N,0.0,K*2D"
```

The last characters (before the quote symbol) in the NMEA string is the checksum. The checksum is the xor of each byte between the \$ and *. NMEA lines with a failed checksum are assumed to be corrupt and not recorded.

5. SEG-Y

The following describes in detail which variables are loaded in the SEG-Y conversion program.

Reel Identification Header - ASCII Portion

The reel identification header is first loaded with the GPR header file (*.HD). This file is copied directly into the ASCII portion.

Reel Identification Header - Binary Portion

The following lists the variables used in the binary portion.

Bytes	Description
3201-3204	Set to zero.
3205-3208	Set to zero.
3209-3212	Set to zero.
3213-3214	Set to one for REFLECTION data.
Set to # of	offsets for CDP data.
3215-3216	Set to zero.
3217-3218	Sample interval down trace in psec.
3219-3220	Sample interval down trace in psec.
3221-3222	Number of points in trace.
3223-3224	Number of points in trace.
3225-3226	Set to three (fixed point 2 bytes).
3227-3228	CDP fold. Set to zero for REFLECTION data. Set to # offsets for CDP data.
3229-3230	Trace Sorting Code. Set to three for single fold data. Set to one for multifold data.
3231-3250	Not used.
3251-3252	Set to two (no binary gain recovery).
3253-3254	Set to one (no amplitude recovery method).
3255-3256	Set to 1 or 2 depending on units used.
3257-3258	Not used.
3259-3260	Not used.
3261-3600	Not used or NON STANDARD (see the following).

Non-Standard

Bytes Description

3261-3262	Number of traces (I*2)
3401-3410	Job number (CHAR*10)
3411-3480	Title 1 (CHAR*70)

3481-3550	Title 2 (CHAR*70)
3551-3570	Date (CHAR*20)
3571-3572	Number of stacks (I*2)
3573-3574	Pulser voltage (I*2)
3575-3594	Survey mode (CHAR*20)
3595-3598	Frequency (R*4)
3599-3600	Dewow (I*2) (0-NOT DONE 1-DONE)

The following lists the variables used in the binary portion.

Bytes	Description
1-4	Trace number from 1 to number of traces.
5-8	Trace number from 1 to number of traces.
9-12	Tape record number 1 to number of traces.
13-16	Set to one.
17-20	Not used.
21-24	CDP ensemble number.
25-28	Trace # within CDP. (one for REFLECTION data)
29-30	Set to one.
31-32	Set to one.
33-34	Set to one.
35-36	Set to one.
37-40	Antenna sep. times 1000. (Not official SEG-Y format)
41-44	Receiver Elevation data times 1000.
45-48	Transmitter Elevation data times 1000.
49-68	Set to zero.
69-70	Set to -1000.
71-72	Set to -1000.
73-76	Transmitter x-coord times 1000.
77-80	Transmitter y-coord (set to zero).
81-84	Receiver x-coord times 1000.
85-88	Receiver y-coord (set to zero).
89-104	Not used.
105-106	Timezero in ns.
107-114	Not used.
115-116	Number of points in trace.
117-118	Sample interval in psec.
119-120	Set to one.
121-240	Not used.

6. Topography Files

- Each line of text must contain a pair of numbers representing position along the GPR line and elevation.
- These numbers can be separated by a space or a tab.
- The range of topographic information does not have to correspond exactly to the range of positions in the GPR line. Positions lying outside the range of available topographic data will be assigned to the elevation of the nearest endpoint.
- Since linear interpolation is used to obtain the elevation at each trace position it is not necessary to have an elevation for every trace in the file. Topographic data can be added to a GPR line with as little as two position and elevation pairs (in the case of a constant slope). The more data points entered, the more detail there will be in the topographic correction.
- Topographic files must have a .top extension.

