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Preparing for Line Optimization In PLS-CADD

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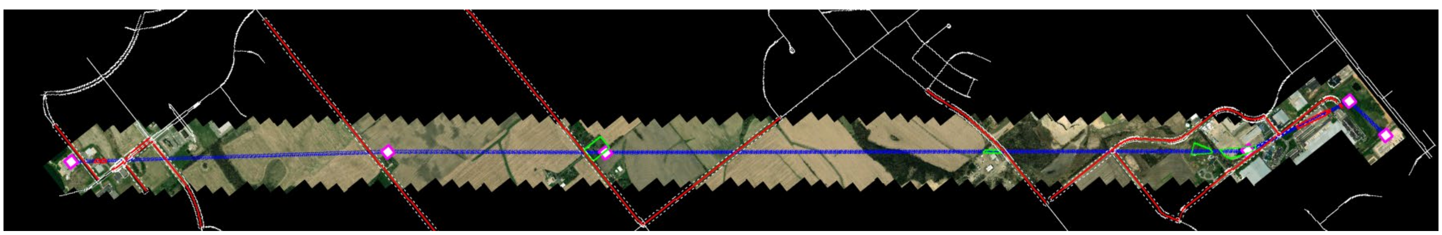
Introduction

Line Optimization is one of the most powerful features of PLS-CADD. It will provide the least-cost solution for spotting a given set of structures for a desired set of design criteria on any desired route. A webinar on optimum spotting is available through the software that is complementary to this technote. This technote is intended to detail the steps that should be done in order to perform an optimization as well as features of the optimization process and even some advanced features after the optimization is complete.

The first step to an optimization is that you must have your route selected in PLS-CADD. Route selection is beyond the scope of this technote and is covered in section 14 of the PLS-CADD manual. Please keep in mind, though, that you could have several projects utilizing the same data in order to optimize numerous routes to get cost comparisons between alternative routes.



Model Setup

While the optimization feature itself is the focus of this technote, setting up the model criteria and structure strength capacity is the majority of the work. Making sure your structure usage criteria, survey point clearance requirements, and wire tensions are defined is important for any model. Failing to set these criteria up prior to optimizing the line will cause errors, result in a less than optimal design, and/or require rework to be done, negating the benefits of doing line optimization. Setting up structure strength capacities is also important as the optimum spotting tool will use this to efficiently size and locate structures along the alignment.

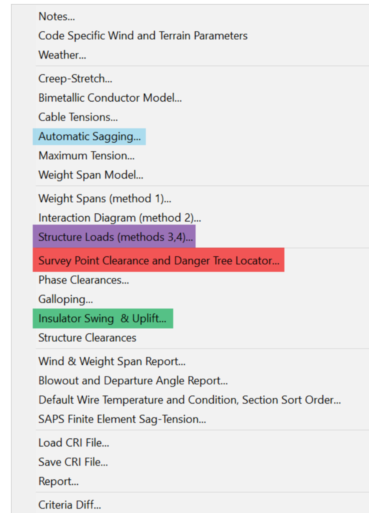
PLS-CADD Criteria

While all necessary criteria should be considered prior to beginning any model, there are a few that more specifically relate to optimum spotting:

Terrain/ Feature Code Data/ Edit... Have the clearances required for the various voltages that you will be using on your line. This is the only way to insure that the proper clearances will be met after your optimization is complete. One option step is to include a spotting buffer for feature codes that will be used as spotting constraints. If the feature code will not be used as a constraint, then this step is not necessary.

	Feat. Code	Feature Description	Prof Symbol	Plan Symbol	Line From Feature Top To Bottom	Aerial Obst-acle	Point is on Ground	Req Vert Clear 0kV (ft)	Req Horiz Clear 0kV (ft)	Req Vert Clear 12kV (ft)	Req Horiz Clear 12kV (ft)	Req Vert	Req Horiz	Req Vert	Req Horiz	Req Vert Clear 345kV (ft)	Req Horiz Clear 345kV (ft)	Required Clearance tr. Base/Gu to Spotting Constraint (ft)
15	240	Country road	△	△	No	No	Yes	35	0	39	0	40	0	41	0	[illegible]	0	0
16	241	Road	△	△	No	No	Yes	35	0	39	0	40	0	41	0	42	0	40

Set clearance for Opt. Spot. constraint



Criteria/ Survey Point Clearance and Danger Tree Locator... This table must be completed with any and all conditions for which clearances to feature codes and ground surface must be maintained. Don't forget to include any cold and/or uplift clearance conditions in the event that your line design will be going under any aerial obstacles or any structures that should be avoided in an uplift scenario.

Criteria/ Insulator Swing & Uplift... Specify up to four weather conditions that will be used to verify that a structure does not have excessive insulator swing leading to structure clearance issues.

