Tipping the Balance

By Daryl Wurster, PE
Wurster Engineering & Construction, Inc.

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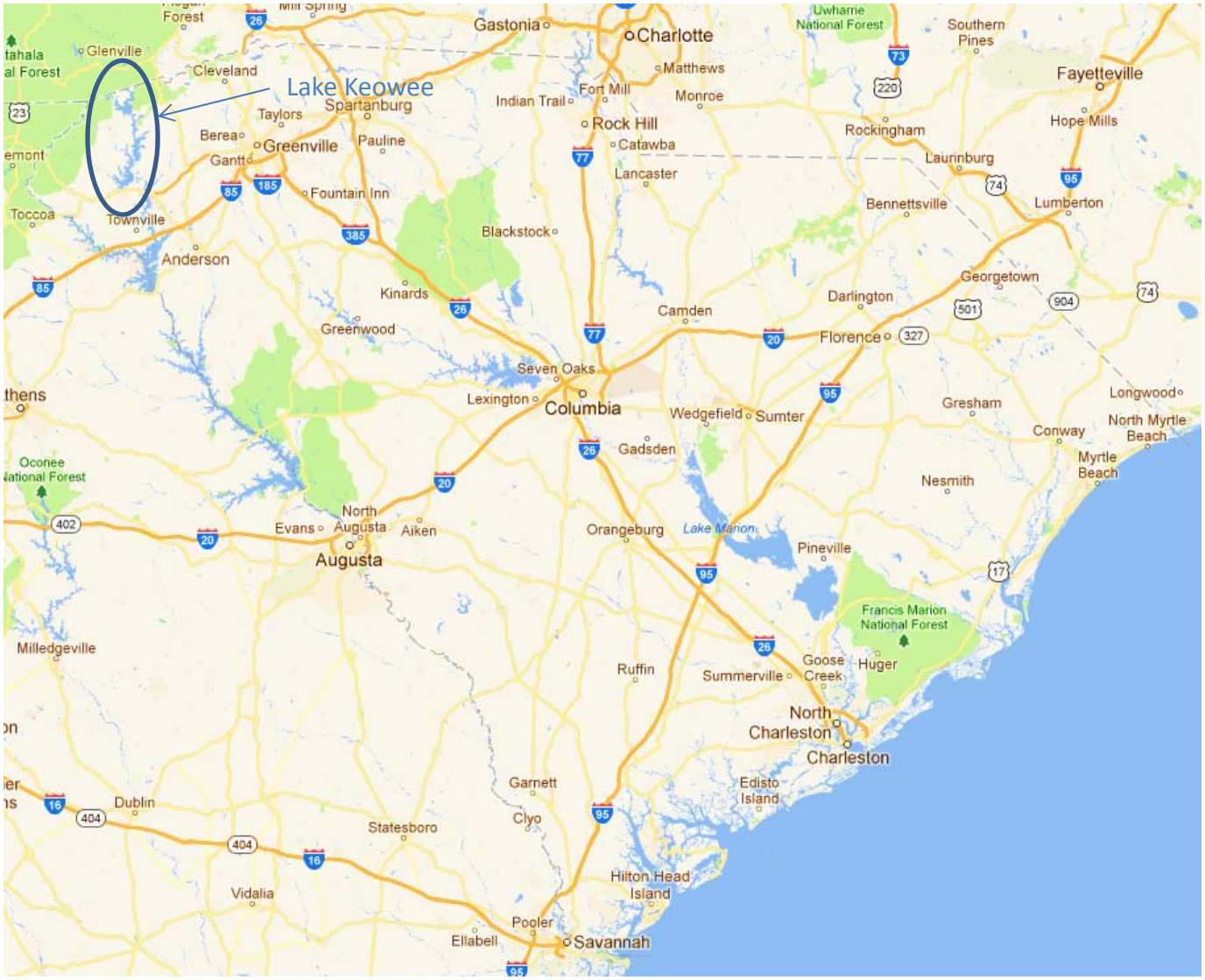
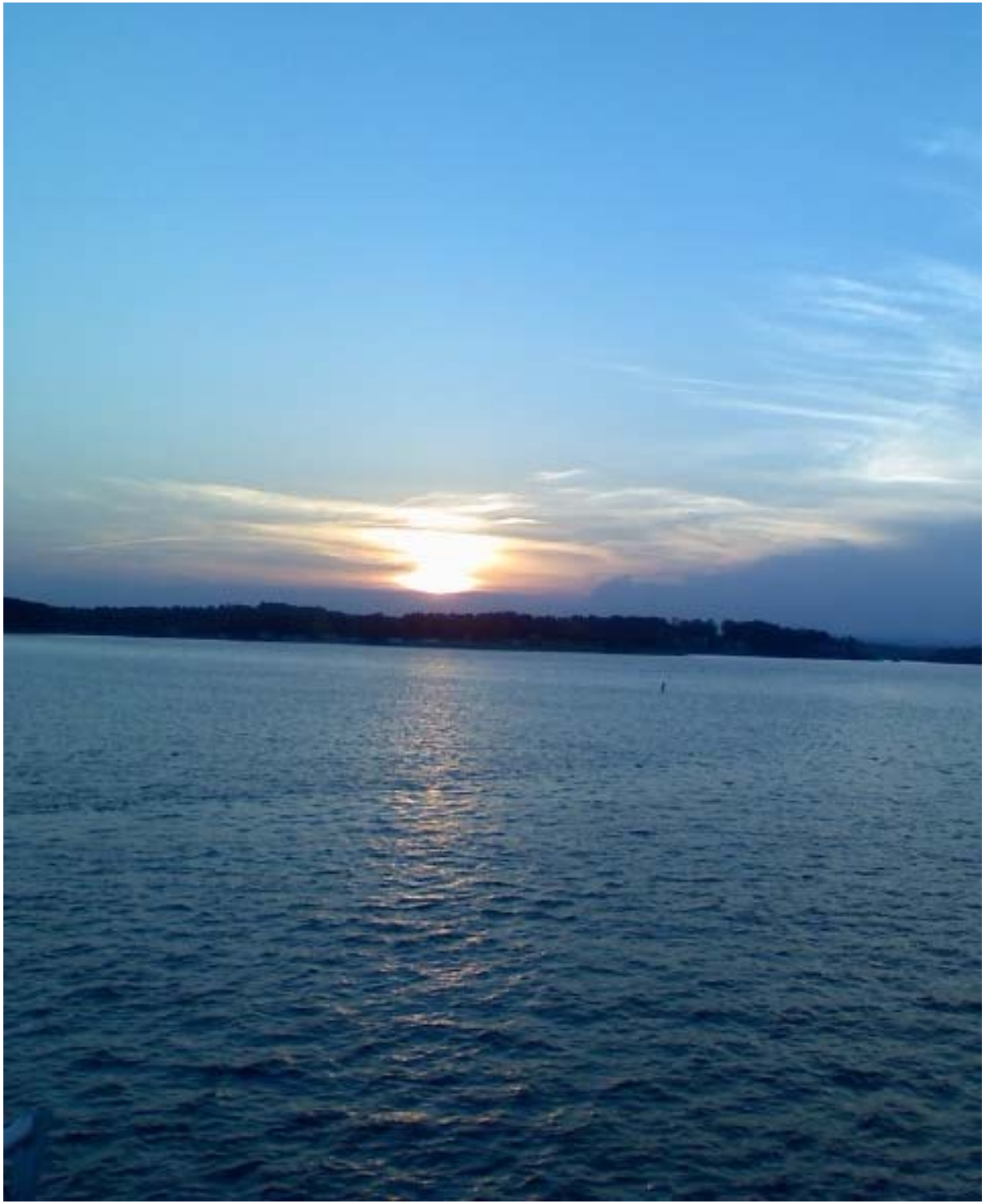


Lake Keowee is located in the Upstate of South Carolina and was created for power production and for recreation.



The Oconee Nuclear plant is located on Lake Keowee and as a result, water levels are held fairly constant. Much of the waterfront has residential development. Lakefront property in the lower portions of the lake is gently to moderately sloping.

The lake is about 26 miles long with about 300 miles of shoreline.

Several slow moving landslides have been observed, affecting some of the residential developments.

Movements so far appear to be isolated to residential properties. However, this movement could also effect transportation and hydropower infrastructure.

This pattern of movement appears to be unique to the Keowee area, as such movements have not been widely observed on the adjacent lakes.

The ground movement is typically very slow moving and deep seated, often encompassing several acres of ground.

Uniquely, the surface profile of the moving areas is often rather flat, ranging from 3H:1V to 7H:1V, and the slides typically exit well below the lake surface

Several known slides in same general area of Lake Keowee with similar characteristics

Three known slides in same general area of Lake Keowee with similar characteristics

- Slope of ground is flatter than might be expected for a slide to occur in this general area. Site grades are typically 3H:1V or flatter

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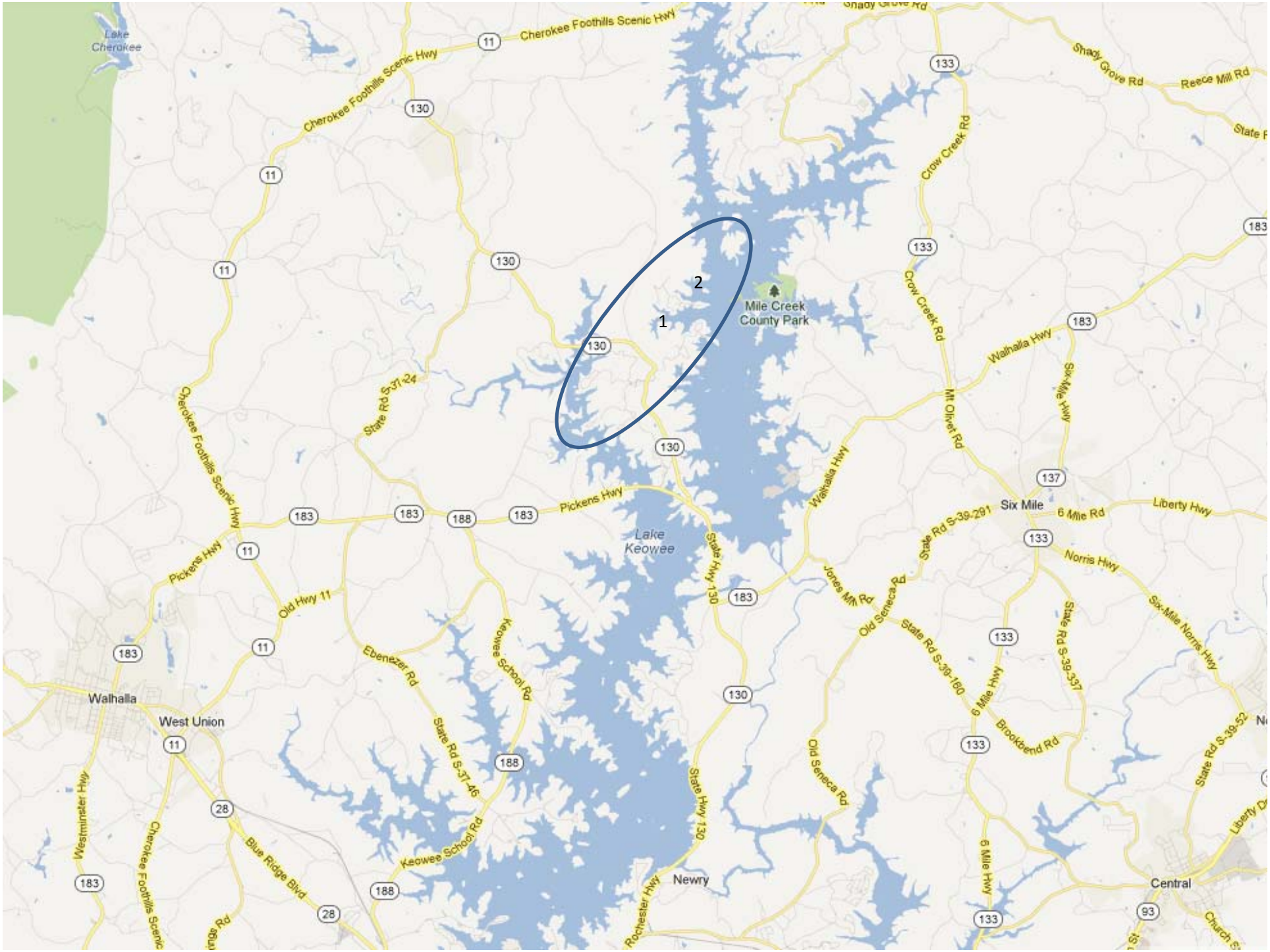
- Slope of ground is flatter than might be expected for a slide to occur in this general area. Site grades are typically 3H:1V or flatter
- Areas with borings and slope inclinometers indicate movement near the soft soil/weathered rock interface
- Failure plane is about 30 to 60 ft deep near the shoreline extending out into Lake Keowee
- Two of the sites experienced ruptured water lines. We are not sure if the ground movement caused the water lines to break or if broken water lines broke on their own and induced ground movement.

Where are these slides located


Lake Cherokee
Cherokee Foothills Scenic Hwy
Shady Grove Rd
Reece Mill Rd
Crow Creek Rd
Mile Creek County Park
2
1
Walhalla Hwy
Six-Mile Hwy
Mt Olivet Rd
State Rd S-37-24
Pickens Hwy
Lake Keowee
State Hwy 130
Six Mile
6 Mile Rd
Liberty Hwy
Norris Hwy
Six-Mile Norris Hwy
Jones Mill Rd
Old Seneca Rd
State Rd S-39-291
State Rd S-39-180
State Rd S-39-337
6 Mile Hwy
Brookbend Rd
State Rd S-39-52
Old Hwy 11
Ebenezer Rd
Keowee School Rd
State Rd S-37-46
Walhalla
West Union
Westminster Hwy
Blue Ridge Blvd
Rochester Hwy
Newry
Central

REPAIRED SITE

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- The site was repaired by WEC using battered micropiles with a concrete cap beam and tieback anchors.

REPAIRED SITE

- Site repaired by WEC using battered micropiles with a concrete cap beam and tieback anchors.
- Site is being monitored with slope inclinometers.

REPAIRED SITE

- Site 3 slide was repaired by WEC using battered micropiles with a concrete cap beam and tieback anchors.
- Site is being monitored with slope inclinometers.
- Staged approach was used.

REPAIRED SITE

- Site was repaired by WEC using battered micropiles with a concrete cap beam and tieback anchors.
- Site is being monitored with slope inclinometers.
- Phased approach was used.
- Slide was deep seated and extended into lake.

REPAIRED SITE

- Site was repaired by WEC using battered micropiles with a concrete cap beam and tieback anchors.
- Site is being monitored with slope inclinometers.
- If movement continues, patterned ground anchors will additionally be installed.
- Slide was deep seated and extended into lake.
- Ground movement showed up as separation cracks in house.

REPAIRED SITE

- Site was repaired by WEC using battered micropiles with a concrete cap beam and tieback anchors.
- Site is being monitored with slope inclinometers.
- Phased approach was used.
- Slide was deep seated and extended into lake.
- Ground movement showed up as separation cracks in house.
- Ground was gently sloping.


