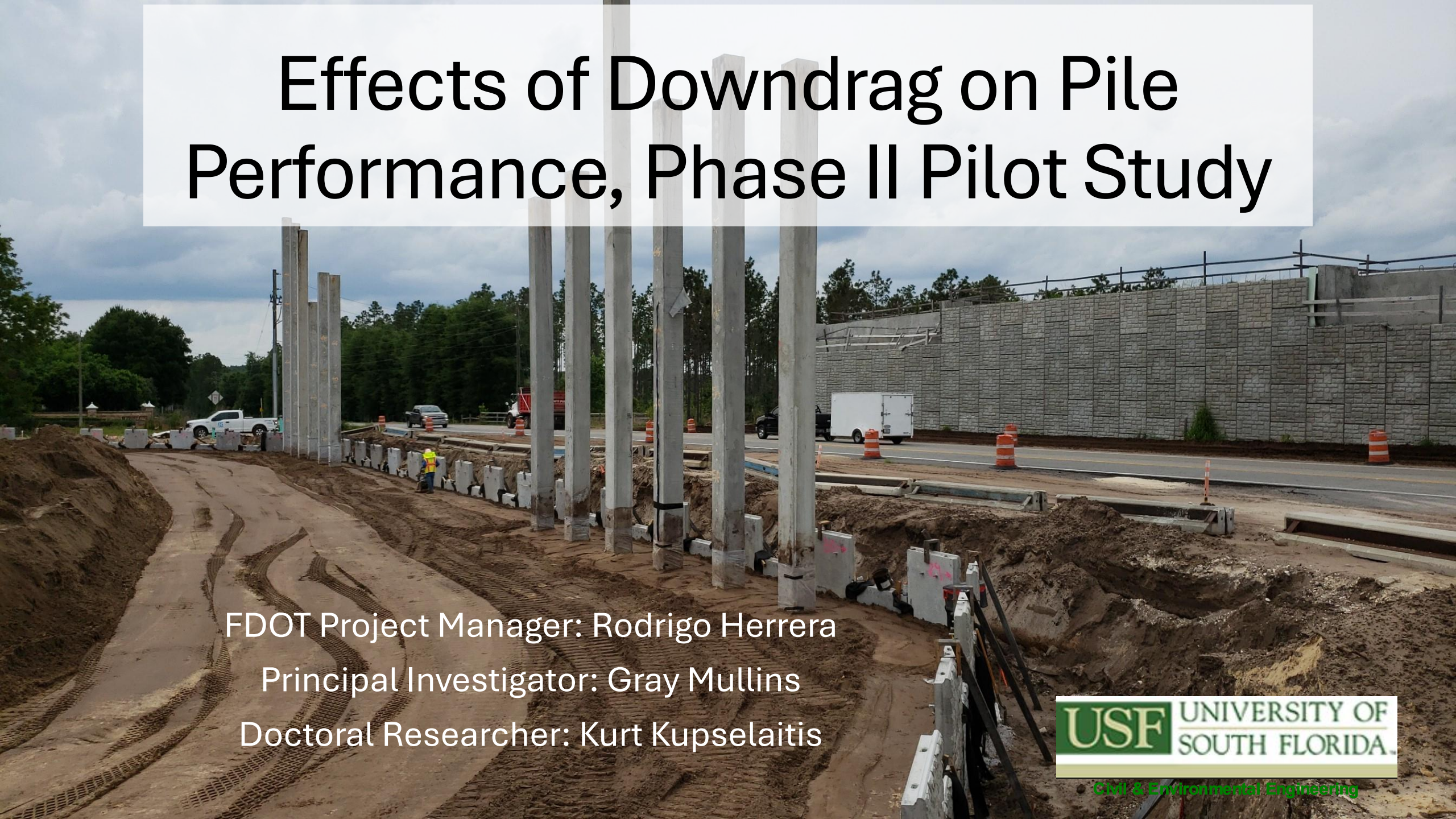
Effects of Downdrag on Pile Performance, Phase II Pilot Study



FDOT Project Manager: Rodrigo Herrera

Principal Investigator: Gray Mullins

Doctoral Researcher: Kurt Kupselaitis

USF UNIVERSITY OF SOUTH FLORIDA

Civil & Environmental Engineering

Outline

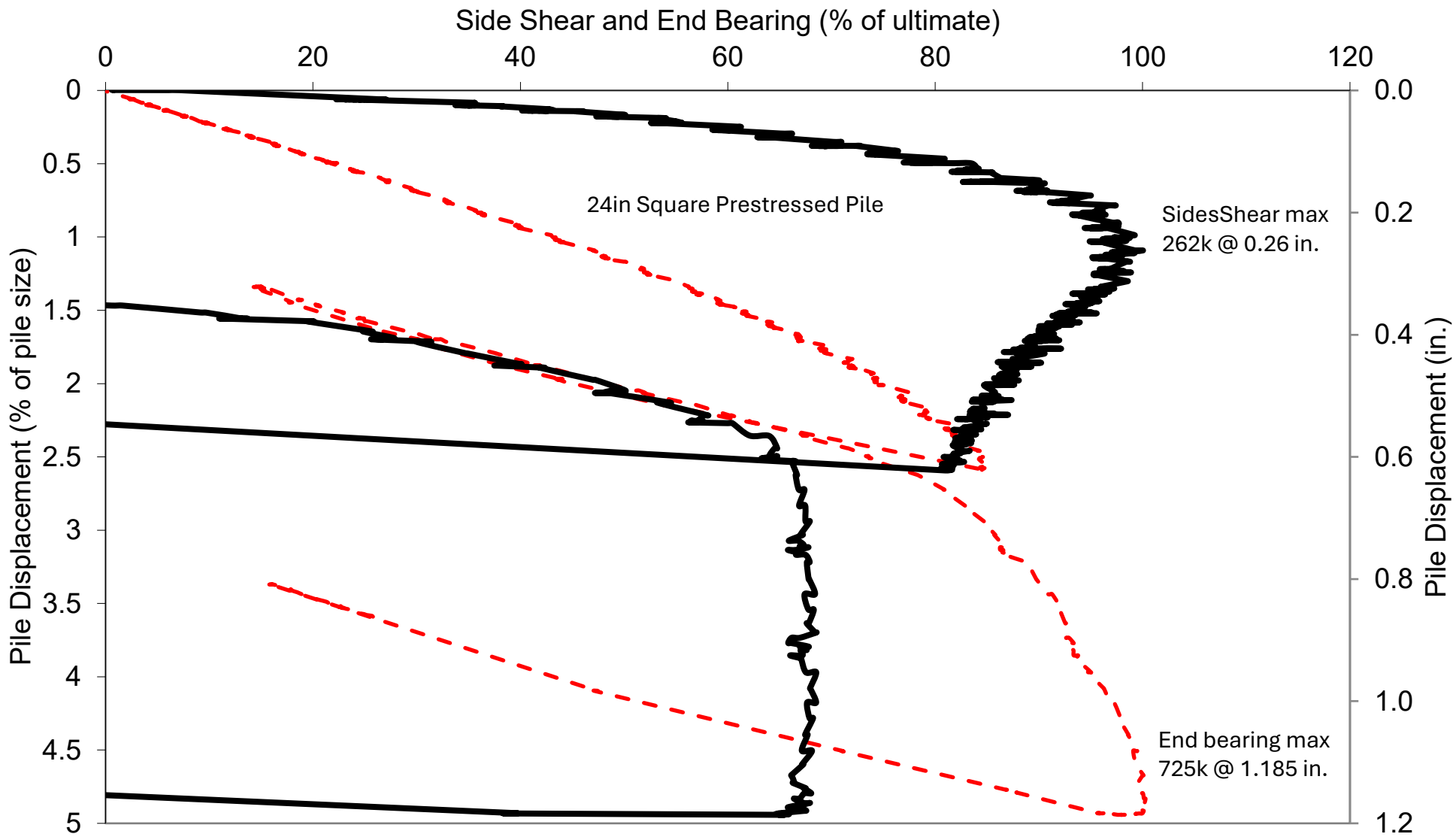
- Phase I summary
- Background
  - Mechanics of pile resistance
  - Embankment settlement
  - Ground improvement
  - Downdrag
- Problem Statement
- Tasks
- Interim Findings
- Summary/Closing

Effects of Downdrag (Phase 1)

- All prior studies focused on clay sites settlement and downdrag effects. None in sandy soil sites

- Instrumented piles and ground settlement at three bridge sites with sandy soils
- Monitored for 1-2 years (now 3-4 years)
- Limited live load records
- Findings showed large, unanticipated downdrag forces from settlement in sandy soils.

Mechanics of Pile Resistance



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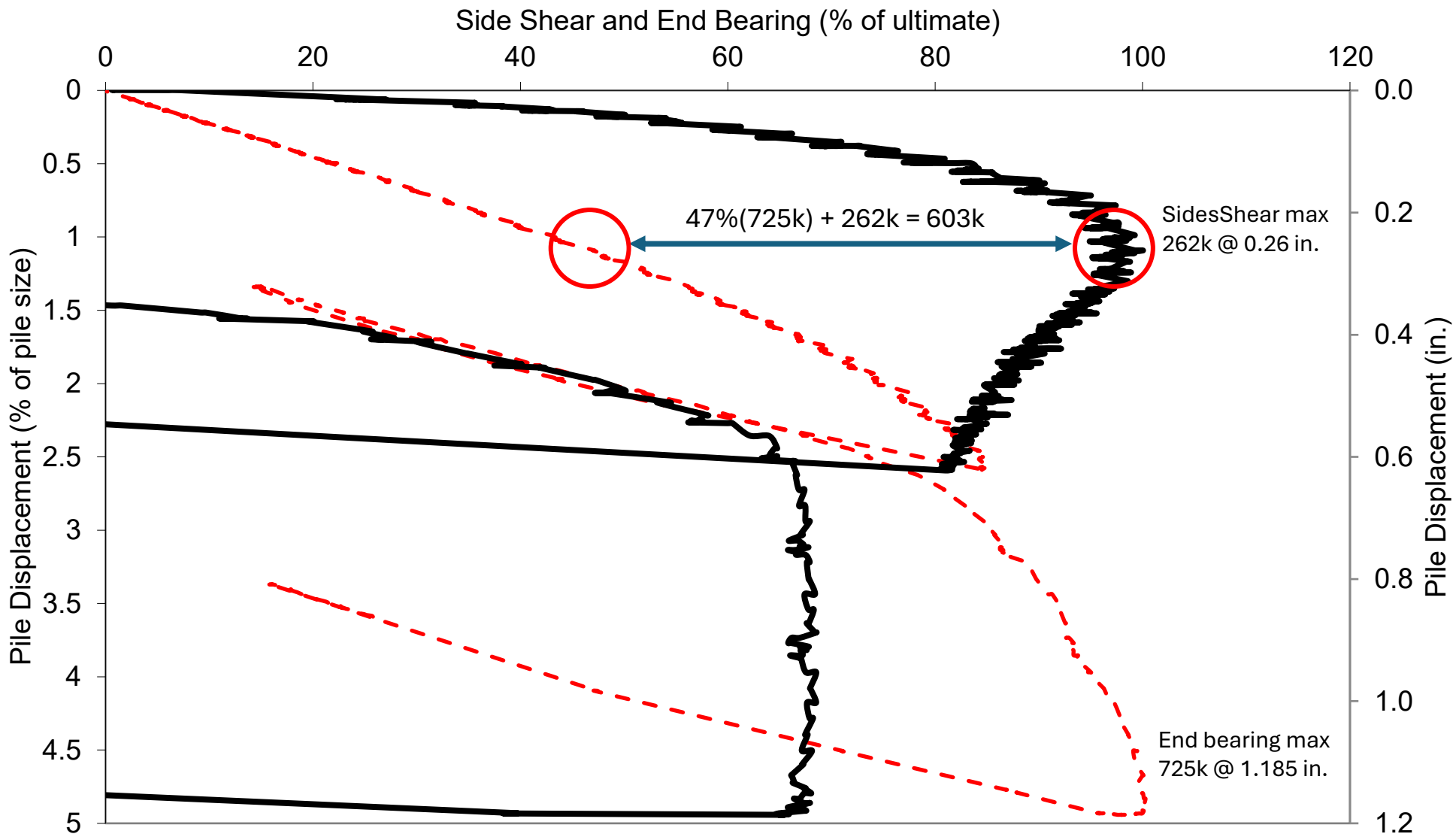

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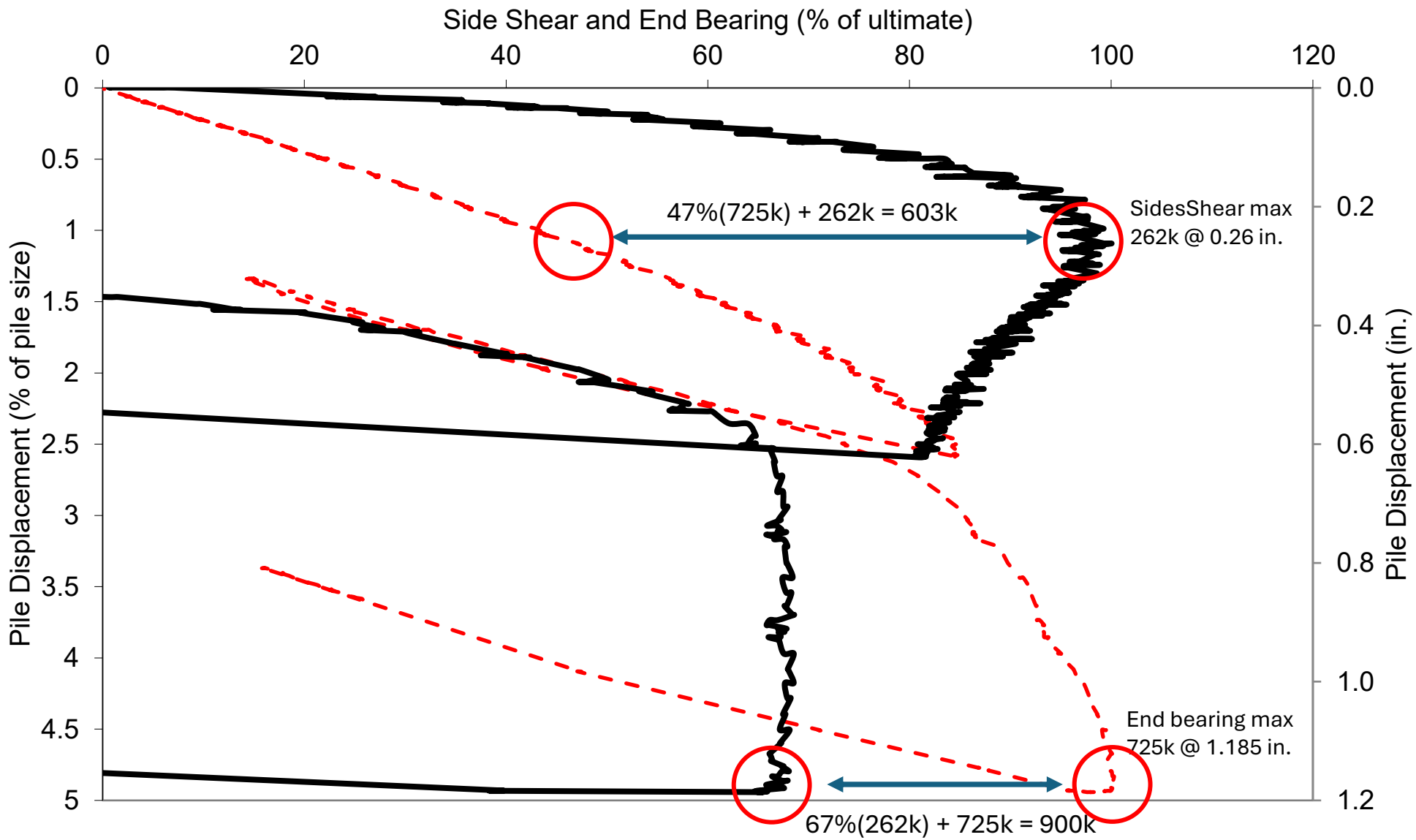
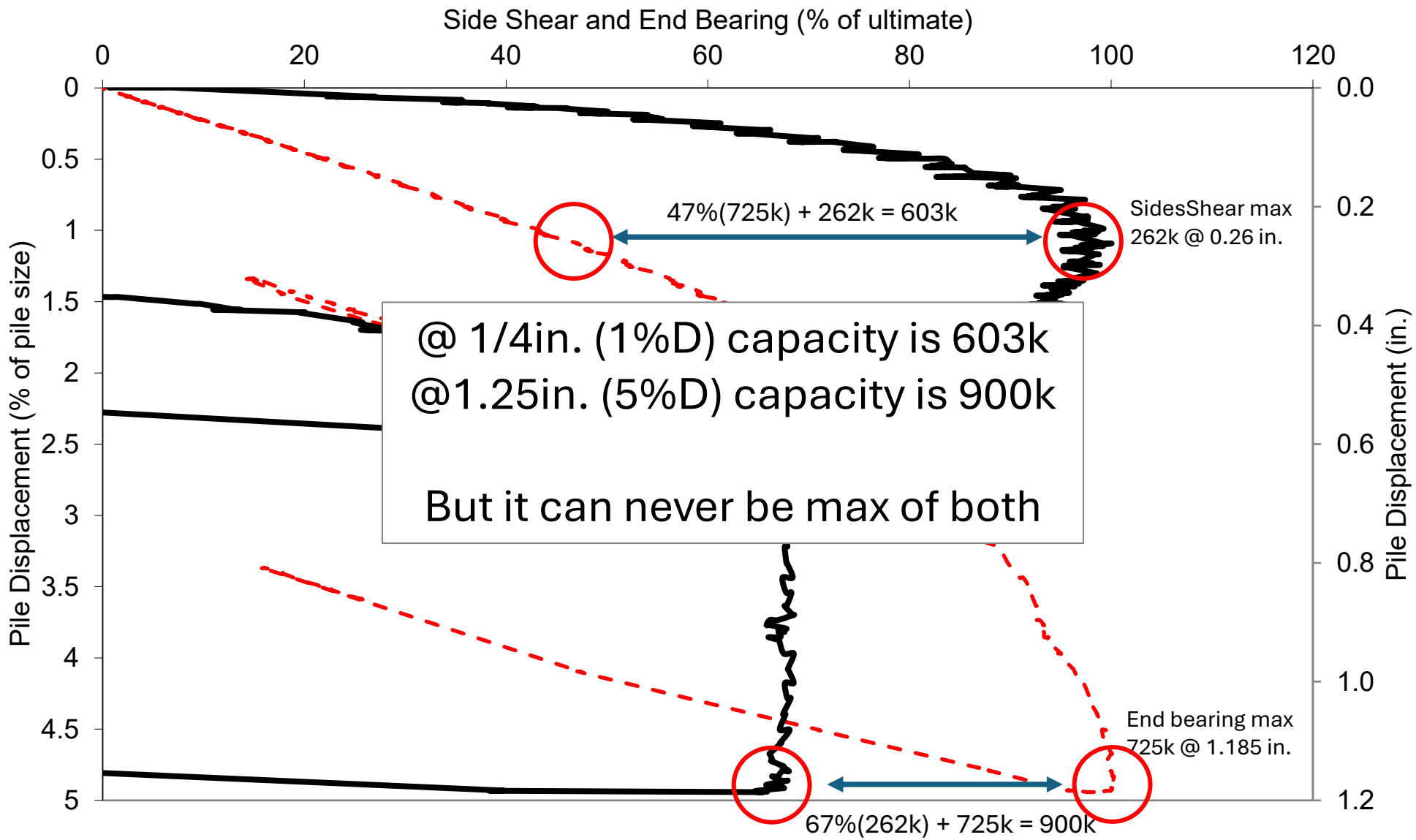
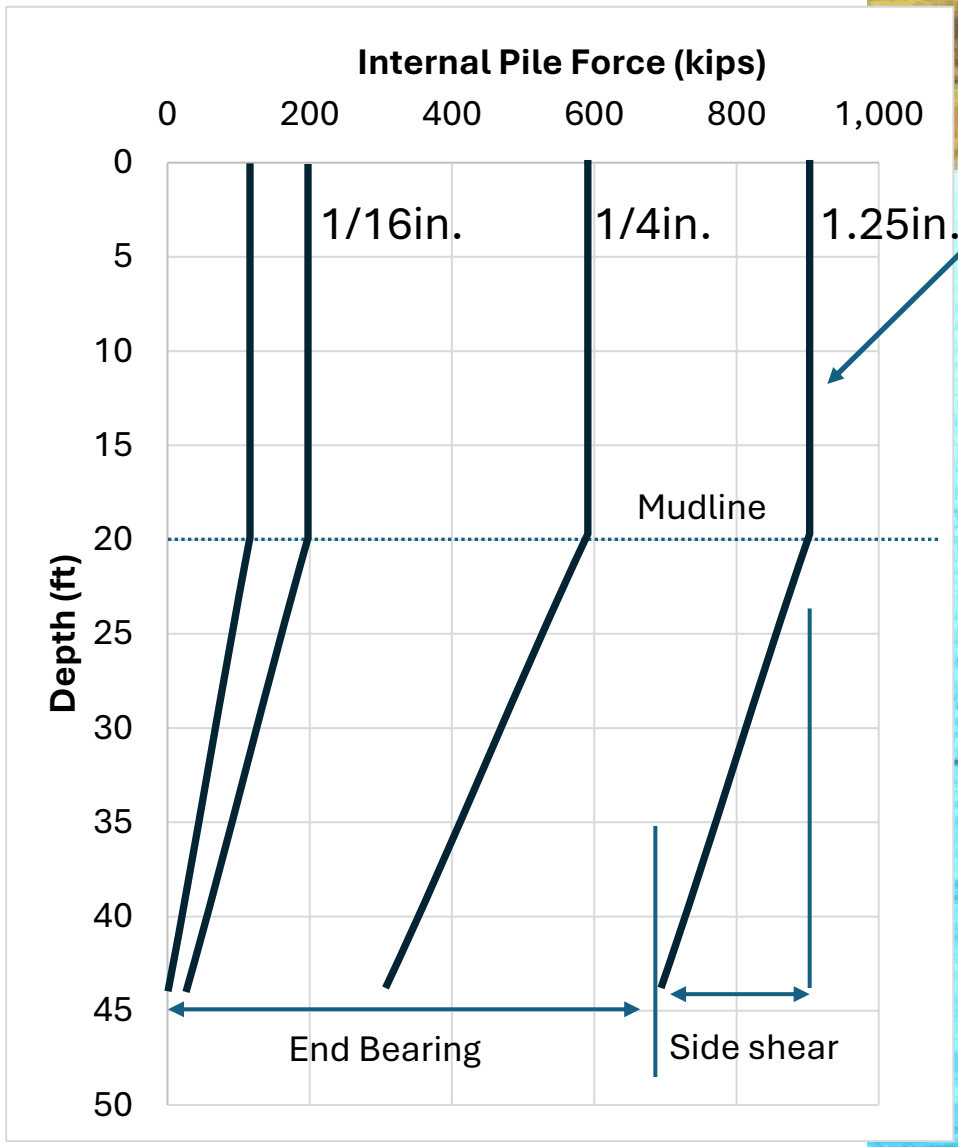


