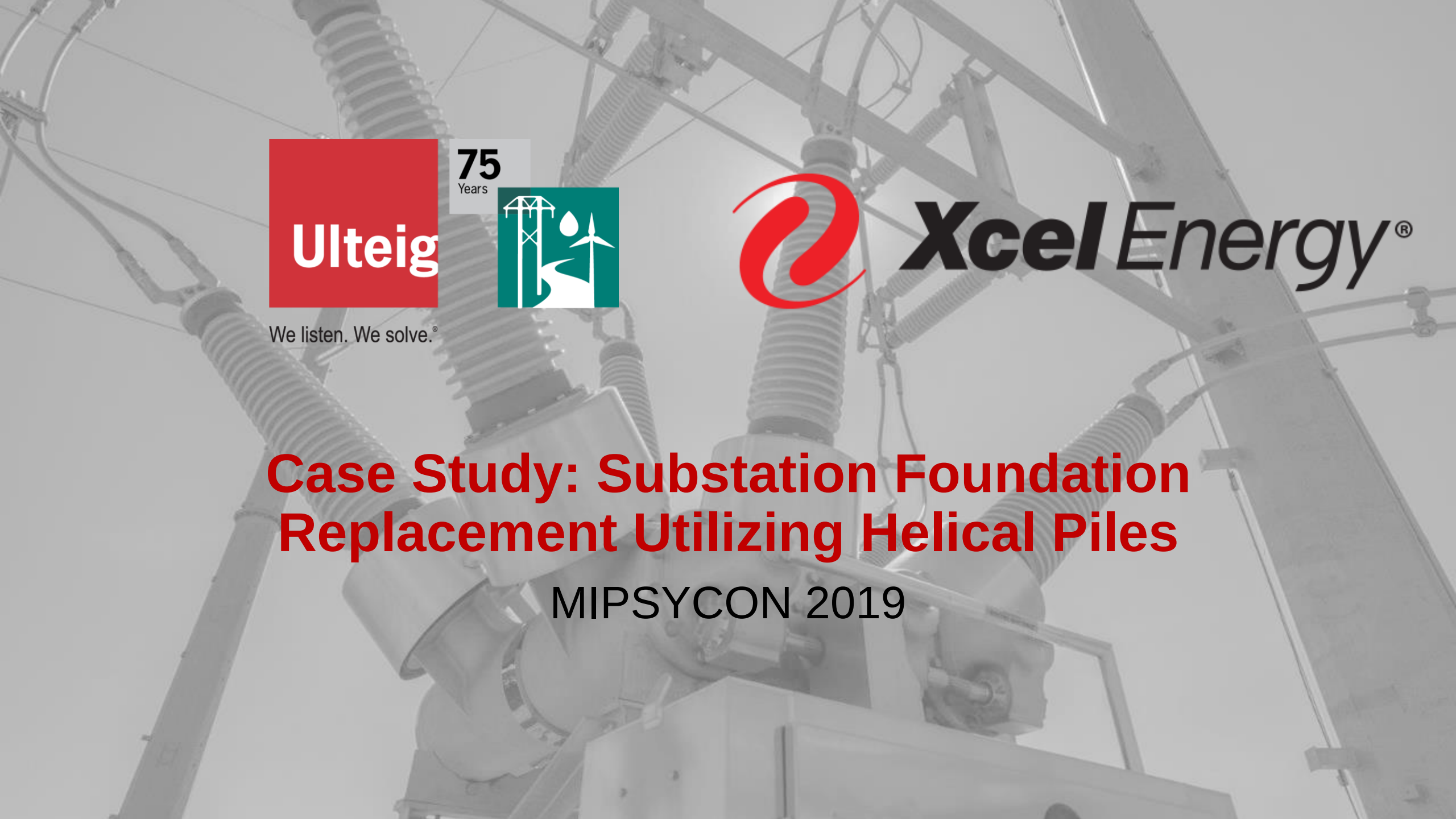


Ulteig

75 Years

We listen. We solve.®

Xcel Energy®

Case Study: Substation Foundation Replacement Utilizing Helical Piles

MIPSYCON 2019

Speaker Introductions

Jordan Guck, P.E.

- **Ulteig**
  - Engineering Supervisor
- **Waterville Project Role**
  - Substation Structural Engineer
- **Favorite Hobby**
  - Hunting/Fishing

Brendan Cohen, PMP

- **Xcel Energy**
  - Transmission Project Manager
- **Waterville Project Role**
  - Project Manager
- **Favorite Hobby**
  - Hockey

Overview

- **Project Background**
  - Waterville Substation
- **Design Considerations**
- **Construction Phase**
- **Q&A**

Project Background

Brendan Cohen

Project Need

- **Distribution**
  - Overloaded and old TR2
    - *107% overload*
    - *Potential customer growth in area*
  - Voltage conversion from 4kV to 23.9kV
    - *Remove 4kV service*
    - *Consolidation of three substation service voltages to two (23.9kV and 12.5kV)*
- **Transmission**
  - More than three elements per bus
    - *Pre-existing issue prior to transformer project*

Project Scope

- **Distribution**
  - Replace existing 69-4kV transformer with new 69-23.9kV transformer
  - Remove deteriorating 4kV equipment from substation
  - Install new 23.9kV feeder
  - Convert 4kV service to 23.9kV
- **Transmission**
  - Install new gas circuit breaker in bus tie position between bus #1 and bus #2
  - Install two 69kV MOD switches for bus tie breaker isolation

