How to Construct an AC Mitigation system from an operator's perspective

From a 6 month to 1 year perspective

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Consumers Energy

AMPP™

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192.473 External Corrosion Control: Interference Currents

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§ 192.473 External corrosion control: Interference currents.

(a) Each operator whose pipeline system is subjected to stray currents shall have in effect a continuing program to minimize the detrimental effects of such currents.

(b) Each impressed current type cathodic protection system or galvanic anode system must be designed and installed so as to minimize any adverse effects on existing adjacent underground metallic structures.

(c) For onshore gas transmission pipelines, the program required by paragraph (a) of this section must include:

(1) Interference surveys for a pipeline system to detect the presence and level of any electrical stray current. Interference surveys must be conducted when potential monitoring indicates a significant increase in stray current, or when new potential stray current sources are introduced, such as through co-located pipelines, structures, or high voltage alternating current (HVAC) power lines, including from additional generation, a voltage up-rating, additional lines, new or enlarged power substations, or new pipelines or other structures;

(2) Analysis of the results of the survey to determine the cause of the interference and whether the level could cause significant corrosion, impede safe operation, or adversely affect the environment or public;

(3) Development of a remedial action plan to correct any instances where interference current is greater than or equal to 100 amps per meter squared alternating current (AC), or if it impedes the safe operation of a pipeline, or if it may cause a condition that would adversely impact the environment or the public; and

(4) Application for any necessary permits within 6 months of completing the interference survey that identified the deficiency. An operator must complete remedial actions promptly, but no later than the earliest of the following: within 15 months after completing the interference survey that identified the deficiency; or as soon as practicable, but not to exceed 6 months, after obtaining any necessary permits.

[Amdt. 192-4, 36 FR 12302, June 30, 1971, as amended by Amdt. 192-33, 43 FR 39390, Sept. 5, 1978; Amdt. 192-132, 87 FR 92269, Aug. 24, 2022; Amdt. 192-133, 88 FR 24711, Apr. 24, 2023]

Company T&S O&M Manual

- AC Interference Investigation Process

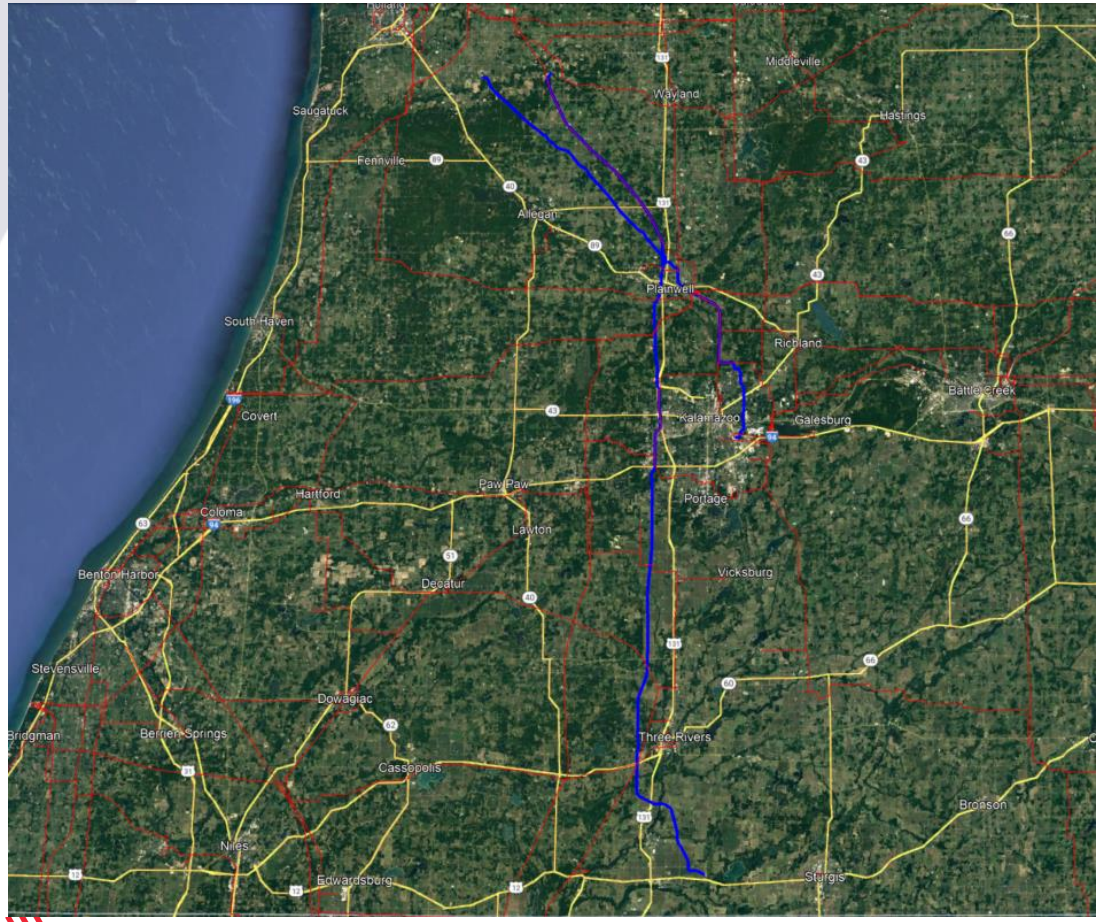
1. When potential monitoring (ex: annuals survey) on a transmission pipeline (T&S or TOD) indicates AC voltages exceeding 15V are identified, perform the following steps to determine the extent and severity of the voltages.
2. Perform additional testing (interference survey) at locations that exceed 15V and adjacent test points that exceed 10V (if known). Perform testing within 3 months of initial reading.
    1. Obtain AC P/S reads
    2. Obtain AC and DC current densities at test stations
        1. Utilize a portable coupon at test stations that do not have an existing coupon.
        2. If AC voltages over 15 volts or if the AC current density exceeds 100A/m^2, initiate a remedial action plan (as described in step 4 below) to mitigate potential AC corrosion.
    3. Record readings in the corrosion database.
3. If the testing from step 2 indicates that the voltages are less than 15 volts and do not indicate an AC corrosion concern (less than 100 A/ m^2).
    1. Initiate installation of a Remote Monitoring Unit (RMU) at the test station(s) with the highest AC voltage readings.
        1. A portable data logger could be substituted for an RMU.
    2. Review location of existing test points. If they are not at locations for highest AC voltages, consider installing additional coupon test stations.
    3. Consider installing AC grounding mats and/or Dead Front test stations at above ground piping.
    4. Monitor voltages on a monthly basis to determine when the voltages are the highest.
        1. If voltages exceed 15 volts install a data logger and record potentials for two weeks (interference survey).
            1. If voltages are equal to or exceed 15 volts or indicate AC corrosion concern during the data logger testing, initiate remedial action.
            2. If voltages are less than 15 volts, continue monitoring with the RMU.
4. Remedial Action Plan
    1. Initiate design of AC mitigation system to reduce AC voltages to a safe level. Document installation in the Corrosion Database.
    2. Complete design work (Remedial Action plan) and apply for permits within 6 months of the interference survey.
    3. Complete the remedial action plan within 15 months after completing the interference survey or as soon as practicable after obtaining necessary permits, easements or permissions to complete the installation.
        1. Document issues that create deviations from the required dates.

20 weeks to file permit if we are hitting on all cylinders (no down time)

Found the problem;

- Clock started, 6 months, 24 weeks, to file permits.
  - Determine the extent of the project and SOW. **(4 weeks)**
  - Desktop and Modeling to produce a concept design. **(4 weeks)**
  - Survey **(6 weeks)**
  - Alignment sheets and final design details **(4 weeks**)
  - File permits **(2 weeks)**

Two Pipelines with Opposing Issue



- L-1300 (1957 to1958) High AC Current Densities
  - Diameter – 12-3/4”
  - Length - 34 miles
  - Coating – Wax with Outer wrap
    - Overisel Comp Sta to 107th Ave, travel line wrapped with Dearborn 6X wax andDearborn GRX-31 wrapper. 107th Ave to G Ave, travel line wrappedwith Dearborn 6X wax and Dearborn No 7 wrapper. G Ave to Palmer St,mill wrapped with Dearborn 6X wax and Dearborn No 7 wrapper, Service Coat #15and Kraft paper.

- L-1800 (1967 to 1968) High AC Voltages
  - Diameter - 20”
  - Length - 70 miles
  - Coating – Tar with Asbestos Felt
    - White Pigeon to Plainwell-Field coated and wrapped with Allied Quick Drying Primer No. 1122, Allied AA Fully Plasticized Pipeline Enamel and Phillip Carey Co., No. 15 Tar Saturated Glass Reinforced and Perforated Asbestos Felt.
    - Plainwell to 30th St Valve Site-Reilly Tar & Chemical, #122 Quick Dry Primer &#230-A Pipeline Enamel, Phillip Carey 15# Tar Saturated, Glass Reinforced, Perforated, Asbestos Pipeline Felt.

L-1300 Annual Survey

- L-1300 (1957 to1958)
  - Diameter – 12-3/4”
  - Length - 34 miles
  - Coating – Wax with Outer wrap
    - Overisel Comp Sta to 107th Ave, travel line wrapped with Dearborn 6X wax andDearborn GRX-31 wrapper. 107th Ave to G Ave, travel line wrappedwith Dearborn 6X wax and Dearborn No 7 wrapper. G Ave to Palmer St,mill wrapped with Dearborn 6X wax and Dearborn No 7 wrapper, Service Coat #15and Kraft paper.
- Annual Survey
  - 6/2/2023 – 7:49 am – 10.1 VAC
  - 6/2/2023 – 9:11 am – 6.4 VAC
- Start interference testing

FACILITY Code and Pipe	Milepost	Location Description	Inspection Date	AC P/S	e P/S	e IRF	Effective Date
LINE: 1300-4	64	107TH AVE	5/19/2023 03:55:48 PM	0	-1.522	-1.112	5/1/2023
LINE: 1300-4	69	MGU PL(E. OF 10TH ST)	5/19/2023 03:56:11 PM	0	-1.269	-1.078	5/1/2023
LINE: 1300-4	70	106TH AVE W/CASING	5/19/2023 03:56:28 PM	0	-1.332	-1.158	5/1/2023
LINE: 1300-4	71	MILLER RD	5/19/2023 03:56:42 PM	-0.001	-1.378	-1.083	5/1/2023
LINE: 1300-4	72	CE ELECTRIC ROW(BTW MILLER & ACORN)	6/2/2023 10:01:33 AM	0.406	-0.972	-0.852	5/10/2023
LINE: 1300-4	74	RR NW OF ACORN ST W/CASING	6/2/2023 09:24:21 AM	1.966	-1.288	-0.908	5/10/2023
LINE: 1300-4	76	M-89 HWY(BRIDGE ST)	6/2/2023 09:21:50 AM	3.028	-1.432	-1.004	5/1/2023
LINE: 1300-4	78	8TH ST	6/2/2023 09:18:04 AM	2.037	-1.645	-1.158	5/1/2023
LINE: 1300-4	80	RIVERVIEW DR(SE OF 8TH ST)	6/2/2023 09:11:52 AM	6.442	-1.529	-1.053	5/1/2023
LINE: 1300-4	83	4TH ST	6/2/2023 08:24:15 AM	4.082	-1.745	-1.151	5/1/2023
LINE: 1300-4	86	B AVE	6/2/2023 08:16:11 AM	2.269	-1.612	-1.136	5/1/2023
LINE: 1300-4	87	1320(S. SIDE OF B AVE)	6/2/2023 08:14:05 AM	1.224	-1.562	-1.158	5/1/2023
LINE: 1300-4	90	TEST LEAD(1.2 MI E. OF B AVE)	6/2/2023 08:07:49 AM	10.141	-1.539	-1.101	5/1/2023
LINE: 1300-4	93	D AVE W/CASING	6/2/2023 07:44:11 AM	4.559	-1.405	-1.079	5/1/2023
LINE: 1300-4	94	E AVE	6/2/2023 07:36:54 AM	3.824	-1.48	-1.082	5/1/2023

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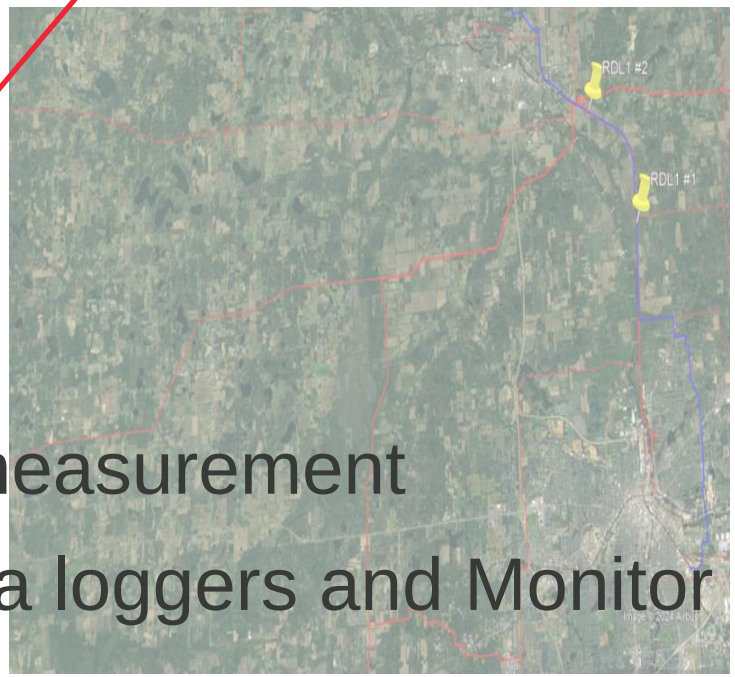
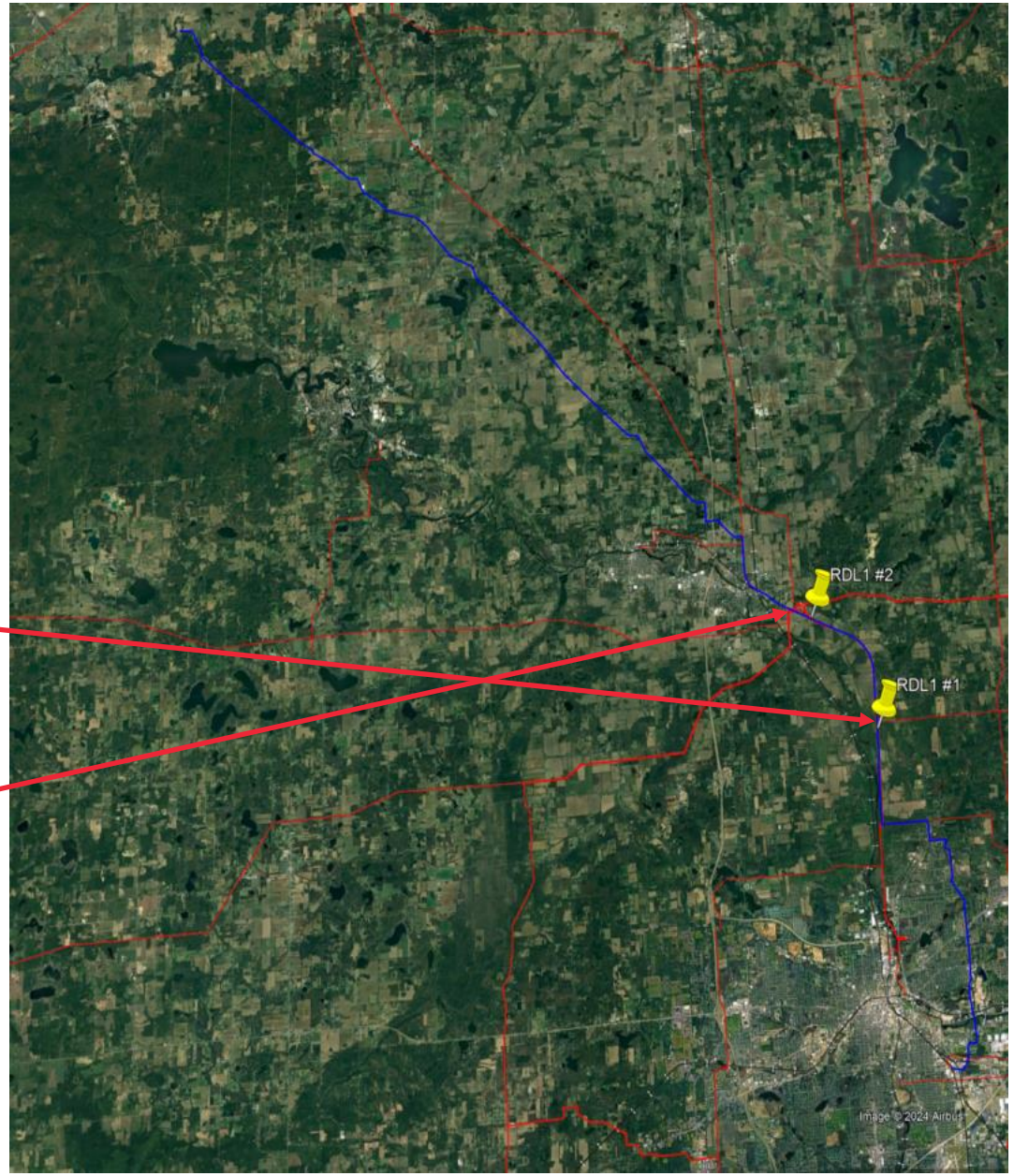


- Verify measurement
- Set Data loggers and Monitor

L-1300

- Two RMU data loggers and monitored.