0.0	935.8
10.1	933.9
22.7	930.3
30.5	932.7
34.6	936.5

Topography files are text files that are easily created using Windows Notepad, which defaults to a .txt file extension

To change the Notepad default to a .top extension:

1. In Notepad click **File > Save As**.
2. In the **Save as** dialog box in the **Save as type** drop-down list, click **All Files**.
3. In the **File name** text box, typing file name and append it with the .top extension.

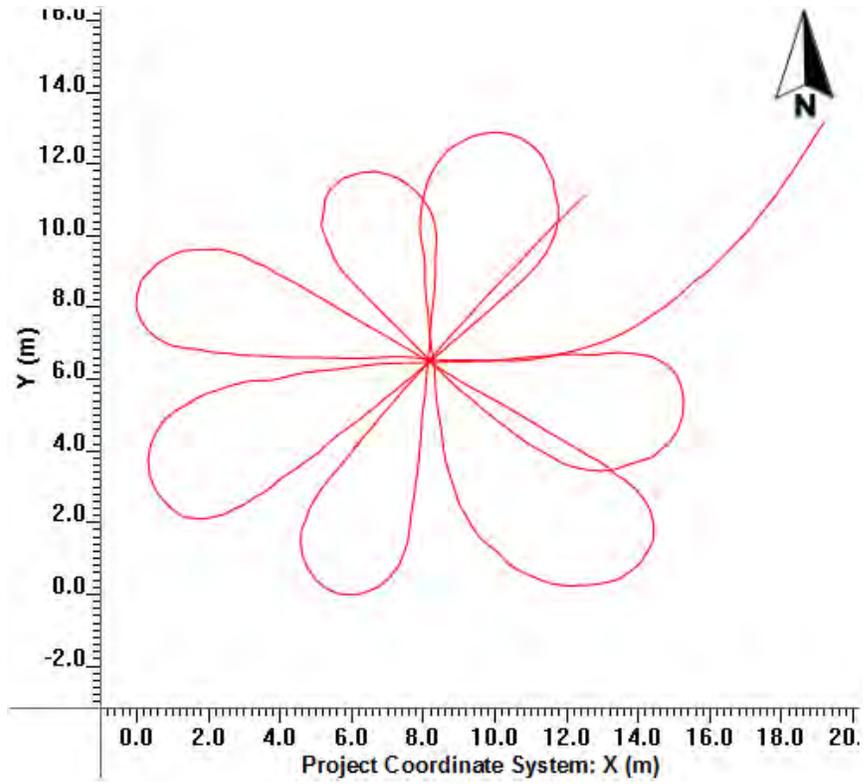
For example, Line87.top.

Appendix B Calculating GPS Latency

