Version

4.0

THE TRANSTEC GROUP

ProVAL User's Guide

PROVAL

Profile Viewing and Analysis

ProVAL User's Guide

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Chapter 1

INTRODUCTION

ProVAL (Profile Viewing and Analysis) is an engineering software application that allows you to view and analyze longitudinal pavement profiles in many ways. You can import profiles from various other formats and view them in the Viewer window. You can edit profile information and manipulate profiles using the Profile Editor. Entire analysis projects can be saved, which preserves user information and analysis inputs. After analyses have been performed, you can print a report of the original profile and the results of any analyses.

The purpose of this document is to describe all software operations and software/hardware requirements for ProVAL.

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Quick Links:

- Download ProVAL: https://www.roadprofile.com/proval-software/current-version/
- ProVAL workshops: https://www.roadprofile.com/proval-workshops/
- Contact us: https://www.roadprofile.com/contact-us/
- Technical Support: https://www.roadprofile.com/proval-support/
- Disclaimer: https://www.roadprofile.com/disclaimer/
- Privacy Policy: https://www.roadprofile.com/privacy-policy/

Chapter 2

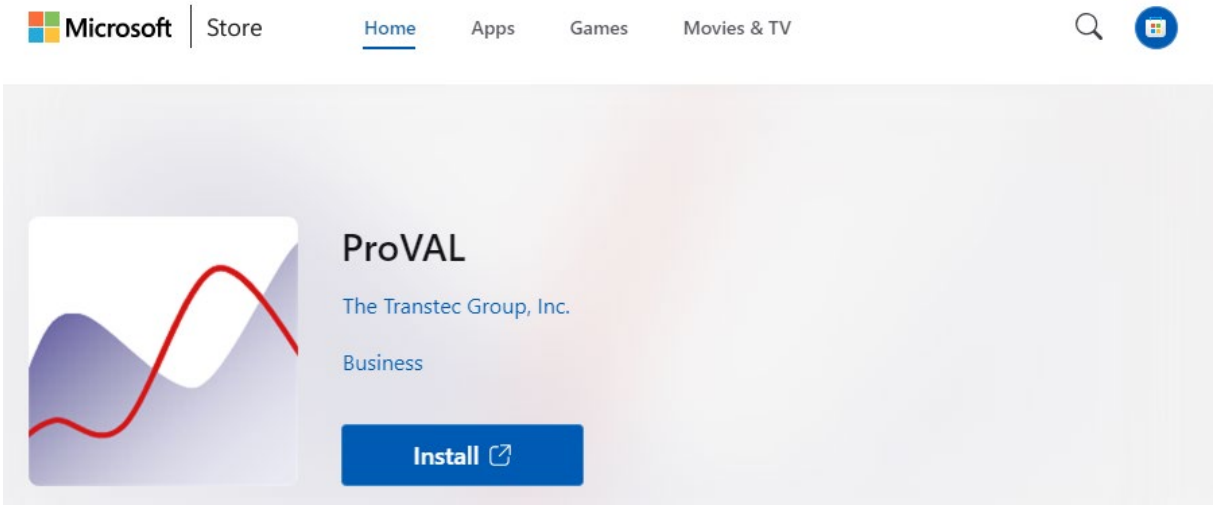
PROVAL INSTALLATION

Download

ProVAL can be downloaded from the www.RoadProfile.com website. Starting ProVAL 4.0, 64-bit versions are available.

The 64-bit version of ProVAL allows for handling larger files than the current 32-bit version of ProVAL, importing files using less memory, and improving the performance of event marker drawing on a chart to prevent freezing.

Alternatively, if you are using Windows 10 Version 1809 or later, ProVAL can be installed from the Microsoft Store. Please uninstall any previous version of ProVAL from the Microsoft Store before installing it. While both versions can co-exist, it is not recommended. Updates on the Microsoft Store may sometimes be delayed because of the need to pass the Microsoft certification process.



Uses can subscribe email software updates announcement.

Requirement

Hardware requirements:

- 2 GHz processor,
- 8 GB RAM,
- 1440x900 display resolution (if widescreen display); 1280x960 resolution (for non-widescreen)

System requirements

- Windows 10 v1903 is the minimum supported operating system.
- Microsoft .NET Framework 4.8 is required (included with Windows 10 v1903 and later).

ProVAL 4.0+ can be installed on the same machine as 3.x or earlier. Previous versions of 4.0 will be replaced.

ProVAL 4.0+ is only available in a 64-bit version and can only be installed on 64-bit Windows.

Installation

Previous versions of the same family will be automatically uninstalled. For example, 4.x will uninstall previous 4.x versions but will not uninstall 3.x. The two versions can co-exist side-by-side.

You must have sufficient privileges to install applications on your computer. If you receive an error during installation regarding "IVF13RuntimesReleasex86.cab", download the software using the Alternate link on the www.RoadProfile.com website. If you receive any other error messages, then please contact us.

The installation process is straightforward by simply following the onscreen instructions. Again, if you have any installation issues, please contact us.

Chapter 3

GETTING STARTED

Welcome Wizard

Launch ProVAL by locating **All Programs** » **FHWA** » **ProVAL 4.0**.

If no earlier versions of ProVAL are installed, the first time the software is started, a welcome screen will ask you some basic questions:

- **Unit System** – Checking the "Use SI Units" would enable the SI unit system. Otherwise, the application will be in the USCS unit system.
- **Enable Recording Log** – Check this option to help report bugs by saving software operations logs.
- **Default File Type** – Select the default file type when adding profile data.
- **Default Project Path** – Select the default project path to speed up file lookup.

This gives you a convenient way to specify preferences. The Welcome Wizard only shows once after each installation. You can also modify those settings later by using the Options dialog box.

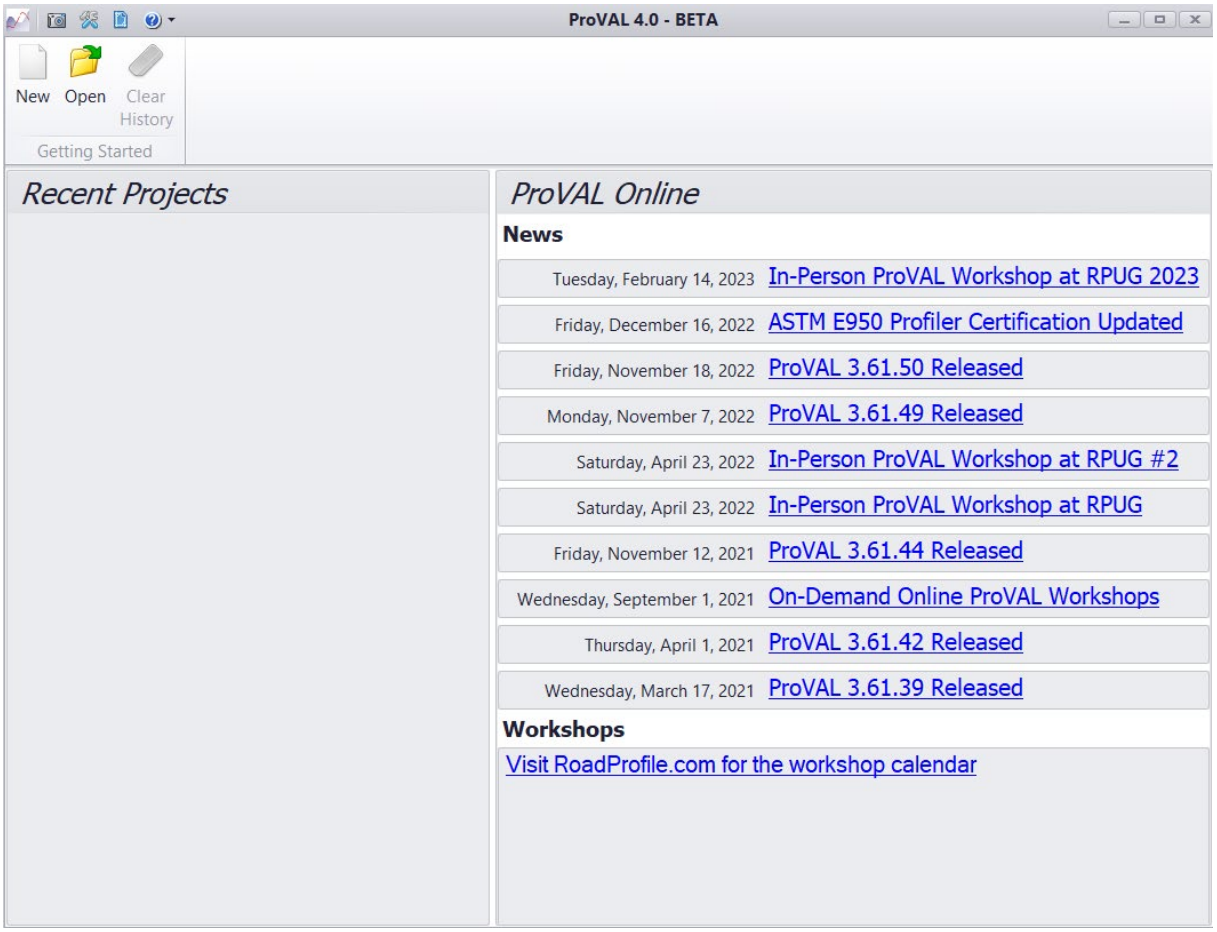
Behavior of User Interface

The following describes the behavior of the ProVAL Graphical User Interface (GUI):

- The window position is saved.
- Allows you to minimize navigation elements and analysis inputs to maximize screen real-estate.
- Window scaling: ProVAL will use the scaling settings of the primary monitor. Moving the software to a monitor with different scaling will not cause the software to rescale. Changing the scaling may not have an effect until signing out/in.

Home Screen

This is the starting screen when no project is currently open. It consists of three main sections: the toolbar, **Recent Projects,** and **ProVAL Online** (if the Internet is accessible and the "Show Online Content on the Start Page" is selected in the program Options screen).



If the Internet is not available, the **ProVAL Online** section will be blank, or on rare occasions, the "Action canceled" message will be displayed instead.

Under **Recent Projects, they** are listed as recently analyzed and saved projects. The most recent unsaved project, if any, will be in the lower left corner. Right-click a recent project and select "open file location" will show the file in Window's explorer.

The Getting Started menu has the following features:

- New: Create a new project.
- Open: Open a previously saved project by specifying the path and filename.
- Clear History: Clear the list of recent projects and unsaved projects.
-

The Tools menu includes:

- Screenshot: Store a screenshot of the entire application to the Windows clipboard.
- Options: Allows you to customize several features of the application. See the Options section for details.

- Manage Analysis Templates: Import and export analysis templates.
- Resources

- ***Save Logs***: Save event logs in zip format to report bugs or issues.
- ***User's Guide***: This opens the PDF version of the ProVAL User's manual for viewing.
- ***Release Notes***: Summary of changes in the current and previous ProVAL versions.
- ***Support***: Online Help via the ProVAL website.
- ***About***: About Window to show version number and other information.

- The Recent Projects screen has the following features:
- List of recent projects and most recent unsaved projects, if any.

The ProVAL Online screen has the following features:

- Shows the latest news and upcoming workshops. You can elect to turn this off in the Options.

Once a project has been created or opened, the Project menu contains the following items:

- **Close Project**: Close the current project.
- **Add Files**: Add profile data to the current project.
- **Save**: Save the current project or save it as a different project.
- **Report**: Create an Excel, Text, or PDF report.

File and Project Management

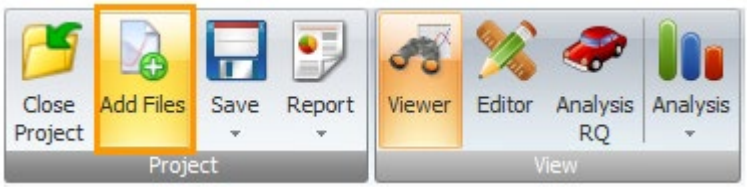
The file and project management in ProVAL is detailed as follows:

- ProVAL can open ProVAL project files and ProVAL-compatible profile data files.
- You may have multiple instances of ProVAL on the same computer. Each instance of the software can have only one project open. The same file or project cannot be opened in multiple instances.
- The project file (*.pvp) contains project settings and profile data (stored in PPF formats - ProVAL's native data format and the ASTM International E2560 standard format).
- Previous versions of projects (e.g., *.pv3, *.pv2, and associated *.ppf files) can be imported.
- Individual profile data files can be extracted in PPF format from the project file in the Viewer window.
- The project files can be opened using standard Windows techniques, including dialog boxes (i.e., via the Open button on the home screen or Open menu from the application menu), drag-and-drop (i.e., drag a project file from Windows explorer to the ProVAL application areas), most recently used (MRU) files (i.e., from the Application Menu/Recent Projects or simply clicking any recent project listed on the panel under the Getting Started of the ProVAL starting page), and file association (i.e., double-clicking a *.pvp, *.pv3, or*.pv2 file within the Windows explorer).
- Once a project is active, profile data files can be imported using the Add Files button on the toolbar or the drag-and-drop option (i.e., drag from Windows explorer to the ProVAL application areas, either to the list of profiles or directly to the chart).
- Profile data files can also be imported using file association (i.e., double-clicking any ProVAL-

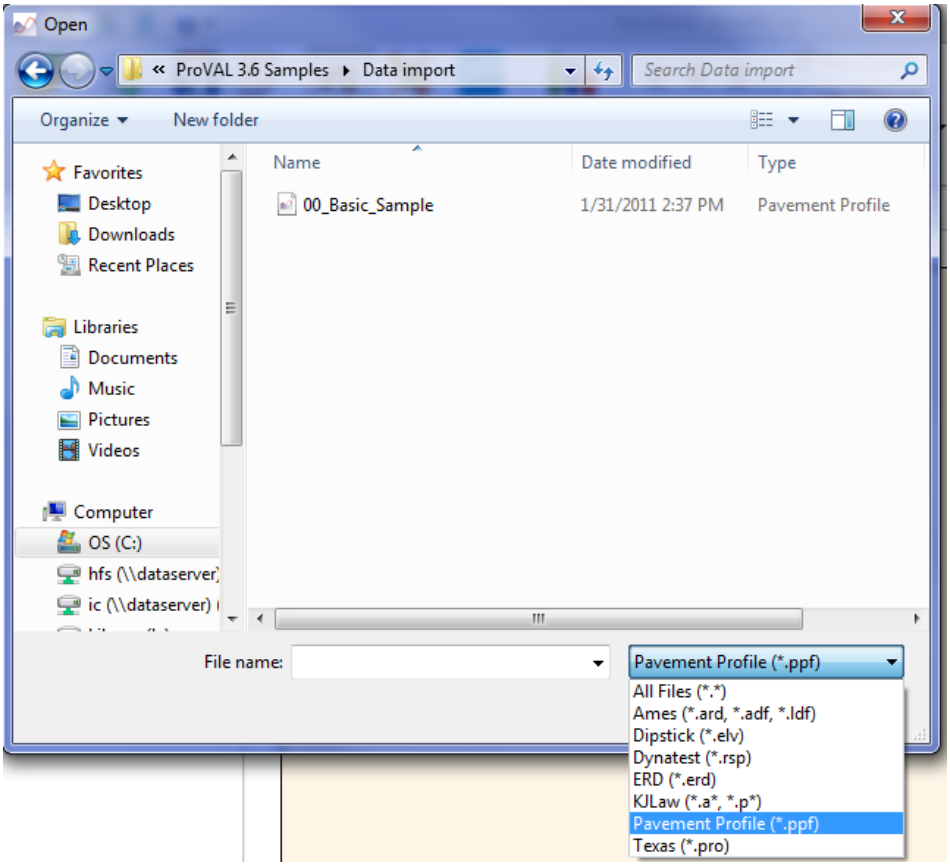
compatible data files such as *.ppf, *.erd, etc. within the Windows explorer). An "Untitled" project will be created automatically. Users can then use Save As to save it to another filename or simply discard it (the latter is useful for a quick view of data without saving any projects).

Add Files

You can use the **Add Files** button in the toolbar to select and add profile data files to the current project.



A dialog box will appear when you click the **Add Files** button. Files of the Default File Type set in the Options are displayed. To view other file types, use the dropdown menu.



ProVAL-Compatible File Formats

ProVAL recognizes the following file types. The file extension is listed in parentheses after the description:

- ProVAL 3.1+ Project and embedded data file (pvp)
- ProVAL 3.0 Project and embedded data file (pv3)
- ProVAL 2 Project (pv2) (note that the associated ppf files need to be within the same folder as the pv2 file)
- Pavement Profile File (ppf): This is based on the native file specification of ProVAL. It is a very efficient and secure format. The latest ppf specifications can be downloaded from the ProVAL website. This format is the basis for the ASTM E2560 Profile Data standard.
- ERD (erd): ProVAL recognizes both text formats and the two 4-byte floating-point binary formats. Information about the ERD files can be found on the UMTRI website (http://www.umtri.umich.edu/our-results/publications/erd-file-format-storage-and-analysis-road-profiles). The profile data and most of the header information are also imported.
- Dipstick (elv) files: They are Dipstick data in text format without any headers.
- KJLaw Text files (a*): These files usually end with file extensions such as "a01", "a02", etc. The profile data and most of the header information are also imported.
- KJLaw Binary files (p*): These files usually end with file extensions such as "p01", "p02", etc. The profile data and most of the header information are also imported.
- Dynatest RSP File (rsp): These files are generated by the field program of Dynatest Mark II or III (version 35.00 or above). The rsp event markers and GPS information can also be imported.
- TxDOT (pro): ProVAL can import the newer TxDOT "pro" format. Event markers will also be imported.
- Ames File (ard, adf, and ldf): These are file formats (adf is newer than ldf) generated by the Ames profiler field programs. The GPS information and event markers can also be imported. Additional event markers for the lead-in and lead-out locations may be added.

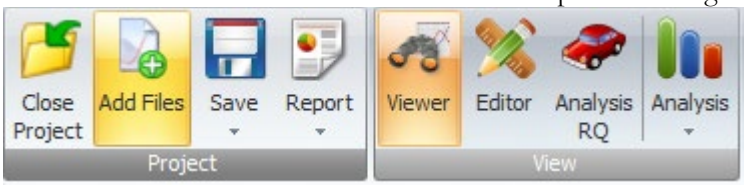
Starting ProVAL 4.0, only the GPS information contained in the profile data are used to create routes to use ProVAL's Map features. Manual adding start and stop GPS locations are not allowed.

File Import Wizard

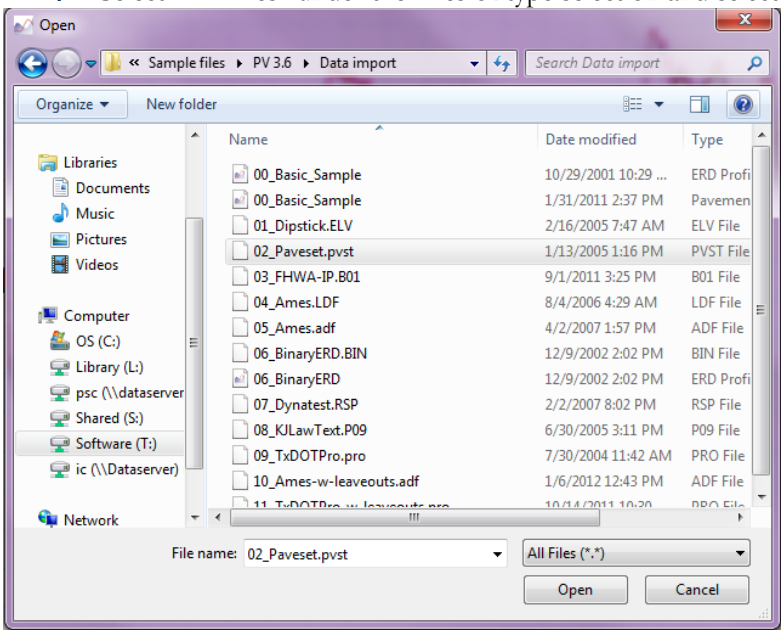
ProVAL can also import generic files in text format using a File Import Wizard. The generic text file must contain profile data in column(s) and be separated by a symbol. Blank lines or other non-data lines shall not be in the data block. The file headers are optional and will be skipped during file import. Inspecting the data using a text editor and finding additional information about the profile before using the File Import Wizard is recommended.

The steps to import such files are as follows:

- Use the **Add Files** button to start the Open file dialog box.



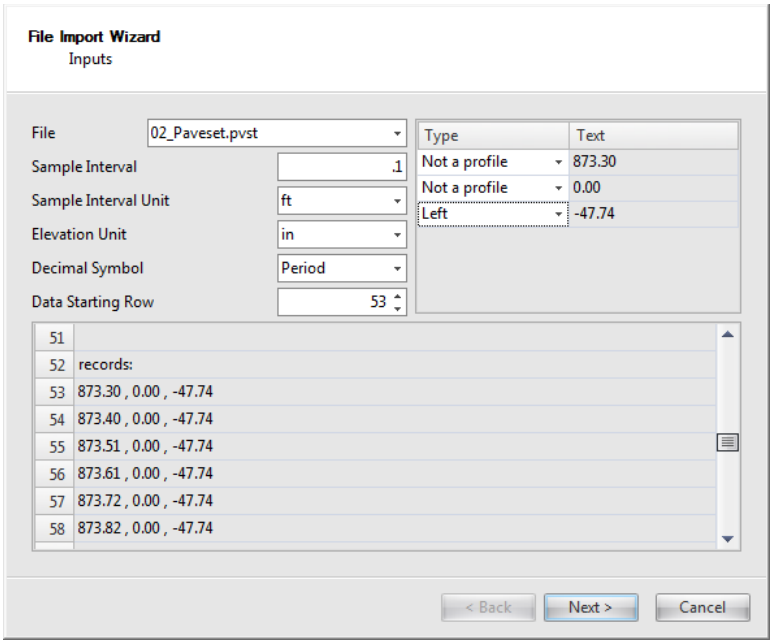
- Select "All Files" under the Files of type selection and select a generic text file.



- A File Import Wizard will pop up with a table displaying the file's first 100 rows of information. Note that the File Import Wizard will launch when the imported ProVAL-compatible format is corrupted.

- Fill in information including Sample Interval, Sample Interval Unit, Elevation Unit, Decimal Symbol, and Data Starting Row. As the correct Data Starting Row is selected, several selections of data types will be displayed depending on the number of columns in the data block.

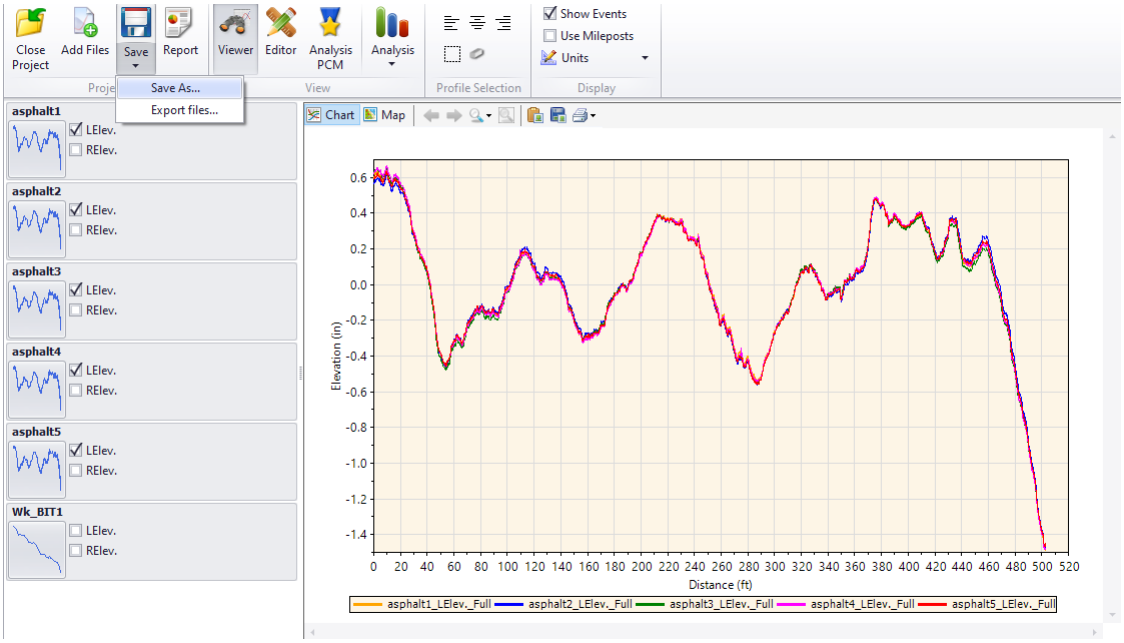
- Select the correct data type from the following options for each data column: Left, Center, Right, Unknown Location, or Not a Profile.



- Click **Next>** and **Finish** to import and save the file into the current project.

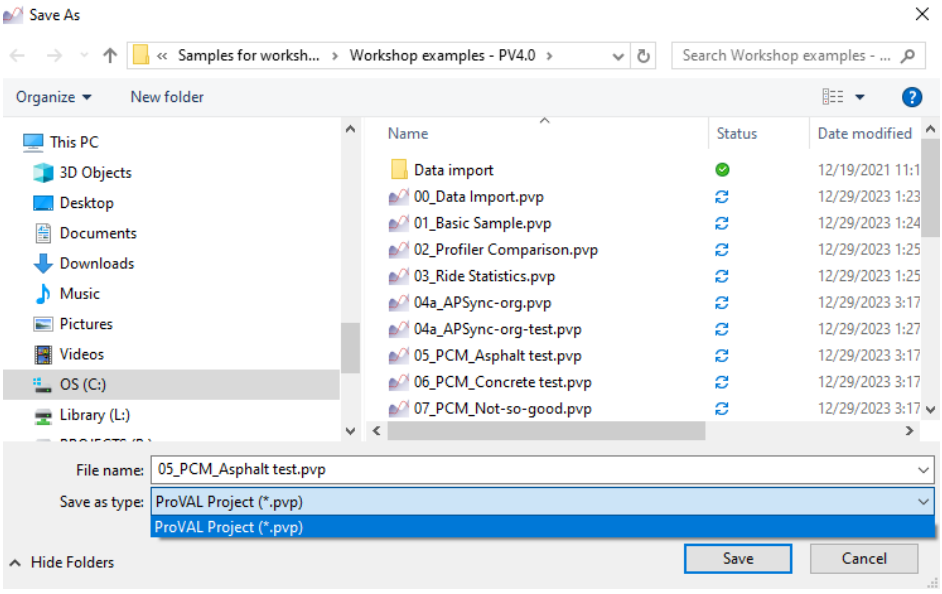
Save As & Export Files

Click the Save menu and select Save as or Export File.



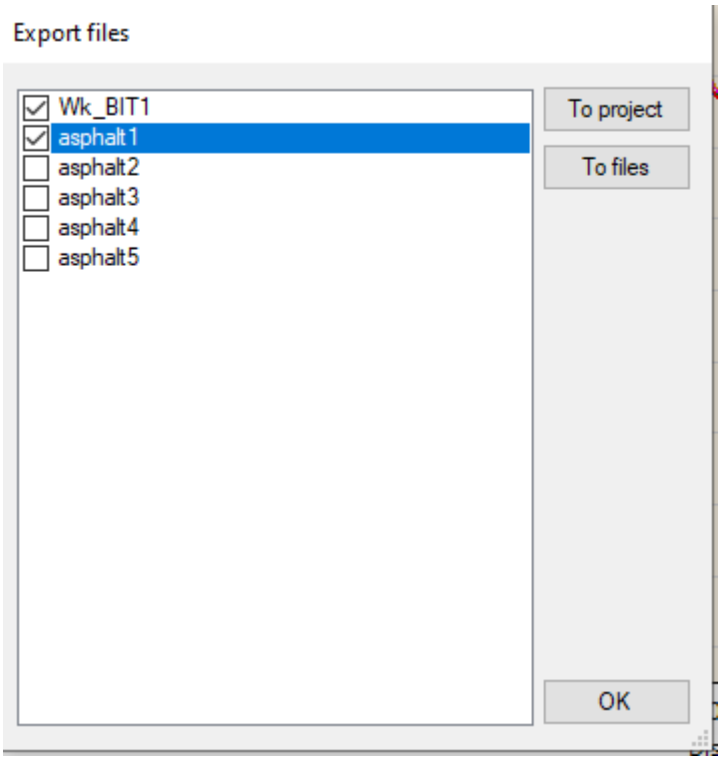
Save As

Use the Save As dialogue to save the current ProVAL project to another file.



Export Files

Use the Export files dialogue to select profiles and save them to ProVAL project files or to individual profile data in the ASTM ppf format. PPF files exported by ProVAL 4 use version 1.06 of the Pavement Profile Format defined in ASTM E2560. These files are not usable by previous versions of ProVAL and may not be usable in other software.



Basic Operation

A step-by-step process for a typical viewing and analysis is as follows:

- **Step 1:** Start a new ProVAL project using the **New** button on the ProVAL home screen, and it creates an "Untitled" project. You can elect to save it as another file name. Let's leave it for now.
- **Step 2:** Use the **Add Files** button on the ProVAL toolbar to select profile data to be imported.
- **Step 3:** After adding a file, a thumbnail of its profile will be added to the list with imported profiles available for selection.
- **Step 4:** Select or de-select the desired profiles by clicking the corresponding checkboxes. Selected profile traces will be displayed on the chart. You can then proceed with viewing and analysis functions.

Report Functions

Once clicked with a mouse, the Report button lists options for report functions. Select the location and type of report. The export functions include **Excel**, **Text**, and **PDF**.

- **Excel**: Save report data to various Excel worksheets.
- **Text**: Save report data in various text files.
- **PDF**: Generate a secured PDF report.
- Click **Create** to generate the report(s). Select **Open folder** to view the report folder in Windows Explorer, or choose a file and click **Open file** to view the selected report.
- Reports contain the data from the current module – the Viewer or one of the analysis modules. First, run the analysis to generate a report in any module besides the Viewer. File names are automatically selected based on the project name and analysis type. New reports overwrite any older files with the same name at that location.
-

Charts in the Viewer and some analysis screens can also be exported as images to files or the Clipboard in the PNG format. See the Viewer and Analyses sections for details.

-

Print to PDF

After viewing profiles or finishing an analysis, click the **Report** button and select **PDF** to generate a "secured" PDF report that cannot be modified.

If the option to use the alternate chart template is selected in the Options, the alternate chart colors will be printed.

The secure PDF has the following restrictions:

- Changing the document
- Document assembly

- Page extraction
- Commenting
- Filling of form fields (NA)
- Signing
- Creation of template pages

Print a SAM analysis PDF report with page breaks between different analyses. The following shows the first five pages of the 15-page report.

Analysis: Smoothness Assurance

Selections

File	Section	Apply 250mm Filter
Profile	Full	Yes

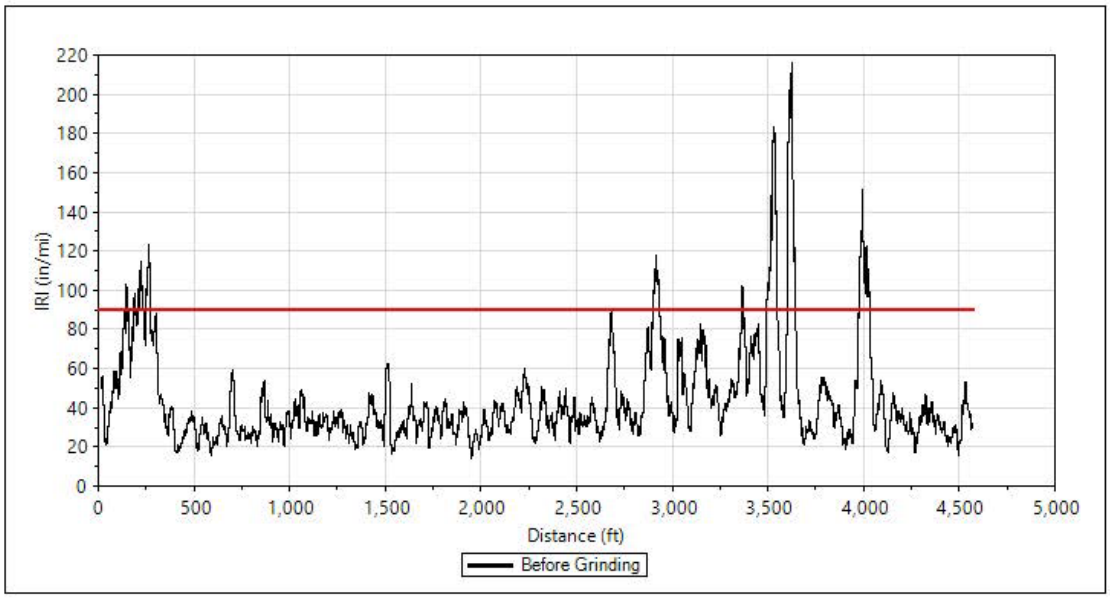
Results

Short Continuous - Left Profile

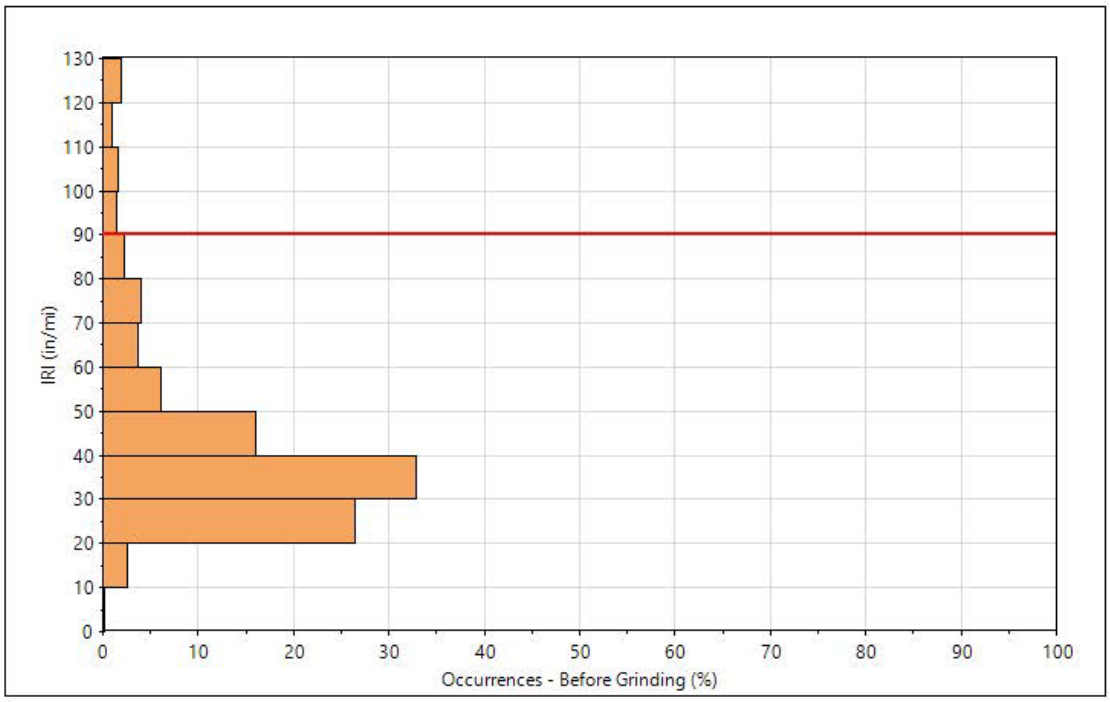
Segment Length (ft): 25.00
Threshold (in/mi): 90.00

Before Grinding
Total Percent Out of Spec (%): 5.97
Total Distance Out of Spec (ft): 272

Max IRI (in/mi)	Min IRI (in/mi)	Before Grinding (%)	Before Grinding (ft)
∞	120.00	1.97	90
120.00	110.00	0.91	41
110.00	100.00	1.66	76
100.00	90.00	1.43	65
90.00	80.00	2.29	104
80.00	70.00	4.01	183
70.00	60.00	3.77	172
60.00	50.00	6.11	279
50.00	40.00	16.10	734
40.00	30.00	32.85	1,497
30.00	20.00	26.40	1,203
20.00	10.00	2.51	114
10.00	0.00	0.00	0



12_SAM_Sample-PV4Beta



Defects before grinding

Start Distance (ft)	Stop Distance (ft)	IRI (in/mi)
142.25	150.42	102.74
186.25	195.33	97.98
205.50	235.67	114.70
248.83	273.75	122.94
2,682.42	2,683.58	90.25
2,901.42	2,933.33	117.85
3,360.42	3,368.67	101.84
3,493.92	3,549.42	183.32
3,600.17	3,645.25	216.33
3,975.42	4,033.42	151.44

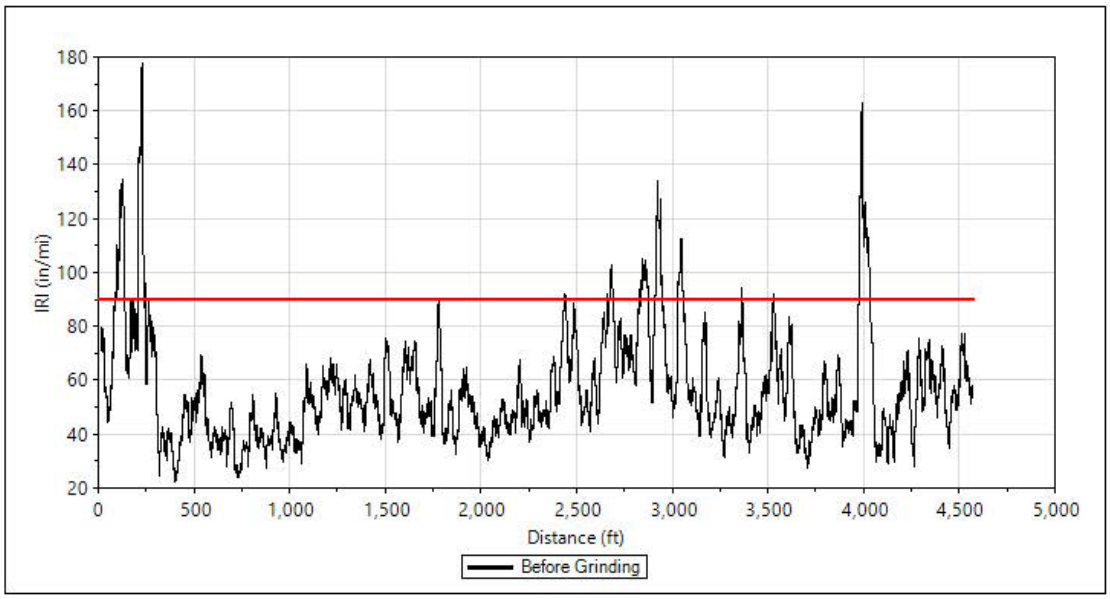
Short Continuous - Right Profile

Segment Length (ft): 25.00
Threshold (in/mi): 90.00

Before Grinding

Total Percent Out of Spec (%): 6.33
Total Distance Out of Spec (ft): 288

Max IRI (in/mi)	Min IRI (in/mi)	Before Grinding (%)	Before Grinding (ft)
∞	120.00	1.77	81
120.00	110.00	0.98	45
110.00	100.00	1.22	56
100.00	90.00	2.36	108
90.00	80.00	4.60	210
80.00	70.00	7.89	360
70.00	60.00	13.41	611
60.00	50.00	22.39	1,020
50.00	40.00	27.97	1,275
40.00	30.00	15.22	694
30.00	20.00	2.20	101
20.00	10.00	0.00	0
10.00	0.00	0.00	0


180
160
140
120
100
80
60
40
20
IRI (in/mi)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance (ft)
Before Grinding

Export to Excel

Chart and table data from all profile analyses can be exported to Excel files by clicking the **Report** button and selecting **Excel**. Detailed reports include all data. For continuous roughness reports, these will include every data point. Summary reports only list defective segments. Each exported Excel file contains analysis results from a specific profile trace.

Users can launch the Excel application and open the ProVAL-exported Excel files. For each worksheet within an Excel file, data will be arranged in columns with appropriate headings and units.

Data in tables and charts will be saved to each worksheet for post-processing (such as plug-in pay schedule for bonus/penalty computation). Due to the limitation of rows in Excel 2003 and earlier, you should be cautious when exporting data that exceeds 65,536 rows (including the data column headers). Excel 2007 and later have a maximum of 1,048,576 rows. Report charts will not be included in the exported Excel files. However, you can use the ProVAL built-in screenshot tool button to export chart images to the Windows clipboard and then insert them into other documents or spreadsheets.

Save to Text

Chart and table data from all profile analyses can be exported to text files by clicking the **Report** button and selecting **Text**. Detailed reports include all data. For continuous roughness reports, these will include every data point. Summary reports only list defective segments. One or more files will be generated to analyze the results of the data sets.

The text file names correspond to each data set. The text files can then easily be viewed in any text editor for any data submission or post-processing.

Utility Functions

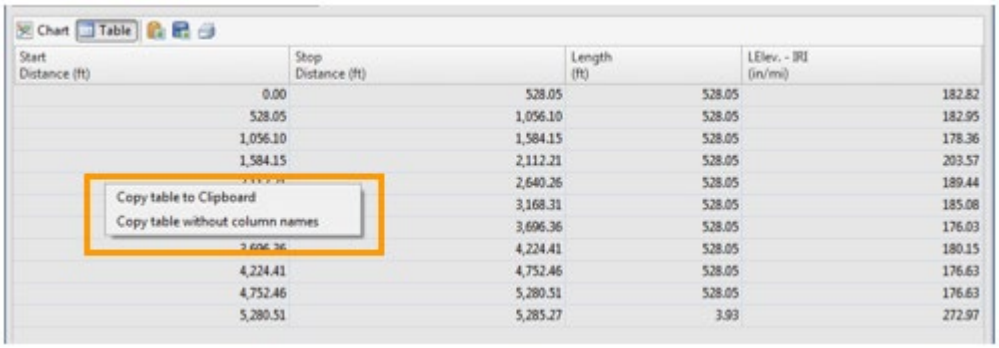
ProVAL has several utility functions for various purposes.

Screenshot Tool

A built-in screenshot tool is included. A screenshot of the entire application will be stored in the Windows clipboard by clicking the Screenshot button on the toolbar. You can then open any other Windows application (such as MS Word) and paste the screenshot there.

Copy-Table-to-Clipboard Tool

By clicking any table results with the mouse while using the right mouse button, the entire table can be stored in the Windows clipboard. Selecting the **Copy table to Clipboard** includes the column headers. Alternatively, choose the **Copy table without column names**. Then, you can open any other Windows application (such as MS Word) and paste the results into the table.



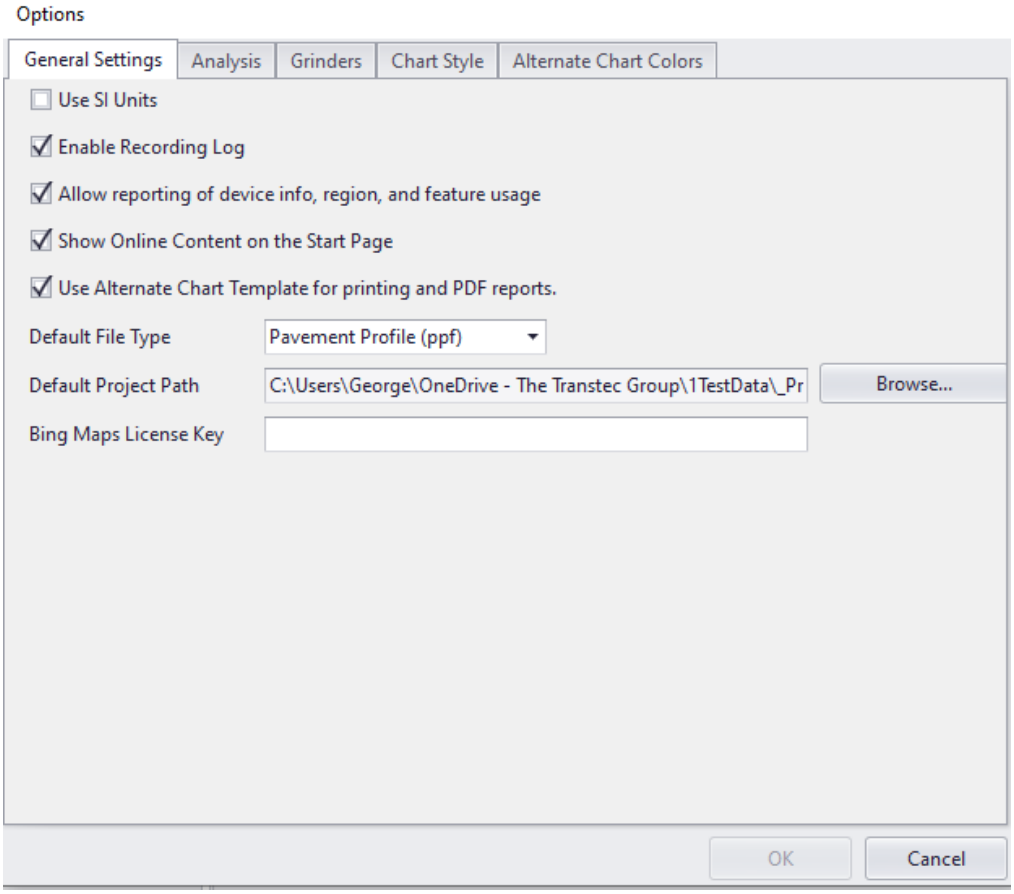
Options

User preferences are divided into four areas: General Settings, Analysis, Chart Style, and Alternate Chart Colors.