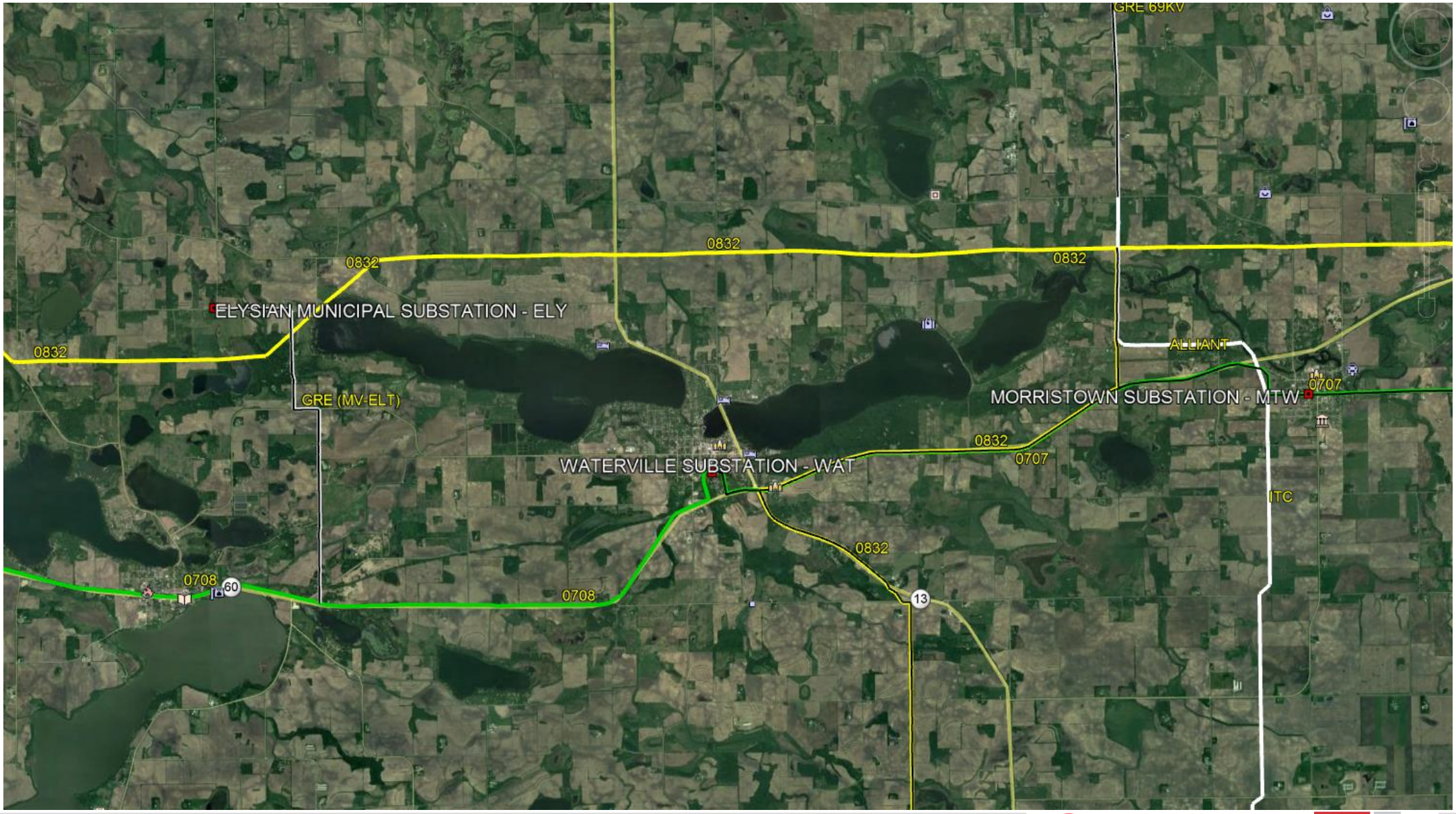
Scope Alternatives

- **Field transfer all 4kV load to TR1 and remove 4kV substation equipment**
  - Larger contingency risk for loss of TR1
  - Limited load growth capability
- **Field transfer all 4kV load to TR1, remove 4kV substation equipment, and upgrade TR1 to 28MVA**
  - Larger eventual contingency risk for loss of TR1
  - Would have required circuit switcher
- **Field transfer all 4kV load to TR3 and remove 4kV substation equipment**
  - Overloads TR3
- **Build new substation**
  - High cost (approx $7-8M)
  - Feeder reroutes to accommodate new substation

Outage Constraints

- **Distribution**
  - Service provided by mobile substation during construction work
- **Transmission**
  - Xcel System Operations requested substation bypass
    - *Elysian and Morristown Substations would have been radial without bypass*
    - *Moved all 69kV line protection to 4S185 breaker to facilitate bypass between West Faribault and Wilmarth Substations*
    - *Relocate existing bus PT's to line*
    - *Preferred solution due to three-terminal configuration between Wilmarth, Waterville, and Cleveland Substations*

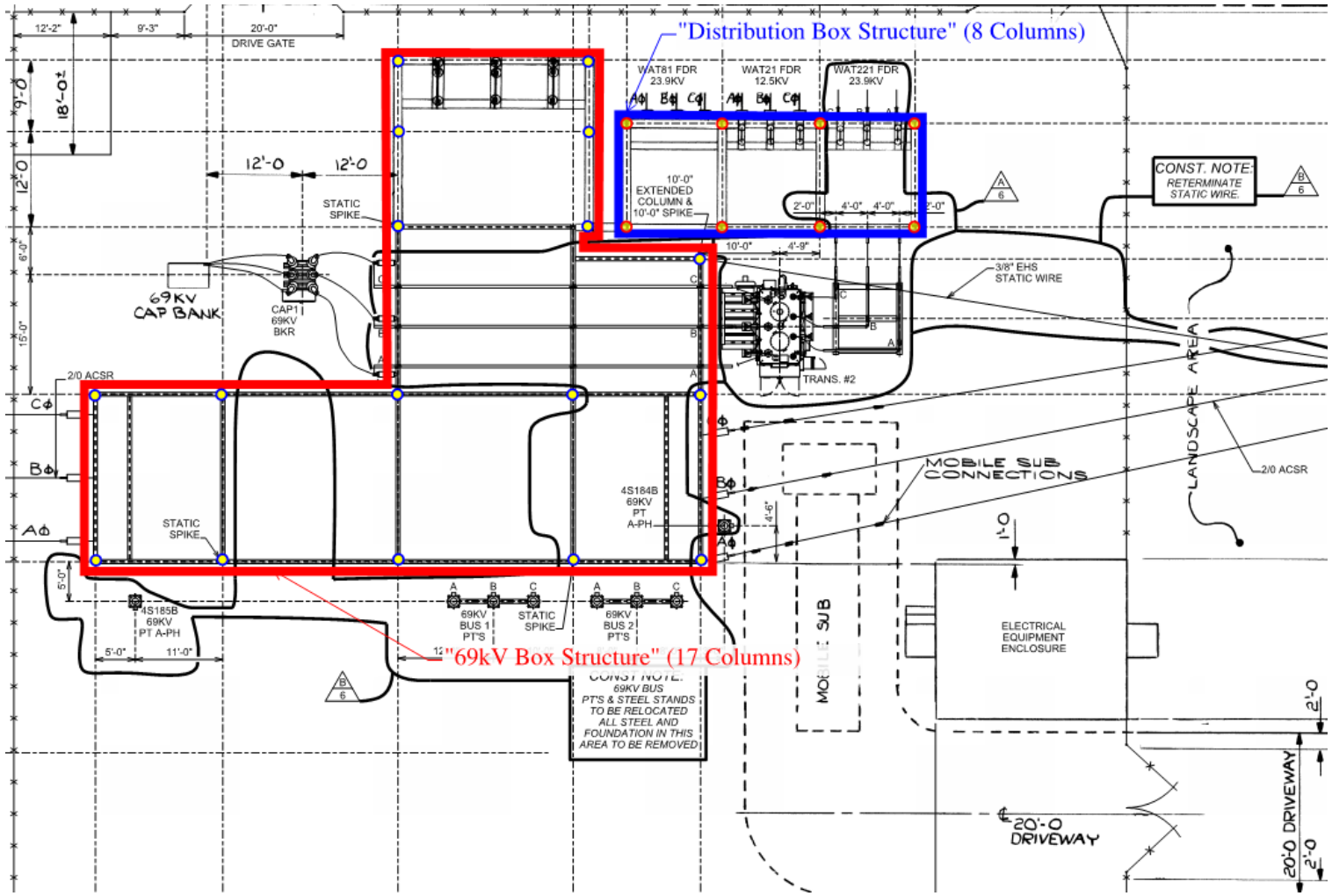
Area Map


GRE 69KV
0832
0832
0832
ELYSIAN MUNICIPAL SUBSTATION - ELY
0832
ALLIANT
GRE (MV-ELT)
MORRISTOWN SUBSTATION - MTW
0707
0832
0707
WATERVILLE SUBSTATION - WAT
ITC
0832
0708
60
0708
13