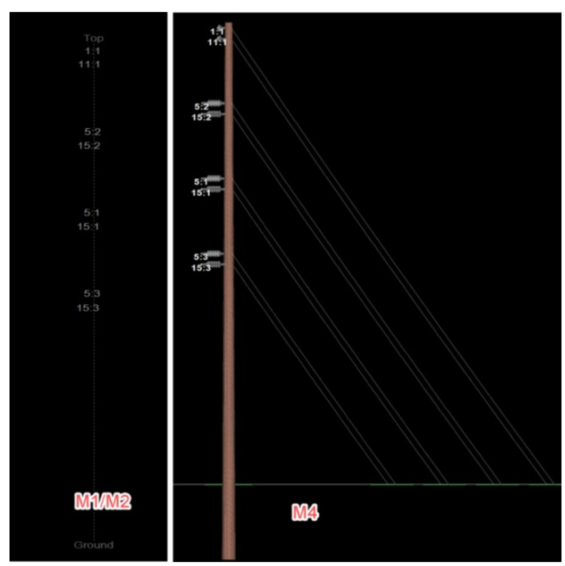
Criteria/ Automatic Sagging... All possible stringing limitations for the conductors on your line should be input. It will be much easier to allow the program to automatically select the tensions during the actual optimization process than trying to figure out an actual single stringing tension at that time.

Criteria/ Structure Loads (methods 3,4)... For optimum spotting purposes it is suggested that the structure loading criteria be pared down to only the most basic intact load cases without cable load adjustments or a max wind direction. Since the majority of the spotting effort pertains to strength of tangent and angle structures, it greatly decreases the time to spot structures if only the load cases that apply to all structures are used. This also means that no structure specific load cases such as containment or stringing should be considered at this time. The full loading criteria can always be added for additional load case options once optimization is complete.

Creating Available Structures

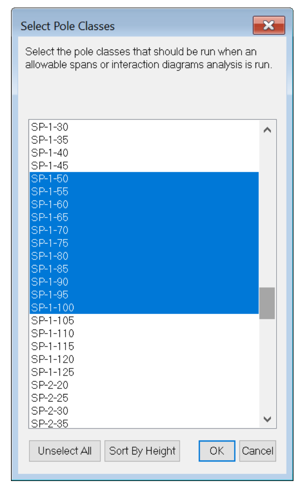
Now for the most important step in line optimization; the designer must model structures for use in the optimization. In order to do this, one must understand the different methods in structure modeling for PLS-CADD.

- Method 1 – Basic Allowable Spans Method
- Method 2 – Allowable Spans Interaction Diagram Method
- Method 3 – Critical Components Method (Deprecated)
- Method 4 – Detailed Structural Analysis Method (PLS-POLE or TOWER)

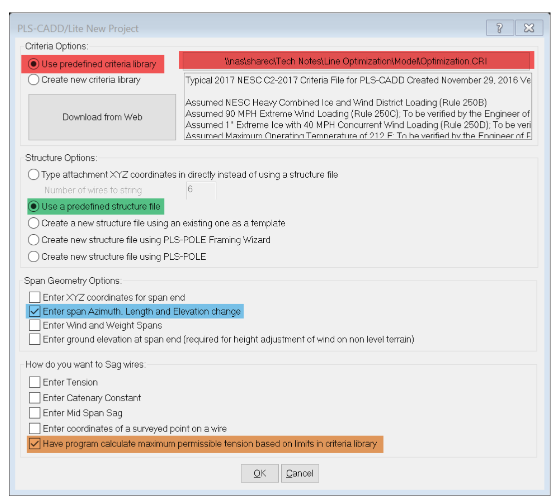


While the full explanation of these various methods is beyond the scope of this technote, information on these methods can be found in Section 8.3 of the PLS-CADD User's Manual. An important concept to understand is that PLS-CADD can currently only optimize with Method 1 or Method 2 structure models. Millions and millions of structure analyses are required for optimization with Method 4 structures, and current computer capabilities do not make this a viable option. For the remainder of this technote, it will be assumed that the designer will be using Method 1 structures for optimization. There will be a brief discussion at the end of the technote for those that wish to utilize the more advanced Method 2 structures.

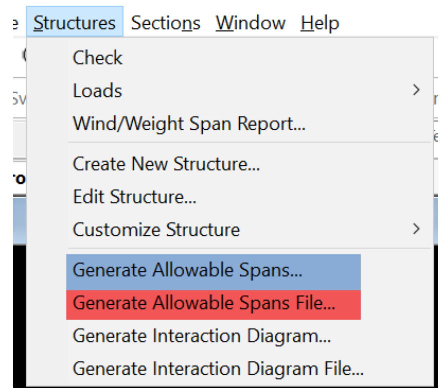
One could just model Method 1 or Method 2 structures directly using the **Structures/ Create New Structure...** function in PLS-CADD as described in Appendix F in the PLS-CADD User's Manual. However, this method has many shortcomings as we will see later, and most designers would be calculating their allowable spans from PLS-POLE and/or TOWER anyway. This brings us to the primary purpose of this technote; how do we optimize a line with structures that we have modeled in PLS-POLE and/or TOWER? The process to do this will now be outlined step-by-step. In this process, we will assume that the designer is using wood poles in PLS-POLE, but the process will be nearly identical for any other material of poles or even structures modeled in TOWER.



