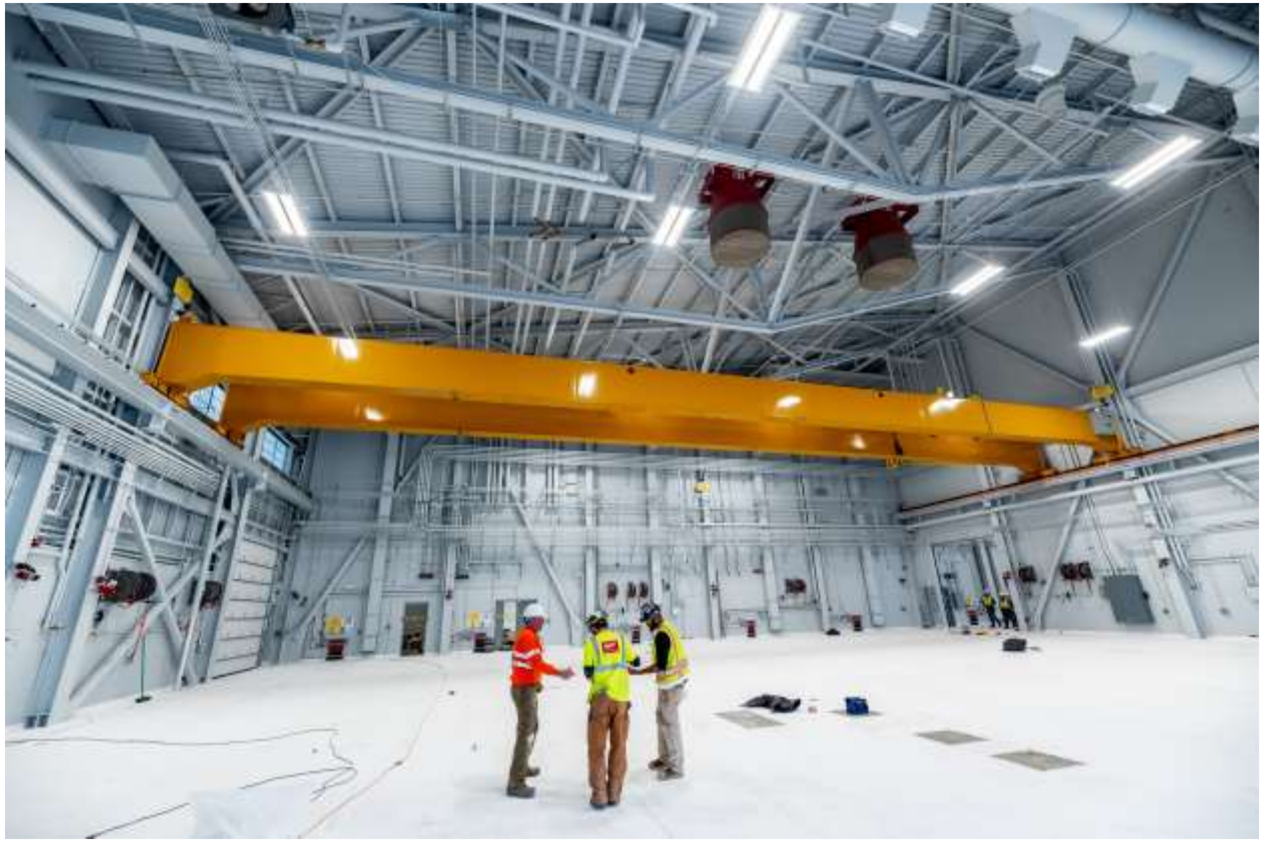
Foundation Design Challenges & Solutions in the Arctic & Subarctic

Overview

ANTHC Environmentally Threatened Communities

EIE376 & EIE379 Eielson F35 Hangars



Overview

Galena Fire Hall Replacement

Cape Lisburne Water Storage Tanks

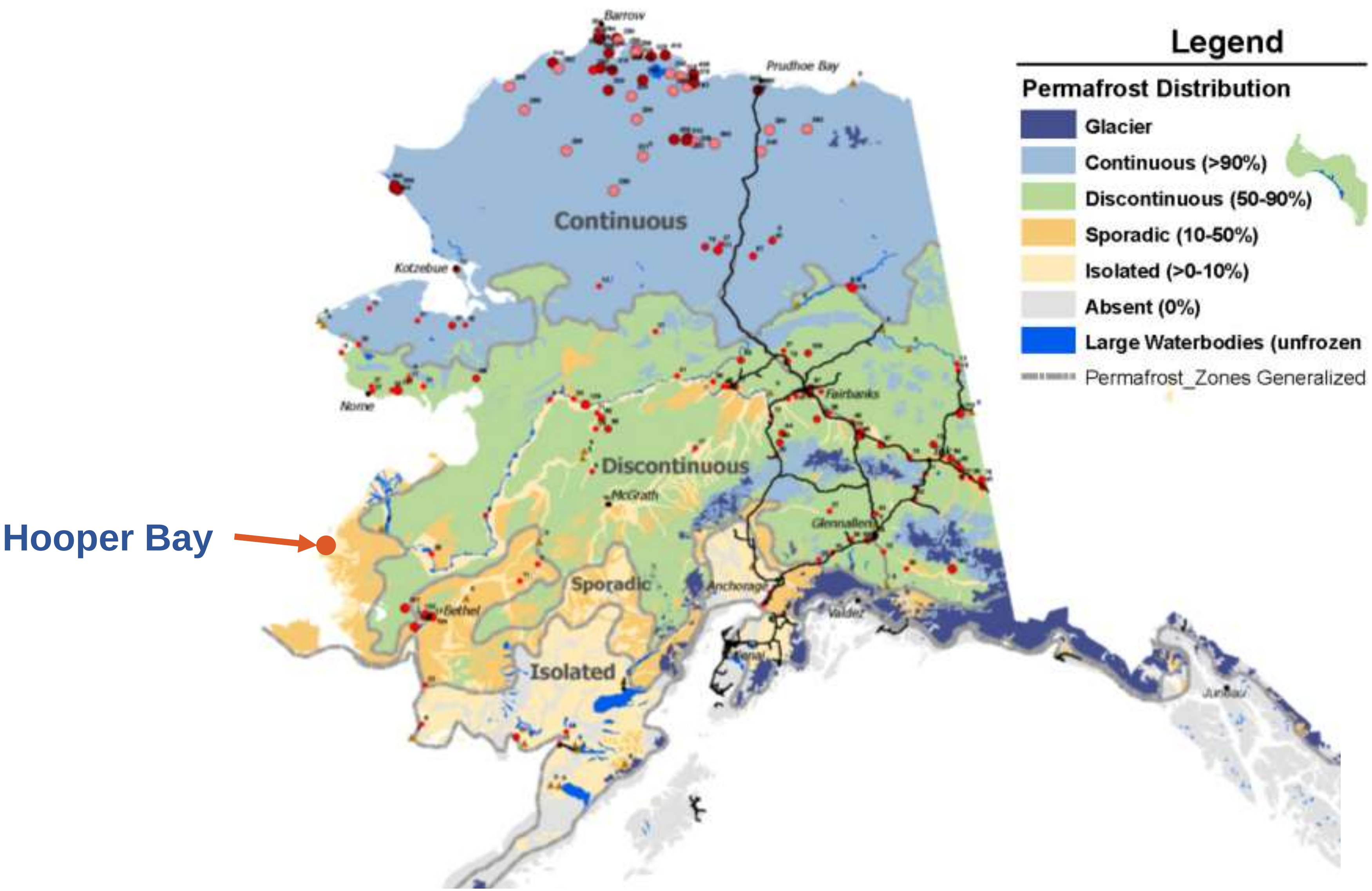
General Approach

- Define project requirements / performance needs
- Evaluate past performance
- Characterize soil/permafrost conditions
- Project future climate trends
- Project future soil behavior
- Pick the "perfect" solution....

ANTHC Environmentally Threatened Communities

Hooper Bay

- 1,400 Residents
- Isolated Permafrost
- Extensive Permafrost-related Damage
- What's Next?