General Settings

Under General Settings, you can change the following to fit your needs:

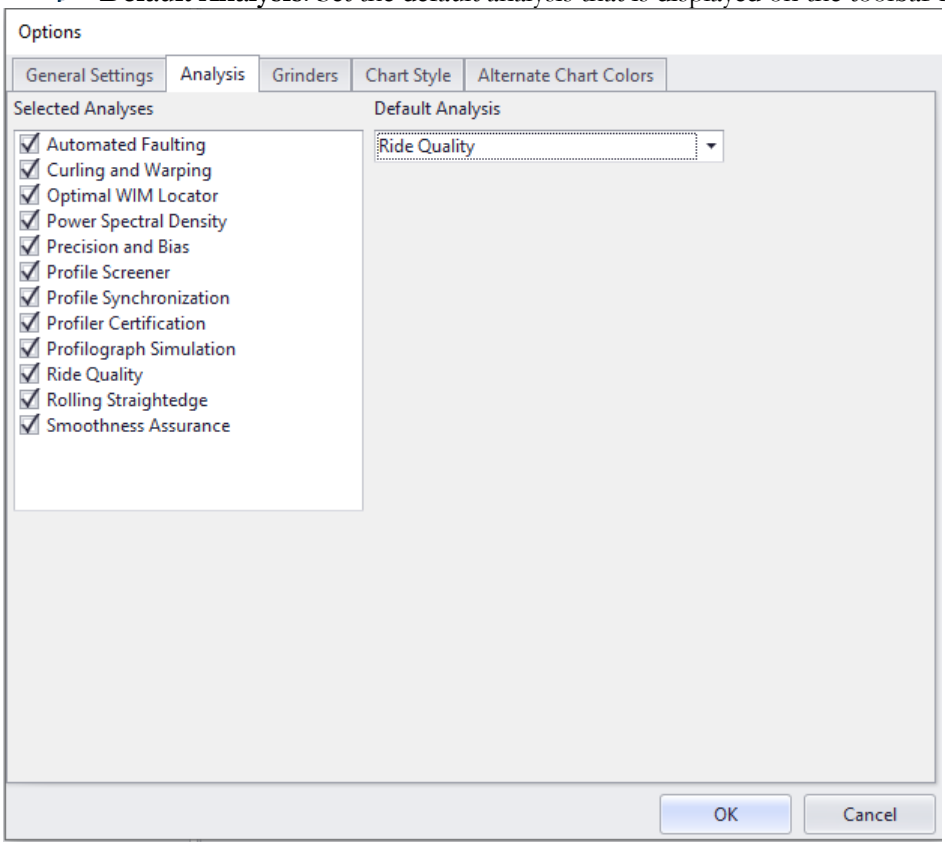
- **Use SI Units**: If checked, SI units will be applied to the application; if not, USCS units will be used.
- **Enable Recording Log**: If checked, event logs will be recorded. Enabling this option is recommended and will enable Support to diagnose issues.
- **Allow Reporting of Device Info, Region, and Feature Use**: If checked, that information will be submitted.
- **Show Online Content on the Start Page**: If checked, the ProVAL Online section will be displayed on the application home screen.
- **Use Alternate Chart Template for printing and PDF reports**: If checked, the chart format on the Alternate Chart Colors tab will be used when printing charts and creating PDFs. If unchecked, the format on the Chart Style tab will be used.
- **Default File Type**: Used to set the default file type for the Add Files dialog box.
- **Default Project Path**: This is a handy setting to quickly access profile data in a frequently used path.
- **Bing Maps License Key**: If you have your license key for Bing Maps, you may enter it here.


Options
General Settings
Analysis
Grinders
Chart Style
Alternate Chart Colors
Use SI Units
Enable Recording Log
Allow reporting of device info, region, and feature usage
Show Online Content on the Start Page
Use Alternate Chart Template for printing and PDF reports.
Default File Type
Pavement Profile (ppf)
Default Project Path
C:\Users\George\OneDrive - The Transtec Group\1TestData_Pr
Browse...
Bing Maps License Key
OK
Cancel

Analysis

The following can be set using this utility:

- **Selected Analyses**: Any checked analyses will be displayed in the Analysis menu.
- **Default Analysis**: Set the default analysis that is displayed on the toolbar for easy access.



Grinders

Use this facility to customize grinder settings.

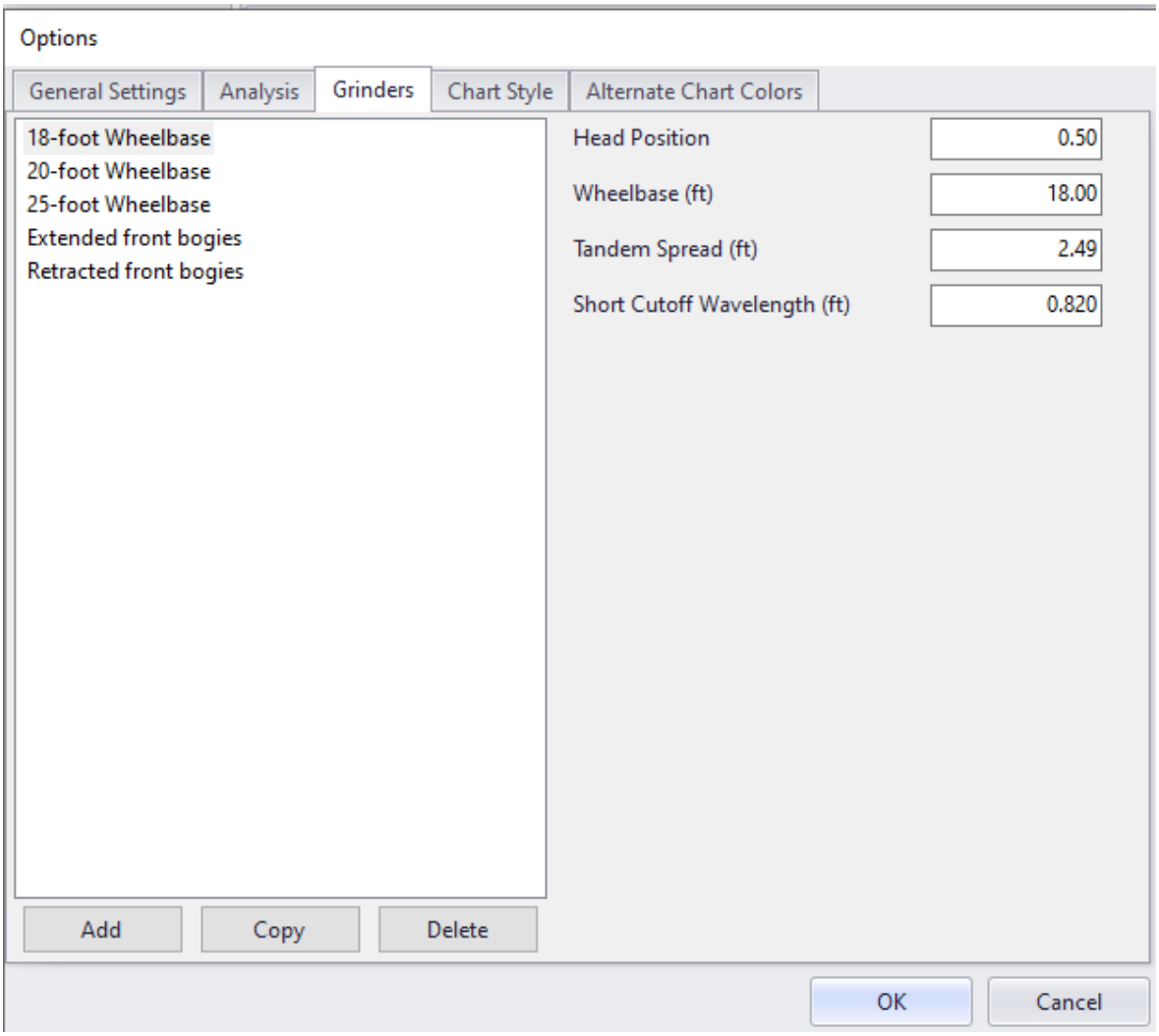
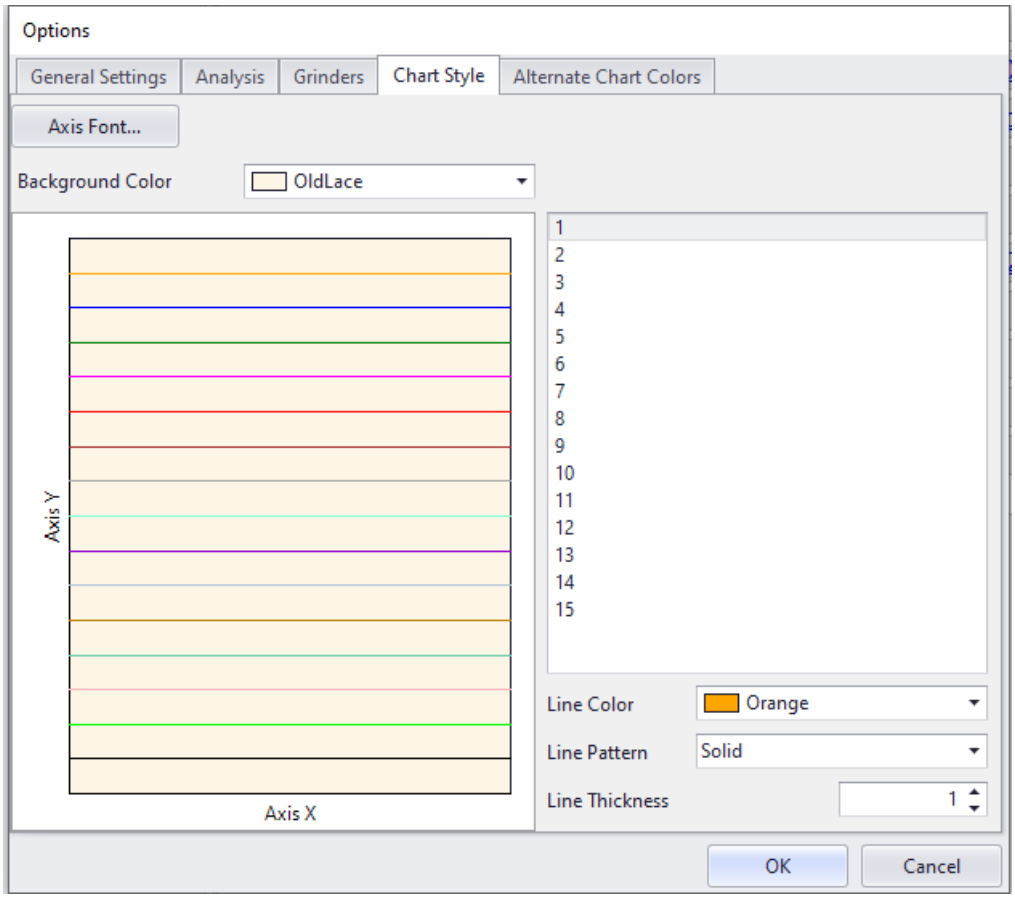


Chart Style

A default color template is provided. A color template defines the chart's background color, line styles, and axis fonts. A line style specifies the line color, pattern, and thickness. The first dataset plotted on each chart will be formatted according to line style 1, the second in line style 2, etc. The template defined on the Chart Style tab is generally used.



Alternative Chart Style

Use Alternate Chart Template, which is selected in the Options/General Settings. The alternate chart colors are used when printing and generating PDF reports.

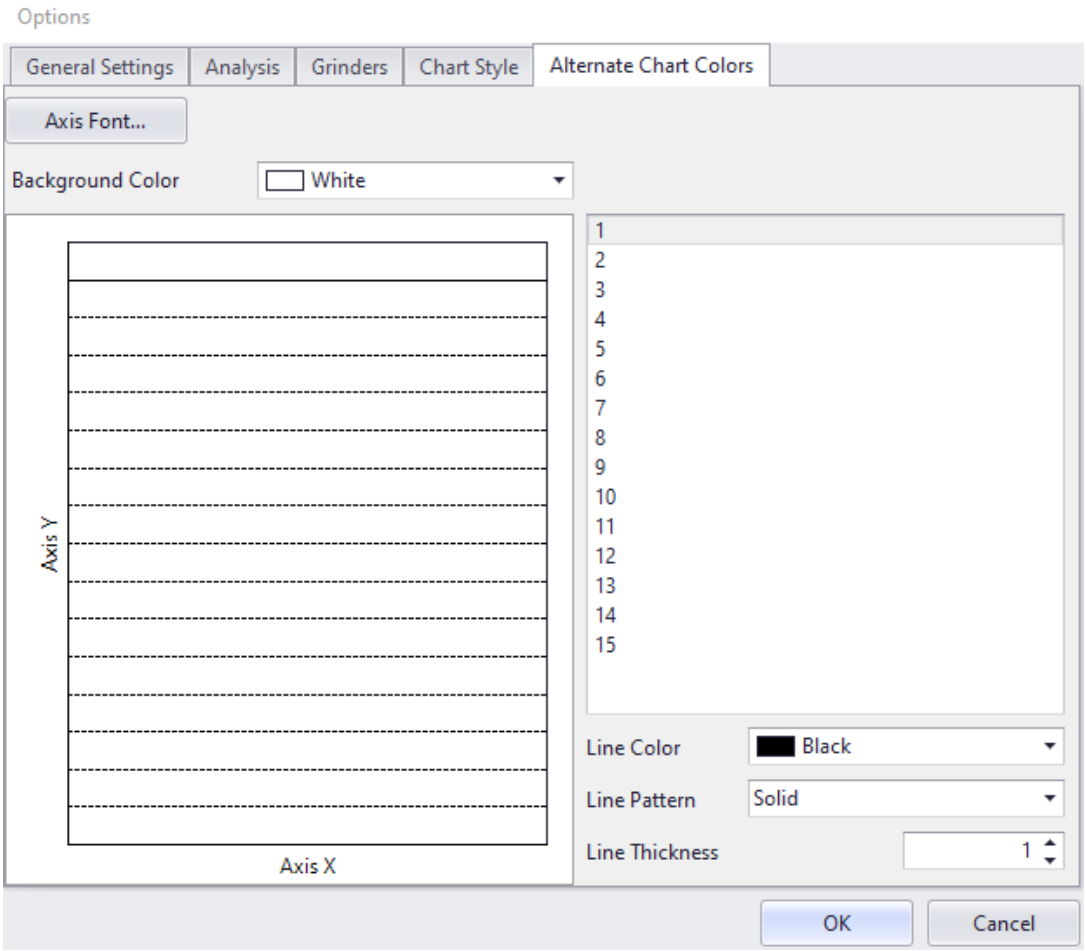


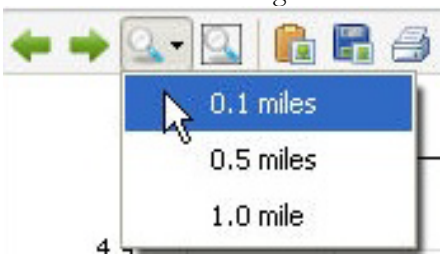
Chart Controls

A standard chart is used throughout the software. This feature helps you become familiar with consistent chart layouts. Specific features include:

- **Scroll Bars**: Both horizontal and vertical. It is only available when zooming into a portion of a chart.

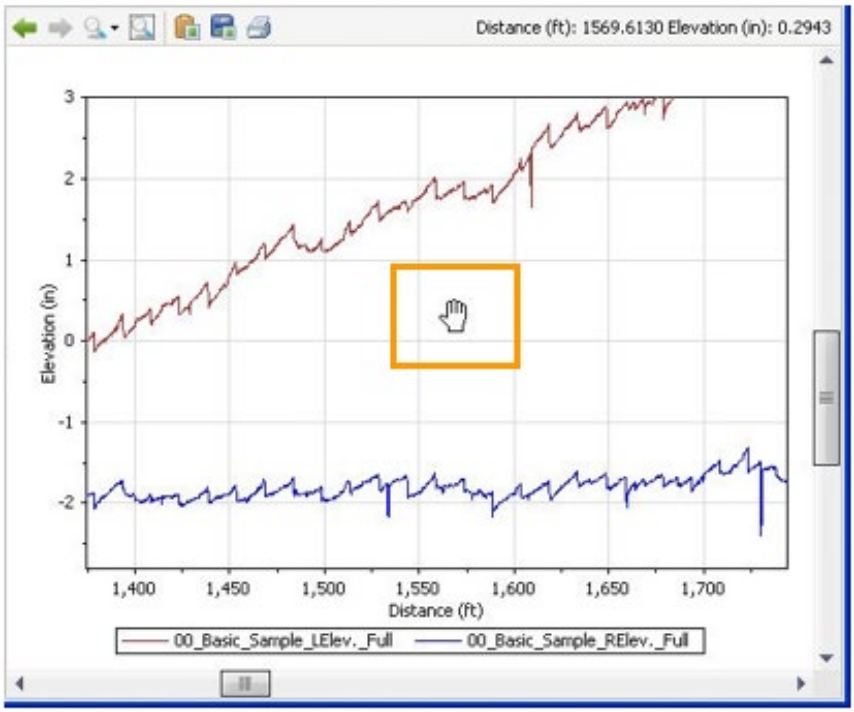
- **Zoom History** (backward and forward arrows): Preserve the zoom history so you can zoom back and forth, similar to back and forward buttons in a Web browser. They will be activated (in green) only when zooming to certain levels.

- **(Zoom) Scale** (magnifying glass symbol): When entering this mode, the chart will set a zoom level equal to a predefined scale. Predefined zoom scales are 0.1 miles, 0.5 miles, and 1 mile (or 0.1 km, 0.5 km, and 1.0 km if the SI unit system is specified in the Options). Zoom scales cannot be changed at this time.



- **(Overview) "Full"** (magnifying glass symbol with a frame): Show the entire length of the chart.

- **Panning**: Allows you to 'grab' the chart using the right mouse button (the mouse icon would change into a "hand" symbol) and move it instead of using the scrollbars.

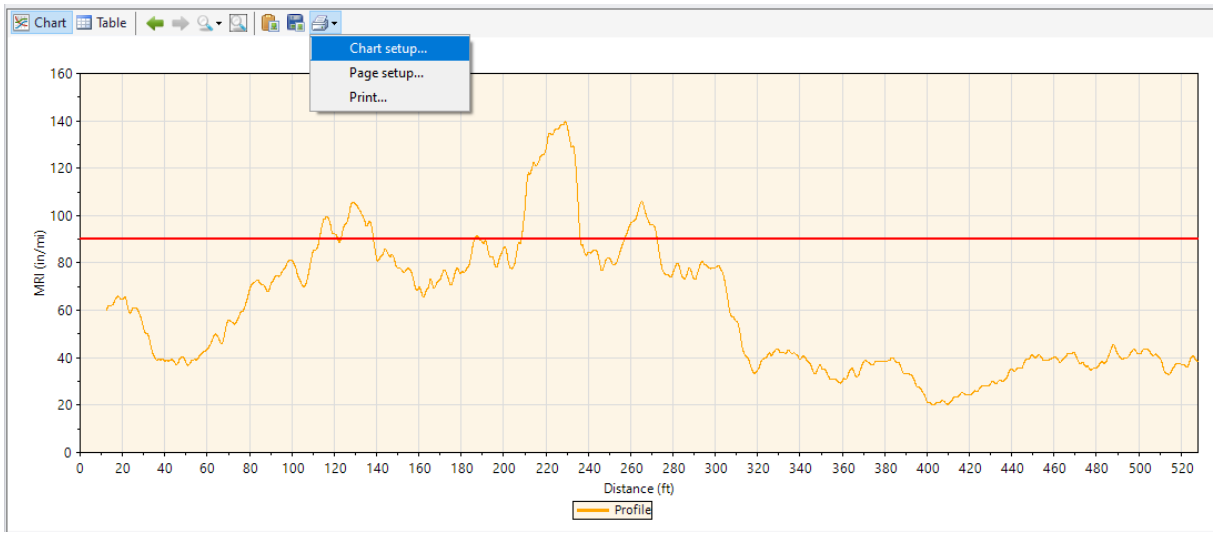


- **Copy Image to Clipboard**: Allows an image of the chart to be exported to the Windows Clipboard.

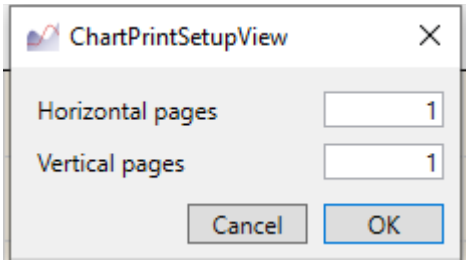
- **Save Image to File**: Allows an image of the chart to be exported to a file in the PNG format.

A dialog box would pop up for you to save the exported image as a PNG file.

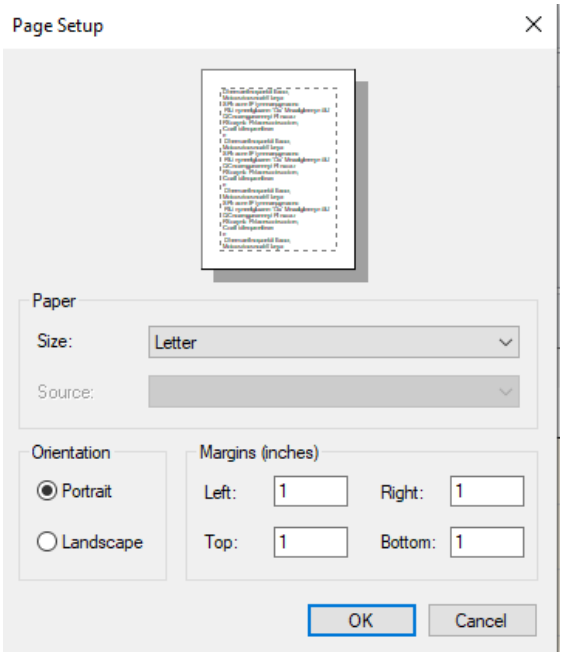
- **Print chart**: Print the chart using the Chart setup and Page Set up.



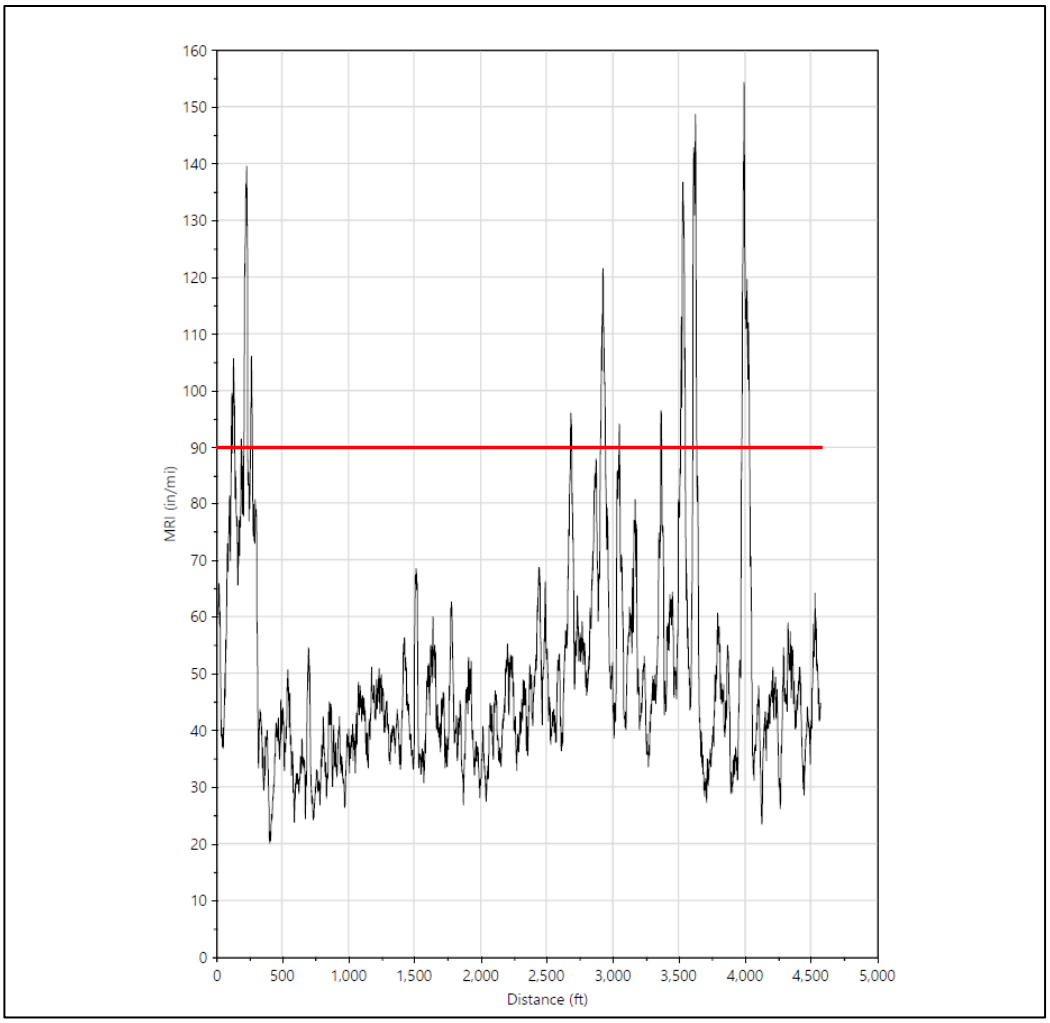
The chart setup allows for the numbers of horizontal and vertical pages.



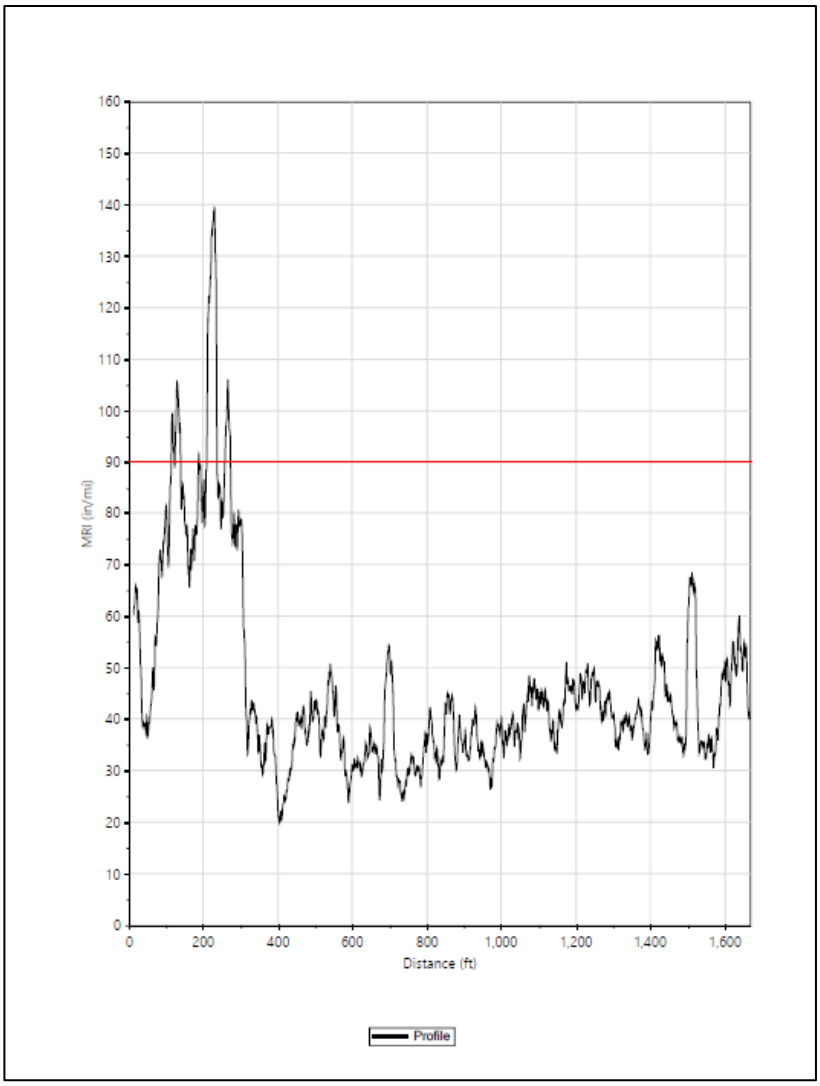
The Page setup is similar to Windows print options.

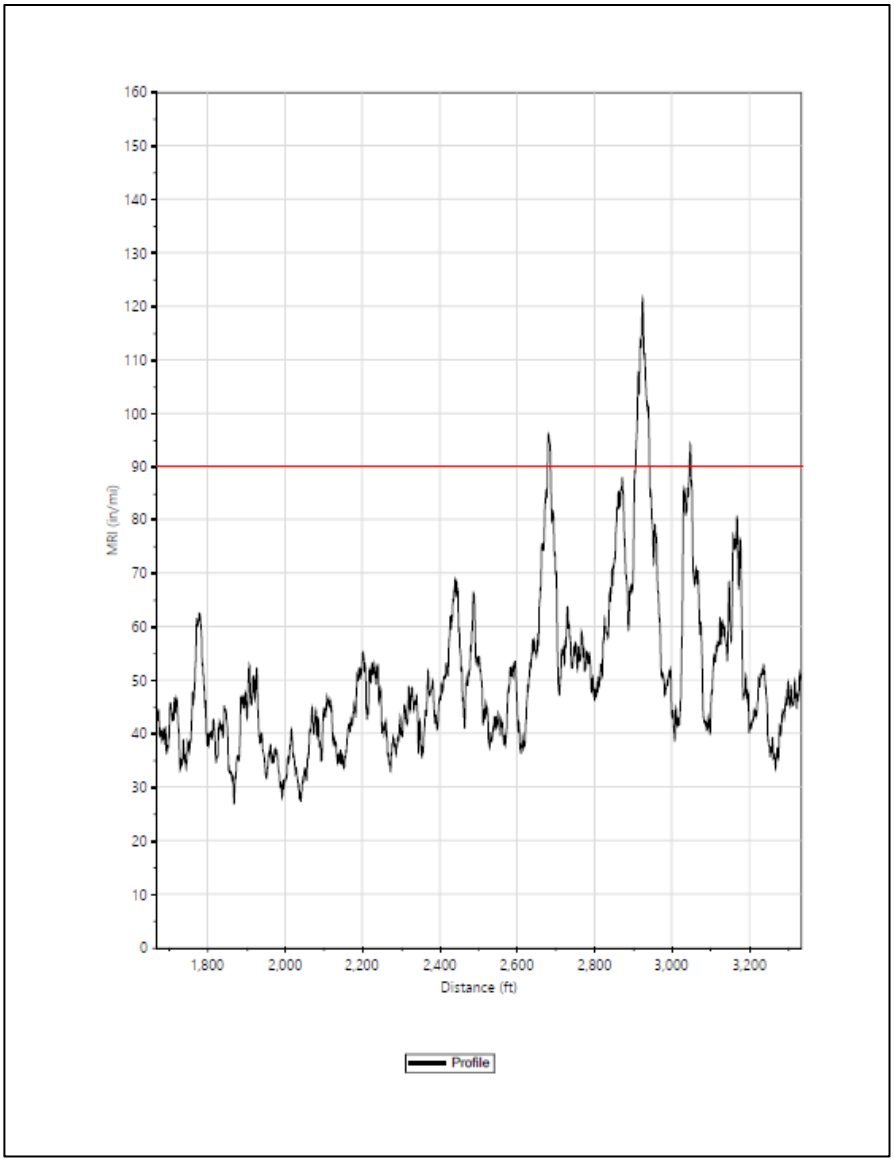


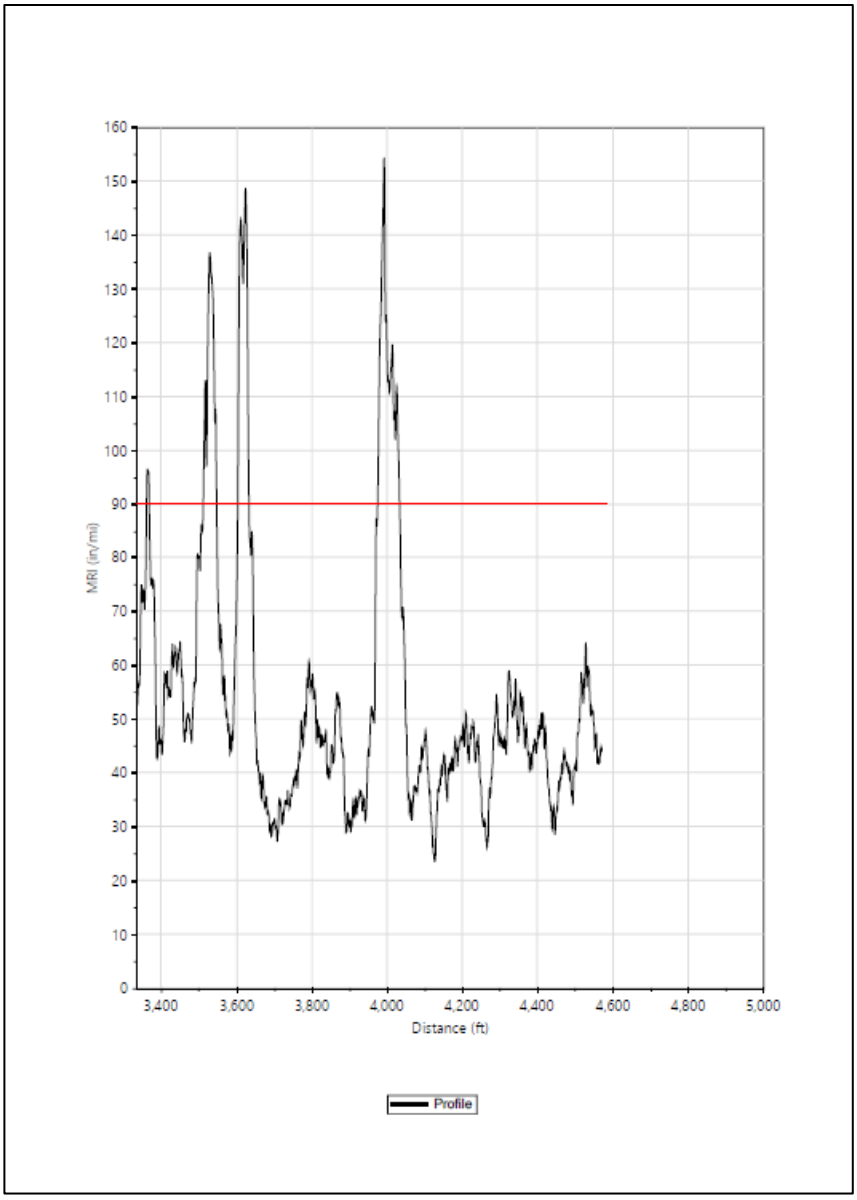
An example of a one-page report is shown below.



An example of a three-page report is shown below (pages 1, 2, and 3).




160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MRI (in/mi)
1,800
2,000
2,200
2,400
2,600
2,800
3,000
3,200
Distance (ft)
Profile



Profile Selection

A group of functions within the Profile Selection menu bar can be used to select one or more profiles.

Five buttons can be used to select all left channels, all middle channels, all right channels, and all channels, as well as clear all selections. This function is available in the Viewer and applicable analyses.

Help and Event Log System

Save Logs

An event log is provided to record any errors that occur. A Recording Log is provided to record all actions taken by you. This is very useful for debugging. You can opt to turn this off. To save logs for submitting issues, you can select Help/Save Logs from the application menu.

A **Save As** dialog box would prompt you to save the event log file to a selected folder in zip format. This file can then be submitted to the ProVAL support team to assist with the diagnostics.

User's Guide

An electronic User's Guide (this document) in PDF format can be viewed through the Help menu on the Home screen.

Release Notes

The release notes in PDF format for this version of ProVAL can be viewed through the Help menu on the Home screen. This document includes new features, changes, and known issues.

Support

Clicking the Support menu under Help will launch the default web browser on your computer and load the ProVAL homepage. Go to the ProVAL Support page for:

- Subscribing for ProVAL updates
- Documentation
- Online HelpDesk Support
- Phone Support

About

Clicking the About menu under Help will display the Window with information about the version of ProVAL running, the link to the ProVAL webpage, etc.

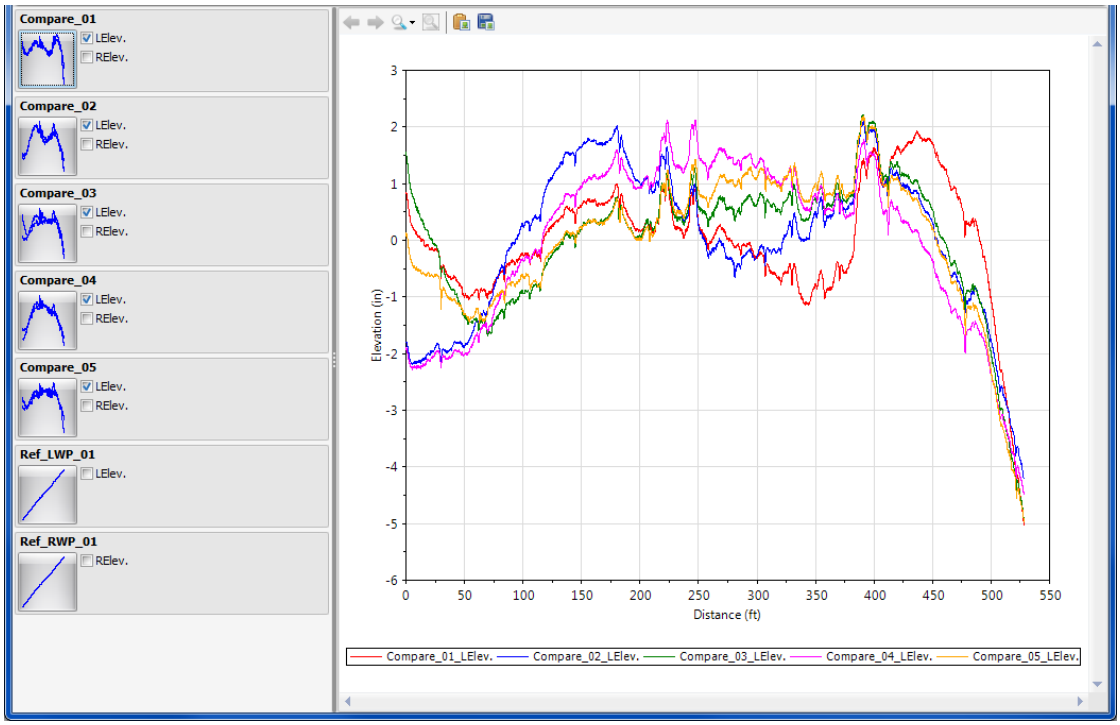
Chapter 4

VIEWER

This module is for viewing profiles. Any number of profiles may be selected. Thumbnails of profiles are displayed on the left of the Viewer screen. Selected profiles will be shown on the right in the chart.

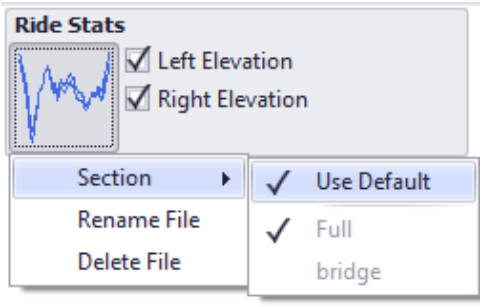
Profile Selection and Display

On the left-hand panel of the Viewer screen, all imported files are displayed as thumbnails and available profiles can be selected for display. Files can be added using the "Add Files" icon on the toolbar within the Project category.



Viewing Profile Sections

Clicking a thumbnail with the left mouse button creates a menu to select which section to view. Choose from the Full profile or a section that has been created in the Editor. See "Sections and Event Markers" in this guide for more details on creating sections and selecting the default.



Profile Rename/Delete/Export

The thumbnail menu also includes actions to manipulate files: **Rename** and **Delete**. Remember that all imported profile data in a single project file. Deleting a file will remove it from the project but will not delete any external files.

File names can be changed by clicking the thumbnail and selecting **Rename Profile**. Profile names can be changed by clicking the existing names with the right mouse button or the context menu key and selecting **Rename Profile**.

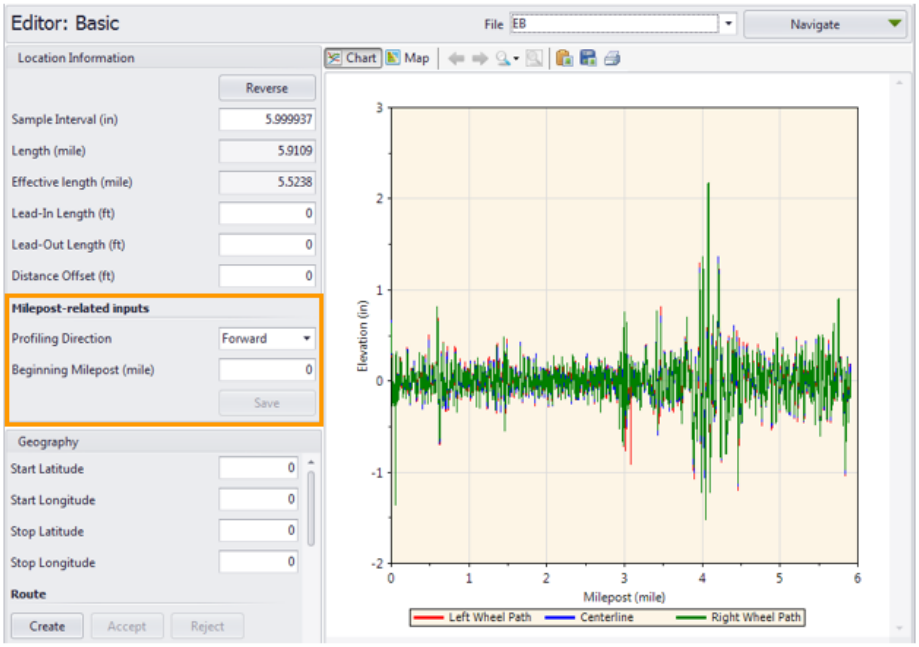
Show Events

Event markers can be turned on and off using the **Show Events** button on the menu bar. They are displayed as Flags at the top frame of the chart area. Placing the cursor over an event flag displays the event name and distance. ProVAL will show up to 500 events to prevent the software from freezing.

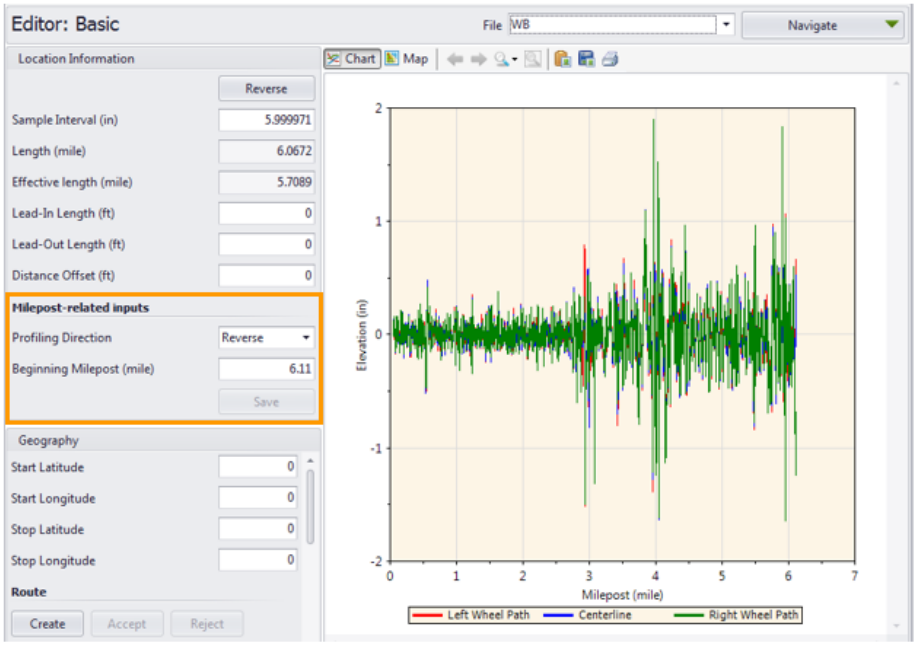
Use Mileposts

Viewing profiles in milepost fashion can be turned on using the **Use Mileposts** button on the menu bar. Both increasing milepost and decreasing milepost can be adequately displayed as long as you define the Profiling Direction and Beginning Milepost on the Editor screen.

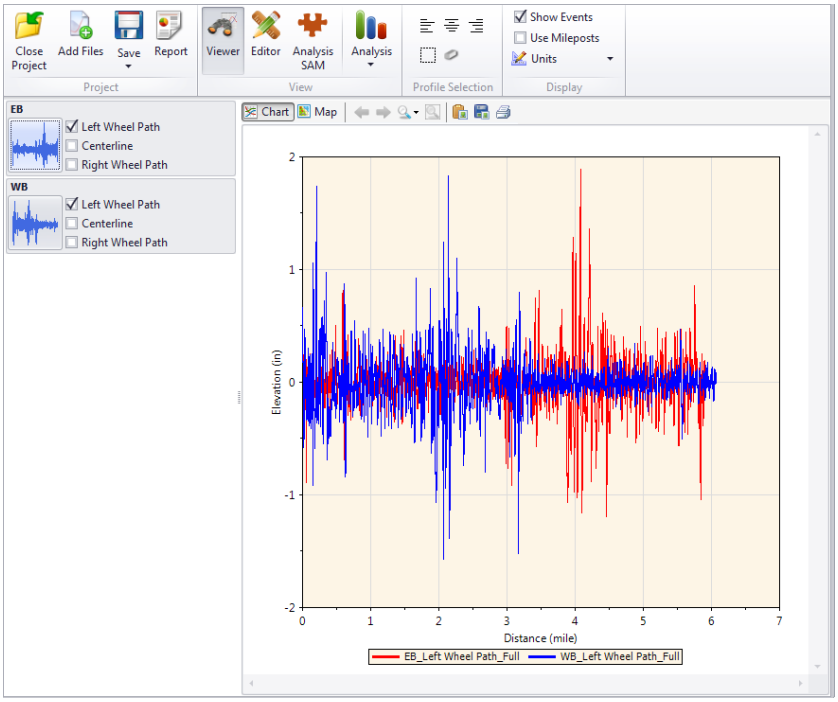
The following is an Editor screen to define an Eastbound profile in the forward direction and its beginning milepost.



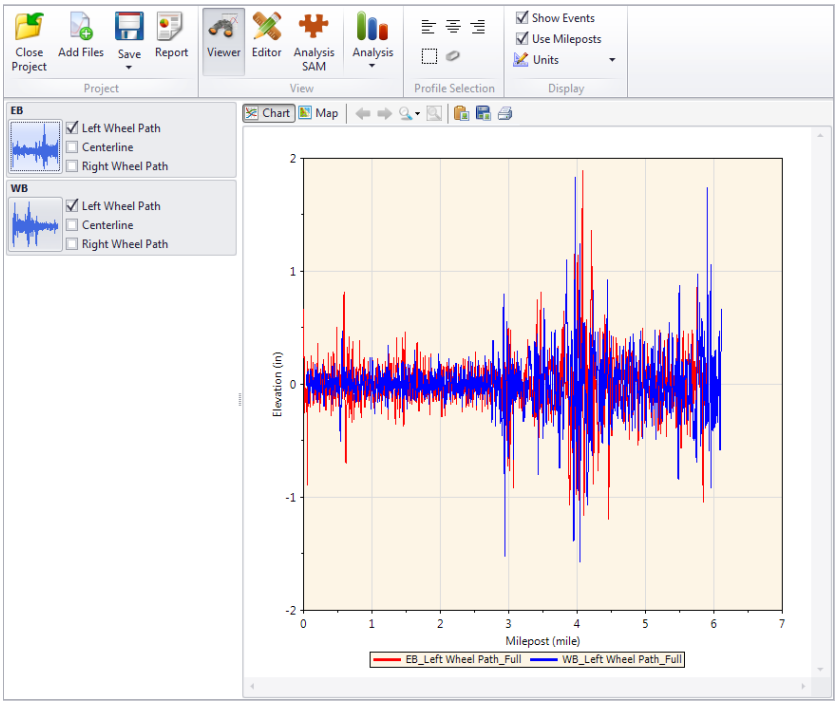
The following is an Editor screen to define a Westbound profile in the reverse direction and its beginning milepost.



The following is a Viewer screen for Eastbound and Westbound profiles with the milepost view turned off.



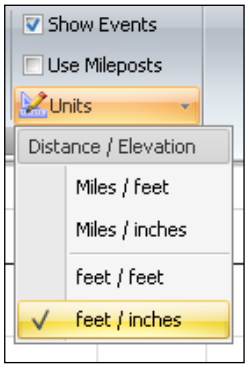
The following is a Viewer screen for Eastbound and Westbound profiles with a milepost view turned on.



