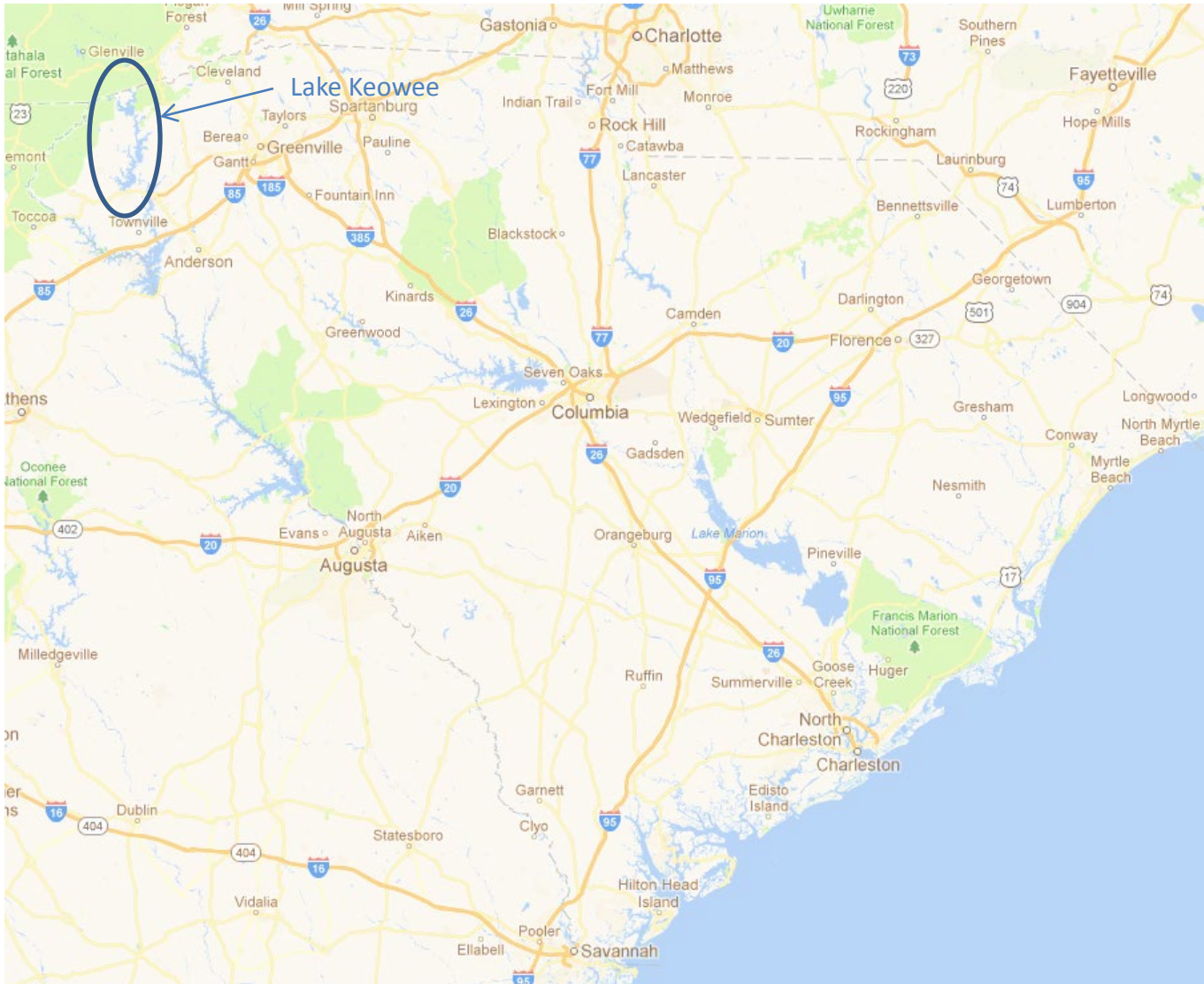


The Keowee Creeper

By Daryl Wurster, PE and
Doug Chappell, PE

Wurster Engineering & Construction, Inc.



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.



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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

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

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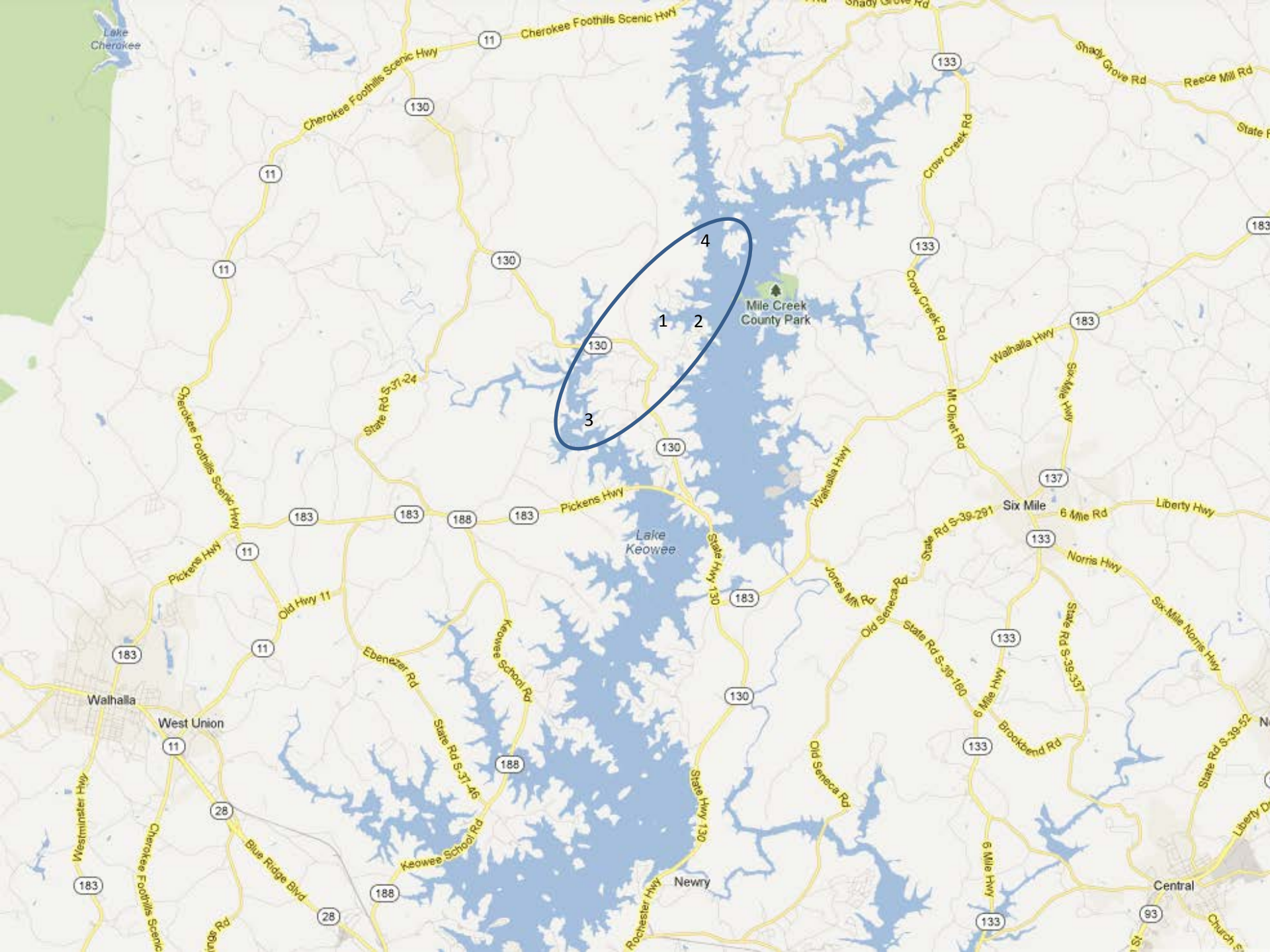
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- Areas with borings and slope inclinometers indicate movement near the soft soil/weathered rock interface
- Failure plane is about 30 to 60 ft deep near the shoreline extending out into Lake Keowee
- Two of the sites experienced ruptured water lines. 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



1

2

3

4

Mile Creek County Park

Lake Keowee

Cherokee Foothills Scenic Hwy

Pickens Hwy

Waihalla

West Union

Newry

Central

Lake Cherokee

Shady Grove Rd

Reece Mill Rd

Crow Creek Rd

Waihalla Hwy

State Rd S-37-24

Cherokee Foothills Scenic Hwy

Ebenezer Rd

Keowee School Rd

Keowee School Rd

Waihalla Hwy

Old Seneca Rd

Old Seneca Rd

State Rd S-39-291

6 Mile Hwy

6 Mile Hwy

Norris Hwy

State Rd S-39-357

Liberty Hwy

Six-Mile Norris Hwy

State Rd S-39-52

Liberty Dr

Blue Ridge Blvd

Westminster Hwy

Cherokee Foothills Scenic Hwy

Rochester Hwy

6 Mile Hwy

Church St

Does geology have anything to do with the location of these slides?