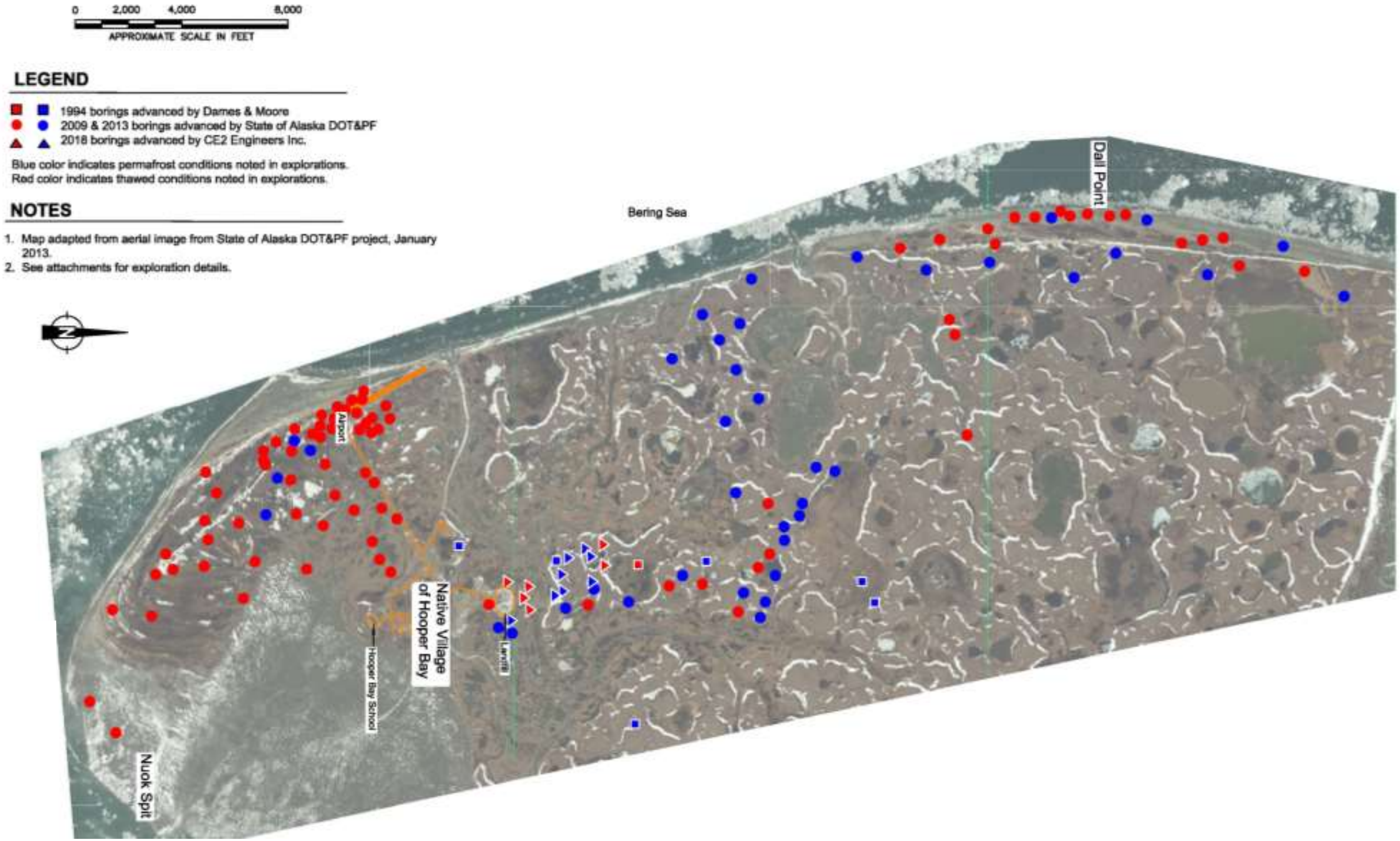


ANTHC Environmentally Threatened Communities

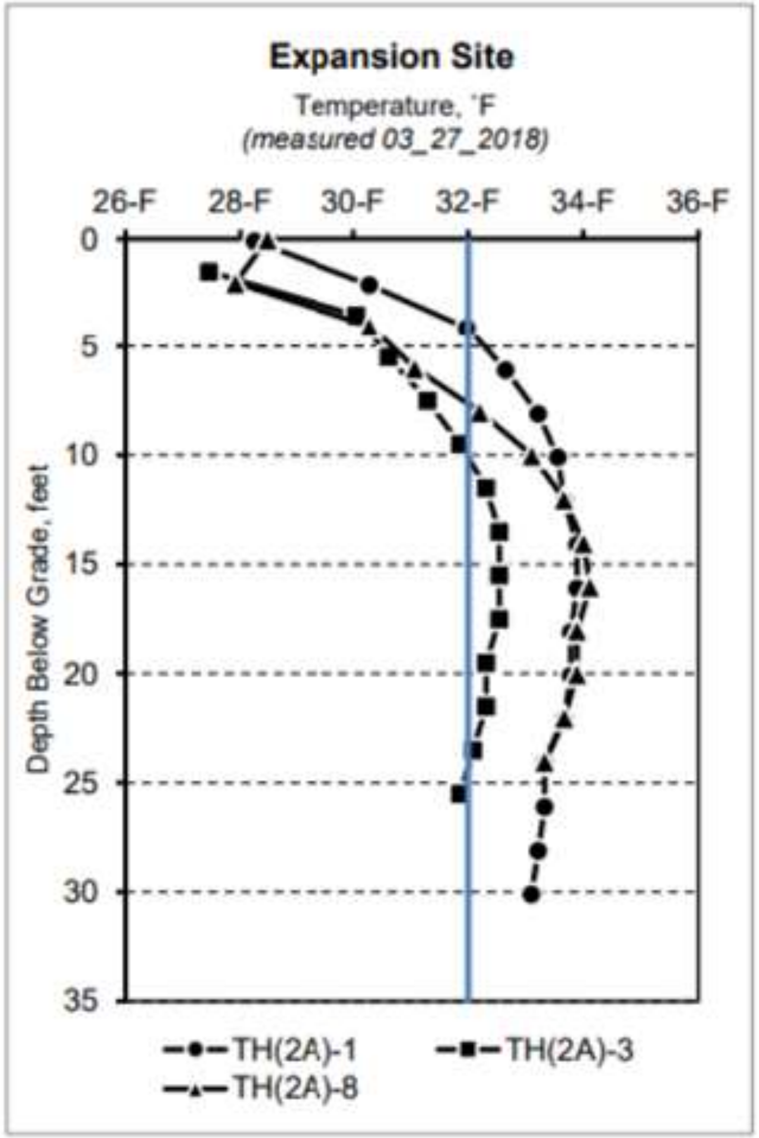
Surrounded by Oceanwater

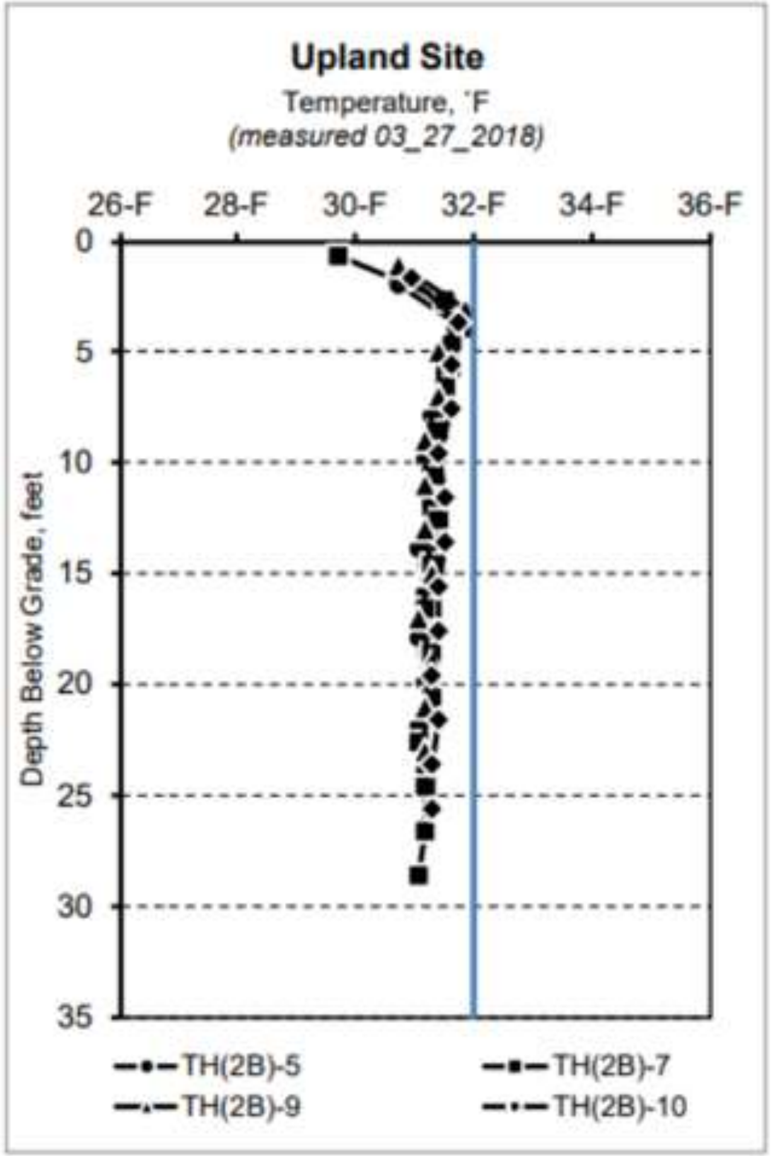
- Dynamic, Erosive Environment
- Low Elevation
- Frequent Coastal Flooding

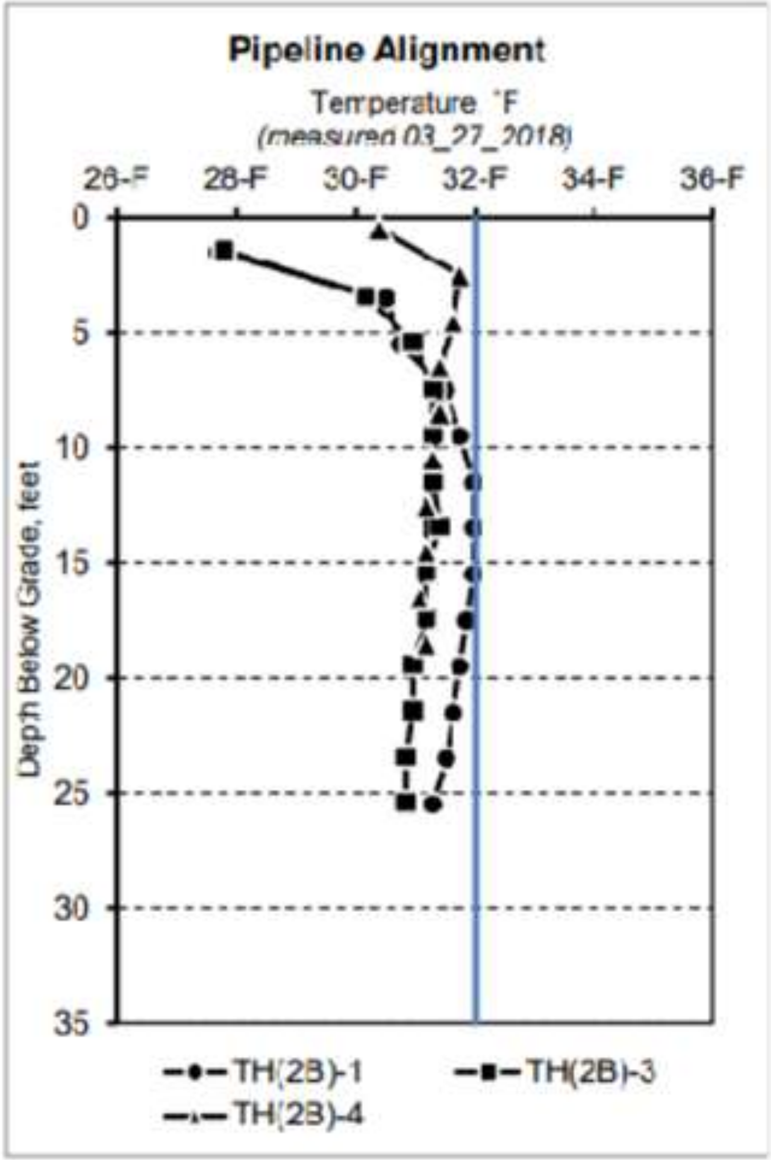
ANTHC Environmentally Threatened Communities



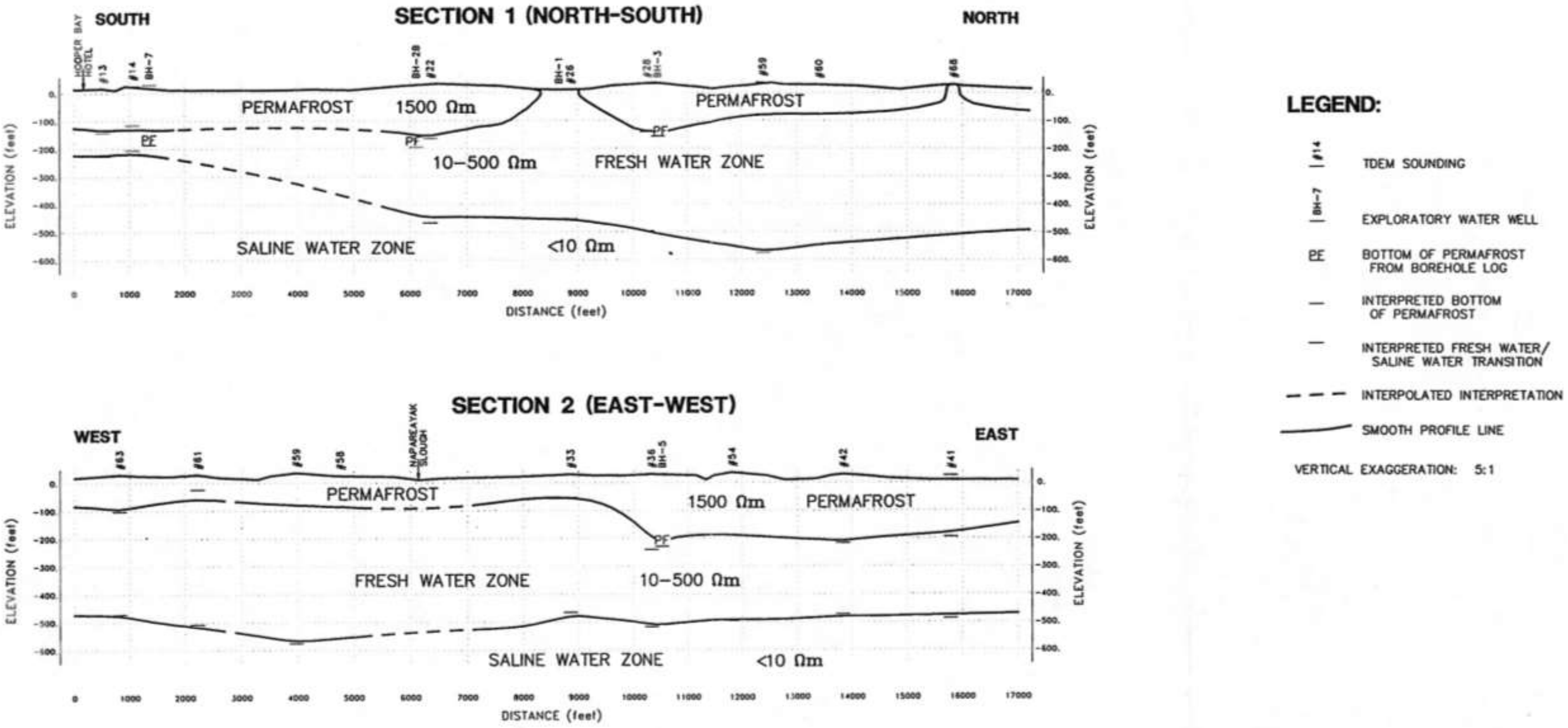
ANTHC Environmentally Threatened Communities





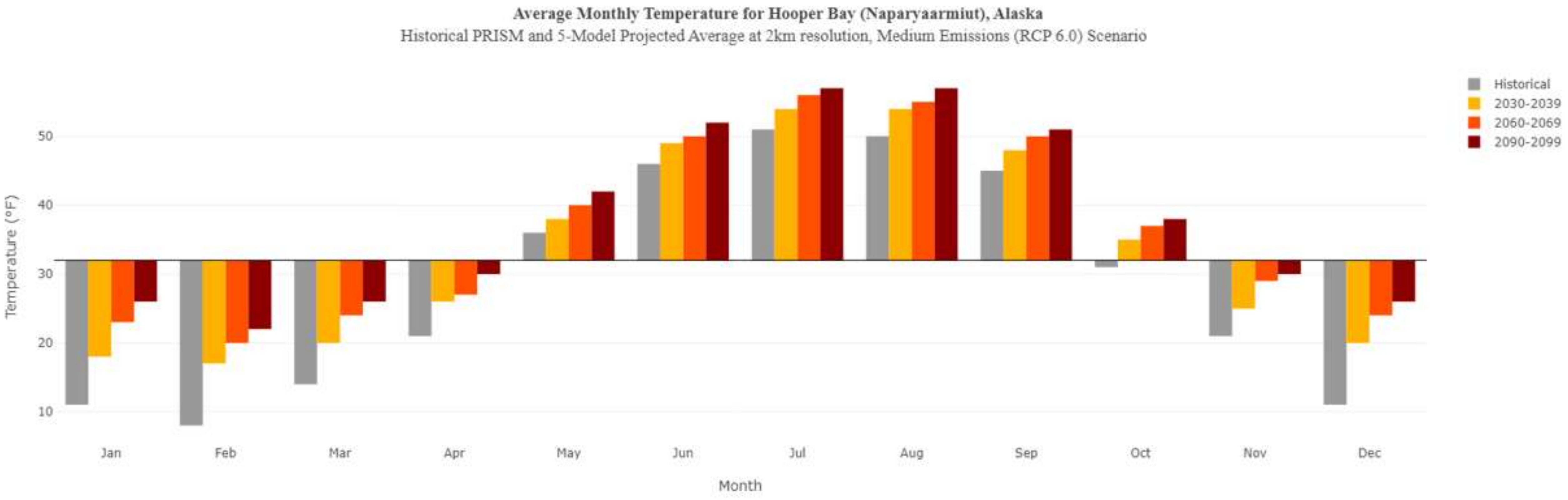


ANTHC Environmentally Threatened Communities



ANTHC Environmentally Threatened Communities

The outlook is not good



ANTHC Environmentally Threatened Communities

Barrier Dune Erosion

Containment Berm Failure

Riverbank Erosion

ANTHC Environmentally Threatened Communities

Are either of these performing?