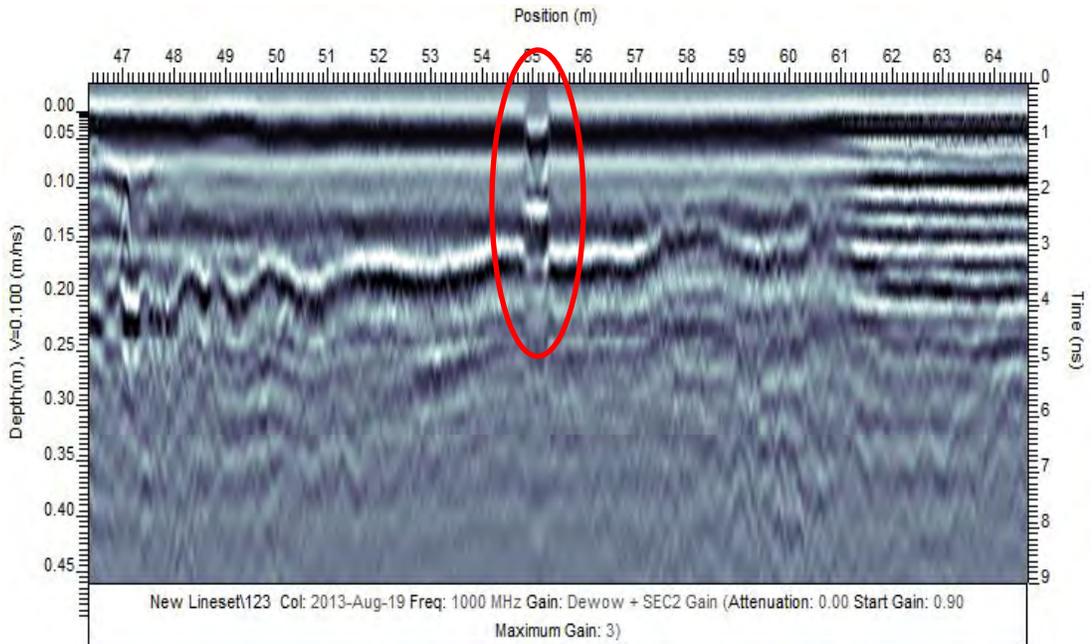
1. Choose a large outdoor area with a clear view of the sky, like a parking lot.
2. In the center of the area, place a metallic disk, roughly 1 ft in diameter. You can use a foil covered piece of cardboard. It is advised that the disk be taped down so that it does not move.
3. Set up your GPR to collect GPS data as well. Make sure that the GPS is centered directly over top of the GPR unit (as shown below).
4. Set GPR recording Depth to 0.50m (10.1ns) so that data can be collected quickly without skipping traces.
5. Start a new line and collect data running over the disk in a flower pattern (see figure below). Try to run over the disk in as many different directions and as many different speeds as you can. The faster the data are collected over the plate, the more accurate the latency value will be.