Generalized Geologic Map of South Carolina

2005



Revised by
Willoughby, Howard, and Nystrom, 2005
Original compilation by
Maybin and Nystrom, 1997

DESCRIPTION OF MAP UNITS

COASTAL PLAIN QUATERNARY

-  Holocene
-  Pleistocene

TERTIARY

-  Pliocene
-  Paleocene, Eocene, and Miocene











CRETACEOUS

-  Upper Cretaceous

TRIASSIC

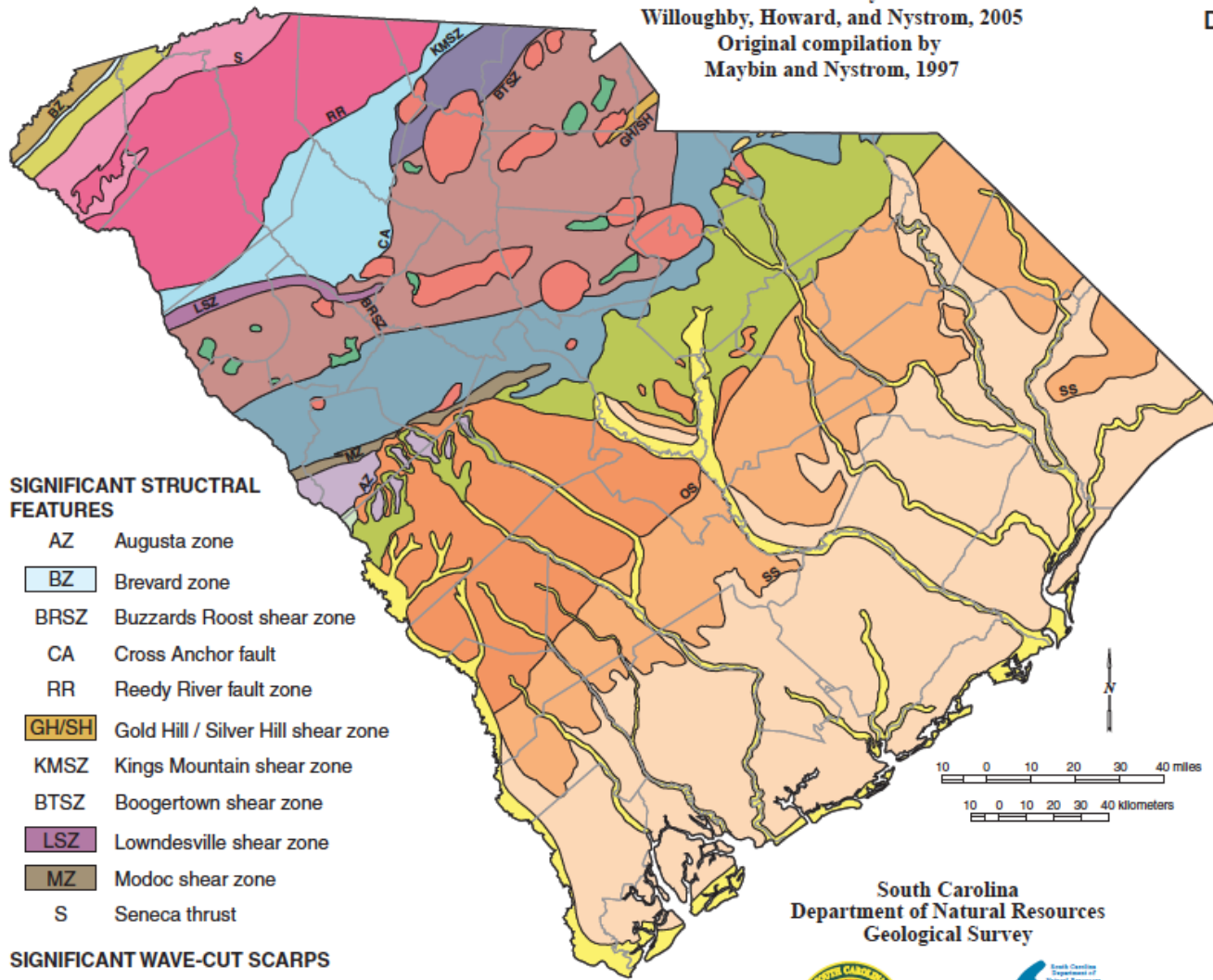
-  Triassic basins

BLUE RIDGE AND PIEDMONT





-  Blue Ridge
-  Chauga belt
-  Walhalla thrust sheet
-  Sixmile thrust sheet
-  Laurens thrust stack
-  Kings Mountain terrane
-  Charlotte terrane
-  Carolina terrane (slate belt)
-  Savannah River terrane
-  Augusta terrane

IGNEOUS ROCKS

-  Gabbro
-  Granite



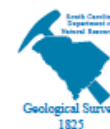
SIGNIFICANT STRUCTURAL FEATURES

- AZ Augusta zone
-  BZ Brevard zone
- BRSZ Buzzards Roost shear zone
- CA Cross Anchor fault
- RR Reedy River fault zone
-  GH/SH Gold Hill / Silver Hill shear zone
- KMSZ Kings Mountain shear zone
- BTSZ Boogertown shear zone
-  LSZ Lowndesville shear zone
-  MZ Modoc shear zone
- S Seneca thrust

