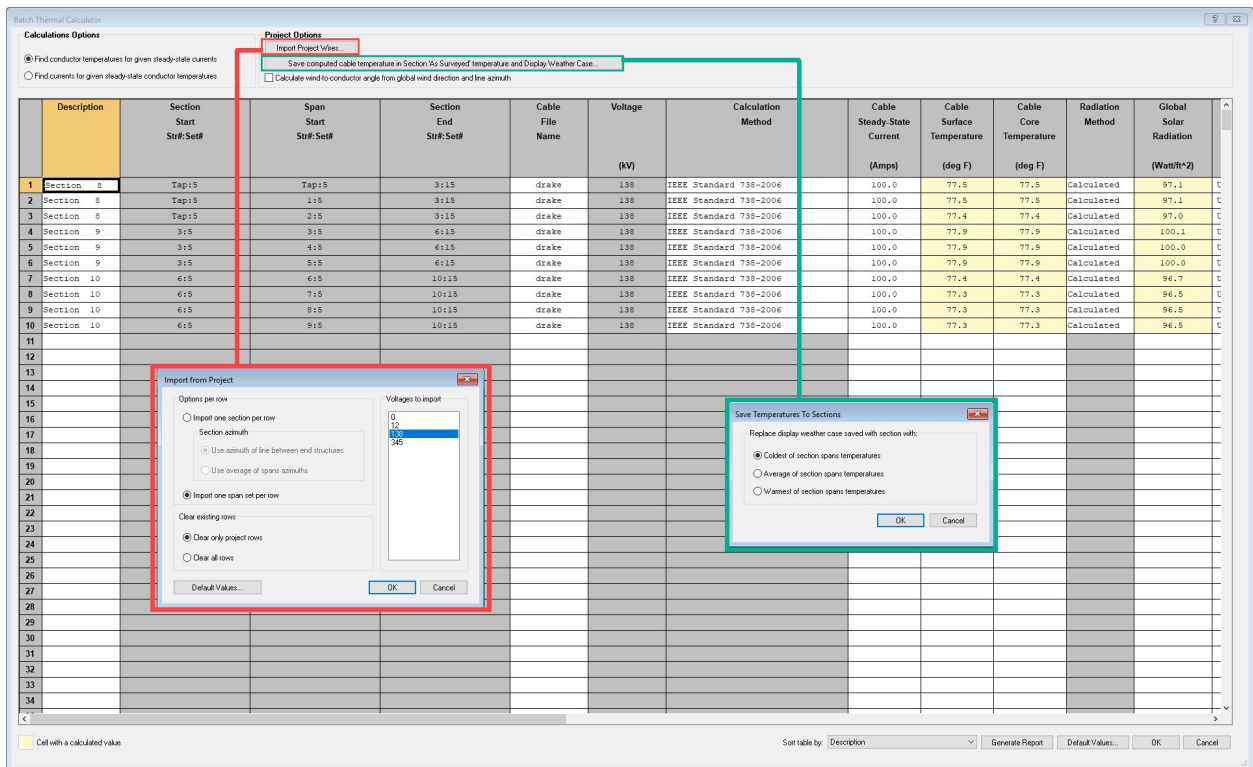


## Graphical Sagging to Match Surveyed Data of Conductors

The purpose of this technote is to show the recommended ways to graphically sag wires in PLS-CADD to accurately model surveyed conditions. Graphically sagging is an operation in which you tell PLS-CADD graphically where you want a wire to be, and then based on the wire's displayed temperature and properties of the wire, PLS-CADD will determine what the tension of the wire needs to be in order to be at the desired position.

Before beginning the process of graphical sagging it is assumed that you have already modeled your structures and strung wire. Be sure that the structures have been modeled accurately to fit the surveyed conditions. Make sure that the insulators have the correct properties of weight and length and that they are positioned to match the surveyed data. It is recommended for suspension and strain insulators to have the cold end (where it connects to the structure) snapped to the location of the LiDAR survey point. The hot ends of the insulator (where the wire connects) can vary depending on the tension of the wire. If you snap the hot end of an insulator to a survey point there is the chance that after graphical sagging and adjusting tensions that it no longer matches the LiDAR data. If you are unsure on this process check out the YouTube video demonstration for classifying LiDAR that will how to have PLS-CADD classify structure points and points of attachment. <https://youtu.be/PgwQP96ffro>

