

2017 PLS-CADD Advanced Training and User Group

## Advanced FE Modeling

by

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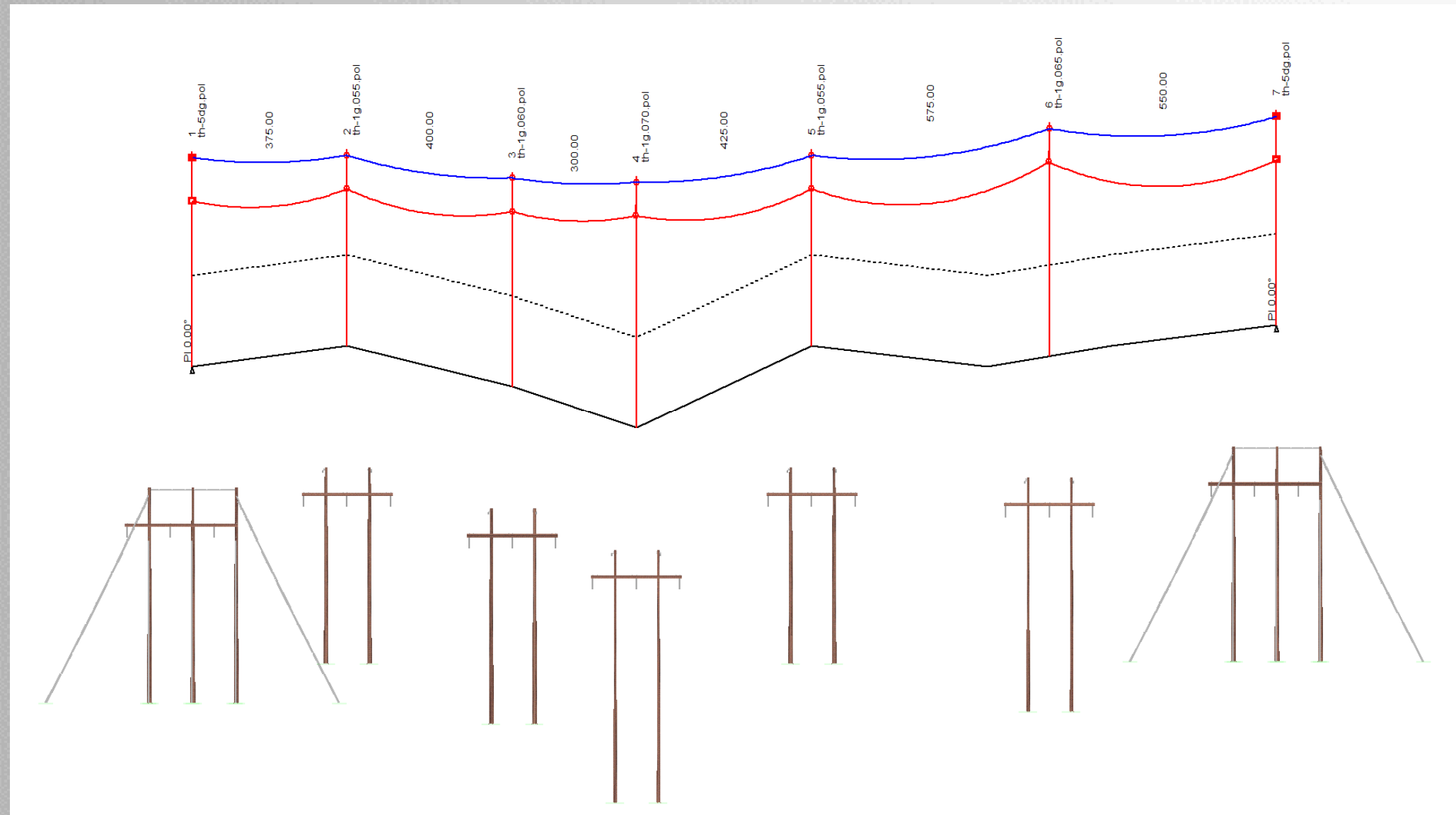
[Click here to save a .bak Backup file of the project](#)

# What We Will Cover

- Discuss Life cycle of a project
- Show how to create xyz points along a wire
- Discuss methods of graphical sagging
  - Show best techniques
  - Discuss common pitfalls and mistakes
  - Explain what sagging data conditions are
  - Explain how after graphical sagging in an ideal world we should match original design conditions
  - Show possible differences in results that can occur from making wrong assumptions
- Show changing a suspension structure to a floating DE
  - Explain what not to do
  - Show various tips and techniques to match existing tensions

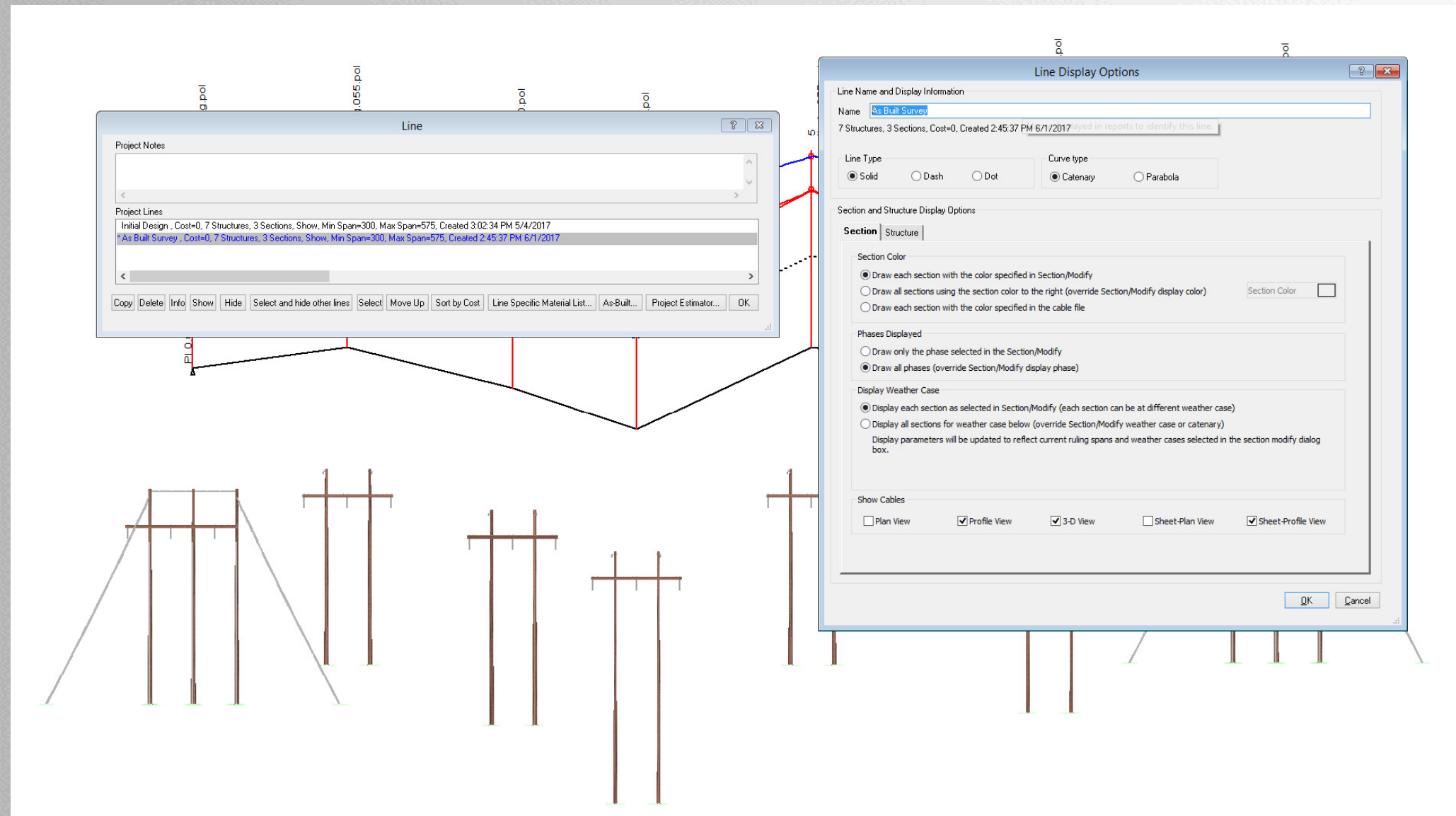
# Step 1: Complete Design

- After automatic sagging the sections are clipped representing the final design.



