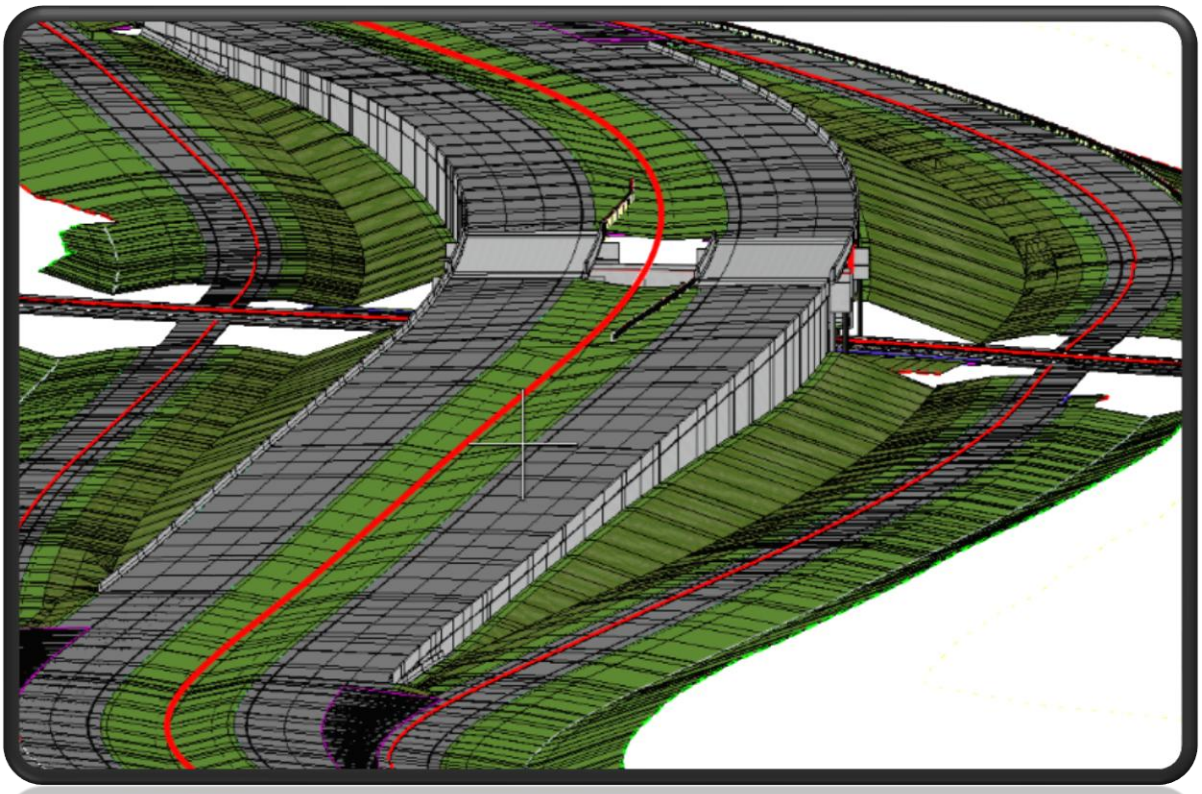


Module 12
Interchange
July 2025

This page intentionally left blank.

About this practice workbook

This PDF file includes bookmarks providing an overview of the document. Click on the bookmark to quickly jump to any section in the file. You may have to turn on the bookmark function in your PDF viewer, such as Adobe Reader.

The Module 12 - Interchange.zip file should be extracted to the root C:\.

All CADD and PDF files are to be accessed at C:\NCDOT Training\Roadway\ Module 12 - Interchange.

All datasets used throughout this module used English units and U.S. Survey Feet.

This module was developed and tested using the latest NCDOT OpenX workspace and OpenRoads Designer 2023

The NCDOT_WorkSets.inp on your desktop should be set to the following variables:

NCDOT_USE_LOCAL_WORKSETS = L2
NCDOT_UNIT_TRAINING_WORKSETS = Roadway

This training module used the DOT-US North Carolina WorkSpace, Training-Rd_R2635C Workset and NCDOT_Roadway Role. These modules were developed with State STIP projects R-2635C. All training files have been updated to be included in the training Workset but retain the STIP project number.

The tool tips and help were copied from Bentley Online Help. See this link for the complete list of tools and common usage.

OpenRoads Designer CONNECT Edition Help (bentley.com)

This module assumes the reader has either completed or can reference all previous training modules referenced herein.

At the development of this module, the refenced survey file (_FS_) was completed in legacy V8i format. Standard ORD survey delivery will vary slightly from what is presented in this module.

This workbook has been written with the NCDOT Roadway Design Manual (RDM) and NCDOT Structures Management Unit Design Manual (SMU).

All training modules are posted on NCDOT Connect at the Roadway Design page.

Legend:

Working Files
Navigation/Selection Guidance
Online Hyperlinks (NCDOT Connect Site Only)
Local Document Reference Link

Table of Contents

This page intentionally left blank.

1.0 Overview

The intent of Interchange is to lean on the lessons learned from the previous modules and to introduce tools and methods that can be used when modeling or designing different elements of a typical interchange. The means and methods introduced in this model do not replace the guidelines set forth by AASHTO for the geometric design of the nation's highways. Several specialized templates have been created and will be presented to provide design controls to set alignments and grades as well as validate designs. Additionally, several techniques will be introduced to improve processes such as earthwork calculations, clearance checks, infield modeling and more.

1.1 Geometry Ribbon

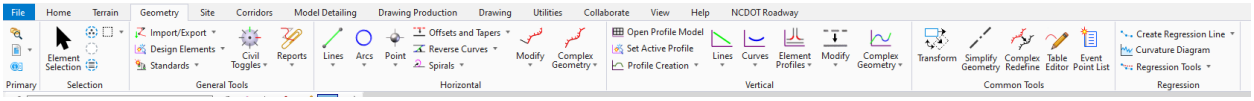


Figure 1-1: Geometry Ribbon

1.2 Corridors Ribbon

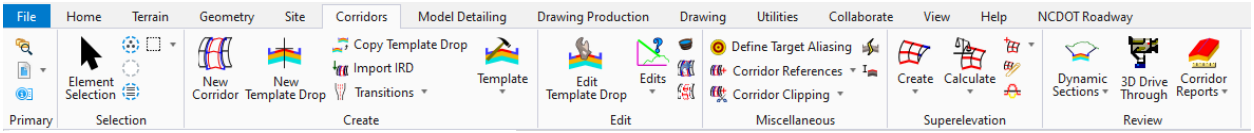


Figure 1-2: Corridors Ribbon

1.3 Modeling Detailing Ribbon

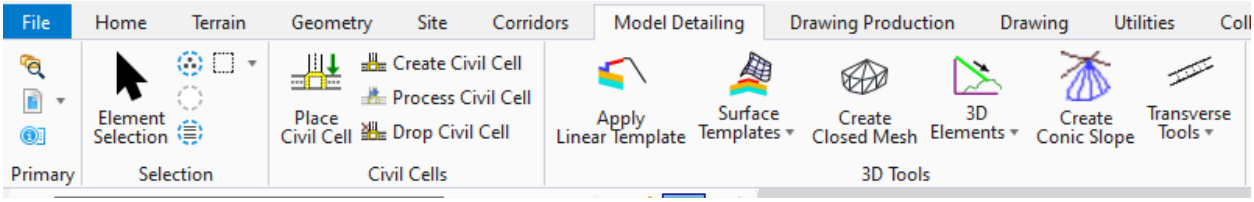


Figure 1-3: Model Detailing Ribbon

1.4 Terrain Ribbon

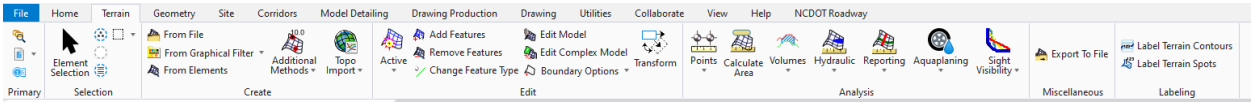


Figure 1-4: Terrain Ribbon

1.5 Drawing Production Ribbon

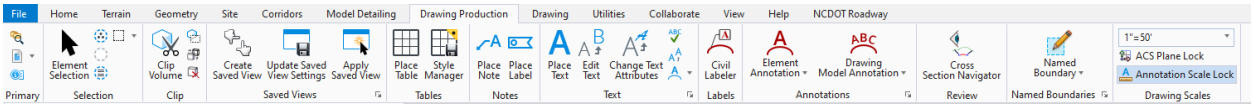


Figure 1-5: Drawing Production Ribbon

1.6 Collaborate Ribbon

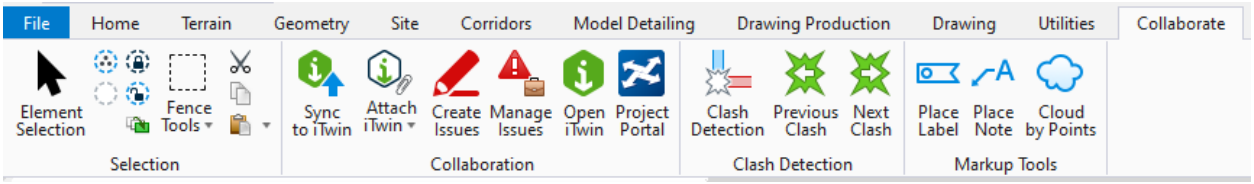


Figure 1-6: Collaborate Ribbon

1.7 Key Concepts, Tools, and Terminology

1.7.1 Design Intent

Design intent is the act of preserving rules and relationships established during the design process to realize downstream benefits of automatic updates.

The information provided in these exercises are not intended to replace typical design controls and procedures.

1.7.2 Linear Templates

Templates that can be applied quickly and easily to 3D linear elements but with less functionality when compared to corridor templates.

1.7.3 Surface Templates

A template made of components with an associated depth. These components are closed shapes such as asphalt, concrete, aggregate, grass etc. Surface Templates are used to apply material thickness to the surface of a terrain.

1.7.4 Terrain Modeling

A set of three-dimensional triangles mathematically computed from point data collected on the surface being modeled. Models are used to define highly irregular surfaces, particularly the surface of earth, but can be generated for proposed surface, subsurface geotechnical layers, etc. Terrain models are also preferred to as digital terrain models (DTMs), triangulated irregular networks (TINs), or triangulated surfaces.

2.0 Interchange Design Tools

2.1 Exercises Overview

Unlike previous modules, this training is a set of multiple exercises aimed at presenting many different trainings within a single module. The working files are contained within the same folder.

In each exercise, you will follow each lesson and complete each outcome using predefined horizontal and vertical geometry and predefined roadway corridors.

The mainline -L- carries our interchange bridge over the Y line.

Complete the following procedure prior to starting each training exercise:

1. **Launch OpenRoads Designer Connect Edition**
   Double-click on the NCDOT OpenRoads Designer 2023 to launch OpenRoads Designer.

2. **Select the Workspace and WorkSet**
   Select DOT-US North Carolina from the Workspace menu.
   Select Training-RD_R-2635C from the Workset menu.
   Select NCDOT_Roadway from the Role menu.

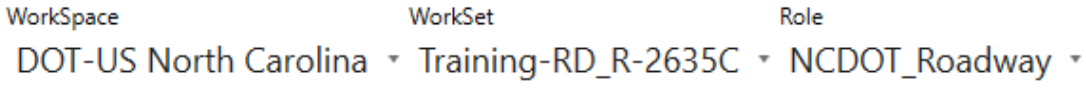


Figure 2-1: WorkSpace and Workset Selection

2.2 Structure Vertical Clearance Checks

Coordinate all vertical and horizontal structure clearances with the approved Design Criteria, Structures Management Unit (SMU) and sections 5.3.3 and 5.3.4 of the RDM.

Coordinate preliminary and final structure depth and bridge digital twin models with SMU or the Bridge Design Engineer. Refer to RDM section 5.3.4.2 for commentary regarding Bridge Superstructure Depths.

In these vertical clearance exercises, you will learn how to prepare vertical clearance checks for interchanges by using templates and running Results Reports and by using the "Clash Detection" tool in OpenRoads.

2.2.1 Clearance Checks Using Templates and Reports

In this exercise, you will learn how to perform vertical clearance checks using templates and OpenRoads reports. You will be using the preliminary roadway bridge model "stand-in" as well as the roadway template for producing vertical geometry graphics.

1. **Open the Roadway Bridge corridor file and zoom to fit view.**
   A. Click the browser button and path to the Module 12 – Interchange–Vertical Clearance\Roadway\Design folder and open the R-2635C_RDY_CMD_Bridge_L.dgn file.

Active References:

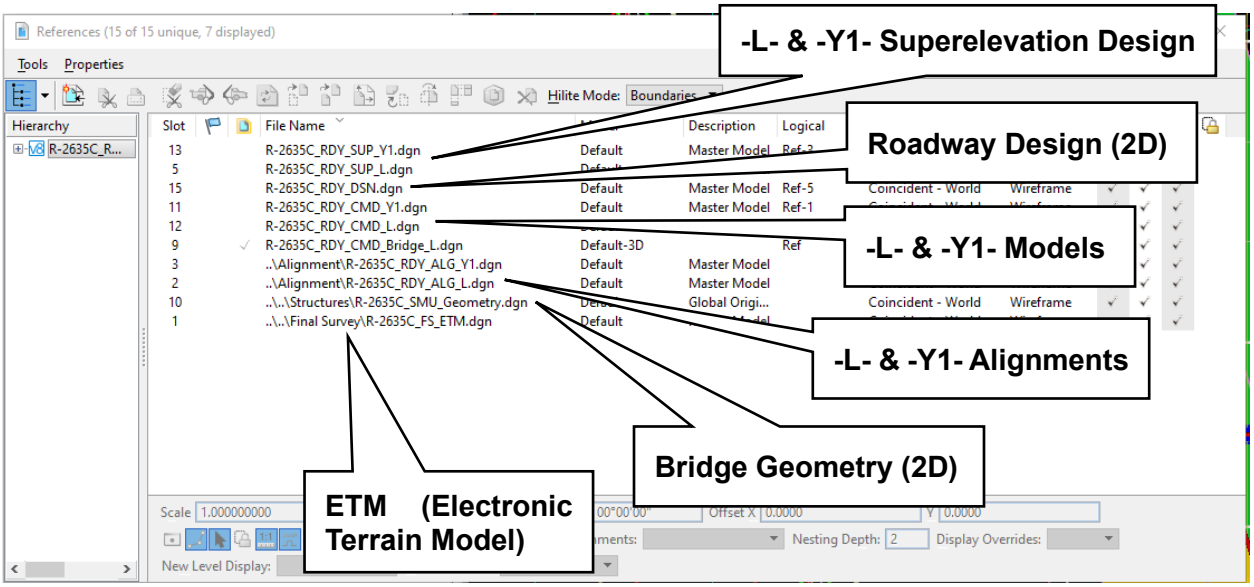


Figure 2-2: R-2635C_RDY_CMD_Bridge_L.dgn References

B. Zoom in near the intersection of -L- and -Y1- as shown below. Notice there is already a base corridor for -L- and -Y- and a preliminary plan view geometry file for the bridge. See the Initial Corridor Modeling Module for detailed instructions for initial corridor development.

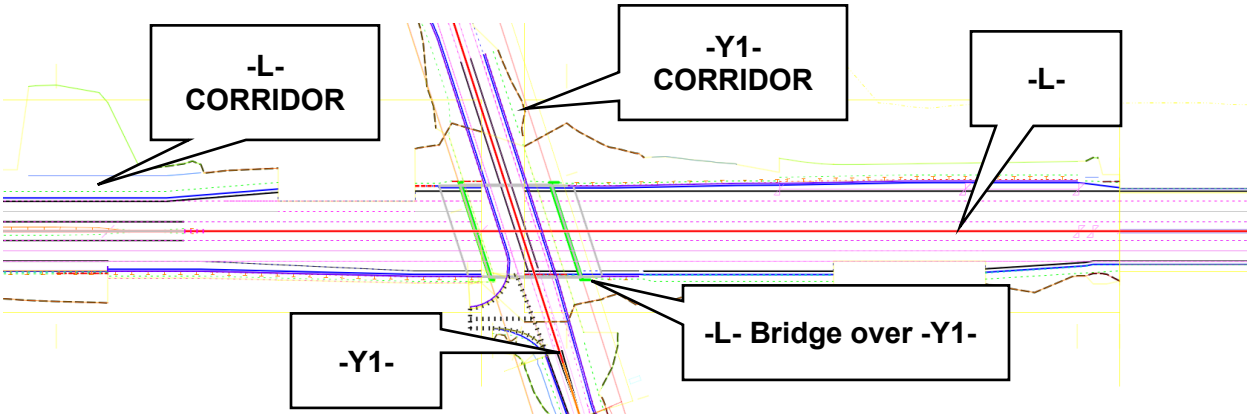
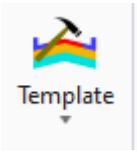


Figure 2-3: R-2635C_RDY_CMD_Bridge_L.dgn

2. Review the Roadway Bridge "Stand-In" template.

Note: the following information is intended to be the preliminary outline of a structure only prior to the development of the Structures Preliminary General Drawings (PGD). This information will be used to set interchange grades and check preliminary vertical clearances. The bridge design engineer is responsible for providing the calculated proposed structure depth and digital twin when the PGD's are approved and accepted as a part of the project.

A. Click on the "Create Template" button (Corridors > Create > Create Template).



B. Select File, then Open and load the R-2635C (Training)_RDY.itl file (Module 12 – Interchange– Vertical Clearance\Roadway\Design folder).

C. Under the Template Library Organizer, window, navigate to the standard template library (Configuration_2023 > Workspaces > DOT-US North Carolina > Roles > NCDOT_Roadway > Standards > Template Library) and select the NCDOT_Standard Templates.itl template library and bring over the Bridge Undivided 4+4 template as shown below.

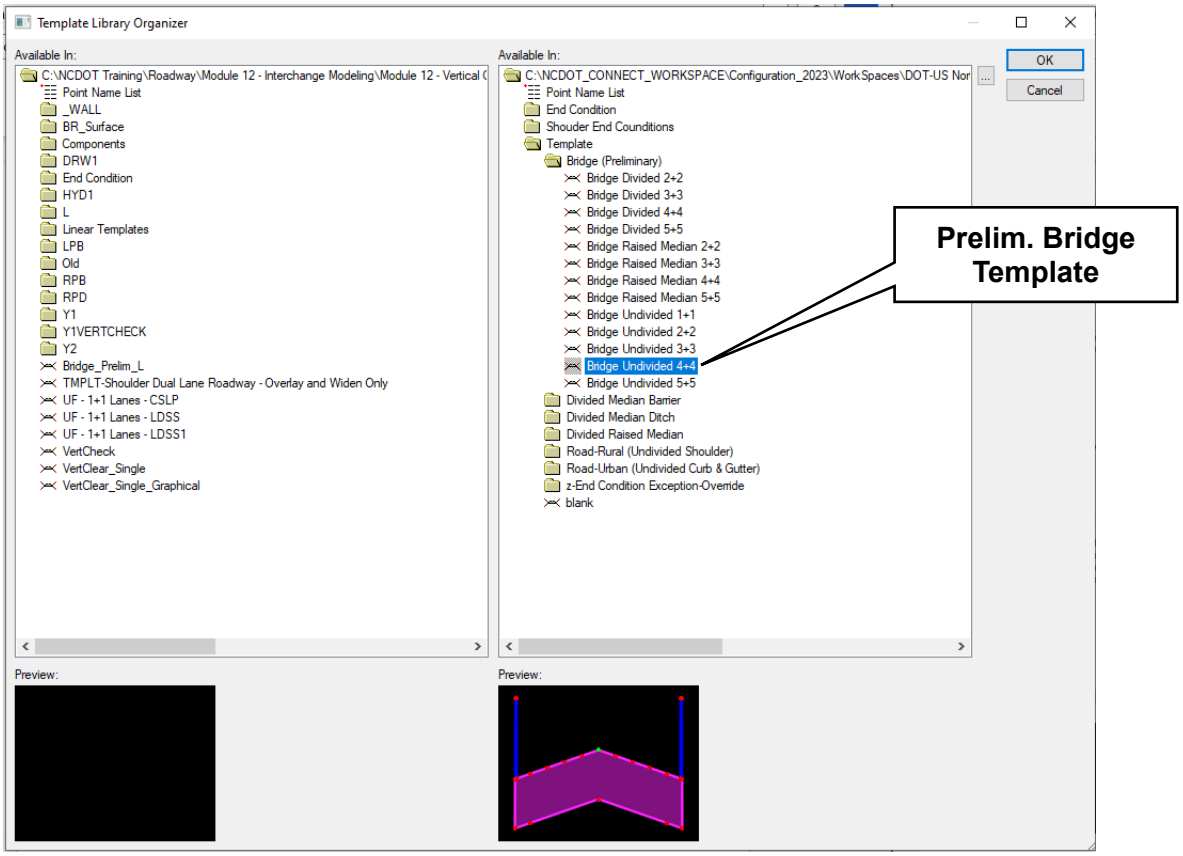


Figure 2-4: Bridge_Prelim_L

D. Select "OK" and return to the Create Template dialog. Rename the template "Bridge_Prelim_L", activate the template and select the "Active Template" dialog.

E. Notice a few of the key Bridge_Prelim_L template points shown below and the loaded parametric constraints.

It is understood that every bridge is different, and the template will need to be adjusted to accommodate each situation. Below are a few key features and components of the template and how they are intended to be used to replicate Roadway's preliminary bridge. Please note, this template has been slightly modified to include a GP line below the CL point to coincide with the grade point of the typical section shown below.

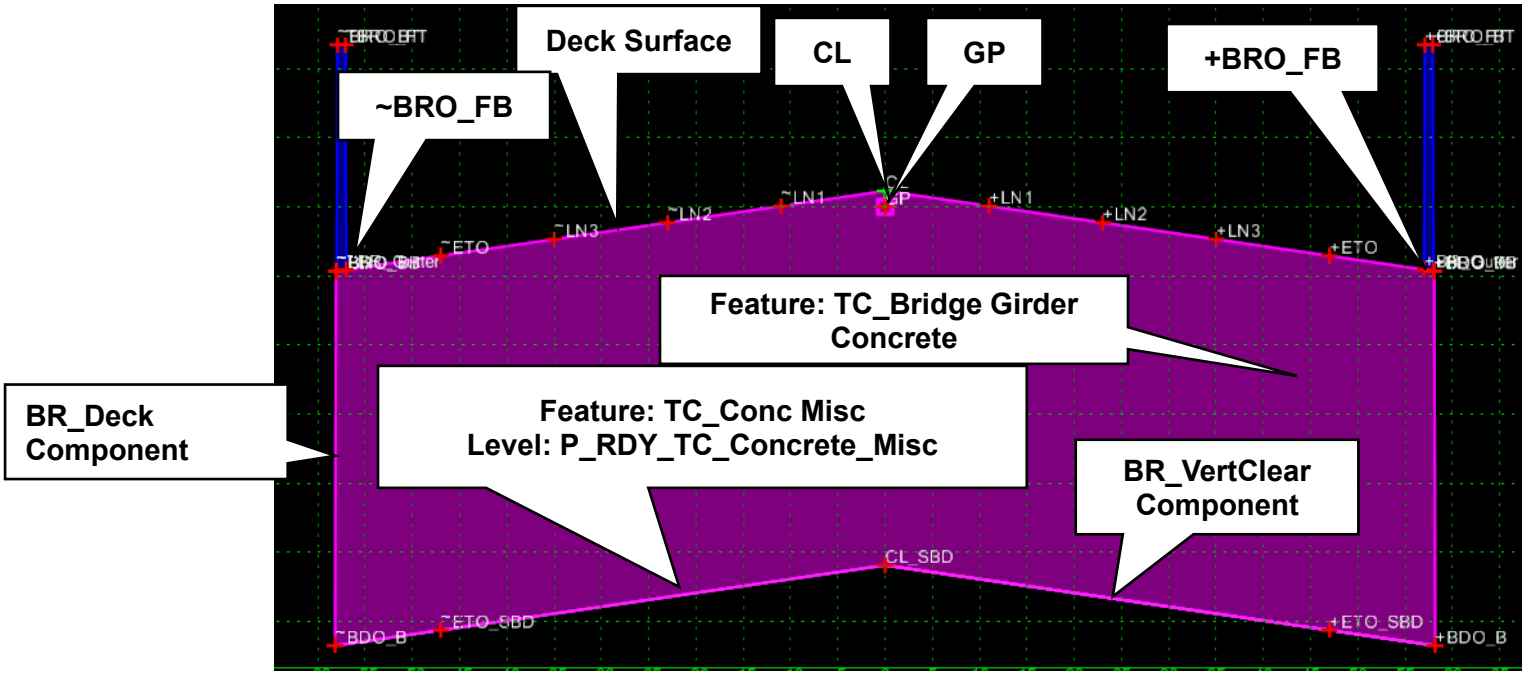


Figure 2-5: Bridge_Prelim_L Template

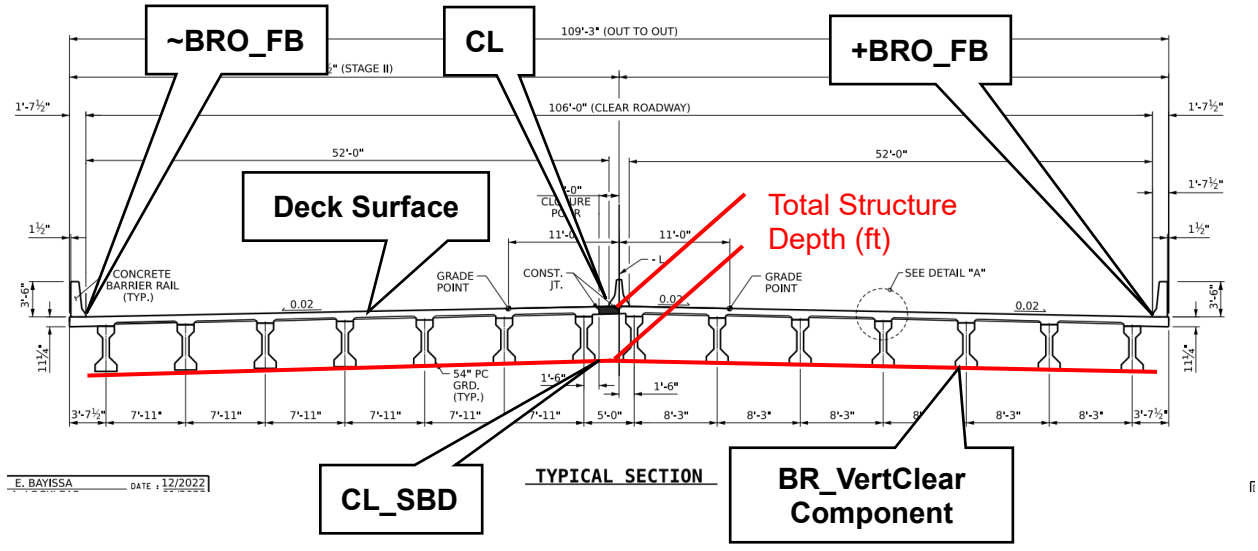


Figure 2-6: Bridge Typical Point Graphic

F. For this exercise, we will set the total structure depth to match the preliminary plans shown above = 5’-5”. In the Active Template dialog, under Parametric Constraints, select BR_Depth Deck and set the value to -5.4167.

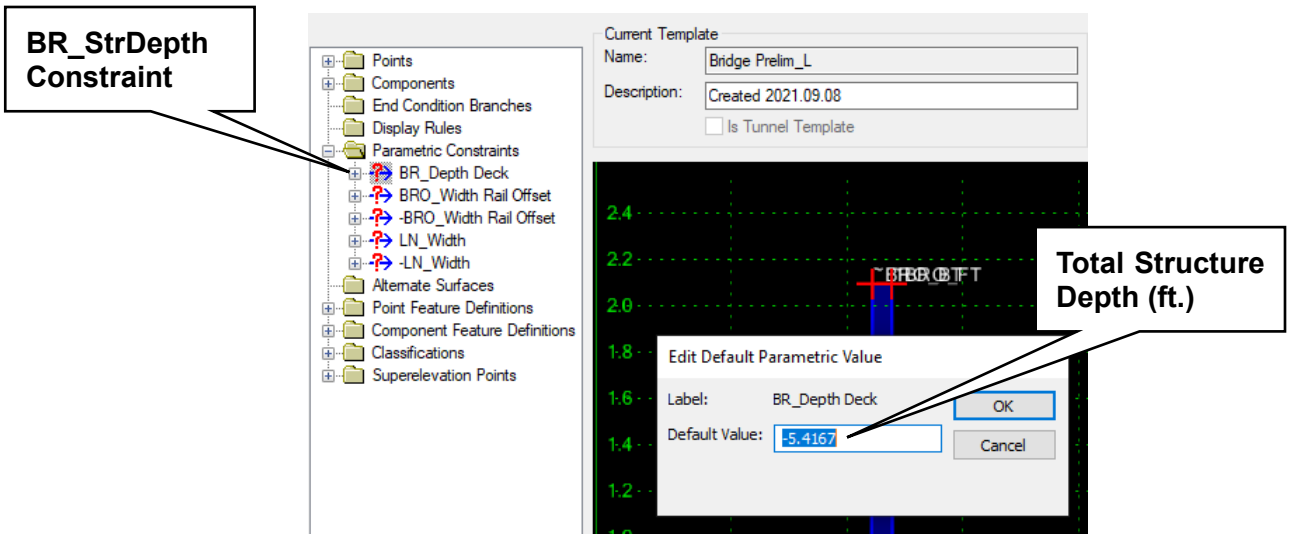


Figure 2-7: Structure Depth Constraint

The main component BR_Deck is **excluded** from the top/bottom mesh so seek elements will not target the surface created by its output.

The BR_VertClear component is **not excluded** from the top/bottom mesh and is intended to be the component the vertical clearance graphics will seek to determine the clearances.

CL = Centerline or Bridge Grade Point
- Template origin and template drop datum.

CL_SBD = Bottom of the template, bottom of the structure depth
- Represents the preliminary full structure depth set by SMU.
- Parametric Constraint = BR_Depth Deck

+/~ BRO_FB = Deck surface, inside edge of bridge barrier.
- Constrained to CL by horizontal and slope.
- Horizontal Feature Constraints
  - ~BRO_FB: CCE_Target_1
  - +BRO_FB: CCE_Target_2

G. Close out of the Create Template dialog and save the changes to the template library.

3. Create the Roadway Bridge model.

A. Open the Reference dialog window and set the files to display as follows (Home > Primary > Attach Tools > References):

In the default view, set the alignments for -L-, -Y1- and the SMU_Geometry file to display and do not display any other references.

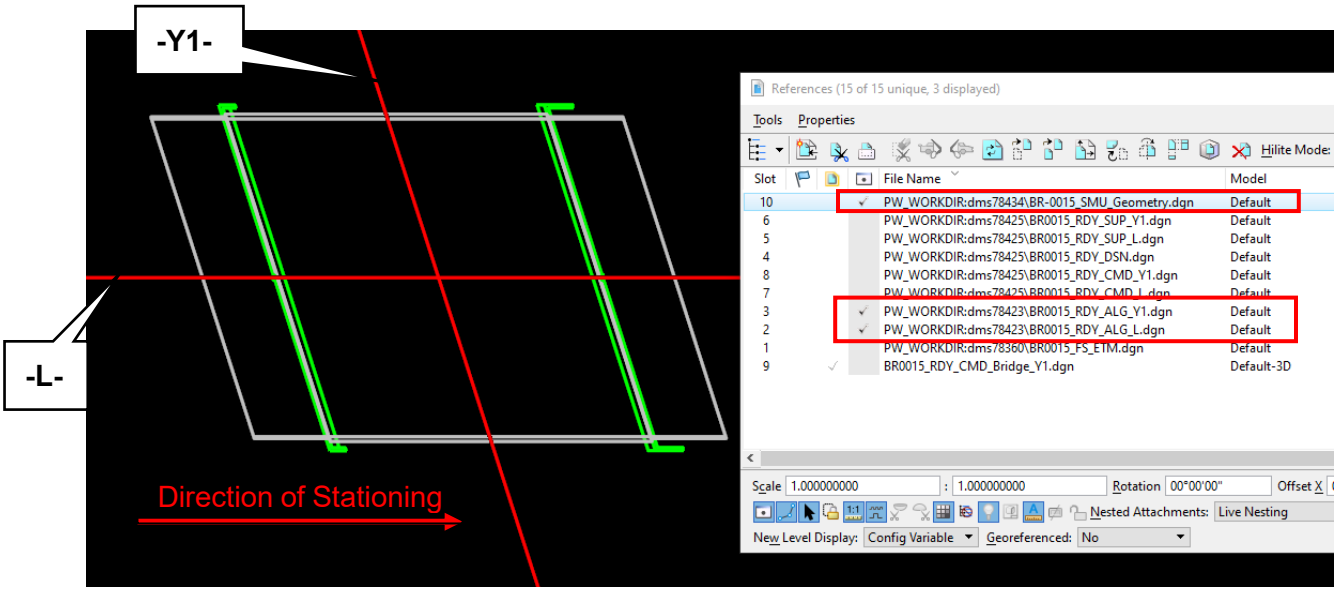


Figure 2-8: Set References Display

B. Close the Reference dialog.

C. Next, we will be placing our construction class elements to target our horizontal feature constraints in our Bridge_Prelim_L model.

Note: this demonstration is for a bridge on a horizontal tangent at a skew. Similar operations will be required for bridges on curved alignments with or without skews.

1. Set the Feature Definition to CCE_Target_1. (left gutter target). This is under (Linear > Roadway > Construction Class Element).
   It is suggested to toggle Persist Snaps and Rules off and to toggle Use Active Feature Definition on.

