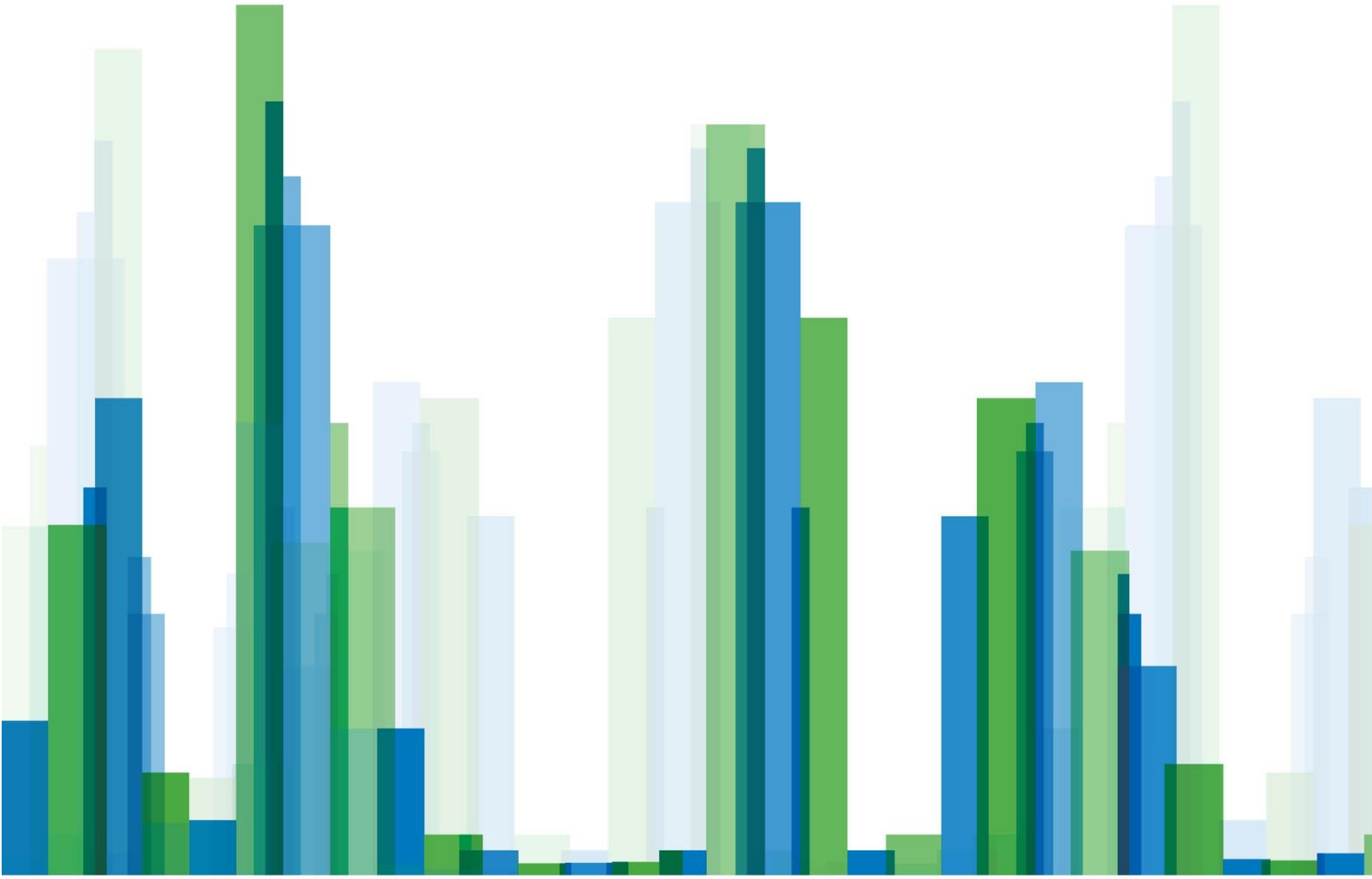
March 2021

ProVAL User Guide

ILLINOIS STATE TOLL HIGHWAY AUTHORITY

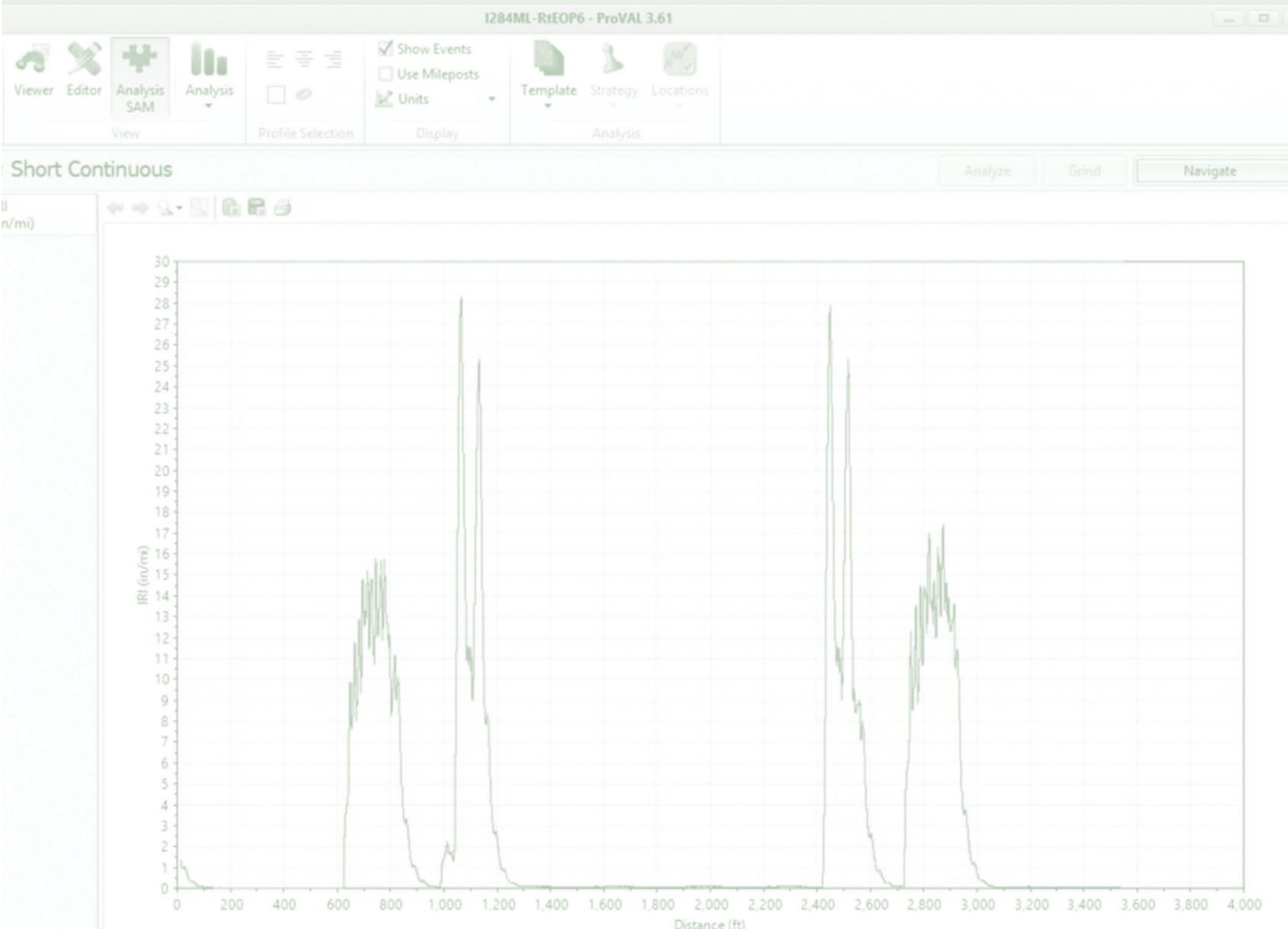


Illinois Tollway

INTRODUCTION

ProVAL User Guide

The ProVAL User Guide provides guidance to Design Section Engineers (DSEs) to ensure pavement smoothness criteria is met during the design stage. Refer to Illinois Tollway Roadway Design Criteria (RDC) Manual, Article 2.5.7, Lane Profile Smoothness, for criteria requirements.



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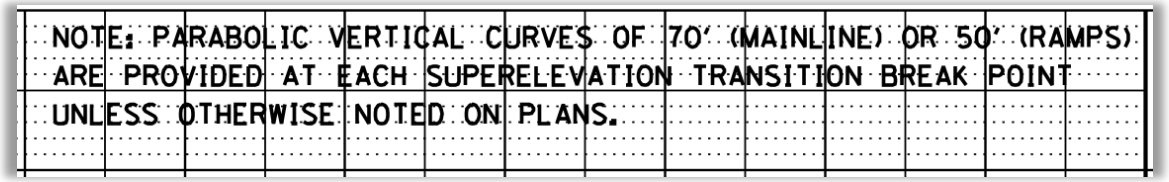
SECTION 1.0 INTRODUCTION

1.1 Illinois Tollway 3-D Paving/Stringless Paving

Modern day construction continues to evolve to improve efficiencies in the field. A construction advancement that maximizes technology is stringless paving (also known as 3-D paving). Whereas, traditional paving required workers to place stakes every 25 feet to guide the machine's paving elevation and grade of the road, stringless paving streamlines this process utilizing electronic guidance to control the paving machine. Overall, stringless paving reduces the time and materials needed compared to traditional paving.

The convenience of stringless paving relies on the accuracy of and adherence to the standards of the designed model. Therefore, a defect in the 3-D model will produce an error in the field, which delays construction and increases expenses. A reoccurring issue with stringless paving is the construction of pavement breaks at superelevation transitions. Traditional construction allowed construction workers to visually smooth out visible breaks at superelevation transitions. When designers disregard the standard to include parabolic transitions at superelevation transitions, the paving machine produces an undesirable pavement break for vehicles.

The Illinois Tollway requires designers to ensure pavement smoothness in their design. **Roadway Design Criteria (RDC) Article 2.5.7 Lane Profile Smoothness** requires superelevation transitions to include a parabolic vertical curve at each lane edge transition break point (70' desirable for Mainline and 50' desirable for Ramps). These transition parabolic curves should be incorporated in the 3-D model and a note shall be included in the Roadway Profile & Superelevation Diagram sheets as shown below (see *Roadway Base Sheet M-RDY-414 Roadway Profile and Superelevation* as an example).



To meet requirements of pavement smoothness during construction, the Illinois Tollway is requiring designers to run an analysis that evaluates the pavement's roughness, measured in IRI. This analysis needs to be submitted as a report in accordance with the submittal requirements in the Design Section Engineer (DSE) manual.

1.2 International Roughness Index (IRI)

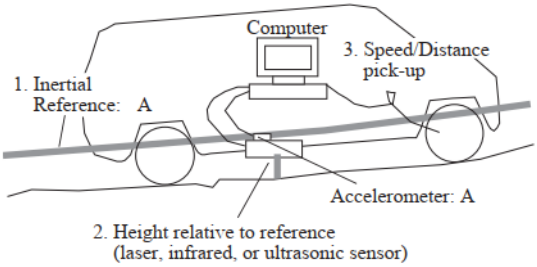
The International Roughness Index (IRI) measures a vehicle's physical response to pavement roughness and has a unit of in/mi. Pavement smoothness directly correlates to rider comfort and is a top priority for the Illinois Tollway in serving its customers. A lane edge profile is analyzed to determine the profile's pavement smoothness (IRI) and reports when there are bumps in the pavement that is physically apparent to drivers (examples of bumps that would affect the IRI includes potholes, pavement cracks, speed bumps and breaks in superelevation transitions).

Objectives of Evaluating IRI:

- *Improve customer experience*
- *Smoother roads have longer life cycle*
- *Smoother roads increase safety*
- *Smoother roads save money by reducing maintenance costs*

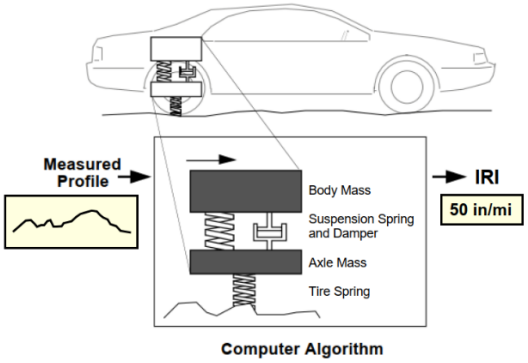
1.2.1 History of IRI Measurement

Transportation agencies have evaluated a pavement's IRI since the 1940s. There have been multiple advancements to the systems that measure a road's profile, from the California Profilograph to inertial road profilers. Currently, agencies use inertial road profilers to measure elevations along a roadway profile. A road profiler has the components of an inertial reference, height relative to reference, speed/distance pick-up, and a computer to calibrate the readings. The profiler's sensors measure the elevation of the roadway along a single point.



Inertial Road Profiler
Source: Little Book of Profiling

Agencies will use data taken by the road profiler and evaluate the pavement profile. Computer programs filter data from the measured profile with the assumptions of the quarter-car. The quarter-car mathematical model computes the suspension deflection of a simulated passenger car. The IRI (in/mi) value is calculated by taking the accumulation of the simulated suspension deflection, divided by the distance. The IRI encapsulates a pavement's ride quality and can depict where a pavement's roughness will impact a vehicle's response.



Inertial Road Profiler
Source. Little Book of Profiling

1.3 Illinois Tollway IRI Criteria

The Illinois Tollway **RDC Article 2.5.7 – Lane Profile Smoothness** outlines the maximum IRI values for its projects. If a design is unable to meet the criteria requirements, a design deviation must be submitted to the Illinois Tollway.