SIGNIFICANT WAVE-CUT SCARPS

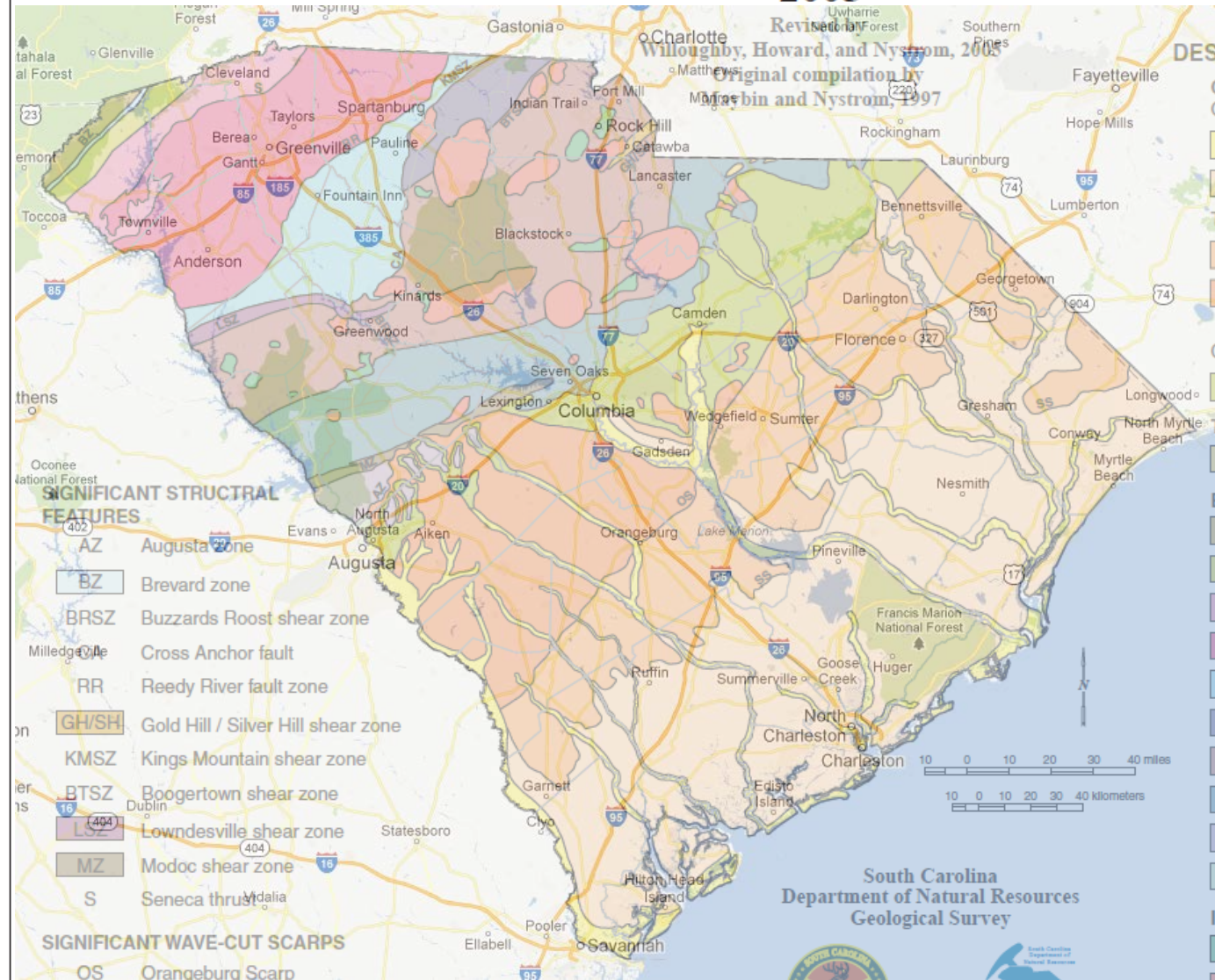
- OS Orangeburg Scarp
- SS Surry Scarp

South Carolina
Department of Natural Resources
Geological Survey



Generalized Geologic Map of South Carolina

2005



DESCRIPTION OF MAP UNITS

- COASTAL PLAIN QUATERNARY**
- Holocene
 - Pleistocene
- TERTIARY**
- Pliocene
 - Paleocene, Eocene, and Miocene
- CRETACEOUS**
- Upper Cretaceous
- TRIASSIC**
- Triassic basins
- BLUE RIDGE AND PIEDMONT**
- Blue Ridge
 - Chauga belt
 - Walhalla thrust sheet
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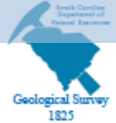
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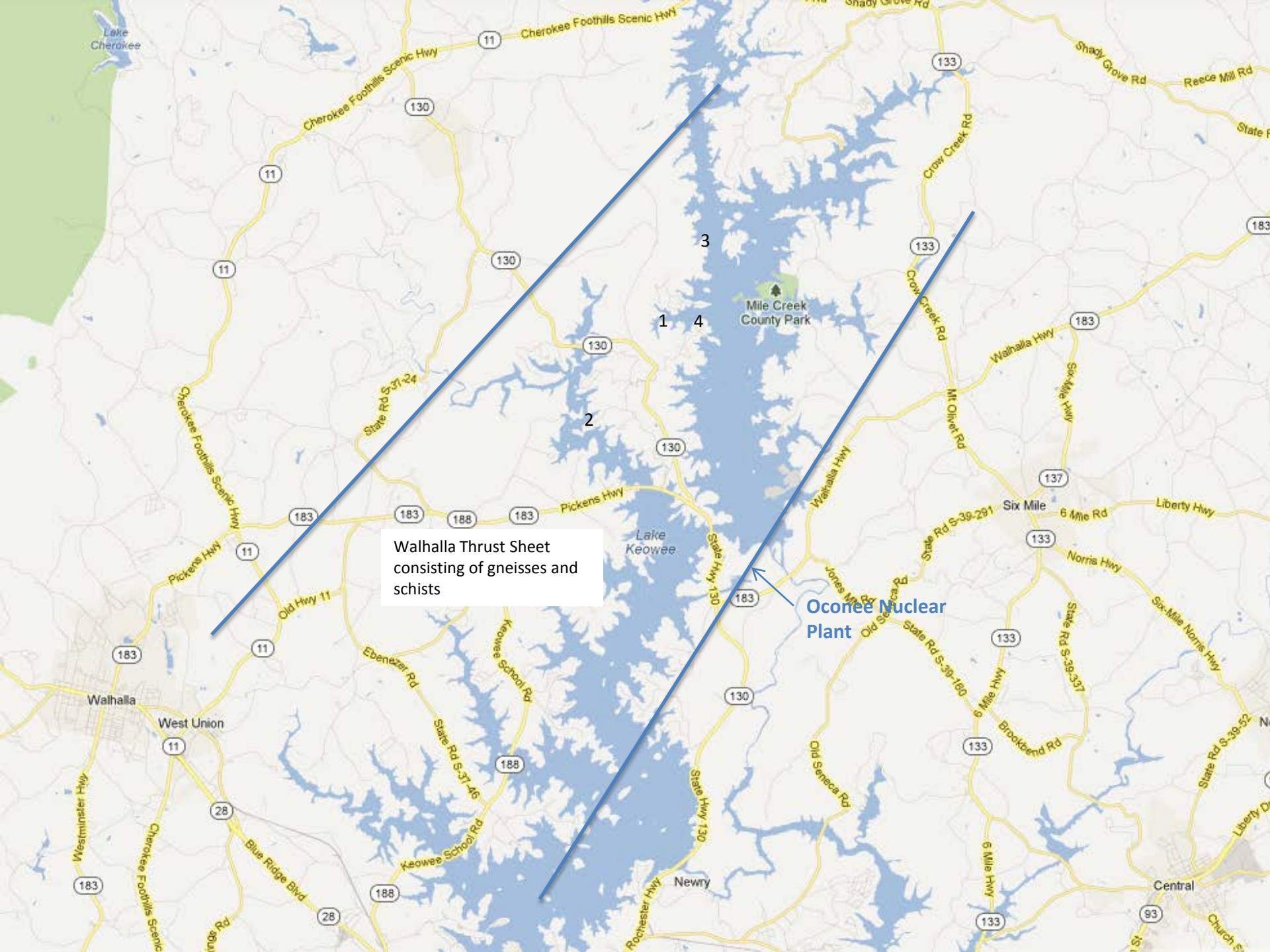
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South Carolina
Department of Natural Resources
Geological Survey





Walhalla Thrust Sheet
consisting of gneisses and
schists

Oconee Nuclear
Plant

Lets look at each of the four slides

Property owners names left off for privacy and one of these slides is in litigation

Site 1



SITE 1

3

4

2

183

130

133

137

133

133

183

188

183

11

11

Mile Creek
County Park

Lake
Keowee

Oconee Nuclear
Plant

Six Mile

State Rd S-39-24

Pickens Hwy

Watahalla Hwy

State Rd S-39-291

Watahalla Hwy

Mt Olinet Rd

Jones Mt Rd

Old Seneca Rd

State Rd S-39-180

Six Mile Hwy

Ebenezer Rd

Keowee
School Rd

Site 1

- Site 1 slide was repaired by others using patterned ground anchors.

Site 1

- Site 1 slide was repaired by others using patterned ground anchors.
- Slide was deep seated and extended into lake.

Site 1

- Site 1 slide was repaired by others using patterned ground anchors.
- Slide was deep seated and extended into lake.
- Ground movement showed up as separation cracks in house.

Site 1

- Site 1 slide was repaired by others using patterned ground anchors.
- Slide was deep seated and extended into lake.
- Ground movement showed up as separation cracks in house.
- Ground was gently sloping.



5.16.2002



5.16.2002

Site 2



SITE 2



3

1

4

Mile Creek
County Park

Lake
Keowee

Oconee Nuclear
Plant

Site 2

- Site 2 slide was repaired by others by regrading slope.

Site 2

- Site 2 slide was repaired by others by regrading slope.
- Effectiveness of repair unknown.

Site 2

- Site 2 slide was repaired by others by regrading slope.
- Effectiveness of repair unknown.
- Slide was deep seated and extended into lake.

Site 2

- Site 2 slide was repaired by others by regrading slope.
- Effectiveness of repair unknown.
- Slide was deep seated and extended into lake.
- Ground movement did not extend as far as house.

Site 2

- Site 2 slide was repaired by others by regrading slope.
- Effectiveness of repair unknown.
- Slide was deep seated and extended into lake.
- Ground movement did not extend as far as house.
- Ground was moderately sloping.

Site 2

- Site 2 slide was repaired by others by regrading slope.
- Effectiveness of repair unknown.
- Slide was deep seated and extended into lake.
- Ground movement did not extend as far as house.
- Ground was moderately sloping.
- Slide is the edge of a larger slide that encompasses most of the adjacent lot and a third lot.

Site 2

- Site 2 slide was repaired by others by regrading slope.
- Effectiveness of repair unknown.
- Slide was deep seated and extended into lake.
- Ground movement did not extend as far as house.
- Ground was moderately sloping.
- Slide is the edge of a larger slide that encompasses most of the adjacent lot and a third lot.
- Adjacent lot was abandoned.

Site 2

- Site 2 slide was repaired by others by regrading slope.
- Effectiveness of repair unknown.
- Slide was deep seated and extended into lake.
- Ground movement did not extend as far as house.
- Ground was moderately sloping.
- Slide is the edge of a larger slide that encompasses most of the adjacent lot and a third lot.
- Adjacent lot was abandoned.
- The third lot has a house on it and repairs were reportedly made by regrading the lot.



10/15/2010 08:51



10/15/2010 09:03



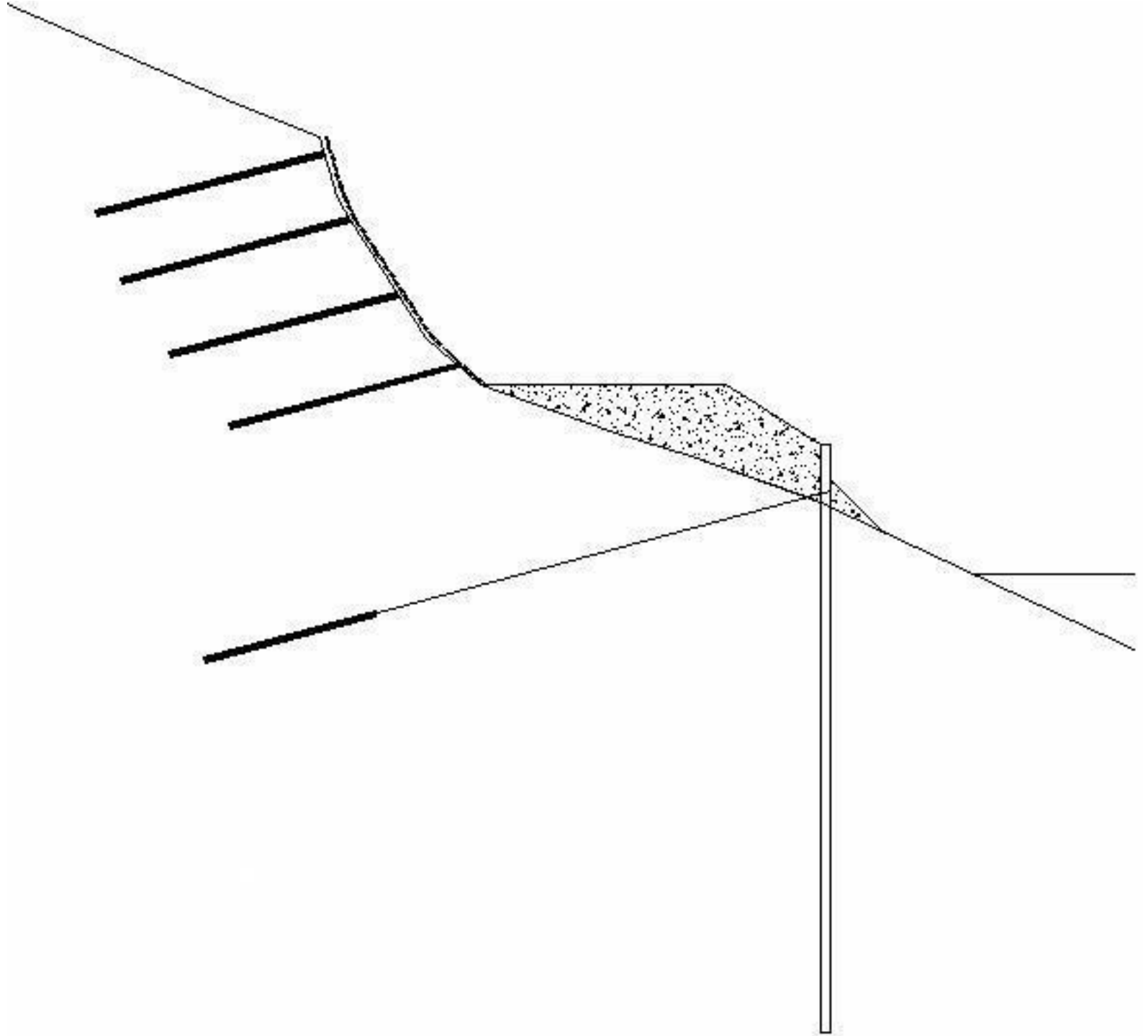
10/15/2010 09:57



10/15/2010 09:56



10/15/2010 09:56



Site 3



SITE 3



Mile Creek
County Park

1

4

2

Lake
Keowee

Oconee Nuclear
Plant

Six Mile

Site 3

- Site 3 slide has not been repaired at this time.