# Step 2: Copy Line Model

- Copy line model in **Lines/Edit...** and create an “as-surveyed” model



# Step 3: Create LiDAR survey points

- To simulate LiDAR survey data I created points along the wires using the command to apply column in **Sections/Table...** with the wires displayed at an example surveyed condition of a hot summer day 10 years later after the wires are fully crept.

\*Note: Wire shots are all placed on 1 feature code. This makes the process of finding graphical sag fit points easier because all wires can be done at once. If wires are on separate feature codes it's best to export them and re-import them into the project on 1 feature code for graphical sagging.

The screenshot shows a software interface with a 'Section Table' window at the top and a wire diagram below. The 'Section Table' window has a 'Sort Sections by' dropdown set to 'Section number' and a table with the following data:

Sec #	Start Str #	End Str #	Ruling Span (ft)	Insul. Clipped	Sec Notes	Cable File Name	Voltage (kV)	Wires Per Phase	Sag Condition	Sag Temp. (deg F)	Sag Horiz. Ten. (lbs)	Display Weather Case	Display Condition	Disp. Wind From	Disp. Phase	Disp. Color	Command To Apply
1	1	1:1	7:1	469 Yes		ehs_steel.wir		1	Initial RS	60.0	3174.6	90 Deg F	Creep FE	Both	1	Blue	Create Points A
2	2	1:2	7:2	469 Yes		ehs_steel.wir		1	Initial RS	60.0	3174.6	90 Deg F	Creep FE	Both	1	Blue	Create Points A
3	3	1:5	7:5	469 Yes		dove_acsr.wir	69	1	Initial RS	60.0	4662.5	120 Deg F	Creep FE	Both	1	Red	Create Points A

Below the table is an 'Add Points Along Wire' dialog box with the following text and options:

This function will create survey points with a specified feature code at set intervals along the selected wires in their currently displayed positions.  
 This feature can be used to create points along a wire if you want distance to that wire to control the thermal rating for wires above it.

Feature code for points created: 203 Wire Shot  
 Interval along wires at which to create points (ft): 200 Ground, 201 Conductor Shot, 202 SW Shot, 203 Wire Shot

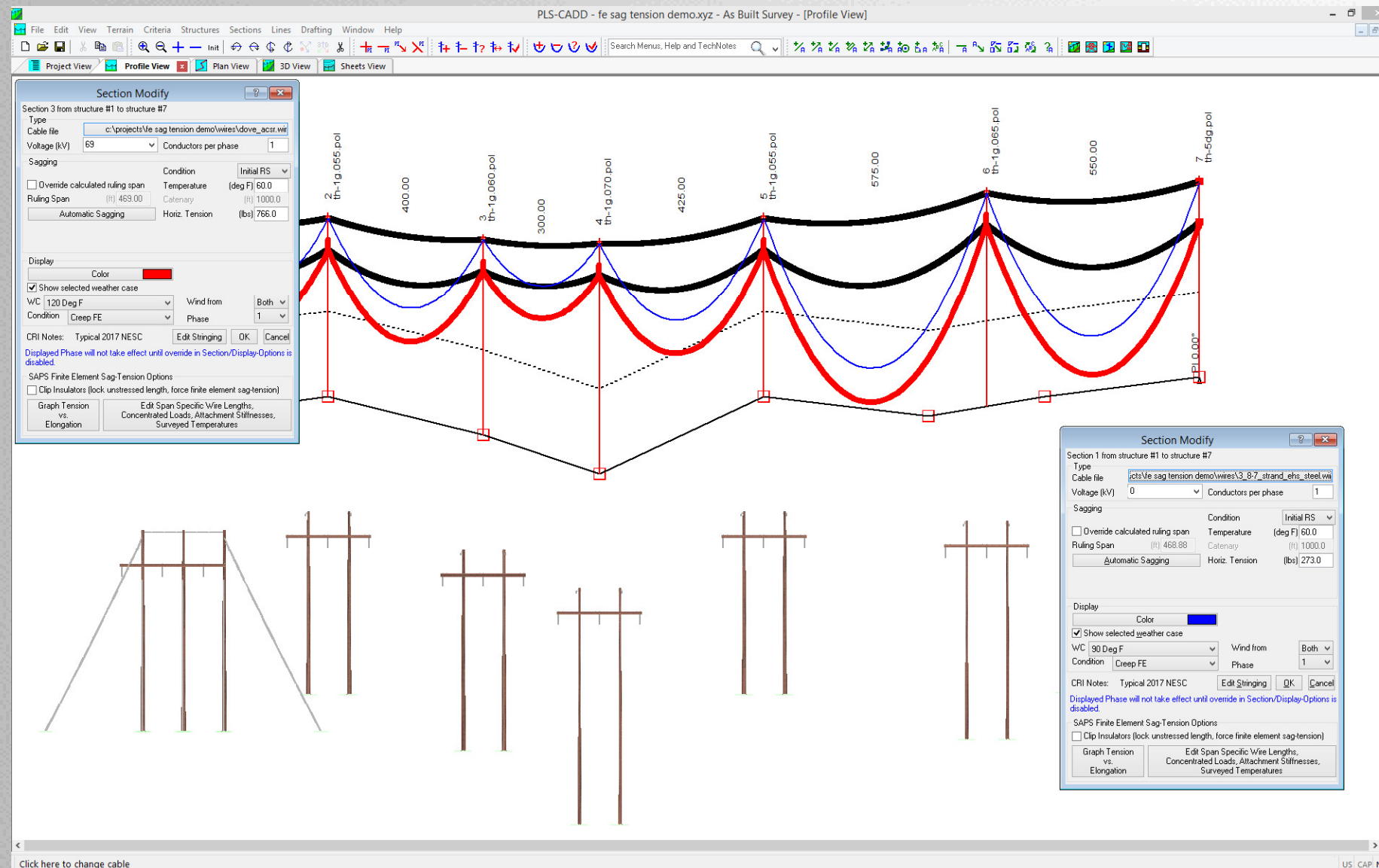
The wire diagram below shows several towers with sagging wires. A dialog box is open over one of the wires, and a vertical line indicates a point being added to the wire. The status bar at the bottom shows 'Ready' and 'US CAP NUM'.

# Step 4: Change tensions and unclip

- To simulate creating a new line to match the survey data I unclipped the sections and lowered the tension to the 1000 foot catenary PLS-CADD defaults to after stringing wire.