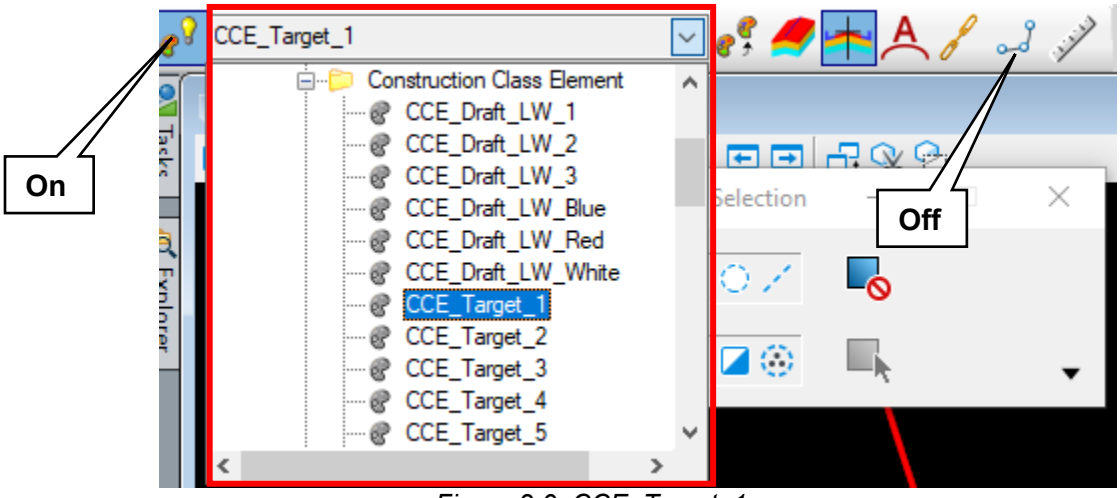


Figure 2-9: CCE_Target_1

2. Select the Single Offset Partial tool (Geometry > Horizontal > Offsets and Tapers).

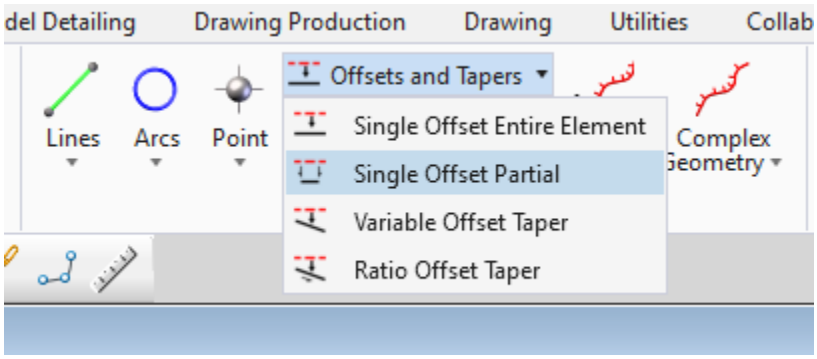


Figure 2-10: Single Offset Partial

3. In this example the left offset from the CL to the ~BRO_FB is 53.0 ft. Select the -L- alignment and set the Offset value to -53.00. Extend your placement limits beyond the most extreme skew limits of the approach slab at each end. This will target point ~BRO_FB point in our Bridge_Prelim_L template. Please note that we are using the extreme skew limits of the approach slab for simplicity in this example but that may not be desired for all projects.

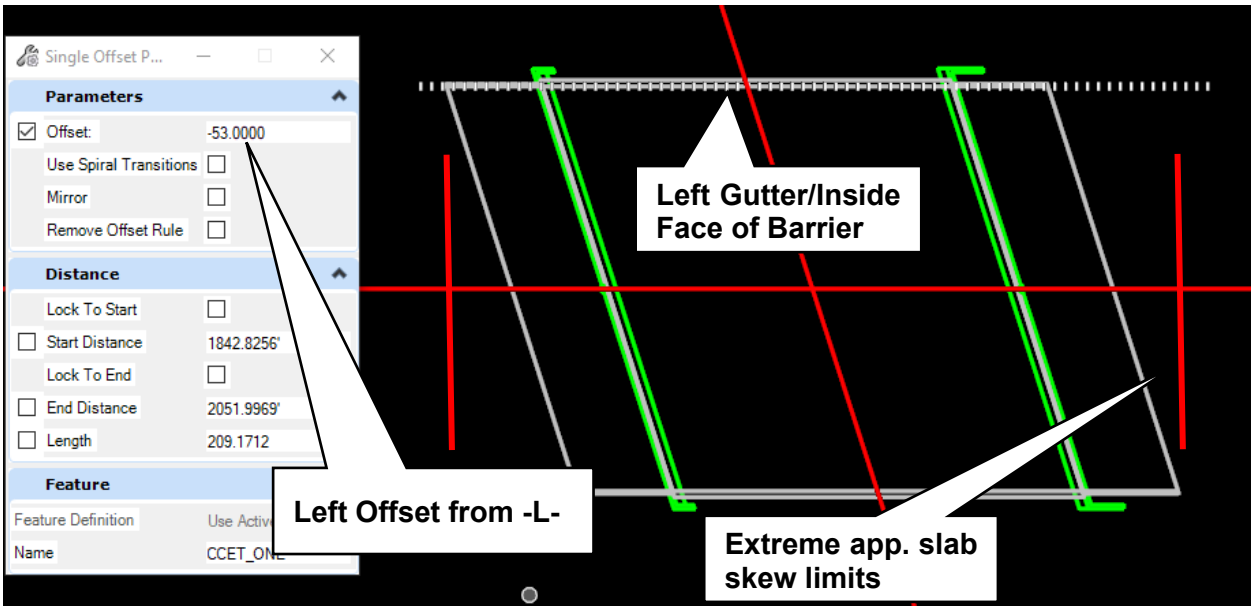


Figure 2-11: Left Gutter Offset

4. Repeat steps 1 through 3, activate the CCE_Target_2 Feature Definition and use a +53.00 offset from the -L- to target the +BRO_FB template point. Be sure to extend your offset lines beyond the extreme limits of the approach slab as indicated in the previous steps.

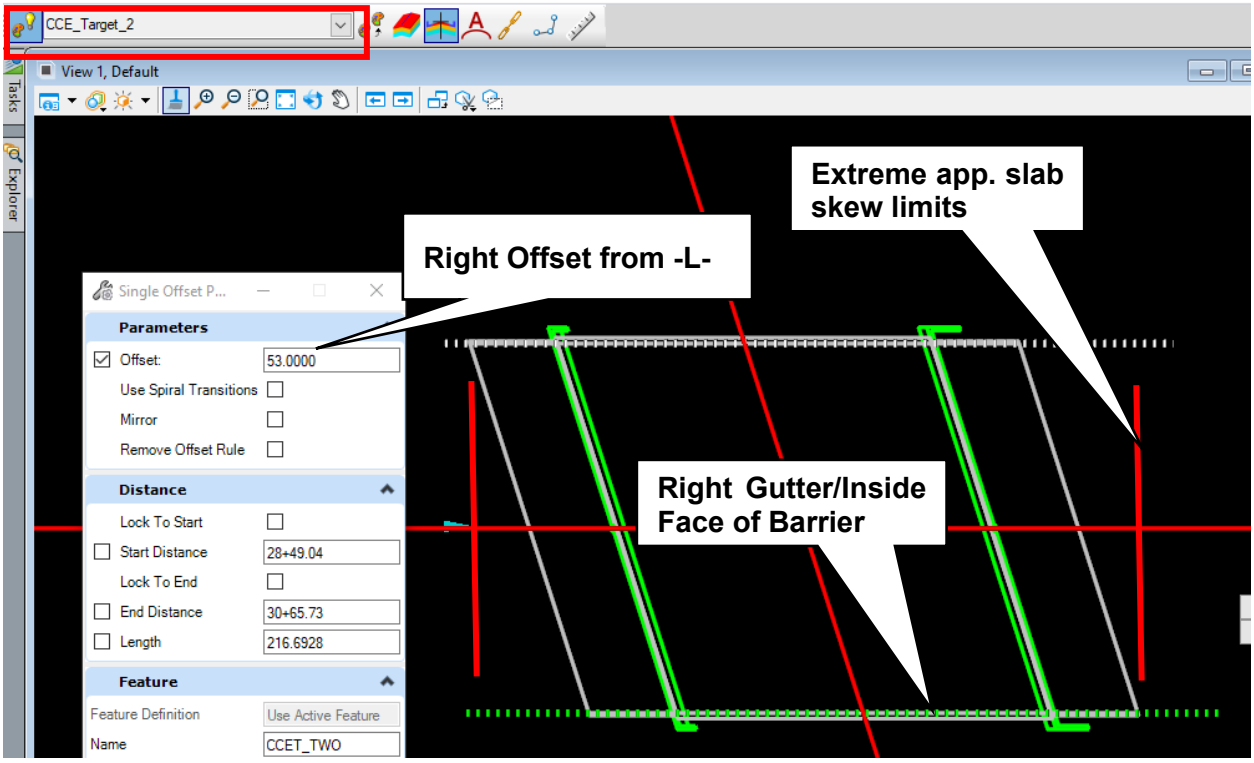


Figure 2-12: Right Gutter Offset

5. Following the steps outlines in Module 6 – Initial Corridor Modeling, create a New Corridor (Corridors > Create > New Corridor) along the -L- alignment within the limits of the Begin and End Approach as shown in Figure 2-11: Left Gutter Offset.

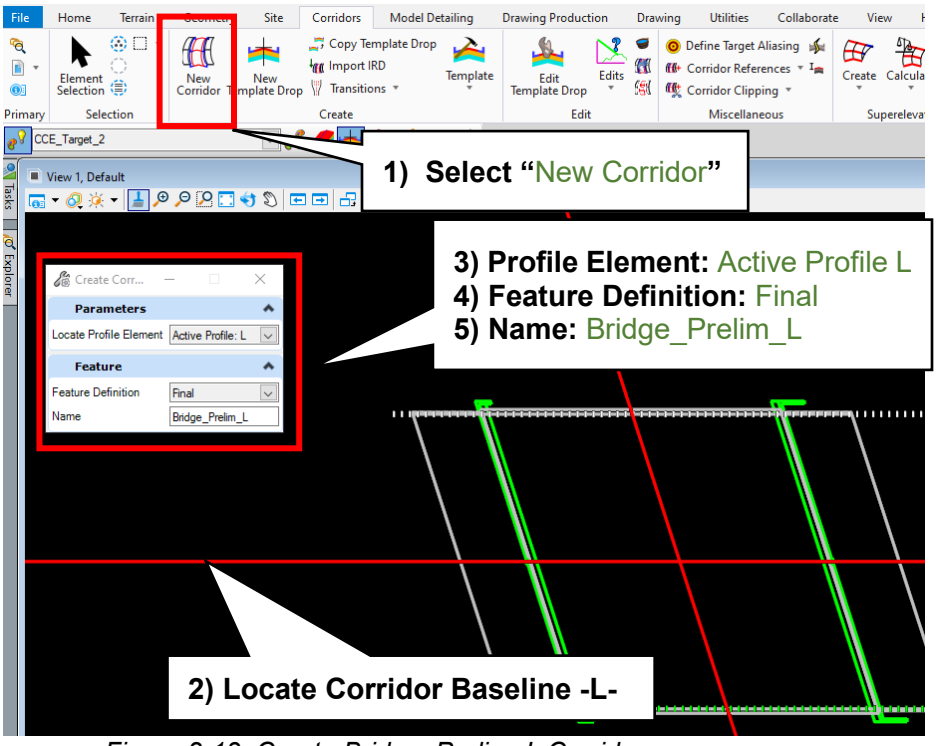


Figure 2-13: Create Bridge_Prelim_L Corridor

D. We are now ready to drop our Bridge_Prelim_L template. Select New Template Drop (Corridors > Create > New Template Drop). Set the beginning and end stations to your extreme approach slab limits as shown previously, set the Drop interval to 5.00 and use our Bridge_Prelim_L template.

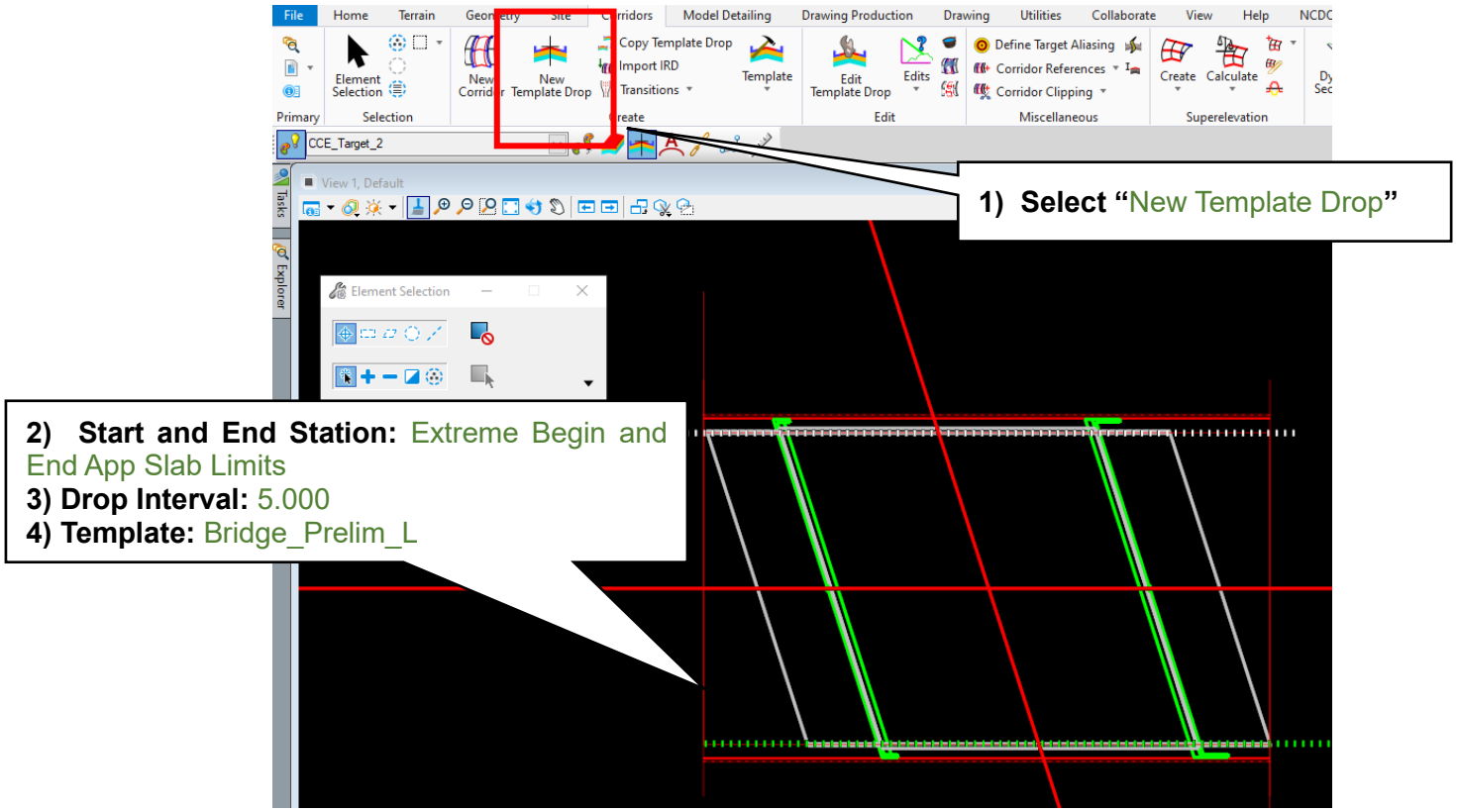


Figure 2-14: Bridge_Prelim_L Template Drop

1. We must add our target elements to the corridor to control the width of the bridge.

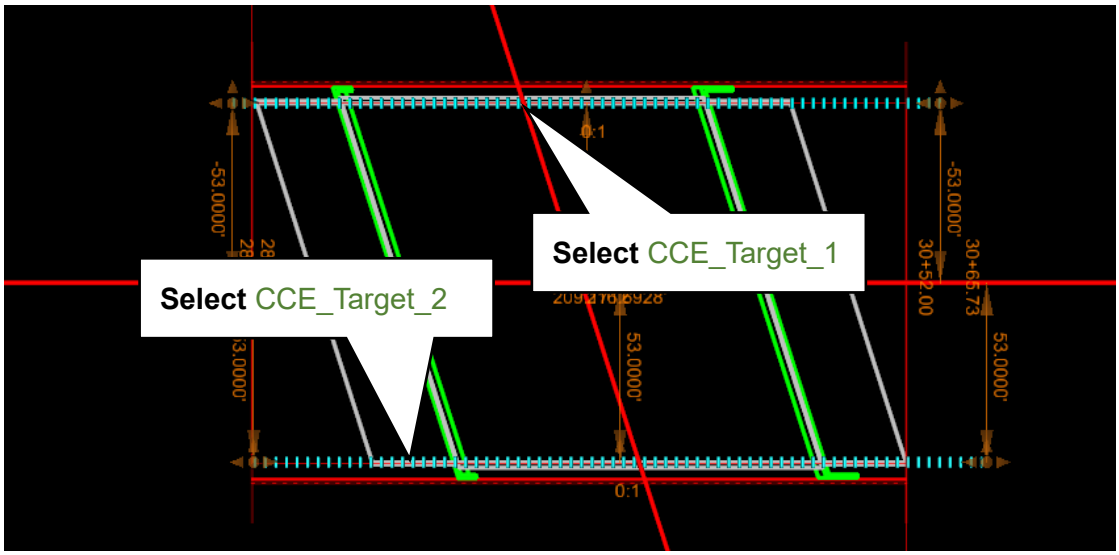


Figure 2-15: Select Target Elements

Click on Corridor References (Corridors > Miscellaneous > Corridor References), locate our Bridge_Prelim_L corridor and use your "Data Point" to add the references to the corridor.

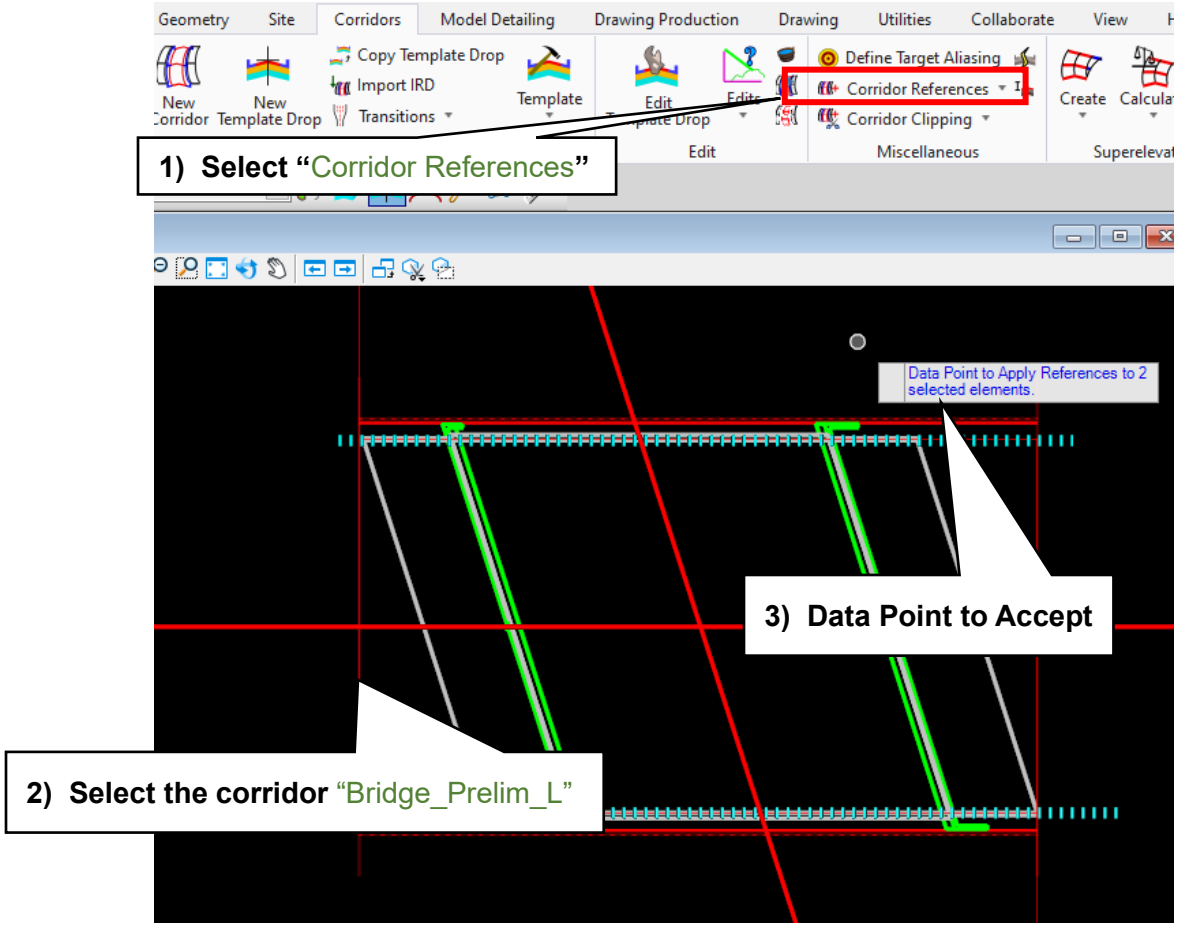


Figure 2-16: Add Corridor References

E. In View 1, right click and hold in space and select View Control > 2 Views Plans/3D and you will see our Roadway Bridge has been created and the corridor references have adjusted the bridge width to match the design but the bridge model needs to be adjusted for the skew.

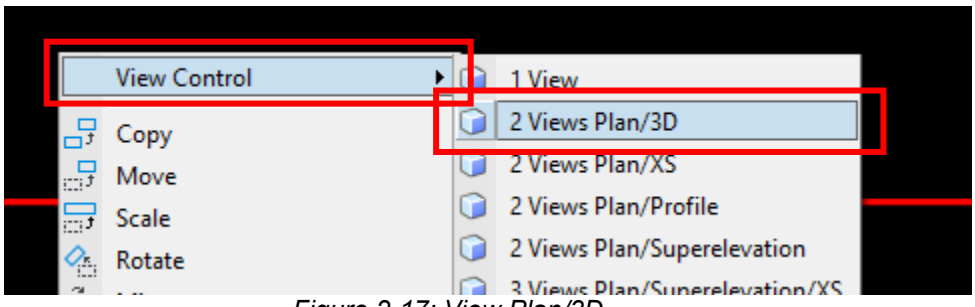


Figure 2-17: View Plan/3D

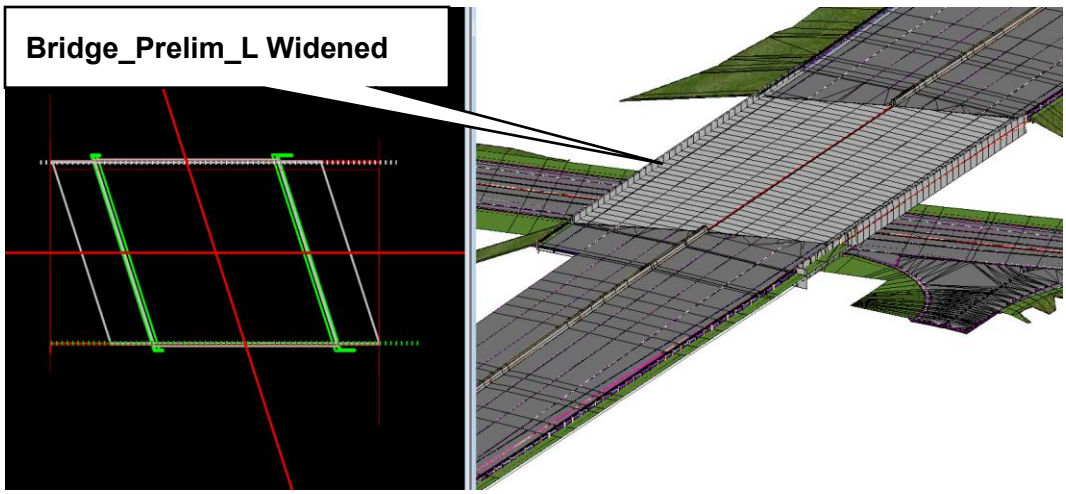


Figure 2-18: Plan and 3D View.

F. We are now ready to clip the Bridge_Prelim_L model for the bridge skew. In the 3D View, turn off the reference for the R-2635C_RDY_CMD_L.dgn so that it is easier to verify the clipping of the Bridge_Prelim_L model. In the 2D View, there are two triangle shapes drawn in, one at the begin bridge and one at the end bridge, that are on Scratch_Level_0.
   1. Go to the Corridors tab on the ribbon and select the Add Clipping Reference (Corridors > Miscellaneous > Corridor Clipping).
   2. Select the Bridge_Prelim_L corridor as the corridor to be clipped, and then data point to select the Scratch_Level_0 shapes as clipping references.

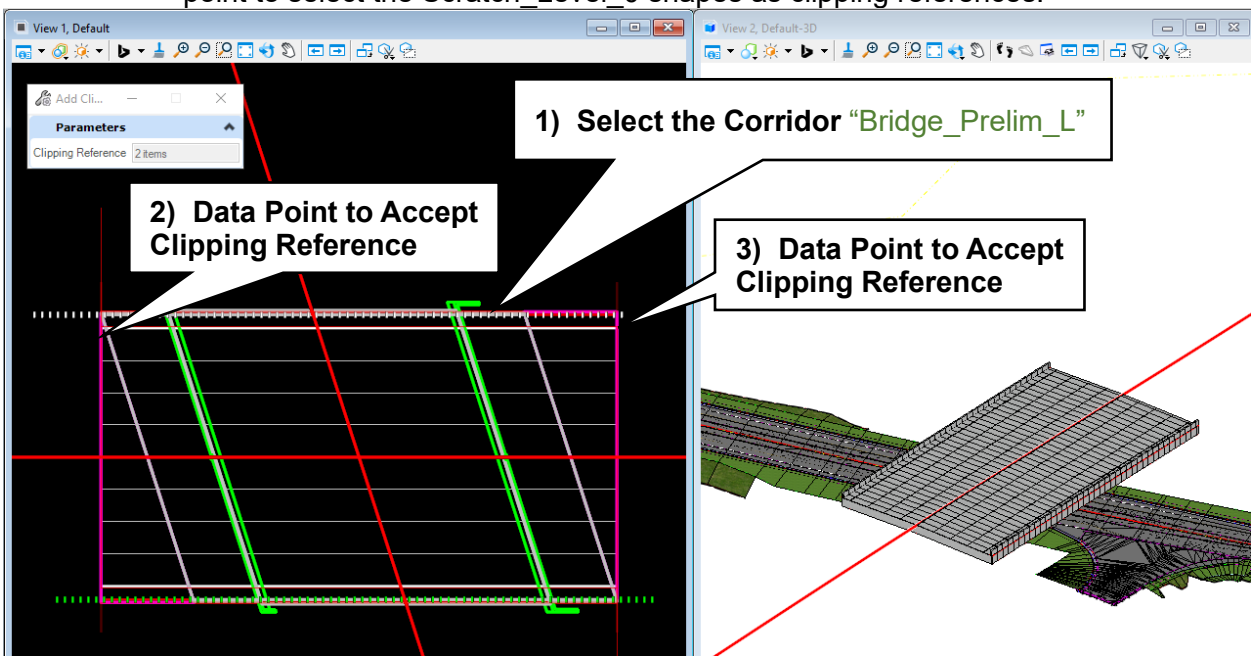


Figure 2-19: Adding a Corridor Clipping Reference.

3. In the 3D View, turn on the reference for the R-2635C_RDY_CMD_L.dgn. You should now see that the bridge model matches the skew and ties into the model for L.

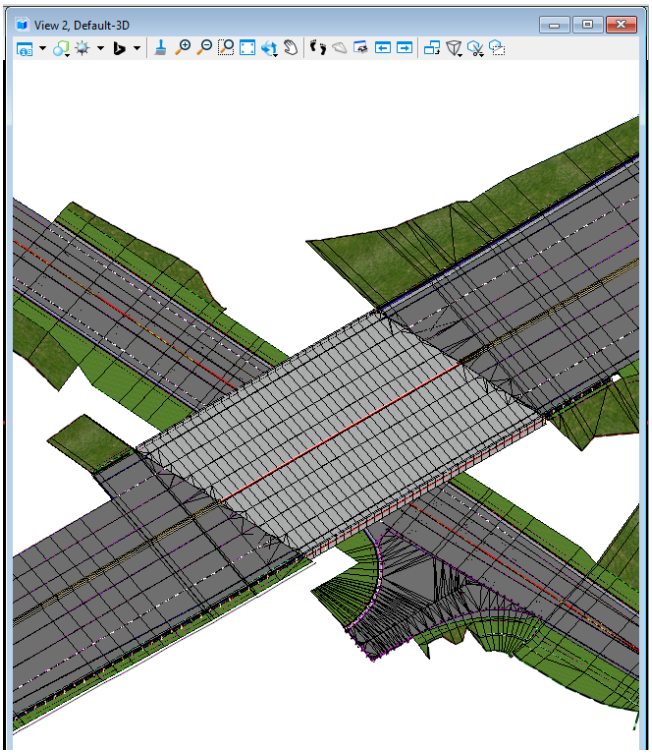


Figure 2-20: 3D View.

G. Using NCDOT Training Module 8 – Superelevation, add superelevation to the bridge if necessary.

4. Vertical Clearance Model

We will now use the Bridge_Prelim_L model along with our L and Y1 models to run a vertical clearance check using a specialized template and export reports.

A. Click the browser button and path to the Module 12 - Interchange – Vertical Clearance\Roadway\Document folder and open the R-2635C_RDY_VertCheck.dgn file.

Active References (Default-3D):

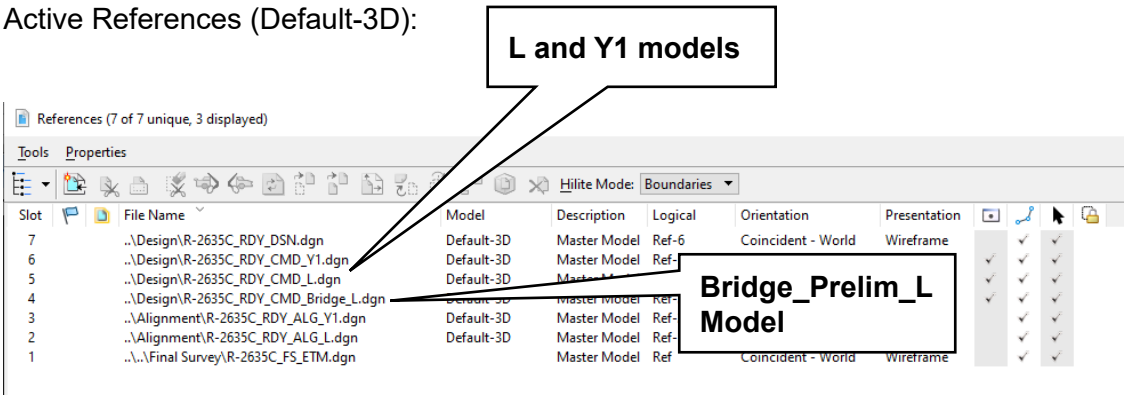


Figure 2-21: Reference Dialog

It is recommended to evaluate the vertical clearance at all possible points for Y1. In this exercise, we will check the vertical clearance and run reports at a single location. Our

possible evaluation points are controlled by the template points output from our Y1 template and typical section.

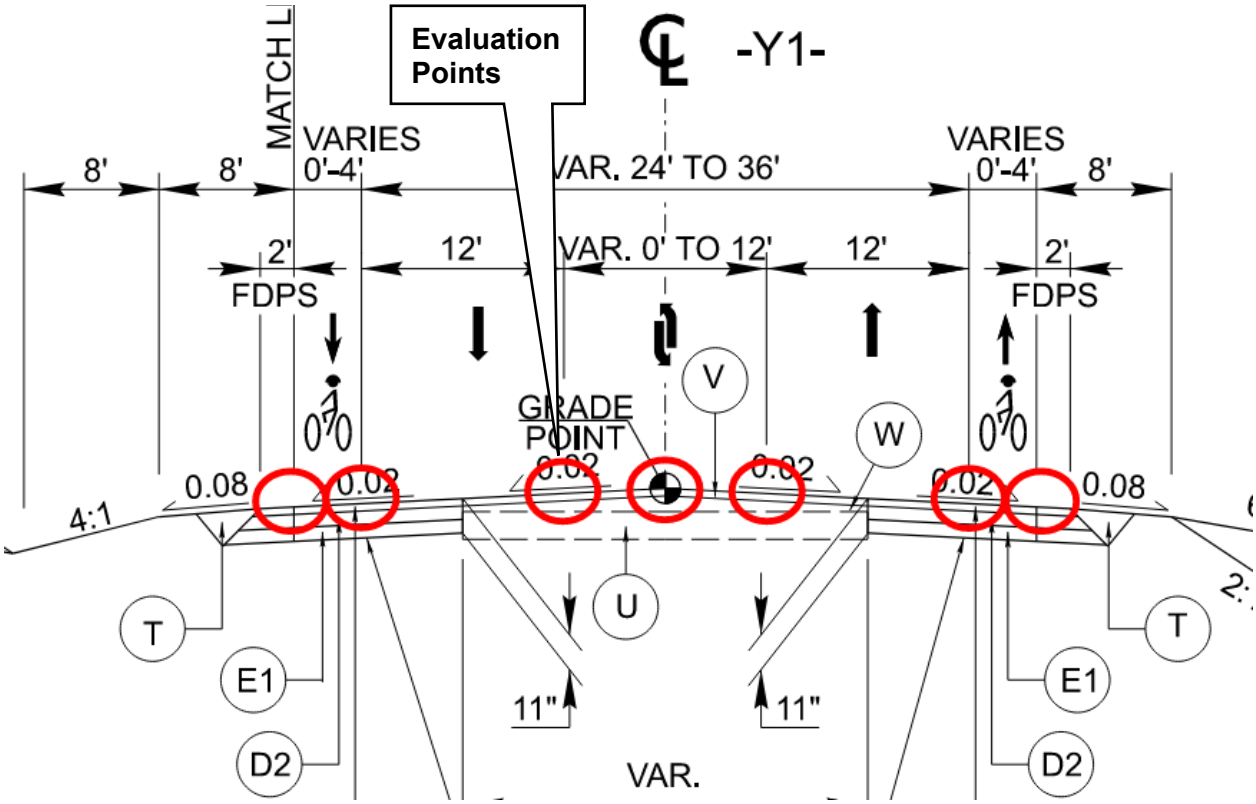


Figure 2-22: Typical Section Evaluation Points

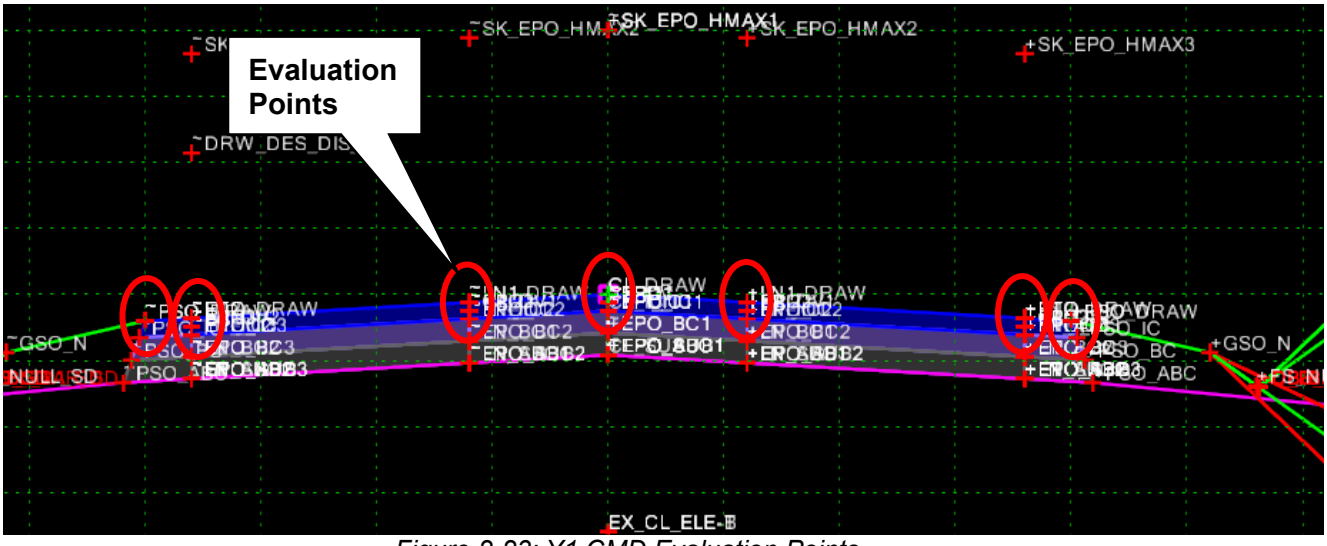


Figure 2-23: Y1 CMD Evaluation Points

In this exercise, we will be creating a corridor for an output template point from the Y1_CMD model for the CL point in the template. It is recommended to recreate a separate corridor for each evaluation point in the template when completing vertical clearance checks.

