Gannett Fleming

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Slope Stabilization with Steel H-Piles

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14th Annual Technical Forum for
Geohazards Impacting Transportation in Appalachia
August 2014

ISO 9001:2008 CERTIFIED

Overview

- Project site – landslide features and subsurface conditions
- Slope stability – existing and stabilized
- Lateral pile design – distribution of lateral load
- Pile layout
- Construction

Site Location

Source: ESRI, Digital Globe, GeoEye, i-Cubed

Site Location

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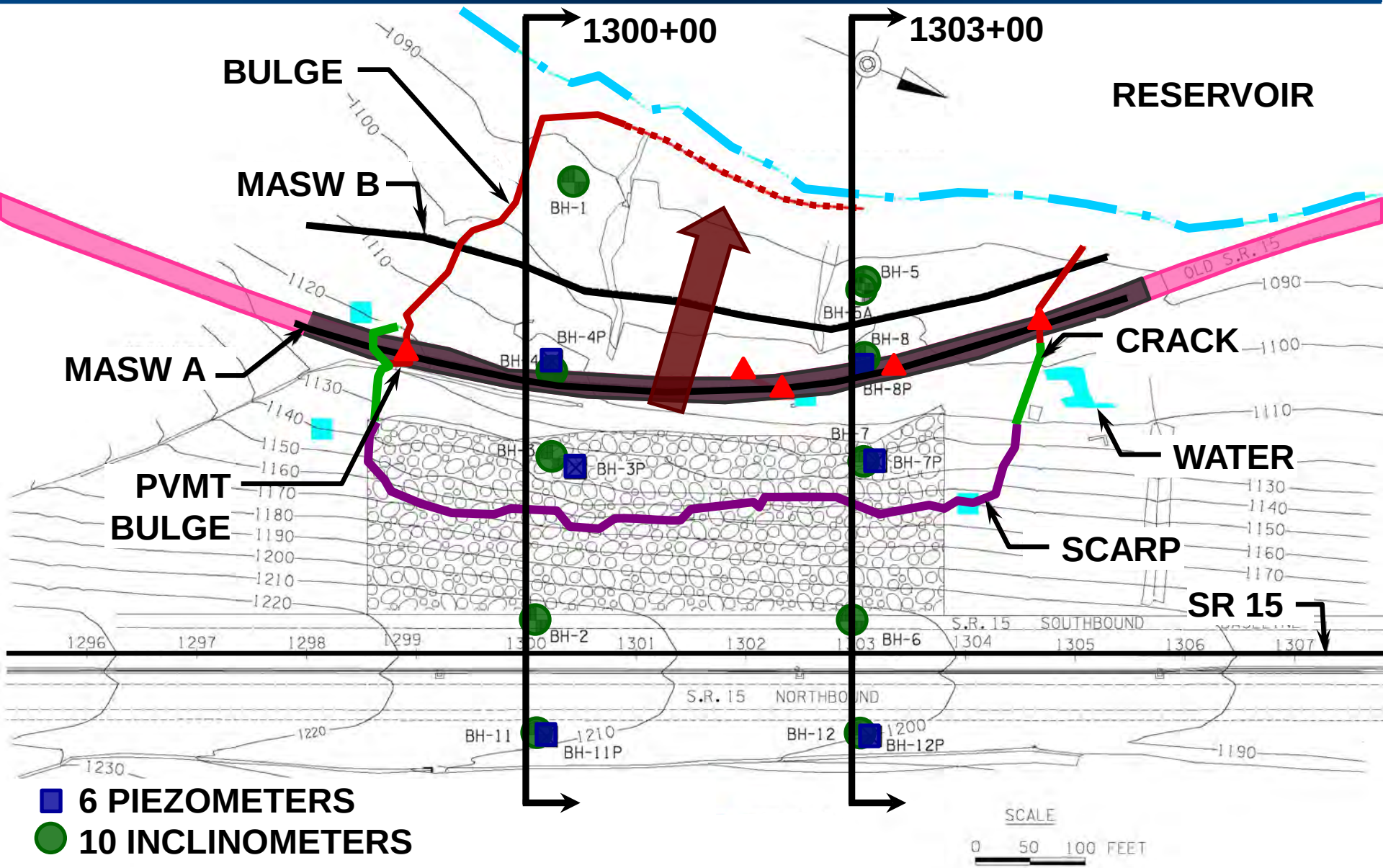
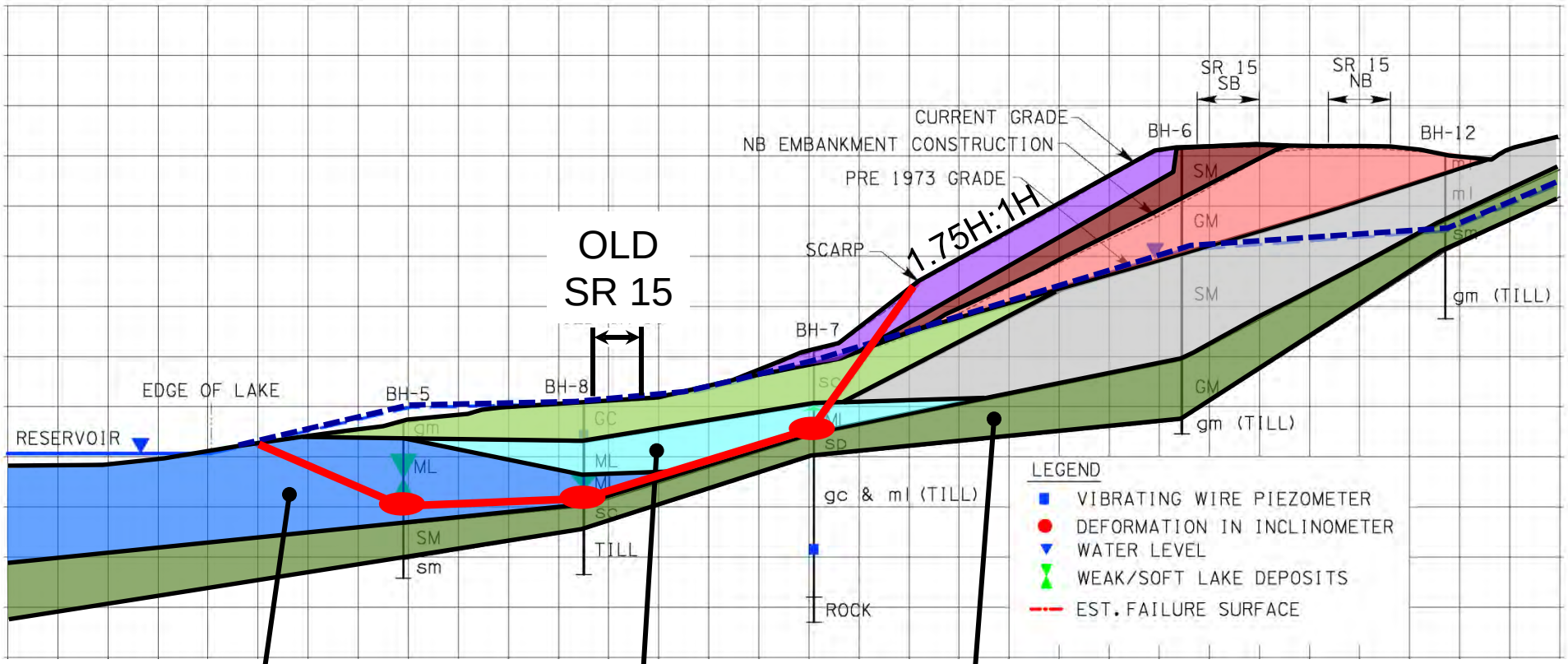
Scarp

