Shielding Transmission Lines against Lightning

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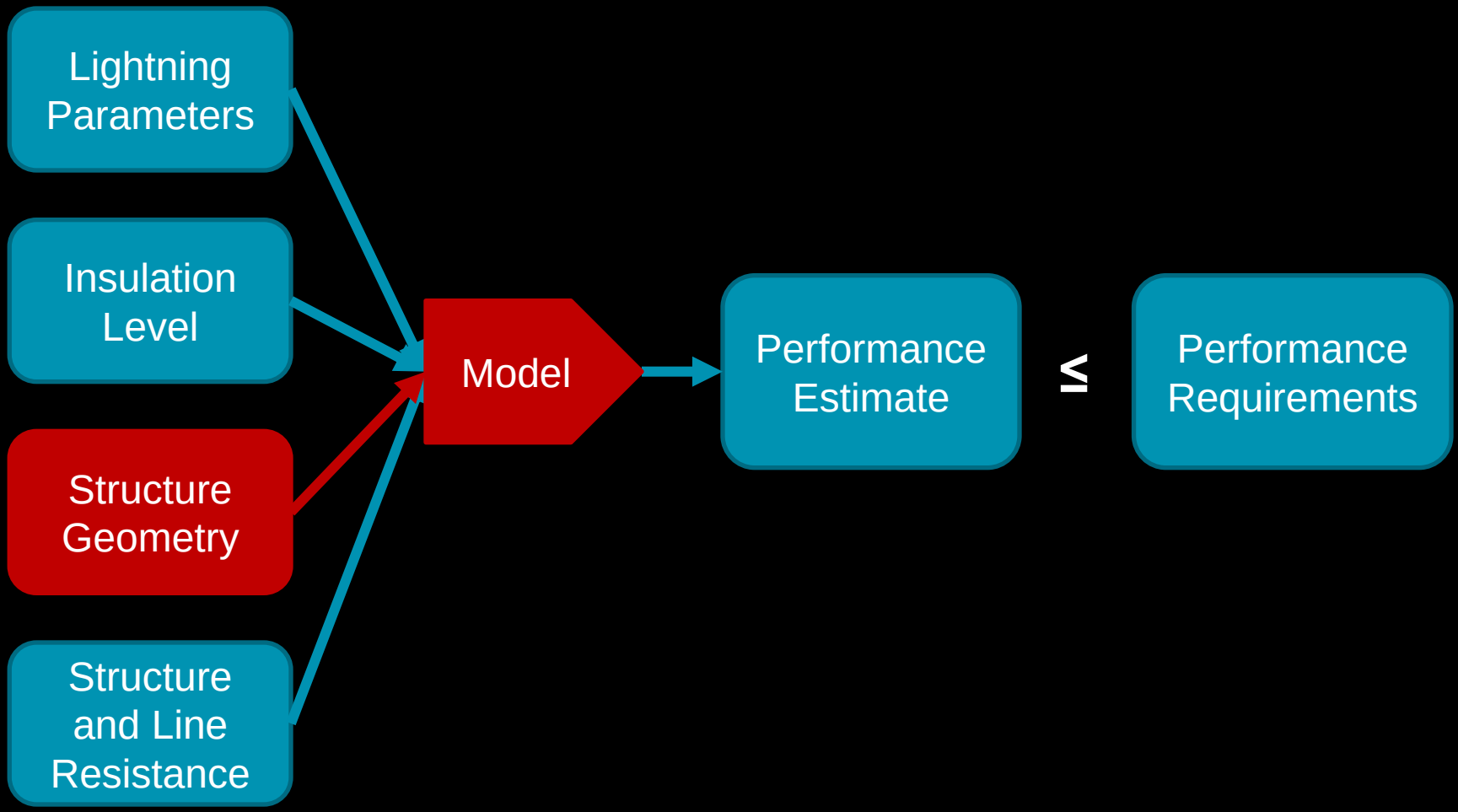
Outline

- Theory
- Setting up models in PLS-CADD
- Using the PLS-CADD tool

THEORY

Lightning Design



Shield Angle

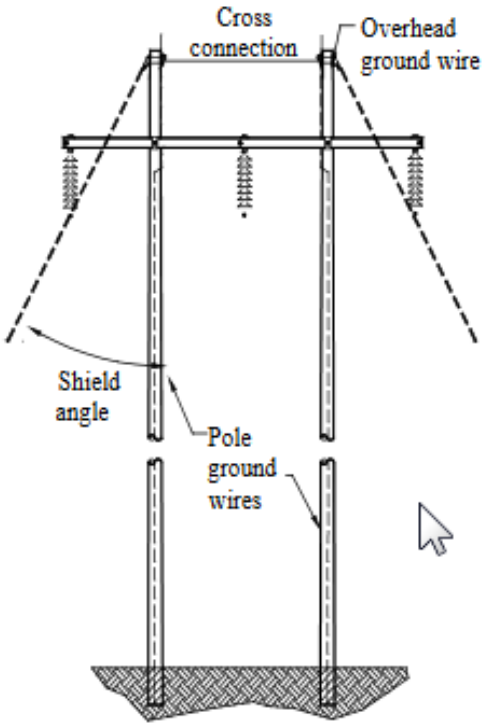


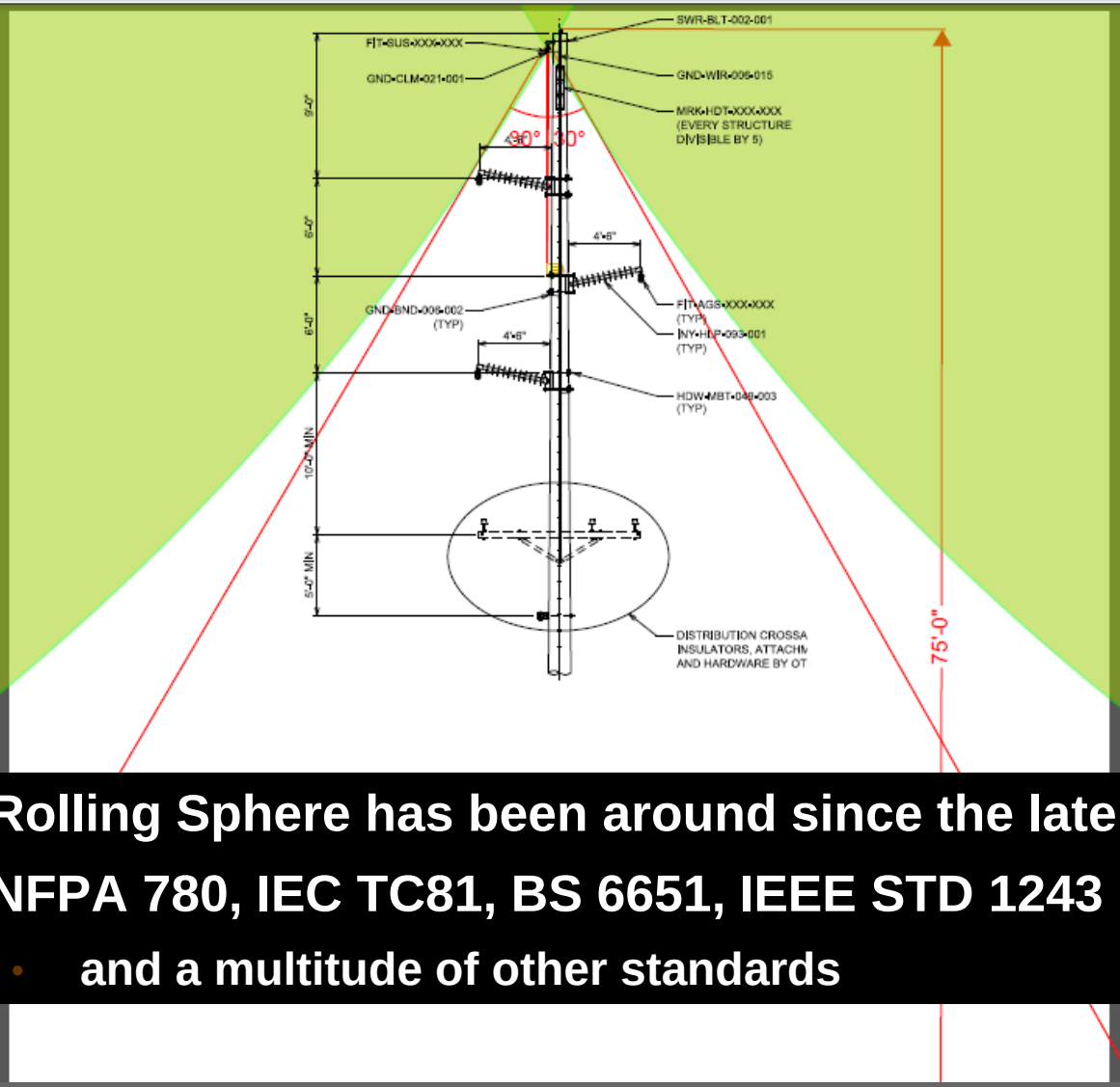
FIGURE 8-4: SHIELDING ANGLE, POLE AND OVERHEAD GROUND WIRES

*From RUS Bulletin 1724E-200 Page 8-6

TABLE 8-3
REDUCED SHIELDING ANGLE VALUES

Structure Height, feet	Recommended Shielding Angle, degrees
92	30
99	26
116	21

Rolling Sphere



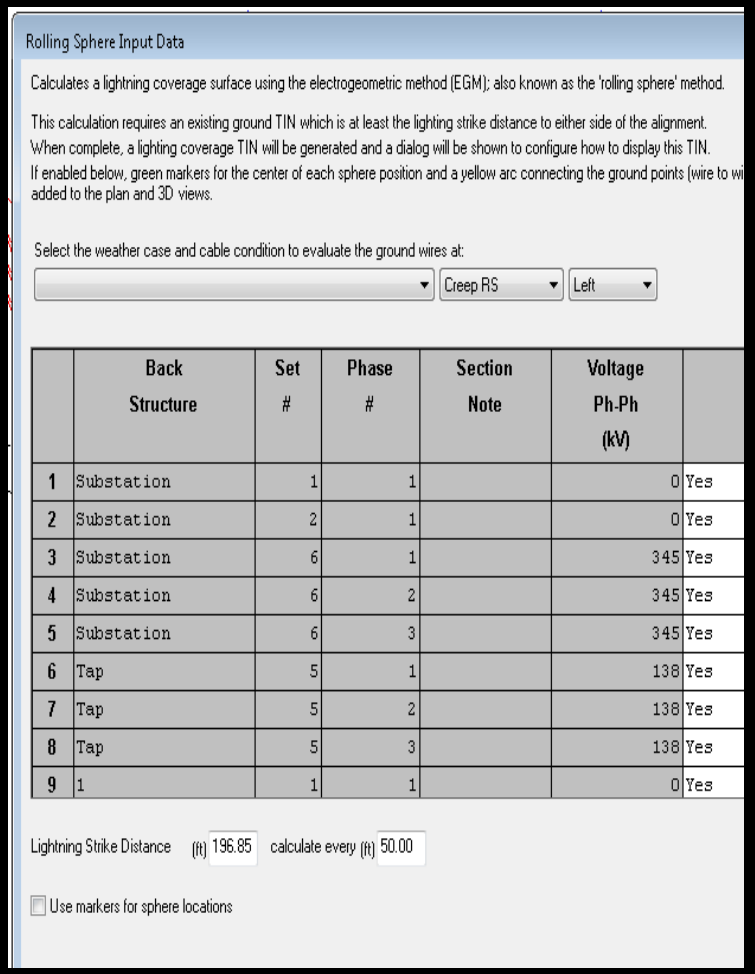
- Rolling Sphere has been around since the late 1950s
- NFPA 780, IEC TC81, BS 6651, IEEE STD 1243
  - and a multitude of other standards

What's the difference?

Shield Angle	Rolling Sphere
Check an angle, with different angles for different heights	Check a circle, circle's curvature incorporates variation with height
Ignore structure resistance	Circle radius a function of structure resistance
Ignore operating voltage	Circle radius a function of operating voltage
Ignore terrain (transversely at structure)	Check model with terrain
Ignore terrain (longitudinally along span)	Check model along span
GO / NO GO	Estimates performance metric

Why change now?

- PLS-CADD now has a rolling sphere tool!
- Much faster for checking
  - Terrain
  - Multiple structures
- Structure adjustments must be done manually



	Back Structure	Set #	Phase #	Section Note	Voltage Ph-Ph (kV)	
1	Substation	1	1		0	Yes
2	Substation	2	1		0	Yes
3	Substation	6	1		345	Yes
4	Substation	6	2		345	Yes
5	Substation	6	3		345	Yes
6	Tap	5	1		138	Yes
7	Tap	5	2		138	Yes
8	Tap	5	3		138	Yes
9	1	1	1		0	Yes

Implementation

- Implementation
  - Change the design process as little as possible
  - Emphasize “manually” checking to teach vocabulary and process
  - Allow but don’t require PLS-CADD
- Look up sphere radius in a table based on
  - Operating voltage
  - Structure impedance
- Performance targets
  - Mandate projects stay within the range of model
    - Limit striking distance range
    - Limit ground resistance range

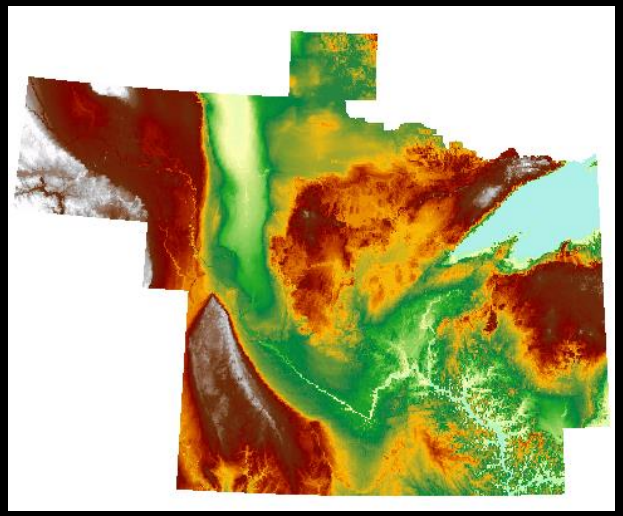
Future Work

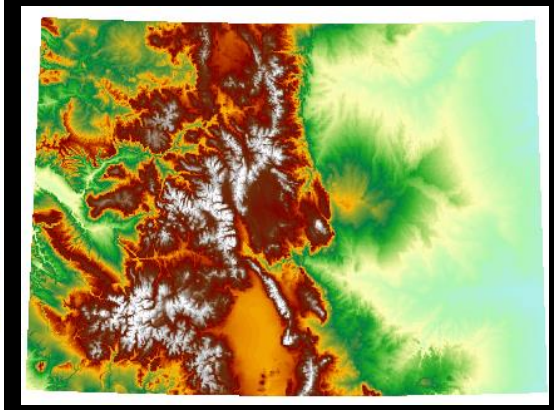
- Problems with lightning models
  - No model has been calibrated against real world outages
  - Large degree of freedom in aggregating performance metrics along the length of a line
- Opportunities for PLS-CADD
  - Measure the rolling sphere radius
  - Error checking the terrain TIN
  - Error checking the shielding TIN