B. In the View 1, Default window, right click and hold and select Views Plan/3D as shown previously in Figure 2-17: View Plan/3D.

C. Select the View 1, Default window again and open the References dialog. Set only the CMD_Y1.dgn and CMD_Bridge_L.dgn to display.

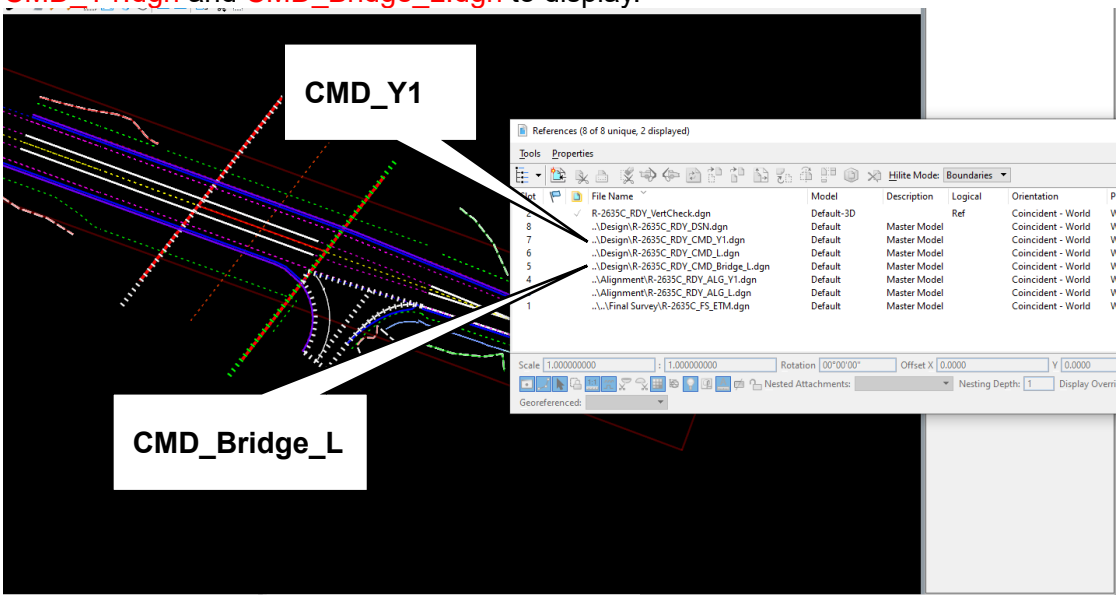


Figure 2-24: View Display

D. Create a new corridor based on the template CL point as shown in the figure below:

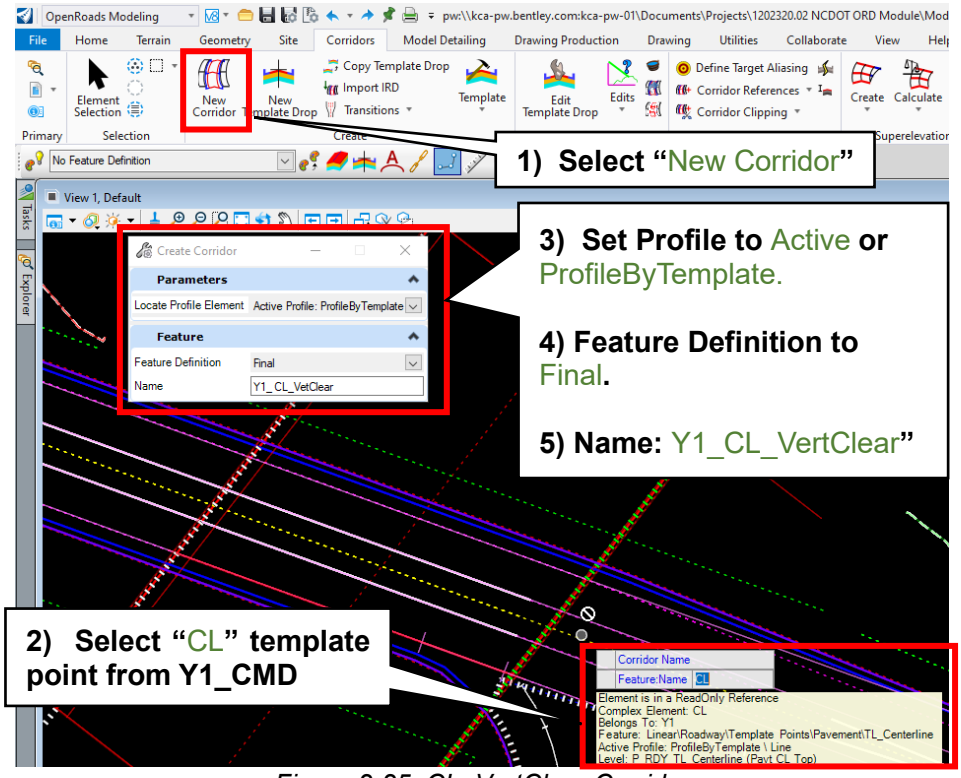


Figure 2-25: CL_VertClear Corridor

E. Create a template drop using the template VertClear_Single_Graphical.

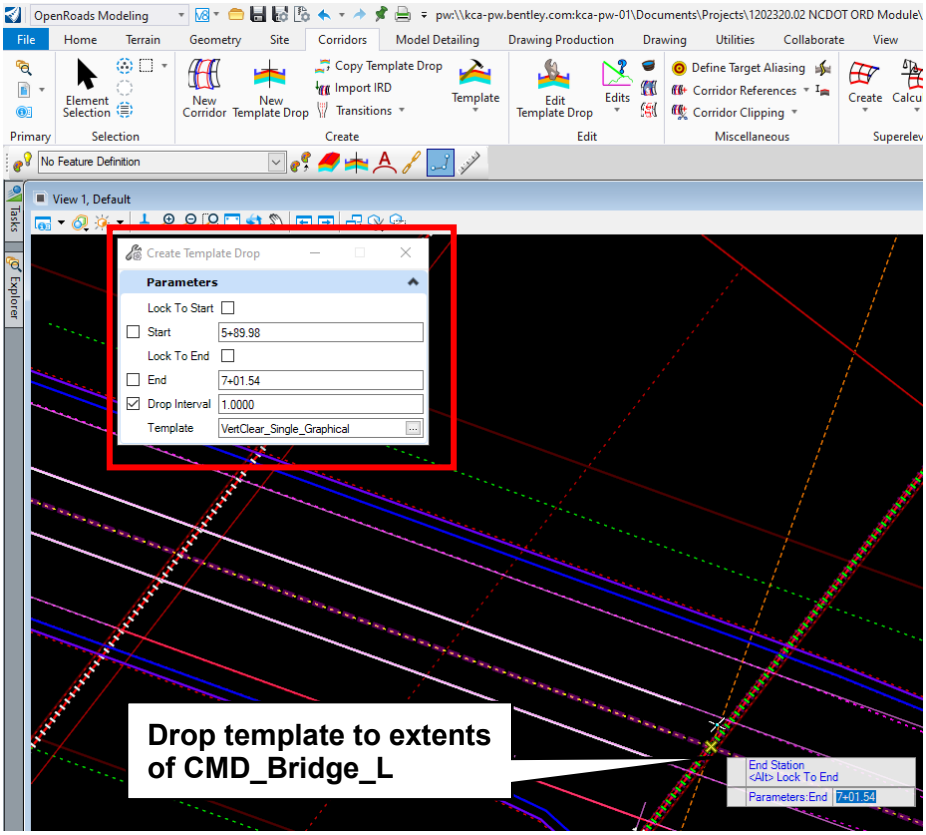


Figure 2-26: Vertical Clearance Template Drop

F. Define the BR_SURF attached to the Bridge_Prelim_L corridor as a Target Alias.

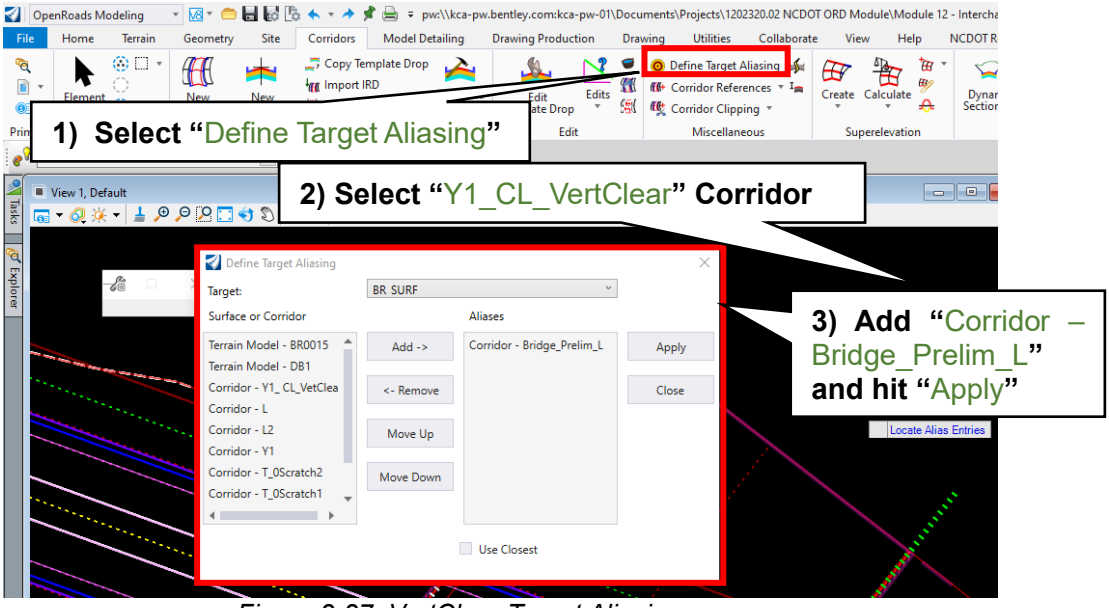


Figure 2-27: VertClear Target Aliasing

G. Activate View 2, Default-3D and view the template drop. Notice how the template seeks only the bottom of the Bridge_Prelim_L.

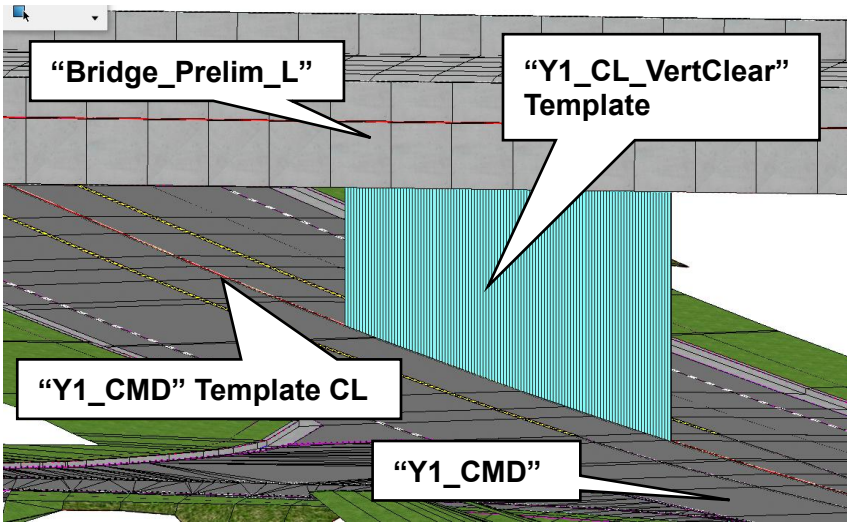


Figure 2-28: VertClear Target Aliasing. Default 3D

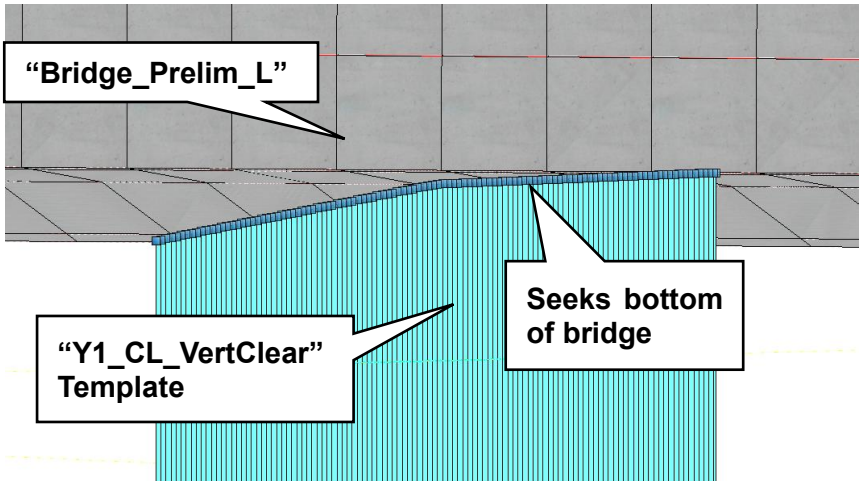


Figure 2-29: VertClear Target Aliasing, Bottom of Bridge

H. Next, we will use corridor "Results Report" to display the calculated vertical clearance of our template drop. In Home > Model Analysis and Reporting > Corridor Reports, select "Results Report".

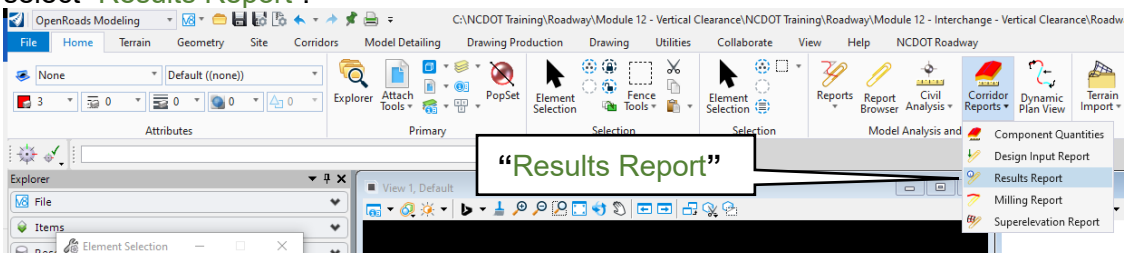


Figure 2-30: Results Report

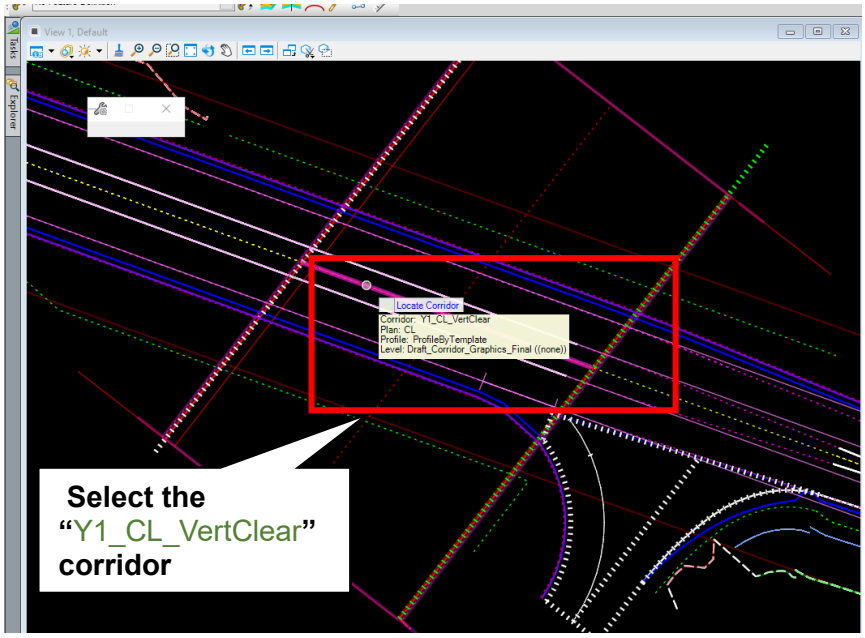


Figure 2-31: Corridor Report, Corridor Selection

I. In the "Report Browser", under "CorridorModeling", select "TemplateDropsContraints.xsl".

Notice how the report shows the vertical clearance in the Vert_Clear_BR row at each template drop point. This report can be exported to a PDF or exported to excel for design documentation.

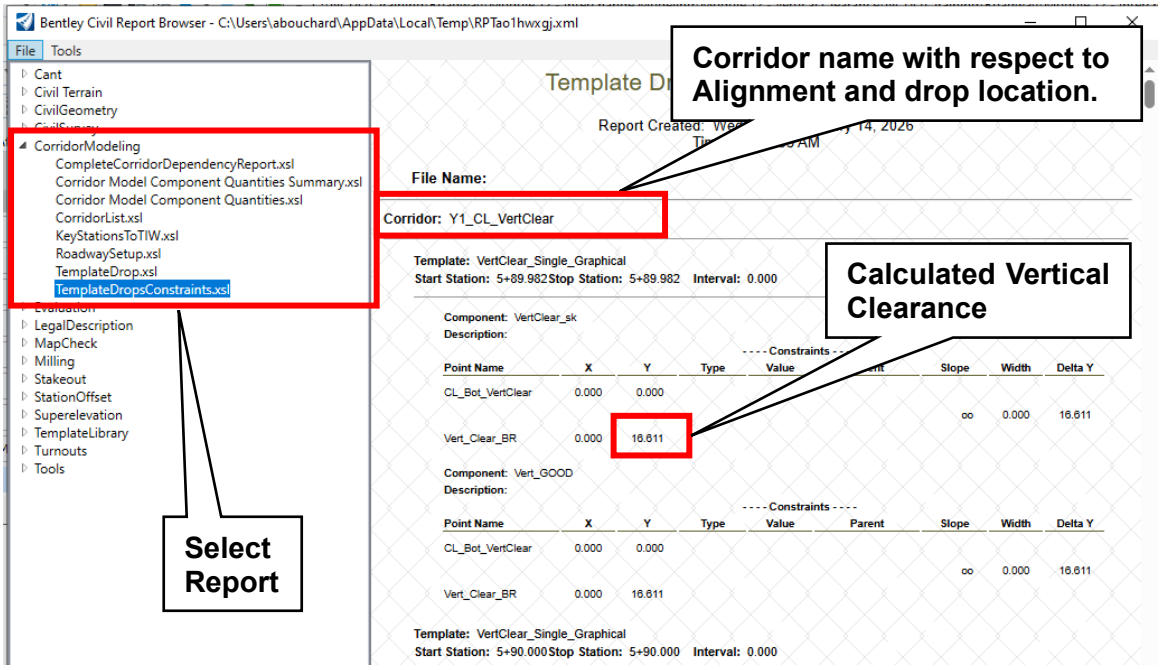


Figure 2-32: Report Browser

J. In addition, there is another useful report that can be created to display this data with respect to the Y1 alignment.

K. In the View 1, Default View, set the Y1 alignment to display.

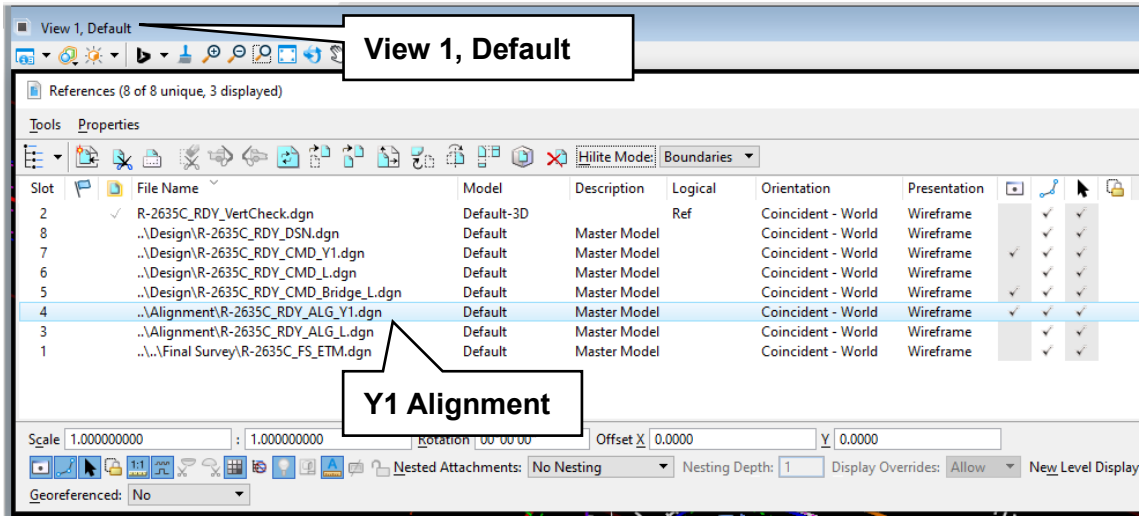


Figure 2-33: Display Y1 Alignment

L. Set the View Control to Plan/3D as previously shown in Figure 2-17: View Plan/3D.

M. Rotate View 2, Default-3D to view the underside of the bridge as shown.

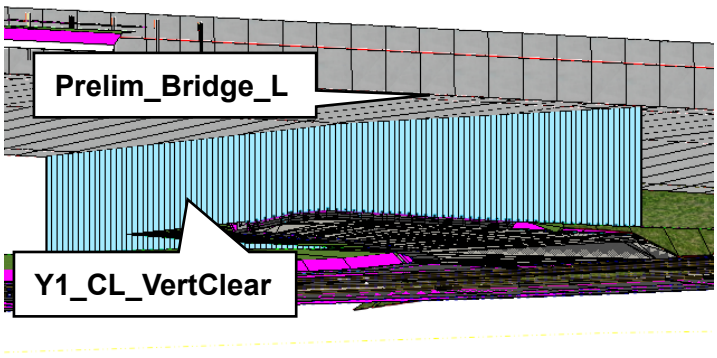


Figure 2-34: 3D View, Bottom of Bridge

N. Using Station Offset Report, create a report that displays the vertical clearance with respect to the Y1 stationing. In Home > Model Analysis and Reporting > Reports, select Station Offset/Base Report.

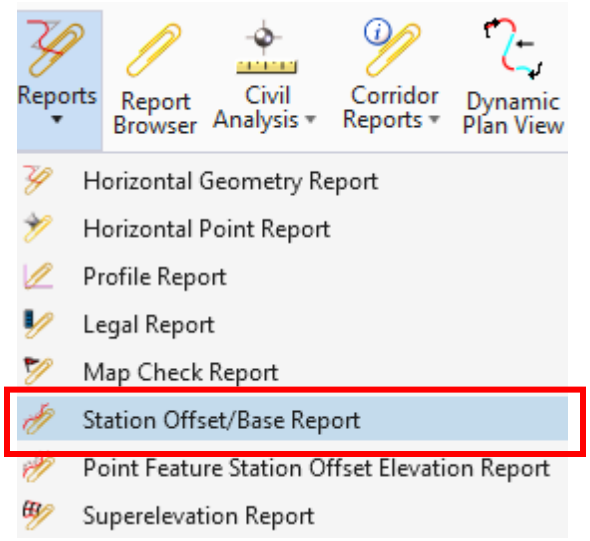


Figure 2-35: Station Offset/Base Report Initiation

O. In View 1, Default, select the Y1 alignment.

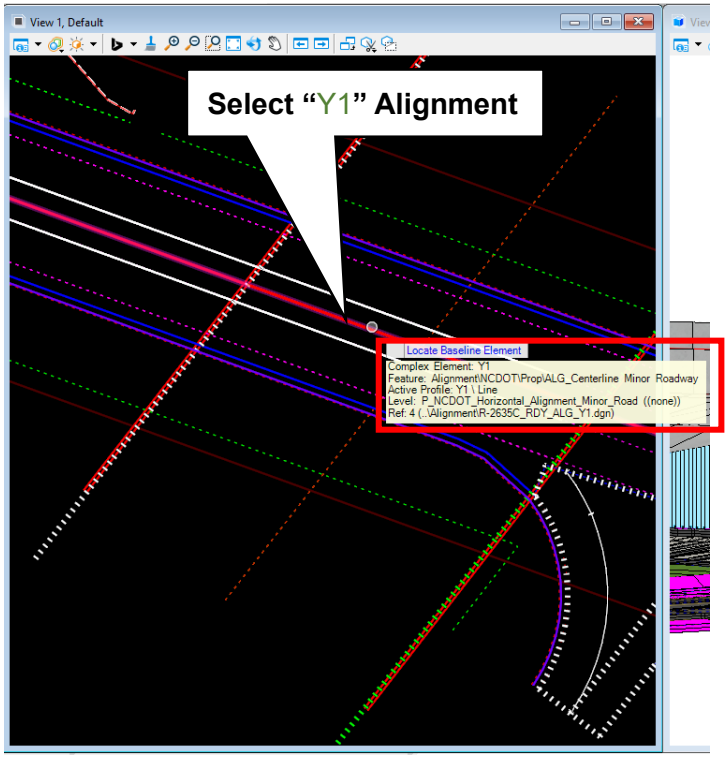


Figure 2-36: Select Y1 Alignment

P. In View 2, Default-3D, select the top of the Vert_Clear_BR as shown below to select the vertical clearance. Set the station limits for Y1 and set the interval along the Baseline. After selection, Reset (right click) to accept the selections.

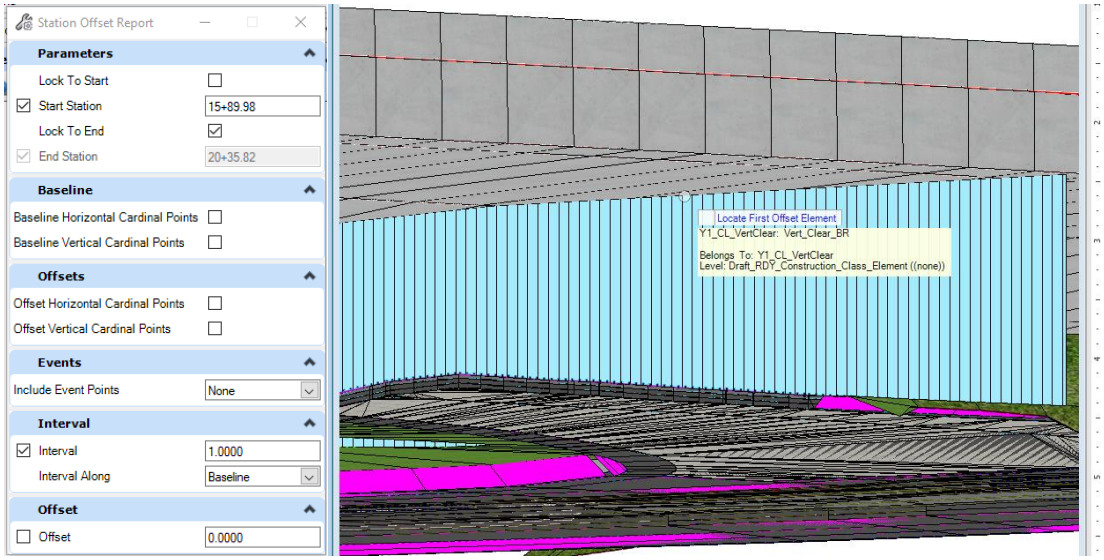


Figure 2-37: Vert_Clear_BR Selection

Q. In the Report Browser, under StationOffset, select the StationBaseVerticalClearance.xsl.

Notice how the report displays the same vertical clearance information with stationing based on Y1. Notice this report does not mention which template point was analyzed. It is recommended to add the corresponding template point to the exported PDF or excel file(s).

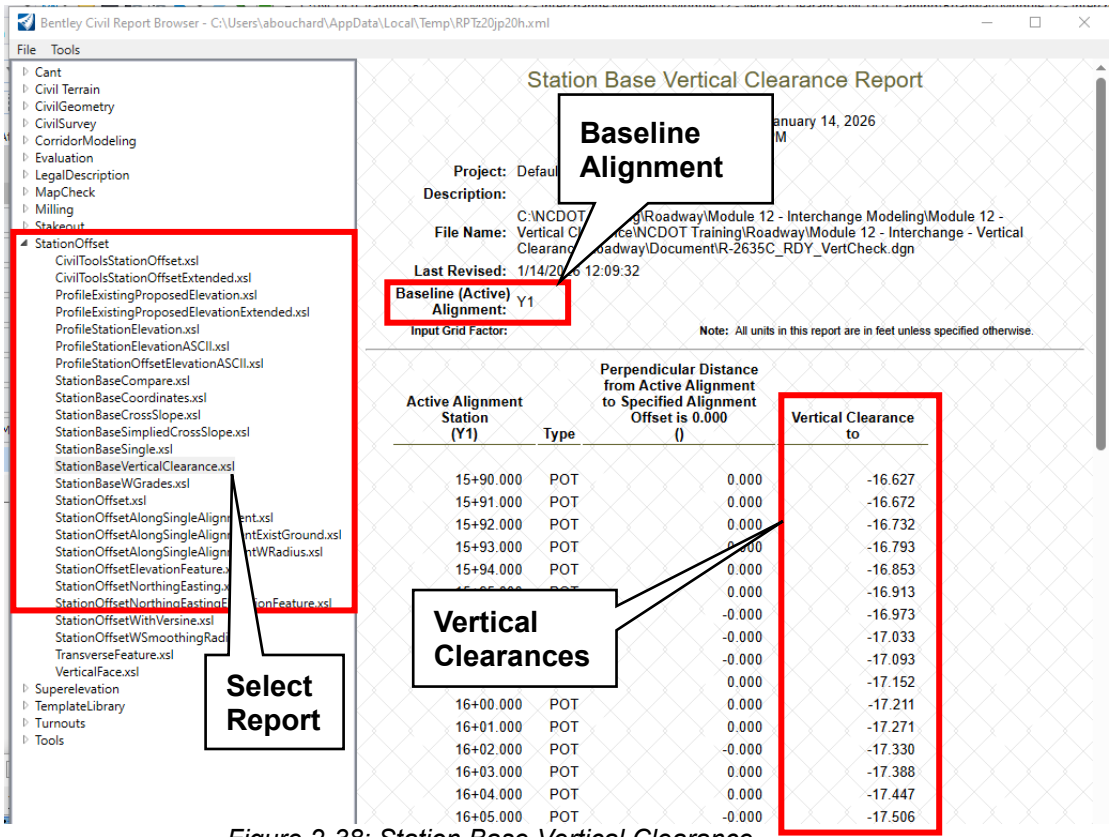


Figure 2-38: Station Base Vertical Clearance

2.2.2 Clearance Checks Using Clash Detection

In this exercise, you will learn how to use the OpenRoads Clash Detection to further evaluate bridge clearances.

Bentley help documentation can be located at their website: Using Clash Detection and Clash Detection Dialog.

This tool is primarily used in the OpenX environment to identity utility conflict but can be used in to check clearances to objects and surfaces.

This exercise uses the Bridge_Prelim_L model from the previous section and continues a mainline -L- which carries our interchange bridge over -Y1-.

Note: the desirable vertical clearance for this exercise is 16.5ft.

1. **Open the Roadway Bridge corridor file and zoom to fit view.**
   A. Click the browser button and path to the Module 12 - Interchange – Vertical Clearance\Roadway\Document folder and open the R-2635C_RDY_Clash.dgn file.

Active References:

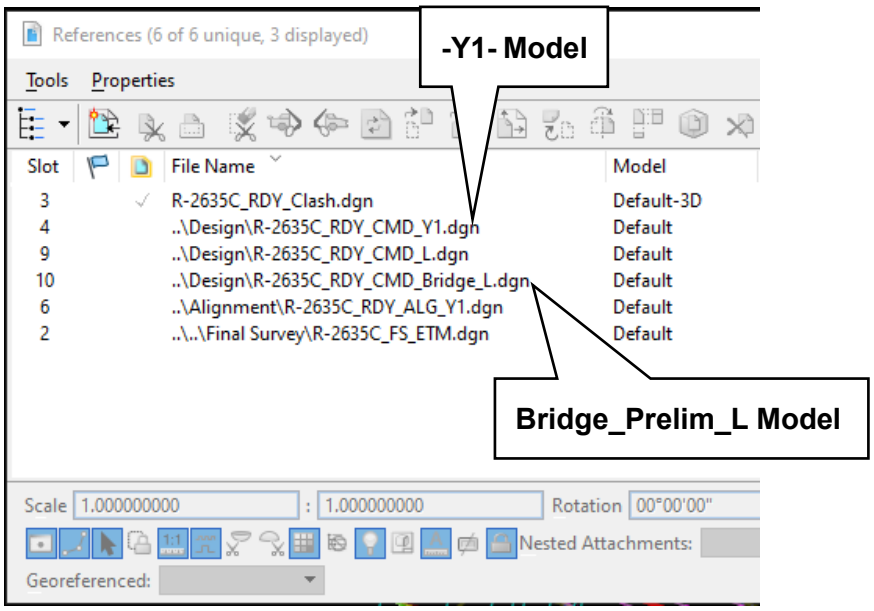


Figure 2-39: R-2635C_RDY_Clash.dgn References

   B. If your views are do not already display the Multi-Model view, right click and hold in space and select View Control > 2 Views Plans/3D and center both views to Fit View, see Figure 2-17: View Plan/3D.

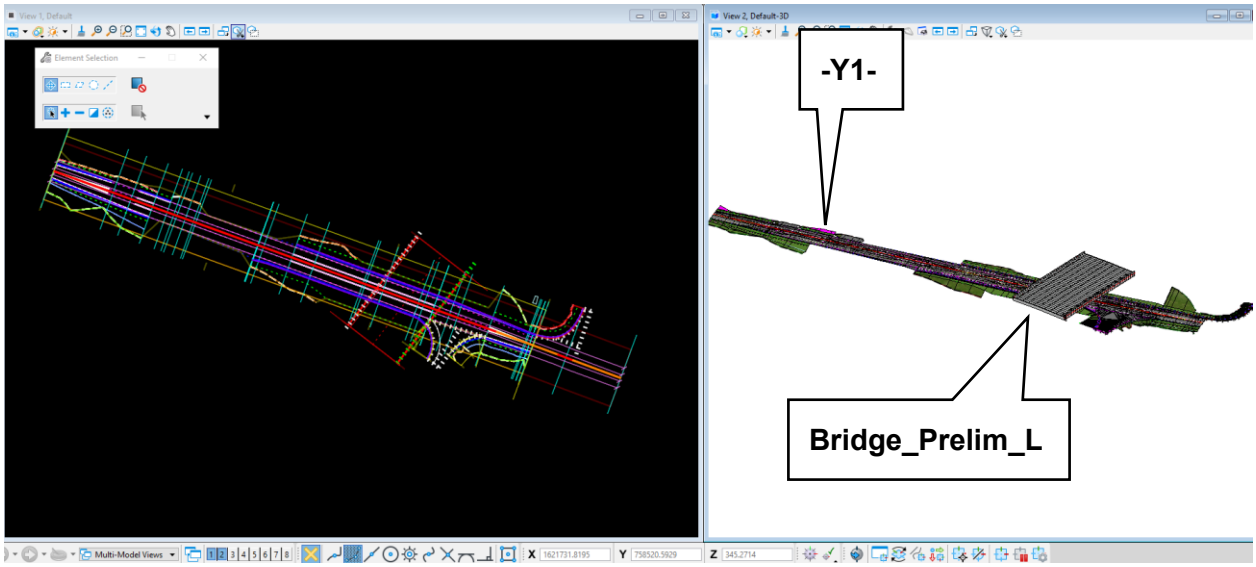


Figure 2-40: R-2635C_RDY_Clash.dgn

2. Isolate the BR_VertClear Component

A. Before we use the Clash Detection function, it is important to note that Clash Detection only works on levels that are displayed in the model you are running the function in. In the View 2, Default 3-D Model, click Level Display to open the dialog (Home > Primary > Level Display).