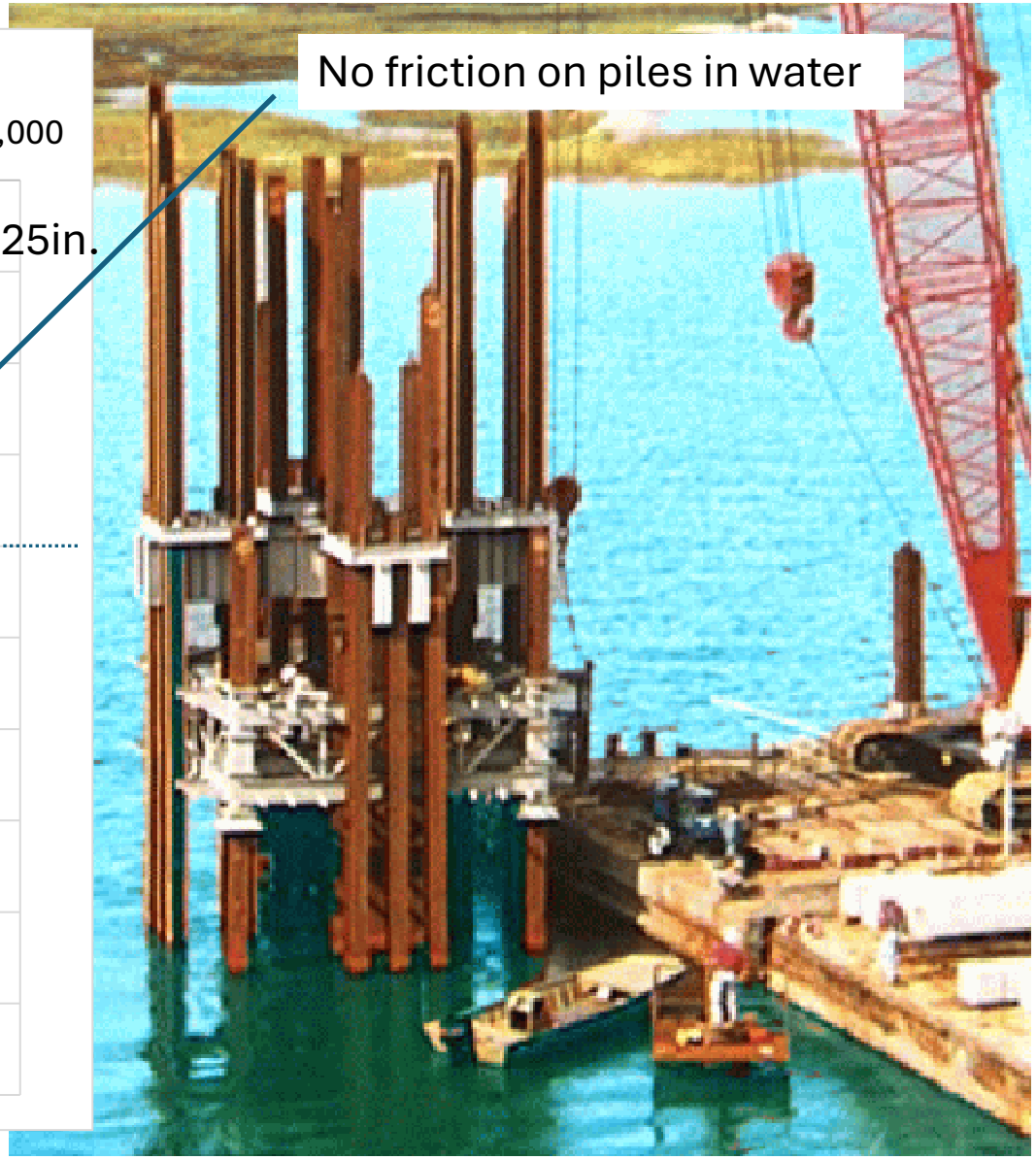
Mechanics of Pile Resistance



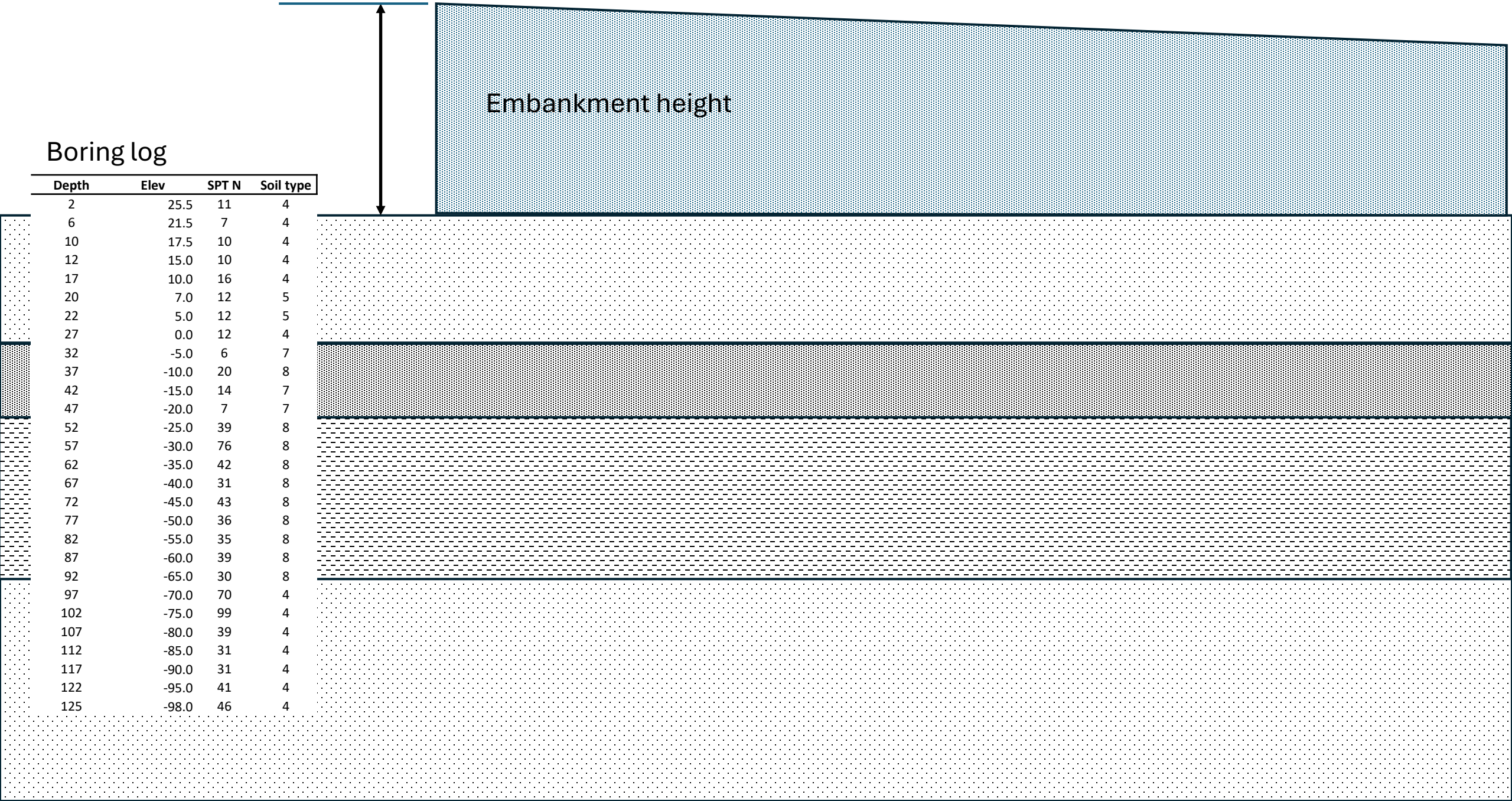
Mechanics of Pile Resistance

- Normal pile load shed distribution
- Max load at top
- Min at toe





Embankment Settlement



Boring log

Depth	Elev	SPT N	Soil type
2	25.5	11	4
6	21.5	7	4
10	17.5	10	4
12	15.0	10	4
17	10.0	16	4
20	7.0	12	5
22	5.0	12	5
27	0.0	12	4
32	-5.0	6	7
37	-10.0	20	8
42	-15.0	14	7
47	-20.0	7	7
52	-25.0	39	8
57	-30.0	76	8
62	-35.0	42	8
67	-40.0	31	8
72	-45.0	43	8
77	-50.0	36	8
82	-55.0	35	8
87	-60.0	39	8
92	-65.0	30	8
97	-70.0	70	4
102	-75.0	99	4
107	-80.0	39	4
112	-85.0	31	4
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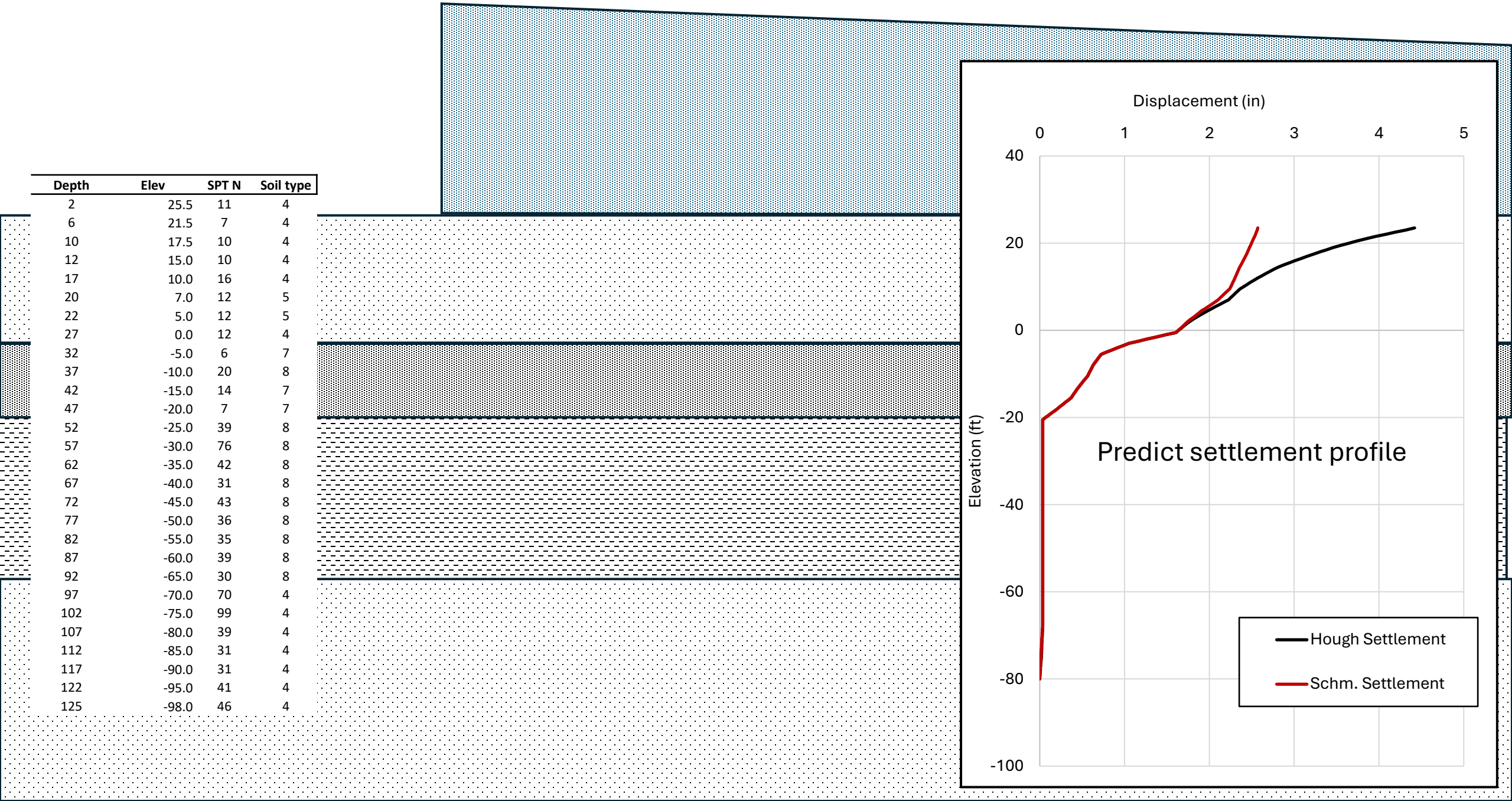