Damage along Old SR 15

Plan View


1300+00
1303+00
RESERVOIR
BULGE
MASW B
MASW A
PVMT
BULGE
CRACK
WATER
SCARP
SR 15
BH-1
BH-2
BH-3
BH-3P
BH-4
BH-4P
BH-5
BH-5A
BH-6
BH-7
BH-7P
BH-8
BH-8P
BH-11
BH-11P
BH-12
BH-12P
OLD S.R. 15
S.R. 15 SOUTHBOUND
S.R. 15 NORTHBOUND
SCALE
0 50 100 FEET
6 PIEZOMETERS
10 INCLINOMETERS

Subsurface Profile – Station 1303+00

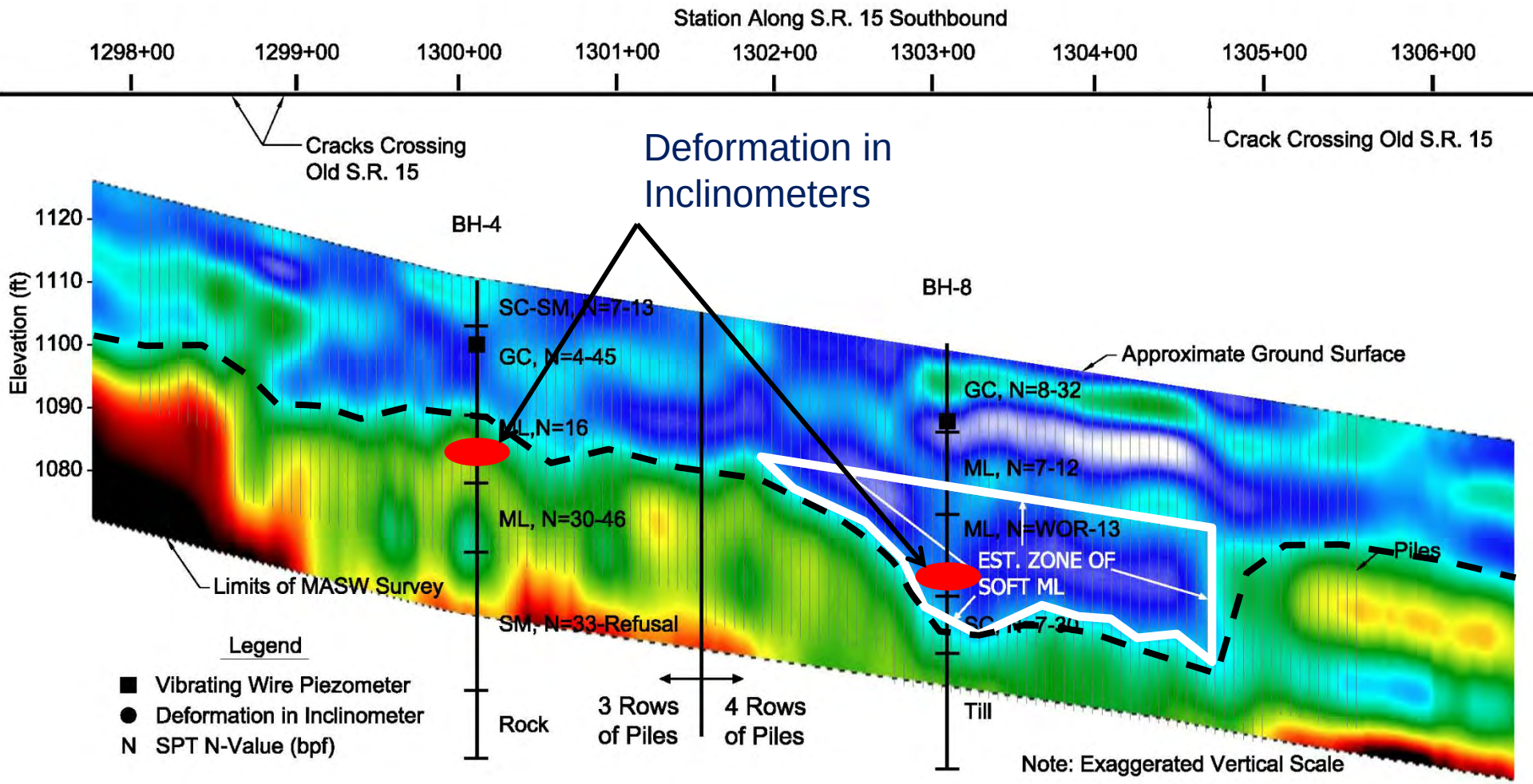


ϕ=16.4º (RESIDUAL)

ϕ=25º (PEAK)