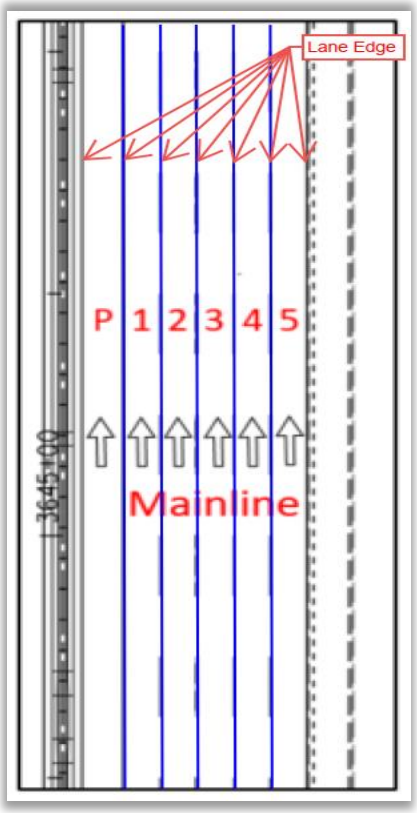
2.5.7 Lane Profile Smoothness

Reconstruction and New Construction Projects	
Mainline, C-D Roadway	IRI value of 30 in./mi. max.
Ramps	IRI value of 50 in./mi. max.
Preservation and Rehabilitation Projects	
Mainline, C-D Roadway	IRI value of 30 in./mi. desired
Ramps	IRI value of 50 in./mi. desired

1.3.1 Mainline Requirements

For mainline and C-D Roadways, designers must evaluate pavement profiles for the following:

- Left edge of preferential lane, if present
- Left edge of pavement (PGL)
- Right edge of each lane
- Right edge of pavement

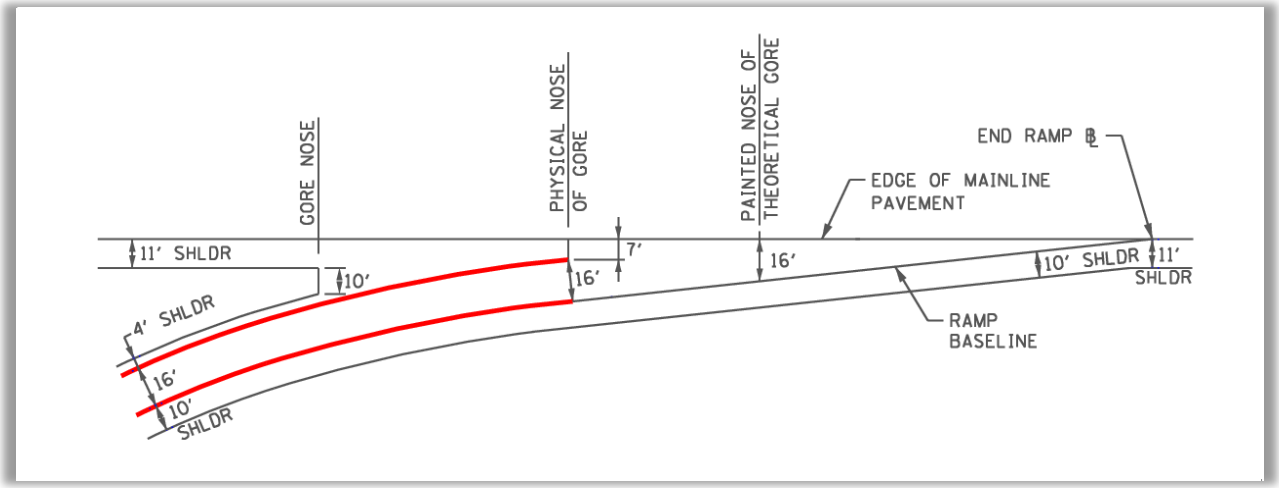


1.3.2 Ramp Requirements

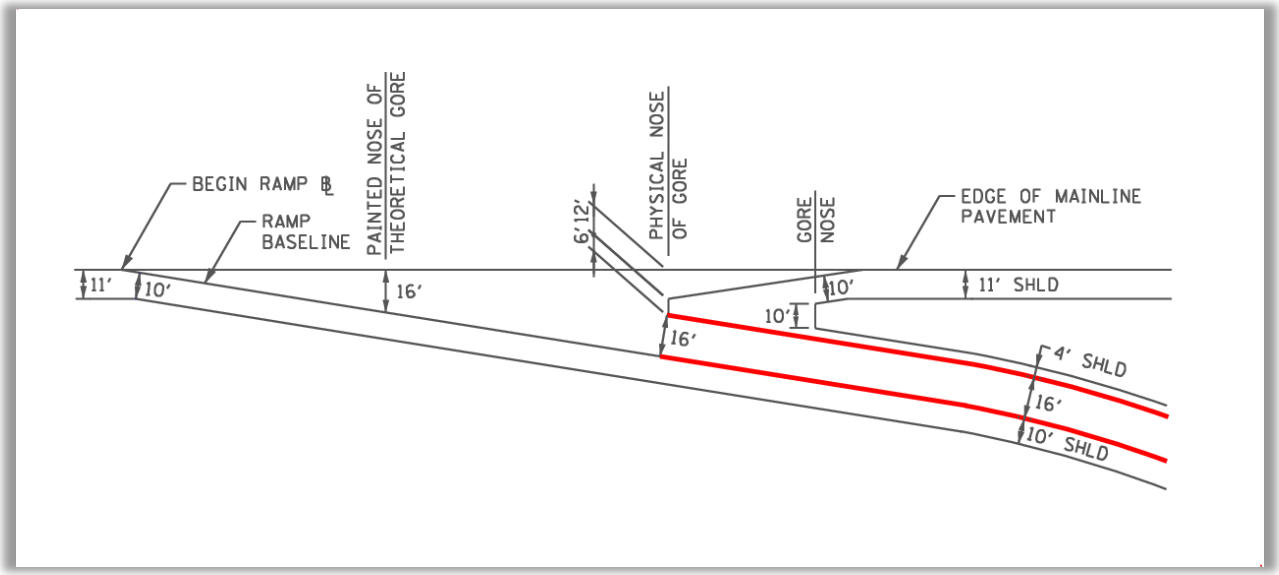
For ramps, designers must evaluate pavement profiles for the following:

- Left edge of pavement
- Lane edge between two lanes (two-lane ramps only)
- Right edge of pavement (Baseline)

Profile along these edges shall extend the entire length of ramp to/from the physical nose of gore.

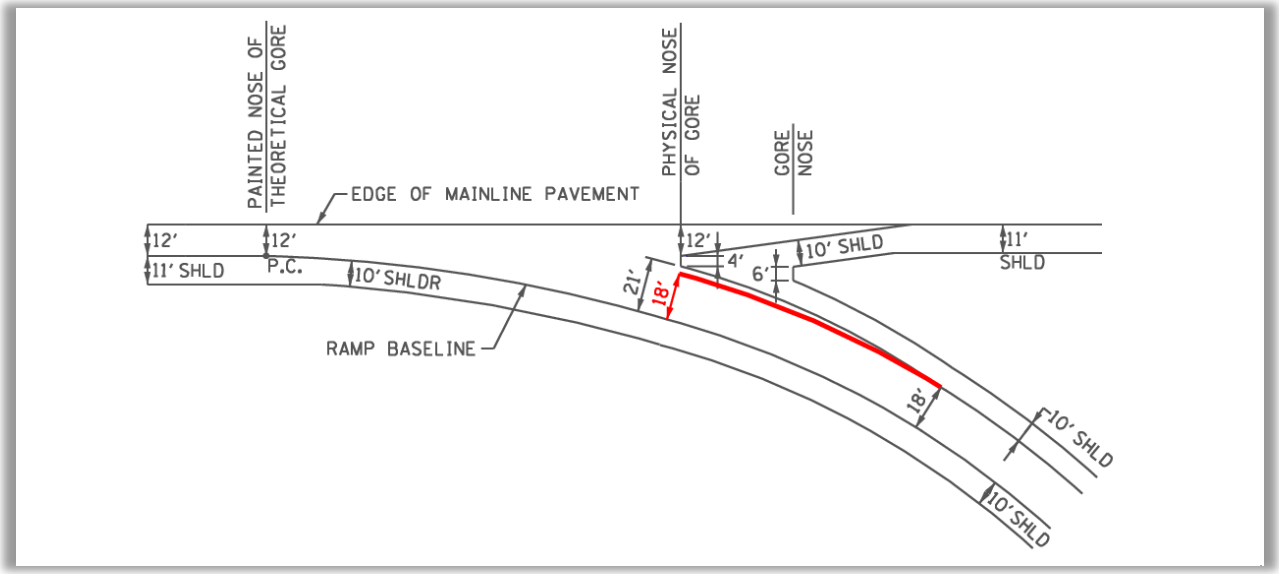


RDC FIGURE 4 TYPICAL ENTRANCE RAMP TERMINAL



RDC FIGURE 5 TYPICAL EXIT RAMP TERMINAL

For parallel exit loop ramps, the profile along the left edge of pavement shall begin at the physical gore where the start point is the theoretical line that is offset 18 feet from the ramp baseline (see figure below).



1.4 Computing IRI During Design with ProVAL

The Illinois Tollway is requiring designers to evaluate their 3-D model during the design stage to ensure pavement smoothness by using ProVAL software.

ProVAL (Profile Viewing and Analysis) is a software program that analyzes longitudinal pavement profiles and generates the profile's IRI value (*directions on how to install and run the ProVAL software can be found in Section 2.2 of this user guide*). Designers will export each lane edge profile from the 3-D model, import the profile elevations into ProVAL, and perform a smoothness assurance report using short continuous analysis to determine if the profile's IRI meets the RDC requirements. Designers shall submit a ProVAL report for each pavement profile at each design milestone submittal as per requirements in the *Design Section Engineers Manual*.

SECTION 2.0 PROVAL USER GUIDE

This step-by-step guide will demonstrate how to:

- Export an edge of lane profile from the corridor
- Analyze the profile in ProVAL to evaluate the IRI
- Tips on adjusting the profile to meet the IRI criteria
- Summarize the deliverable requirements

2.1 Corridor Requirements

2.1.1 Overview of Example Corridor Model

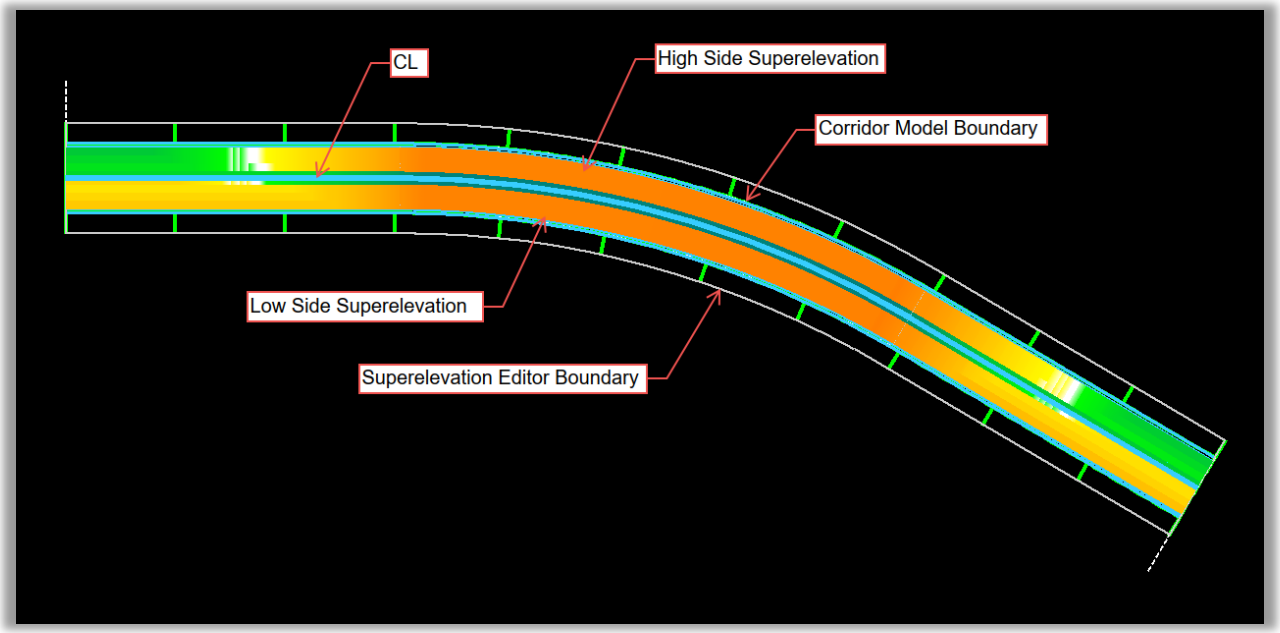
The Tollway has developed an exercise for the user to follow along and understand how to use ProVAL. The example will use a hypothetical 6-lane (including a preferential lane) divided highway. The example section is on a curve that is superelevated at 5.31% (e_{max} = 6%).

Provided Files (Can be found in Illinois Tollway WBPM eBuilder site)
File Path: 0016 WBPM e-Builder Program Wide\Documents\Public Communications\ProVAL

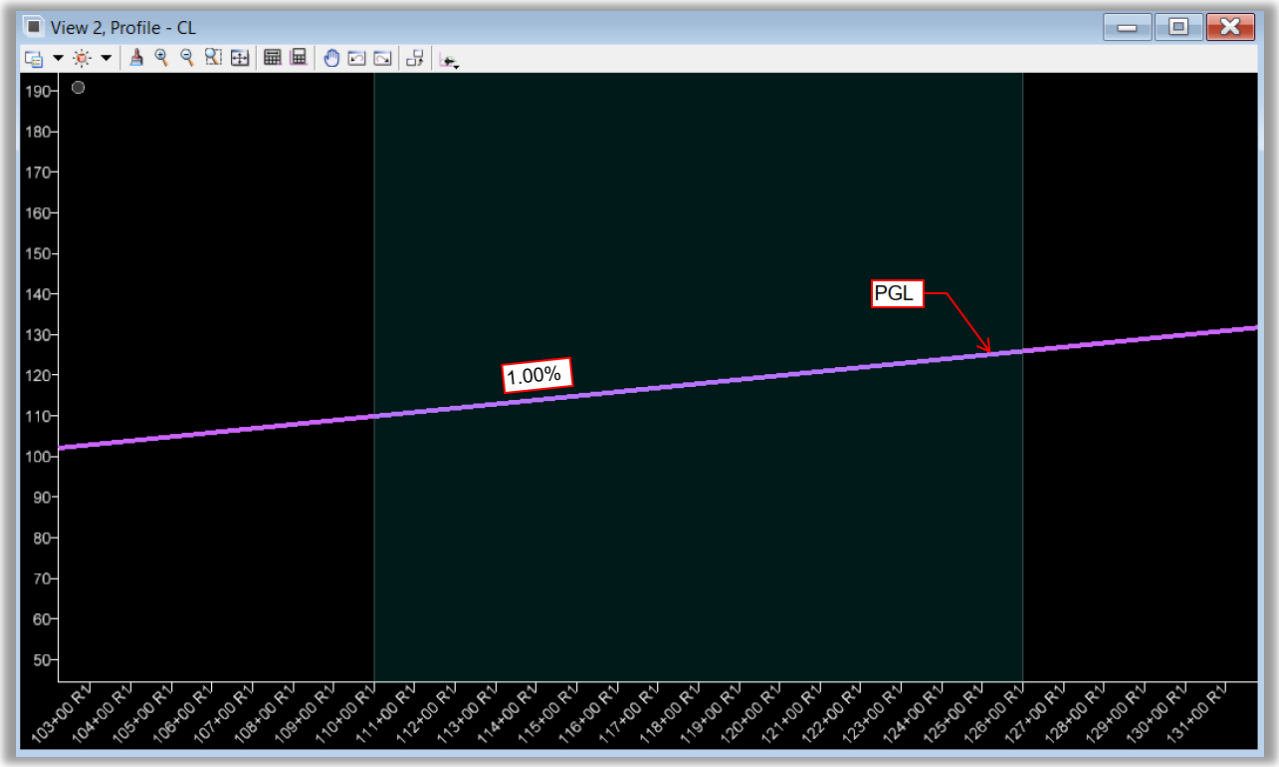
- *Illinois Tollway ProVAL User Guide Example.dgn*
- *ProVAL Report-I294-EB_Lane6_RtEdge.pdf (example final ProVAL Report)*

Open the provided example file in Geopak SS4/SS10. The *corridor model plan view* displays a 6-lane (plus a preferential lane) divided highway including a colored depiction of the pavement cross-slope direction.