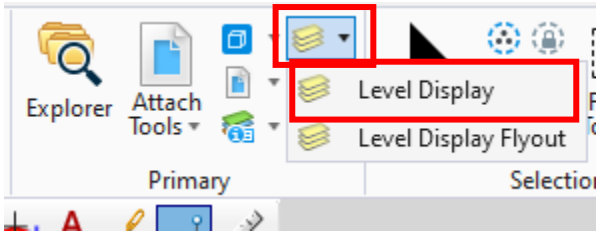


Figure 2-41: Level Display

B. In the Level Display dialog, select R-2635C_RDY_CMD_Bridge_L.dgn, Default-3D and only display the level:

P_RDY_TC_Concrete_Misc.

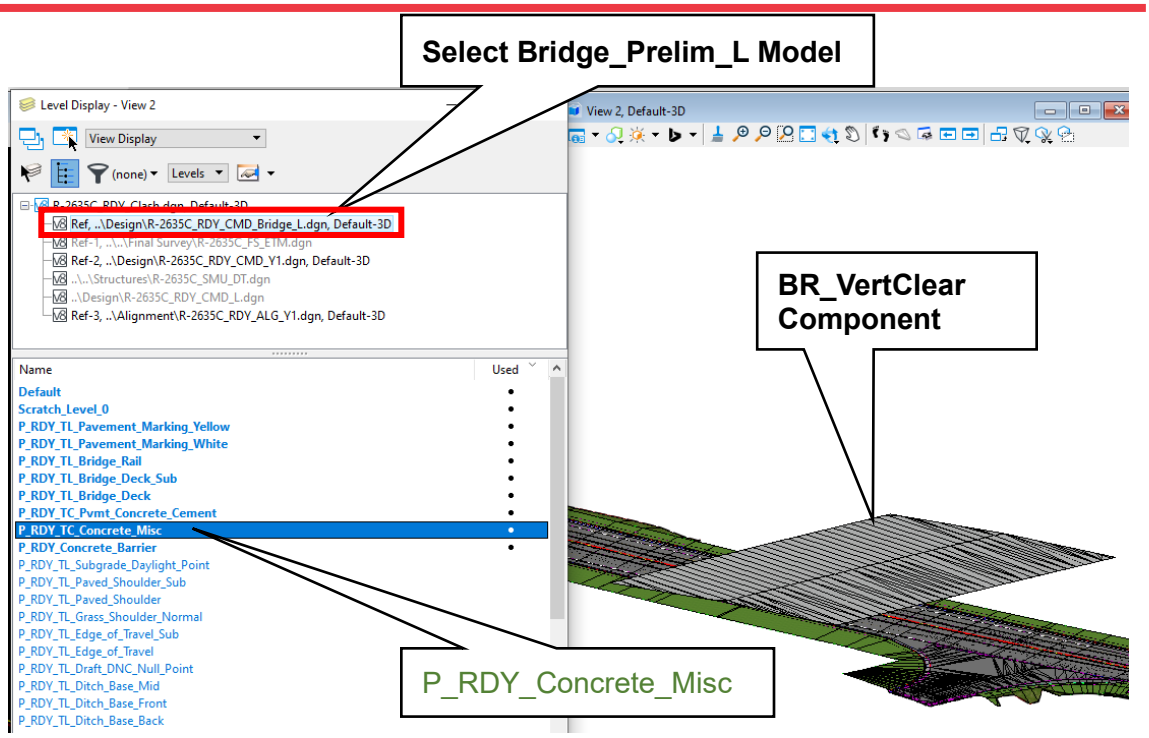


Figure 2-42: Isolate Levels for Clearance Check

This isolates the bottom feature and level from the Bridge_Prelim_L Model – the BR_VertClear Component as shown in Figure 2-5: Bridge Prelim L Template and Figure 2-6: Bridge Typical Point Graphic. This isolates the top surface of the proposed roadway to evaluate for vertical clearances.

3. Isolate -Y1- Roadway Surface

A. In the Level Display dialog, select R-2635C_RDY_CMD_Y1.dgn, Default-3D and only display the following levels:

P_RDY_TC_Pvmt_Asphalt_Surface_Course_Wedge
P_RDY_TC_Pvmt_Asphalt_Surface_Course

Note: if you have a mountable median, include the appropriate levels in your selection set.

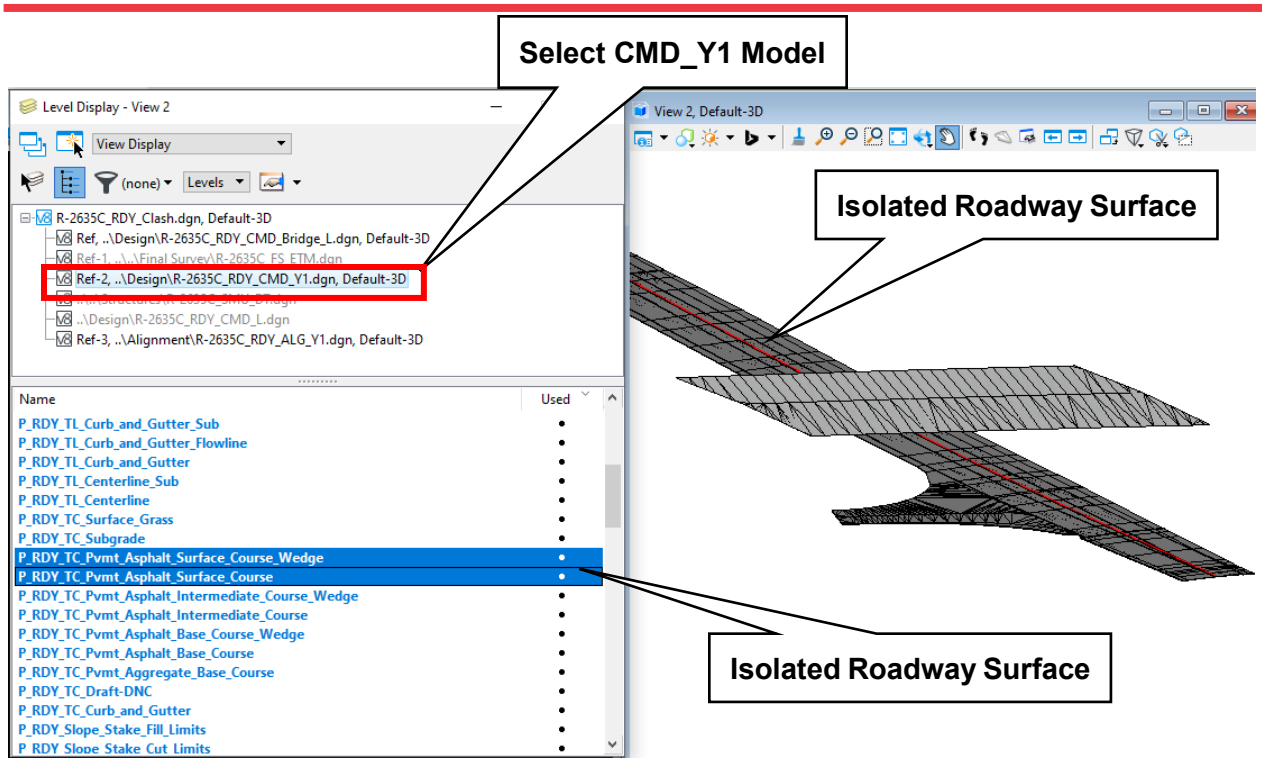


Figure 2-43: Isolate Y1 Roadway Surface

4. **Using Clash Detection to Evaluate Clearances.**
   A. Remain in View 2, Default-3D window and Open the Clash Detection dialog box (Collaboration > Clash Detection > Clash Detection).

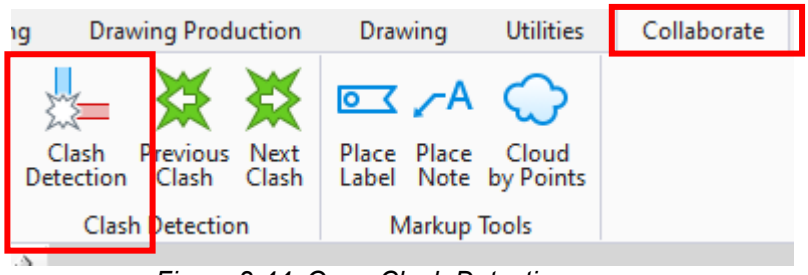


Figure 2-44: Open Clash Detection

   B. Under Job, select "New Job" and call it Y1_L_VertClear.

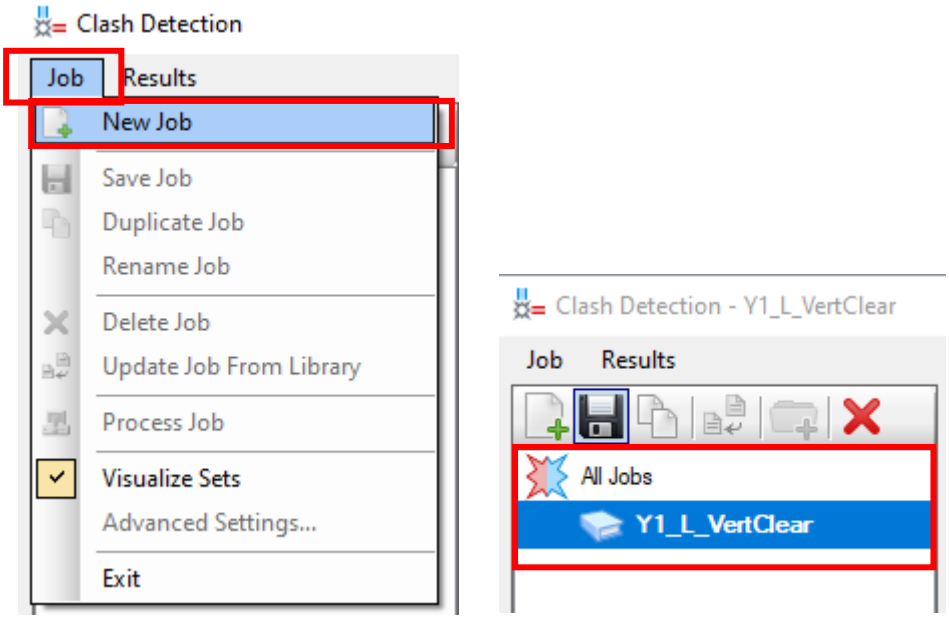


Figure 2-45: New Clash Job

C. Navigating the Clash Detection Dialog Window:

There are several ways to perform a Clash Detection, in this demonstration, we will be using Levels in our Criteria to perform our analysis. The same can be completed with entire reference files.

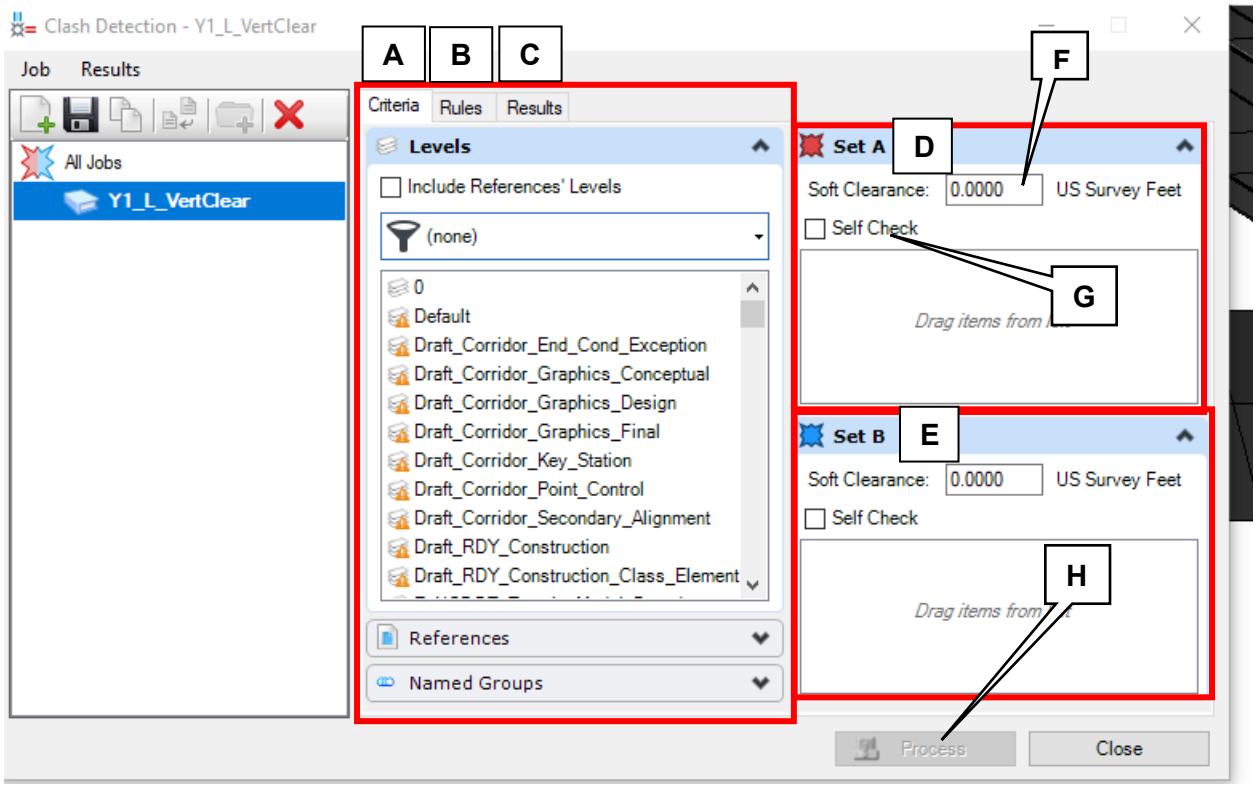


Figure 2-46: Clash Detection Window

A = Criteria Window
- Area to select levels, references or named groups to be included in the clash detection.

B = Rules Window
- Used to turn on or off and manipulate suppression rules for the clash detection – we will not focus on this window during this exercise.

C = Results Window
- Displays the details of each clash as well as the properties of the clashing elements.

D = Set A
- Criteria Set 1 (A) to be evaluated.

E = Set B
- Criteria Set 2 (B) to be evaluated.

F = Set A Clearance Check Value (ft.)
- Vertical Clearance value check.

G = Self Check Box
- Leave unchecked.

H = Process Button
- Once all parameters have been established for the Clash, processes the Clash.

D. In the Criteria window, under the Levels selection set, check the box "Include References' Levels".

Locate the level for the bottom of the deck from the Bridge_Prelim_L model: P_RDY_TC_Concrete_Misc and drag it to the Set A box.

Set the Set A Soft Clearance to 16.5ft – the desirable Vertical Clerance for this facility.

Do not check the box "Self Check" for Set A.

In View 2, Default-3D, you will notice the level will be highlighted.

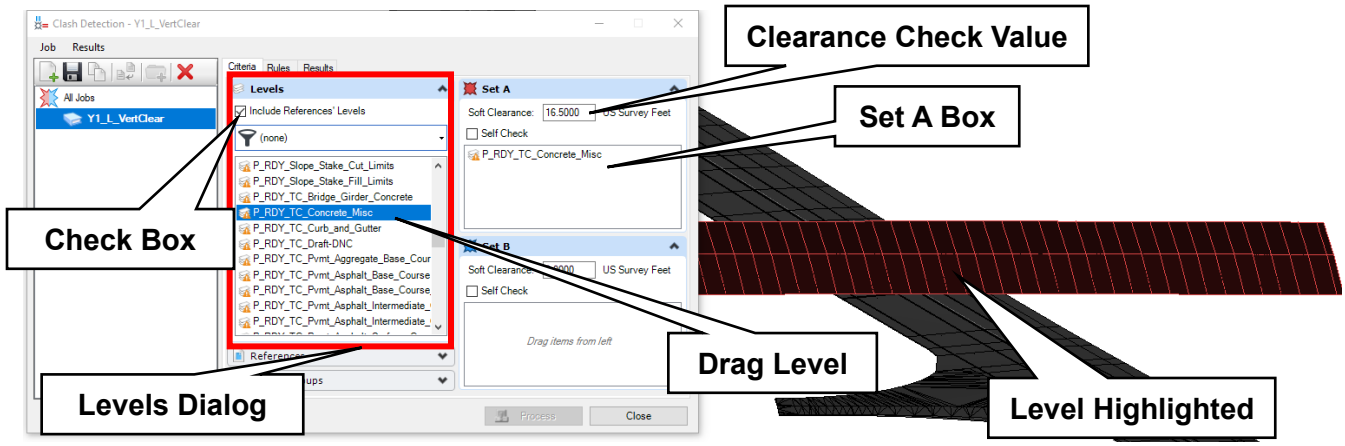


Figure 2-47: Set A Setup

E. Locate the levels for the -Y1- roadway model: P_RDY_TC_Pvmt_Asphalt_Surface_Course & Wedge and drag it to the Set B box.

Do not check the box "Self Check" for Set B.

Do not set any values for the Soft Clearance for Set B.

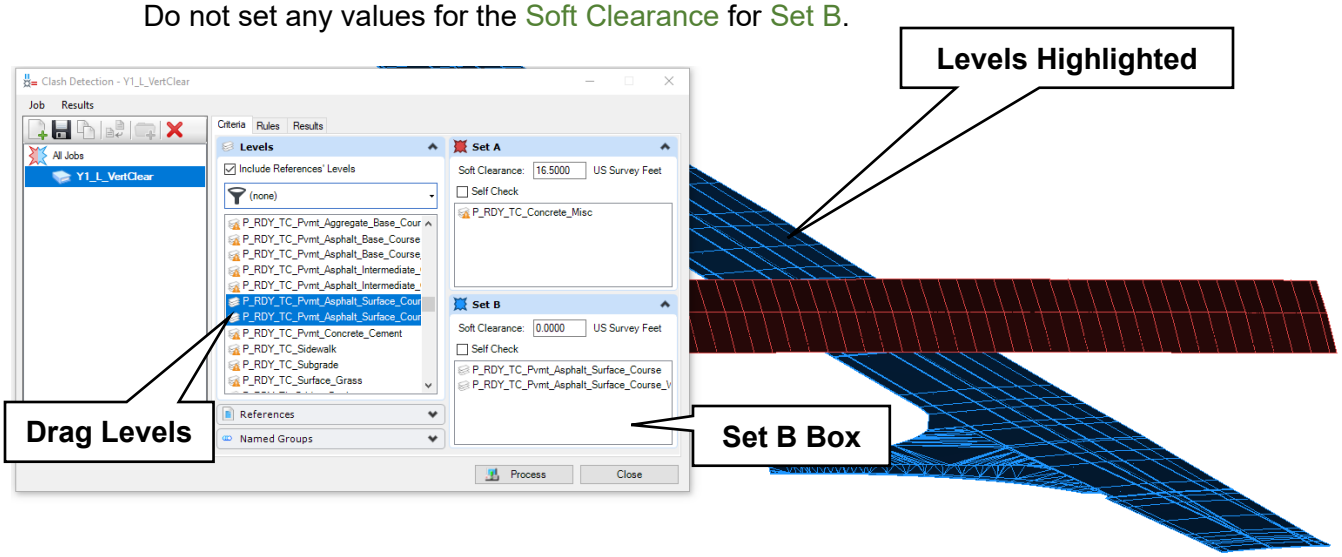


Figure 2-48: Set B Setup

F. Select Process and select the Results tab.

The analysis did not find any locations that violated our given vertical clearance criteria.

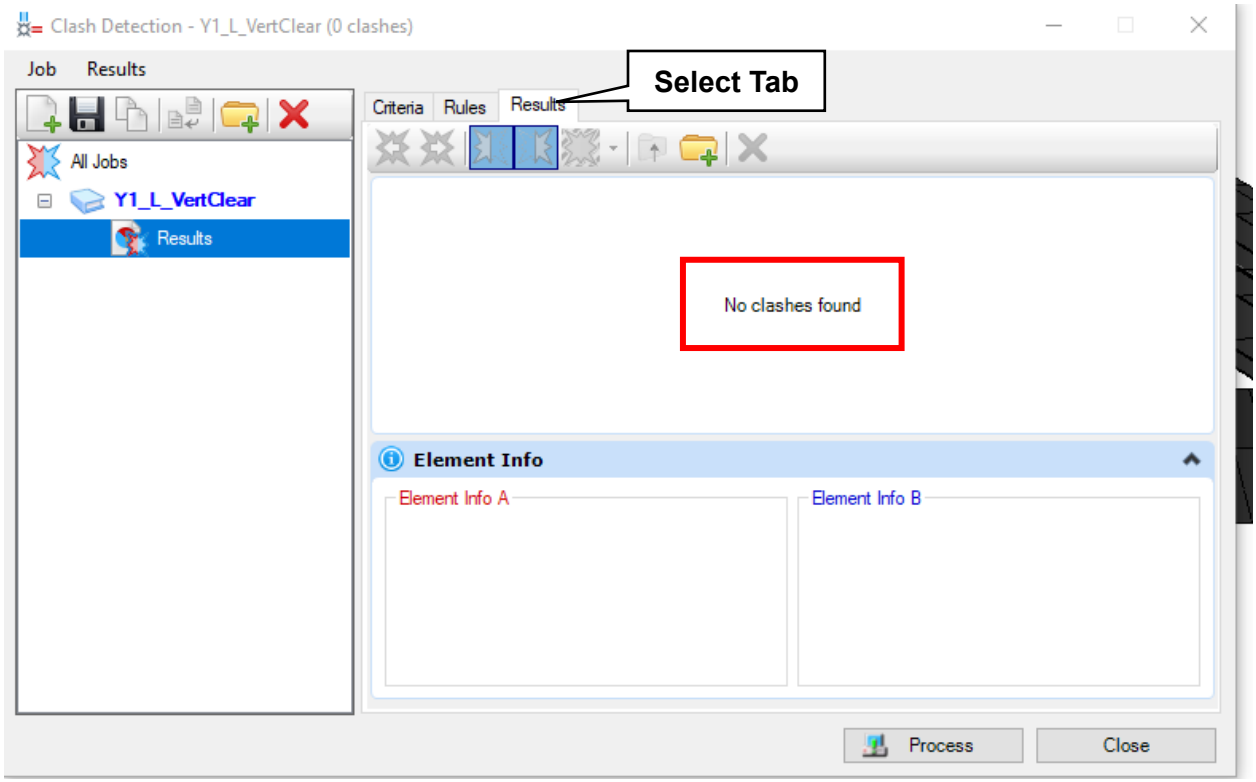


Figure 2-49: Vertical Clearance Empty Results

G. Right Click Results under Y1_L_VertClear on the right window under All Jobs and select Clear All. Click Yes to confirm.

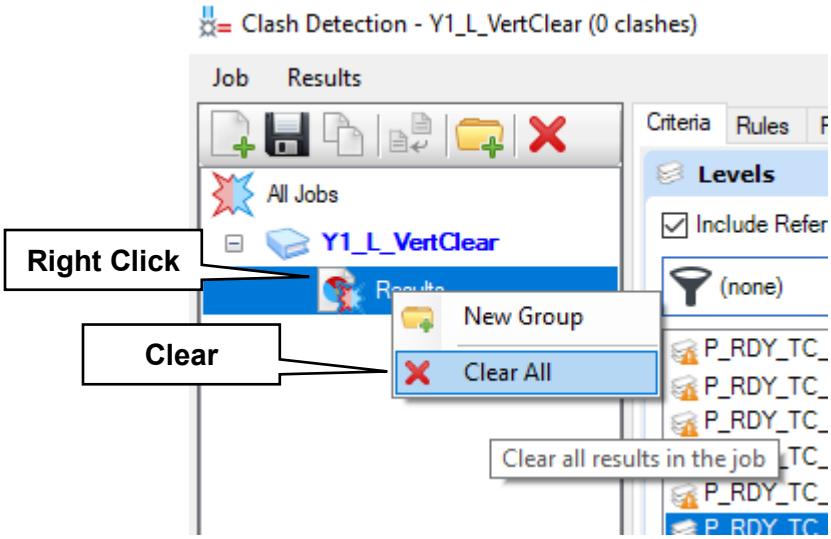


Figure 2-50: Clear Clash Job

Repeat the previous steps and change the Soft Clearance of Set A to be 17.0ft.

Hit Process and view the Results tab again.

In the Results tab, right click on any of the columns and select Show Columns and Clearance to display the calculated clearance at locations where the Soft Clearance "Clashed".

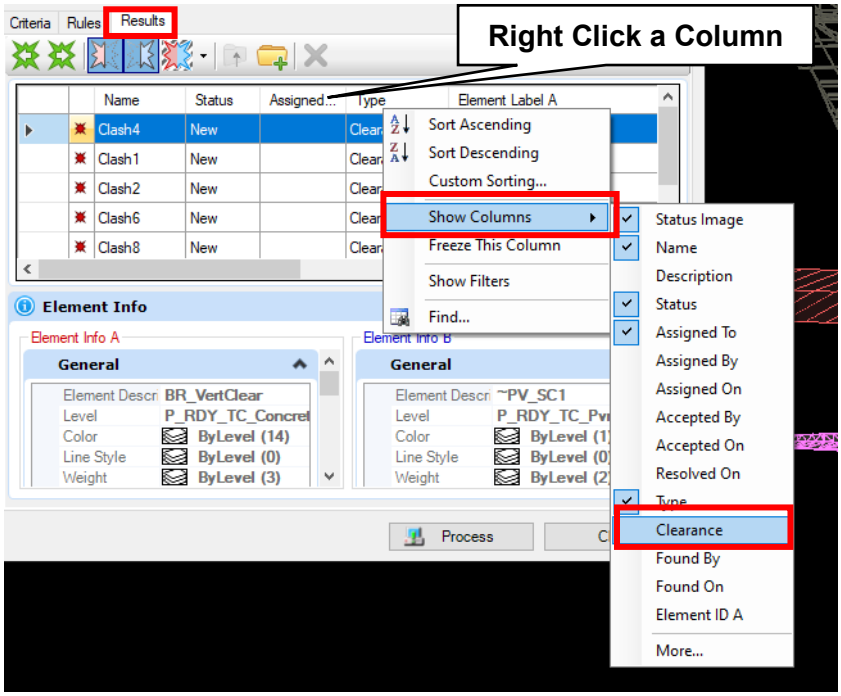


Figure 2-51: Clear Clash - Add Clearance Column

The analysis found several instances where the clearance of 17.0ft was not satisfied between the Set A and Set B components.

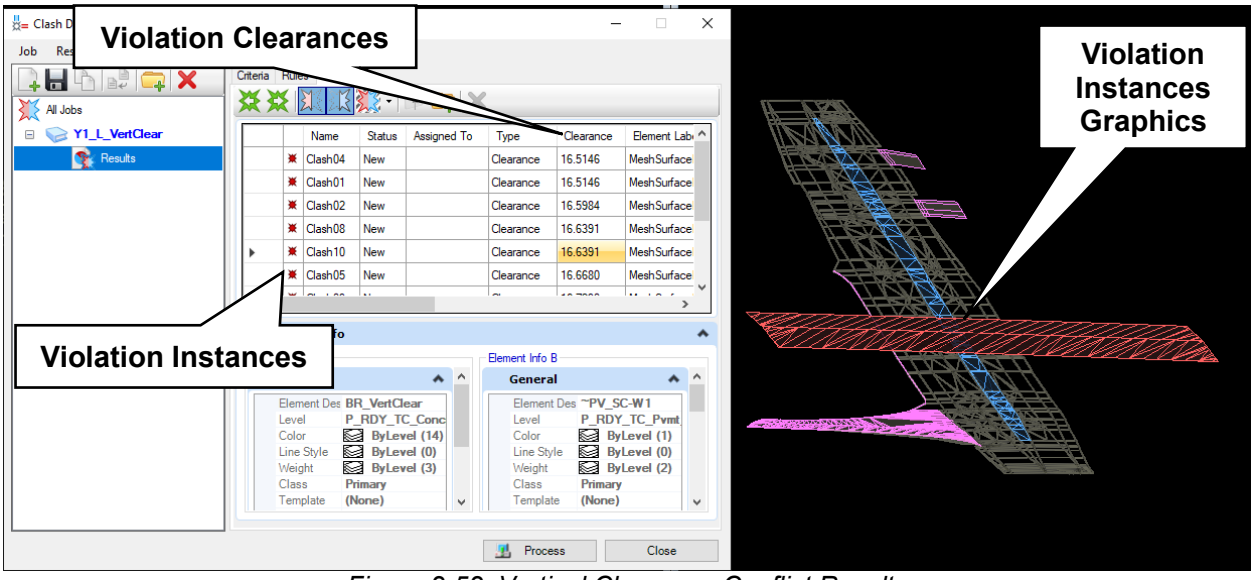


Figure 2-52: Vertical Clearance Conflict Results

H. The clash results can be exported to an excel file for record keeping.

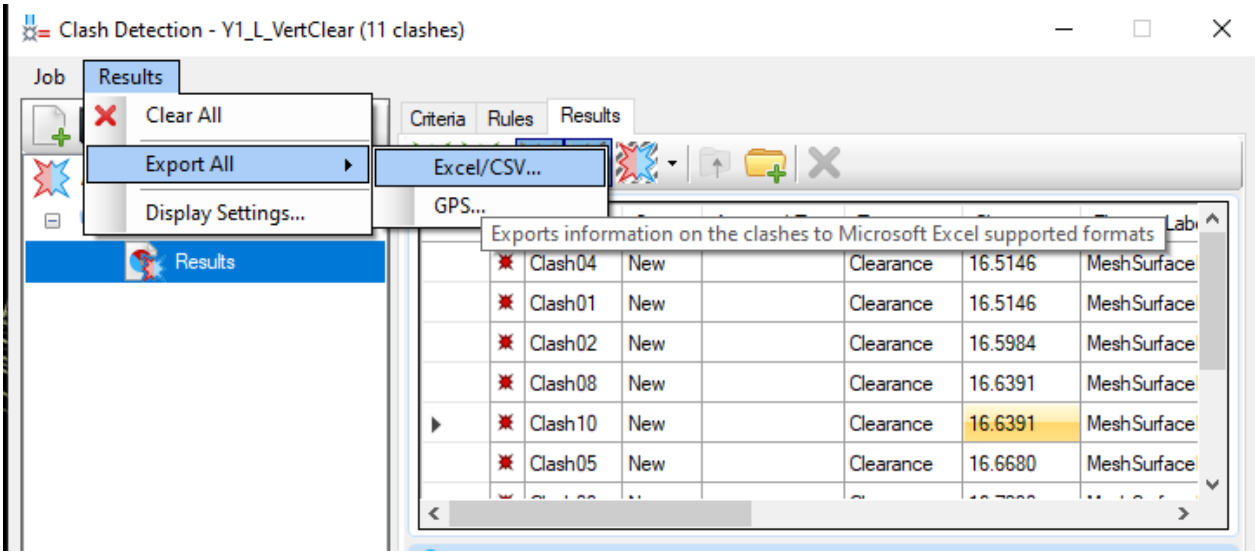


Figure 2-53: Export Clash Results

	A	B	C	D	E	F	G	H	I	J
1	**Job Name**	**Status**	**Number of Clashes**	**Started At**	**Ended At**					
2	Y1_L_VertClear	Completed successfully	11	1/14/2026 15:28	1/14/2026 15:28					
3										
4	**Parent**	**Name**	**Job Name**	**Status**	**Assigned To**	**Type**	**Clearance**	**Element Label A**	**Element Label B**	**Location (WGS84 Datum - Longitude, Latitude, Elevation)**
5	Root	Clash01	Y1_L_VertClear	New		Clearance	16.5146	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'30.8", 35°49'34.3", 223.3350
6	Root	Clash02	Y1_L_VertClear	New		Clearance	16.5984	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'30.8", 35°49'34.3", 223.3350
7	Root	Clash03	Y1_L_VertClear	New		Clearance	16.7584	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'30.8", 35°49'34.3", 223.3350
8	Root	Clash04	Y1_L_VertClear	New		Clearance	16.5146	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'30.8", 35°49'34.3", 223.3350
9	Root	Clash05	Y1_L_VertClear	New		Clearance	16.668	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'30.8", 35°49'34.3", 223.3350
10	Root	Clash06	Y1_L_VertClear	New		Clearance	16.9666	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'30.8", 35°49'34.4", 223.1684
11	Root	Clash07	Y1_L_VertClear	New		Clearance	16.8094	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'31.2", 35°49'34.4", 222.2276
12	Root	Clash08	Y1_L_VertClear	New		Clearance	16.6391	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'30.8", 35°49'34.4", 223.3350
13	Root	Clash09	Y1_L_VertClear	New		Clearance	16.723	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'30.8", 35°49'34.4", 223.3350
14	Root	Clash10	Y1_L_VertClear	New		Clearance	16.6391	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'30.8", 35°49'34.5", 223.3350
15	Root	Clash11	Y1_L_VertClear	New		Clearance	16.7929	MeshSurfaceEntity	Linear - Stations Offsets	-80°16'30.8", 35°49'34.3", 223.3350
16										

Figure 2-54: Exported Clash Result Excel Table

2.2.3 Clearance Checks Using Structures Digital Twin (DT)

YouTube video: https://www.youtube.com/watch?v=kEKXS17ZQ1w

Clash Detection can be used in the same manner as previously described to verify vertical clearances with an official Digital Twin once provided by SMU or the Structures Engineer of Record. A "Digital Twin" is the 3D digital bridge output by OpenBridge.

A. Click the browser button and path to the Module 12 - Interchange – Vertical Clearance\Roadway\Document folder and open the R-2635C_RDY_Clash.dgn file.

B. Select View 2, Default-3D and expand the window to the full screen.

C. In the References dialog, set the structure's Digital Twin to display and do not display the Preliminary Bridge Model (R-2635C_RDY_CMD_Bridge_L.dgn).