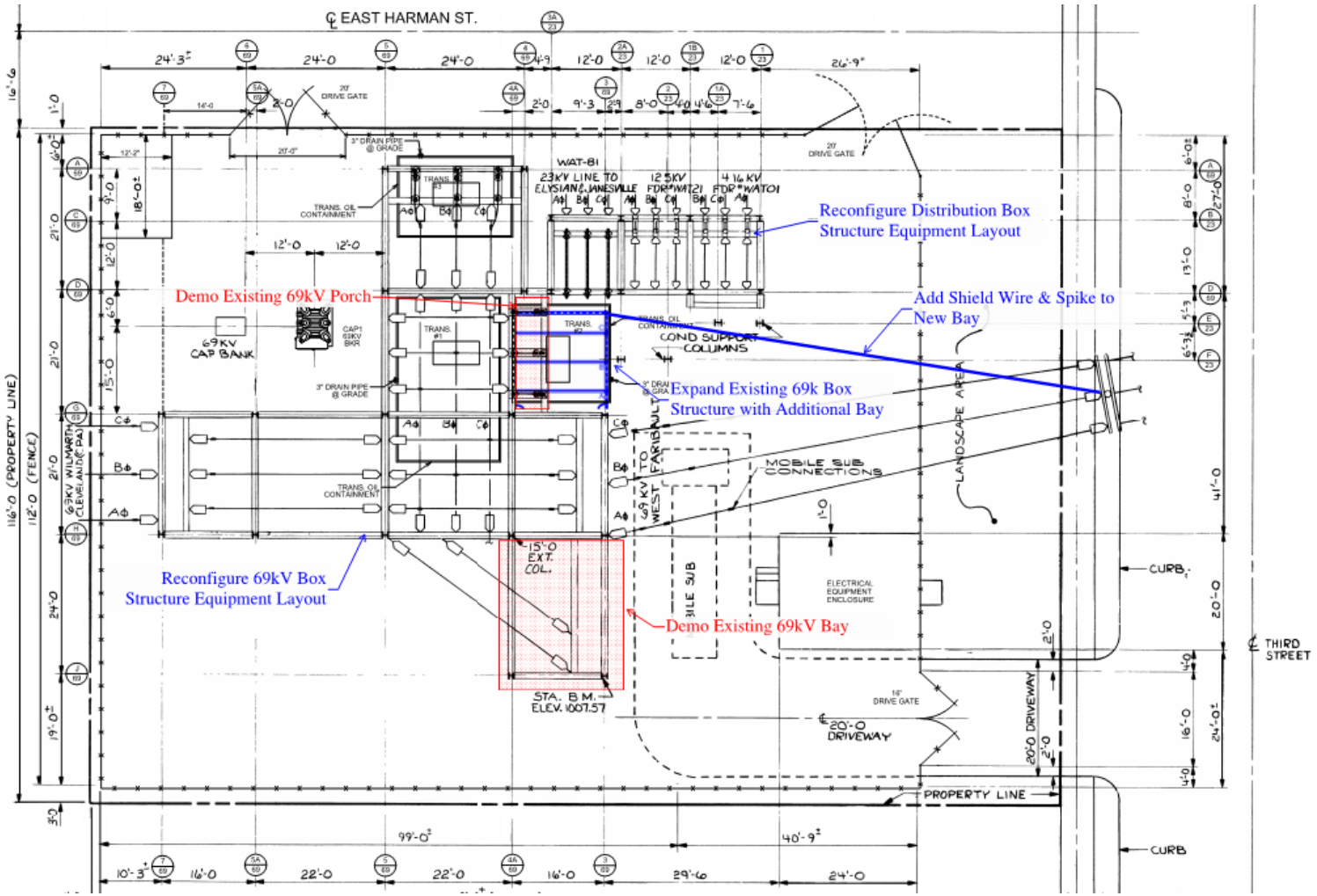
Design Considerations

Jordan Guck

Final Physical Arrangement



Summary of Physical Scope



Structural Design Considerations

» 69kV Box Structure

- New line tension
- New equipment load
- New bay
- Demo existing bay
  - Impact to Lateral System
- Cross-bracing removed