- RDL#1- 1.2 miles of B Ave.
  - 6/2/2023 – 7:49 am – 10.1 VAC
- RDL#2 – Riverview Drive
  - 6/2/2023 – 9:11 am – 6.4 VAC

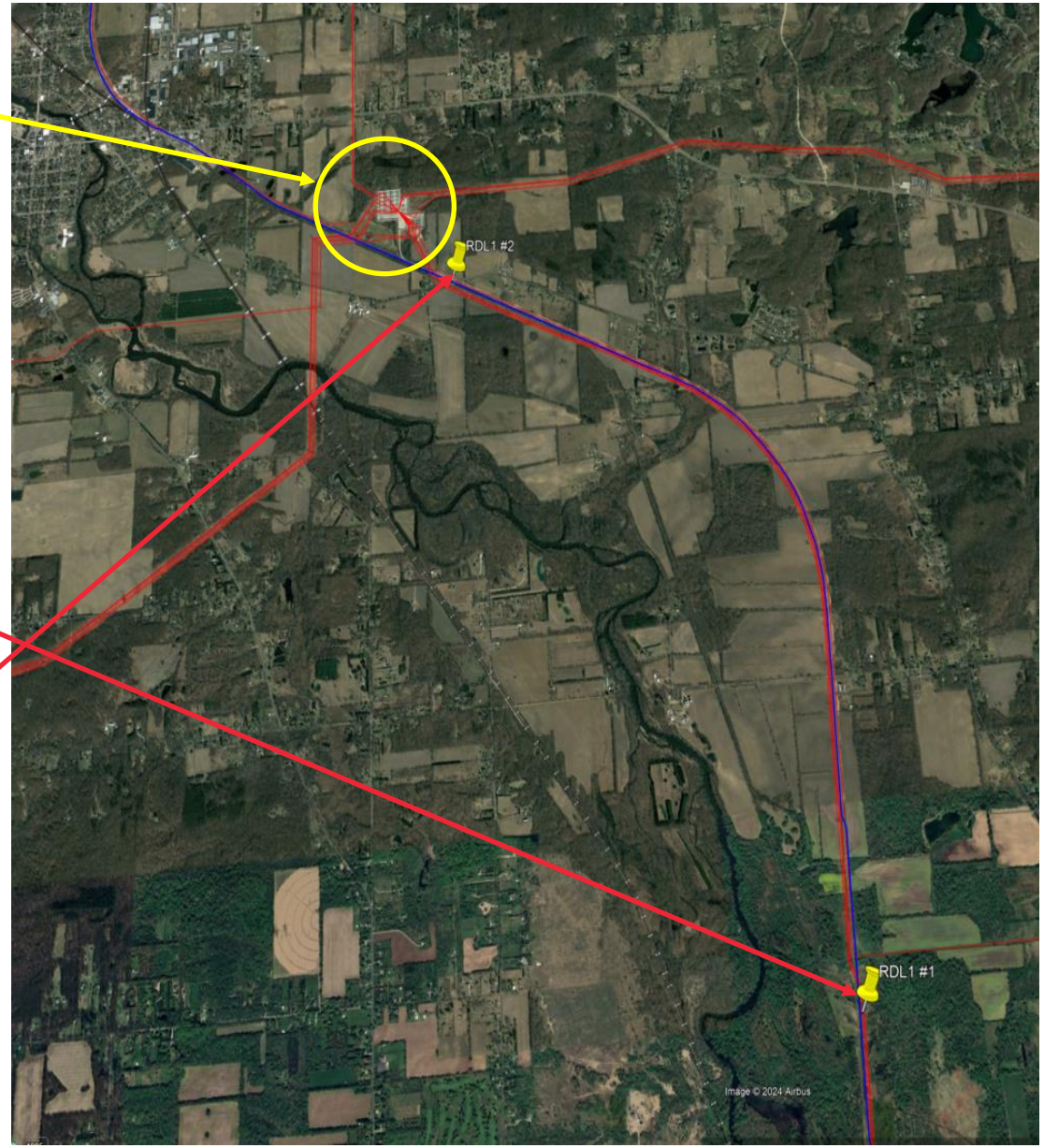


L-1300

- Two RMU data loggers and monitored.

Substation

- RDL#1- 1.2 miles of B Ave.
  - 6/2/2023 – 7:49 am – 10.1 VAC
- RDL#2 – Riverview Drive
  - 6/2/2023 – 9:11 am – 6.4 VAC

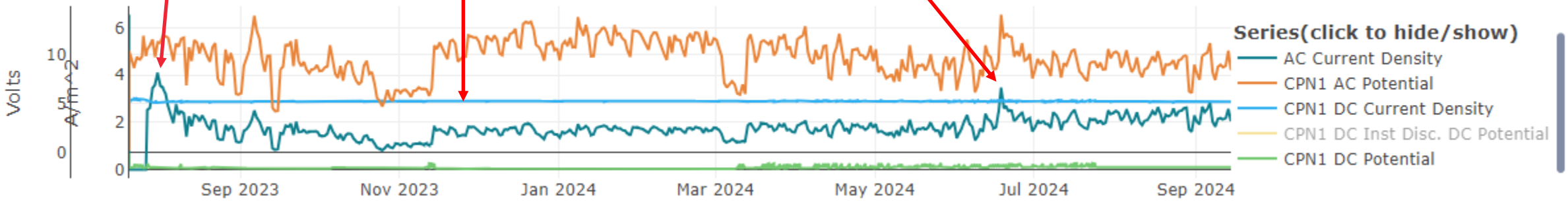


L-1300 RDL#1

- RDL#1- 1.2 miles of B Ave.
  - 6/2/2023 – 7:49 am – 10.1 VAC

No Real Concern

- AC Current Density less than 4 A/m^2
- AC voltage less than 15 VAC
- **DC** Current Density averages around 2.5 A/m^2