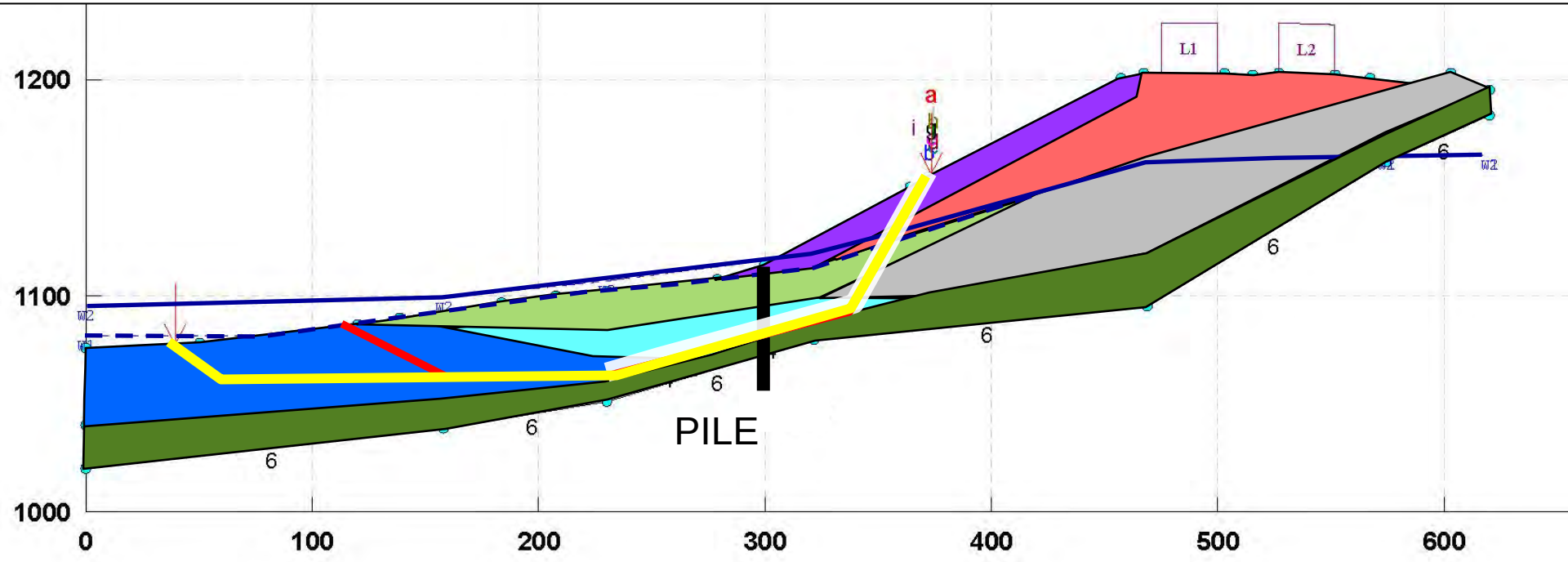
ϕ=36º

Geophysics Profile along Old SR 15



Slope Stability

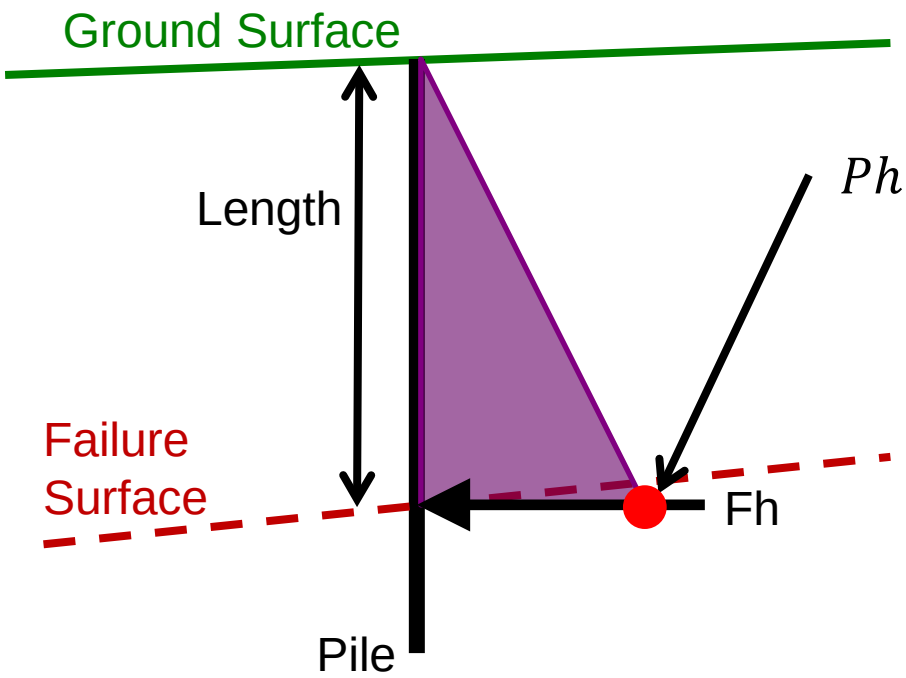
- **GSTABL7 – Wedge**
- **Existing slope without piles: FS = 1.0**
- **Remediated slope with piles: FS = 1.3**
  - Pile resistance input as lateral load
  - Lateral load input per foot of embankment



Pile Design

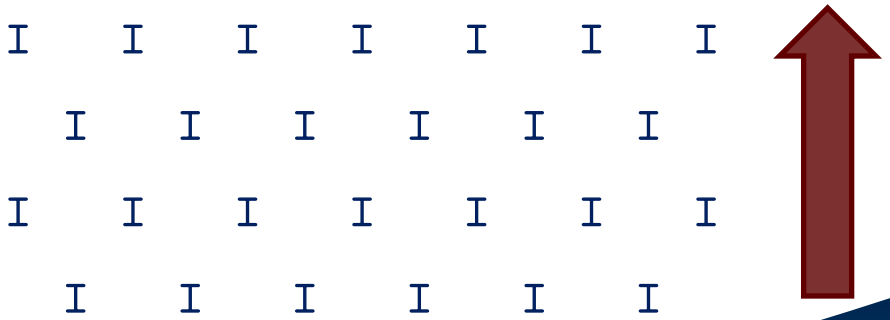
- Computer software LPILE
- Lateral load triangularly distributed
- p-multiplier
- Pile tip fixity
- Moment criteria for $M_{MAX} \leq M_{RESISTING}$
- Pile layout