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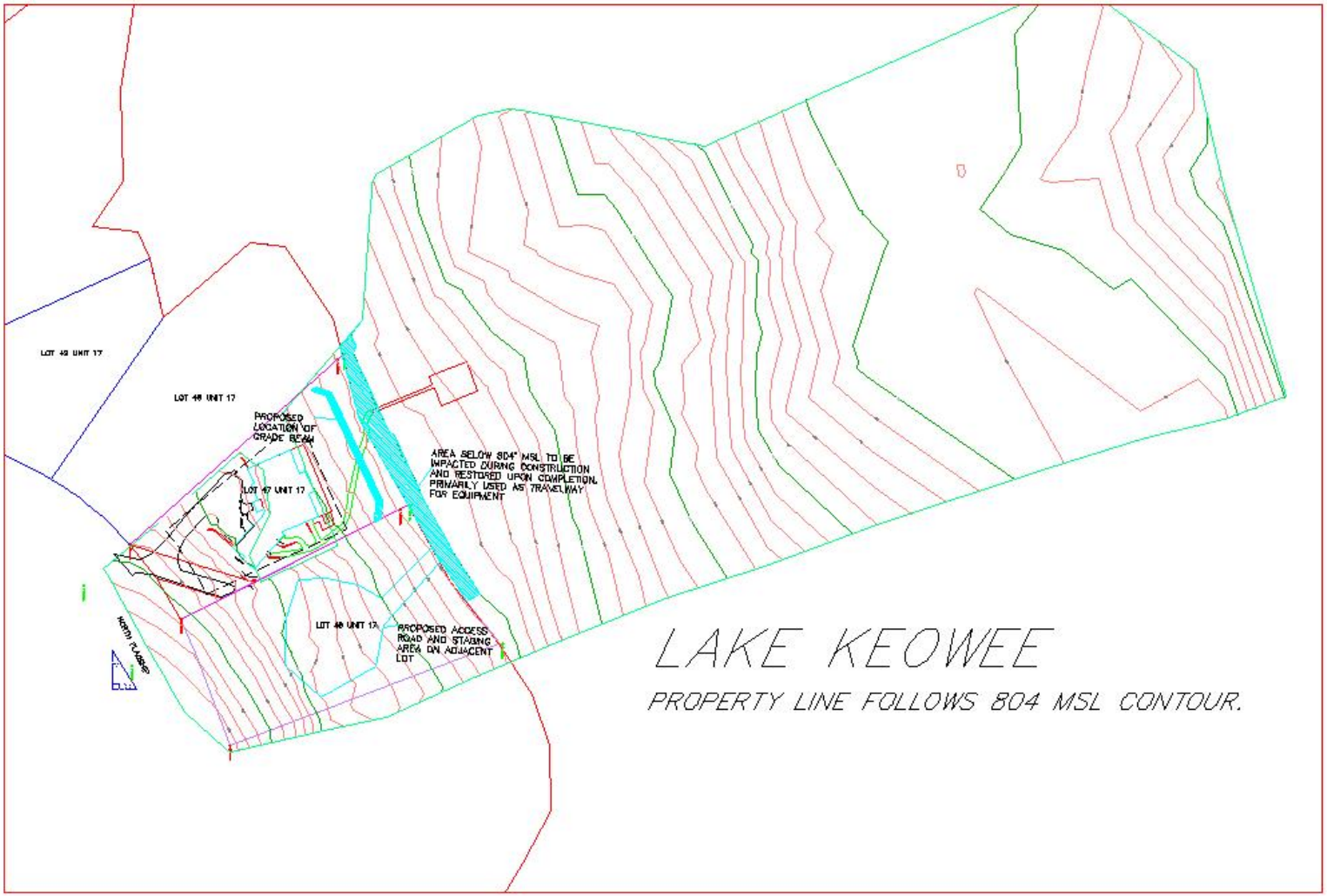


PLAT PREPARED FOR:

DOUG CHAPPEL

MICHAEL L. HENDERSON, PS 5845

Recorded this _____ day of _____, 20____

Vol _____ page _____ and Certified

Register of Deeds, Oconee County

FROEHLING & ROBERTSON, INC.

BORING LOG

Boring: B-4 (1 of 1)

Project No: 65M0144
Client: Roger Keranen
Project: Keranen Residence Distress Evaluation
City/State: Lake Keowee, SC

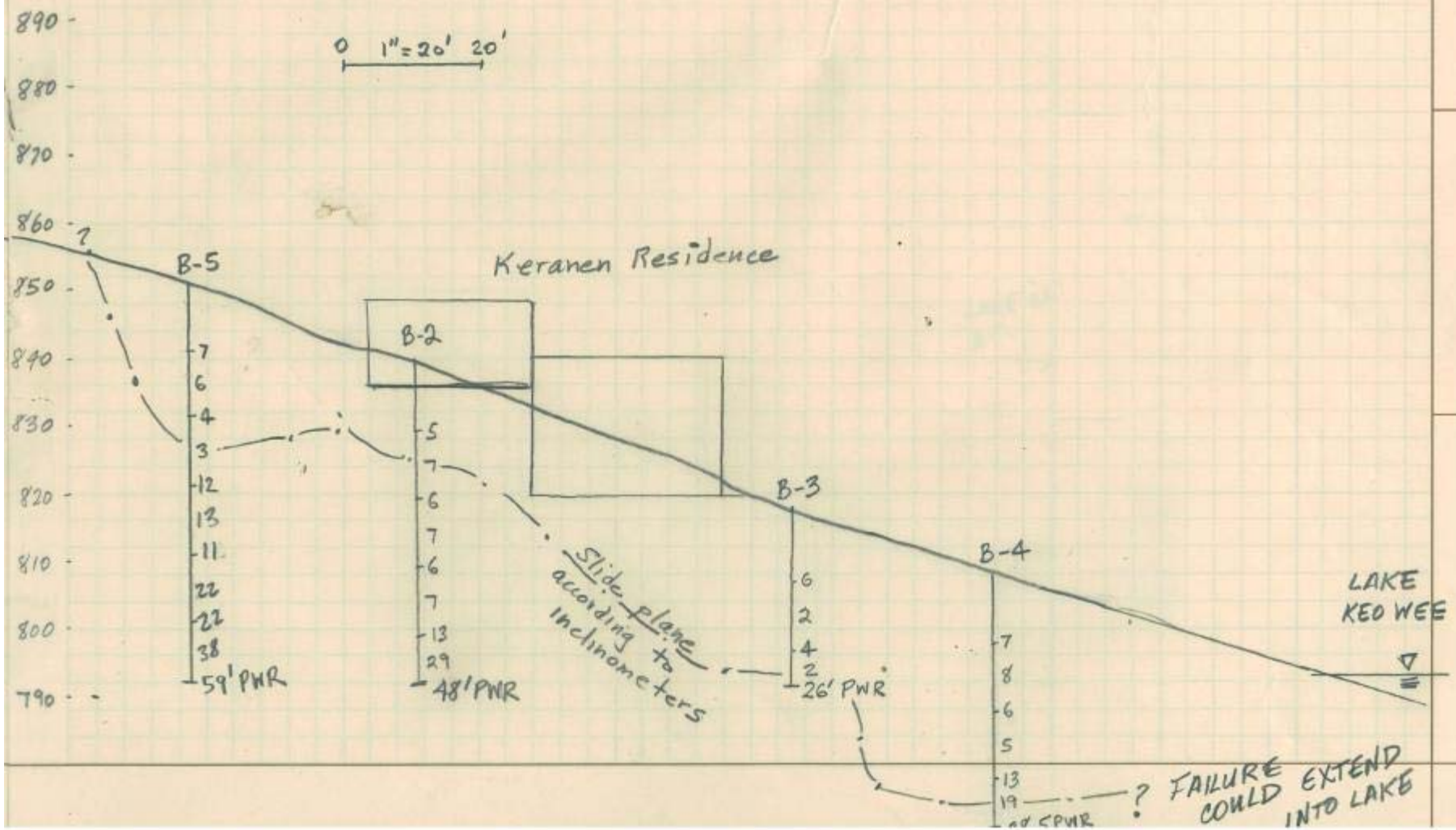
Elevation:
Total Depth: 41.0'
Boring Location: See Attached Figure 1

Drilling Method: HSA
Hammer Type:
Date Drilled:
Driller: Richmond, Va

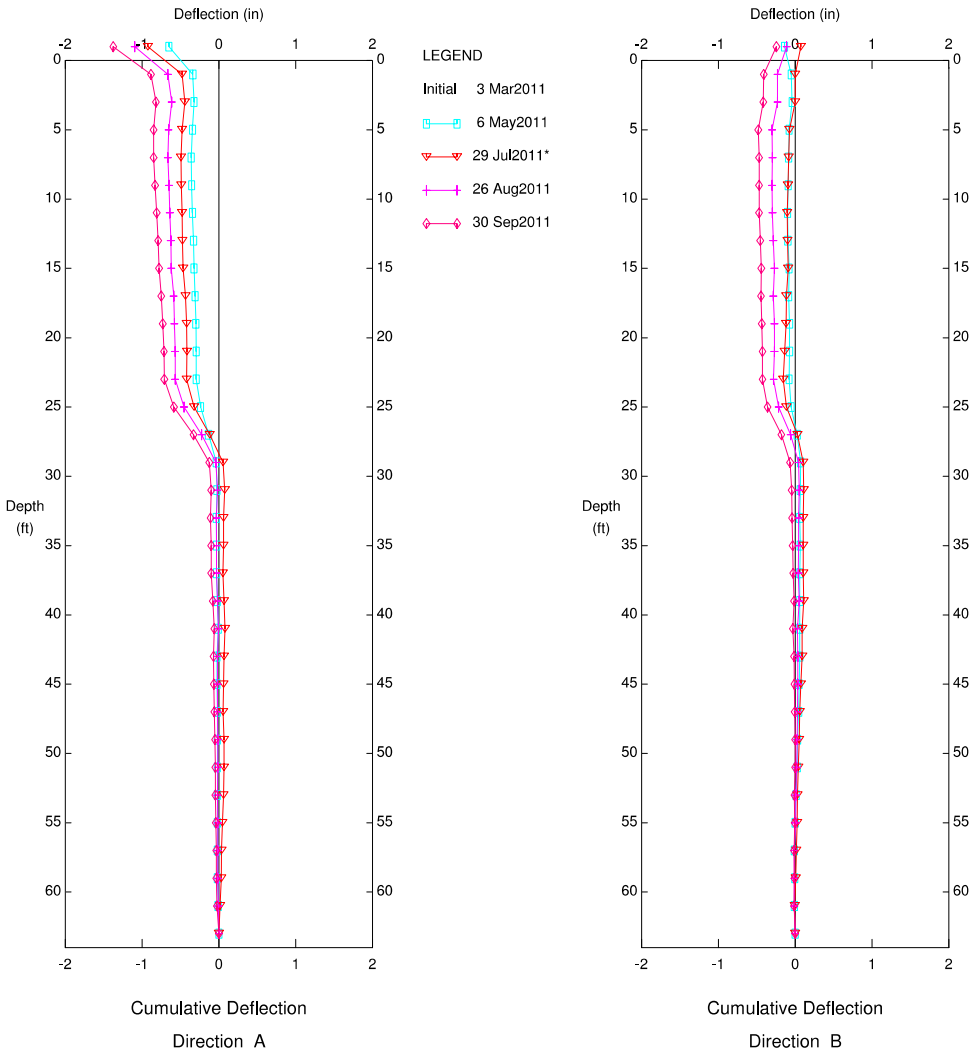
Elevation	Depth	Description of Materials (Classification)	* Sample Blows	Sample Depth (feet)	N-Value (blows/ft)	Remarks
		FILL - Soft to firm, moist, dark red clayey SILT (MH) with little sand	1-2-1	0.0		
			3-3-3	1.5	3	
			WOH-2-2	3.0	6	
	4.0	**APPARENT RESIDUAL** - Firm, moist, dark reddish brown clayey SILT (MH)	3-3-3	4.5	4	
				6.0	6	
	7.0	Firm, moist to wet, reddish brown to light tan sandy SILT (ML)	2-3-4	8.5		
				10.0	7	
			2-3-5	13.5		
				15.0	8	
	16.0	Loose to medium dense, moist, dark brown and red silty fine to medium SAND (SM) with trace mica flakes	2-3-3	18.5		
				20.0	6	
			2-2-3	23.5		
				25.0	5	
			6-6-7	28.5		
				30.0	13	
	32.0	Medium dense, moist white, tan, orange and gray silty fine to medium SAND (SM) with mica	8-9-10	33.5		
				35.0	19	
	38.5	**SOFT WEATHERED ROCK** - Sampled as white, tan, orange and gray silty fine to medium SAND (SM)	50/4"	38.5		
	40.5		50/2.5"	40.0	100+	
		Auger refusal encountered at approximately 41 feet below the existing site grades			100+	

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.

TCS


0 1"=20' 20'
890
880
870
860
850
840
830
820
810
800
790
Keranen Residence
B-5
B-2
B-3
B-4
7
6
4
3
12
13
11
22
22
38
59' PWR
5
7
6
7
6
7
13
29
48' PWR
6
2
4
2
26' PWR
7
8
6
5
13
19
Slide plane according to inclinometers
LAKE KEO WEE
? FAILURE COULD EXTEND INTO LAKE

Froehling & Robertson - Sterling, VA

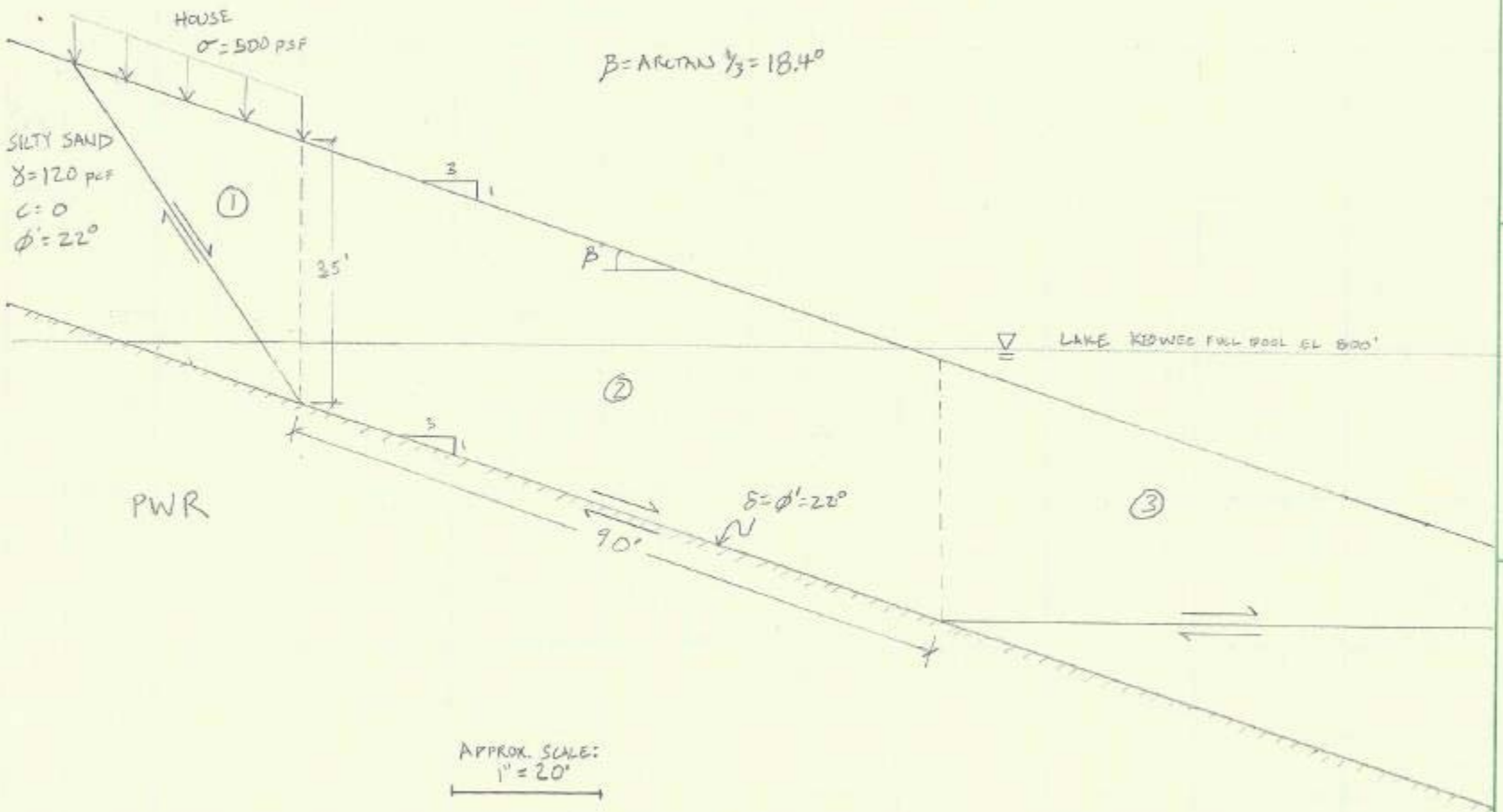


Keranen Residence, Inclinometer K-5

Roger Keranen

Sets marked * include zero shift and/or rotation corrections.