ANTHC Environmentally Threatened Communities

Shallow foundation solutions

ANTHC Environmentally Threatened Communities

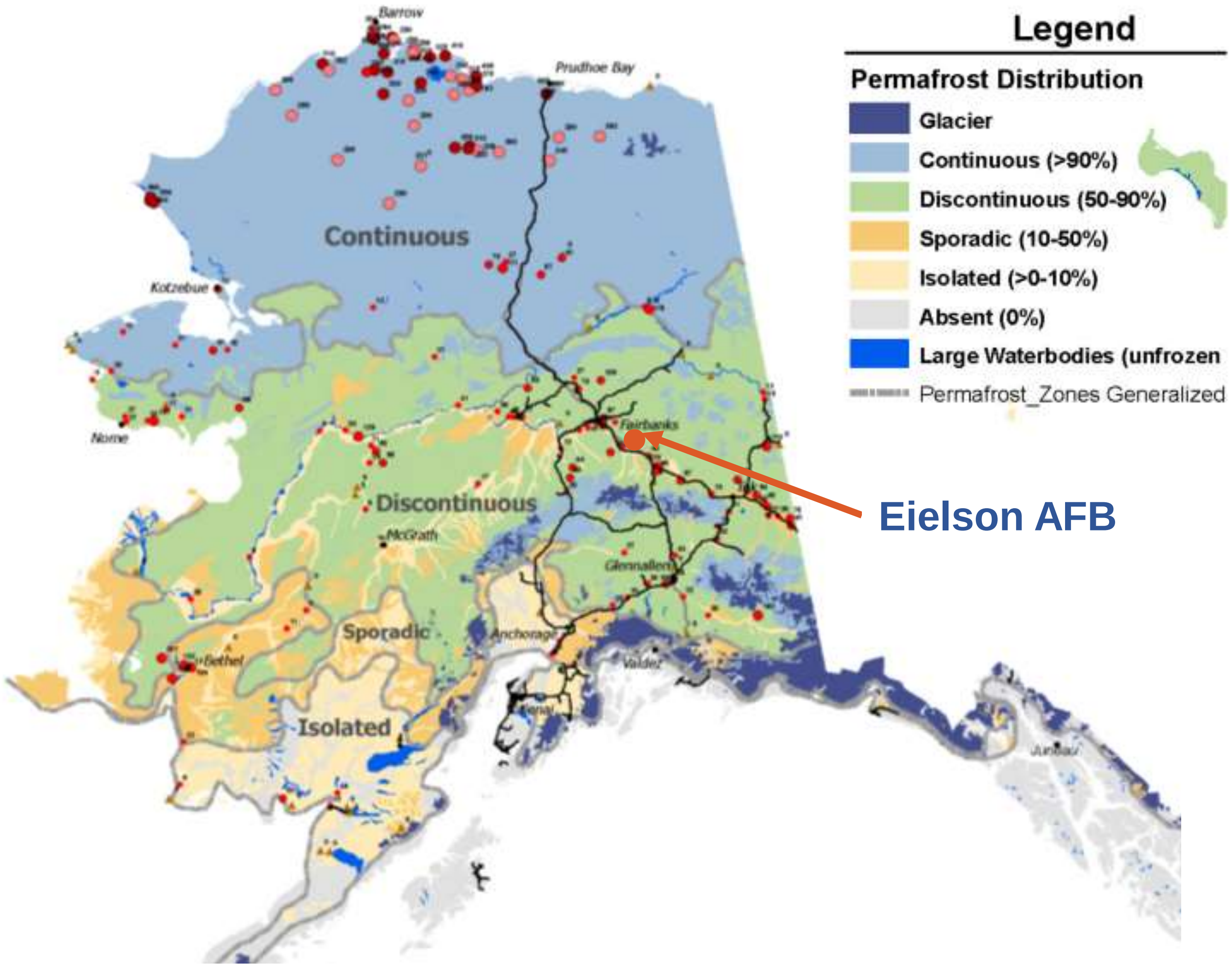
Deep foundation solutions

Passive cooling

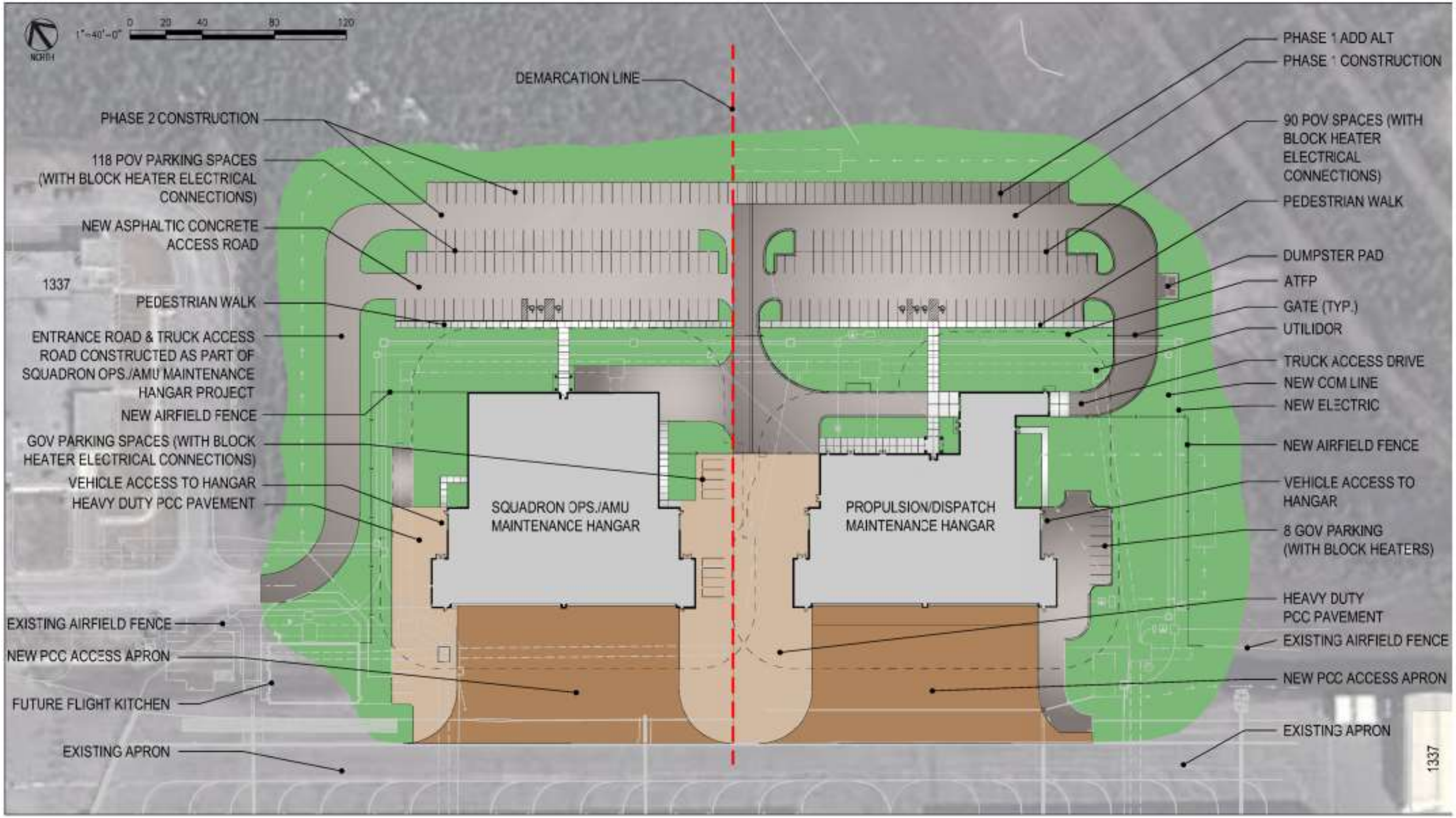
EIE376 & EIE379 Eielson F35 Hangars

Eielson Air Force Base

- New F35 Hangars
- Discontinuous Permafrost
- Critical Long Term Performance Needs
- Compounded Geotechnical Challenges



EIE376 & EIE379 Eielson F35 Hangars



EIE376 & EIE379 Eielson F35 Hangars

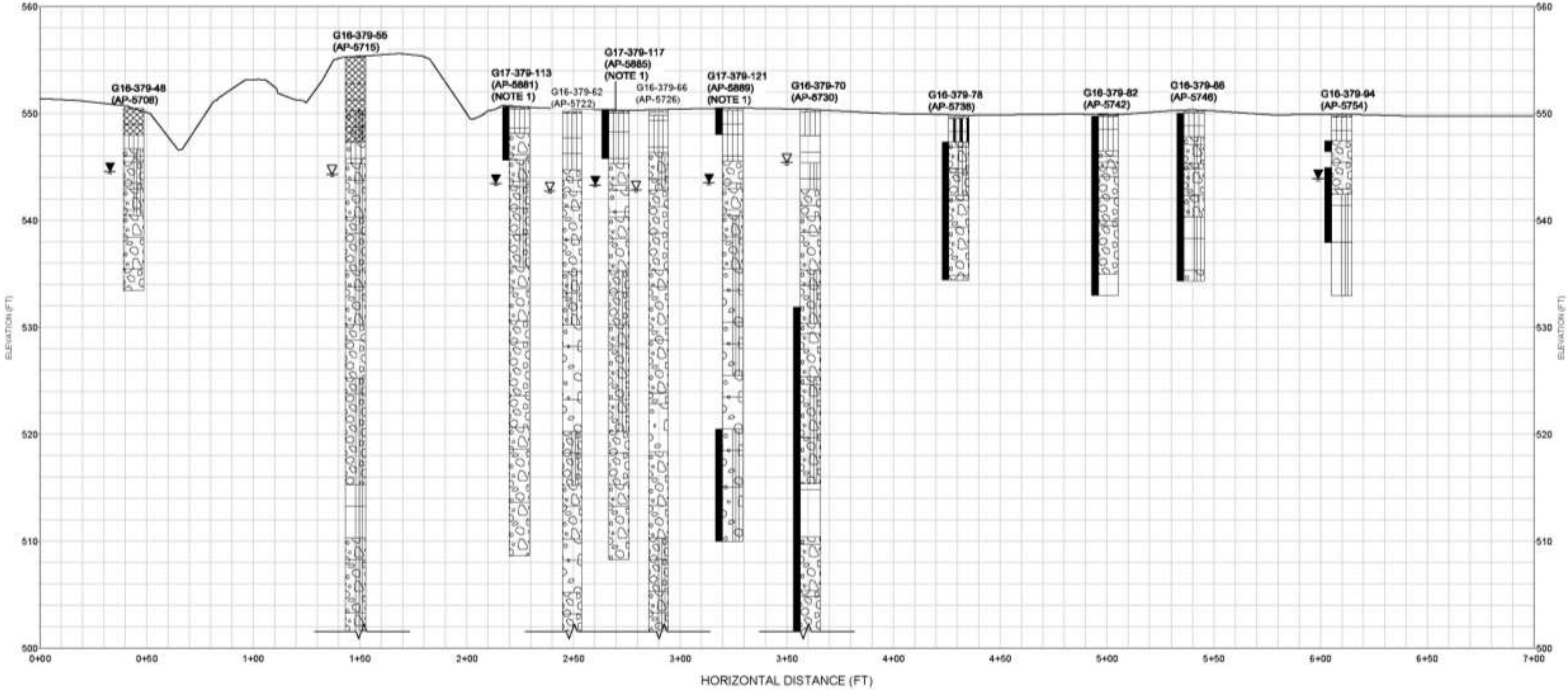
F-35A HANGAR / PROPULSION / DISPATCH (EIE376)

F-35A HANGAR / SQUAD OPS / AMU (EIE379)

- Active and previously developed apron areas
- Discontinuous permafrost soils
- Unfrozen soils present liquefaction hazard