Lateral Load Distribution



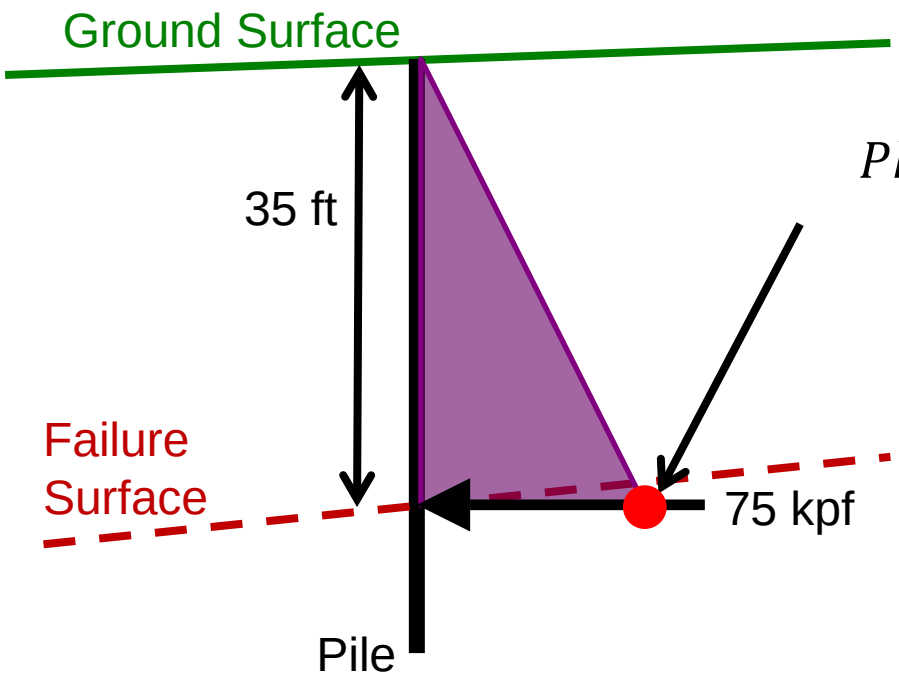
$$Ph = 2 * \frac{Fh}{Length}$$

Pile Layout – Plan View



Triangular distribution per ODOT (2011) Geotechnical Bulletin 7

Lateral Load Distribution - Example

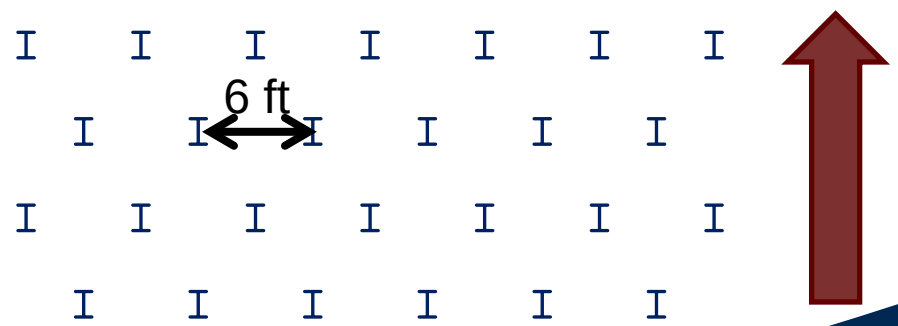


$$Ph = 2 * \frac{75\ k/ft}{35\ ft} * \frac{6\ ft}{4\ rows}$$

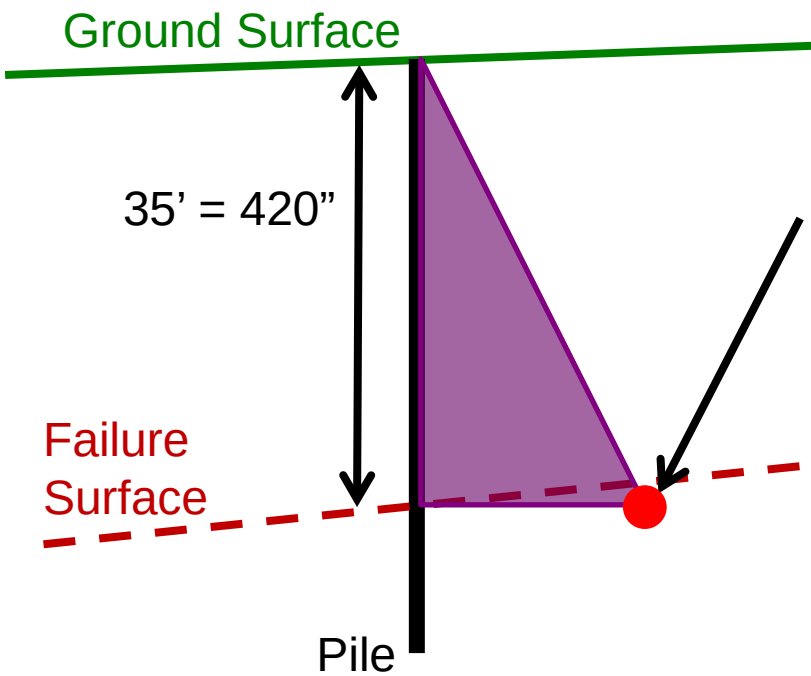
= 6.43 kips/ft per pile

= 536 lbs/in

Pile Layout – Plan View



Lateral Load Distribution - Example



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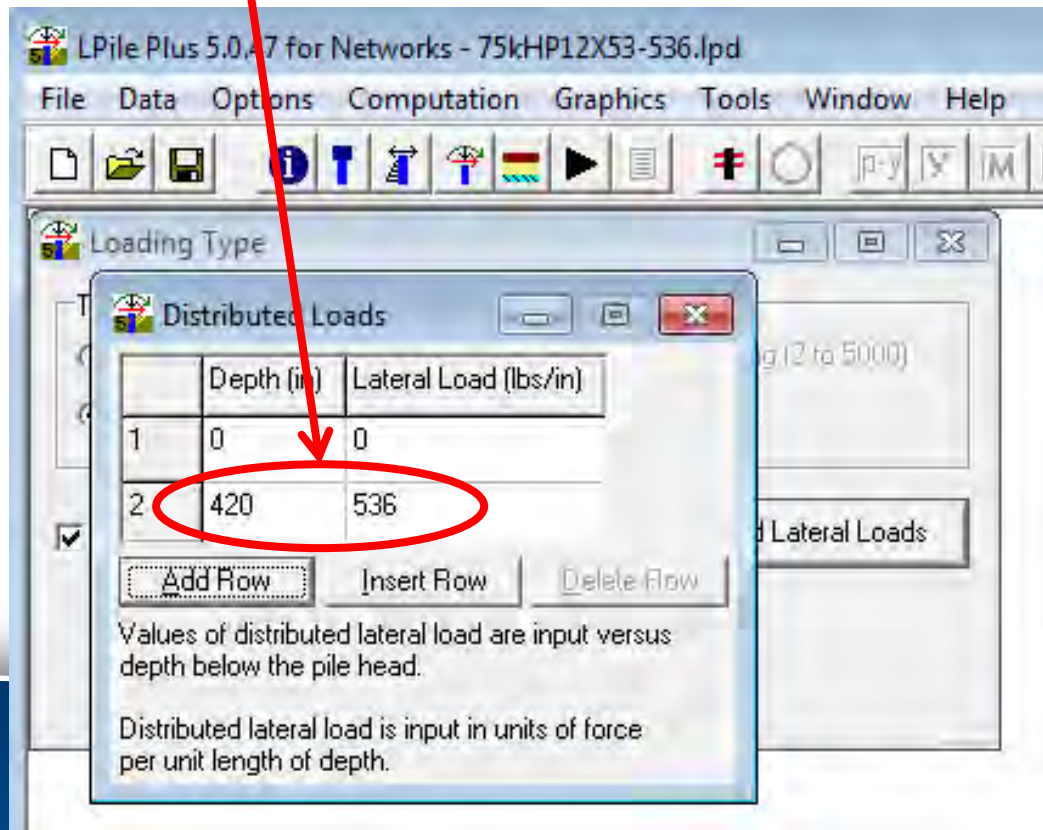
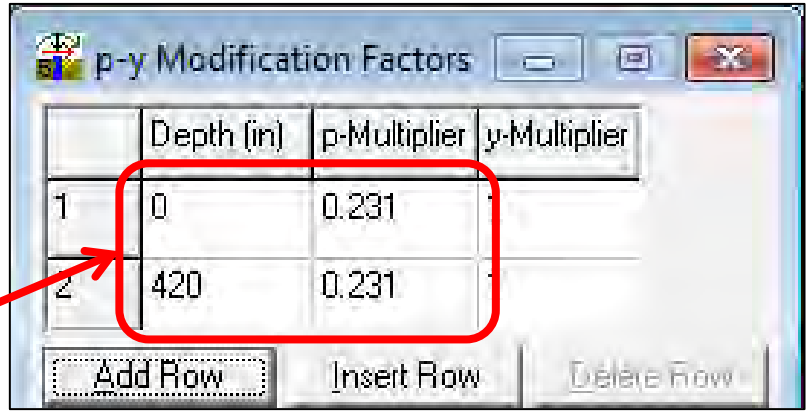
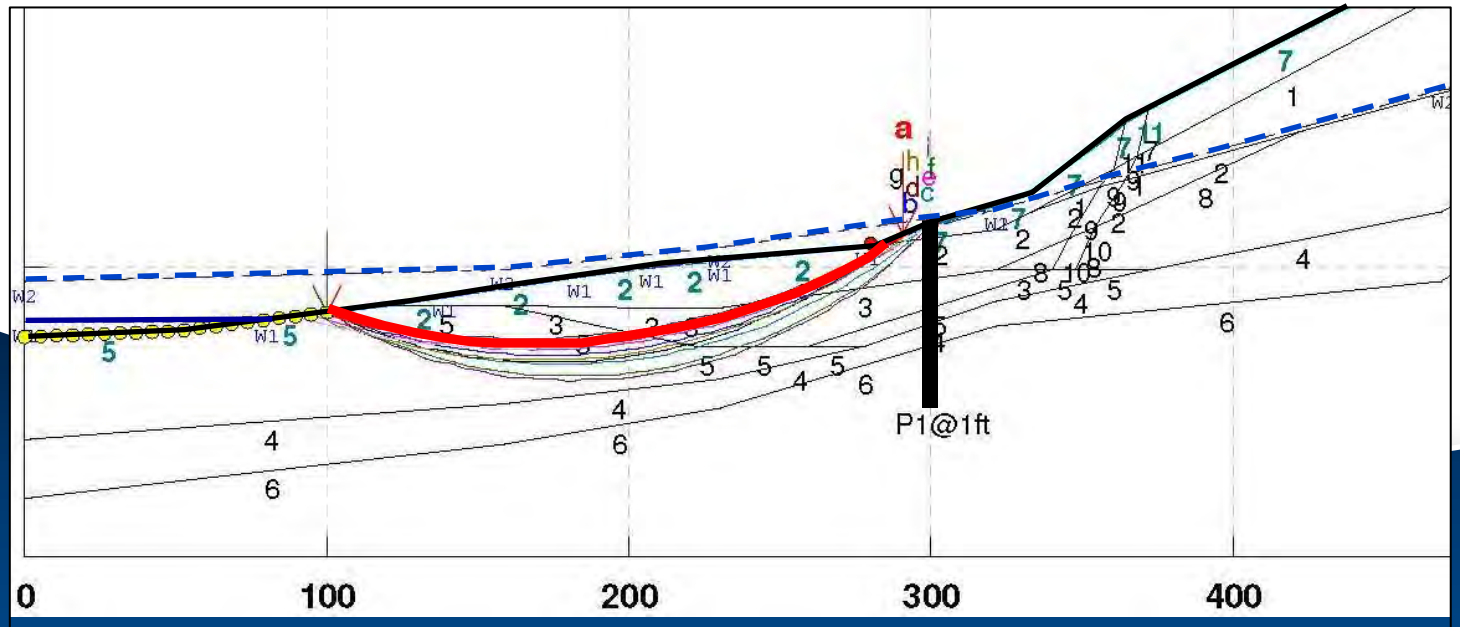