*Make sure no traces are skipped.



6. Export the GPZ data from the flash memory card and open it in the EKKO_Project software. MapView should display your GPS path like this:

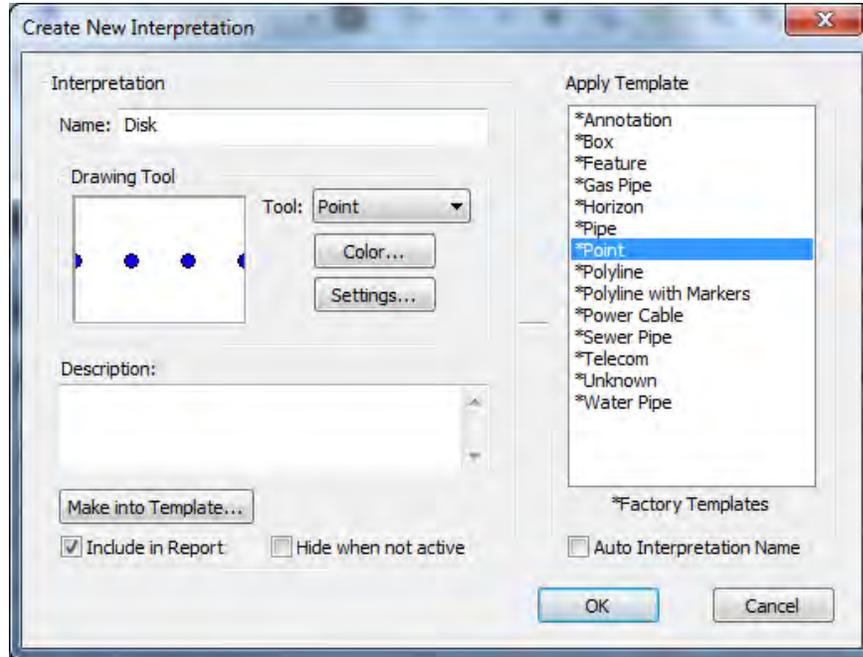


7. Double click the line name in the Project Explorer to open in LineView. Each time you ran over the disk you should see a disturbance in the direct wave like this:

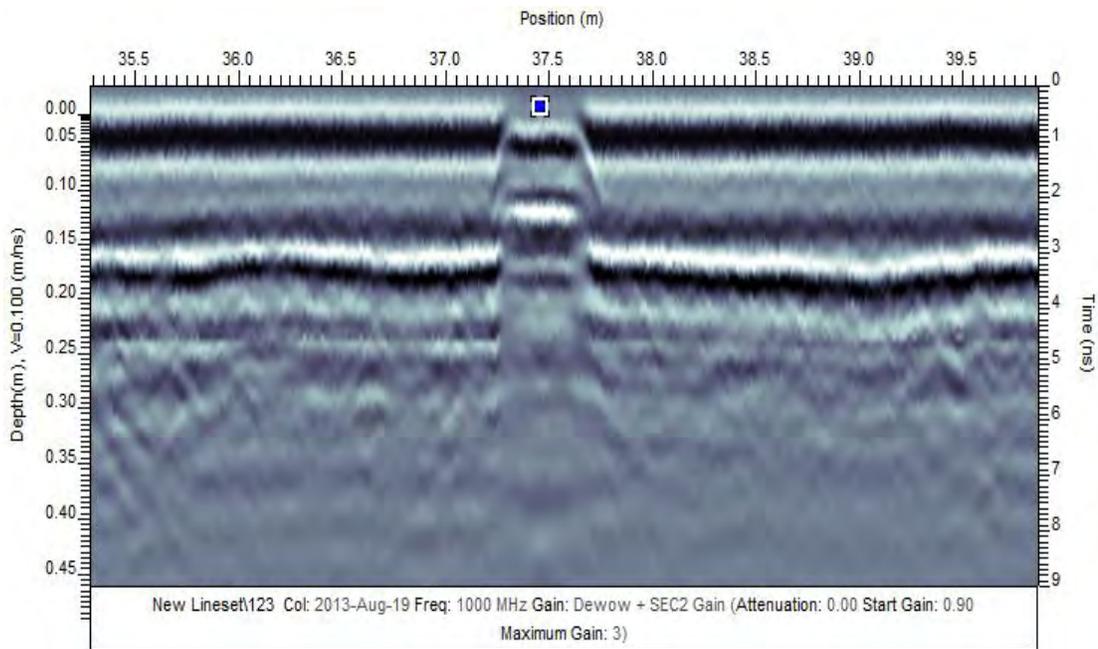


8. Create a new Point type interpretation.

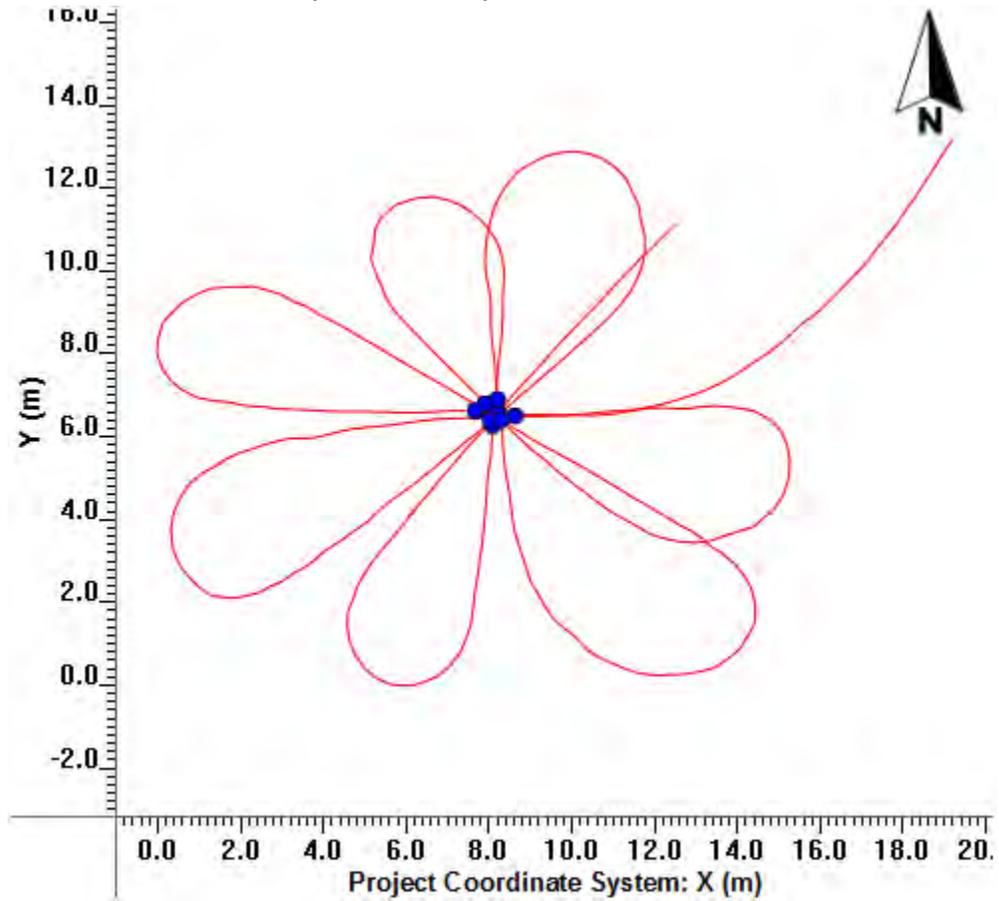
Note: If the Interpretation module is not enabled, use the mouse cursor and the F8 key for steps 8 to 13. Pressing the F8 key with the mouse cursor on the disk response in the GPR line saves the position information to the Clipboard. Copy the position information of each disturbance to a csv file.