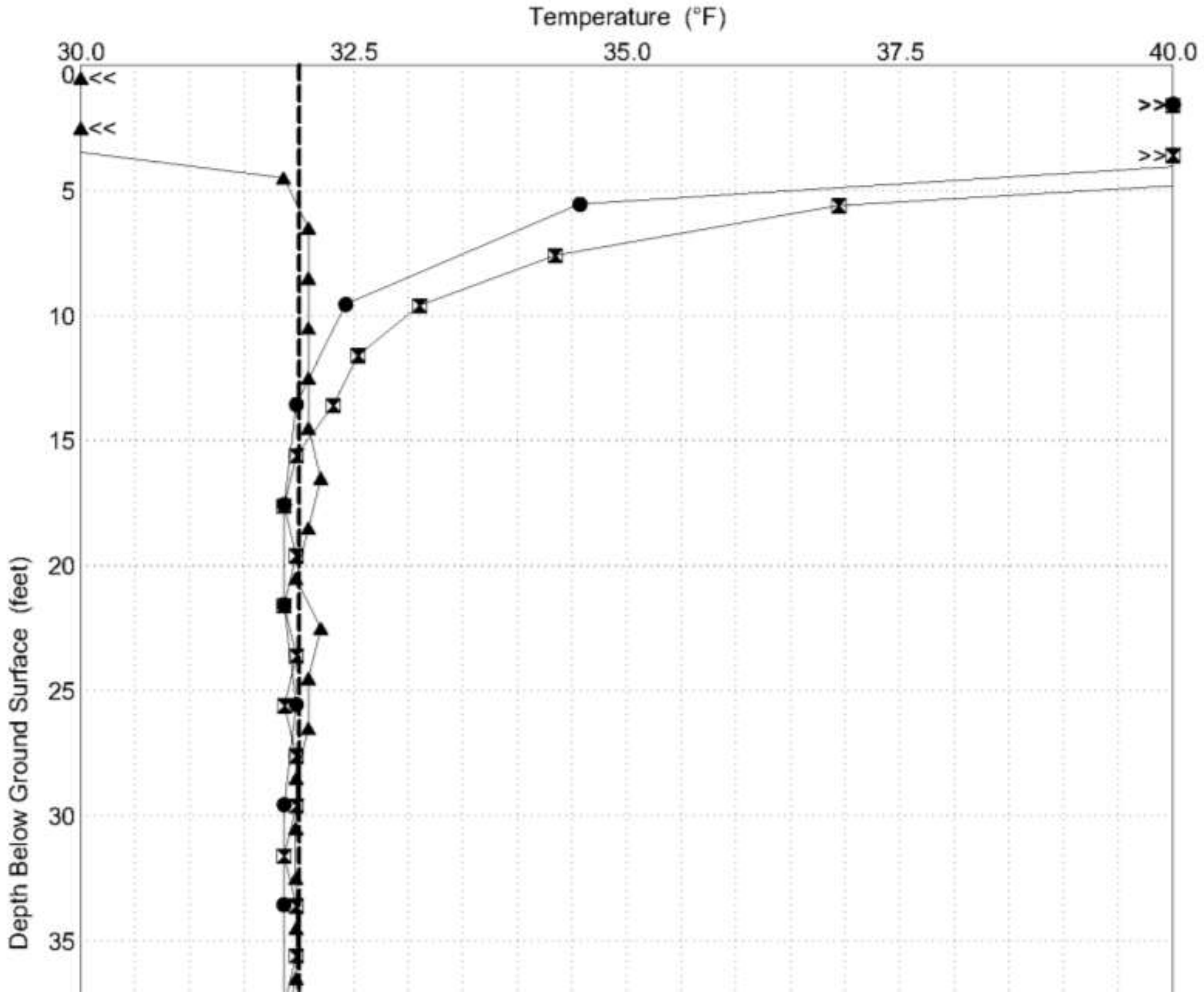
EIE376 & EIE379 Eielson F35 Hangars

USACE provided geotechnical borings



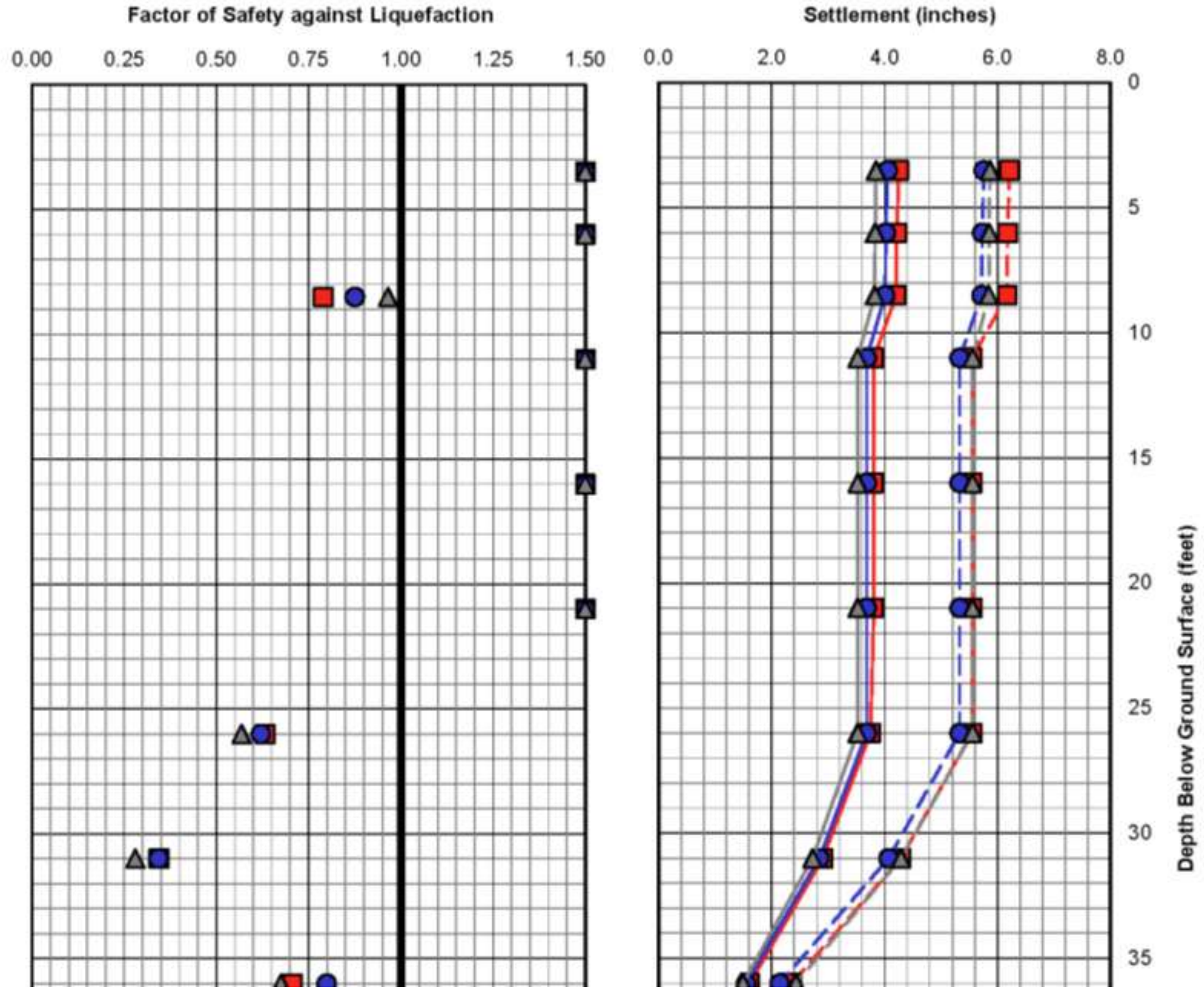
EIE376 & EIE379
Eielson F35 Hangars

USACE provided
ground temperatures

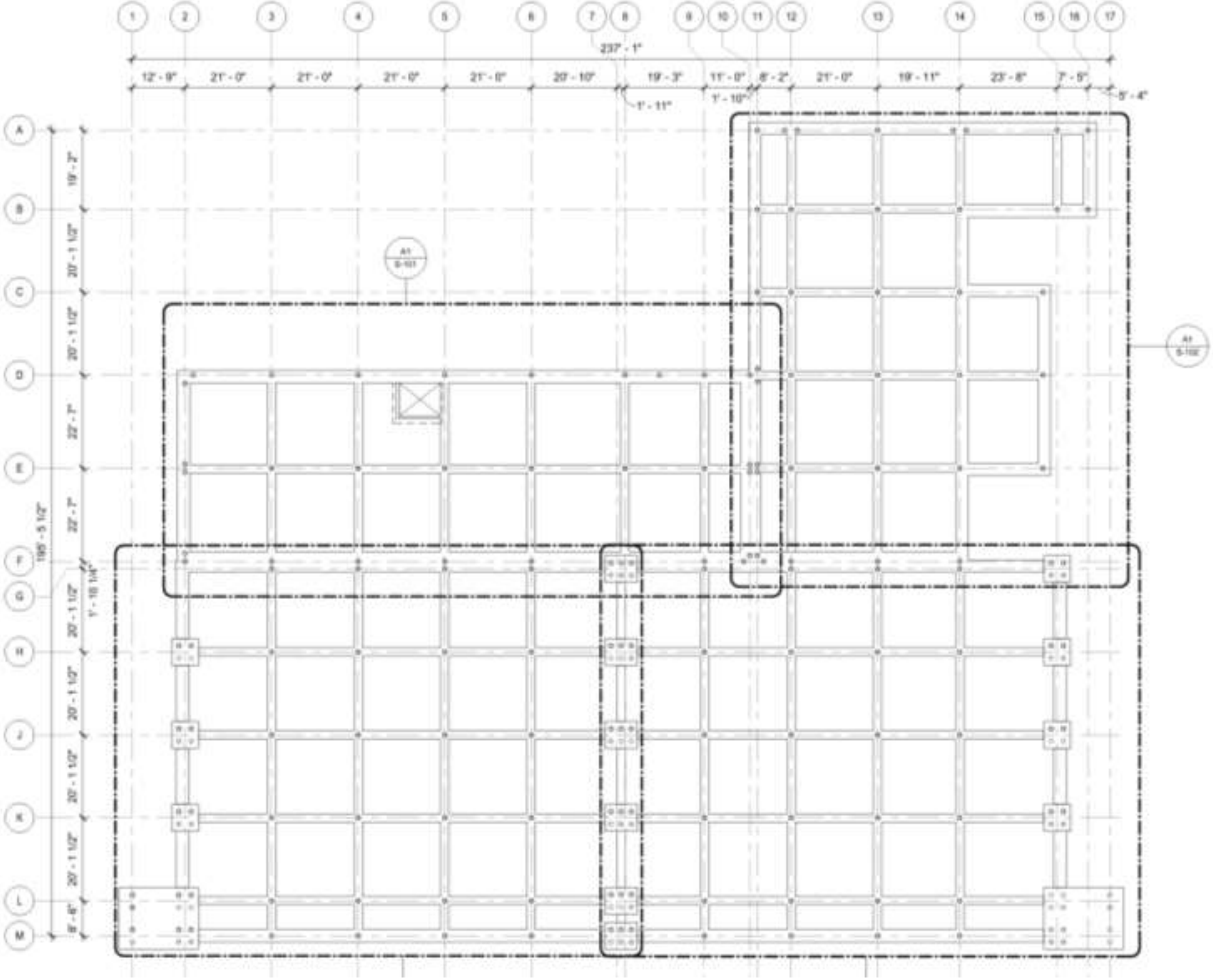


EIE376 & EIE379 Eielson F35 Hangars

What happens when (not if) the ground thaws???



EIE376 & EIE379 Eielson F35 Hangars



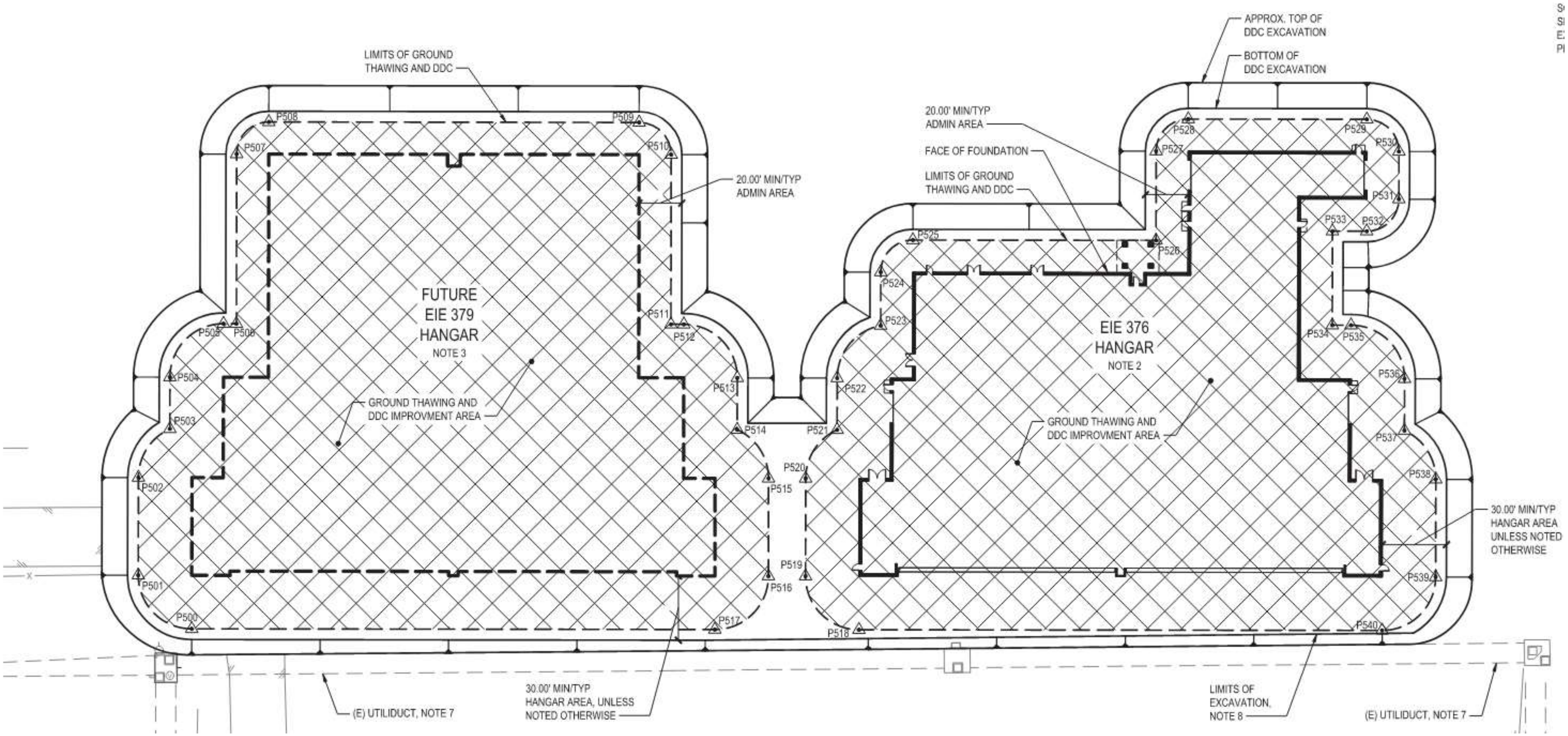
Pile Foundation Concept

- Driven Steel Pipe Piles
- Concrete Grade Beams
- Structural Slabs

Concerns

- Hard driving through permafrost
- Differential settlement w/ apron
- Differential settlement w/ utilities

EIE376 & EIE379 Eielson F35 Hangars



EIE376 & EIE379 Eielson F35 Hangars

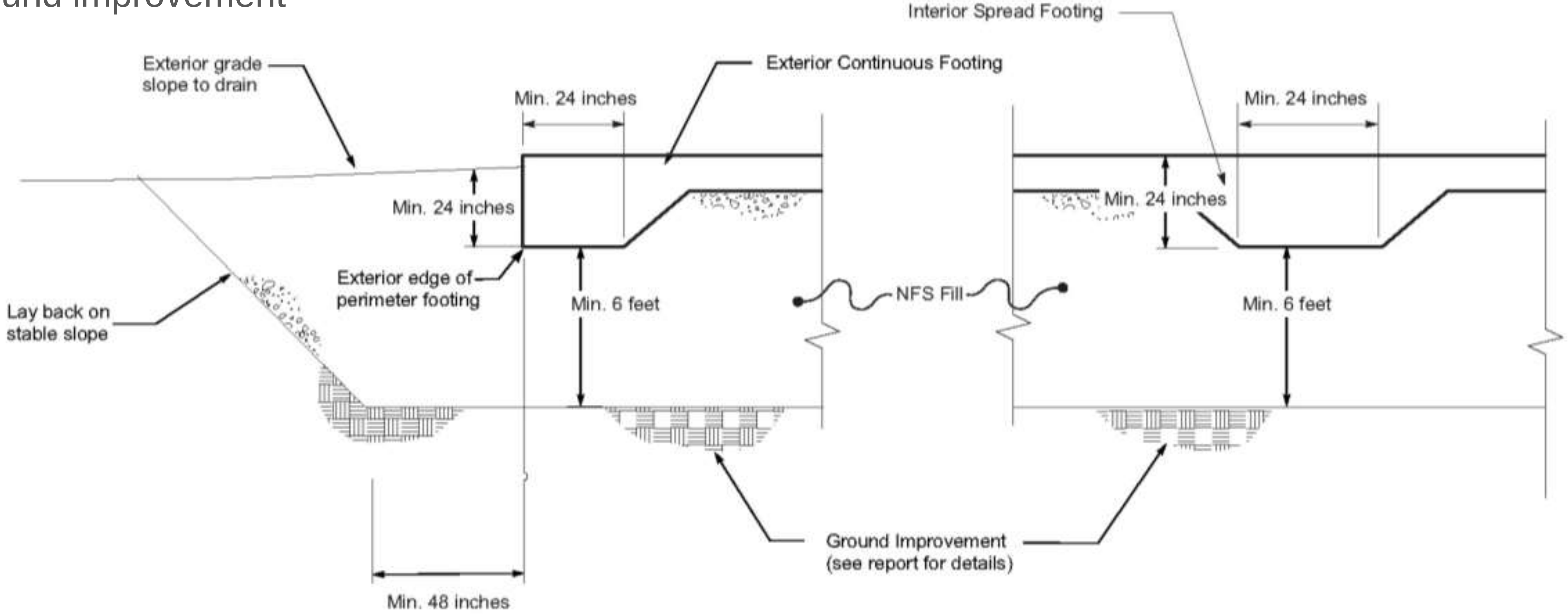
Ground Improvement Measures

- Thawing
- Deep Dynamic Compaction (DDC)