To start the graphical sag process you first need to establish what the temperature of the wire was on the day that it was surveyed. Knowing the surveyed wire temperature is crucial because by using this temperature and the properties of the wire PLS-CADD can calculate the tension by graphically shaping a catenary curve to fit the LiDAR data. The surveyed wire temperature is calculated by performing a thermal calculation using the IEEE 738, CIGRE 207 / 601, or the TNSP 2009 methods. Each of these methods works in a very similar fashion. They are heat balance equations that take inputs like weather, electrical current, and conductor properties and solve for a conductor temperature. It is recommended to use the Batch Thermal Calculator (BTC) in PLS-CADD located at **Sections/Thermal Calculations (IEEE, CIGRE and TNSP)/Batch Thermal Calculator...** to make these calculations. This is because the BTC allows you to import the wire information from your project and perform a thermal calculation with the wire geometry inputs entered automatically for you based on your model. In the figure below you can see the process of importing the wires from a project to perform a thermal calculation on each span and store that temperature into a surveyed wire temperature weather case. Keep in mind that performing a different temperature calculation for each span of wire will necessitate the use of FE graphical sagging and require the SAPS module.



The calculated wire temperatures can be stored in a special weather case called \*\*\*Surveyed Wire Temp.\*\*\* This eliminates the need to create multiple temperature weather cases and displaying sections at different conditions to match the surveyed conditions. You can choose to perform these calculations on a tension section basis (dead end to dead end) so all spans in a section have the same temperature. Or you can make the calculations on a span by span basis and have a possibly different temperature in each span.

The next step in the process is to set up the **Sections/Modify...** dialog. In the "sagging data" portion of the dialog shown below you'll want to enter the temperature and condition of the cable on the day it was installed.

**Section Modify**

Section 9 from structure #3 to structure #6

Type

Cable file: .Public\Documents\PLS\pls\_cadd\examples\cables\drake

Voltage (kV): 138 Conductors per phase: 1

**Sagging**

☐ Override calculated ruling span

Ruling Span (ft): 801.92

Automatic Sagging

Condition: Initial RS

Temperature (deg F): 60.0

Catenary (ft): 6672.8

Horiz. Tension (lbs): 7300.0

**Display**

Color: [Pink Box]

☒ Show selected weather case

WC: 77.9 (deg F)

Condition: Max Sag RS

Catenary (ft): 5262.7

Swing angle (deg):

Wind from: Left

Phase: 1

Sec Notes:

CRI Notes: Typical 2012 NESC

Edit Stringing OK Cancel

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

SAPS Finite Element Sag-Tension Options

☐ Clip Insulators (lock unstressed length, force finite element sag-tension)

Graph Tension vs. Elongation

Edit Span Specific Wire Lengths, Concentrated Loads, Attachment Stiffnesses, Surveyed Temperatures

There's a common misconception that this information should match the surveyed wire conditions, when in fact they should almost always be set to 60 Degrees F, Initial RS. The sagging data conditions represent 2 things. The first is that they represent the condition the insulators were plumb when the line was originally built. Unless a line has identical level spans the insulators can only be plumb under one condition, which would be when the line was originally built. Since most people do not know the exact temperature on the day the line was constructed they assume 60 Degrees F or something close to that. The cable condition should also almost always be Initial RS because lines are typically constructed with brand new wire that hasn't been stretched at all. However, if a line was ever retensioned or reusing old conductor when it was built and the insulators were plumb, then you would pick the Creep RS or Load RS cable condition. If you enter in the surveyed cable conditions in this field and perform a graph sag fit there is a chance that the insulator positions may not arrive at a good fit and throw off sag/tension results.

The second thing the sagging data information represents is the conditions the line exists at for the majority of its life. PLS-CADD uses these conditions to calculate the permanent stretch from creep.

So if an unreasonable tension value is entered into this field the creep elongation values and tensions will be thrown off, even if a FE fit is performed later on and the wires match the LiDAR shots perfectly.

The next step is to have PLS-CADD look at the LiDAR data and find a data point for each span of wire that it can use to graphically sag to. To do this PLS-CADD looks at LiDAR survey points that are close to the conductor's current position. Another common misconception is that PLS-CADD graphically sags wire to match LiDAR shots. Technically what PLS-CADD does is look at the LiDAR shots to find a single representative fit point, and then graphically sag the wire to hit that fit point. It's a good idea to change the display weather case to the surveyed wire temperature case and adjust the sagging data tension so that the wire positions are fairly close to their corresponding LiDAR shots. They don't have to match exactly, PLS-CADD will take care of that later, but they need to be close enough to the LiDAR shots so PLS-CADD can find a representative fit point for each wire in each span. The command **Sections/Graphical Sag...** can be used to perform a quick RS fit on the sections to rough adjust them so they're near the LiDAR shots.