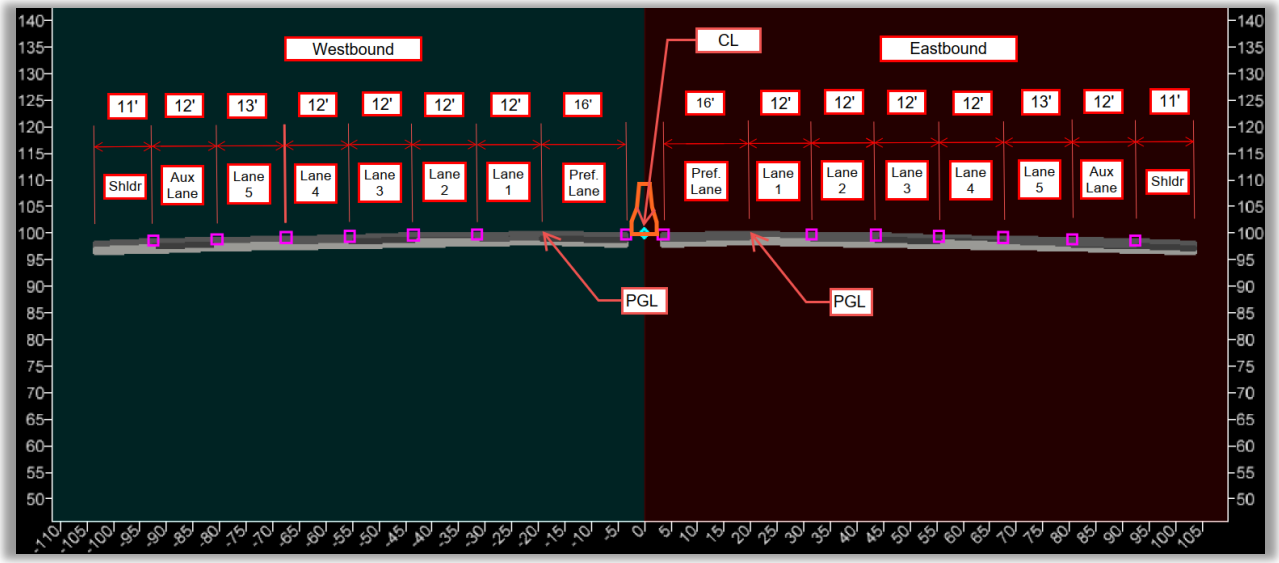
Corridor Model Plan View



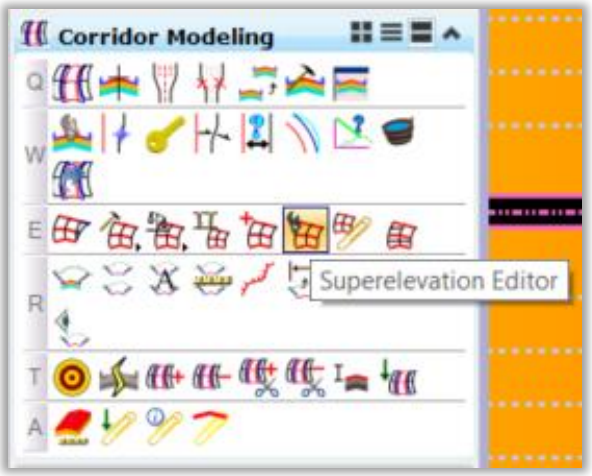
The sample vertical profile is a tangent at 1% upgrade with no vertical curve.



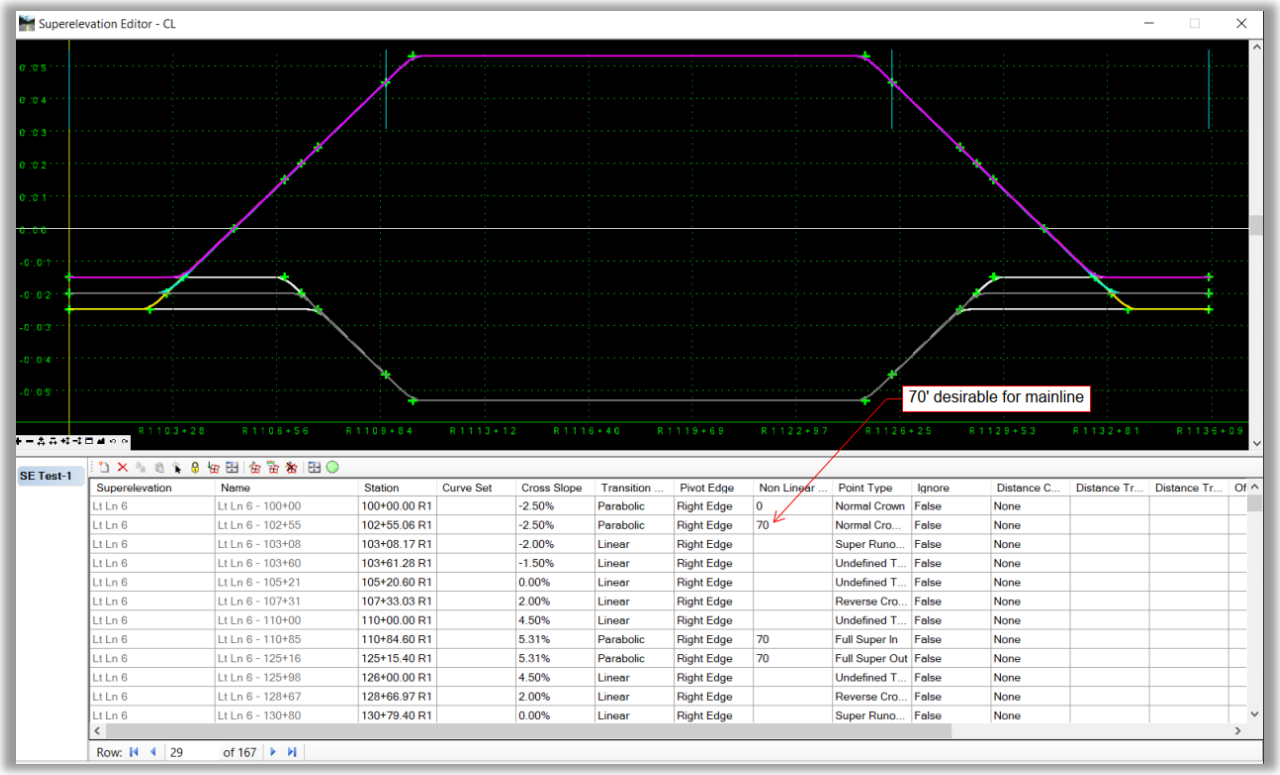
The sample cross-section is a 6-lane section with a preferential lane, and an outside shoulder in each direction.



Go to *Corridor Modeling* from *Civil Tools* and select the *Superelevation Editor,* click on the Superelevation Editor Boundary (See Corridor Model Plan View figure in Section 2.1.1)



The *Superelevation Editor* displays the lane edge transition from normal crown to design superelevation rate. Parabolic curves of 70' length is incorporated at each superelevation transition break point.



Superelevation	Name	Station	Curve Set	Cross Slope	Transition ...	Pivot Edge	Non Linear ...	Point Type	Ignore	Distance C...	Distance Tr...	Distance Tr...	Of
Lt Ln 6	Lt Ln 6 - 100+00	100+00.00 R1		-2.50%	Parabolic	Right Edge	0	Normal Crown	False	None			
Lt Ln 6	Lt Ln 6 - 102+55	102+55.06 R1		-2.50%	Parabolic	Right Edge	70	Normal Cro...	False	None			
Lt Ln 6	Lt Ln 6 - 103+08	103+08.17 R1		-2.00%	Linear	Right Edge		Super Runo...	False	None			
Lt Ln 6	Lt Ln 6 - 103+60	103+61.28 R1		-1.50%	Linear	Right Edge		Undefined T...	False	None			
Lt Ln 6	Lt Ln 6 - 105+21	105+20.60 R1		0.00%	Linear	Right Edge		Undefined T...	False	None			
Lt Ln 6	Lt Ln 6 - 107+31	107+33.03 R1		2.00%	Linear	Right Edge		Reverse Cro...	False	None			
Lt Ln 6	Lt Ln 6 - 110+00	110+00.00 R1		4.50%	Linear	Right Edge		Undefined T...	False	None			
Lt Ln 6	Lt Ln 6 - 110+85	110+84.60 R1		5.31%	Parabolic	Right Edge	70	Full Super In	False	None			
Lt Ln 6	Lt Ln 6 - 125+16	125+15.40 R1		5.31%	Parabolic	Right Edge	70	Full Super Out	False	None			
Lt Ln 6	Lt Ln 6 - 125+98	126+00.00 R1		4.50%	Linear	Right Edge		Undefined T...	False	None			
Lt Ln 6	Lt Ln 6 - 128+67	128+66.97 R1		2.00%	Linear	Right Edge		Reverse Cro...	False	None			
Lt Ln 6	Lt Ln 6 - 130+80	130+79.40 R1		0.00%	Linear	Right Edge		Super Runo...	False	None			

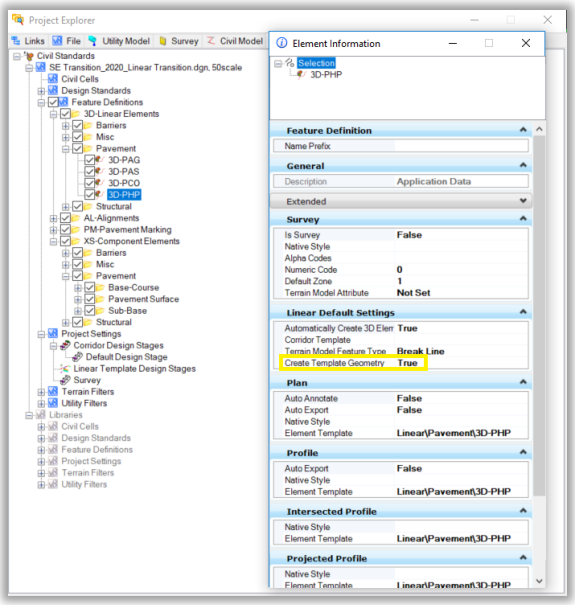
Row: 29 of 167

2.1.2 Change Feature Definition Settings

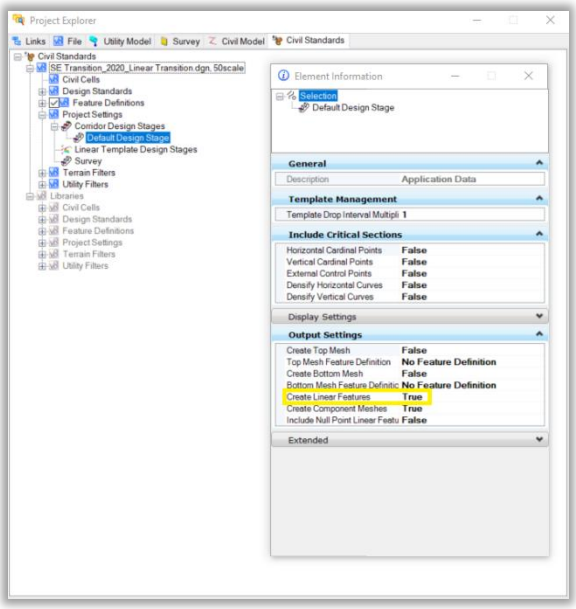
(Note: If you are working on a project that is using 2020 Illinois Tollway CAD Standards or newer, continue to Section 2.1.3)

The profile will be extracted from a corridor feature – a linear element drawn by connecting one of the points in a template from station to station along the corridor.