EIE376 & EIE379 Eielson F35 Hangars

Continuous Spread Footings

- Shallow excavations
- Seismically resilient with the ground improvement



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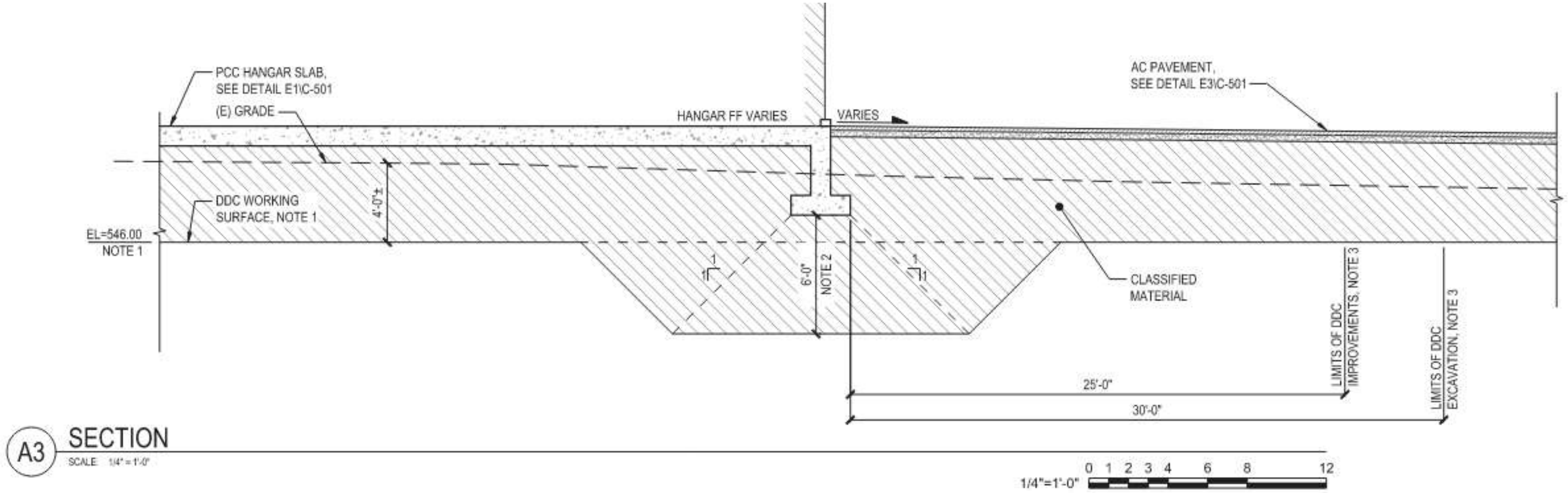
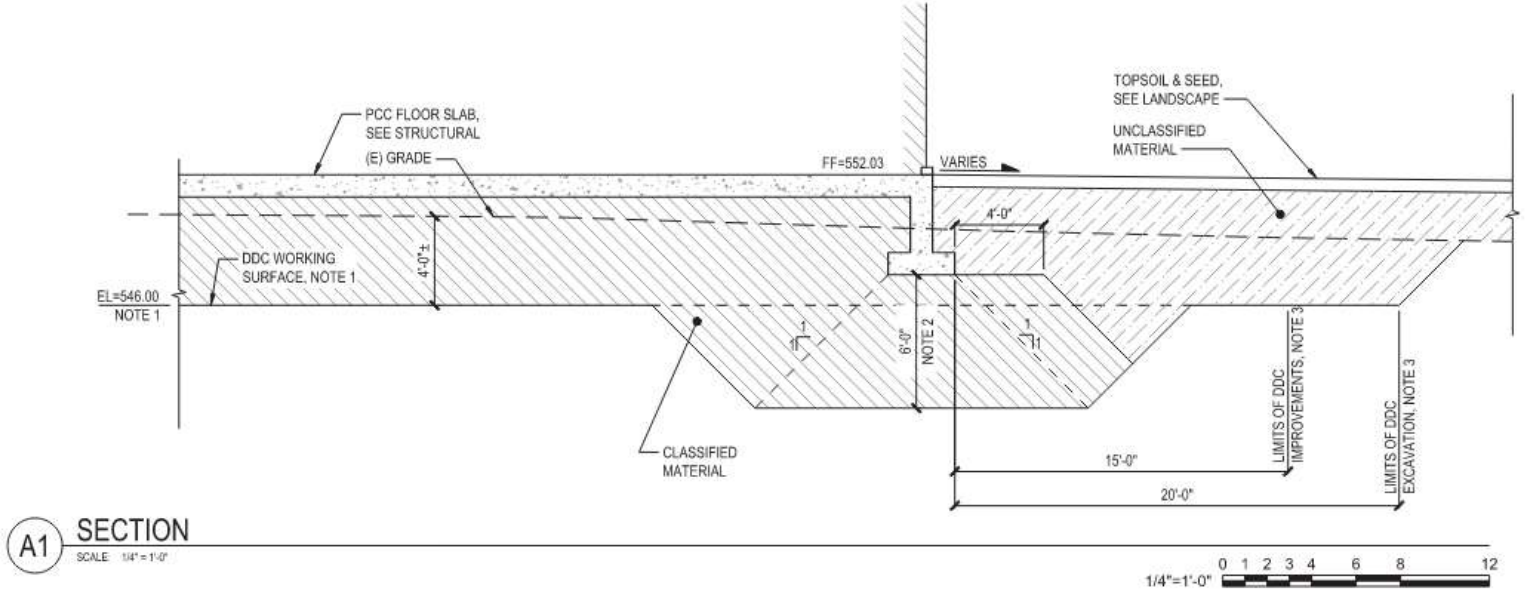


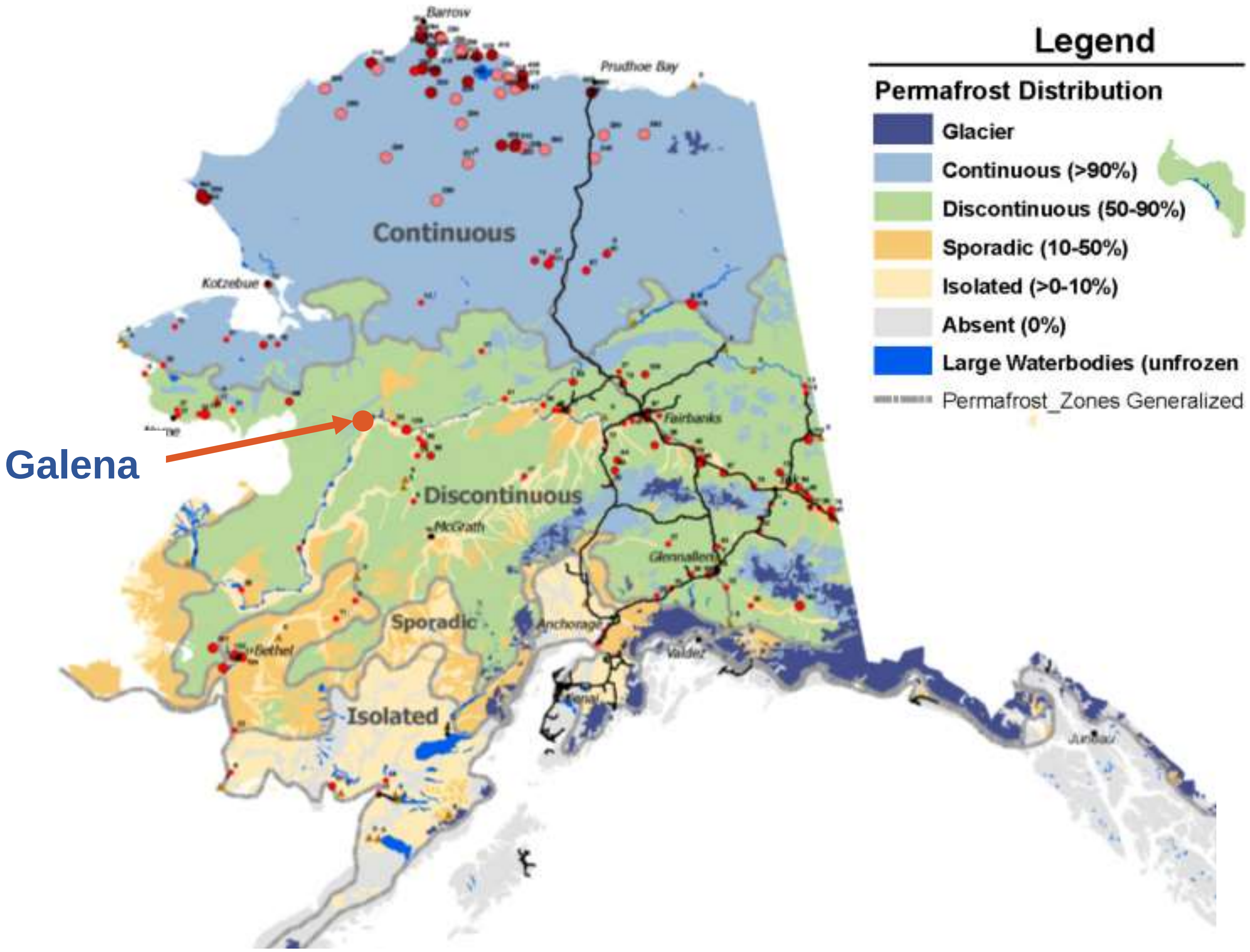


EIE376 & EIE379 Eielson F35 Hangars

Galena Fire Hall Replacement

Galena, Alaska

- Fire Hall Replacement
- Failing Passively Cooled Foundation
- Critical Community Facility



Galena Fire Hall Replacement

Governor Dunleavy Issues Three Disaster Declarations: Spring Floods, Lowell Point Landslide, and Galena Fire Hall

By Shannon Mason | State of Alaska on May 15, 2022 Featured, State

(Juneau) – Governor Mike Dunleavy has issued three disaster declarations. The 2022 Spring Floods, the 2022 Lowell Point Landslide in the City of Seward, and the Galena Fire Hall roof collapse will now be eligible for State of Alaska disaster recovery programs.   Governor Dunleavy activated Public Assistance and Individual Assistance for the 2022 Spring [...]

Galena Fire Hall Replacement

Galena Fire Hall Replacement

Galena Fire Hall Replacement

Galena Fire Hall Replacement

Existing foundation

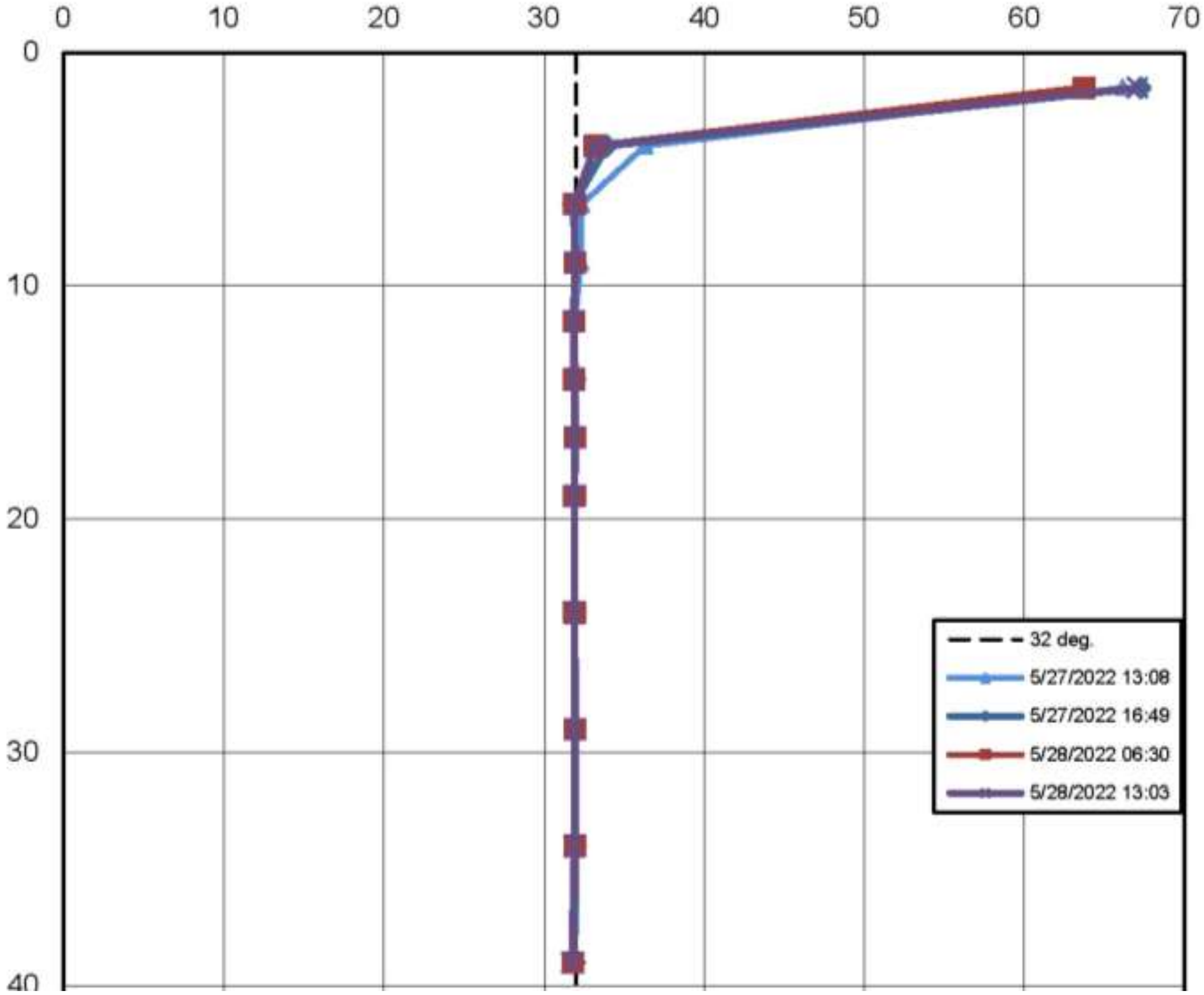
- Old school thermosyphons
- Flat loop cooled pad
- Severe differential settlement
- Poor maintenance on system

Galena Fire Hall Replacement

Soil Characterization

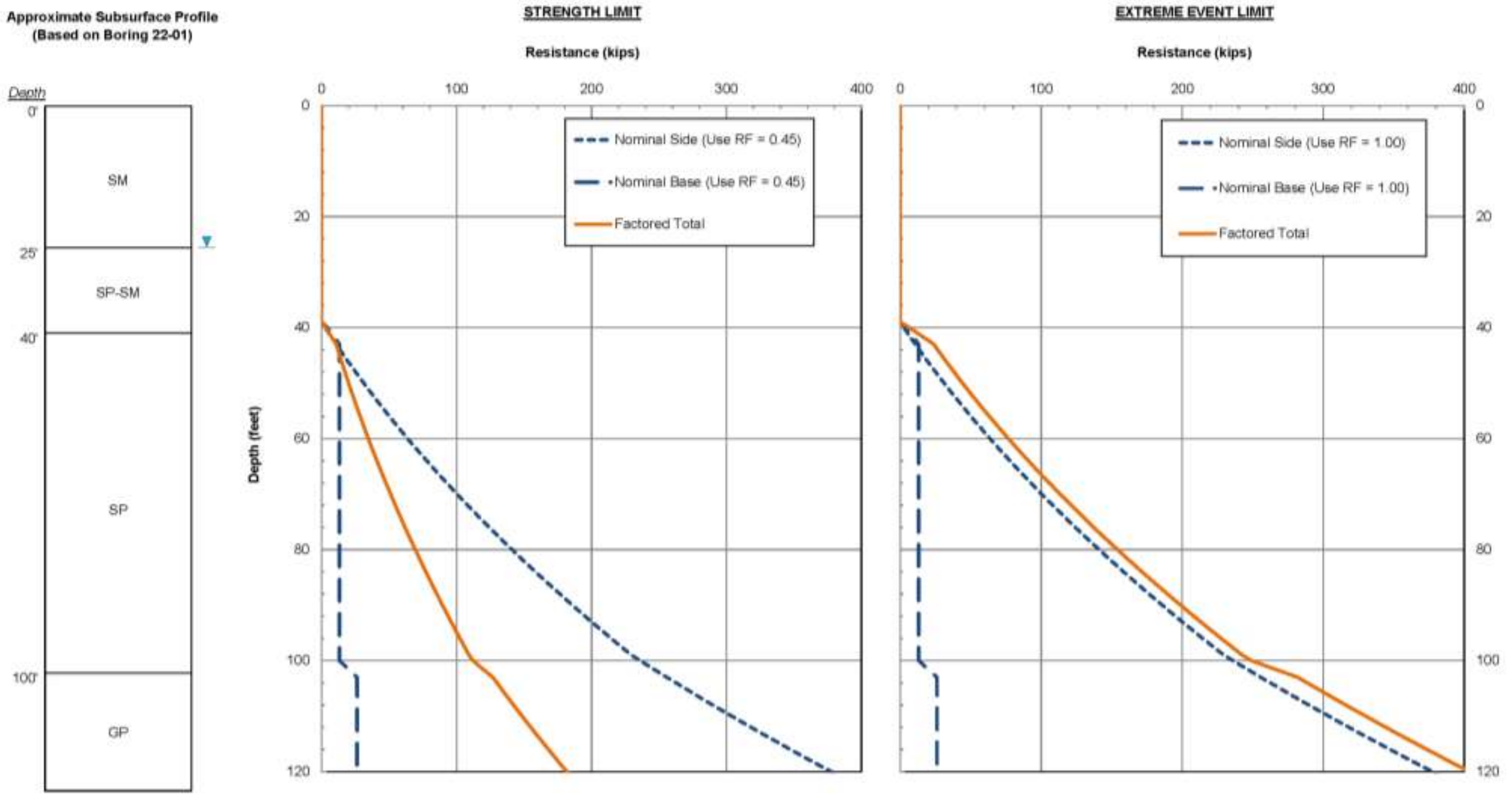
- Geotechnical borings
- Ground temperature measurements
- Lab testing