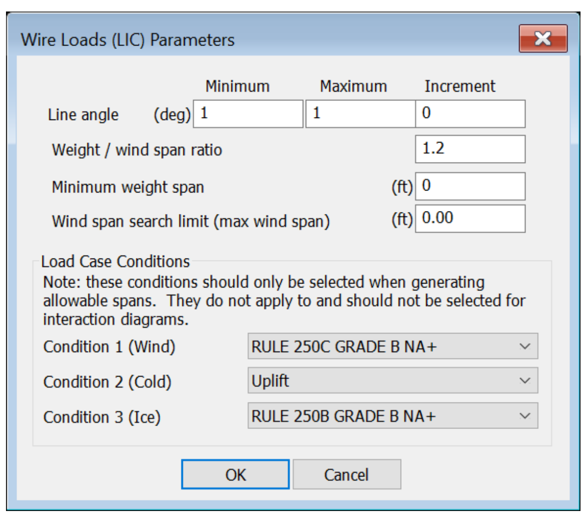
1. Model your tangent structure in PLS-POLE. It is suggested that you use your shortest and smallest wood pole for this base model. We'll call this model TANGENT.POL.
2. In PLS-POLE, go to **Geometry/ Wood Poles**, click on the Multiple Pole Selection button at the bottom of the dialog box, and select the heights and classes of poles to be used for the entire tangent structure family.
3. Ensure that you have completed the **Geometry/ PLS-CADD/ Insulator Link** table with the desired Sets and Phases for the various wires that will be strung on the structures.
4. There is no reason to define any loads for this structure, so it is suggested that the designer not even define anything under the Loads menu item.
5. Save the structure (TANGENT.POL) and close PLS-POLE.
6. Open PLS-CADD Lite (if you have PLS-CADD, you can just open up PLS-CADD).
7. Select File / New / PLS-CADD Lite from the menu, and give it a name – for our this technote, we will call it TANGENT.LOA (don't forget to add the "LOA" extension when typing the name so that the program will know you are wanting to create a PLS-CADD/Lite project.)
8. For the Lite Options:
   a. Select the Criteria File (*.CRI) from your PLS-CADD project that you are going to optimize for the Criteria Options.
   b. Select "Use a predefined structure file" for the Structure Options.
   c. Select only the "Enter span Azimuth, Length, and Elevation change" option for the Span Geometry Options.
   d. Select only the "Have program calculate maximum permissible tension based on limits in the criteria library" for the How do you want to Sag wires options.
9. Click the OK button and then find and select the TANGENT.POL model from step 5 above.



10. Modify the Model Setup table to select the conductors at each attachment point on the structure as well as any other changes that might be desired. It is suggested that the Span Horizontal Projection be modified to the approximate spans anticipated on the line (The span length chosen isn't terribly important – many designers use the anticipated Ruling Span for this number). It is further suggested that the Ruling Span column be set to "0" for all wires (this forces PLS-CADD/Lite to use the actual span length for the Ruling Span). There are several other technotes as well as all of Chapter 15 in the PLS-CADD User's Manual if you have any further questions on using Lite.
11. Click OK on the Model Setup dialog box and you will be presented with a Profile and 3D view of the structure with the conductors strung and displayed as defined in the previous step.



12. Creating Method 1 structures from this model now is as easy as selecting the **Structures/ Generate Allowable Spans File** from the menu. If you do not have much experience with a certain structure or with the allowable spans dialog, using **Structures/ Generate Allowable Spans** will calculate the allowable spans without generating the structure files making troubleshooting easier.
13. In the case of this wood pole example, select "No" when prompted to run all structures in an available structure list. (In the event of using multiple TOWER or PLS-POLE models, you could select "Yes" and select the available structure list from your project to run them all at one time.)
14. You will then be presented with an explanation that all pole heights and classes selected in the Multiple Pole Selection in PLS-POLE (see Step 2 above.) This step also allows you to exclude structures in the family that you don't want allowable spans generated for.
15. The designer should then complete the Wire Loads Parameters as desired.
    a. For a true tangent, the minimum and maximum line angle would be left at 0 degrees.
    b. Some tangents are designed to handle even small line angles, which can be used for the maximum line angle.
    c. Many designers design tangents for some sort of small angle to account for construction tolerances, which can be used for the minimum line angle.
    d. It is very common for designers to use the same numbers for both the minimum and maximum line angles for tangents to address both of these issues (say 0.5 degrees).
    e. In the case of an angle structure, the minimum and maximum angle can be specified, and the increment option will calculate allowable spans based on each increment of line angles. It is common for designers to just use the maximum line angle for both the minimum and maximum line angles to duplicate existing design practices.

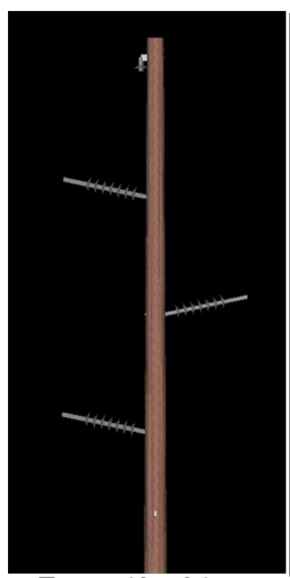


f. A major limitation of the simplistic wind and weight span concept is that only one Wind to Weight Span ratio can be used. Set too small for the terrain, grading will be very flat and many taller structures will be selected than required due to the limiting vertical factor. Set too large for the terrain, many spans will be limited based on the vertical capacity. The Weight / Wind Span Ratio used is best selected based on the designer's personal experiences for their regions. In very flat areas, one might want to use a small number such as 1.1 or 1.2 to get the most out of their span lengths, while those in mountainous regions may want to use 1.5 or even 2.0 in order to allow more variations in grading and keeping their structures as short as possible. (Note: creating Method 2 Interaction Diagrams will allow the use of all Wind/Weight Span ratios.)