Site 3

- Site 3 slide has not been repaired at this time.
- Slide is deep seated and extends into lake.

Site 3

- Site 3 slide has not been repaired at this time.
- Slide is deep seated and extends into lake.
- Ground movement showed up as small to large tension cracks.

Site 3

- Site 3 slide has not been repaired at this time.
- Slide is deep seated and extends into lake.
- Ground movement showed up as small to large tension cracks.
- Large tension cracks at first appear to be ditches and old roads.

Site 3

- Site 3 slide has not been repaired at this time.
- Slide is deep seated and extends into lake.
- Ground movement showed up as small to large tension cracks.
- Large tension cracks at first appear to be ditches and old roads.
- Ground was gently sloping (i.e. 7H:1V), however, ground offshore is as steep as 1H:1V.

Site 3

- Site 3 slide has not been repaired at this time.
- Slide is deep seated and extends into lake.
- Ground movement showed up as small to large tension cracks.
- Large tension cracks at first appear to be ditches and old roads.
- Ground was gently sloping (ie 6H:1V), however, ground offshore is as steep as 1H:1V.
- Initial repairs were made by others to a new house located in the middle of the slide area included helical piers. Piers could be tightened up, then would loose. WEC was then asked to look at site.



01/10/2012 12:36



01/10/2012 12:34

Ruler

Line Path

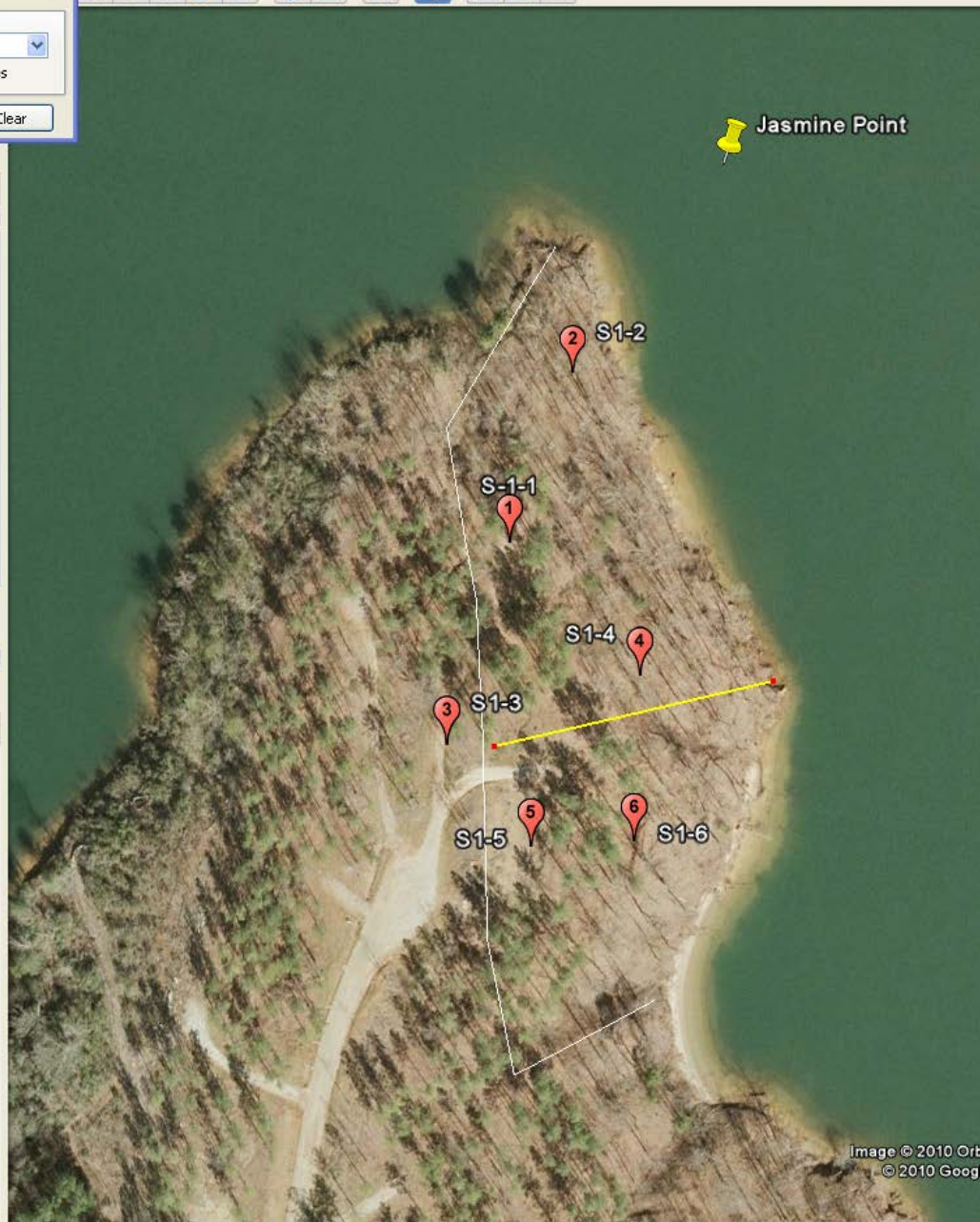
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Heading: 84.04 degrees

Mouse Navigation Save Clear

- Places**
- My Places
 - Sightseeing Tour
 - Make sure 3D Buildings layer is checked
 - Kitchings Mill Tower
 - Willard Street Bridge
 - Gaston mall
 - Blue Ridge MM 400.8
 - Foothills Parkway Missing Link
 - Craggy View
 - Bear Lake Reserve
 - Meet FHWA at 1:30
 - 757 Old Place Drive
 - 279 Falcon
 - Waterdance
 - Jasmine Point
 - S1-2
 - S1-1
 - S1-3
 - S1-4

- Layers** Earth Gallery >>
- Primary Database
 - Borders and Labels
 - Places
 - Panoramio Photos
 - Roads
 - 3D Buildings
 - Ocean
 - Street View
 - Weather
 - Gallery
 - Global Awareness
 - More