9. Scroll through the line and enter and add an observation at the center of each of the disturbances. The vertical placement of the observation is not important.



10. Close LineView. Now you should see all of the observations clustered near the center of the flower pattern in MapView.



11. Run the Project Report under **File > Report > Project Report**, make a new folder called **0s_latency** and save the report inside.
12. Go to **Tools > GPS > Latency** and set it to 1 second, click **OK**.
13. Run the Project Report again under **File > Report > Project Report**, make a new folder called **1s_latency** and save the report inside.

14. Open a new spreadsheet in Excel. Copy and paste the UTM coordinates from the two project reports into the columns of the new spreadsheet.

0s Latency Set		1s Latency Set	
Easting	Northing	Easting	Northing
609895.67	4831925.06	609895.1	4831924.38
609895.55	4831924.67	609895.69	4831926.31
609895.36	4831925.25	609897.68	4831923.17
609896.07	4831924.94	609892.26	4831924.66
609895.51	4831924.85	609896.8	4831925.95
609895.65	4831925.42	609896.04	4831922.3
609895.77	4831924.83	609894.77	4831925.44
609895.1	4831925.07	609899.3	4831925.17

15. In the column to the right, calculate the speed in each axis by differencing the Eastings and the Northings. So Speed in Easting is Easting at 0s latency – Easting at 1s latency

0s Latency Set		1s Latency Set		Speed	
Easting	Northing	Easting	Northing	Easting	Northing
609895.67	4831925.06	609895.1	4831924.38	0.57	0.68
609895.55	4831924.67	609895.69	4831926.31	-0.14	-1.64
609895.36	4831925.25	609897.68	4831923.17	-2.32	2.08
609896.07	4831924.94	609892.26	4831924.66	3.81	0.28
609895.51	4831924.85	609896.8	4831925.95	-1.29	-1.1
609895.65	4831925.42	609896.04	4831922.3	-0.39	3.12
609895.77	4831924.83	609894.77	4831925.44	1	-0.61
609895.1	4831925.07	609899.3	4831925.17	-4.2	-0.1

16. In the next two columns calculate a corrected Easting and Northing based on some defined latency value. So the Corrected Easting is Easting at 0s latency – Speed_Easting * Latency_s (0s,1s)

Avg Standard Deviation:

0.056759662

19. Once you have found the minimum Average Standard Deviation, this is the latency value to use for this GPS unit.

Appendix C Glossary

1. Definitions

Term	Description
Attenuation	Represents the radar wave attenuation given in decibels/meter. The higher the attenuation value, the faster the exponential function rises the more gain applied at earlier times on the GPR Line.
Attributes	Characteristics derived from original data. Examples are the average amplitude of the dominant frequency between two times or depths.
Automatic Gain Control (AGC)	The Automatic Gain Control (AGC) gain attempts to equalize the amplitudes of all GPR signals by applying a gain which is inversely proportional to the signal strength. This type of gain is most useful for defining continuity of reflecting events.
Average Frequency Spectrum (AFS)	Use AFS plots to determine the frequency of a signal on which to base processing and filtering, similar to band-pass.
Average Trace Amplitude (ATA)	The Average Trace Amplitude (ATA) plot displays the average signal amplitudes (in microvolts) for an entire data file. This plot is a good way to display how rapidly the signal amplitude decays to the background level, giving you an idea of the maximum penetration for the data file.