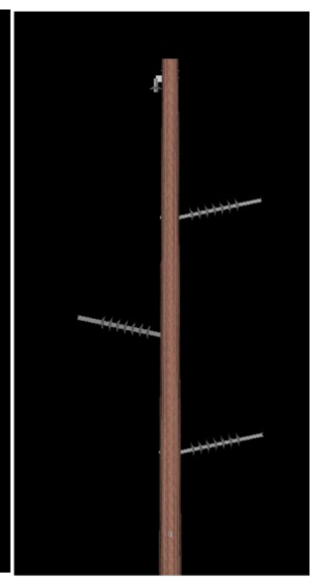
g. Minimum weight span is another way to allow the user to define the uplift capacity, if any, of a structure. Leaving it on the default "0" will not allow any uplift on a structure. Some designers like to use a small distance on this to always require some downward vertical force be present; one example of this might be on a post insulator line where trunion clamps are used. In the case of a dead end structure, a designer would probably want to allow some uplift on a structure, in which case a negative distance would be used.

h. For the Wind span search limit, this should probably be left on "0" for tangent and self-supporting structures. On guyed structures, particularly in-line guyed structures, a change of span length has very little effect on the structure (as the tensions are usually limited), so a reasonable number might be desired to be used here in order to keep the program from spending precious time calculating excessively long spans that will never be used on the line. This can also be used to limit span length to prevent the potential for large galloping ellipses.

i. Finally, three loading conditions should be selected that will match the three weight spans desired. Keep in mind that the Load Case Conditions that can be selected come from the **Criteria/ Structure Loads (methods 3,4)** and the three weight span conditions are those that are specified in **Criteria/ Weight Spans (method 1)**. It is important that these three load cases in PLS-CADD/Lite match the load cases in PLS-CADD. If there isn't a Structure Load case that corresponds with a desired Weight Span condition, the designer will need to add one. Additionally, the direction of the structure should be paid particularly close attention to. The Line Angle in the LIC Parameters is assumed to be positive (i.e. to the right). On some structures (such as the one shown in this example and the RUS structures from the PLS website), the orientation of the structure can create different allowable spans. The orientation that results in the worst loading condition should be chosen. In our example structure, orienting the structure with the side with the two post insulators to the left will actually HELP the structure. Therefore, it should be oriented so that the side with the two post insulators is oriented to the right. The optimization will automatically check both positive and negative wind directions, so selecting the positive wind direction Load Case Conditions is sufficient.

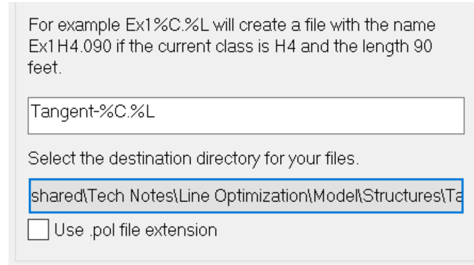


Two post insulators on left



Two post insulators on right

j. Click OK. You will now be presented with a dialog box with the various poles selected in Step 2, and the ability to save the various structure models with a desired name and location. The code options %L, %C, and %P will allow you to use the structure length, class, and property label in the resulting structure file names. It is suggested that the height of the structure be used as the extension and the option to add .POL to all the files unchecked. Note the folder that you are saving of these structures to as they will need to be later picked for the optimization process.



k. Click OK and go get a cup of coffee. Depending on many parameters (the number of structures, the number of load cases, the range of angles selected, linear or nonlinear structure analysis method chosen, etc.), this could take just a few seconds or several minutes. A progress bar will indicate the process status.

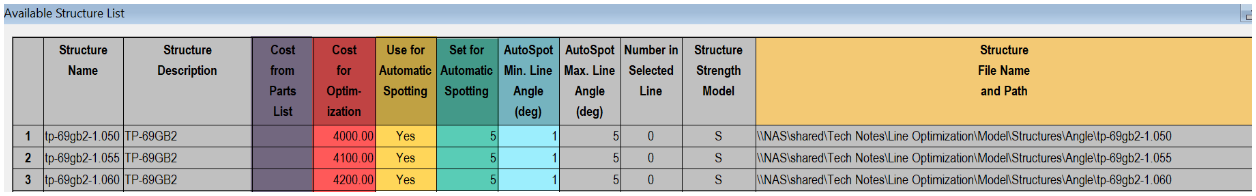
16. When complete, save the Lite project so that if there is a change in the weather or loading conditions during the project, the allowable spans files can then be recreated very easily.
17. Repeat the above steps for each of the members of the structure family that will be used on the project.
18. Close out of PLS-CADD Lite and all PLS-POLE models that are open.