C:\TEMP\VIRTUA~1\PROGRA~1\GTILT\K5SEPT.GTL



11-010
KIRANEH RES.

SKETCH FOR HAND CALC.
BLOCK STABILITY ANALYSIS

BY: DSG
DATE: 1/3/2012

checked by: TCS

1/7

W_x

$W_x = W \sin\beta = 248.6 \sin 18.4°$

$W_x = 78.5$ k/FT

F

$F = N \tan\phi' = 235.9$ k/FT $\tan 22°$

$F = 95.3$ k/FT

FS WITH HOUSE LOAD

$$FS = \frac{\Sigma F_x \text{ RESISTING}}{\Sigma F_x \text{ DRIVING}} = \frac{P_{px} + F}{W_x + P_{AH}} = \frac{40.9 \text{ k/FT} + 95.3 \text{ k/FT}}{78.5 \text{ k/FT} + 56.4 \text{ k/FT}} = \frac{136.2}{134.9}$$

$\boxed{FS = 1.00}$

FS WITHOUT HOUSE LOAD

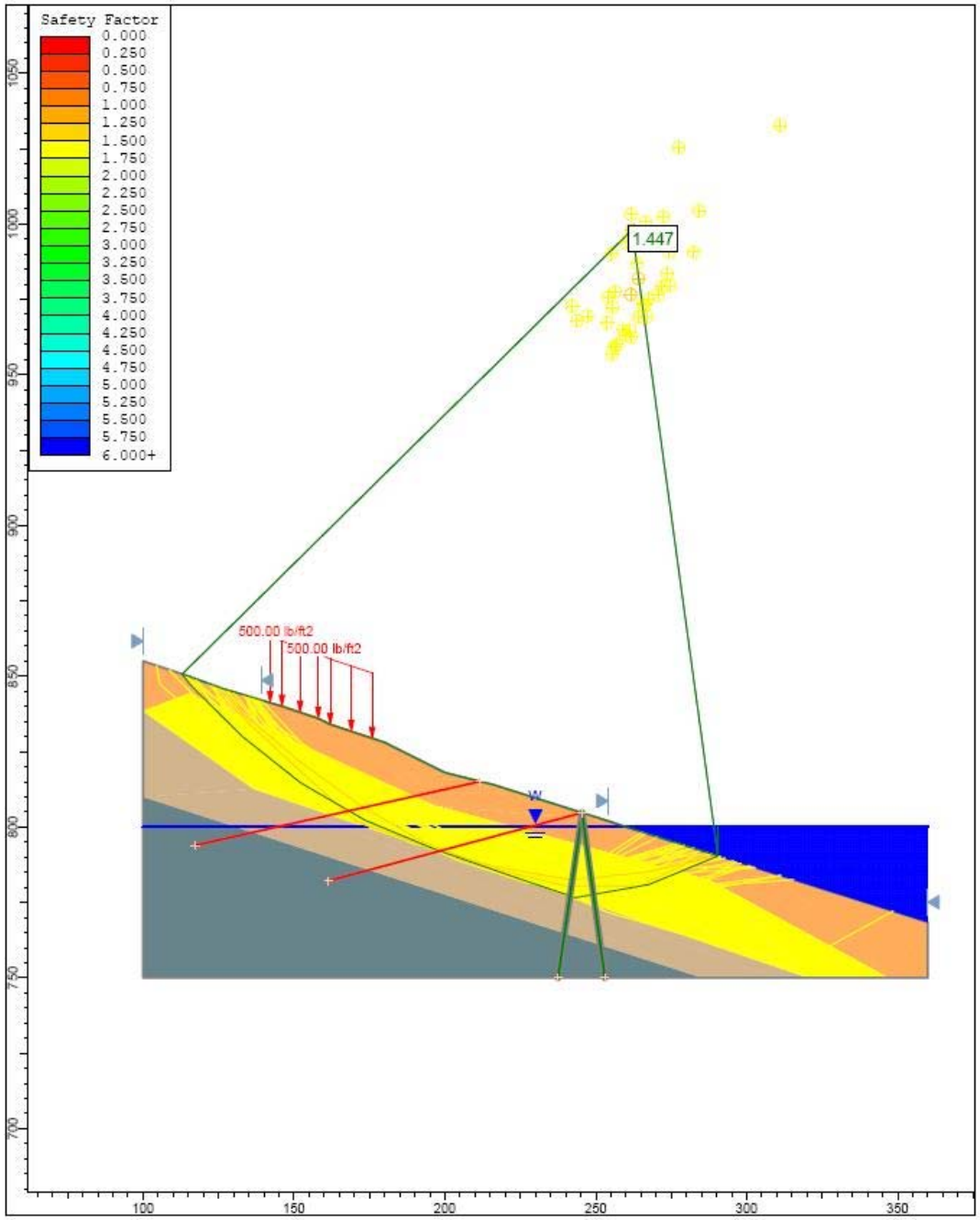
$$FS = \frac{P_{px} + F}{W_x + P_A} = \frac{136.2}{78.5 + 45.6} = \frac{136.2}{124.1}$$

$\boxed{FS = 1.09}$

The results of the block analyses support that the existing factor-of-safety is near 1 assuming that the friction angle along the slide interface is 22 degrees.

Analytical considerations:

- WEC retained Dan Brown Associates to assist with design on the project.
- Repair consisted of
  - 10-inch micropiles socketed into rock on 5’ centers
  - Alternating batter on the micropiles.
  - Micropile casing joints reinforced with outer sleeves for additional moment resistance/section modulus.
  - 80-foot, 160 kip tiebacks on 10’ centers.
  - Piles and tiebacks connected by a reinforced concrete grade beam.
  - An option to install a second row of anchors if movement is not arrested


Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.447
500.00 lb/ft2
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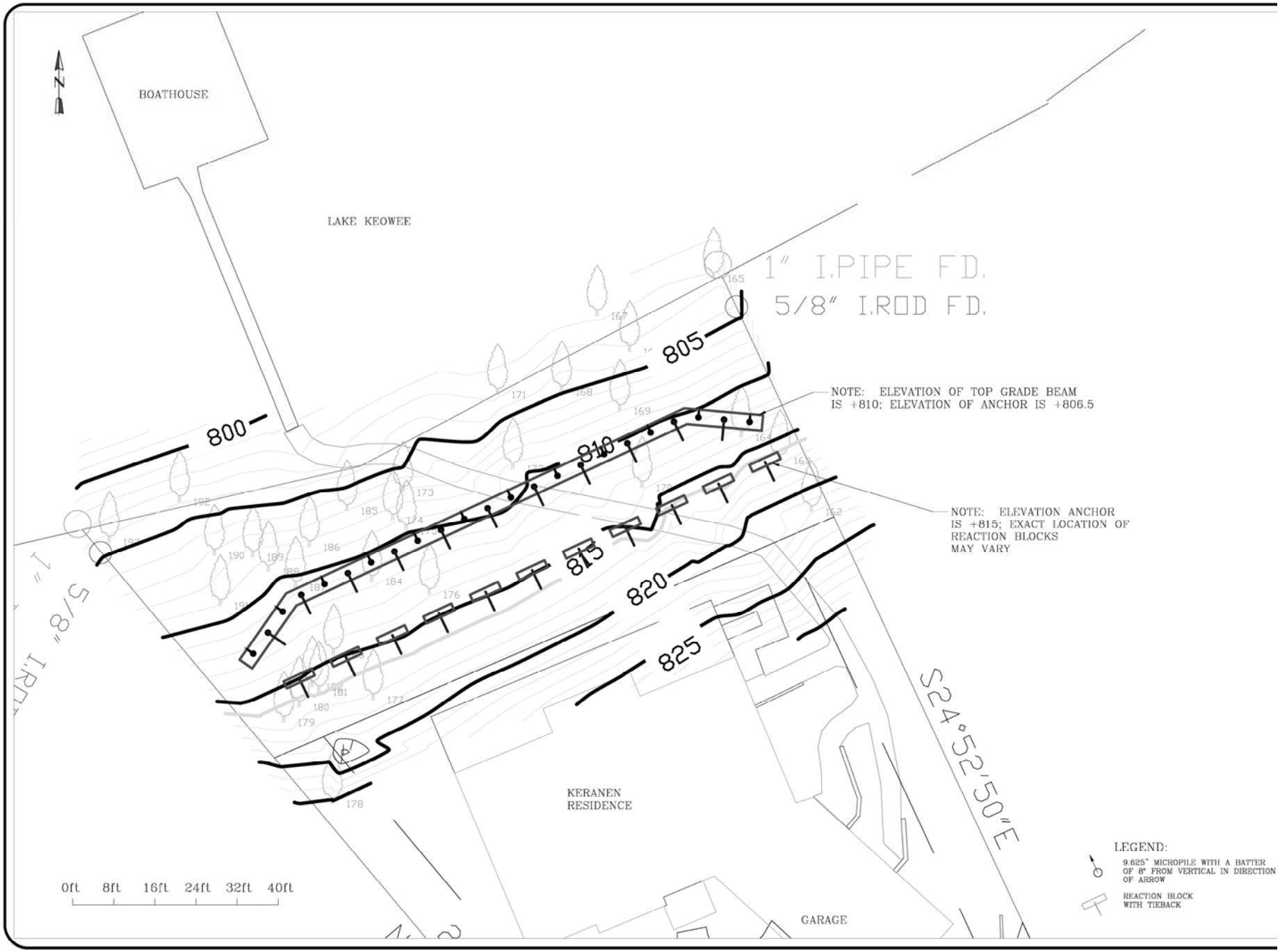
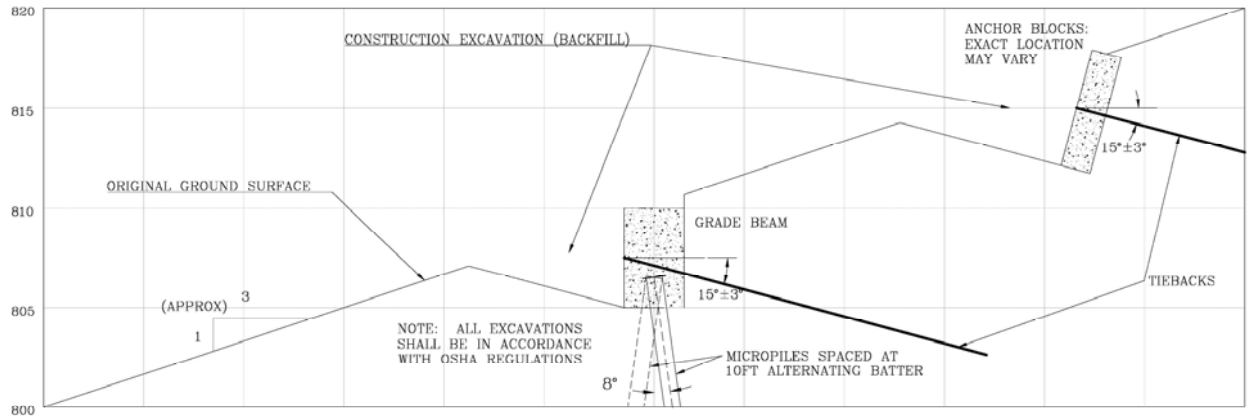
850
800
750
700
100
150
200
250
300
350


N
BOATHOUSE
LAKE KEOWEE
1" I.PIPE F.D.
5/8" I.ROD F.D.
800
805
810
815
820
825
NOTE: ELEVATION OF TOP GRADE BEAM IS +810; ELEVATION OF ANCHOR IS +806.5
NOTE: ELEVATION ANCHOR IS +815; EXACT LOCATION OF REACTION BLOCKS MAY VARY
KERANEN RESIDENCE
GARAGE
S24°52'50"E
0ft 8ft 16ft 24ft 32ft 40ft
LEGEND:
9.625" MICROPILE WITH A BATTER OF 8° FROM VERTICAL IN DIRECTION OF ARROW
REACTION BLOCK WITH TIEBACK



TYPICAL SECTION

SCALE 1"=3'

1. General

1. General Notes:

1.1 The Contractor shall be responsible for observing all applicable safety laws and regulations.

1.2 The Contractor shall be solely responsible for site safety and under no circumstances shall the Engineer (Dan Brown and Associates, PC) be responsible for construction safety.

1.3 The Contractor shall field verify all conditions, grades and dimensions at the site prior to construction. If the contractor discovers any errors, omissions or discrepancies, the contractor shall contact the Engineer prior to continuing construction.

1.4 Topographical information was provided by Wurster Engineering & Construction, Inc. All grades information shown is interpolated or interpreted from this information. The Contractor shall field verify this information.

1.5 The Contractor shall be responsible for ensuring that all property boundaries, easements, and restrictions are respected.

1.6 The Contractor shall be responsible for acquiring permission and all permits for construction.

1.7 The Contractor shall be responsible for identifying and protecting all underground utilities and other structures in the area of construction.

1.8 The Contractor shall be responsible for installing all drainage features necessary to minimize excessive runoff and erosion during and after construction.

1.9 All construction activities shall be observed and documented by experienced personnel to confirm that construction is in accordance with the design plans.

2. Design Criteria:

2.1 The design reflected on the Plans is intended for construction of a permanent slope stabilization system. As with any earth retaining or stabilization system, some limited lateral and/or vertical movement may be expected to occur.

2.2 Subsurface conditions on site were interpreted based on boring data and slope inclinometer data from Froehling and Robertson, Inc.

2.3 The design factor-of-safety against global instability is 1.3.

2.4 The soil friction angle along the failure surface is estimated to be 22 degrees by back-calculation.

2.5 The design factor-of-safety against tieback pullout is 2.0 or greater.

2.6 Ultimate bond strength for grout-to-partially weathered rock interface is 50 psi and 150psi for grout-to-rock interface.

2.7 The anchor design load is 160 kips.

2.8 Cap beam and reaction blocks are designed for an average maximum contact pressure of 4.5 ksf with the adjacent soil.

3. Materials:

3.1 Admixtures shall conform to the requirements of ASTM C494 Standard Specification for Chemical Admixtures for Concrete. Admixtures that control bleed, improve flowability, reduce water content, and/or retard set of the concrete shall be subject to review by the Engineer. Admixtures shall be compatible with the concrete and mixed in accordance with the manufacturer's recommendations.