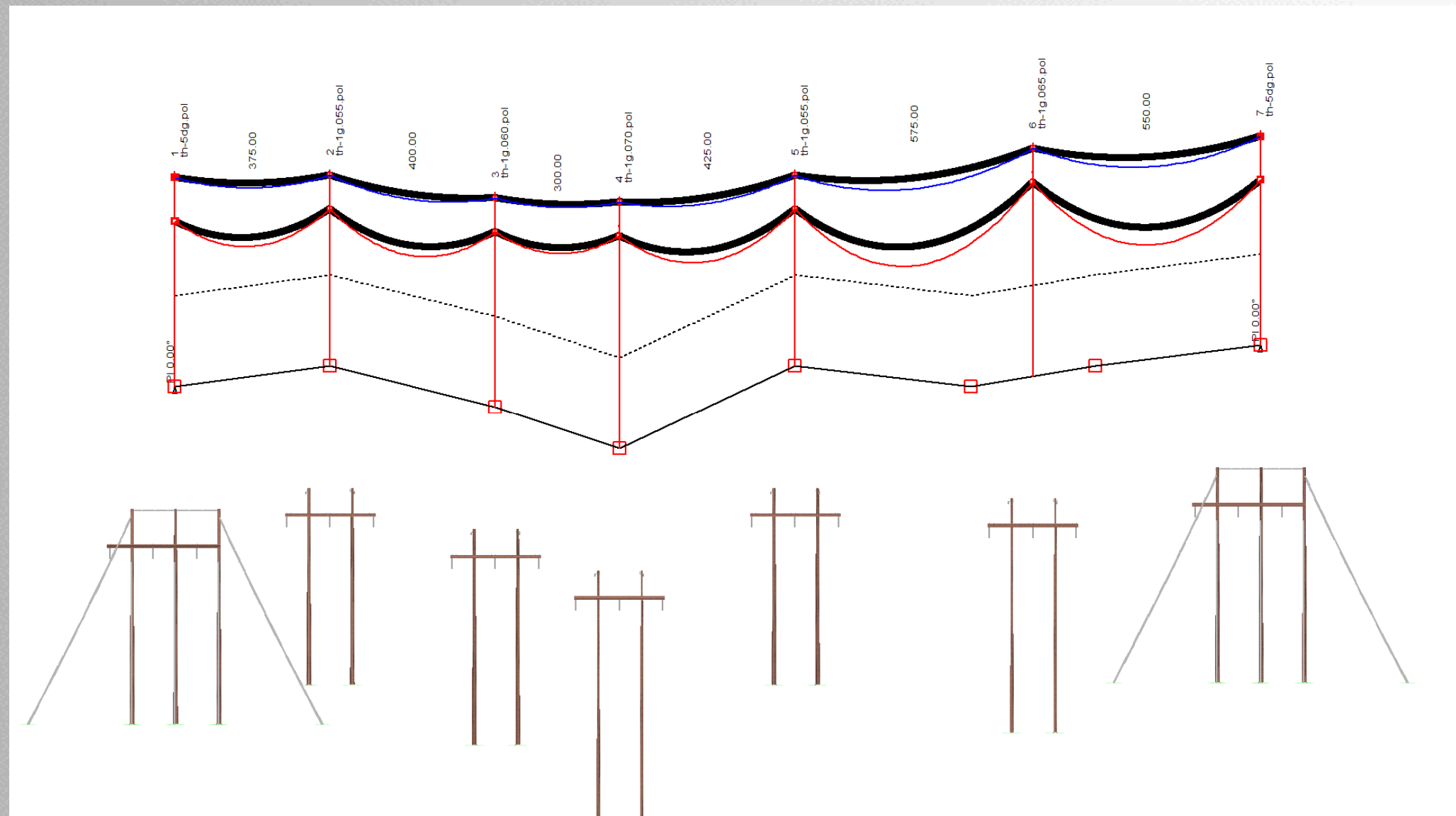
\*Note: Sections have their sagging data set to Initial RS and 60 degrees F. These conditions represent the initial install conditions of the wire when the insulators were plumb and they represent the conditions the line exists at for the majority of its life which is what PLS-CADD bases the creep elongation on.

\*Note: Wires are displayed at survey conditions and the cable condition is set to Creep FE. When we perform the ruling span graphical sag “fit mode A” it will be the equivalent of option 2 in **Sections/Graphical Sag...** This means it’s more accurate because it looks for the 60 Degree plumb condition tension that yields the wire display at surveyed conditions in FE.



# Step 5: Adjust sagging data tension

- I now adjust the sagging data tension so the wires are somewhat near the LiDAR shots and the find graphical sag fit points command can work properly.



# Step 6: Find graphical sag fit points

- Depending on your data and bundle geometry choose one of the options for finding graph sag fit points by going to **Sections/Table...** and using the command to apply column to apply the command Find Graph Sag Fit Points

The screenshot shows the 'Section Table' dialog box with the following data:

Sec #	Start Str #	End Str #	Ruling Span (ft)	Insul. Clipped	Sec Notes	Cable File Name	Vol-tage (kV)	Wires Per Phase	Sag Condition	Sag Temp. (deg F)	Sag Horiz. Ten. (lbs)	Display Weather Case	Display Condition	Disp. Wind From	Disp. Phase	Disp. Color	Command To Apply
1	1	1:1	7:1	469 No		ehs_steel.wir		1	Initial RS	60.0	2000.0	90 Deg F	Creep FE	Both	1	Blue	Find Graph Sag
2	2	1:2	7:2	469 No		ehs_steel.wir		1	Initial RS	60.0	2000.0	90 Deg F	Creep FE	Both	1	Blue	Find Graph Sag
3	3	1:5	7:5	469 No		dove_acsr.wir	69	1	Initial RS	60.0	2500.0	120 Deg F	Creep FE	Both	1	Red	Find Graph Sag

The 'Find Fit Points For Batch Graphical Sag' dialog box is open, showing the following options:

- Feature code for wire fit: 203 Wire Shot
- Use single point closest to current mid span wire position (old way)
- Use centroid of all points within 1m of current mid span wire position (tends to err on high side for bundles)
- Use center of rectangle encompassing all points within 1m of current mid span wire position (good for bundles but sensitive to outliers)
- Use lowest of all points within 1m of current wire position (good for bundles but sensitive to outliers)
- Use center of smallest circle enclosing all points within 1m of current wire mid span (good for bundles but may be sensitive to outliers)
- Use bundle-aware centroid: centroid of bundle shape fitting points within 1m of current mid span wire position (less sensitive to outliers)

Enter either the bundle diameter: (in) 0.0 or the bundle spacing: (in) 0.0  Use centroid of bottom wire

Least Squares Fitting Options  
 Enabling this option will cause replacement of the point derived from the settings above with one computed using points through the span. Enabling the least squares curve fit option will cause the program to:

- 1) Find preliminary catenary passing through current wire attachment points and the mid span point computed using settings above.
- 2) Find XYZ points within specified distance of catenary from step 1 and fit a catenary through them via least squares curve fit.
- 3) Find point at mid span on catenary computed in step #2 and use this as the final fit point.