Line Optimization

Now that the structure models that will be used in line optimization have been created it is time to reference them in the PLS-CADD model. These structures, once specified included in the model will be available for use during the optimum spotting process. One must also set up spotting constraints through one of the potential spotting constraint options. The final step in the process is to run the optimization, and rerun with adjusted values until a totally optimized solution is found.

Adding Available Structures

Now, go to PLS-CADD, go to **Structures/ Available Structure List/ Add/Delete Structure** to add all of the Method 1 structures and then **Structures/ Available Structure List/ Edit** to assign costs and to determine the other variables for optimization. The four variables that must be determined for each structure are the cost to use for optimization, whether or not use the structure for optimization, the set for optimization, and the minimum line angle. If you want to automate the pricing, make sure in PLS-POLE you go to **Geometry/ PLS-CADD/ Material Options** to include your materials. Then, back in PLS-CADD, in **Structures/ Available Structure List/ Edit**, the automated cost from the materials will be available and you can just copy/paste that column to use the developed cost for the optimization cost. It is worth mentioning that if inputting a cost, the cost of a structure only needs to be relative to the cost of other structures. Taller structures, larger structures, and structures with guys or additional material are most expensive than short, small tangents. The set to use for spotting will be up to the designer, structures with underbuild may require a different set number be used than structures without. A minimum line angle may be required to maintain clearances for some running angle structures. This should be accounted for here to be included in the optimization.