Subsurface Profile for Lateral Pile Analysis

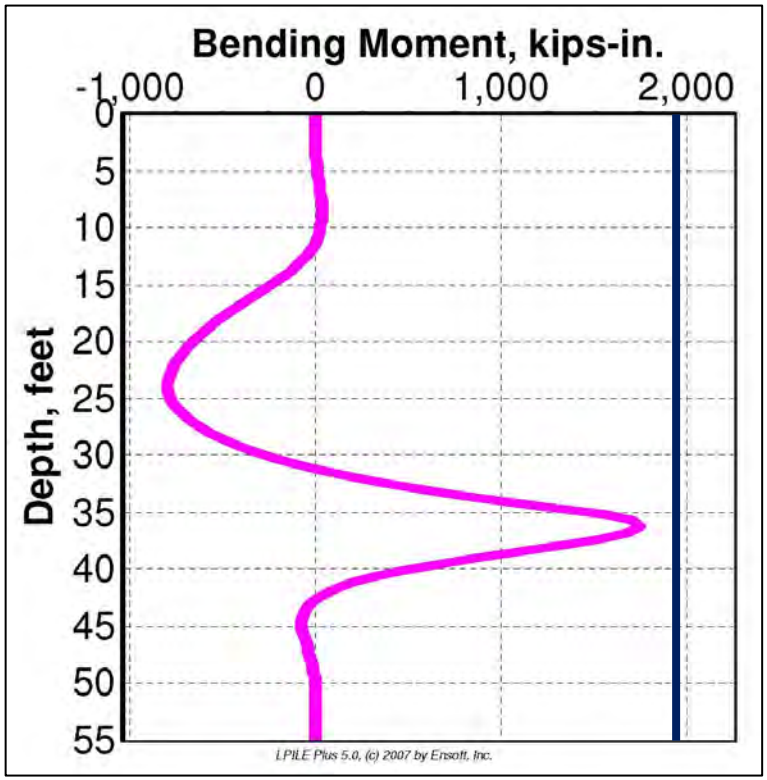
- **Reduction to soil resistance (p-y curves)**
  - Active landslide
  - Pile spacing:diameter
  - FS in front of pile
  - p-multiplier = 0. 231





Ref: ODOT (2011) GB 7

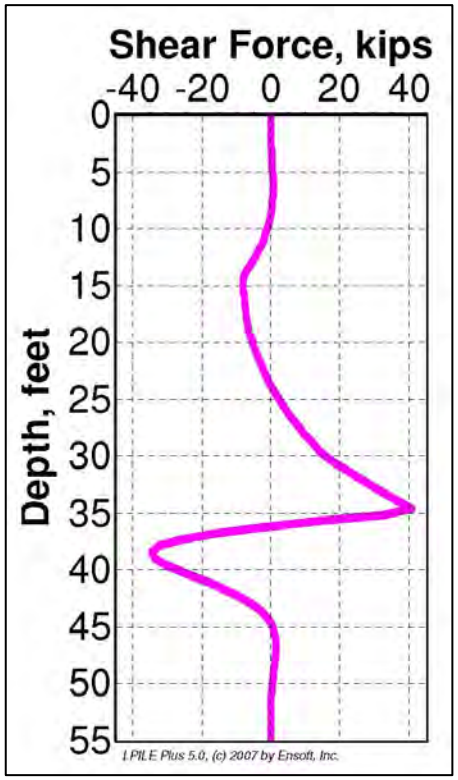
Lateral Pile Analysis Results (HP 12x53)