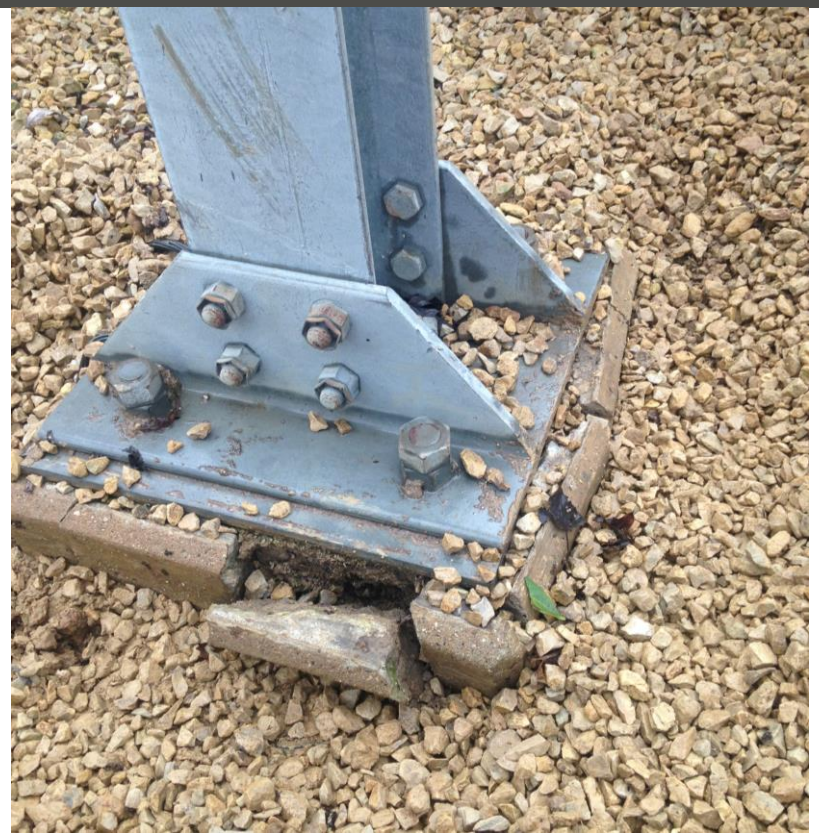
» Distribution Box Structure

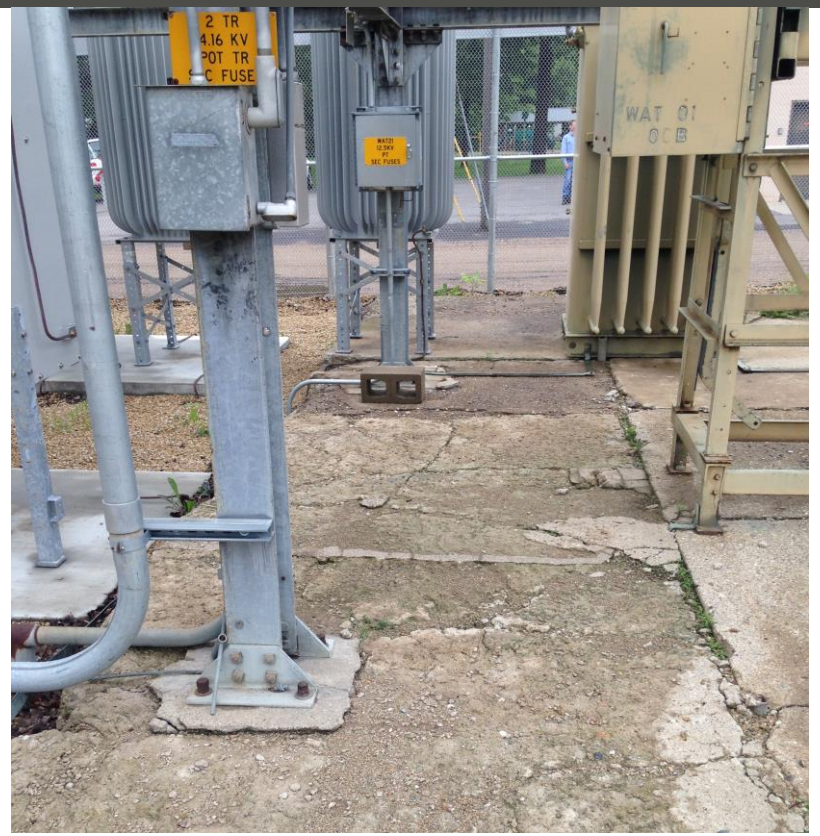
- Upgrade to 23.9kV from 4kV
  - Larger Equipment
- New equipment

Structural Design Considerations

Design Challenges

- Original drawings date back to 1949
- As-built conditions differ from drawings
- No existing calculations on record
  - Designed to outdated loading criteria
- Congestion/Space constraints
- Foundations…

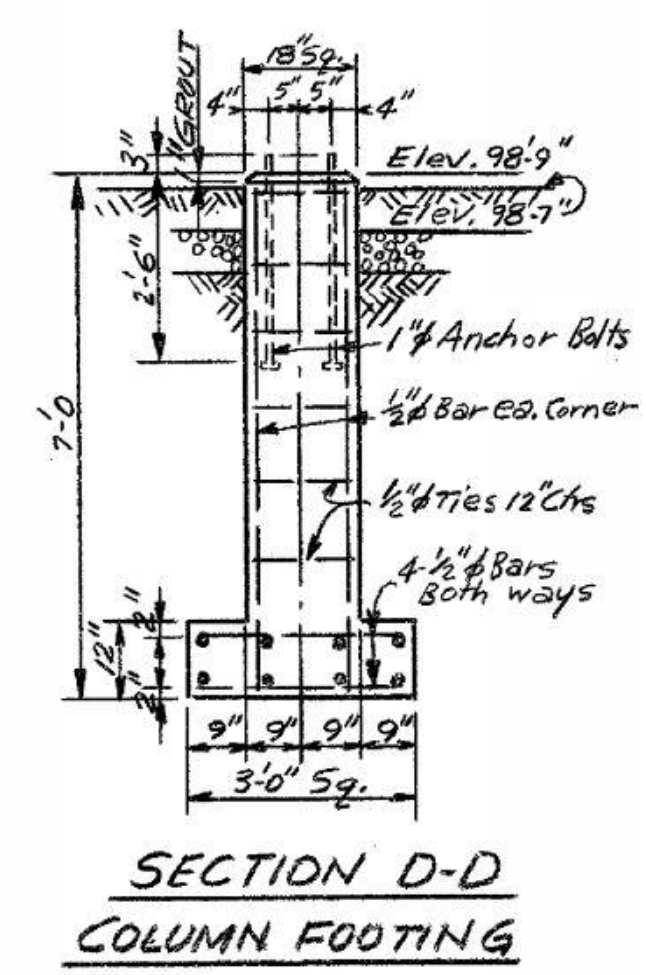




Existing Foundations

What's wrong with these photos?

Typical Existing Column Footing (69kV Box)



Report of Additional Geotechnical Exploration and Review
Waterville Substation Install Bus Tie Breaker & Replace TR2; Waterville, Minnesota
August 30, 2018
Report No. 01-20138

Deeper deposits of very soft to soft clays and swamp deposits exist at Borings S
and SB-7. Boring SB-3 showed soft to very soft clays to a depth of about 9 fe
loose silty sands from about 9 to 13½ feet. It is our opinion, however, that these s
and likely would have had higher N-values had drilling flu
while sampling. The very soft to soft clays and the swamp deposits have very low s
are considered compressible under more heavily loaded structures like the transform
lightly loaded structures like the 69kV breakers could be supported on grade but woul
excavation and placement of sand fill to limit settlements to less than 1 inch.

Based on the soil conditions depicted by Boring SB-7, we calculated that the transformer w
supported on grade with a typical s
and sand refill would not limit settlements t
Therefore, it is our judgment that the transformer should be supported by
deep foundations such as drilled piers. Adequate bearing could be achieved by drilled piers
between depths of about 20 to 30 feet, or possibly less. We have also considered the use of helical
piles to support the transformer; however, it is our opinion that drilled piers would work adequately
and would not require mobilization of another contractor.

It is our judgment that the 23kV and 69kV box structures can also be supported by drilled piers.
Because of the depths of compressible soils, the piers will have to be drilled deeper than normal
to reach soils that would provide adequate bearing capacities.

Geotechnical Considerations

- **"The very soft to soft clays and the swamp deposits have very low strength…"**
- **"Adequate bearing could be achieved by drilled piers between depths of about 20 to 30 feet…"**

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE BORING LOG

AET No: 01-07548 Log of Boring No. SB2 (p. 1 of 2)
Project: Waterville Substation Install Bus Tie Breaker & Replace TR 2; Waterville, MN
rface Elevation 1007.4 Le Sueur Co. Coordinates: N 107726 E 386335