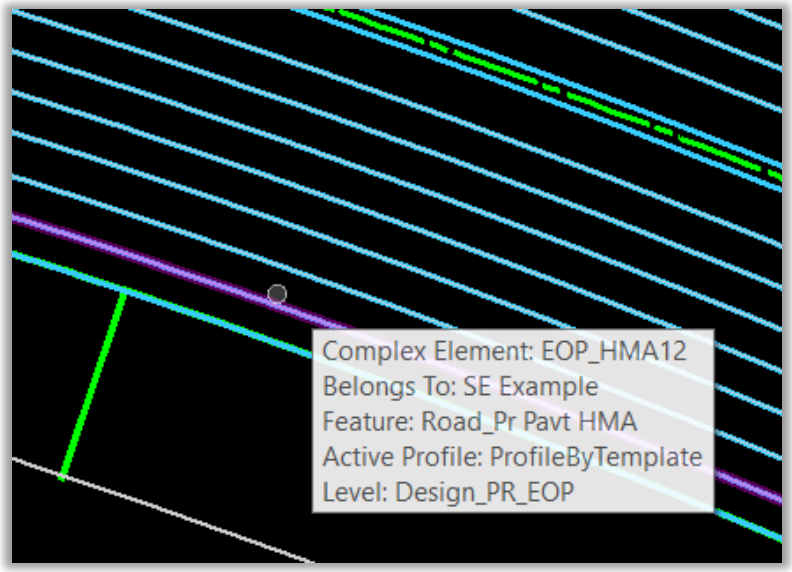
The *Feature Definition* used by the template point must have *Create Template Geometry* set to **True** in *Linear Default Settings.* The Feature used for the pavement edge in this example is **3-D-PHP**. This can be verified through the *Civil Standards* panel on the *Project Explorer*.



The Design Stage used by the corridor must have *Create Linear Features* set to **True** in *Output Settings*. This can be verified through the *Civil Standards* panel on the *Project Explorer*.



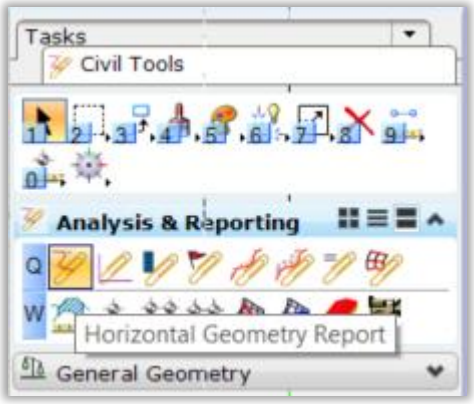
The tooltip will identify the feature as a *Complex Element* named the same as the template point from which it is generated, that belongs to a corridor, with an active profile called **ProfileByTemplate**.



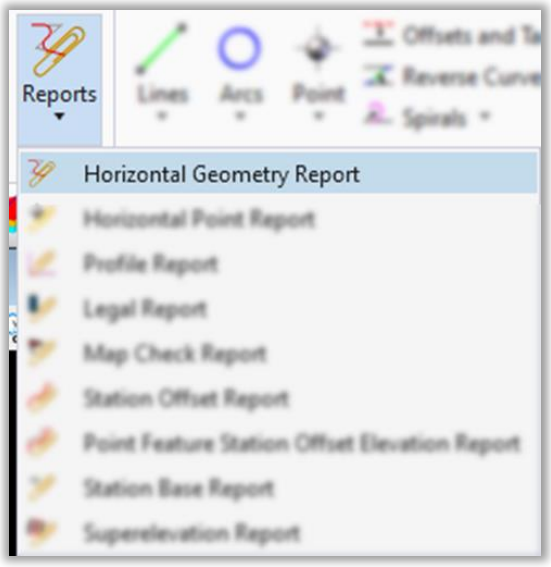
2.1.3 Export Profile Geometry

Go to *Analysis & Reporting* from *Civil Tools* and select the **Horizontal Geometry Report** tool.

Geopak SS4/SS10:

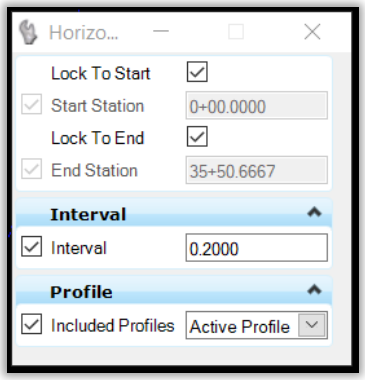


OpenRoads Designer:

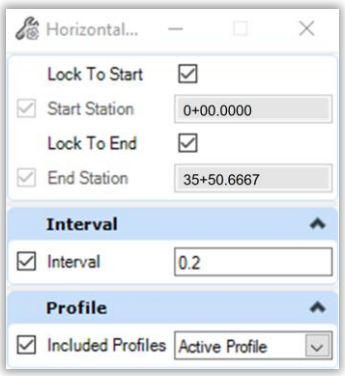


Select the desired 2-D corridor feature to be analyzed and follow the *Horizontal Geometry Report* tool prompts. For this example, select the corridor feature with the *Complex Element: EOP_HMA 12* (edge of right lane).

Geopak SS4/SS10:



OpenRoads Designer:

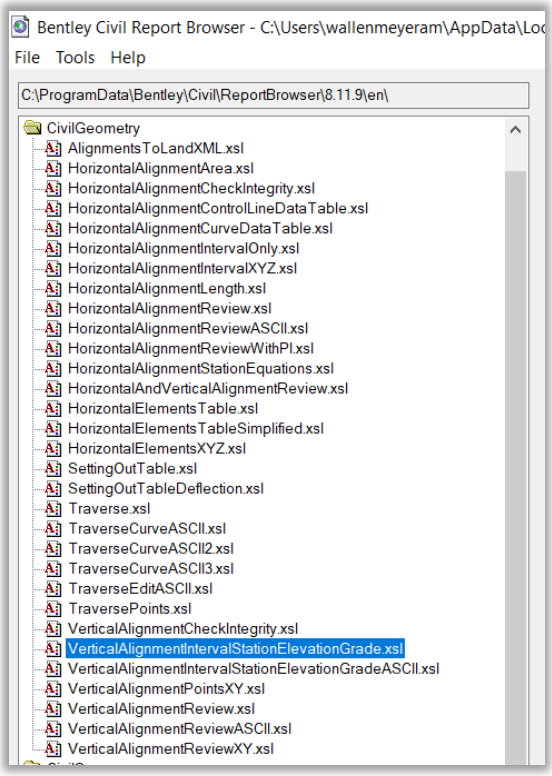


Set the *Interval* to 0.2 (unit is in feet). Check the box for *Included Profiles* and select **Active Profile**.

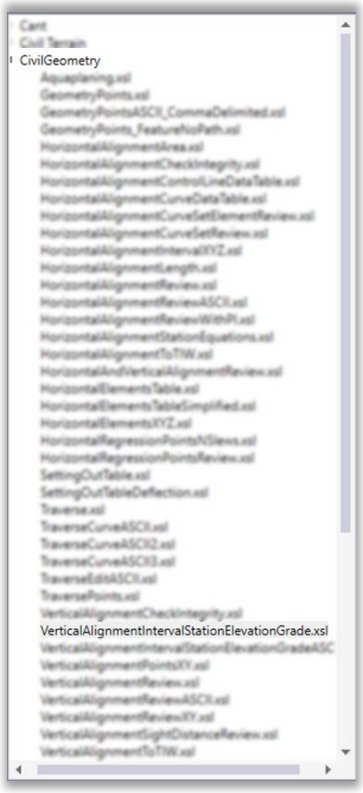
2.1.4 Format the Elevation Data

When the *Civil Report Browser* appears, select **VerticalAlignmentIntervalStationElevationGrade.xsl** from the list of reports.

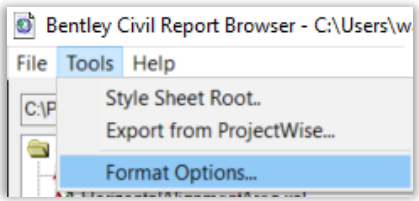
Geopak SS4/SS10:

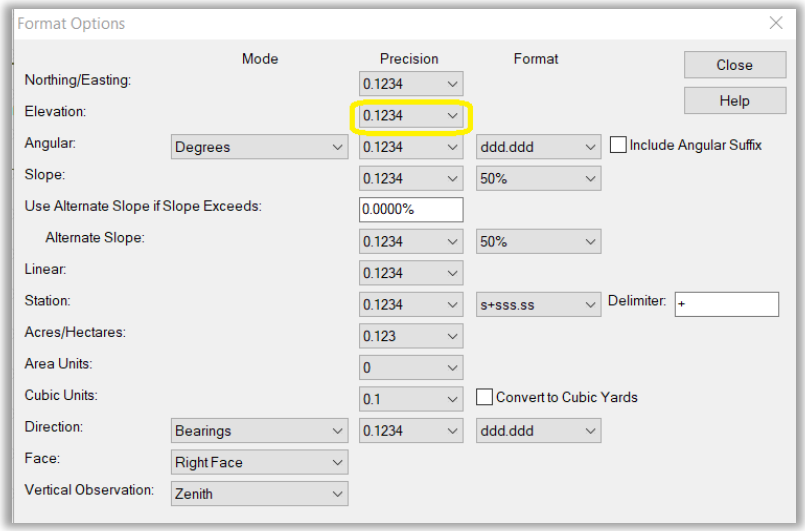


OpenRoads Designer:

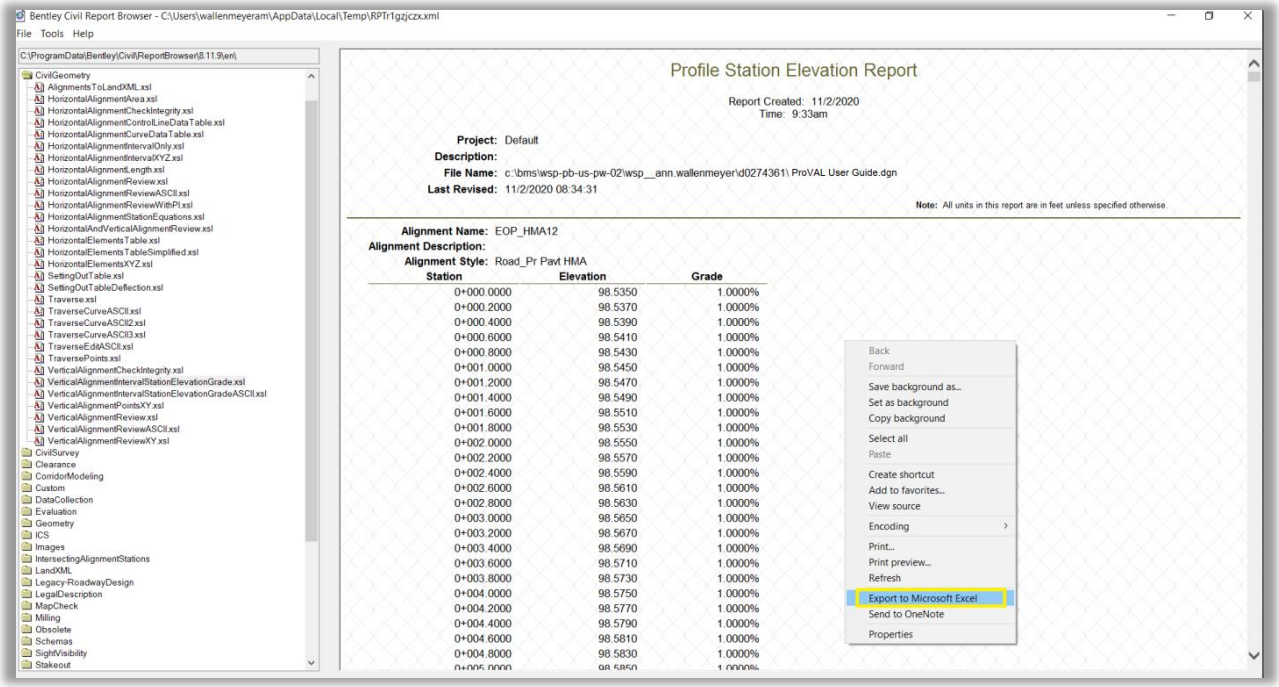


The Profile Station Elevation Report will display the profile elevations along the stationing, as well as the grade. Elevations should be listed to the fourth decimal place at a minimum. The greater the number of decimals the better the accuracy of the results. If necessary, select **Format Options** from the *Tools* drop-down and change the elevation precision to **0.1234.**