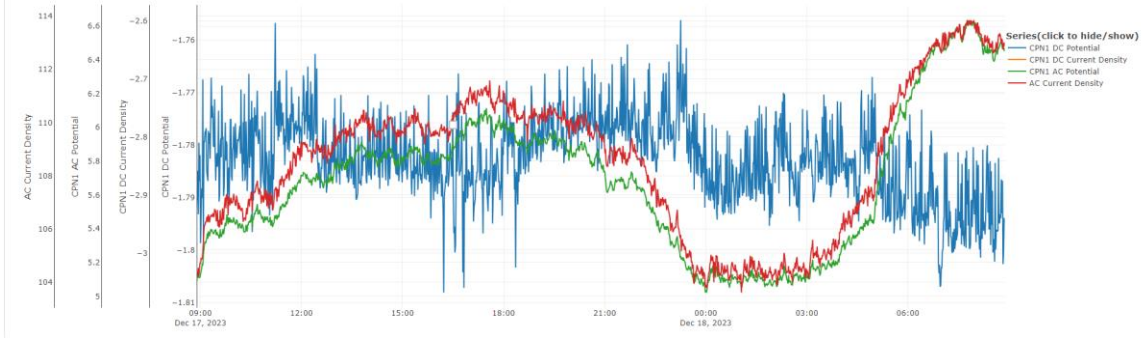


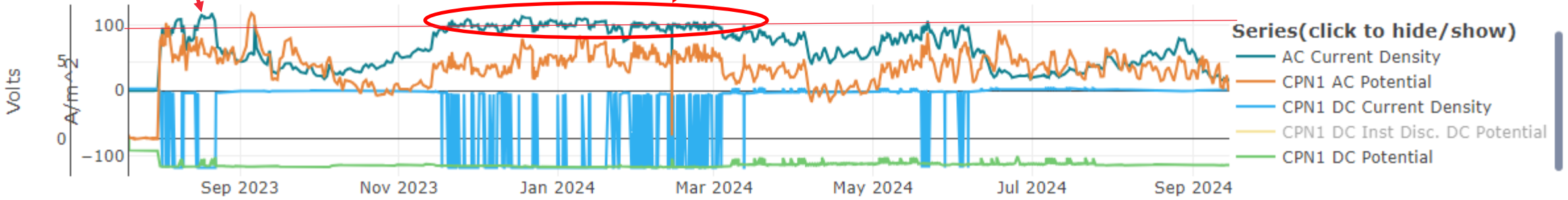
L-1300 RDL#2

- RDL#2 Riverside Drive
  - 6/2/2023 – 7:49 am – 10.1 VAC

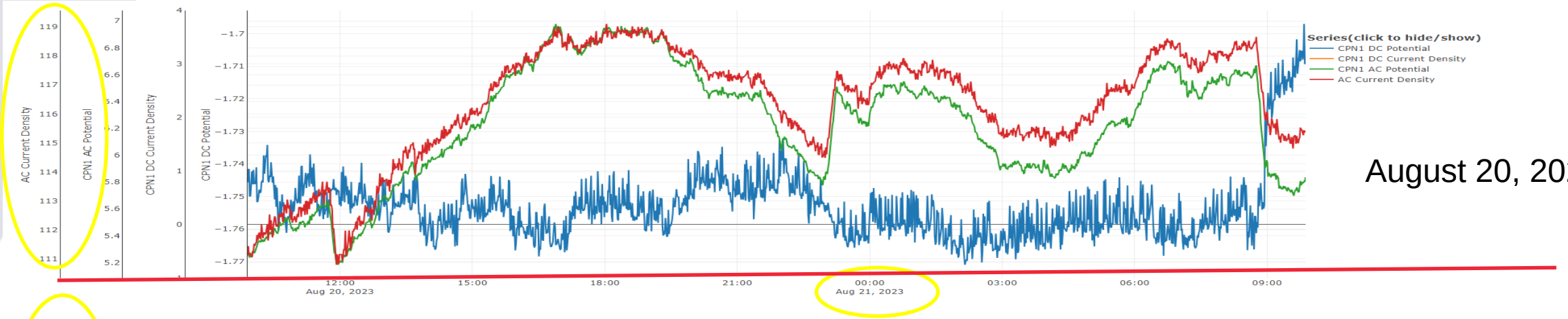
No Real Concern

- AC Current Density over 100 A/m^2
- AC voltage less than 15 VAC

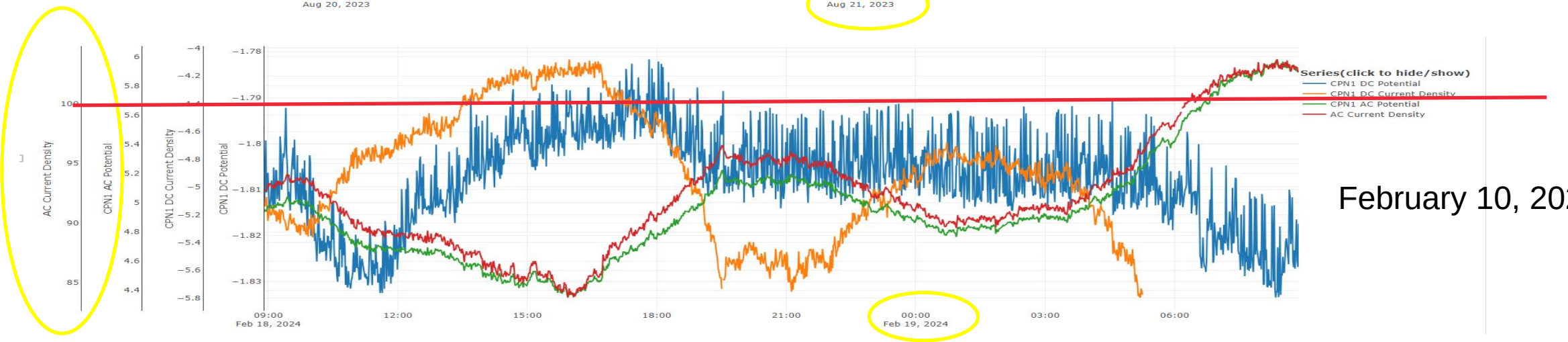




L-1300 RDL#2



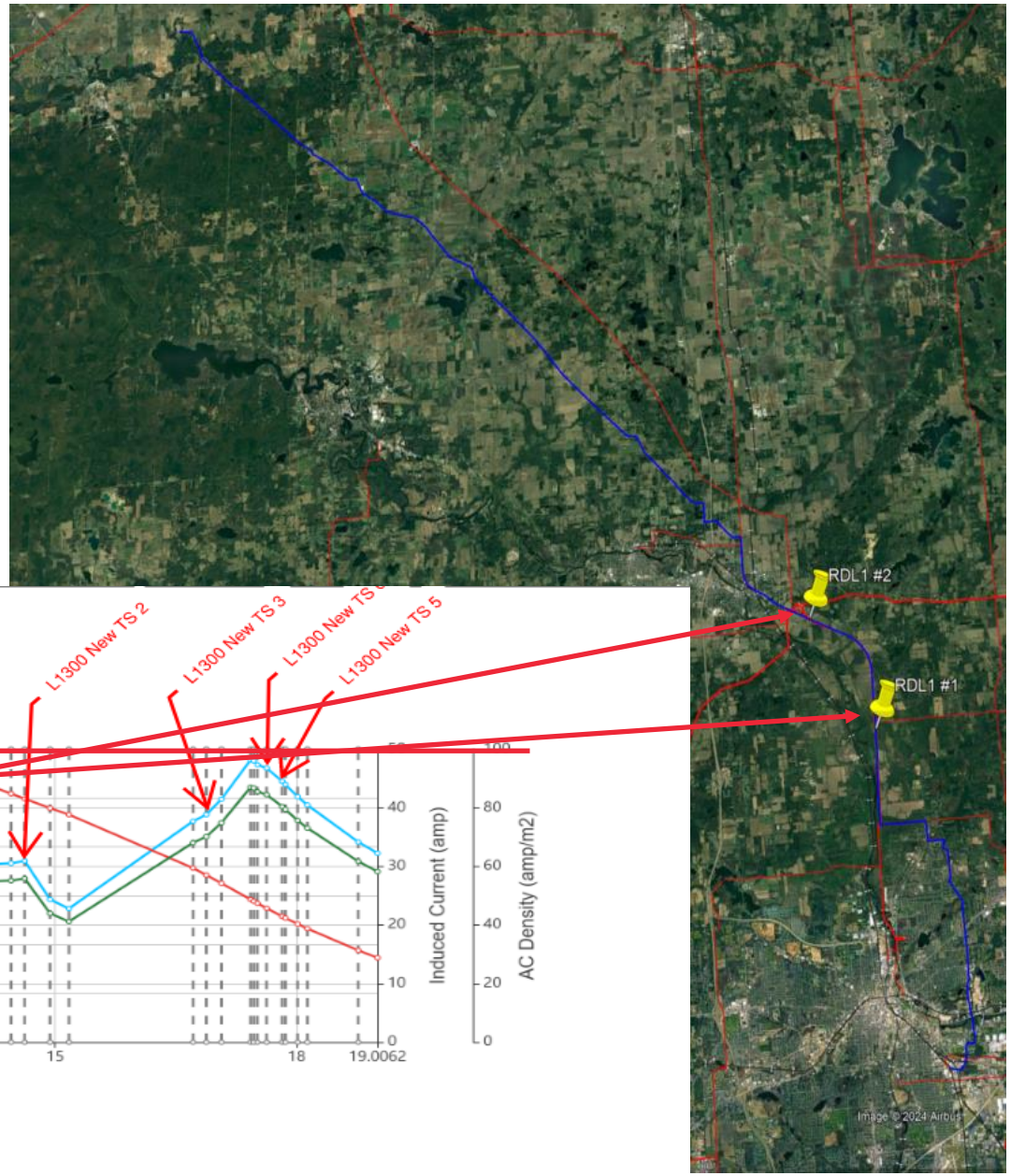
August 20, 2023

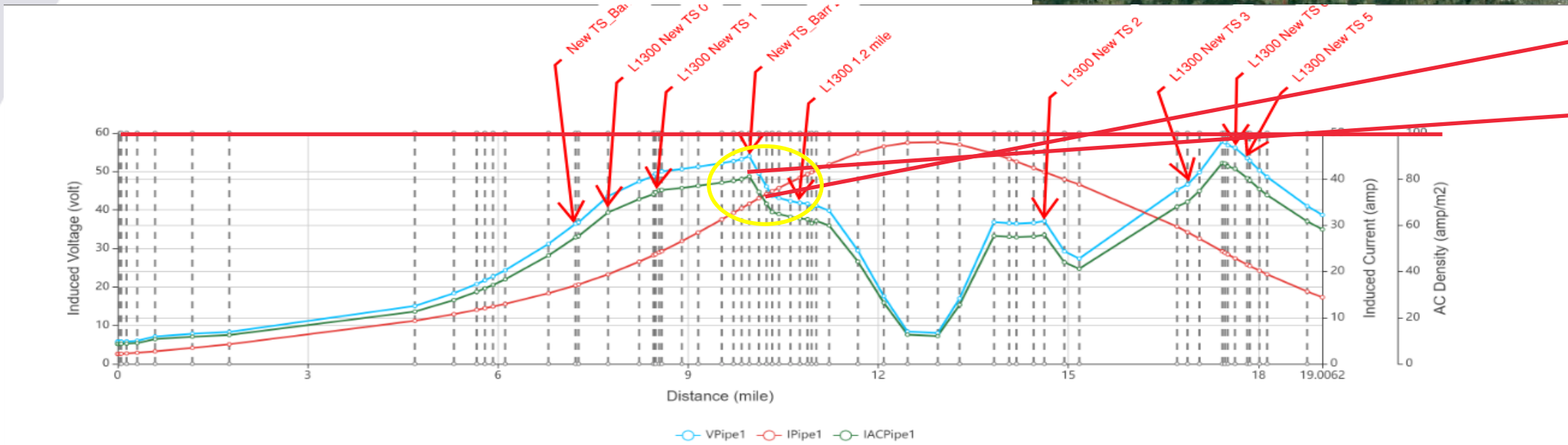


February 10, 2024

L-1300

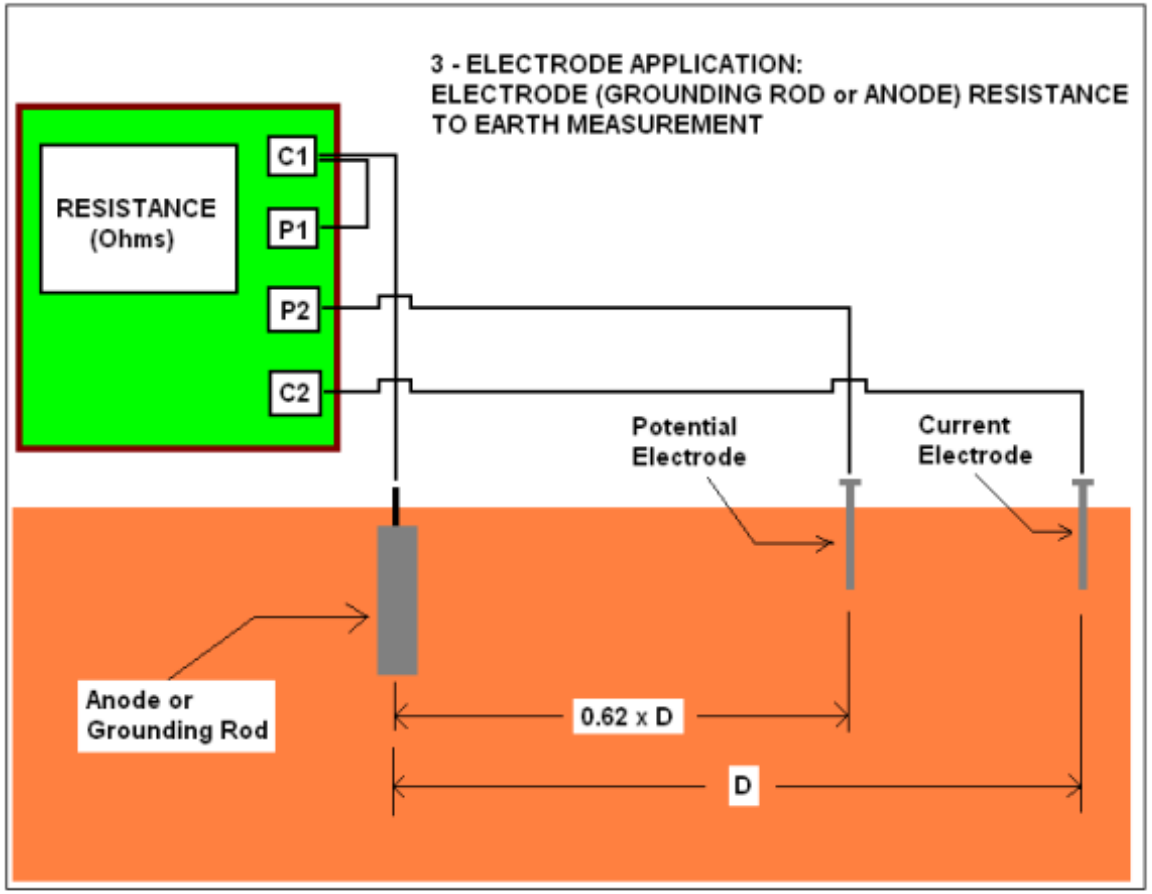
- First Model (PRCI)
  - Zero is South
  - Some Soil res included (5', 10' & 15')
  - Model shows peaks
    - 90 VAC – Is this real?
  - Need more inputs
    - Coating Quality
    - Real Pipeline Data
      - AC Voltages
      - DC Potentials
      - Coupon Current Densities
        - AC - 1cm^2
        - DC – 10 cm^2





L-1300 Coating Quality Testing

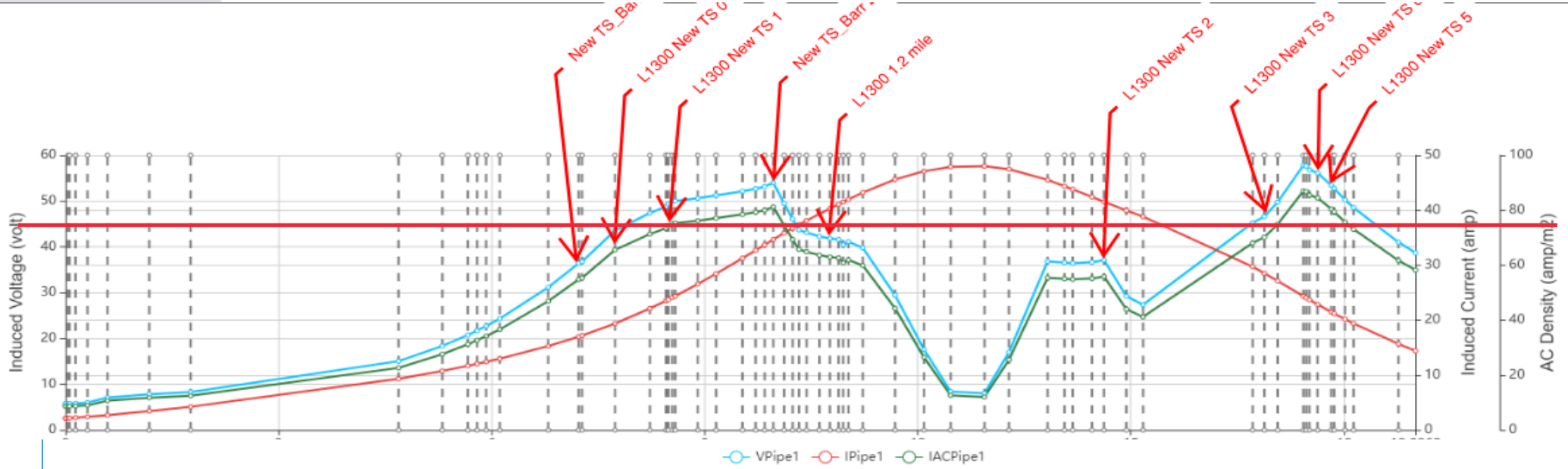
Measurement Ref #	Line	Measured R (ohm)	Conductance (S)2	OD (in)
1	1300-12"	0.88	1.1	12.75
2	1300-12"	0.33	3.0	12.75
3	1300-12"	1.03	1.0	12.75
4a	1300-12"	0.55	1.8	12.75
4b	1300-12"	0.41	2.4	12.75
5	1300-12"	1.18	0.8	12.75
6	1300-12"	1.01	1.0	12.75
21	1300-12"	0.92	1.1	12.75
7	1800-20"	5.75	0.2	20
8	1800-20"	5.23	0.2	20
9	1800-20"	6.02	0.2	20
10	1800-20"	4.54	0.2	20
11	1800-20"	5.25	0.2	20
12a	1800-20"	0.96	1.0	20
12b	1800-20"	1.11	0.9	20
13	1800-20"	5.04	0.2	20
14	1800-20"		#DIV/0!	20
15	1800-20"	0.93	1.1	20
16	1800-20"	2.37	0.4	20
17	1800-20"	3.21	0.3	20
18	1800-20"	1.55	0.6	20
19	1800-20"	0.11	9.1	20
20	1800-20"	0.04	25.0	20



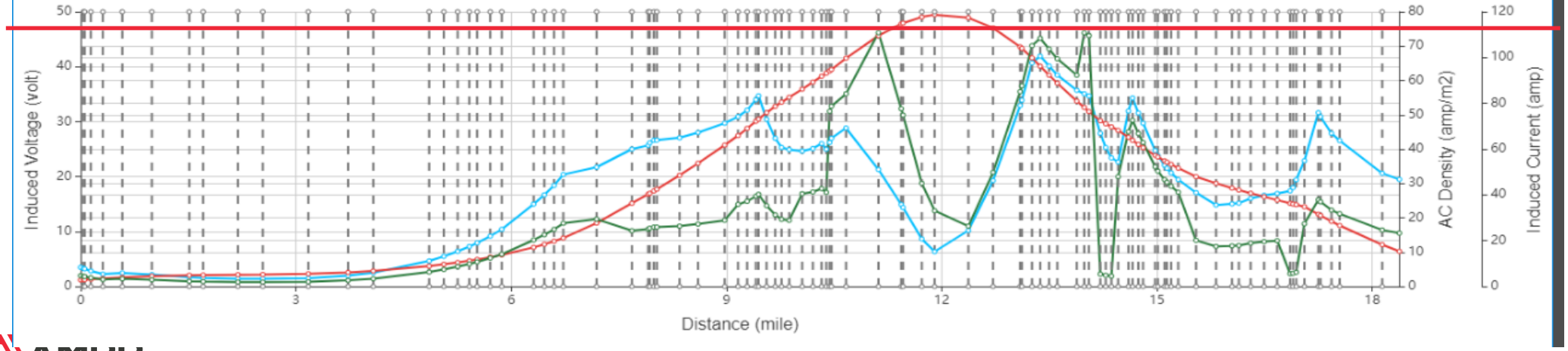
Fall to Earth Resistance Testing

Figure 3

L-1300 Updated Model with New Soil Res Data

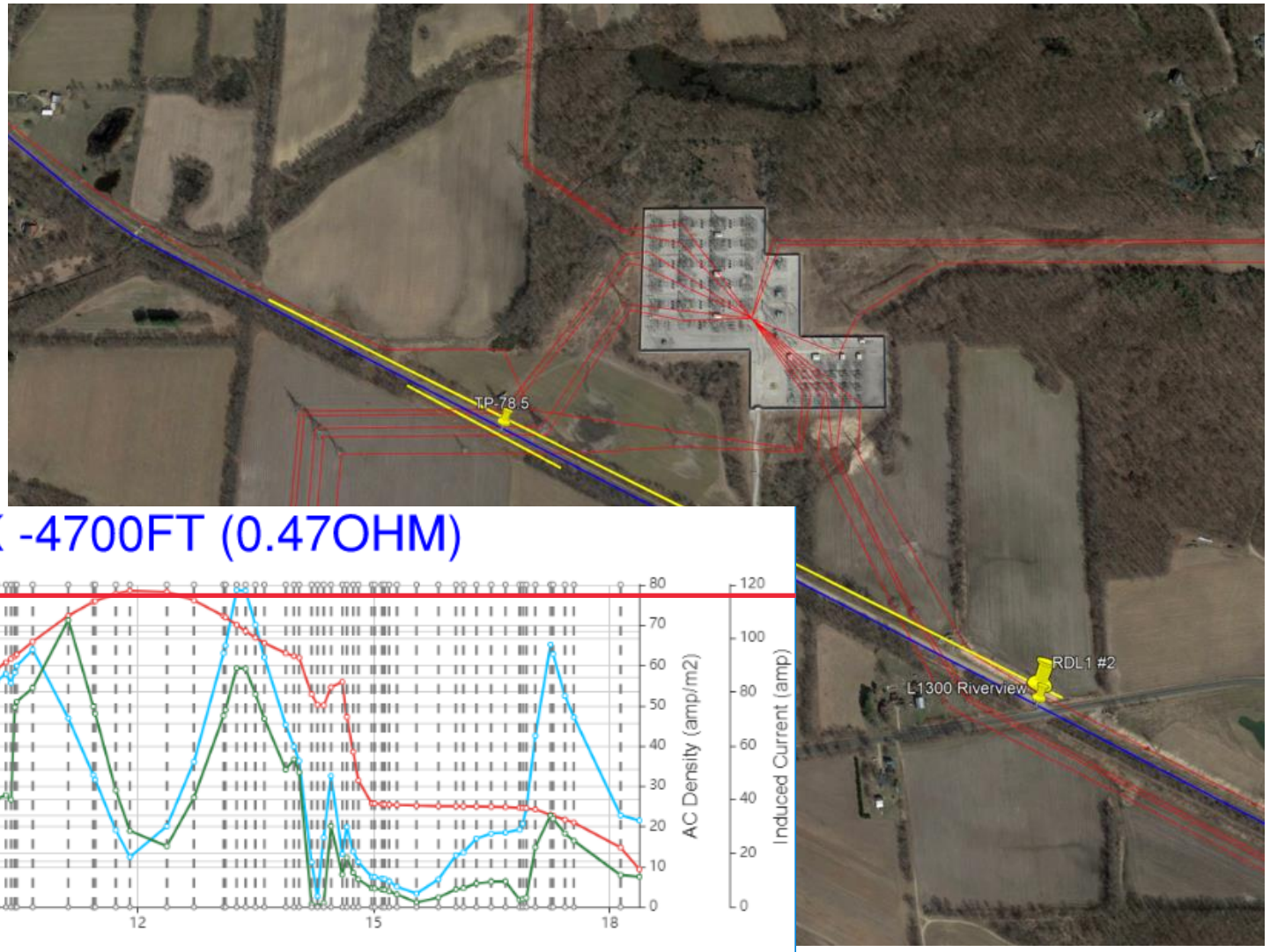


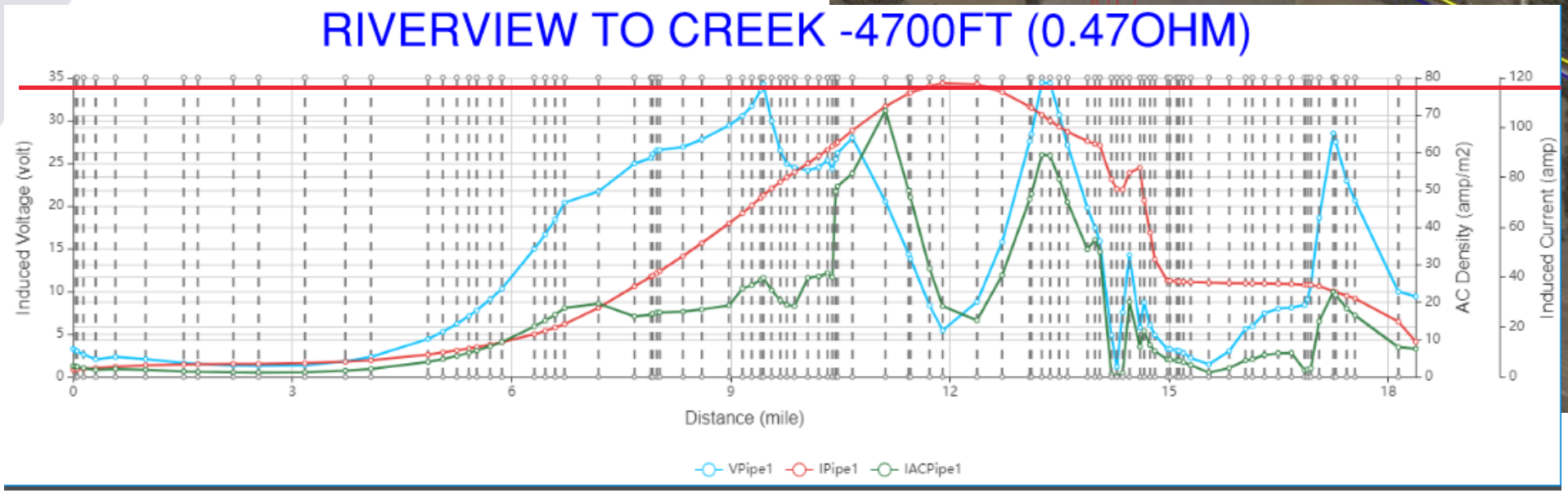
NO MITIGATION (UPDATED COATING RESISTANCE)



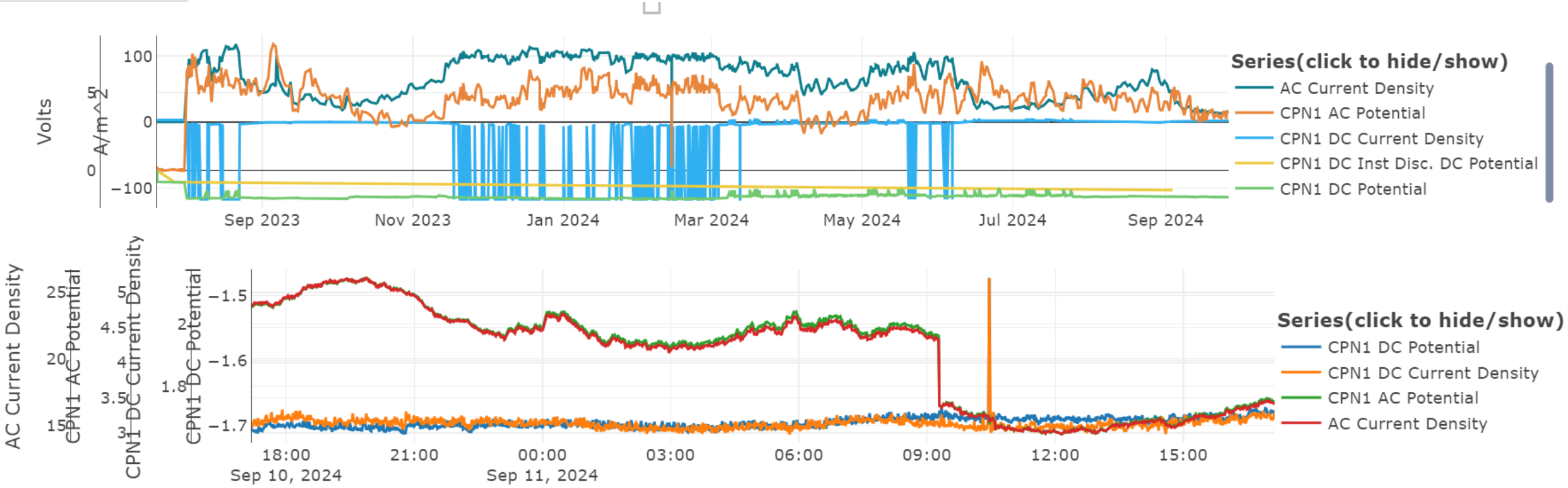
L-1300

- 3rd Model
  - 4700’ of 2/0 Copper
  - Might need more mitigation, but we got mitigation installed with our time frame
  - Now-
    - Monitor and add more mitigation as needed.
    - The clock has started again.