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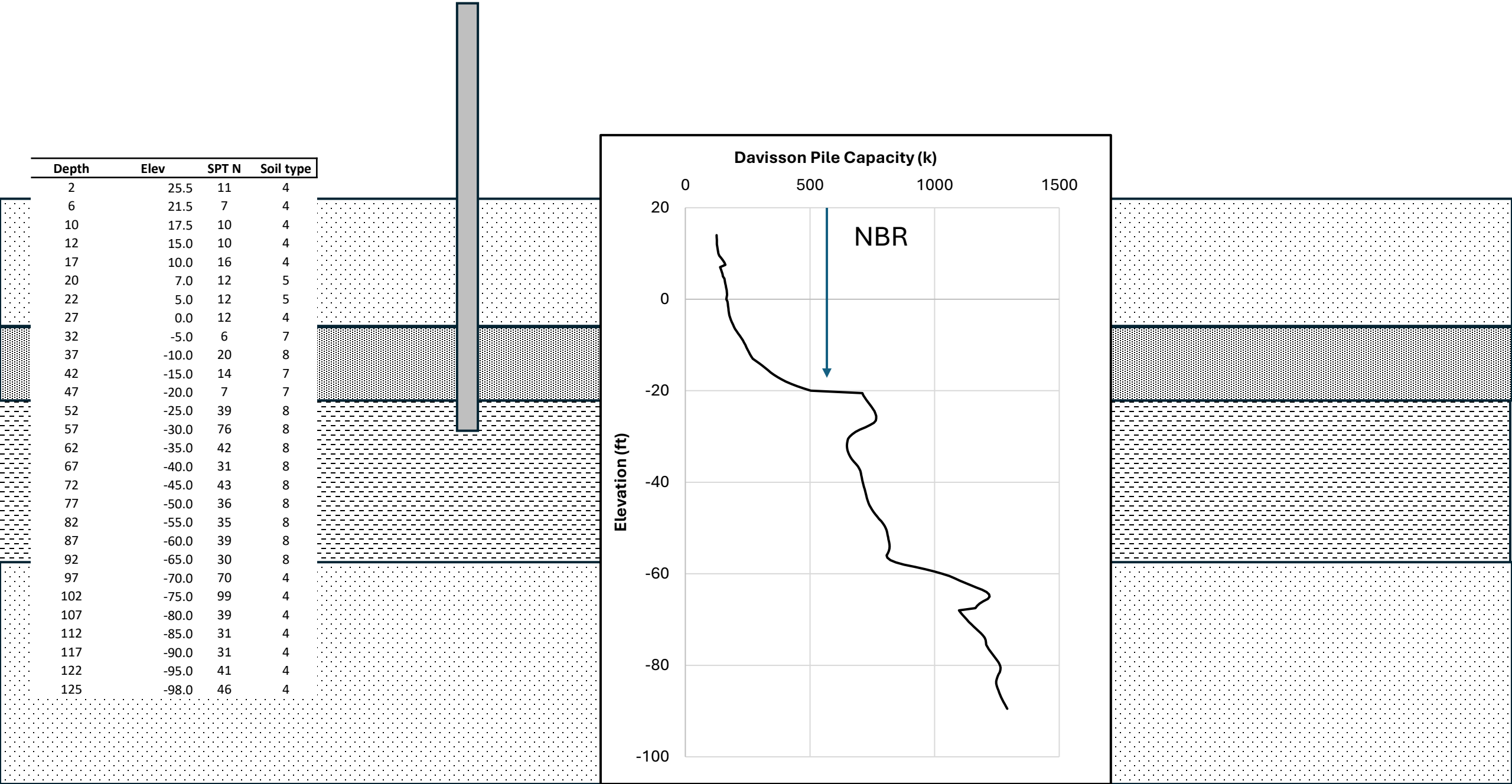

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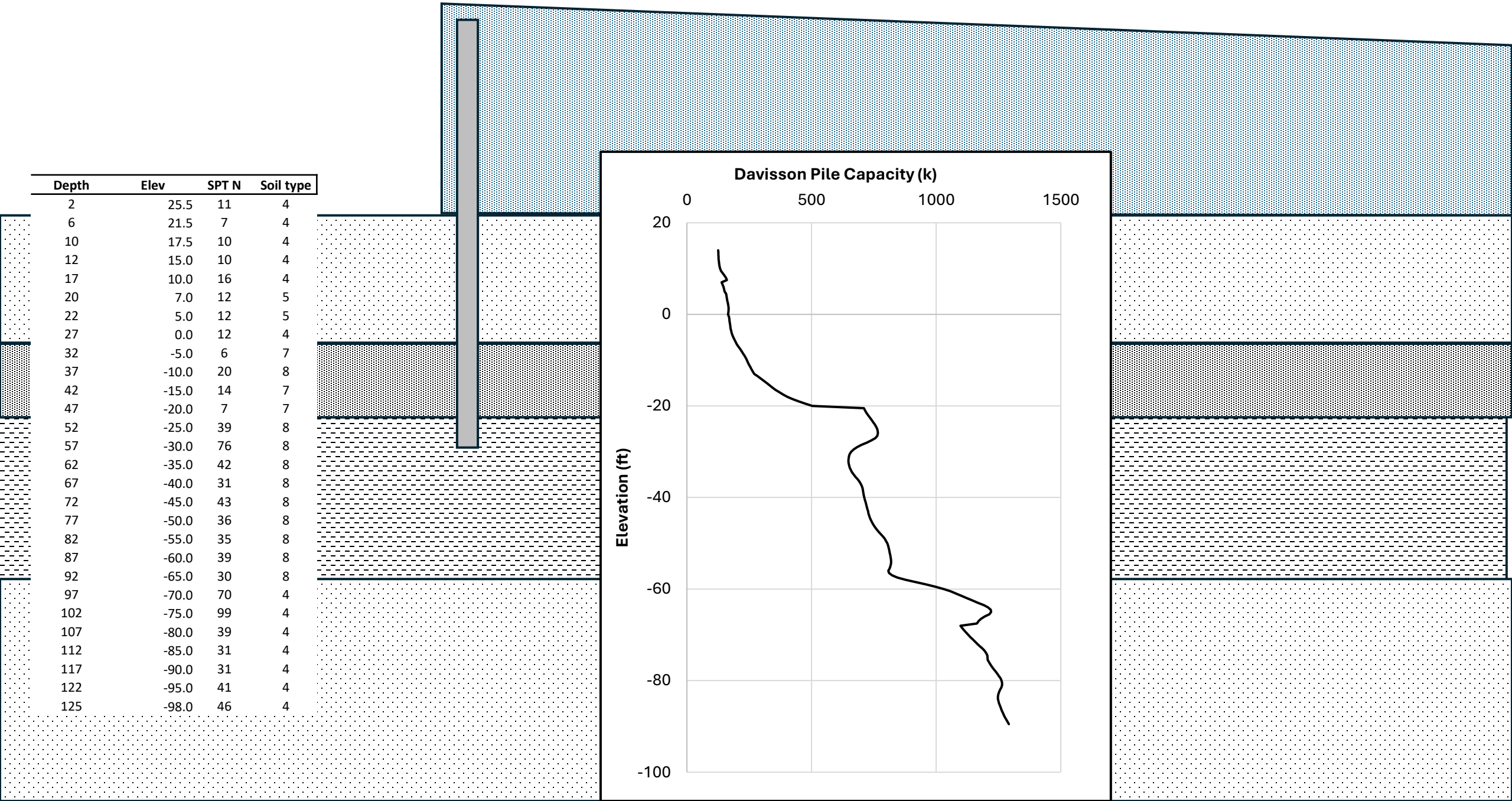

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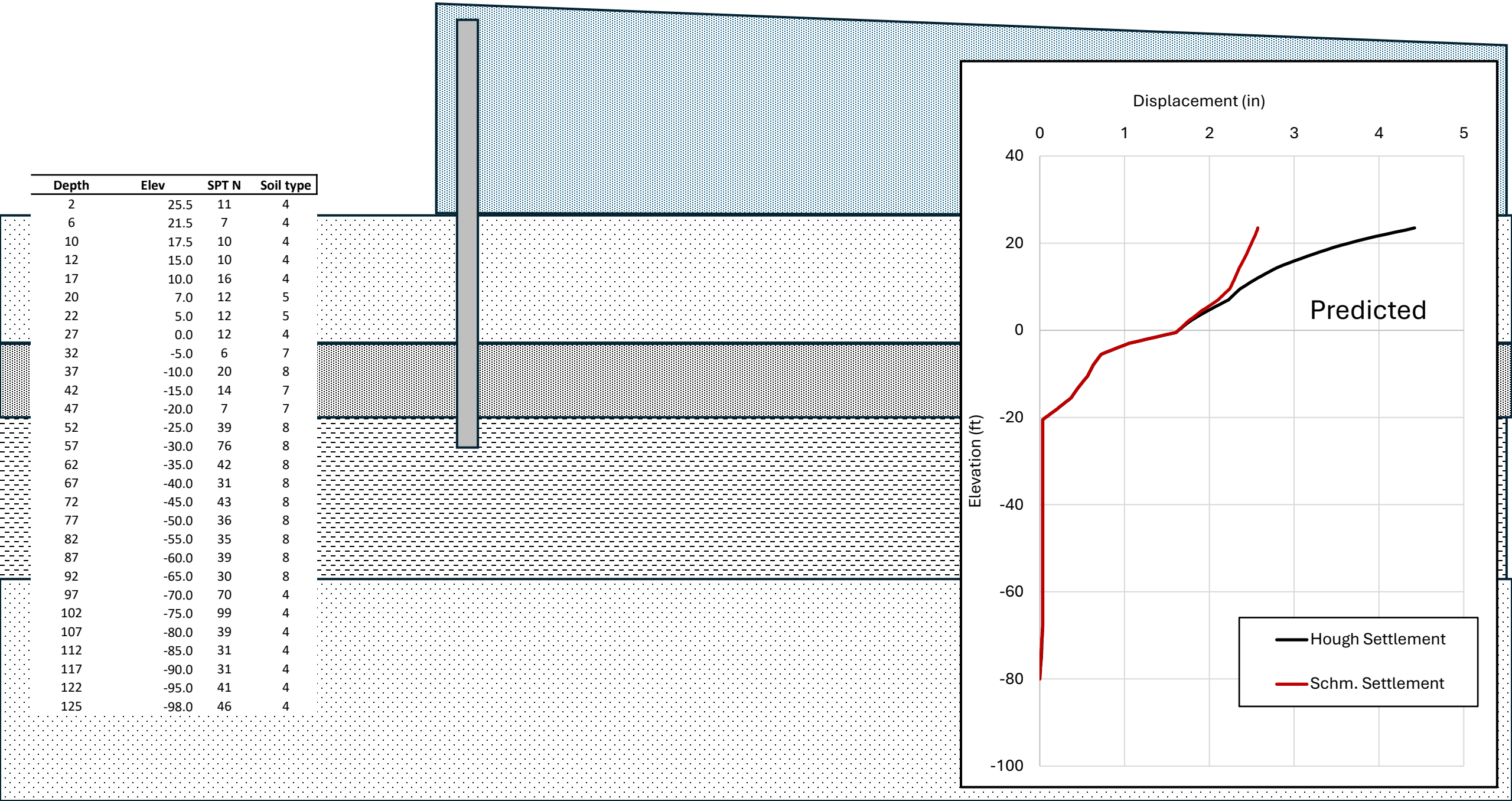

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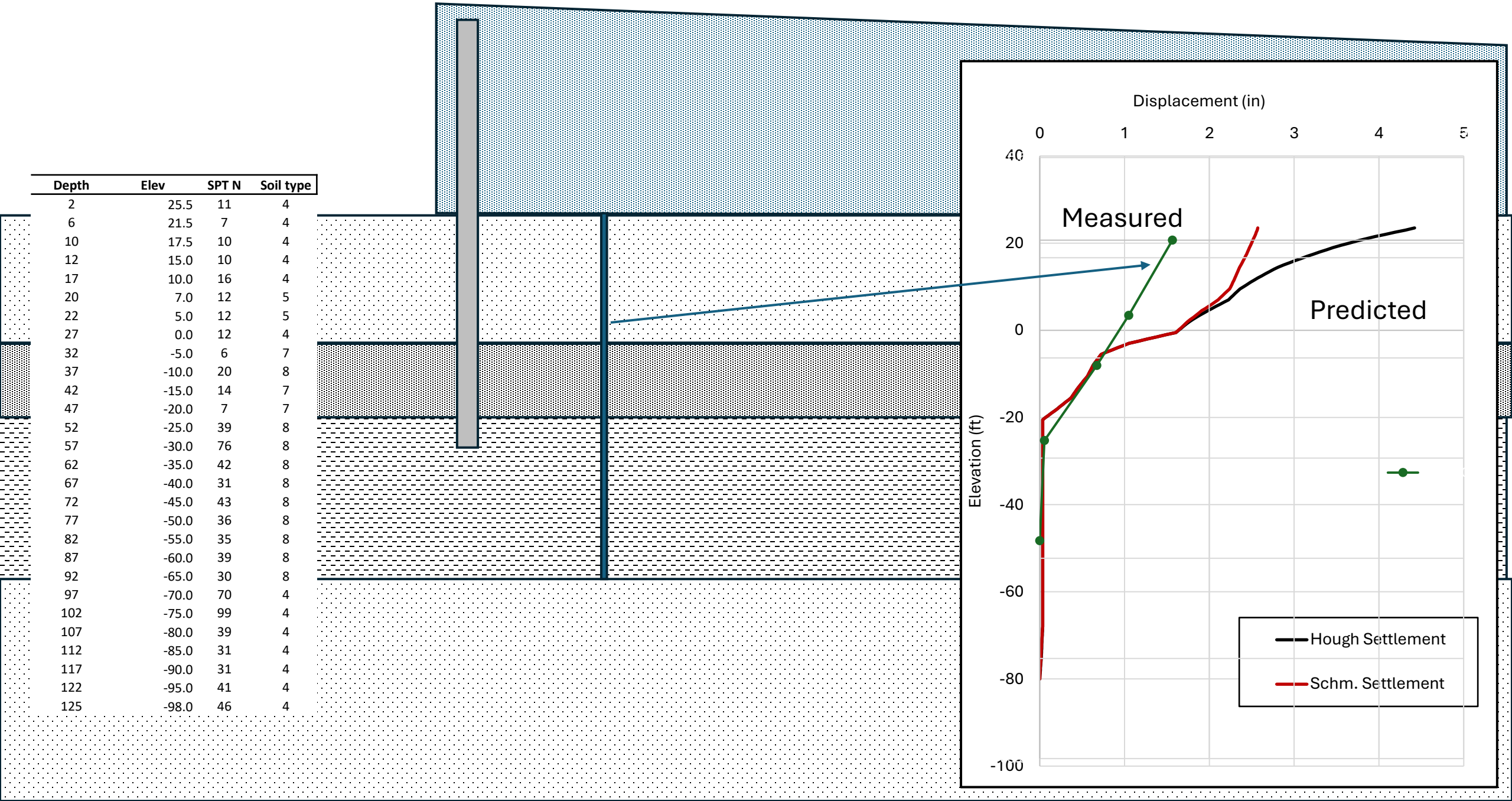

Zone affected by pile reinforcement

Depth	Elev	SPT N	Soil type
2	25.5	11	4
6	21.5	7	4
10	17.5	10	4
12	15.0	10	4
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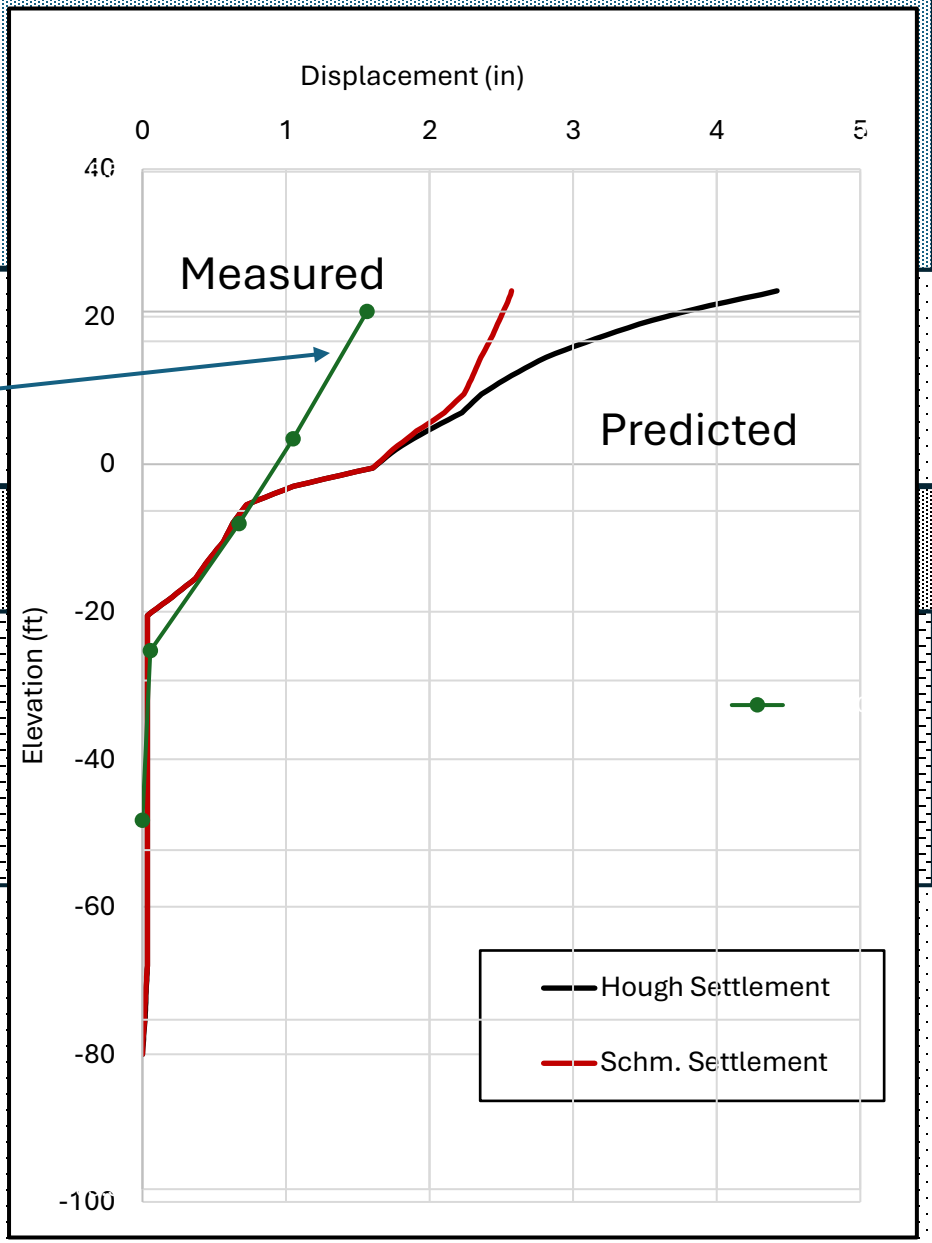