Units

The unit system can be specified in the **Options** by checking or un-checking the **Use SI Units** option.

The distance and elevation units within the selected unit system (in **Options**) can be selected using the **Units** dropdown button on the toolbar.



Map

A route must be created in Editor/Basic/Geography to use the Map feature.

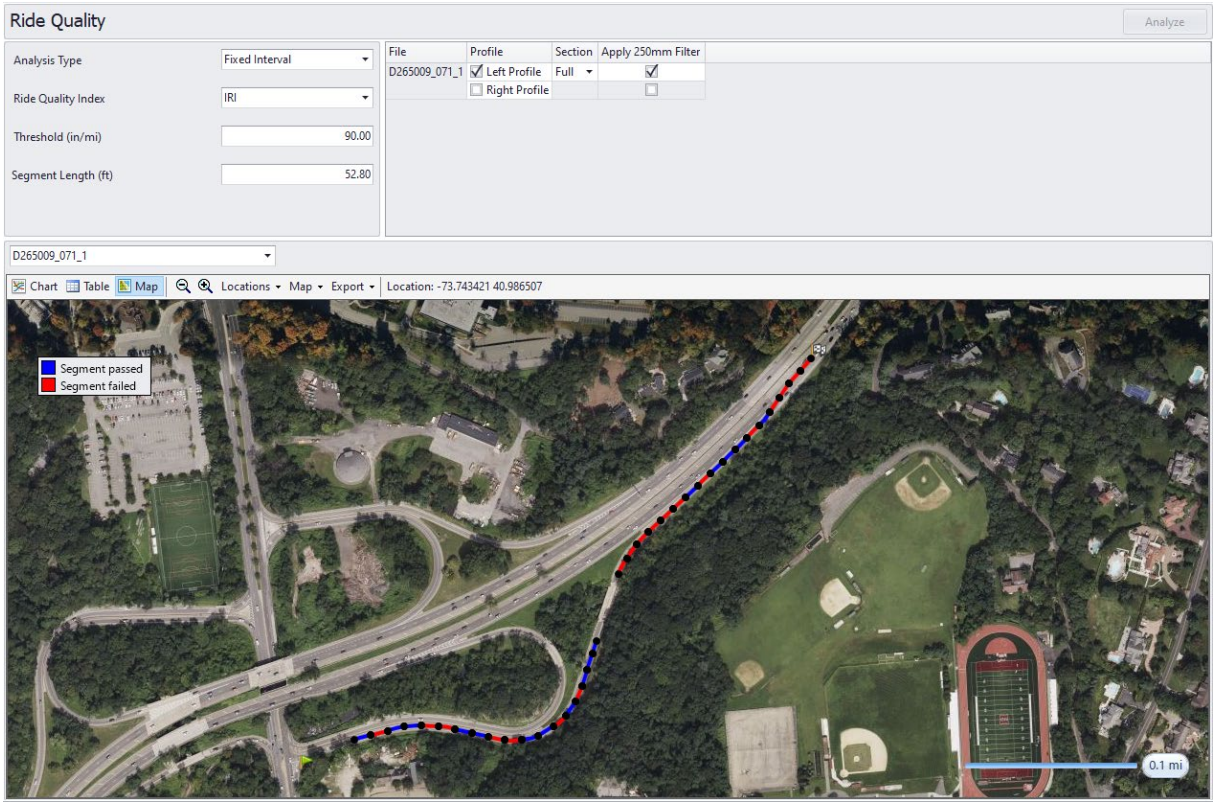
Current map options include Road and Aerial. Select the map type under the Map dropdown when in the Map view.

Zoom in and out using the magnifying glass buttons. Alternatively, click or tap on the map and use the mouse wheel or +/- keys.

Select the location to display using the **Locations** dropdown.

Under **Export,** maps can be exported to images to clipboard/file, KML, or KMZ files.

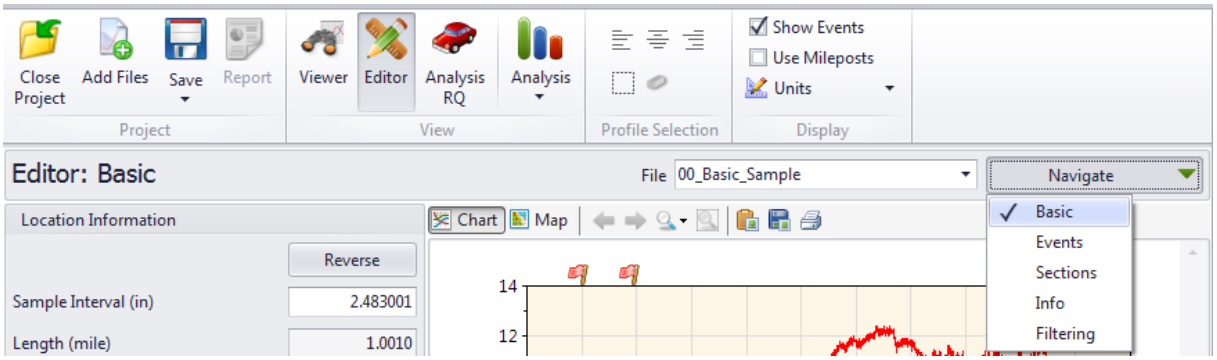
The following is an example of a Fixed Interval Report on an aerial map.



Chapter 5

EDITOR

You can select the file to be edited first, then use the **Navigate** dropdown button to view the **Basic**, **Events**, **Sections**, **Info**, and **Filtering** screens.

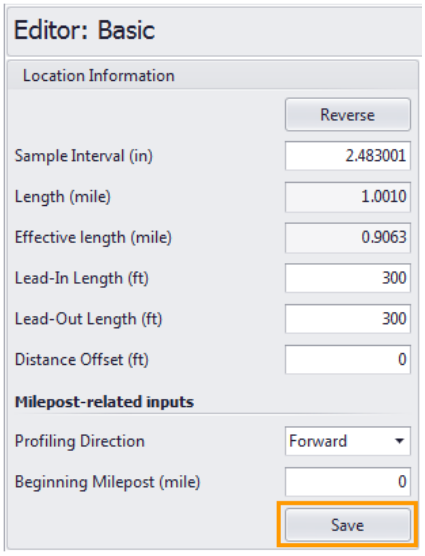


Basic

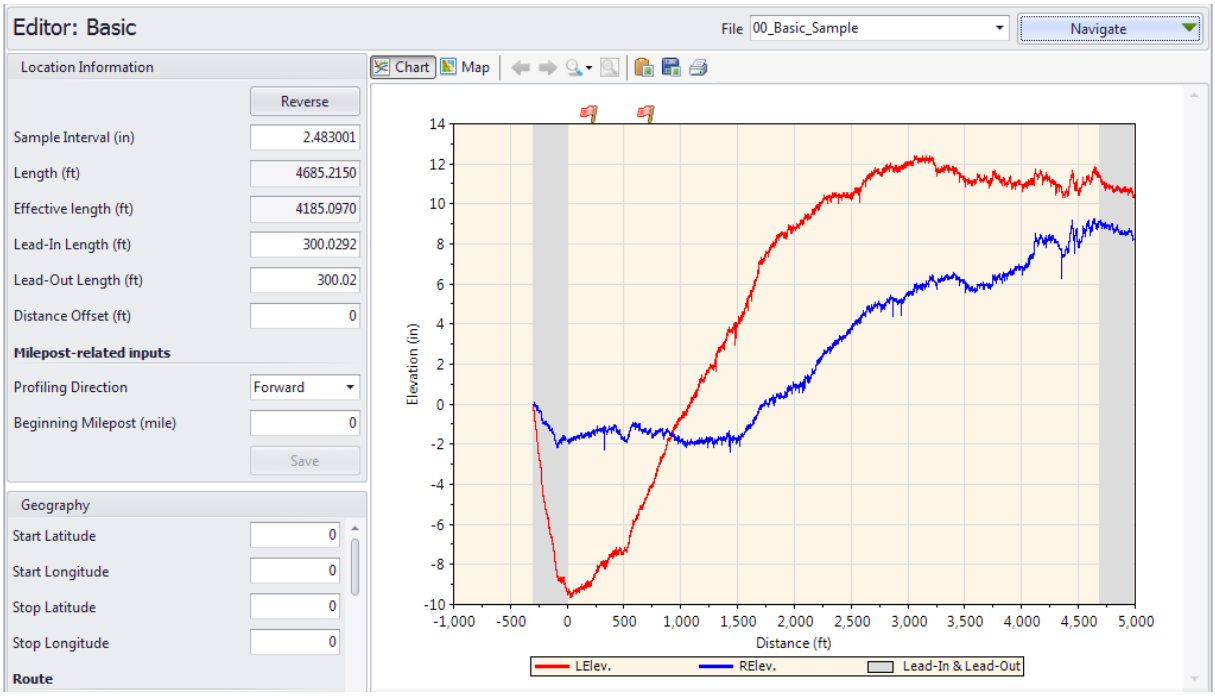
The following profile modifications are allowed in the **Editor**/**Basic** screen:

Location Information

- **Reverse**: flips the profile so it is a mirror image of the original
- **Sample Interval**: distance between stored sampling points
- **Length**: distance for the entire trace
- **Effective Length**: distance for the trace, omitting leave-out sections.
- **Lead-In Length**: lead-in distance to start location
- **Lead-Out Length**: lead-out distance from the end location
- **Distance Offset**: offset to the start location (i.e., zero distance reference)
- Click **Save** to save changes to the location information.



Shaded areas will indicate the lead-in and lead-out portions of the profile if assigned as non-zero values.



Milepost-related Inputs

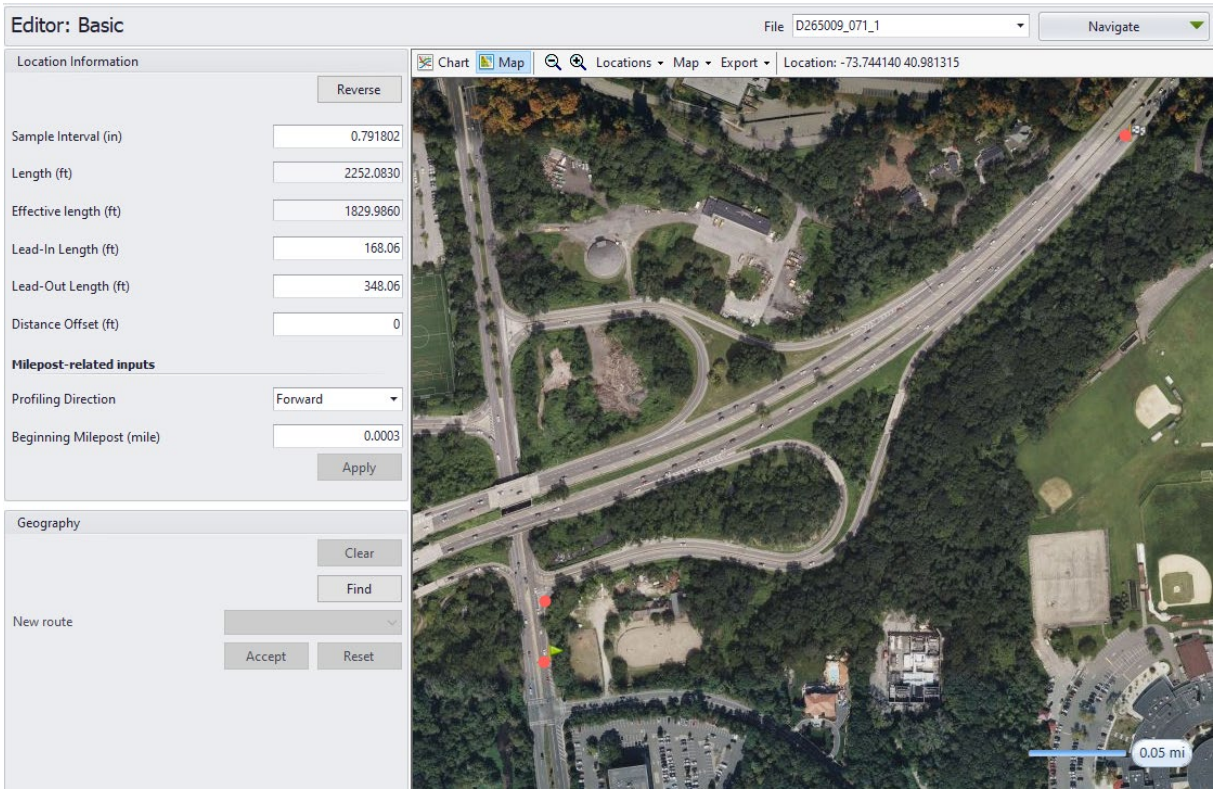
- **Profiling direction**: direction regarding the distance reference system (such as milepost)
- **Beginning milepost**: reference milepost at the start location
- Click **Save** to save changes to the location information.

Geography-Route Tool

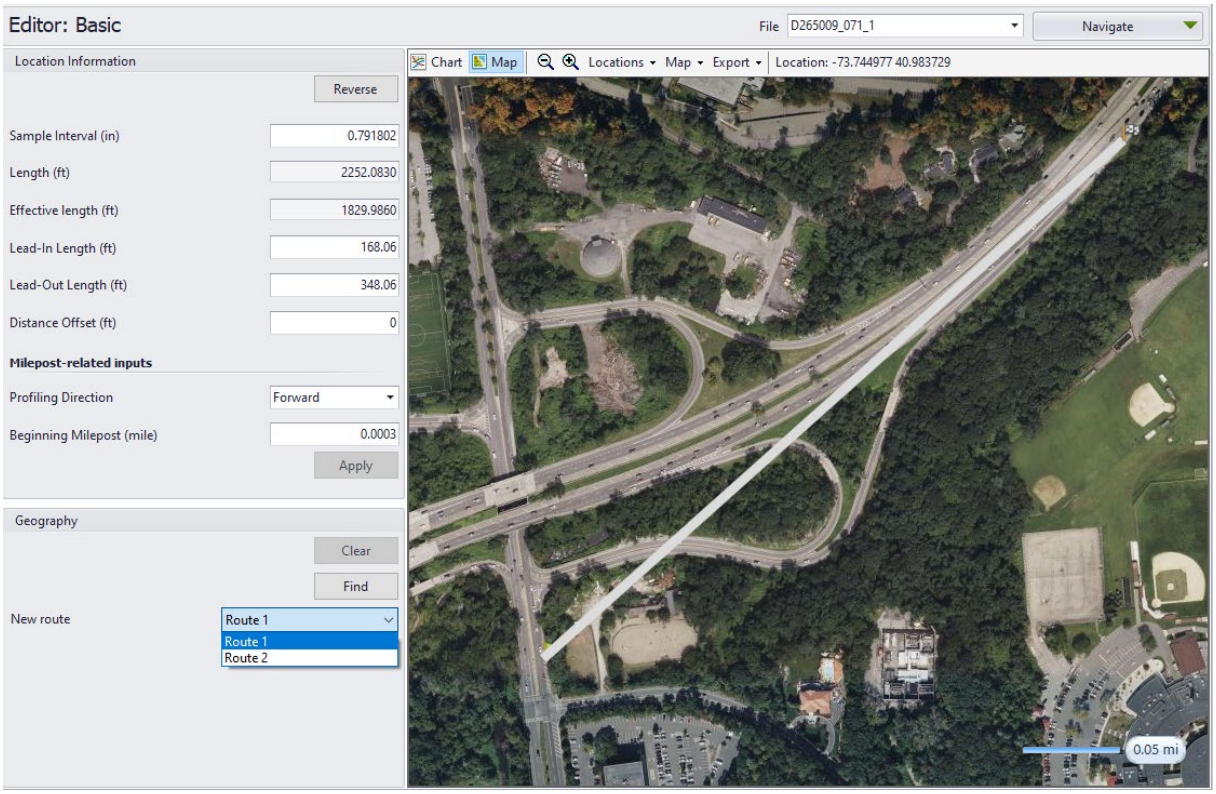
The geography allows a route to be created for the profile data. This would enable the Map feature in various ProVAL modules.

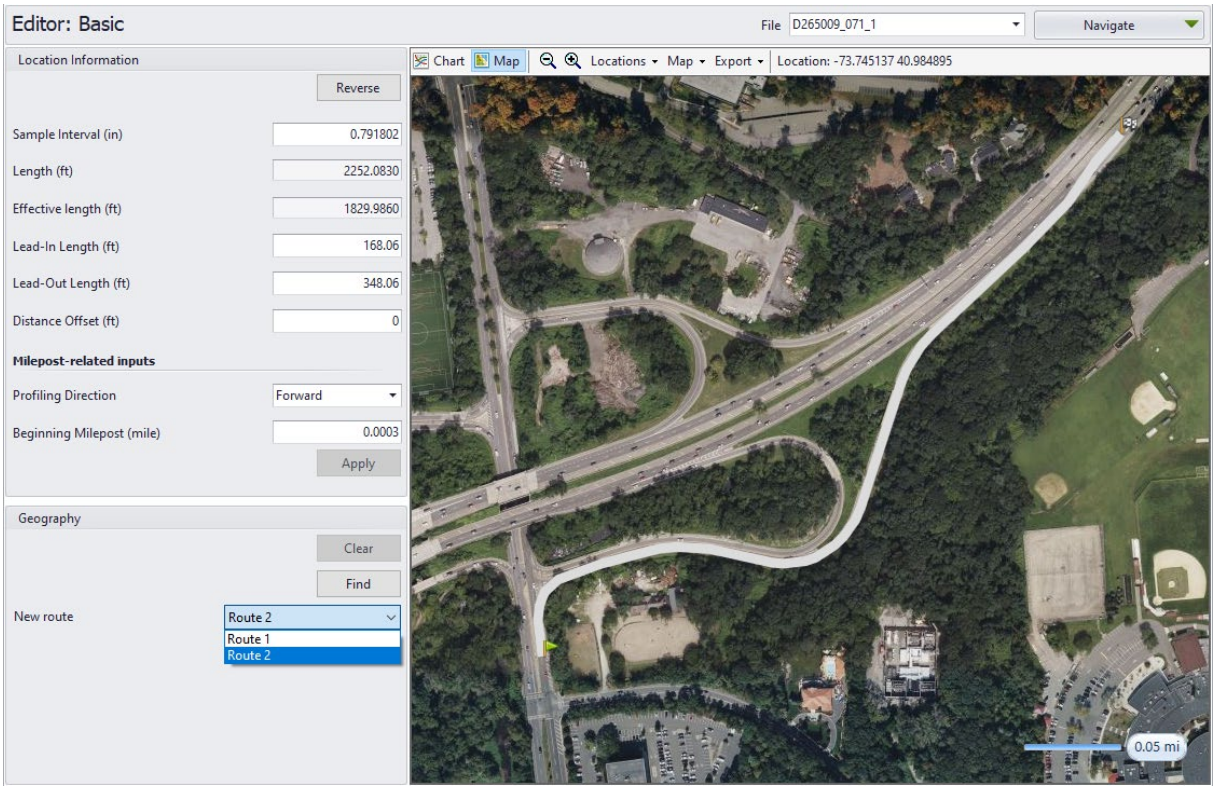
Starting ProVAL 4.0, the route needs to be determined based on the GPS information in the data file:

Click the Find button to allow ProVAL to find the GPS information in the profile data.



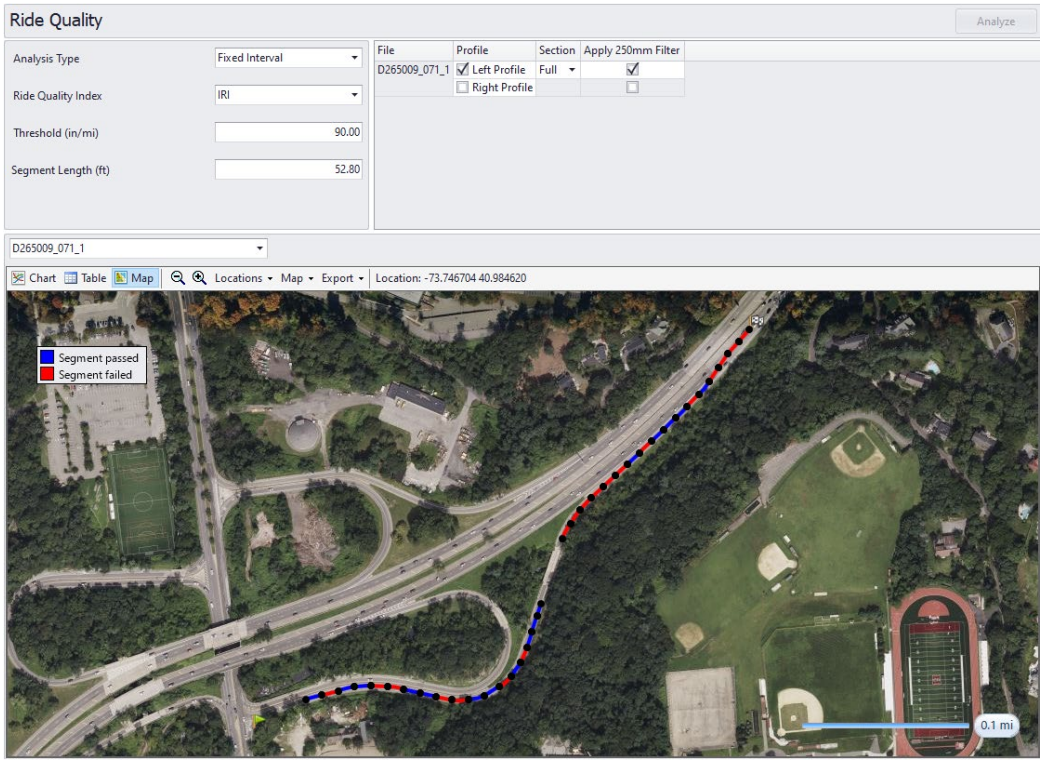
Depending on the GPS data available in the file, ProVAL will produce 2 to 8 candidate routes. Examine the results and select the desired route output. Then, click Accept to acknowledge the acceptance of the created route.



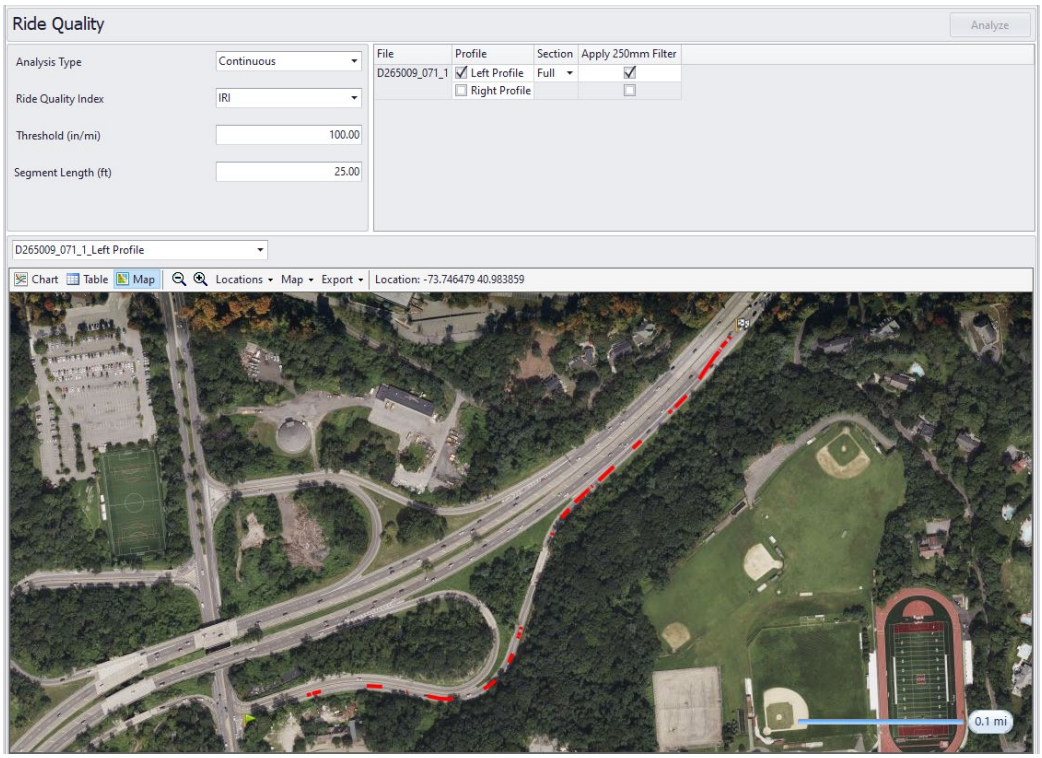


Users can also reset it and do it again.

The following is an example Map view of a Ride Quality Fixed Interval report if a route is created.

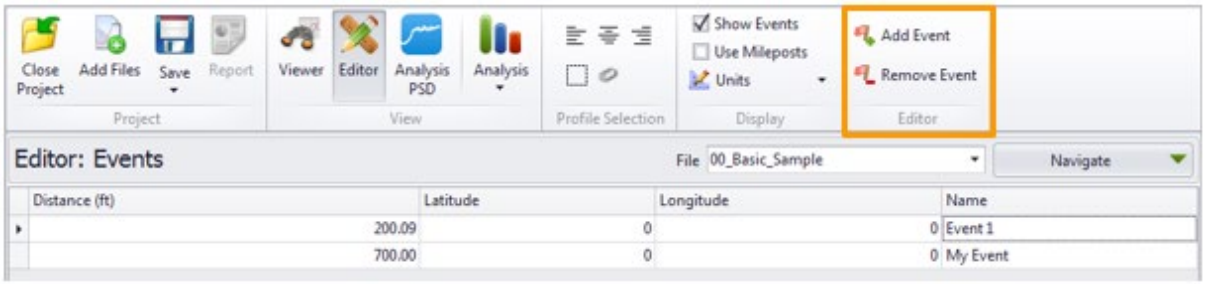


The following is an example Map view of a Ride Quality Continuous roughness report if a route is created.

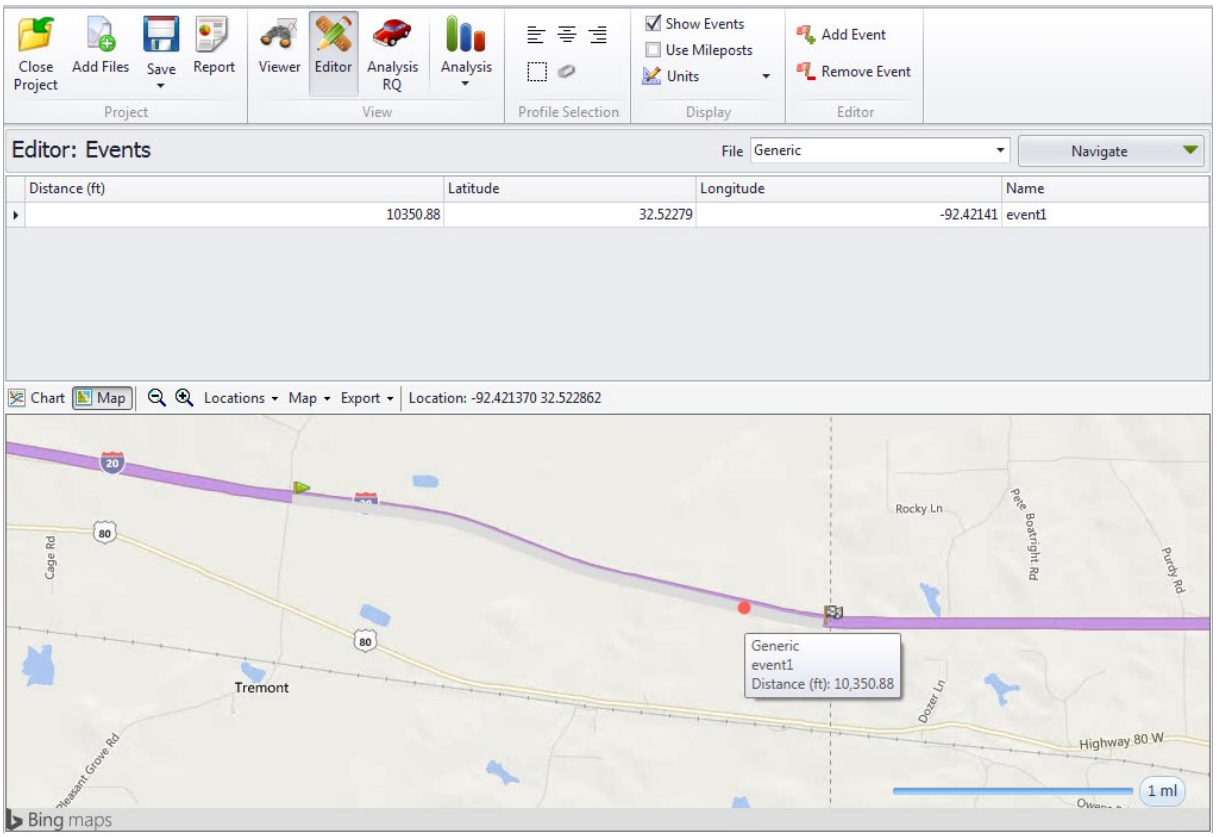


Events

When switching to the **Editor**/**Events** window, the **Editor** button group would be activated in the toolbar to add and remove Event Markers:



Add or remove events using the toolbar by right-clicking the table or by right-clicking the map in Editor: Events. Events are displayed on the map as red dots. Hover over the location to display information. Right-click the location to remove that event.

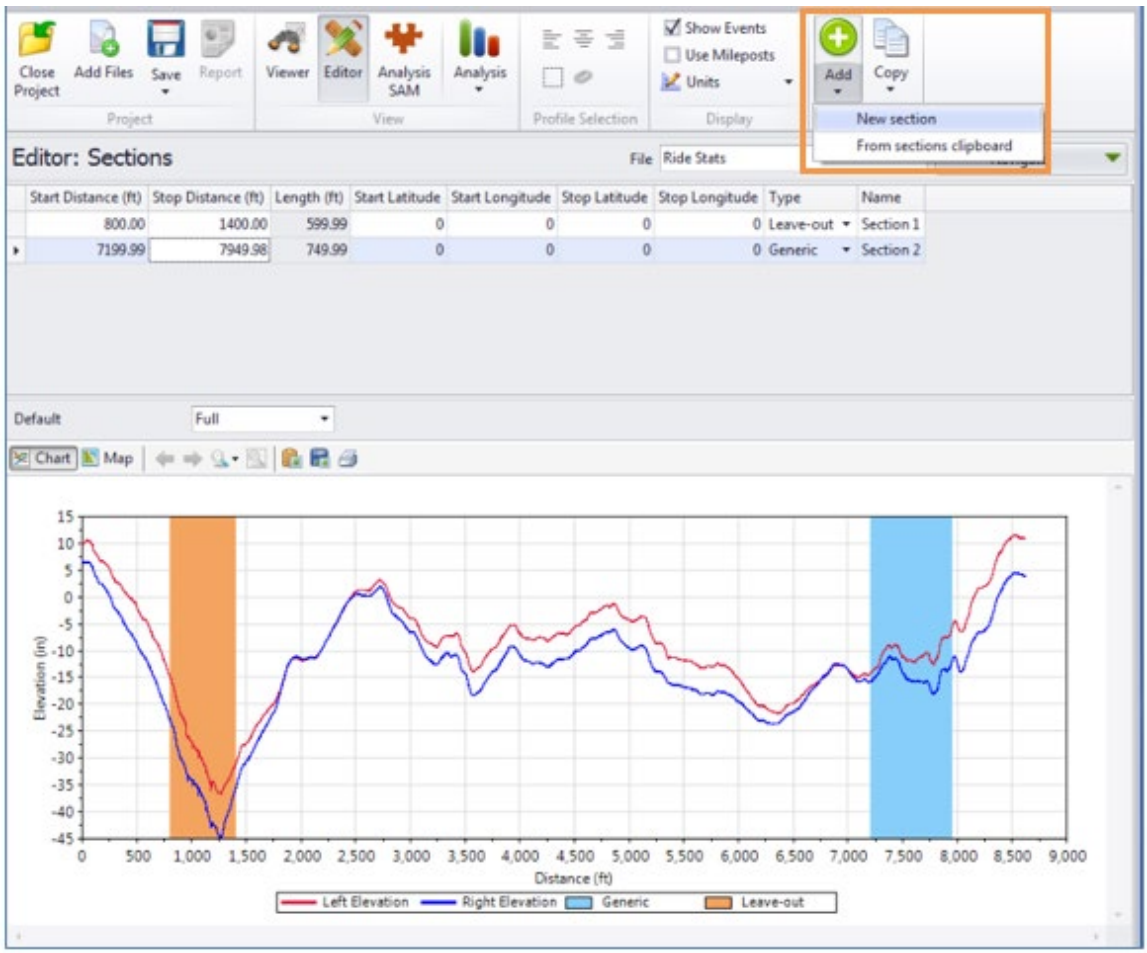


Import of Event Markers: Currently, event markers in the ProVAL (ppf), TxDOT (pro), Dynatest (rsp) and Ames (ldf, adf) profile data files can be imported.

Sections

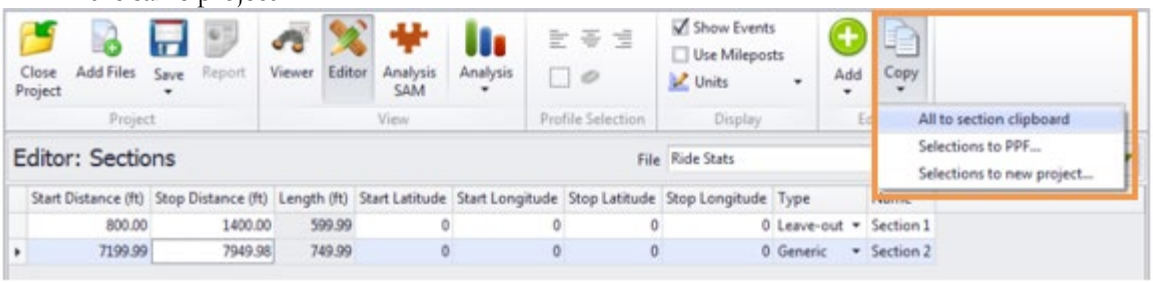
When switching to the **Editor/Sections** window, the **Editor** button group would be activated in the toolbar.

- Add a Section. A section can added by clicking the **Add** speed button and selecting **New Section** or **From Section Clipboard** (if previously Copy all to section clipboard). As new sections are added, they will sort automatically by start distance. The types of sections include Generic and Leave-out. The default analysis section is the Full (or entire profile trace) section but can be changed using the Default Section dropdown.



After adding a section, enter the section name, start distance, and stop distance. Set the type to Generic or Leave-out. Optionally enter the GPS coordinates.

- Copy all Section definitions to clipboard: Click the **Copy** button and select **All to section clipboard**. The definition of sections will then be available to be reused for other profiles in the same project.



- Export data in the selected Sections. While the row of the desired section is selected, click the **Copy** button and select **Selections to PPF** or **Selections to new project**. For a PPF, browse to the target folder for the file. For a new project, select the target folder and enter the desired name.

Sections can also be managed on maps by right-clicking the table or the map. Right-click a location on the map to set it as the start or stop position for the section selected in the table. If a route is defined, the entire route is white on the map, generic sections are blue, and leave-out sections are orange.

Leave-out sections are automatically excluded in the Automated Fault Measurement (AFM), Ride Quality, and Smoothness Assurance Modules (SAM) analyses and reports. However, the leave-out feature is not available to the Profilograph simulation module.

Joint Locations

Prior to running Automated Joint Fault and Curling and Warping analyses, the profile's joint locations need to be identified using the ProVAL Editor/Joint Locations.

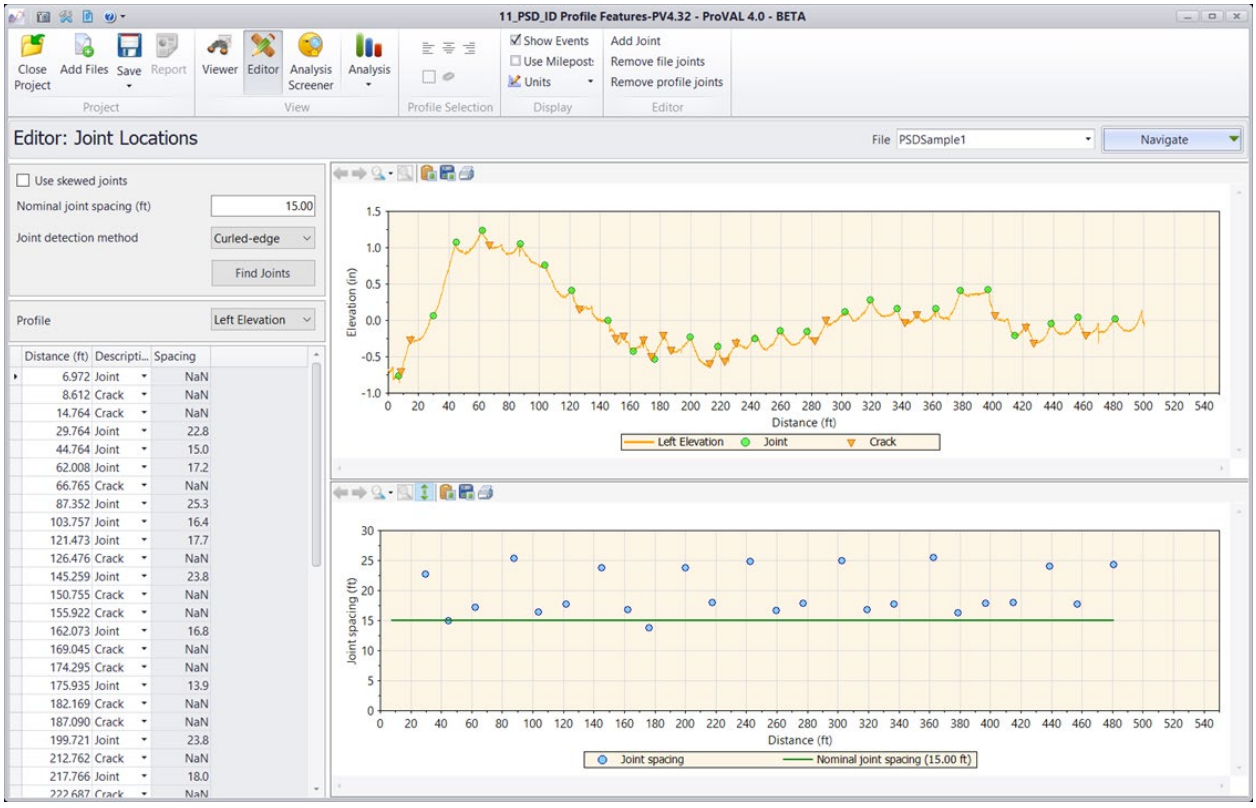
Users can select the joint detection methods among step, downward spike, and curled-edge methods depending on the characteristics of the profiles, then examine the results and modify them as needed.

The inputs:

- Use Skewed Joints – whether skewed joints present
- Nominal Joint Spacing – nominal joint spacing
- Joint Detection Method – method used to identify joint locations

Available techniques for joint identification are:

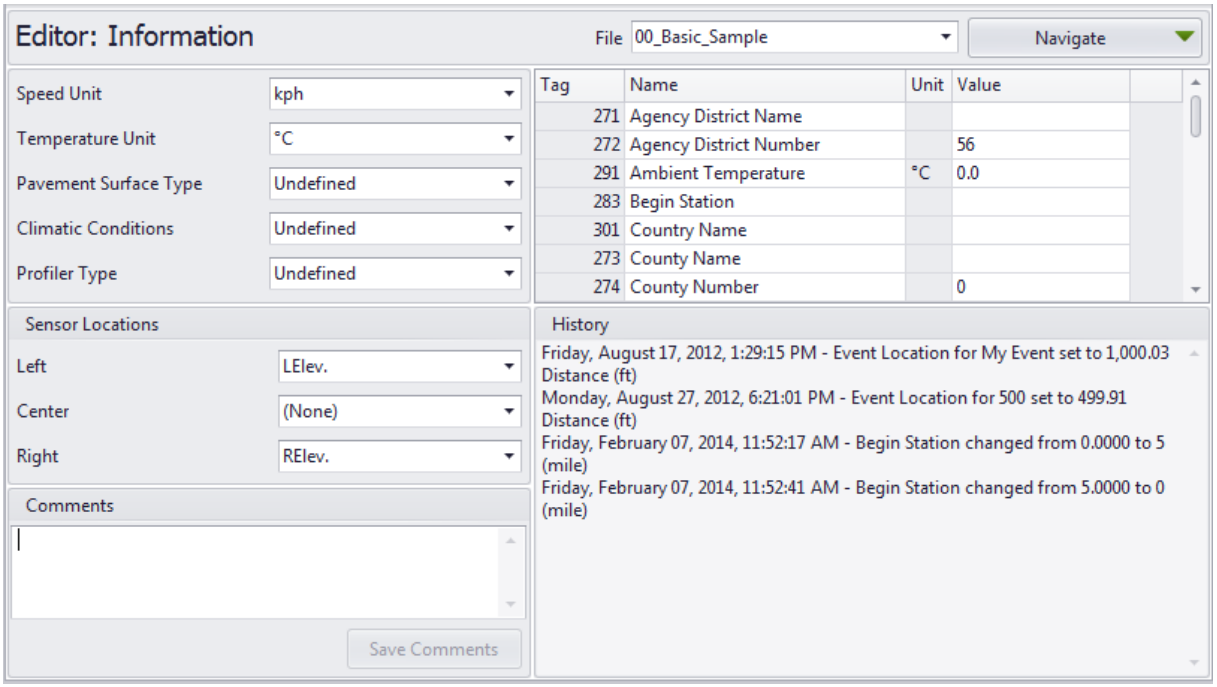
- Downward Spike
- Step
- Curled-edge



For more information about joint detection, refer to the ASTM paper (Chang, G.K., Watkins, J., and Orthmeyer, R., Practical Implementation of Automated Fault Measurement Based on Pavement Profiles, International Symposium on Pavement Performance: Trends, Advances, and Challenges, STP 1555, ASTM International, ISBN13: 978-0-8031-7541-9, 2012.).

Information

The following modifications are allowed in the **Editor/Information**:



- Change values or units of non-optional properties or tags. Tags are metadata or "data about data."

- Designate sensor locations.

Often the imported profile data (e.g. ERD) may not identify channels (i.e., left or right channel correctly). These errors may be caused by incorrect channel labels in the original profile data. Users would need to correct that using the Editor/Info facility. Without the correct channel designation, many analyses cannot be run properly (e.g. Profiler Certification).

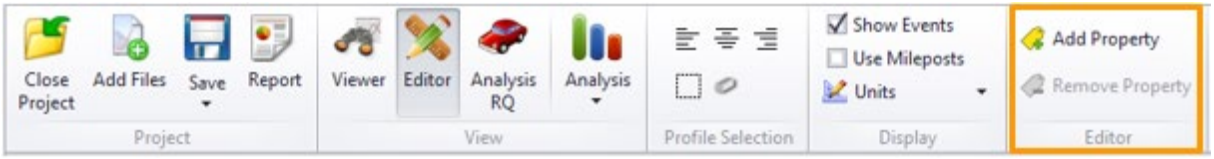
- Add and edit comments (users must click the **Save Comments** button to save the changes).

- View (profile editing) History. History includes all changes made to the profile data and properties.

- Add, remove, and change values or units of user-defined properties.

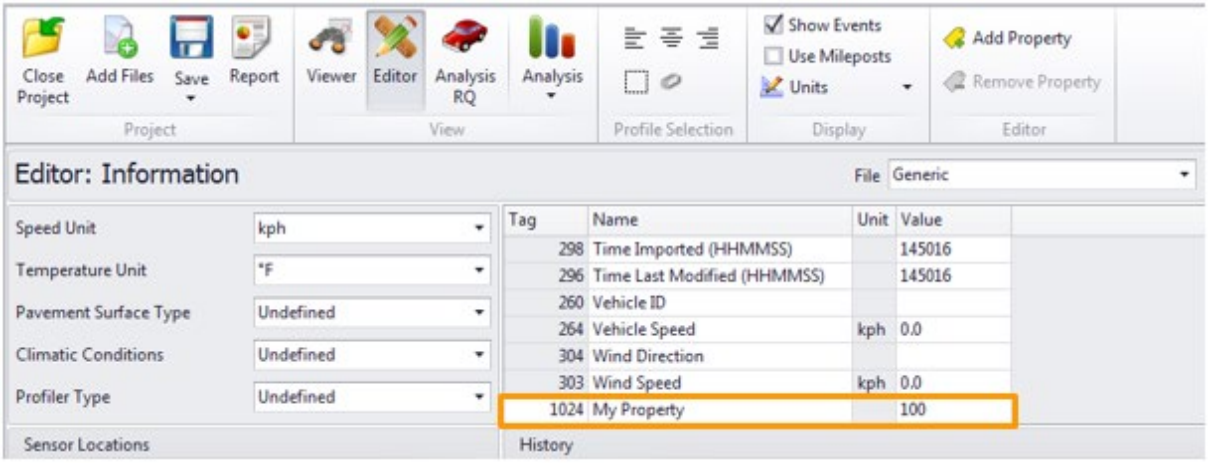
You can use the following steps to add a user-defined property in the Editor/Information screen:

- **Step 1**. Select the Add Property icon from the toolbar.



- **Step 2**. Enter the tag number (between 1024 and 2047) in a pop-up dialog box.

- **Step 3**. Enter the name and value for this tag number.



Removing a user-defined property is easy. Simply select the tag to be removed and click the Remove Property button from the toolbar:

The tag numbers for default non-optional tags cannot be changed.

History cannot be modified.

Filtering

The following modifications are allowed in the **Editor/Filtering**:

- Apply filtering.
- Save filtered file. Default file names will be used, with the current name as the base name.

Different wavelength filters can be specified. The following filter types are available:

- Butterworth Band-pass
- Butterworth Low-pass
- Butterworth High-pass

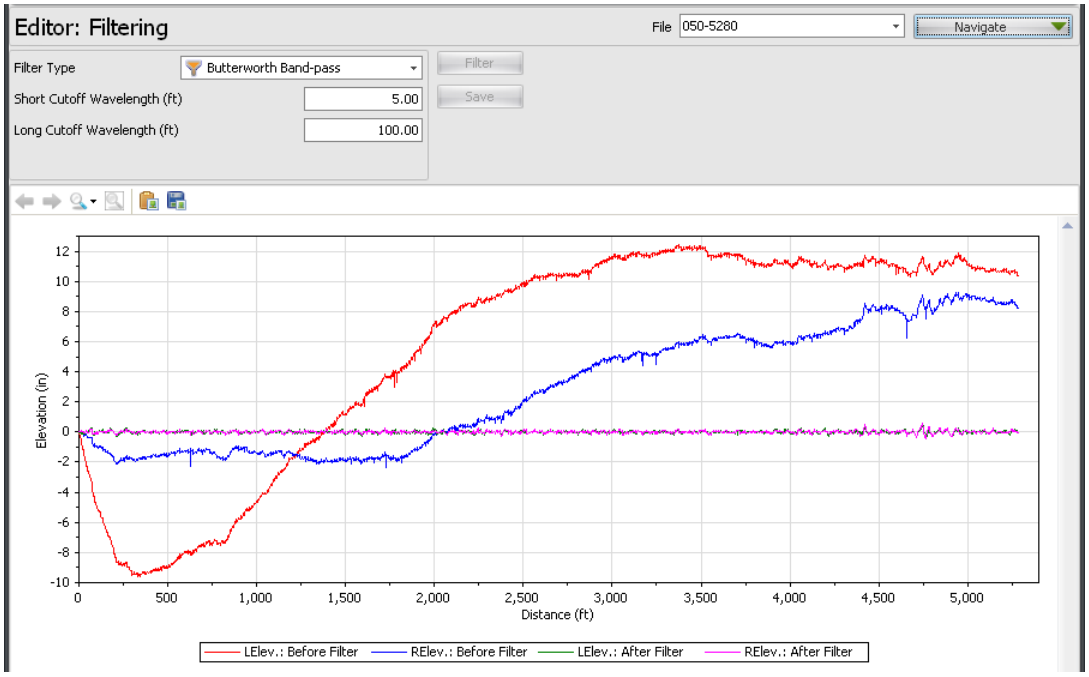
- IRI
- Moving average Band-pass
- Moving average Low-pass
- Moving average High-pass

The Butterworth filter set is effectively a 6th-order Butterworth filter. It is implemented by cascading first-order and second-order Butterworth filters in the forward direction, then repeating in the backward direction. The performance of this filter was validated with numerous profile data, including those from the FHWA 2004 Profiler Roundup.