3.2 All cement shall be Type I, II, III, or V Portland cement conforming to ASTM C150 Standard Specification for Portland cement.

3.3 Water shall be potable and free of sewage, oils, acid, alkali, salts and organics.

3.4 Micropile grout shall consist of Portland cement and water and may contain approved admixtures. The components shall be proportioned and combined to produce a mix which may be pumped without difficulty. The materials shall be proportioned to produce a hardened grout that will achieve a minimum compression strength of 4000 psi in 28 days.

4. Cap Beam and Reaction Blocks:

4.1 Concrete compressive strength shall be at least 4000 psi after 28 days.

4.2 All reinforcing steel shall be Grade 60.

4.3 Rebar lap splice shall be 62 inches or greater at all construction joints.

4.4 Rebar clear cover shall be 3 inches or greater from all exterior faces.

4.5 Rebar clear cover shall be 2 inches or greater from anchor hole walls.

4.6 A clear spacing of 1.5 inches or greater shall be maintained between bars.

4.7 A clear spacing of 1.5 inches or greater shall be maintained between bars and embedded micropiles.

4.8 The cap beam shall be formed and cast-in-place.

4.9 Reaction blocks may be cast-in-place or pre-cast.

4.10 Lap splices will be offset at least 24 inches from adjacent bars

4.11 Longitudinal reinforcing bars shall be supplied with standard 90 degree hooks of at least 12 inches at each termination of the cap beam

5. Tieback Anchors:

5.1 Grout strength shall be at least 4000 psi after 28 days.

5.2 Tieback inclination (from horizontal) shall be 15±3 degrees.

5.3 Tieback spacing along slope face shall be 10 feet

5.4 Minimum drill hole diameter shall be 6 inches

5.5 Unbonded length shall be based on the length required to reach PWR as determined during drilling.

5.6 Minimum bond length in partially weathered rock (PWR) shall be 35 feet or 20 feet in hard rock. Bond length may be adjusted based on proof testing as approved by the Engineer.

5.7 The anchor lock-off load shall be 70% of the design load or 112 kips.

5.8 The maximum anchor test load shall be 1.33 x design load of 160 kips or 213 kips

5.9 All tieback anchors shall be proof tested in accordance with the FHWA Manual for Ground Anchors and Anchored Systems (FHWA-IF-99-015).

5.10 All tieback drilling, installation and testing shall be observed and documented by experienced personnel to confirm that construction is in accordance with the design plans.

5.11 Anchor corrosion protection shall be PTI Class-I double corrosion protection.

5.12 Anchors shall include a minimum of five (5) 0.6 inch diameter 270 ksi strands.

5.13 Each anchor strand shall be encapsulated in continuous HDPE tube filled with grease in unbounded zone in accordance with ASTM D 1248.

5.14 The anchor shall include a full-length grout filled corrugated PVC or PE (1/16 inch min. thickness) sheath along the entire length, with end cap.

5.15 The bearing plate shall consist of a Grade 36 ksi 10 inch x 10 inch x 1 inch steel plate with a standard 12 inch trumpet

5.16 Cover head plate and strand shall be protected with grease filled cover cap.

5.17 Centralizers and spacers shall be provided every 5 feet in bond zone.

6. Micropiles:

6.1 The micropiles shall be installed at the locations shown on the Plans. Adjustments shall be subject to approval by the Engineer.

6.2 Grout compressive strength shall be at least 4000 psi after 28 days.

6.3 Casing shall be Grade 80 steel with 9 5/8 inch OD with a minimum 0.472 inch wall thickness.

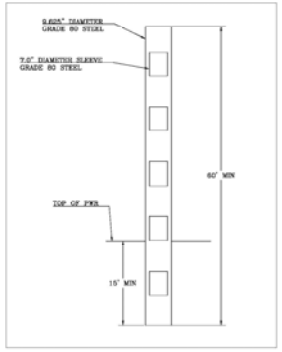
6.4 All threaded joints shall be reinforced with a sleeve consisting of Grade 80 steel with 7.0 inch OD and 0.498 inch wall thickness as shown on the Plans.

6.5 All micropiles shall be embedded a minimum of 15 feet into PWR as determined during drilling. The minimum micropile length shall be 60 feet.

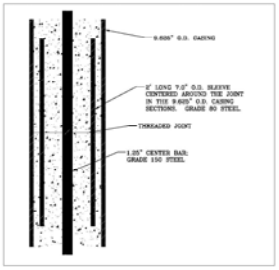
6.6 Micropiles shall have a 14 inch x 14 inch x 1.0 inch thick A36 steel plate at the top of each.

6.7 Micropiles shall have a 1.25 inch grade 150 centerbar, with a 9 foot development length. Below 9 feet, the centerbar can be reduced as determined by the Contractor.

6.8 Optional: The 1.25 inch grade 150 centerbar can be replaced by welding a grade 80, 10.75 inch O.D. outer casing having a wall thickness of 0.5 inch (or equivalent) to the top plate and micropile casing as shown on the Plans. A centerbar will still be needed to install the 7.0 inch O.D. casing. The size of this centerbar will be determined by the Contractor.



MICROPILE DETAIL
NOT TO SCALE



JOINT DETAIL
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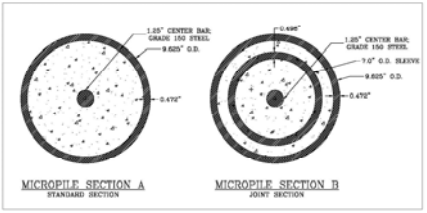
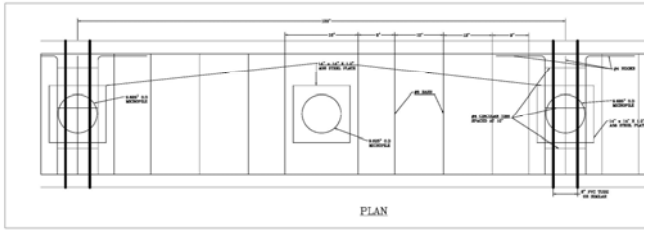
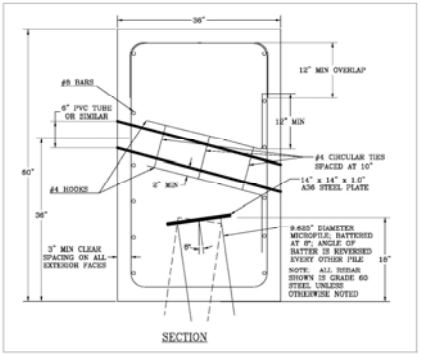
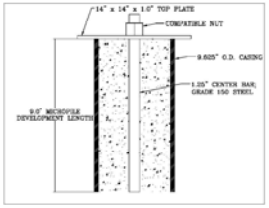


MICROPILE SECTIONS
NOT TO SCALE

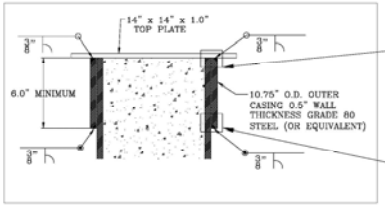


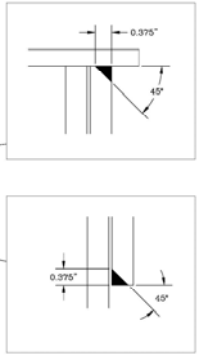
REACTION BEAM DETAILS
NOT TO SCALE



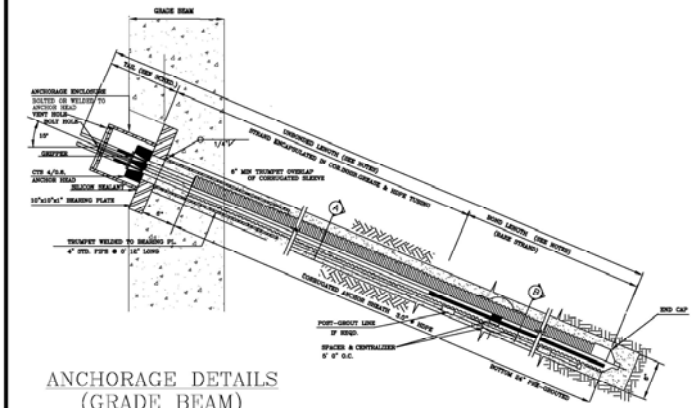


MICROPILE/TOP PLATE CONNECTION DETAIL
NOT TO SCALE





ALTERNATE MICROPILE/TOP PLATE CONNECTION DETAIL (WELD OPTION)
NOT TO SCALE



ANCHORAGE DETAILS (GRADE BEAM)
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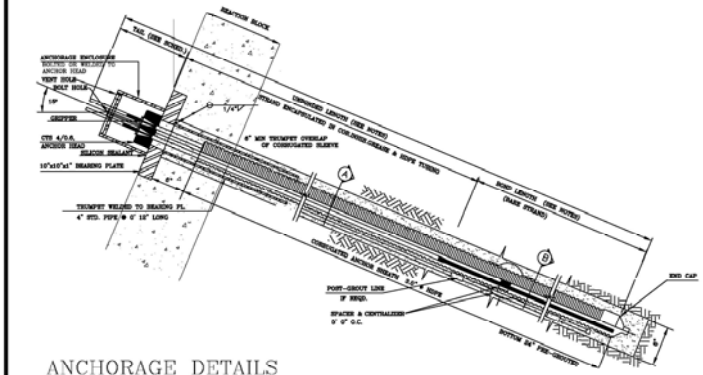

ANCHORAGE DETAILS (REACTION BLOCK)
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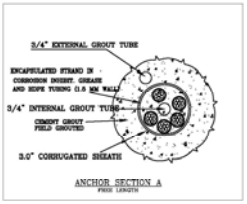
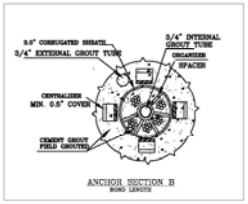
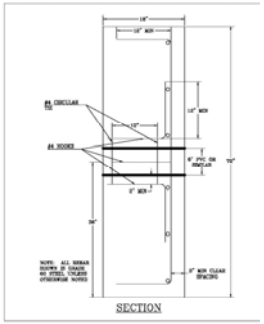
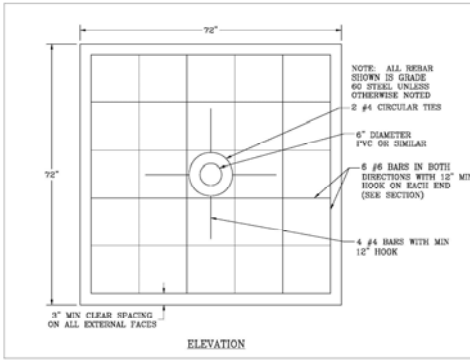