Galena Fire Hall Replacement



Galena Fire Hall Replacement

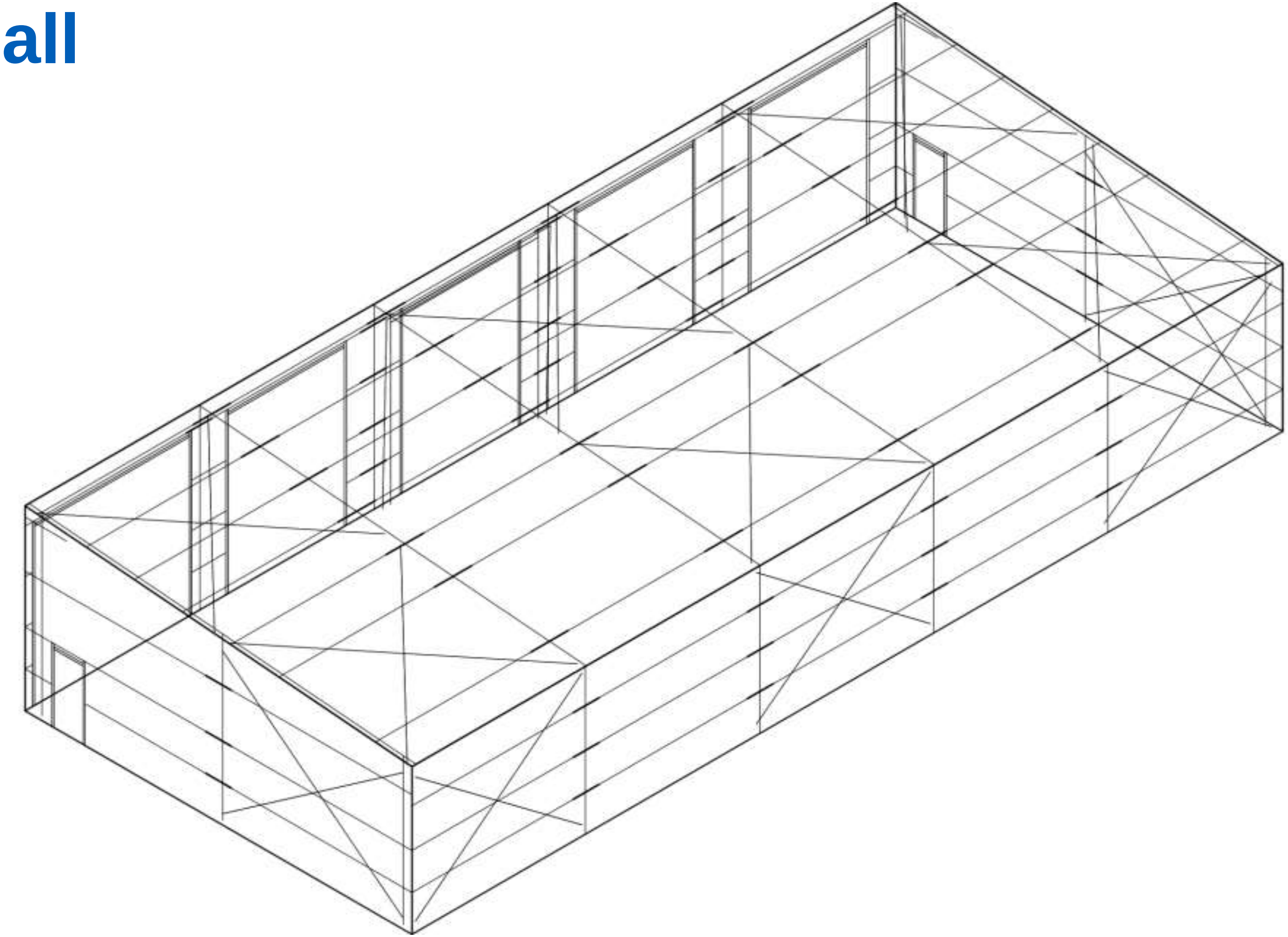
Pile Foundations - Assumed eventual ground thawing and account for downdrag



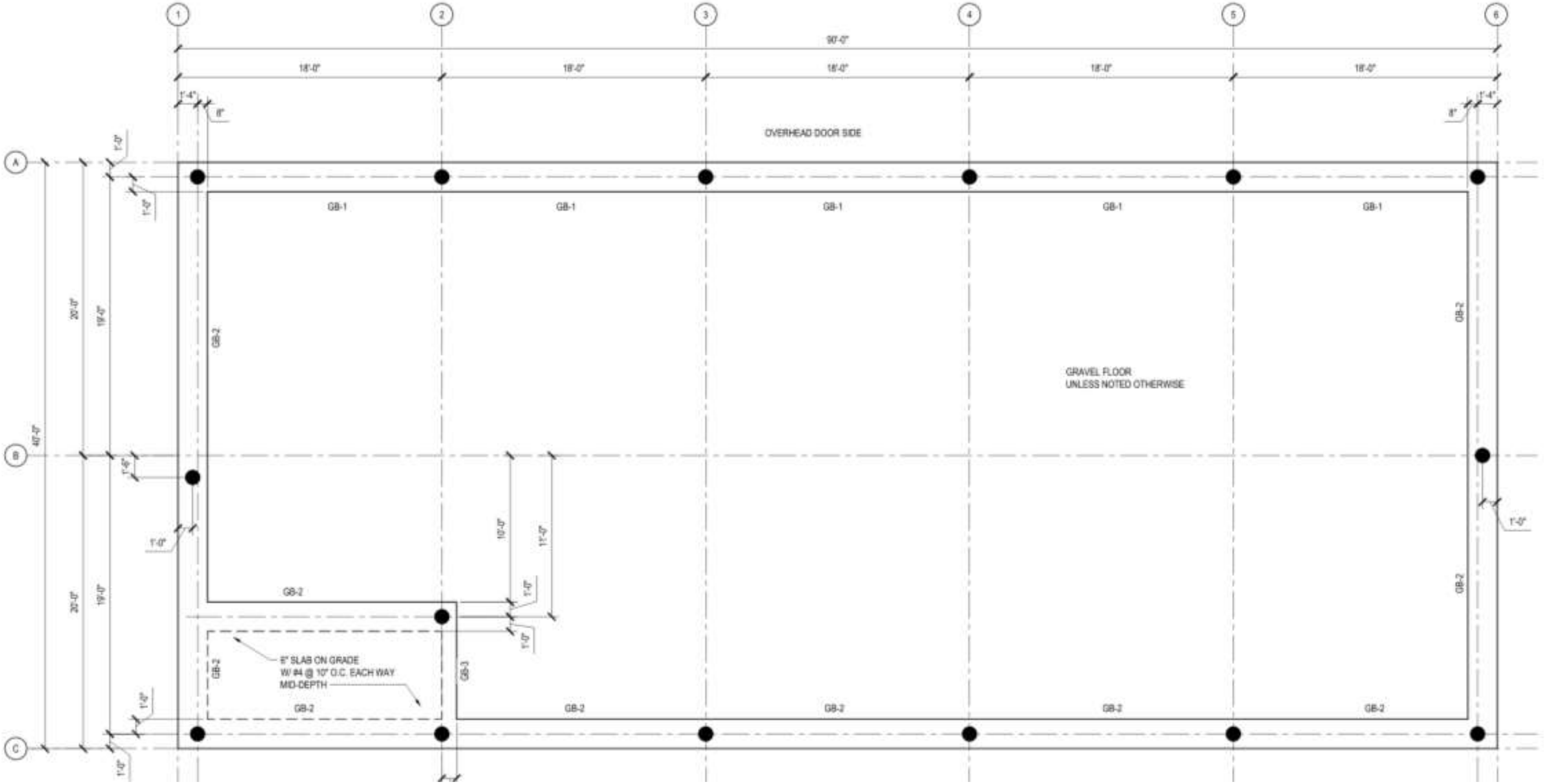
Galena Fire Hall Replacement

Pre-Engineered Metal Building

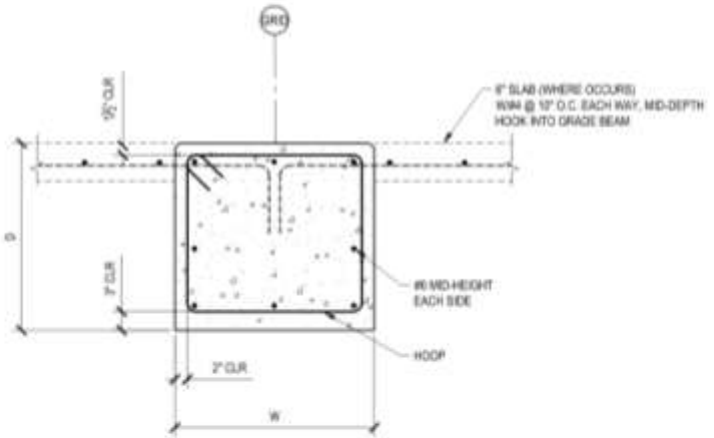
- Fast lead time for submittal process and procurement
- Short onsite erection time



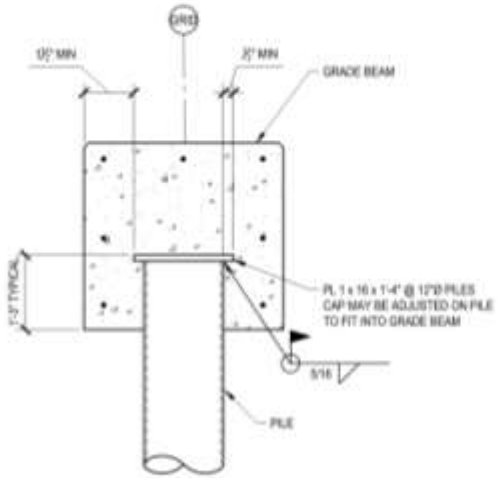
Galena Fire Hall Replacement



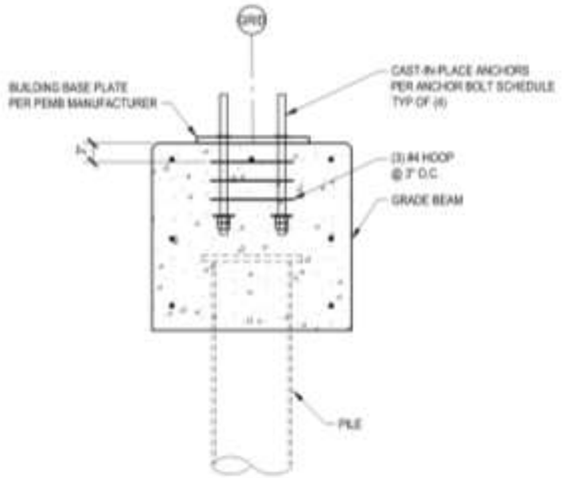
Galena Fire Hall Replacement



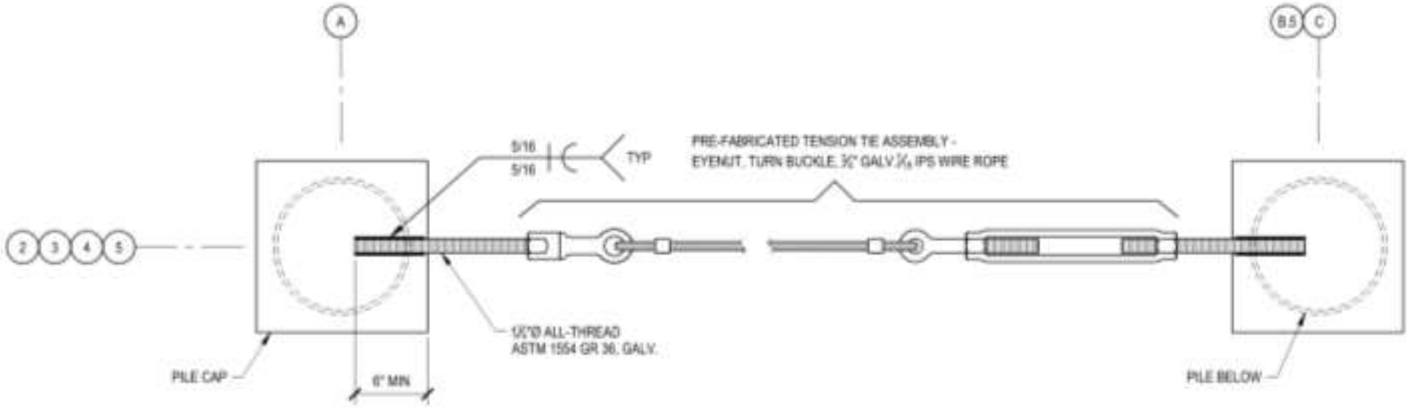
1 GRADE BEAM SECTION
S200 SCALE: 1" = 1'-0"