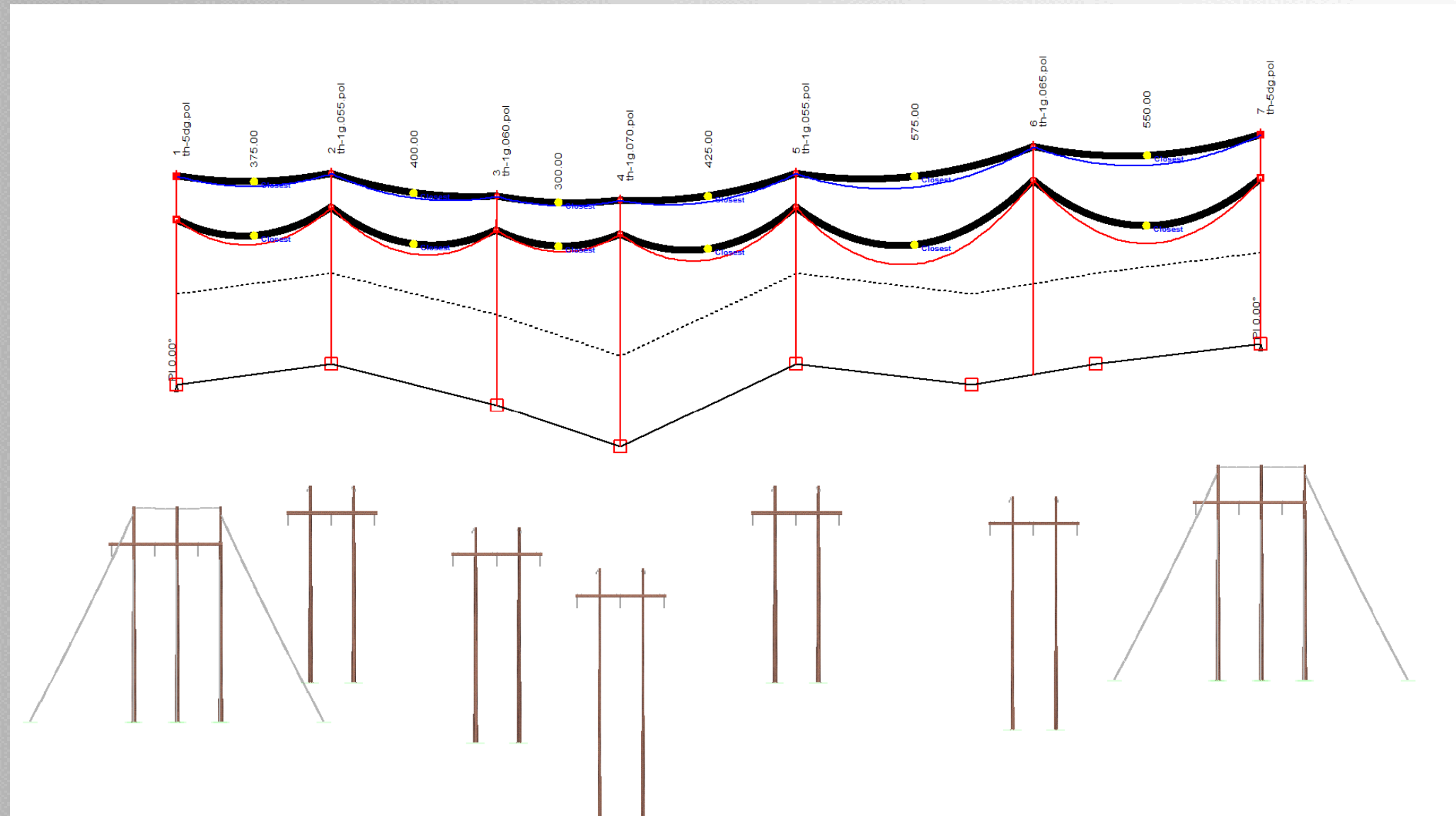
This option makes use of the current wire attachment coordinates and may not work well if they aren't accurate. Bundles with higher wire density at the top of the bundle are likely to result in a wire that is above bundle center when using this option.

Enable least squares curve fit option  
 Maximum distance between XYZ points and the preliminary catenary (ft) 1.000  
 Create markers showing XYZ points that we've used for least squares fit (slow diagnostic feature that uses lots of memory)



# Step 7: Check graph sag fit points

- Look at the QA/QC report and look at the markers in the profile and 3D views to ensure a valid fit point was found for every wire in every span.



# Step 8: Perform ruling span fit mode A

- Using the command to apply column again in **Sections/Table...** the graph sag fit to points command gives 2 options. Choose the A type fit first

The screenshot shows the 'Section Table' dialog box with the following data:

Sec #	Start Str #	End Str #	Ruling Span (ft)	Insul. Clipped	Sec Notes	Cable File Name	Vol-tage (kV)	Wires Per Phase	Sag Condition	Sag Temp. (deg F)	Sag Horiz. Ten. (lbs)	Display Weather Case	Display Condition	Disp. Wind From	Disp. Phase	Disp. Color	Command To Apply
1	1	1:1	7:1	469 No		ehs_steel.wir		1	Initial RS	60.0	2000.0	90 Deg F	Creep FE	Both	1	Blue	Graph Sag Fit t
2	2	1:2	7:2	469 No		ehs_steel.wir		1	Initial RS	60.0	2000.0	90 Deg F	Creep FE	Both	1	Blue	Graph Sag Fit t
3	3	1:5	7:5	469 No		dove_acsr.wir	69	1	Initial RS	60.0	2500.0	120 Deg F	Creep FE	Both	1	Red	Graph Sag Fit t

The 'Batch Graphical Sag' dialog box is open, showing the following options:

- A: Replace sagging tension with largest tension that keeps wire at or below target points (may only hit target point in one span). Assumption is that you can predict post sagging wire behavior given the attachment geometry and the single value of tension that existed at all spans at the time of sagging. This will not fit all the target points well if tension imbalances existed at sagging or if there were any post sagging changes to geometry (wire lengths or insulator attachment positions). Quality of fit can be gauged by distance from wire to target points. Fit (display) condition can be either RS (option 1 in Sections/Graphical Sag) or FE (option 2 in Sections/Graphical Sag). FE is likely to produce better results with uneven terrain and span lengths.
- B: Adjust length of wire in each span independently (simultaneously hit target point in each span). This method should be able to hit all the target points even if tension imbalances existed at sagging or post sagging changes to geometry occurred. This is the same as option 4 in Sections/Graphical Sag (mid span sags will be maintained in spans w/o target points). For best results use option A to get the sagging tension reasonably close before proceeding with this option.
- C: Report on mismatch between target points and displayed wire position (no changes to wire position)

Notes:

- Sagging condition and temperature should be as close as possible to the original sagging state (state where all spans should be at same horizontal tension with plumb insulators).
- Display weather case and condition should be for the "as surveyed" state in which wire is to hit target points.

\*Note: Wires are displayed at survey conditions and the cable condition is set to Creep FE. When we perform the ruling span graphical sag "fit mode A" it will be the equivalent of option 2 in **Sections/Graphical Sag...** This means it's more accurate because it looks for the 60 Degree plumb condition tension that yields the wire display at surveyed conditions in FE.

# Step 9: Perform finite element fit mode B

- Follow up using the same command but choosing fit mode B, which is a FE fit equivalent to Option 4 in **Sections/Graphical Sag...**

The screenshot displays a software interface for power line design. At the top, a 'Section Table' window is open, showing a table of section data. Below it, a 'Batch Graphical Sag' dialog box is overlaid on a 3D wire diagram. The dialog box contains three options (A, B, and C) for adjusting sagging tension or length, with option B selected. The background shows a power line structure with towers and wires, with a sagging wire highlighted in red.

**Section Table**

Sort Sections by:

- Section number
- Structure number section starts upon
- Attachment set section starts upon
- Voltage
- Cable file name

Displayed Phase will not take effect until override in Section/Display-Options is disabled.

Sec #	Start Str #	End Str #	Ruling Span (ft)	Insul. Clipped	Sec Notes	Cable File Name	Voltage (kV)	Wires Per Phase	Sag Condition	Sag Temp. (deg F)	Sag Horiz. Ten. (lbs)	Display Weather Case	Display Condition	Disp. Wind From	Disp. Phase	Disp. Color	Command To Apply
1	1	1:1	7:1	469 No		ehs_steel.wir		1	Initial RS	60.0	3174.6	90 Deg F	Creep FE	Both	1	Blue	Graph Sag Fit t
2	2	1:2	7:2	469 No		ehs_steel.wir		1	Initial RS	60.0	3174.6	90 Deg F	Creep FE	Both	1	Blue	Graph Sag Fit t
3	3	1:5	7:5	469 No		dove_acsr.wir	69	1	Initial RS	60.0	4662.5	120 Deg F	Creep FE	Both	1	Red	Graph Sag Fit t

**Batch Graphical Sag**

This feature will change the sagging tension or length of wire allocated to each span depending on the option selected below. See notes below for appropriate settings of sagging temperature condition and display weather case condition.

A: Replace sagging tension with largest tension that keeps wire at or below target points (may only hit target point in one span)

Assumption is that you can predict post sagging wire behavior given the attachment geometry and the single value of tension that existed at all spans at the time of sagging. This will not fit all the target points well if tension imbalances existed at sagging or if there were any post sagging changes to geometry (wire lengths or insulator attachment positions). Quality of fit can be gauged by distance from wire to target points. Fit (display) condition can be either RS (option 1 in Sections/Graphical Sag) or FE (option 2 in Sections/Graphical Sag). FE is likely to produce better results with uneven terrain and span lengths.