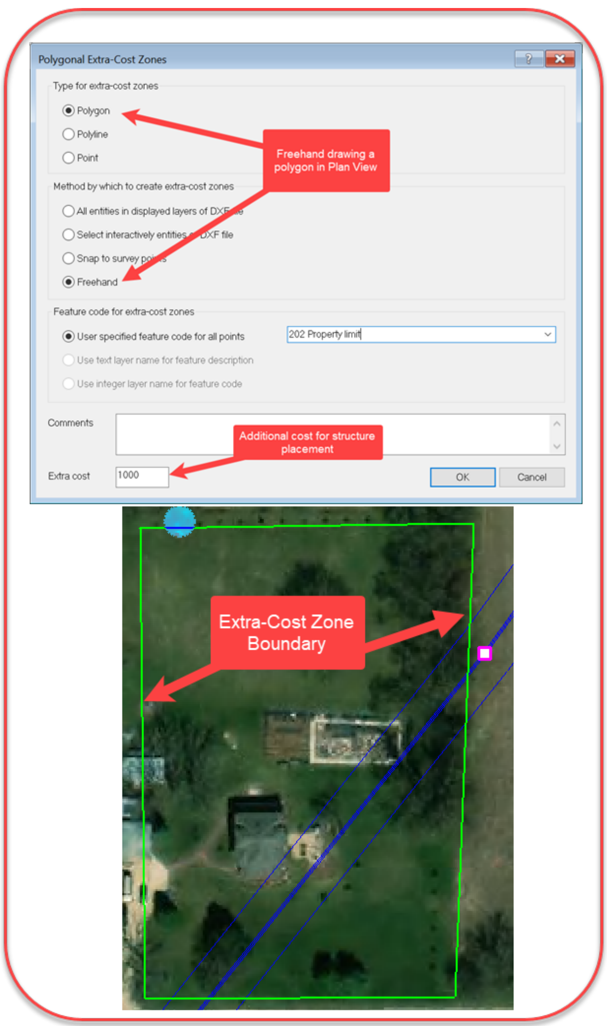


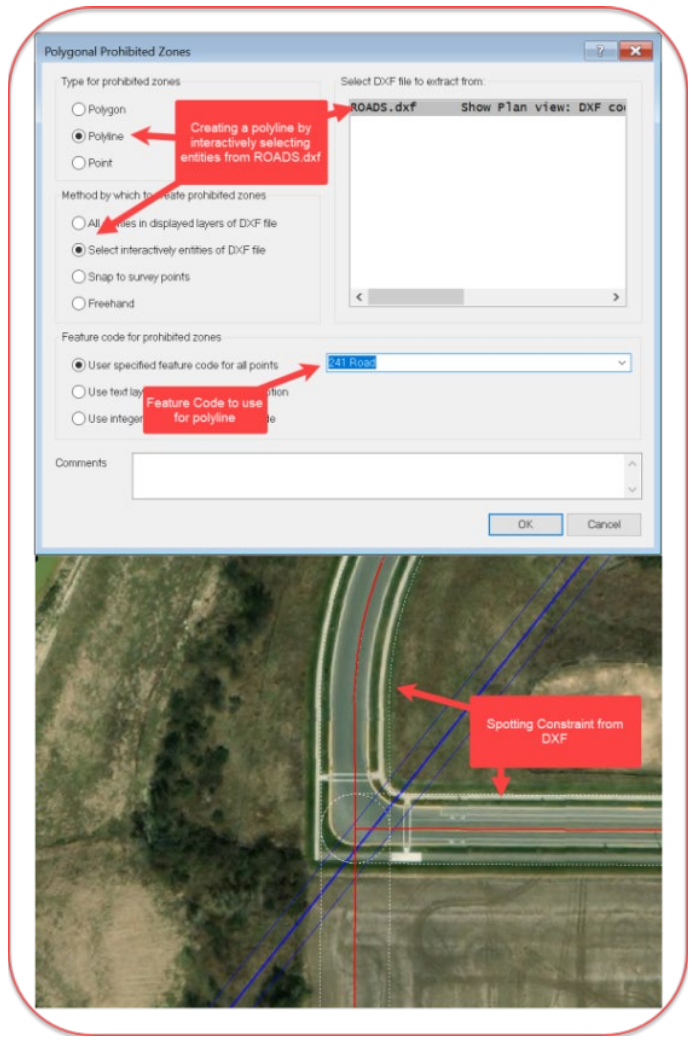
Available Structure List

	Structure Name	Structure Description	Cost from Parts List	Cost for Optim-ization	Use for Automatic Spotting	Set for Automatic Spotting	AutoSpot Min. Line Angle (deg)	AutoSpot Max. Line Angle (deg)	Number in Selected Line	Structure Strength Model	Structure File Name and Path
1	tp-69gb2-1.050	TP-69GB2		4000.00	Yes	5	1	5	0	S	\\NAS\shared\Tech Notes\Line Optimization\Model\Structures\Angle\tp-69gb2-1.050
2	tp-69gb2-1.055	TP-69GB2		4100.00	Yes	5	1	5	0	S	\\NAS\shared\Tech Notes\Line Optimization\Model\Structures\Angle\tp-69gb2-1.055
3	tp-69gb2-1.060	TP-69GB2		4200.00	Yes	5	1	5	0	S	\\NAS\shared\Tech Notes\Line Optimization\Model\Structures\Angle\tp-69gb2-1.060

Specifying Spotting Constraints

The second process that needs to be completed before optimization is determining where structures can and cannot be placed, and extra costs associated with doing so, and where any specific structures must be used. These constraints can all be added (and deleted) under **Structures/ Automatic Spotting/ Spotting Constraints**. The **/ Add (graphical)** function allows the constraints to be determined much quicker than the alternate Edit (table based) method. It is also suggested that constraints be added in both the Plan view to find the obvious constraints such as roads, but also in the Profile view to look for areas where constructability of the line should be considered. A tip that is often not thought of is the use of negative costing for Extra Cost Zones; using a negative price for a region will make that region appear more favorable for spotting. This will not necessarily force a structure to be spotted in this region like the Required Structure constraint will, but it will dictate that structures will gravitate to this area if that is the most economical option. A common misconception is that Optimization is only for rural projects; this couldn't be further from the truth. With the ability to quickly determine constraints, optimizing in urban areas not only still develops the least cost option, but is also much easier than manually determining the structure locations and heights in these highly constrained areas.

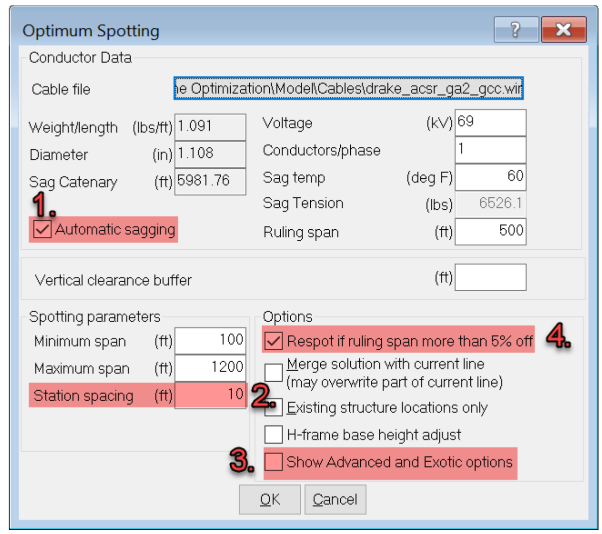




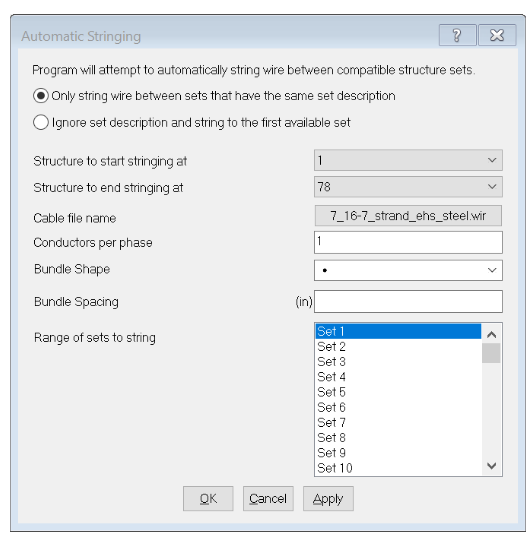
Tips on Running an Optimization

Once the Allowable Structures and the Spotting Constraints have been determined, you are now ready to optimize. Chapter 14 of the PLS-CADD manual covers the actual optimization process in depth, so it will not be covered here in this technote. However, a couple of extra “tips” will be discussed here:

1. Automatic Sagging should ALWAYS be used. If you don’t have the proper constraint determined yet, go add it under *Criteria / Automatic Sagging*.
2. Optimization is an iterative process. It is suggested that a Station Spacing of 100 feet (the default) be used to get the first “rough” optimization and to aid the designer in quickly determining if any design mistakes have been made (i.e. one of the most common being that you don’t have any structures capable of spanning a Prohibited Zone or not having any structures capable of a certain line angle.) Once the designer is comfortable with the “rough” optimization, the “final” optimization can be performed and a Station Spacing of 25 or even 5 feet could be used. There is a point of diminishing return, however. The time it takes to run the optimization with smaller station spacing can increase exponentially, costing more in optimization time than would be saved in structure design.