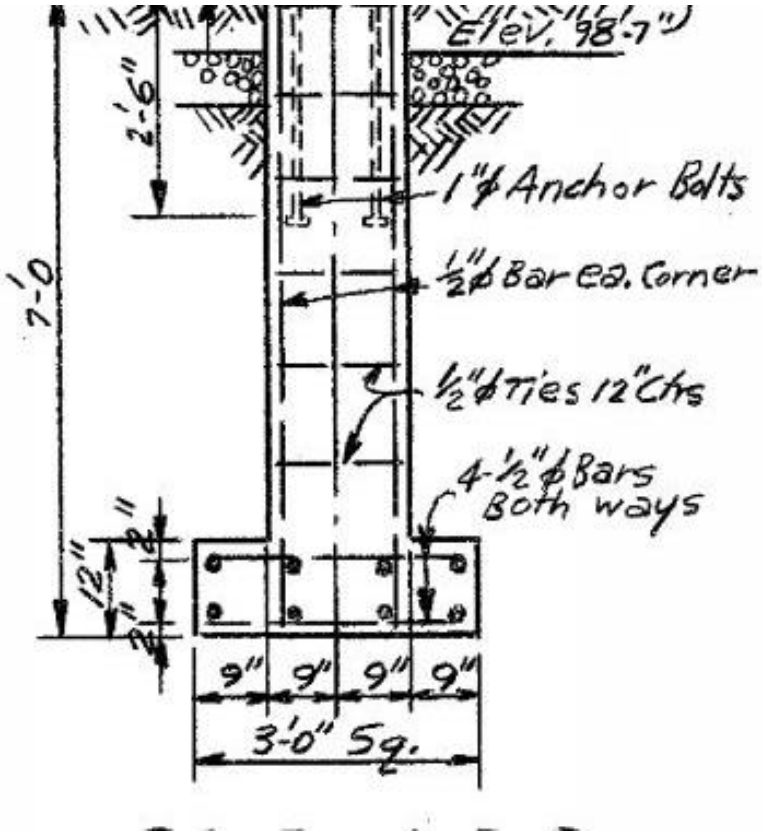
TH	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS WC	DEN	LL	PL	%-#200
	FILL, mostly crushed limestone, light brown	FILL									
	ILL, mostly clayey sand, a little gravel, brown						23				
	RGANIC LEAN CLAY, a little gravel, black)	SWAMP DEPOSIT									
	ues not recorded to 6.5'; soils removed by truck. Samples obtained from sidewall m truck hole.)										
	slightly organic, trace roots, enses of wet sand (CL-ML)	FINE ALLUVIUM	WH	W	SS	22	30				
			1	W	SS	21	34				
	gray, very soft		WH	M/W	SS	22	29 38				
					TW	24					
	ens		10	W/M	SS	22	39				
			5	M	SS	18	47				

R LEVEL MEASUREMENTS

CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL

NOTE: REFER TO THE ATTACHED

Red Flags?



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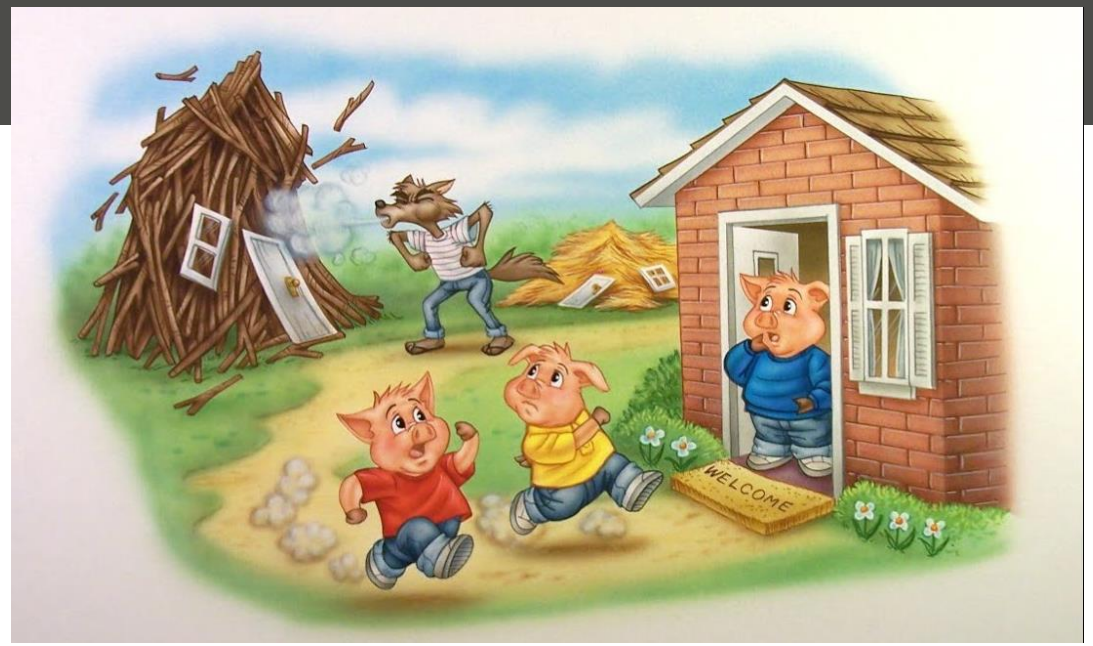
DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DEN	LL	PL	% -#200
1	FILL, mostly crushed limestone, light brown	FILL									
	FILL, mostly clayey sand, a little gravel, brown						23				
2	ORGANIC LEAN CLAY, a little gravel, black (OH)	SWAMP DEPOSIT									
3	(N-values not recorded to 6.5'; soils removed by vacuum truck. Samples obtained from sidewall of vacuum truck hole.)										
4											
5				▼							
6											
7	CLAYEY SILT, slightly organic, trace roots, gray, very loose, lenses of wet sand (CL-ML)	FINE ALLUVIUM									
8			WH	W	SS	22	30				
9											
10											
11			1	W	SS	21	34				
12							29				
13	LEAN CLAY, slightly organic, gray, very soft (CL)		WH	M/W	SS	22	38				
14											
15											
16					TW	24					
17											
18	LEAN CLAY WITH SAND, gray, stiff. a lens of sand (CL)		10	W/M	SS	22	39				
19	LEAN CLAY, slightly organic, dark gray, firm (CL)										
20			5	M	SS	18	47				
21											

7548.GPJ AET+CPT+WELL.GDT 5/30/18



Now What?

Decisions, Decisions…

Why Helical Piles?

» **Advantages**

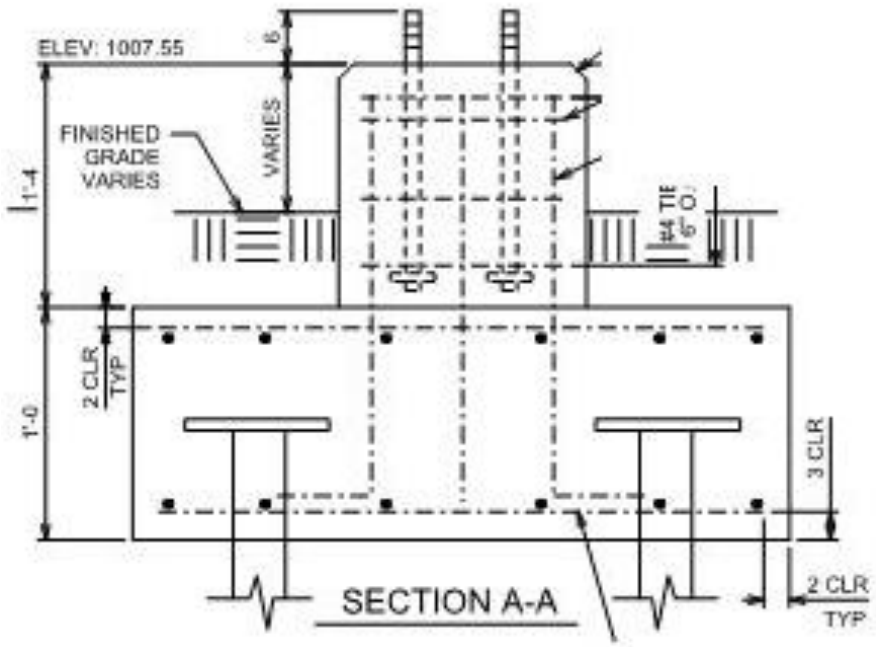
- Install without demo of existing structure
  - Advantageous to construction duration/cost
  - Minimize outage requirements
- Minimal Overhead Clearance requirement
- Penetrate thru weak soil layers to firm bearing
- Straddle existing spread footings
- Steel-Steel Connections in some instances
- Xcel Energy In-House crews able to install without specialty contractor