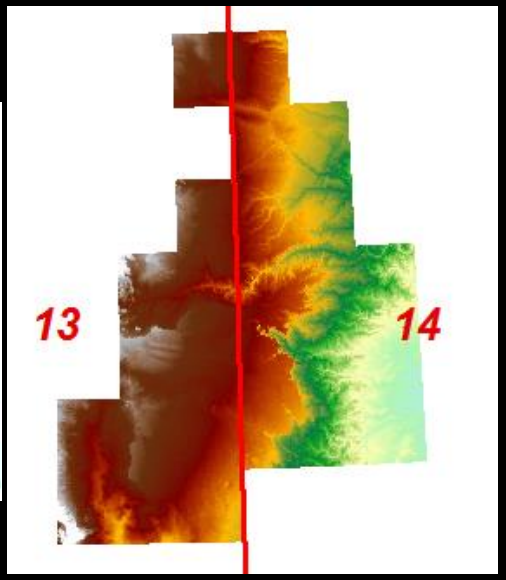
SETTING UP A LINE MODEL

Number of Models

- NSP - 852
- PSCO - 472
- SPS - 1263



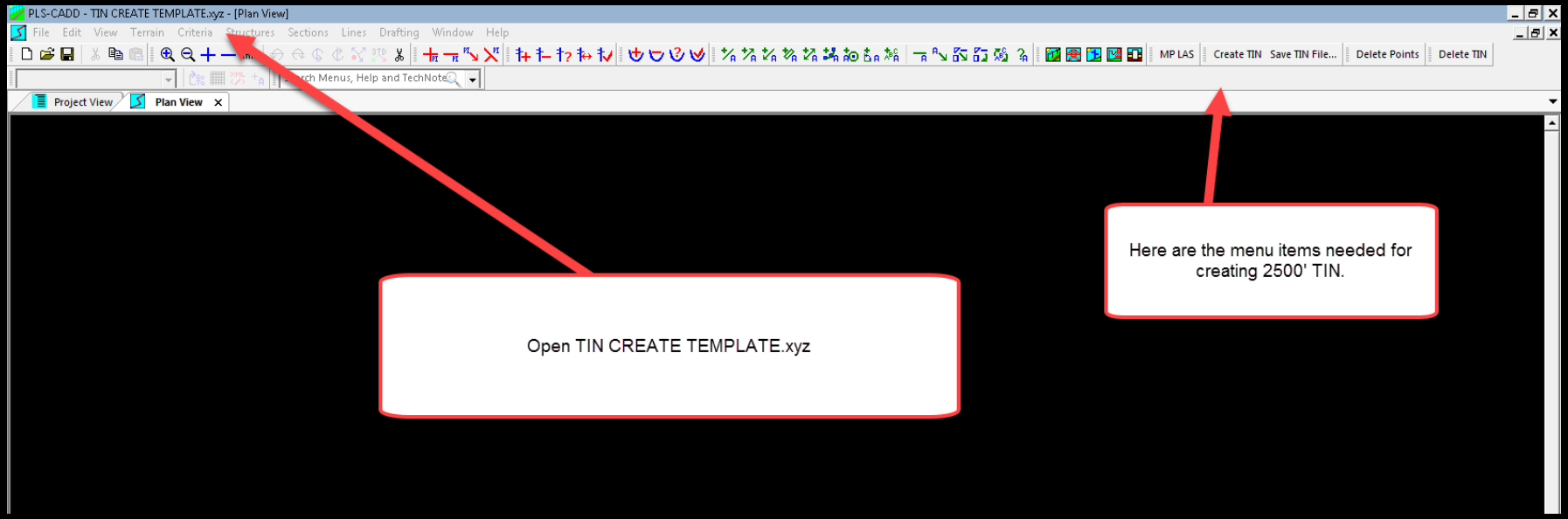




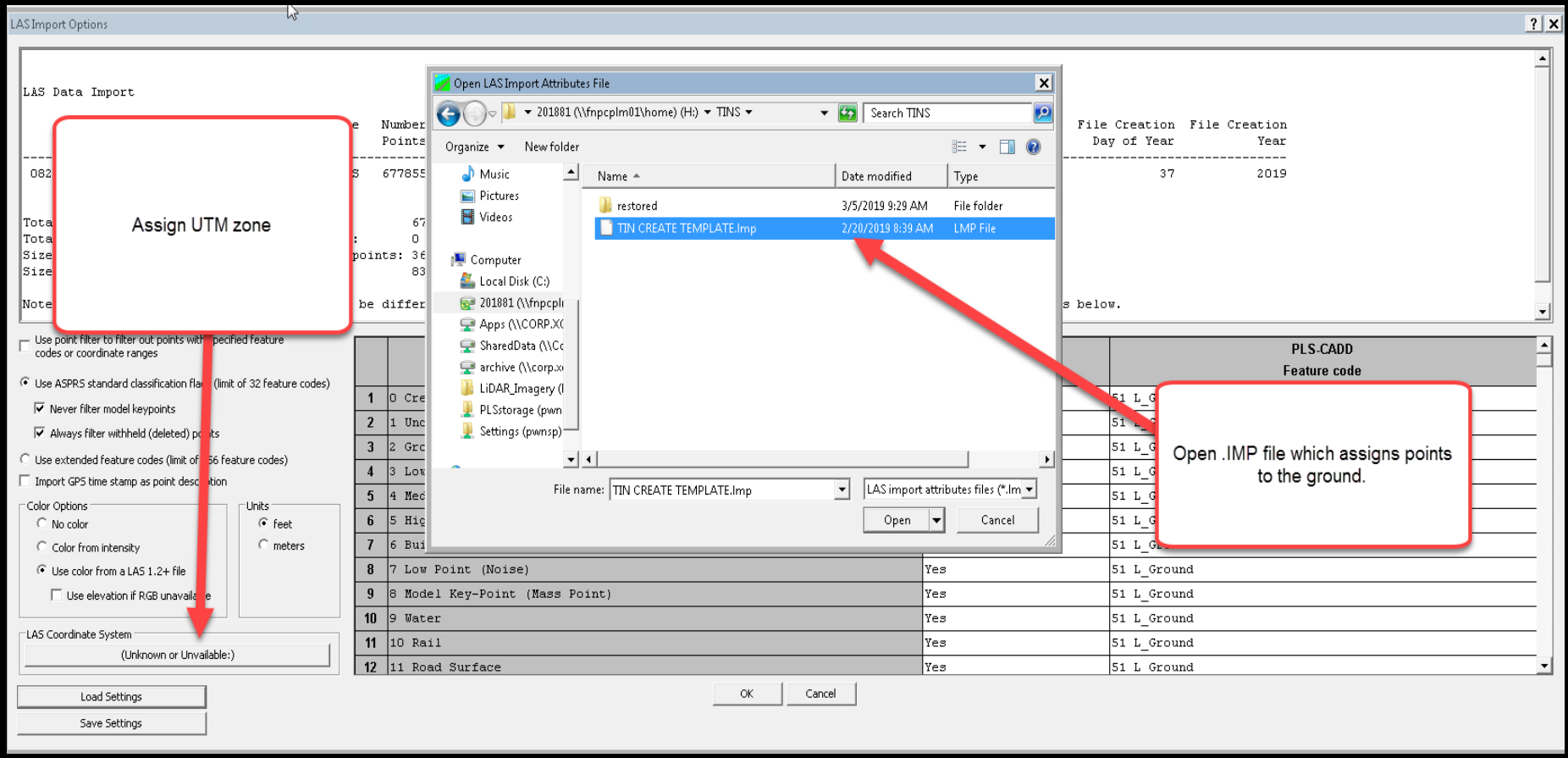
TIN Sizing

- Basically need sphere diameter x 2 plus structure width to properly connect the circles to the ground.

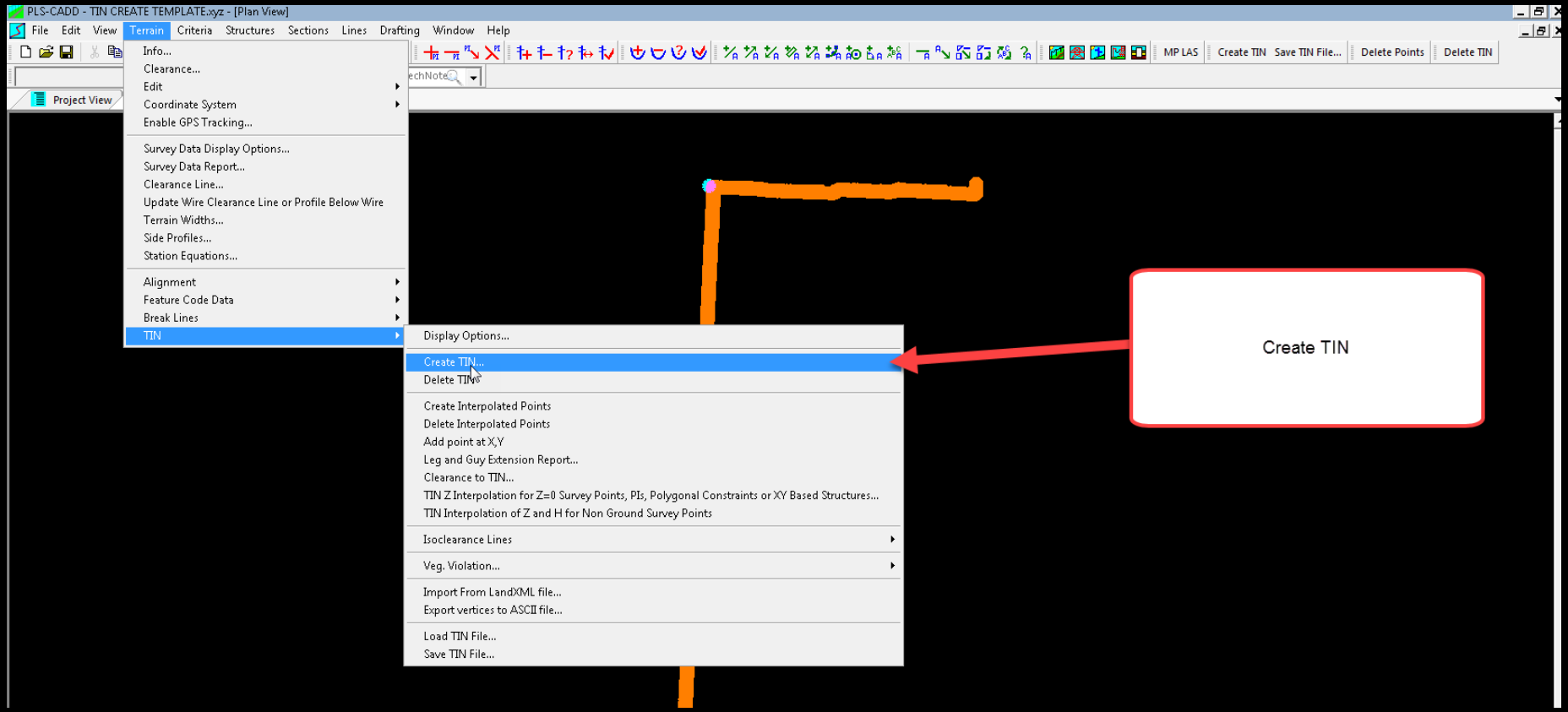
Open Template Model



Assign Zone and Load IMP file



Create TIN


PLS-CADD - TIN CREATE TEMPLATE.xyz - [Plan View]
File Edit View Terrain Criteria Structures Sections Lines Drafting Window Help
Info...
Clearance...
Edit
Coordinate System
Enable GPS Tracking...
Survey Data Display Options...
Survey Data Report...
Clearance Line...
Update Wire Clearance Line or Profile Below Wire
Terrain Widths...
Side Profiles...
Station Equations...
Alignment
Feature Code Data
Break Lines
TIN
Display Options...
Create TIN...
Delete TINs
Create Interpolated Points
Delete Interpolated Points
Add point at X,Y
Leg and Guy Extension Report...
Clearance to TIN...
TIN Z Interpolation for Z=0 Survey Points, PIs, Polygonal Constraints or XY Based Structures...
TIN Interpolation of Z and H for Non Ground Survey Points
Isoclearance Lines
Veg. Violation...
Import From LandXML file...
Export vertices to ASCII file...
Load TIN File...
Save TIN File...
MP LAS
Create TIN
Save TIN File...
Delete Points
Delete TIN
Project View
Create TIN

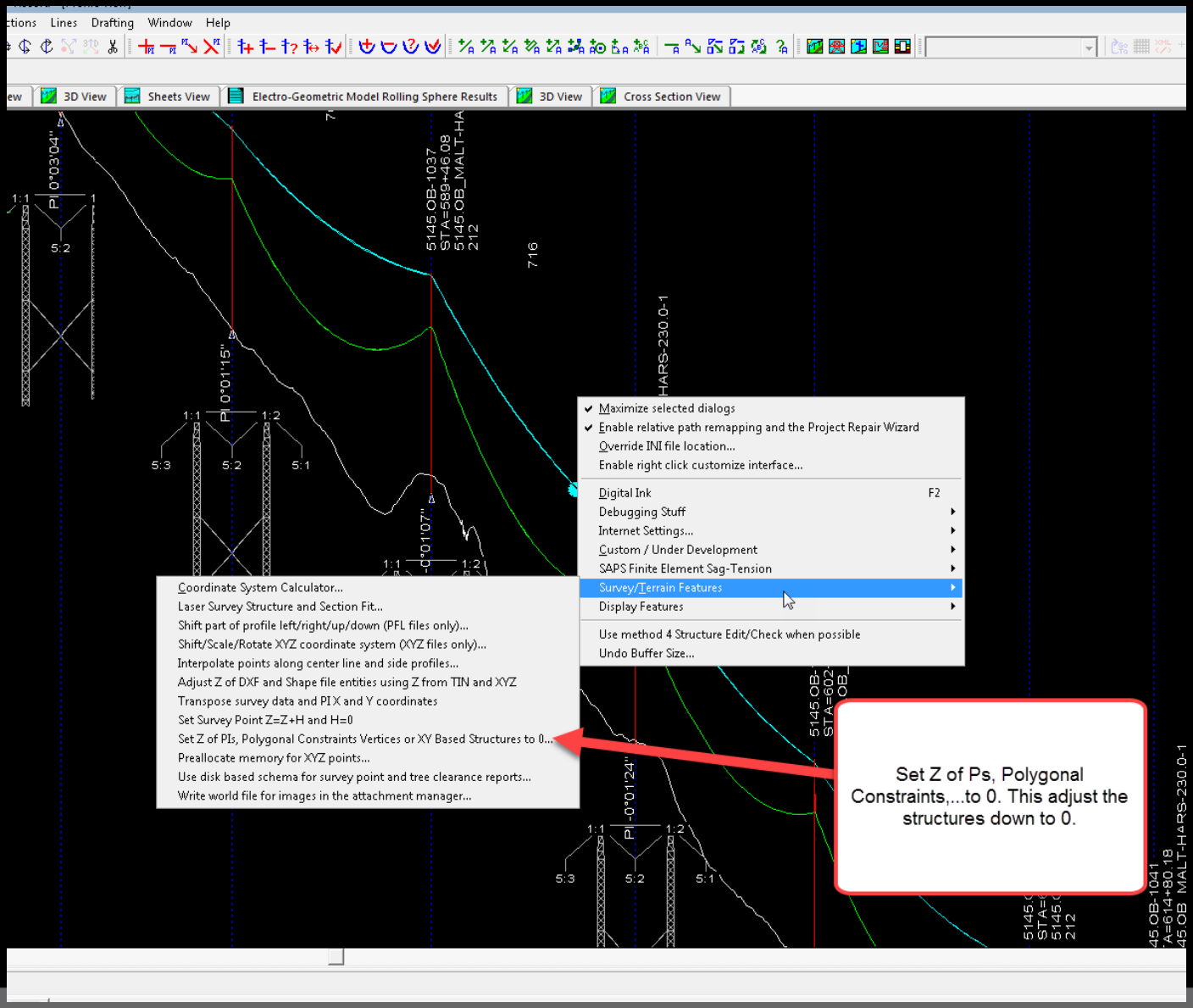
Z adjustments

- Survey data shows differences in time for a given ground profile
- The average TIN elevation difference is usually going to be within a few inches to a few feet throughout a given model, but any given structure can be off by a substantial amount 20 feet.
- A PI Z adjustment is the most accurate way of assessing a model.