M_{MAX} = 1,744 kip-in

<

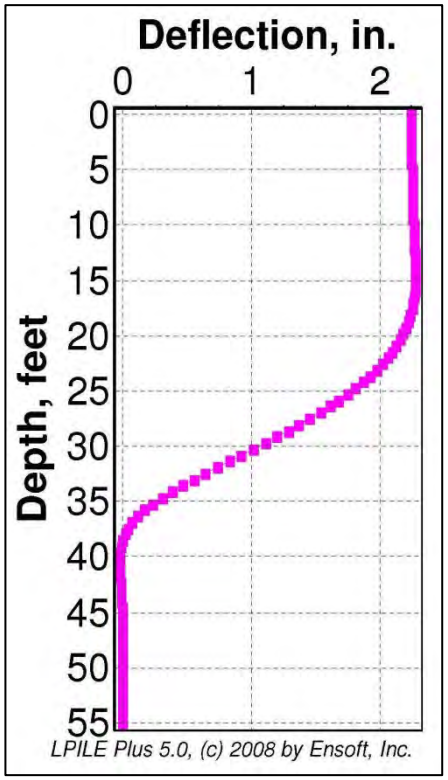
M_{RES} = 1,983 kip-in



V_{MAX} = 41 kips

<

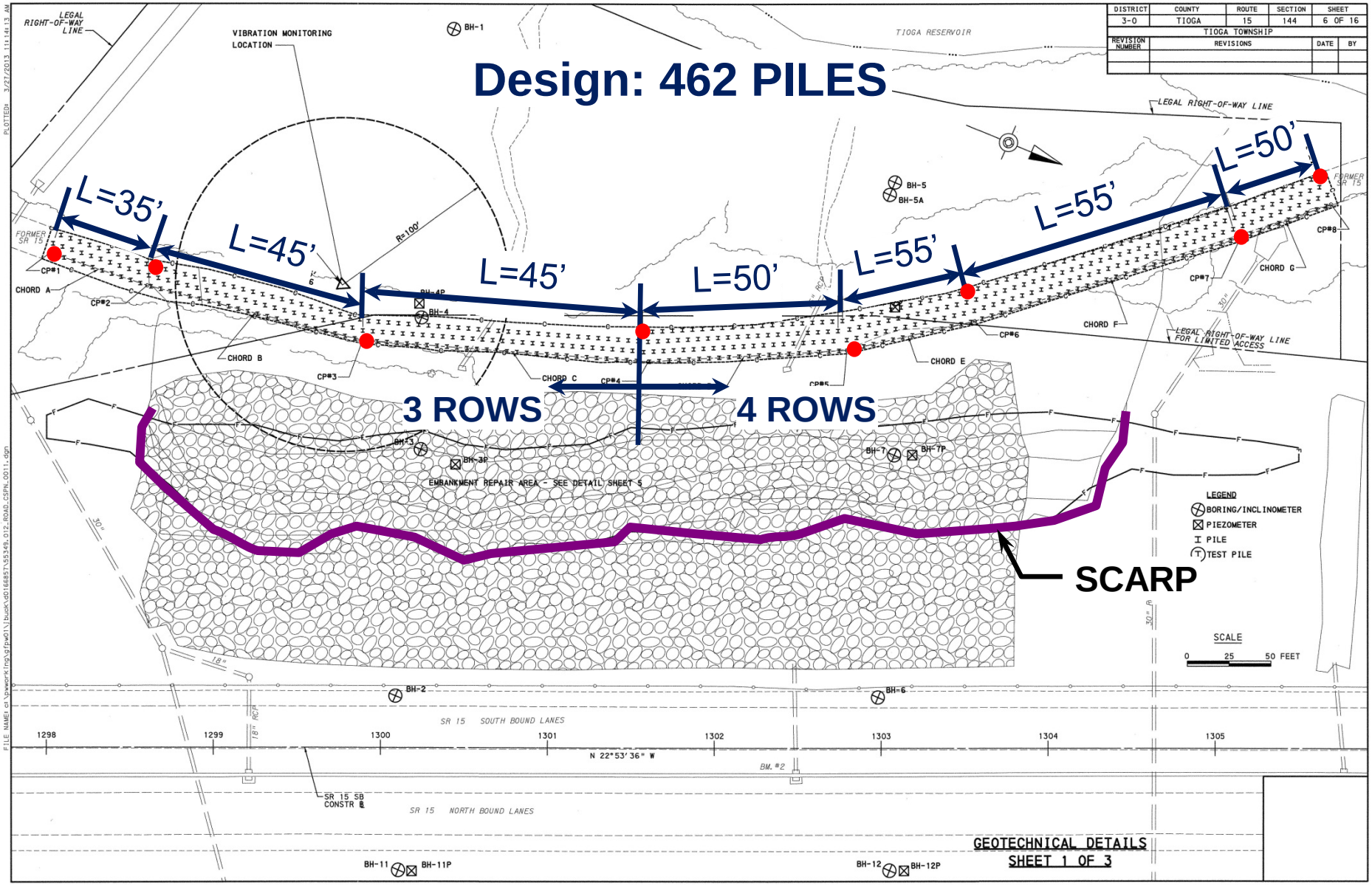
V_{RES} = 98 kips



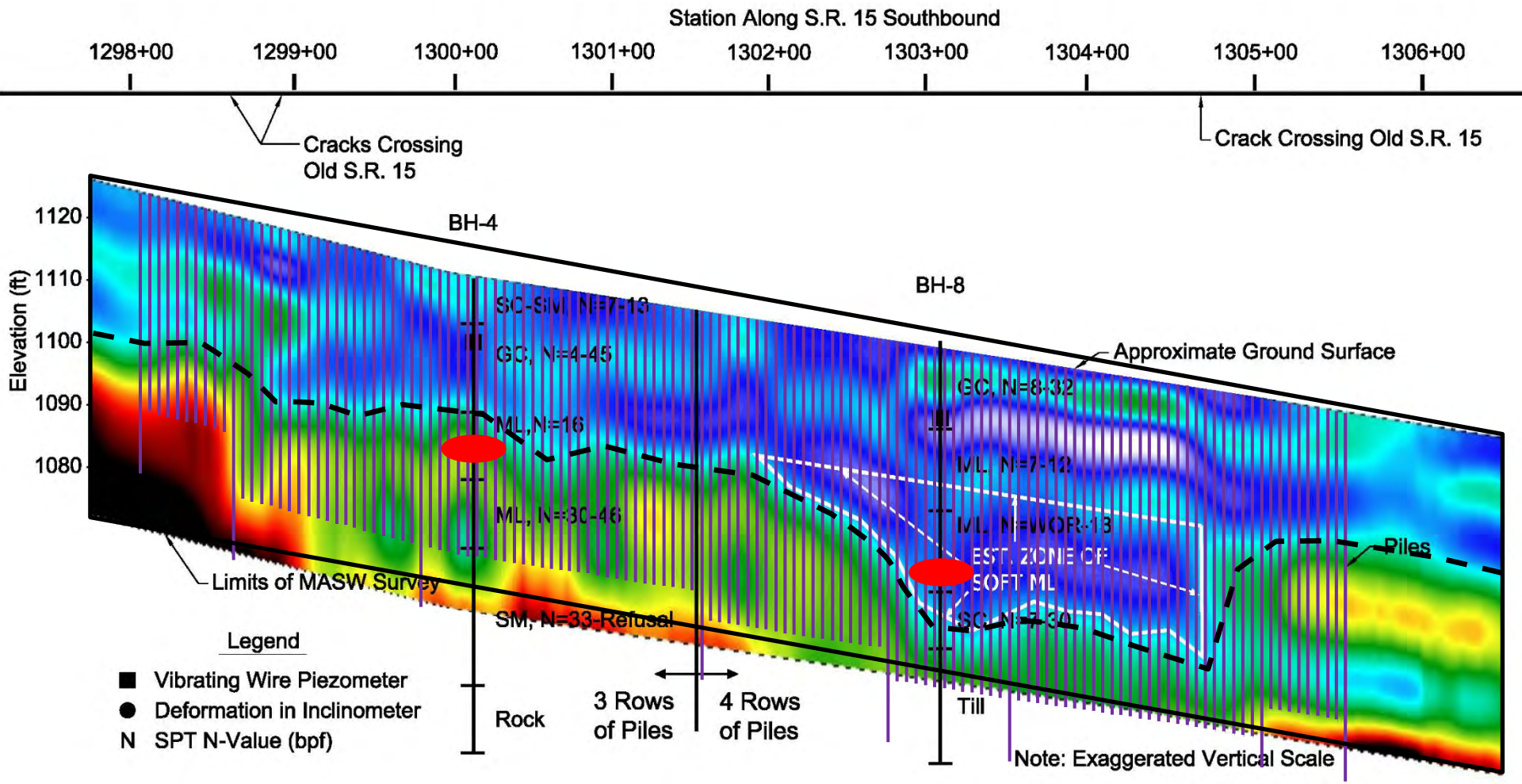
Just for interest

δ = 2.2 in.