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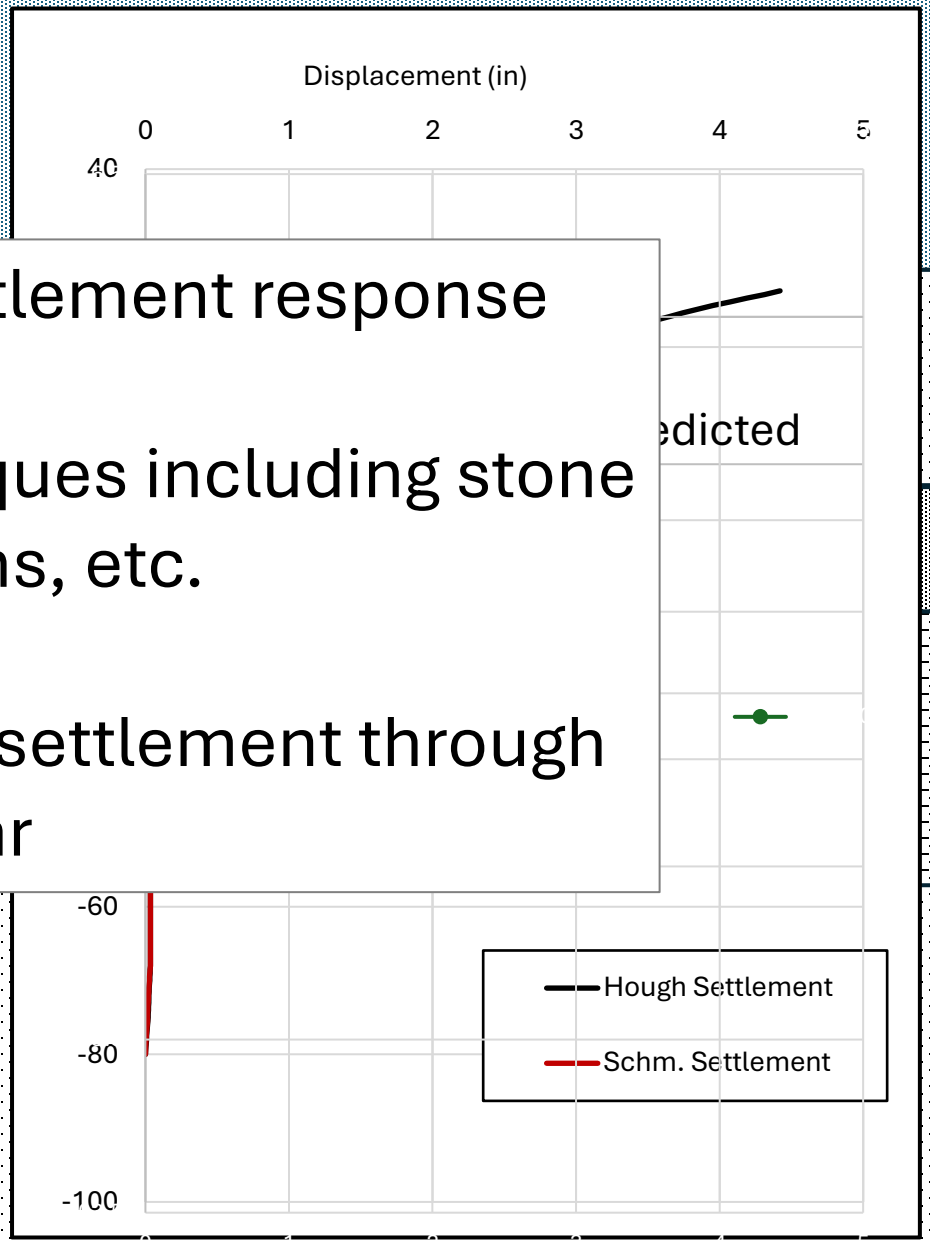
The presence of piles changes settlement response

Same as ground modification techniques including stone columns, rigid inclusions, etc.

Piles (like rigid inclusions) minimize settlement through negative side shear



Problem Statement

- Piles in end bents are subjected to settlement induced surcharge loads in addition to structural bridge loads.
- Depending on the site-specific conditions the additional loads may exceed the structural and/or geotechnical pile capacity.

Misconception: sandy soils settle immediately so there are no downdrag forces

- Phase I showed excessively large internal pile forces
- Settlement of pile caps from bridge deadloads was also larger than expected
- Need to better quantify effects of downdrag (focus on sandy soils but downdrag in all soil types may be inappropriately addressed by AASHTO)

Phase 2 Tasks

- Develop downdrag design software
- Continue monitoring existing bridges
- Instrument and monitor another bridge site with more piles/site
- Survey existing bridge end bent pile caps
- Advanced numerical modeling
- Reporting

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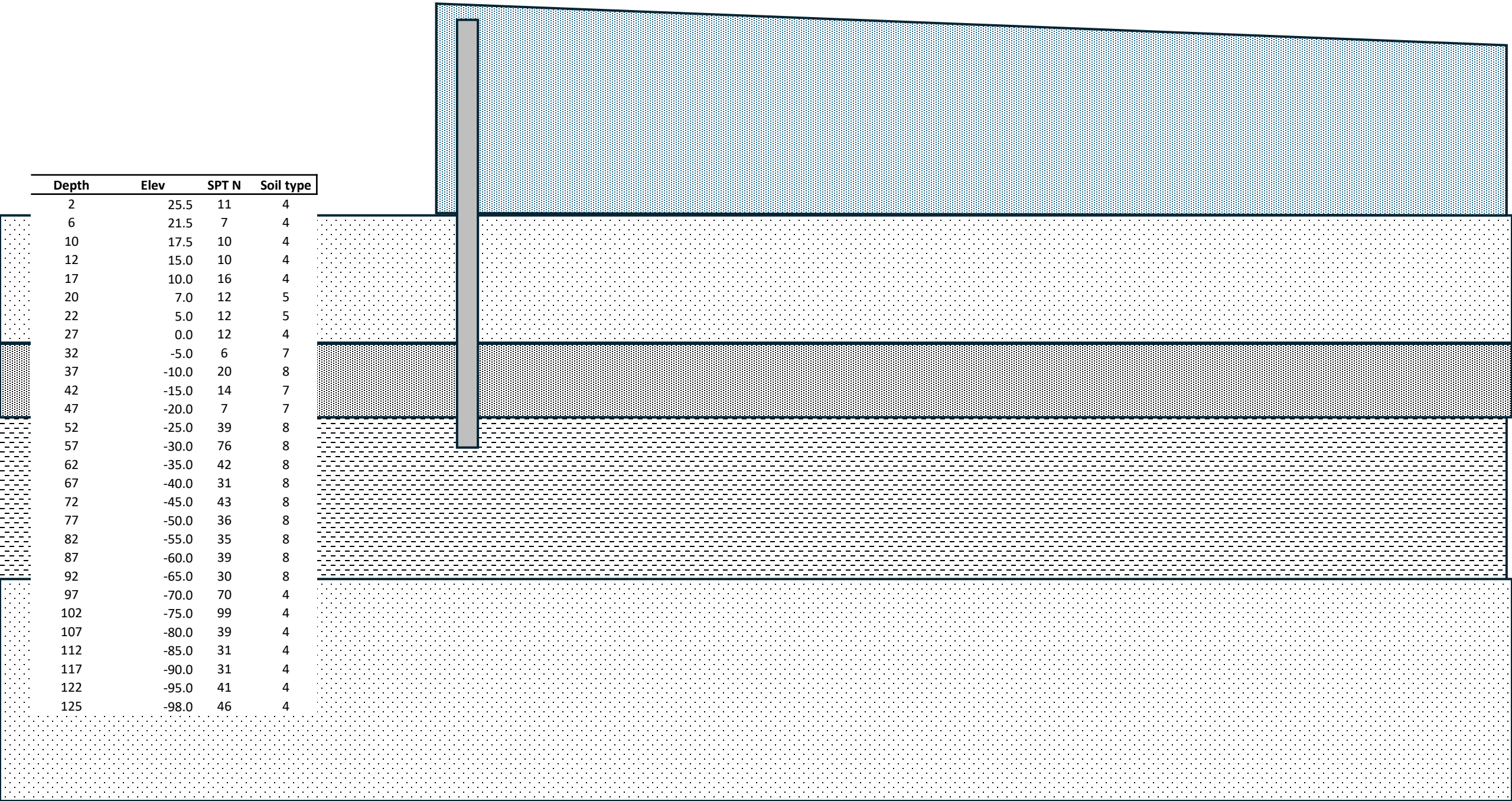

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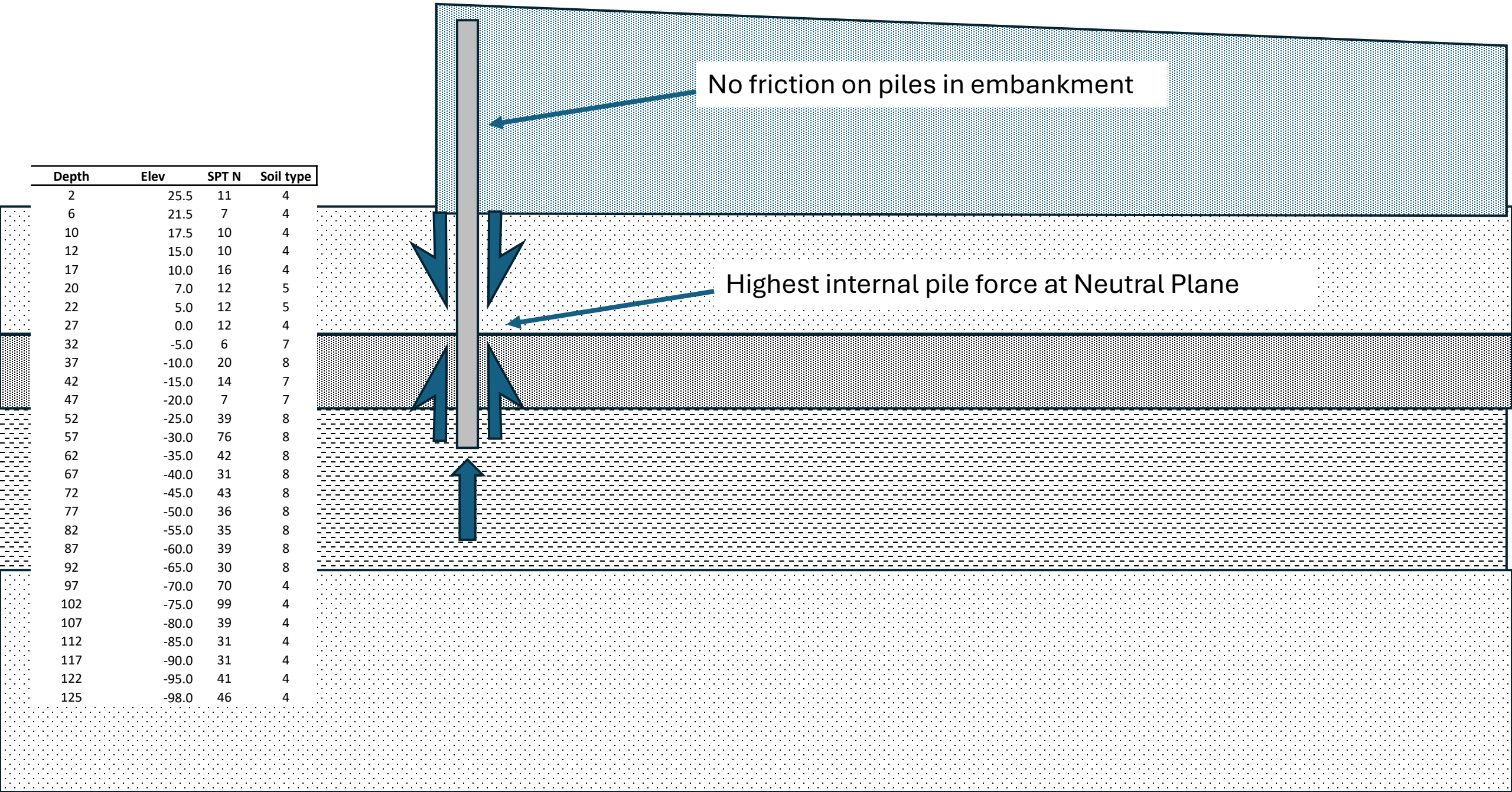
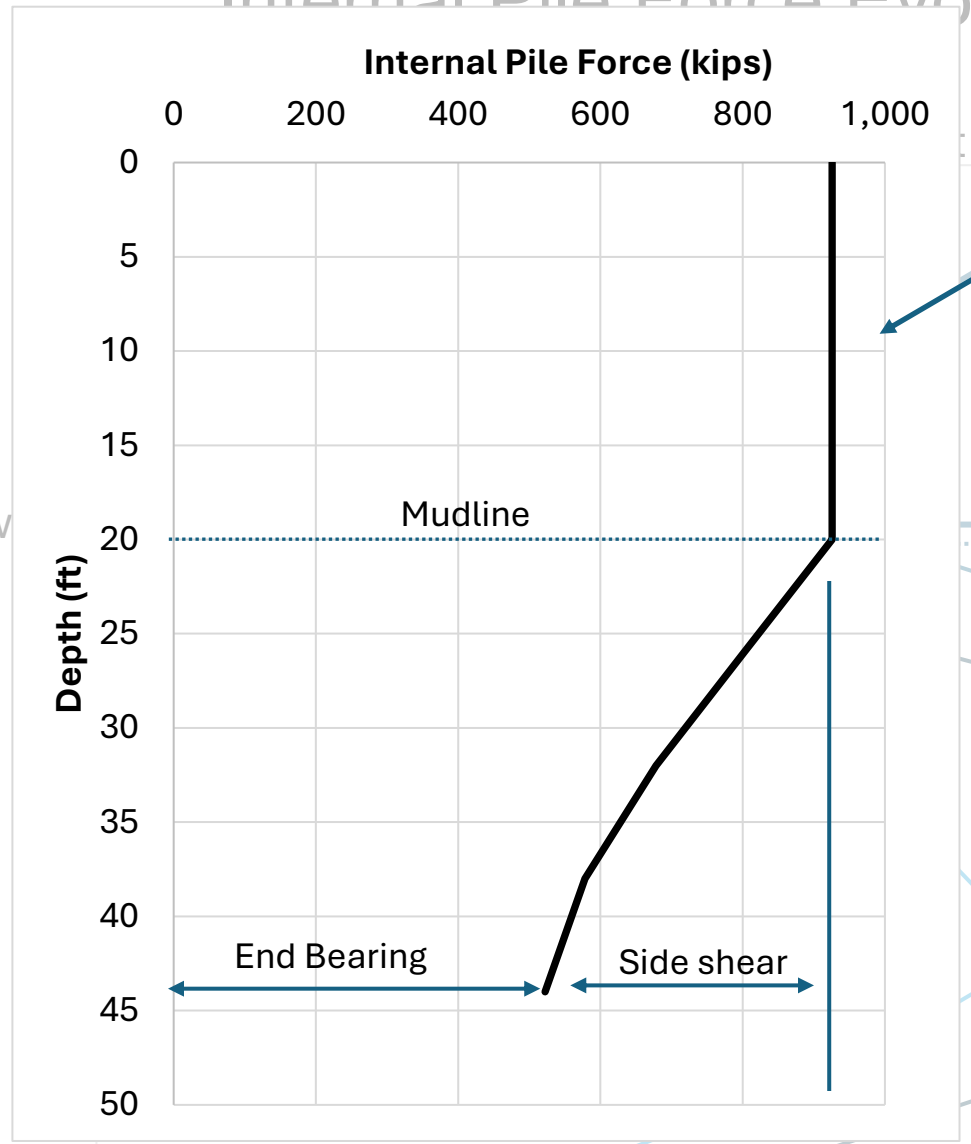


Internal Pile Force Evolution (SR23 over Henley Rd)



No friction on piles in water

Negative side shear
Downdrag Force (291k)