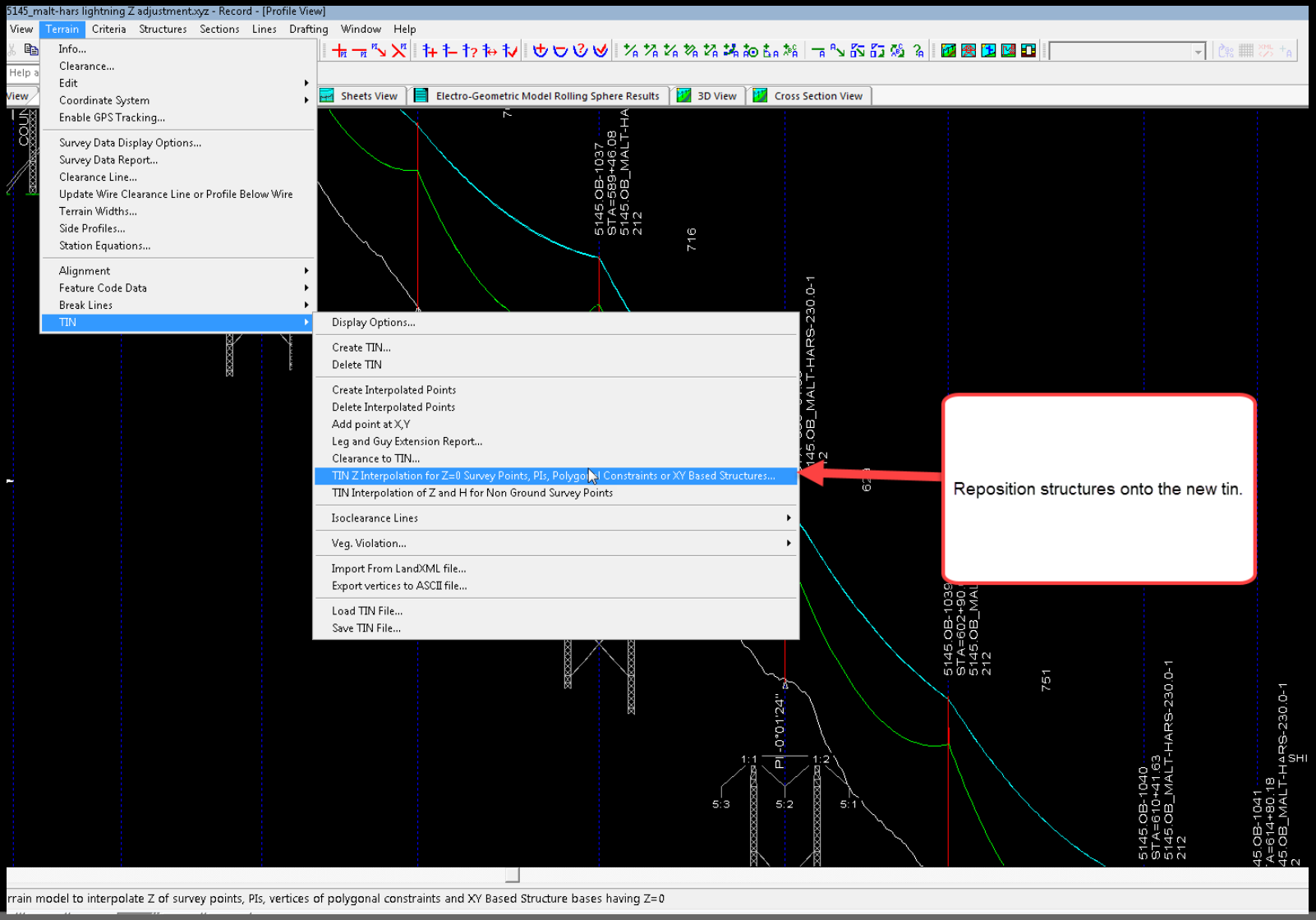
Example –TIN Comparison

5516-5569 WSG-BLG
Average – 0.14 ft
Standard deviation – 1.91 ft
Max – 6.559 ft
Median – 0.18 ft

Shift everything down to 0

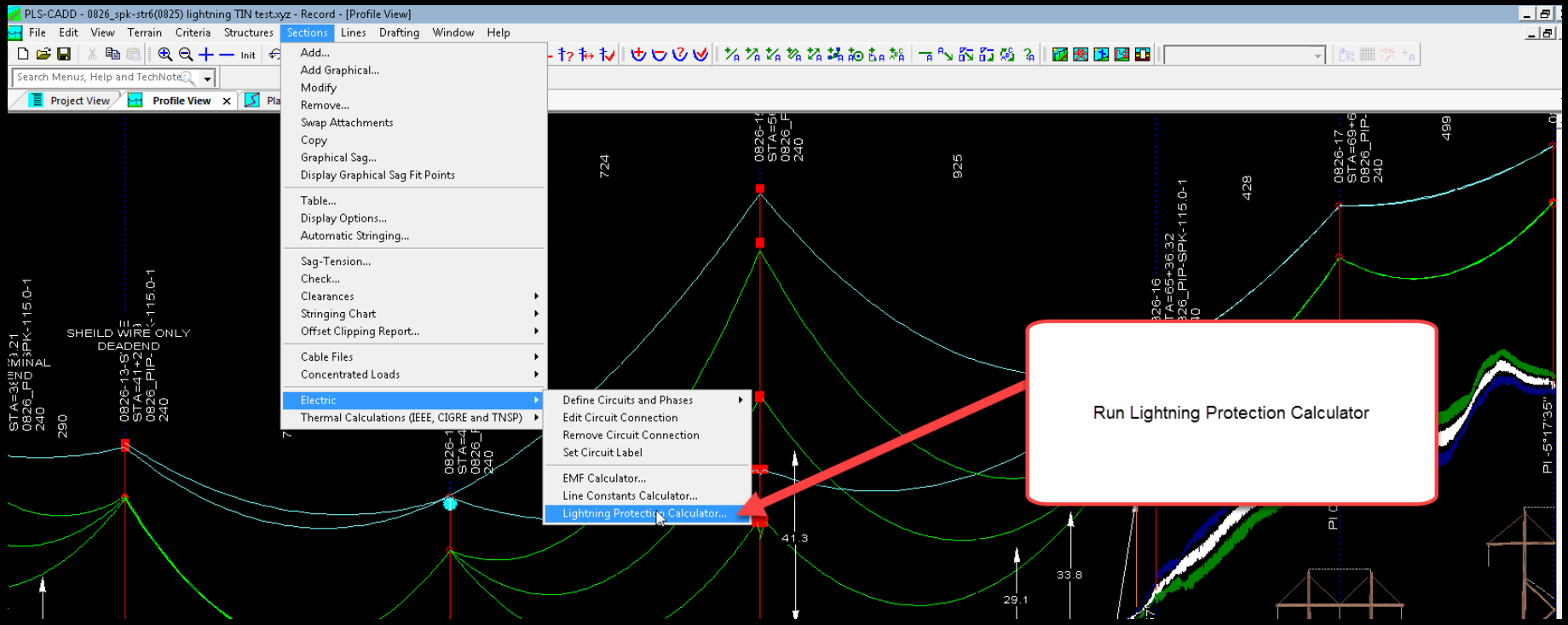


Shift Structures back

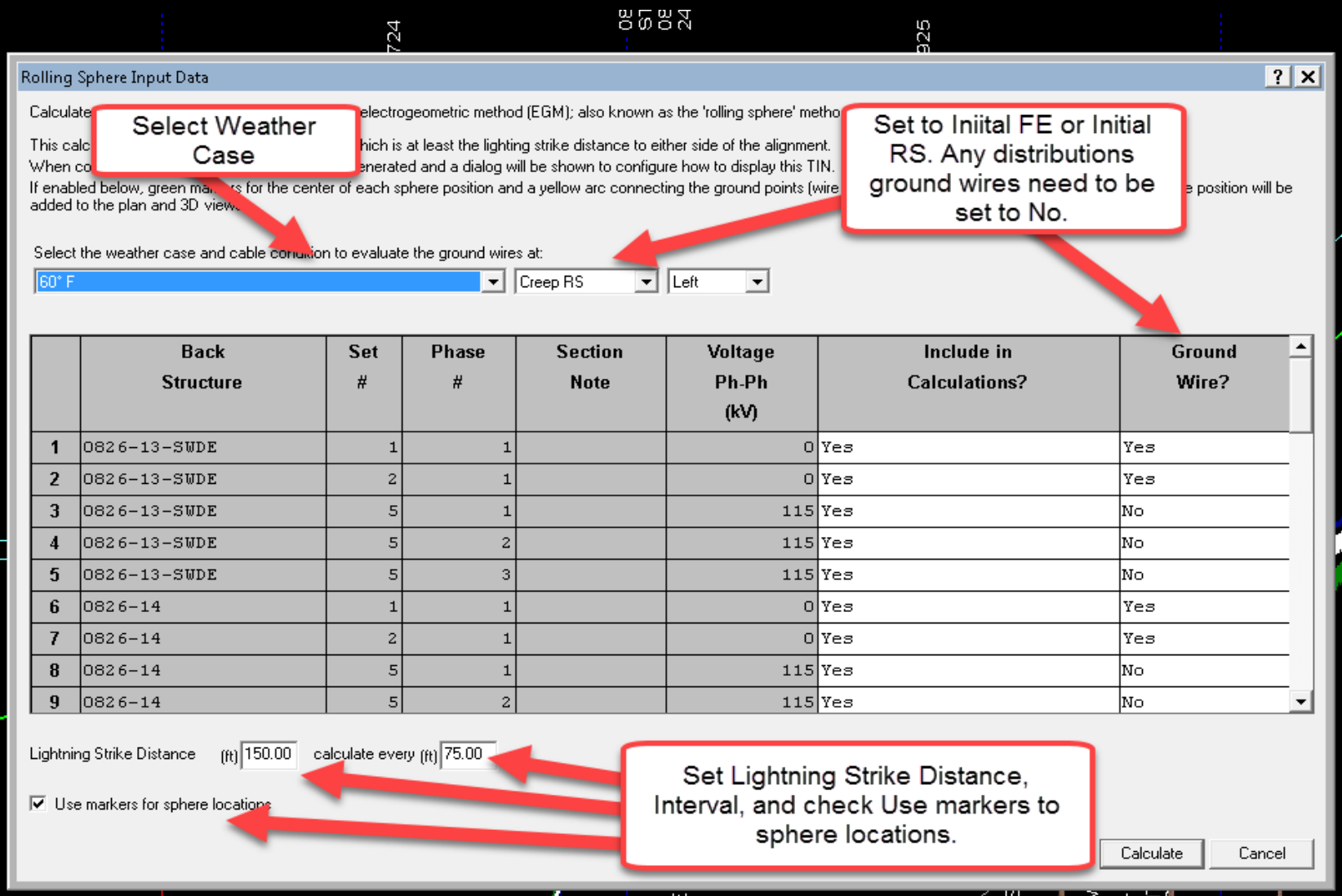


LIGHTNING DESIGN IN PLS-CADD

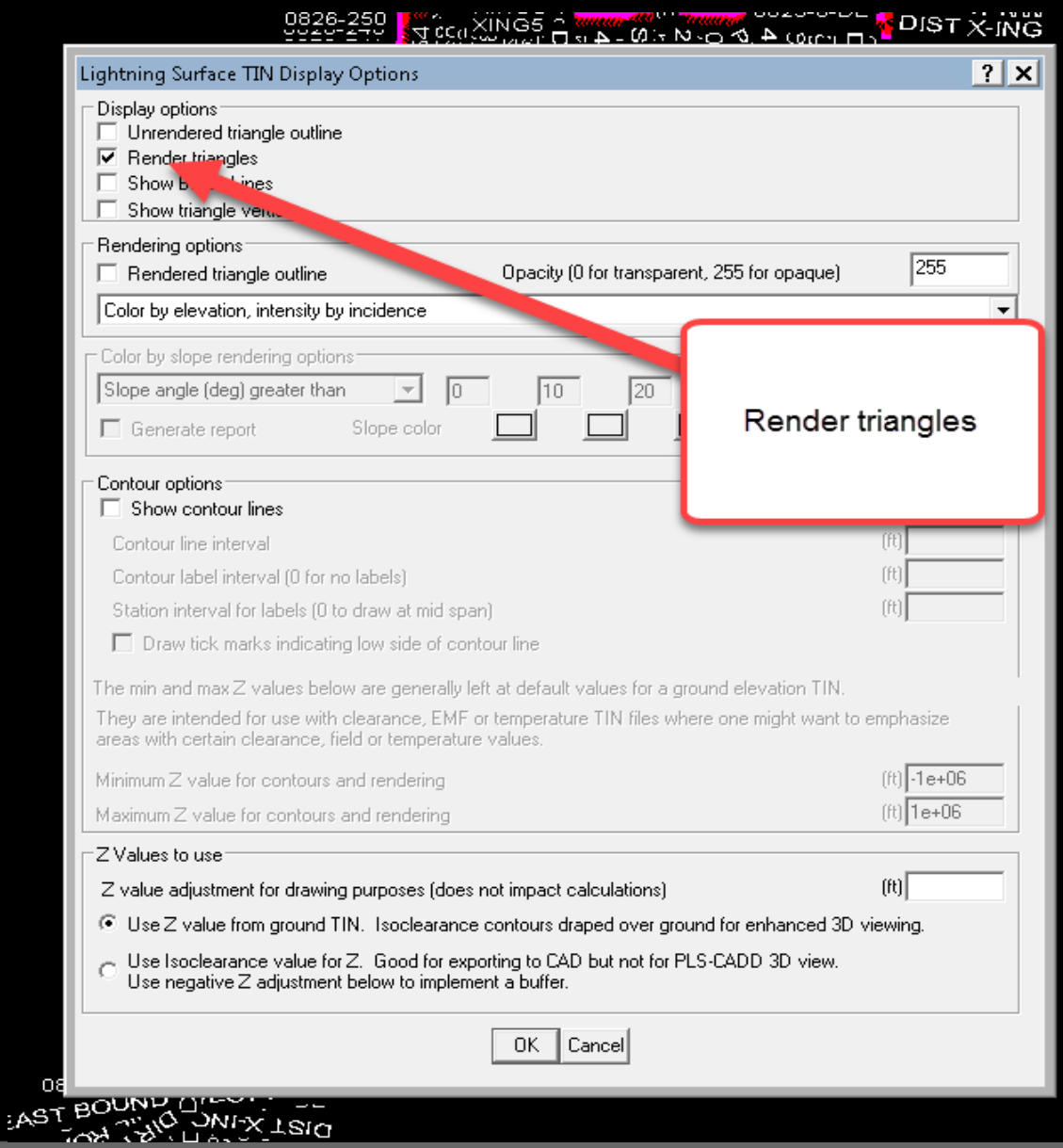
Run LPC


PLS-CADD - 0826_spk-str6(0825) lightning TIN test.xyz - Record - [Profile View]
File Edit View Terrain Criteria Structures Sections Lines Drafting Window Help
Add...
Add Graphical...
Modify
Remove...
Swap Attachments
Copy
Graphical Sag...
Display Graphical Sag Fit Points
Table...
Display Options...
Automatic Stringing...
Sag-Tension...
Check...
Clearances
Stringing Chart
Offset Clipping Report...
Cable Files
Concentrated Loads
Electric
Thermal Calculations (IEEE, CIGRE and TNSP)
Define Circuits and Phases
Edit Circuit Connection
Remove Circuit Connection
Set Circuit Label
EMF Calculator...
Line Constants Calculator...
Lightning Protection Calculator...
Run Lightning Protection Calculator
SHEILD WIRE ONLY
DEADEND
724
925
428
499
41.3
33.8
29.1

LPC Settings



Display Lightning TIN



Understanding the Report

Gaps in Lightning Coverage:
The following spans have gaps in coverage provided by the specified ground wire starting near the specified distance along the span.