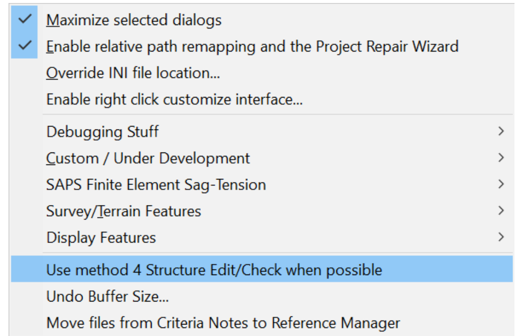


3. It is suggested that only the Forward solution be selected unless the “rough” optimization is not selecting a desired spotting pattern in a difficult area. Then, the Reverse option could be selected. If you desire to spot Both and then compare the two optimizations, be sure and deselect the “Merge” option so that the Reverse does not overwrite the Forward solution. You will then have to use the **Lines/ Edit** function to make either line active and then hide or even delete the undesired spotting solution.
4. It is strongly suggested that the option to “Respot if ruling span more than 5% off” is selected. It is not necessary that this be done during one of the first “rough” optimizations, but it should definitely be selected when the final optimization is being performed. If this option is not selected, the optimization will be based solely on the user entered Ruling Span and not the actual Ruling Span after the optimization is complete. While other programs will make this appear that this solution is valid, PLS-CADD actually recalculates the actual Ruling Span for each section, which will lead to conductors either being slightly too tight or some minor clearance violations (depending on whether the actual Ruling Span was longer or shorter than the assumed Ruling Span.) Selecting the Respot option will ensure that your final design meets all of the proper design criteria.



Once the optimization is complete, you can then use the **Sections/ Automatic Stringing** or **Sections/Add Graphical** to string all of the other sections of wire, and then the **Sections/ Table** to modify them. It is suggested in the **Sections/ Table** that the Sort Sections By be set to "Attachment Set Section Starts Upon" for easier editing. If this is done, the properties for the first wire in each Attachment Set can be input, and then that row can easily be copied and then pasted for the remaining Attachment Sets in the line. This means a 1000 span line could be completed nearly as fast as just a 1 span line. (It is assumed that the designer has followed the recommendations of using the same set number for all like wires for all structures in a family in order for these options to be used most effectively. If this has not been done, then **Sections/ Modify/ Edit Stringing** might need to be used to ensure that the wires are connecting properly to all the structures on the line.) Note that you can select the "AutoSag" command in the *Command To Apply* column to have all wires sagged automatically so that they reflect any changes you made in the Sections Table.

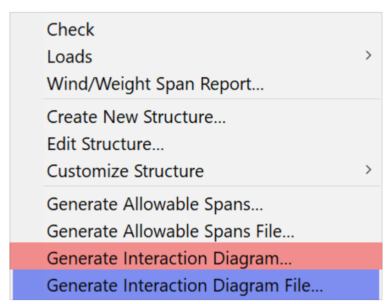
If you have used PLS-POLE and PLS-CADD Lite as described above to create your Method 1 structures for optimizing, you can hit the **F1** key, choose Use Method 4 Structure Check/Edit When Possible, and you can then check your structures via PLS-POLE instead of the simplified wind-weight spans. Running a **Lines/ Reports/ Structure Usage** before doing this will show you the structure usage based on Wind and Weight Span limits. Switching to Method 4 and rerunning this report will show you how conservative the Wind and Weight Span design method is. If the designer feels that this is too conservative for their project, then one might consider using Method 2 (Interaction Diagrams) structures. This is a bit more complex and takes additional time to calculate all of the Interaction Diagrams, but the process is nearly identical as above and can easily be done with both TOWER and PLS-POLE structures.

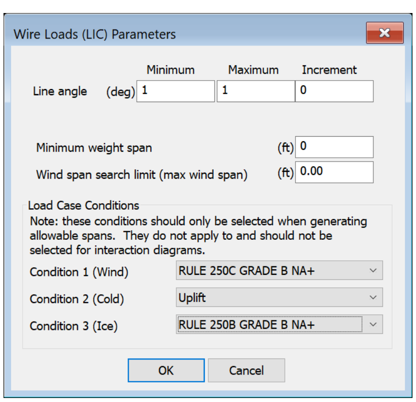


Finally, as discussed in the [Wind & Weight Spans technical note], Wind and Weight span designs have many problems. Using PLS-POLE (and TOWER) with PLS-CADD Lite to develop the Method 1 (or Method 2) structures for PLS-CADD optimization allows the designer to take advantage of the best that both methods have to offer and really completes the "design circle". Toggling to the Method 1 side, one can quickly optimize a line, and toggling to Method 4 will allow a full finite element structural analysis of the structures to be completed. In the event of a conductor change out, this can simply be done and then a full structural check be performed again. Since a conductor or even just a wire change out voids the Wind and Weight span limits of a structure, the Method 1 checks can now be ignored, or, the conductor change out can be made in the PLS-CADD Lite models for each structure type and the Method 1 structures can quickly be regenerated for reoptimizing the line with the revised conductor.