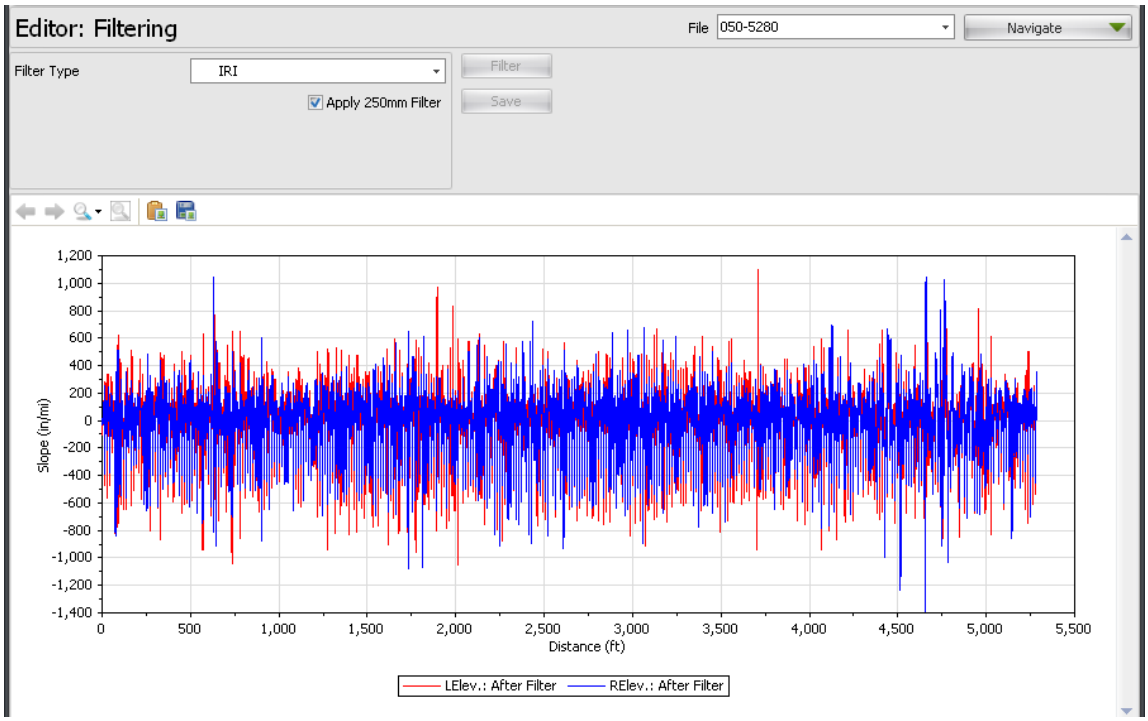
The moving average filter is based on the standard two-way moving average algorithm.

The IRI filter is a quarter-car filter with the golden car parameters in the ASTM IRI standard. Unlike others, the output of the IRI filter is in profile slope.

After filtering (except IRI), both the original profile and the filtered profile will be displayed on the same chart.



After IRI filtering, only the filtered profile "slope" will be displayed on the chart.

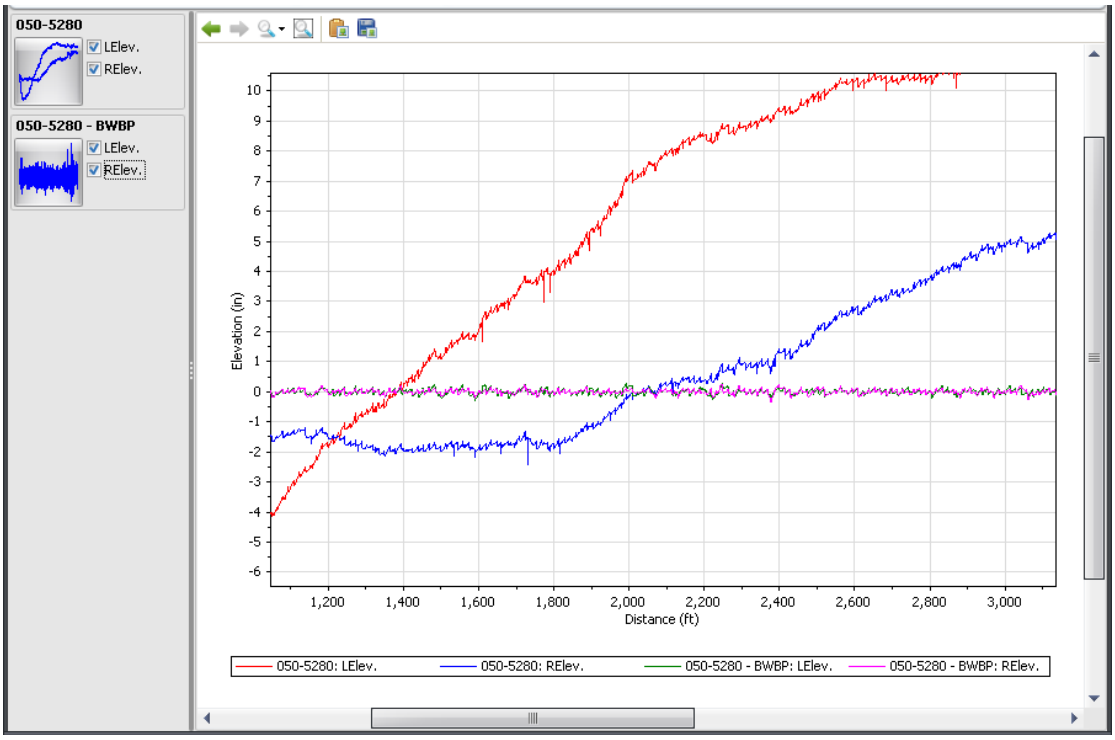


Except for IRI-filtered slopes, you can save the filtered profile by clicking the Save button below the Filter button. The filtered profiles will then be stored in the project file with a default filename. The default filtered filenames are the original file name - tag name. Tag names are added depending on the filter type as follows:

- Butterworth Band-pass - BWBP
- Butterworth Low-pass - BWLP
- Butterworth High-pass - BWHP
- Moving Average Band-pass - MABP
- Moving Average Low-pass - MALP
- Moving Average High-pass – MAHP

IRI-filtered slope results can not be saved since they are "slope" values instead of profile elevations.

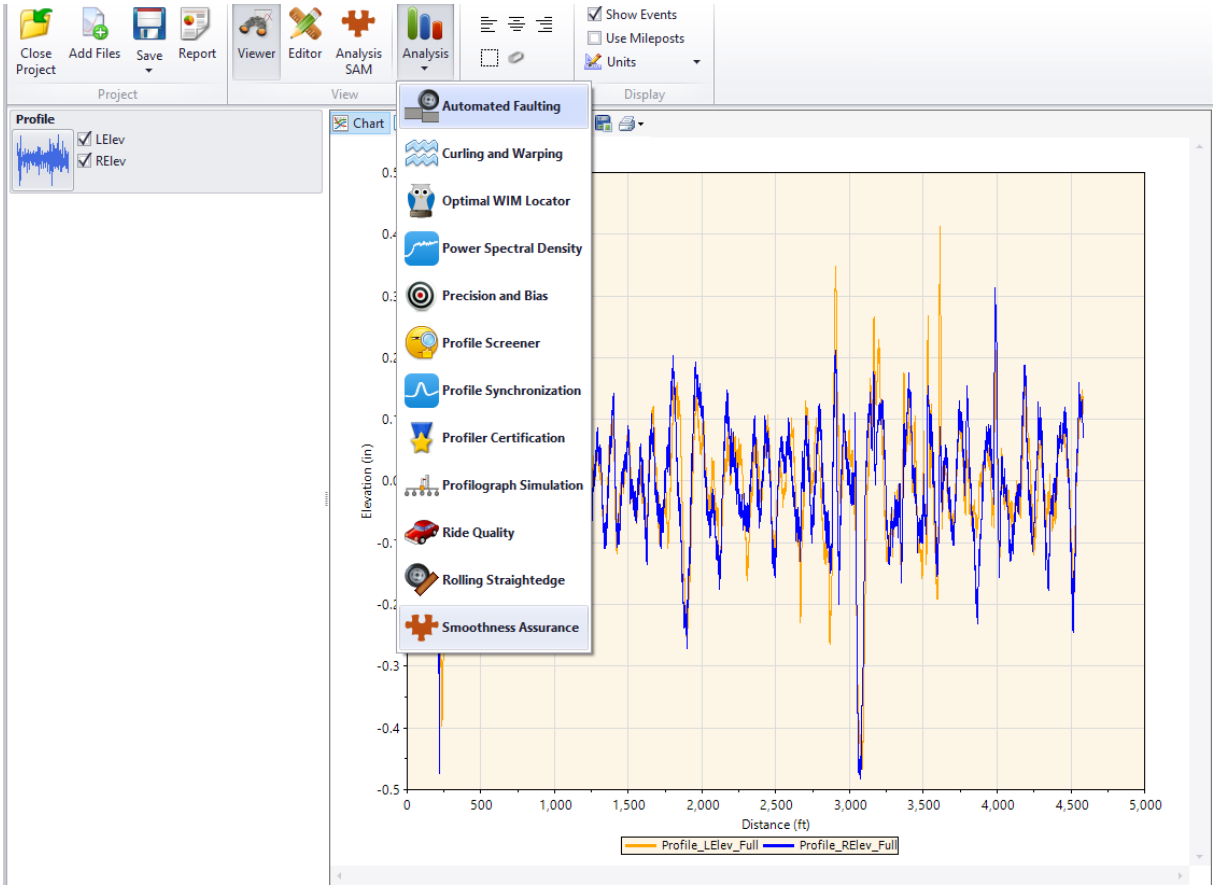
You can then switch to the **Viewer** window for further comparisons.



Chapter 6

ANALYSES

An analysis can be selected by using the Analysis button on the menu bar. The icon of the currently selected analysis is displayed next to the Analysis button on the left.



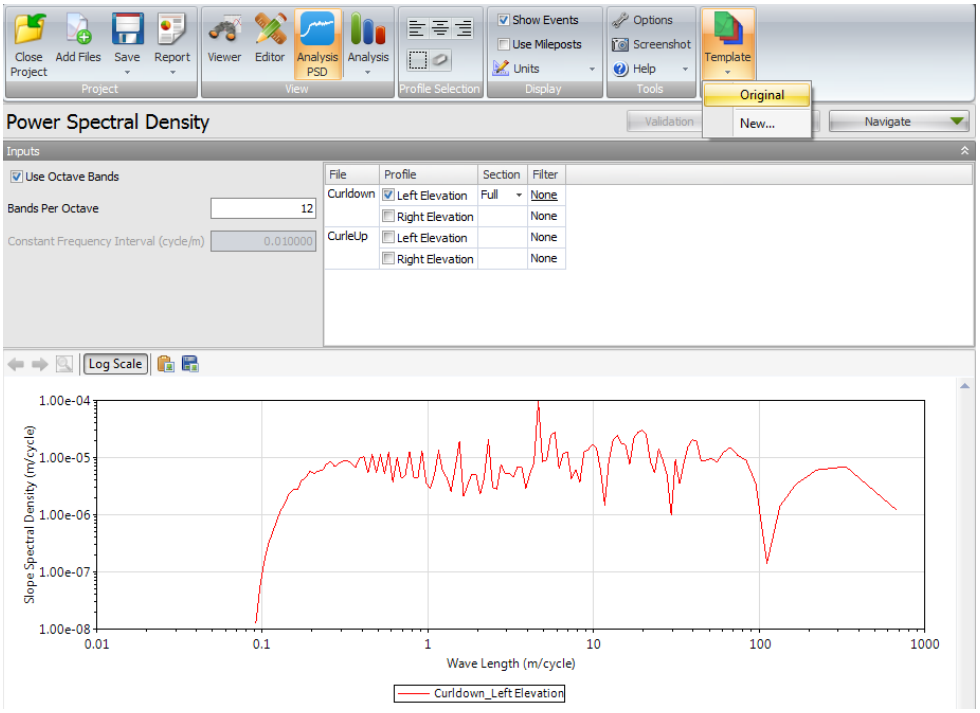
Templates

A template defines a set of input values for an analysis. A default template is provided for each analysis. You can create new templates and set which template will be the default.

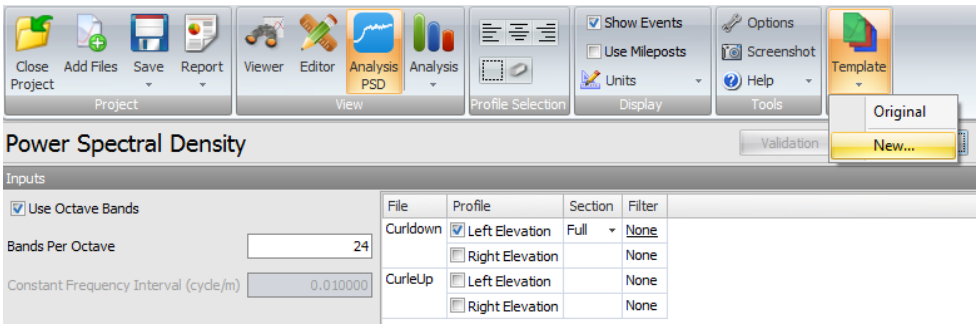
Templates can be imported, exported, renamed, and deleted using the Template dropdown button on the menu bar.

The Analysis Template function can be illustrated in the example below.

Step 1. Use the Original (program default) analysis template

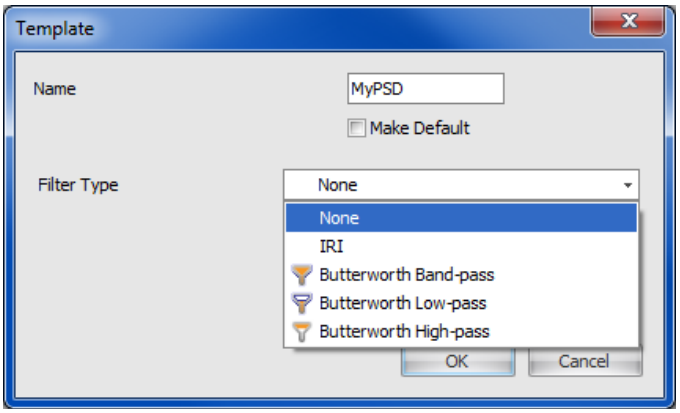


Step 2. Now, change the "bands per octave" from the default value, 12, to a new value, 24. Then, click the Template button in the toolbar and select "New" to save the current inputs to an analysis template:

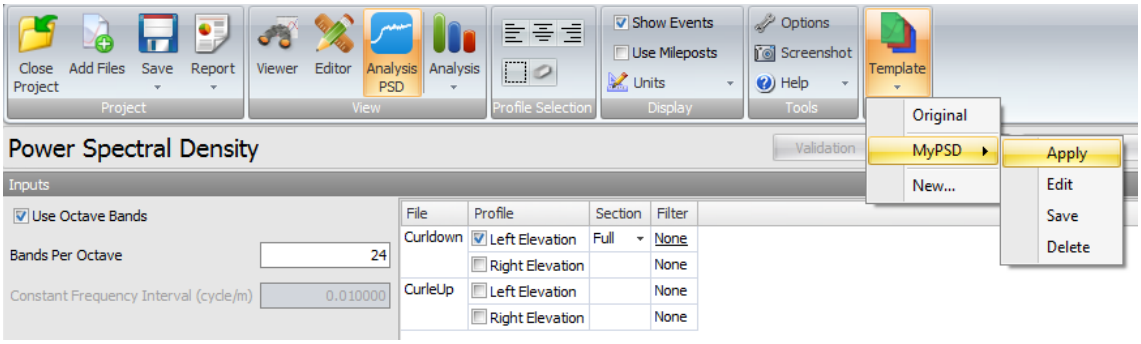


Step 3. Then, supply a name for the new template and select other input settings. The template filter

must be specified here because wavelength filters can often be set on a per-profile or per-file basis.



Step 4. You can then select the Original (to the default settings) or use the template menu to Apply, Edit, Save, or Delete a previously created template.



Step 5. After selecting a desired template, click the Analyze button to run the analysis based on the current input settings.

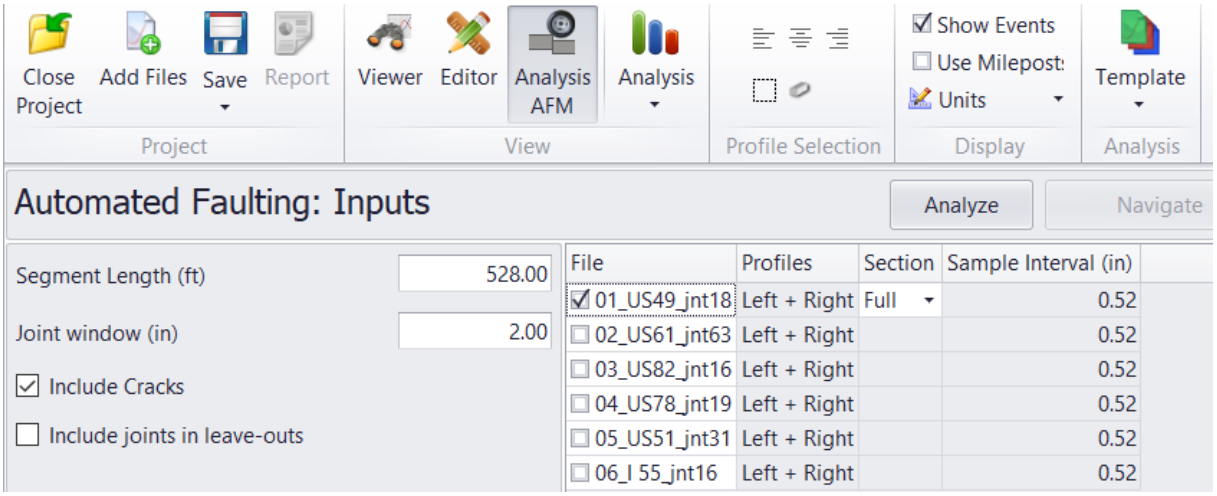
Automated Faulting Measurements (AFM)

Prior to running the Automated Faulting Measurements analysis, the profile's joint locations need to be identified using the ProVAL Editor/Joint Locations.

The Automated Faulting analysis identifies joints and reports faults in jointed concrete pavement. Faulting is calculated based on the AASHTO R36 "Standard Practice for Evaluating Faulting of Concrete Pavements".

Profile Selection

At least one profile data must be selected. Each profile data must consist of profiles from the right and left wheel tracks.



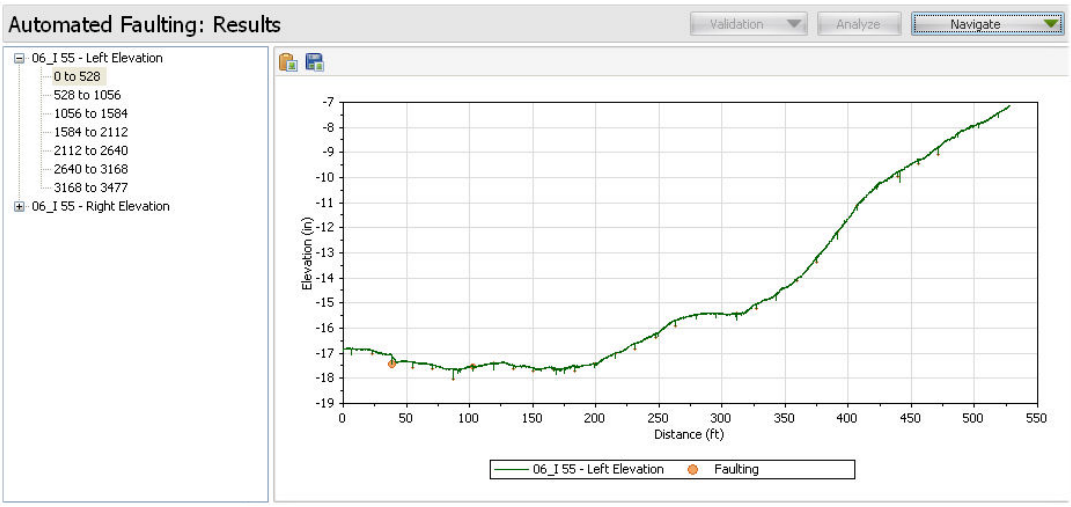
Inputs

Input Templates are available for this analysis. Changing the selected profiles will not affect the template. However, the template will set the joint and segment inputs, which affect joint and crack detection. The inputs include:

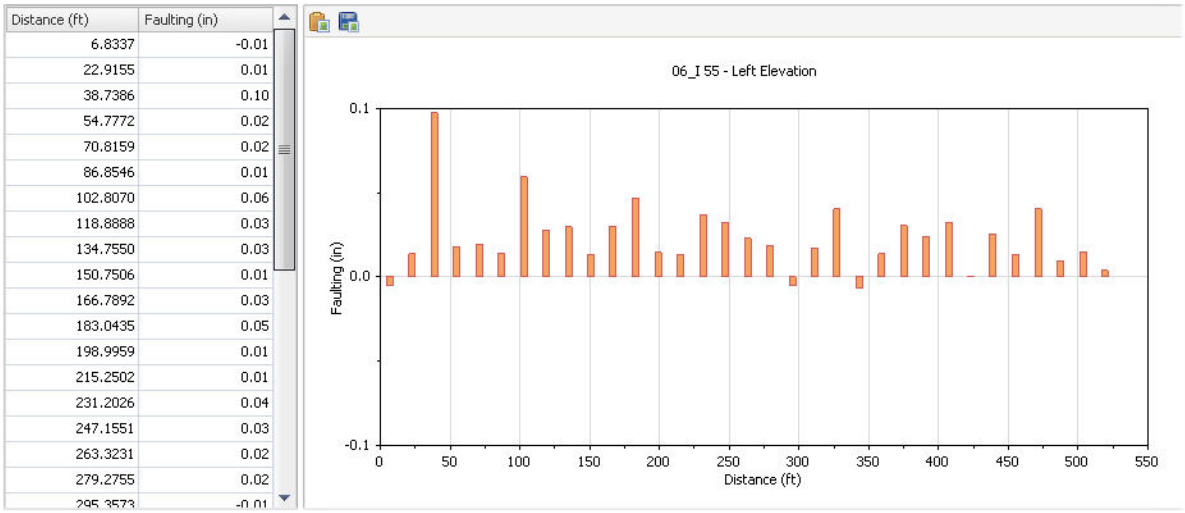
- Segment Length – segment or lot length for summary reports
- Joint Window – tolerance for exact joint locations
- Include Cracks – whether to include cracks in the report
- Include joints in leave-outs – whether to include joints in leave-outs

Outputs

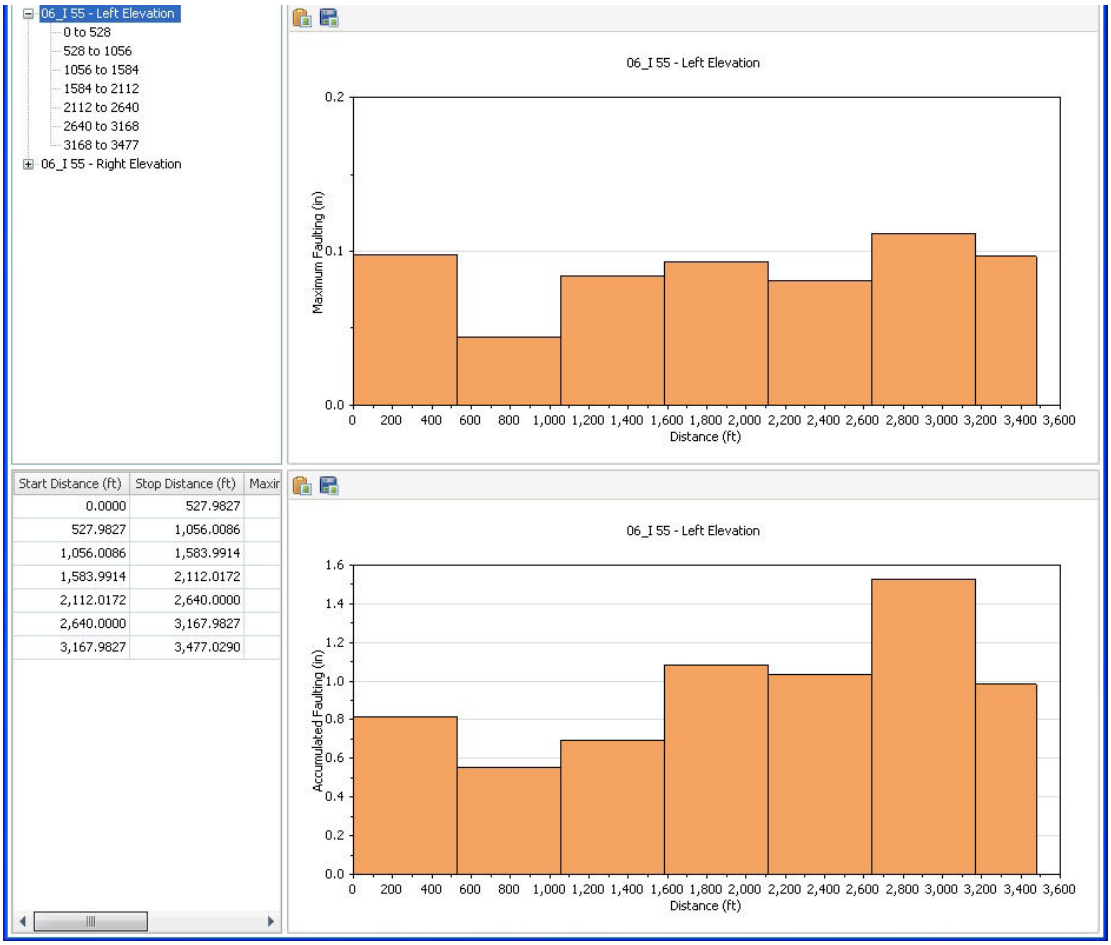
After analysis, results are displayed for each segment. On the left, choose which segment to view. The top chart plots elevation versus distance. Faults are marked with points proportional to the magnitude.



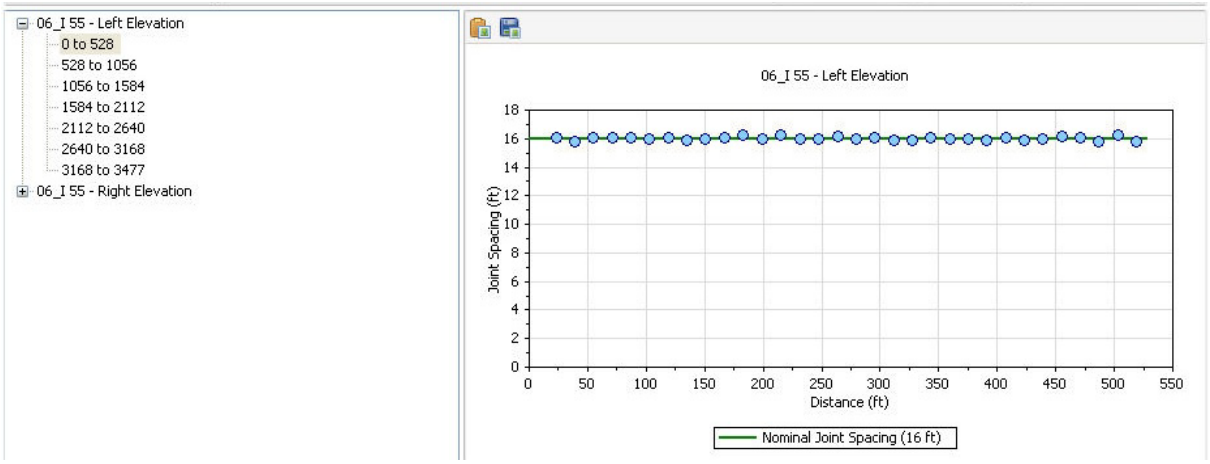
The lower chart shows the location and height of each fault.



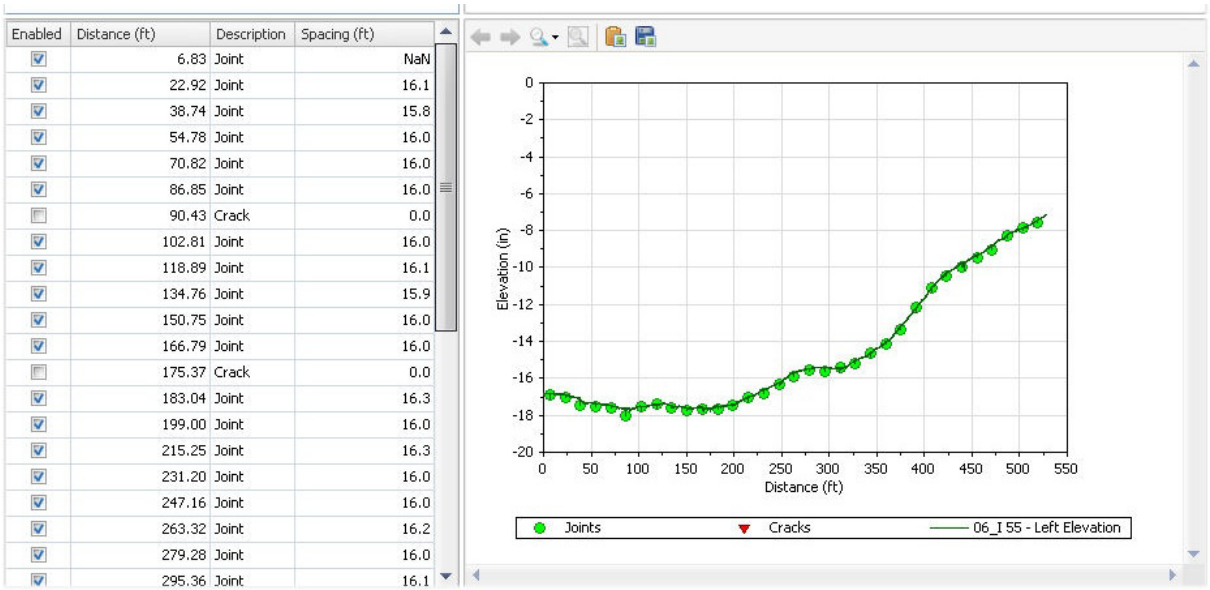
Select the top-level profile to show the maximum faulting and accumulated faulting for each segment.



Use the Navigate button to switch to the Joint Locations view. The top chart shows joint spacing in comparison to the nominal joint spacing specified in the inputs.

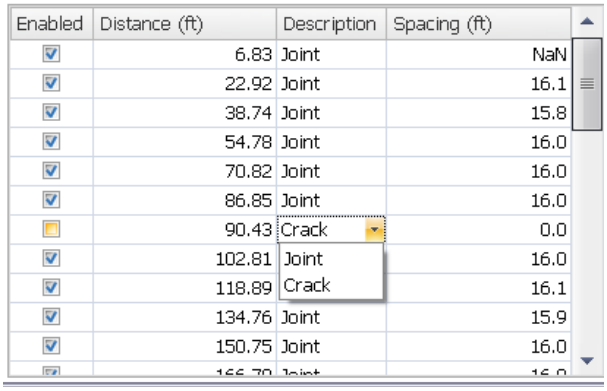


The lower chart marks joints and cracks on the elevation plot.

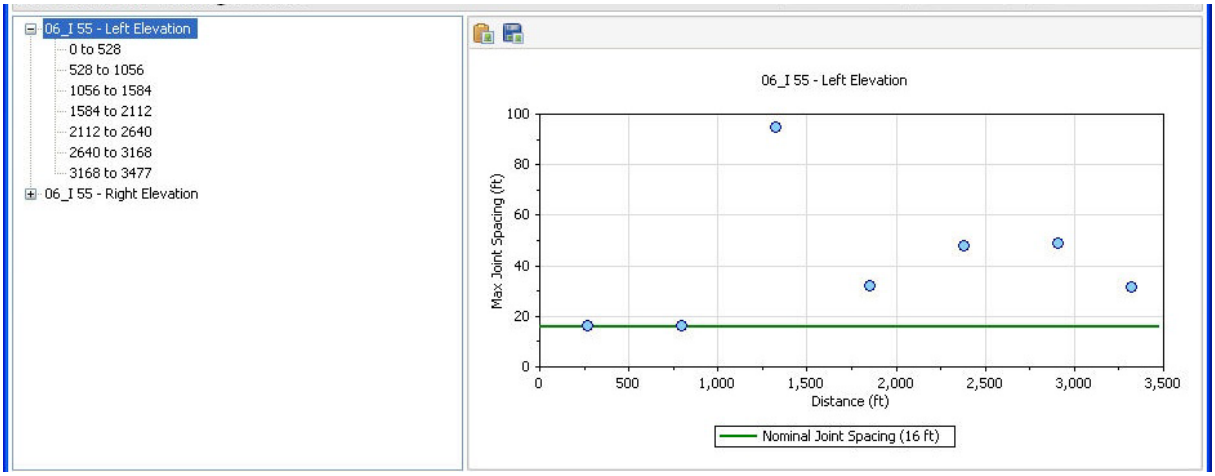


Enabled	Distance (ft)	Description	Spacing (ft)
☑	6.83	Joint	NaN
☑	22.92	Joint	16.1
☑	38.74	Joint	15.8
☑	54.78	Joint	16.0
☑	70.82	Joint	16.0
☑	86.85	Joint	16.0
☐	90.43	Crack	0.0
☑	102.81	Joint	16.0
☑	118.89	Joint	16.1
☑	134.76	Joint	15.9
☑	150.75	Joint	16.0
☑	166.79	Joint	16.0
☐	175.37	Crack	0.0
☑	183.04	Joint	16.3
☑	199.00	Joint	16.0
☑	215.25	Joint	16.3
☑	231.20	Joint	16.0
☑	247.16	Joint	16.0
☑	263.32	Joint	16.2
☑	279.28	Joint	16.0
☑	295.36	Joint	16.1

Enable, disable, or reclassify joints and cracks in the lower-left panel.



Select the top-level profile to show the maximum joint spacing for each segment. It is helpful to identify missing joints for given segments.



Use the Add Joint button to add missing joints if necessary. Users need to click the Analyze button to refresh the fault results if any changes to the joint results occur.

ProVAL AFM will disable any joints and faults within any exclusions defined in the Editor/Sections.

Automated Profile Synchronization (APS)

Automated Profile Synchronization (APS) is a tool to synchronize profiles using cross-correlation.

Cross-correlation (CC) is a statistical metric to measure correlation between two random signals. A CC value of 100% (or 1.0) indicates the signal pairs are perfectly correlated; 0, no correlation; and -100% (or -1.0), perfect but "negatively" correlated. This technique has been proven successful in comparing pavement profiles for repeatability and accuracy tests.

When CC is applied to pavement profile comparison, the process would require additional unique treatments (or conditioning) of raw pavement profiles.

The "conditioning" includes the same filtering history for both basis and comparison profiles and interpolates the comparison profile to the recording interval of the basis profile (only when the recording intervals are different).

"Conversion to slope," as a part of the conditioning, is recommended to compare large wave bands to ensure the influence of the long wavelength content does not eclipse the influence of the shorter wavelength content.

Once the CC rating for the comparison pair is obtained based on the standard CC formula, the value is scaled to consider the variance ratio of each conditioned profile.

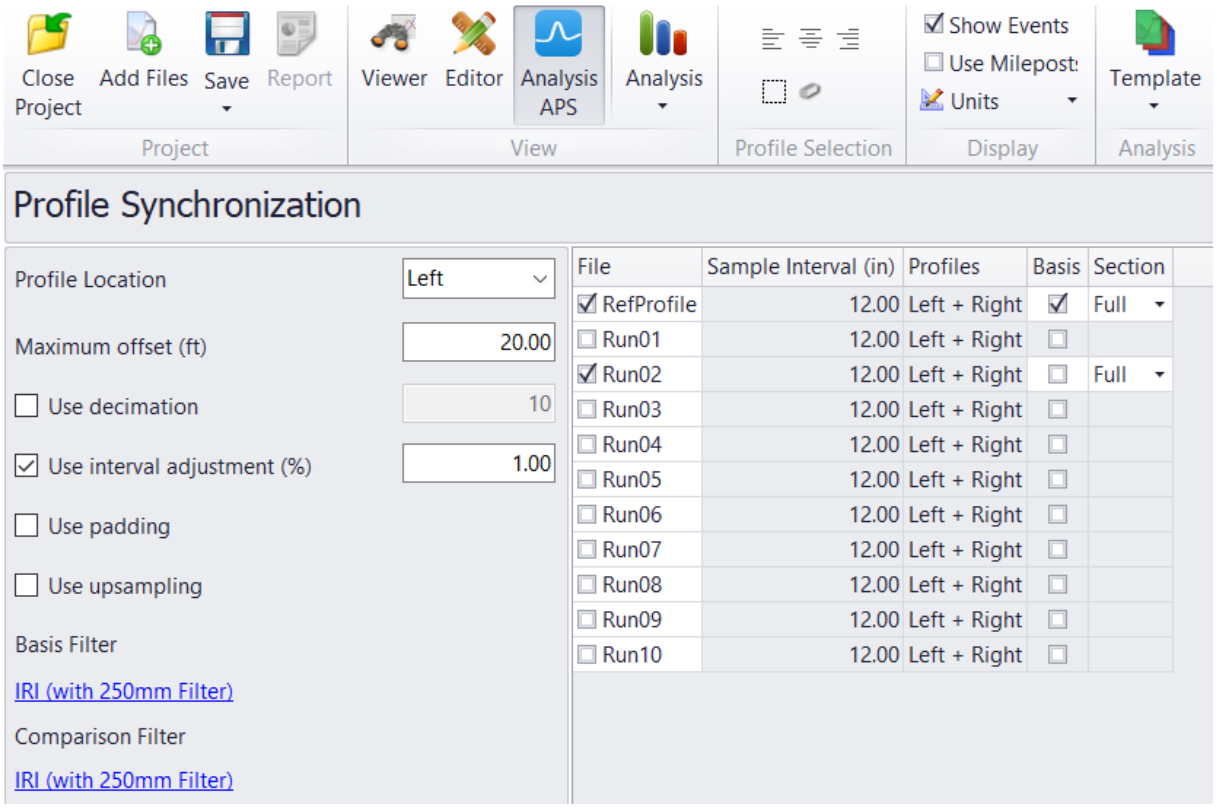
This last process compensates for the CC error when two profiles have the same shape but very different amplitudes.

The CC analysis fully complies with the AASHTO standard, R56, "Standard Practice for Certification of Inertial Profiling Systems."

The ProVAL Profile Synchronization analysis uses two or more profiles of the same section measured at approximately the same time (usually subsequent runs). The starting points of the data in the measured profiles do not always match. To correct this, Profile Synchronization can be used to determine the proper offset of the comparison profile(s) to match the starting point of the basis profile. Since any two measured profiles are not exact copies of each other, the software must utilize statistical techniques to determine the optimum offset.

Profile Selection

At least two profiles must be selected, each in a different file. One profile must be designated as the "basis" while the others are considered "comparison." For informational purposes, the sampling interval is shown for each file.



Inputs

Input Templates are available for this analysis. The template sets the wavelength filter for each profile, but changing the selected profiles would not affect the template.

- Profile Location: Profile Location is the channel of profiles to be used for the cross-correlation analysis.
- Maximum offset: Maximum offset is the range of horizontal offset within the CC sweep analysis. While the basis profile is fixed, the comparison profile would be shifted to the left or to the right side of the basis profile at any possible sample interval increments (i.e., offsets).
- Use decimation: Users may want to enter a decimation factor for huge files, like the curl/warp study data. Once data is decimated to 10 times the sample interval, one can run the CC procedure, learn the approximate offset, and then use the fully detailed profiles to search a small area near the approximate offset. In ProVAL, one could run the CC once with the decimated profile, go back and reset the offset, and then rerun the CC procedure in full detail with a minimal maximum offset value. This would save a lot of time.
- Use interval adjustment: With the basis profile in place, the comparison profile's sampling interval can be adjusted to increase or decrease the value so that the CC value can be maximized. This way, the influence of Distance Measurement Instrument (DMI) error can be excluded from the CC evaluation.
- Use padding: This is to accommodate profiles that don't have sufficient lead-in. The array size is adjusted to (3 * i_size_org - 2). First, reflect the profile both vertically and horizontally about the starting point. Then, reflect the profile of the endpoint both vertically and horizontally. Then, fill the middle section. Finally, return the profile to the original size.
- Use upsampling: This increases the sampling frequency or decreases the sampling interval. Firstly, determine the start trial interval, then search for the final interval. Then, generate a

new profile.

- Basis Filter and Comparison Filter: A different wavelength filter setting can be specified for the Basis and Comparison profile(s) by clicking the hyperlinks. A Wavelength Filter dialog box would pop up for user-defined settings.

The following filters are available:

- None
- IRI
- Butterworth Band-pass
- Butterworth Low-pass
- Butterworth High-pass

The cross-correlation module will automatically pre-process/condition the entire profile traces, crop the profile between the lead-in and lead-out (i.e., the Full section), and perform interpolation (if sampling intervals are different between the basis and comparison profile) prior to computation of coefficient of cross correlation. This process complies with the US AASHTO R56 specification.

Users need to input lead-in/lead-out distances, left/right channels for each profile on the Editor/Basic screen, if they are not defined.

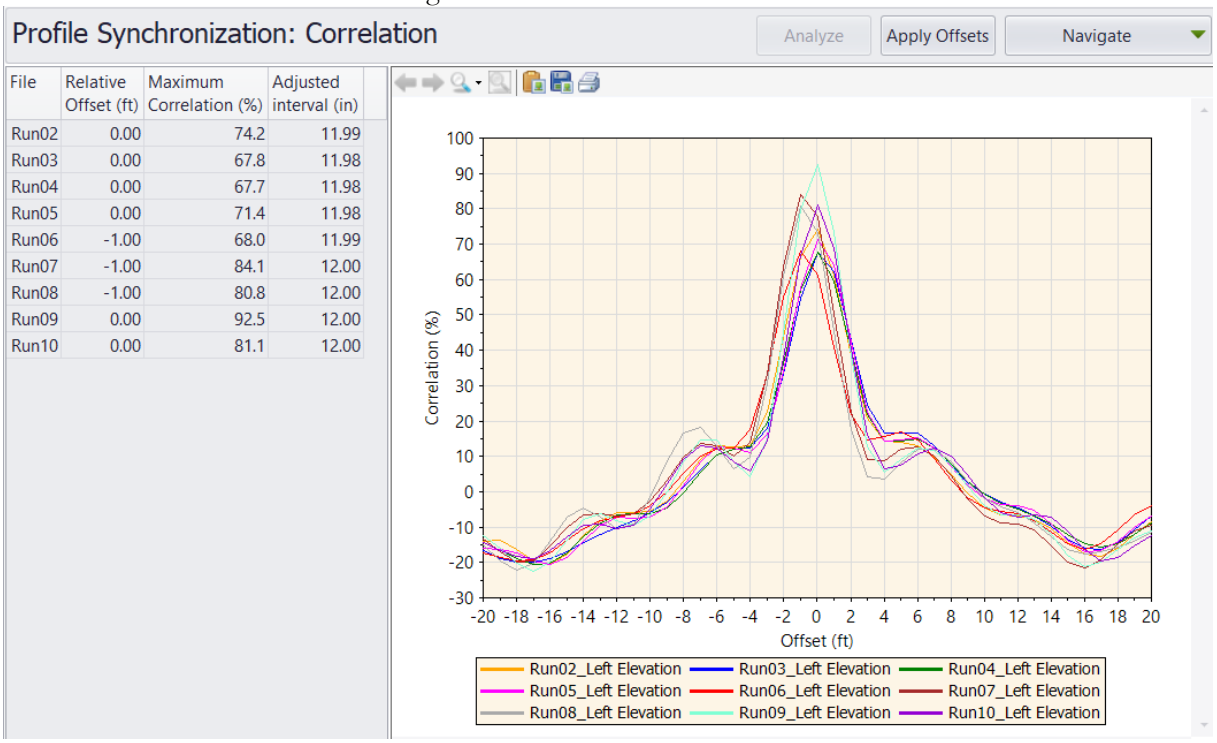
Outputs

The outputs of Profile Synchronization include a table of relative offsets and maximum correlation with the basis profile.

File	Relative Offset (ft)	Maximum Correlation (%)	Adjusted interval (in)
Run02	0.00	74.2	11.99
Run03	0.00	67.8	11.98
Run04	0.00	67.7	11.98
Run05	0.00	71.4	11.98
Run06	-1.00	68.0	11.99
Run07	-1.00	84.1	12.00
Run08	-1.00	80.8	12.00
Run09	0.00	92.5	12.00
Run10	0.00	81.1	12.00

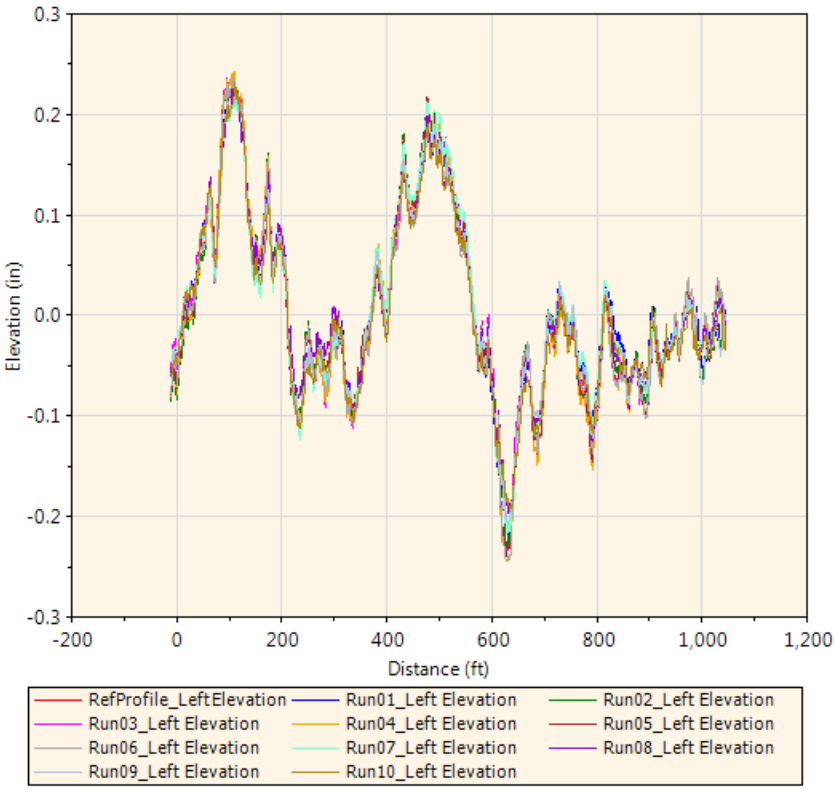
The Navigate button can be used to switch among different output charts, which include:

- Correlation Chart or Correlogram - Correlation coefficient values at all tested offsets.