L-1300



25% Reduction in current density

L-1300 Summary and Moving Forward

- It is hard to believe that a 1960's era pipeline is experiencing this high of AC current density.
  - This is old coating
  - Very poor coating
    - Hard to cathodically protect
    - Pipe to Earth resistance confirms coating quality
  - ILI and integrity digs are not showing external metal loss due to AC corrosion
- Issue with measurement
  - Coupon size
    - 1 cm^2
      - Is there really this small of holiday on this pipe where AC current is discharging?

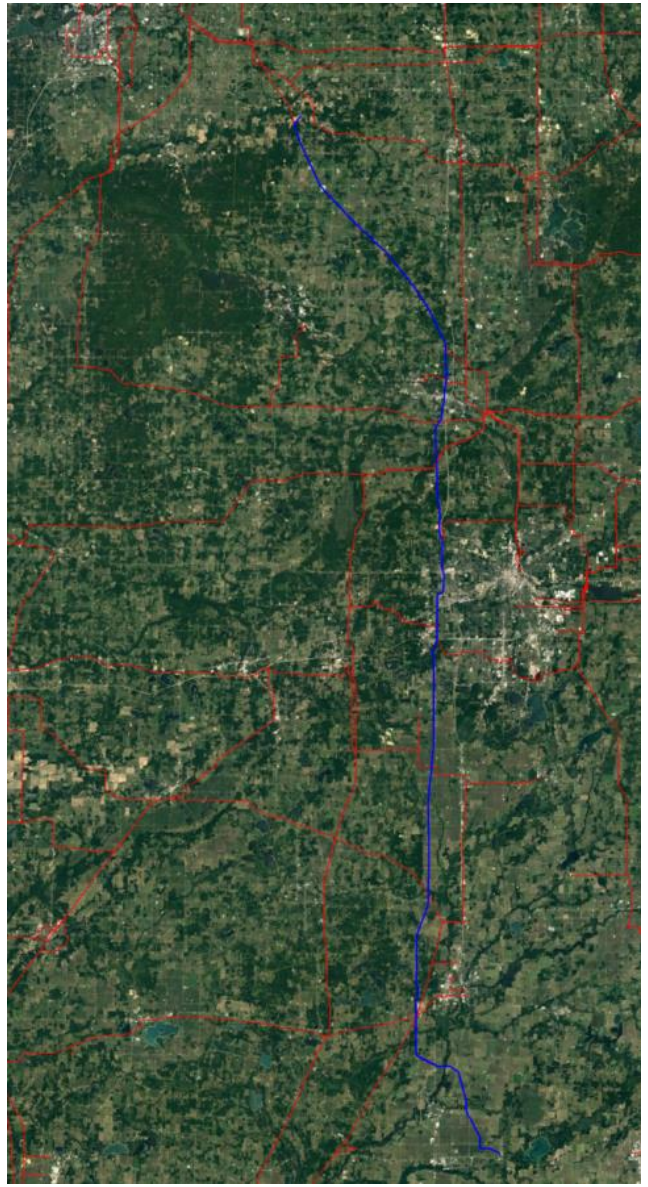
- Moving forward:
  - Monitor AC current densities with a 10 cm^2 coupon.
  - Continue to monitor
  - Consider increases to HVAC loads

Timeline

- **Identified Problem in September of 2023**
- **Installed and Commissioned in September of 2024**

L-1800

- L-1800 (1967 to 1968) High AC Voltages
  - Diameter - 20”
  - Length - 70 miles
  - Coating – Tar with Asbestos Felt
    - White Pigeon to Plainwell-Field coated and wrapped with Allied Quick Drying Primer No. 1122, Allied AA Fully Plasticized Pipeline Enamel and Phillip Carey Co., No. 15 Tar Saturated Glass Reinforced and Perforated Asbestos Felt.
    - Plainwell to 30th St Valve Site-Reilly Tar & Chemical, #122 Quick Dry Primer &#230-A Pipeline Enamel, Phillip Carey 15# Tar Saturated, Glass Reinforced, Perforated, Asbestos Pipeline Felt.



L-1800 - Identification of Issue

- Annual Surveys
- Data loggers
- CIS surveys
- Remote monitors (RMU)

20.817 VAC at 138th Ave on 4/19/2024

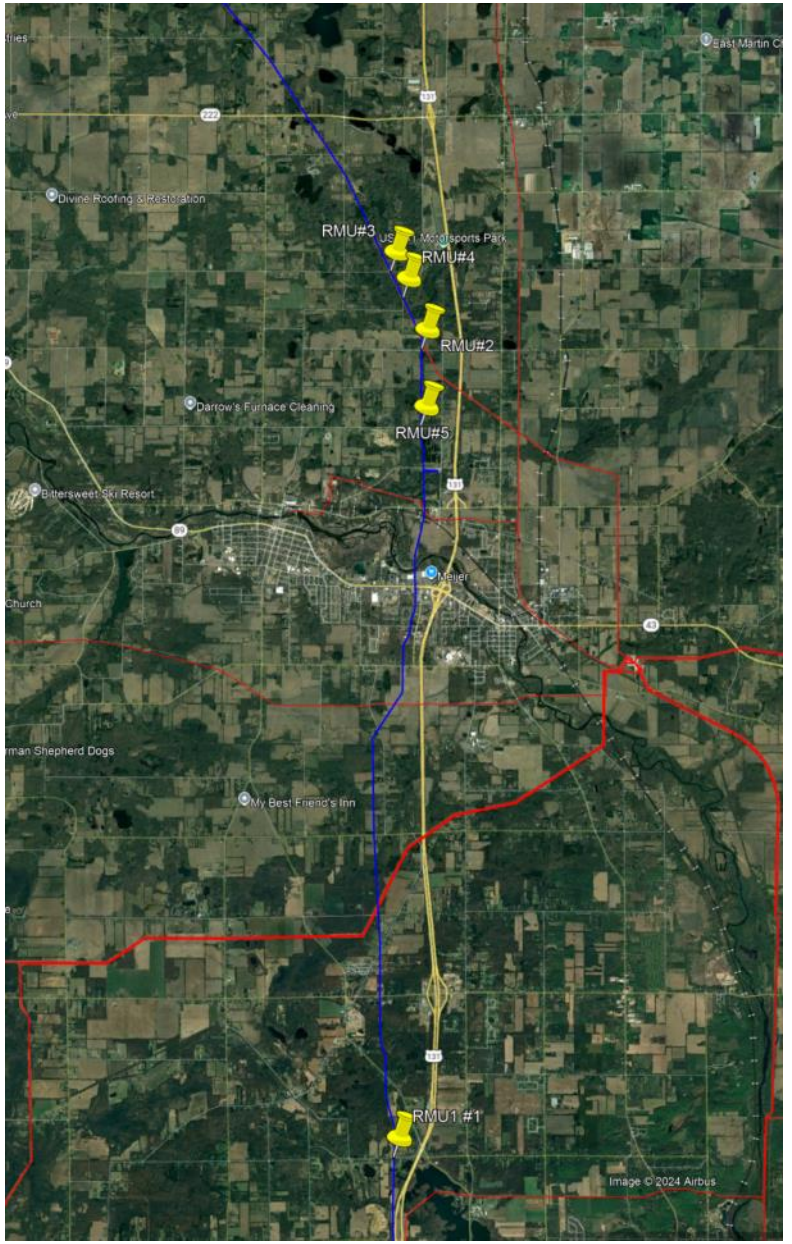
WORK HQ: OVERISEL
DIVISION: PIPELINE
FACILITY Code: LINE: 1800-3

LINE: 1800-3	132.000	134TH AVE	42.66623700	-85.83337783	4/19/2024 08:02:28 AM	-1.674	-1.128	10.915	JLP	owl 2018-0739
LINE: 1800-3	134.000	30TH ST W/CASING	42.67537616	-85.83969033	4/19/2024 08:01:59 AM	-1.699	-1.158	13.211	JLP	
LINE: 1800-3	135.000	136TH AVE	42.68116216	-85.84277650	4/19/2024 07:57:50 AM	-1.612	-1.182	13.046	JLP	
LINE: 1800-3	136.000	138TH AVE	42.69550466	-85.84688316	4/19/2024 07:52:44 AM	-1.730	-1.164	20.817	JLP	
LINE: 1800-3	137.000	INSULATOR @ 30TH ST VS	42.70137950	-85.84062816	4/19/2024 07:48:04 AM	-1.619	-1.151	12.616	JLP	

FACILITY Code: LINE: 1800-3 Records: 5

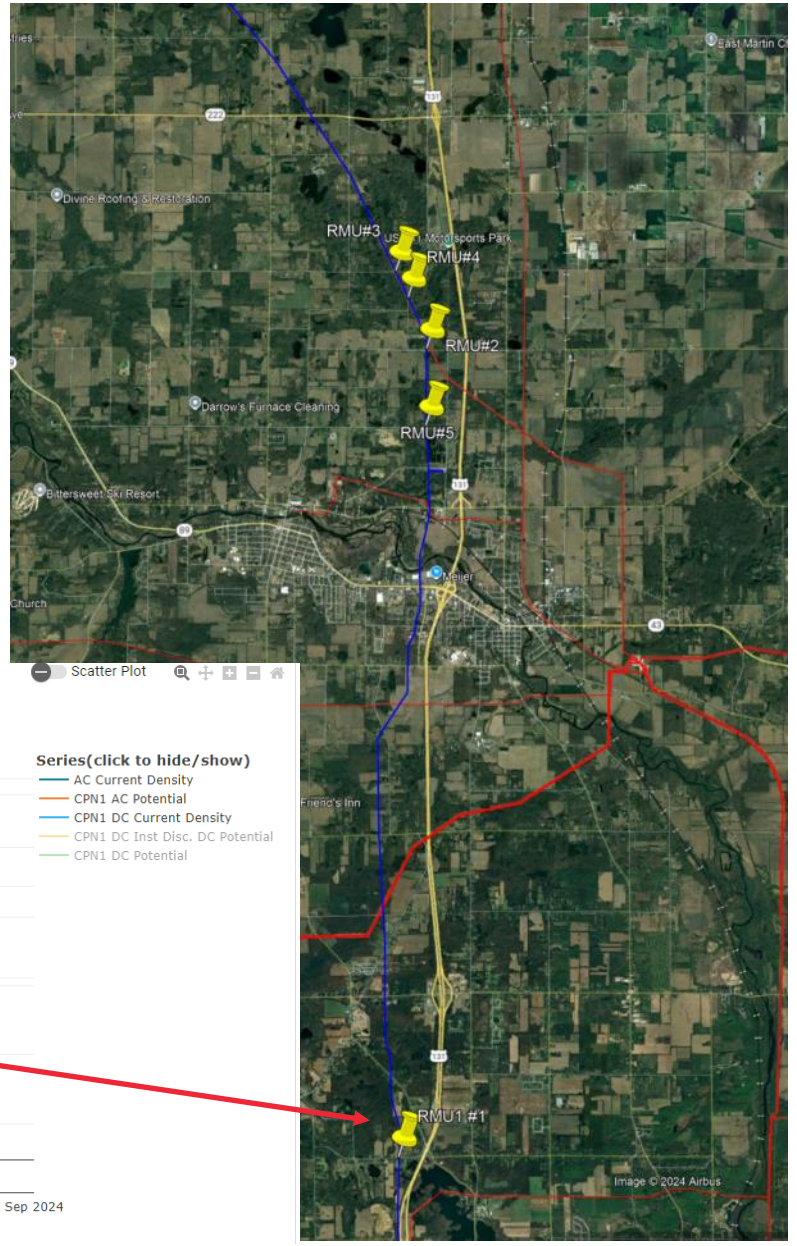
L-1800

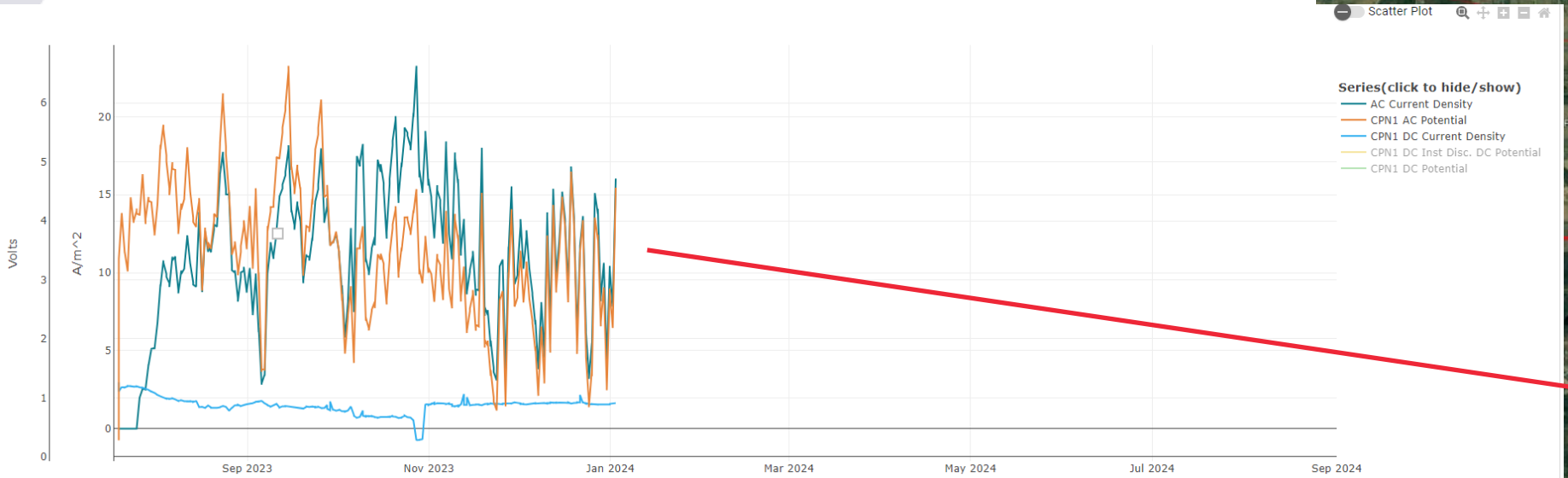
- AC Investigation Starts July of 2024
  - 3 months after annual survey
  - 5 RMU Data Loggers Installed in 2023