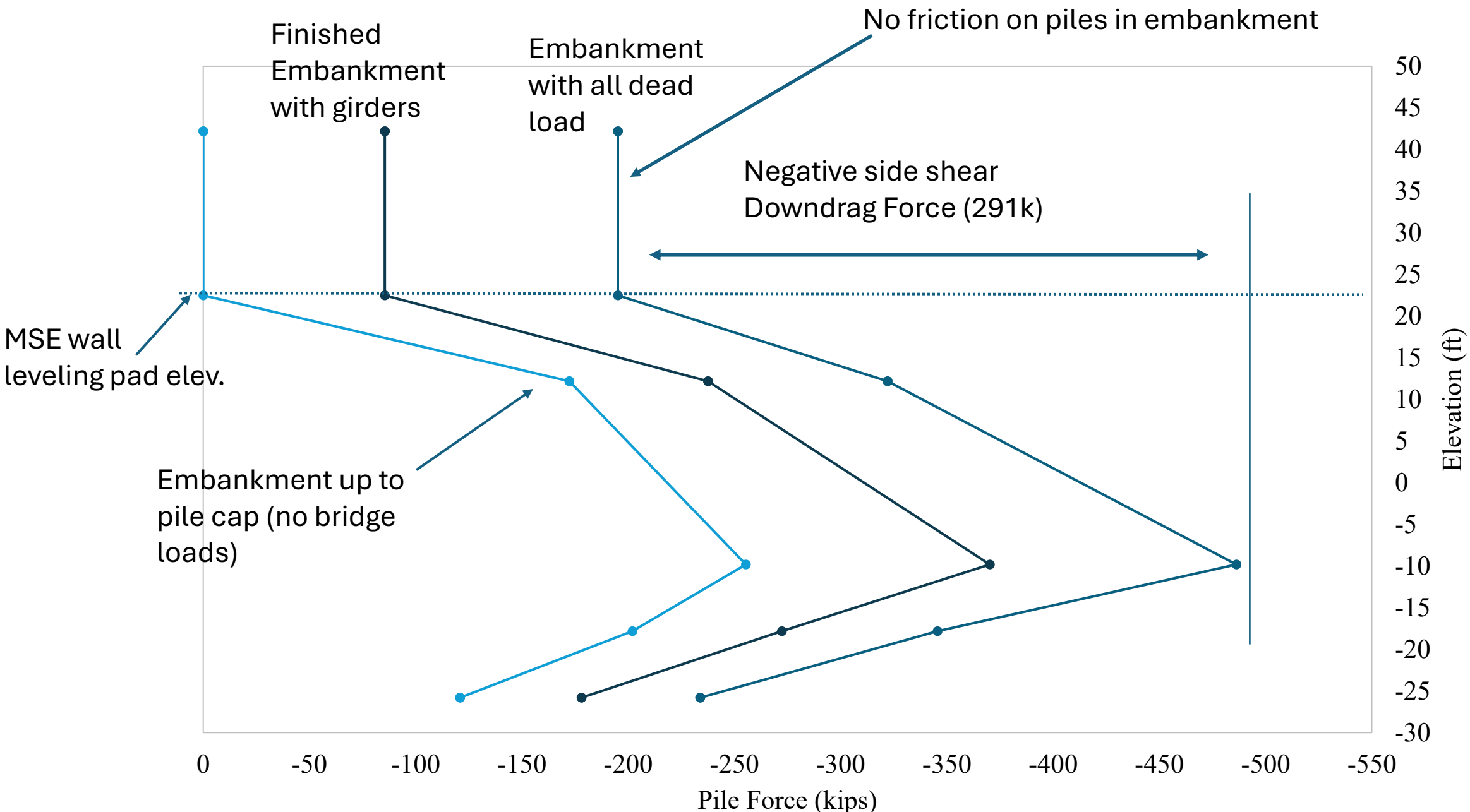
MSE w

Elevation (ft)
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30

25
-25
-75
-125
-175
-225
-275
-325
-375
-425
-475
-525

Pile Force (kips)

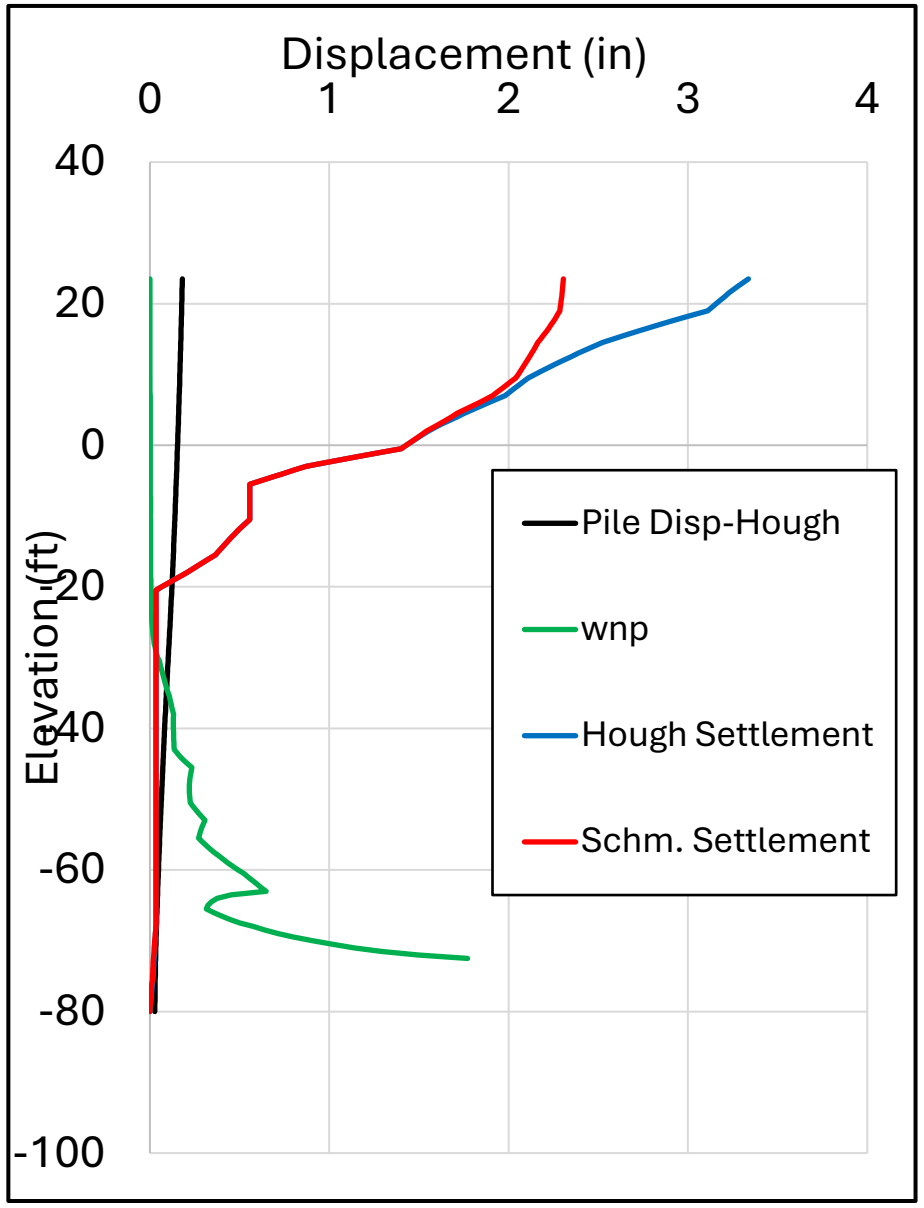
Internal Pile Force Evolution (SR23 over Henley Rd)

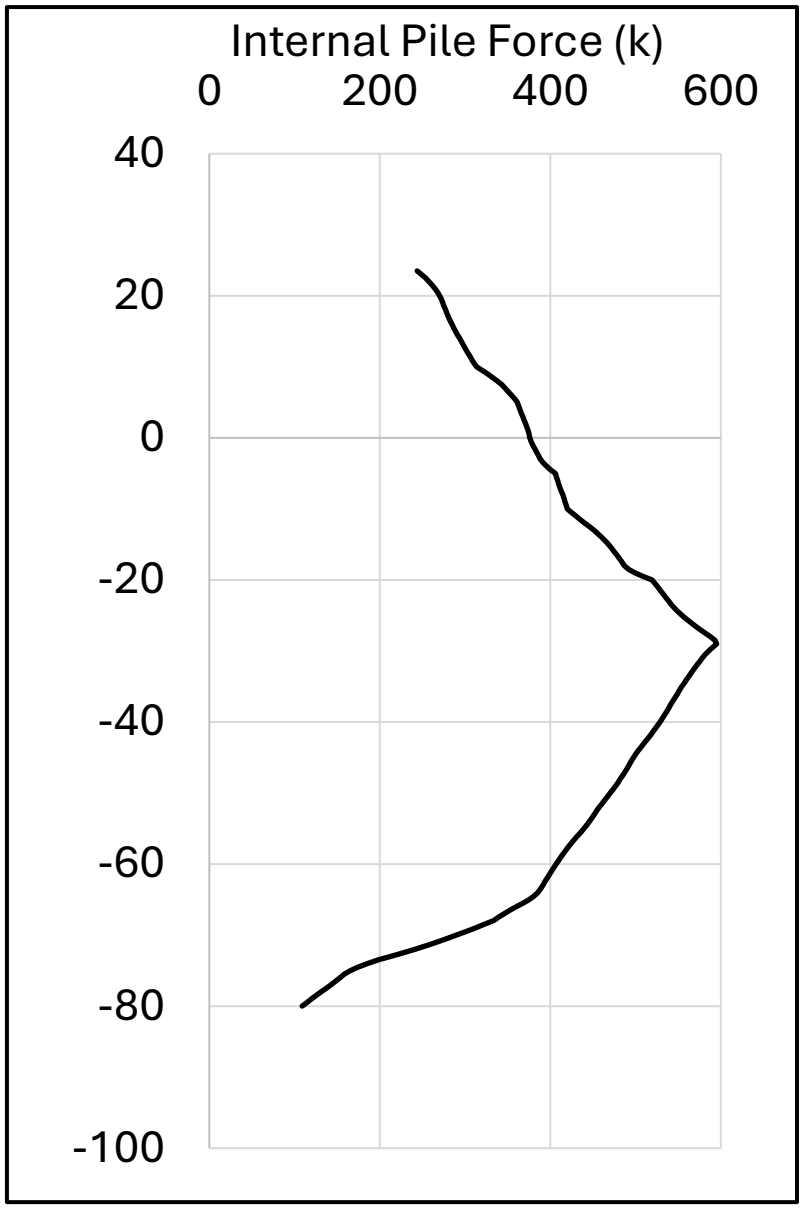


Task 1
New Software

Computes

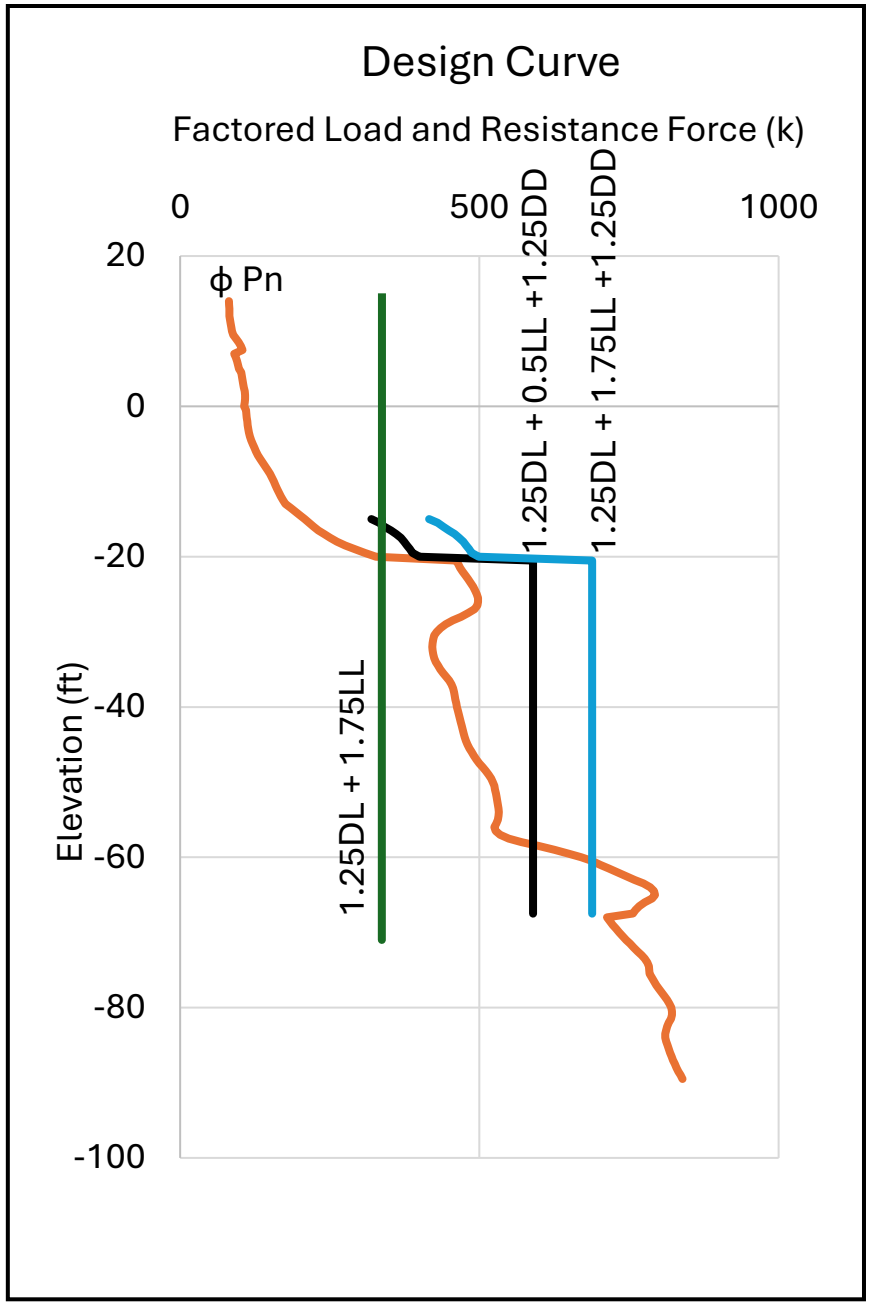
- embankment settlement
- pile capacity
- downdrag force

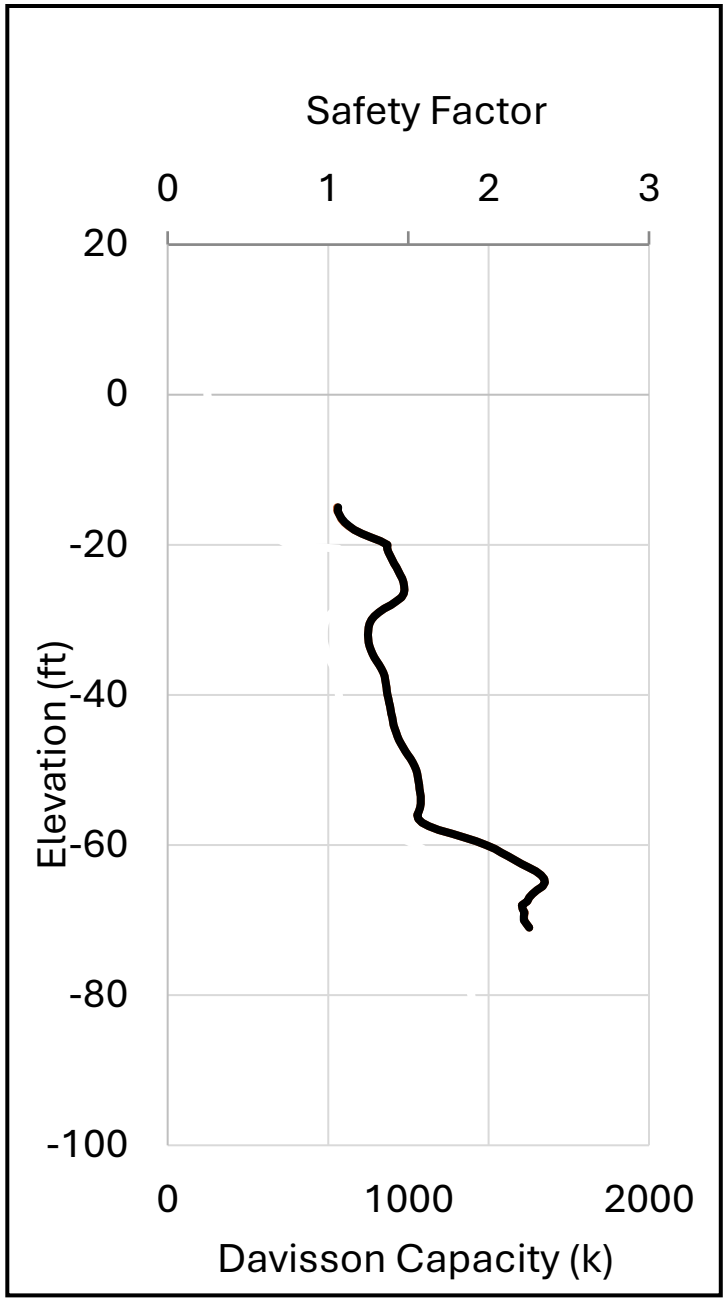




Task 1
New Software

- Iterates a range of pile lengths
- compares factored load and resistance
- service load safety factor