REACTION BLOCK DETAILS
NOT TO SCALE




KLEMM
03/19/2012 15:23

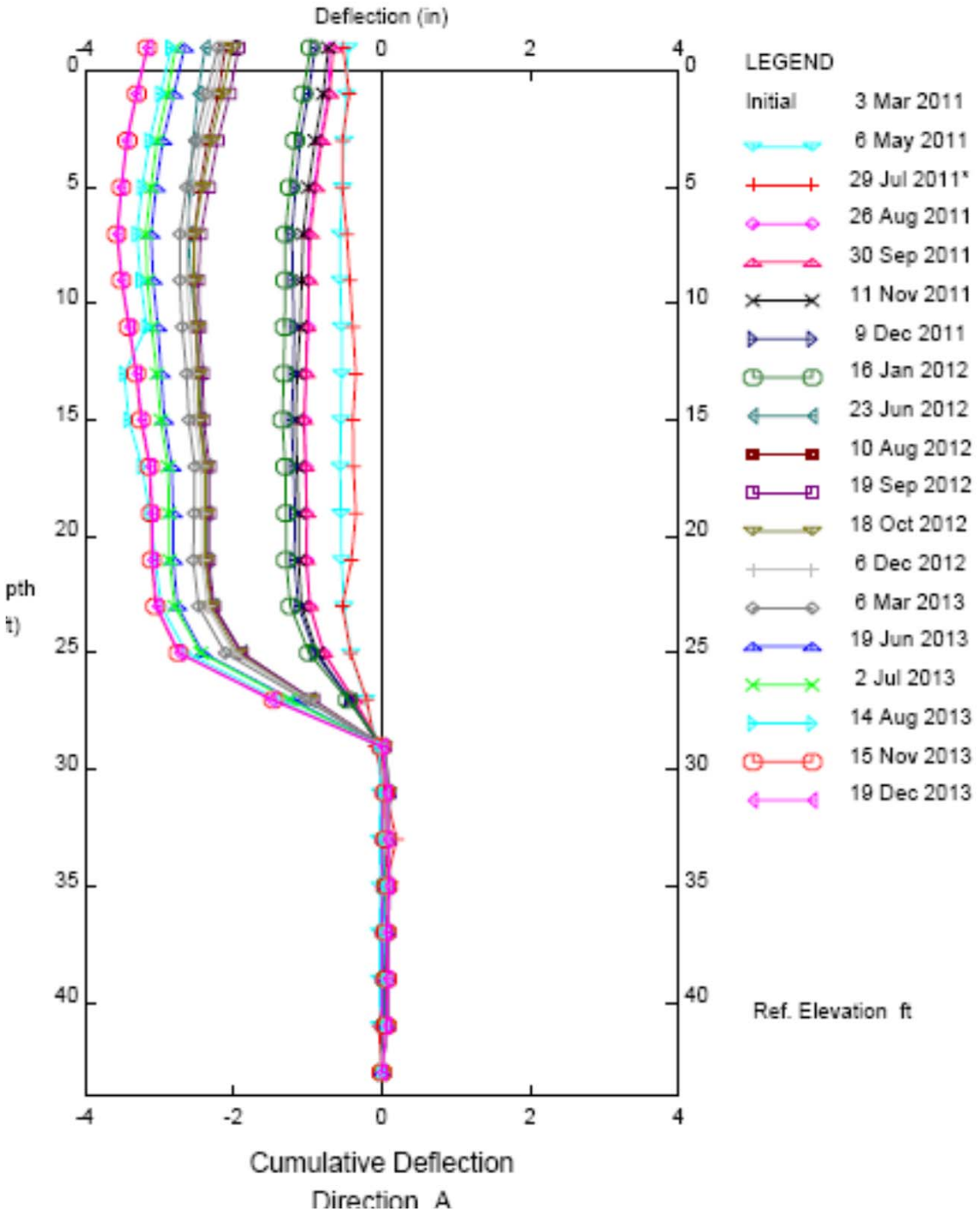

BRADCO

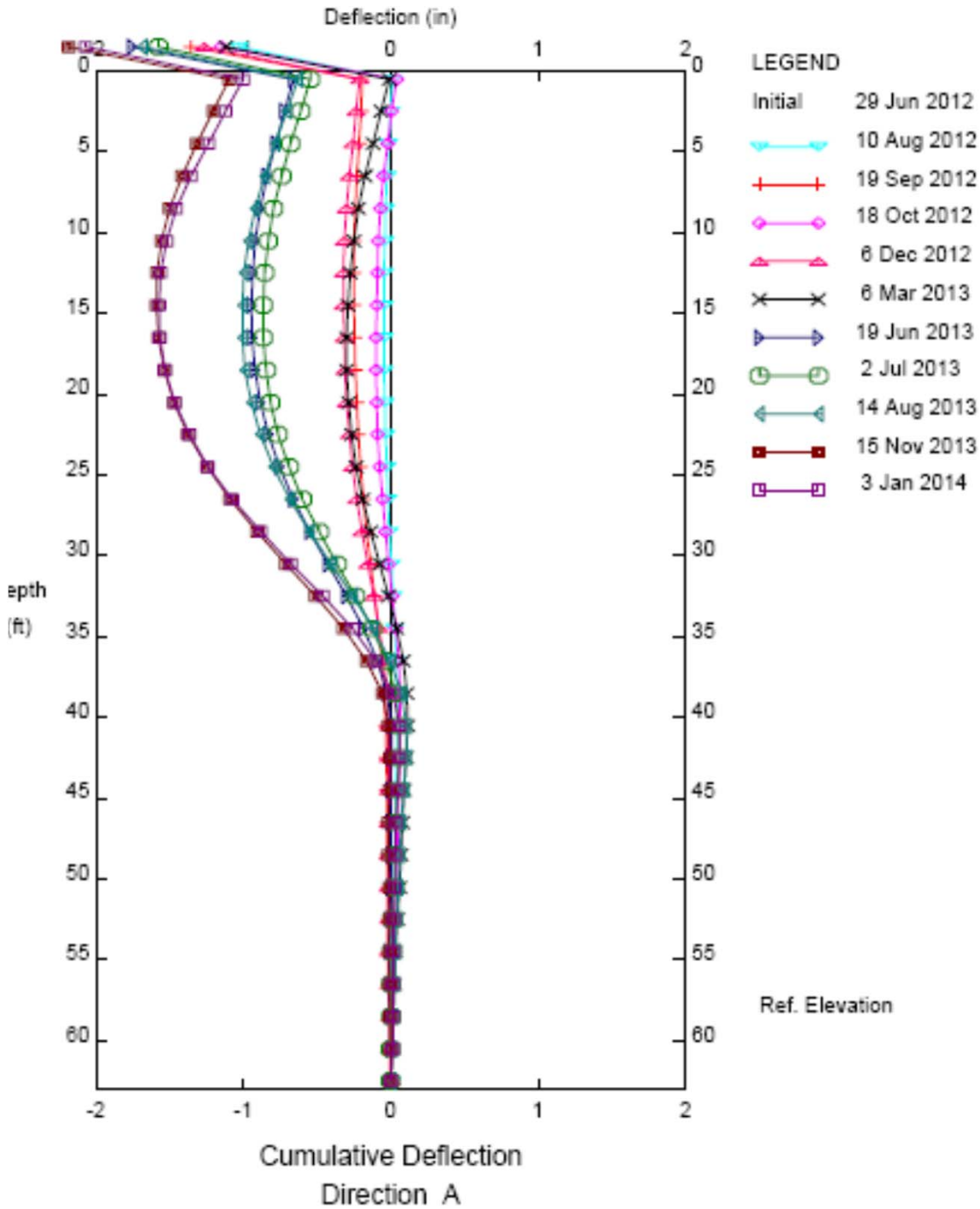

05/10/2012 12:18

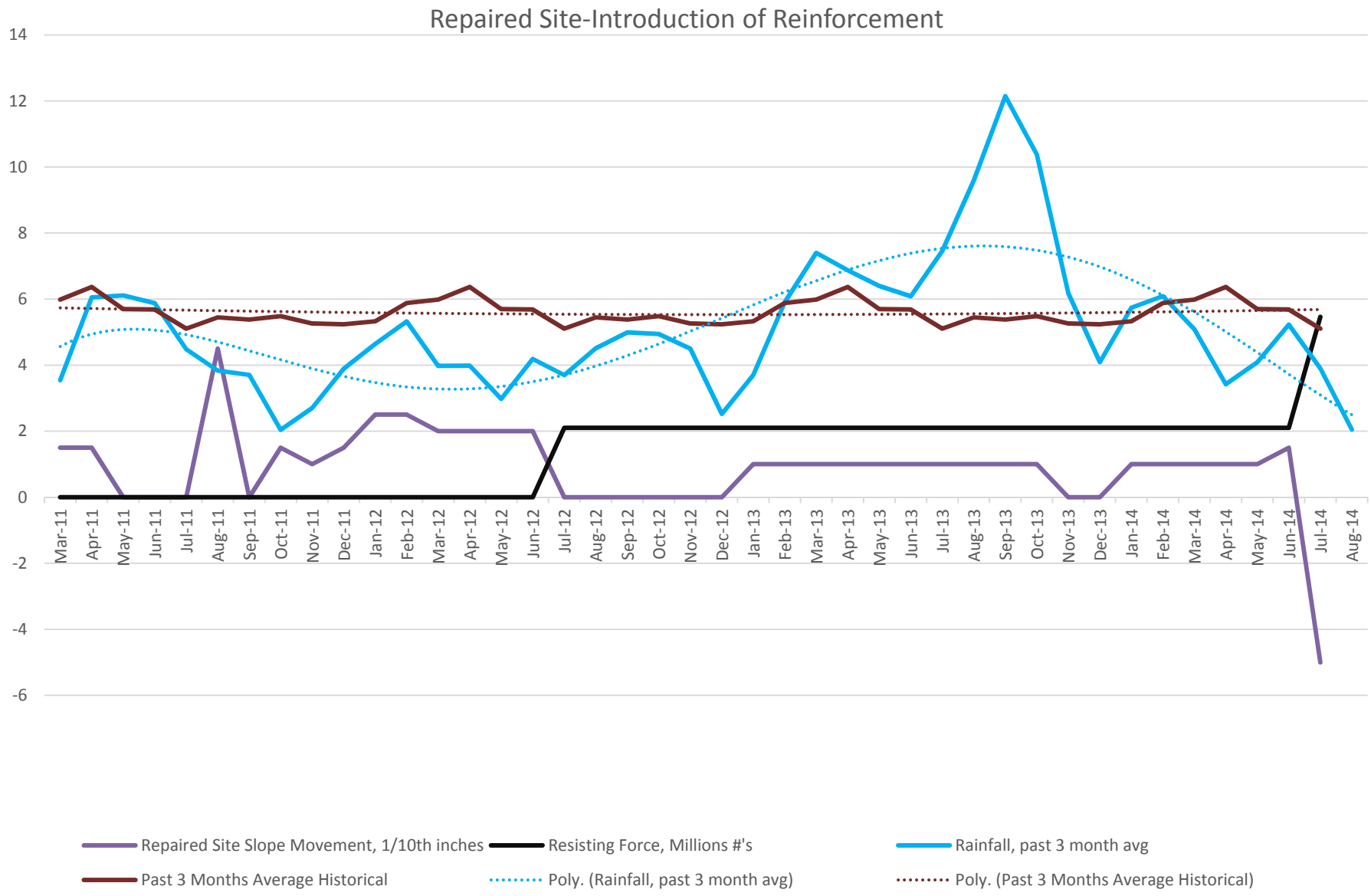

05/10/2012 12:24

PHASE II

- The site initially stabilized following the installation of the micropiles and tiebacks for a period of 6 months.
- Gradual movement commenced again in early 2013, coinciding with a period of record rainfall.
- WEC installed the remaining tiebacks and added horizontal drains, as the interim inclinometer data indicated that precipitation was the driving factor in re-starting the downslope movement

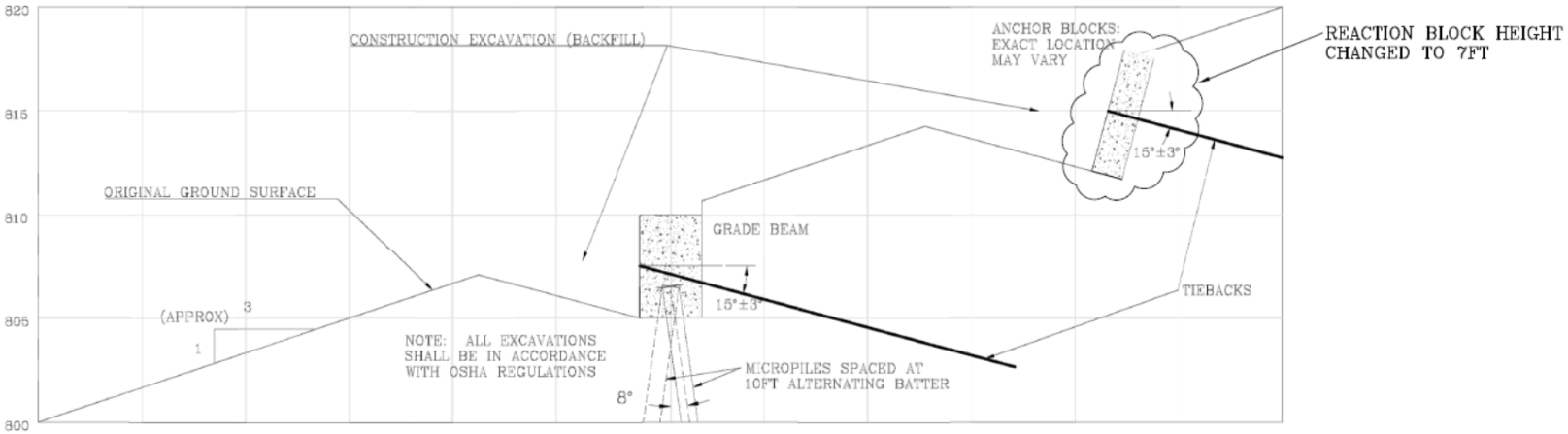

Deflection (in)
-4
0
2
4
0
5
10
15
20
25
30
35
40
pth
t)
LEGEND
Initial 3 Mar 2011
6 May 2011
29 Jul 2011*
26 Aug 2011
30 Sep 2011
11 Nov 2011
9 Dec 2011
16 Jan 2012
23 Jun 2012
10 Aug 2012
19 Sep 2012
18 Oct 2012
6 Dec 2012
6 Mar 2013
19 Jun 2013
2 Jul 2013
14 Aug 2013
15 Nov 2013
19 Dec 2013
Ref. Elevation ft
-4
-2
0
2
4
Cumulative Deflection
Direction A


Deflection (in)
LEGEND
Initial 29 Jun 2012
10 Aug 2012
19 Sep 2012
18 Oct 2012
6 Dec 2012
6 Mar 2013
19 Jun 2013
2 Jul 2013
14 Aug 2013
15 Nov 2013
3 Jan 2014
Ref. Elevation
epth
(ft)
Cumulative Deflection
Direction A


Repaired Site-Introduction of Reinforcement
14
12
10
8
6
4
2
0
-2
-4
-6
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Repaired Site Slope Movement, 1/10th inches
Resisting Force, Millions #'s
Rainfall, past 3 month avg
Past 3 Months Average Historical
Poly. (Rainfall, past 3 month avg)
Poly. (Past 3 Months Average Historical)

Analytical considerations-DESIGN MODIFICATIONS:

- WEC made relatively low-cost modifications to the design of the additional anchors
  - Enlarged anchor pads to 7’ by 7’, adding 36% more bearing area
  - Added 2 additional strands to each anchor, allowing for 40% more tensile force to be applied.
  - Added horizontal drains to reduce pore pressures indicated to be driving slope movement.
  - Shotcreted anchor pads in place to reduce potential for disturbance.
  - Grouted existing tension cracks to reduce water infiltration.