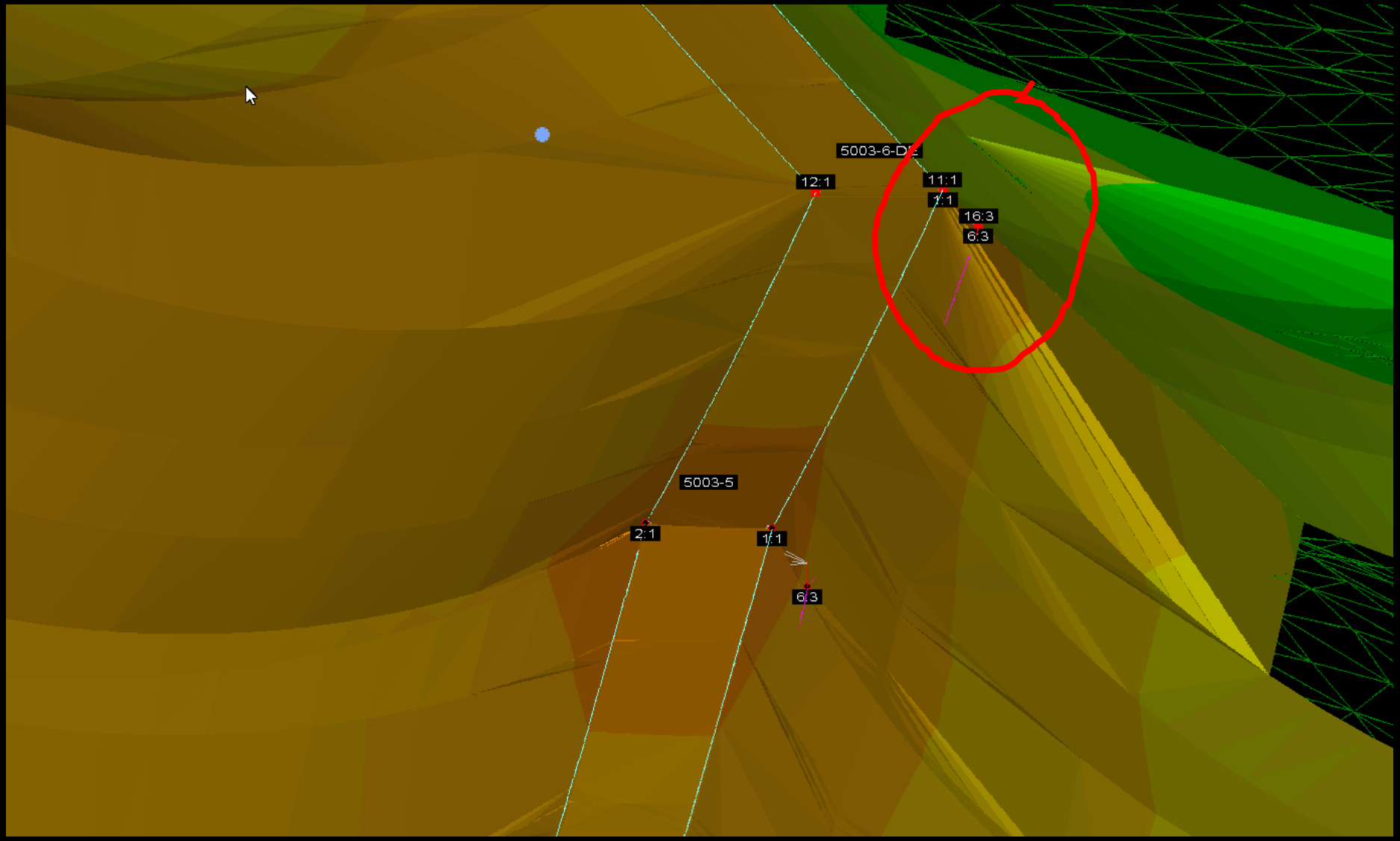
Back Structure	Set #	Phase #	Section Note	Distance to Gap (ft)
0810-18	2	1		200
0810-19	2	1		0

Lightning Coverage Exposed Conductors:

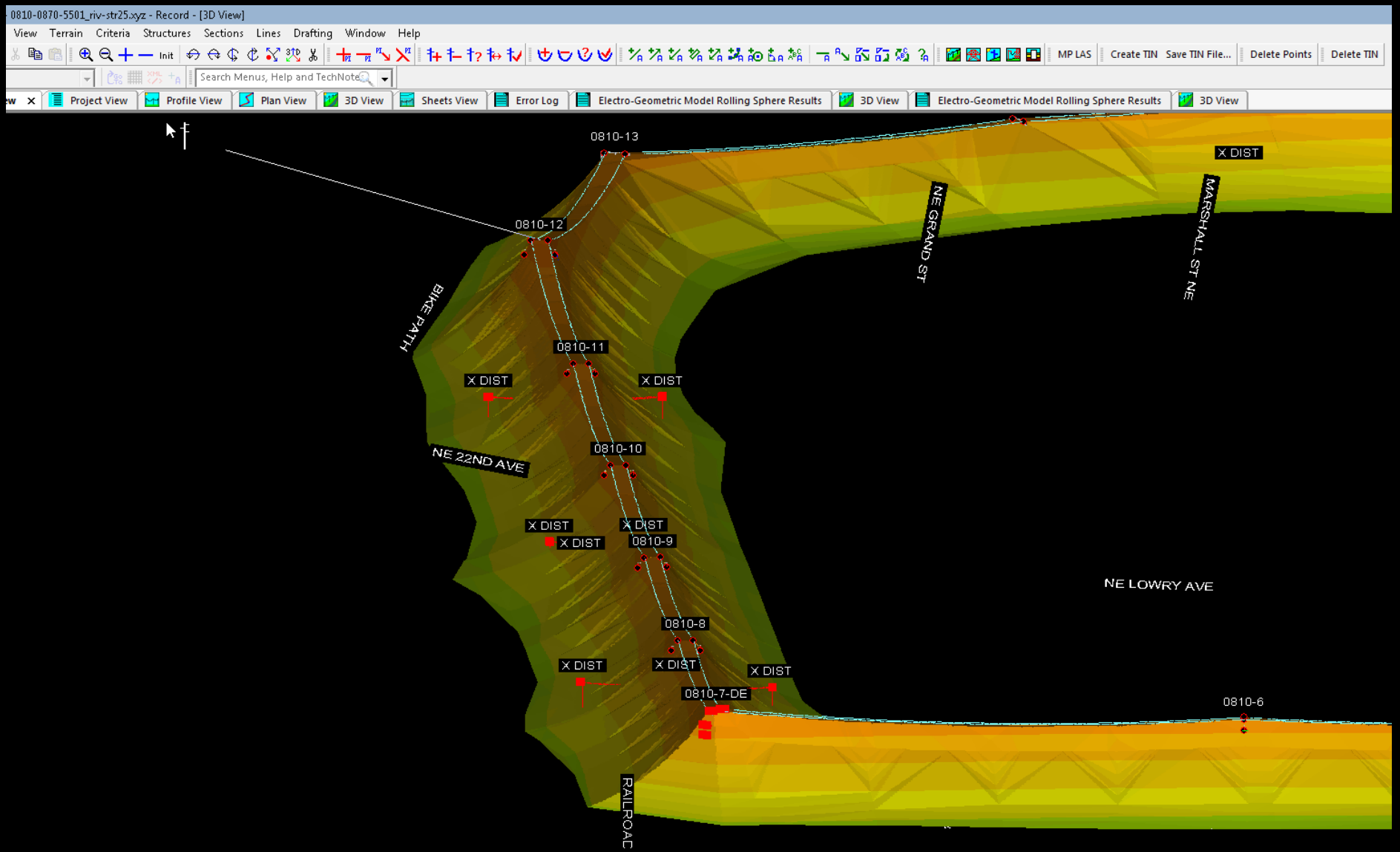
Back Structure	Set #	Phase #	Section Note	Distance to Start (ft)	Length Exposed (ft)	Start of Exposed Wire X (ft)	Start of Exposed Wire Y (ft)	Start of Exposed Wire Z (ft)	End of Exposed Wire X (ft)	End of Exposed Wire Y (ft)	End of Exposed Wire Z (ft)
0810-3	7	1		528	46	1569804.44	16355978.62	926.10	1569811.23	16355936.86	928.94
0810-4	7	1		0	30	1569811.23	16355936.86	928.94	1569813.73	16355910.78	926.41
0810-5-DE	15	1		604	16	1570524.01	16355197.77	925.83	1570533.91	16355197.20	926.75
0810-5-DE	17	1		0	7	1569894.76	16355203.44	933.06	1569898.03	16355203.23	932.66
0810-6	5	1		0	16	1570533.91	16355197.20	926.75	1570547.00	16355197.17	925.60
0810-11	7	1		843	75	1571122.31	16351336.15	940.28	1571121.86	16351264.53	949.11
0810-12	7	1		0	75	1571121.86	16351264.53	949.11	1571110.94	16351193.38	939.54
0810-12	7	1		843	85	1570994.29	16350433.28	919.44	1570981.88	16350352.41	926.13
0810-12	7	2		843	85	1570994.06	16350433.32	907.42	1570981.65	16350352.46	914.13
0810-12	7	3		843	85	1570993.88	16350433.53	895.27	1570981.46	16350352.67	902.10
0810-13	7	1		10	39	1570973.31	16350343.20	925.53	1570943.90	16350322.35	922.34
0810-13	7	2		7	43	1570975.76	16350345.20	913.84	1570943.68	16350322.47	910.34
0810-13	7	3		7	43	1570975.57	16350345.35	901.81	1570943.48	16350322.61	898.27
0810-14	7	1		446	26	1570064.17	16349915.57	931.60	1570041.74	16349910.82	933.83
0810-14	7	1		482	10	1570028.92	16349908.11	935.16	1570025.33	16349907.35	935.53
0810-17-DE	15	1		3	30	1569853.77	16348114.73	895.61	1569865.17	16348091.11	893.99
0810-17-DE	15	2		3	30	1569853.94	16348114.77	883.68	1569865.33	16348091.14	882.23
0810-17-DE	15	3		0	33	1569852.70	16348117.76	871.91	1569865.49	16348091.17	870.38
0810-22	5	1		400	69	1570913.76	16345923.91	888.48	1570941.18	16345866.45	892.57
0810-22	5	2		400	69	1570913.78	16345924.02	876.73	1570941.25	16345866.50	880.59
0810-22	5	3		400	69	1570913.84	16345924.04	864.75	1570941.30	16345866.59	868.53
0810-23	5	1		0	59	1570941.18	16345866.45	892.57	1570988.56	16345837.43	888.37
0810-23	5	2		0	59	1570941.25	16345866.50	880.59	1570988.62	16345837.46	876.35
0810-23	5	3		0	59	1570941.30	16345866.59	868.53	1570988.66	16345837.55	863.98

Approximate total length of exposed conductor: 1158 (ft)