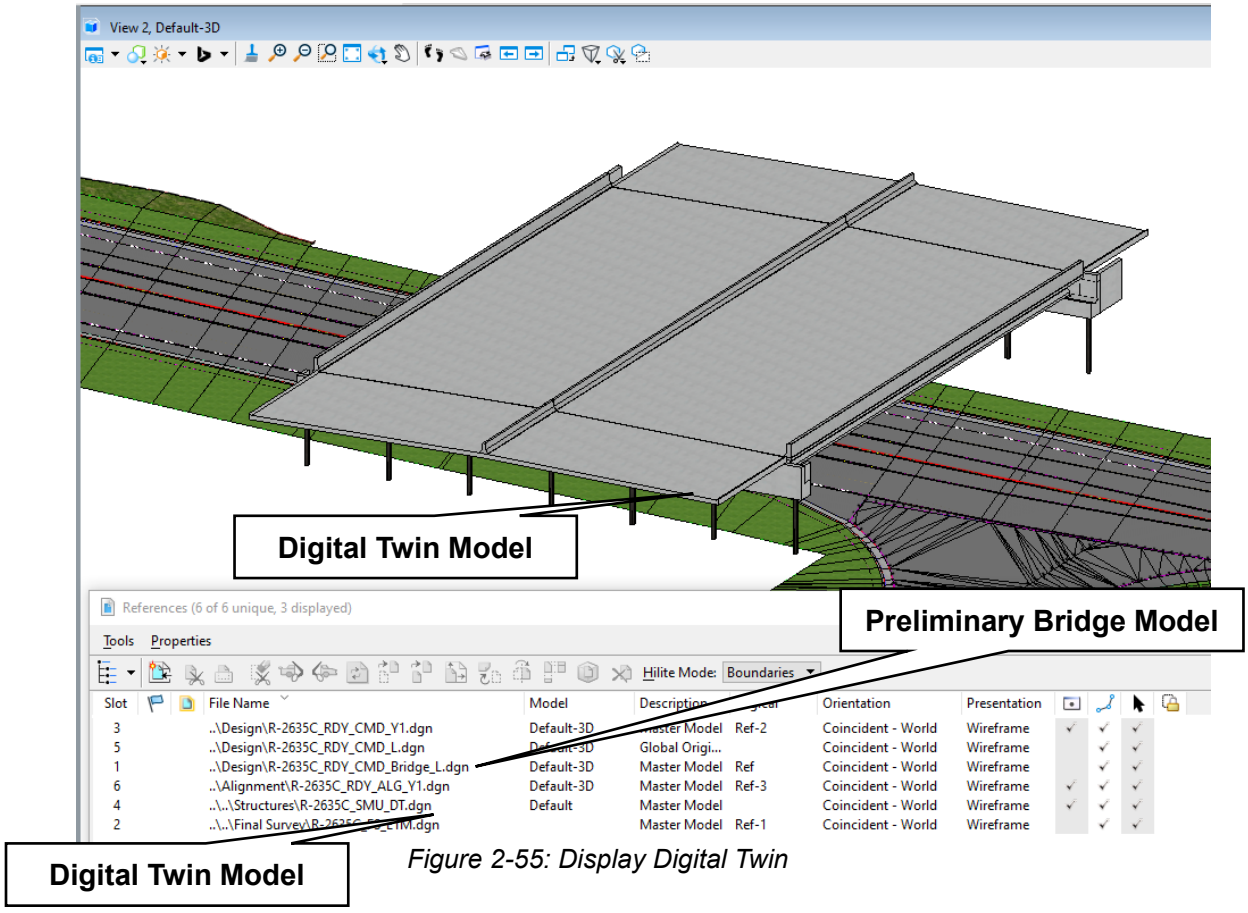


Figure 2-55: Display Digital Twin

D. Open the Level Display dialog and isolate the P_SMU_Concrete_Girder level in the Digital Twin model.

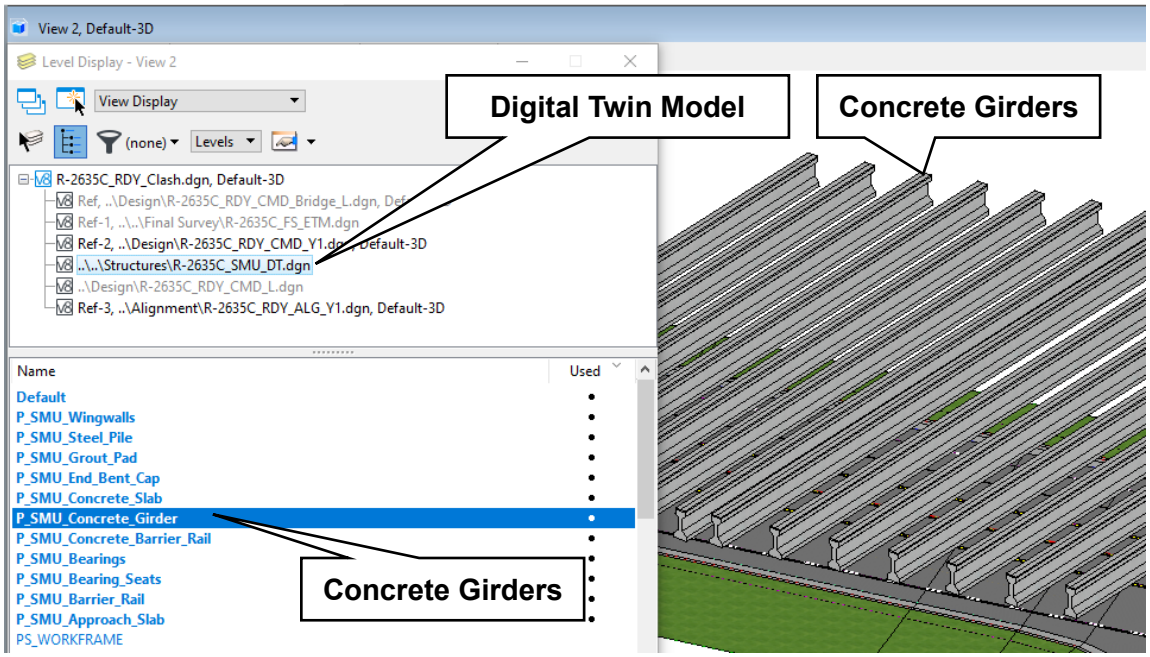


Figure 2-56: Isolate Girders

E. Create another clash job called DT_VertClear and set the conditions as shown.

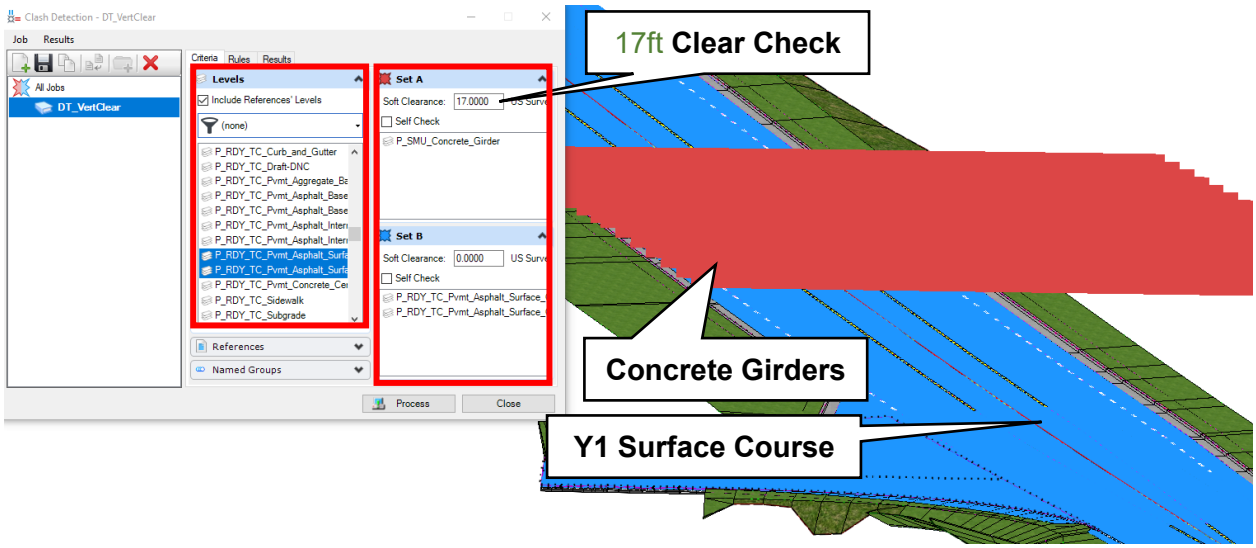


Figure 2-57: Digital Twin Clash Set-Up

F. Clash Results are similar to the Preliminary Bridge Model and can be analyzed and exported similarly for the project record.

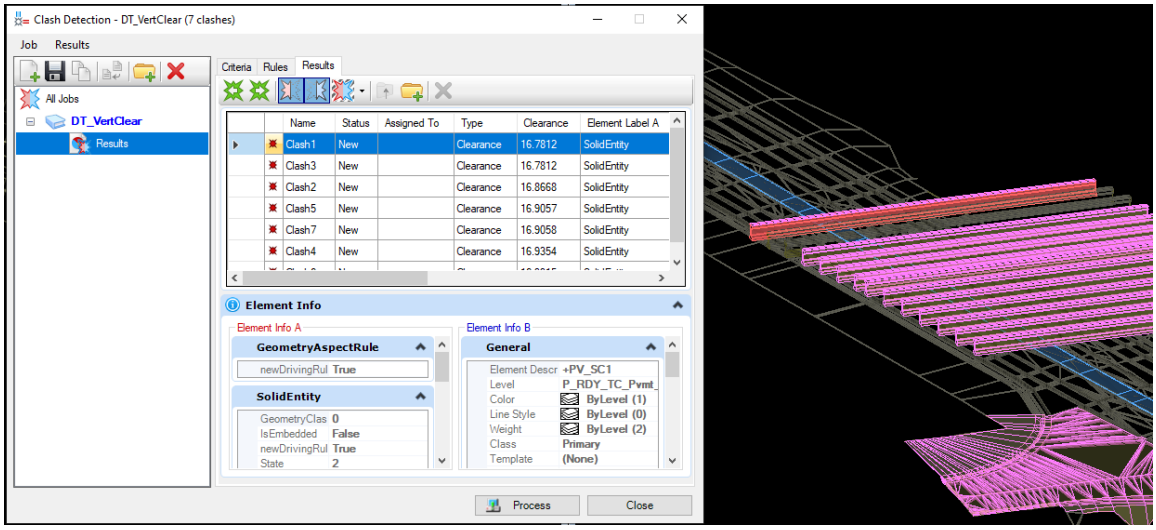


Figure 2-58: Digital Twin Clash Results

3.0 Infield Modeling

The NCDOT Standard drawings references in the following exercises are:

- 225.07 Grading for False Cuts at Grade Separations
- 225.09 Guide for Shoulder and Ditch Transition at Grade Separations

We will be using the same file to build out all modeling details at the -L- and -Y4- grade separation. The suggested workflow presented in these exercises keep the -L-, -Y4-, and the details in separate CMDs to allow for flexibility when creating cross sections and performing earthwork calculations. The working DSN file used in this exercise has been trimmed to contain linework only within the limits of the grade separation and should not be considered complete. The concrete slope protection has been added to both bridge end bents. For simplicity, the concrete slope protection does not extend beyond the limits of the bridge. The concrete slope protection and the bridge digital twin is not 100% modeled in these exercises.

1. **Launch OpenRoads Designer Connect Edition**
   Double-click on the NCDOT OpenRoads Designer 2023 to launch OpenRoads Designer.

2. **Select the Workspace and WorkSet**
   Select DOT-US North Carolina from the Workspace menu.
   Select Training-RD_R-2635C from the Workset menu.
   Select NCDOT_Roadway from the Role menu.

3.1 False Cuts at Interchanges (Standard 225.07)

In this exercise, you will learn how to model the NCDOT Standard 225.07 for False Cuts and Grade Separations. Please see video titled NCDOT Module 12 – Std 225.07.

1. **Open the -L- and -Y4- details CMD model and set your window to display the plan and 3D view.**
   A. Click the browser button and path to the Module 12 – Interchange Module – Infield Modeling\Roadway\Design folder and open R-2635C_RDY_CMD_Details_L_Y4.dgn.

Active References (Default View):

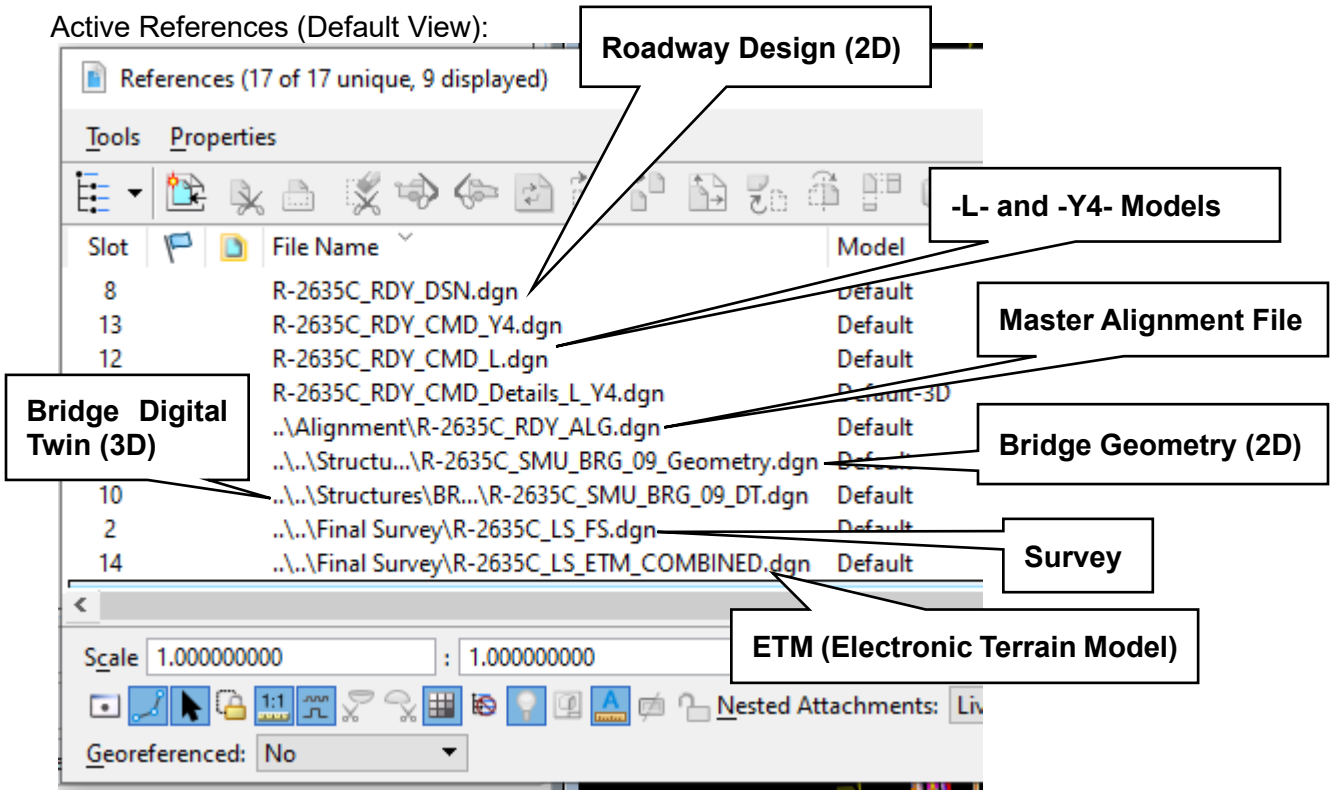


Figure 3-1: R-2635C_RDY_CMD_Details_L_Y4.dgn References

B. In View 1, Default view, zoom near the grade separation of -L- and -Y4- as shown below. Notice there is already a design layout for -L- and -Y4-. If you navigate to the 3D View (as shown in Figure 2-17: View Plan/3D), notice the -L-, -Y4-, the Bridge and the concrete slopes have already been modeled. There are marked, dedicated quadrants where we will be modeling the various standards listed previously along with scratch lines that have already been laid out which corresponds to the standards.

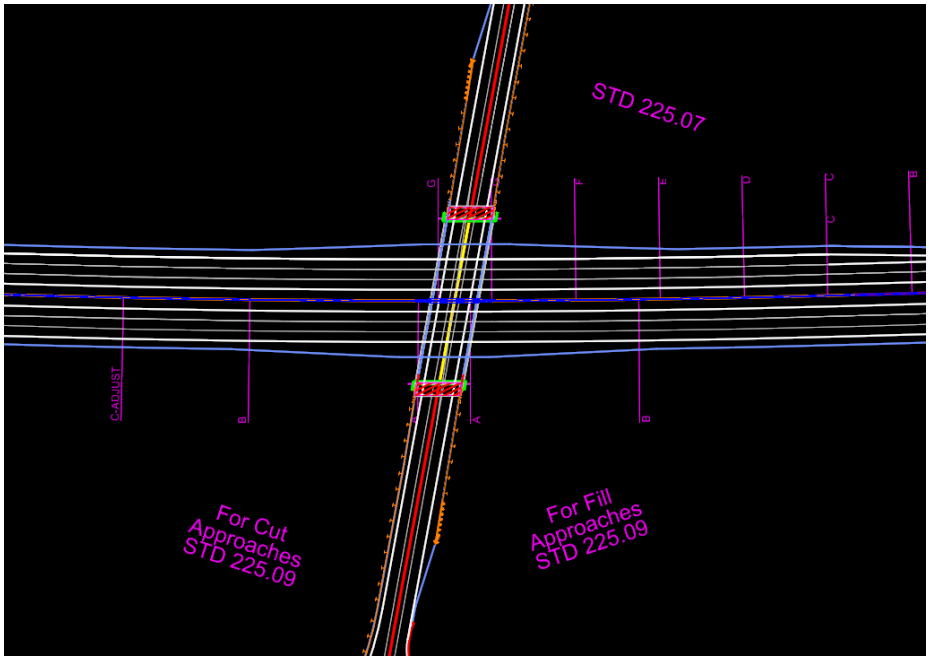


Figure 3-2: Infield Details, Plan View

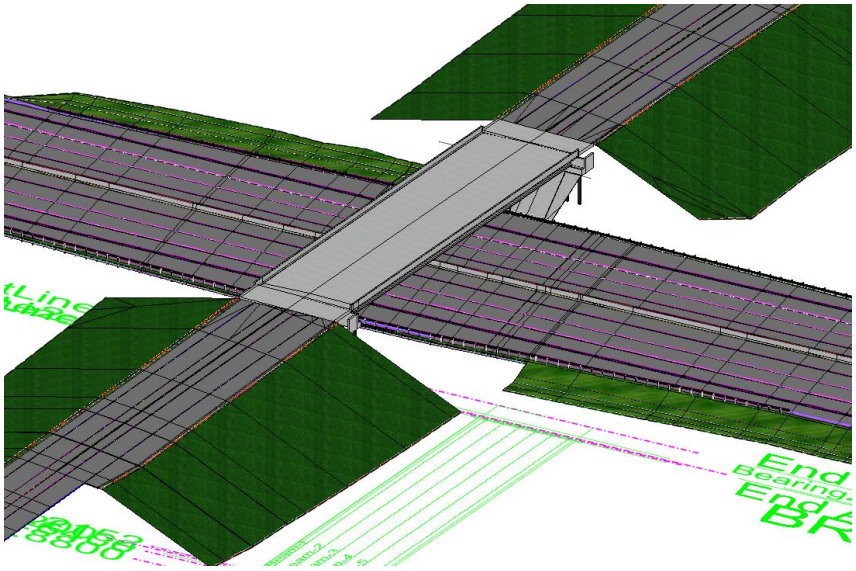


Figure 3-3: Infield Details, 3D Models

2. Modeling 225.07

A. It is important to note that while we are modeling the grade separation details in a standalone model, it will be necessary to update the models of -L- and -Y4- to correspond to the modeled limits of the details.

B. The -L- model has an End Condition Exception applied to remove the end conditions past the grass shoulder at the areas we are about to model.

C. In the View 1, Default – References dialog, turn the references for the -L- and -Y4- CMDs to display.

D. In the upper right quadrant, we will now model the Standard 225.07.

E. Navigate in the Corridors ribbon to Create – Template – Create Template and load the R-2635C (Training)_RDY.itl from the Design folder.

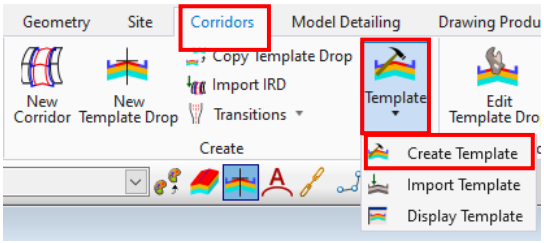


Figure 3-4: Load Template Library

F. We will be using the FalseCut template located in the Infield Modeling folder.

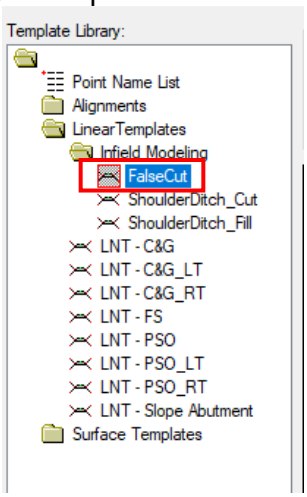


Figure 3-5: Template Location

G. Close the Template Library Dialog.
H. Navigate in the Model Detailing ribbon to 3D Tools – Apply Linear Template and apply the FalseCut linear template to the grass shoulder between marks G and A.

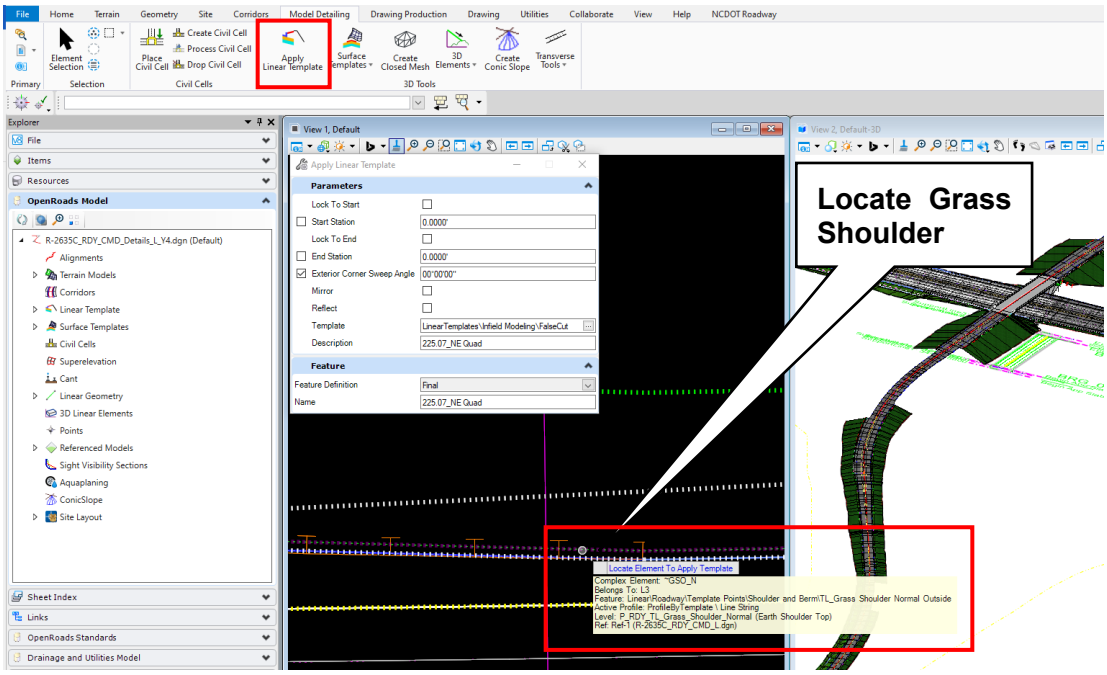


Figure 3-6: Apply FalseCut Linear Template

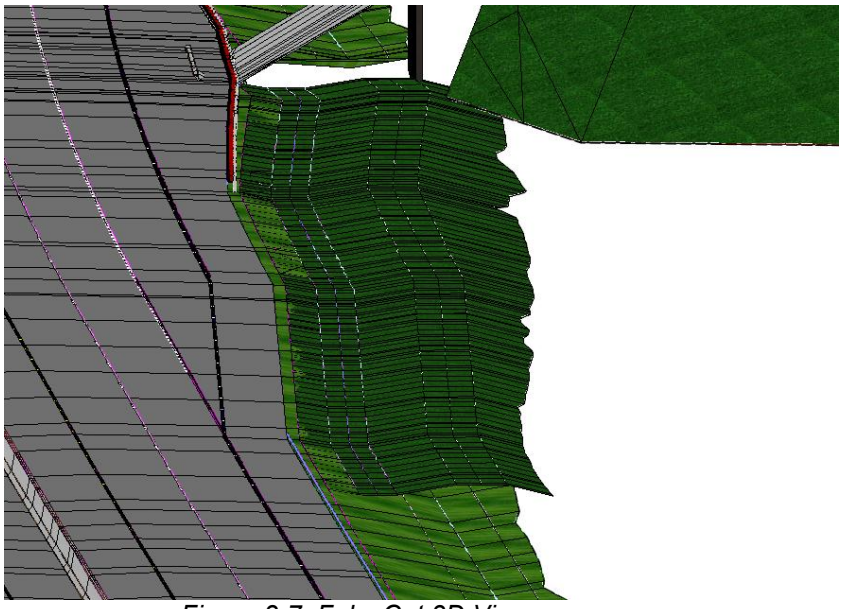


Figure 3-7: FalseCut 3D View

I. Next, we are going to set the 30:1 ditch taper that begins at the concrete slope protection that controls the center of the ditch.

The center of the ditch taper is controlled by the DBM_NULL point in the template and seeks the Construction Class Element: CCE_Target_1 feature definition.

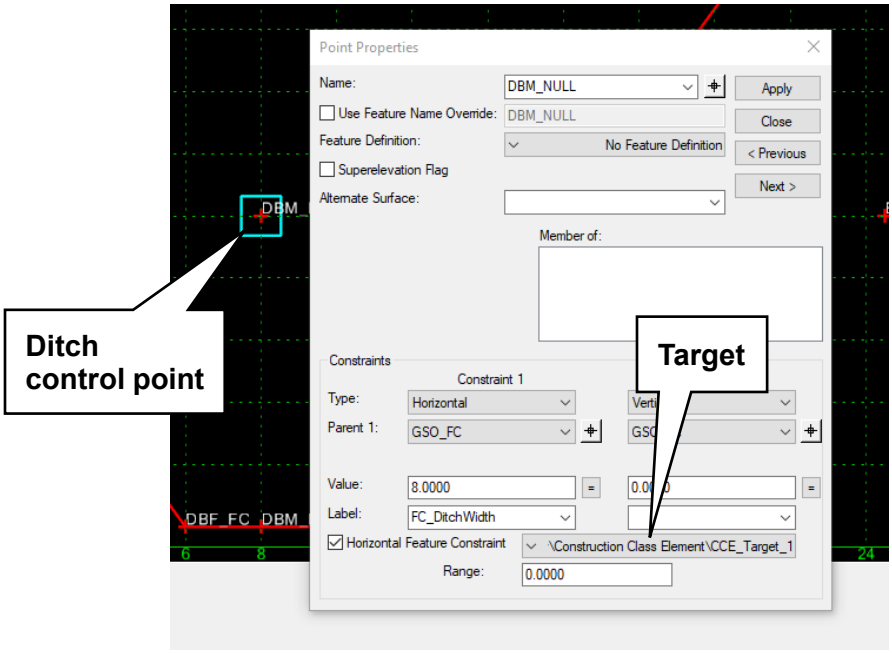


Figure 3-8: FalseCut Template Ditch Control

Using the Geometry > Horizontal Geometry tools > Ratio Offset Taper, place the 30:1 taper with respect to the -L- alignment between points G and C, with CCE_Target_1 as the active feature definition.

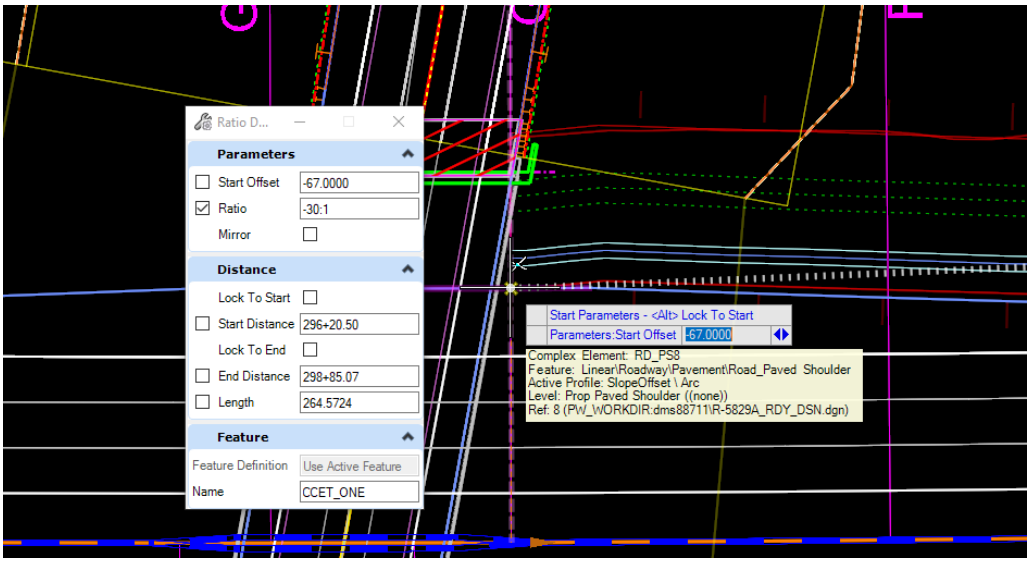


Figure 3-9: FalseCut, 30:1 Taper Start

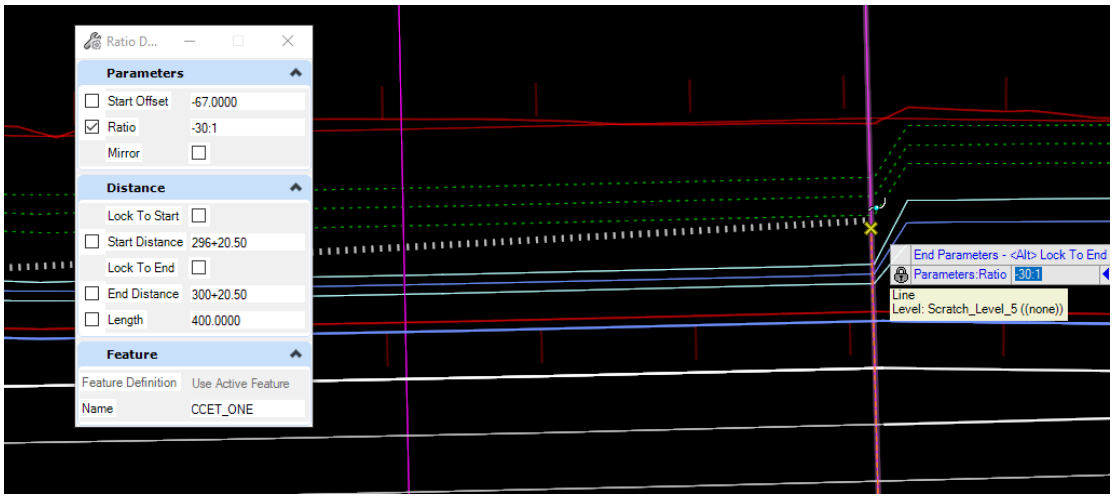


Figure 3-10: FalseCut, 30:1 Taper End

Apply the target to the corridor as a reference. Go to the Corridor > Miscellaneous > Corridor References > Add Corridor Reference, and select the 225.07 NE Quad Linear Template as the corridor, and select the CCE_Target_1 line drawn in the previous step.

J. Now we are going to set parametric constraints to control the back slopes to match the Standard. Set parametric constraints as follows:

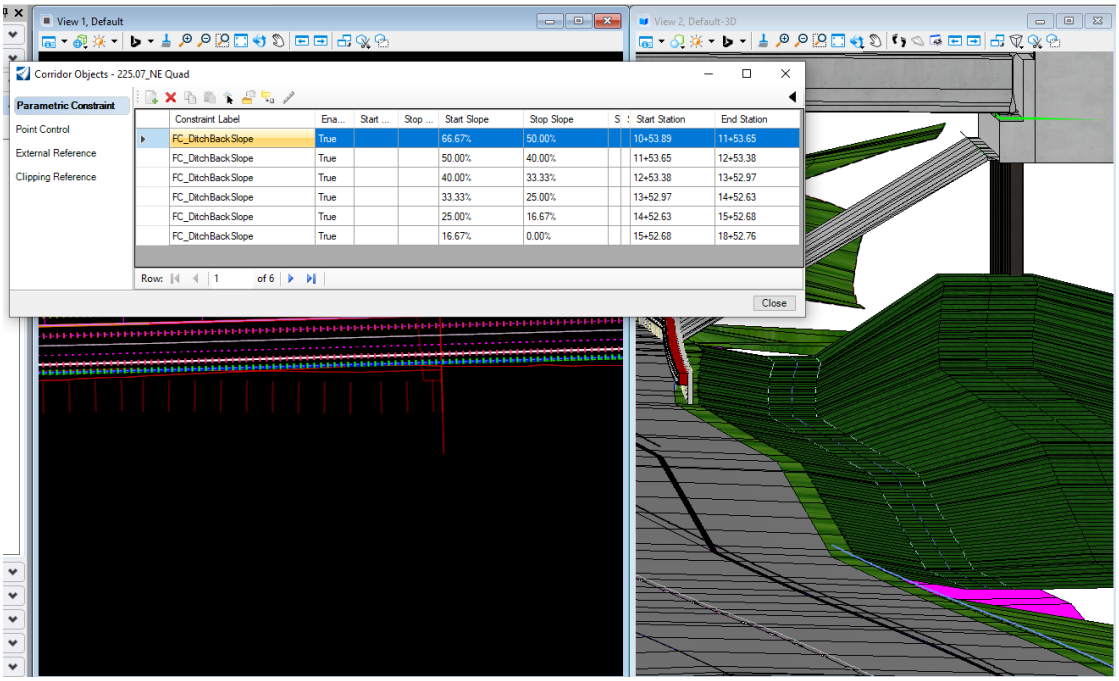


Figure 3-11: Ditch Back Slope Parametric Constraints & 3D View

Station values are where the reference scratch lines intersect the paved shoulder point.

K. Next, we are going to set and control the top of the berm.

The center of the top of the berm is controlled by the BermMid_NULL point in the template and seeks the Construction Class Element: CCE_Target_2 feature definition.

Using the Horizontal Geometry tools > Single Offset Partial, place the Construction class element at a constant offset from the paved shoulder following the targeted scratch line in plan view alignment between points G and C. This location was determined by drawing a line tangent to the wingwall on -Y4- to where it intersects with the paved shoulder on -L-. This intersection point is where the concrete slope protection under the bridge will meet the paved shoulder on -L-. This is where the NCDOT Std 225.07 will end (point G in the figure). The offset distance for the berm can be found by drawing a line perpendicular to the paved shoulder on -L- from the end of the wingwall, in this case it is 37.7318'.