01/10/2012 12:35





28

04/29/2010 12:07



04/29/2010 12:08



11/04/2010 14:01



11/04/2010 14:03



11/04/2010 13:04



11/04/2010 13:05



11/04/2010 13:07



04/29/2010 12:23



04/29/2010 12:23



11/04/2010 13:08



11/04/2010 13:09



04/29/2010 12:31



11/04/2010 13:37



11/04/2010 13:38



11/04/2010 13:42



04/29/2010 11:52

Ruler

Line Path

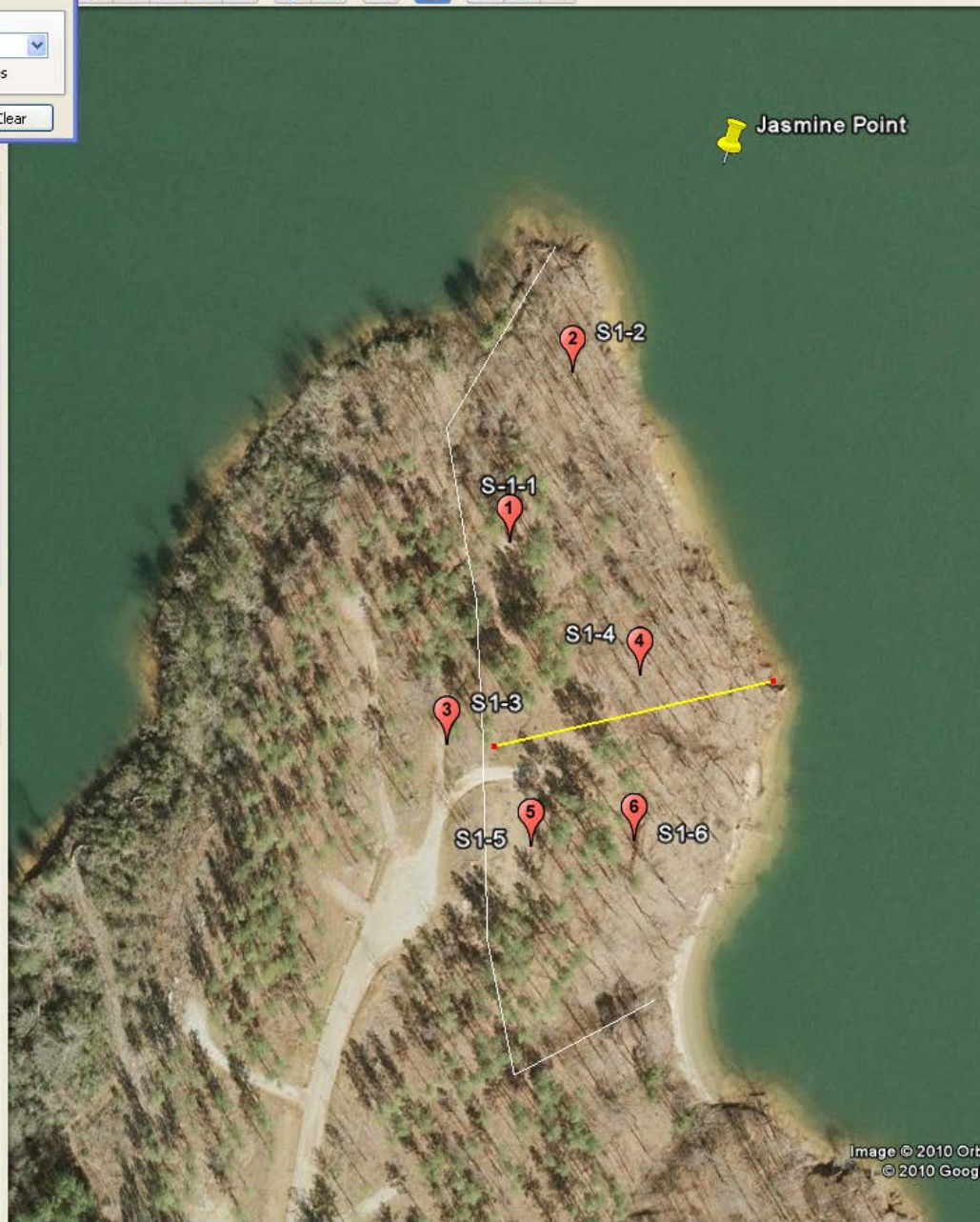
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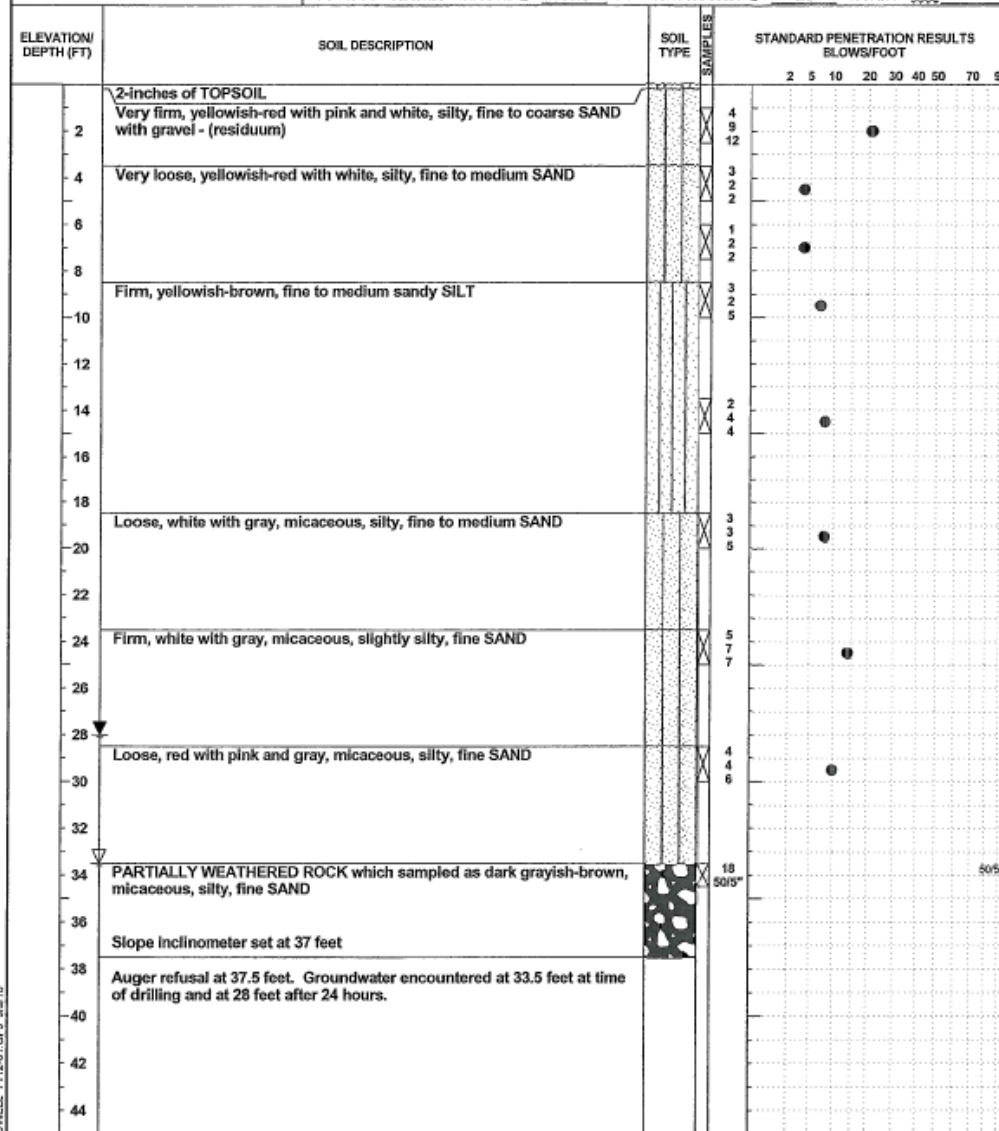




**BUNNELL-LAMMONS
ENGINEERING, INC.**
GEOTECHNICAL AND ENVIRONMENTAL
CONSULTANTS

SOIL TEST BORING NO. B-1

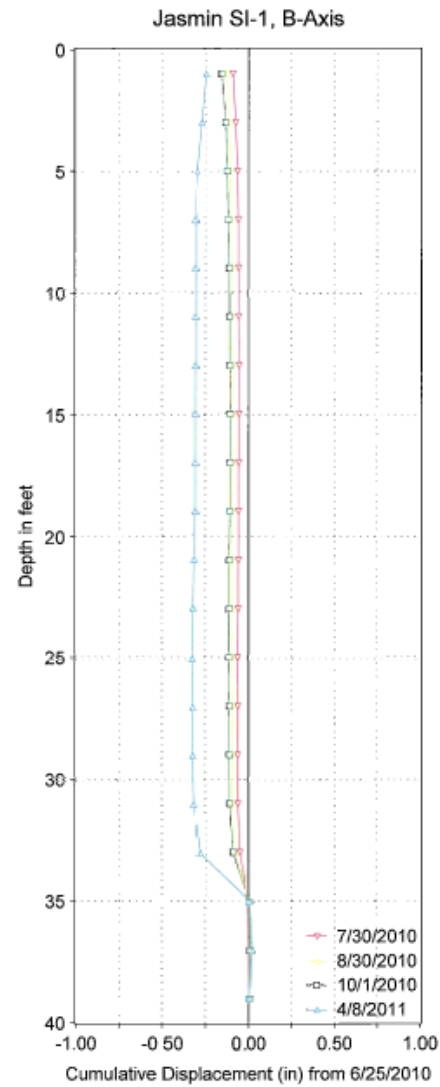
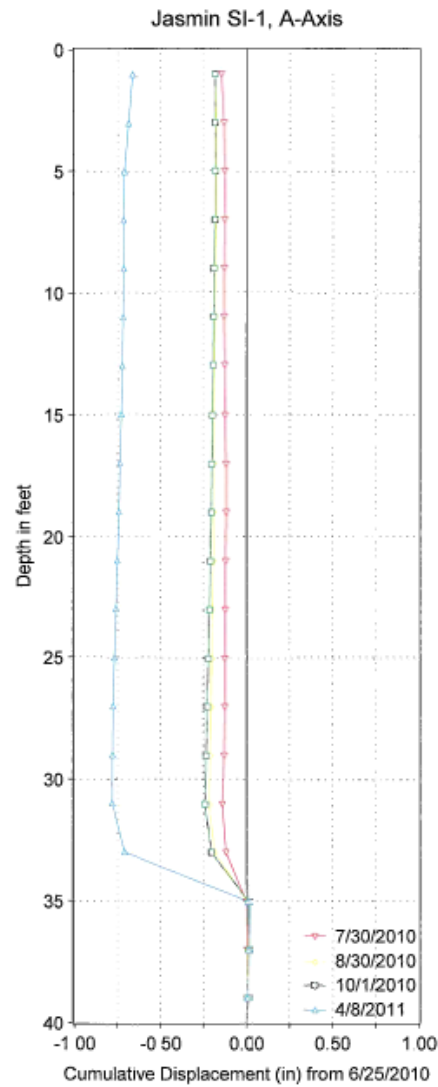
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 LOCATION: Lot 30 ELEVATION: _____
 DRILLER: Metro Drill, Inc., Reid and Keith LOGGED BY: D. Parkins
 DRILLING METHOD: BK-51, 2-1/4 inch ID hollow stem auger
 DEPTH TO - WATER> INITIAL: ∇ 33.5 AFTER 24 HOURS: ∇ 28 CAVING>