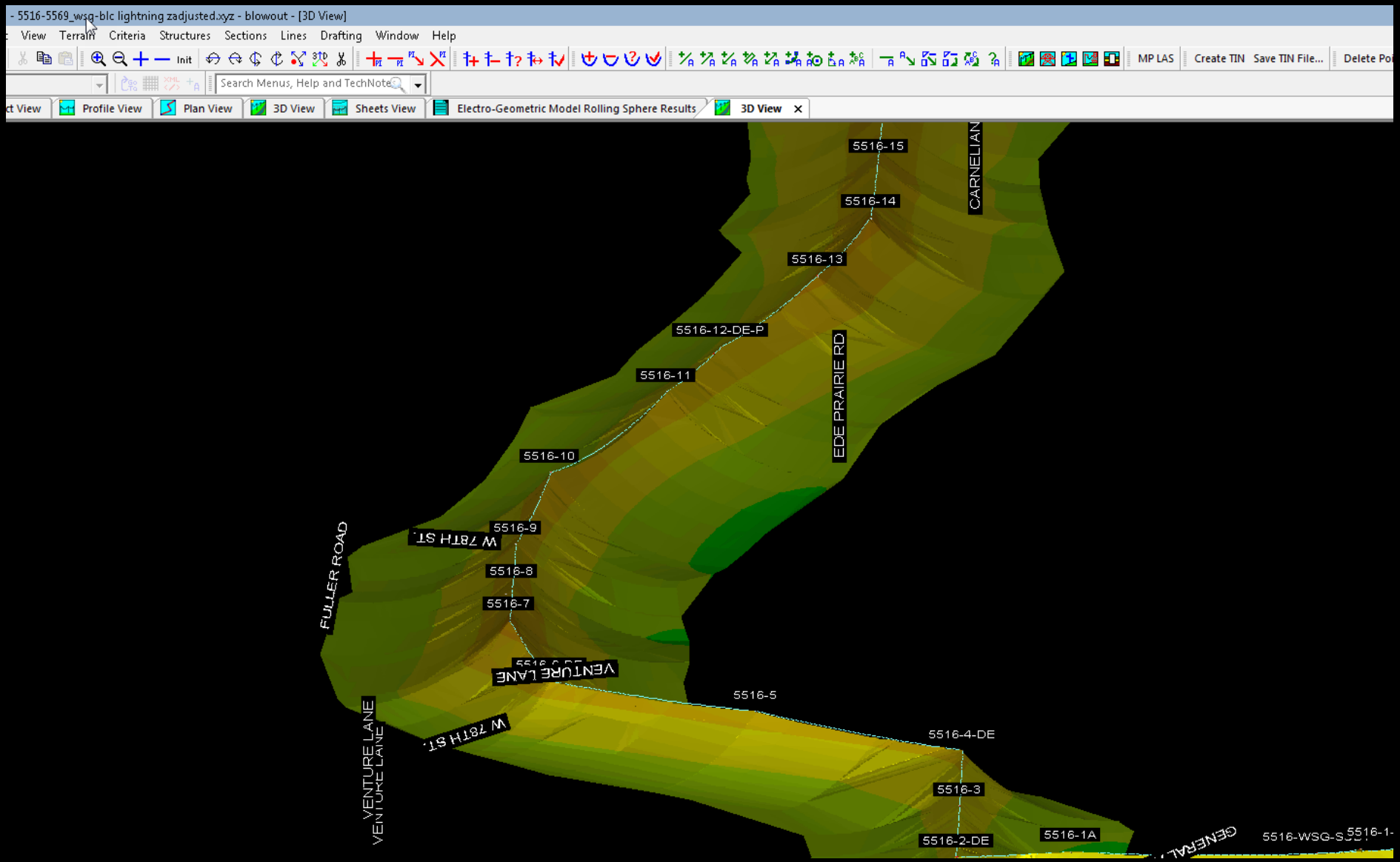
Examples – Exposed phase wire



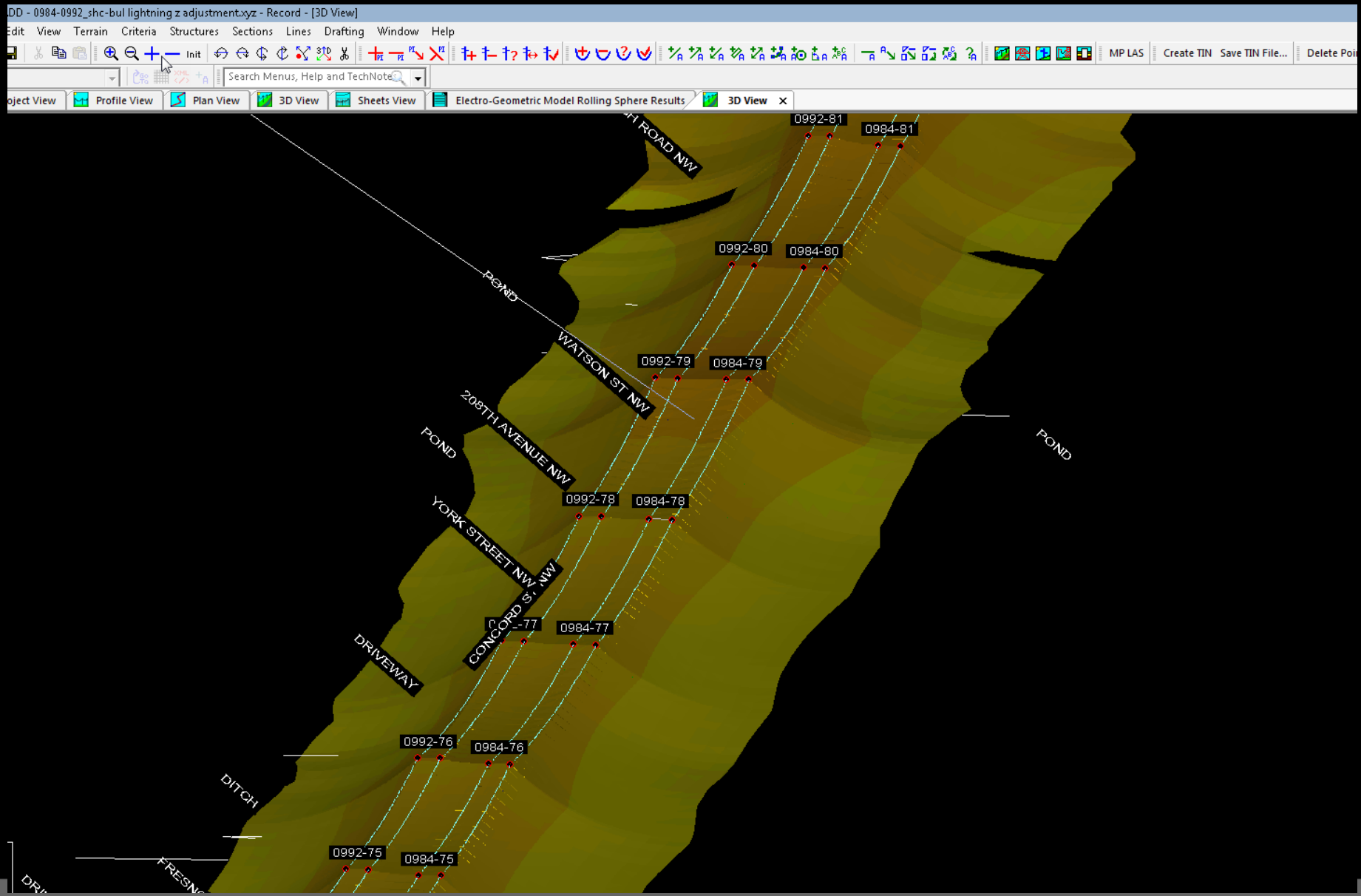
Examples – Triple Circuit



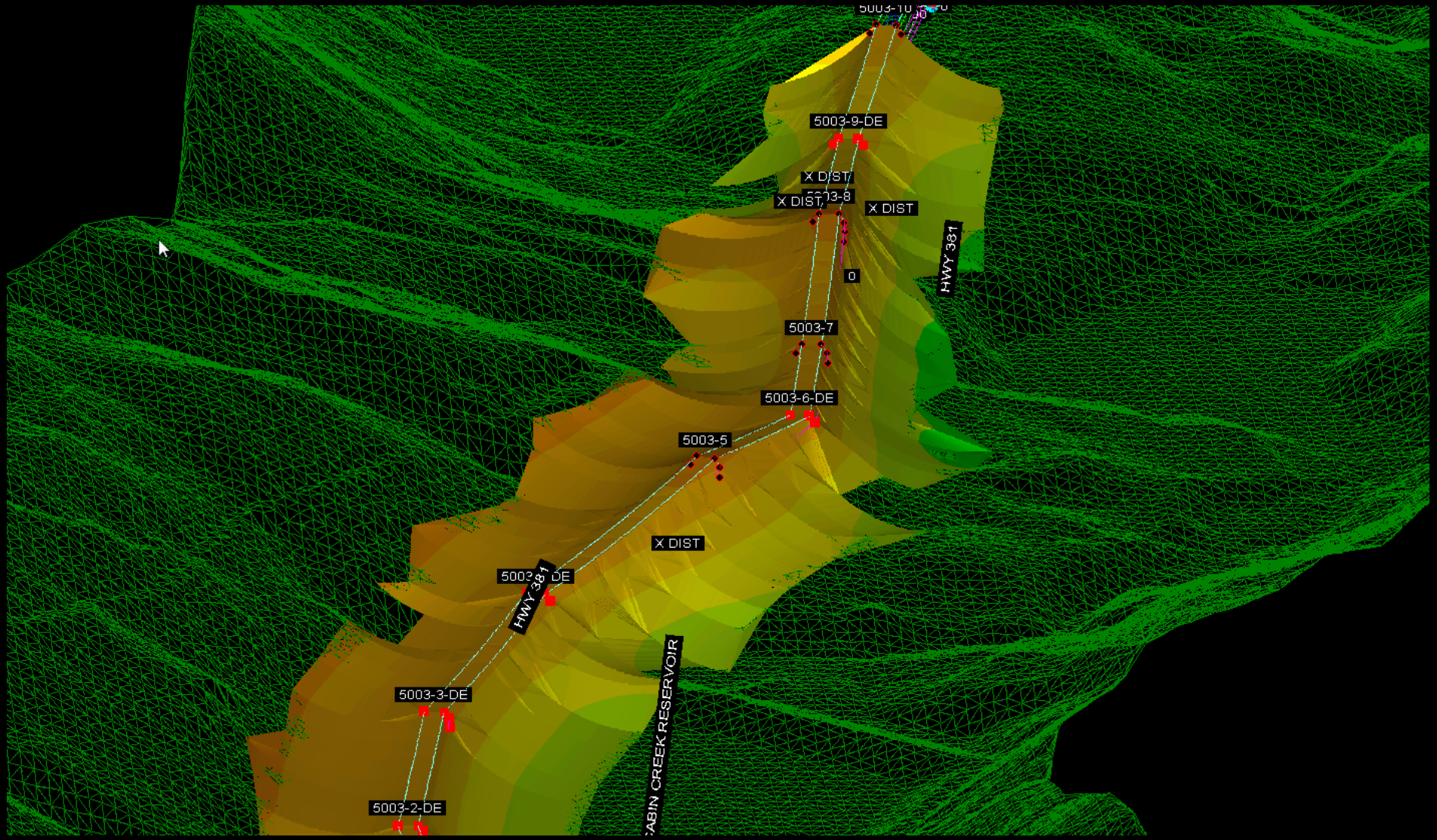
Examples – Single Static



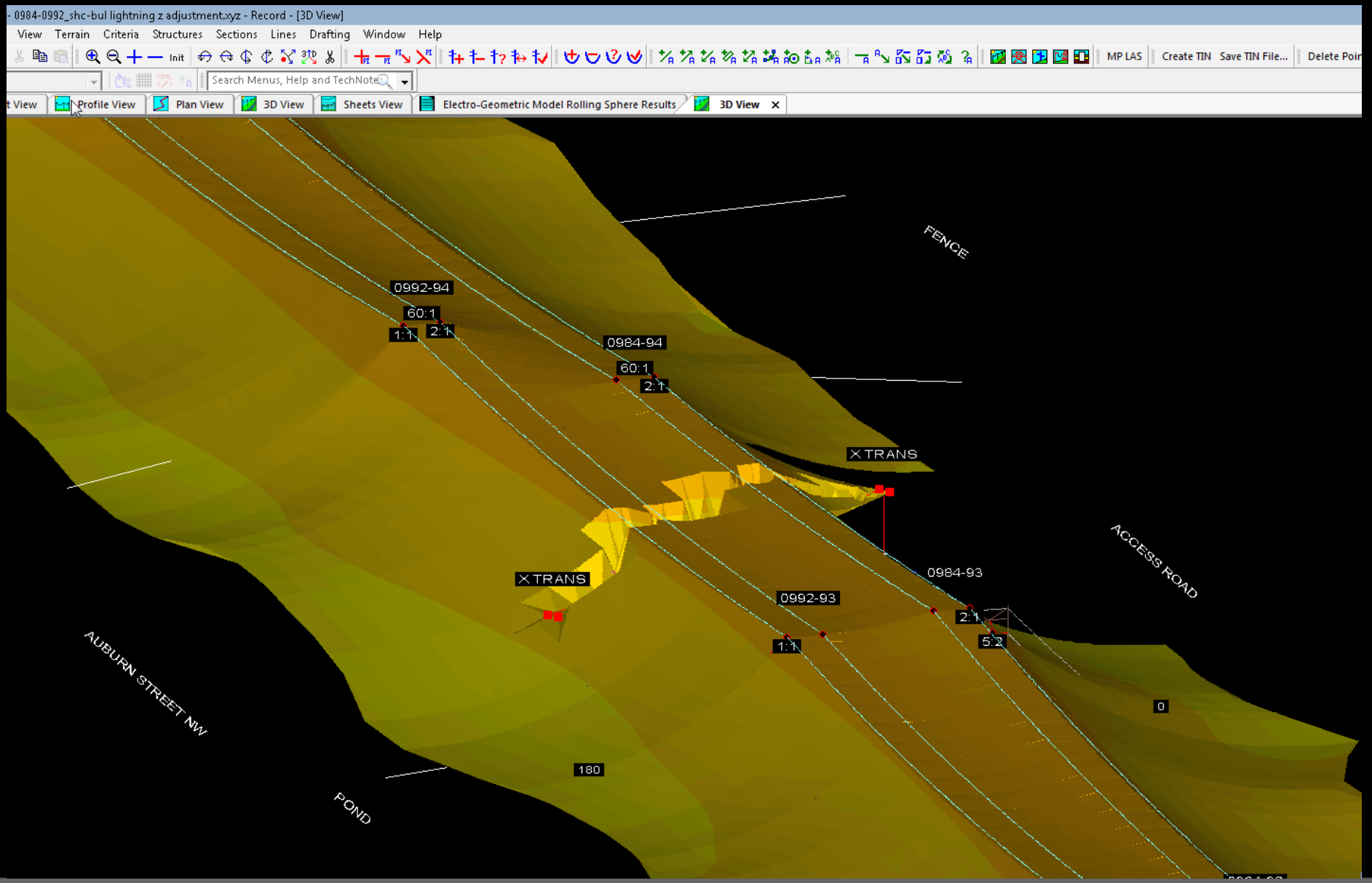
Examples – Multiple Alignments



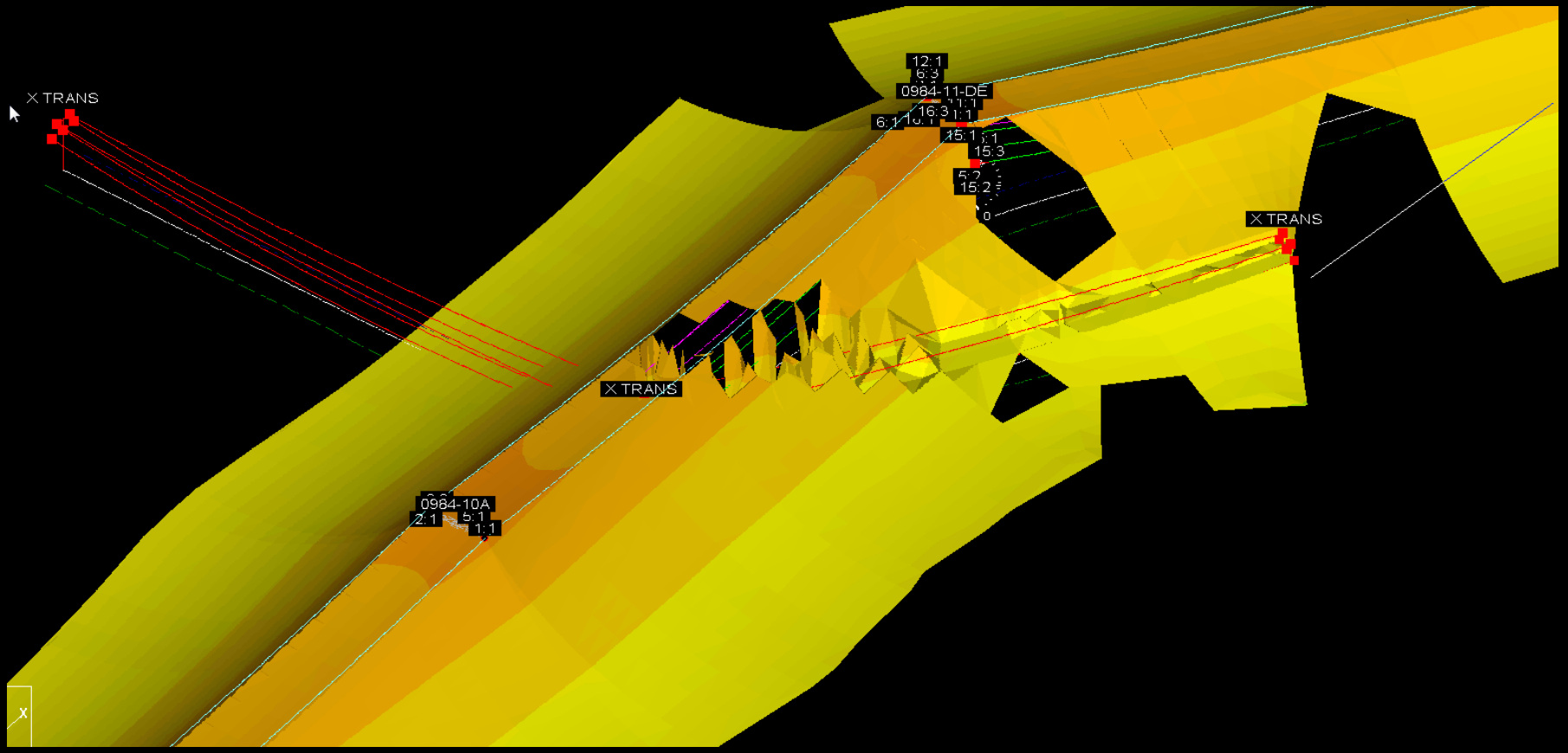
Examples – Quad Circuit



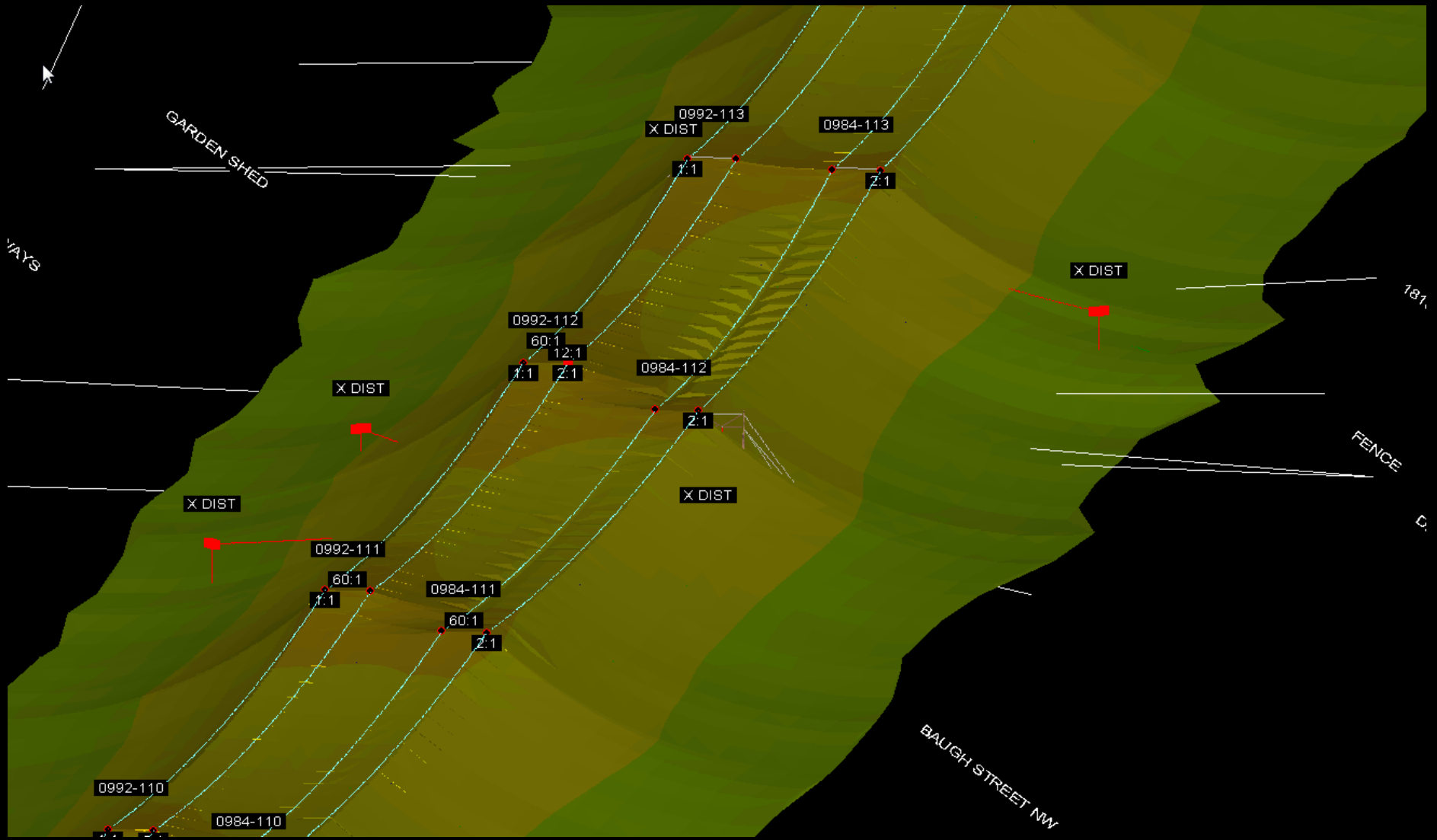
Examples – Crossing problems



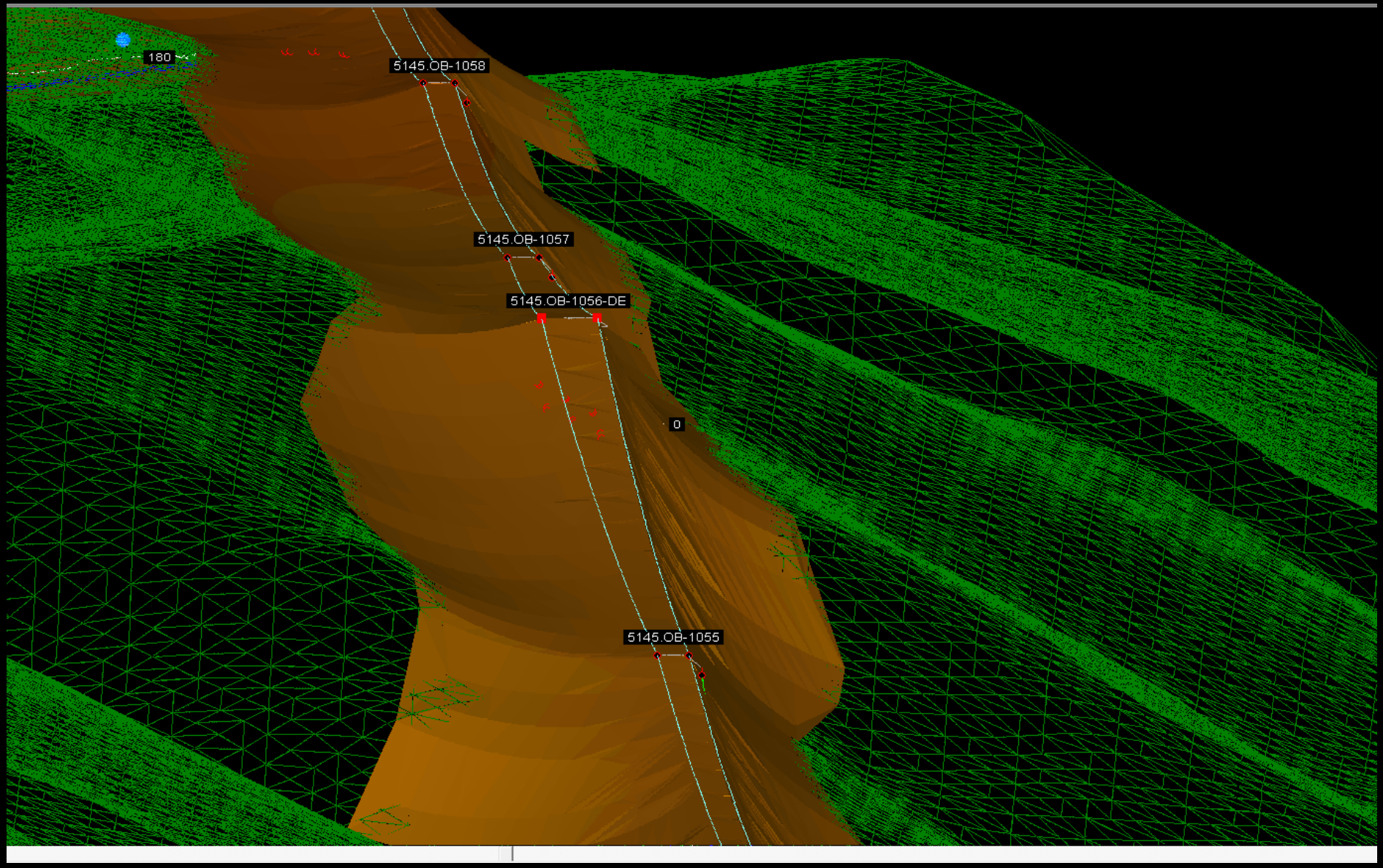
Examples – Crossing problems Cont.



Examples – Crossing Cont.



Examples – Mtn. Side Slopes



Examples – Valleys

Examples – Valleys Cont.