B: Adjust length of wire in each span independently (simultaneously hit target point in each span)

This method should be able to hit all the target points even if tension imbalances existed at sagging or post sagging changes to geometry occurred. This is the same as option 4 in Sections/Graphical Sag (mid span sags will be maintained in spans w/o target points). For best results use option A to get the sagging tension reasonably close before proceeding with this option.

C: Report on mismatch between target points and displayed wire position (no changes to wire position)

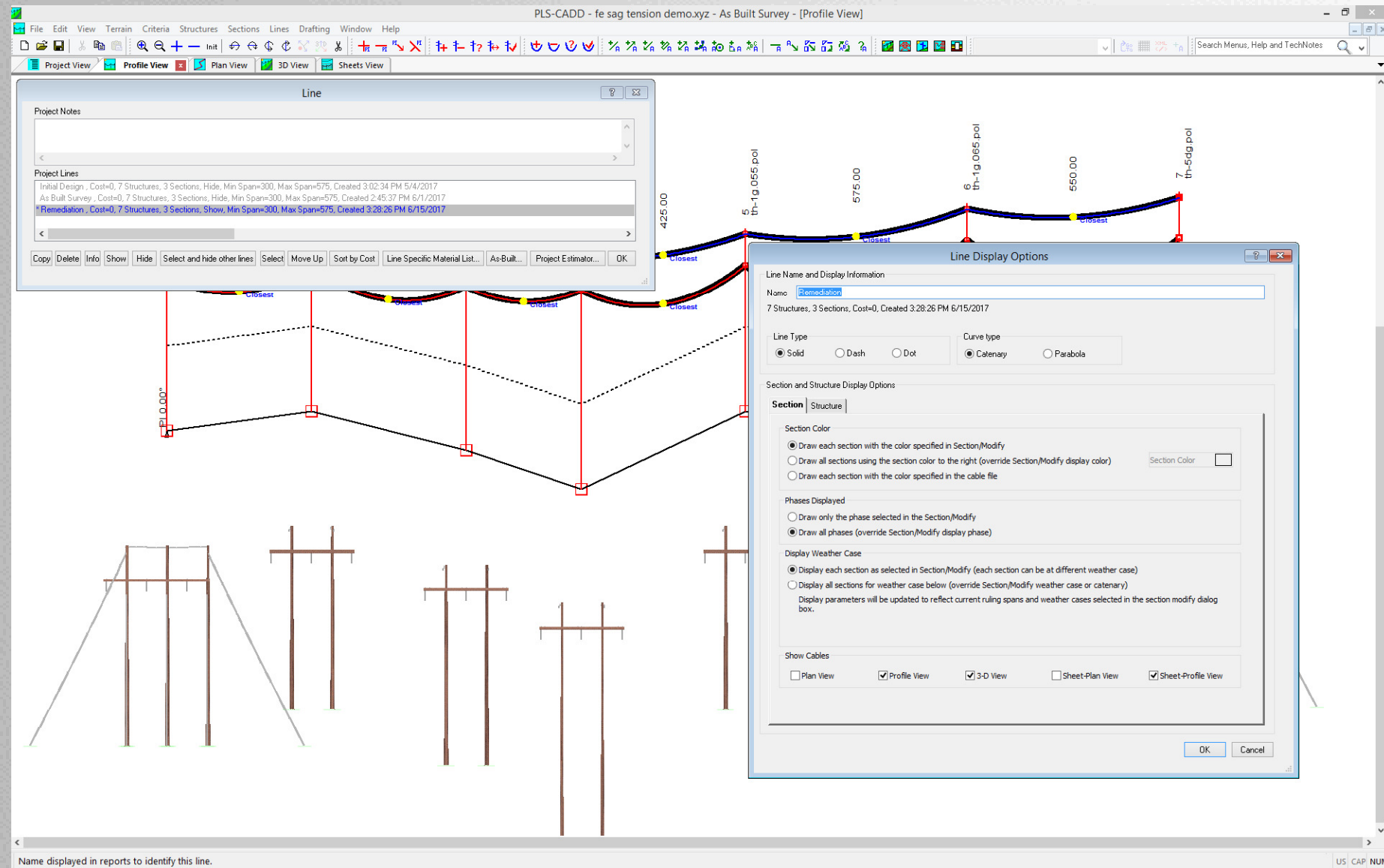
Notes:

Sagging condition and temperature should be as close as possible to the original sagging state (state where all spans should be at same horizontal tension with plumb insulators). Display weather case and condition should be for the "as surveyed" state in which wire is to hit target points.

OK Cancel

# Step 10: Create line model copy for remediation

- Create another line model copy in **Lines/Edit...** to store remediation work to fix a clearance problem



# Step 11: Merge unstressed lengths

- In **Sections/Table...** use the command to apply column and select the Merge length adjustment command. This takes any FE unstressed length changes from graphical sagging and adds them to the unstressed length column leaving a nice blank slate in the change column for keeping track of changes made to fixed lengths in future steps.

\*Note: Check the ahead span unstressed length change column. If large values are present, i.e. >1 foot, it's a good indication that an initial RS fit (A mode) wasn't performed and the creep elongation calculations will be off since the sagging data tension didn't get set properly.

\*Note: The ahead span unstressed length and unstressed length change columns are added together to represent the total length of wire in a span. The change column exists to easily keep track of changes made. Merging the values prior to remediation work makes this much easier and more useful.

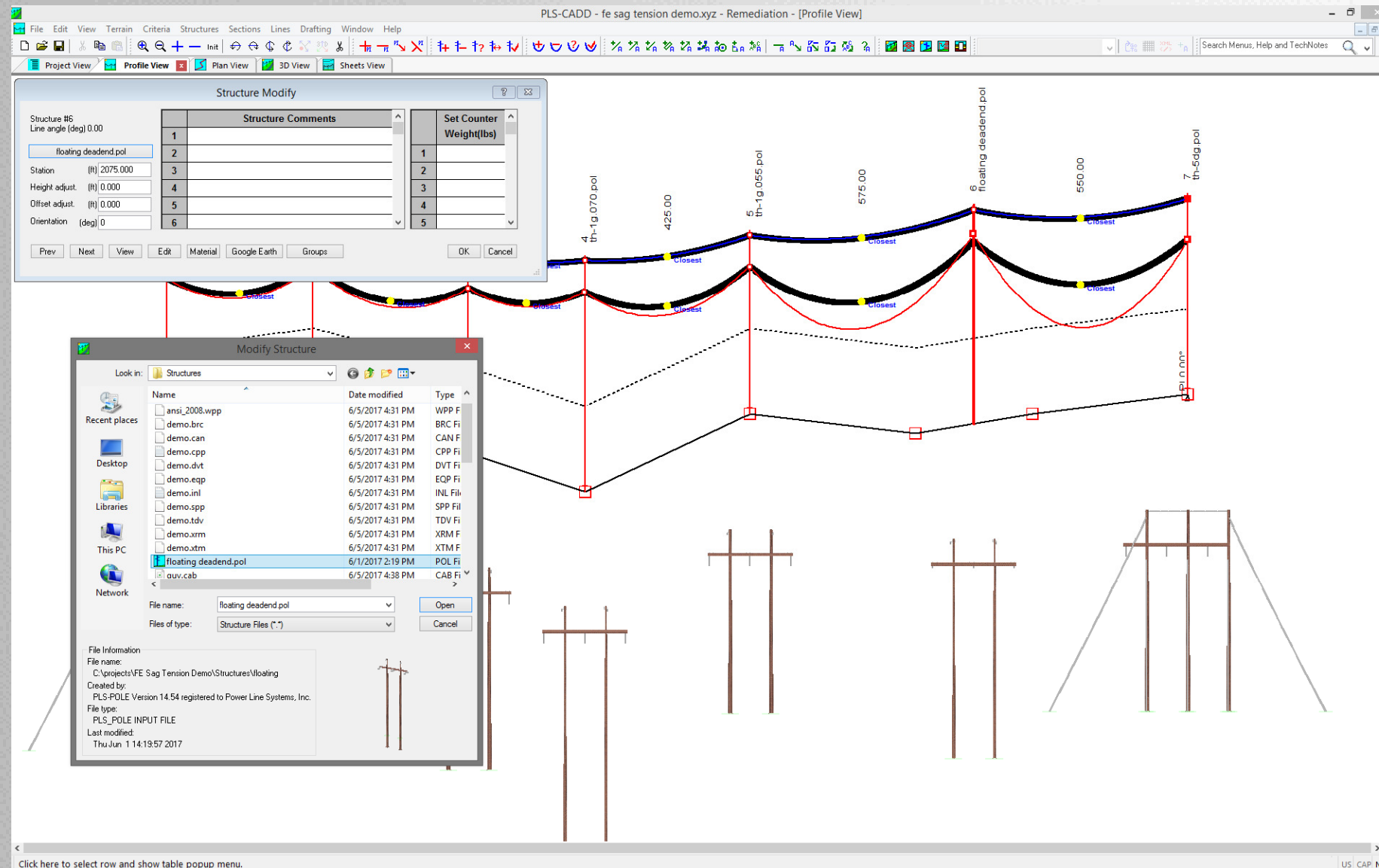
The screenshot shows the 'Section Table' window with the following data:

Sec #	Start Str # Set #	End Str # Set #	Ruling Span (ft)	Insul. Clipped	Sec Notes	Cable File Name	Voltage (kV)	Wires Per Phase	Sag Condition	Sag Temp. (deg F)	Sag Horiz. Ten. (lbs)	Display Weather Case	Display Condition	Disp. Wind From	Disp. Phase	Disp. Color	Command To Apply	
1	1	1:1	7:1	469	Yes	ehs_steel.wir		1	Initial RS	60.0	3174.6	90 Deg F	Creep FE	Both		1	Blue	Merge length
2	2	1:2	7:2	469	Yes	ehs_steel.wir		1	Initial RS	60.0	3174.6	90 Deg F	Creep FE	Both		1	Blue	Merge length ad
3	3	1:5	7:5	469	Yes	dove_acsr.wir	69	1	Initial RS	60.0	4662.5	120 Deg F	Creep FE	Both		1	Red	Merge length ad

The graphical view below the table shows a sagging diagram of a power line with several towers. The conductors are shown in black, and the towers are in brown. The diagram illustrates the sagging of the wires between the towers, with vertical lines indicating the span lengths.

# Step 12: Swap out tangent structure to floating DE

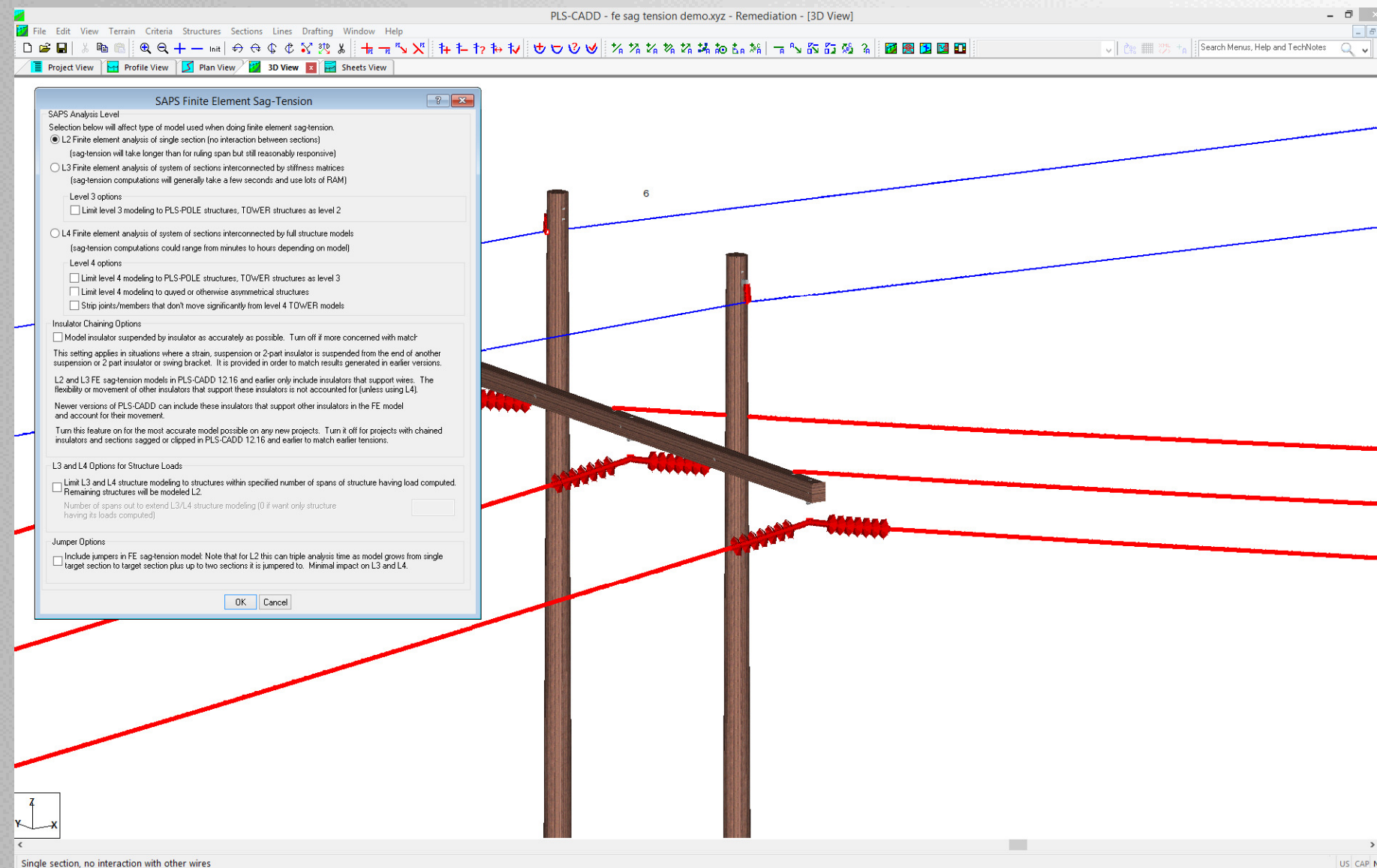
- Change display conditions to reflect a typical construction condition. Most choose 60 Deg F. and assume creep.
- Create a floating dead end structure and substitute it at the structure location needed



\*Note: Extra sag in wires in spans adjacent to floating dead end caused by inserting strain insulators into the span