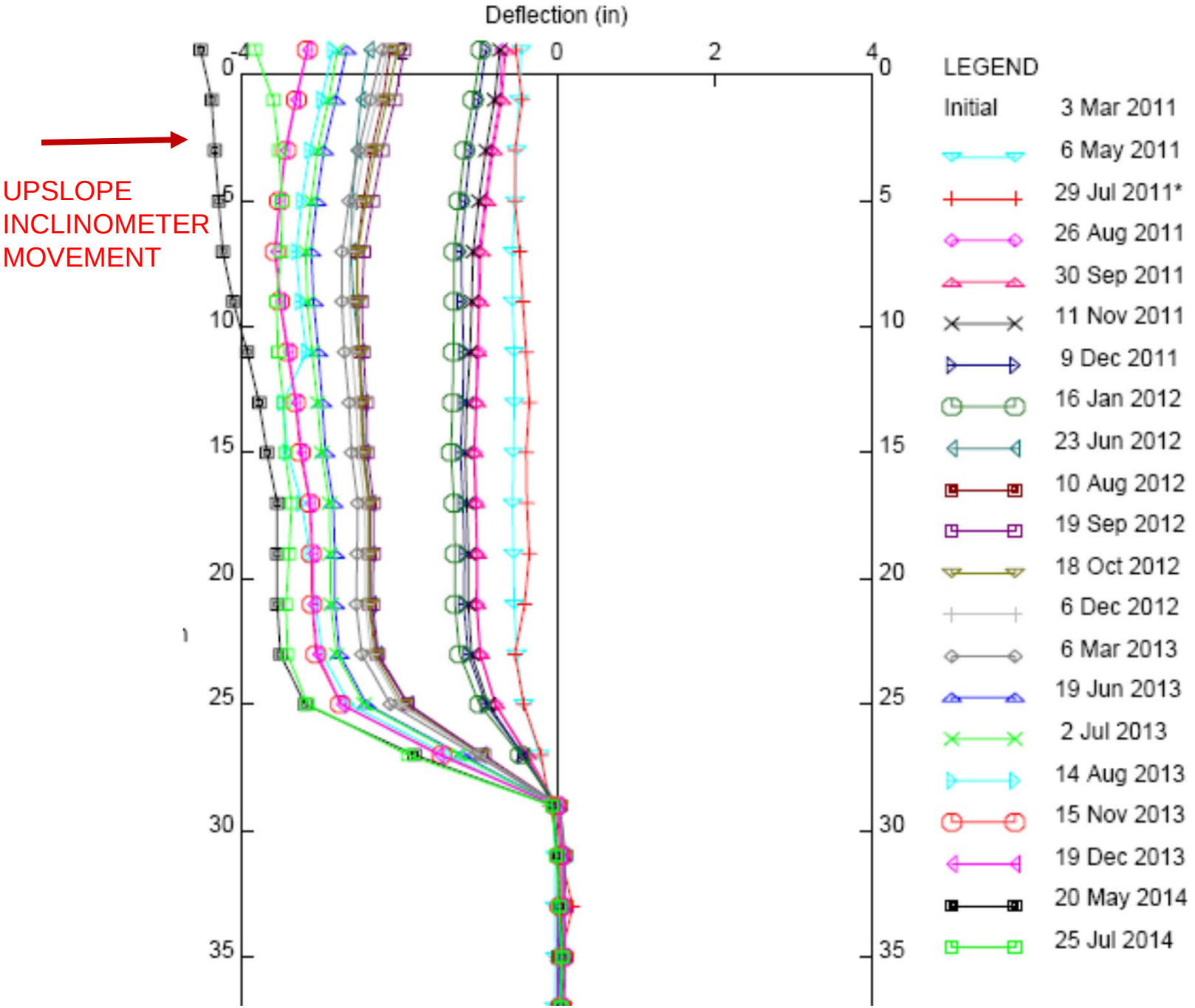
TYPICAL SECTION

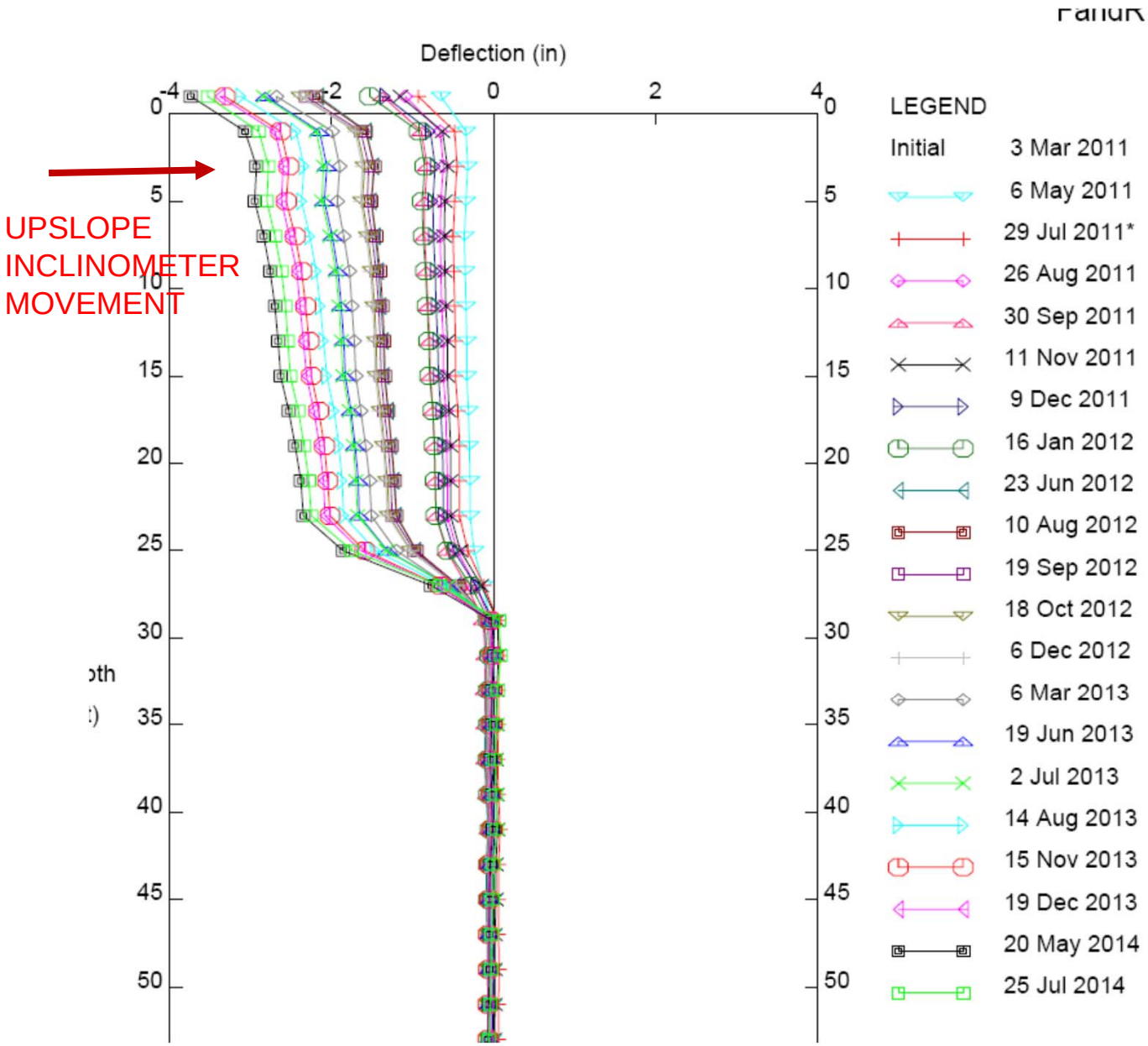
SCALE 1"=3'

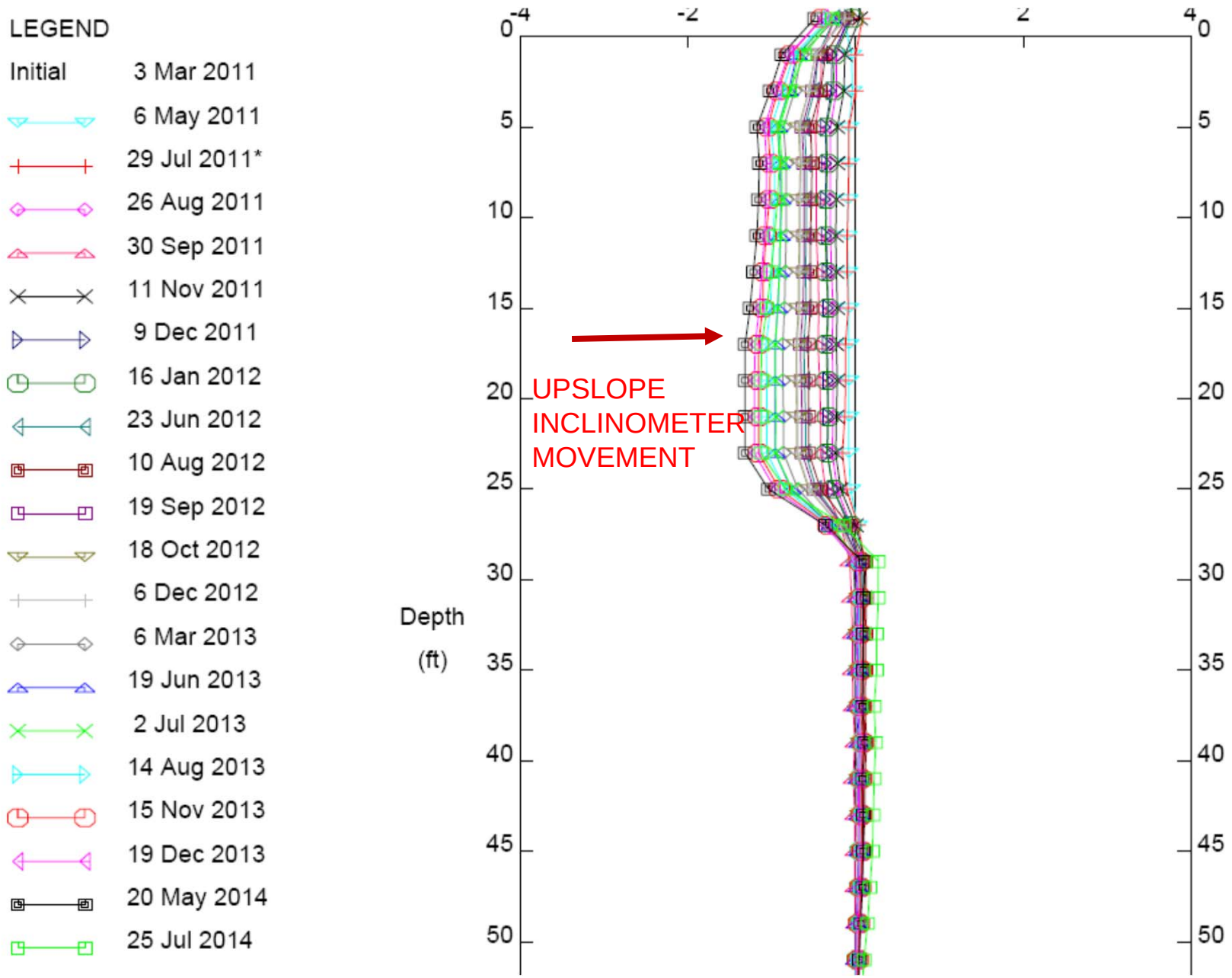

CAUTION / CUIDADO

The results……

- Subequent inclinometer readings indicated measurable upslope movement, indicating the repair had overcome the driving force of the moving mass….

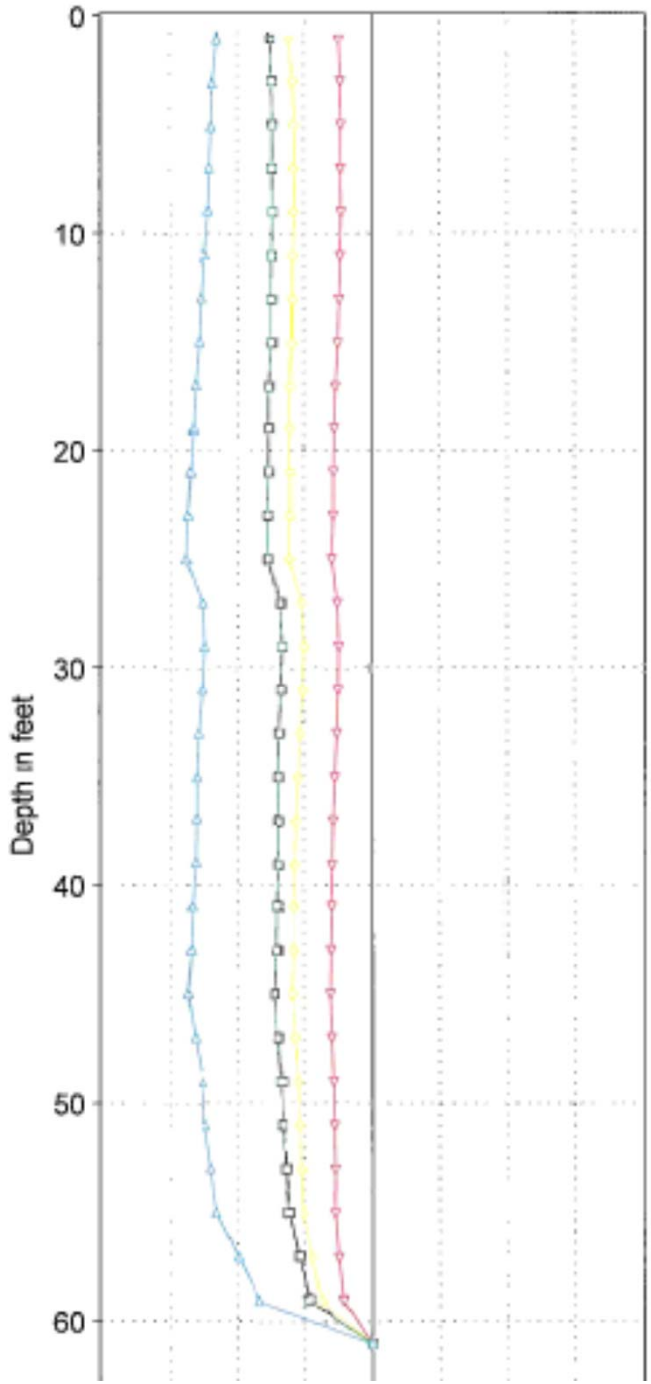

UPSLOPE
INCLINOMETER
MOVEMENT
Deflection (in)
-4
0
2
4
0
5
10
15
20
25
30
35
LEGEND
Initial 3 Mar 2011
6 May 2011
29 Jul 2011*
26 Aug 2011
30 Sep 2011
11 Nov 2011
9 Dec 2011
16 Jan 2012
23 Jun 2012
10 Aug 2012
19 Sep 2012
18 Oct 2012
6 Dec 2012
6 Mar 2013
19 Jun 2013
2 Jul 2013
14 Aug 2013
15 Nov 2013
19 Dec 2013
20 May 2014
25 Jul 2014

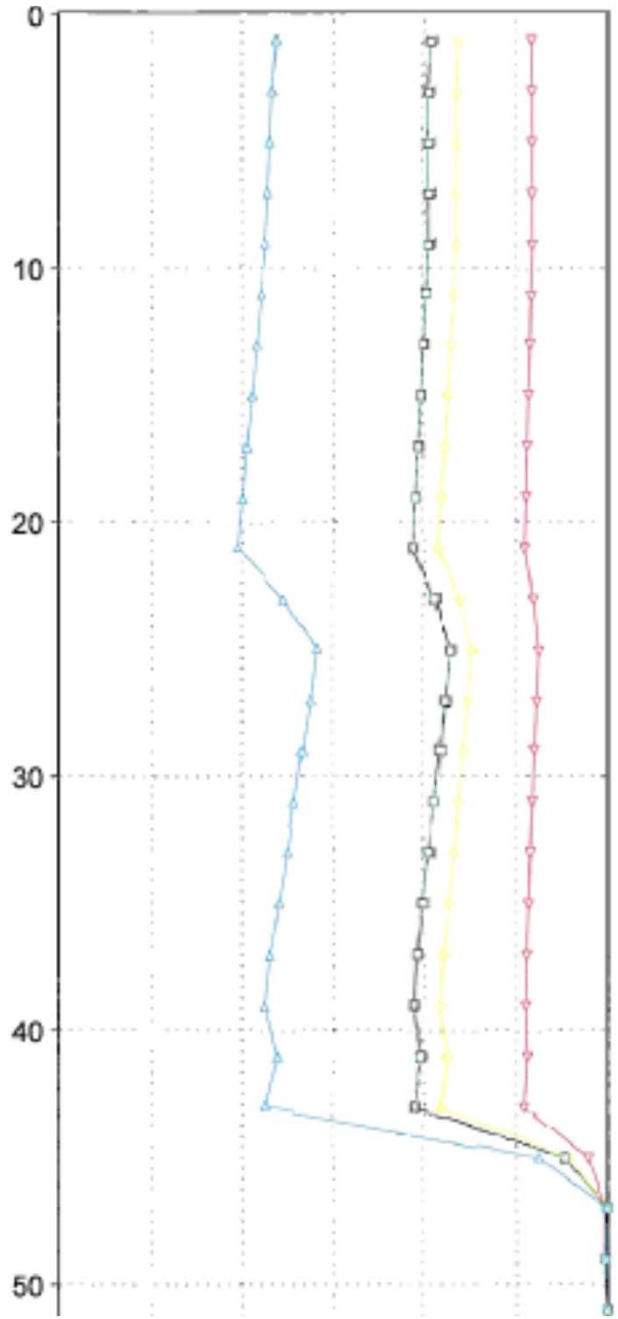

Deflection (in)
-4
-2
0
2
4
0
5
10
15
20
25
30
35
40
45
50
UPSLOPE
INCLINOMETER
MOVEMENT
LEGEND
Initial 3 Mar 2011
6 May 2011
29 Jul 2011*
26 Aug 2011
30 Sep 2011
11 Nov 2011
9 Dec 2011
16 Jan 2012
23 Jun 2012
10 Aug 2012
19 Sep 2012
18 Oct 2012
6 Dec 2012
6 Mar 2013
19 Jun 2013
2 Jul 2013
14 Aug 2013
15 Nov 2013
19 Dec 2013
20 May 2014
25 Jul 2014