Calculating coverage from ground wires starting from structure 5003-96-DE to structure 5003-100-DE
Weather Case: 60° F
Cable Condition: Initial FE
Wind from the Left
Lightning Stroke Distance (radius of sphere): 225.000 (ft)
Evaluating ground wires every 125.000 (ft)

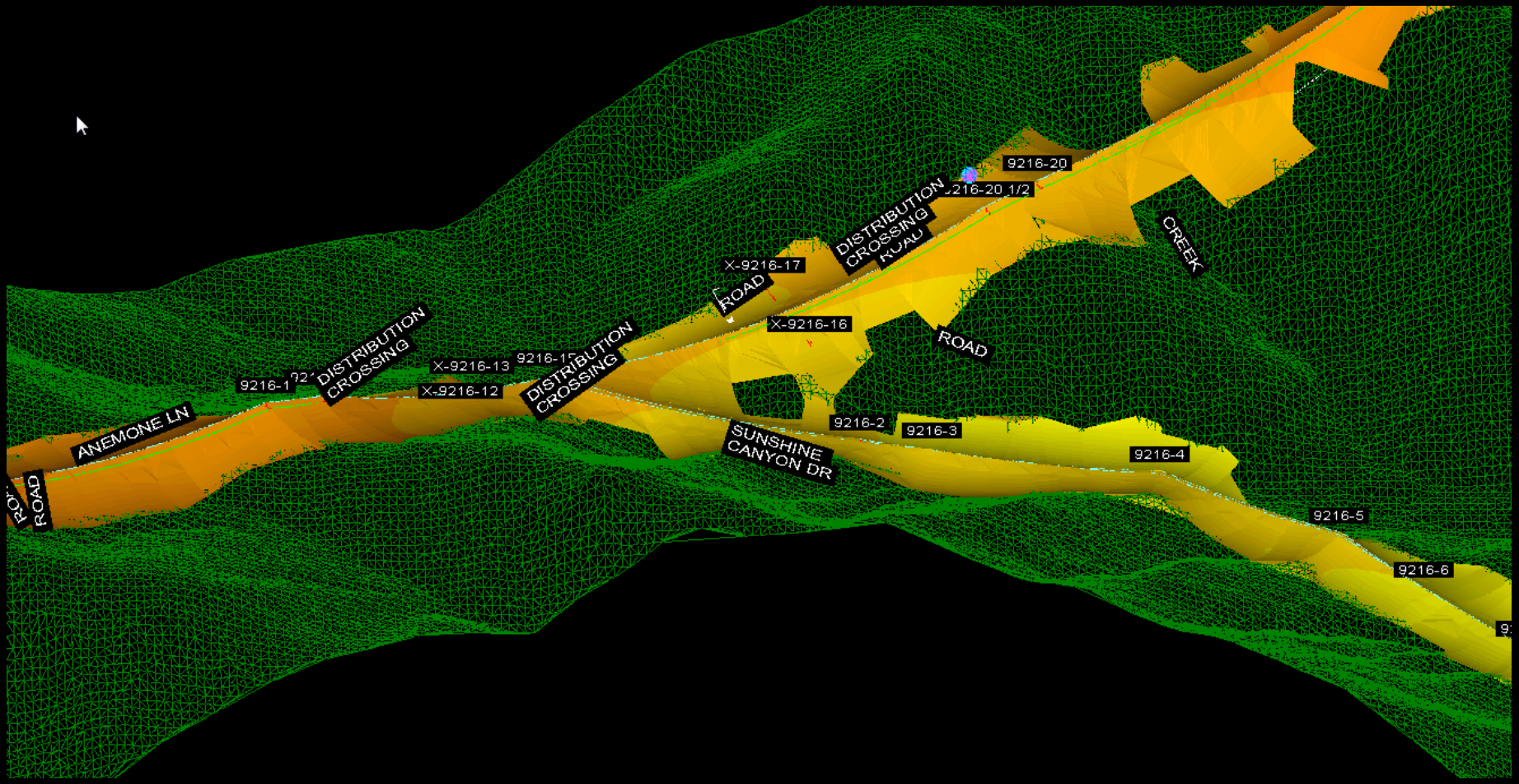
Gaps in Lightning Coverage:
The following spans have gaps in coverage provided by the specified ground wire starting near the specified distance along the span.

Back Structure	Set #	Phase #	Section Note	Distance to Gap (ft)
5003-97	1	1		748

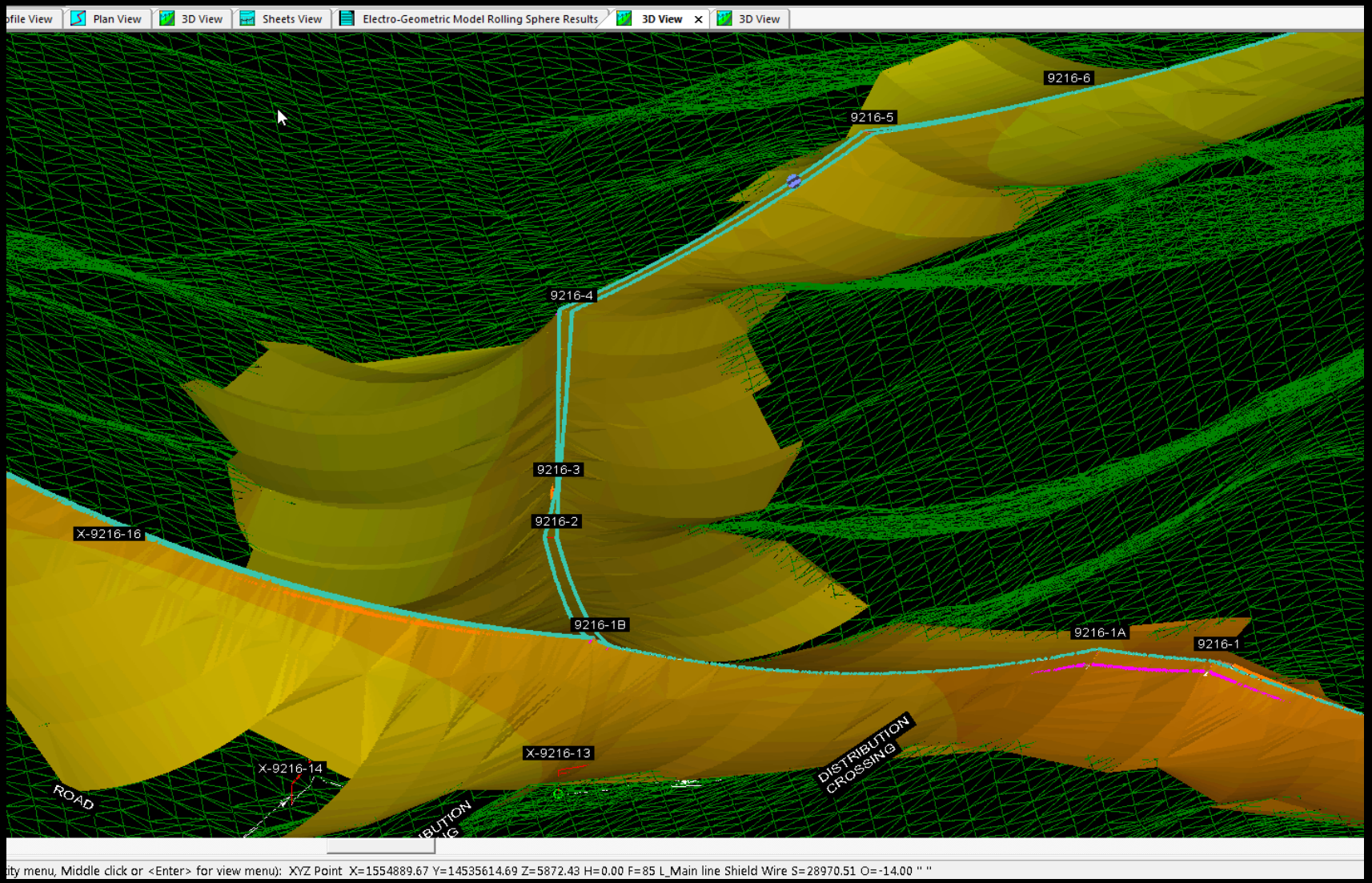
Lightning Coverage Exposed Conductors:

Back Structure	Set #	Phase #	Section Note	Distance to Start (ft)	Length Exposed (ft)	Start of Exposed Wire X (ft)	Start of Exposed Wire Y (ft)	Start of Exposed Wire Z (ft)	End of Exposed Wire X (ft)	End of Exposed Wire Y (ft)	End of Exposed Wire Z (ft)
5003-96-DE	5	1		0	46	1494234.63	14431326.80	8140.82	1494276.32	14431326.60	8127.30
5003-96-DE	5	1		876	7	1495090.93	14431322.56	7966.32	1495092.81	14431322.55	7966.17
5003-97	5	1		0	16	1495092.81	14431322.55	7966.17	1495105.79	14431322.49	7963.34
5003-97	5	1		463	689	1495550.47	14431320.51	7895.30	1496228.84	14431317.49	7902.39
5003-97	5	2		463	689	1495550.47	14431320.51	7877.68	1496228.91	14431317.49	7884.85

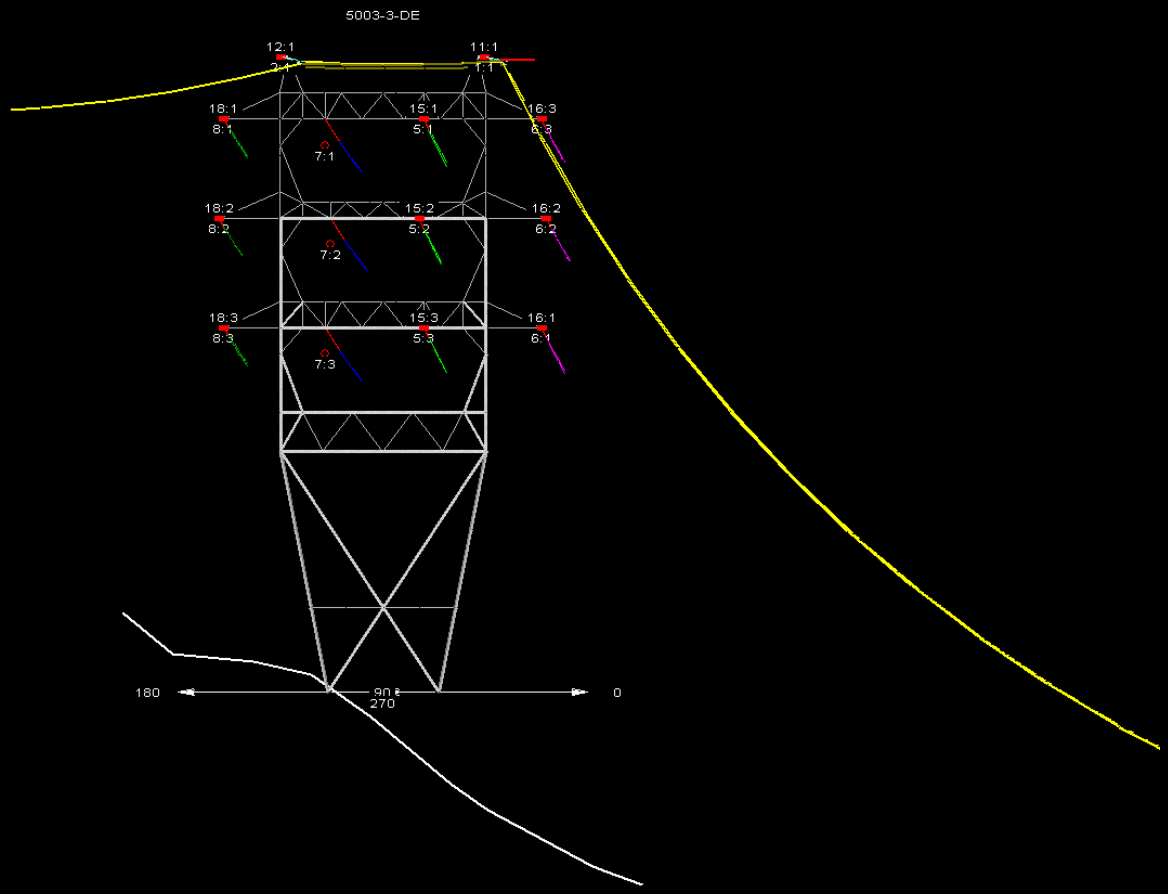
Examples – Canyon



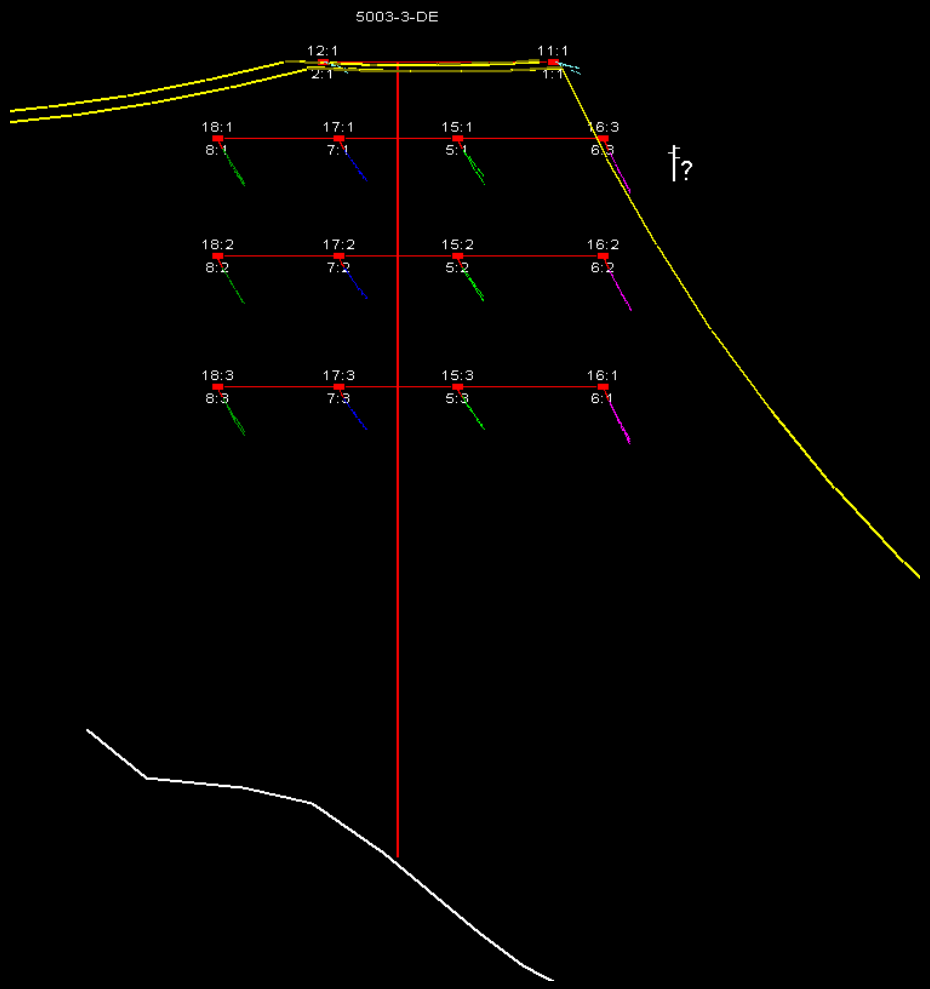
Examples – Canyon Cont.