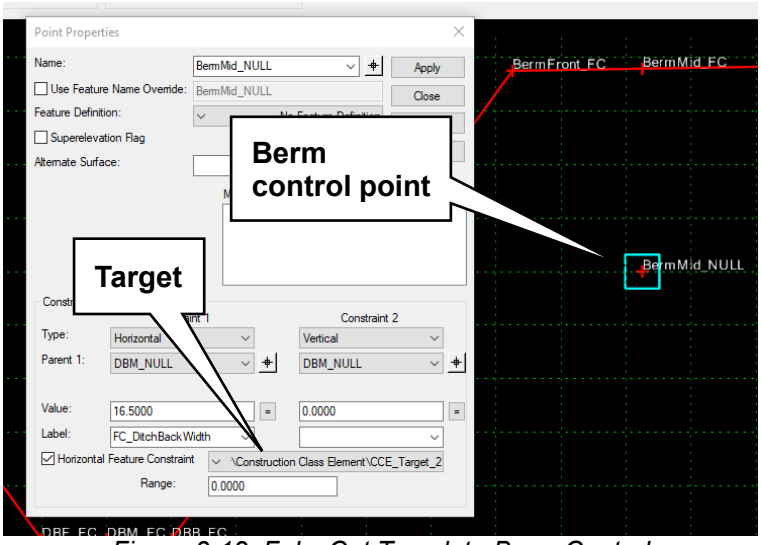


Figure 3-12: FalseCut Template Berm Control

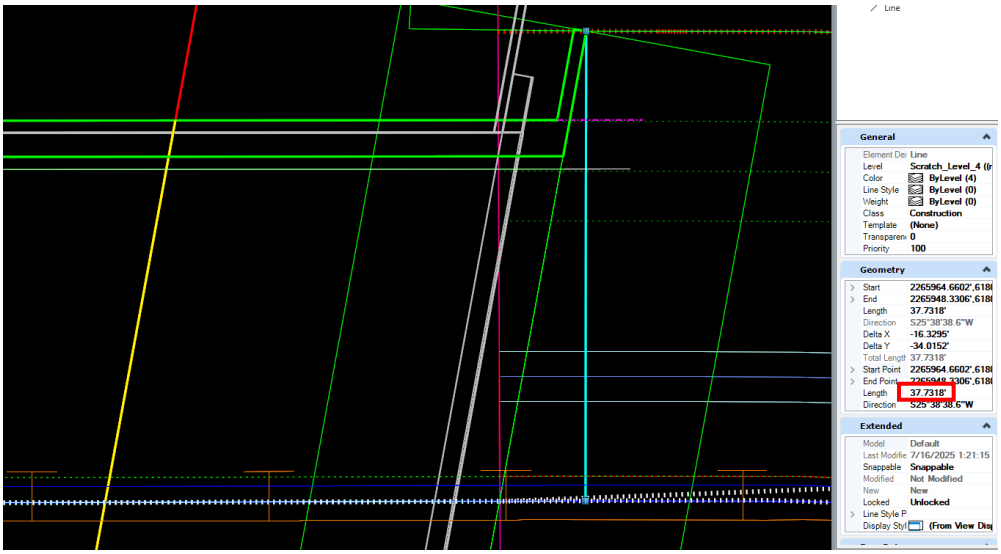


Figure 3-13: Distance for Top of Berm Offset to -L- Paved Shoulder

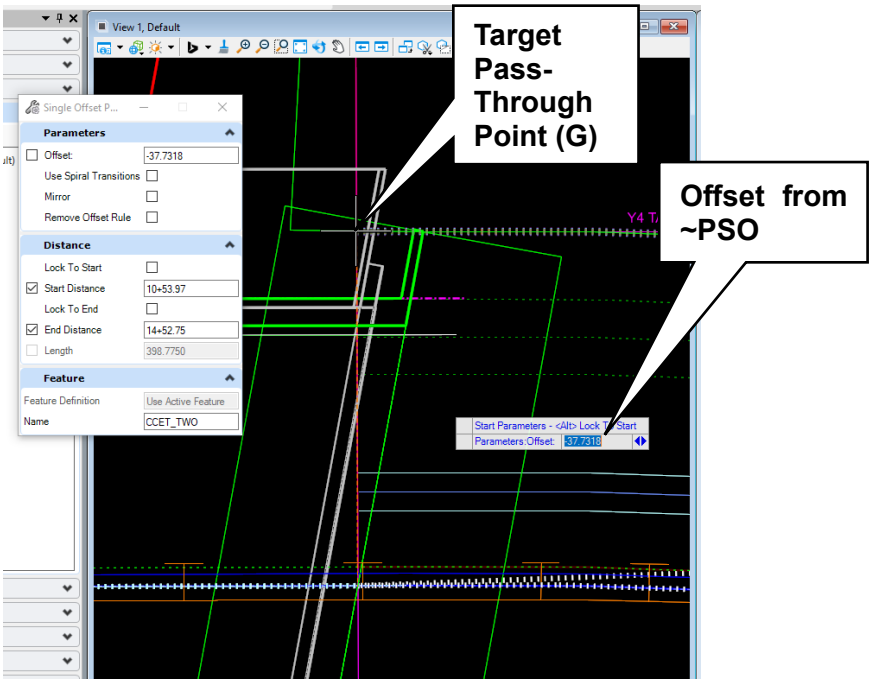


Figure 3-14: FalseCut, Berm Top Begin

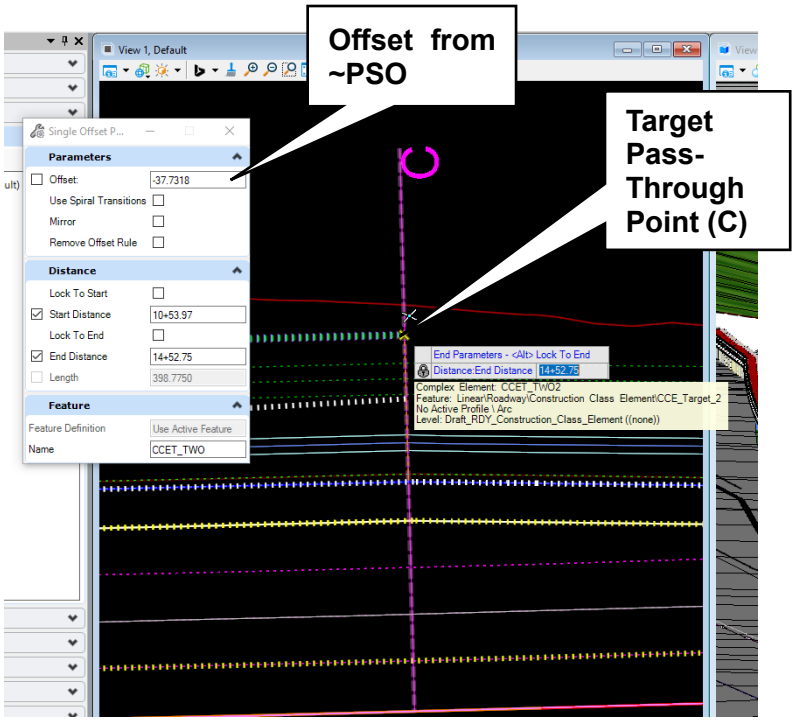


Figure 3-15: FalseCut, Berm Top End

Apply the target to the corridor as a reference.

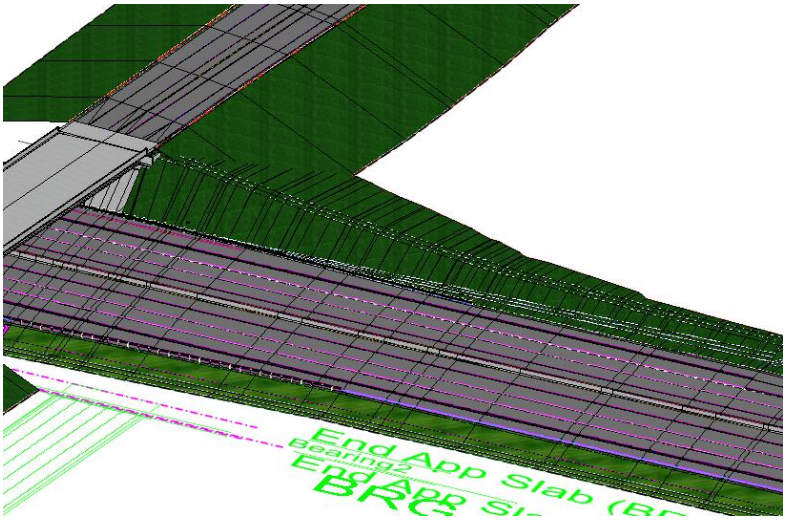


Figure 3-16: FalseCut, Berm

L. We are now ready to clean up the interaction of -Y4- and our linear template.

Open the Define Target Aliasing dialog (Geometry > Miscellaneous > Define Target Aliasing). Select the Corridor – Y4 corridor, move it above the Terrain Model – Complex Terrain, and add it to the Aliases selection, Select Use Closest and hit apply.

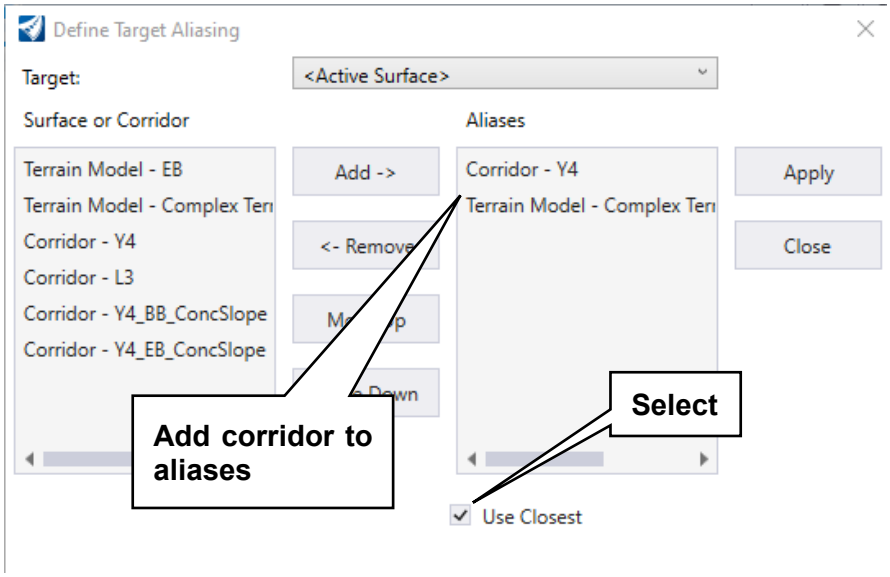


Figure 3-17: Define Target Alias

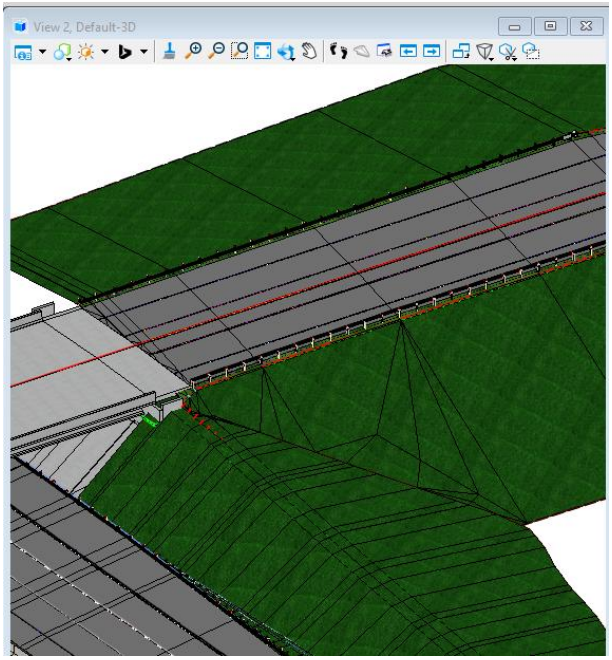


Figure 3-18:FalseCut -Y4- Targeted

In the View 1, Default view, locate the green Scratch Level 2 shape. This will be used to clip the linear template 225.07_NE Quadrant around the concrete slope and -Y4- corridor.

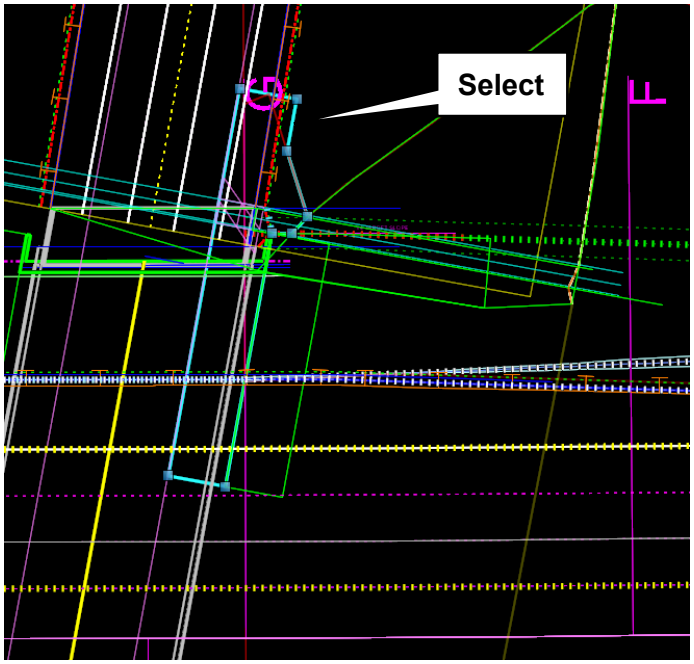


Figure 3-19: FalseCut Concrete Slope and -Y4- Clipping Shape

Add that shape as a clipped reference for your linear template 225.07_NE Quadrant.

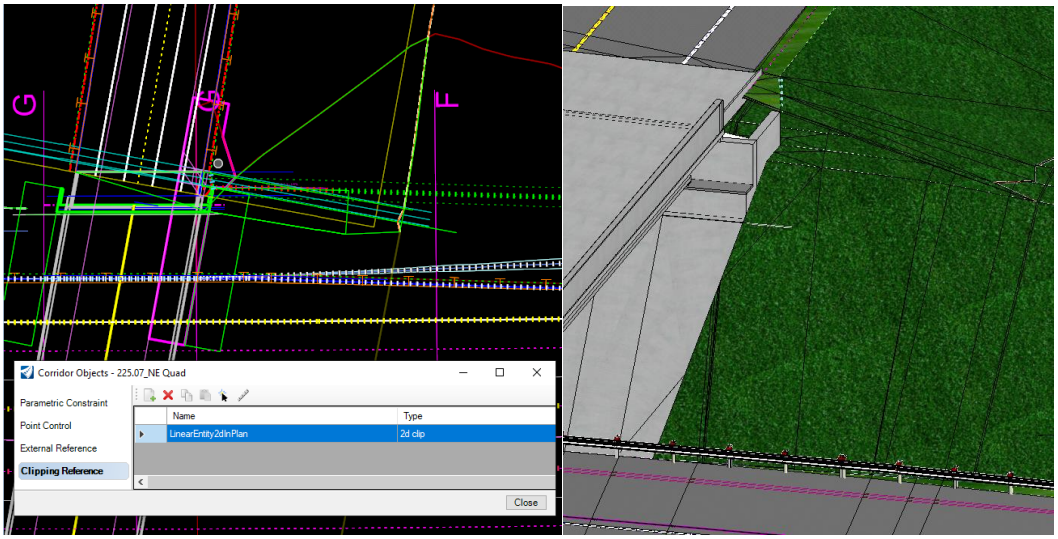


Figure 3-20: FalseCut, Clipped Slope

Now we need to clip out the -Y4- model for the overlap area with the linear template 225.07_NE Quadrant. Open the R-2635C_RDY_CMD_Y4.dgn file.

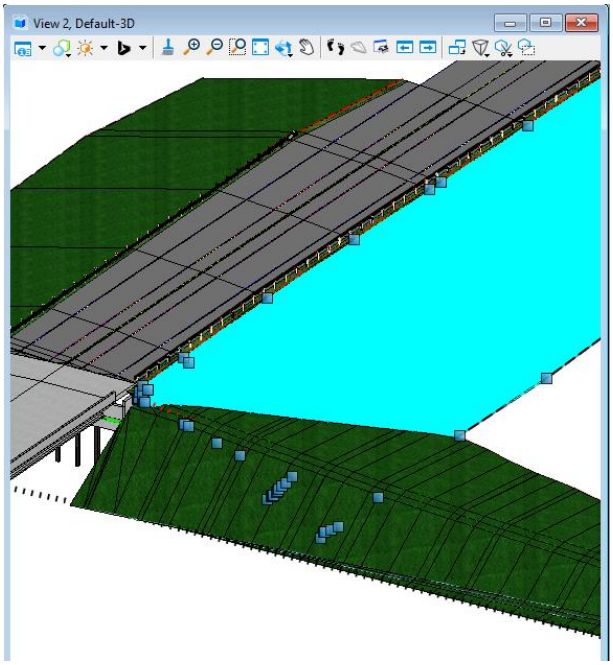


Figure 3-21: FalseCut, Overlap of -Y4- Corridor

We need to revise both corridors to tie in to each other. We cannot use the -Y4- corridor as a clipping reference for the linear template in this instance or we get a result that looks like this:

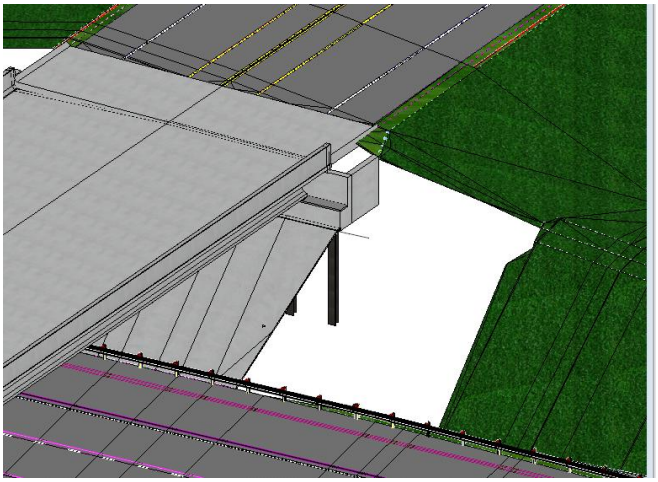


Figure 3-22: FalseCuts, -Y4- Added as Clipping Reference to 225.07_NE Quadrant Corridor, Incorrectly

We cannot use the 225.07_NE Quadrant corridor as a target alias for the -Y4- Corridor because the -Y4- Corridor is being used as a target alias for 225.07_NE Quadrant.

To solve this issue, we will need to clip the -Y4- Corridor to a shape where it overlaps with the 225.07_NE Quadrant Corridor:

1. In the R-2635C_RDY_CMD_Y4.dgn, locate the Scratch_Level_2 shape in View 1, Default.

Figure 3-23: Scatch_Level_2 Clipping Shape

2. Add the Scratch_Level_2 Shape to the -Y4- Corridor as a clipping reference (Corridors > Miscellaneous > Corridor Clipping > Add Clipping Reference).

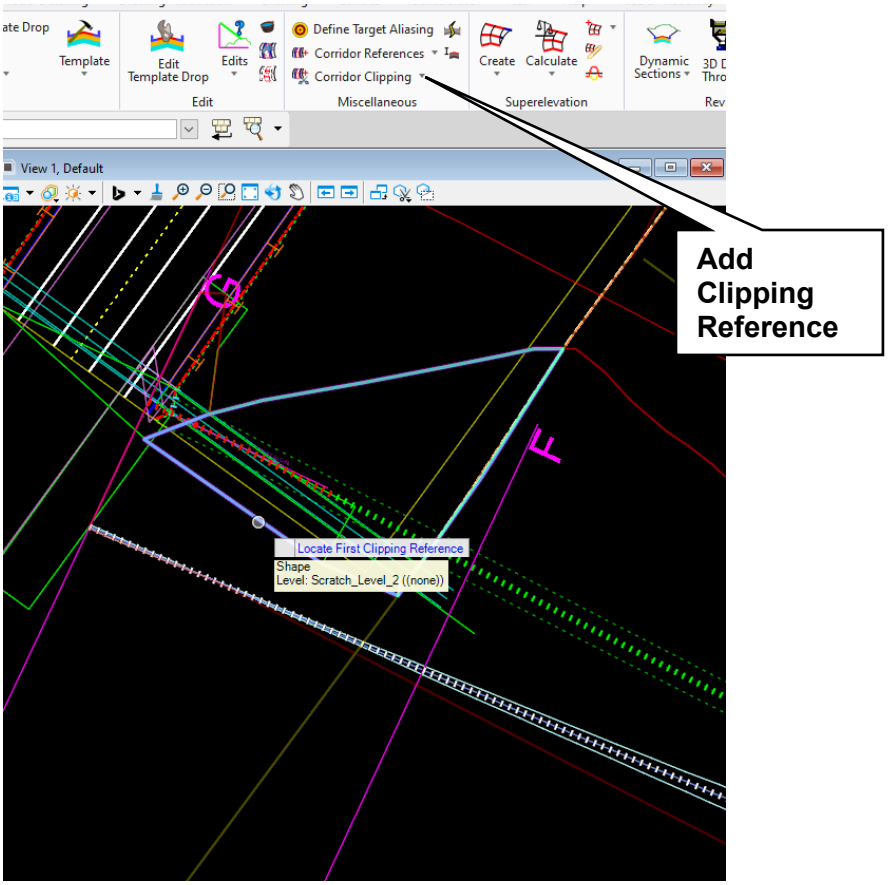


Figure 3-24: Add Clipping Reference for -Y4- Corridor

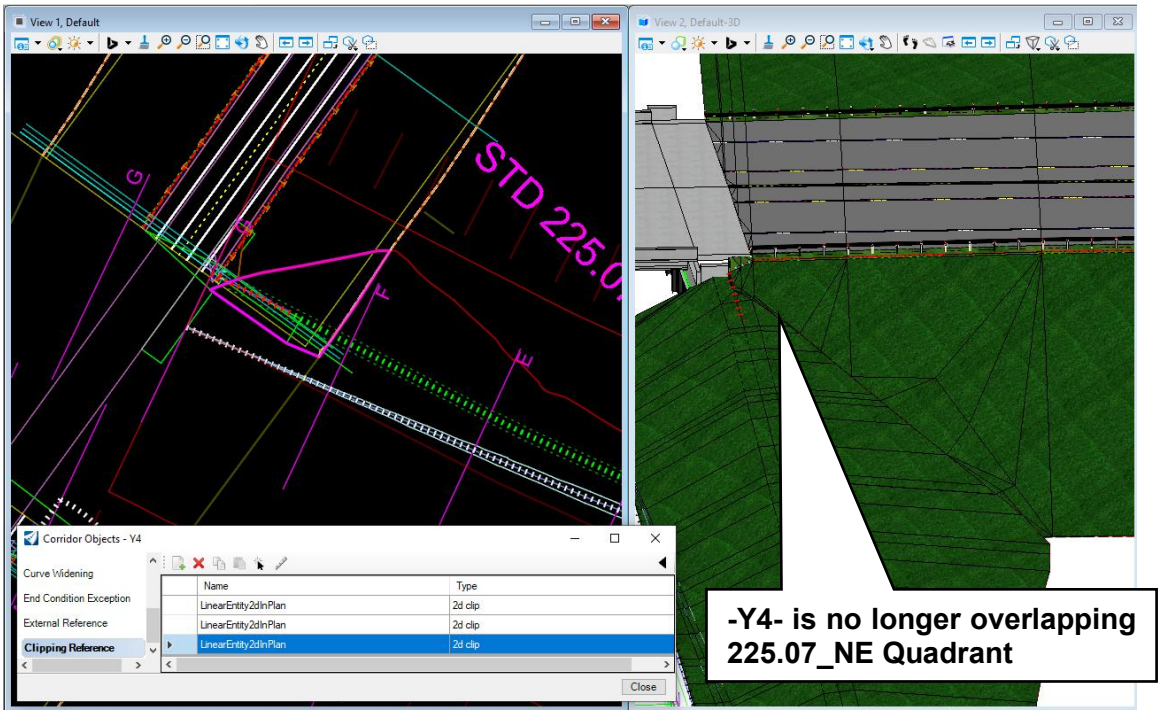


Figure 3-25: -Y4- Corridor Clipped

And add that shape to your clip references and your model should then be clipped to Y4.

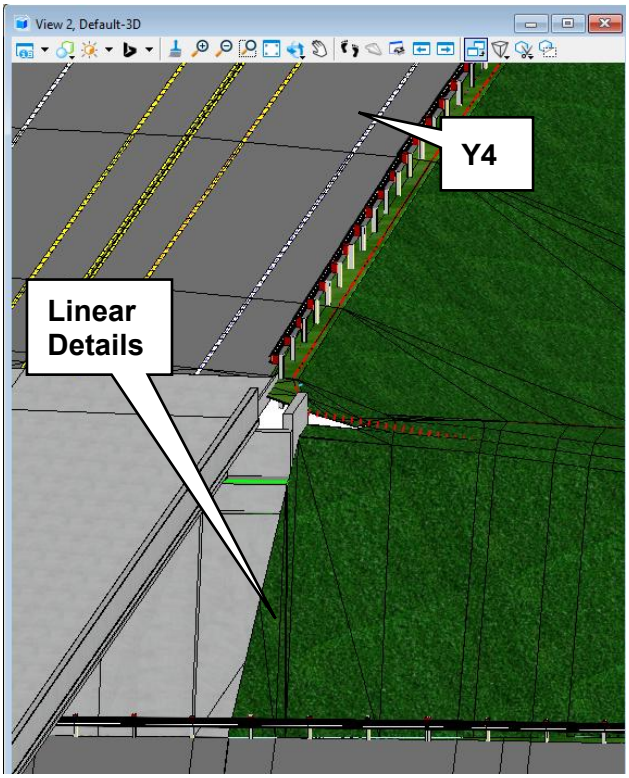


Figure 3-26: FalseCuts, Y4 Clip

The last step is to fil in the gap between the two templates at the wing wall. We will complete this by using a point control and a profile. Open the R-2635C_RDY_CMD_Details_L_Y4.dgn.

First, create a piece of geometry with any construction class element (CCE_Target_3) with an offset of 0ft from the piece of geometry we used to control the horizontal location of the top of the berm (CCE_Target_2).

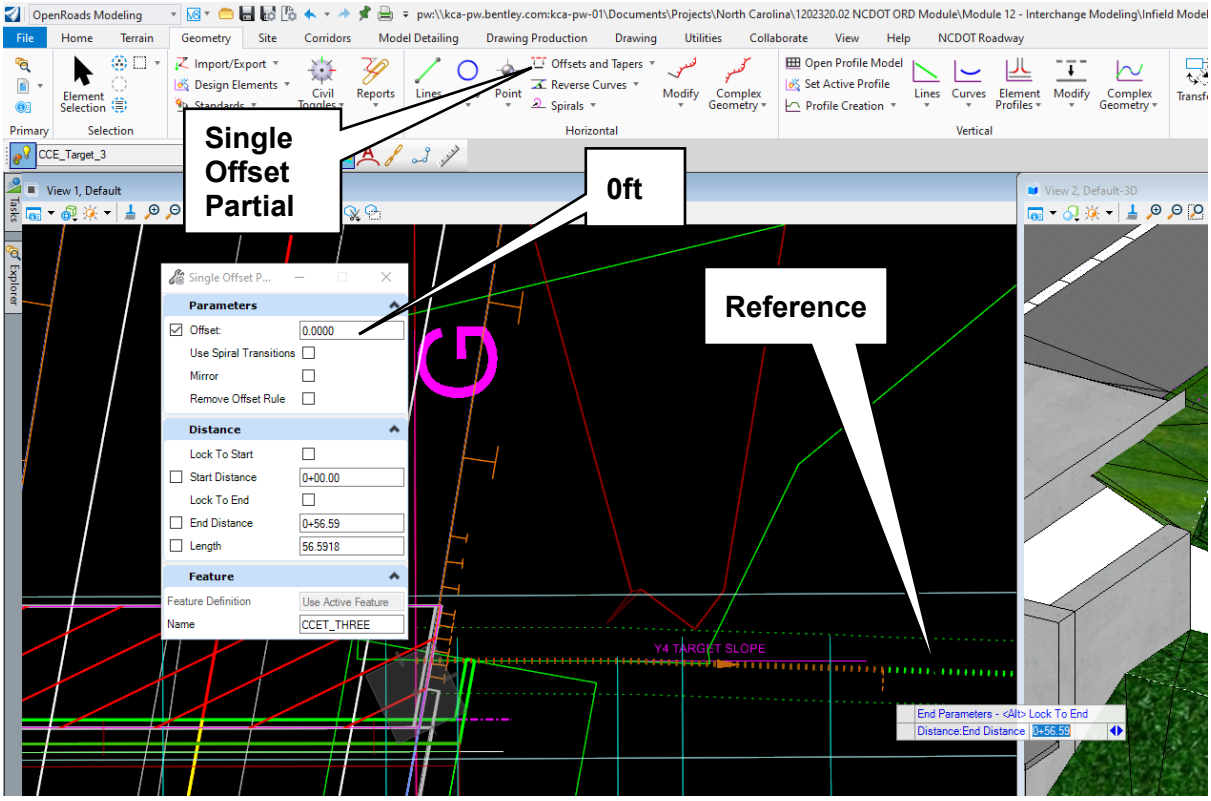


Figure 3-27: FalseCuts Reference Profile

Then open the profile model of the piece of horizontal geometry you just created and perform a 3D Cut at approximate elevations shown in the figure below. Use the placement method Full Profile.

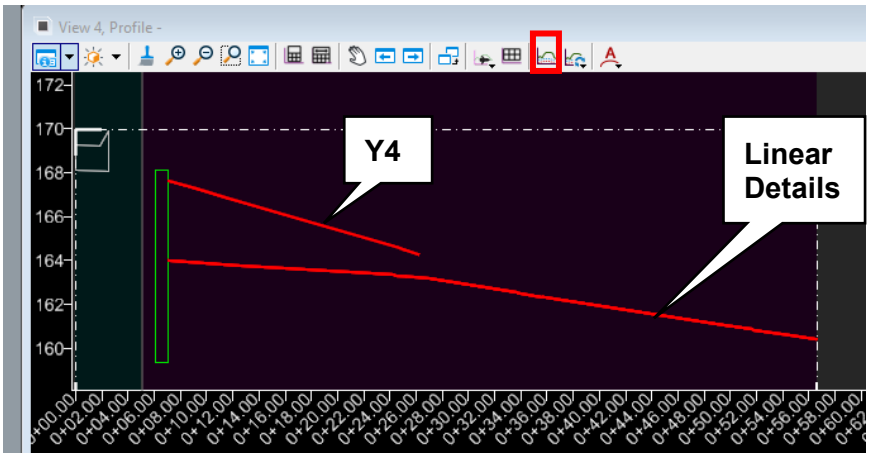


Figure 3-28: FalseCuts 3D Cut

On the Geometry tab, use the Profile Line Between Points tool (Geometry > Vertical > Lines) to create a quick profile that follows the Y4 slope and intersects the Linear Details, and set the profile as active.

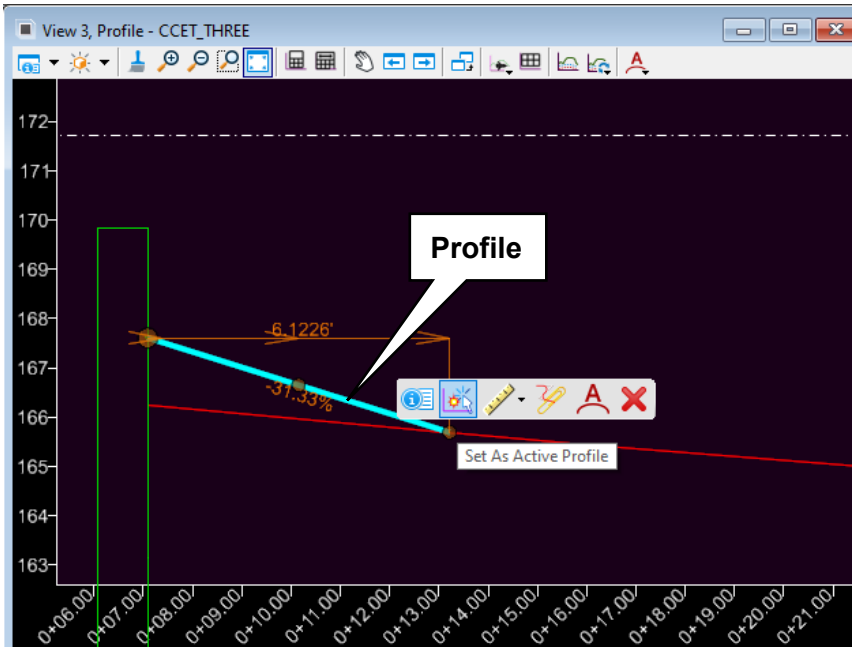
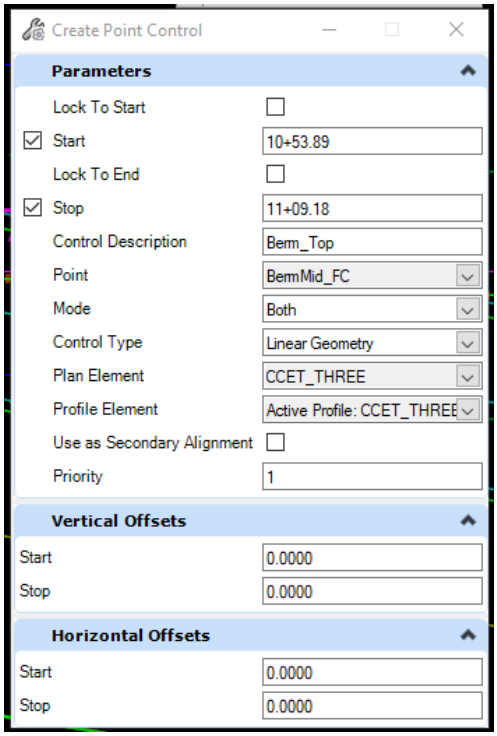


Figure 3-29: FalseCuts, Berm Profile

Finally, create a Point Control in the 225.07_NE Quad Corridor to control the BermMid_FC point to be controlled by the profile we just created.