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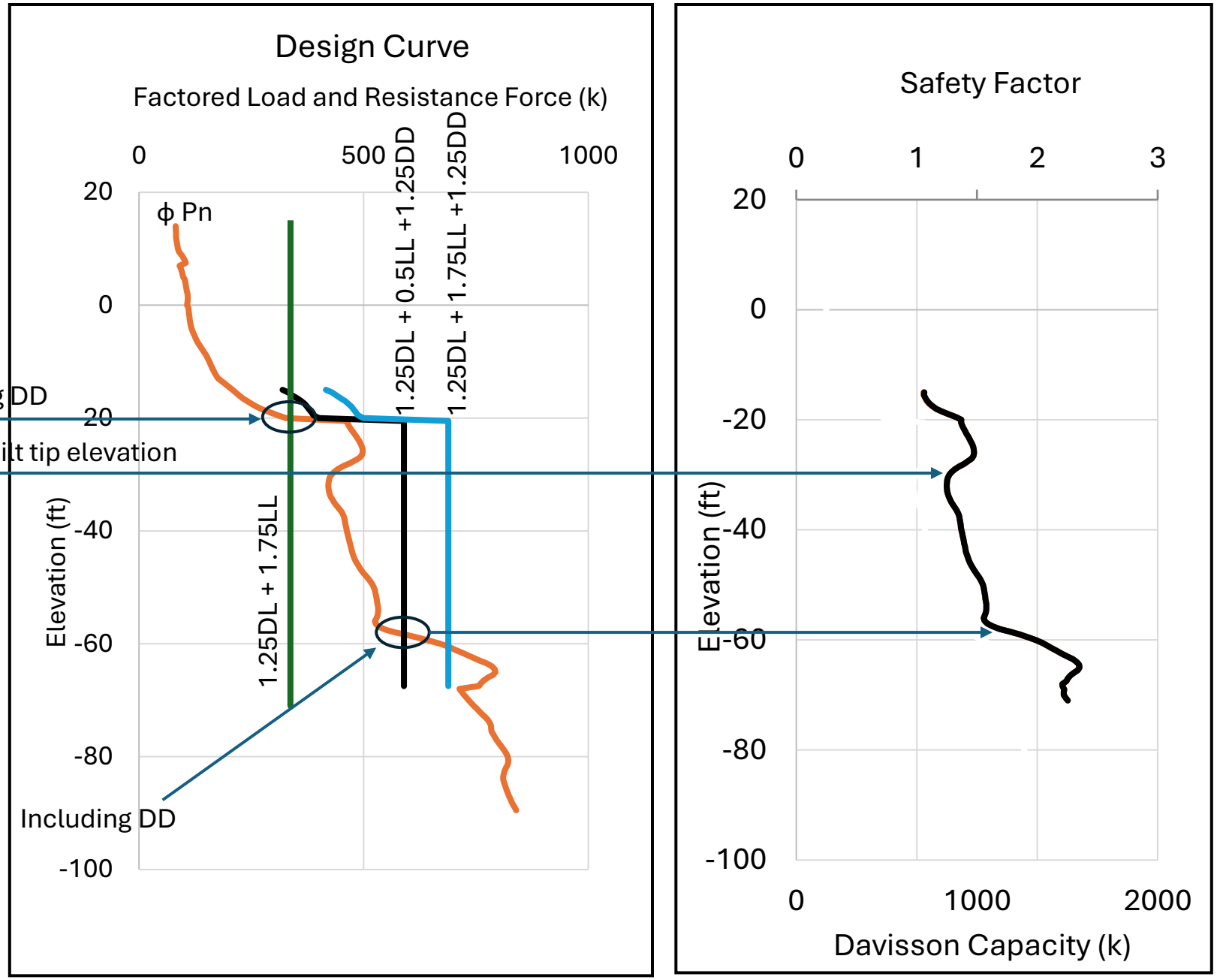
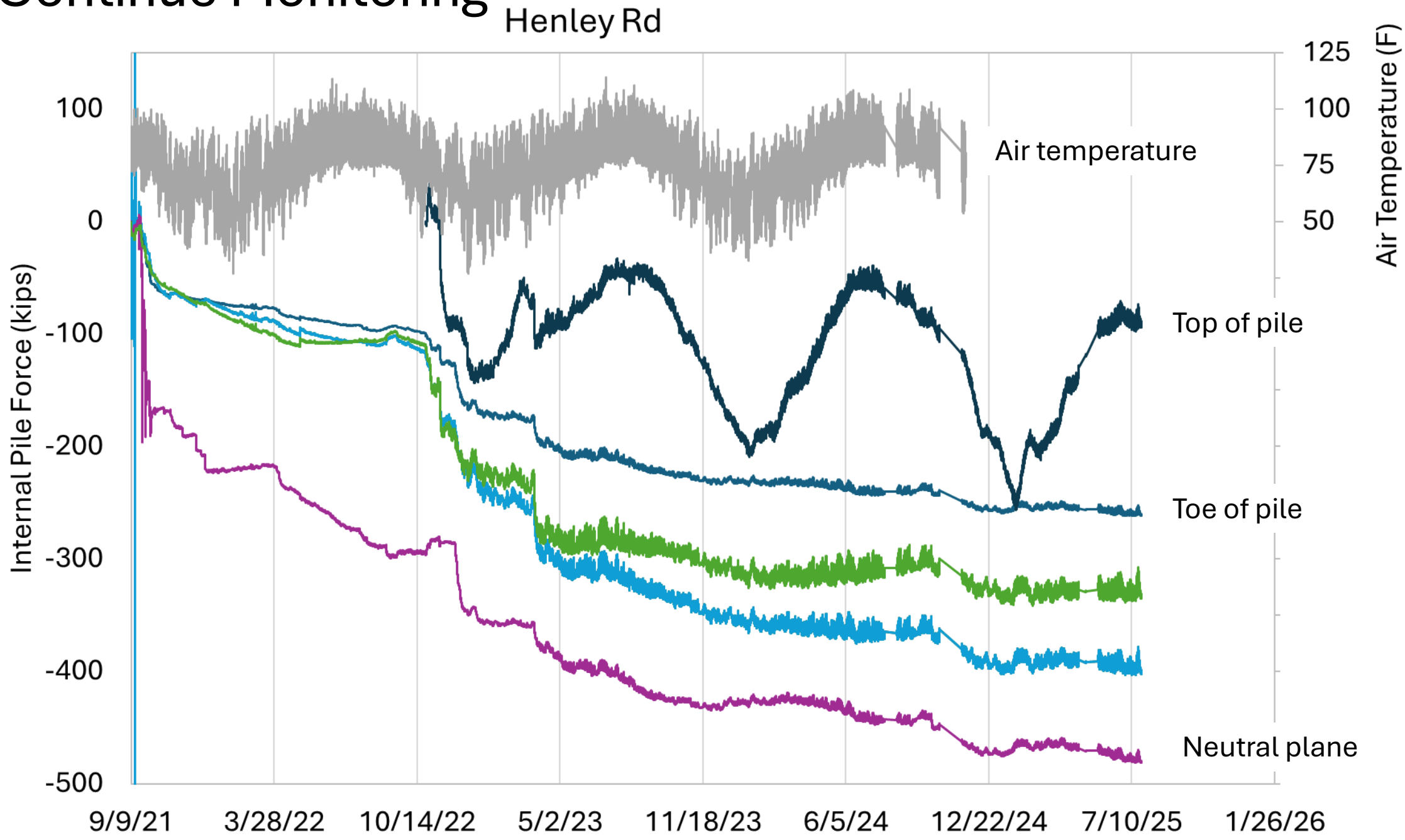
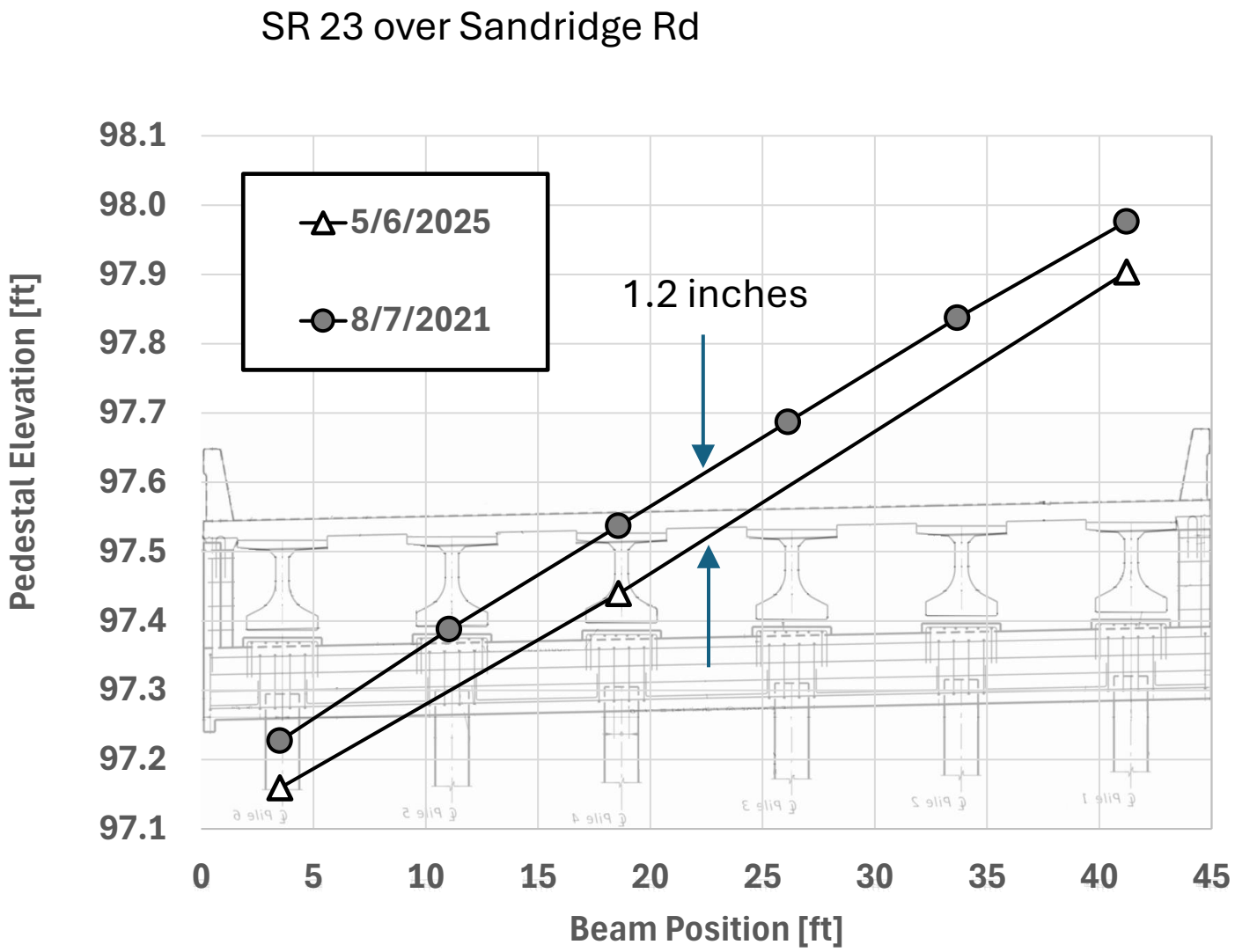


Task 2 Continue Monitoring



Task 3 Pile Cap Surveys



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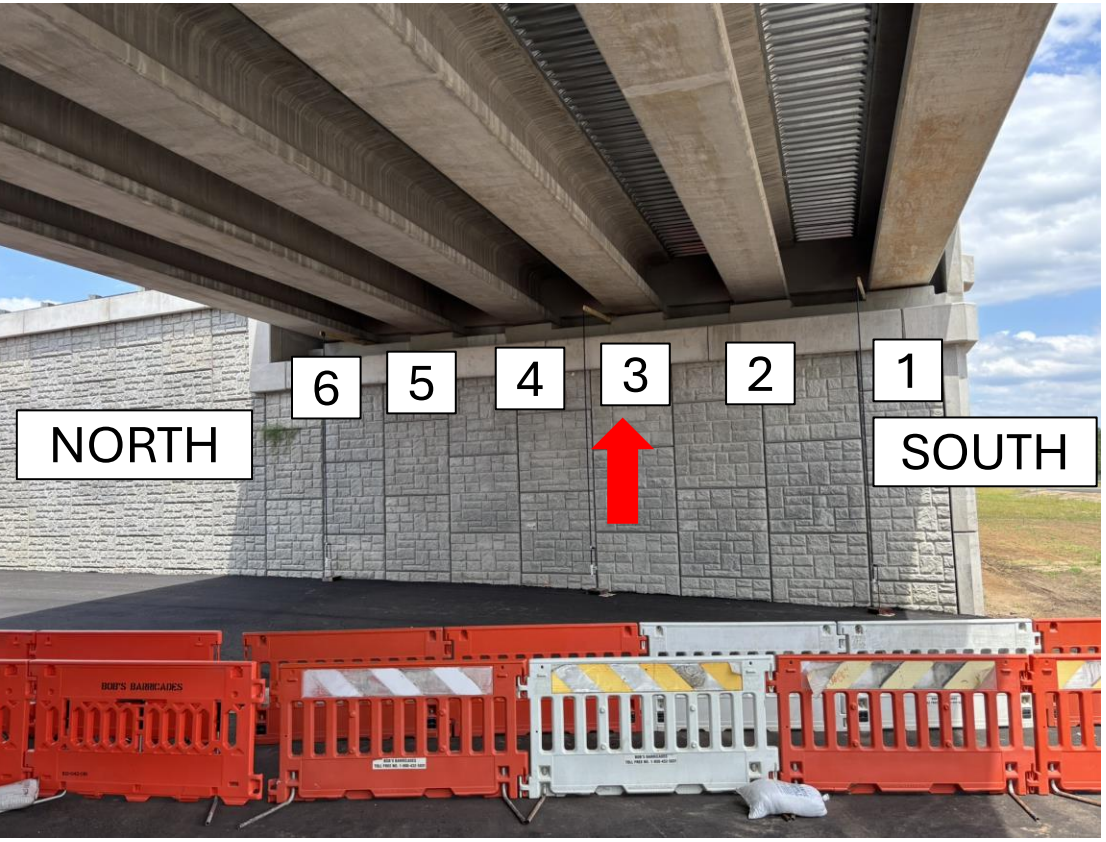
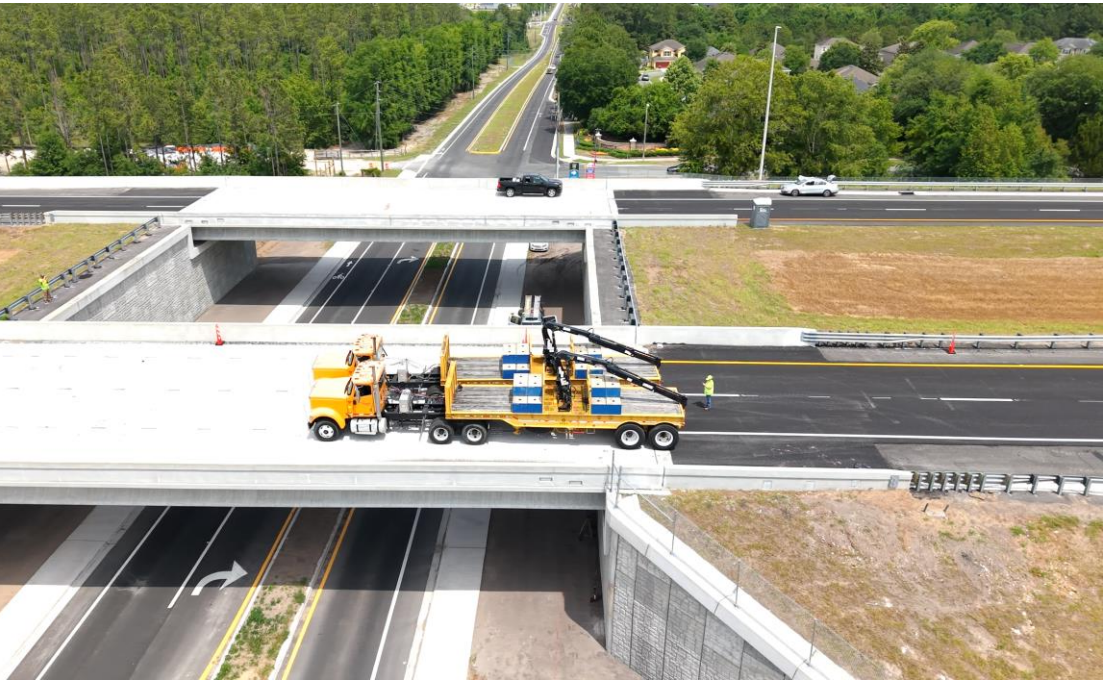
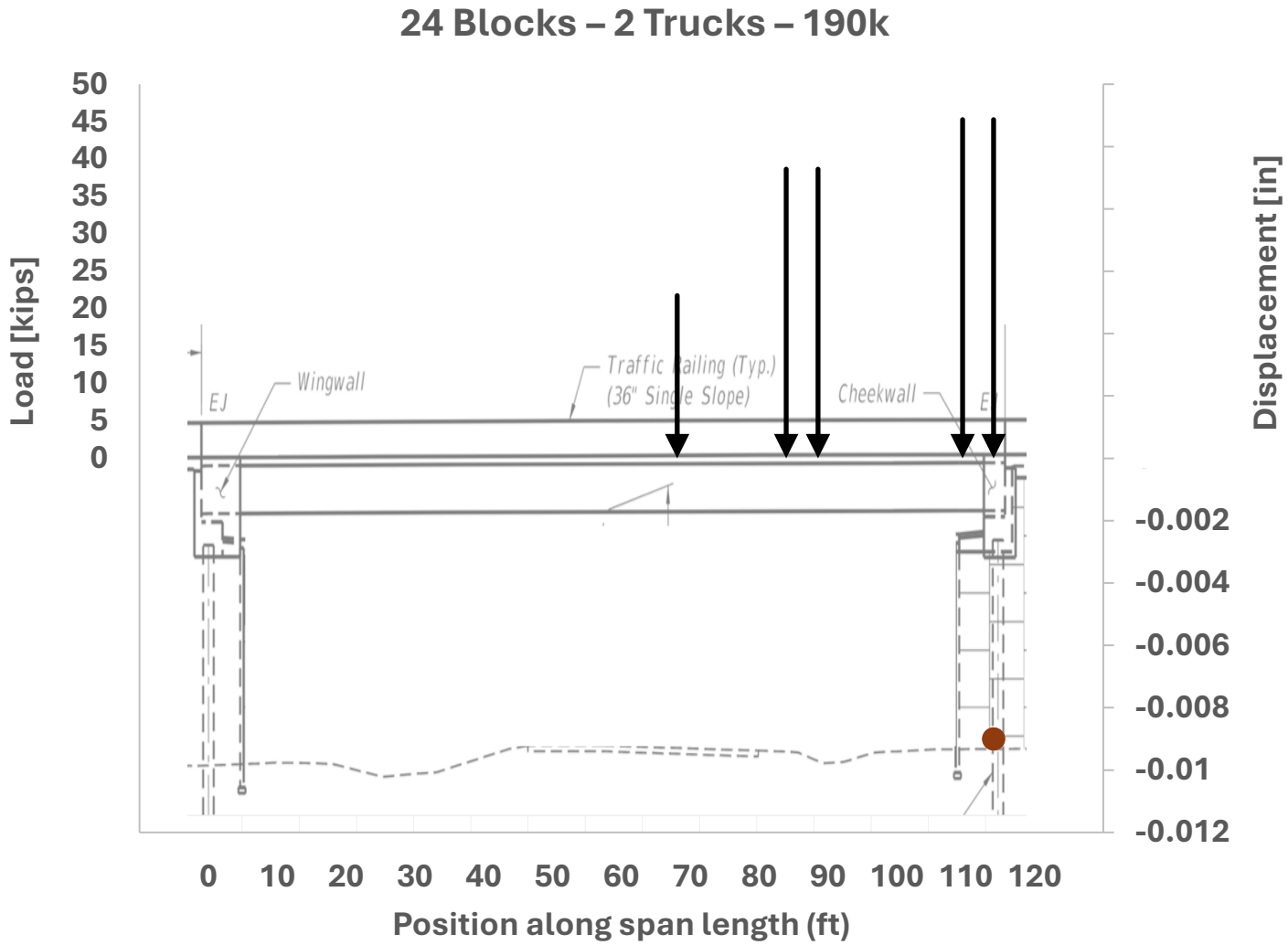