2 PILE TO GRADE BEAM
S200 SCALE: 1" = 1'-0"



3 ANCHOR ROD DETAIL
S200 SCALE: 1" = 1'-0"

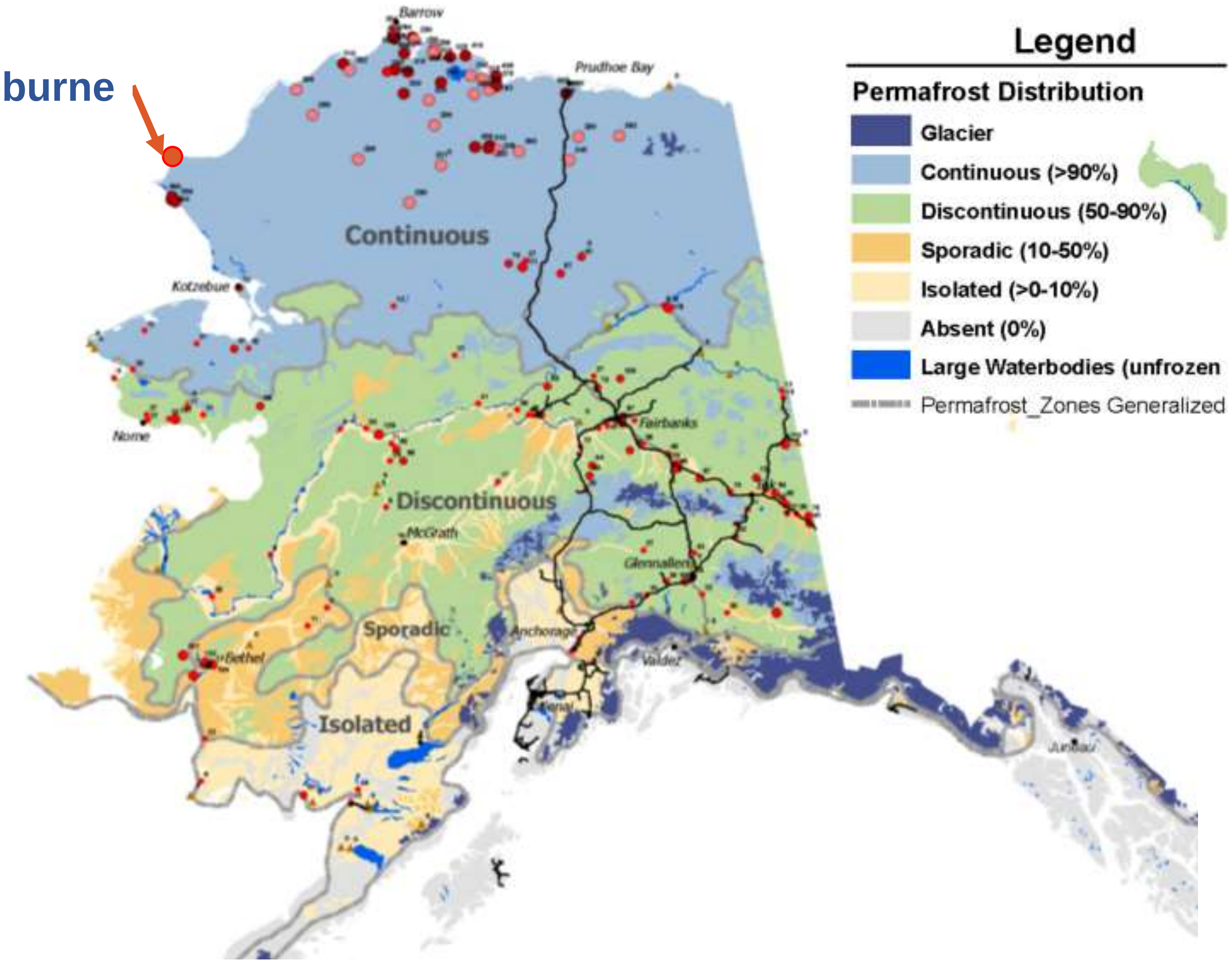


5 FOUNDATION TENSION TIE PLAN
S200 SCALE: 1 1/2" = 1'-0"

Cape Lisburne Water Storage Tanks

Cape Lisburne LRRS

- Replacement of Aging Water Storage Tanks
- Continuous Permafrost
- Mission Critical Facility
- Challenging Environment



Cape Lisburne Water Storage Tanks

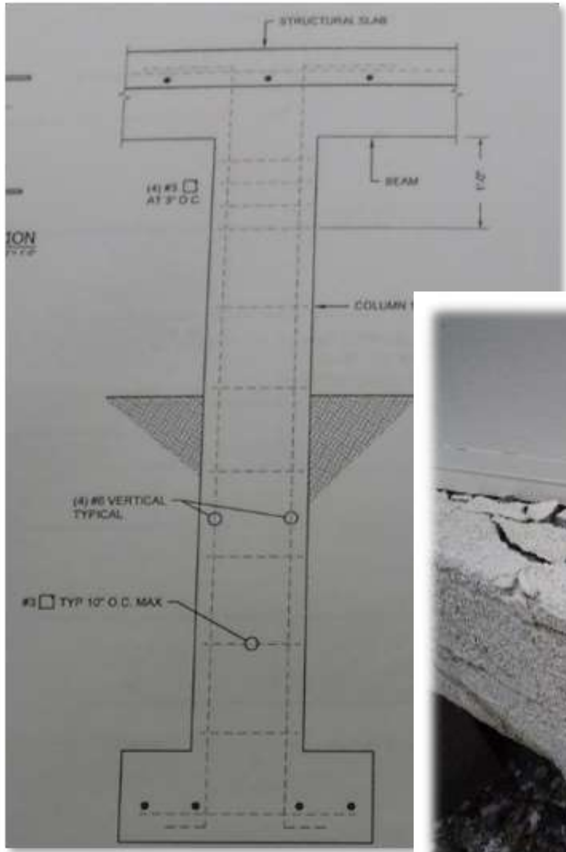
Water Tank Replacement

- Existing tanks constructed in the 1970s
- Conventional isolated footings
- Settlement issues along with spalling concrete

Cape Lisburne Water Storage Tanks

Cape Lisburne Water Storage Tanks

Existing Foundation Conditions



Cape Lisburne Water Storage Tanks

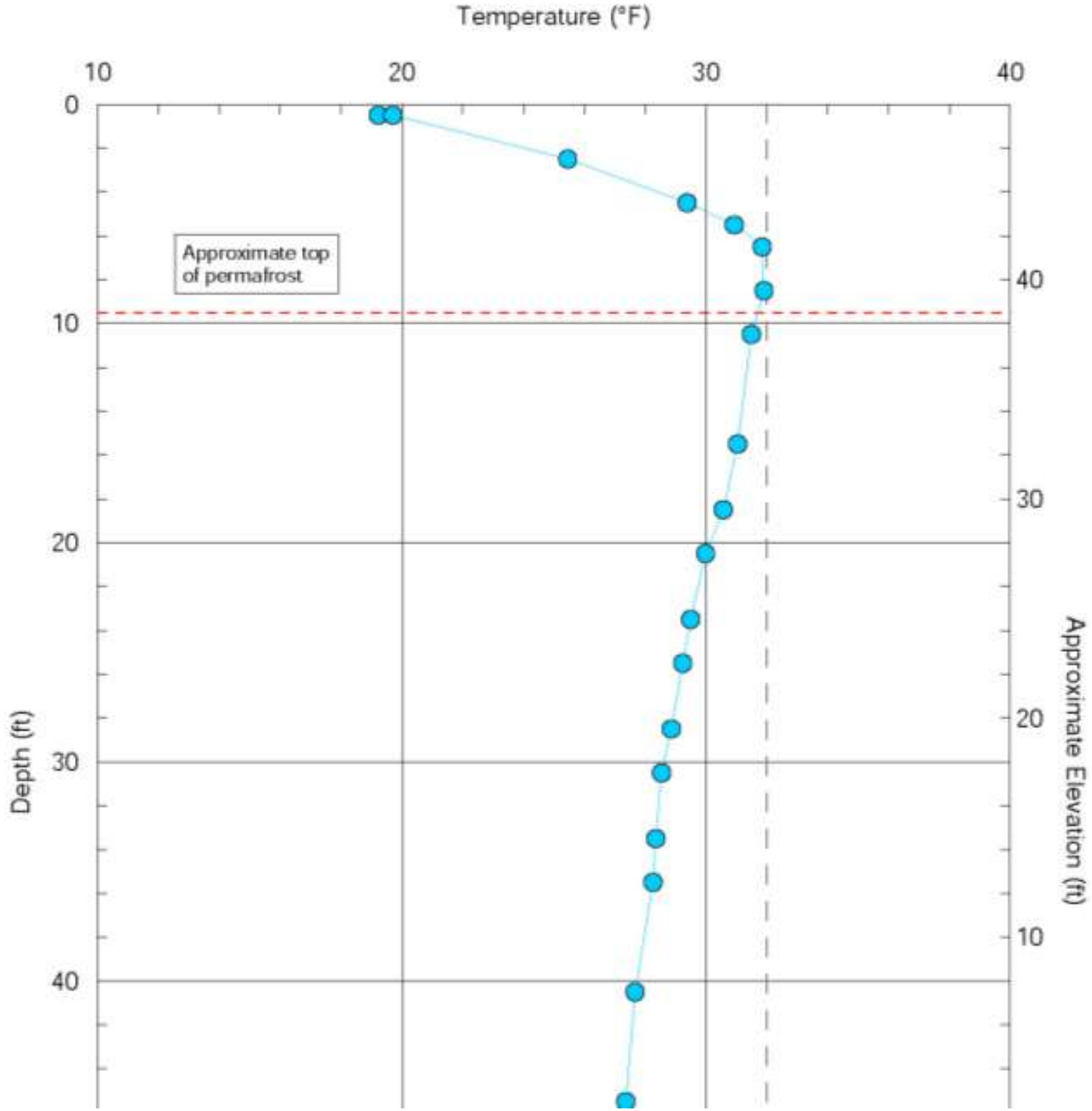
Depth (ft.)	Lithology	Sample Recovery	ASTM D 4083 Frozen	Frost Class ufc3-250-01fa	Blow Count	N-Value	Sample Type	Symbol	Classification ASTM D 2487 or D 2488	PID (ppm)	% Water	Description and Remarks
		1	Nbn		26 50/5"			GP	Poorly graded GRAVEL with Sand	0.4	9	Gray, *Poorly Graded Gravel with Sand (GP)*; frozen, Nbn, NF, fractured gravel in sampler. Fill (Hf)
2		2	Nf		5 6 7	13				0.9	3	
4								GP	Poorly graded GRAVEL with Sand			Gray, *Poorly Graded Gravel with Sand (GP)*; moist; few organics. Fill (Hf)
		3			5 3 1	4				0.3	5	
6								OL	Gravelly organic SILT			Dark brown, *Gravelly Organic Soil (OL)*; moist.
8		4			10 14 13	27			Silty GRAVEL with Sand	0.3	15	Brown, *Silty Gravel with Sand (GM)*; moist above 10 feet bgs then frozen, Vx, 3% visible ice.
10		5	Vx		13 15 20	35		GM	Silty GRAVEL with Sand	0.7	13	Brown, *Silty Gravel with Sand (GM)*; frozen, Nbe, Vx, 2-5% visible ice by volume.
12		6	Vx		21 21 24	45					12	
14, 16		7	Vx		40 43 42	85					12	
18		8	Vx		40 48 37	85					14	
20		9	Vx		27 34 45	79					12	
22, 24												
		10	Nbn		50/5"						10	
26								GM	Silty GRAVEL with Sand and Cobbles			Brown, *Silty Gravel with Sanf (GM)*; frozen, Nbe to Nbn

Depth (ft.)	Lithology	Sample Recovery	ASTM D 4083 Frozen	Frost Class ufc3-250-01fa	Blow Count	N-Value	Sample Type	Symbol	Classification ASTM D 2487 or D 2488	PID (ppm)	% Water	Description and Remarks
28		11									8	
30, 32, 34		12									6	
36								GP-GM	Poorly graded GRAVEL with Silt, Sand, and Cobbles			Brown, *Poorly Graded Gravel with Silt and Sand (GP-GM)*; frozen Nbe to Nbn.
38, 40		13									6	
42, 44		14									6	
46, 48		15									17	
50, 52												Bottom of Hole 50.0 ft. Elevation 0.0 ft. ± Groundwater Not Encountered PID = (Cold/Hot) Photo Ionization Detector

Cape Lisburne Water Storage Tanks

Ground Temperature Data, used for

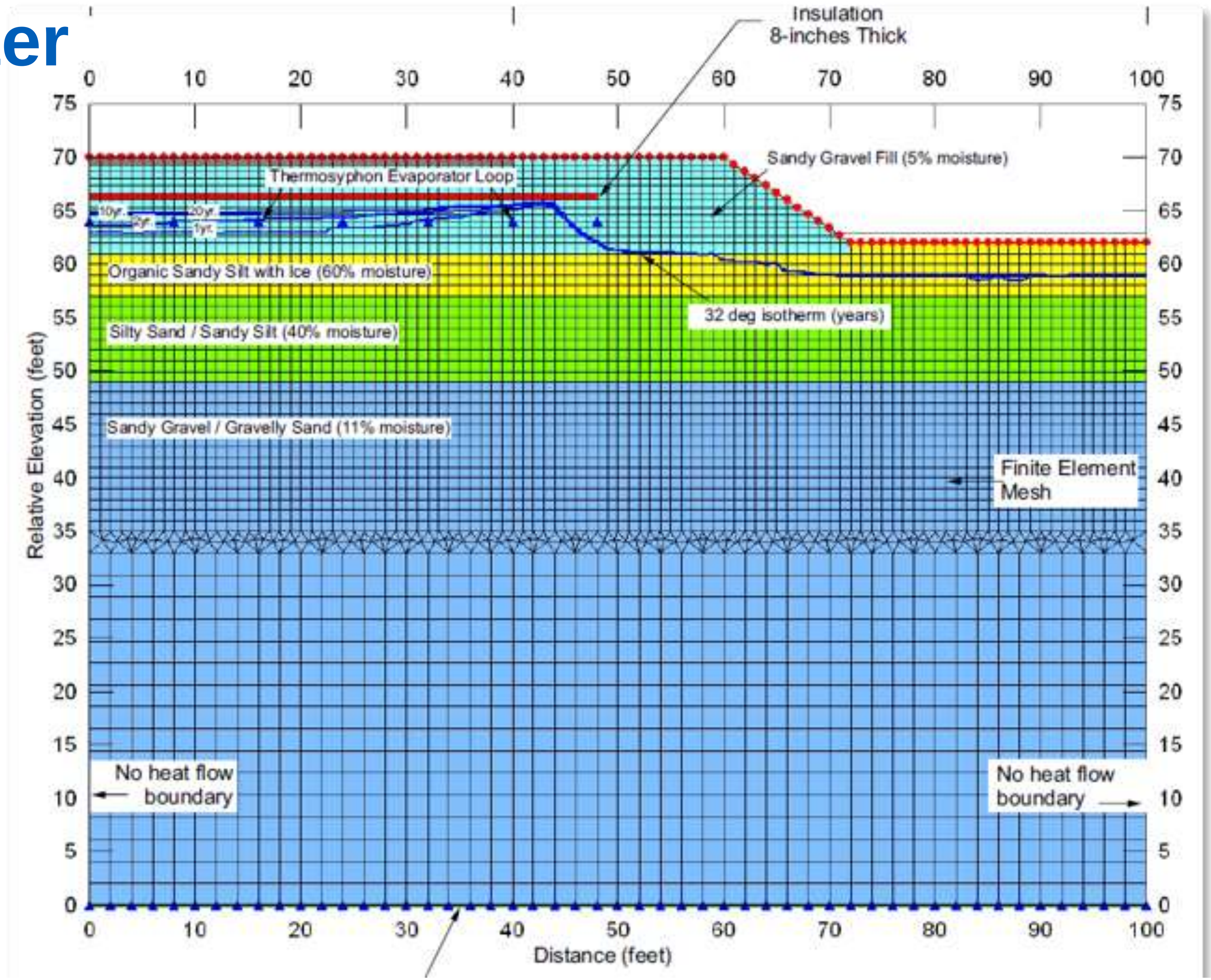
- Thermal modeling
- Thermosiphon design