L-1800

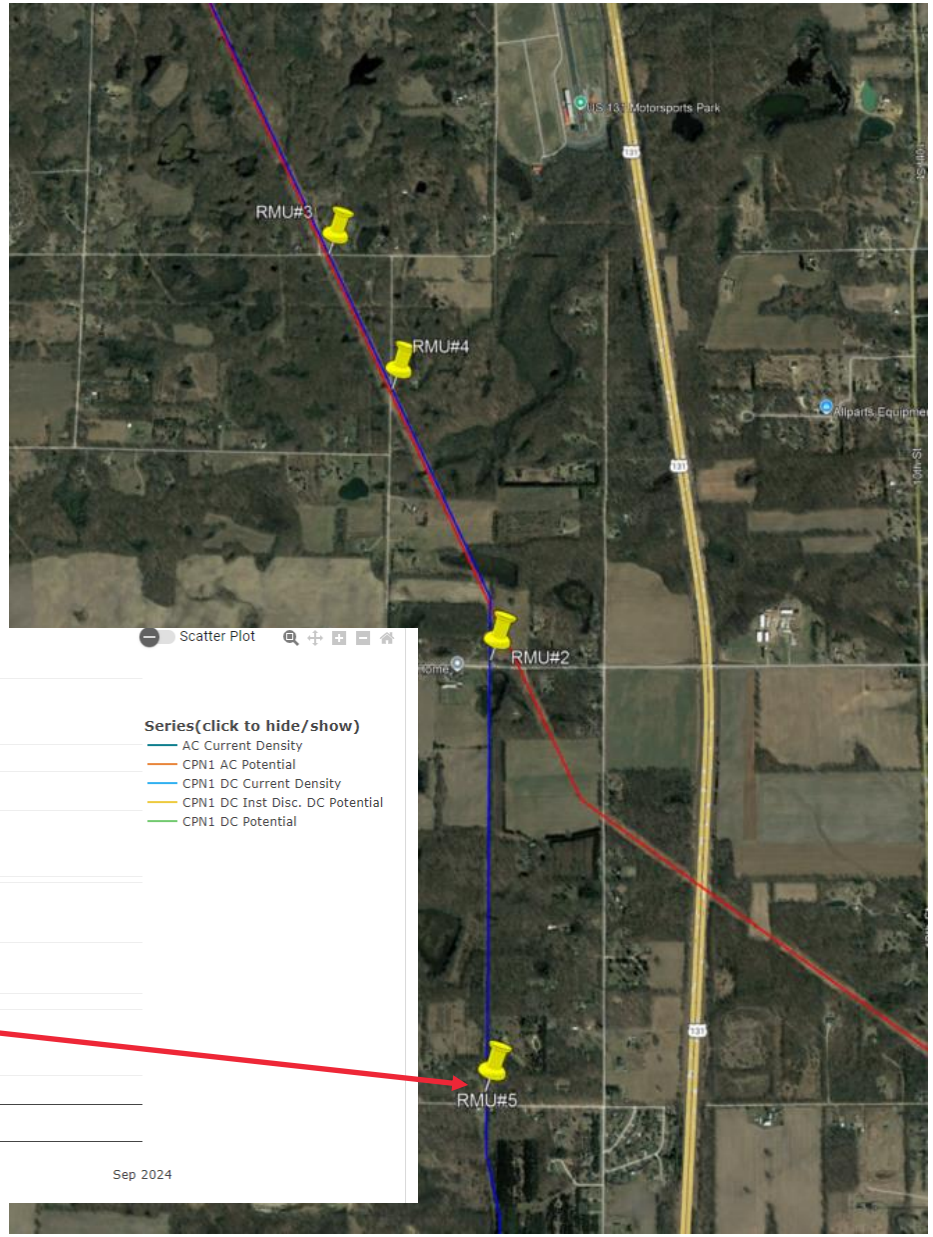
- AC Investigation Starts July of 2023
- RMU #1
  - Stopped working in Winter of 2024
  - Low AC Voltages
  - AC Current Densities 10 to 20 A/m^2
  - DC Current Densities over 1 A/m^2
- Continue to Monitor, but does not appear to be any real AC interferences.





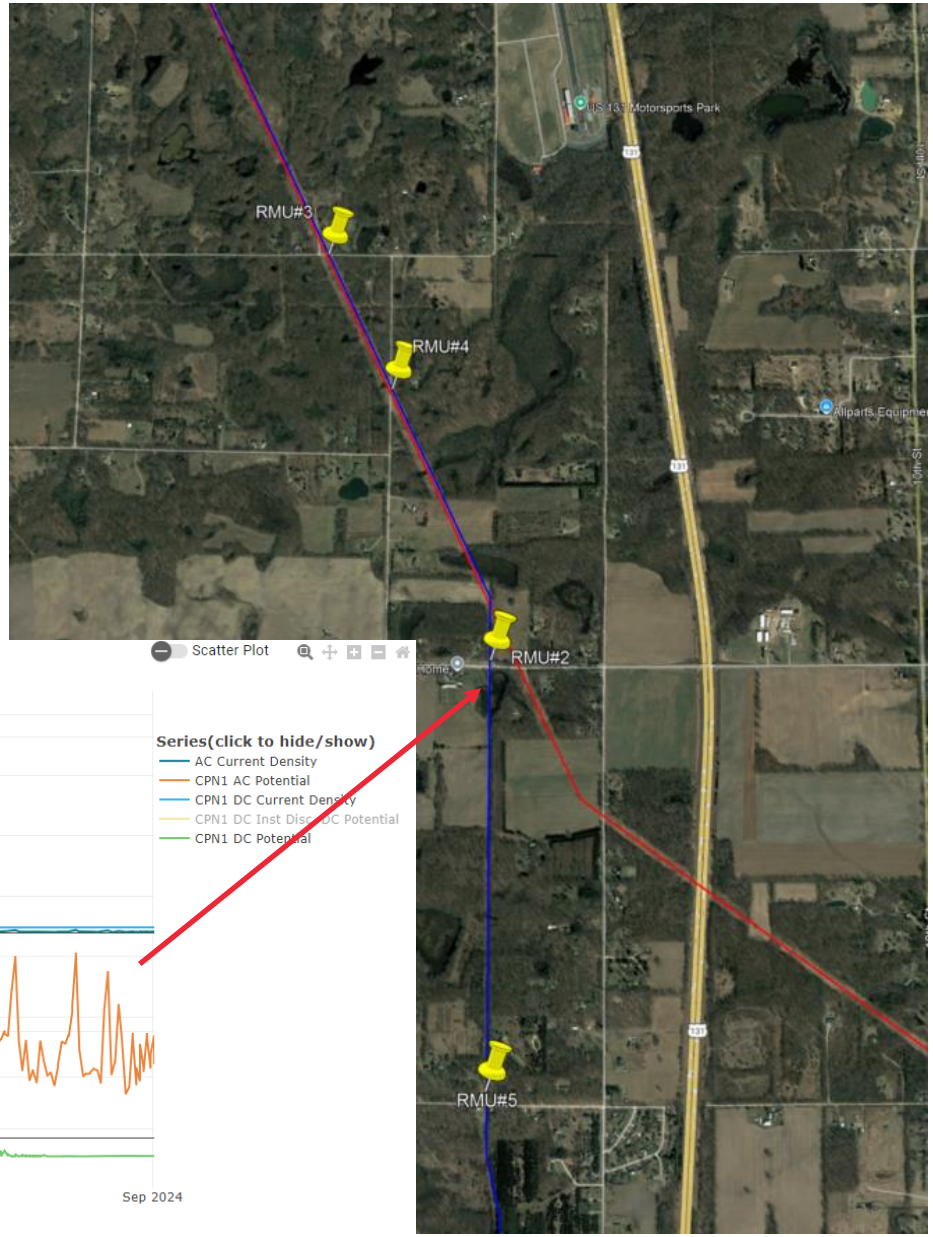
L-1800

- AC Investigation Starts July of 2023
- RMU #5
  - Stopped working in September of 2023
  - AC Voltages between 10 and 15
  - AC Current Densities very low
  - DC Current Densities over 2 A/m^2



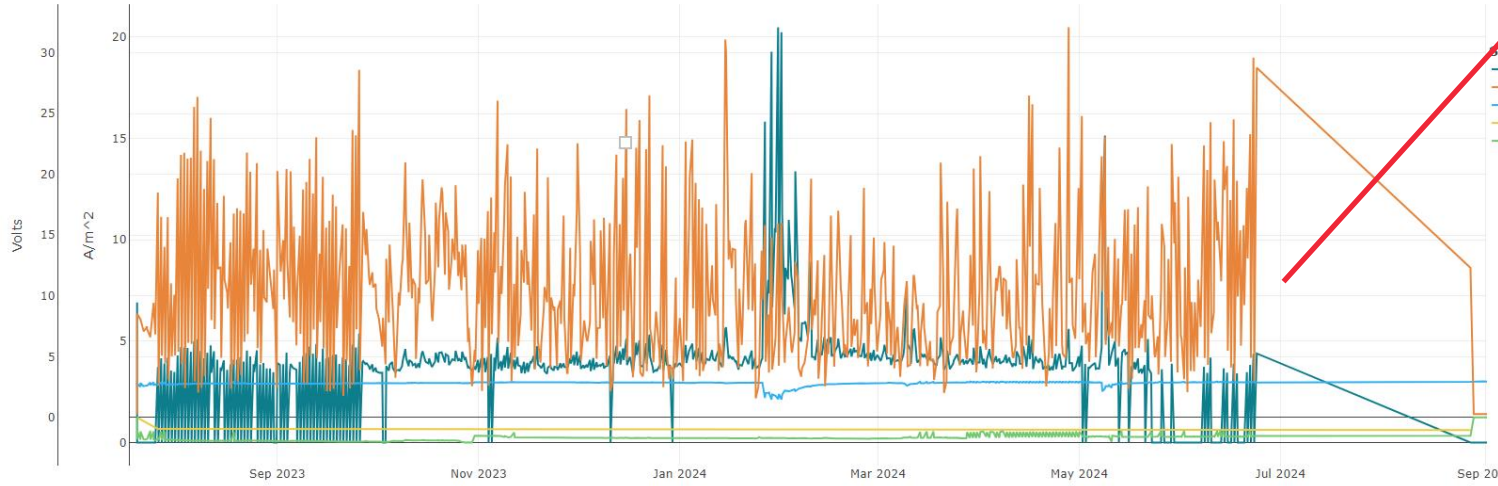
L-1800

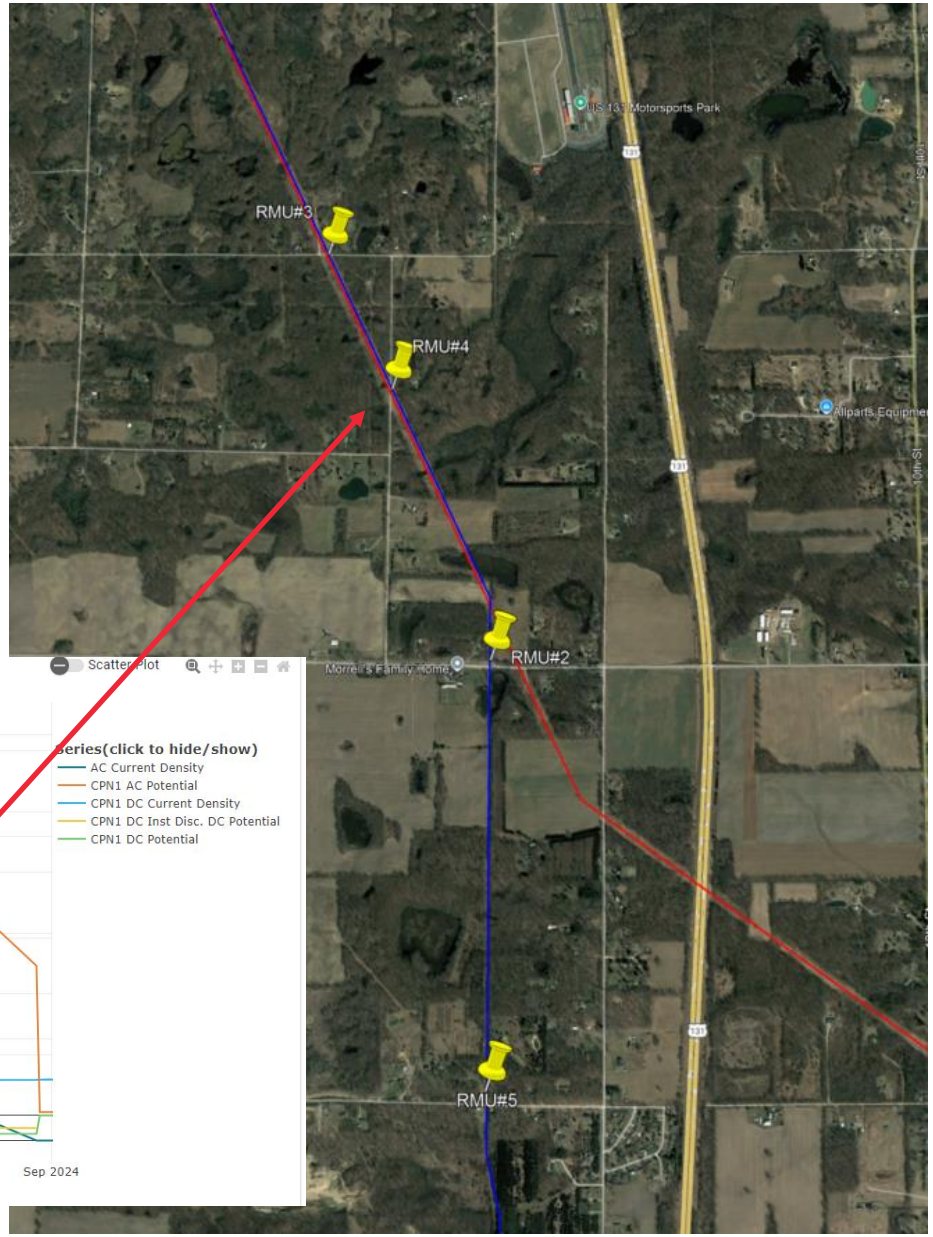
- AC Investigation Starts July of 2023
- RMU #2
  - AC Voltages 30+ VAC
  - AC Current Densities between 5 and 30 A/m^2
  - DC Current Densities over 2 A/m^2



L-1800

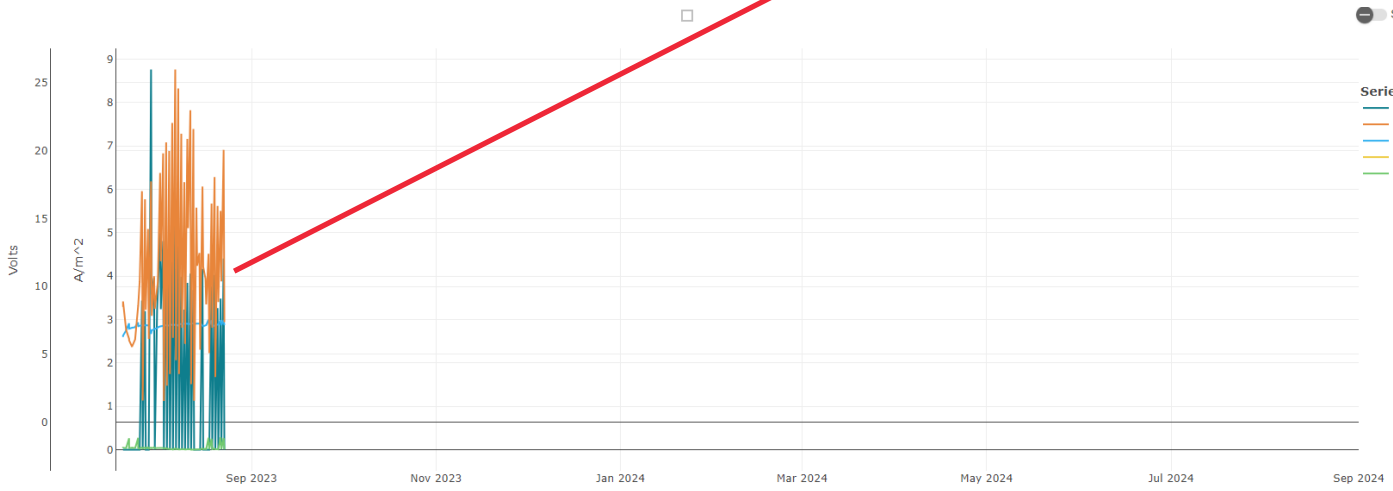
- AC Investigation Starts July of 2023
- RMU #4
  - AC Voltages between 5 and over 25 VAC
  - AC Current Densities between 5 and 15 A/m^2
  - DC Current Densities over 2 A/m^2