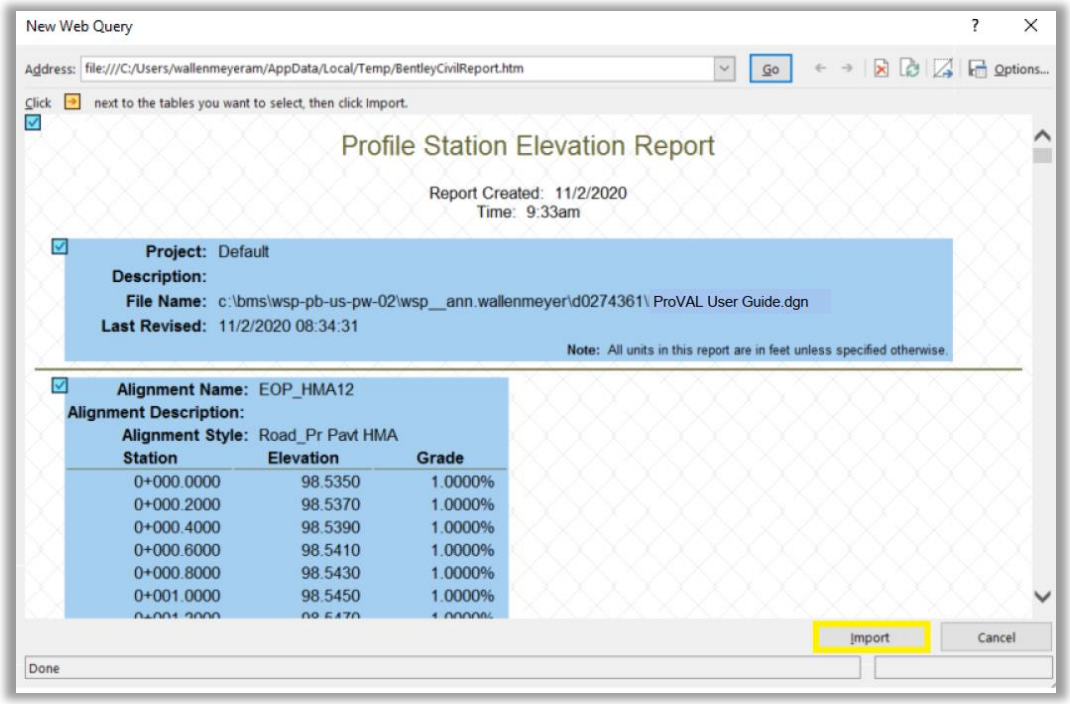




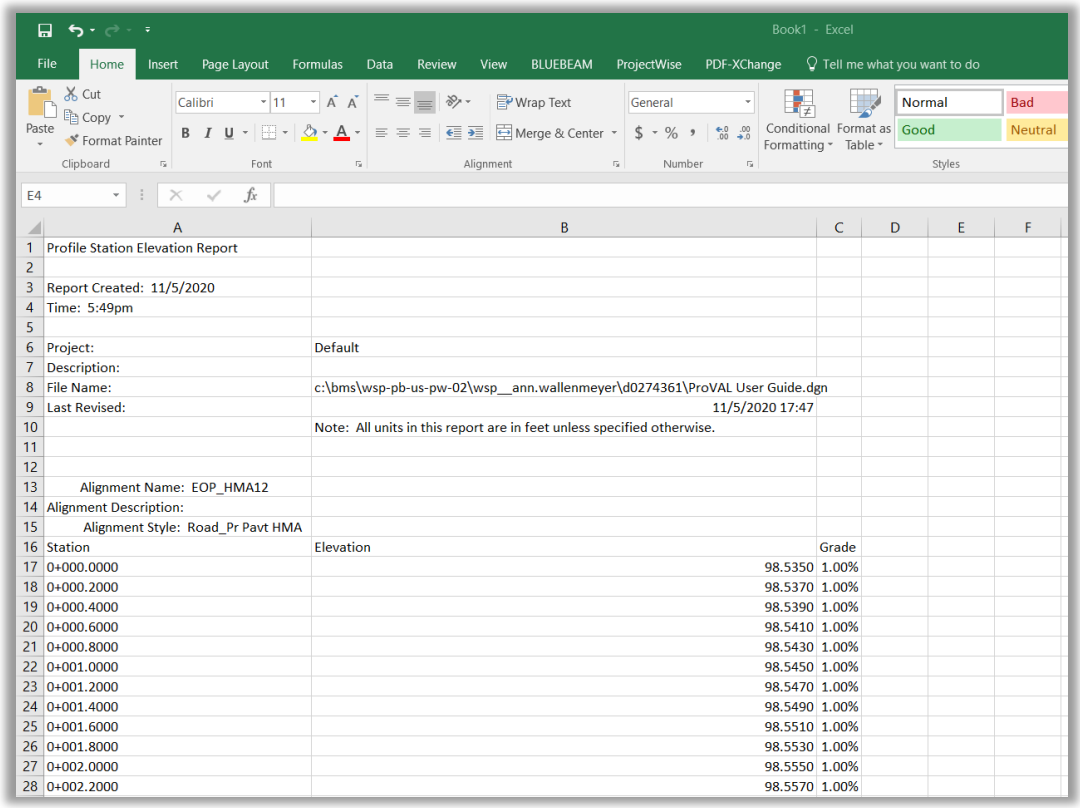
Right-click below the line separating the data from the report header, near the rows of data, and select Export to Microsoft Excel.



In *New Web Query* dialog, check the boxes next to each of the tables and click **Import**.



An Excel spreadsheet will display with the selected information.

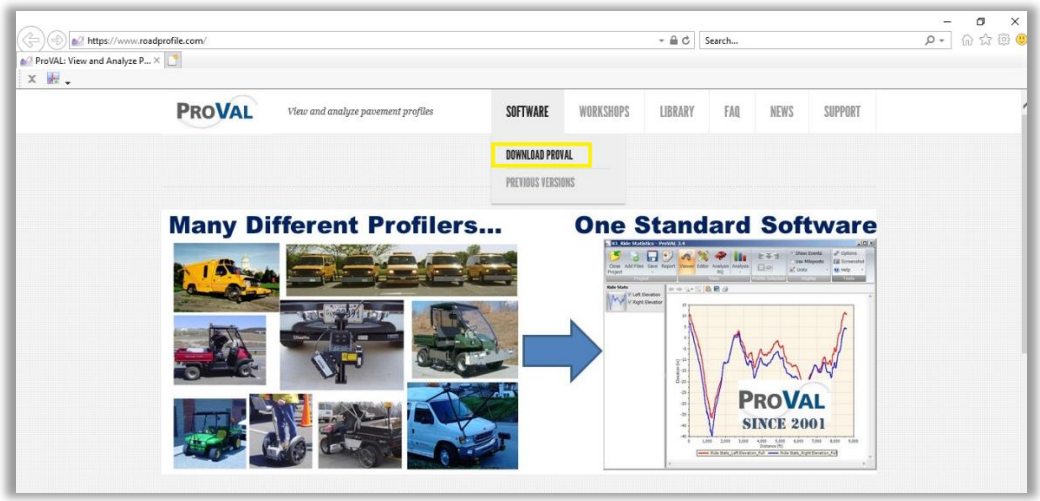


Save the file as EB_Lane6_RtEdge.csv. The .csv file must be closed in order to open in ProVAL.

2.2 Run ProVAL Analysis

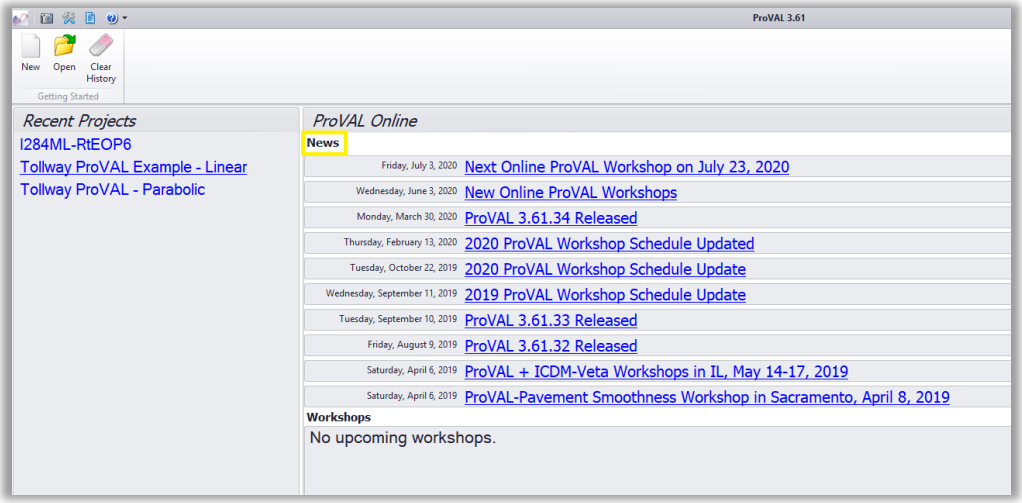
2.2.1 ProVAL Installation

Go to www.RoadProfile.com and select **DOWNLOAD PROVAL** from the *SOFTWARE* drop-down menu. Download the latest version of the ProVAL software. Check for software updates frequently and prior to each DMR submittal to ensure the latest version is installed.

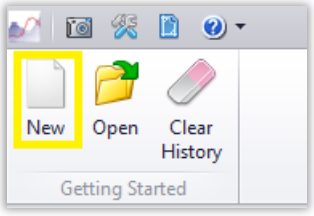


2.2.2 Open ProVAL

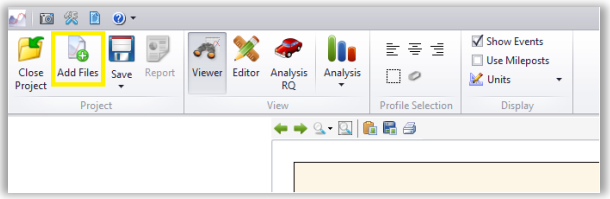
The ProVAL program window will display ProVAL news, future workshops, and recent projects. Software update releases will appear under the News section. Be sure to check the News section to confirm you are using the current version.

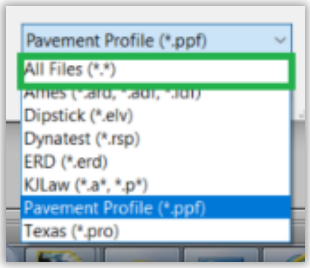


Select **New** start a project.

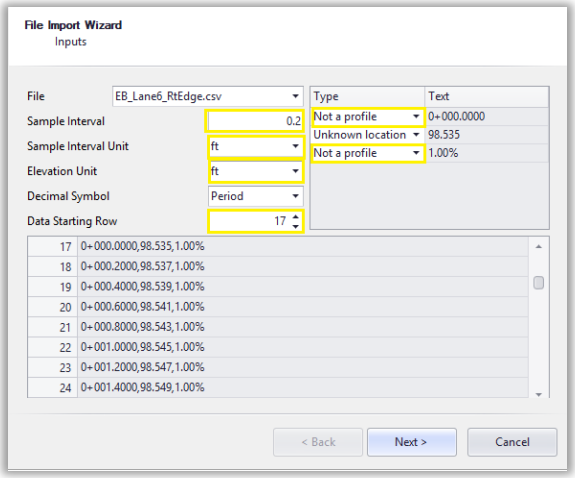


Select **Add Files** and change file selection type to **All Files (*.*)** to select the generated *.csv* file.

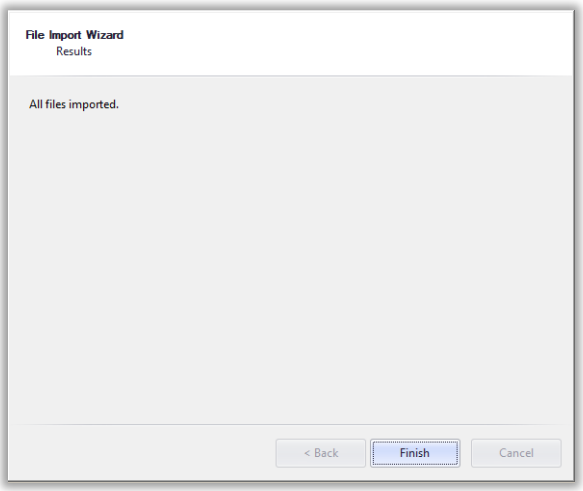




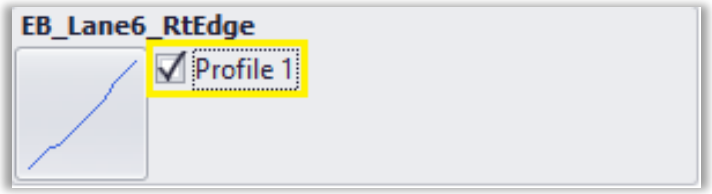
Once the file is loaded, enter the following highlighted inputs in the *File Import Wizard* window and press **Next**.



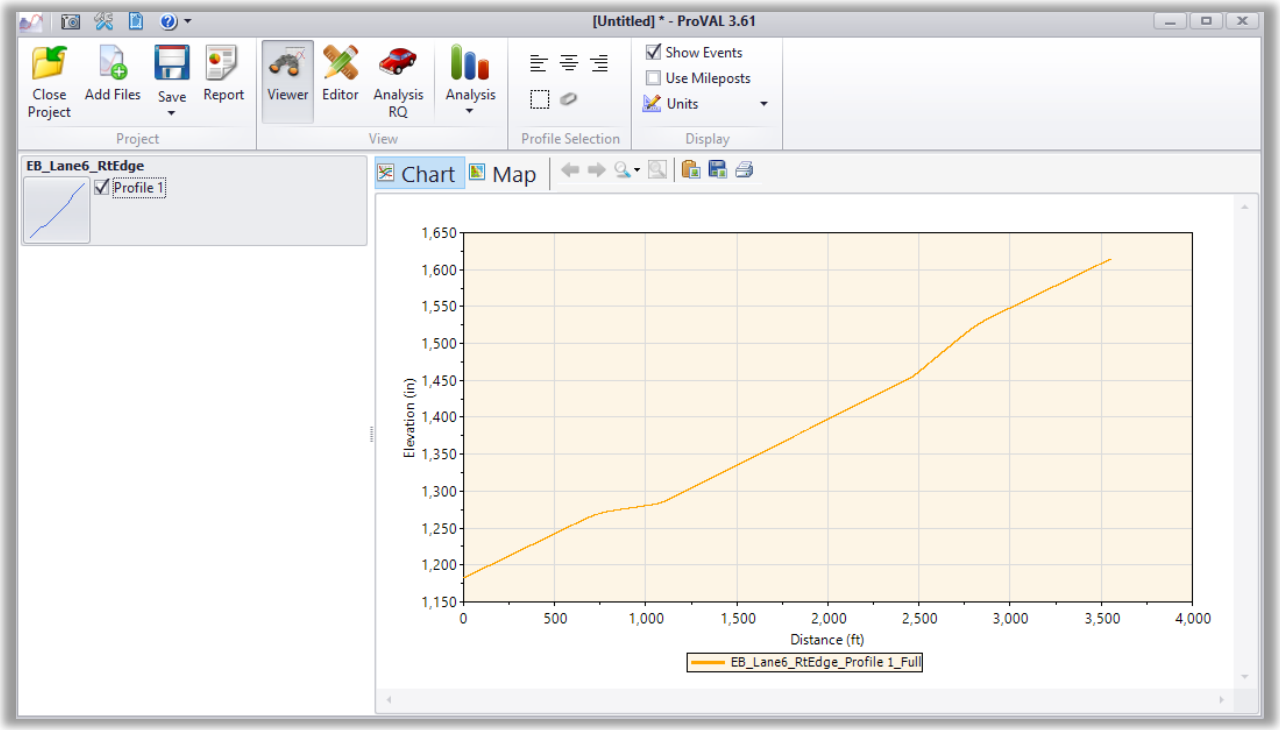
Then, select **Finish**.



The EB_Lane6_RtEdge.*csv* file will display the upper left corner of the window. Select it to view the profile as a chart.