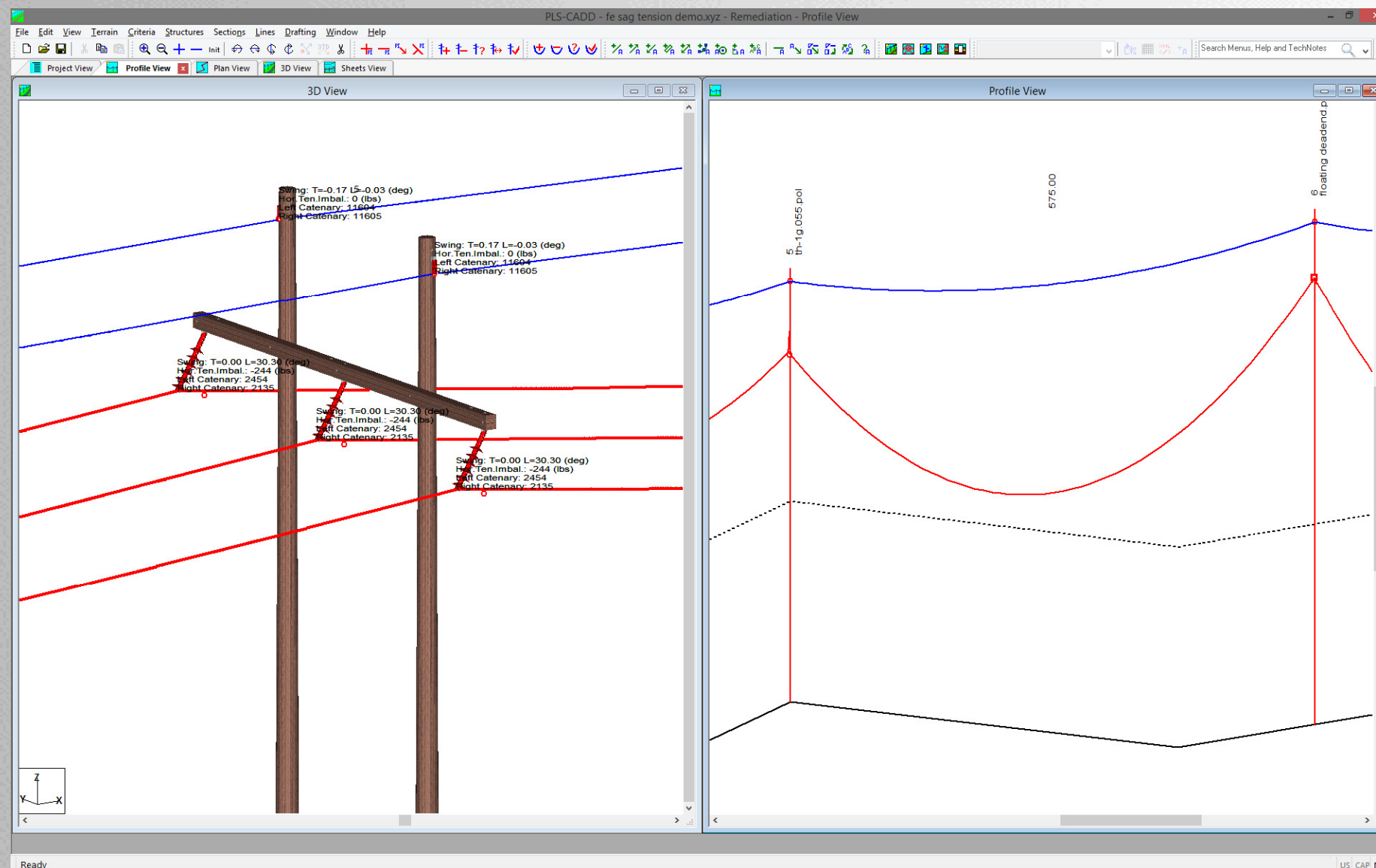
# Step 13: Uncheck option for chained insulators

- Navigate to **Criteria/SAPS Finite Element Sag-Tension...** to uncheck the chained insulator option so the small suspension insulator at the floating dead end remains vertical and doesn't swing while adjusting lengths in further steps.



# Step 14: Set up views to see tension imbalance

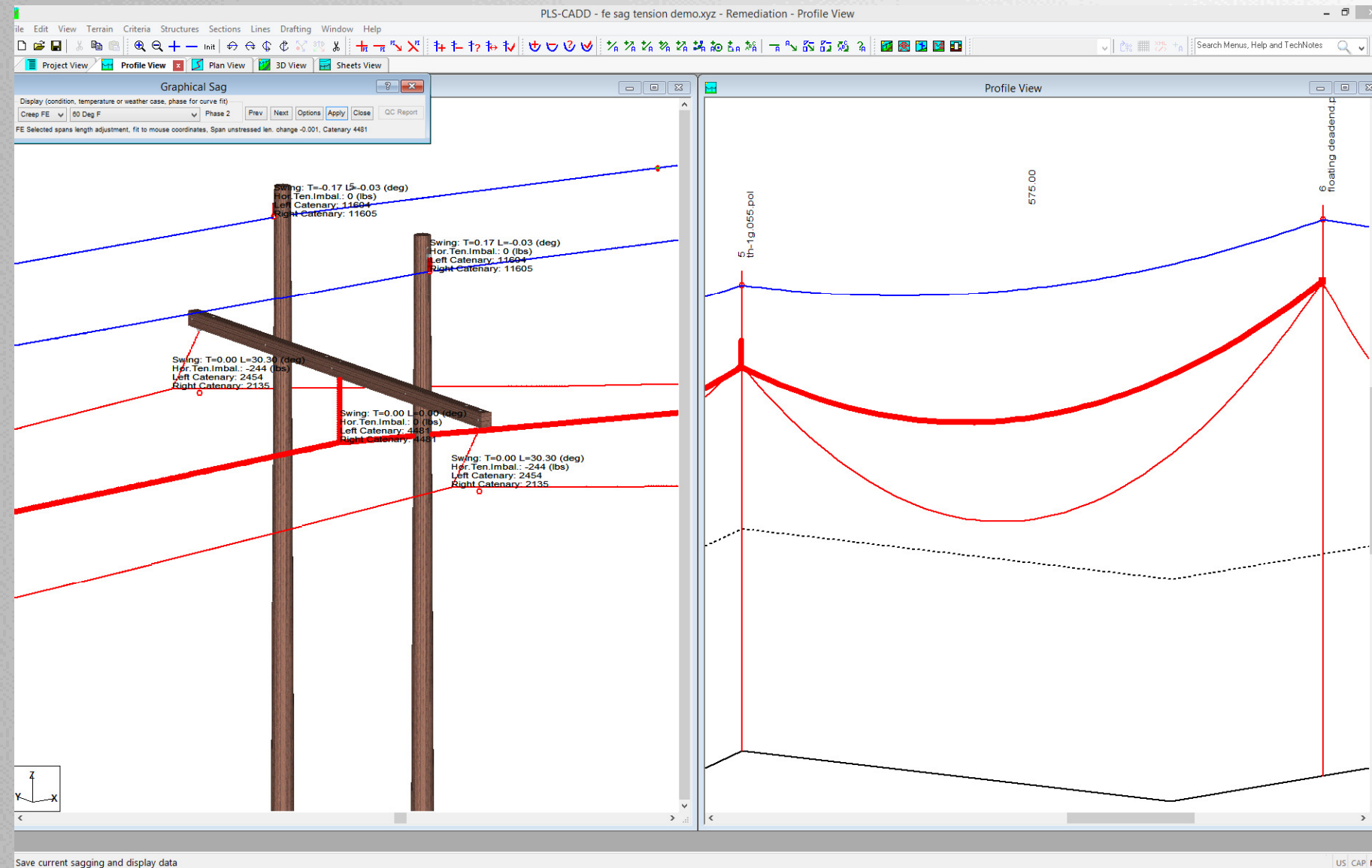
- Open a 3D view and profile view side by side and press the F1 key and go to **F1/SAPS Finite Element Sag-Tension/Label insulator swings, attachment displacements and/or loads...** to turn on labels for insulator swing angles, imbalance in horizontal tension, and catenary constants