GEO. NOWELL 7/12/01 GP-1 8/8/10



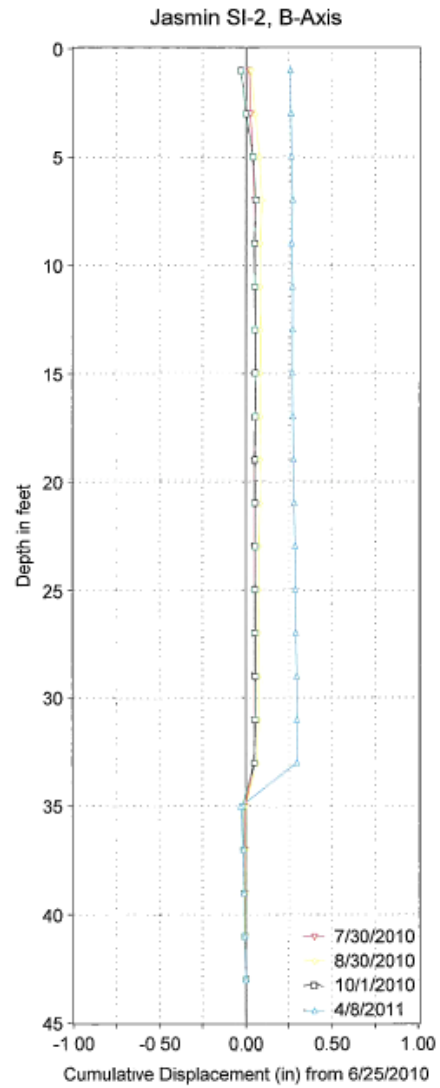
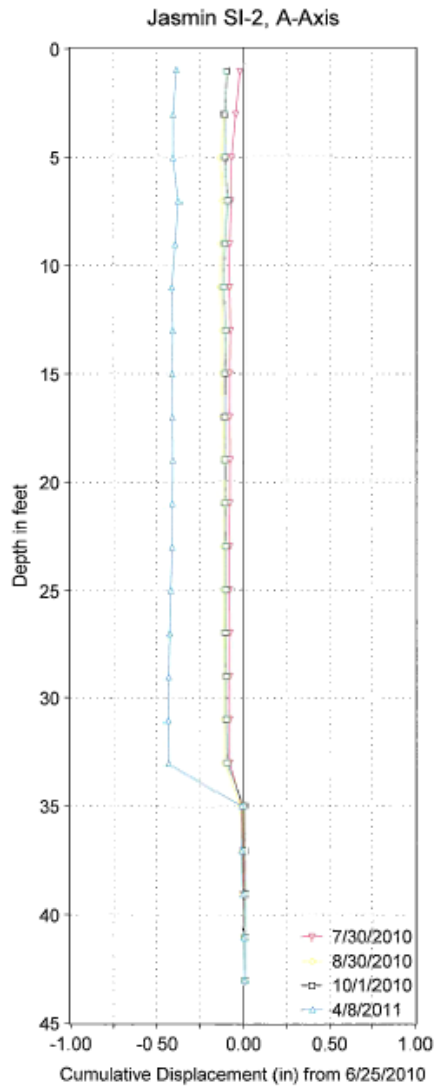
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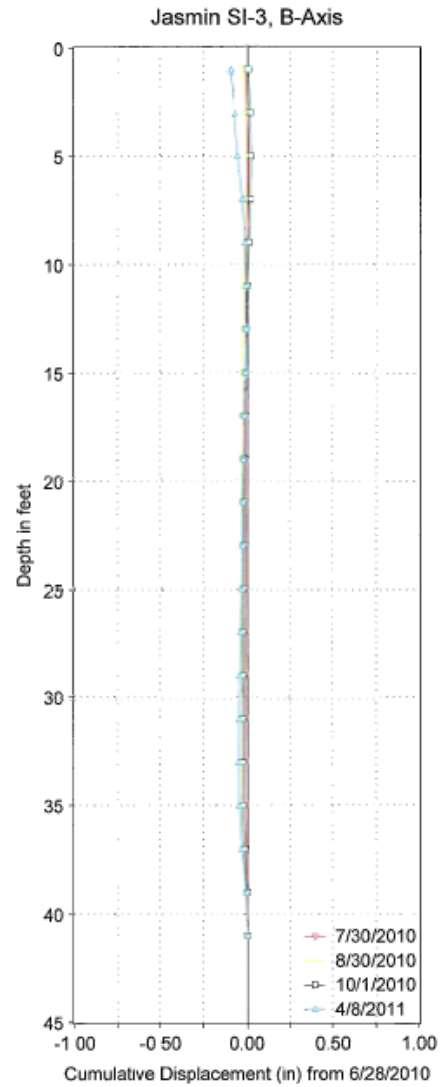
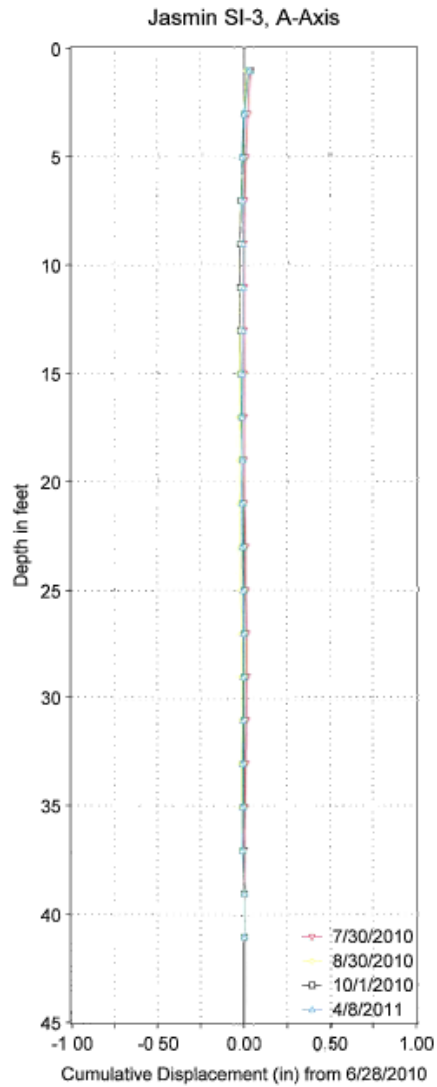
Jasmine Point

BLE Project No. J10-7112-01

Cliffs at Keowee Falls South



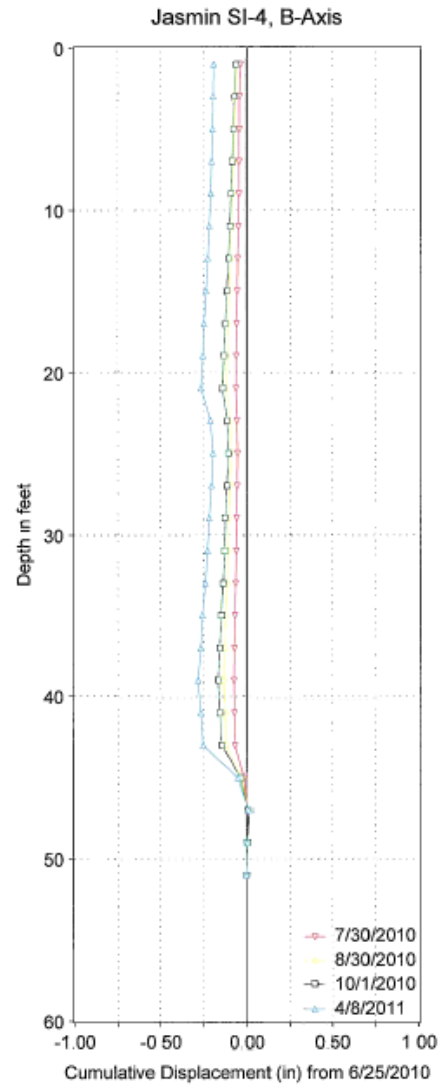
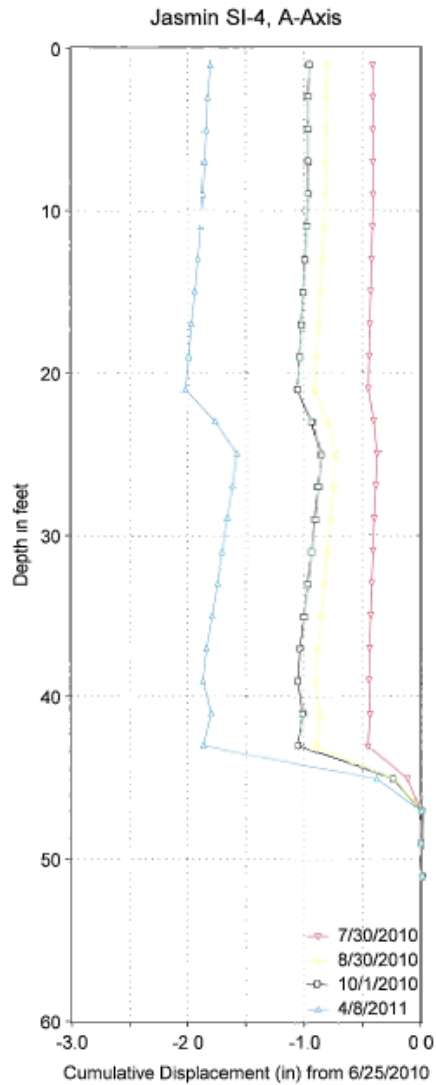
Jasmine Point Cliffs at Keowee Falls South	BLE Project No. J10-7112-01
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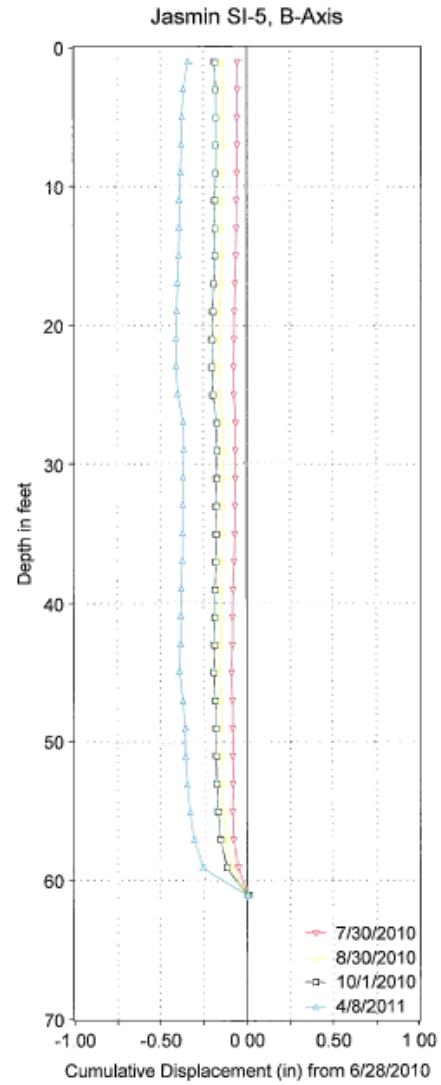
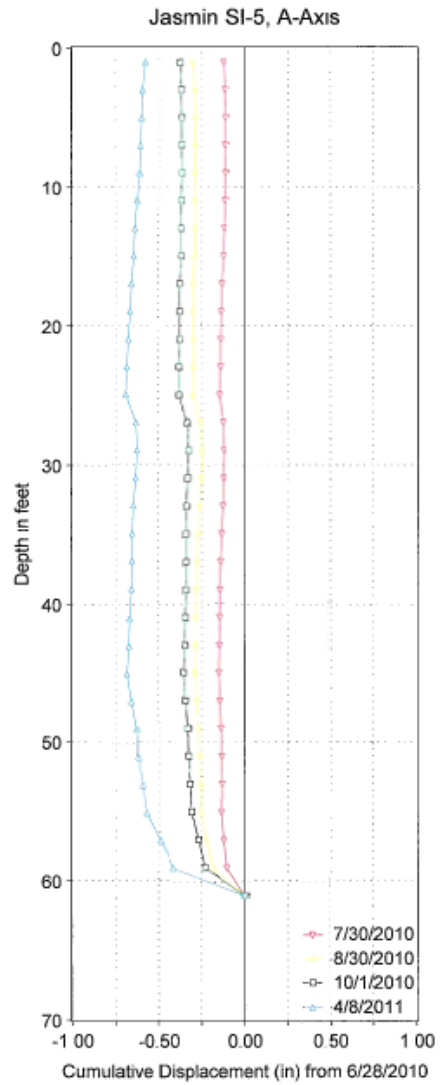
Jasmine Point