Live Load Test (Sandridge Rd)





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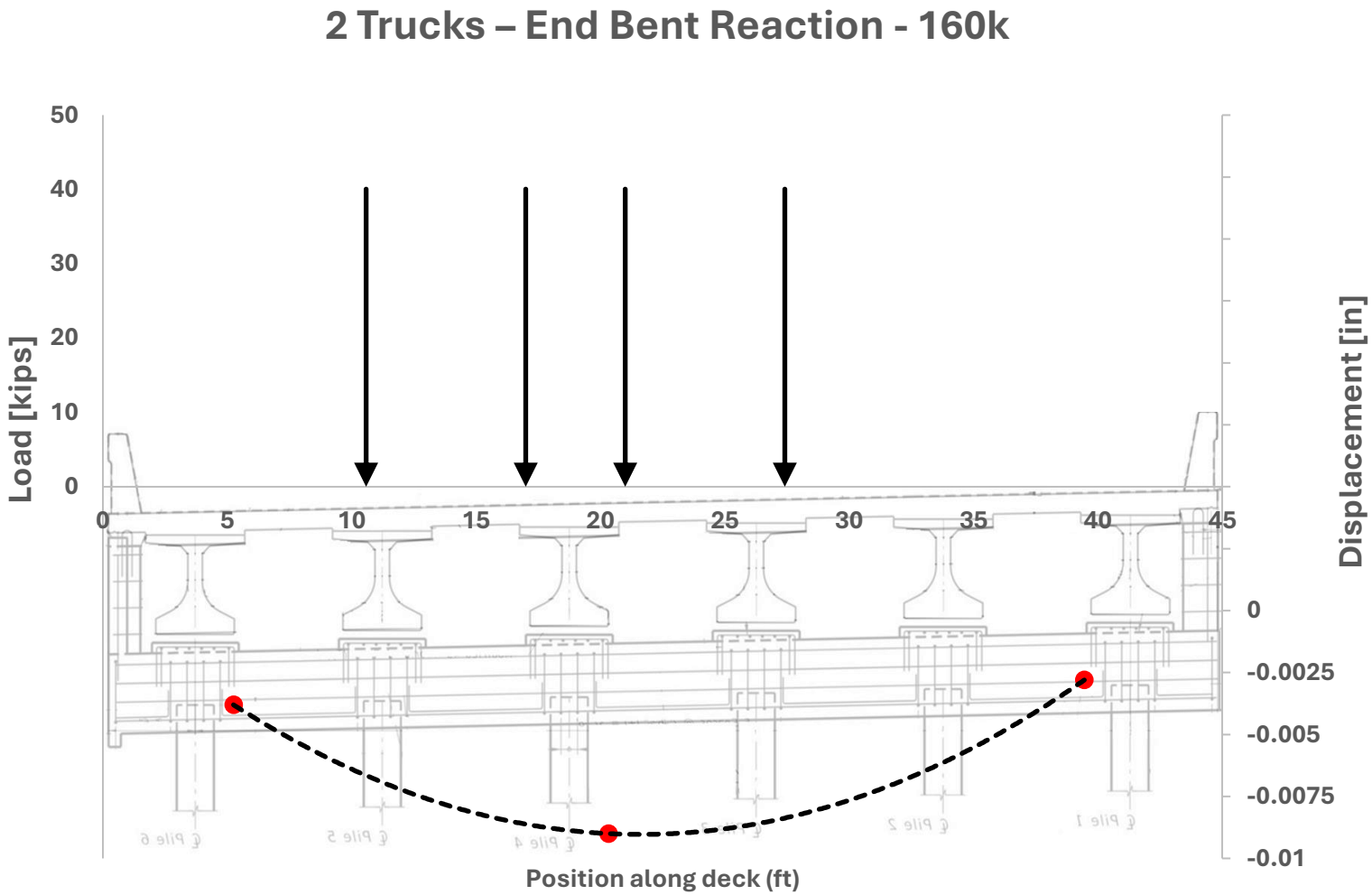
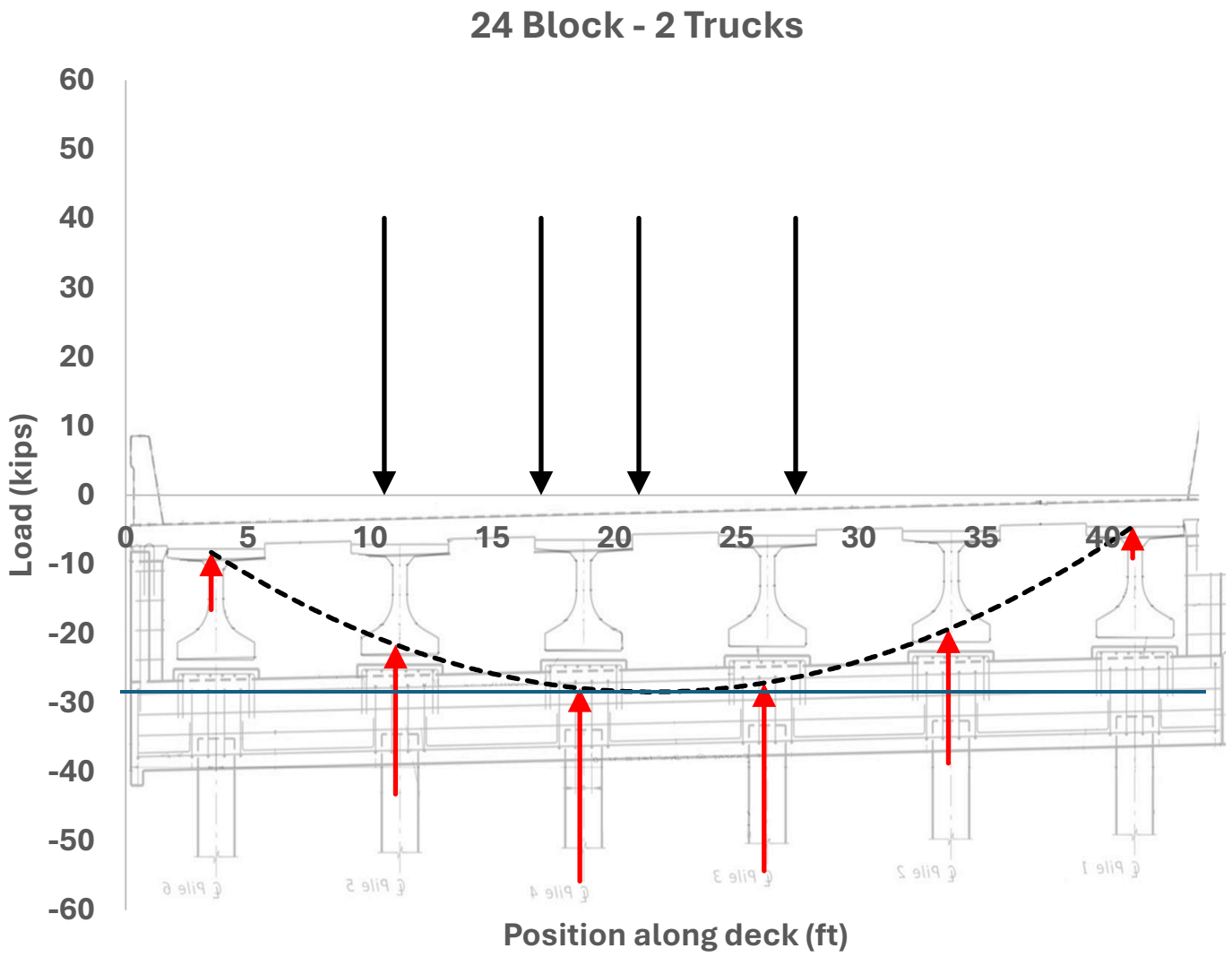