Background Average Subtraction (BAS)	Use BAS to subtract the average trace of the entire GPR line from every trace in the line. This process enhances dipping events (such as hyperbolas from point targets) and removes horizontal responses common to all traces in the line. It is also used to remove the direct air and direct ground waves (transmit pulse) visible at the top of the line. BAS also removes horizontal bands in the data present throughout the length of the line.
Background Subtraction	Use Background Subtraction to apply a running-average background subtraction to the data set. This process enhances dipping events (such as hyperbolas from point targets) and suppresses or completely removes horizontal responses. This can be very useful for removing localized flat-lying events.
Bandpass Filter	Use bandpass filtering when the GPR signal is contained in a defined band of frequencies and there is "noise" energy in the remainder of the spectrum. Applying bandpass filtering enhances the desired signals at the expense of the out-of-band noise (Dewow). Bandpass is based on Fourier transform filtering concepts.
Dewow	The process of removing a very low frequency component from GPR data. These low frequency data components are associated with either inductive phenomena or possible instrumentation dynamic range limitations.

Term	Description
DynaQ	DynaQ is an advanced, patented technology that dynamically adjusts stacking as system speed varies. In most situations, moving the system at a comfortable speed stacks enough to generate good quality data.
Enveloping	<p>Enveloping converts a trace from a wavelet with both positive and negative components to a monopulse wavelet with all positive components.</p> <p>The process removes the oscillatory nature of the radar wavelet and shows the data in its true resolution. Enveloping can also simplify radar section display making it easier to interpret.</p>
Filter Type	Dictates the weighting the traces on the edges of the Filter Width have on the average trace calculation.
First Break Offset	The number of nanoseconds from the start of the trace to the first break.
GPS Files	<p>Attaching a GPS file adds Latitude and Longitude, UTM coordinates, and GPS elevation to every trace in the GPR line.</p> <p>A GPS file is created by attaching a GPS system to the GPR system during data collection. GPS files contain lines of standard GPS positional output text (called NMEA strings) and the associated GPR trace number. When the GPS file is attached, latitude, longitude, and GPS elevations for every GPR trace are saved into the GPR file.</p>
GPZ Files	Compressed files containing GPR lineset and grid data
Grid	<p>A square or rectilinear set of straight lines which cover an area. Acquiring data on a grid means acquiring data along each line forming the grid.</p> <p>Acquiring data on a grid is a pre-requisite for creating depth or time slice images. Conventional notation is to use a Cartesian coordinate system with X and Y axes.</p>
Highpass Filter	<p>Removes frequencies below a cut-off frequency. Used for removing low frequency content in the GPR data; sometimes used instead of the Dewow filter.</p> <p>High Pass is a recursive filter designed for filtering GPR lines in the time domain. It is an infinite impulse response zero phase filter.</p>
Interpretation Module	Interpretation module in LineView to create interpretations of Points, Polylines, Boxes, and Annotations, view them in GPR lines, and then output the interpretational information in reports.
KMZ Files	<p>The KMZ files generated by a Noggin contain GPS information describing the path travelled during line collection.</p> <p>These files can be configured to display depth measurements along the line, making the data easier to interpret. Noggin enables you to export KMZ files which can be opened in Google Earth.</p>
Lineset	<p>All GPR lines in a project contained in one folder; collections of GPR lines that may or may not be related to one another.</p> <p>Linesets can be edited to add or delete GPR lines. GPR lines in linesets can also be cut and/or copied and pasted into other linesets.</p>

Term	Description
LineView	Shows GPR line data cross sections. Uses EKKO_View/Interp application modified to work with and get launched from EKKO_Project.
Lowpass Filter	Removes frequencies above a cut-off frequency - useful for removing high frequency noise in GPR data. Low pass is a recursive filter designed for filtering GPR lines in the time domain. It is an infinite impulse response zero phase filter.
Migration	The migration process applies a synthetic aperture image reconstruction process to the GPR line.
nanosecond	A nanosecond is 10^{-9} seconds (one billionth of a second).
Overlap	Overlap (% of slice thickness) between the adjacent depth/time slices.
picosecond	A picosecond is 10^{-12} seconds (one trillionth of a second).
Polylines	A polyline is a list of points, where line segments are drawn between consecutive points.