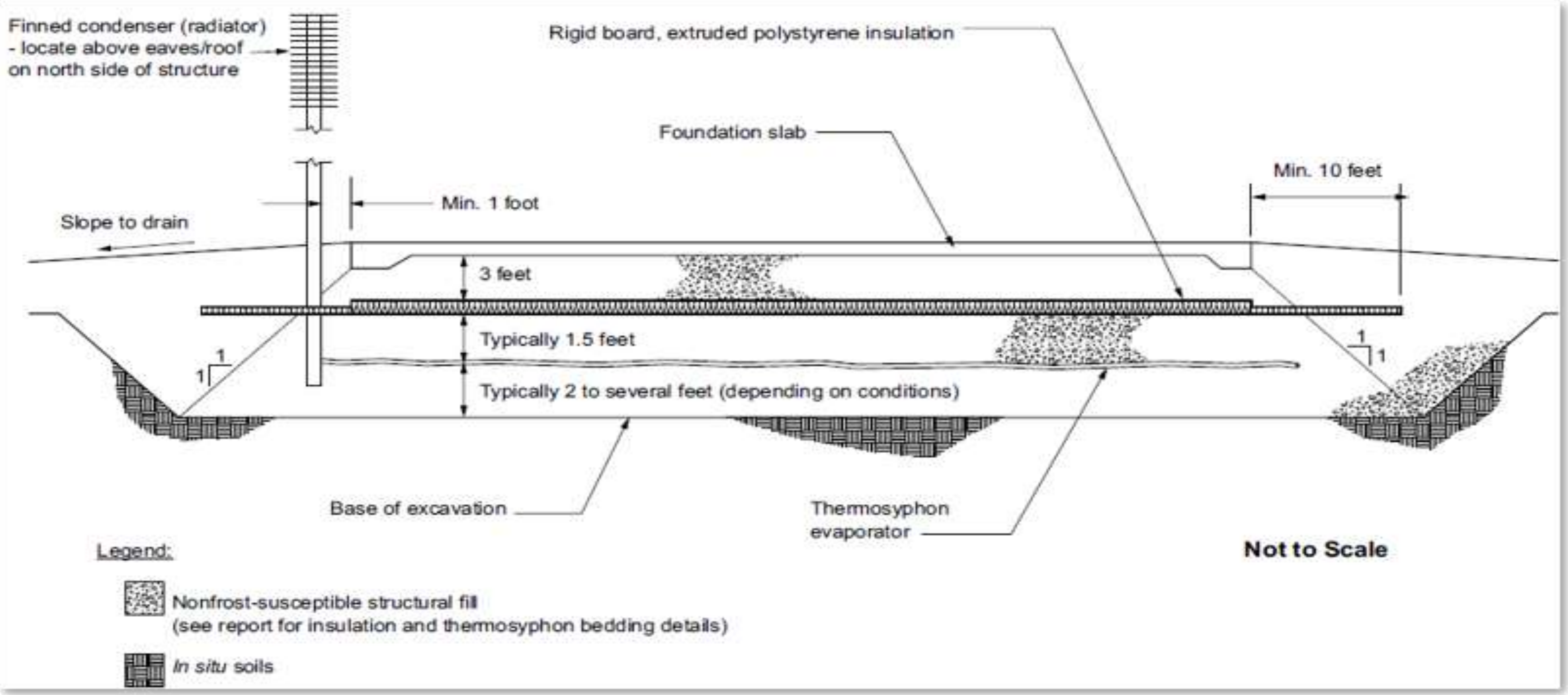
Cape Lisburne Water Storage Tanks

Thermal modeling

- Assuming flat loop thermosyphon-cooled pad
- Shallow foundation bearing on pad
- Insulation above thermosyphons
- Establish parameters for foundation/pad design
  - Insulation thickness
  - Embankment width
  - Fill slope angles
  - Thermosyphon spacing and specifications



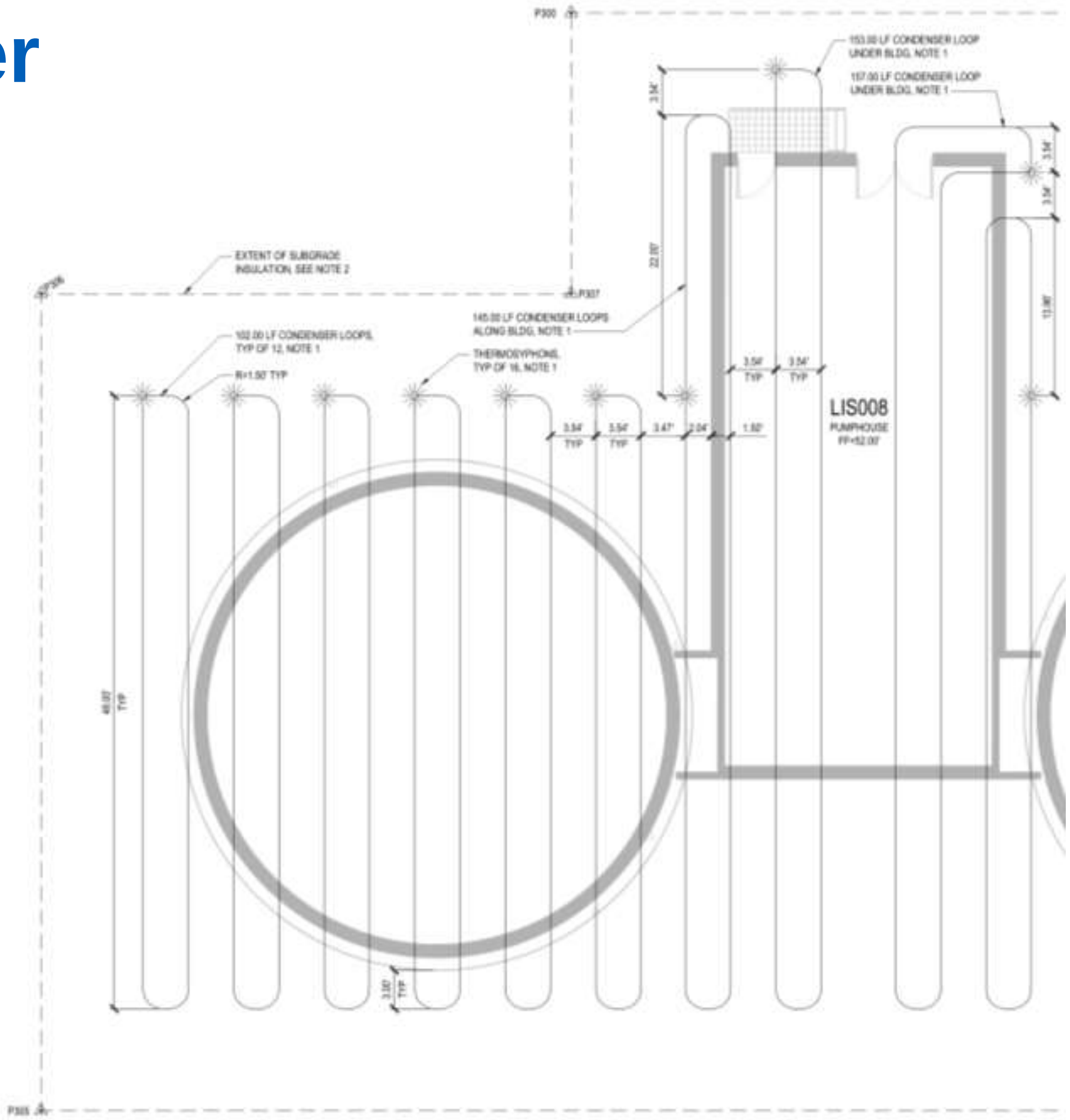
Cape Lisburne Water Storage Tanks



Cape Lisburne Water Storage Tanks

Civil General Arrangement Plan

- Thermosiphon locations
- Condenser loops layout



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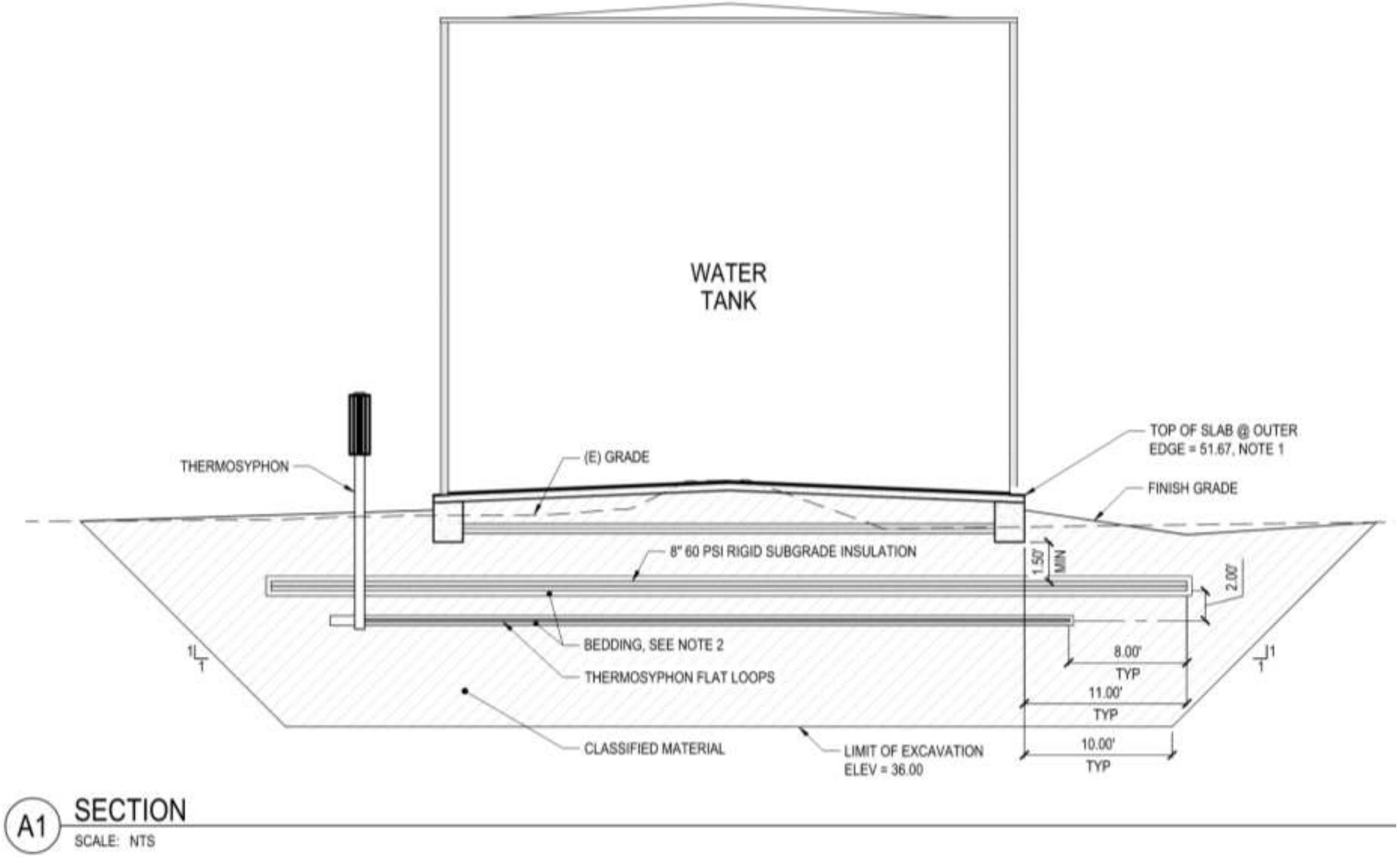
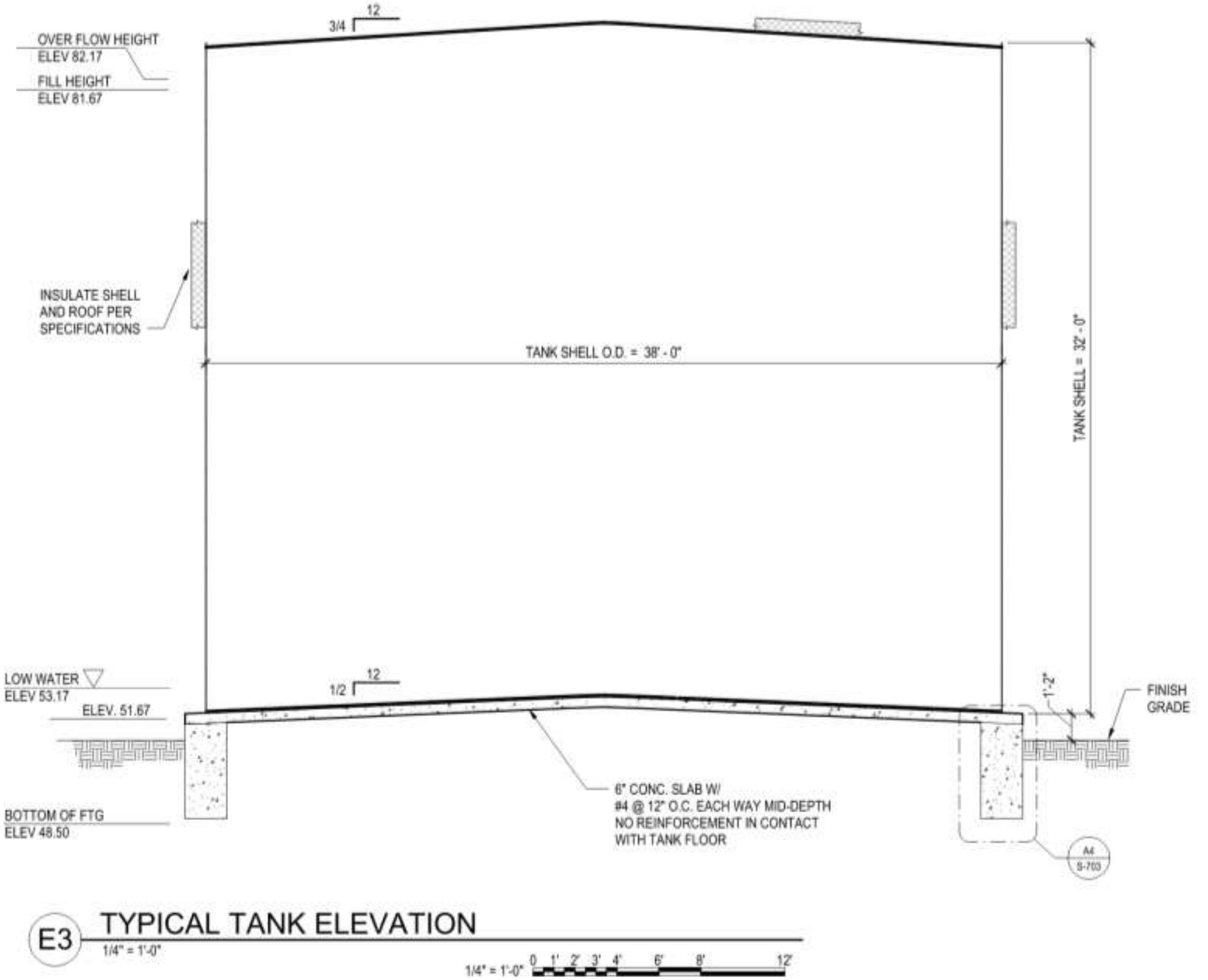


Cape Lisburne Water Storage Tanks

Structural Section

- Insulated steel tank
- Concrete cone bottom
- Concrete ring wall



Summary

- Site-specific soils data w/ ground temperature data is crucial
- Thermal modeling for ice-rich soils; forecasting temperatures
- Facility use and service life
- Consider long-term performance

- Different options
  - Deep foundations (e.g. piles)
  - Shallow foundations – maintenance?
  - Ground Improvements
  - Refrigeration (i.e. thermosiphons)
    - Active or Passive

Thank you! Questions?