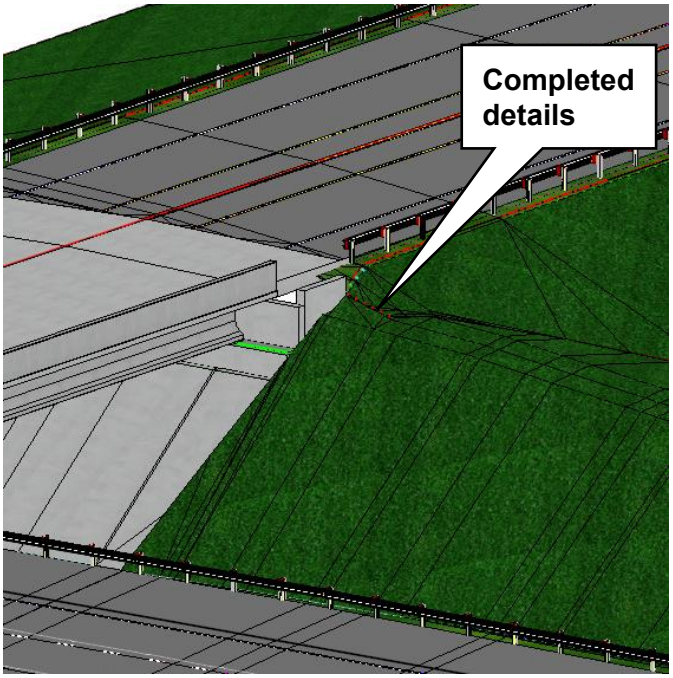


Figure 3-30: FalseCuts, Top of Berm Tie

3.2 Shoulders at Interchanges (Standard 225.09)

In this exercise, you will learn how to model the NCDOT Standard 225.09 both for fill and cut approaches.

3.2.1 Fill Approaches (Standard 225.09)

In this exercise, you will learn how to model the NCDOT Standard 225.09 for Fill Approaches. We are going to use surface templates to create a conical slope around the bridge abutments. The paved shoulder taper as has already been modeled. Please see video titled NCDOT Module 12 – Std 225.09 Cut.

1. **Open the -L- and -Y4- details CMD model and set your window to display the plan and 3D view.**

   A. Click the browser button and path to the Module 12 – Interchange Module – Infield Modeling\Roadway\Design folder and open R-2635C_RDY_CMD_Details_L_Y4.dgn.

   See Figure 3-1: R-2635C_RDY_CMD_Details_L_Y4.dgn References for references.

   B. Set your View Controls to Plan/3D and navigate to the Southeast Quadrant.

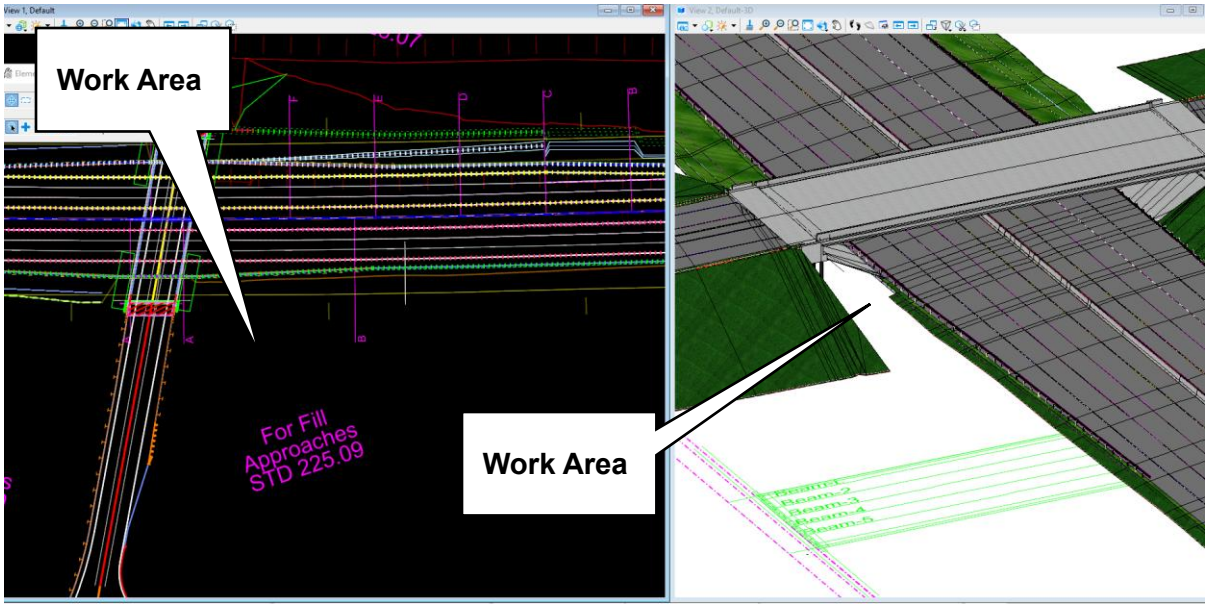


Figure 3-31: Infield Details, Southeast Quadrant

C. Select the View 1, Default window, open the References Dialog and add the file R-2635C_RDY_CMD_Y4.dgn to the plan view and select the Default-3D model.

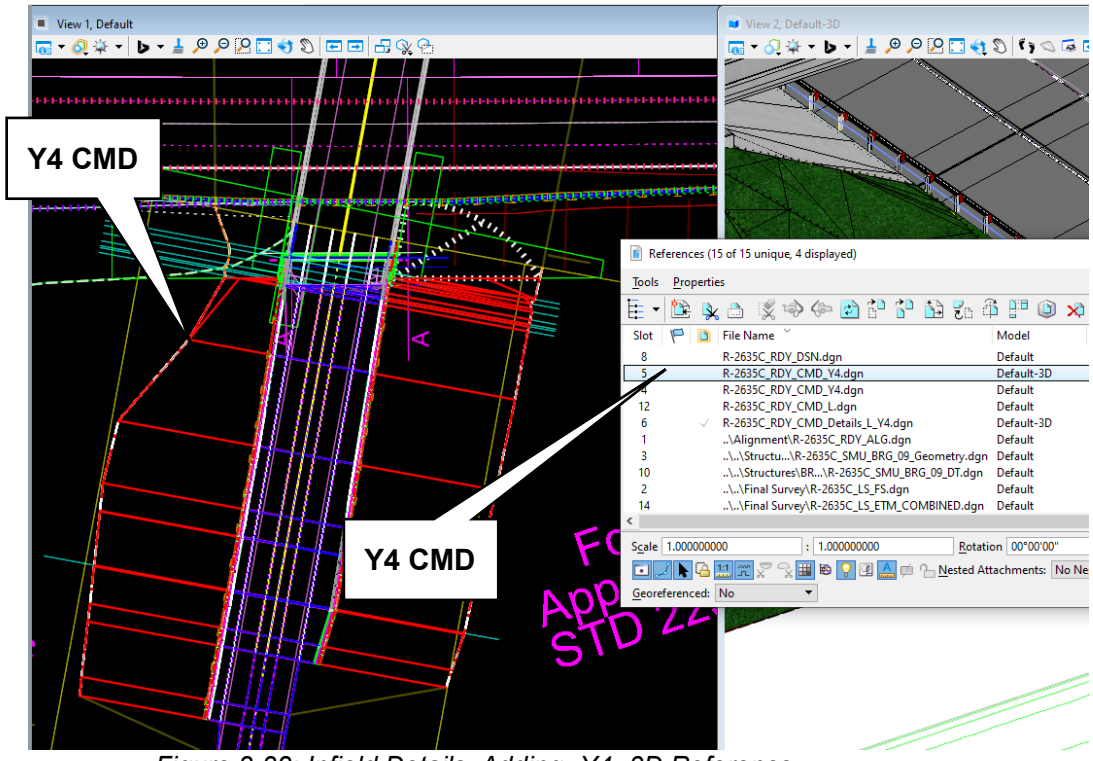


Figure 3-32: Infield Details, Adding -Y4- 3D Reference

D. There are several ways to create a conical slope around bridges, in this example, we are going to make a terrain and utilize surface templates.

Select the feature definition CCE_Target_1, set as Active Feature Definition, and use the Horizontal Geometry – Lines -Line Between Points tool to trace a horizontal line along the Y4 fill slope.

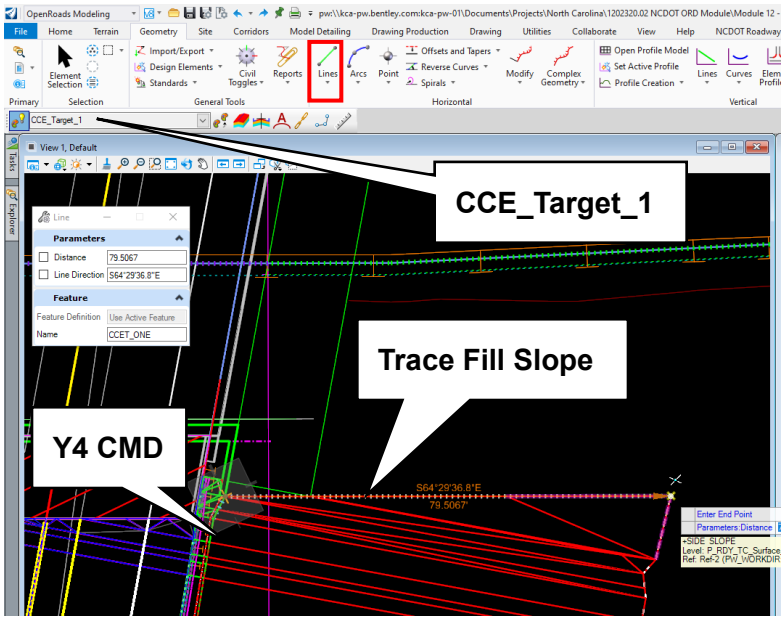


Figure 3-33: Trace Y4 fill slope

Open the profile view of the recently placed line and create a 3D Cut (Full Profile Placement Method). Create a piece of vertical geometry that traces the Y4 fill slope (Geometry > Vertical > Lines > Profile Line Between Points) and make the vertical geometry the active profile.

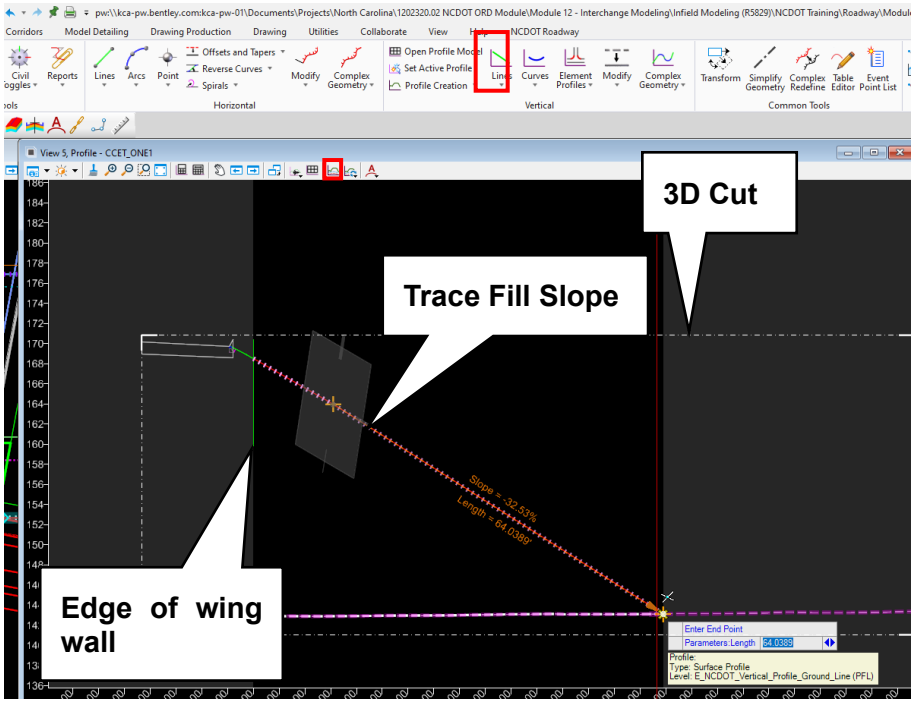


Figure 3-34: Y4 Fill Slope Profile

Next, repeat the same steps to create horizontal and vertical geometry to trace along the concrete slope protection.

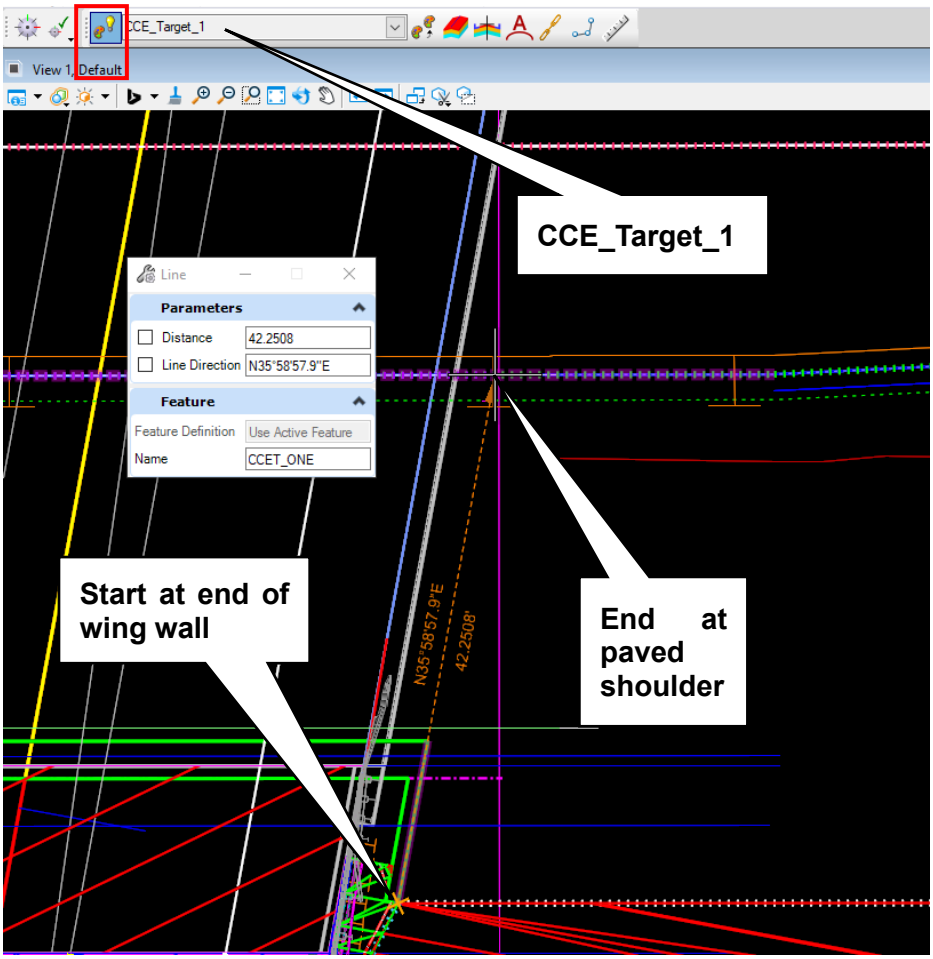


Figure 3-35: Concrete Slope Horizontal Trace

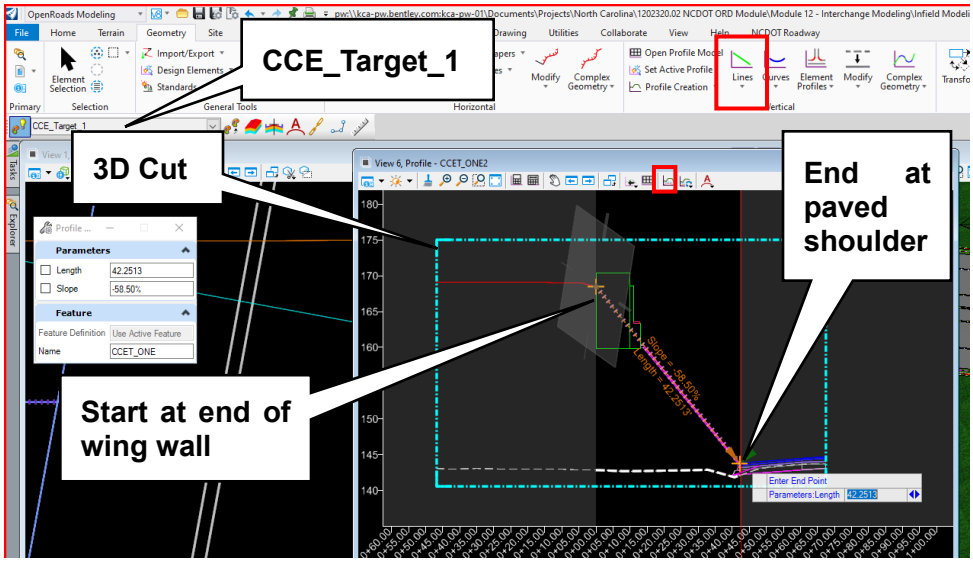


Figure 3-36: Trace Concrete Slope Protection

The last step before we make our terrain is to make the conical base and geometry. Use the Horizontal – Arcs – Arc Between Points tool and create an arc that connects the end of the concrete slope protection trace and Y4 fill slope trace.

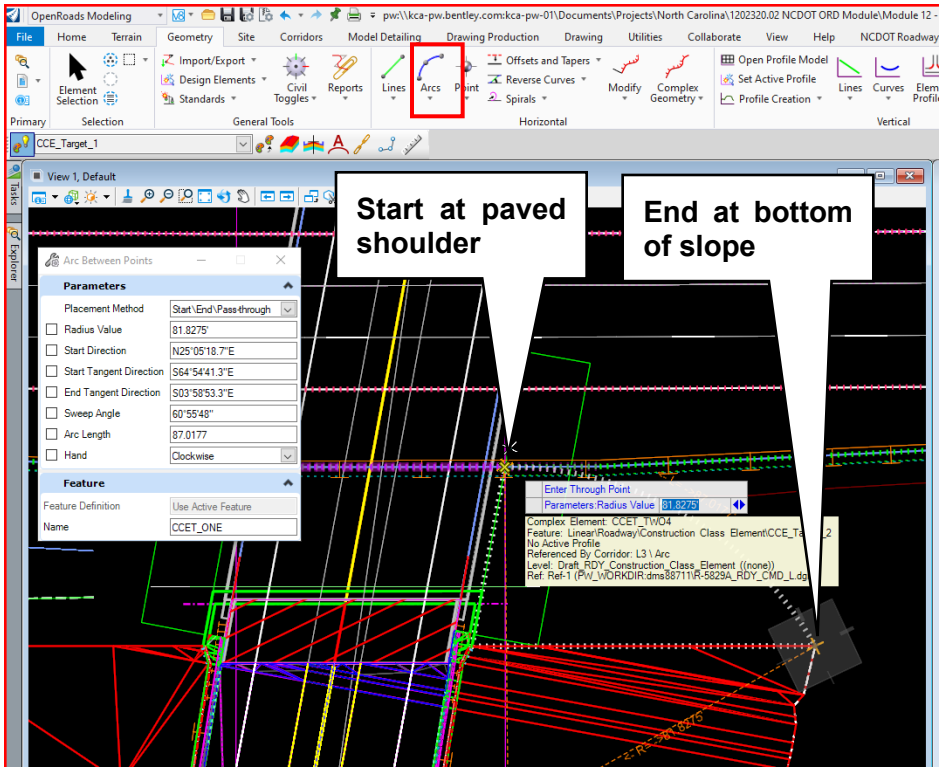


Figure 3-37: Horizontal of Bottom of Conical Slope

Open the profile view of your newly placed arc and trace the top surface of the proposed ground and existing ground to create the bottom profile of your conical fill (Geometry > Vertical > Complex Geometry > Simple Profile by PI).

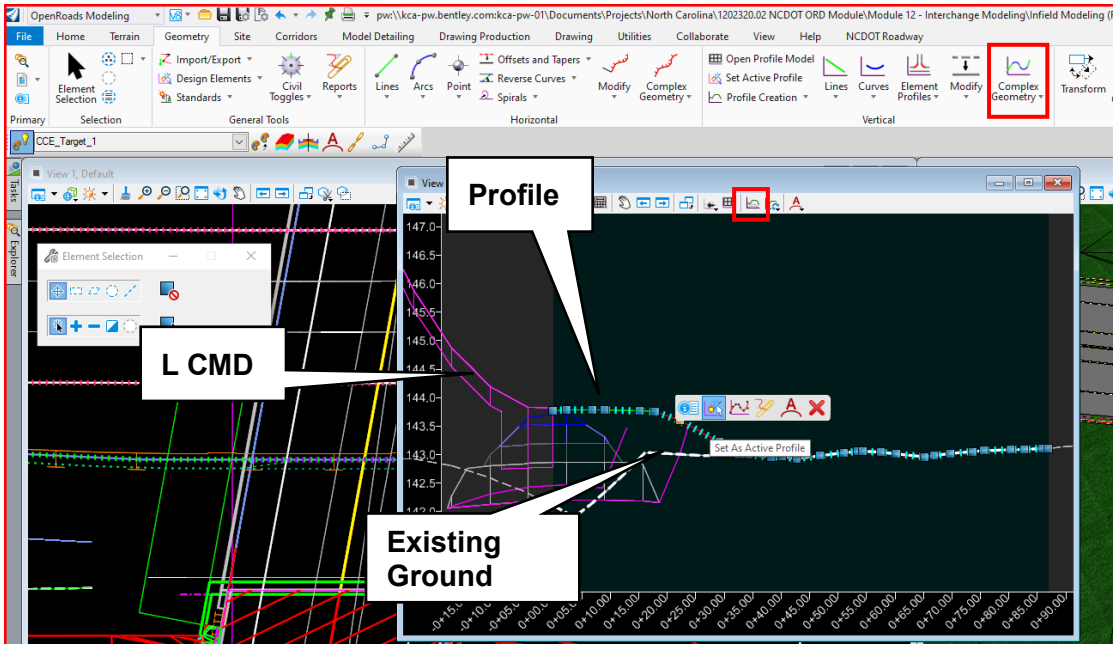


Figure 3-38: Profile of Bottom of Conical Slope

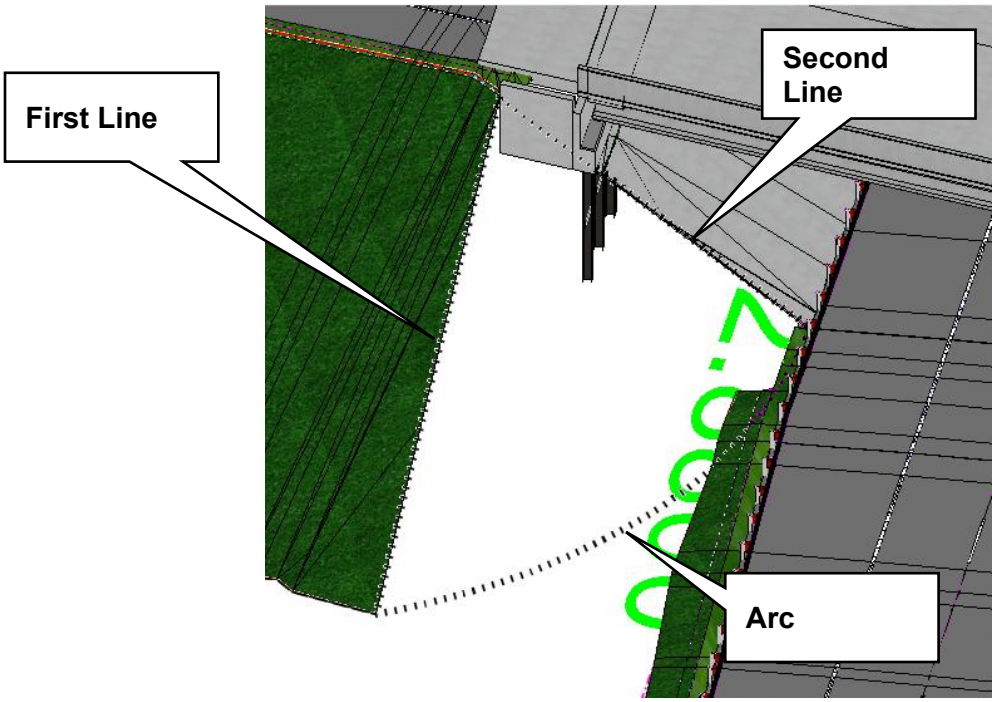


Figure 3-39: Outline of Conical Slope

Next, we will make a terrain out of the 3 pieces of horizontal and vertical geometry that outlines our conical slope.

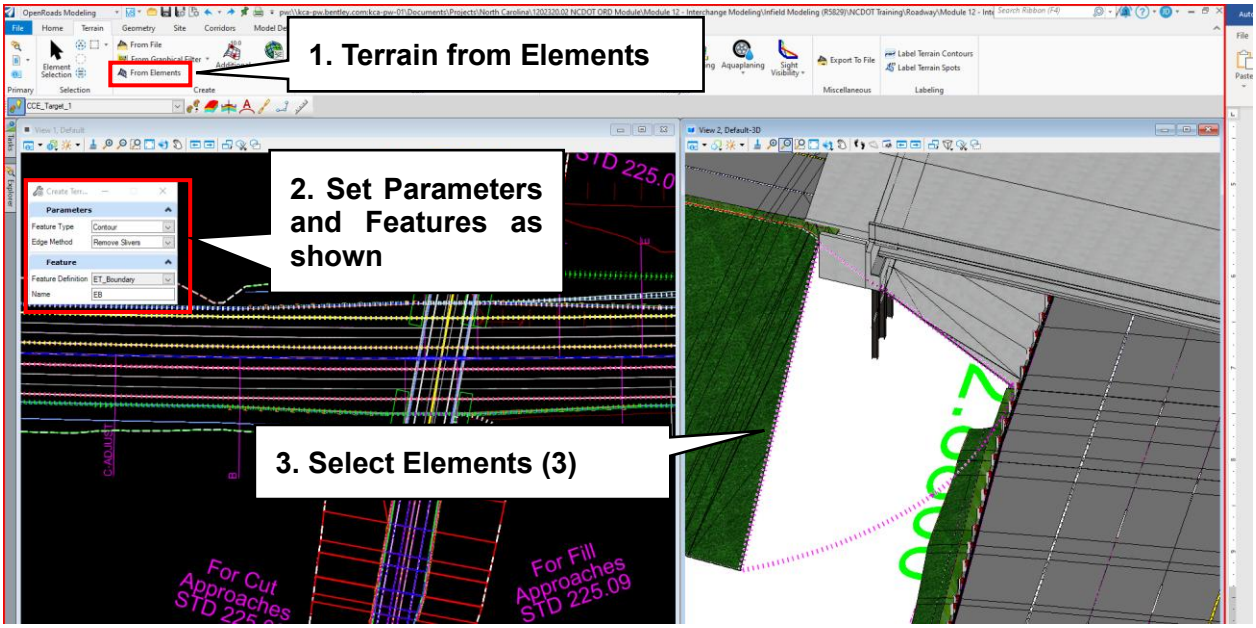


Figure 3-40: Create Terrain

Now that we have a terrain created, we can add a surface template to it. Note that you may need to open the R-2635C (Training)_RDY.itl again to access the SFT-Grass Surface Template.

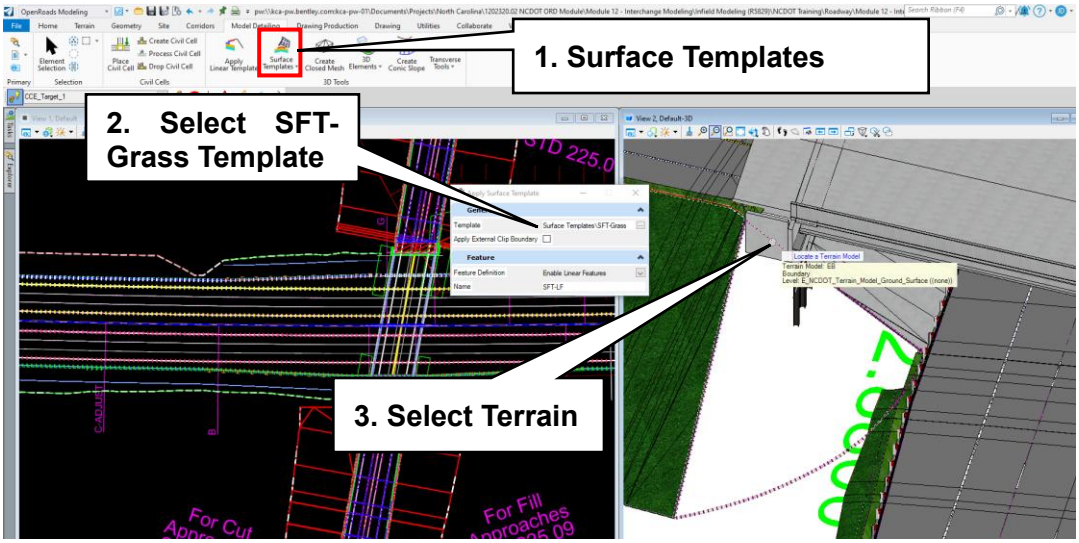


Figure 3-41: Apply Surface Template

These actions create a flat conical slope based on our outline.

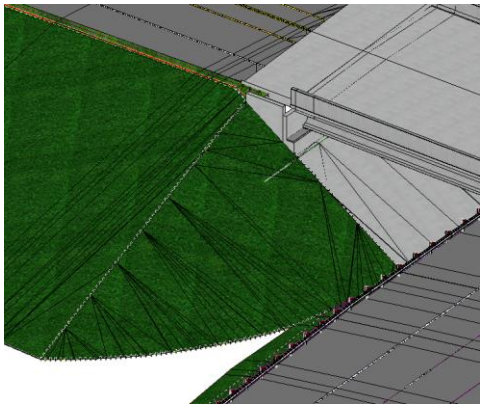


Figure 3-42: Flat Conical Slope

To give the slope advanced definition, we can add a break line to the terrain. Start by adding a line that starts at the wing wall and intersects the middle of the arc.

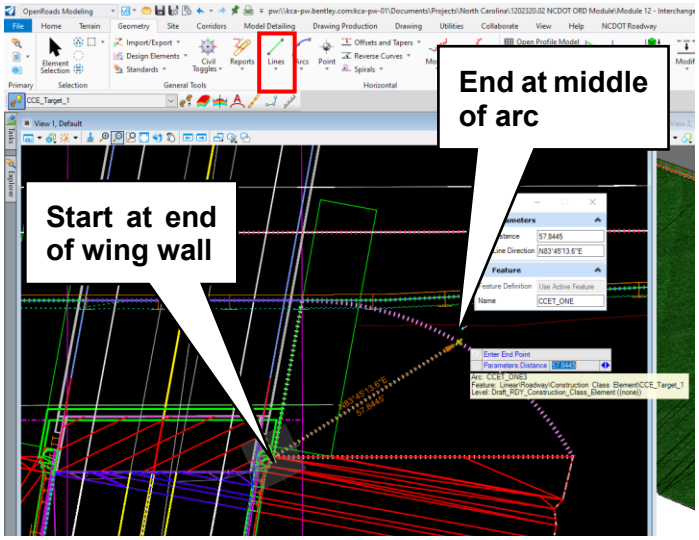


Figure 3-43: Terrain Break Line

Use the Profile Intersection Point tool to help create the profile of your break line.

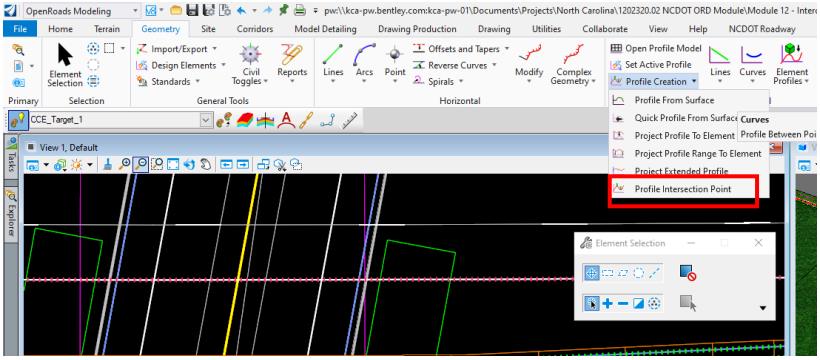


Figure 3-44: Profile Intersection Tool

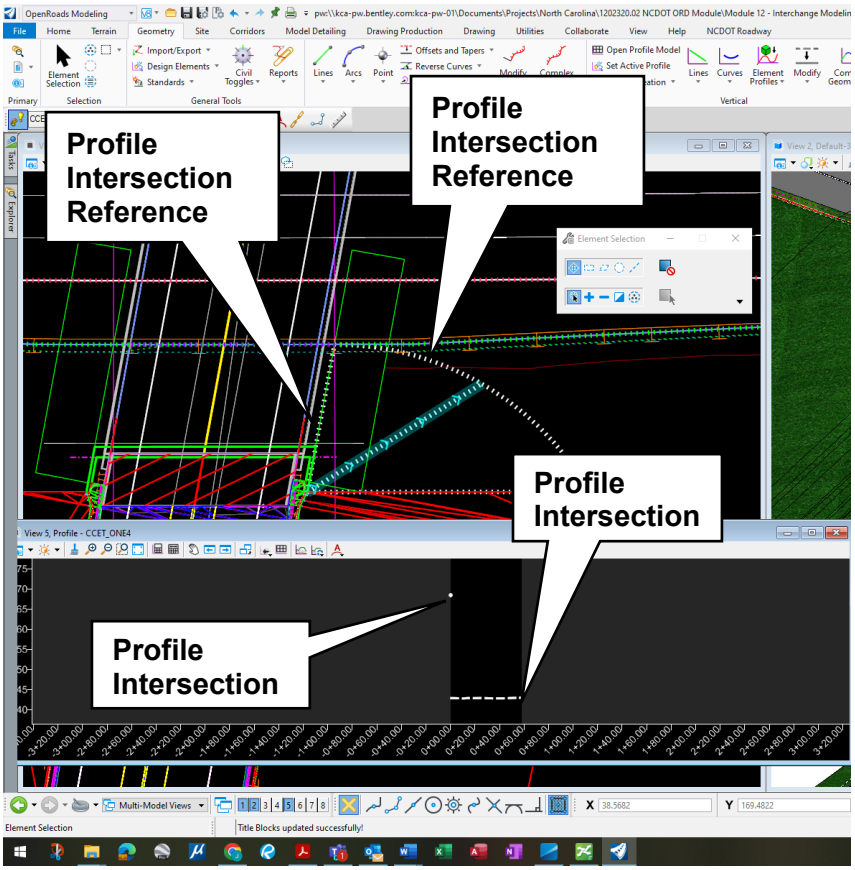


Figure 3-45: Profile Intersection Tool

Then create a vertical profile between the two intersection points and set it as active.

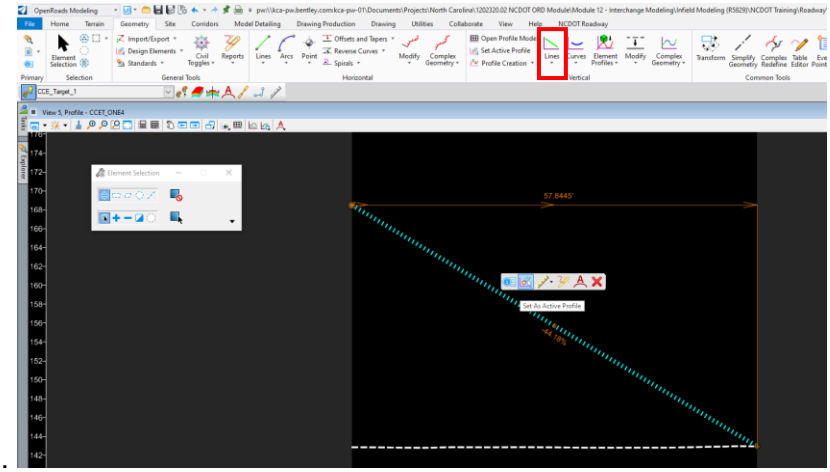


Figure 3-46: Break Line Vertical Profile

Finally, add the break line to the surface template/terrain to add advanced definition to the conical slope.