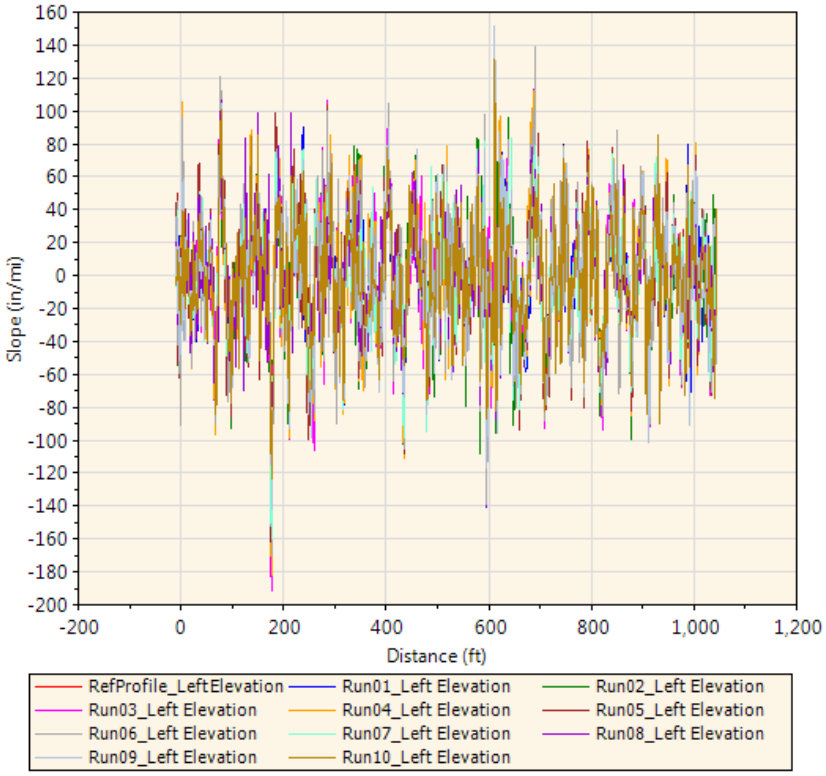


File	Relative Offset (ft)	Maximum Correlation (%)	Adjusted interval (in)
Run02	0.00	74.2	11.99
Run03	0.00	67.8	11.98
Run04	0.00	67.7	11.98
Run05	0.00	71.4	11.98
Run06	-1.00	68.0	11.99
Run07	-1.00	84.1	12.00
Run08	-1.00	80.8	12.00
Run09	0.00	92.5	12.00
Run10	0.00	81.1	12.00

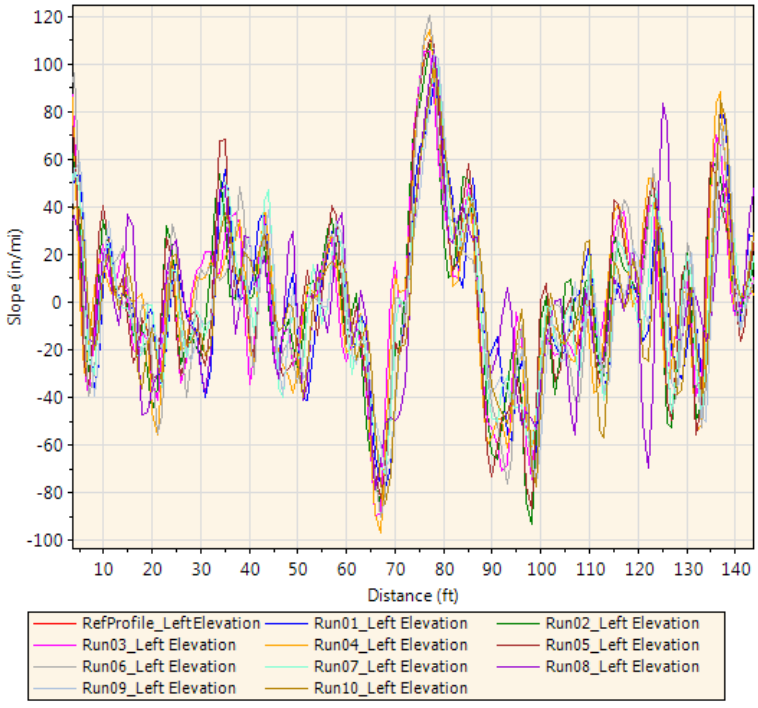
- Shifted Profiles Chart (Elevation) - Basis profile compared with the shifted comparison profile.



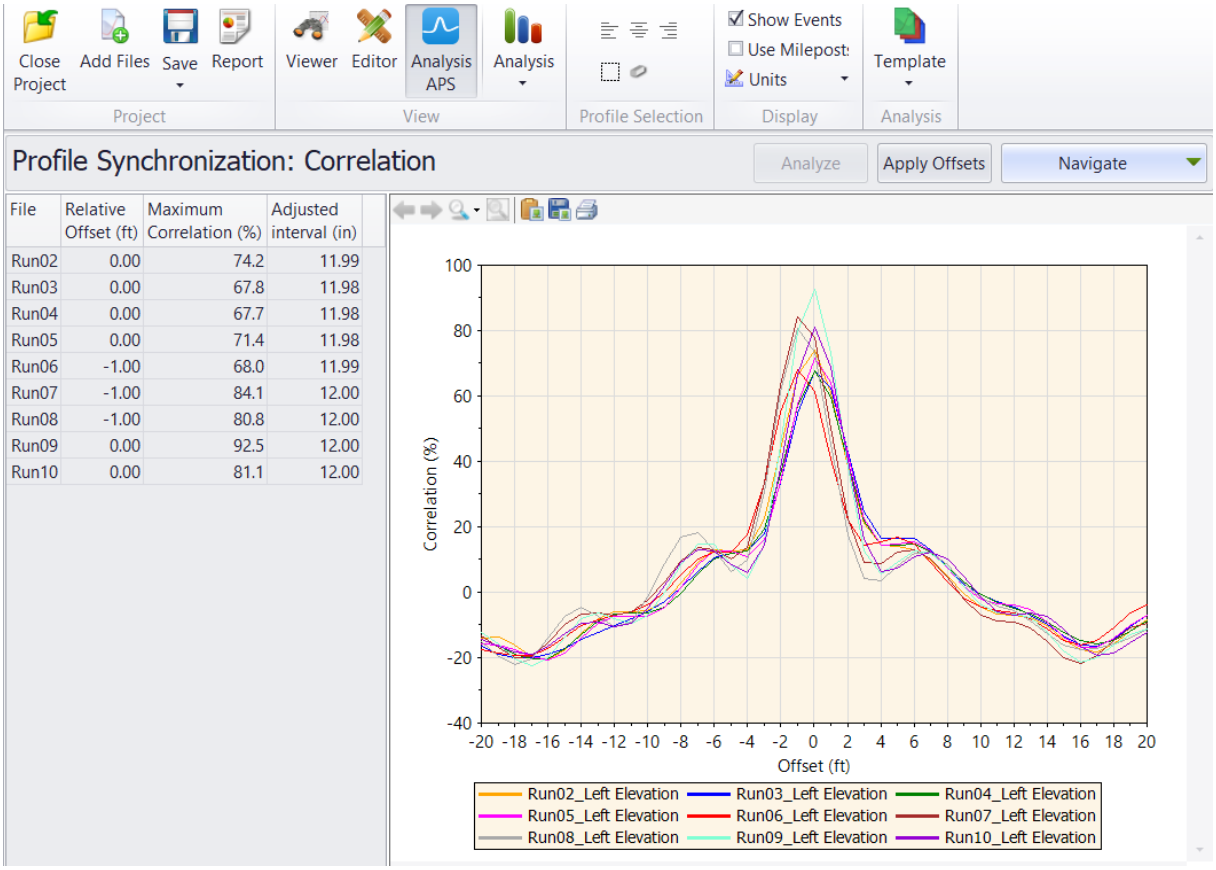
- Shifted Filtered Profiles Chart (Slope) - Basis profile slope compared with the shifted comparison profile slope after filtering (if applicable).



A zoom-in view between 10 and 140 ft:



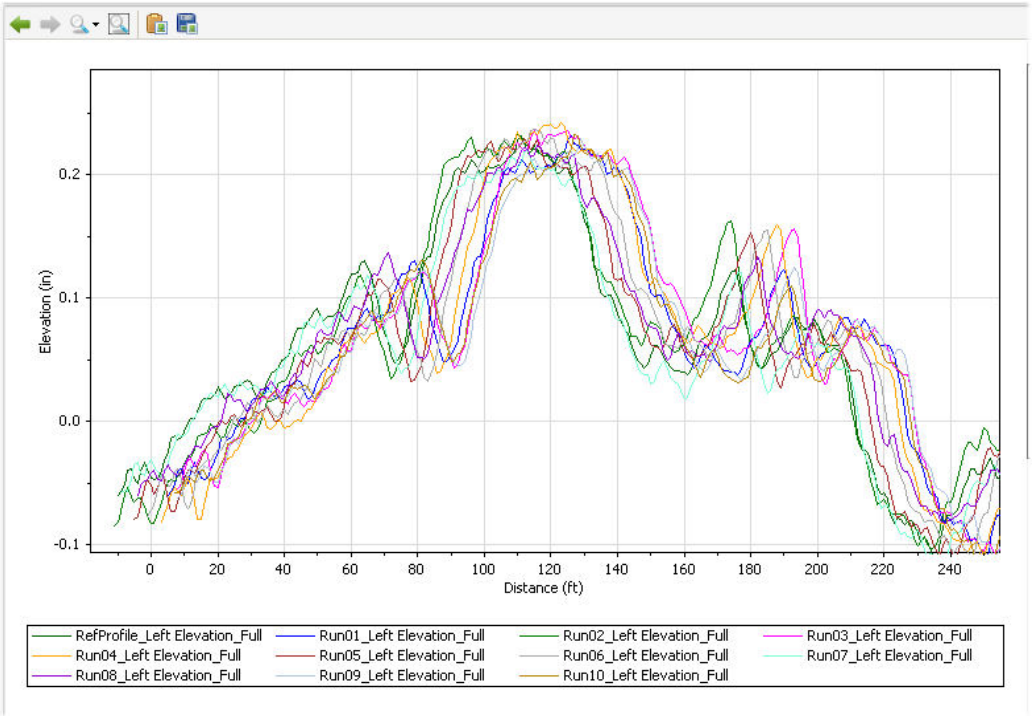
You can apply the optimal offsets to all comparison profiles by clicking the "Apply Offsets" button. You can then examine the synchronized profiles in the Viewer and the specific offsets applied to each profile in the Editor.



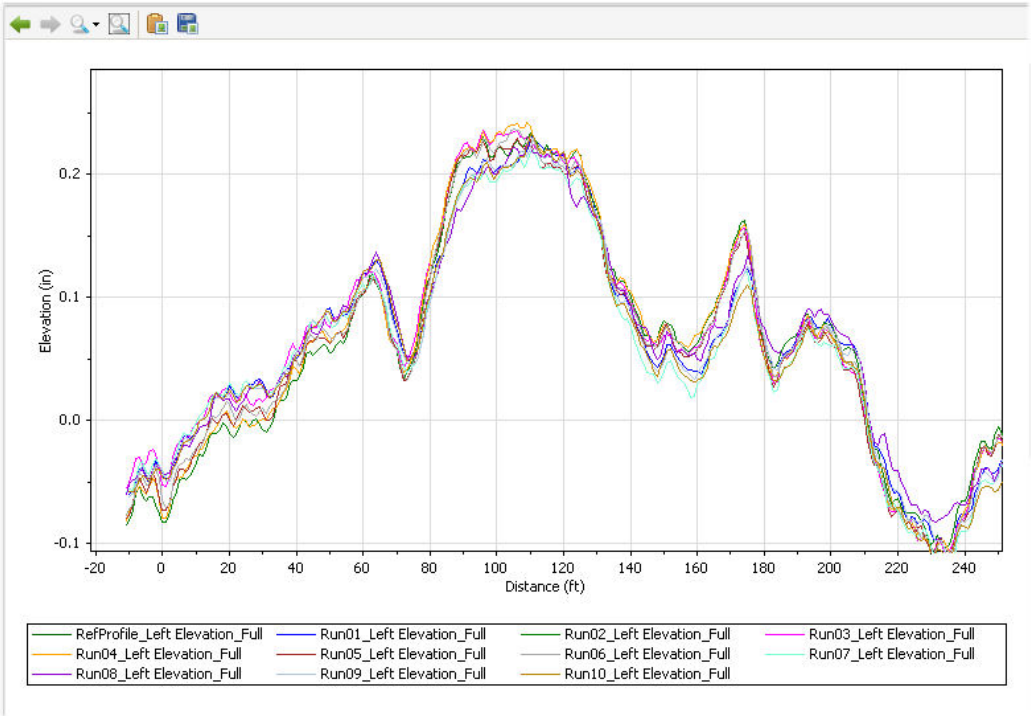
File	Relative Offset (ft)	Maximum Correlation (%)	Adjusted interval (in)
Run02	0.00	74.2	11.99
Run03	0.00	67.8	11.98
Run04	0.00	67.7	11.98
Run05	0.00	71.4	11.98
Run06	-1.00	68.0	11.99
Run07	-1.00	84.1	12.00
Run08	-1.00	80.8	12.00
Run09	0.00	92.5	12.00
Run10	0.00	81.1	12.00

The following is an example of profiles before and after the automated profile synchronization.

Before automated profile synchronization:



After automated profile synchronization:



Curling and Warping

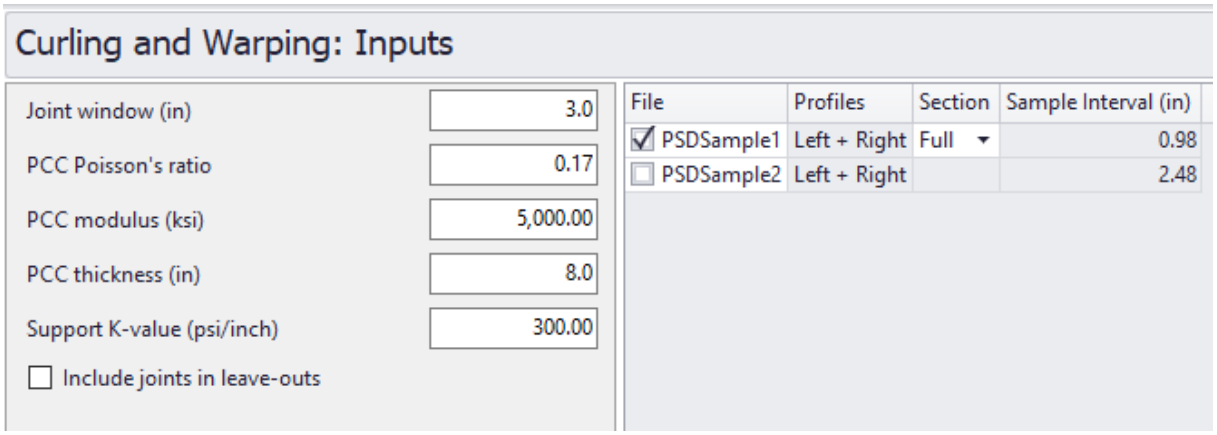
Prior to running the Curling and Warping analysis, the profile's joint locations need to be identified using the ProVAL Editor/Joint Locations.

The FHWA Jointed Concrete Pavements (JCP) Curl and Warp study in 2002-2007 by the ProVAL team has produced an excellent algorithm to characterize the impacts of JCP curl and warp effects on IRI. The algorithm's core is a non-linear fitting of the Westergaard curling function to a sliced profile within a single slab. The resulting curl and warp metric is called pseudo-gradient or Second Generation Curvature Index (2GCI) or simplified as Curvature Index (CVI). The CVI with positive values indicates curling down, and negative values curling up at the edges. This module is to implement the CVI for JCP profiles.

For more information, refer to George K. Chang, Steven M. Karamihas, Robert Otto Rasmussen, David Merritt, Mark Swanlund, Quantifying the Impact of Jointed Concrete Pavement Curling and Warping on Pavement Uneveness, 6th Symposium on Pavement Surface Characteristics (SURF), Slovenia, 2008.

Profile Selection

Any number of profiles may be selected for the analysis.



Inputs

The inputs include:

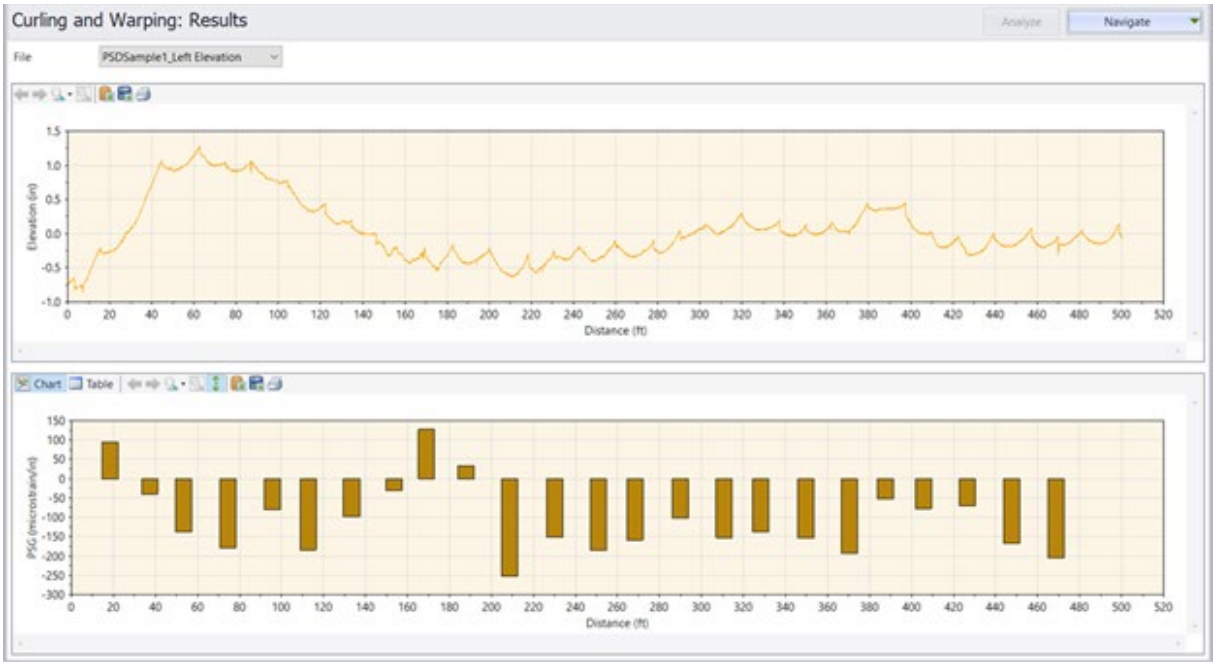
- Joint Window: tolerance for the joint locations
- PCC Poisson's ratio
- PCC Modulus
- PCC thickness
- Support K-value
- Include joints in leave-outs

Outputs

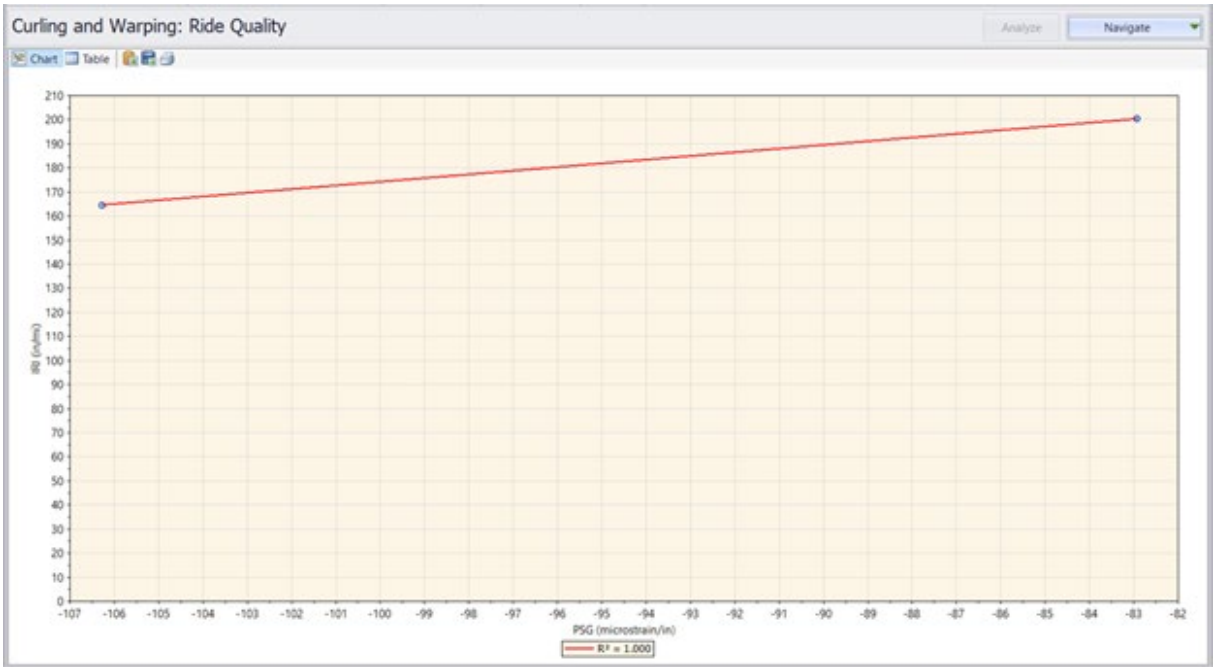
The Curling and Warping outputs include (1) Profile Chart and Pseudo-Gradient (PSG) Chart and (2) Ride Quality Index (IRI) and Pseudo-Gradient (PSG) Chart.

Note that negative PSG indicates a curled-up JCP slab. With only one profile pair of two-channel files, only two data points result in R^2= 100%. The correlation will be performed accordingly if there are more profile repeats in the same section.

An example of a Profile Chart and Pseudo-Gradient (PSG) Chart:



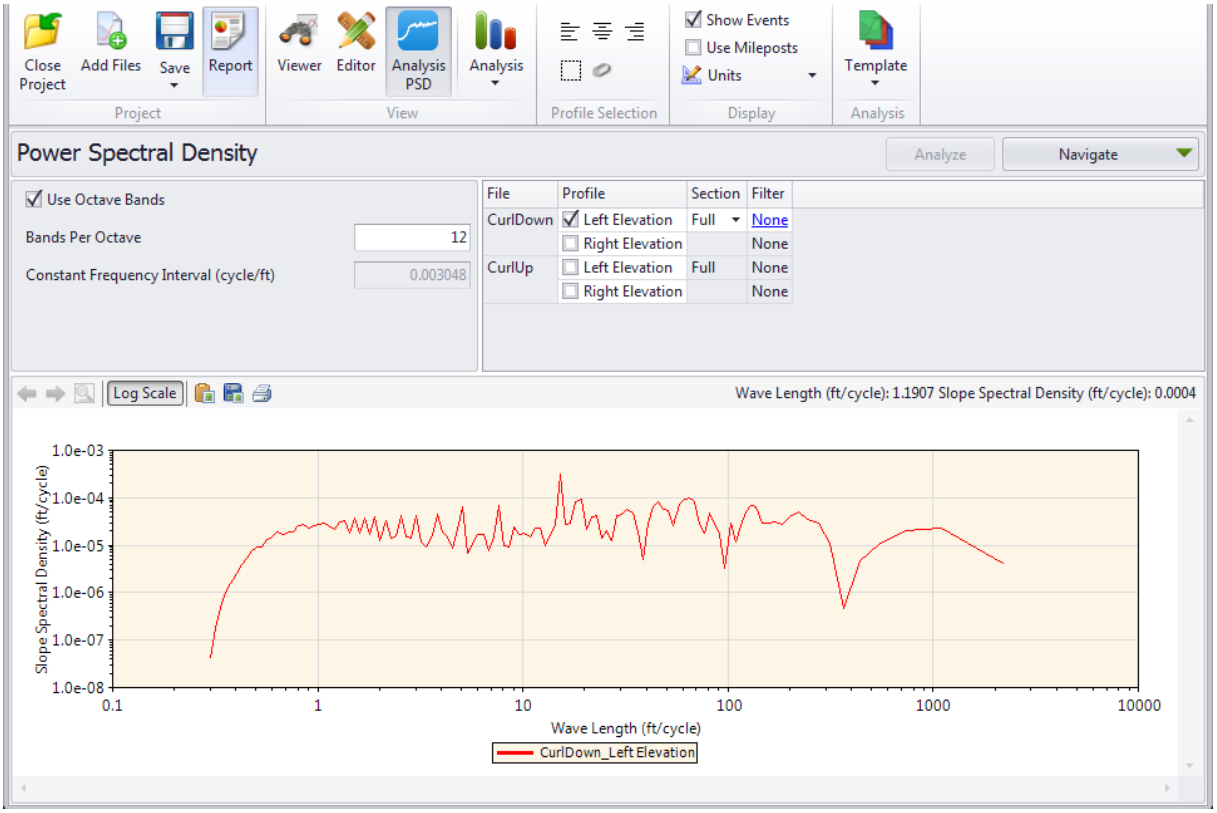
An example of the Ride Quality Index (IRI) and Pseudo-Gradient (PSG) Chart with only two one-channel profiles.



Power Spectral Density (PSD)

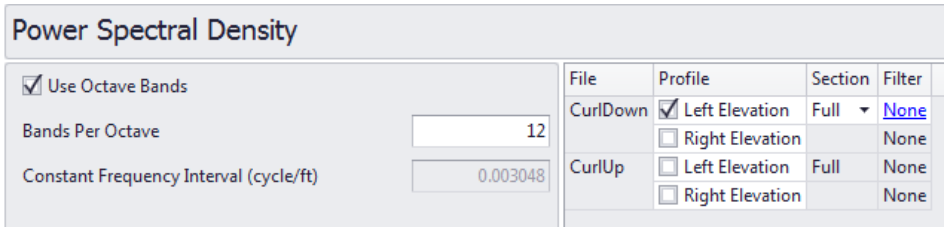
The Power Spectral Density (PSD) function of road profiles is a statistical representation of the importance of various wave numbers (or wave lengths). Pavement profiles can be decomposed into series of sinusoids using techniques (such as Fast Fourier Transform or FFT) to show how the variance is distributed over wave numbers.

The PSD implementation in ProVAL is similar to the method used by University of Michigan – Transportation Research Institute (UMTRI) researchers with a drift removal technique.



Profile Selection

Any number of profiles may be selected.



A different filter can be specified for each profile by clicking the hyperlink in each input field. A dialog box would prompt you to select a filter.

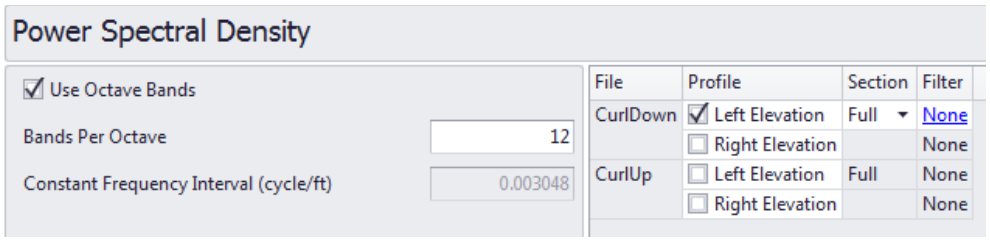
The following filters are available:

- None
- IRI
- Butterworth Band-pass
- Butterworth Low-pass
- Butterworth High-pass

Inputs

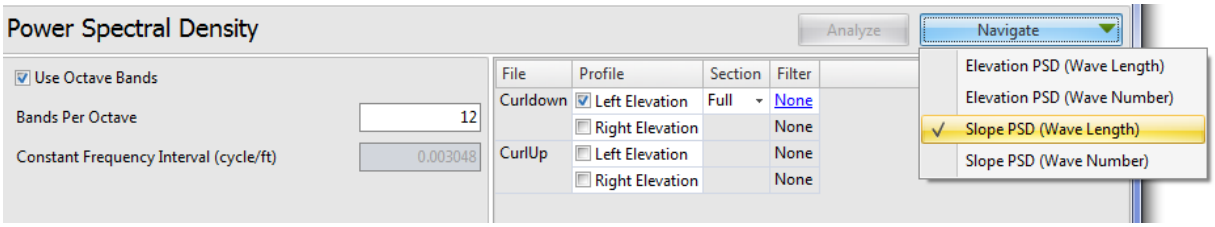
Input Templates are available for this analysis. Changing the selected profiles will not affect the template. However, the template will set the wavelength filter for each profile.

- Octave Bands - Enabling Octave Bands will enable Bands Per Octave and disable Constant Frequency Interval.
- Bands Per Octave - Number of reported data points when a frequency or wavelength is doubled or halved.
- Constant Frequency Interval - The frequency interval when the narrow band report is desired.

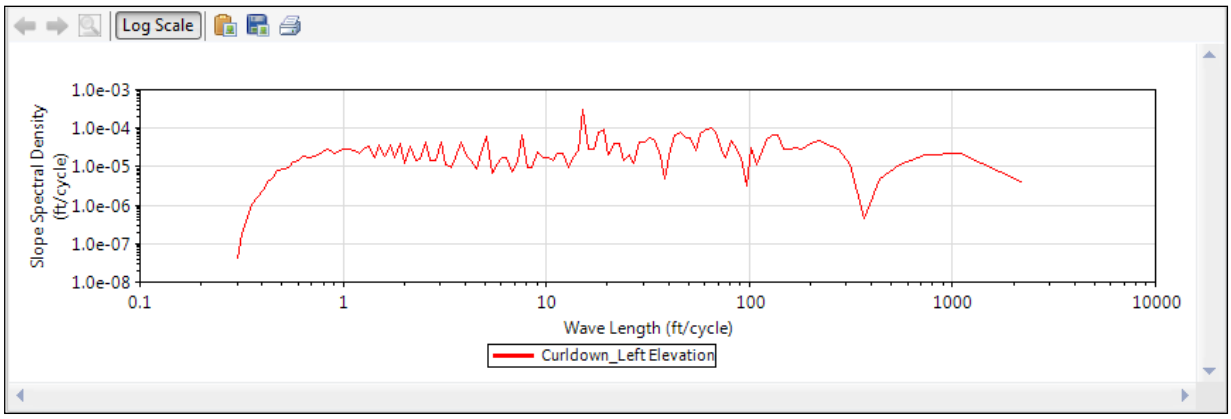


Outputs

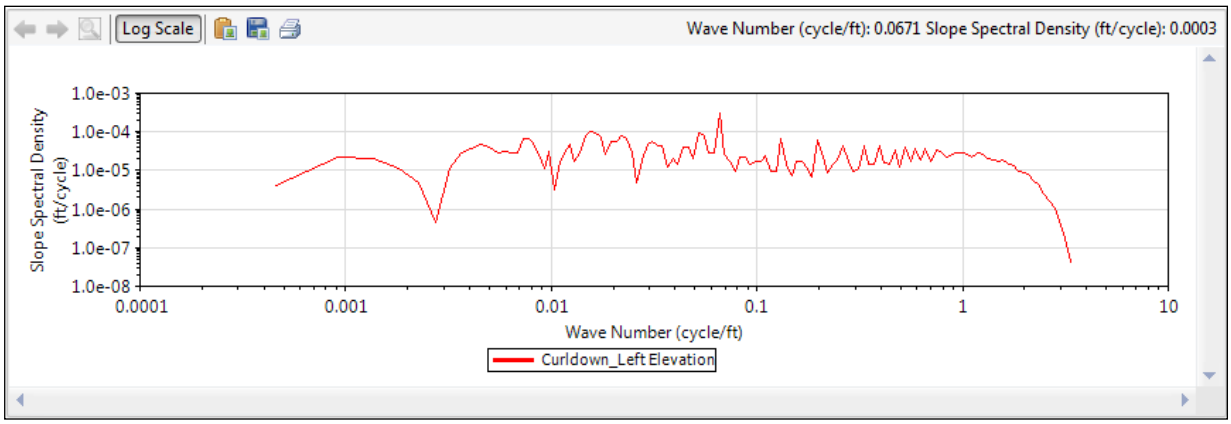
Four output charts are available via the Navigate button: Elevation PSD against Wave Length, Elevation PSD against Wave Number, Slope PSD against Wave Length, and Slope PSD against Wave Number. The Slope PSD vs. wavelength is recommended as the default view.



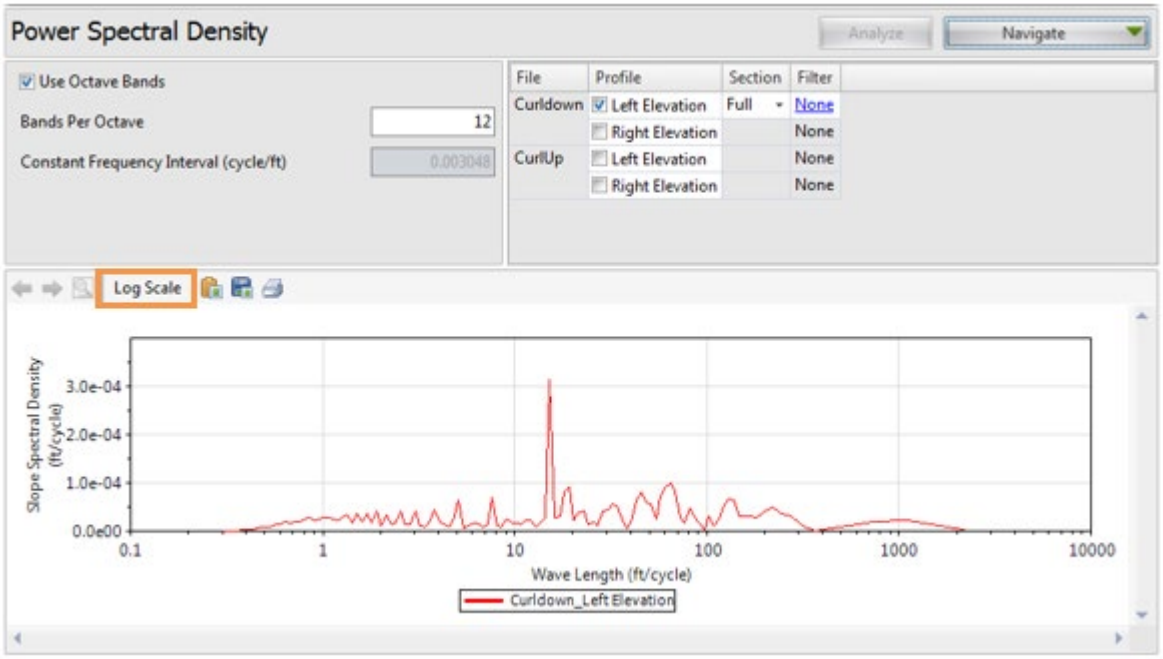
1. Slope PSD vs. Wave Length chart



2. Slope PSD vs. Wave Number chart



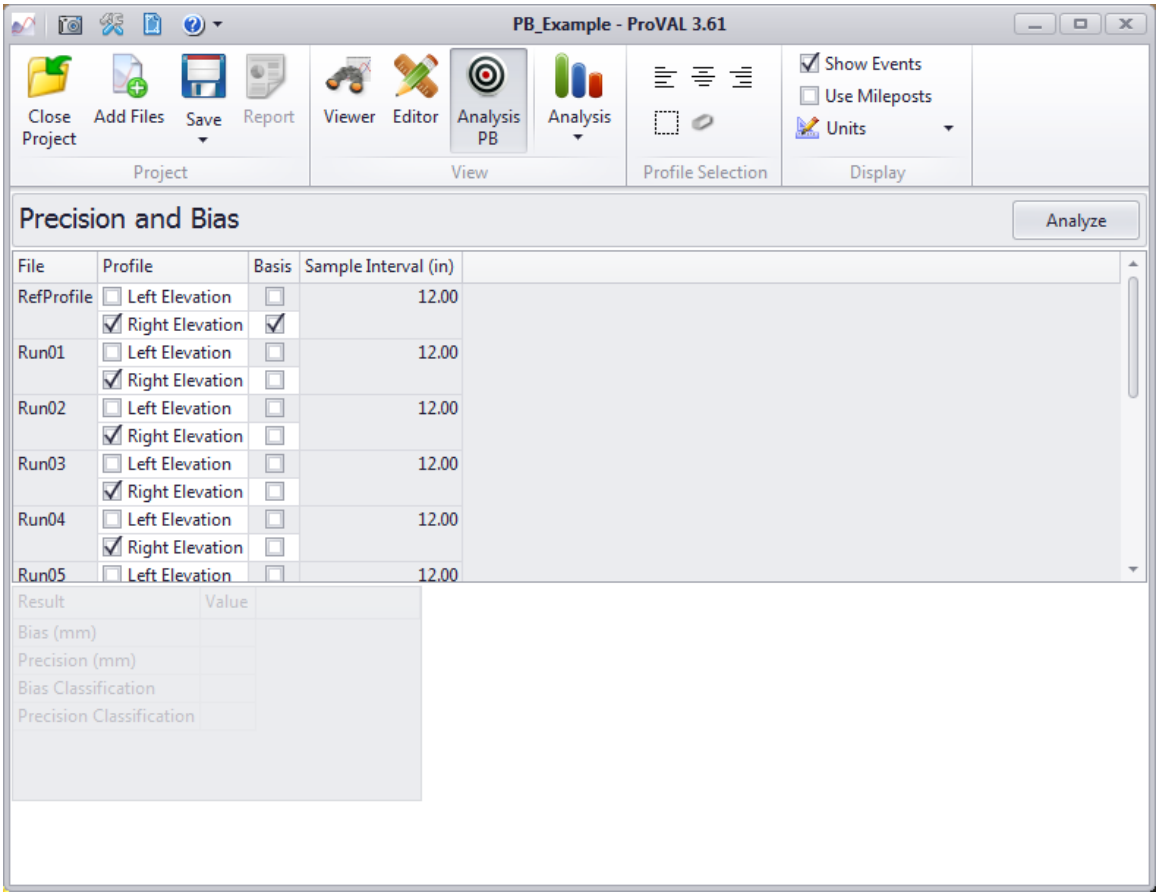
A Log Scale button in the chart control toolbar can be used to toggle the chart y-axis between the log scale and linear scale. This is useful to make peaks easier to see.



Precision and Bias

The precision and bias analysis is based on the old ASTM E 950-98 "Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference."

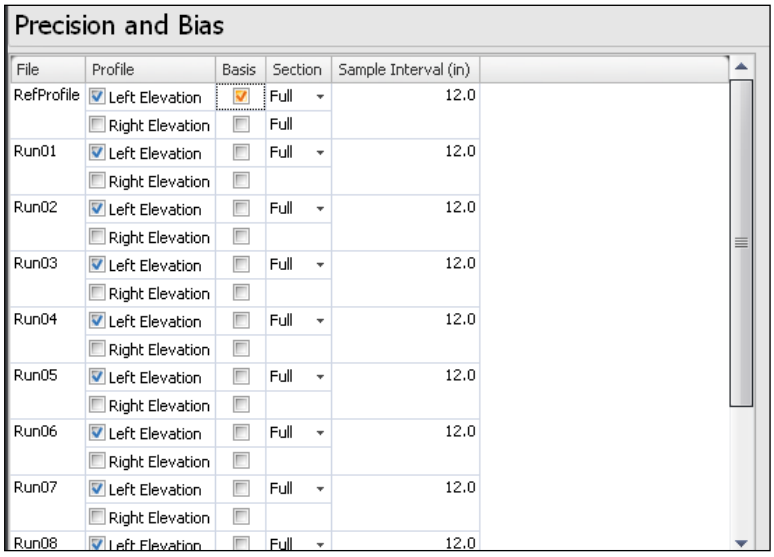
This analysis requires 11 profiles (including one reference profile measured with a reference profiler such as rod-and-level) along the same pavement section. This ASTM specification also requires that the pavement section be 321.8 m (1056 ft) long, with the profile measured at increments of 0.3048 m (1 ft). Beginning at 0 and taking 1056 additional measurements, each profile must have 1057 data points.



The ASTM E17 Vehicle-Surface Interaction committee revised the ASTM E950-22 to use the cross-correlation method, as in AASHTO R56-2018. This module stays for users who may use the precision and bias method.

Profile Selection

Eleven profiles **must** be selected: one reference profile and ten comparison profiles. The section length **must** be 1056 ft, and the sample interval **must** be 1 ft, for 1057 data points.



Inputs

N/A

Outputs

The outputs of the precision and bias analysis are:

- Bias
- Precision
- Bias Classification
- Precision Classification

Profiler Certification Module (PCM)

The Profiler Certification analysis includes the ability to compare multiple profiler runs (i.e., repeatability test) and compare those repeats with a basis profile (i.e., accuracy test).

The Profiler Certification analysis is based on the guidelines in the AASHTO R56 "Standard Practice for Certification of Inertial Profiling Systems."

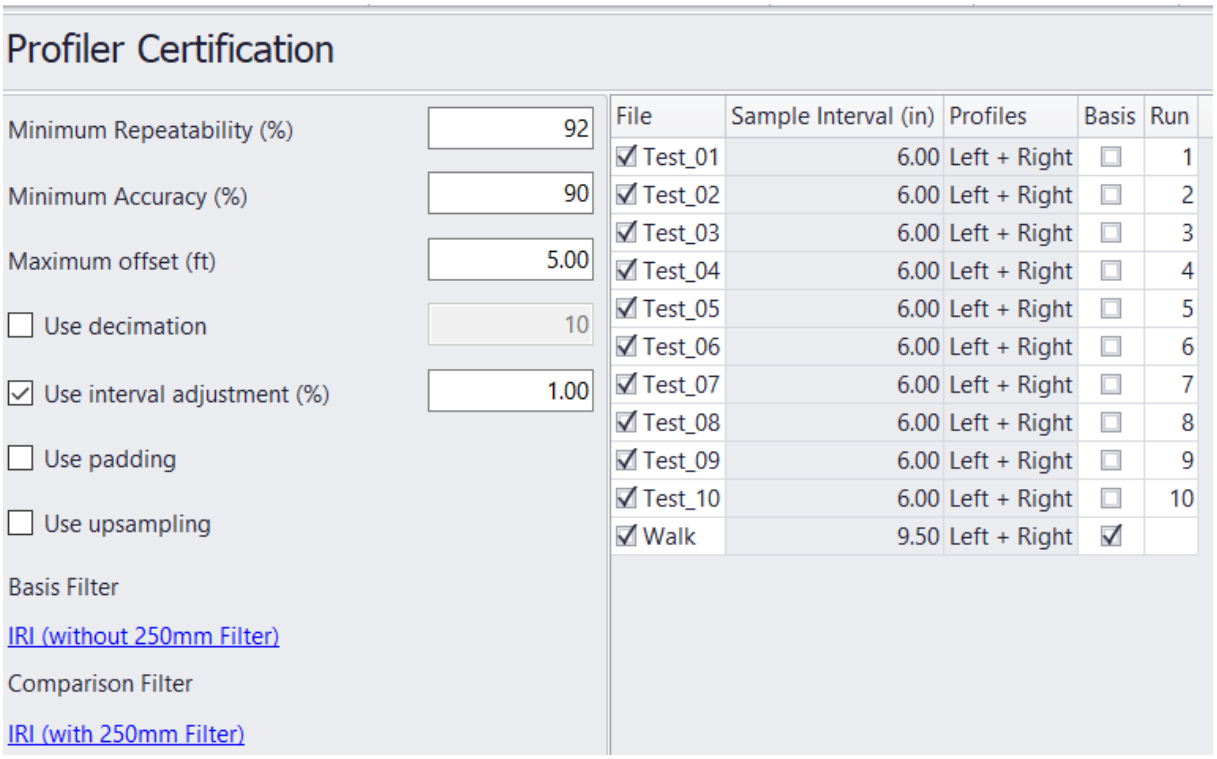
Profile Selection

Comparison profiles and one-basis (in a two-channel format) or two-basis (in a one-channel format) profiles may be selected. The selection of a basis profile is only required for the accuracy test. Selection is on a file basis; all profiles in a selected file will be used, if possible.

Only profiles marked as Left or Right will be analyzed. Left profiles will only be compared against other left profiles, and the same will be valid for right profiles.

The program will assign All user-selected files a run number, starting at number 1 or whatever is the lowest missed consecutive number for the current selection. The maximum run number is 12. The users, however, can edit the numbers as needed.

The run numbers will disappear if a selected profile is assigned as a "basis" or reference profile. The profiles available in each file will be listed for informational purposes, as will the sample interval.



Two wavelength filters can be specified: one for the basis profile(s) and one for the comparison profiles. You can click on the hyperlink for either Basis Filter or Comparison Filter to access a pop-up window and change the filter settings.

The following filters are available:

- None
- IRI
- Butterworth Band-pass
- Butterworth Low-pass
- Butterworth High-pass

Inputs

Input Templates are available for this analysis. Changing the selected profiles will not affect the template. However, the template will set the wavelength filter for each profile. The inputs include:

- Minimum Repeatability: The passing score for the average coefficient of cross-correlation among comparison profiles
- Minimum Accuracy: The passing score for the average coefficient of cross correlation between basis profile and comparison profiles
- Maximum offset: Maximum offset is the range of horizontal offset within the CC sweep analysis. While the basis profile is fixed, the comparison profile would be shifted to the left or to the right side of the basis profile at any possible sample interval increments (i.e., offsets).
- Use decimation: Users may want to enter a decimation factor for huge files, like the curl/warp study data. Once data is decimated to 10 times the sample interval, one can run the CC procedure, learn the approximate offset, and then use the fully detailed profiles to search a small area near the approximate offset. In ProVAL, one could run the CC once with the decimated profile, go back and reset the offset, and then rerun the CC procedure in full detail with a minimal maximum offset value. This would save a lot of time.
- Use interval adjustment: With the basis profile in place, the comparison profile's sampling interval can be adjusted to increase or decrease the value so that the CC value can be maximized. This way, the influence of distance measurement instrument (DMI) errors can be excluded from the CC evaluation.
- Use padding: This is to accommodate profiles that don't have sufficient lead-in. The array size is adjusted to (3 * i_size_org - 2). First, reflect the profile both vertically and horizontally about the starting point. Then, reflect the profile of the endpoint both vertically and horizontally. Then, fill the middle section. Finally, return the profile to the original size.
- Use upsampling: This increases the sampling frequency or decreases the sampling interval. Firstly, determine the start trial interval, then search for the final interval. Then, generate a new profile.
- Basis Filter and Comparison Filter: A different wavelength filter setting can be specified for the Basis and Comparison profile(s) by clicking the hyperlinks. A Wavelength Filter dialog box would pop up for user-defined settings.