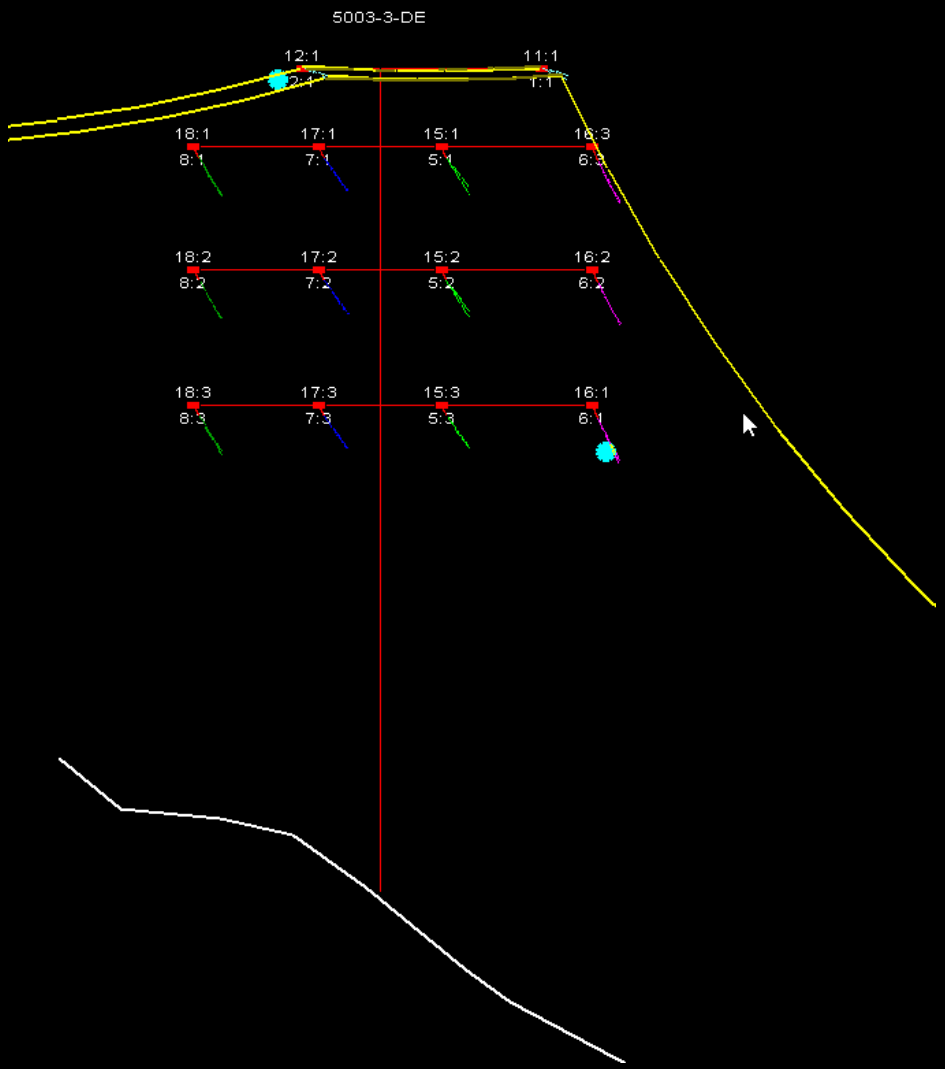
Issues- 18.25’ Arm



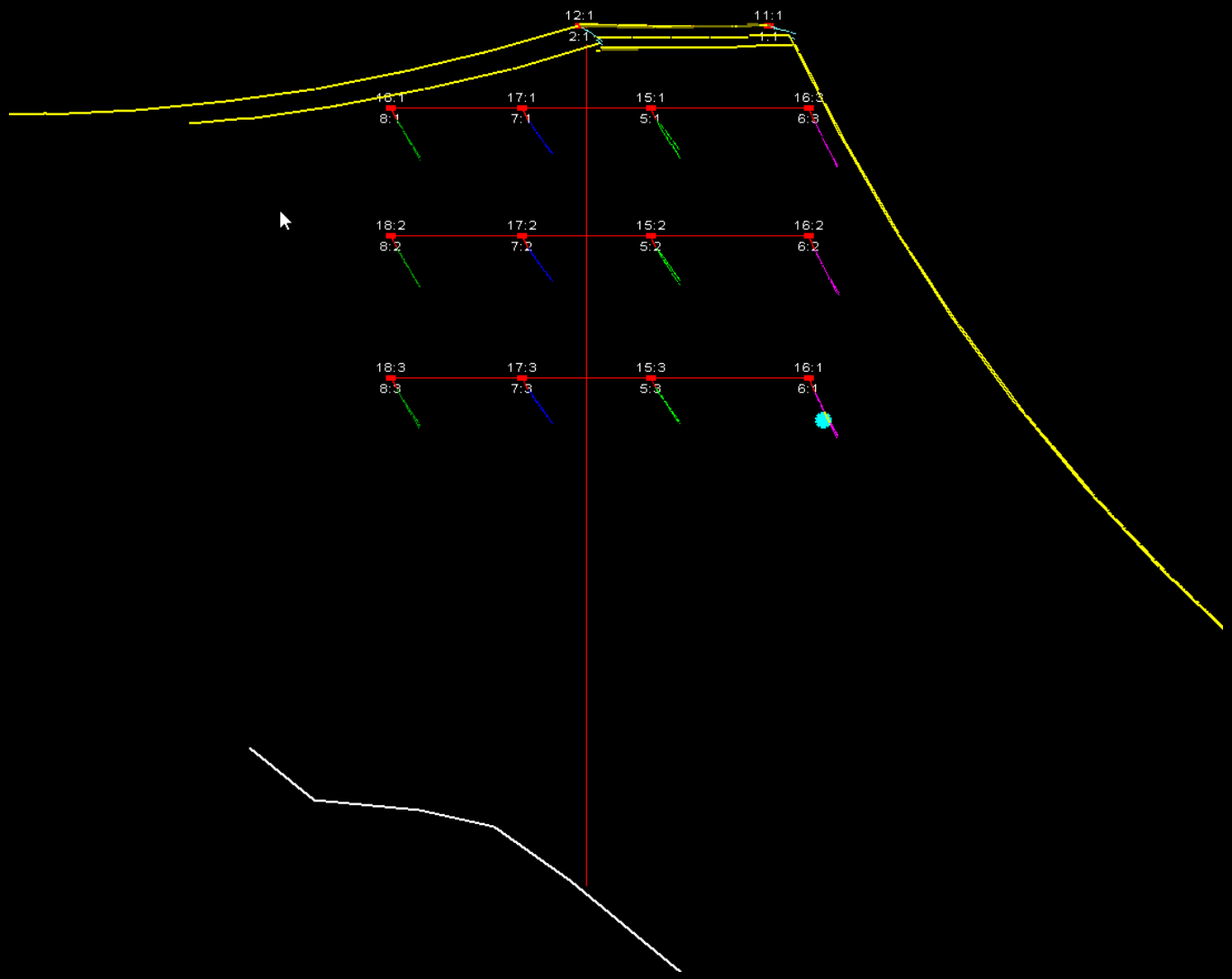
Issues-23’ Outside Arm



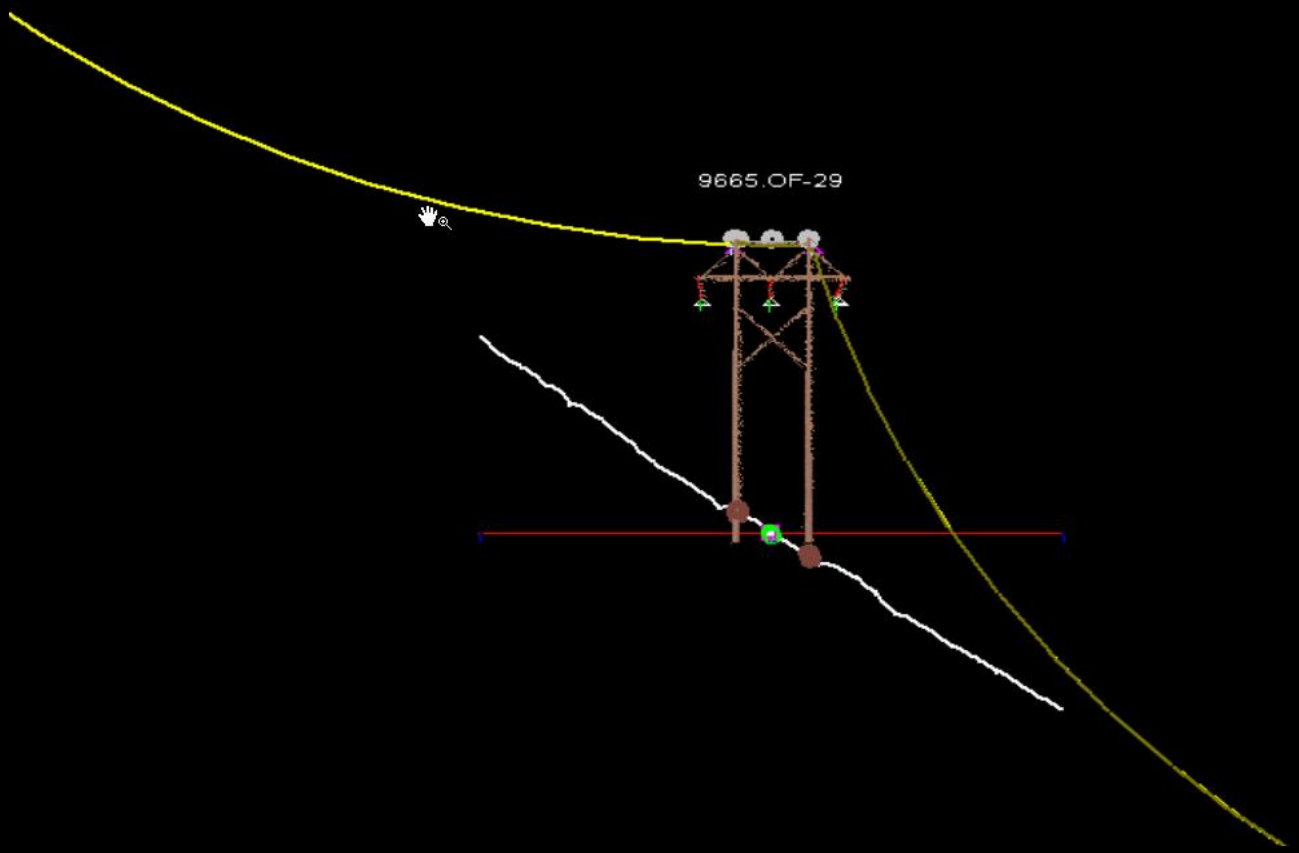
Issues-25’ Outside Arm



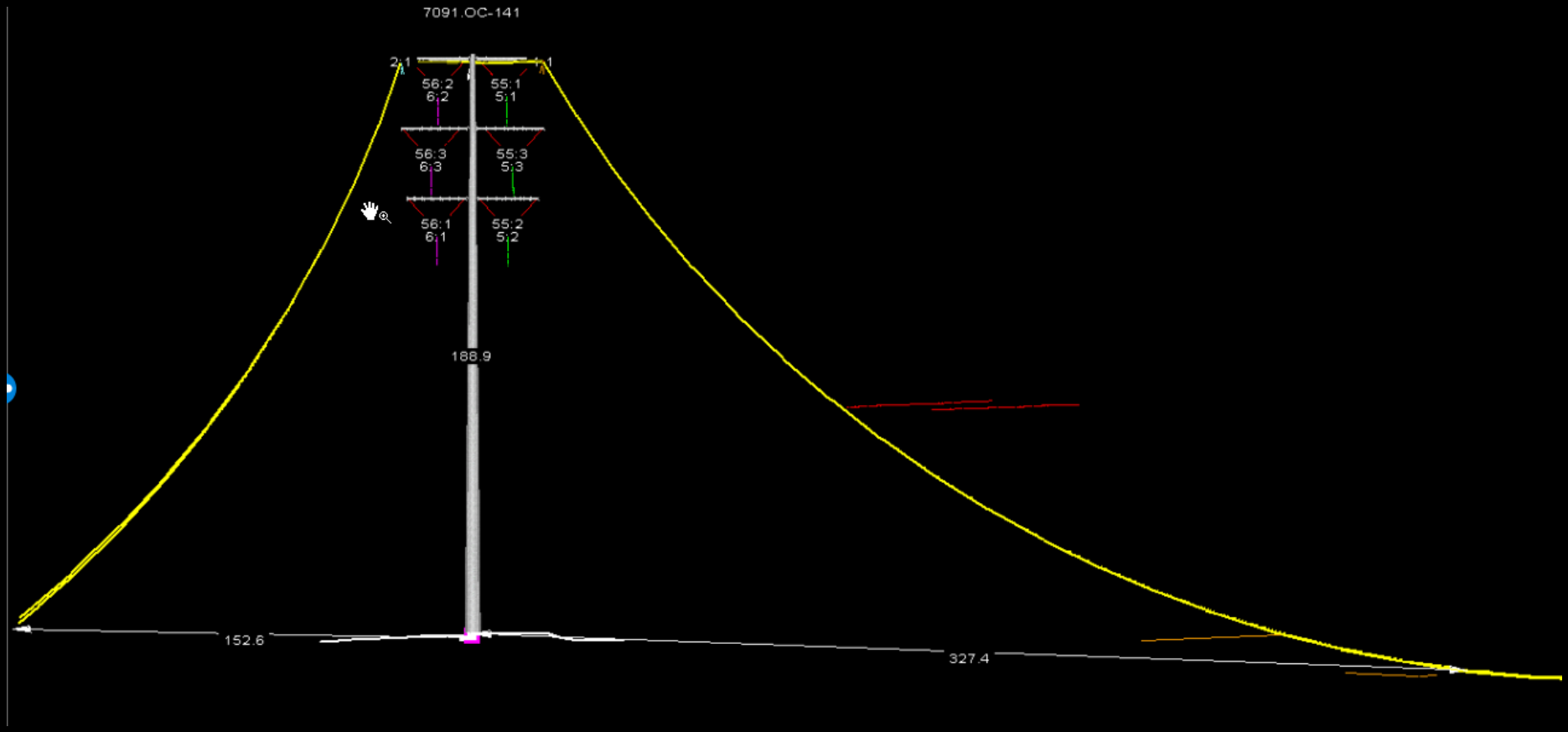
Issues-25’ Outside Arm 1’ Inside Arm



Extreme side slope



Issues


7091.OC-141
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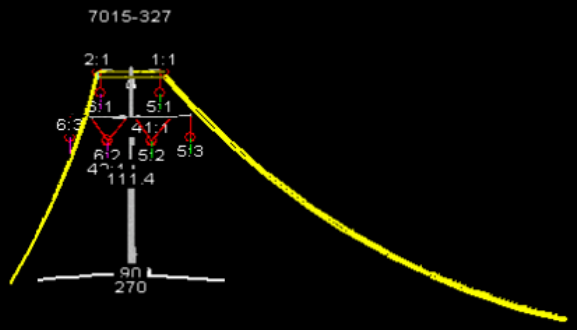
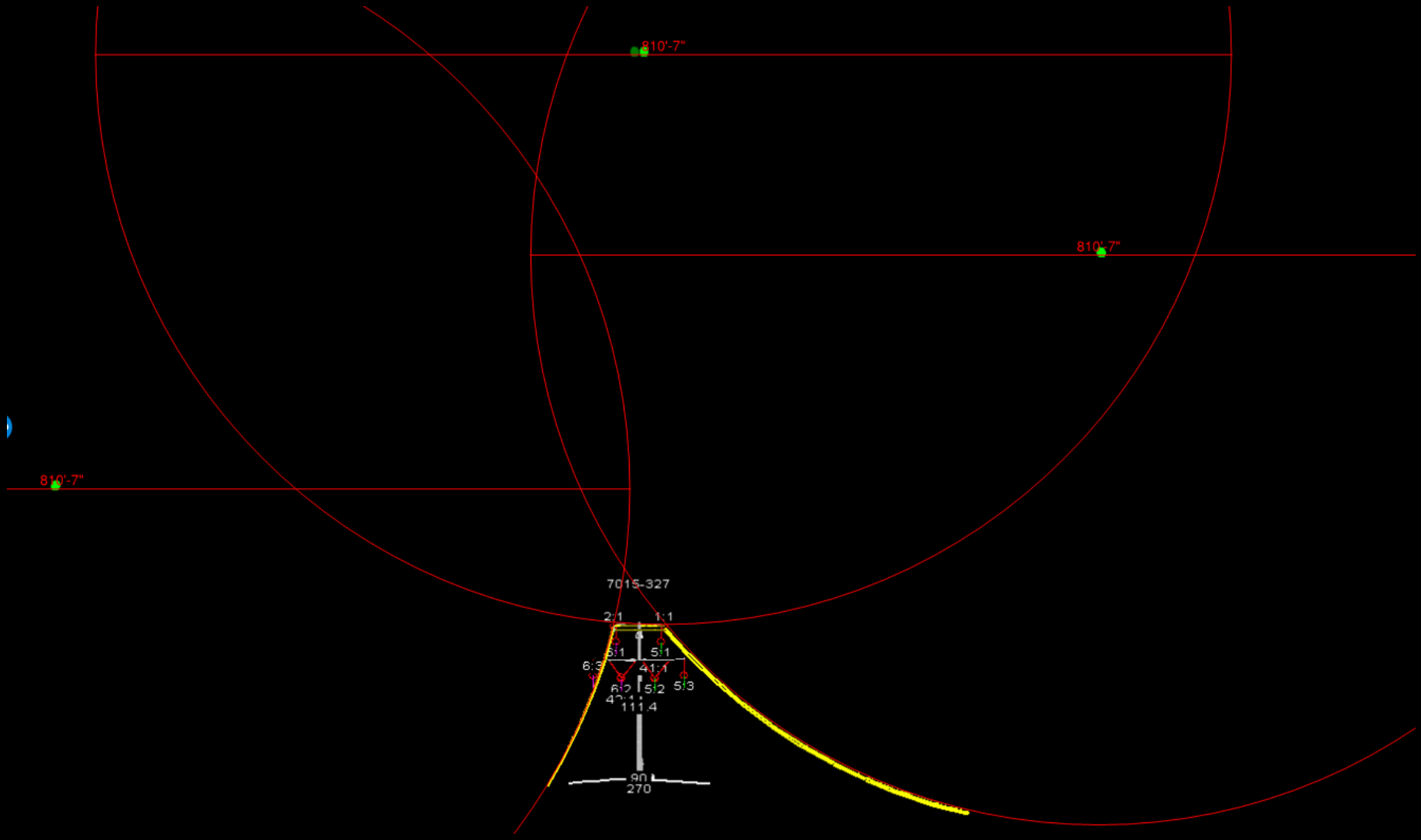
56:2
6:2
55:1
5:1
56:3
6:3
55:3
5:3
56:1
6:1
55:2
5:2
188.9
152.6
327.4

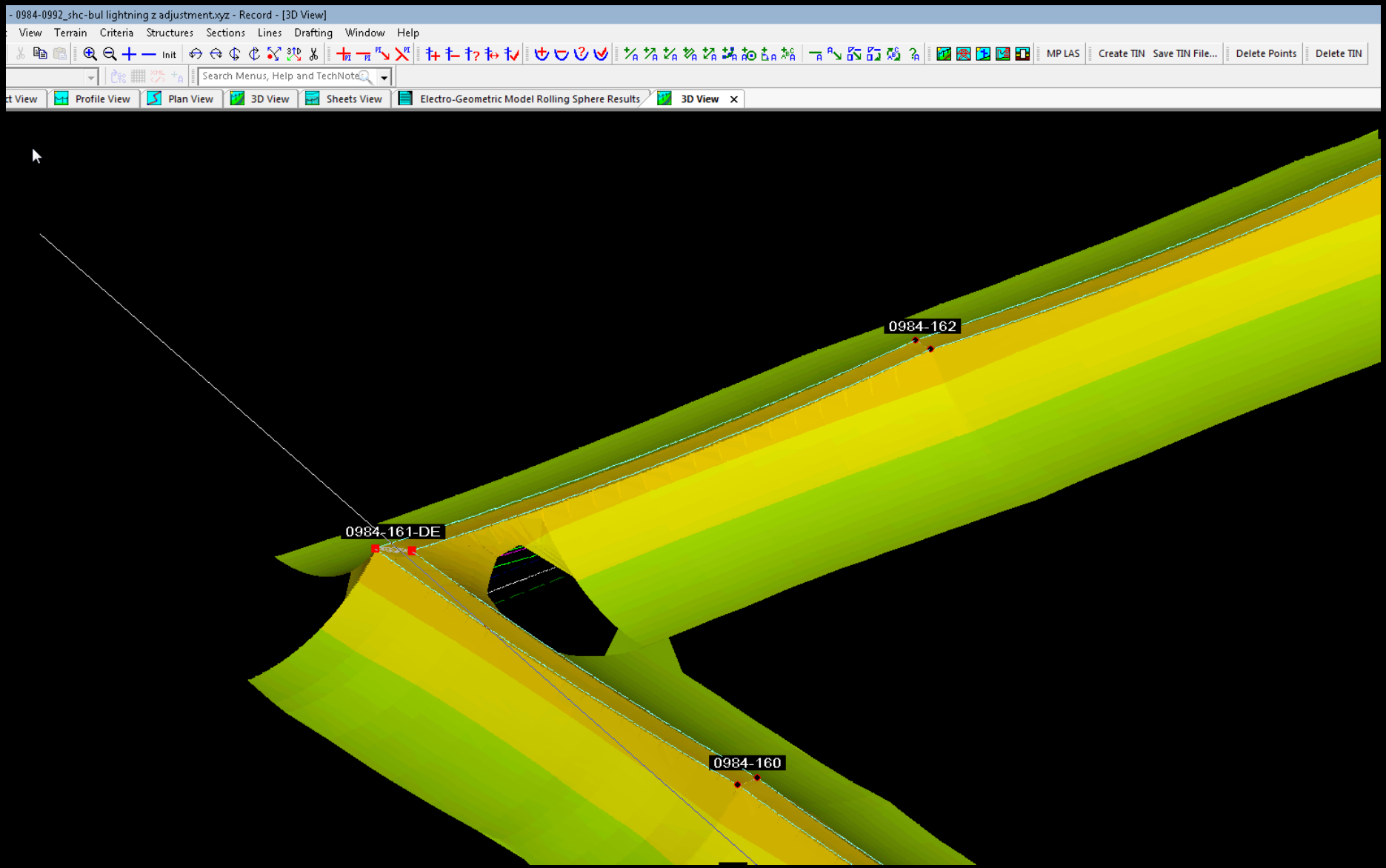
Issues Cont.



Issues Cont.



Issues Cont.


- 0984-0992_shc-bul lightning z adjustment.xyz - Record - [3D View]
View Terrain Criteria Structures Sections Lines Drafting Window Help
Init
MP LAS
Create TIN
Save TIN File...
Delete Points
Delete TIN
Search Menus, Help and TechNote
Profile View
Plan View
3D View
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QUESTIONS?!?