Under Terrain – Edit, select Add Features tool. Select the EB terrain we recently completed in the 3D View and set the Feature Type to Break Line.

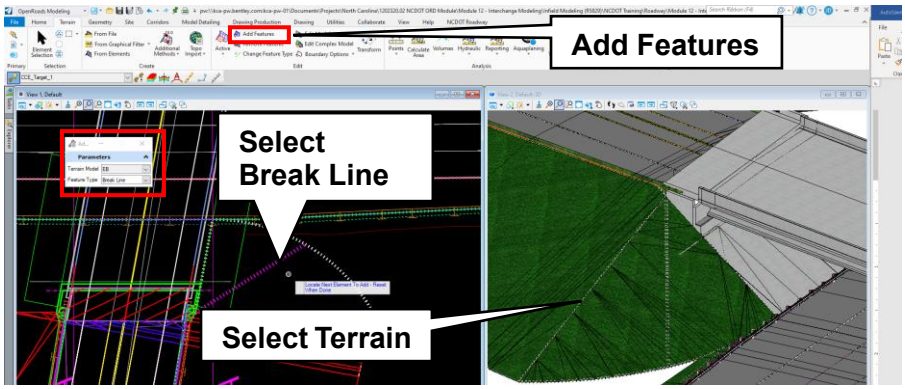


Figure 3-47: Add Break Line

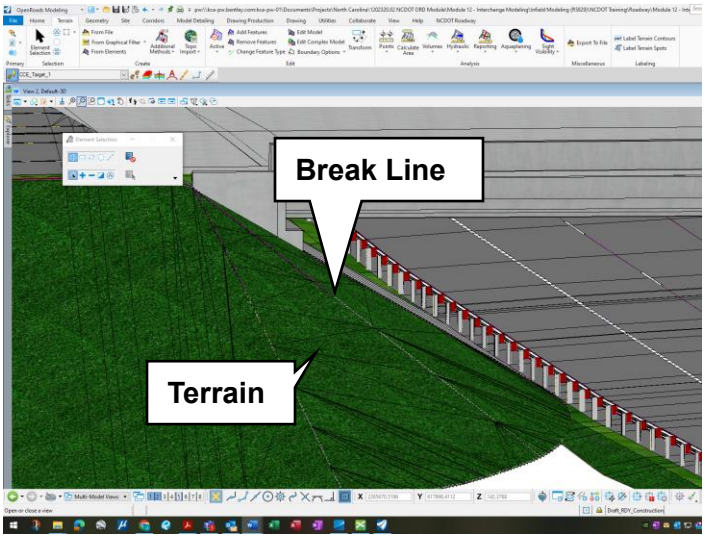


Figure 3-48: Break Line Added to Terrain

3.2.2 Cut Approaches (Standard 225.09)

In this exercise, you will learn how to model the NCDOT Standard 225.09 for Cut Approaches. We are going to use and modify the existing -L- CMD. Please see video titled NCDOT Module 12 – Std 225.09 Fill.

1. **Open the -L- CMD model and set your window to display the plan and 3D view.**

   A. Click the browser button and path to the Module 12 – Interchange Module – Infield Modeling\Roadway\Design folder and open R-2635C_RDY_CMD_L.dgn.

      See Figure 3-1: R-2635C_RDY_CMD_Details_L_Y4.dgn References for references.

   B. Set your View Controls to Plan/3D and navigate to the Southwest Quadrant.

Figure 3-49: Cut Approaches Work Areas

C. Make sure the R-2635C_CMD_Details_L_Y4.dgn is set to display in View 1, Default. This will provide you with the scratch lines mentioned previously.

D. In either the Create Template or Edit Template Drop dialog, open the -L- template for editing.

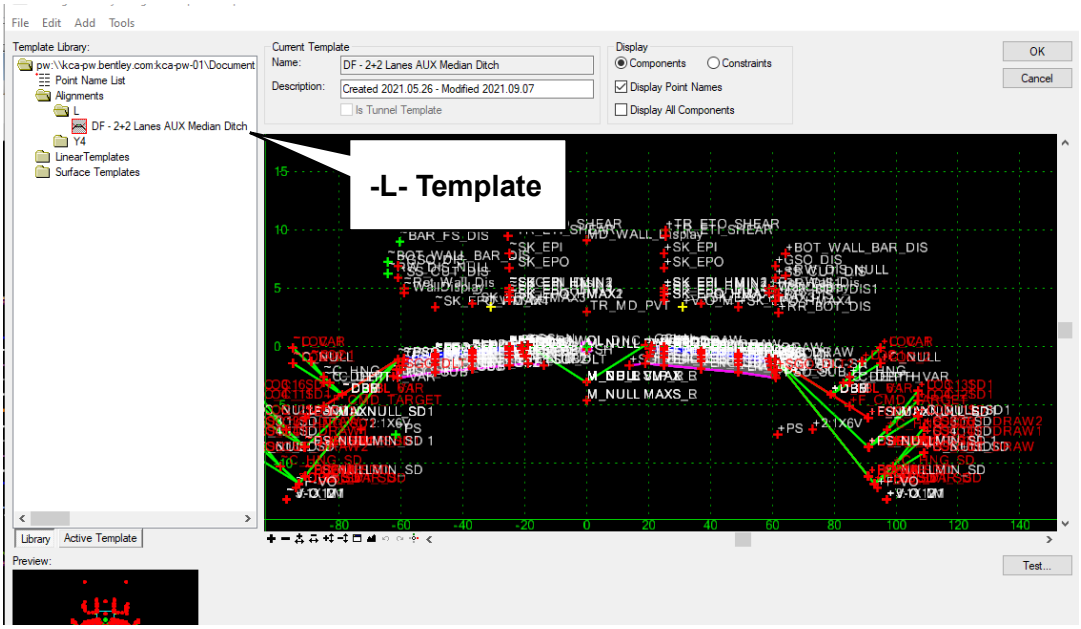


Figure 3-50: Open -L- Template

E. Make the following changes to the template to manipulate the end conditions later:

Modify the +DBF point to have a horizontal feature constraint of Ditch_Bottom_Front with a range of 0.

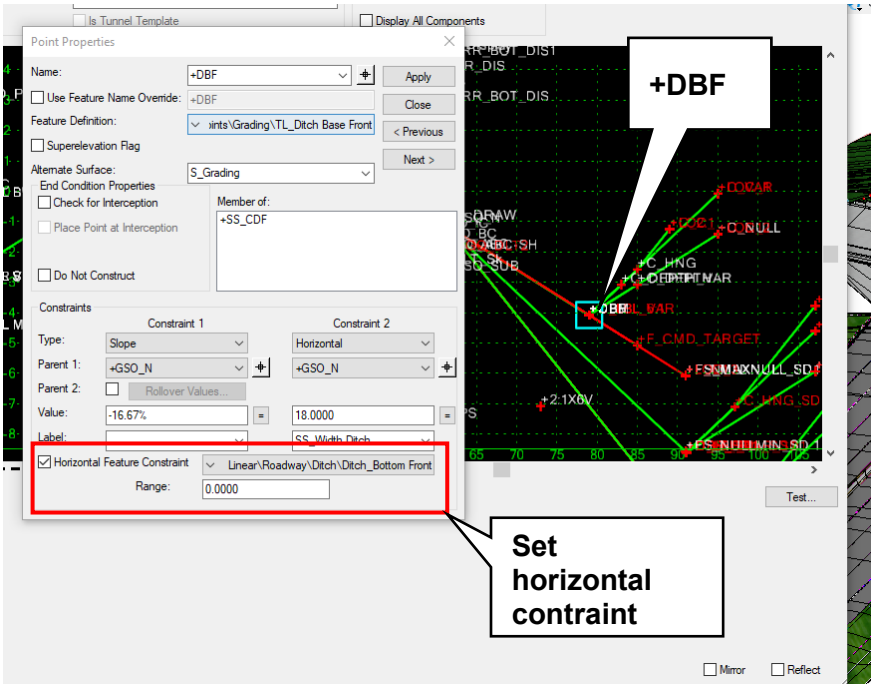


Figure 3-51: +DBF constraints

Modify the +C_HNG point to have a label for Constraint 2 to control the hinge height as shown.

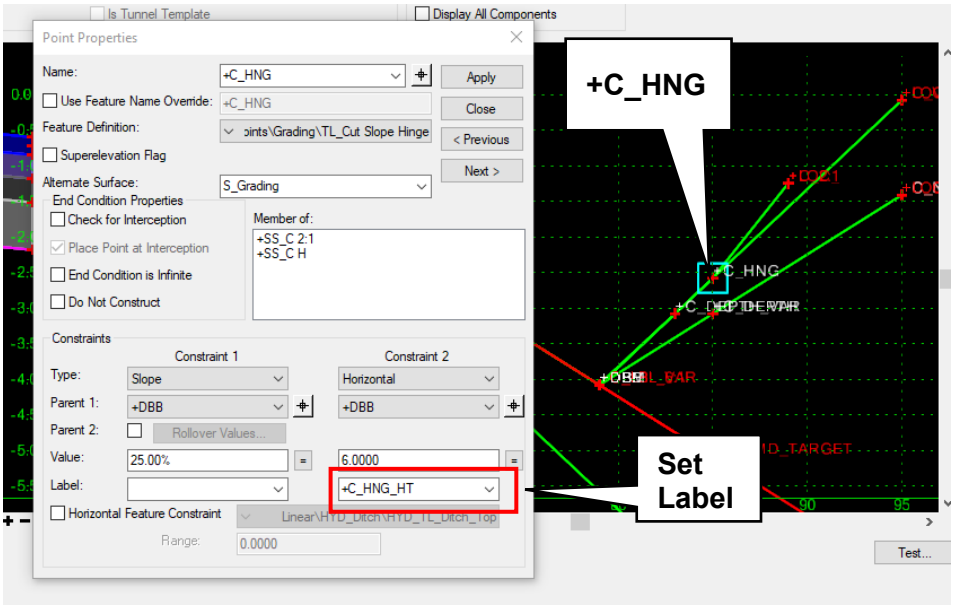


Figure 3-52: +C_HNG_HT label

F. Apply all your changes and save the template. If you updated the template in the template library, be sure to Synchronize the template.

Use the Horizontal – Offsets and Tampers – Ratio Offset tool to make a 30:1 taper, referenced to the -L- that will guide our ditch transition, using the feature definition Ditch_Bottom Front. Start the geometry at the intersection of the concrete slope and

the paved shoulder and end the geometry where it intersects the proposed center of the ditch (from points A to C-Adjust).

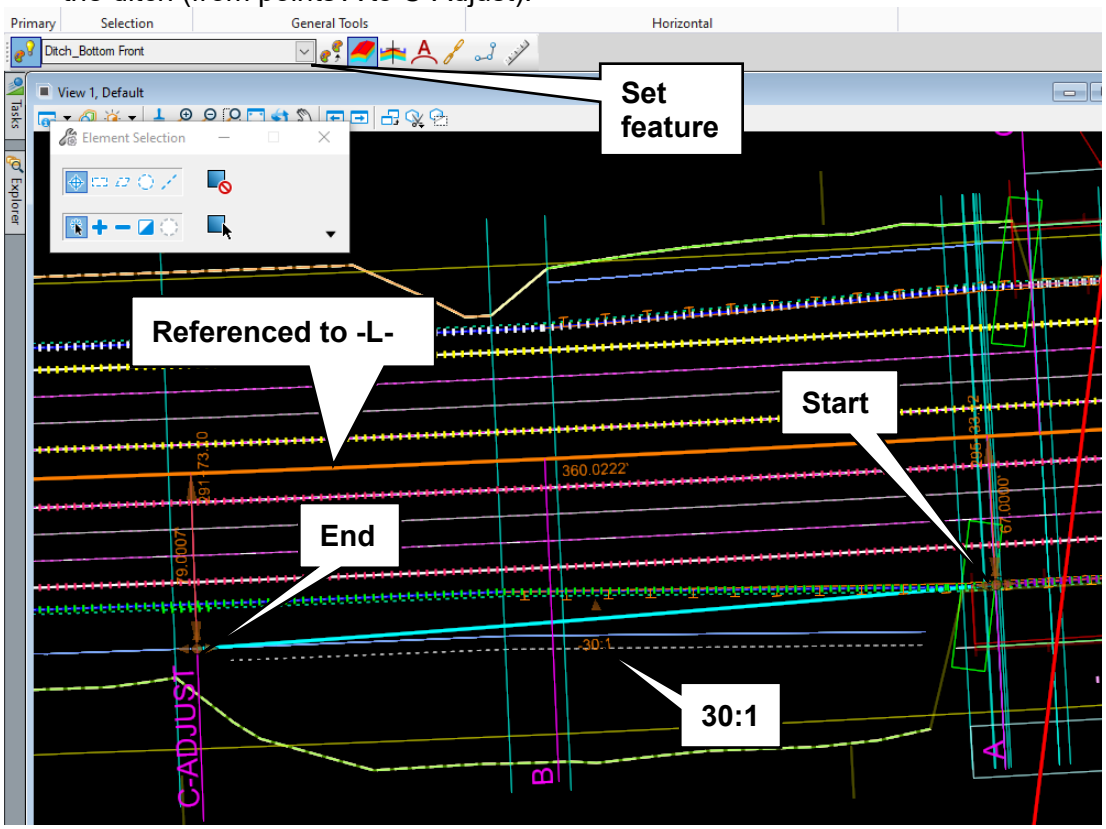


Figure 3-53: Ditch Control

G. Now create a piece of geometry that will control the 8:1 taper for the grass shoulder using the feature definition CCE_Target_GSO_RT. Use the existing +PSO point as your reference line and continue the geometry until it intersects the ditch line we placed in the previous step.

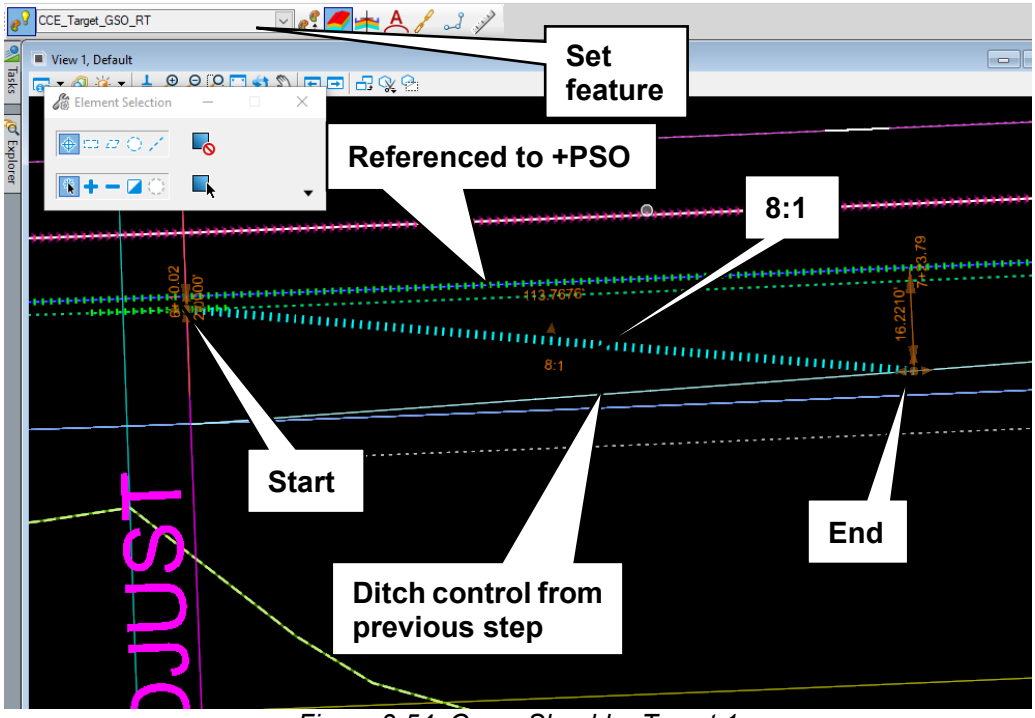
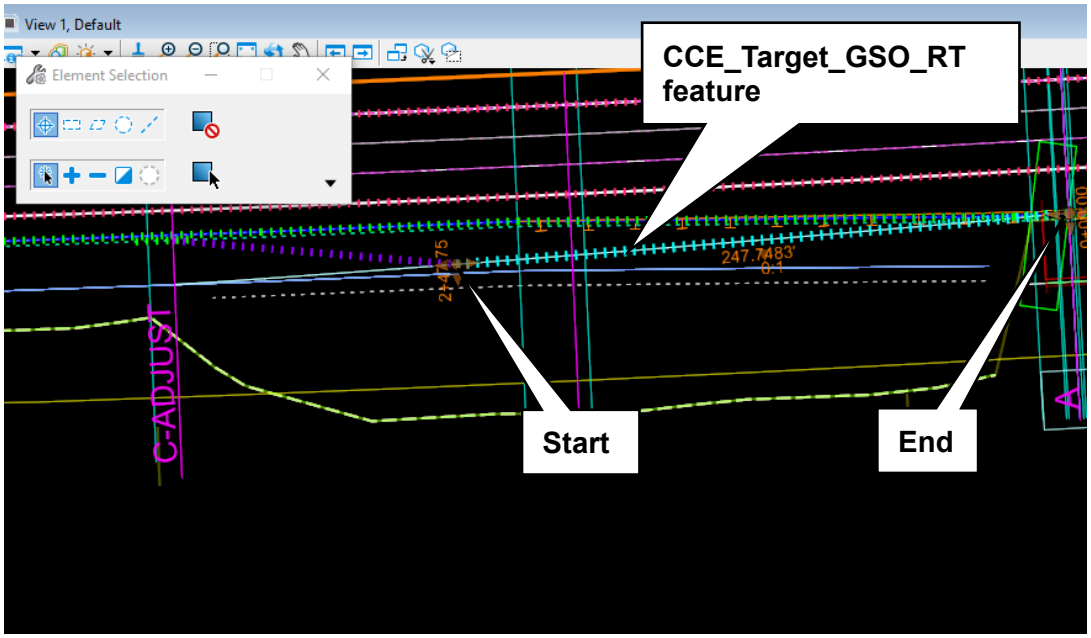


Figure 3-54: Grass Shoulder Target 1

H. Next, use the tool Horizontal – Offsets and Tapers – Single Offset Partial and offset the remaining ditch control line with the grass shoulder control geometry as shown:



I. Add key stations at the start of the grass taper and at the intersection of the new grass taper and the ditch control (Corridors > Edit > Edits > Create Key Station).

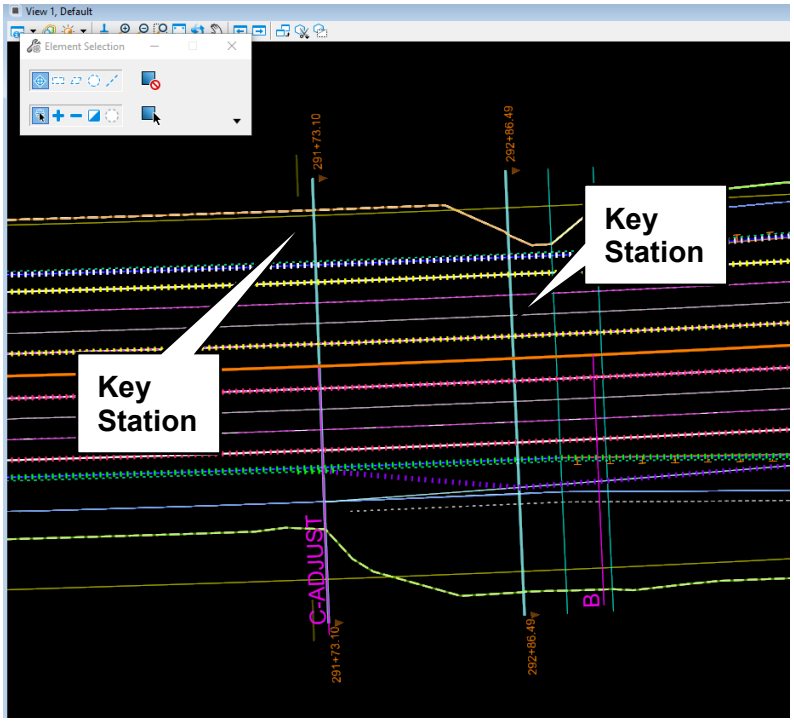


Figure 3-55: Key Stations

J. Now add all the three control lines to the corridor as external references and notice how the grass shoulder tapers to the ditch line and the ditch and grass shoulder now taper to the paved shoulder at the concrete slope protection.

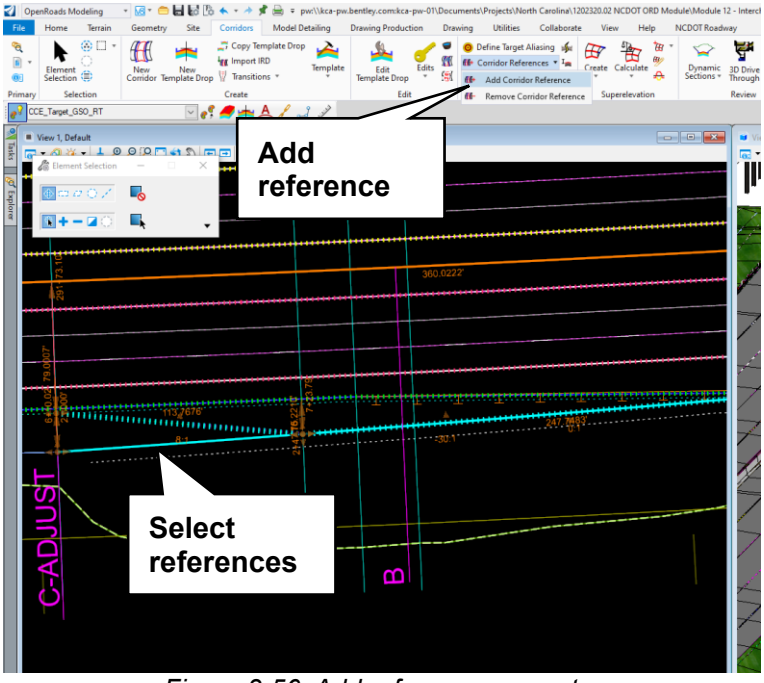


Figure 3-56: Add reference geometry

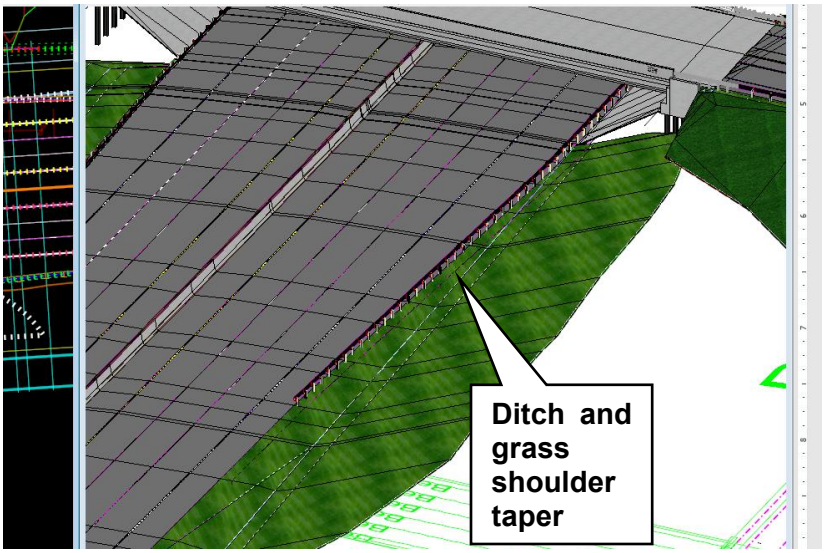


Figure 3-57: Ditch and grass shoulder taper

K. Next we are going to add several parametric constraints to further control the ditch width hinge slope and back slopes.

Add a parametric constraint to the L3 Corridor from C-Adjust to B to control the hinge height as shown:

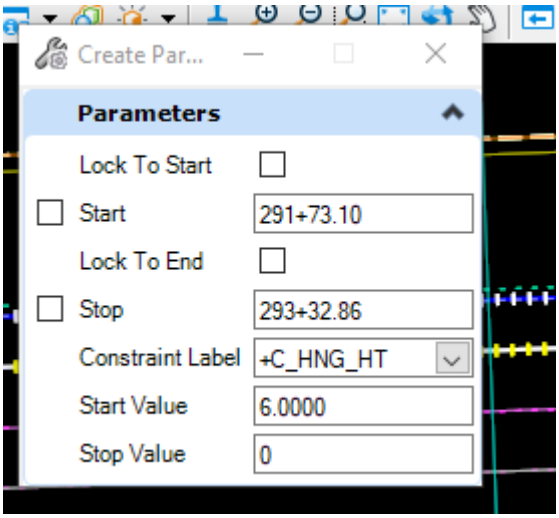


Figure 3-58: Begin Hinge Values

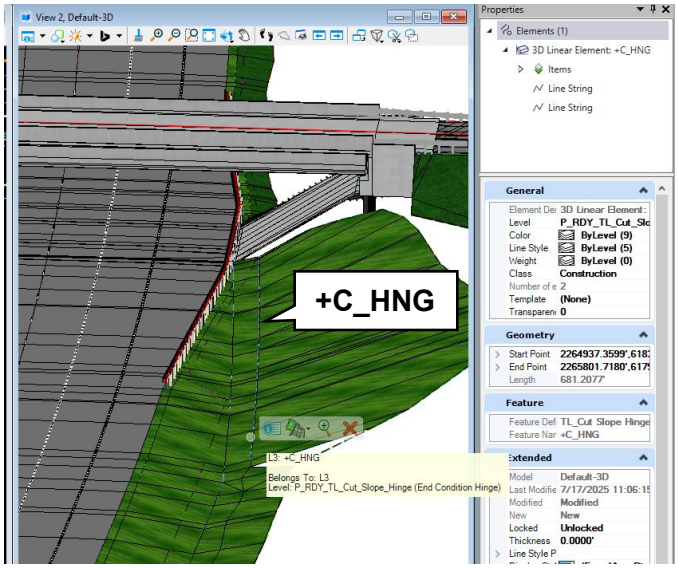


Figure 3-59: Begin Hinge, 3D View

Add a constraint from B to A to control the hinge height as shown:

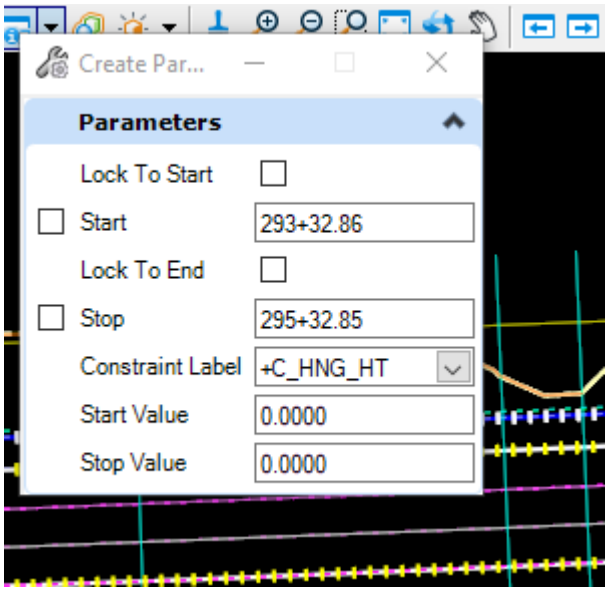


Figure 3-60: End Hinge Values

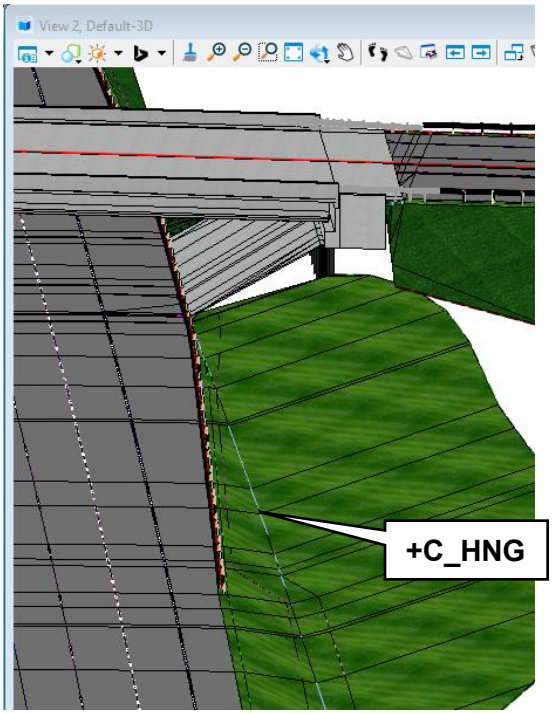


Figure 3-61: End Hinge, 3D View

The +DBF point is already controlled by the horizontal feature constraint but in case you have any issues with the ditch tying in at the slope protection, a parametric constraint can be added to make the ditch width zero in this area. Add a constraint with the same start and end values to set the ditch width to zero in this range:

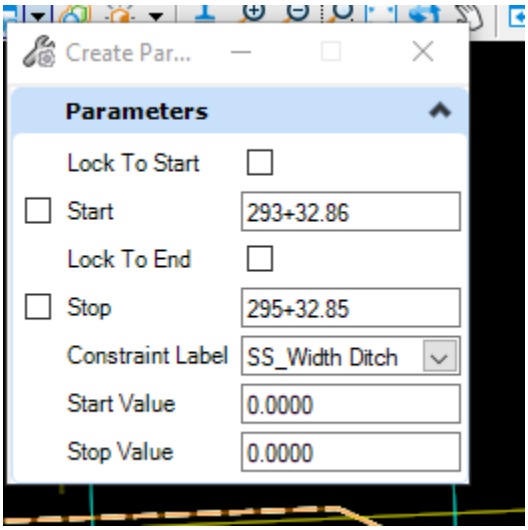


Figure 3-62: Set ditch width

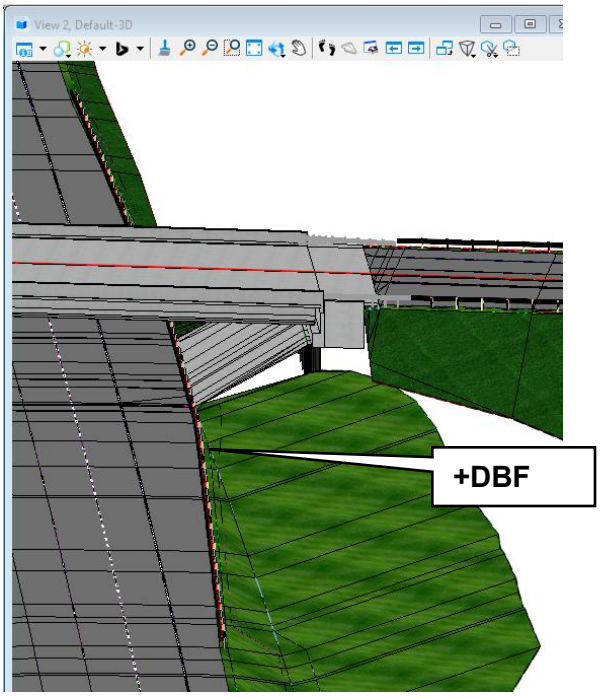


Figure 3-63: Set ditch width, 3D View

Lastly, add a constraint with the same start and end values to set the back slope to adjust between B to A to match the slope of the concrete slope protection (59.16 used in this example – 100% accurate slope protection not modeled as a part of this exercise)

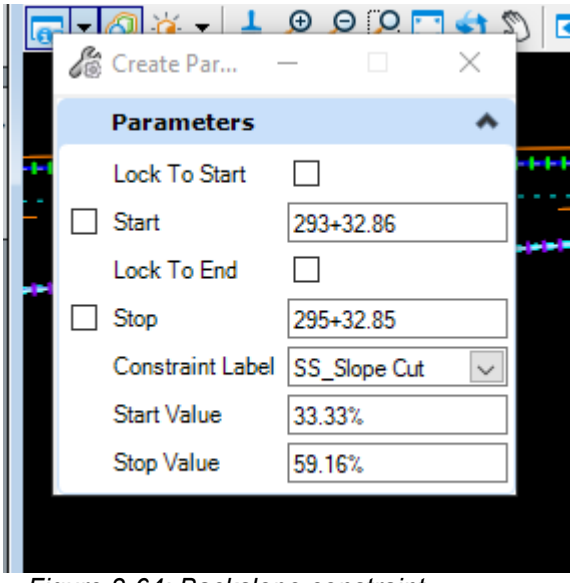


Figure 3-64: Backslope constraint

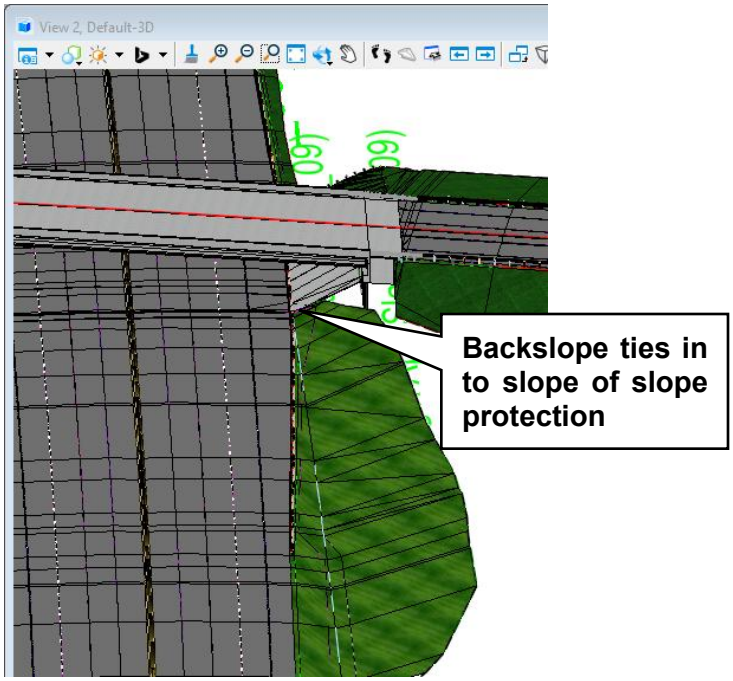


Figure 3-65: Backslope constraint, 3D View

L. Any additional cleanup can be completed by following similar steps shown in other modules or steps shown in this module.

References

AASHTO, A. A. (2018). *A Policy on Geometric Design of Highways and Streets, 7th Edition.*
Roadway Design, N. C. (2023). *Roadway Design Manual.* Raleigh: NCDOT.
SMU, N. C. (2023). *SMU Design Manual.* Raleigh: Structures Management Unit.

List of Figures