~160k truck load to end bent = 111k piles + 79k pile cap shallow footing

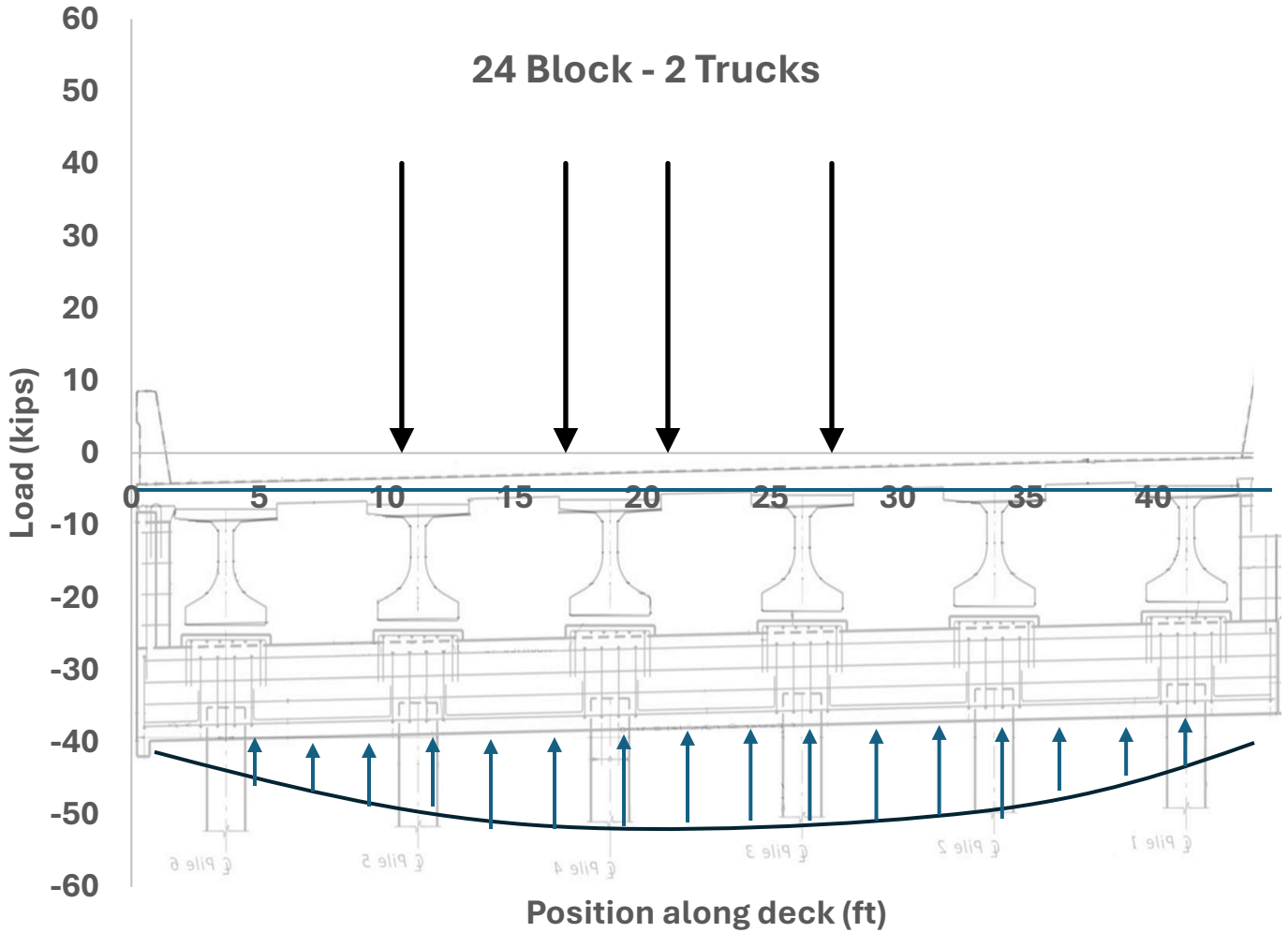
Live Load Test



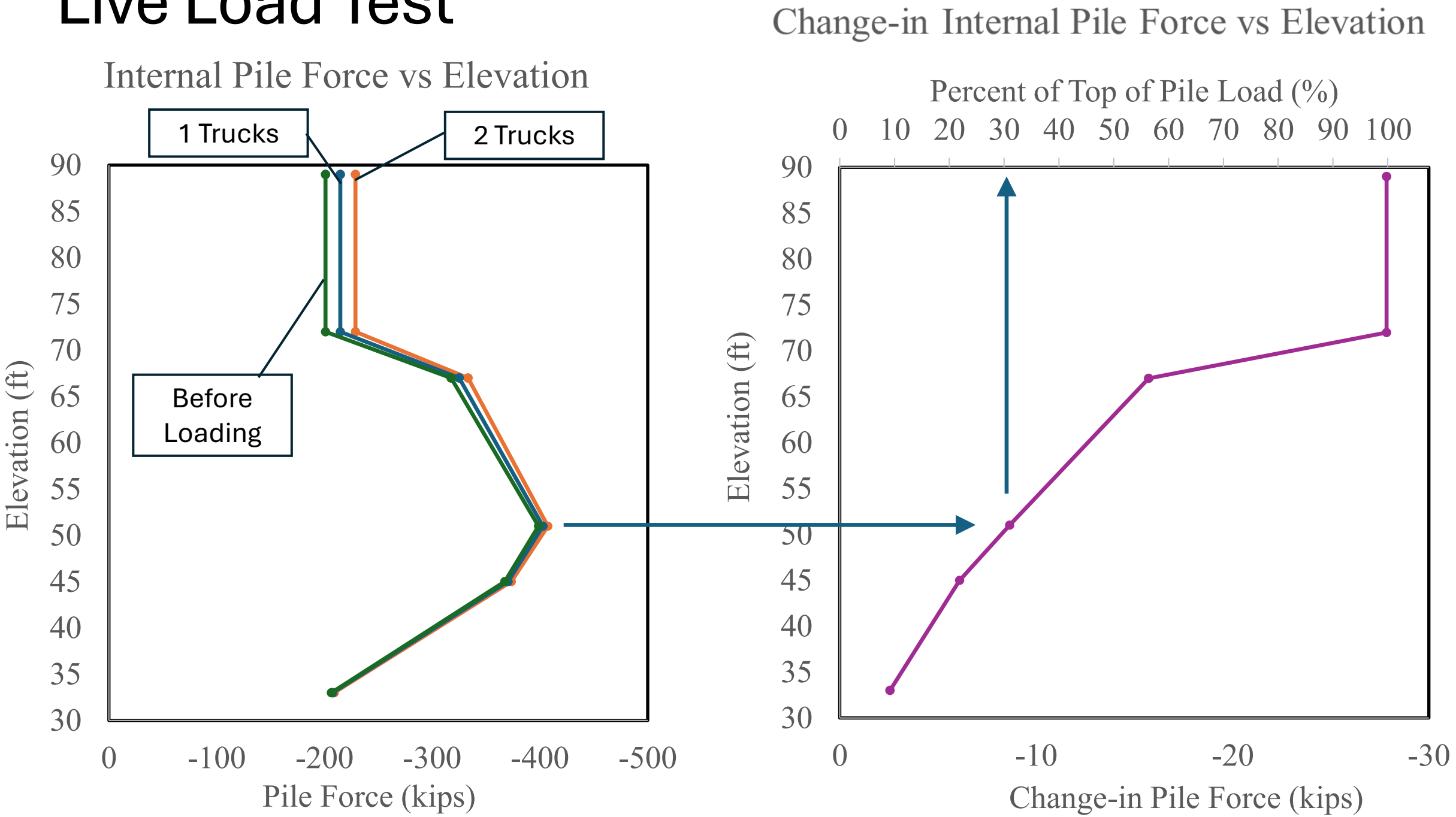
Live Load Test

~160k truck load = 108k piles + 51k pile cap shallow footing

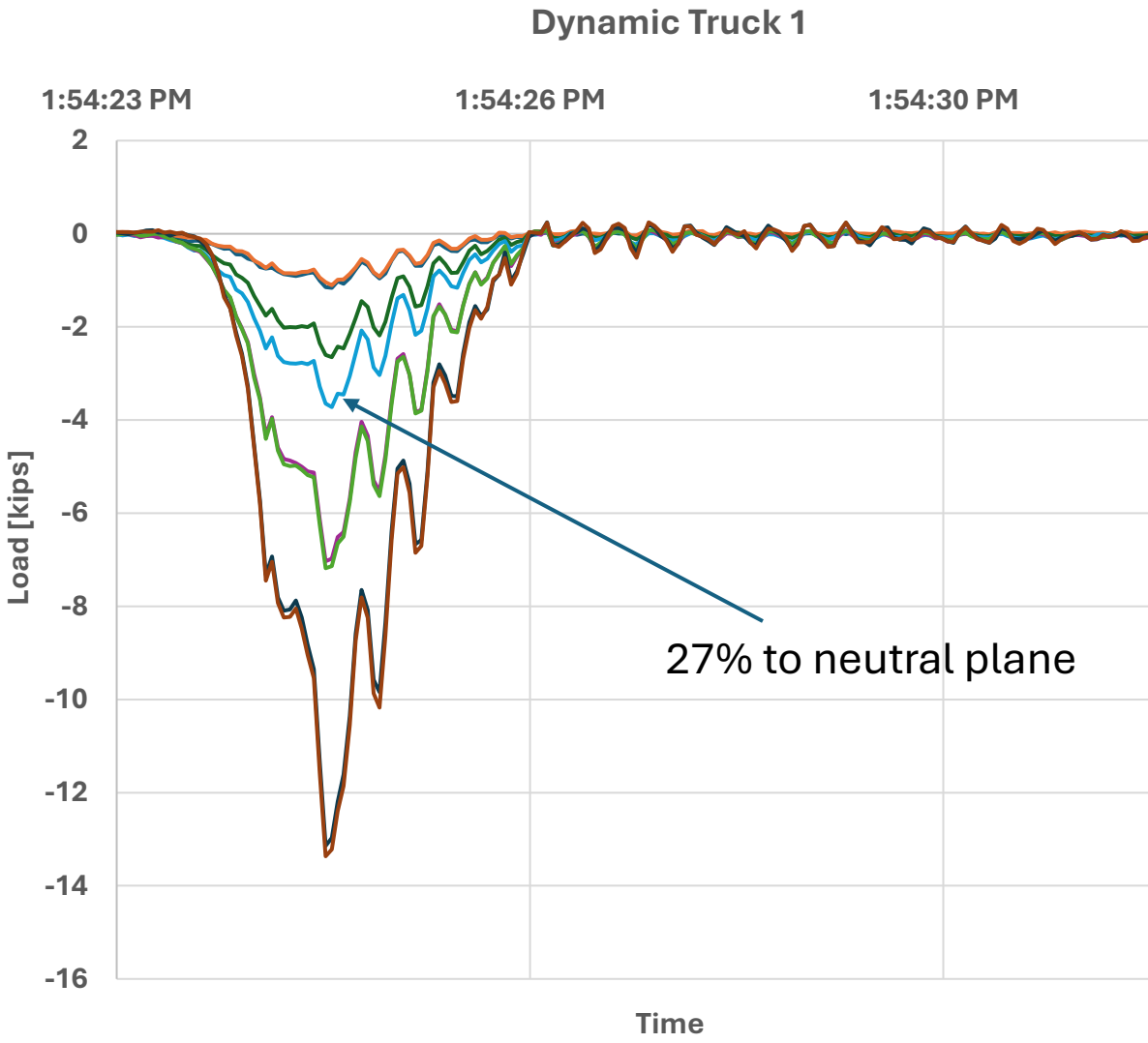
32% of live load taken by pile cap



Live Load Test



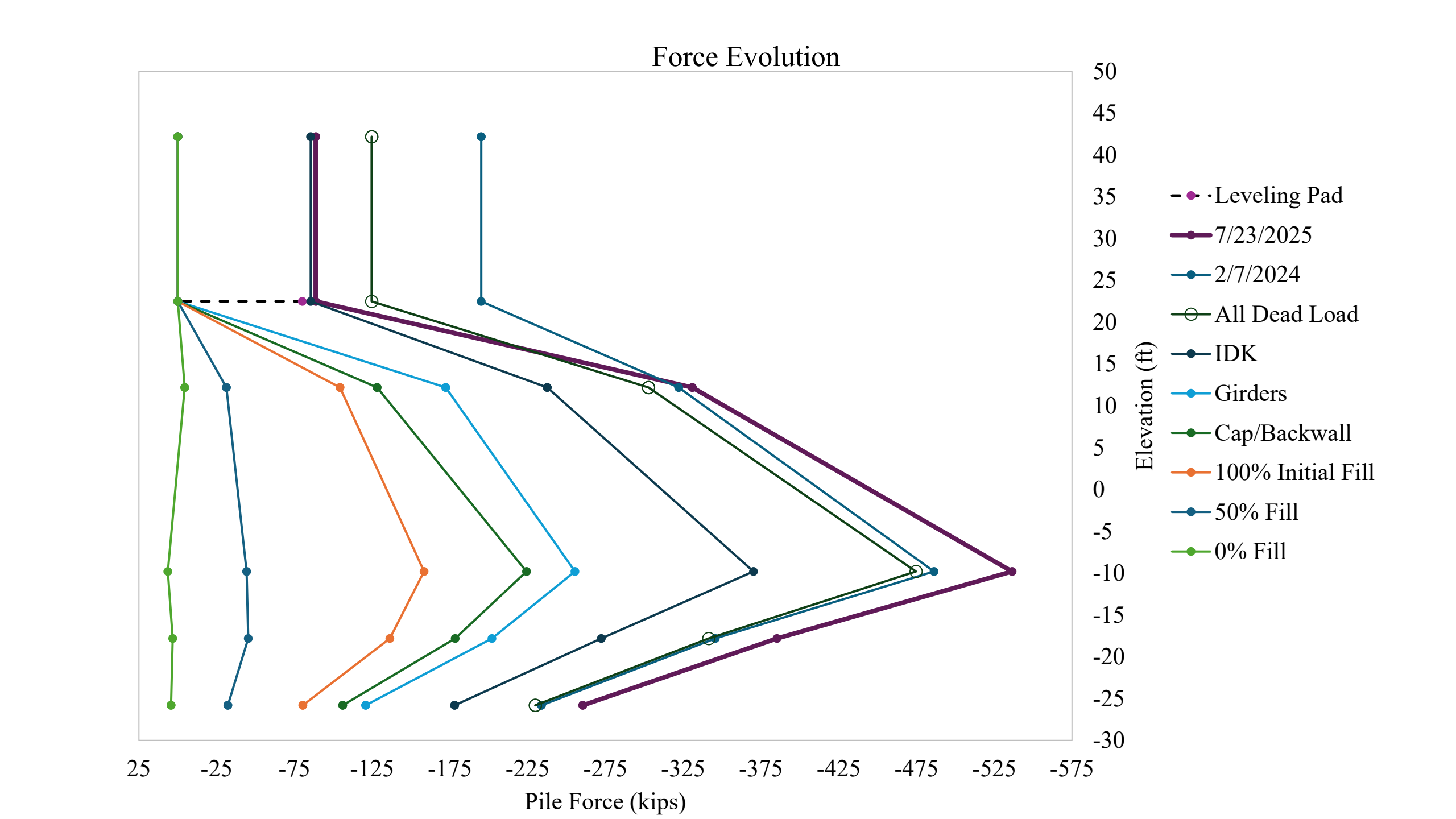
Live Load Test

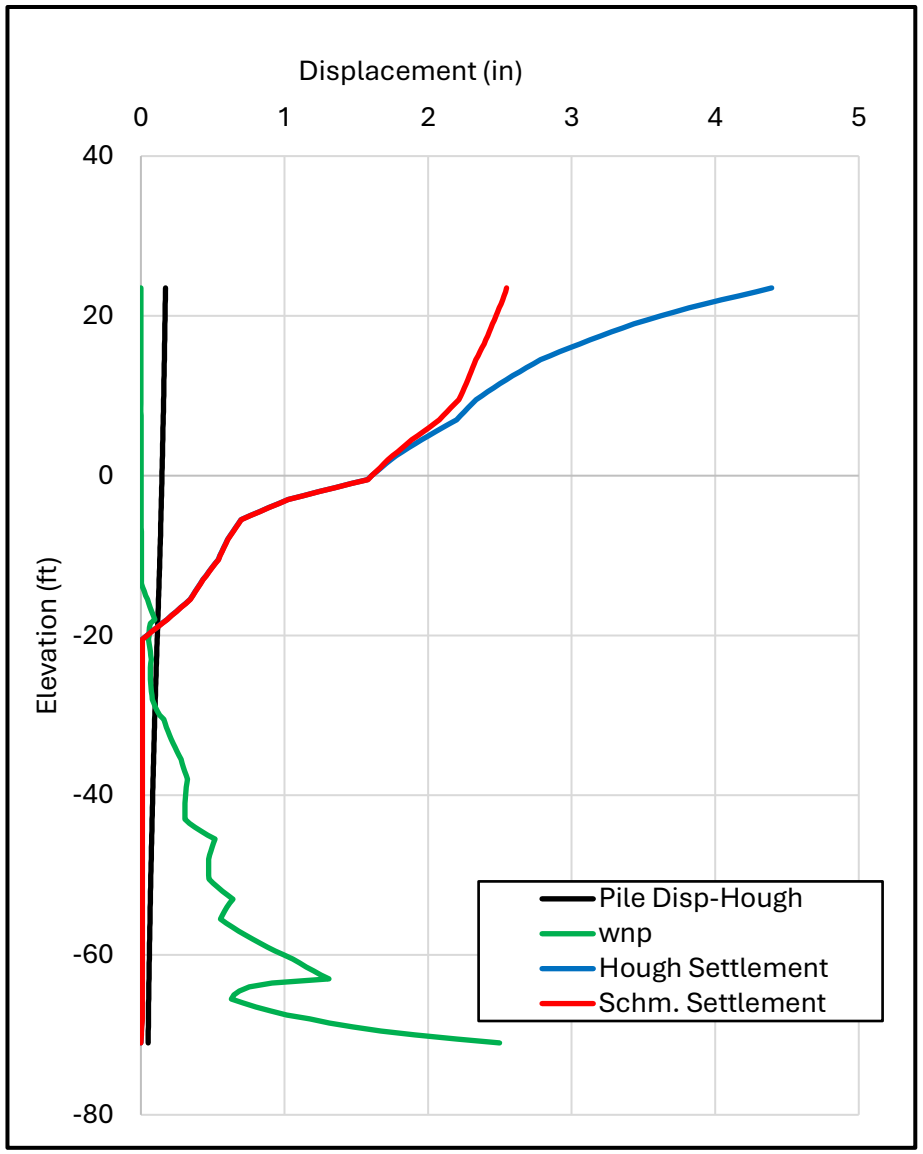


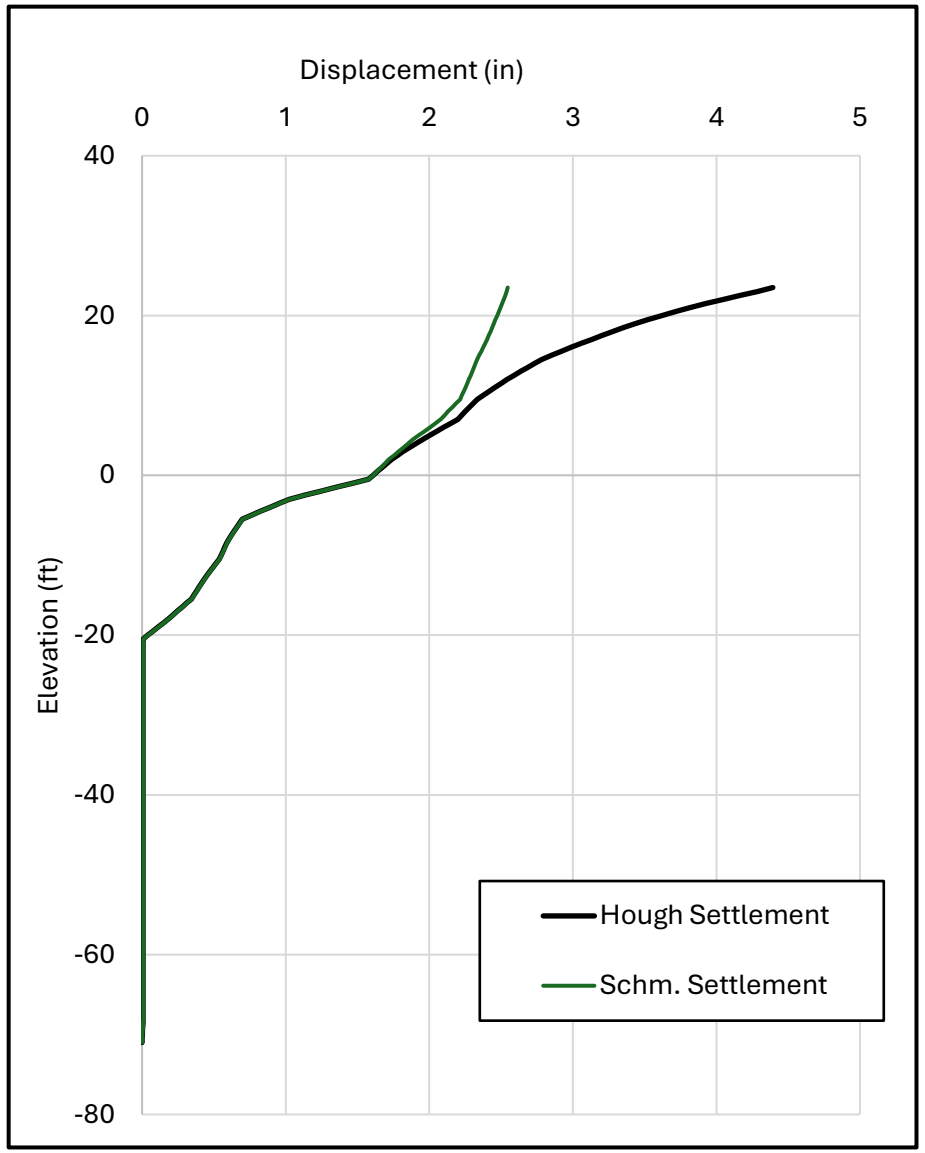
Summary/Closing

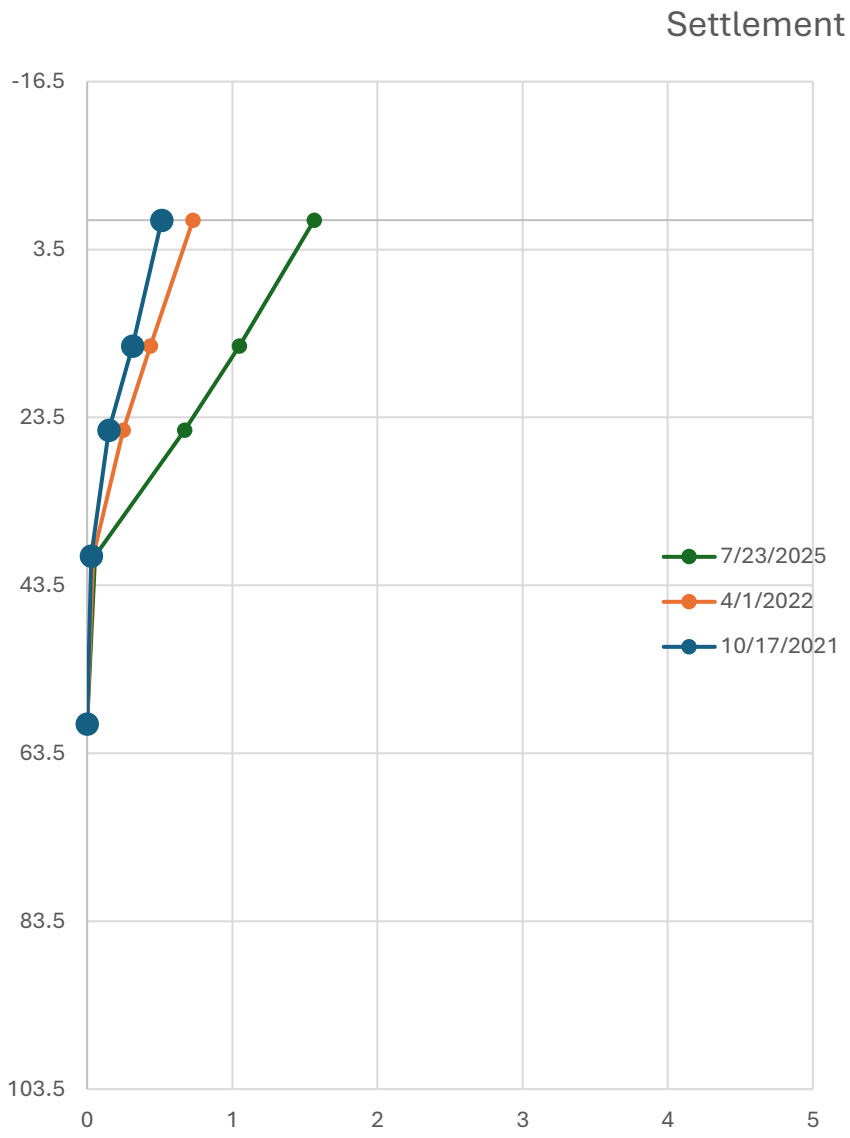
- Geotechnical strength limit state is argued to be independent of displacement. This has long been recognized to be incorrect (1972) but for downdrag it has been forgotten.
- Cannot use 100% of pile capacity until the pile displacement is equals the unreinforced soil settlement; this is often 3 to 4 inches.
- Downdrag is often (if not always) ignored if the settling soil layer is sand. Even the most recent FHWA publication gives no examples of cases where sand causes the downdrag force.
- Internal pile forces from negative side shear (downdrag) can be significantly higher than the factored design load


Questions


Force Evolution
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
Elevation (ft)
Leveling Pad
7/23/2025
2/7/2024
All Dead Load
IDK
Girders
Cap/Backwall
100% Initial Fill
50% Fill
0% Fill
25
-25
-75
-125
-175
-225
-275
-325
-375
-425
-475
-525
-575
Pile Force (kips)


Displacement (in)
0
1
2
3
4
5
40
20
0
-20
-40
-60
-80
Elevation (ft)
Pile Disp-Hough
wnp
Hough Settlement
Schm. Settlement


Displacement (in)
0
1
2
3
4
5
40
20
0
-20
-40
-60
-80
Elevation (ft)
Hough Settlement
Schm. Settlement


Settlement
-16.5
3.5
23.5
43.5
63.5
83.5
103.5
0
1
2
3
4
5
7/23/2025
4/1/2022
10/17/2021