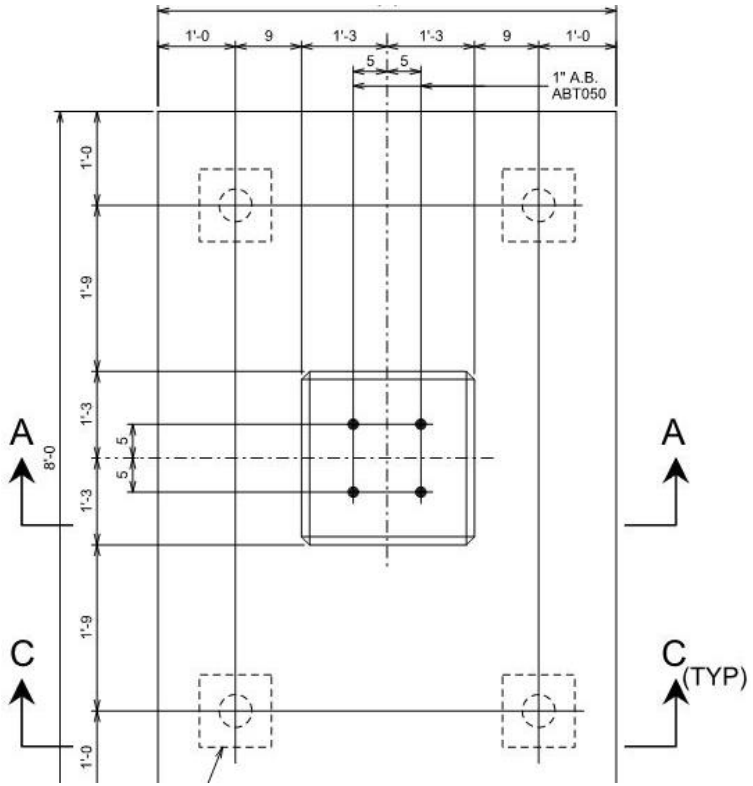
What is a Helical Pile?

- **In General…**
  - A helical pile is a deep foundation system used to resist compression, tension, and lateral forces.
  - Installed to a pre-defined torque using a helical drill rig
  - High strength steel flighting and shafts vary in size depending on design needs
- **Other Known Alias'**
  - Helical Pier
  - Helical Anchor
  - Screw Pile/Pier
  - Screw Anchor
- **Photo Credit to Viking Helical Anchors, our supplier for this project**