Piles Layout

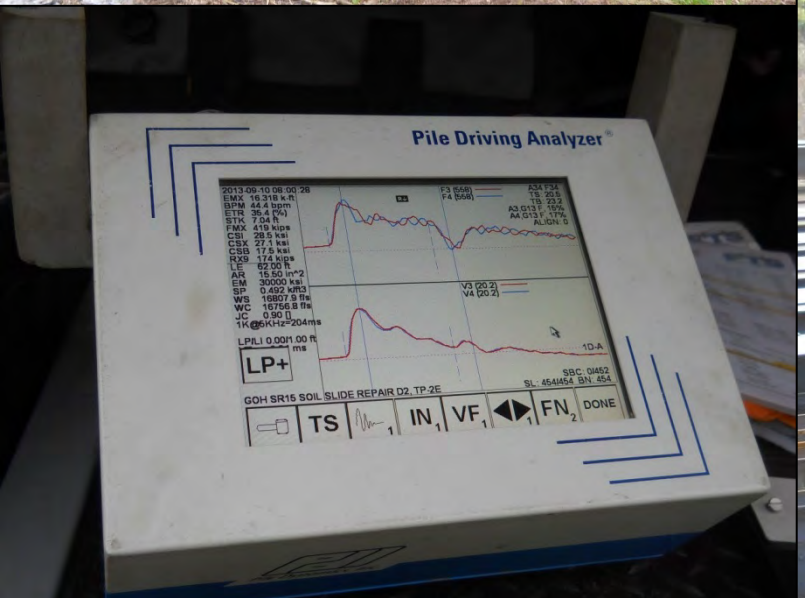


Piles Layout



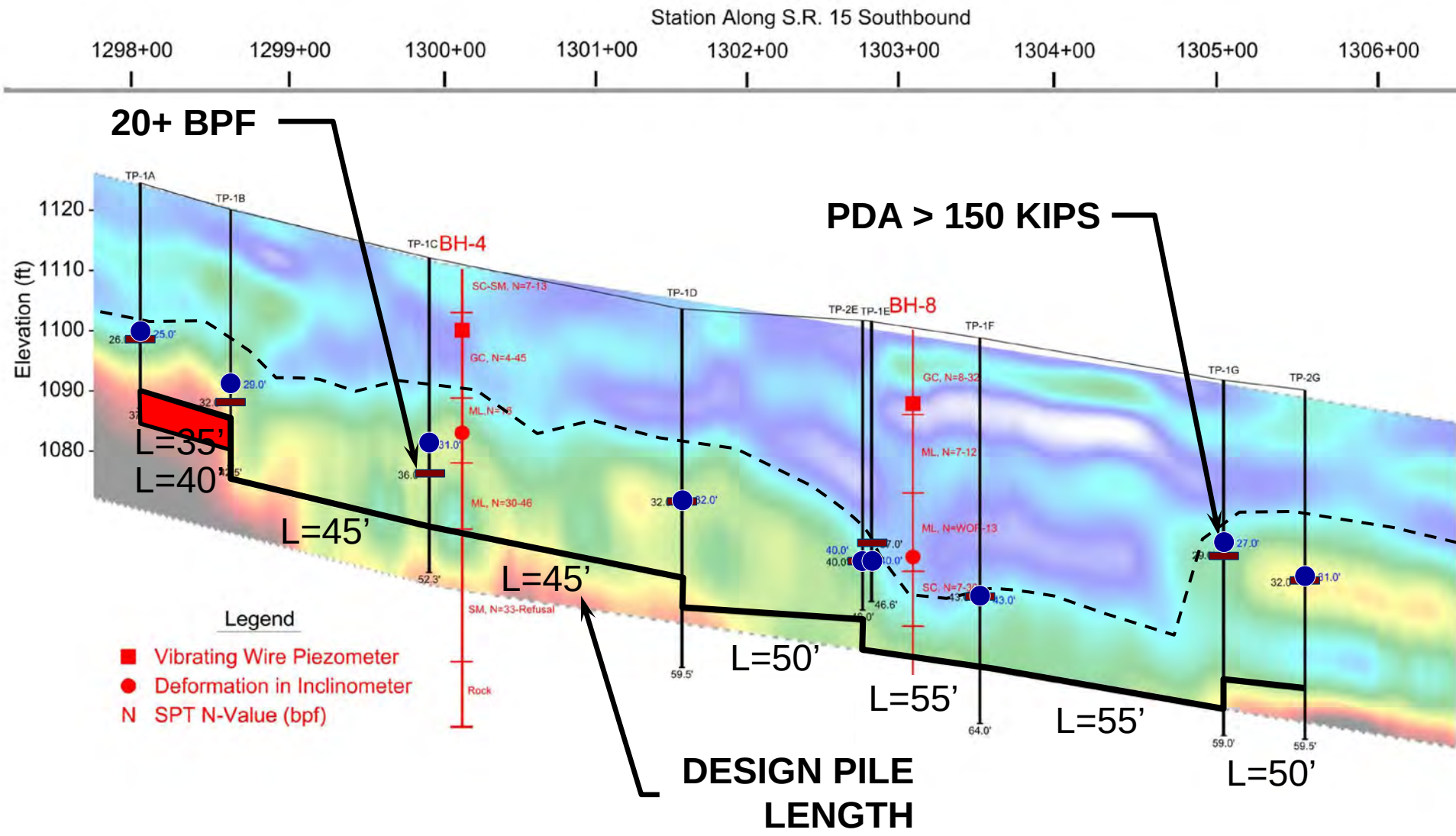
Test Piles

Test Piles



Test Piles

Test Piles


Station Along S.R. 15 Southbound
1298+00
1299+00
1300+00
1301+00
1302+00
1303+00
1304+00
1305+00
1306+00
Elevation (ft)
1120
1110
1100
1090
1080
20+ BPF
PDA > 150 KIPS
TP-1A
TP-1B
TP-1C
BH-4
TP-1D
TP-2E
TP-1E
BH-8
TP-1F
TP-1G
TP-2G
SC-SM, N=7-13
GC, N=4-45
ML, N=30-46
SM, N=33-Refusal
Rock
GC, N=8-32
ML, N=7-12
ML, N=WOR-13
L=35'
L=40'
L=45'
L=45'
L=50'
L=55'
L=55'
L=50'
DESIGN PILE LENGTH
Legend
Vibrating Wire Piezometer
Deformation in Inclinometer
N SPT N-Value (bpf)

Production Driving

Photo courtesy of Glenn O. Hawbaker, Inc.