BLE Project No. J10-7112-01

Cliffs at Keowee Falls South



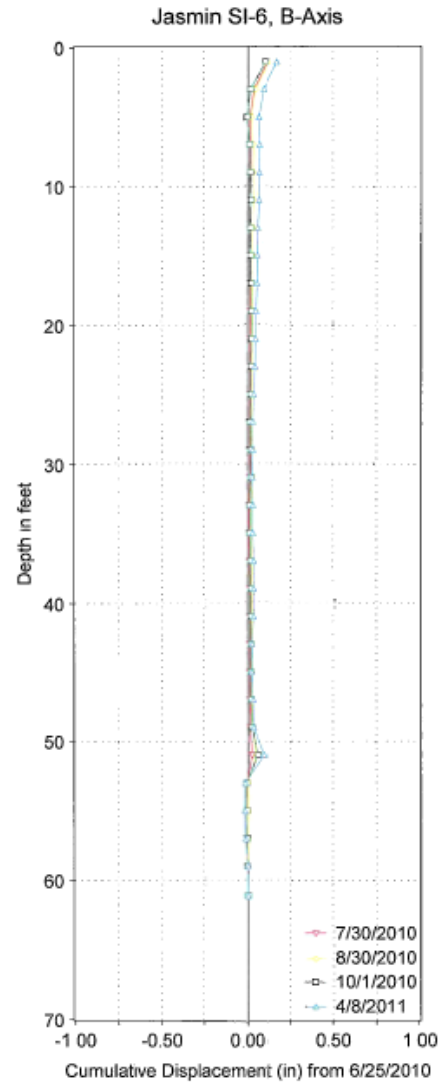
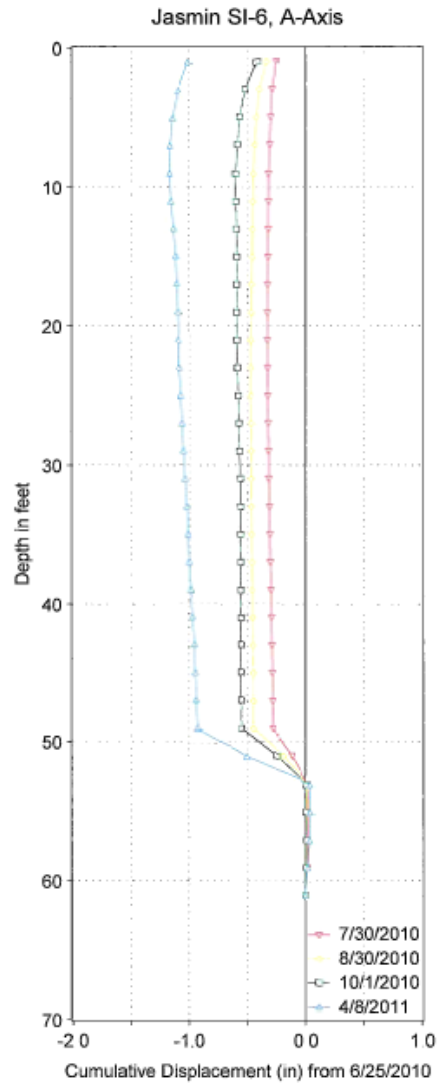
Jasmine Point	BLE Project No. J10-7112-01
Cliffs at Keowee Falls South	



Jasmine Point

BLE Project No. J10-7112-01

Cliffs at Keowee Falls South



Jasmine Point
Cliffs at Keowee Falls South

BLE Project No. J10-7112-01

National Map 183 km NE of Atlanta, Georgia, United States 7/1/1980

[Download](#) | [E-mail](#) | [Info](#) | [Print](#) | [Order Map](#) | [Bing Maps](#)

Size

Topo Map

Aerial Photo

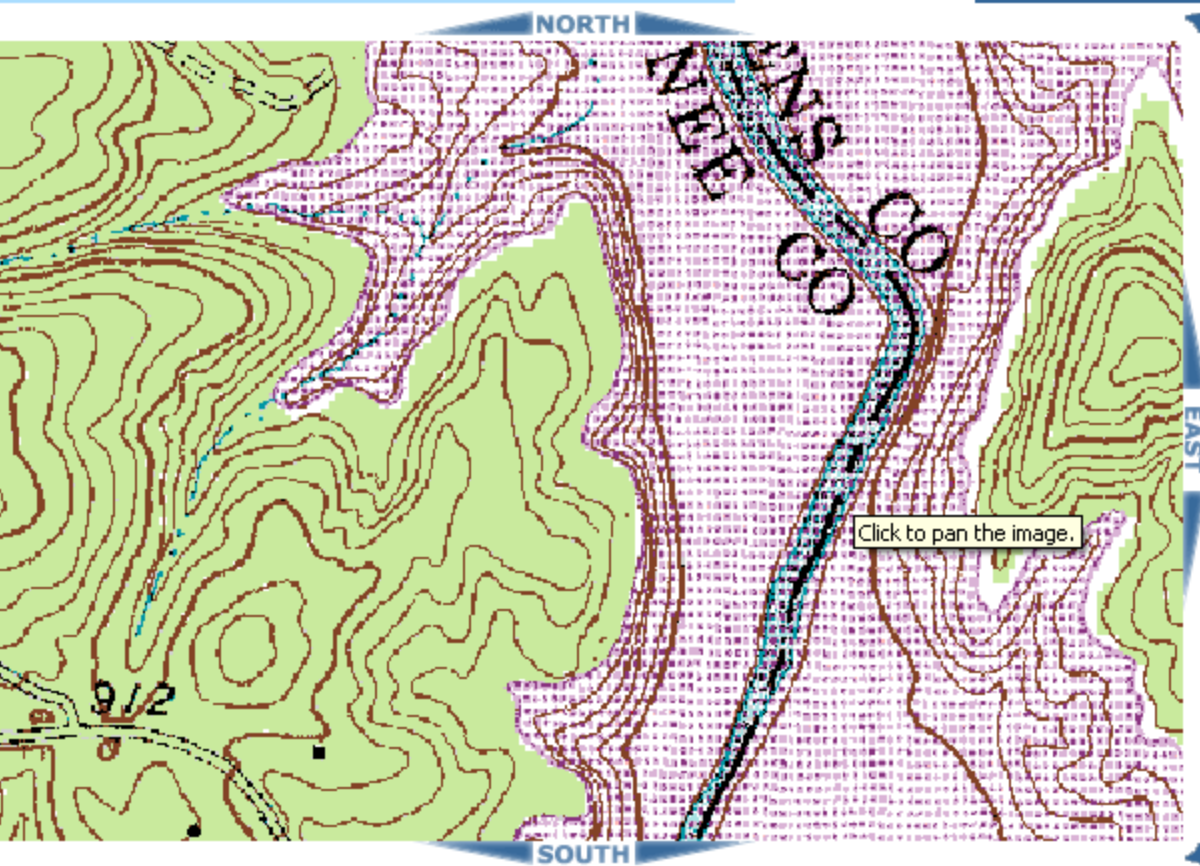
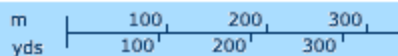
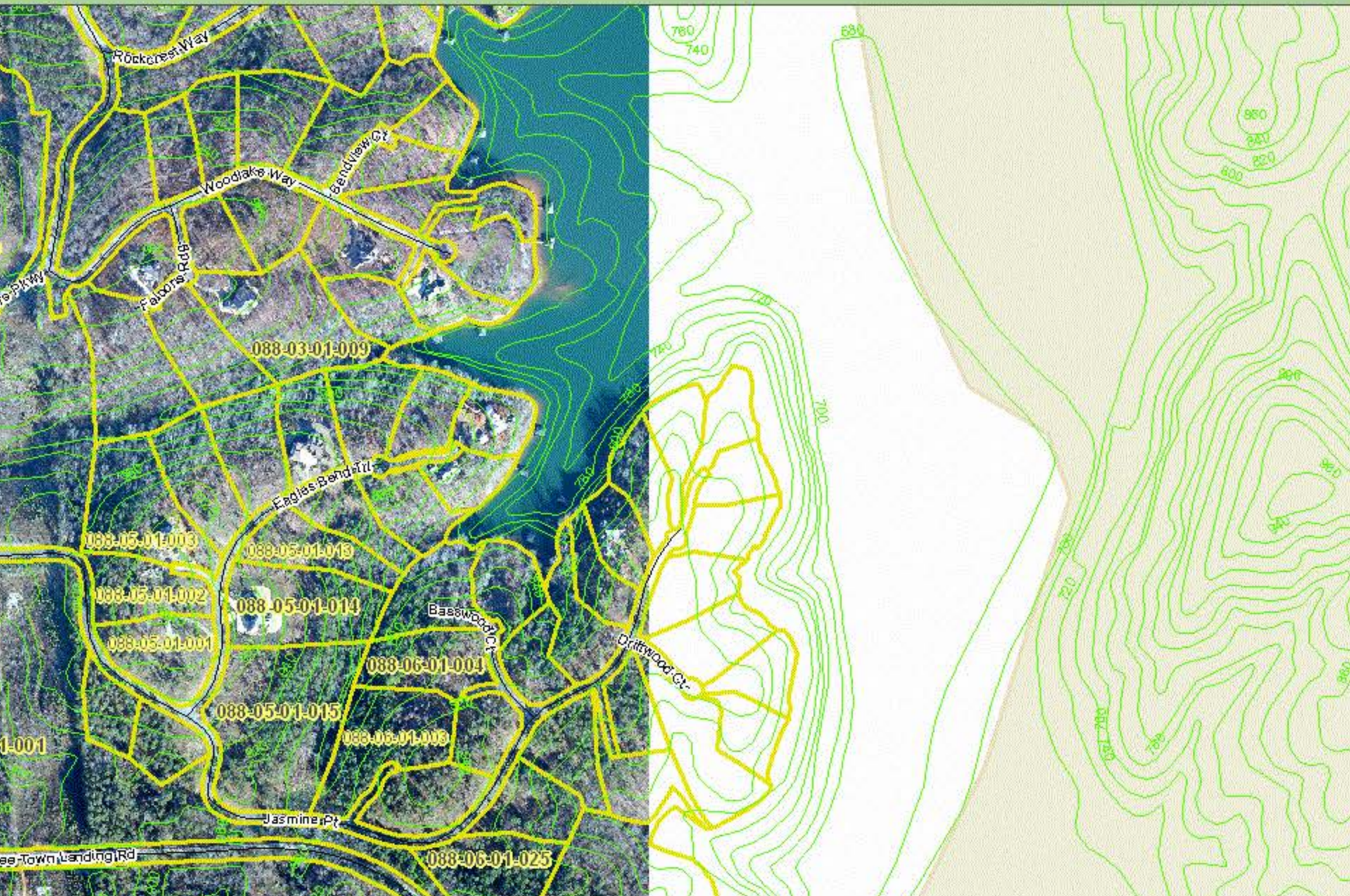
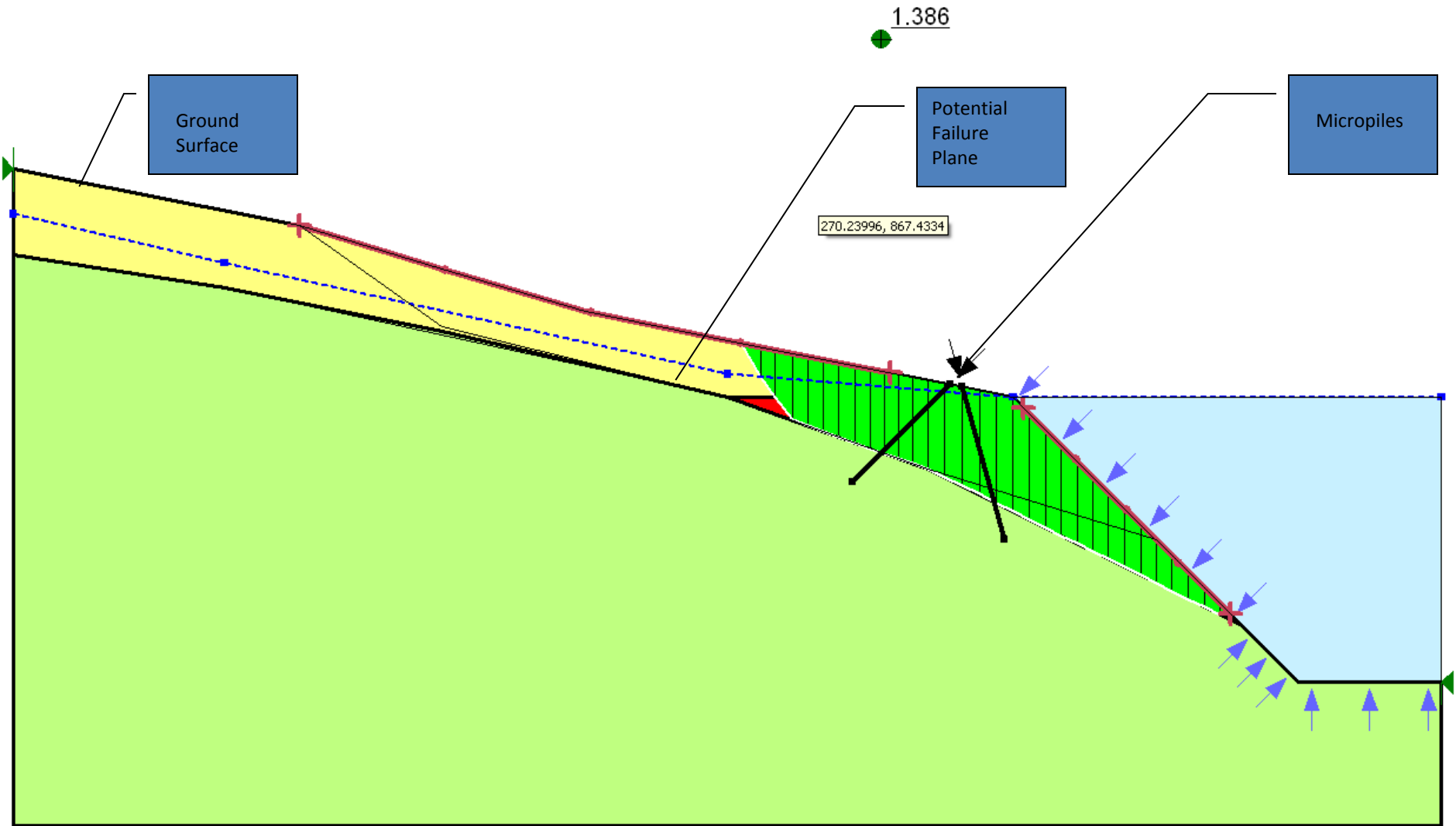