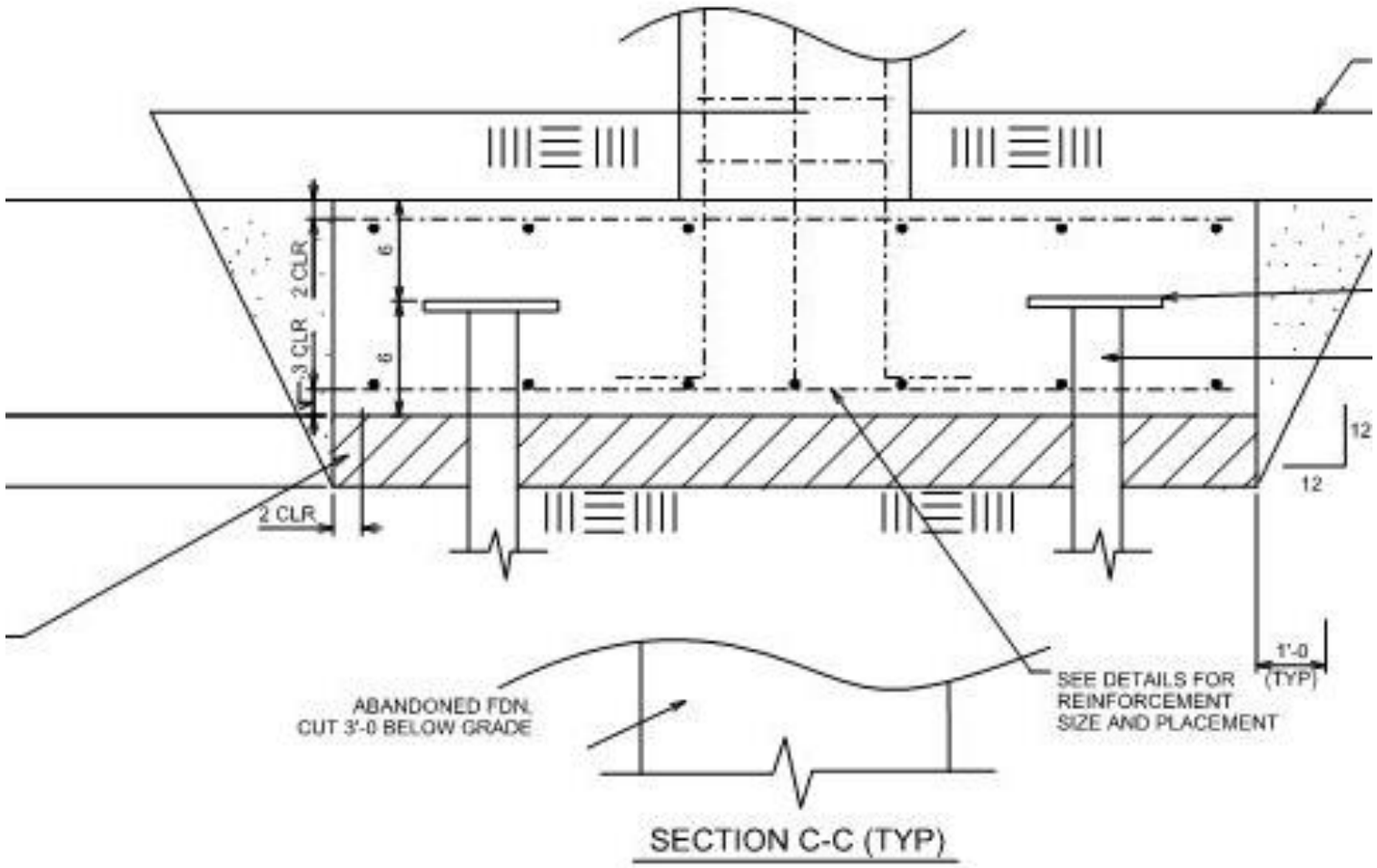

SS-12
VEIT
257B

Foundation Details

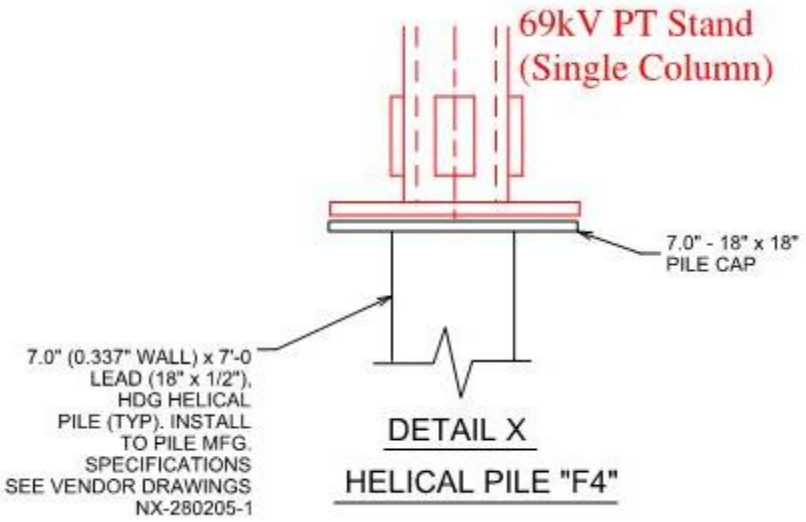


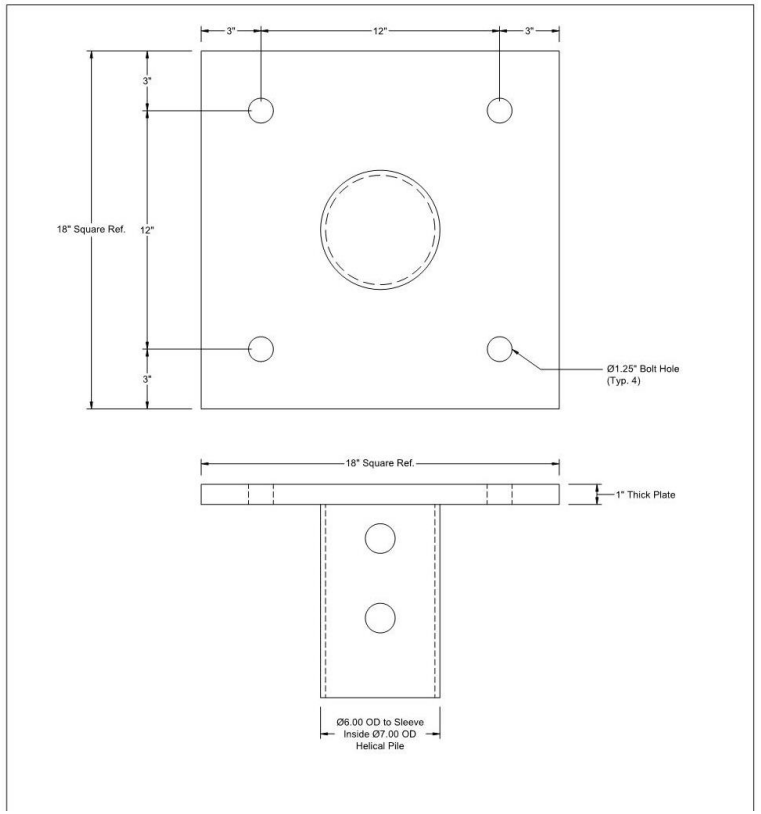


Frost Considerations



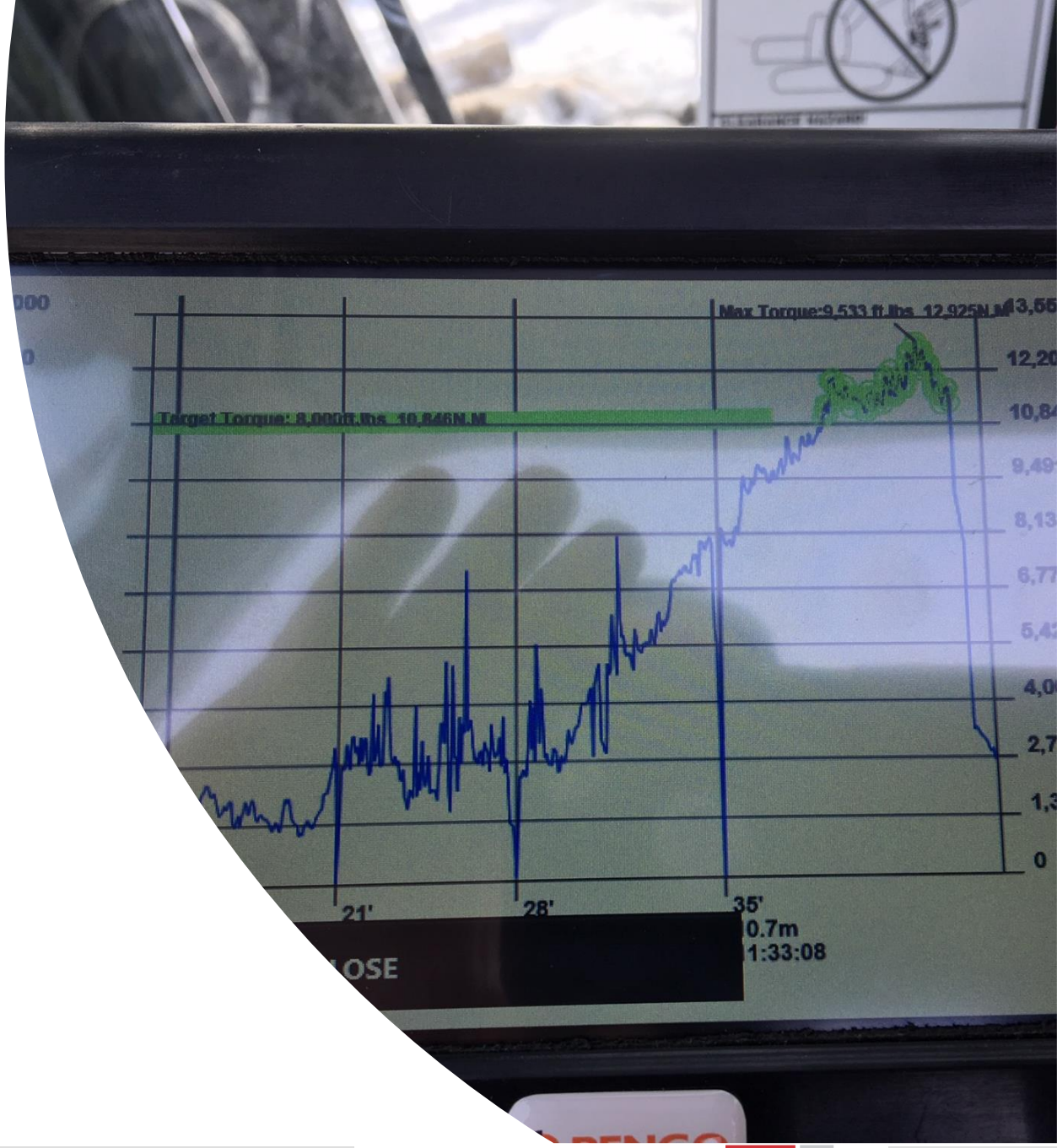
Steel-Steel Bolted Connection



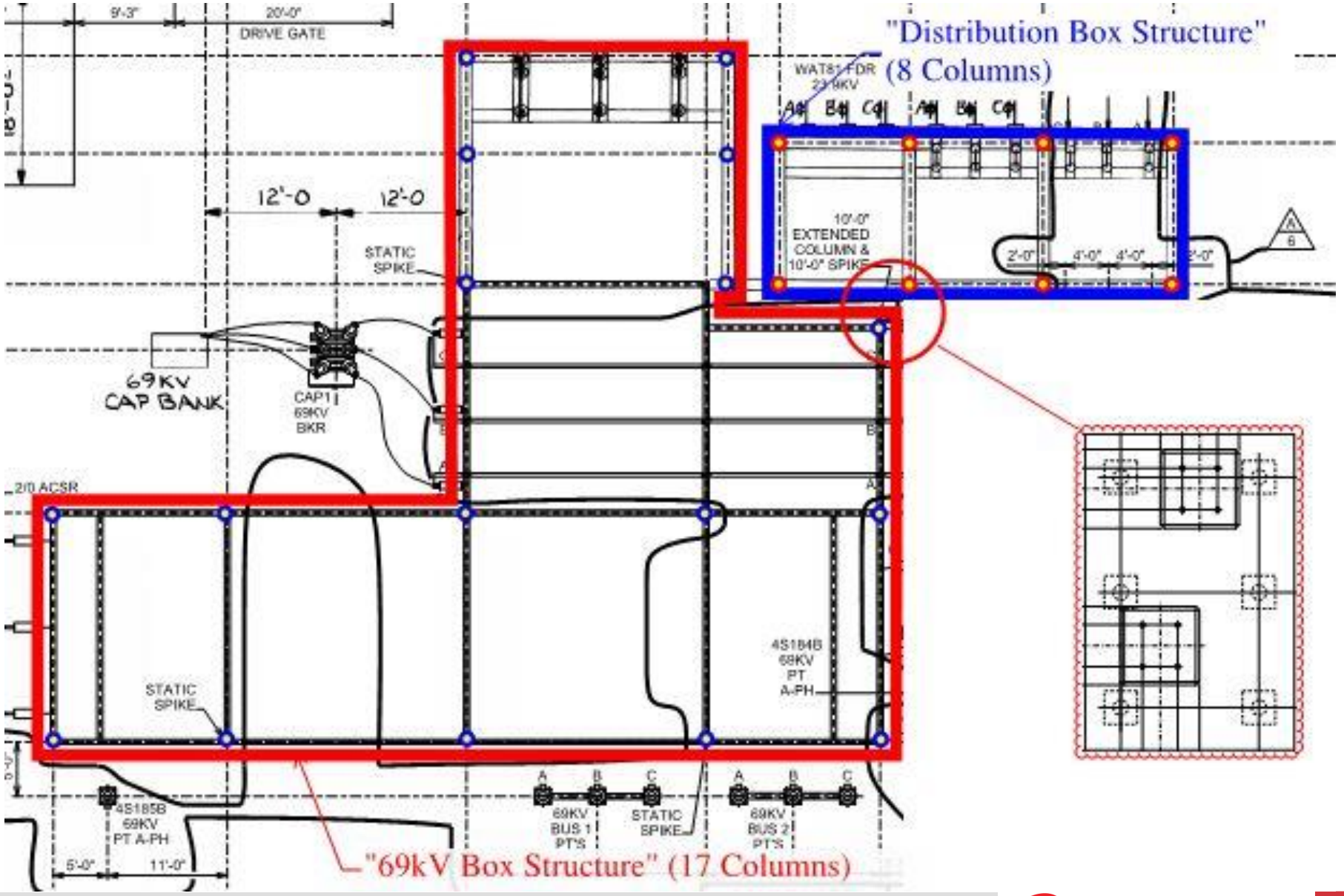


Waterville Foundation Fun Facts

- **4.50” OD Piles used: 104**
  - Average depth to required install torque around 40ft
  - Some piles started to run; torque reductions considered
- **7.00” OD Piles used: 4**
  - Used at steel-steel connections
- **7 Different Foundations with Helical Piles**
  - Transformer slab
  - Congested areas required some foundations to support 2 columns
- **New Breakers & Regulators utilized Slabs-on-Grade**
  - With soil correction provisions



Foundation Plan



Construction Challenges

- **Existing substation with energized equipment**
- **Winter construction**
- **Congestion/Space constraints**
- **New technology for Xcel Energy in-house crews**
  - Prior to this project, helical pile work was subcontracted out to specialty contractors
- **Weather…**
  - Fall 2018:Waterville Tornado
    - Pre-Mobilization
  - Jan 2019: MN Polar Vortex
    - During Construction
  - Spring 2019: Waterville Flooding
    - During Construction

Construction Phase

Brendan Cohen

Construction Preparation

- **Held 3 Pre-Construction Meetings**
  - Each meeting oriented around four readiness categories