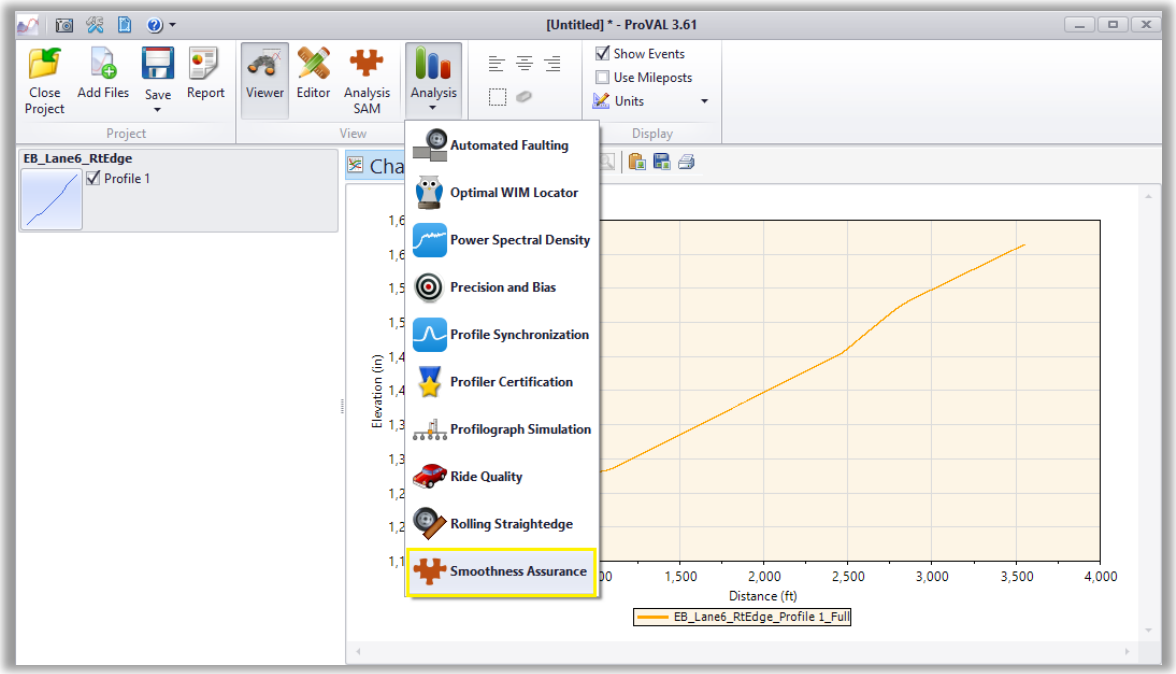
The chart will display the lane edge profile with Distance (ft) along the x-axis and the Elevation (in) along the y-axis.



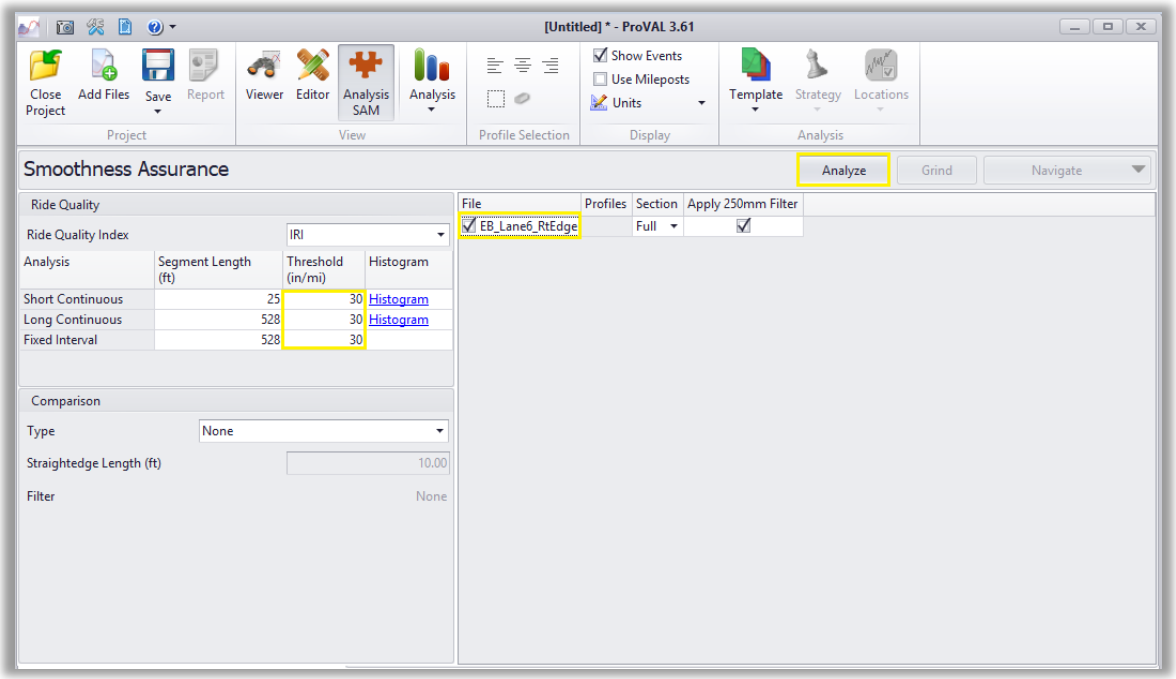
2.2.3 Perform Smoothness Assurance Module

A *Smoothness Assurance* analysis will be performed to analyze the pavement smoothness (IRI) of the profile. The Smoothness Assurance module generates ride quality reports by evaluating edge of lane profiles exported from the corridor model.

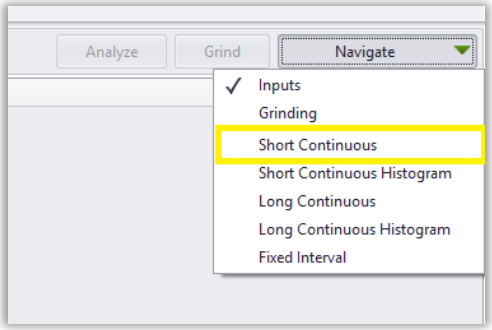
Select **Smoothness Assurance** from the *Analysis* menu.



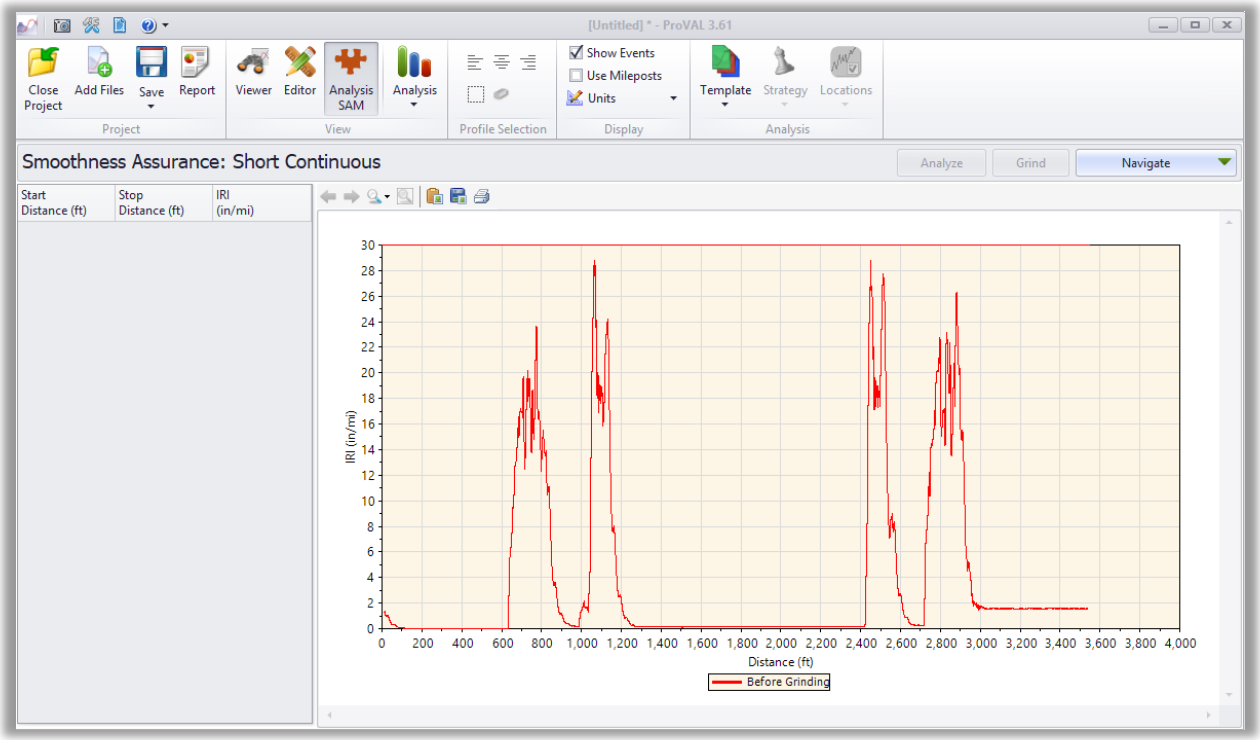
A *Smoothness Assurance* window appears. Adjust the IRI Threshold to be 30 in/mi (mainline roadway). (The Threshold for a ramp is 50 in/mi). Select the *EB_Lane6_RtEdge*, then click **Analyze**.



An analysis will run, which will activate the *Navigate* selection. Select **Short Continuous** from the *Navigate* drop down menu. The *Short Continuous* analysis indicates localized roughness and navigates locations of bumps in the pavement. The *Long Continuous* analysis evaluates the general condition of the pavement.



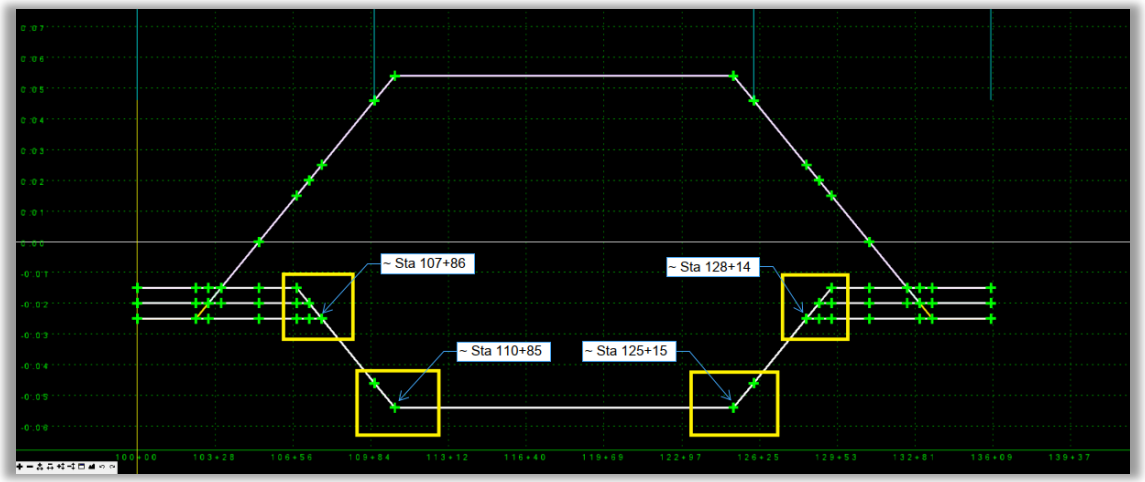
The results from the Smoothness Assurance Short Continuous analysis will be presented as a chart that displays the Distance (ft) along the x-axis and the IRI (in/mile) along the y-axis. The IRI threshold is shown as a red straight line along 30 in/mi.



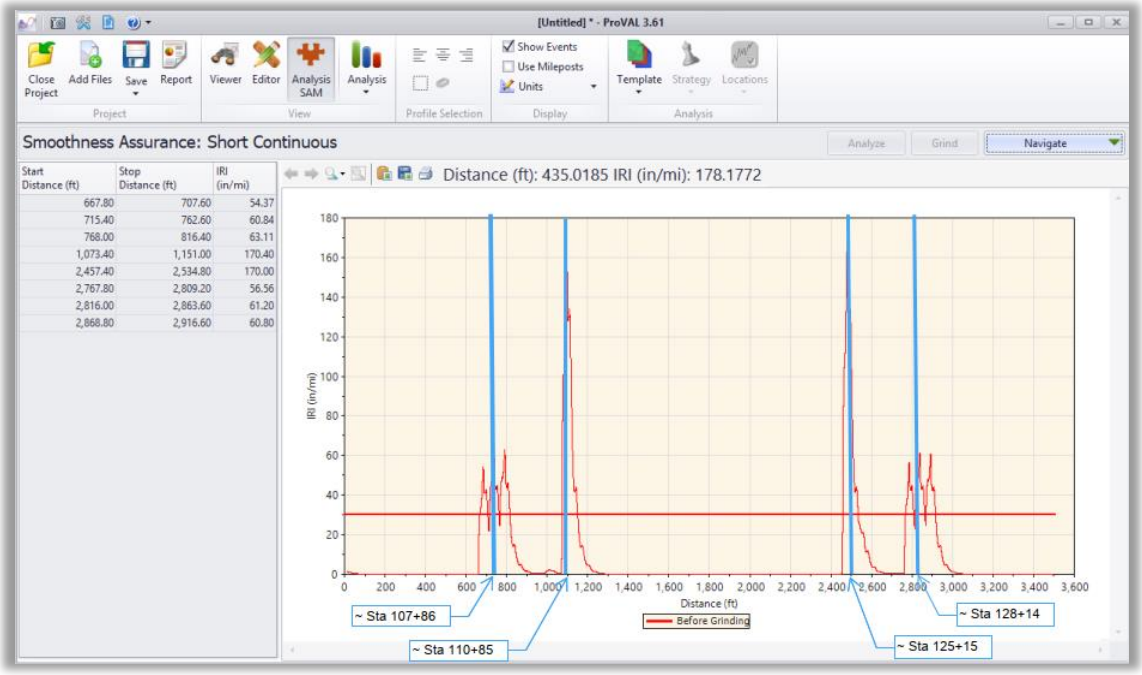
The peaks on the smoothness assurance graph are below the 30 in/mi IRI threshold and hence meets RDC requirements for mainline.

Comparative Analysis (For information only, proceed to Sec. 2.2.4 to continue user guide steps.)

The following is a comparative analysis showing the effects of not including the parabolic curve at the superelevation transition break points. Let's take the same corridor and *EOP_HMA 12* example but remove the parabolic curves at the superelevation transition breaks. The *Superelevation Editor* below contains linear transitions for each superelevation break.



After repeating the steps of exporting the profile geometry and performing the Smoothness Assurance Module for this scenario, the ProVAL results yield peaks well in excess of the 30 in/mi IRI at STA 107+86, STA 110+85, STA 125+15, and STA 128+14, which correspond to the SE transition breakpoints in the above *Superelevation Editor*.