# Step 15: Graphical sag to fix tension imbalance

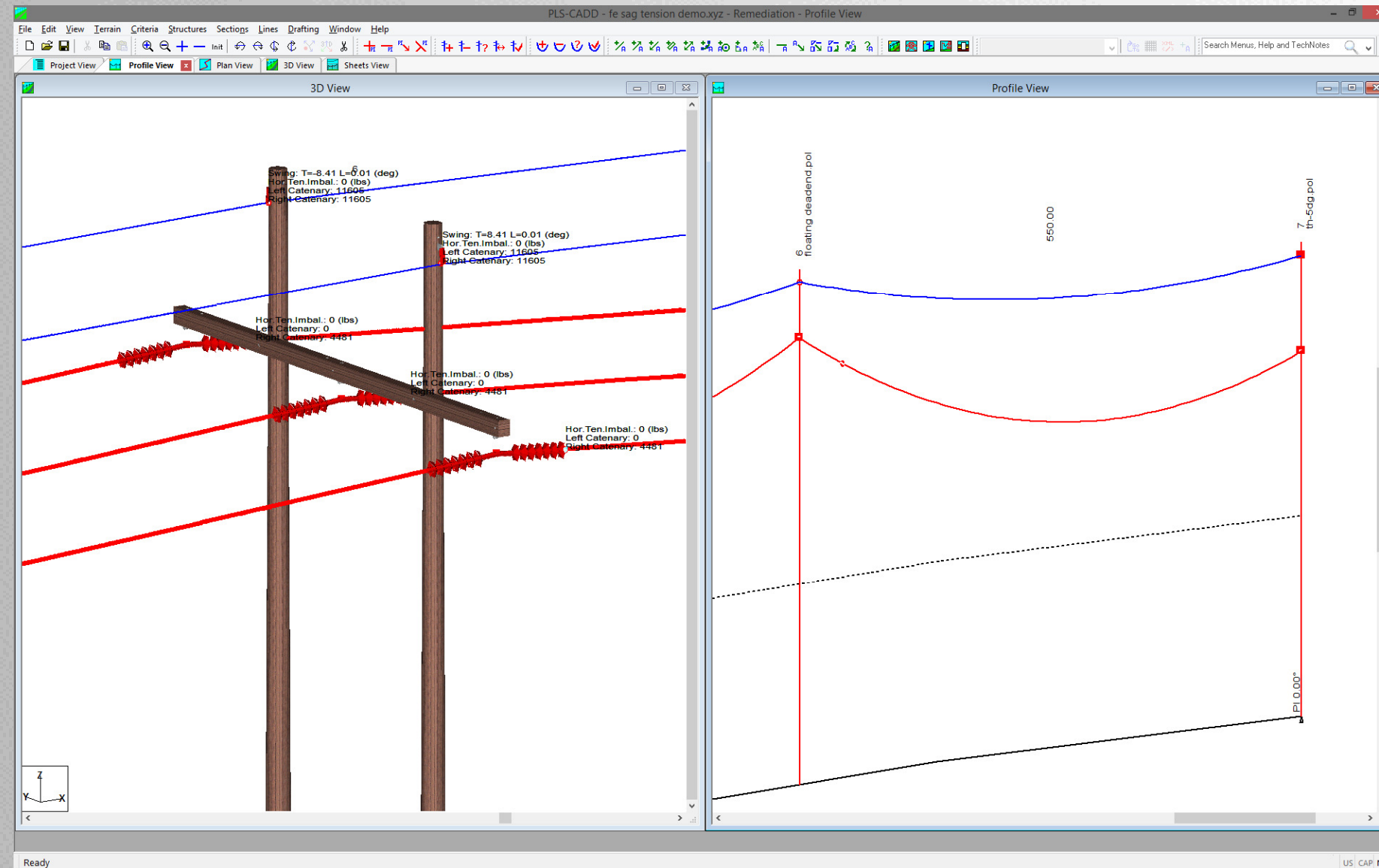
- Using **Sections/Graphical Sag...** option 3, adjust the sag in the profile view and watch the imbalance at the adjacent structure until it's nearly 0, then click apply and repeat for all phases.



\*Note: The catenary constant after adjustment is 4481 ft.

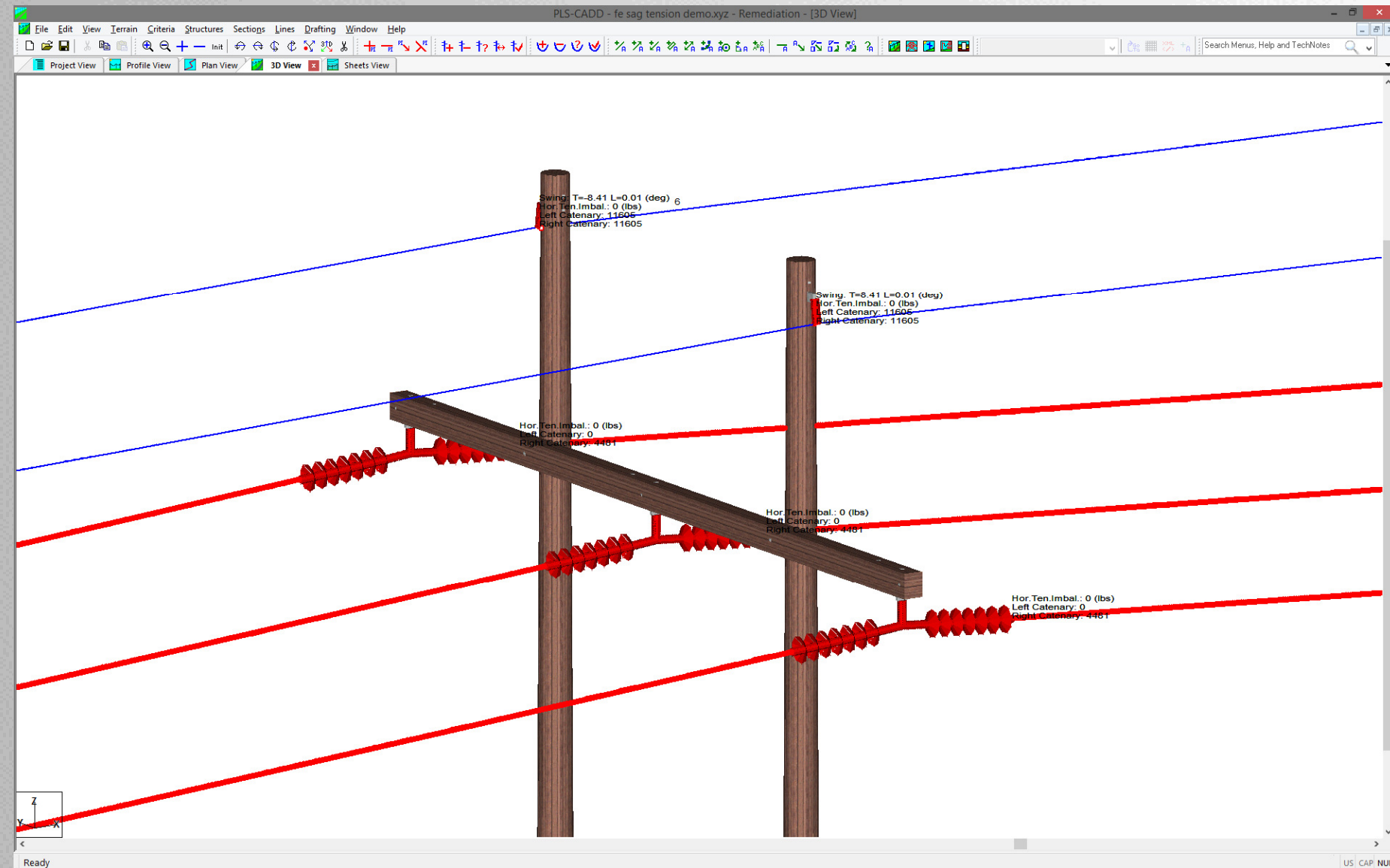
# Step 16: Repeat process for other adjacent span

- Using the same process for the other span but this time using the catenary constant and making sure it matches what the previous span of 4481 ft had since this span is dead end to dead end.



# Step 17: Switch back on chained insulators

- Now that the lengths are all adjusted properly you can switch back on the chained insulator feature and perform any structural or clearance analyses needed.



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