Once the wires are close to the LiDAR shots and displayed at the correct surveyed wire temperatures the graphical sag fit points can be found. It is recommended to use the *Command to Apply* column in **Sections/Table...** instead of the **Sections/Graphical Sag...** command for 3 reasons. The first is that it allows you to be able to review the fit points first before graphical sagging. This way you can experiment with different fit point algorithms to see which algorithm gives the best fit point to match your data and to make sure a valid fit point is found in every span. The second reason for using the table is it allows all sections in a line to be done in one operation instead of one section at a time. The third reason the table is preferred is that it simplifies the graphical sag commands into just 2 types of fit modes, whereas the **Sections/Graphical Sag...** command has 6, some of which have various options and settings. So using the *Command to Apply* column the first command to run is the *Find Graph Sag Fit Points...* command. As shown in the screen shot below this allows you to select a desired fit point algorithm that best fits your data and bundle geometry and determine what feature code to look at. It is beneficial to have one feature code for all wire shots so that you don't have to run this command for shield wires, conductor phase wires, and other wires separately. If your LiDAR shots are classified with multiple feature codes it may save some time by condensing them to only one feature code. If you still would like to maintain the classification work but still get the benefit of only one feature code for wire shots you can use the **Terrain/Edit/Deactivate, Delete, or Export Points/Non-Graphical...** command to export all wire shot feature codes to a separate .xyz file. Then open that .xyz file in a separate instance of PLS-CADD and load your project's .fea feature code file. Then use the **Terrain/Edit/Change Feature Code/Search Replace** command to remap all of the points to the single feature code used for all wire shots and save the file. And back in the original project you can merge that .xyz file back in with the **Terrain/Edit/Merge Points from External File/Merge Points from XYZ Files...** command. Now you can run the command to find graph sag fit points on all sections in one operation since all of the points are now on only one feature code. If you don't want to take these extra steps to condense all the points to a single feature code you will need to run the find graph sag fit points command multiple times, one for each unique wire feature code. Also note that in this dialog

there is a feature for performing a least squares fit. This option should only be used if there are significant gaps in the LiDAR data. Modern day LiDAR doesn't typically suffer from this, and if you have good LiDAR, using this feature could actually yield a poorer fit point. Once the command is run, go through the QA/QC report to see if there are any fit points found with large offset values from the target wire and graphically look at the line in both the profile and 3D views to ensure that a good valid fit point is found in every span for each wire. If a good fit point isn't found in every span for every wire try another fit point algorithm and double check your wires are currently located close to the LiDAR survey shots.

**Find Fit Points For Batch Graphical Sag**

Feature code for wire fit: 200 Survey point

☒ 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 1 m 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

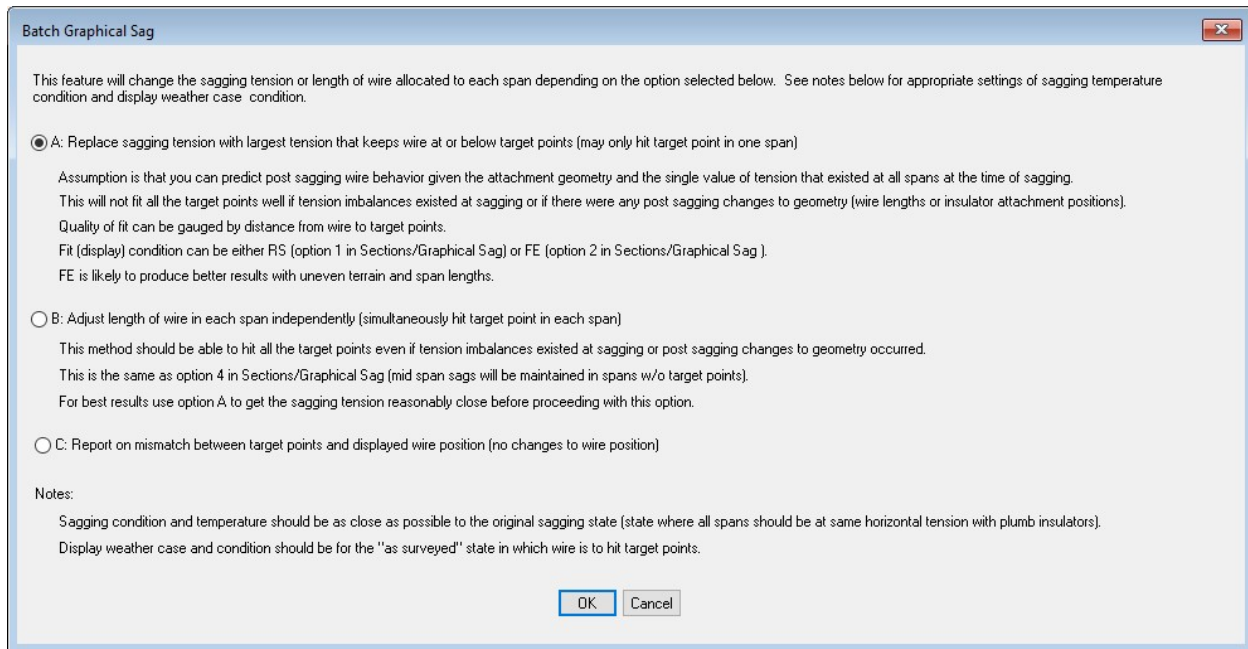
Maximum distance between XYZ points and the preliminary catenary (ft) 1.000