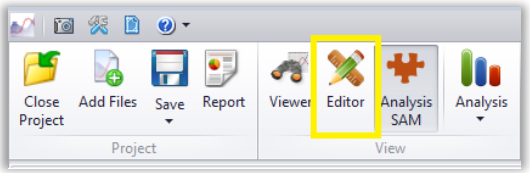


These stations in the *Superelevation Editor* in Geopak SS4/SS10 align with the locations of the superelevation break points. Vehicles traveling at these locations would experience undesirable bumps at the breaks. This supports the importance of incorporating vertical parabolic curves at superelevation breaks to ensure pavement smoothness for vehicles.

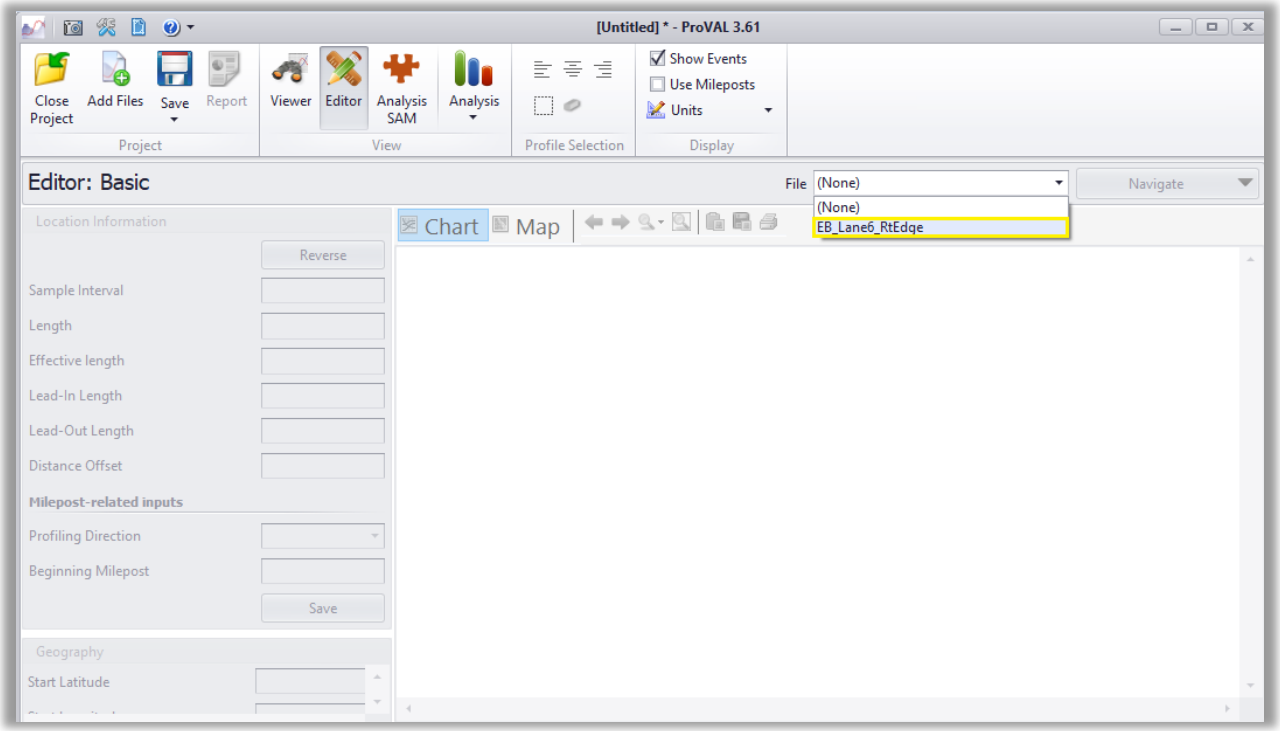
2.2.4 Change Distance Along X-Axis

When the Smoothness Assurance Module analysis is performed, the starting distance on the x-axis is 0 feet. The following steps describes how to change the starting distance on the x-axis to match the starting station of the profile.

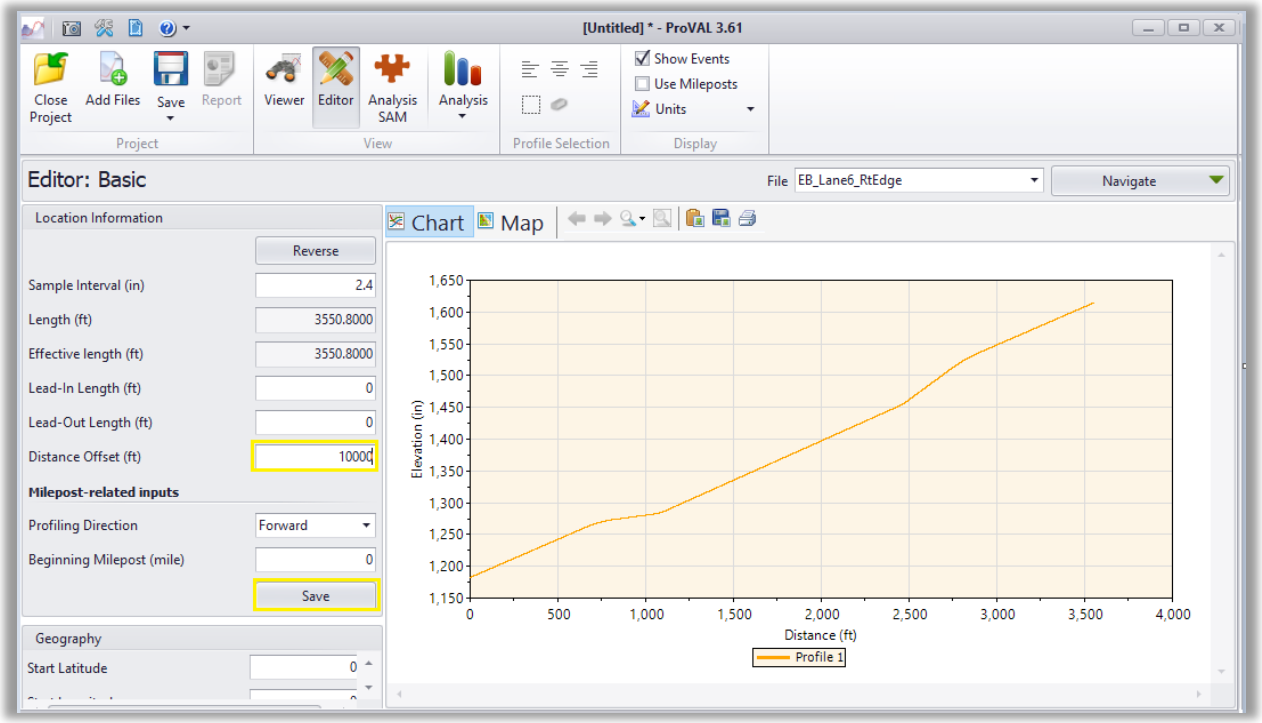
First, select *Editor*.



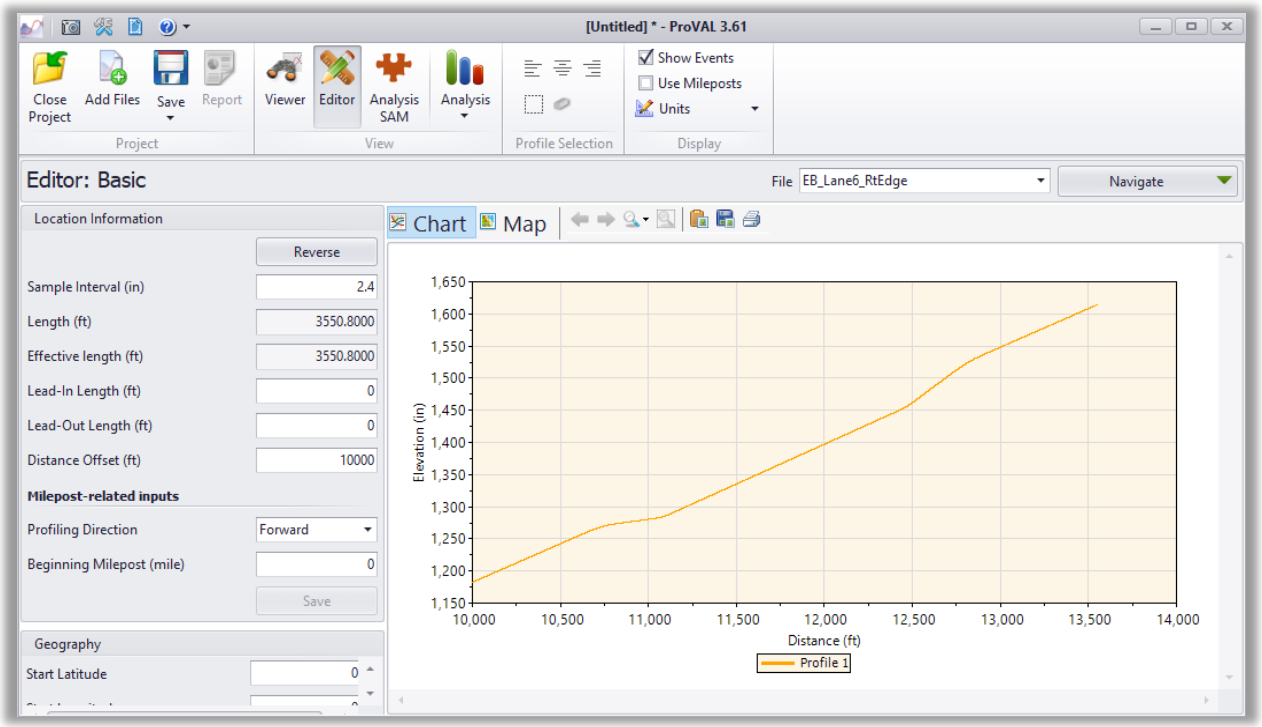
When the *Editor* view appears, select the **EB_Lane6_RtEdge** profile from the *File* menu.



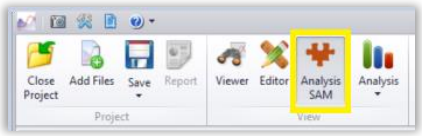
In the *Location Information* section, type the starting station (STA 100+00 = **10000**) in the *Distance Offset (ft).* Then press *Save*.



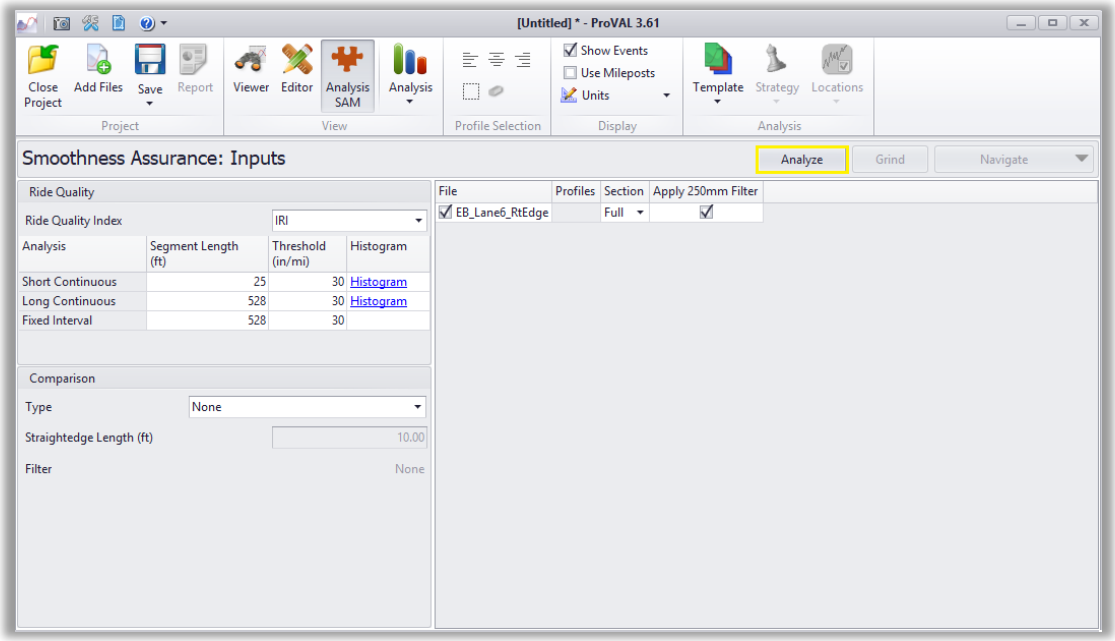
The distance along the X-axis will be adjusted to reflect the starting station of the project.



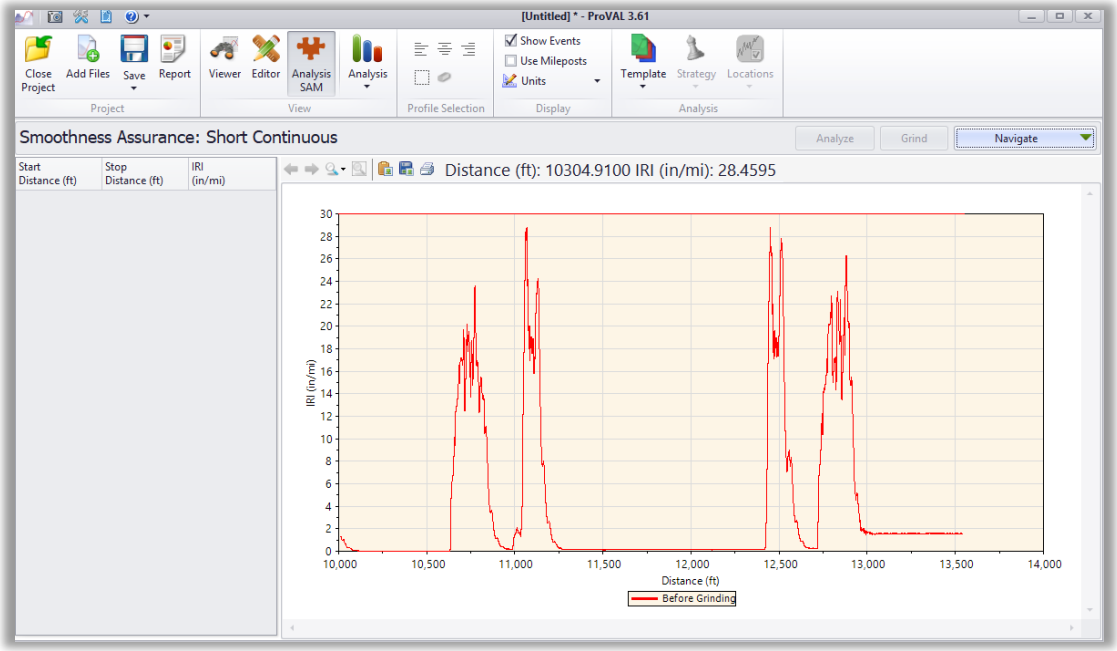
Click Analysis *SAM* to go back to the *Smoothness Assurance Module*.