If a basis profile is selected, the sample interval should be less than 2.75 in. If not, a warning would be issued along with the analysis results.

Similar to the Profile Synchronization module, the Profiler Certification Module will automatically pre-process (condition) the entire profile traces, crop the profile between the lead-in and lead-out (i.e., the Full section), and perform interpolation (if sampling intervals are different between the basis and comparison profile) prior to computation of coefficient of cross correlation.

Users need to define lead-in/lead-out distances on the Editor/Basic screen, and left/right channels for each profile on the Editor/Info screen.

Outputs

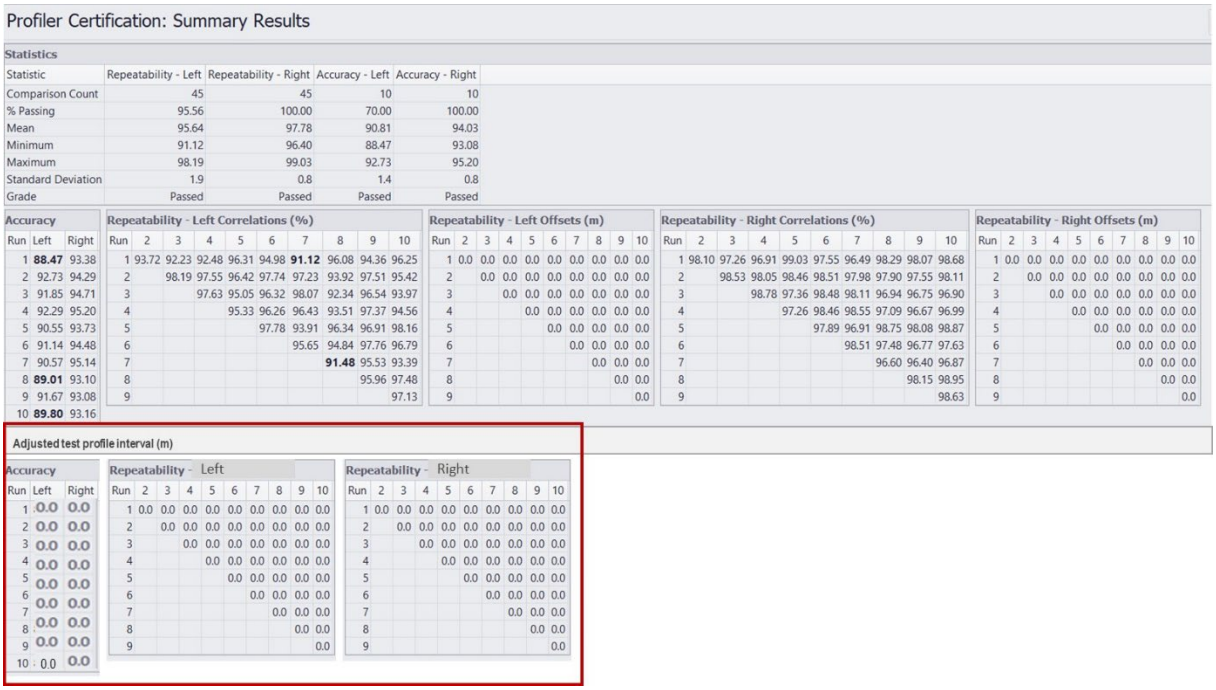
Under Navigate, choose from the Summary Results or Detailed Results.

The summary results include the following:

Repeatability - Separate results will be listed for each profile type (left and right). The distance and correlation value at the point of maximum correlation will also be shown for each combination of profiles.

Accuracy - Separate results will be listed for each channel type.

Summary Results - Summary of statistics (including comparison count, % passing, mean, minimum, maximum, standard deviation, and grade.).



Profiler Certification: Summary Results

Statistics

Statistic	Repeatability - Left	Repeatability - Right	Accuracy - Left	Accuracy - Right
Comparison Count	45	45	10	10
% Passing	95.56	100.00	70.00	100.00
Mean	95.64	97.78	90.81	94.03
Minimum	91.12	96.40	88.47	93.08
Maximum	98.19	99.03	92.73	95.20
Standard Deviation	1.9	0.8	1.4	0.8
Grade	Passed	Passed	Passed	Passed

Accuracy

Run	Left	Right
1	**88.47**	93.38
2	92.73	94.29
3	91.85	94.71
4	92.29	95.20
5	90.55	93.73
6	91.14	94.48
7	90.57	95.14
8	**89.01**	93.10
9	91.67	93.08
10	**89.80**	93.16

Repeatability - Left Correlations (%)

Run	2	3	4	5	6	7	8	9	10
1	93.72	92.23	92.48	96.31	94.98	**91.12**	96.08	94.36	96.25
2		98.19	97.55	96.42	97.74	97.23	93.92	97.51	95.42
3			97.63	95.05	96.32	98.07	92.34	96.54	93.97
4				95.33	96.26	96.43	93.51	97.37	94.56
5					97.78	93.91	96.34	96.91	98.16
6						95.65	94.84	97.76	96.79
7							**91.48**	95.53	93.39
8								95.96	97.48
9									97.13

Repeatability - Left Offsets (m)

Run	2	3	4	5	6	7	8	9	10
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3			0.0	0.0	0.0	0.0	0.0	0.0	0.0
4				0.0	0.0	0.0	0.0	0.0	0.0
5					0.0	0.0	0.0	0.0	0.0
6						0.0	0.0	0.0	0.0
7							0.0	0.0	0.0
8								0.0	0.0
9									0.0

Repeatability - Right Correlations (%)

Run	2	3	4	5	6	7	8	9	10
1	98.10	97.26	96.91	99.03	97.55	96.49	98.29	98.07	98.68
2		98.53	98.05	98.46	98.51	97.98	97.90	97.55	98.11
3			98.78	97.36	98.48	98.11	96.94	96.75	96.90
4				97.26	98.46	98.55	97.09	96.67	96.99
5					97.89	96.91	98.75	98.08	98.87
6						98.51	97.48	96.77	97.63
7							96.60	96.40	96.87
8								98.15	98.95
9									98.63

Repeatability - Right Offsets (m)

Run	2	3	4	5	6	7	8	9	10
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3			0.0	0.0	0.0	0.0	0.0	0.0	0.0
4				0.0	0.0	0.0	0.0	0.0	0.0
5					0.0	0.0	0.0	0.0	0.0
6						0.0	0.0	0.0	0.0
7							0.0	0.0	0.0
8								0.0	0.0
9									0.0

Adjusted test profile interval (m)

Accuracy

Run	Left	Right
1	0.0	0.0
2	0.0	0.0
3	0.0	0.0
4	0.0	0.0
5	0.0	0.0
6	0.0	0.0
7	0.0	0.0
8	0.0	0.0
9	0.0	0.0
10	0.0	0.0

Repeatability - Left

Run	2	3	4	5	6	7	8	9	10
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3			0.0	0.0	0.0	0.0	0.0	0.0	0.0
4				0.0	0.0	0.0	0.0	0.0	0.0
5					0.0	0.0	0.0	0.0	0.0
6						0.0	0.0	0.0	0.0
7							0.0	0.0	0.0
8								0.0	0.0
9									0.0

Repeatability - Right

Run	2	3	4	5	6	7	8	9	10
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3			0.0	0.0	0.0	0.0	0.0	0.0	0.0
4				0.0	0.0	0.0	0.0	0.0	0.0
5					0.0	0.0	0.0	0.0	0.0
6						0.0	0.0	0.0	0.0
7							0.0	0.0	0.0
8								0.0	0.0
9									0.0

Detailed Results -The detailed results contain additional information about each repeatability and accuracy comparison. Statistics include correlation, shape coefficient, roughness coefficient, offset, basis IRI, comparison IRI, and IRI difference.

Profiler Certification: Detailed Results

Repeatability - Left

Basis	Comparison	Correlation (%)	Shape Coefficient	Roughness Coefficient	Offset (ft)	Basis IRI (in/mi)	Comparison IRI (in/mi)	IRI Difference (%)
Test_01	Test_02	93.72	0.959	97.73	0.0	104.88	101.87	-2.86
Test_01	Test_03	92.23	0.953	96.76	0.0	104.88	101.56	-3.16
Test_01	Test_04	92.48	0.964	95.98	0.0	104.88	101.50	-3.21
Test_01	Test_05	96.29	0.979	98.37	0.0	104.60	103.62	-0.94
Test_01	Test_06	94.97	0.969	98.02	0.0	104.60	102.58	-1.93
Test_01	Test_07	**91.08**	0.944	96.54	0.0	104.60	101.48	-2.98
Test_01	Test_08	96.04	0.991	96.96	0.0	104.60	104.63	0.03
Test_01	Test_09	94.32	0.966	97.60	0.0	104.60	101.76	-2.71
Test_01	Test_10	96.23	0.982	97.98	0.0	104.60	104.30	-0.29
Test_02	Test_03	98.19	0.994	98.78	0.0	101.87	101.56	-0.31
Test_02	Test_04	97.55	0.995	98.03	0.0	101.87	101.50	-0.36
Test_02	Test_05	96.38	0.978	98.53	0.0	101.55	103.62	2.04
Test_02	Test_06	97.70	0.988	98.84	0.0	101.55	102.58	1.01
Test_02	Test_07	97.23	0.985	98.70	0.0	101.55	101.48	-0.07
Test_02	Test_08	93.91	0.967	97.14	0.0	101.55	104.63	3.03
Test_02	Test_09	97.51	0.991	98.40	0.0	101.55	101.76	0.21
Test_02	Test_10	95.38	0.975	97.83	0.0	101.55	104.30	2.71
Test_03	Test_04	97.63	0.989	98.69	0.0	101.56	101.50	-0.05
Test_03	Test_05	95.00	0.972	97.69	0.0	101.21	103.62	2.38
Test_03	Test_06	96.27	0.983	97.98	0.0	101.21	102.58	1.36
Test_03	Test_07	98.09	0.991	98.97	0.0	101.21	101.48	0.27
Test_03	Test_08	92.32	0.961	96.07	0.0	101.21	104.63	3.38
Test_03	Test_09	96.53	0.985	98.00	0.0	101.21	101.76	0.55
Test_03	Test_10	93.92	0.969	96.91	0.0	101.21	104.30	3.05
Test_04	Test_05	95.20	0.979	97.20	0.0	100.94	103.62	2.66
Test_04	Test_06	96.13	0.990	97.15	0.0	100.94	102.58	1.63
Test_04	Test_07	96.68	0.984	98.25	0.0	100.94	101.48	0.54
Test_04	Test_08	93.37	0.968	96.47	0.0	100.94	104.63	3.66
Test_04	Test_09	97.23	0.992	98.01	0.0	100.94	101.76	0.81
Test_04	Test_10	94.42	0.976	96.73	0.0	100.94	104.30	3.33
Test_05	Test_06	97.78	0.990	98.80	0.0	103.62	102.58	-1.00
Test_05	Test_07	93.87	0.964	97.41	0.0	103.37	101.48	-1.83
Test_05	Test_08	96.38	0.988	97.53	0.0	103.37	104.63	1.22
Test_05	Test_09	96.86	0.987	98.14	0.0	103.37	101.76	-1.56
Test_05	Test_10	98.16	0.997	98.48	0.0	103.37	104.30	0.90
Test_06	Test_07	95.61	0.974	98.20	0.0	102.32	101.48	-0.82
Test_06	Test_08	94.89	0.978	97.01	0.0	102.32	104.63	2.26
Test_06	Test_09	97.71	0.997	97.98	0.0	102.32	101.76	-0.54
Test_06	Test_10	96.79	0.987	98.11	0.0	102.32	104.30	1.94

Profile Screener

This module (aka Profile Sniffer) checks the profile data for the following potential issues:

Check if the profile data was smoothed or low-pass filtered - if so, warn users not to apply the 250-mm moving average filter for IRI analysis. Also, issue a warning if the low-pass filter has removed too much profile content that matters to IRI.

Issue a warning for a recording interval that is too large or excessive quantization.

Check if it is high-pass filtered - if so, provide users with the estimated cut-off wavelength for the high-pass filtering.

Check if any abnormalities exist in the data and highlight the locations- if so, warn users of the locations within the data for further investigation – for example (the following three may be merged as "unrealistic disturbance"):

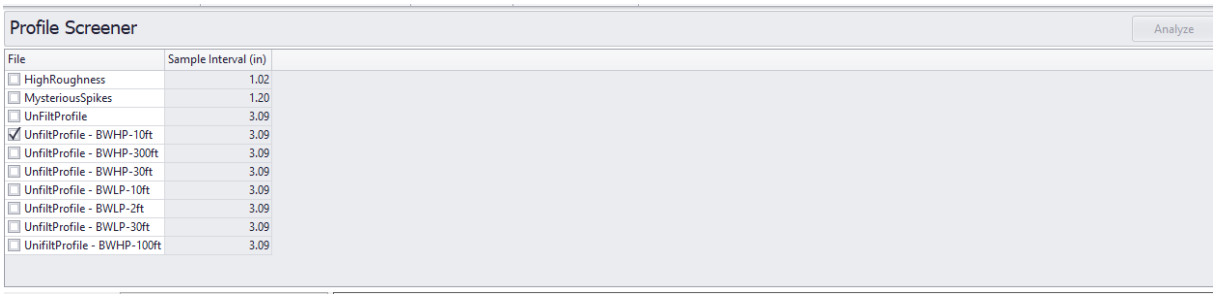
- Spikes: Possible problems identified by an anti-smoothing technique where the baselength for the anti-smoothing is set to be the greater of 0.3 meters (~ 12 inches) or five times the sampling interval and the threshold is set to be 5 mm (0.2 inches).
- High Straightedge Response: Possible problems associated with high Rolling Straightedge (RSE) responses – a 3 meter (9.8 feet) wheelbase is used with high and low response thresholds (for detecting high and low RSE responses) set to be 3 mm (0.12 inches) and -5 mm (-0.2 inches), respectively.
- Extreme Roughness: Possible problems with extremely high roughness values – the threshold is set to be 5 times the average roughness value.

Check unusually low roughness as a sign of trouble and highlight the locations.

Check skewed spectral content (either too wavy or too choppy) that suggests a significant malfunction in one of the sensors.

Profile Selection

Multiple profiles can be selected.



Inputs

NA

Outputs

If there are issues with profile data, the result selection will be displayed in the lower left panel in a tree structure for the Summary and Abnormality Checks with Charts and Tables.

By clicking the result, elements in the tree structure will display further details or a chart on the lower right panel.

Summary

The summary includes the results.

Abnormality Charts and Tables

The Abnormality Charts and Tables include the charts with highlighted areas with issues and a table option.

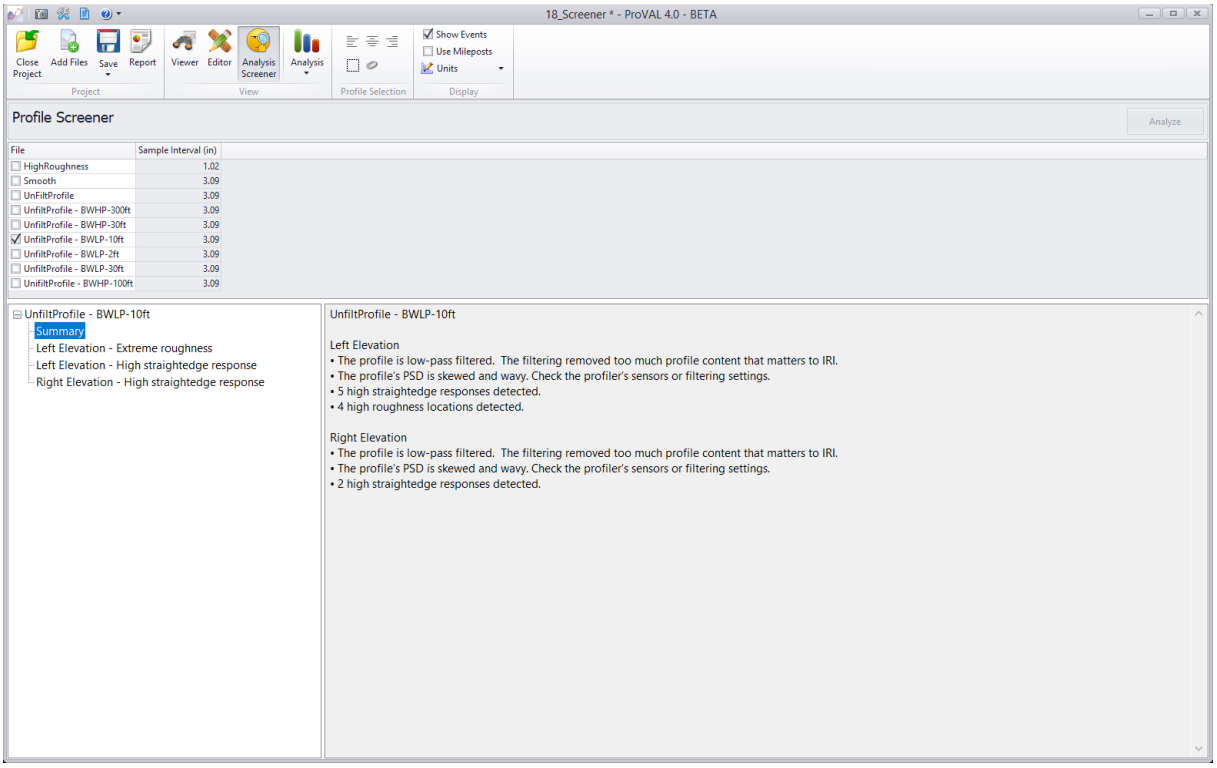
- Spikes: Possible problems identified by an anti-smoothing technique where the baselength for the anti-smoothing is set to be the greater of 0.3 meters (~ 12 inches) or five times the sampling interval and the threshold is set to be 5 mm (0.2 inches).
- High Straightedge Response: Possible problems associated with high Rolling Straightedge (RSE) responses – a 3 meter (9.8 feet) wheelbase is used with high and low response thresholds (for detecting high and low RSE responses) set to be 3 mm (0.12 inches) and -5 mm (-0.2 inches), respectively.
- Extreme Roughness: Possible problems with extremely high roughness values – the threshold is set to be 5 times the average roughness value.

Examples

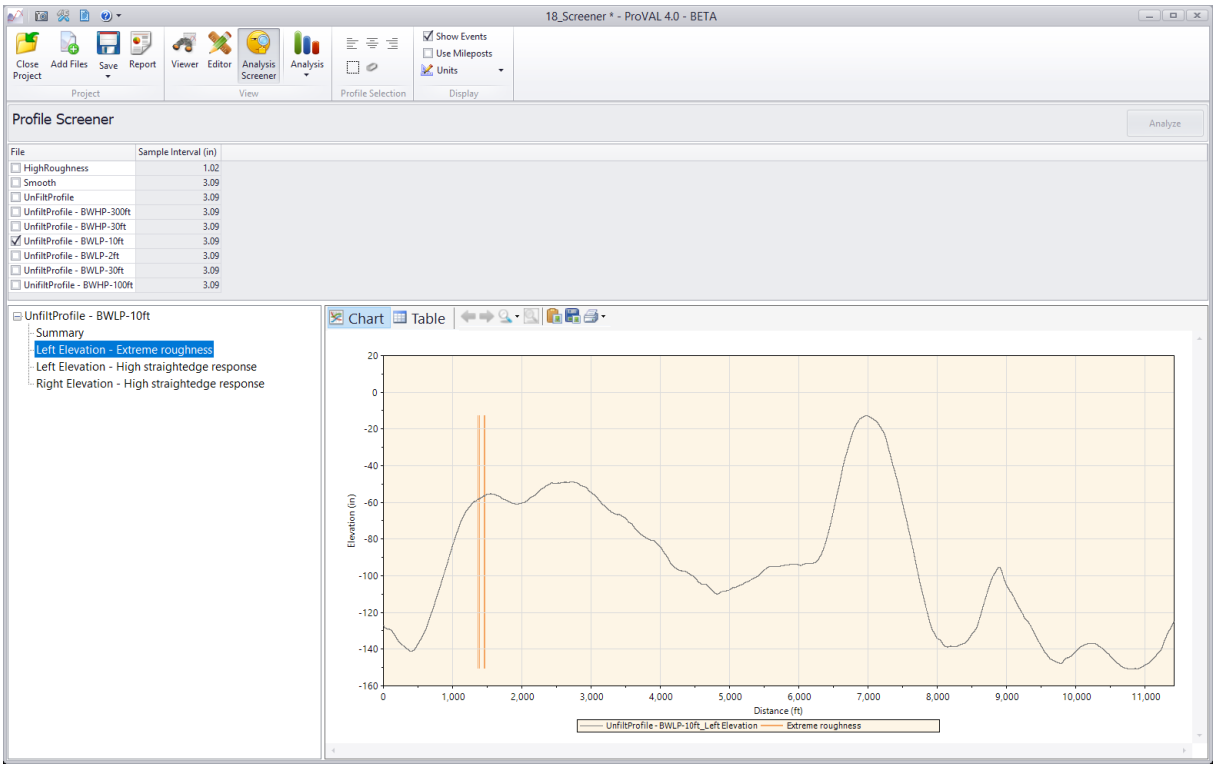
The following demonstrate several examples.

Artificially low-pass filtered profile with a 10-ft cut-off.

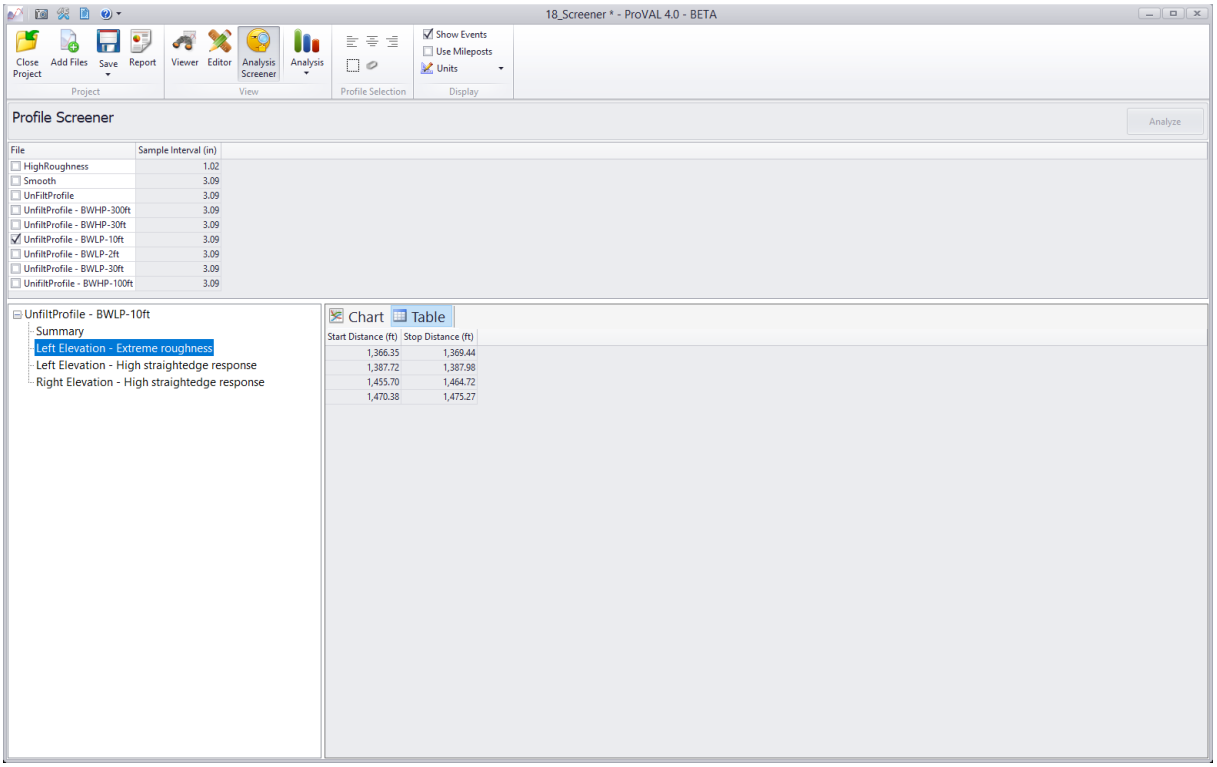
Summary:



Left elevation – extreme roughness chart

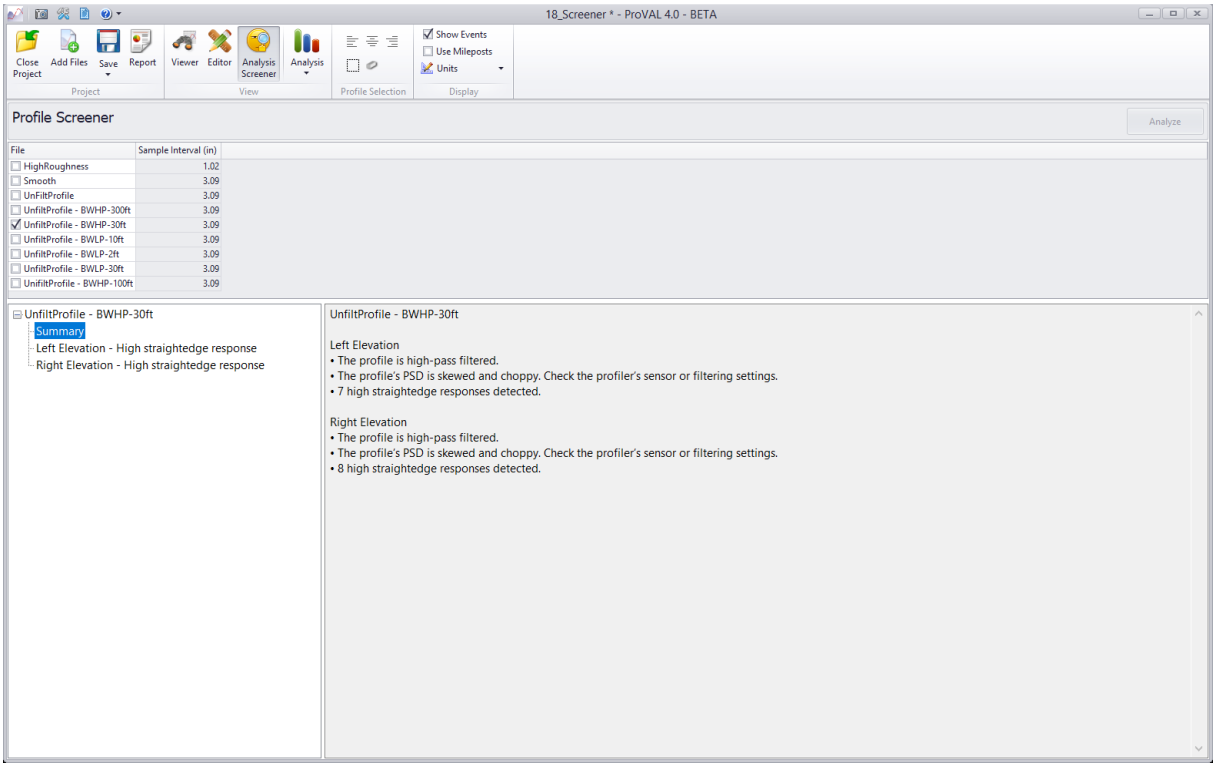


Left elevation – extreme roughness table

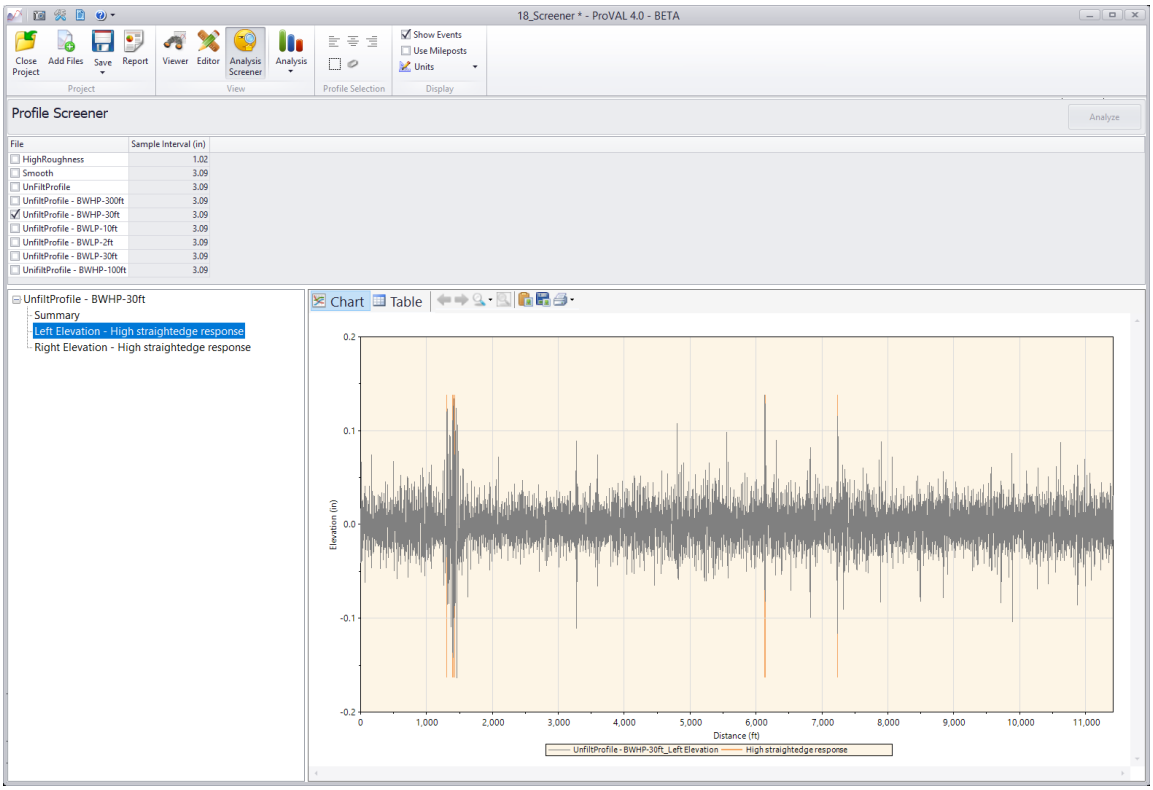


Artificially high-pass filtered profile with a 30-ft cut-off.

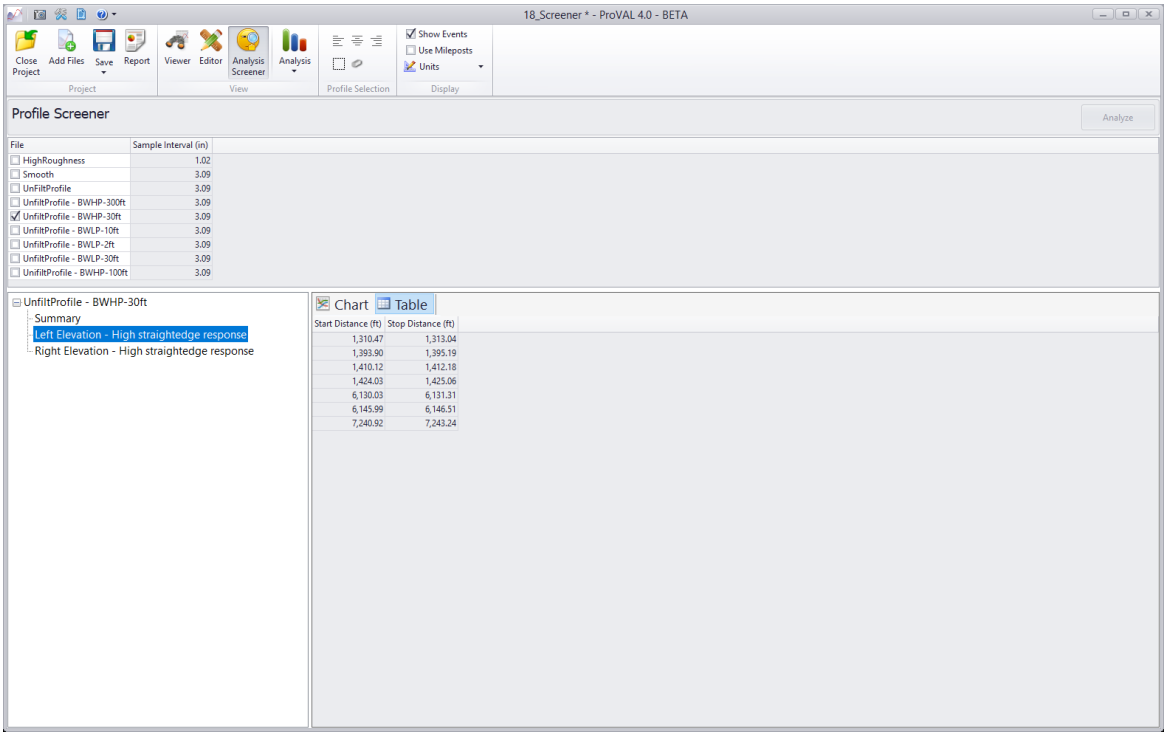
Summary:



Left elevation – high straightedge response chart.



Left elevation – high straightedge response table.



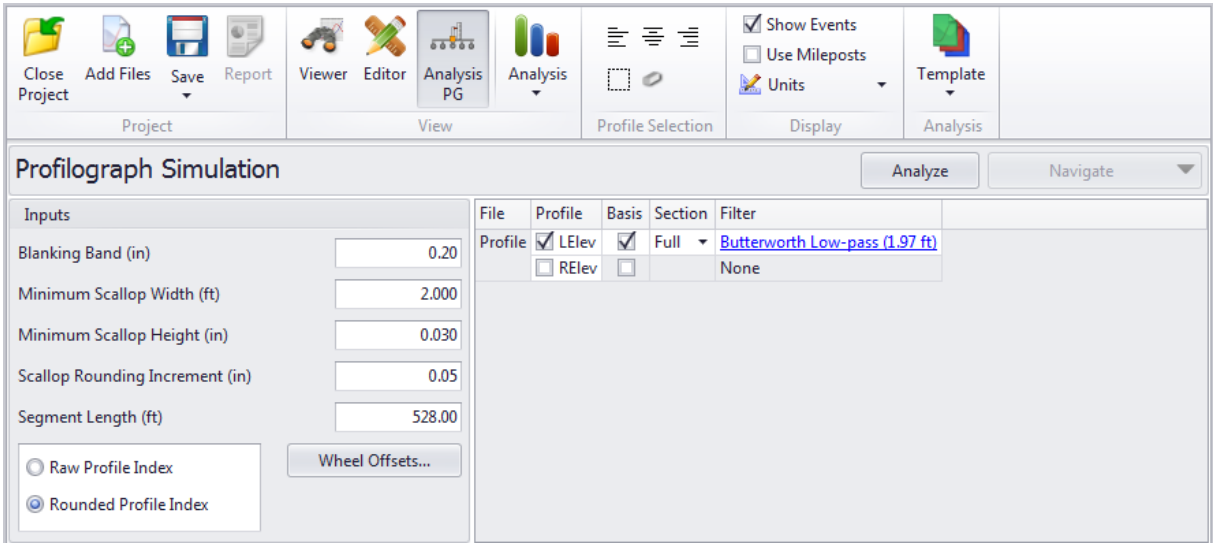
Profilograph Simulation

The Profilograph simulation emulates Profilograph traces (such as California Profilograph) from true profiles collected using inertial profilers or other capable devices.

Profilograph indexes are computed, and scallops can be identified and viewed graphically.

Profile Selection

Any number of profiles may be selected. The section to be analyzed can be specified for each file. A basis profile must be selected. When profiles from different files are selected, the basis profile will be used to determine the locations of segments.



A different wavelength filter can be specified for each file by clicking the hyperlink for each input field. A pop-up dialog box would appear to allow you to select filter settings.

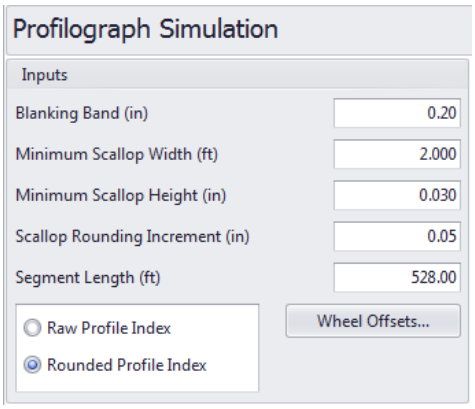
The following filters are available:

- Butterworth Low-pass
- Moving Average Low-pass

Inputs

Input Templates are available for this analysis. Changing the selected profiles will not affect the template. However, the template will set the wavelength filter for each file. The inputs include:

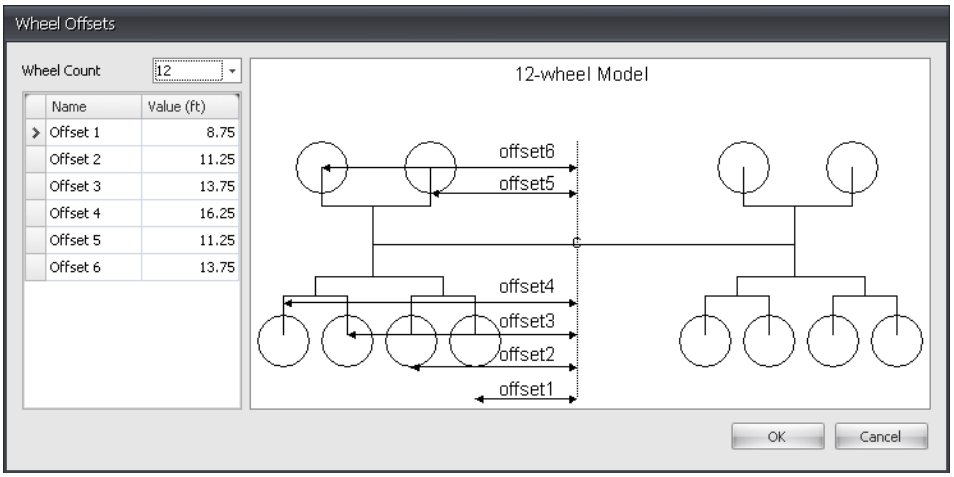
- Blanking Band
- Minimum Scallop Width
- Minimum Scallop Height
- Scallop Rounding Increment
- Segment length
- Selection for reporting Raw or Rounded Profilograph Index
- Wheel Offsets



Segments can be defined, and the analysis will report statistics for each segment rather than the entire section. You can specify the length of the segment, and multiple segments will be added at that interval. For example, if the segment length is 528 feet, segments would be added every 528 feet. A length of 0 means no segments would be added. Segments at the end of a profile may be less than the specified length.

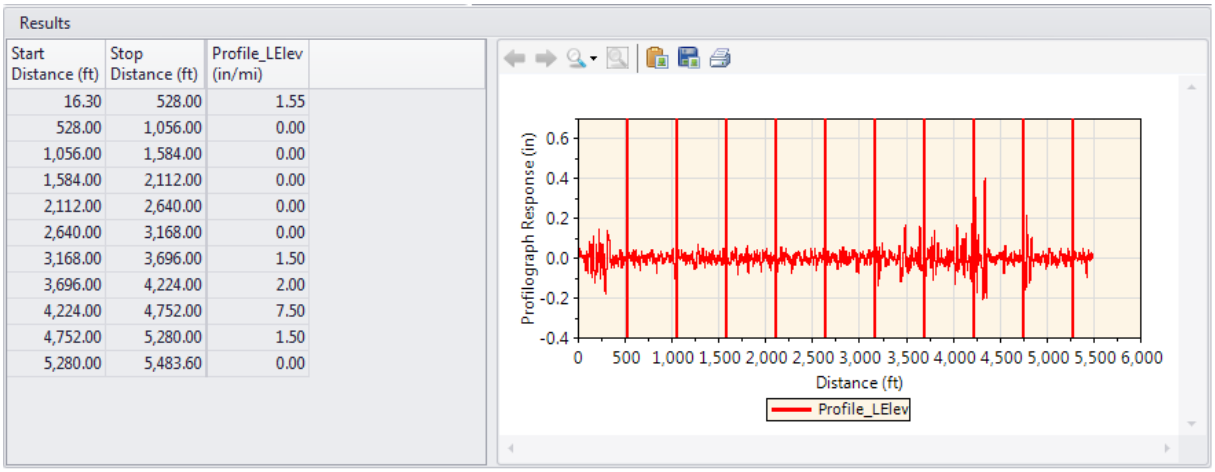
The rounded Profilograph index is computed by rounding to the scallop rounding increment.

Users can click the Wheel Offsets button to pop up a dialog box to define the number of wheel offsets and wheel offset values.

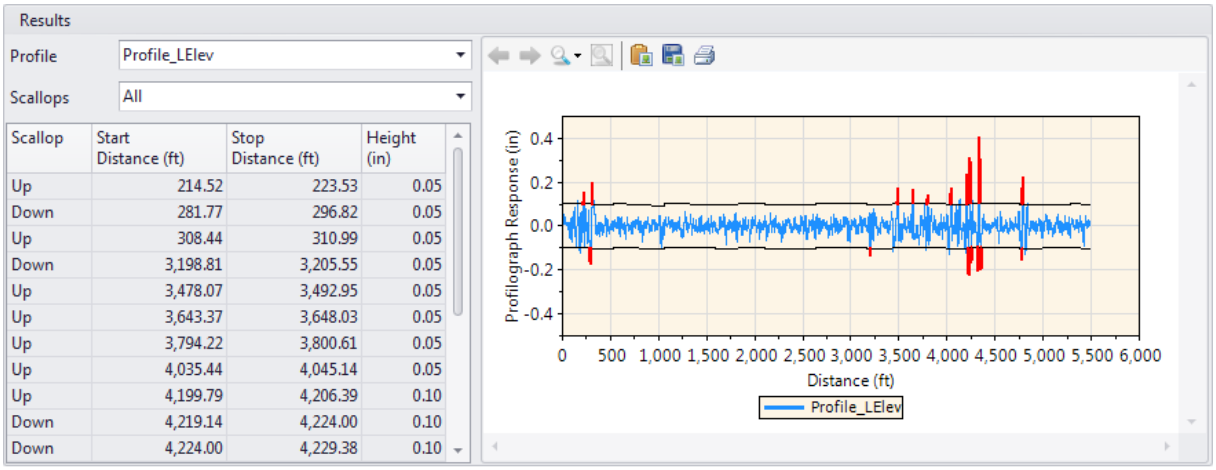


Outputs

Simulated Profilograph traces and computed Profilograph indexes- A chart will display the Profilograph response for the selected profiles. The segment markers will be shown. A table will display the Raw or Rounded Profilograph index for each segment. The start and stop positions for each segment would be listed. The Average index would also be displayed for files with a selected left and right profile. An index value of N/A will be displayed for segments that do not fall within the section of a profile.

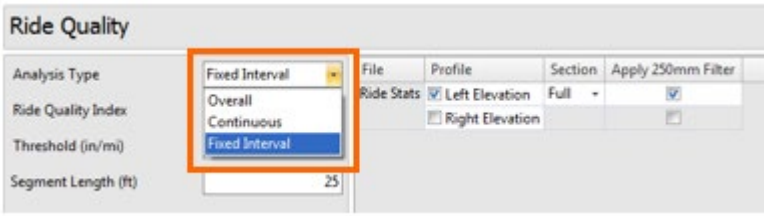


Scallops - A chart will display the Profilograph response for the selected profiles. Scallops will be highlighted on the chart. You can select to show Up, Down, or All scallops. A table will show a tabular version of the chart.



Ride Quality

The Ride Quality module includes three types of ride statistics analyses: Overall (for the entire trace), Continuous (reporting at every sample location), and Fixed Interval (reporting at a fixed interval or a lot length).



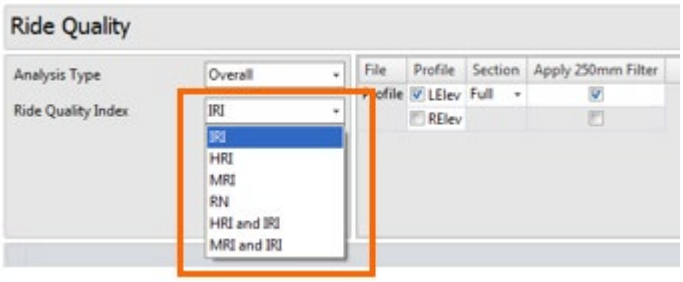
Profile Selection

Any number of profiles may be selected. The section to be analyzed can be specified for each file. You need to determine whether the Apply 250mm Filter should be applied depending on whether the profile has been previously smoothed or filtered with a low-pass filtering. If in doubt, contact your profiler manufacturers.

Inputs

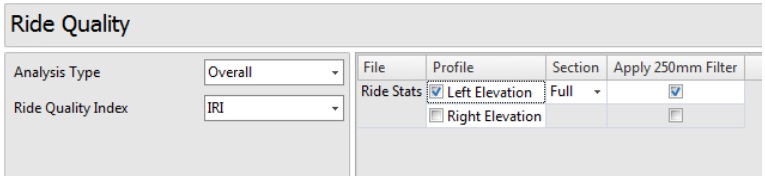
Input Templates are available for this analysis. Changing the selected profiles will not affect the template. The inputs include:

- **Analysis Type**: Selection from Overall, Fixed Interval, Continuous
- **Ride Quality Index**: Select from IRI, HRI, MRI, and RN. Overall and Fixed Interval analyses also include options for simultaneously determining HRI and IRI and MRI and IRI.
- **Threshold**: Available if the Analysis Type is Fixed Interval or Continuous. Note that you must input the proper input value depending on the Baselength input due to averaging effects.
- **Segment Length**: Used for Continuous and Fixed Interval analyses. The input value should be less than the entire length of the profile. Otherwise, the Analysis button will be grayed out.

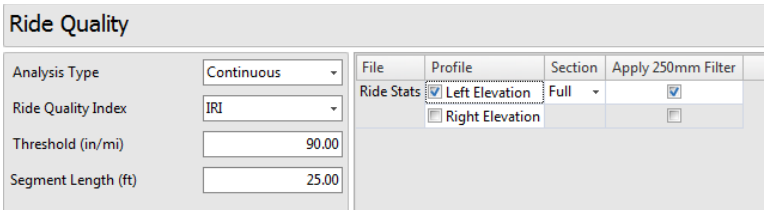


The display of profile selection is determined by the ride indexes you select. If IRI is selected, both left and right profiles are available for selection (i.e., check boxes appear next to each profile). If either HRI, MRI, or RN is selected, only entire files can be selected (i.e., check boxes appear only next to files).

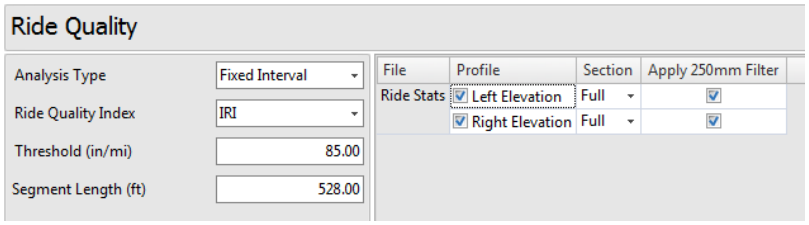
If the **Overall** analysis is selected, no additional inputs are needed.