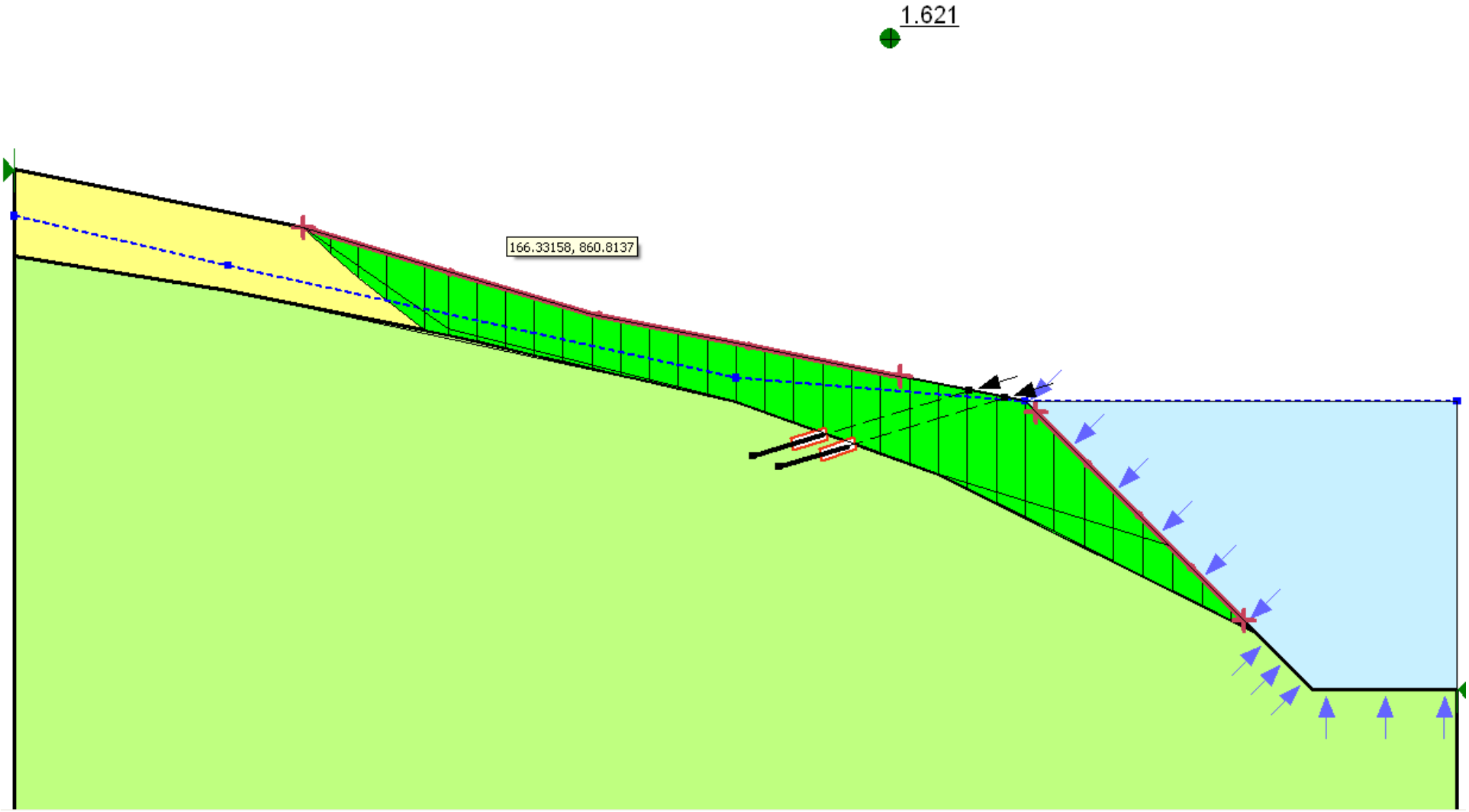

LEGEND
Initial 3 Mar 2011
6 May 2011
29 Jul 2011*
26 Aug 2011
30 Sep 2011
11 Nov 2011
9 Dec 2011
16 Jan 2012
23 Jun 2012
10 Aug 2012
19 Sep 2012
18 Oct 2012
6 Dec 2012
6 Mar 2013
19 Jun 2013
2 Jul 2013
14 Aug 2013
15 Nov 2013
19 Dec 2013
20 May 2014
25 Jul 2014
Depth
(ft)
-4
-2
2
4
0
5
10
15
20
25
30
35
40
45
50
UPSLOPE
INCLINOMETER
MOVEMENT

UN-REPAIRED SITE-SIMILARITIES

- The second site is also located on the lakeshore, approximately 1 mile from the repaired site.
- Weather patterns are similar at both sites
- Both sites are relatively gently sloping
- Inclinometer data suggests that both sites are highly sensitive to precipation/pore water pressure
- Both sites exhibit silty sands with unusually low fines contents at depth (10% passing)
- Both sites exhibited similar rates of movement pre-repair

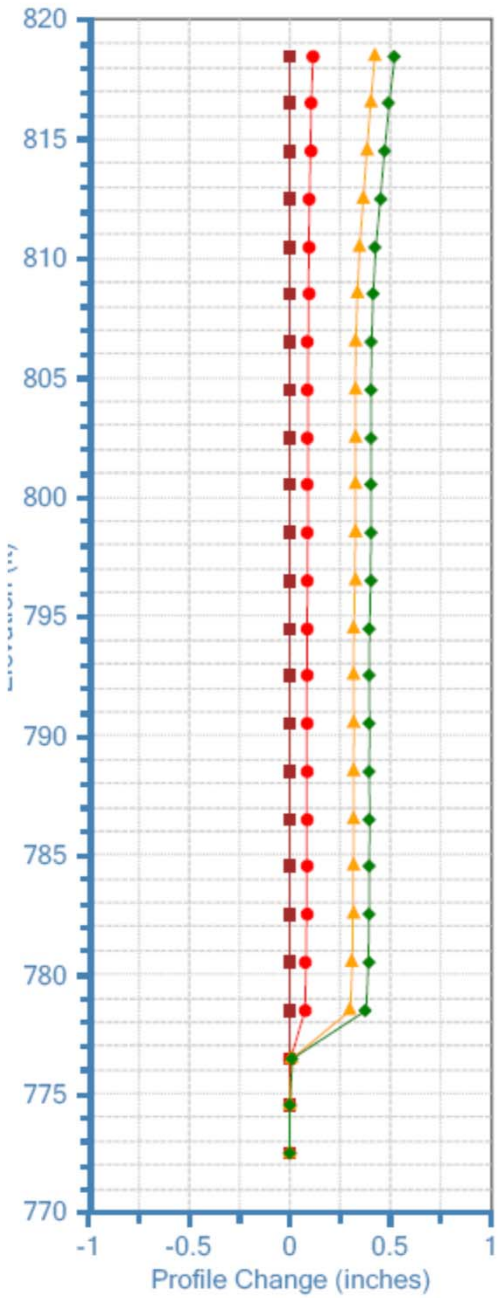

Depth in feet
0
10
20
30
40
50
60


0
10
20
30
40
50

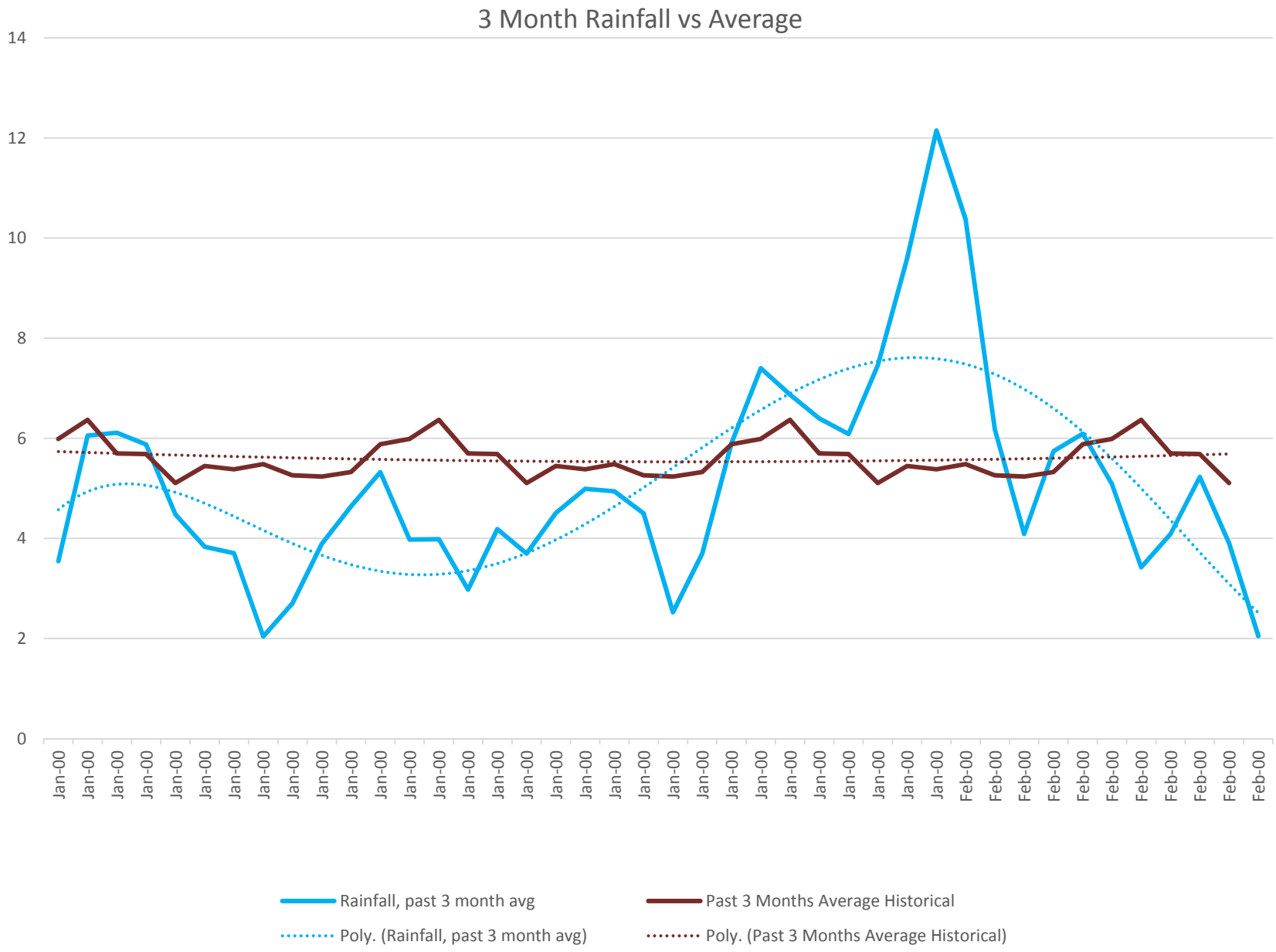

1.621
166.33158, 860.8137

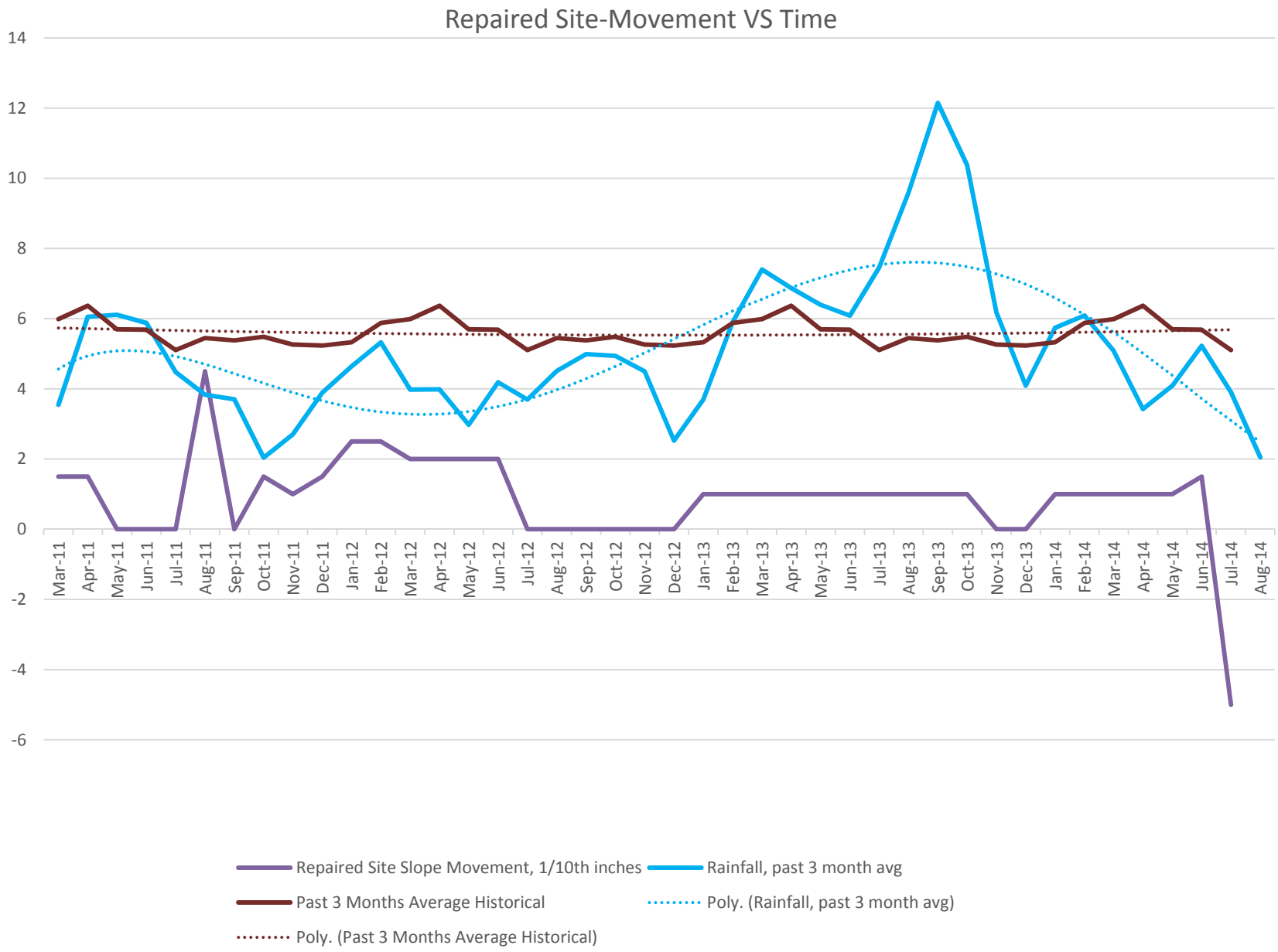
UN-REPAIRED SITE-OBSERVATIONS

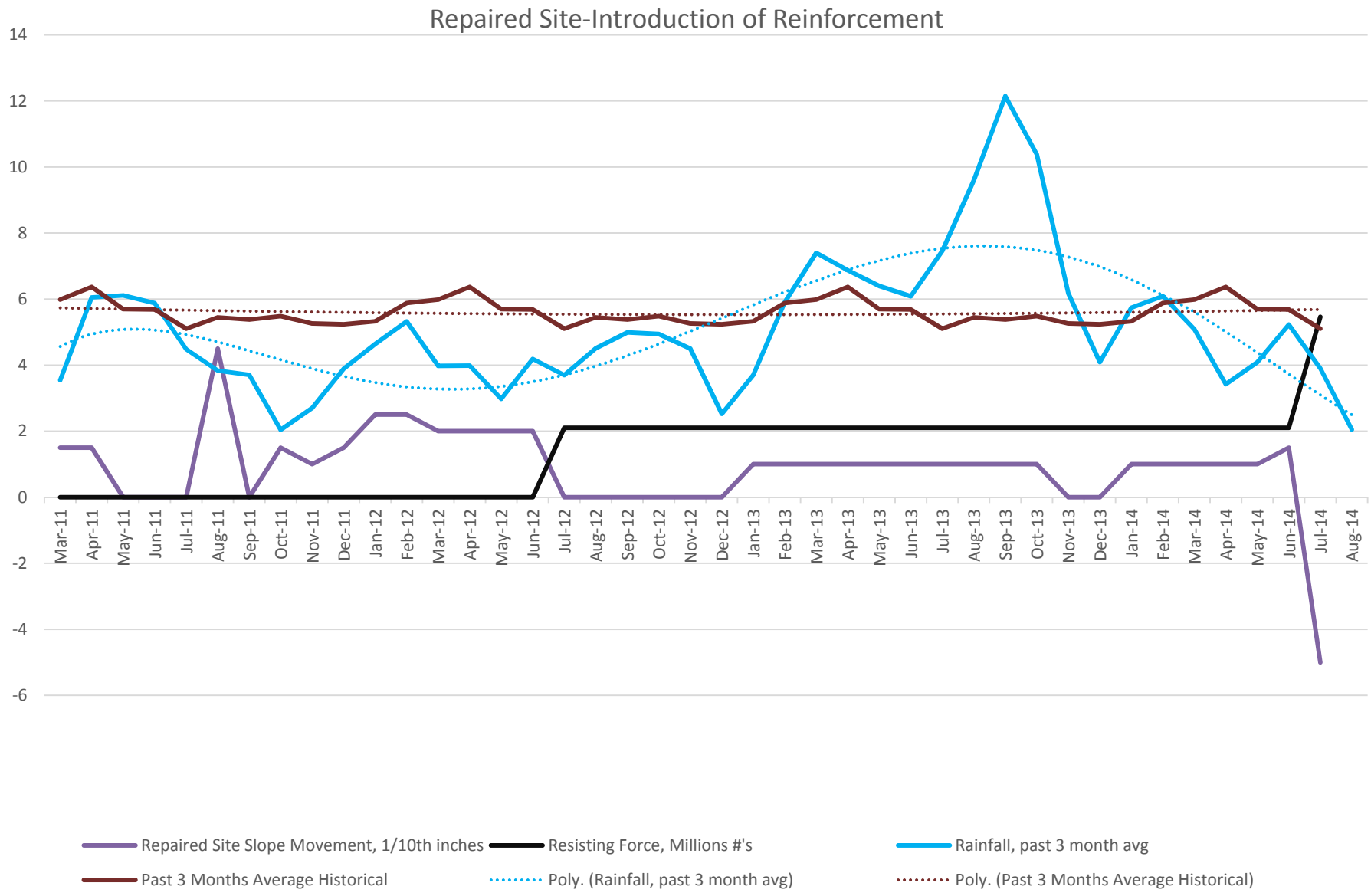
- Significant data gaps exist in the unrepaired site inclinometer readings
- Anecdotal information indicates movement slowed to a near standstill during 2013
- Site observations indicate movement resumed in 2013 (Record rainfall), and total movements during the year may have been on the order of 6 inches or more