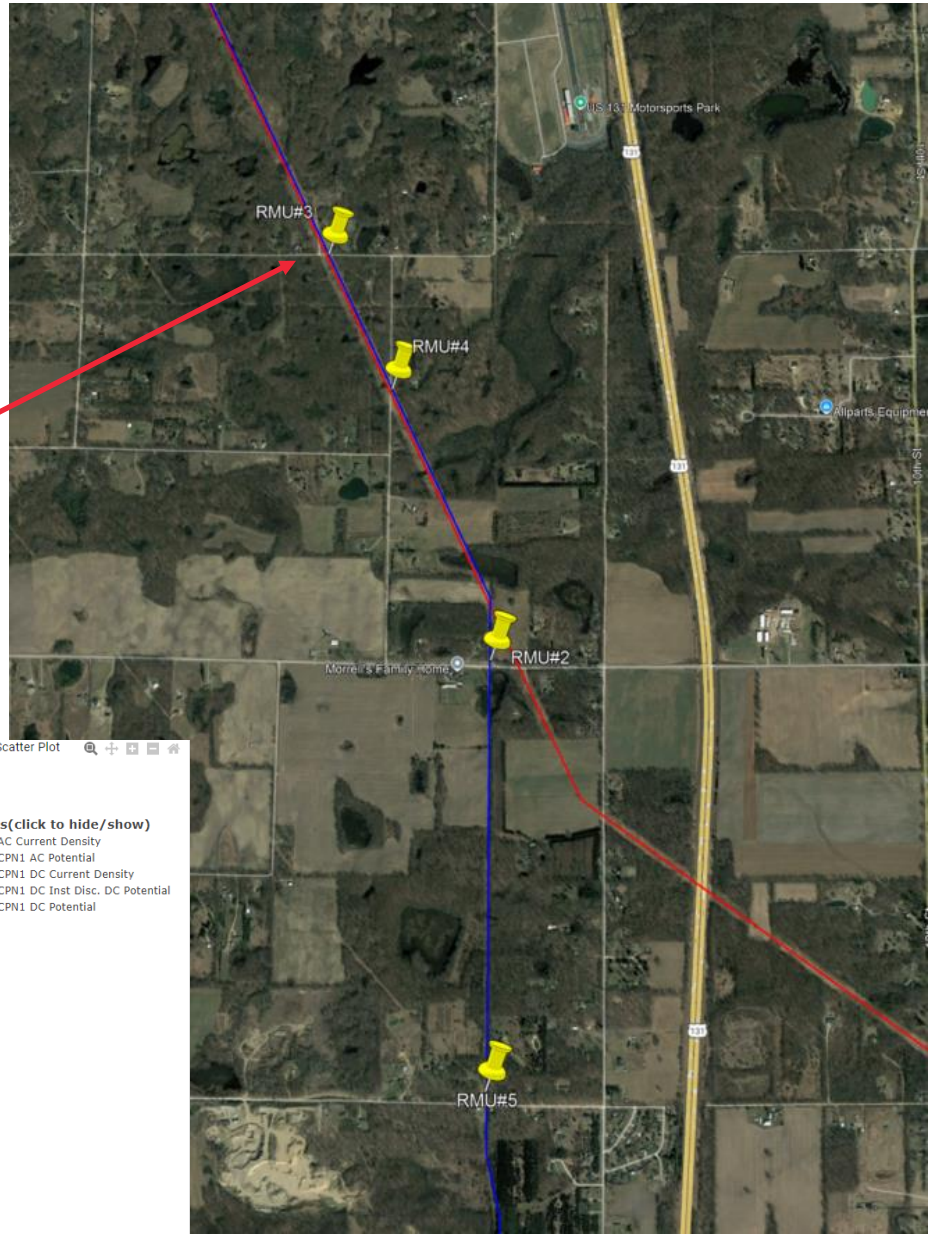




L-1800

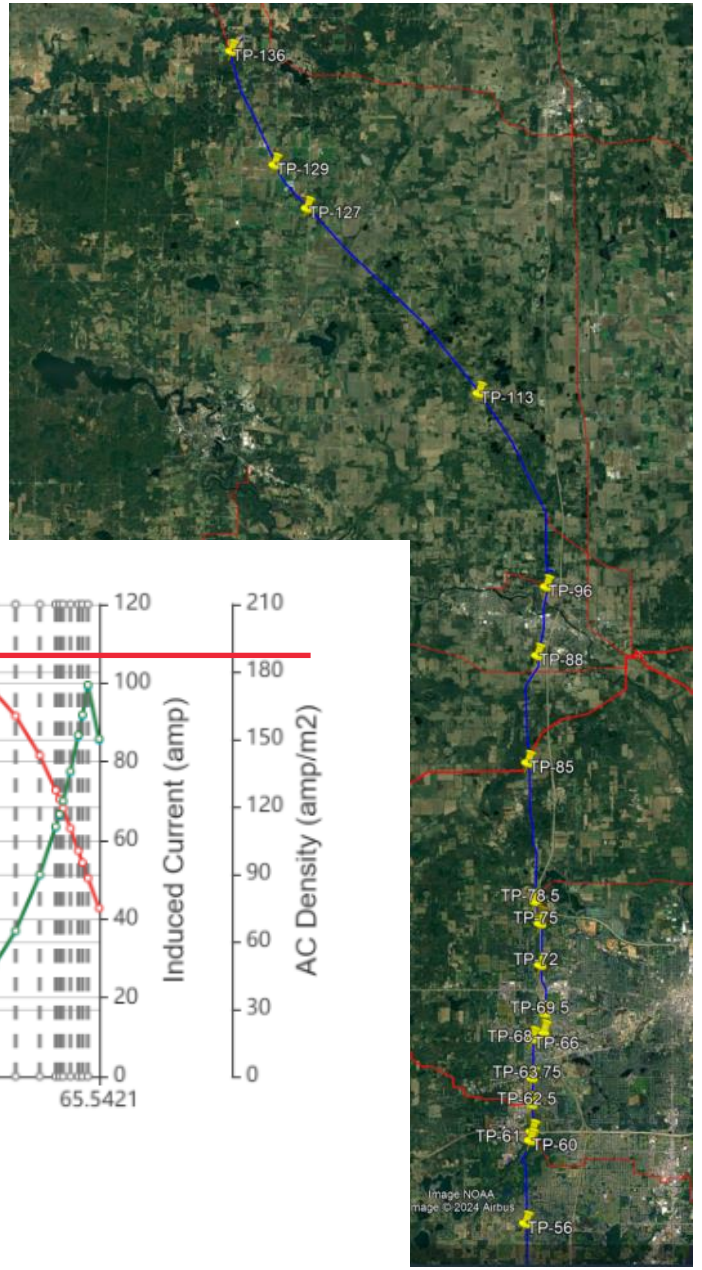
- AC Investigation Starts July of 2023
- RMU #3
  - Stopped before September of 2023
  - AC Voltages between 5 and over 25 VAC
  - AC Current Densities between 0 and 5 A/m^2
  - DC Current Densities over 2 A/m^2

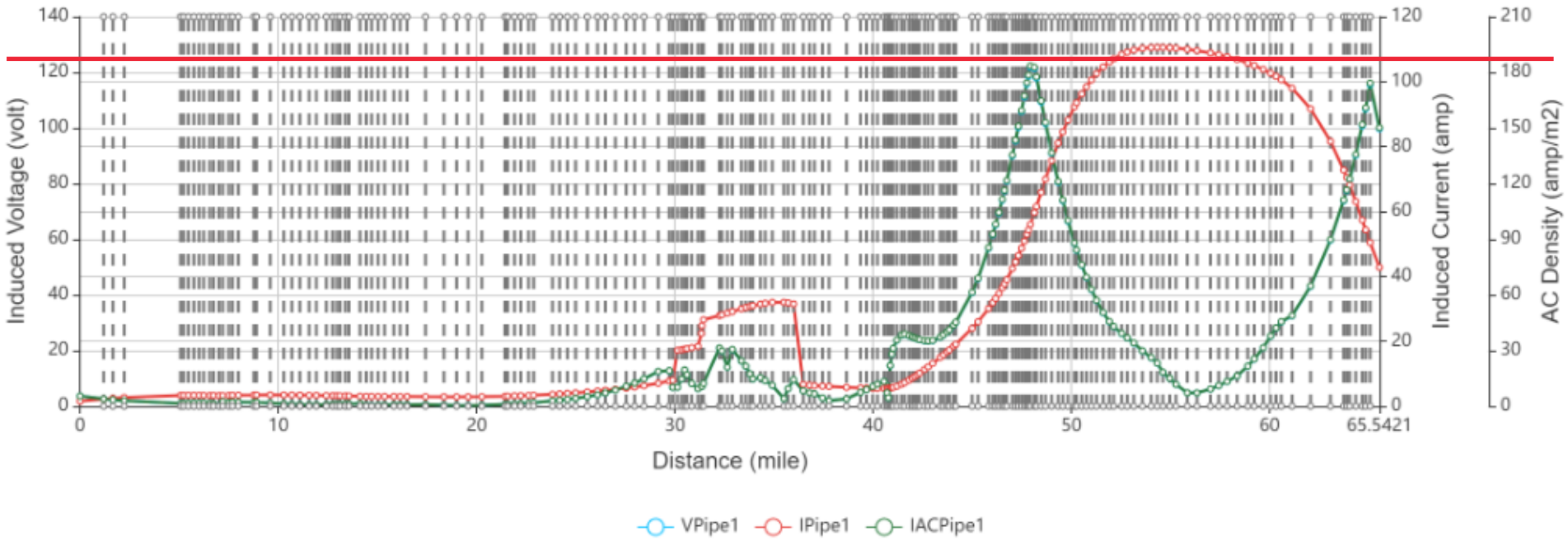




L-1800

- 1st model (PRCI)
  - Installed coupon test stations at peak locations
  - Monitored with data logger

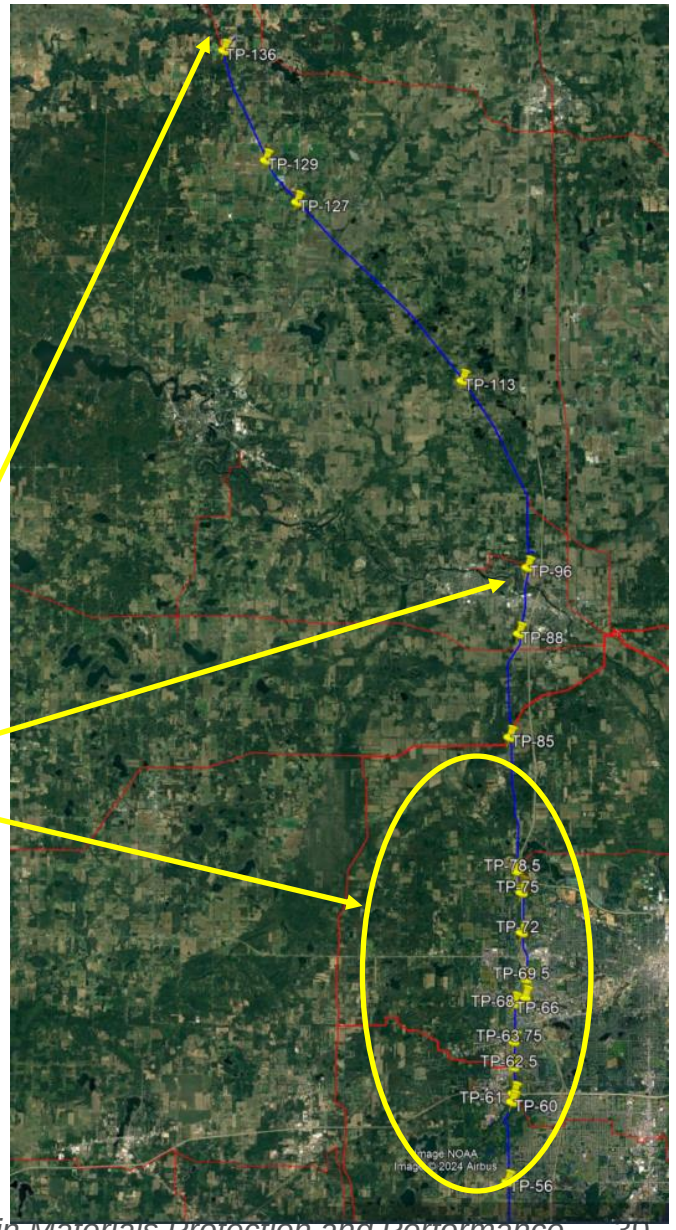




L-1800 Data Logger Data

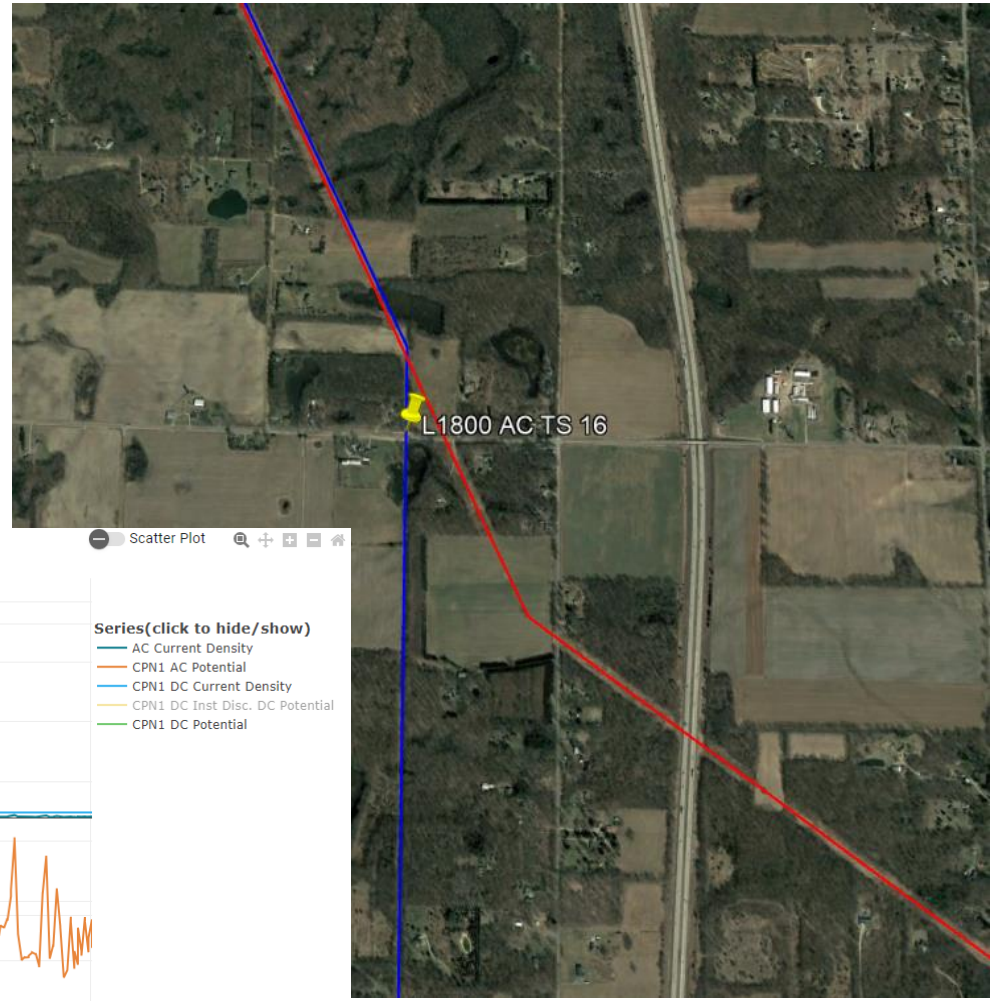
Data Logger Data

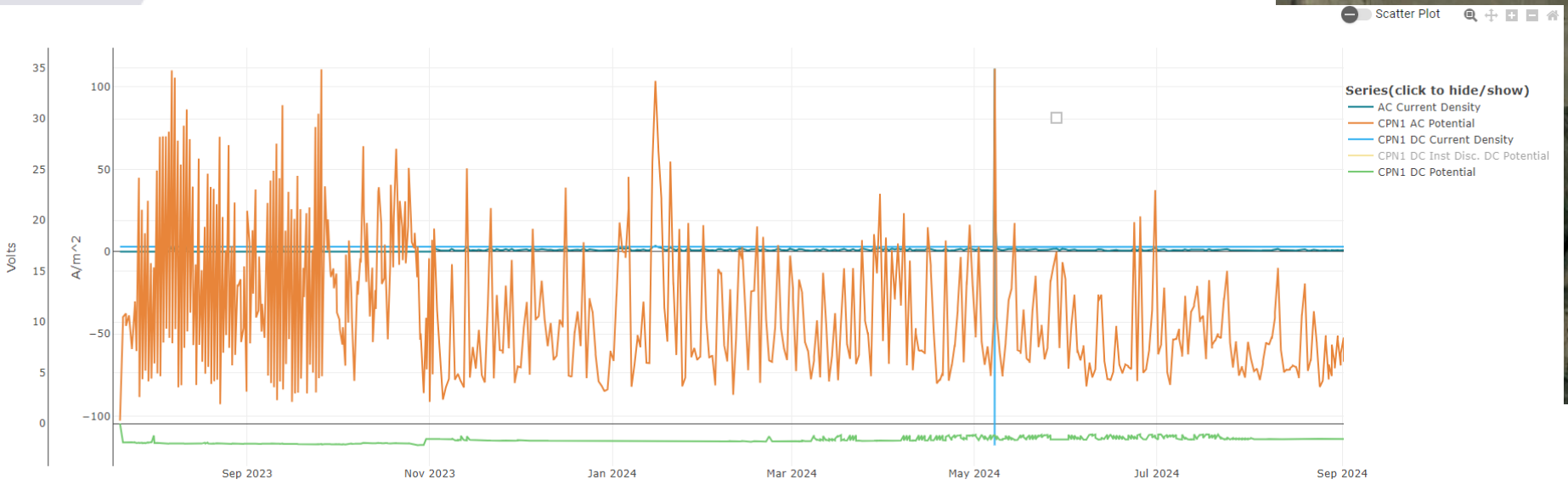
- The Southern portion of the line shows very little AC interference
- Pulled all southern data loggers
- Two locations show high AC voltages
  - Both where the pipeline and HVAC separate (North and South)