If the **Continuous** analysis is selected, a sliding baselength can be defined to apply a moving average to produce continuous reports.



If the **Fixed Interval** analysis is selected, segments can be defined, and the analysis reports statistics for each segment rather than the entire profile. The length of the segment can be specified, and multiple segments will be added at that interval. For example, if the segment length is 528 feet, segments will be added every 528 feet. The exception is when exclusions are defined in the Editor/Sections. In this case, segments will be added until one hits the beginning location of an exclusion area. Therefore, the length of the last segment before an exclusion area may be less than the fixed length. Segments will then be added again starting at the end of an exclusion area, and the above process will be repeated if any additional exclusion areas occur.

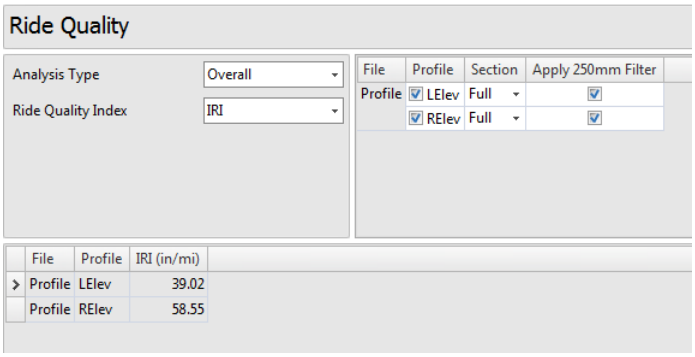


Once inputs have been entered, click **Analyze** to display the results.

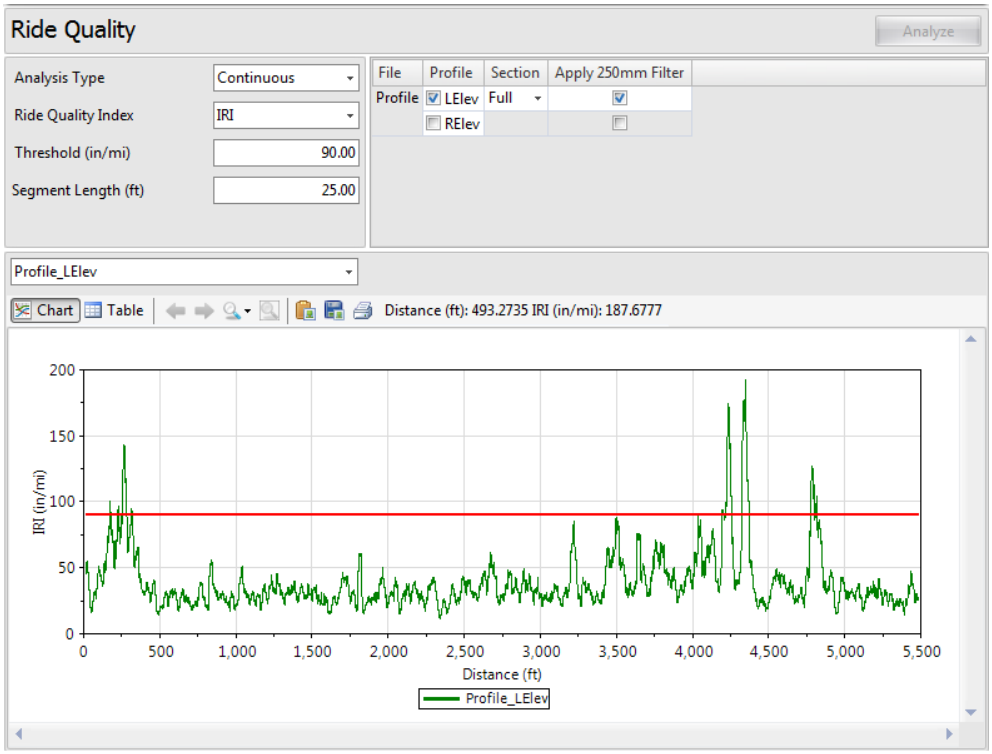
Outputs

- Overall: The Ride Quality statistic for each profile or file is displayed.
- Continuous: Table listing the locations and maximum value of the out-of-threshold or "hot spots" statistic. A chart shows continuous roughness results for the selected profiles.
- Fixed Interval: The Ride Quality statistic for each profile or file is displayed for each segment. A chart shows a graphical representation of the stats.

Overall analysis results.



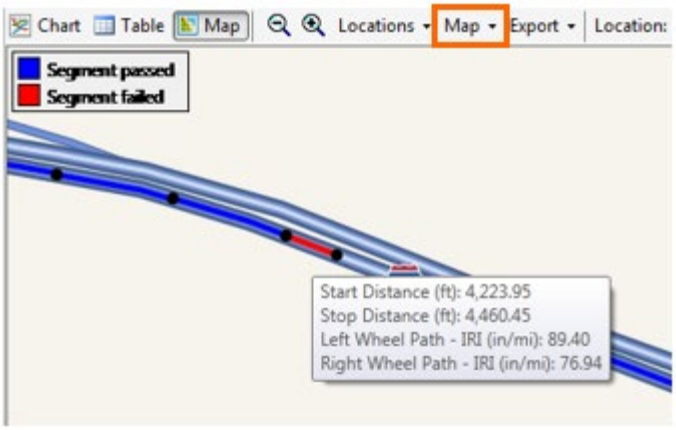
Continuous analysis results. You can select each profile or file (for two-channel indexes) to display the analysis results. Select which profile to view using the dropdown box above the output window. Toggle between the chart, table, and map data (if a route is defined). On the chart, the threshold is shown as a horizontal red line. Locations above the threshold are displayed as red-coded segments on the map, indicating hot spots or failed areas. Mouse over each hot spot to show information, including the start/stop distance and the ride index value.



Fixed Interval analysis results. You can select each file to display the analysis results. Toggle between the chart, table, and map data (if a route is defined). Color-coded segments on the map indicate pass (blue) or fail (red). Mouse over each segment to show information, including the start/stop distance and the ride index value.

Chart | Table | Map

Start Distance (ft)	Stop Distance (ft)	Length (ft)	Left Wheel Path - IRI (in/mi)	Right Wheel Path - IRI (in/mi)
0.00	527.99	527.99	55.08	60.86
527.99	1,055.99	527.99	65.42	54.37
1,055.99	1,583.98	527.99	58.88	49.61
1,583.98	2,111.98	527.99	59.80	42.44
2,111.98	2,639.97	527.99	55.03	45.14
2,639.97	3,167.96	527.99	60.86	51.65
3,167.96	3,695.96	527.99	49.58	44.36
3,695.96	4,223.95	527.99	42.54	44.45
4,223.95	4,460.45	236.50	89.40	76.94
4,799.45	5,326.44	526.99	58.97	63.83
5,680.44	6,208.43	527.99	51.75	62.90
6,208.43	6,512.43	304.00	80.89	68.86

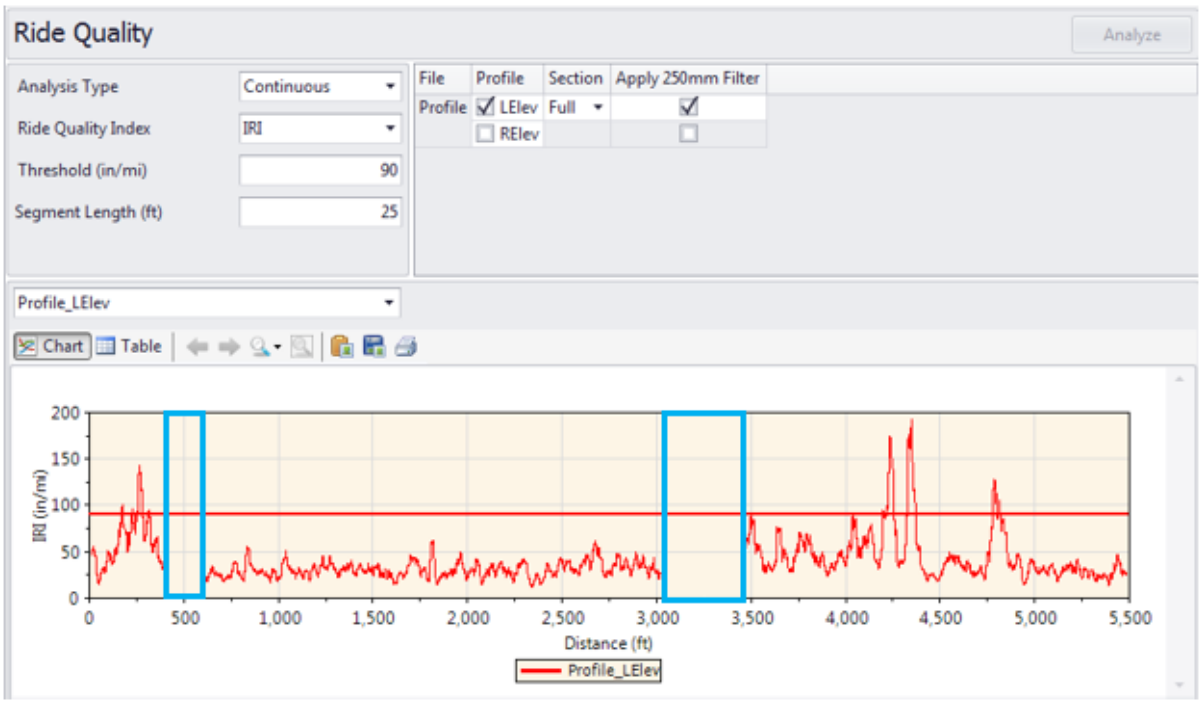


Analysis by Excluding Leave-outs

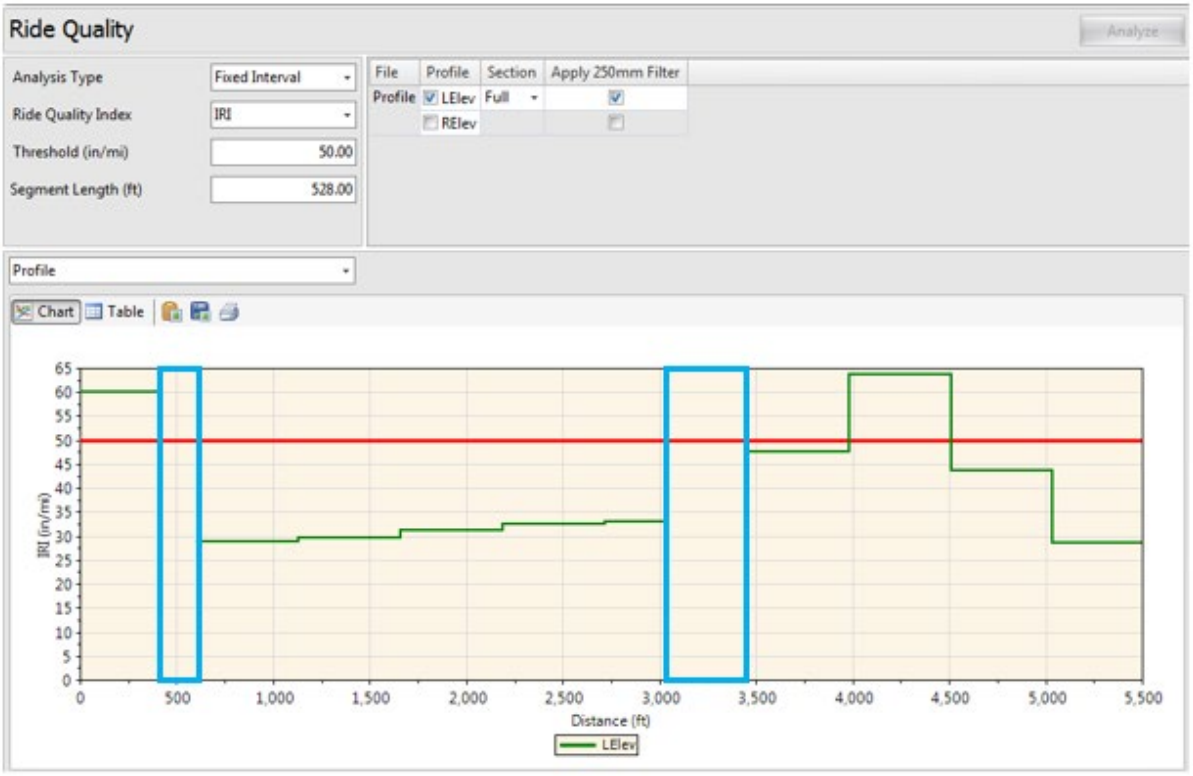
The exclusion analysis excludes the results with the leave-out sections. Leave-out sections can be defined using the Editor/Section screen. An example with two leave-out sections is shown below:

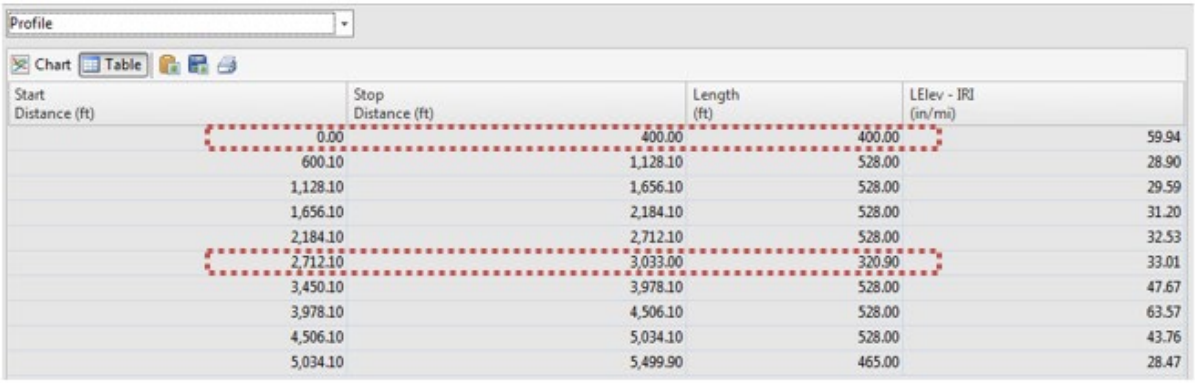
Overall analysis results are computed by including only the results within non-leave-out sections.

Continuous analysis results excluding leave-outs. You can select each profile or file (for two-channel indexes) to display the analysis results. The "hot spots" table will exclude any hot spots falling within the leave-outs, and the continuous roughness plots within the leave-out will not be displayed. For the continuous analysis, one-half of the segment length before and after a leave-out is also excluded.



Fixed Interval analysis results excluding leave-outs. You can select each profile or file (for two-channel indexes) to display the analysis results. The table's Length column shows the length used for ride index computation by excluding the leave-out sections. The segments would advance until one reaches the start of a leave-out location, and this specific segment may contain less than an entire interval. After passing the end of a leave-out, the segments would re-start advancing with the fixed interval again. It would repeat the above process once it encounters other leave-outs. Roughness indexes will be reported within each segment (full fixed interval or partial interval), and the actual lengths for all segments will also be reported. Leave-out areas are not plotted in the bar chart.





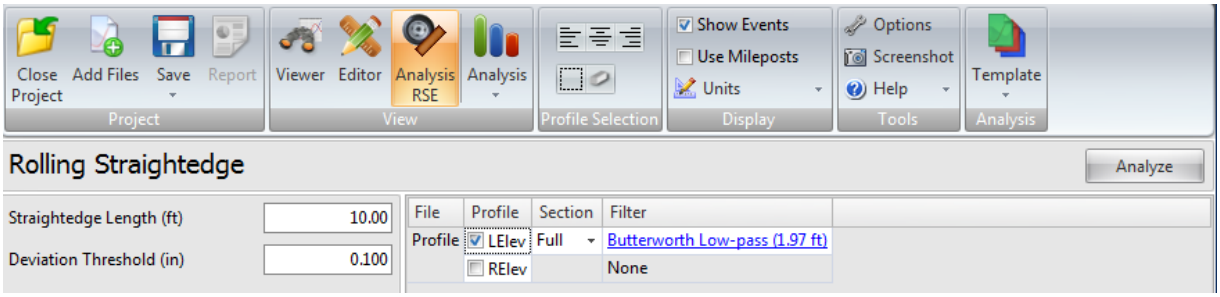
Start Distance (ft)	Stop Distance (ft)	Length (ft)	LElev - IRI (in/mi)
0.00	400.00	400.00	59.94
600.10	1,128.10	528.00	28.90
1,128.10	1,656.10	528.00	29.59
1,656.10	2,184.10	528.00	31.20
2,184.10	2,712.10	528.00	32.53
2,712.10	3,033.00	320.90	33.01
3,450.10	3,978.10	528.00	47.67
3,978.10	4,506.10	528.00	63.57
4,506.10	5,034.10	528.00	43.76
5,034.10	5,499.90	465.00	28.47

Rolling Straightedge (RSE)

This analysis simulates the rolling straightedge (RSE) measurement from profiles collected using inertial profilers. It can determine the vertical deviation between the center of the straightedge and the profile for every increment in the profile data.

Profile Selection

Any number of profiles may be selected. The section for each profile may be selected.



A different wavelength filter can be specified for each file by clicking the hyperlink for each input field. A pop-up dialog box would appear to allow you to select filter settings.

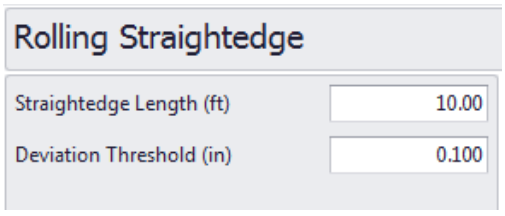
The following filters are available:

- None
- Butterworth Low-pass
- Moving Average Low-pass

Inputs

Input Templates are available for this analysis. Changing the selected profiles will not affect the template. However, the template would set the wavelength filter for each profile.

- Straightedge Length: This is the baselength of the simulated straightedge.
- Deviation Threshold: This is the threshold value to determine out-of-spec areas.

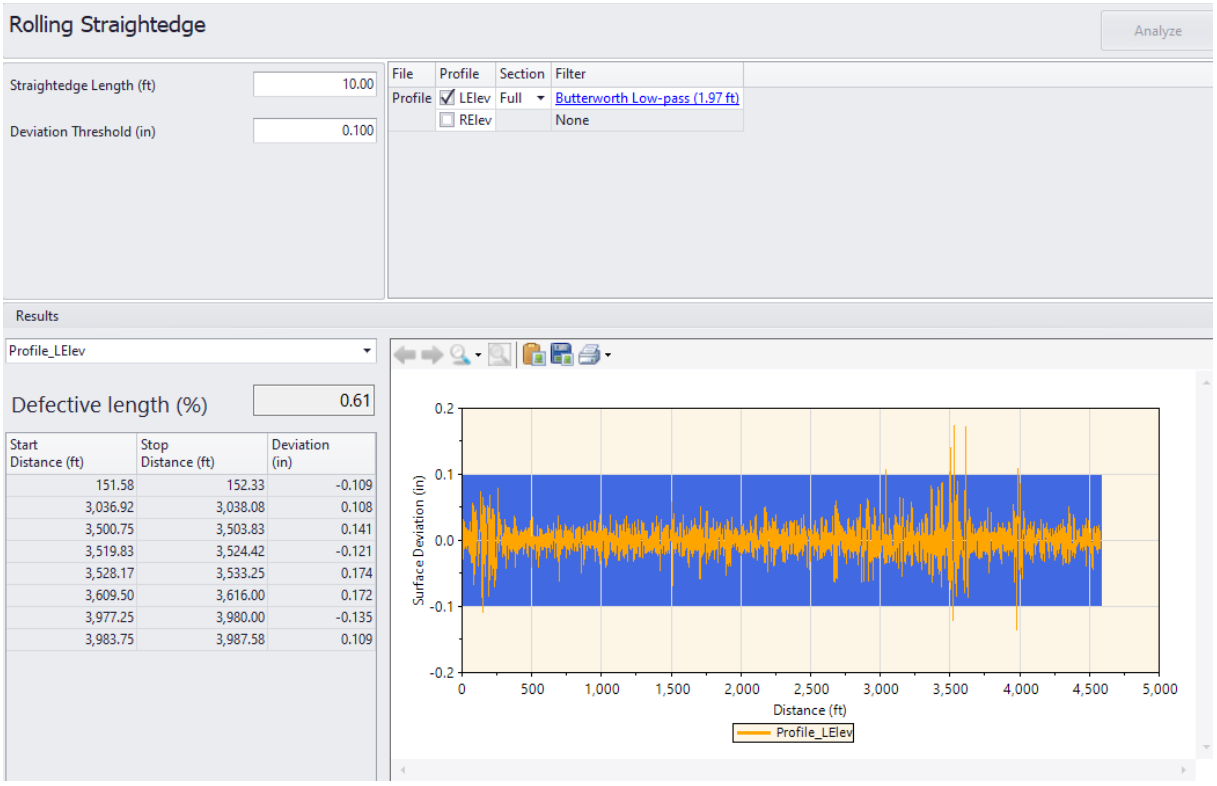


Outputs

The outputs include:

- Surface Deviation Chart (the ranges within the thresholds are shaded)
- Defective length (%)
- Defective Segments Table (i.e., hot-spots or out-of-spec areas and maximum surface deviations)

An example of a surface deviation chart:



Smoothness Assurance Module (SAM)

The Smoothness Assurance Module can be used to produce ride quality reports and optimize grinding strategies by analyzing measurements from profiles collected using inertial profilers. It can determine the out-of-spec locations and recommend must-grind locations. It also provides very flexible user-defined grinding strategies. A comprehensive report can then be generated, including ride quality reports before and after grinding.

Three types of ride quality (RQ) analyses can be performed: Short Continuous, Long Continuous, and Fixed-interval. This module is divided into four sections: Inputs, Ride Quality Analysis, Grinding, and Grinding Analysis. The comparison analysis shows a chart side-by-side with the other analyses. The comparison chart can be synchronized with the continuous charts so that zooming and scrolling coincide.

Inputs

Profile Selection

The number of profiles required varies depending on the Ride Quality Index selected. IRI requires a file containing at least one profile. Other indices (HRI, MRI, and RN) require selecting a file with both the Left and Right profiles marked. The section must be specified for the file or profile. You may also select whether or not to apply a 250mm Filter to the profile.

You need to determine whether the Apply 250mm Filter should be applied depending on whether the profile has been previously smoothed or filtered using the 250mm moving average filter. If in doubt, contact your profiler manufacturers.

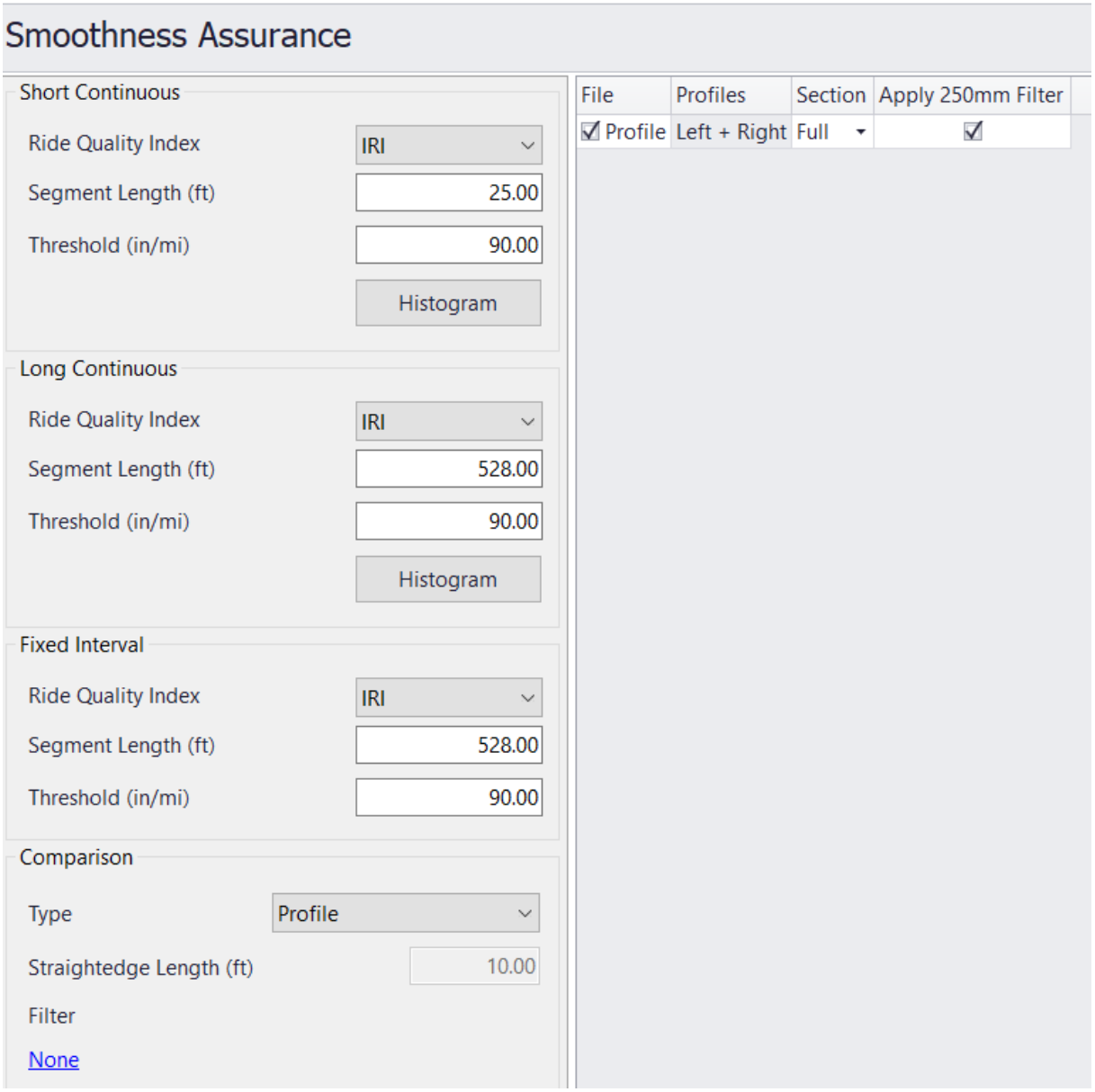
Input Templates are available for this analysis. Changing the selected profiles would not affect the template. The inputs include Inputs (for ride quality analyses) and Grinding (for grinding simulation). The latter is optional, and the "after-grinding" results would be included in all result screens for comparison if performed.

Only two-channel files can be used.

Ride Quality Analysis Inputs

ProVAL 4.0+ allows users to select different ride indexes for short continuous roughness analysis, long continuous roughness analysis, and fixed interval analysis and enable/disable the analyses.

For example, a user may select IRI for short continuous roughness analysis, disable long continuous roughness analysis, and select MRI for the fixed interval analysis. The report would reflect these users' choices.



The **Short and Long Continuous** Ride Quality inputs include:

- **Ride Quality Index**: Select from IRI, HRI, MRI, and RN. This input determines if you need to select a file and profile or just a file. See the above Profile Selection section for details.
- **Segment length**: A sliding base length can be defined as the application of a moving average to produce continuous reports. Typically, a shorter segment or baselength would be used for the Short Continuous analysis (e.g., 25 ft for finding localized roughness), while a longer one would be used for the Long Continuous analysis (e.g., 528 ft for ride quality report).
- **Threshold**: The passing score for this Ride Quality analysis.
- **Histogram**: A default histogram will be provided for the continuous analyses. A dialog box would pop up when clicking the Histogram hyperlink input.

The **Fixed Interval** Ride Quality inputs include:

- **Ride Quality Index**: Select from IRI, HRI, MRI, and RN. This input determines if you need to select a file and profile or just a file. See the above Profile Selection section for details.
- **Segment length**: The segment length can be defined, and the analysis reports statistics for each segment rather than the entire profile. The length of the segment can be specified, and multiple segments will be added at that interval. For example, if the segment length is 528 feet, segments will be added every 528 feet. The exception is when exclusions are defined in the Editor/Sections. In this case, segments will be added until one hits the beginning location of an exclusion area. Therefore, the length of the last segment before an exclusion area may be less than the fixed length. Segments will then be added again starting at the end of an exclusion area, and the above process will be repeated if any additional exclusion areas occur.
- **Threshold**: The passing score for this Ride Quality analysis.

The **Comparison** inputs include:

- **Comparison Analysis**: Select from None, Profilograph Simulation, Profile, and Rolling Straightedge
- **Straightedge Length**: If Rolling Straightedge is selected, straightedge baselengths need to be an input.
- **Filter**: If the comparison selection is other than None, you can click the filter hyperlink to access the Wavelength Filter dialog box.

Filter can be selected from:

- None
- Butterworth Low-pass
- Butterworth High-pass
- Butterworth Band-pass
- Moving Average Low-pass
- Moving Average High-pass
- Moving Average Band-pass

When Profilograph is selected as Comparison, California Profilograph simulation is used.

To perform ride quality analysis, click the **Analyze** button on the analysis menu bar. Use the **Navigate** button to view all results or proceed to **Grinding** to perform the grinding simulation.

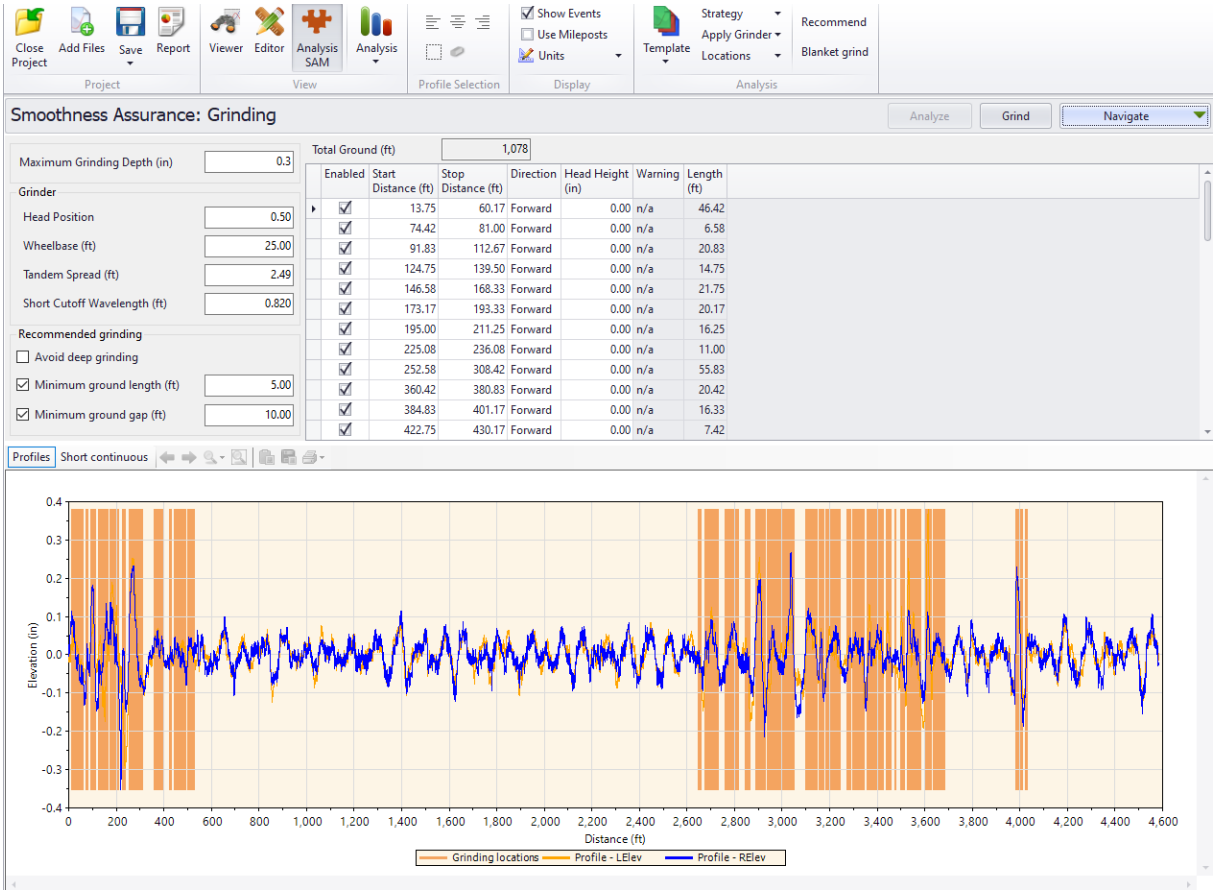
Grinding

1) Grinding Overview

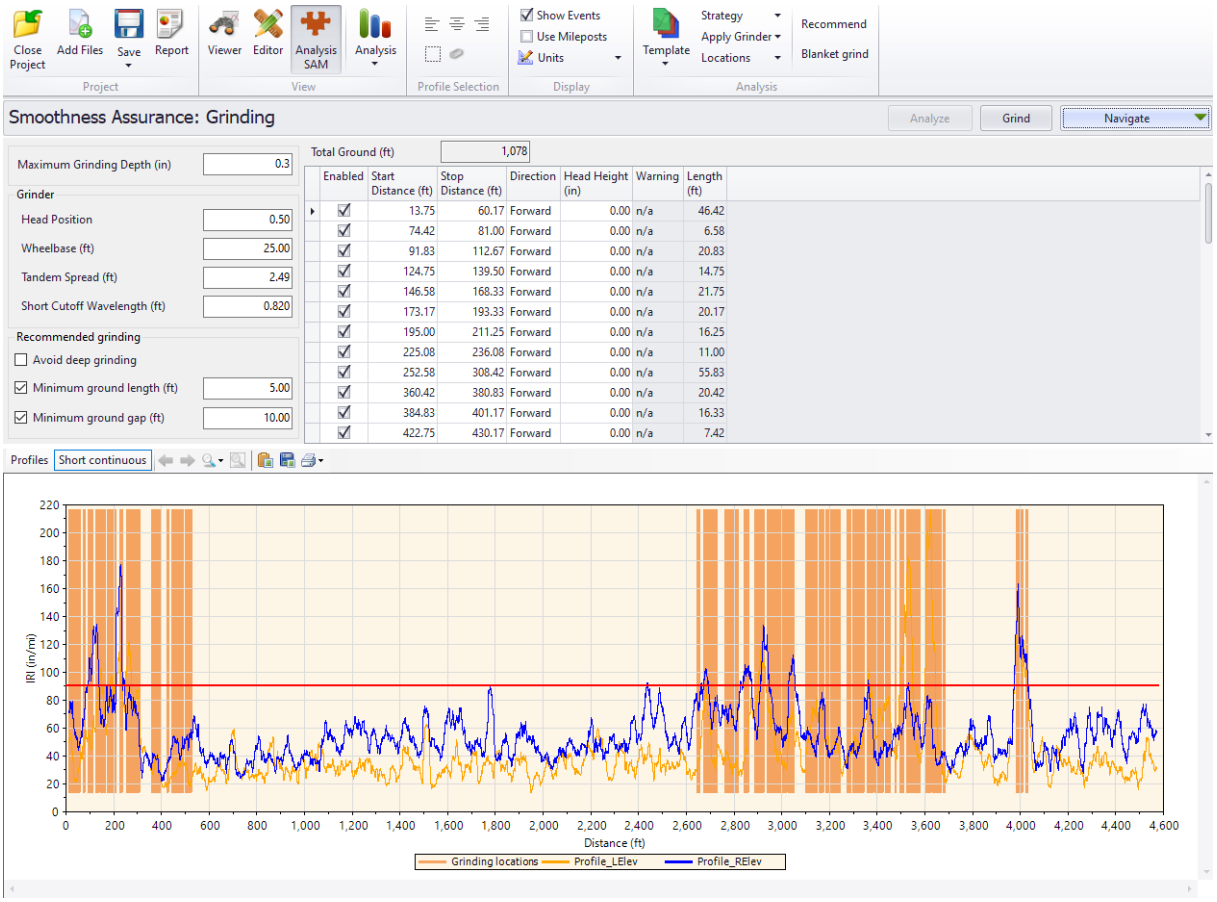
The Grinding Screen of SAM provides options for grinder selection and grinding strategy management. The toolbar also includes a group of speed buttons for grinding simulation, managing strategy, and selecting grinding locations. The screen panels include:

- Ribbon menu: analysis input template, grinding strategy, grinder selection, grinding locations, recommended grinding, and blanket grinding.
- Grinder and grinder Settings: Maximum grinding depths, grinder parameters, and recommended grind settings.
- Grinding length and method table: show the total grinding length and grinding methods and warning (if any) and length for each grinding location.
- Comparison charts: toggle between profile chart and short continuous chart with highlighted grinding locations to find-tune grading location, if desired.

Grinding screen with a profile chart

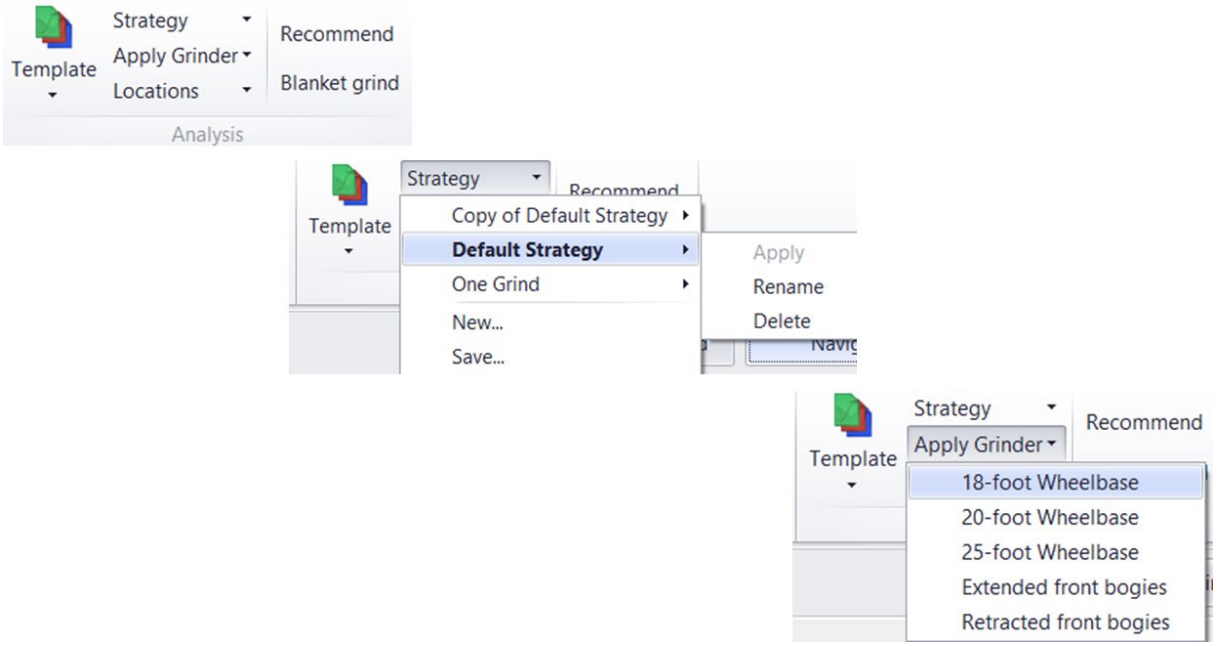


Grinding screen with a short continuous roughness chart



2) Grinding Strategy and Grinding Selection

The hierarchial structure of the grinding strategy is shown as follows:



Three grinding options under the grinding strategy:

- Recommend: provide first-cut grinding locations for users or pick-and-choose suggested grinding locations.
- Blanket grind: grind the entire length of the pavement surface.

Based on the Recommended results, users may fine-tune grinding locations for Manual Grind and Suggested Grind:

- Add and delete ground locations,
- Edit start/stop of grinding locations,
- Select some passes and grinding directions, and
- Sort and select ground locations based on grinding depths.

If grinding occurs at the beginning or end of a profile, there may be a sharp change in the raw profile. Because of the grinder's wheelbase, grinding cannot occur at the very beginning or end of the profile, so those segments should be ignored.

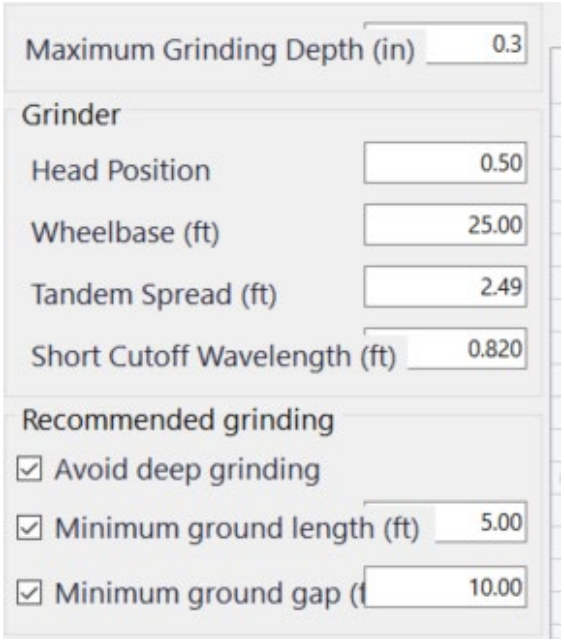
It is recommended to provide profile that extends beyond the project range, with extra lengths at the beginning and end in order to properly "sit" the grinder.

Several default grinder setups are provided based on standard grinders used in the industry, and users can save the grinder settings with user-defined settings.

Grinder Settings	Max Grinding Depth (in)	Head Position	Wheelbase (ft)	Tandem Spread (ft)	Short Cut-off Wavelength (ft)
18-foot wheelbase	0.30	0.50	18.00	2.49	0.820
20-foot wheelbase	0.50	0.60	20.25	2.00	0.820
25-foot wheelbase	0.50	0.50	25.00	2.49	0.820
Extended front bogies	0.5	0.86	13.00	2.00	0.820
Retracted front bogies	0.50	0.83	11.00	2.00	0.820

3) Max Grinding Depth

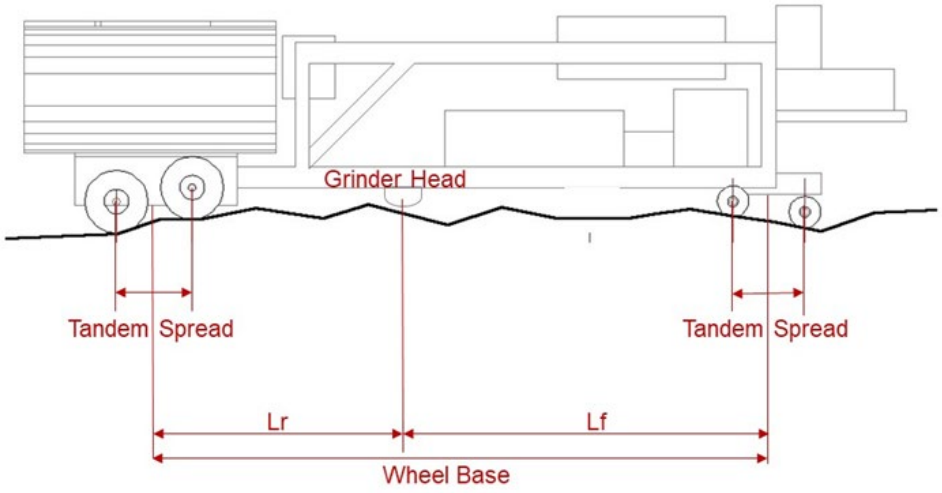
The Max Grinding Depth input is a threshold value for warning reports only but is not used in the grinding simulation.



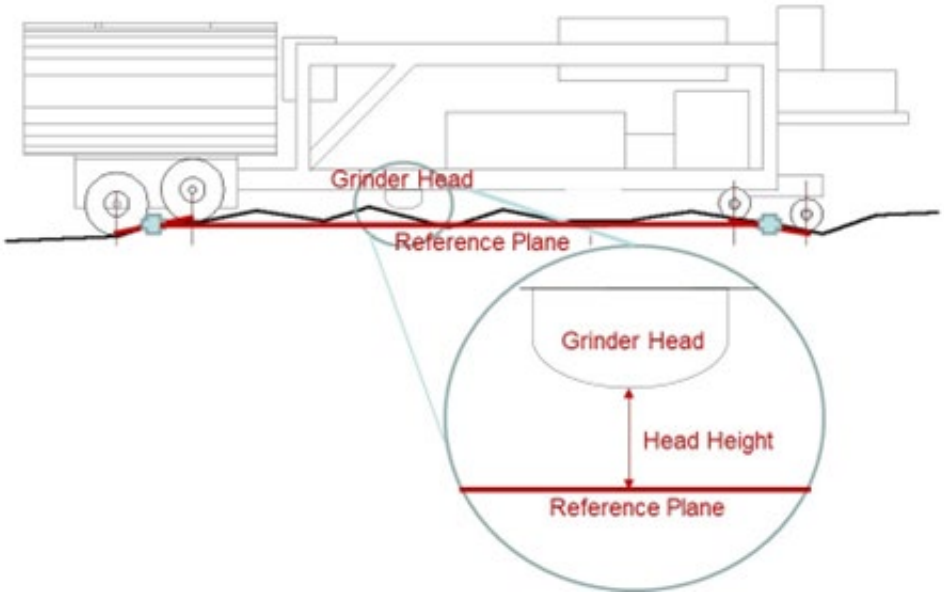
4) Grinder Settings

If you select to create a custom grinder, you can edit all of the grinder inputs. Otherwise, you can only edit the maximum grinding depth for warning reporting.

- Head Position
- Wheelbase
- Tandem Spread
- Short Wavelength Cut-off (used to simulate the tire filtering of the grinder)



Head Position = Lf / Wheel Base



The above diagram does not include an additional support wheel to reflect grinder dimensions during grinding operation.

5) Recommended Grinding Settings

- Avoid deep grinding: Skip the deep grinding locations
- Minimum ground length: Skip short grinding spots
- Minimum ground gap: Merge grinding spots that are close together

6) Simulated Ground Locations and Methods

Based on the user's inputs, the simulated ground locations and grinding methods will produced or updated.

The total ground length is shown.

A grinding location table includes the following information that can be edited:

- Enabled (Yes/No)
- Start Distance
- Stop Distance
- Direction; Selection from:
  - Forward
  - Forward, Forward
  - Forward, Reverse
  - Reverse
  - Reverse, Forward
  - Reverse, Reverse
- Head Height (distance between the grinding head and the pavement surface at the starting location)
- Warning (e.g., deep grinding or when the grinding depth exceeds the user-defined maximum grinding depth)
- Length

Total Ground (ft) 290

Enabled	Start Distance (ft)	Stop Distance (ft)	Direction	Head Height (in)	Warning	Length (ft)
☑	91.83	112.67	Forward	0.00	n/a	20.83
☑	124.75	138.92	Forward	0.00	n/a	14.17
☑	186.33	193.33	Forward	0.00	n/a	7.00
☑	205.58	211.25	Forward	0.00	n/a	5.67
☑	225.08	236.08	Forward	0.00	n/a	11.00
☑	252.58	273.58	Forward	0.00	n/a	21.00
☑	2673.58	2689.50	Forward	0.00	n/a	15.92
☑	2843.17	2862.08	Forward	0.00	n/a	18.92
☑	2901.50	2926.83	Forward	0.00	n/a	25.33
☑	2938.67	2947.25	Forward	0.00	n/a	8.58
☑	3029.17	3052.33	Forward	0.00	n/a	23.17
☑	3360.50	3368.50	Forward	0.00	n/a	8.00
☑	3496.50	3512.75	Forward	0.00	n/a	16.25
☑	3525.42	3549.25	Forward	0.00	n/a	23.83
☑	3604.92	3627.17	Forward	0.00	n/a	22.25
☑	3634.08	3645.08	Forward	0.00	n/a	11.00
☑	3981.17	4008.42	Forward	0.00	n/a	27.25

The table contents can be sorted by clicking the desired column header, e.g., length.