Press *Analyze*. (Refer to Section 2.2.3 for steps on performing the Smoothness Assurance Analysis)

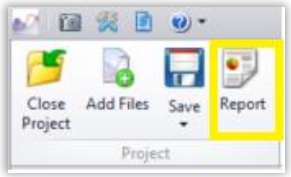


The Smoothness Assurance Short Continuous graph X-axis distance is now updated to align with the profile stationing.

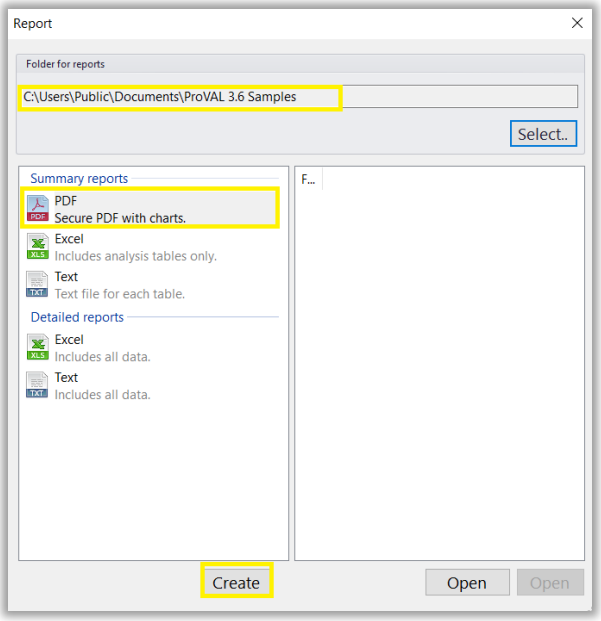


2.2.5 Create ProVAL Report

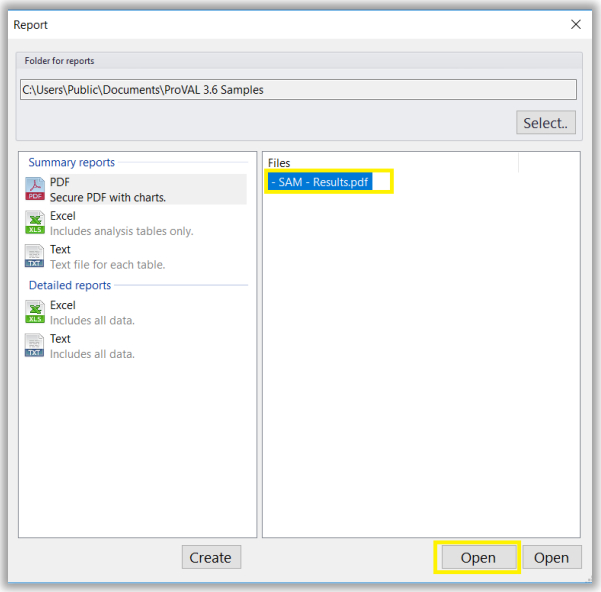
Select **Report** to create a ProVAL Report.



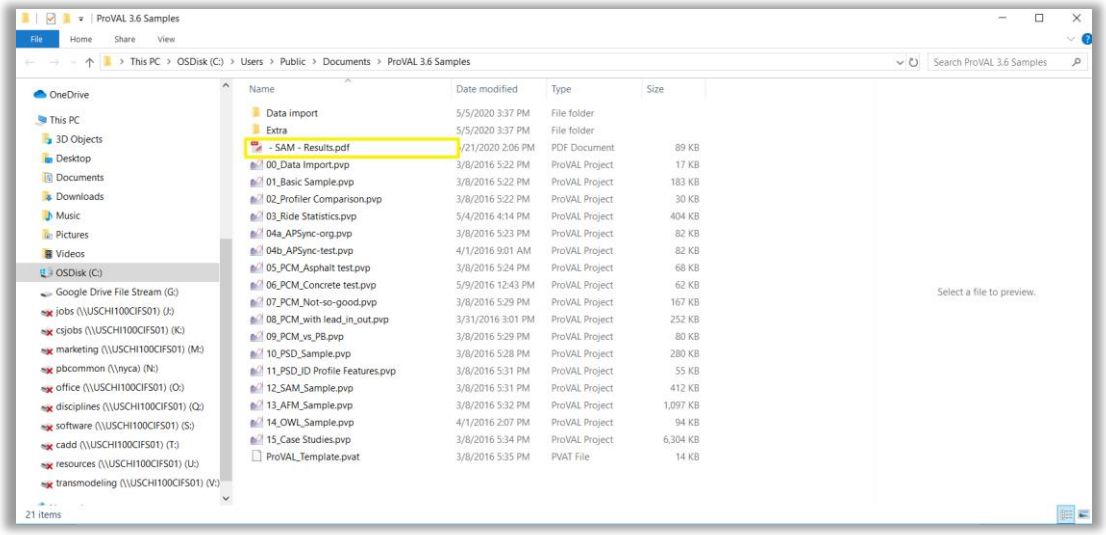
Select a folder to export the ProVAL report. Then, select *PDF* and click **Create.**



Once the report is generated, a file will display in the *Files* window. Select the *– SAM – Results.pdf* and click **Open**.



A *File Explorer* window will appear showing the location of the report.



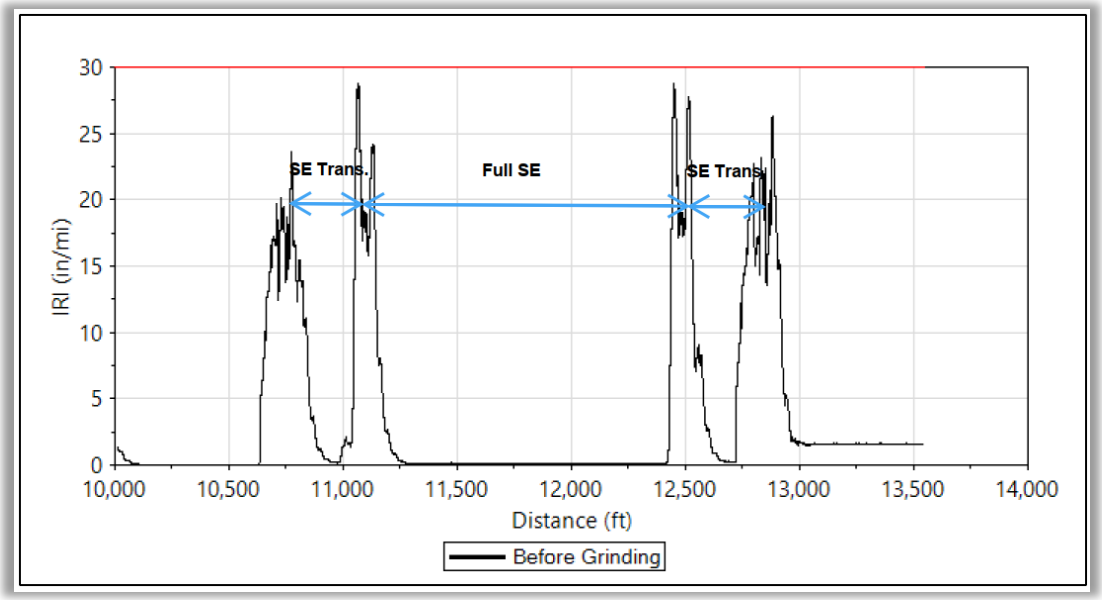
Rename the file to "*ProVAL Report-I294-EB_Lane6_RtEdge.pdf*" (sample file can be found in eBuilder – refer to section 2.1.1). The file naming convention shall be as follows: ProVAL Report–Roadway Name–Direction_Lane Number_Rt/Lt Edge.pdf.

2.2.6 Labeling ProVAL Report

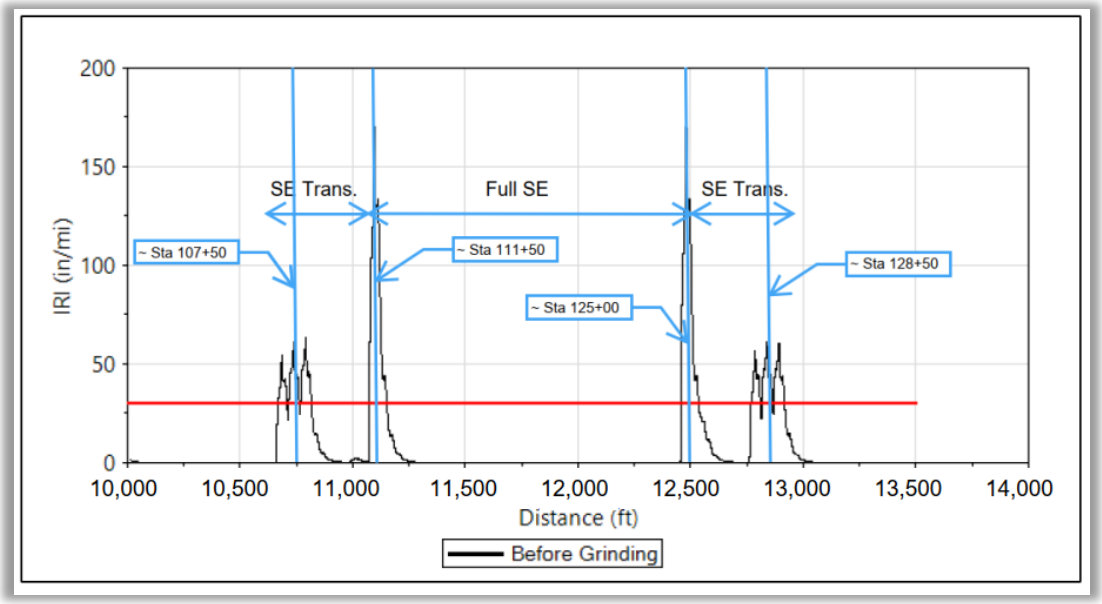
Before submitting the ProVAL Report(s) to the Illinois Tollway, please edit the .pdf report to include the following labels:

1. As outlined in section **2.2.4 Change Distance Along X-Axis,** update the distance along the X-axis to match profile stationing.

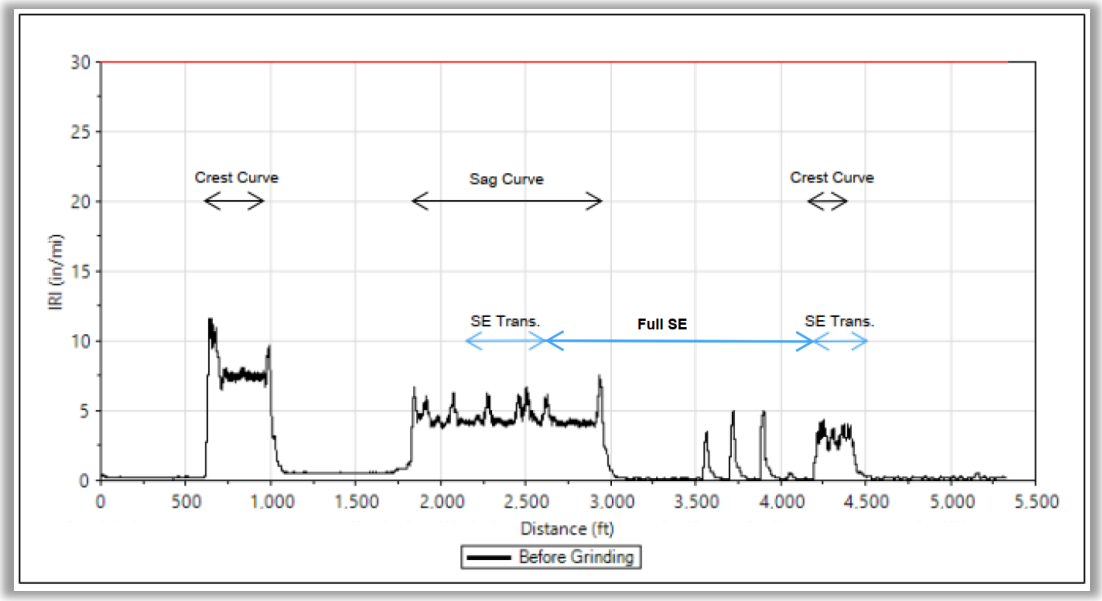
2. Label the locations of the *SE Transitions* and *Full SE.*



3. If there are spikes in the graph that are above the IRI threshold, label the station locations.



4. If vertical curves are present on the project, label the locations of vertical curves and denote if they are a sag or crest curve.



This process of exporting the geometry from corridor model, analyzing with ProVAL, and submitting a ProVAL report should be repeated for each edge of lane. For further details on mainline and ramp requirements, refer to Roadway Design Criteria Article 2.5.7.

2.3 IRI Exceeds Design Criteria

2.3.1 Troubleshooting Design to Meet IRI Requirements

Designers may need to adjust their design to lower the IRI value of the pavement profiles. The following list provides possible solutions on how to decrease a profile's IRI value**:**

- Increase superelevation parabolic curve length
- Adjust the grade of profile
- Adjust length of the profile's vertical curve
- Increase the superelevation transition length (i.e. increase the rate of transition but maintaining the same distribution ratio as required by the *Roadway Design Criteria Manual*. If this is one of the solutions, the DSE is requested to discuss this with the Tollway GEC and get it approved prior to implementing it.)

2.3.2 Design Deviation

If the design is unable to meet the Illinois Tollway criteria, a design deviation must be submitted for approval. In the ProVAL Report, label the stations where the IRI is exceeded on the graph. The report shall be in pdf format and submitted to the Illinois Tollway as per requirements of the *Design Section Engineers Manual*.