☐ Create markers showing XYZ points that we're used for least squares fit (slow diagnostic feature that uses lots of memory).

OK Cancel

Once a good fit point is found in every span for every wire you can now begin the graphical sagging operation. Again use the *Command to Apply* column in the **Sections/Table...** and select the *Graph Sag Fit to Points...* command. When you click apply or OK in the sections table you'll be presented with the dialog shown below where you have 2 different fit modes to choose from, mode A and mode B. The A type fit is the ruling span fit and should be run first. It is equivalent to options 1 and 2 in the **Sections/Graphical Sag...** command depending on the display conditions of your sections. If your wires are displayed in RS then the graphical sag operation will be a simple RS operation assuming the insulators are plumb at the surveyed conditions. As mentioned earlier though, the insulators can only be plumb for the initial installation conditions. So if you display your sections in FE (keeping them unclipped) PLS-CADD will perform a RS graphical sag operation while looking at FE conditions at the surveyed wire temp when the insulators can be out of plumb. This is equivalent to option 2 in **Sections/Graphical Sag...** and provides for a more accurate RS sagging data tension. What PLS-CADD

is essentially doing is determining the Initial RS 60 Degree F tension so that when the sections are clipped it will give you the FE sag at the surveyed wire temperature closest to the graph sag fit points. It is very important to run this A type RS fit first because it sets that sagging data tension in the **Sections/Modify...** dialog mentioned earlier, which is what PLS-CADD uses to determine the permanent elongation due to creep. After you perform the A type RS fit your wires will be pretty close to the graph sag fit points. The next step is to run the command a second time and choose the B type fit it will perform a FE graph sag operation. Fit mode B is equivalent to option 4 in **Sections/Graphical Sag...** PLS-CADD clips in the sections to lock the fixed lengths of cables and then adjusts the cable length in each span so that the wires match even closer to the graph sag fit points. And after this you should have all of your sections graphically sagged properly to match your surveyed conditions.



You may notice that after performing FE graphical sagging that your wire attachment points are not exactly in the correct positions. This is typically caused by insulators not having the correct properties of length and weight, or more likely the cold end of the insulator is not in the correct position. You may then need to adjust the positions of your insulators, unclip the sections, and then perform the RS and FE graph sagging operations again to get a better fit of the insulators.

The last thing to mention is graphical sagging with higher levels of SAPS analysis. When performing sag/tension in FE you have the ability to change the level of SAPS analysis from L2, to L3, or L4. For a more in depth discussion of the differences between these methods it is recommended to review Appendix N of the PLS-CADD manual. In short though, L2 SAPS, which is the default, assumes that all structures are infinitely rigid while calculating sag/tension. L3 and L4 SAPS allow for structures to move and deflect in the sag/tension analysis. L1, while not mentioned in the program, is ruling span sag/tension. And while at first it may seem to be a good idea to account for structure deflection while graphically sagging, since structures will move and deflect in reality, it's actually not recommended. It's not recommended because it can cause the program to essentially chase its tail, making for long

analysis convergence times or it may not converge at all. The FE graphical sag process works by making small adjustments to cable lengths in one span at a time. Each time the cable length changes it adjusts the tension, which in turn changes the load on the structures making them deflect, which then adjusts the sag/tension of the wire in other spans. And this cycle can make for many loops and iterations trying to find cable lengths that give proper sags with structures deflected in every span. And even if a section converges successfully and the fit is good, when PLS-CADD moves on to the next section it will change the deflection of the dead end and throw off the sag in the previous section that was good. Most of the time during survey conditions structures are deflecting very little as well, so much to the point that its very likely negligible. So it is for these reasons that it is recommended to perform FE graphical sagging in L2 SAPS. Then if later desired for structure loading or clearances switch to a higher level of analysis.