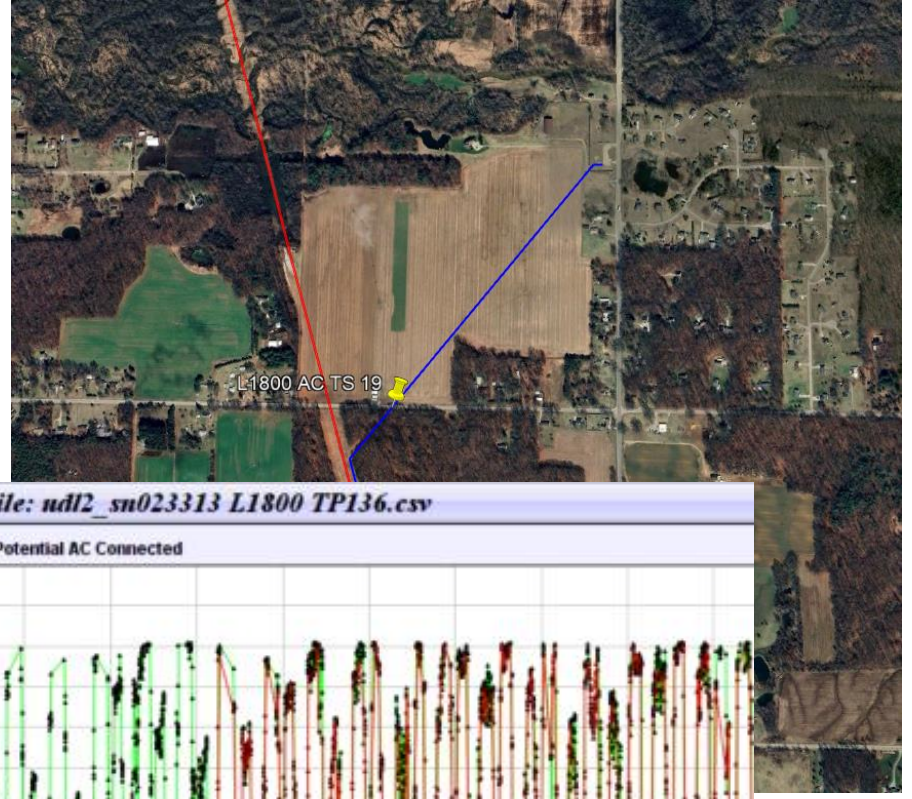
L-1800 Data Logger Data

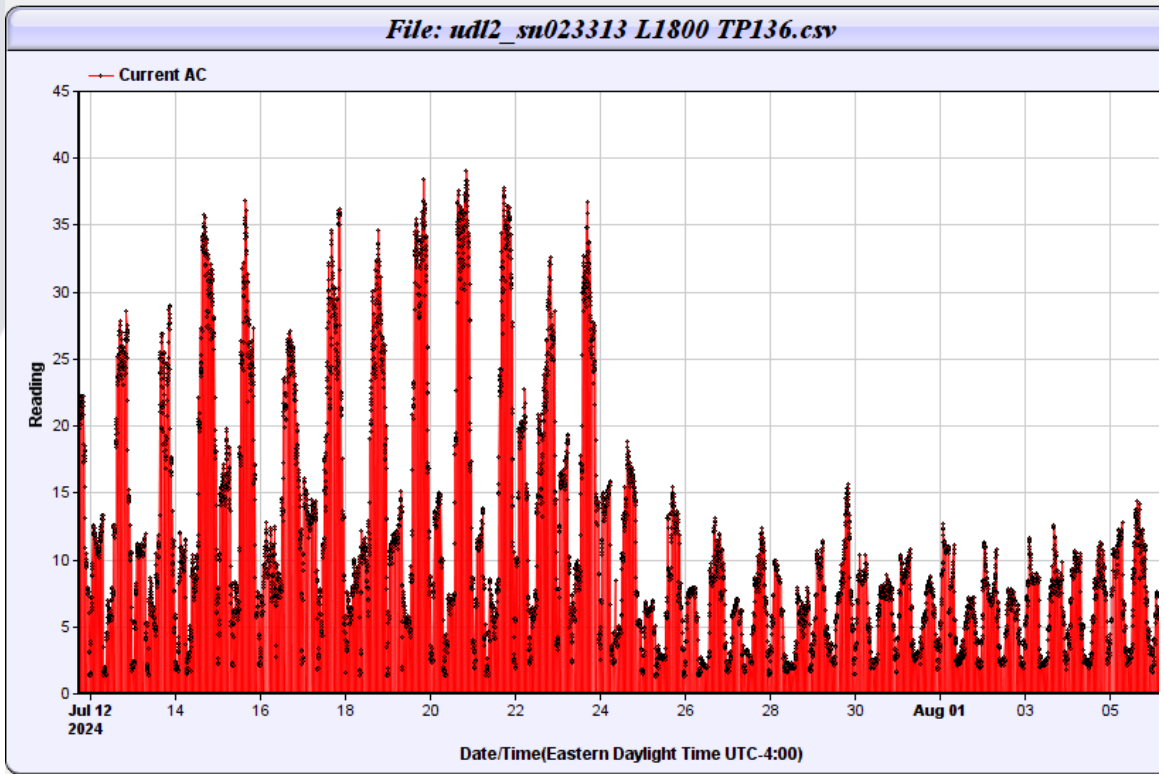
30+ VAC

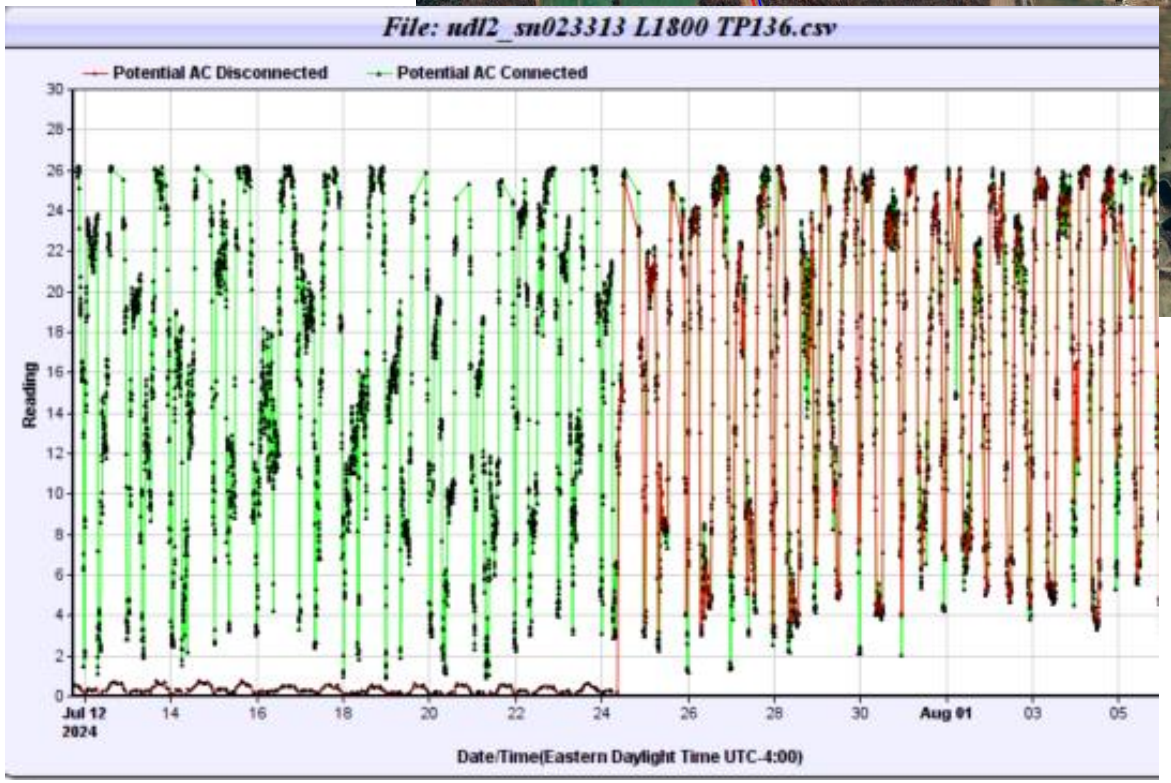




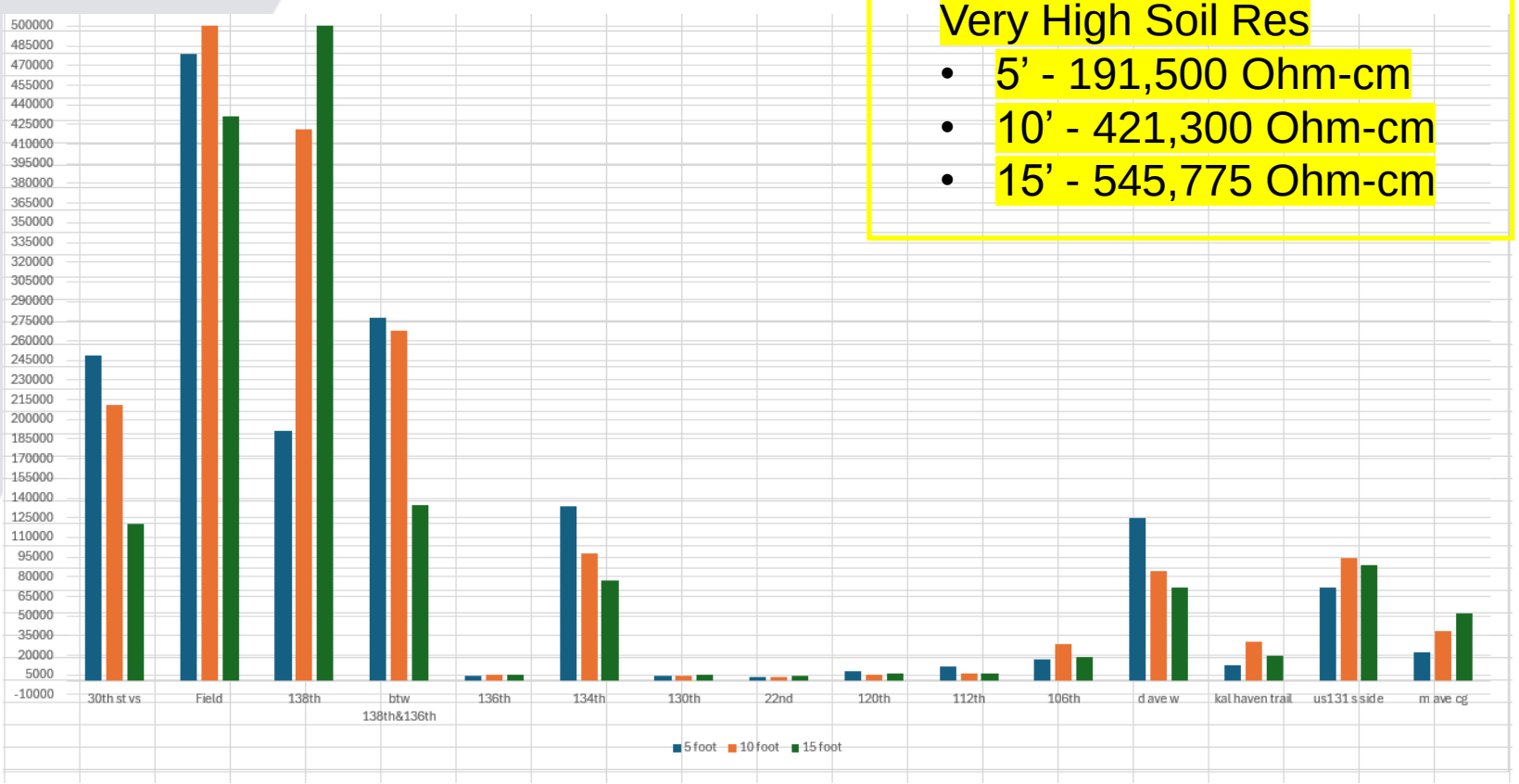
L-1800 Data Logger Data





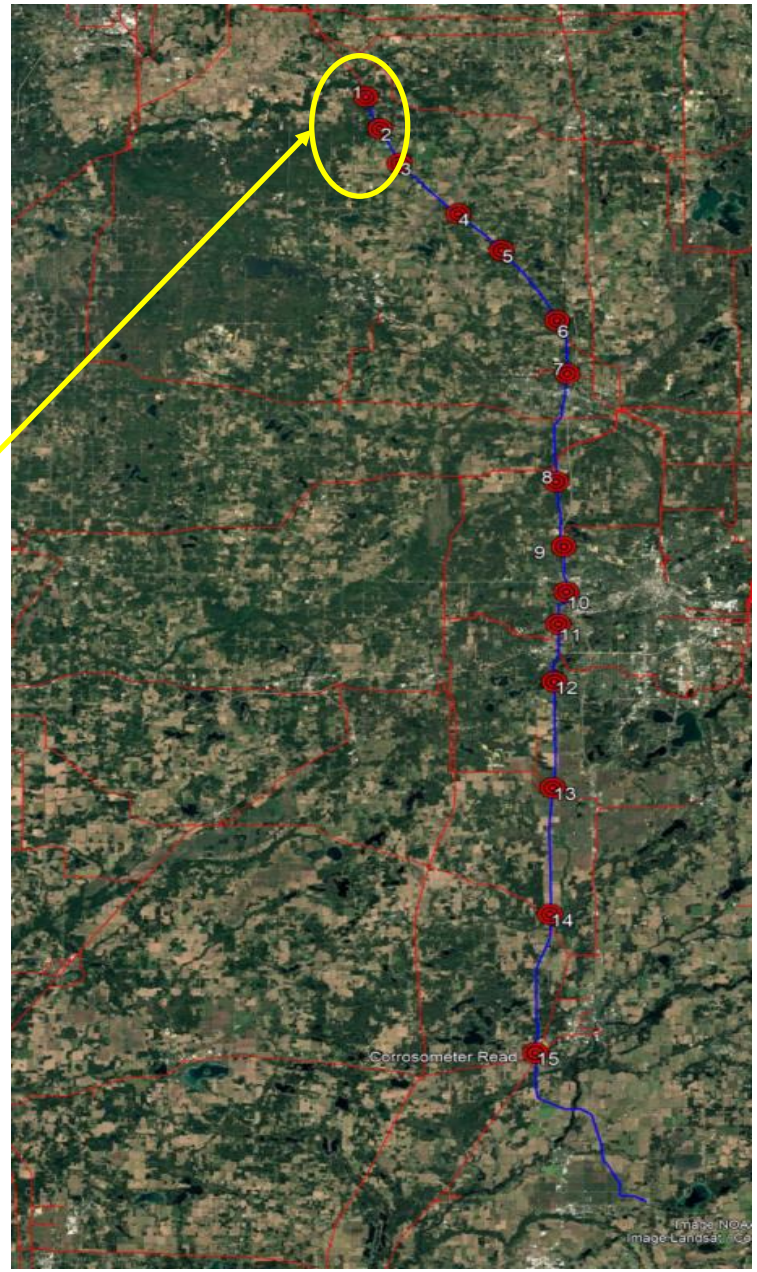


L-1800 Soil Resistivities

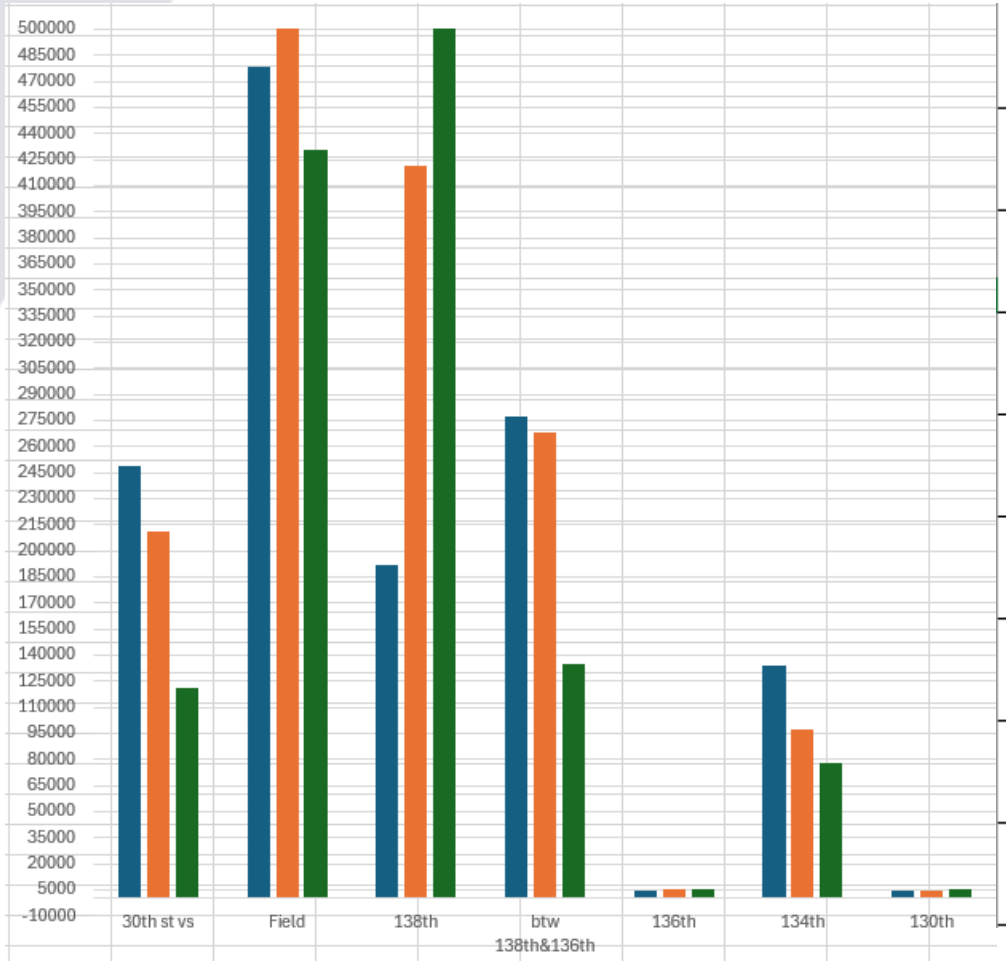


Very High Soil Res

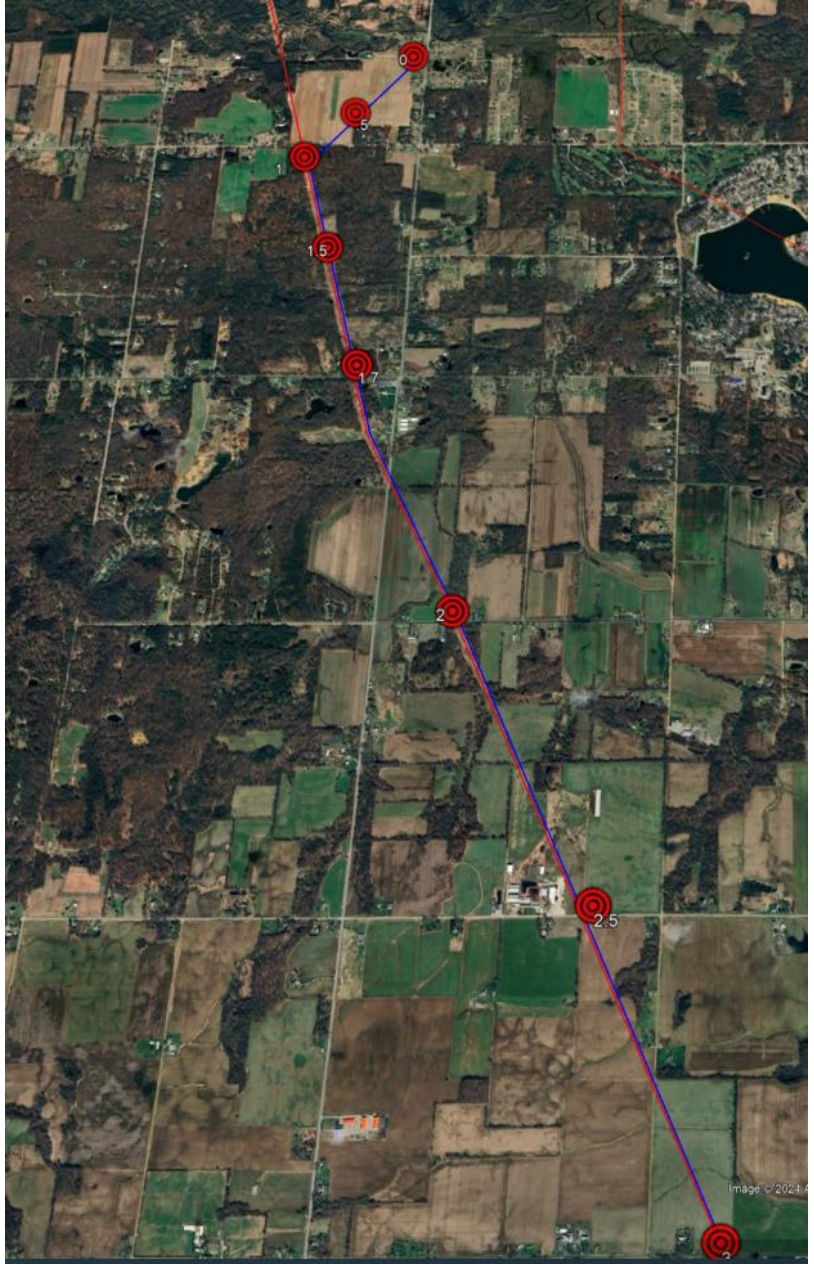
- 5’ - 191,500 Ohm-cm
- 10’ - 421,300 Ohm-cm
- 15’ - 545,775 Ohm-cm



L-1800 Soil Resistivities



Location	pin space (ft)	Resistivity (ohms-cm)
0	5	248,950.0
	10	210,650.0
	15	120,645.0
0.5	5	478,750.0
	10	555,350.0
	15	430,875.0
1	5	191,500.0
	10	421,300.0
	15	545,775.0
1.5	5	277,675.0
	10	268,100.0
	15	135,007.5
1.7	5	4,404.5
	10	4,979.0
	15	5,457.8
2	5	134,050.0
	10	97,665.0
	15	77,557.5
2.5	5	4,883.3
	10	4,979.0
	15	6,032.3
3	5	4,117.3
	10	4,596.0
	15	5,457.8



L-1800 Mitigation and Next Steps

- Install mitigation ribbon on the North and South end where L-1800 exits/enters the HVAC corridor.
- Improve model to assist with changes in future HVAC loads

L-1800 Coating Quality Testing

Measurement Ref #	Line	Measured R (ohm)	Conductance (S)2	OD (in)
1	1300-12"	0.88	1.1	12.75
2	1300-12"	0.33	3.0	12.75
3	1300-12"	1.03	1.0	12.75
4a	1300-12"	0.55	1.8	12.75
4b	1300-12"	0.41	2.4	12.75
5	1300-12"	1.18	0.8	12.75
6	1300-12"	1.01	1.0	12.75
21	1300-12"	0.92	1.1	12.75
7	1800-20"	5.75	0.2	20
8	1800-20"	5.23	0.2	20
9	1800-20"	6.02	0.2	20
10	1800-20"	4.54	0.2	20
11	1800-20"	5.25	0.2	20
12a	1800-20"	0.96	1.0	20
12b	1800-20"	1.11	0.9	20
13	1800-20"	5.04	0.2	20
14	1800-20"		#DIV/0!	20
15	1800-20"	0.93	1.1	20
16	1800-20"	2.37	0.4	20
17	1800-20"	3.21	0.3	20
18	1800-20"	1.55	0.6	20
19	1800-20"	0.11	9.1	20
20	1800-20"	0.04	25.0	20

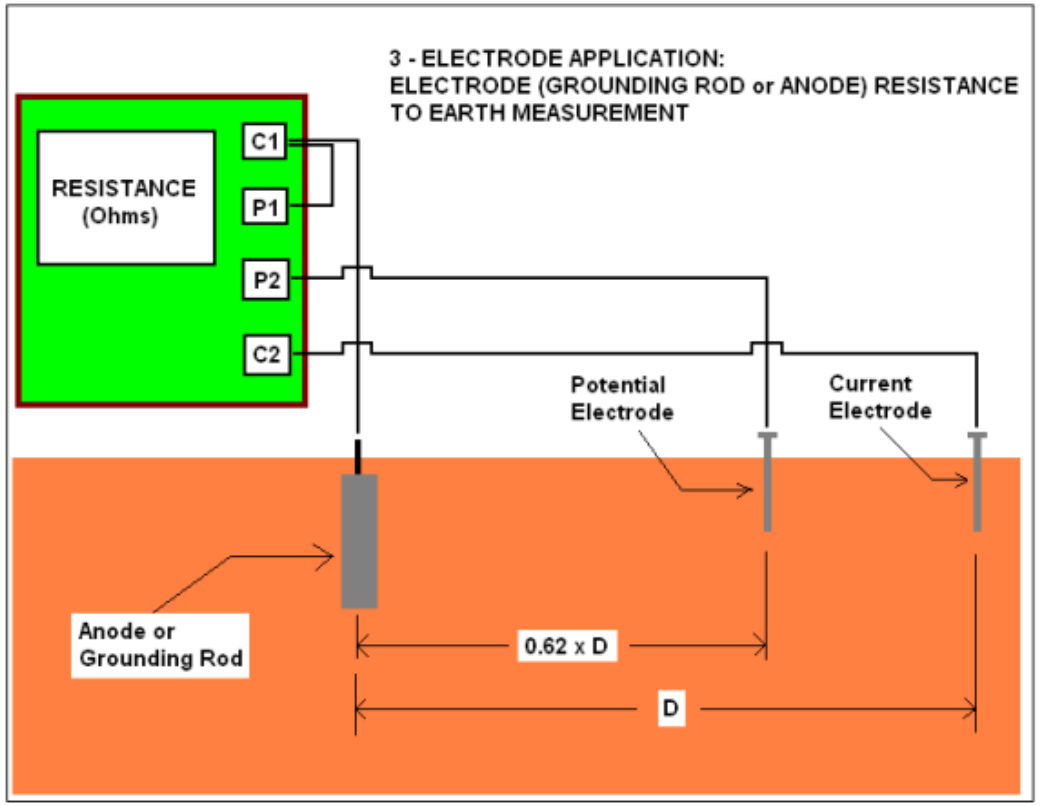


Figure 3

Construction Dos and Don’ts

- Make it easy to install
  - Plowing 3’ to 5’
  - HDD
  - Trenching
  - Evacuation

Monitoring HVAC Systems

- MISO
  - MISO is the electric grid operator for the central US.
    - https://www.misoenergy.org/meet-miso/about-miso/
  - Transmission Expansion Plan (MTEP)
    - Public access to view and track future projects
    - https://www.misoenergy.org/planning/transmission-planning/mtep/#t=10&p=0&s=&sd=

Project Level Fields			Facility Level Fields											
Submitting TO	Project	Name	Facility Description	Current Cost	Expected ISD	Facility Type	Facility Sub-Type	From Sub	To Sub	Circuit	Max kV	Min	Miles Upgrad	State 1
ITC	Greenwood-Rapson(Banner)-J1196 GIA(Wedge) NU	27776-Wedge-Substation	J1196 is a generation interconnection requ	11387184	3/4/2027	Substation	Substation (breaker	Wedge	Substation		345	345		MI
ITC	Greenwood-Rapson(Banner)-J1196 GIA(Wedge) NU	27777-Greenwood-Rapson	Loop the Greenwood-Rapson #1 345kV circu	1233600	3/4/2027	Line New	New Transmission	Greenwood	Rapson	1	345	345		MI
METC	Thetford-J1203 GIA NU	27779-Thetford-Substation	Complete Thetford 345kV Row 29. Install bu	4245703	4/30/2027	Substation	Substation (breaker	Thetford	Substation		345	345		MI