Total Ground (ft) 290

Enabled	Start Distance (ft)	Stop Distance (ft)	Direction	Head Height (in)	Warning	Length (ft)
☑	205.58	211.25	Forward	0.00	n/a	5.67
☑	186.33	193.33	Forward	0.00	n/a	7.00
☑	3360.50	3368.50	Forward	0.00	n/a	8.00
☑	2938.67	2947.25	Forward	0.00	n/a	8.58
☑	4023.33	4033.33	Forward	0.00	n/a	10.00
☑	225.08	236.08	Forward	0.00	n/a	11.00
☑	3634.08	3645.08	Forward	0.00	n/a	11.00
☑	124.75	138.92	Forward	0.00	n/a	14.17
☑	2673.58	2689.50	Forward	0.00	n/a	15.92
☑	3496.50	3512.75	Forward	0.00	n/a	16.25
☑	2843.17	2862.08	Forward	0.00	n/a	18.92
☑	91.83	112.67	Forward	0.00	n/a	20.83
☑	252.58	273.58	Forward	0.00	n/a	21.00
☑	3604.92	3627.17	Forward	0.00	n/a	22.25
☑	3029.17	3052.33	Forward	0.00	n/a	23.17
☑	3525.42	3549.25	Forward	0.00	n/a	23.83
☑	2901.50	2926.83	Forward	0.00	n/a	25.33

7) Perform Grinding Simulation

Click the Grind button on the analysis menu bar to simulate grinding.

Outputs

The SAM outputs may include the followings depending on the user's analysis selections. Users need to select at least one type of analysis.

Short Continuous (if selected):

- Short Continuous – Left Profile (if IRI is selected)
- Short Continuous Histogram – Left Profile (if IRI is selected)
- Short Continuous – Right Profile (if IRI is selected)
- Short Continuous Histogram – Right Profile (if IRI is selected)
- Short Continuous (if MRI, HRI, or RN is selected)
- Short Continuous Histogram (if MRI, HRI, or RN is selected)

Long Continuous (if selected):

- Long Continuous – Left Profile (if IRI is selected)
- Long Continuous Histogram – Left Profile (if IRI is selected)
- Long Continuous – Right Profile (if IRI is selected)
- Long Continuous Histogram – Right Profile (if IRI is selected)
- Long Continuous (if MRI, HRI, or RN is selected)
- Long Continuous Histogram (if MRI, HRI, or RN is selected)

Fixed Interval (if selected)

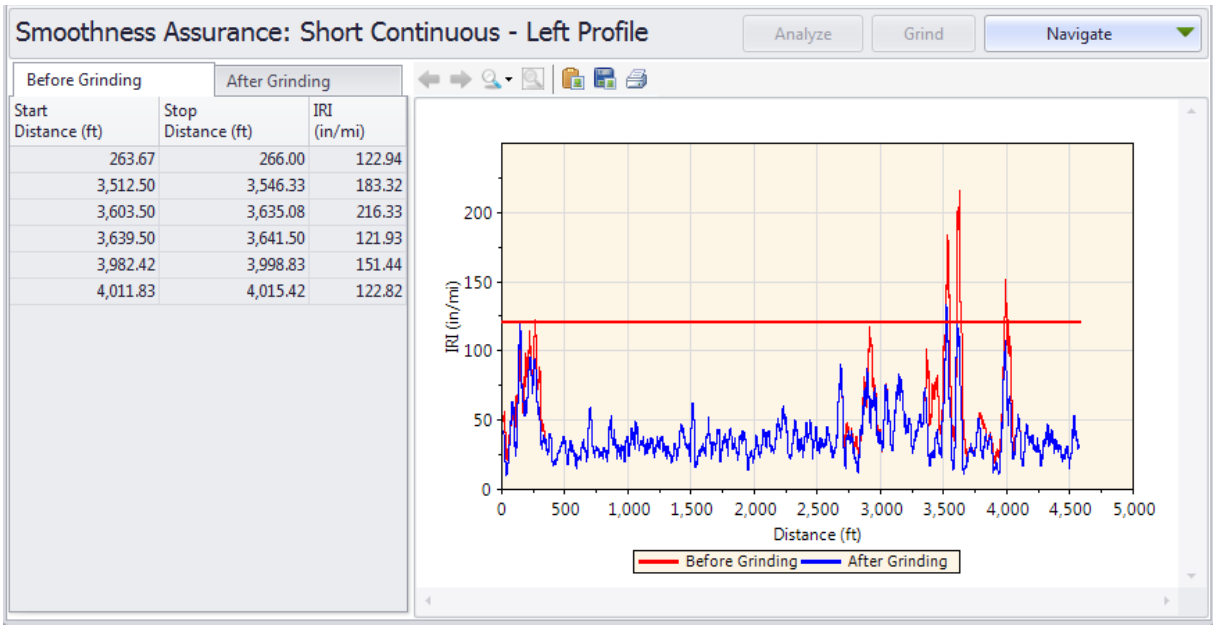
- Fixed Interval – Left Profile (if IRI is selected)
- Fixed Interval – Left Profile (if IRI is selected)
- Fixed Interval (if MRI, HRI, or RN is selected)

Short Continuous Report

The **Short Continuous** roughness report (typically indicates localized roughness) includes the following for before and after grinding:

- Defective segments table, with tabs for No Grinding and After Grinding
- Continuous ride index chart and comparison chart
- Map showing locations above the threshold, indicating hot spots or failed areas. Mouse over each hot spot to show information, including the start/stop distance and the ride index value.

An example of a continuous report without a comparison chart:

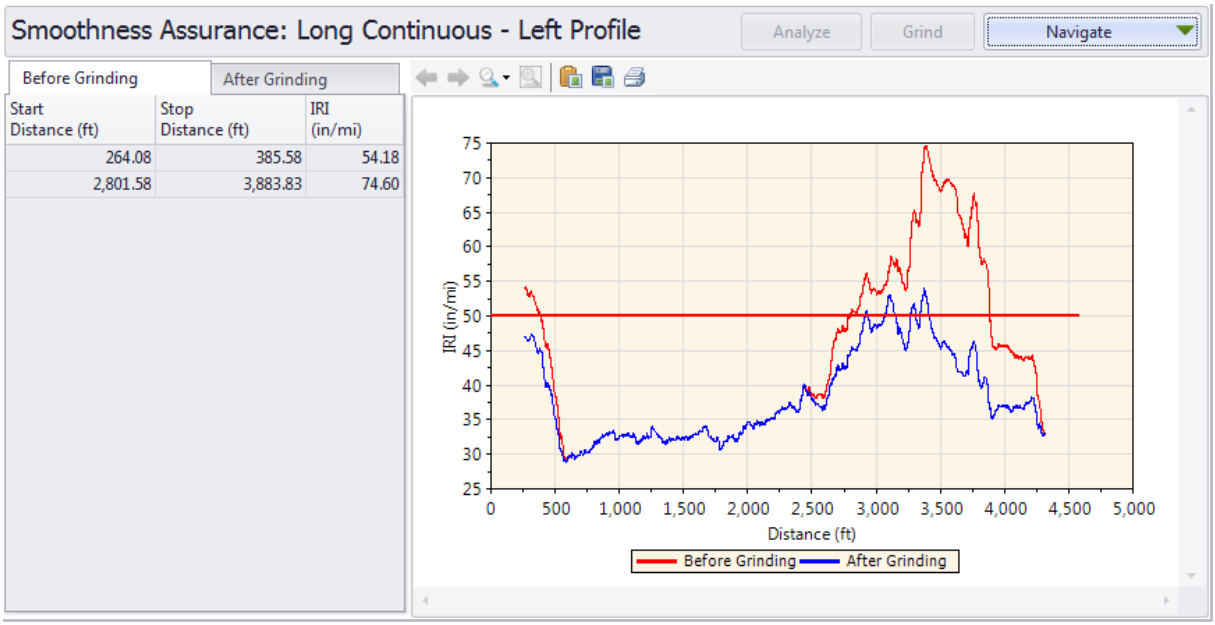


Long Continuous Report

The Long Continuous roughness report (typically indicates general ride quality) includes the following for before and after grinding:

- Defective segments table, with tabs for No Grinding and After Grinding
- Continuous ride index chart and comparison chart
- Map showing locations above the threshold, indicating hot spots or failed areas. Mouse over each hot spot to show information, including the start/stop distance and the ride index value.

An example without a comparison chart:

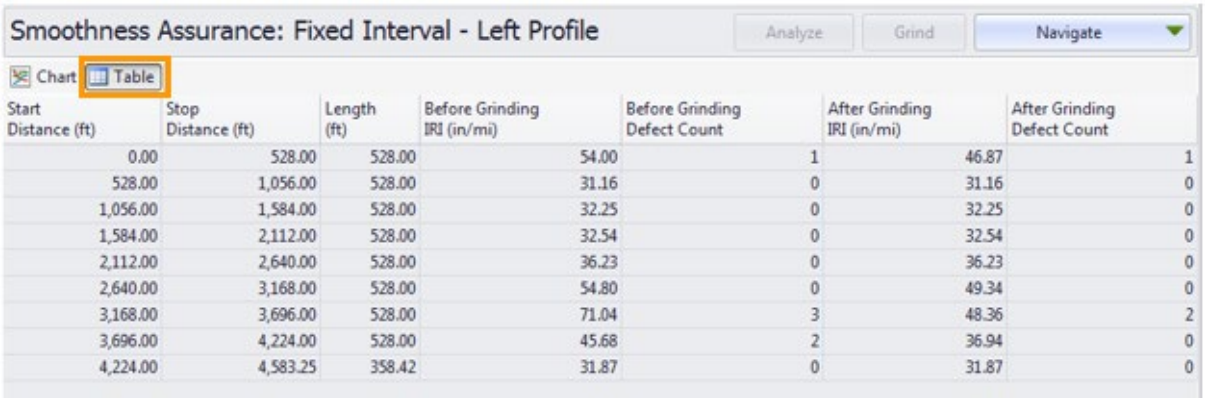


Fixed Interval Report

The Fixed Interval roughness report (typically for most agencies' lot reports) includes the following for before and after grinding:

- Fixed interval ride index report table
- Fixed interval ride index chart and comparison chart
- Fixed interval ride index map
- Toggle between the Chart, Table, and Map views using the buttons.

The table data includes the following for each Interval: location, length, IRI, and number of defective segments within the Interval (based on Short Continuous specifications).



Start Distance (ft)	Stop Distance (ft)	Length (ft)	Before Grinding IRI (in/mi)	Before Grinding Defect Count	After Grinding IRI (in/mi)	After Grinding Defect Count
0.00	528.00	528.00	54.00	1	46.87	1
528.00	1,056.00	528.00	31.16	0	31.16	0
1,056.00	1,584.00	528.00	32.25	0	32.25	0
1,584.00	2,112.00	528.00	32.54	0	32.54	0
2,112.00	2,640.00	528.00	36.23	0	36.23	0
2,640.00	3,168.00	528.00	54.80	0	49.34	0
3,168.00	3,696.00	528.00	71.04	3	48.36	2
3,696.00	4,224.00	528.00	45.68	2	36.94	0
4,224.00	4,583.25	358.42	31.87	0	31.87	0

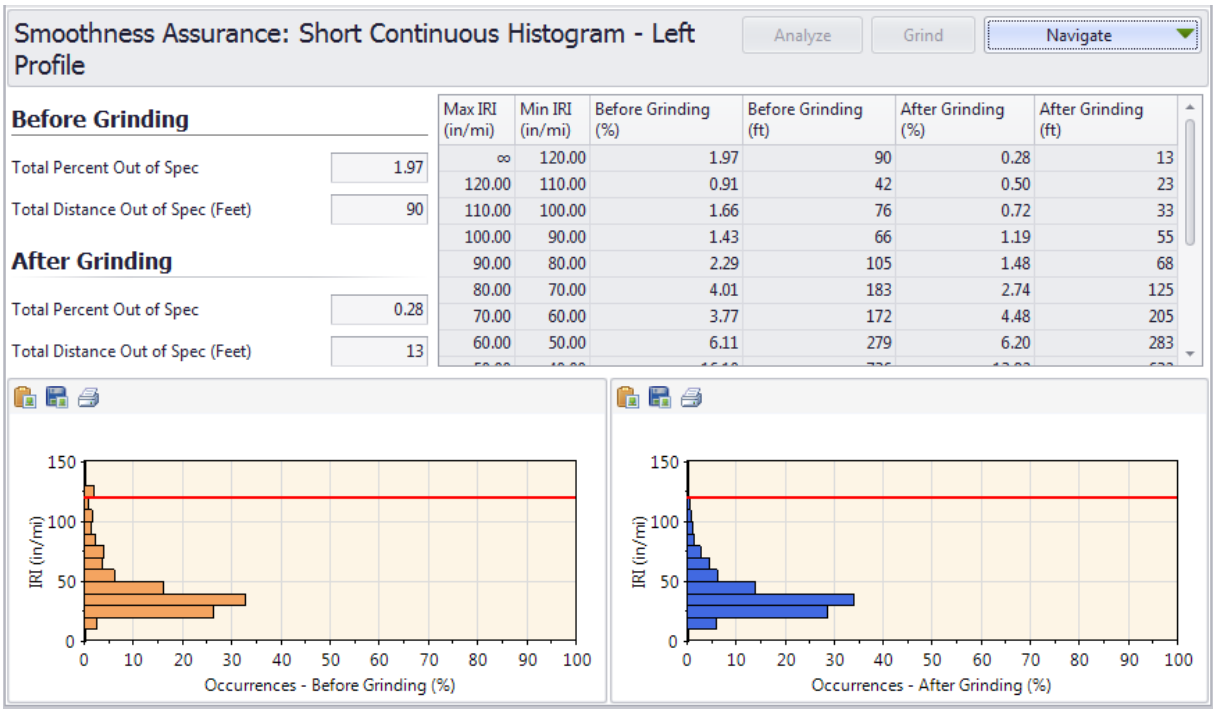
The map includes information for each Interval, displayed when hovering over a section.

Short Continuous Histogram Results

The results for the histogram of the Short Continuous roughness reports include:

- Percent of Pavement Out of Spec
- Distance Out of Spec
- Histogram tables (Max IRI, Min IRI, Before-griding hot spot %, Before-griding hot spot length, after-griding hot spot %, After-griding hot spot length.)
- Histogram charts

A view of the short continuous histogram data before and after grinding:

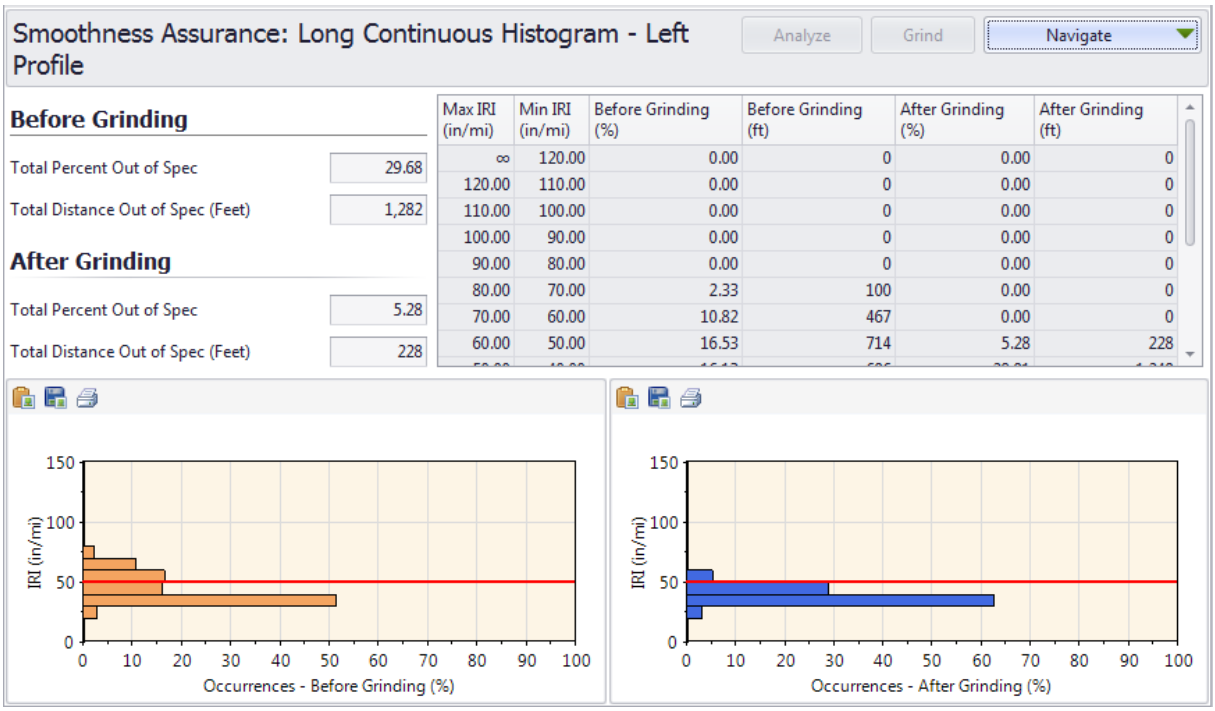


Long Continuous Histogram Results

The results for the histogram of the Long Continuous roughness reports include:

- Percent of Pavement Out of Spec
- Distance Out of Spec
- Histogram tables (Max IRI, Min IRI, Before-griding hot spot %, Before-griding hot spot length, after-griding hot spot %, After-griding hot spot length.)
- Histogram charts

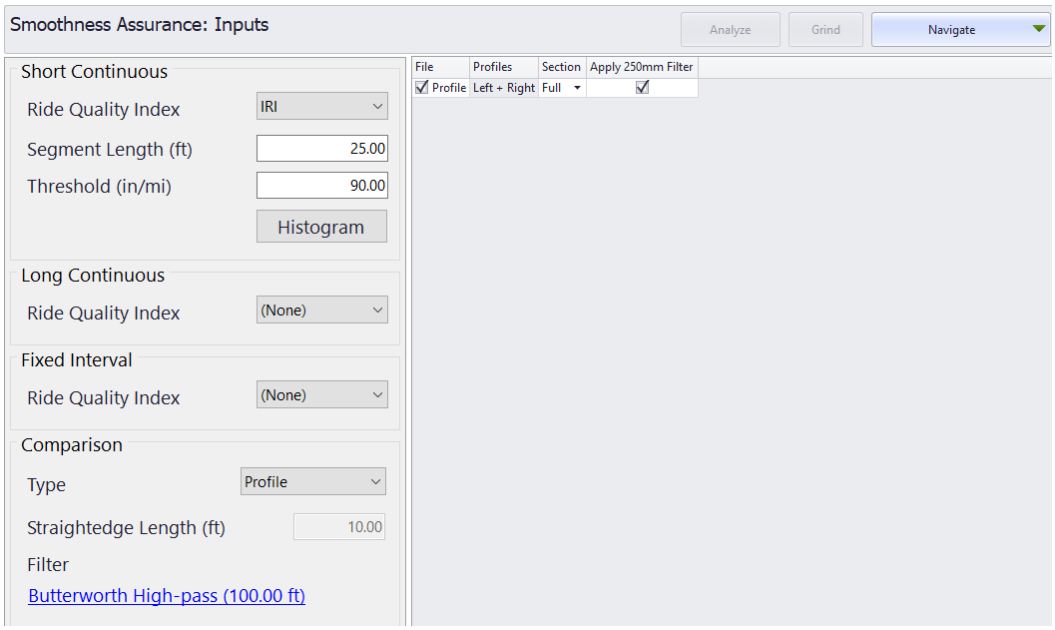
A view of the histograms of long continuous reports for before and after grinding:



Analysis with a Comparison Chart

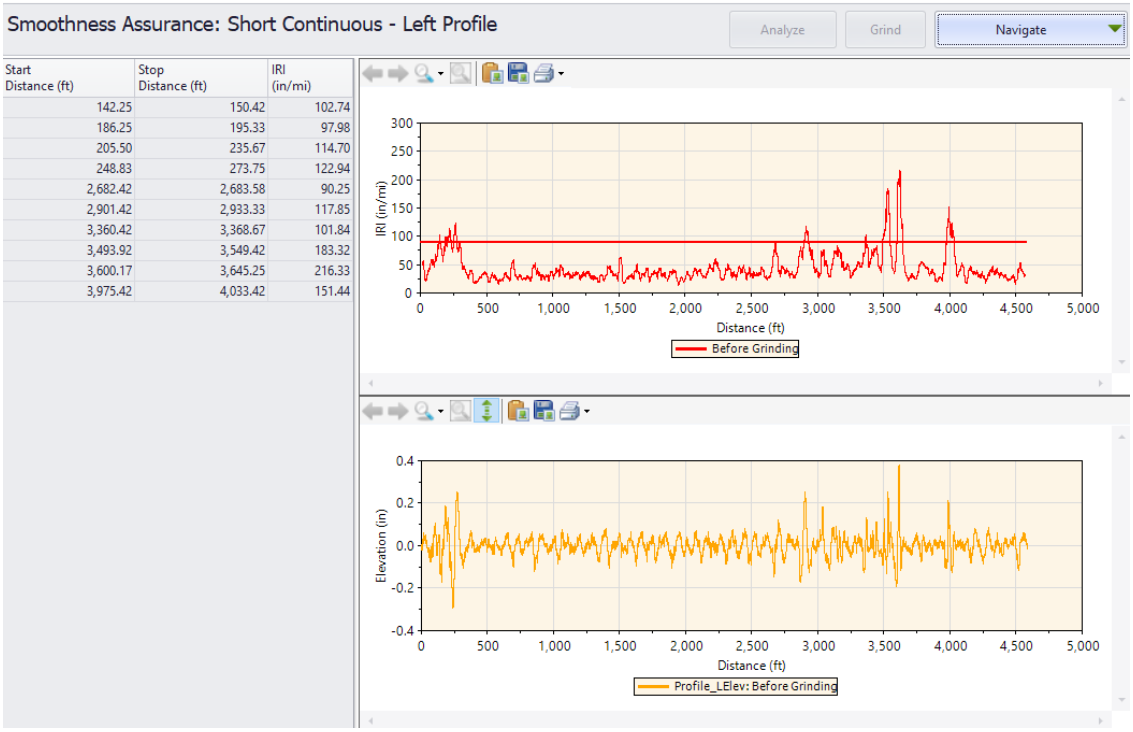
The above-illustrated SAM analysis results do not include any comparison charts. We show an analysis example with the comparison chart below:

Step 1. Select a desired comparison type and associated input settings in the Inputs screen. (For example, select Profile and Moving Average High-Pass filter with a cut-off wavelength at 100 ft. This way, you can compare the roughness plot side-by-side with the filtered profile plot.)



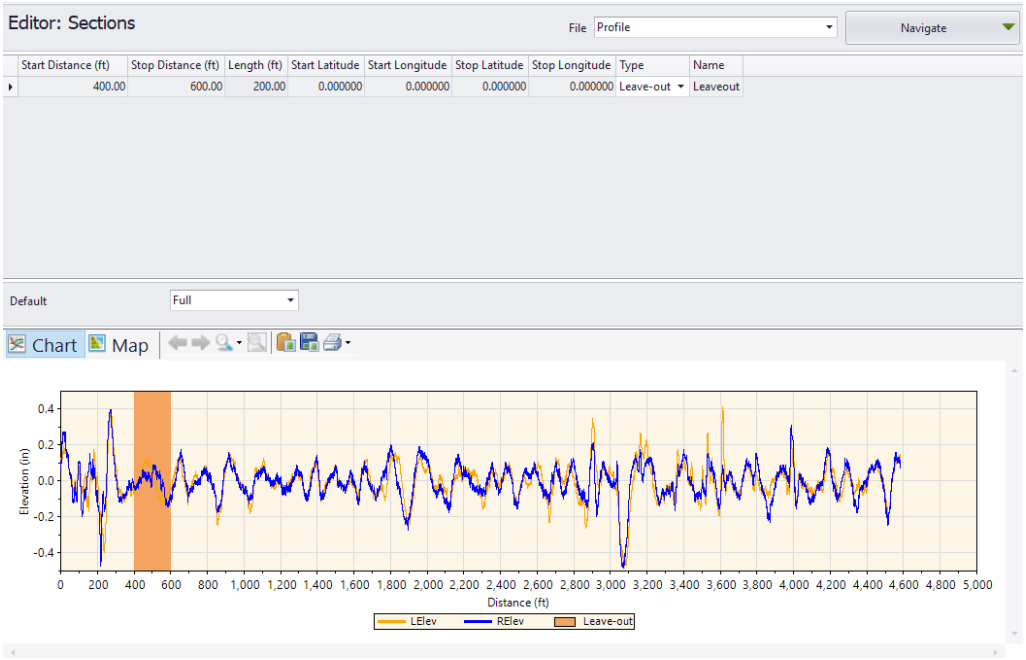
Step 2. Click the Analyze button and Navigate to Short Continuous to view the short continuous roughness report vs. filtered profile plot.

The chart control for the comparison charts includes a button with two-way arrows to turn on and off the synchronized viewing for both charts.



Analysis with Exclusions

If leave-out sections are defined, the SAM analysis will exclude results from the leave-out sections.

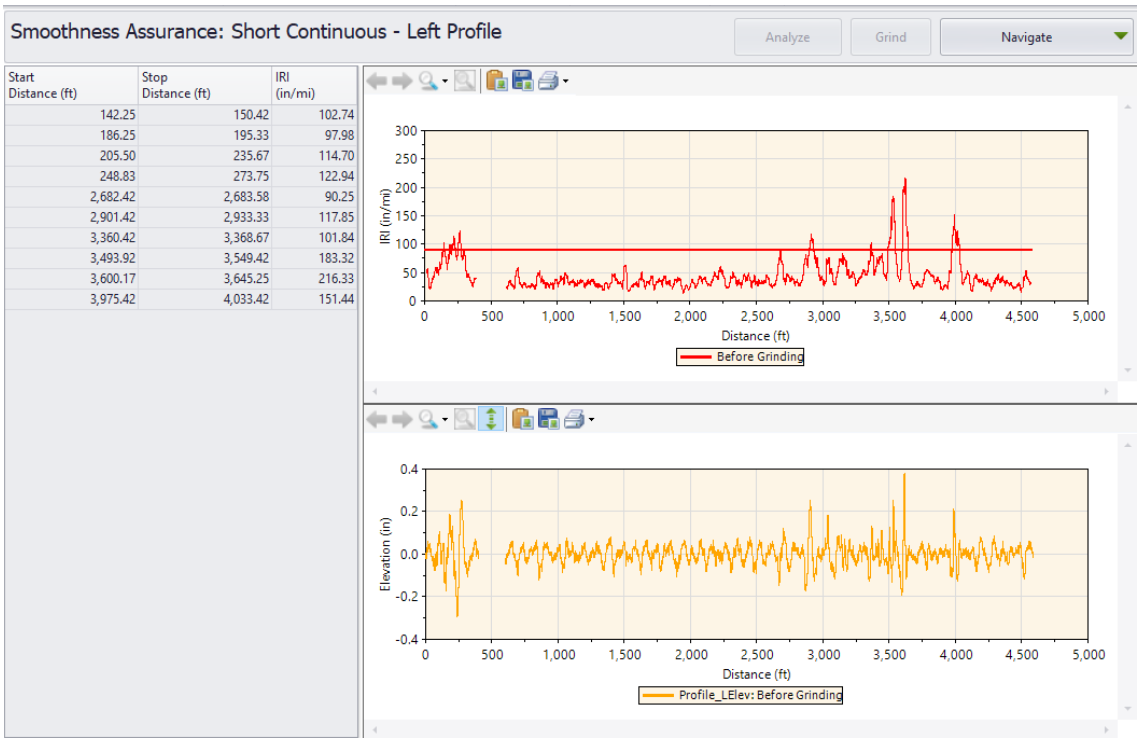


Continuous roughness analysis:

For the continuous analysis, one-half of the segment length before and after a leave-out is excluded. The behaviors are similar to those for the Ride Quality analysis module.

The grinding locations and profile plots within leave-outs will also be excluded. The short continuous report will exclude the roughness plots and profiles within the leave-outs.

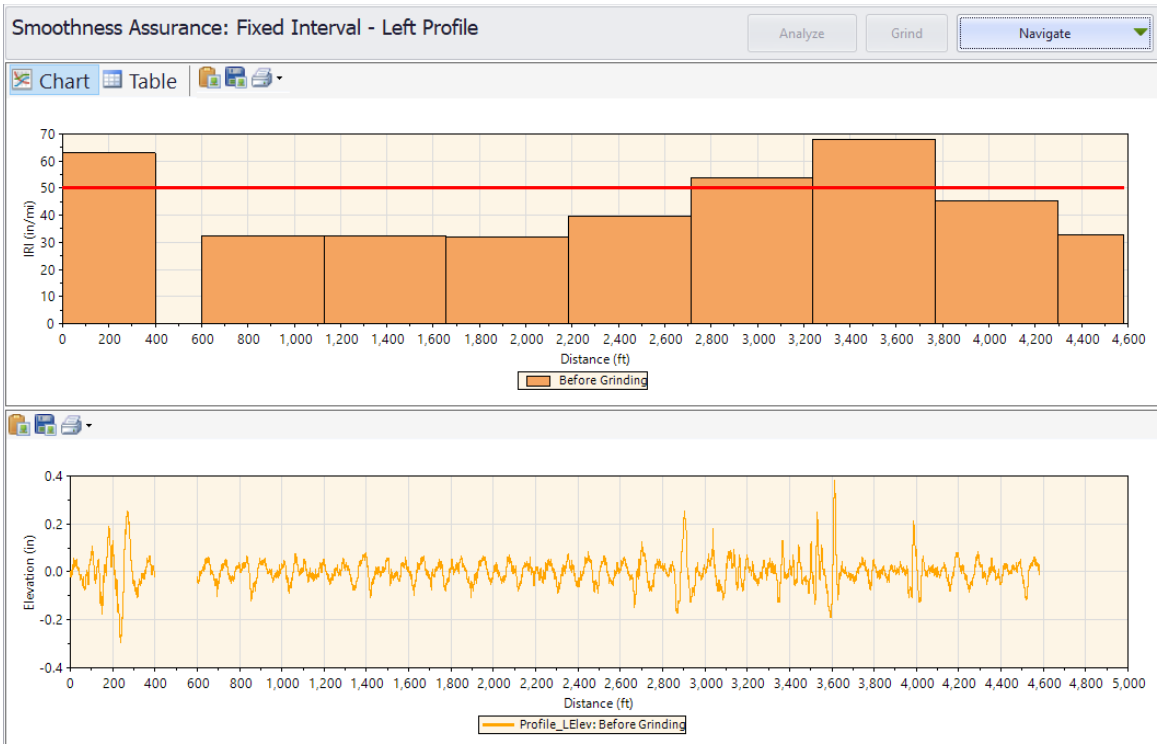
The roughness plots and profiles within the leave-outs will be excluded in the long continuous report.



Fixed interval roughness analysis:

The profiles within the leave-outs will be excluded from the fixed interval report.

The Length column in the fixed interval result table shows the length used for ride index computation, excluding the leave-out sections. The segments would advance until one reaches the start of a leave-out location, and this specific segment may contain less than a full interval. After passing the end of a leave-out, the segments would re-start advancing with the fixed interval again. It would repeat the above process once it encounters other leave-outs. Roughness indexes will be reported within each segment (entire fixed interval or partial interval), and the actual lengths for all segments will also be reported. Leave-out areas are not plotted in the bar chart.



Optimal WIM Site Locator (OWL)

The Optimal Weigh-In-Motion Site Locator (OWL) module can be used to determine qualified locations for Weight-In-Motion (WIM) sites from profiles collected using inertial profilers. It is based on the AASHTO M 331 "Standard Specification for Smoothness of Pavement in Weigh-in-Motion (WIM) Systems." It also provides optional but very flexible user-defined grinding strategies. A comprehensive report can then be generated, including WIM index reports before and after grinding.

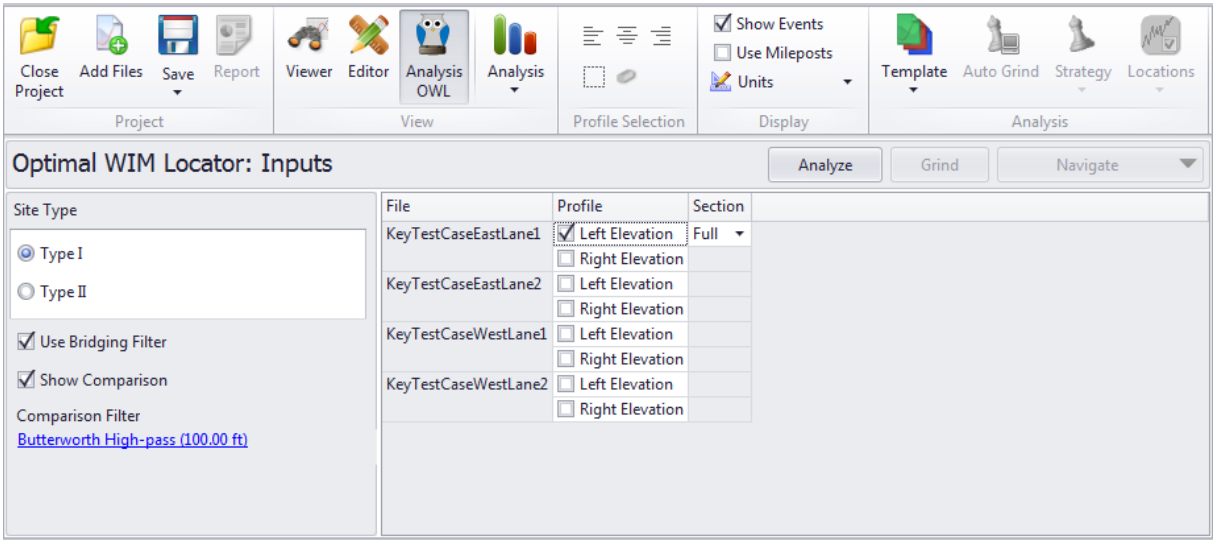
The WIM error index thresholds are adopted from the AASHTO M 331 Standard Specification for Smoothness of Pavement in Weigh-in-Motion (WIM) Systems:

- Type I: lower threshold is 1.339 m/km, upper threshold is 2.700 m/km.
- Type II lower threshold is 1.861 m/km, upper threshold is 3.752 m/km.

This module is divided into three sections: Inputs, Grinding, and Results.

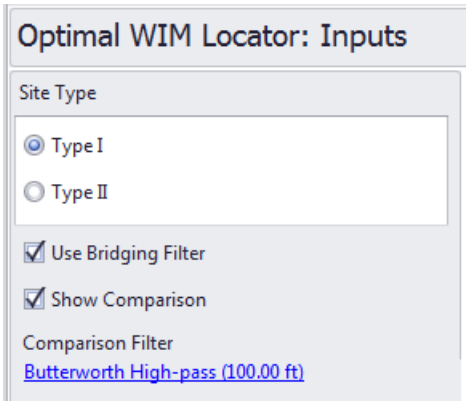
Profile Selection

The OWL analysis requires one file profile. The section must be specified for the file or profile.



Input Templates are available for this analysis. Changing the selected profiles would not affect the template. The Grinding simulation is optional, and the "after-grinding" results would be included in all result screens for comparison if performed.

WIM Index Inputs and Analysis



The inputs include:

- **Site Type**: Select from Type I and Type II. This input would determine what WIM index threshold values should be used per the AASHTO MP331 specification.
- **Tire Bridging Filter**: The user can apply the tire-bridging filter to the profile before WIM index analysis. If the Tire-bridging filter option is not selected, a default moving average filter will be applied with a cut-off baselength of 250 mm.
- **Show Comparison Chart**: The user can choose a comparison profile chart. If so, the user can select a filter type and associated cut-off wavelength inputs to apply to the comparison profile.

Comparison Filter can be selected from:

- None
- Butterworth Low-pass
- Butterworth High-pass
- Butterworth Band-pass
- Moving Average Low-pass
- Moving Average High-pass
- Moving Average Band-pass

Grinding Inputs

The Grinding Inputs work like the one in the Smoothness Assurance Module (SAM). Please refer to the *SAM Grinding Screen* for further details.

WIM Locator Report

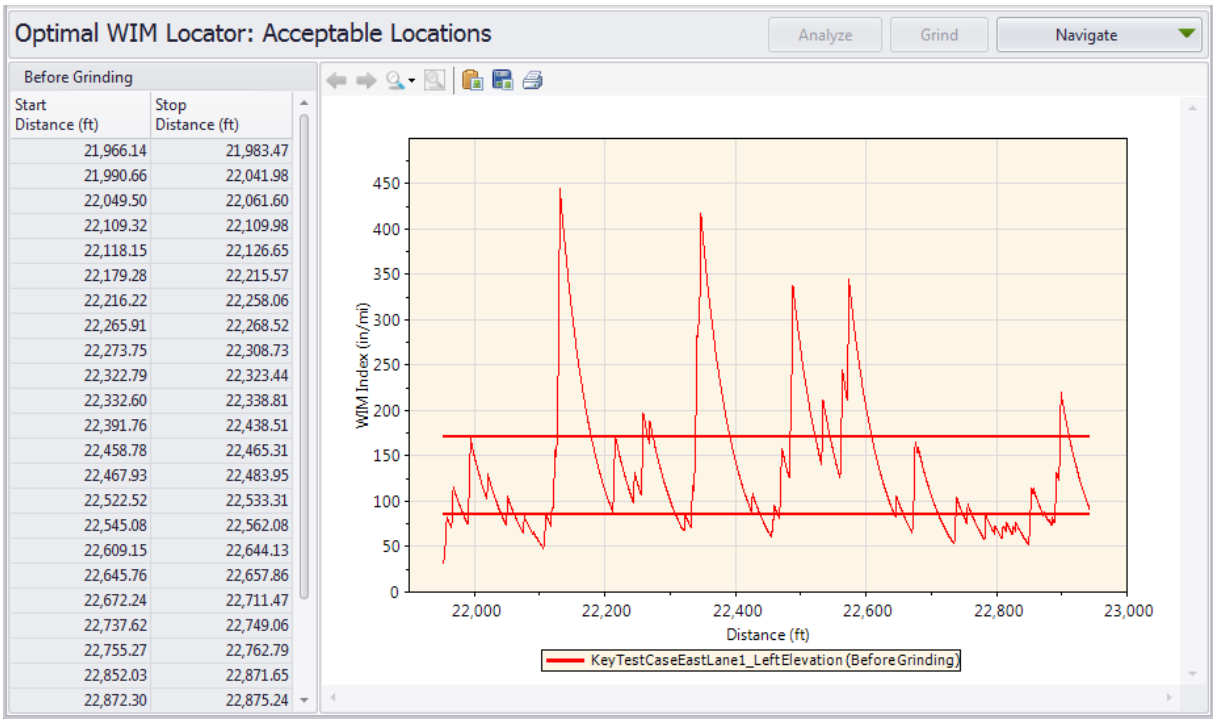
The **WIM Index** report includes the following items:

- A table for qualified WIM site locations
- A WIM index chart

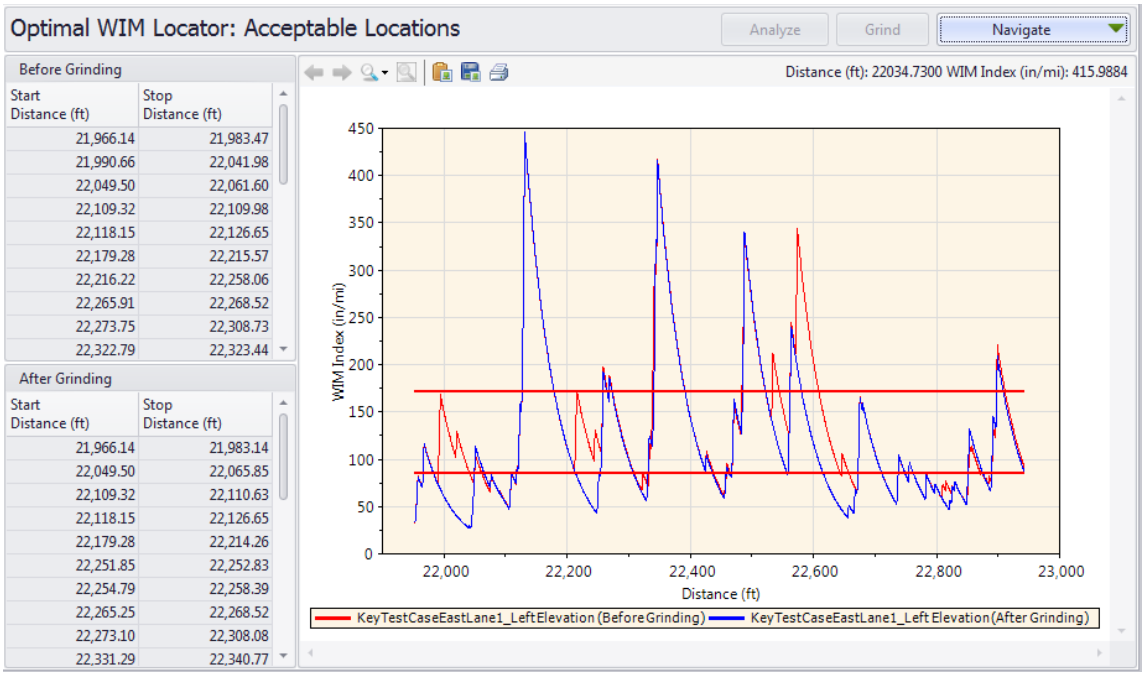
Qualified WIM sites are those where the WIM index is within the specified upper and lower thresholds. If the grinding simulation is performed, the **WIM Index** report will include reports before and after grinding.

Analysis without a Comparison Chart

An example of a WIM index report without a comparison chart and grinding results:

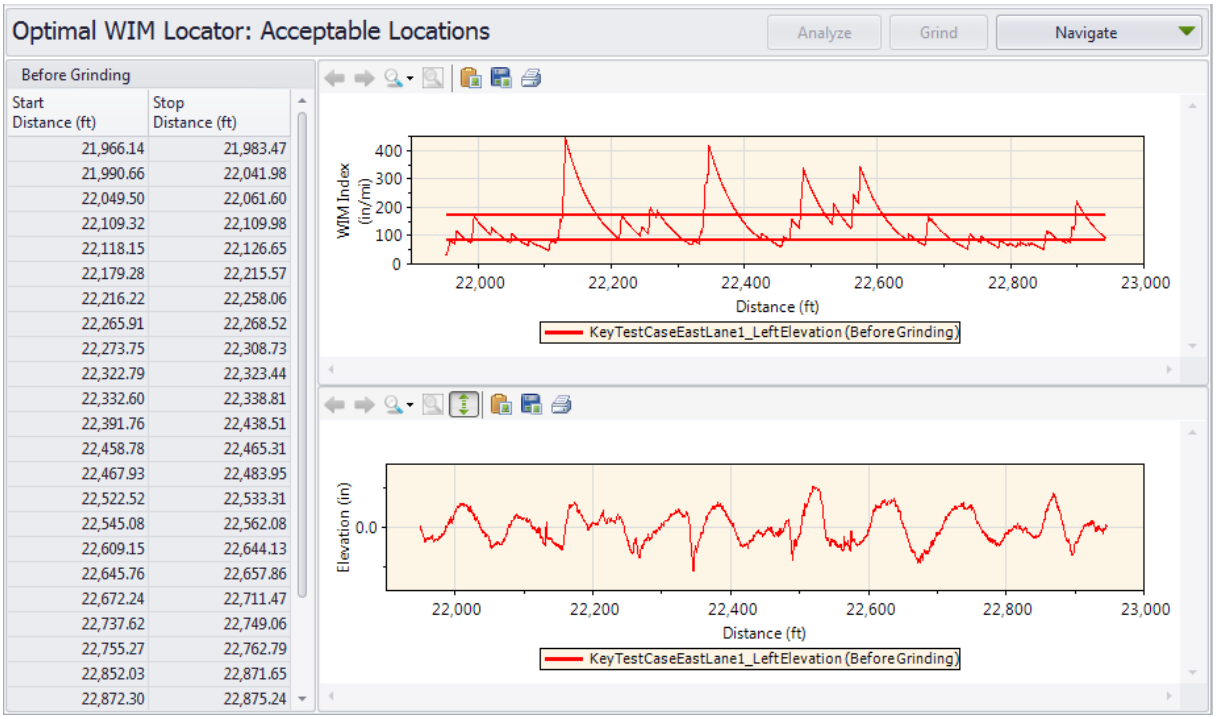


An example of a WIM index report without a comparison chart but with grinding results:



Analysis with a Comparison Chart

An example of a WIM index report with a comparison chart but without grinding results:



An example of a WIM index report with a comparison chart and (auto-grind) grinding results: This is a powerful combination of charts to examine grinding effects on the WIM index report. Therefore, an adequate grinding strategy can be selected to obtain a desired location for a WIM site.

Chapter 7

FURTHER INFORMATION

Web Sites

The ProVAL website is http://www.RoadProfile.com.

The Smoothness Specification website is http://www.SmoothPavements.com.

The Road Profile Users' Group: http://www.rpug.org

The University of Michigan Transportation Research Institute (UMTRI) Road Roughness Home Page: http://www.umtri.umich.edu/erd/roughness/index.html

References

AASHTO M 331-17 Standard Specification for Smoothness of Pavement in Weigh-in-Motion (WIM) Systems.

AASHTO R 56-2018, Standard Practice for Certification of Inertial Profiling Systems.

ASTM E2560-23 Standard Specification for Data Format for Pavement Profile

ASTM E950-22 Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer-Established Inertial Profiling Reference

Chang, G.K., et al., Implementation Of A Grinding Simulation Tool in The Profile Viewing And Analysis (ProVAL) Software Tool, SURF 2008, Slovenia, Oct. 2008.

Chang, G.K., Watkins, J., and Orthmyer, R., Practical Implementation of Automated Fault Measurement Based on Pavement Profiles, International Symposium on Pavement Performance: Trends, Advances, and Challenges, STP 1555, ASTM International, ISBN13: 978-0-8031-7541-9, 2012.

Chang, G.K., Karamihas, S.M., Rasmussen, R.O., Merritt, D.K., Swanlund, M., Quantifying the Impact of Jointed Concrete Pavement Curling and Warping on Pavement Unevenness, 6th symposium on pavement surface characteristics (SURF), Slovenia, 2008.

Sayers, M.W., and S.M. Karamihas, The Little Book of Profiling, The University of Michigan Transportation Research Institute (UMTRI), October 1997.

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