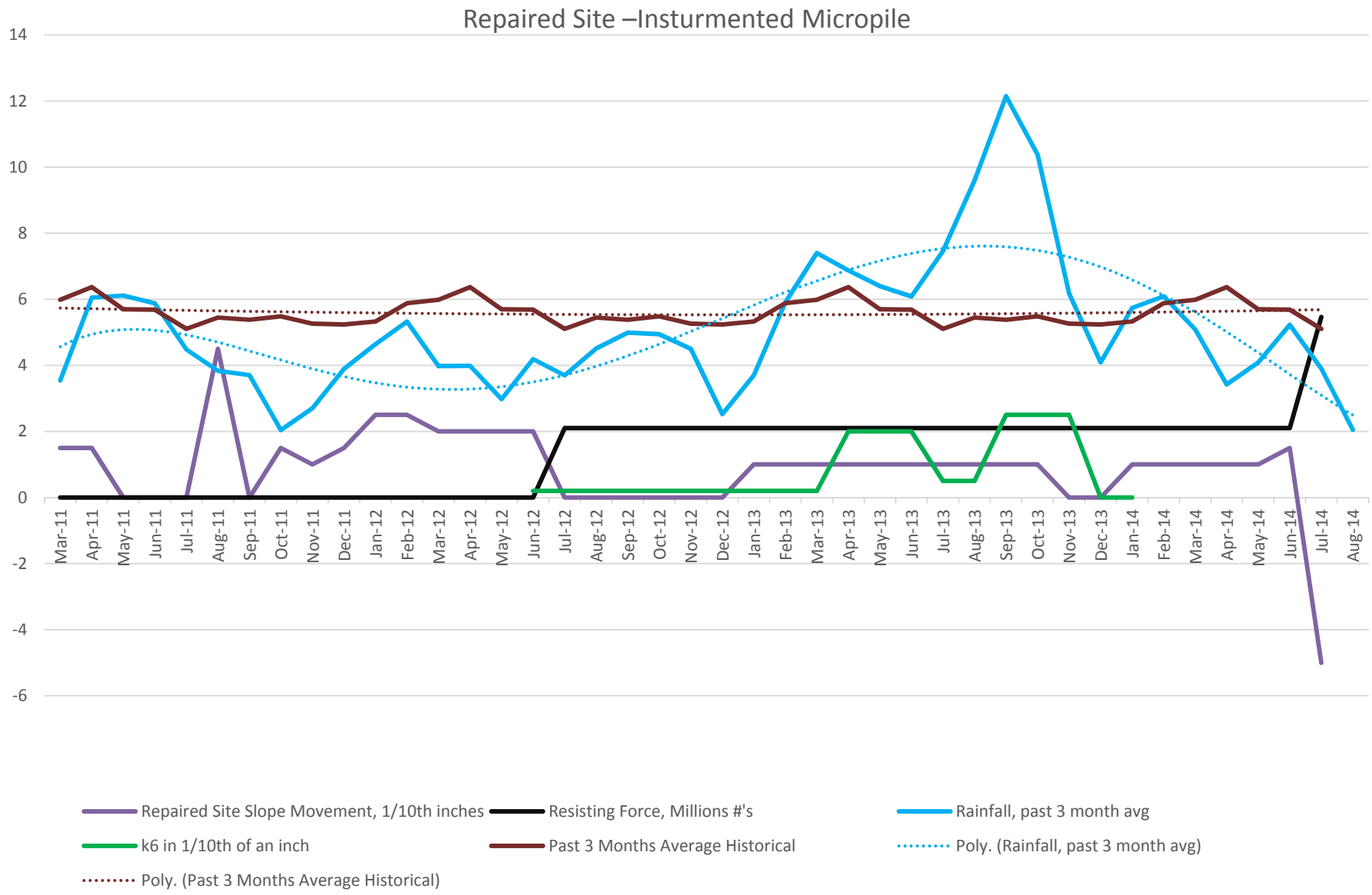


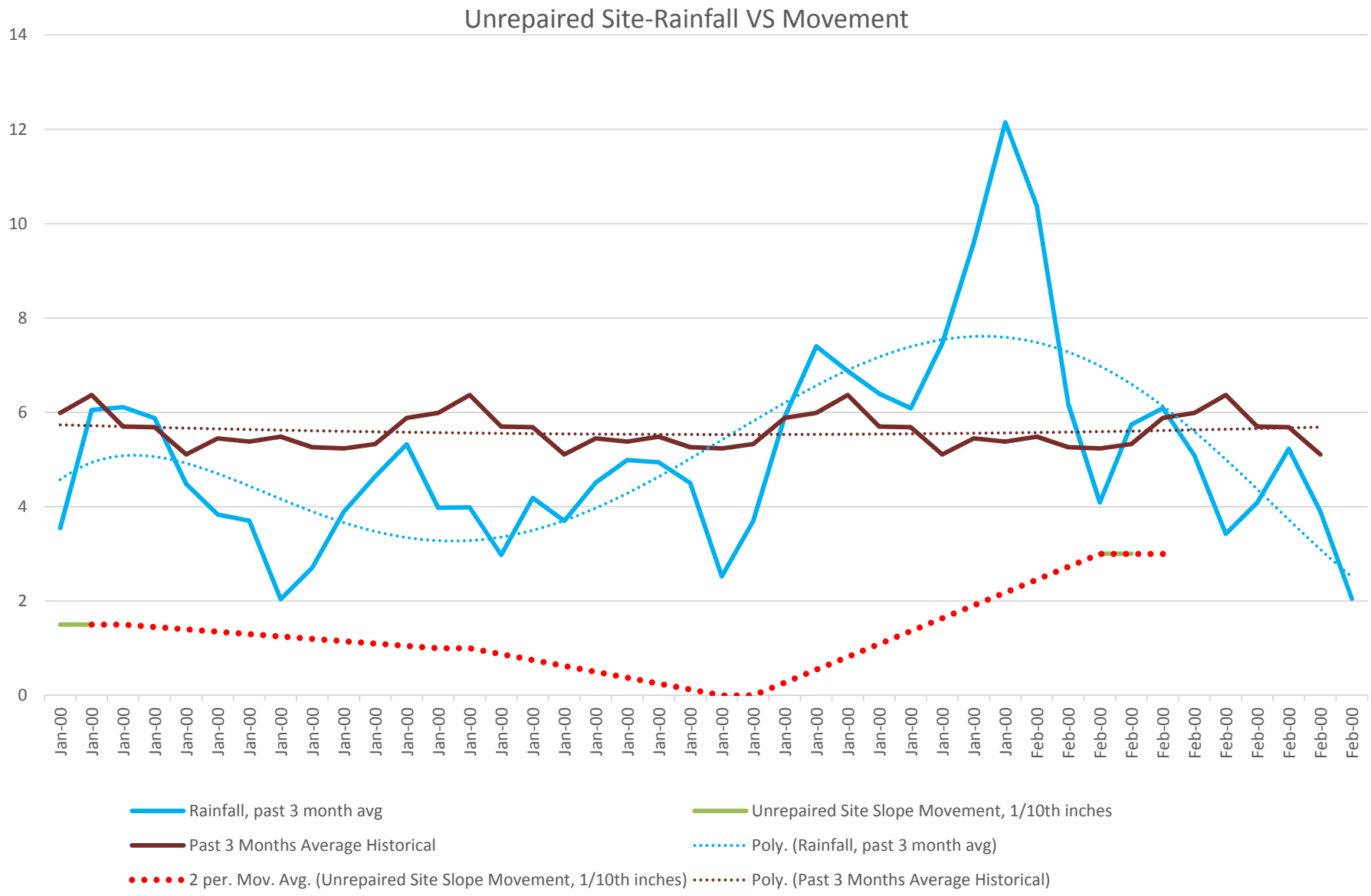
- Weekly readings during December 2013 indicate as much as 0.5” of movement over a 1-month period.
- Readings during the same month at the repaired site indicated movements on the order of 0.1” during the same timeframe.
- Partial repairs obviously had a significant arresting downslope movement even during periods of slope saturation.

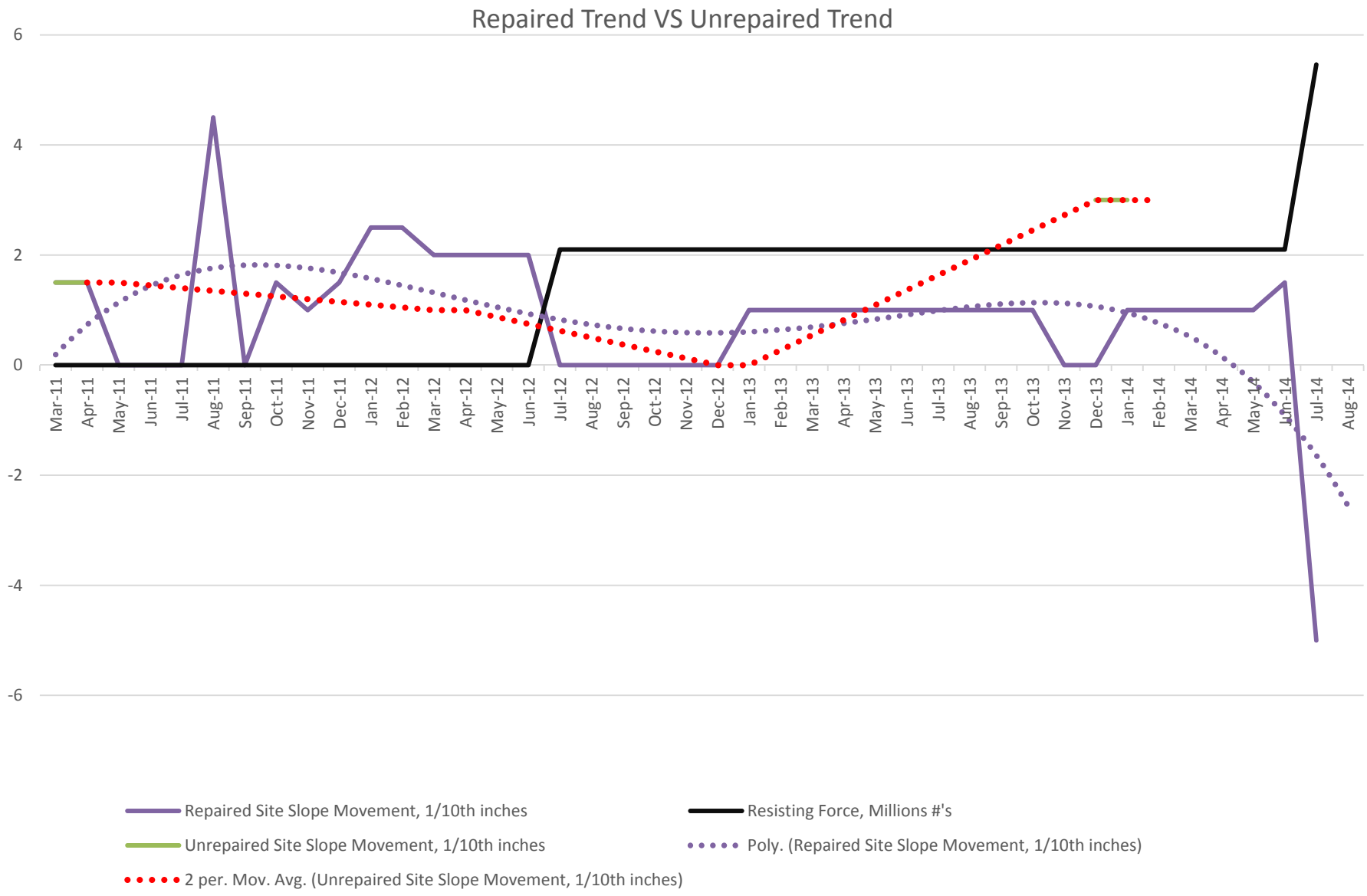

3 Month Rainfall vs Average
14
12
10
8
6
4
2
0
Jan-00
Feb-00
Rainfall, past 3 month avg
Past 3 Months Average Historical
Poly. (Rainfall, past 3 month avg)
Poly. (Past 3 Months Average Historical)


Repaired Site-Movement VS Time
14
12
10
8
6
4
2
0
-2
-4
-6
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Repaired Site Slope Movement, 1/10th inches
Rainfall, past 3 month avg
Past 3 Months Average Historical
Poly. (Rainfall, past 3 month avg)
Poly. (Past 3 Months Average Historical)


Repaired Site-Introduction of Reinforcement
14
12
10
8
6
4
2
0
-2
-4
-6
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Repaired Site Slope Movement, 1/10th inches
Resisting Force, Millions #'s
Rainfall, past 3 month avg
Past 3 Months Average Historical
Poly. (Rainfall, past 3 month avg)
Poly. (Past 3 Months Average Historical)


Repaired Site –Insturmented Micropile
14
12
10
8
6
4
2
0
-2
-4
-6
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Repaired Site Slope Movement, 1/10th inches
Resisting Force, Millions #'s
Rainfall, past 3 month avg
k6 in 1/10th of an inch
Past 3 Months Average Historical
Poly. (Rainfall, past 3 month avg)
Poly. (Past 3 Months Average Historical)


Unrepaired Site-Rainfall VS Movement
14
12
10
8
6
4
2
0
Jan-00
Feb-00
Rainfall, past 3 month avg
Unrepaired Site Slope Movement, 1/10th inches
Past 3 Months Average Historical
Poly. (Rainfall, past 3 month avg)
2 per. Mov. Avg. (Unrepaired Site Slope Movement, 1/10th inches)
Poly. (Past 3 Months Average Historical)


Repaired Trend VS Unrepaired Trend
6
4
2
0
-2
-4
-6
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Repaired Site Slope Movement, 1/10th inches
Resisting Force, Millions #'s
Unrepaired Site Slope Movement, 1/10th inches
Poly. (Repaired Site Slope Movement, 1/10th inches)
2 per. Mov. Avg. (Unrepaired Site Slope Movement, 1/10th inches)


THANK YOU