  - All meetings included Project Management, Distribution, Substation Engineering, and Construction representatives
- **Focus on Four Construction Readiness Categories**
  - Construction Drawing Packages
  - Material Delivery
  - Outage Sequencing & Coordination
    - *Including bypass plan*
  - Mobile Substation Setup

Lead Time & Quantity

» Lead Time

– Viking Helical Anchors provided a 3-4-week lead time

» Cost & Quantity

Distribution Equip Foundations (Total Material Cost: $73,000)

Foundation Type	Foundation Quantity	Piles (Per Found)
Transformer Slab	1	6 (6)
23.9kV Bus Support Stand – F3	1	4 (4)
23.9kV Box Structure – Foundation F2	1	6 (6)
23.9kV Box Structure – Foundation F3	5	20 (4)
Total	**8**	**36**

Transmission Equip Foundations (Total Material Cost: $160,000)

Foundation Type	Foundation Quantity	Piles (Per Found)
69kV 3-Phase PT Stand	2	2 (1)
69kV 1-Phase PT Stand	2	2 (1)
69kV Box Structure – Foundation F1	14	56 (4)
69kV Box Structure – Foundation F2	2	12 (6)
Total	**20**	**72**

Construction Cost & Duration

- **Duration**
  - 3 Months
- **Cost**
  - Labor & Equipment: $445,500
    - *Avg Per Foundation: $15,910*
  - Material (Concrete and Helical Piles): $243,000
    - *Avg Per Foundation: $8,680*
  - **Total: $688,500**
  - ***Per Foundation: $24,590***

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Questions?
Thank You!

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