Polyline Output Interval	The horizontal distance (meters or feet) between points on any polylines in the project. To interpolate and list more points than just the input observation points, enter them text box. A common interval is the step size for the GPR line
Project Explorer	The Project Explorer is similar to Windows Explorer, which lists folders and files. In Project Explorer, grids and linesets are used just like folders in Windows, and GPR lines are similar to Window Explorer files.
Processing Module	The optional Processing module allows you to edit and process data, including cropping data, time filters, migration and gain. Popular processing streams can be saved as Recipes and applied to other GPR projects.
Properties Window	Displays details of each GPR line including acquisition parameters and associated files
Slice	Describes the GPR data in a depth slice when the data is displayed as a computer generated image. Normally shortened to slice.
SliceView (EKKO_Mapper)	SliceView creates and displays GPR depth slice maps quickly and easily. Using the systematic grid data acquisition process common to pulseEKKO PRO, Noggin, or Conquest systems, images at multiple depths are generated in minutes.
Spatial Filter	Spatial filters act on radar data in the spatial (or positional) direction. These filters use adjacent traces during the filtering procedure and alter the shape of the trace through various mathematical manipulations designed to enhance or eliminate certain features.
Spreading & Exponential Calibrated Compensation (SEC2)	SEC2 gain is a composite of a linear time gain and an exponential time gain which attempts to compensate for the spherical spreading losses and the exponential ohmic dissipation of energy in the GPR Line.

Term	Description
Time Window	The maximum time selected for viewing, processing or data acquisition along a line. The length of the time window in nanoseconds (ns).
Time Sampling Interval	The time in picoseconds at which the GPR signal is sampled. Often set automatically by the system based on GPR frequency.
Topography Files	A topography file is a text file containing GPR line positions and the elevations at those positions. When a topography file is attached to a GPR line, elevations for every GPR position are saved into the elevation field of the GPR trace header.
Trace Plot	View Traces when you want to display subtle features in the data file or view the effect of different editing and processing types have on individual traces. Viewing traces can help you determine whether time-zero point needs to be edited. Normally the time-zero point should occur at the first large deflection in the signal. If not, time scales and depth scales on section plots will be inaccurate.
Universal Transverse Mercator (UTM)	UTM is a geographic coordinate system that uses a 2-dimensional Cartesian coordinate system to give locations on the surface of the Earth. It is a horizontal position representation, i.e. it is used to identify locations on the Earth independently of vertical position, but differs from the traditional method of latitude and longitude in several respects.
UTM Zone	The UTM system divides the Earth between 80°S and 84°N latitude into 60 zones, each 6° of longitude in width.
UTM Zone Number	Zone 1 covers longitude 180° to 174° W; zone numbering increases eastward to zone 60 that covers longitude 174 to 180 East.
UTM Letter	Each zone is segmented into 20 latitude bands. Each latitude band is 8 degrees high, and is lettered starting from "C" at 80°S, increasing up the English alphabet until "X", omitting the letters "I" and "O" (because of their similarity to the numerals one and zero). The last latitude band, "X", is extended an extra 4 degrees, so it ends at 84°N latitude, thus covering the northernmost land on Earth. Latitude bands "A" and "B" do exist, as do bands "Y" and "Z". They cover the western and eastern sides of the Antarctic and Arctic regions respectively.
Velocity	Speed at which GPR signals travel. Velocity is a critical parameter when creating depth slice images and estimating target depth since velocity is used to convert travel-time to depth.
Vertical Filter	Applies a running average filter vertically (down the trace) to a GPR line. The signal is averaged by replacing the data value at a given point by the average data value over a window centered about that point. Its primary purpose is to reduce random or high frequency noise by acting as a low pass temporal filter.

2. Abbreviations

Abbreviation	Full Phrase
AFS	Average Frequency Spectrum
ATA	Average Trace Amplitude
AGC	Automatic Gain Control
BAS	Background Average Subtraction
GPR	Ground Penetrating Radar
GPZ	GPR Project Zip file
MAPI	Messaging Application Programming Interface
MHz	Megahertz
ns	nanoseconds
ps	picoseconds
SEC2	Spreading & Exponential Calibrated Compensation
UTM	Universal Transverse Mercator