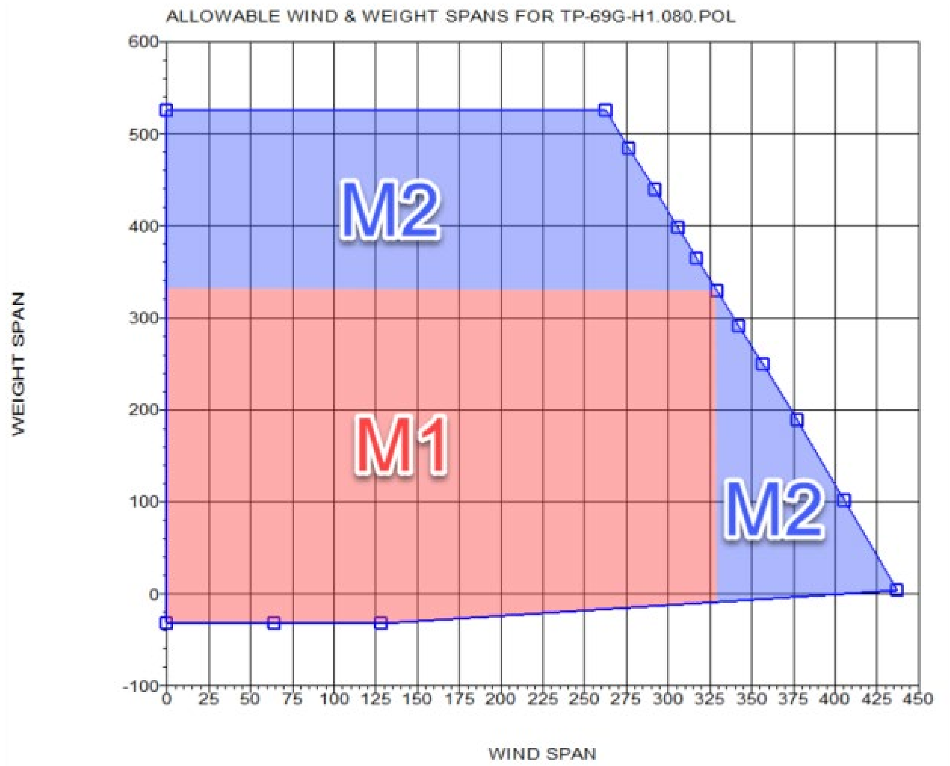
Method 2 Structures

As mentioned Method 2 structures are the more sophisticated, but more accurate relative of Method 1 structures. Method 1 structures are generally adequate for line optimization, but do not account for interaction between different wind and weight spans. This is where Method 2 structures come in. By creating an interaction diagram between maximum allowable wind and weight spans, a more efficient design is possible by allowing the ratio of maximum wind to weight span to vary. Method 1 structures in contrast only allow for a single ratio. Another advantage of Method 2 structures over Method 1 structures is that Method 2 structures can be evaluated for many different weight span conditions. Method 1 structures are restricted to just 3 conditions for weight span limits.





Creating interaction diagrams follows a similar process to creating allowable spans. In step 12 of creating available structures above, PLS/CADD lite gave two options for generating allowable spans. One option was to generate a report of the calculated allowable spans, the other was to generate the actual file containing the allowable spans for the structures. The dialog for generating interaction diagrams is very similar to the dialog for allowable spans, but without the input for a wind/weight span ratio or the selection of 3 conditions for weight spans. This is because of the interaction allowed between different wind and weight spans. The image at the top of the next page shows how a Method 1 structure's capacity is defined vs. a Method 2 structure. You can see that the blue M2 area shows a substantial amount of additional capacity that is not considered when using M1 structures.



The amout of time to generate interaction diagrams will be greater than allowable spans, but the result will be a design that is more optimized than the more simple Method 1 structures.Users may also notice that during the generation of interaction diagrams a warning will appear when negative weight spans are being analyzed. This notifies the user that there may be uplift on the structure, and that correct uplift limits should be set for the structures being analyzed. It may be diserable to restrict the weight spans considered, for example, if no uplift is allowed. To adjust this in PLS-POLE the user must first go to **General/General Data** and select the radio button to *Create a Method 2 File for PLS-CADD.* The **General/Interaction Diagram Options** option will become available where the user can change the range of weight spans for that structure.

Optimization will easily beat any manual spotting process in overall project costs and time required. In many comparisons done by knowledgeable utilities and consultants, the PLS-CADD Optimization provided the absolute least cost constructed line alternative *that met the project design criteria* when compared to any other spotting optimization program. Not only does PLS-CADD provide the least cost constructed line cost, the few hours spent setting up the optimization process as described above will save a significant amount of engineering and design time (and therefore money) over any manual spotting process.