METC	Mio Dam - Twining - J1210 GIA (Quarry) - NU	27781-Mio Dam-Twining	Loop the Mio Dam - Twining 138kV circuit i	2204400	5/12/2025	Line New	New Transmission	Mio Dam	Twining	1	345	345		MI
ITC	Majestic-Milan - J1224 & J1329 GIA (Neblo) NU	27784-Neblo-Substation	Construct the new station as a 345kV statio	10631002	10/30/2025	Substation	Substation (breaker	Neblo	Substation		345	345		MI
ITC	Majestic-Milan - J1224 & J1329 GIA (Neblo) NU	27785-Majestic-Milan	Extend the Majestic - Milan 345kV line by a	1678800	10/30/2025	Line New	New Transmission	Majestic	Milan	1	345	345		MI
ITC	Majestic-Milan - J1224 & J1329 GIA (Neblo) NU	27786-Majestic-Substation	Upgrade relaying at Majestic 345kV positio	426272	10/30/2025	Substation	Substation (breaker	Majestic	Substation		345	345		MI
ITC	Majestic-Milan - J1224 & J1329 GIA (Neblo) NU	27787-Milan-Substation	Upgrade relaying at Milan 345kV position (	420320	10/30/2025	Misc.	Relaying, protectior	Milan	Substation		345	345		MI
METC	Morocco - J1226 GIA NU	27788-Morocco-Substation	Complete 345kV rows 34 and 36. Install 34	4260888	3/29/2027	Substation	Substation (breaker	Morocco	Substation		345	345		MI

Reconductoring

- The biggest issues with the amount of current that can travel through a conductors is the heat that is generated.
- This causes sag.
- New technologies has delivered new materials that can reduce thermal expansion while allowing more current to flow.

- Reconductoring can be accomplished without building new towers.
  - No lengthy public hears for easements and or permits
  - Construction can be done quickly and sometimes without notice or noticing construction is even happening
- Increase in currents and interference can happen at anytime without notice.
- Most current HVAC systems can handle bigger loads than currently running.
  - Increase loads can come from many sources and with-out notice.

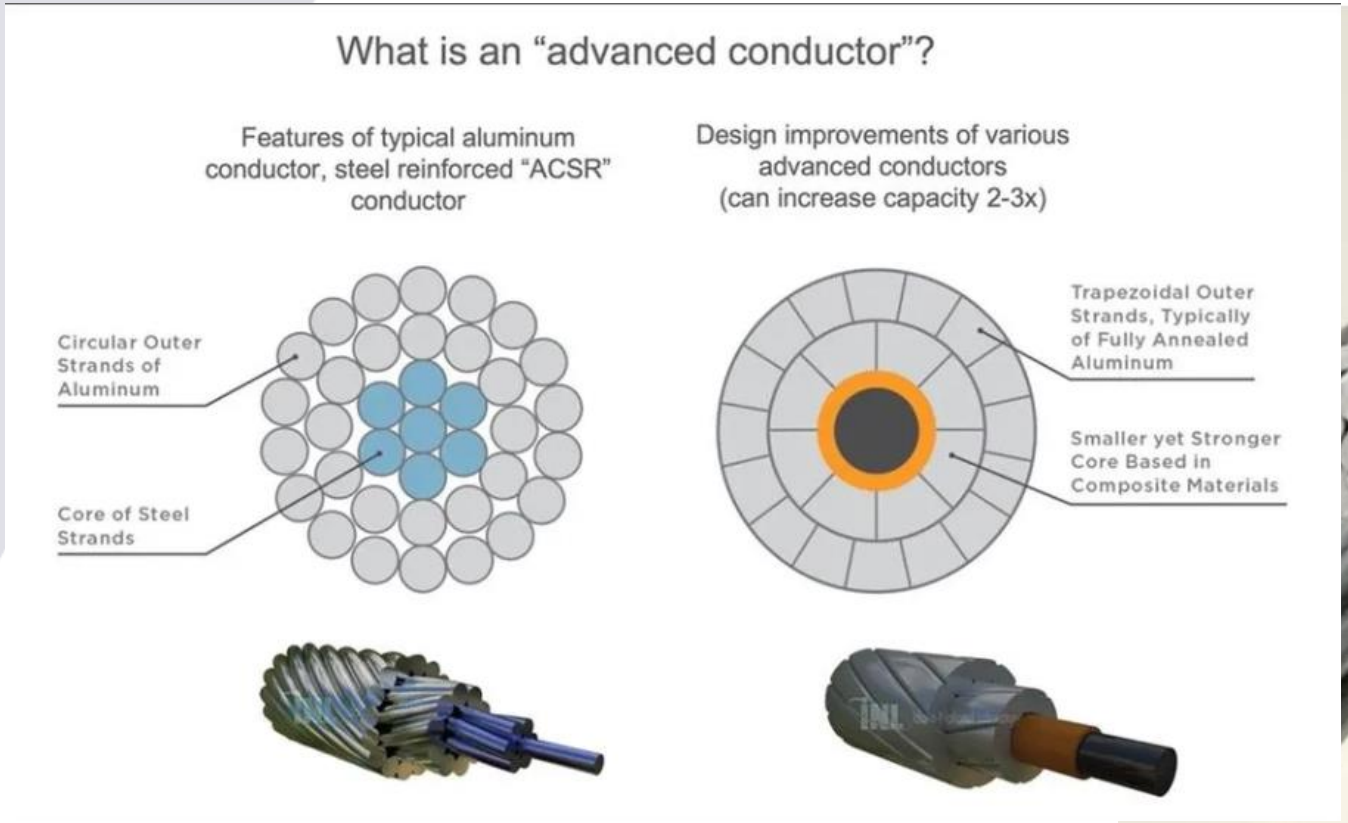
Conductors

- Today
  - Aluminum Conductor Steel Reinforced
    - Strength and material cost
    - Skin Effect
  - Strength, Weight, and Sag

An example of an ACSR (aluminum cable, steel-

https://hackaday.com/2019/06/11/a-field-guide-to-transmission-lines/

New Conductors



https://energycentral.com/o/ctc-global/benefits-advanced-reconductoring-united-states

Summery & Conclusions

- Must file for permits with-in 6 months from identifying the problem.
- Must have a plan and act fast
- Models can point you in the right direction, but monitoring is the best way to determine real-life situations.
- Be careful what the monitoring data is telling you:
  - Coupons might not represent your pipeline
- Continue to monitor and mitigate, as necessary as electrical loads are increasing without much notice

Questions, Comments, Concerns?

Sources

- https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-D/part-192/subpart-I/section-192.473
- https://documents.mcmiller.com/documents/manuals/meters/Miller%20400A%20Users%20Manual.pdf
- https://hackaday.com/2019/06/11/a-field-guide-to-transmission-lines/