Production Driving

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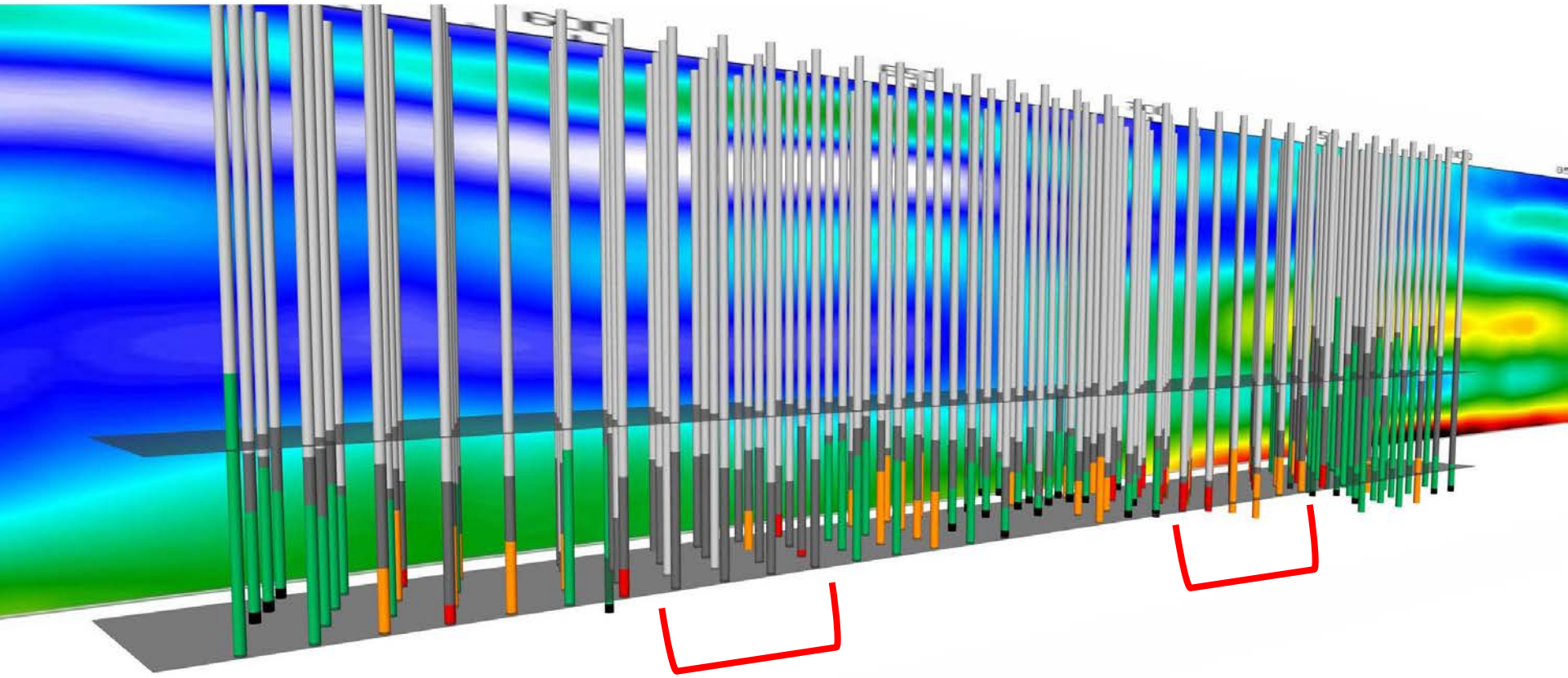
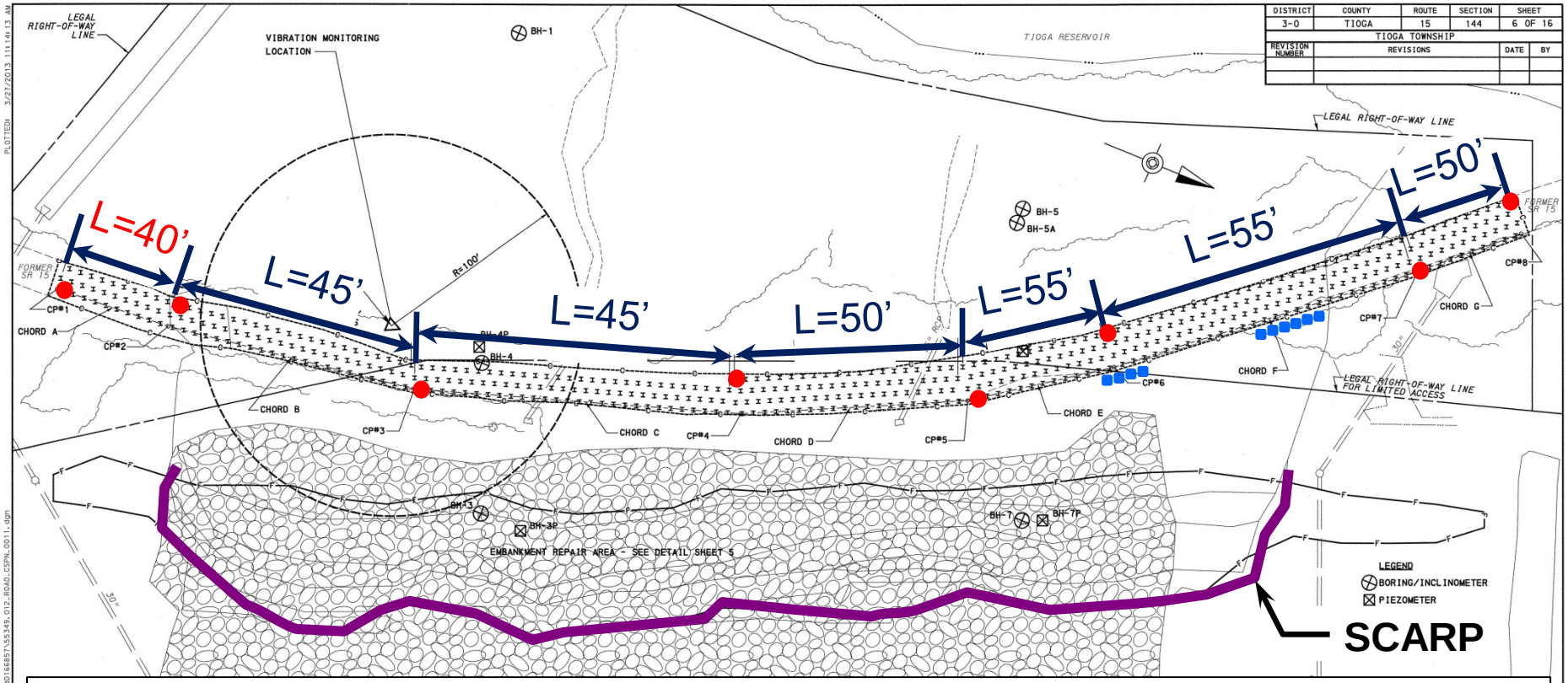
Production Driving



Pile Quantities



DISTRICT	COUNTY	ROUTE	SECTION	SHEET
3-0	TIOGA	15	144	6 OF 16
TIOGA TOWNSHIP				

REVISION NUMBER	REVISIONS	DATE	BY

Design: 8 test piles with total length = 465 LF
454 production piles with total length = 22,325 LF

Construction: 29 piles lengthened by 5'
10 piles added with L = 60'
} Δ Total Length = 3%

Summary

- **Slope failure and subsurface conditions**
- **Existing slope model calibrated to FS = 1.0**
- **Slope stability**
  - FS=1.3 ⇨ Strength limit state of lateral pile load
- **Lateral pile design**
  - Lateral load triangularly distributed
  - p-multiplier
- **Pile layout based on geophysics profile**
- **Quantity of installed piles only 3% > design**

Acknowledgements