Image courtesy of the U.S. Geological Survey

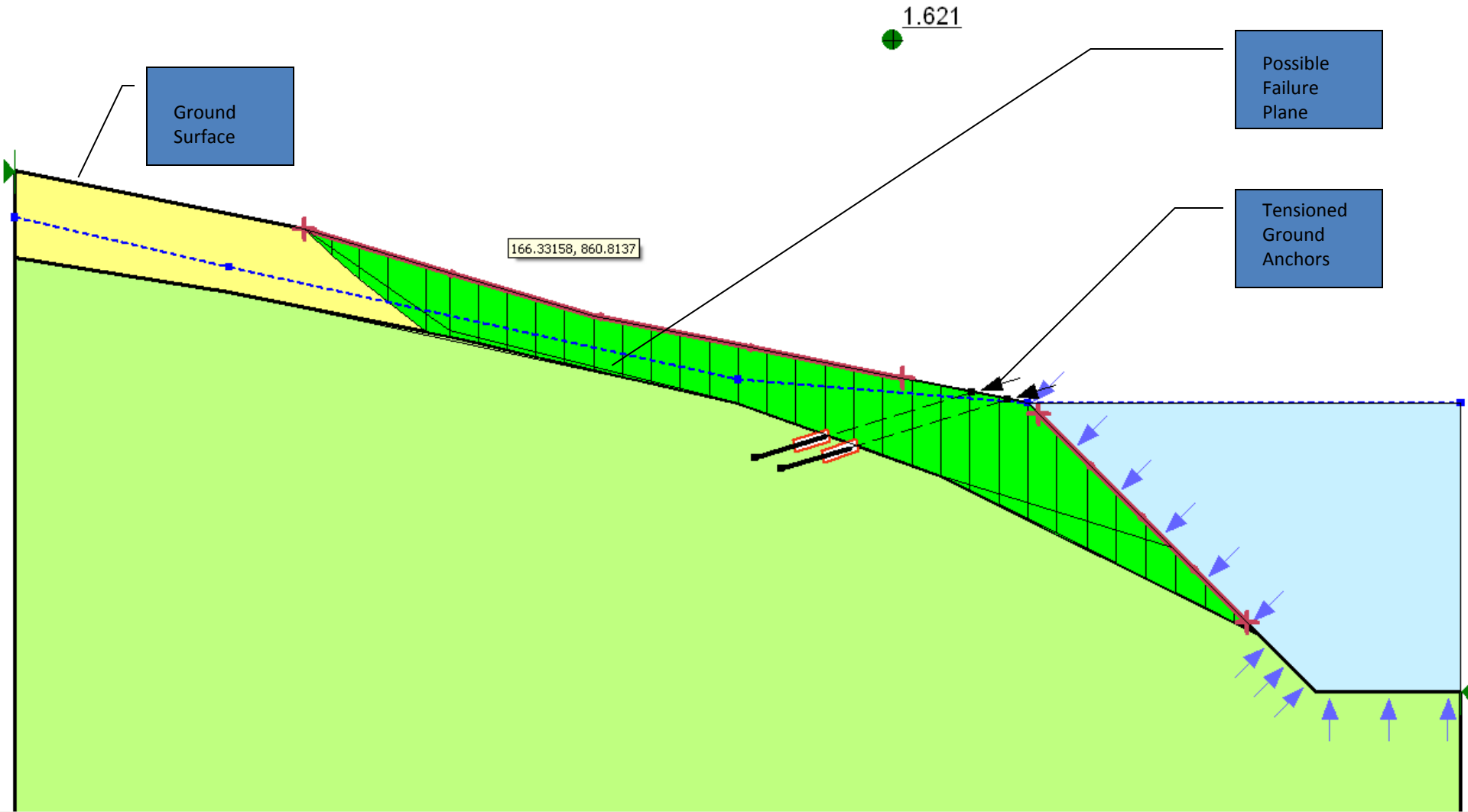




Reticulated/Battered Micropiles



Patterned Ground Anchors



Site 4



SITE 4

Mile Creek
County Park

Lake
Keowee

Oconee Nuclear
Plant

130

130

130

183

188

183

133

137

133

130

133

Site 4

- Site 4 slide was repaired by WEC using battered micropiles with a concrete cap beam and tieback anchors.

Site 4

- Site 4 slide was repaired by WEC using battered micropiles with a concrete cap beam and tieback anchors.
- Site is being monitored with slope inclinometers.

Site 4

- Site 4 slide 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.

Site 4

- Site 4 slide 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.

Site 4

- Site 4 slide 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.

Site 4

- Site 4 slide 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.
- Ground was gently sloping.

Site 4

- Site 4 slide 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.
- Ground was gently sloping.
- Slide encompasses adjacent lot where house was demolished.



01/10/2012 12:26





01/10/2012 11:55



01/10/2012 11:46



01/10/2012 11:37

PLAT 17-1000
SHEET 1 OF 1
NO. 1000
NO. 1000



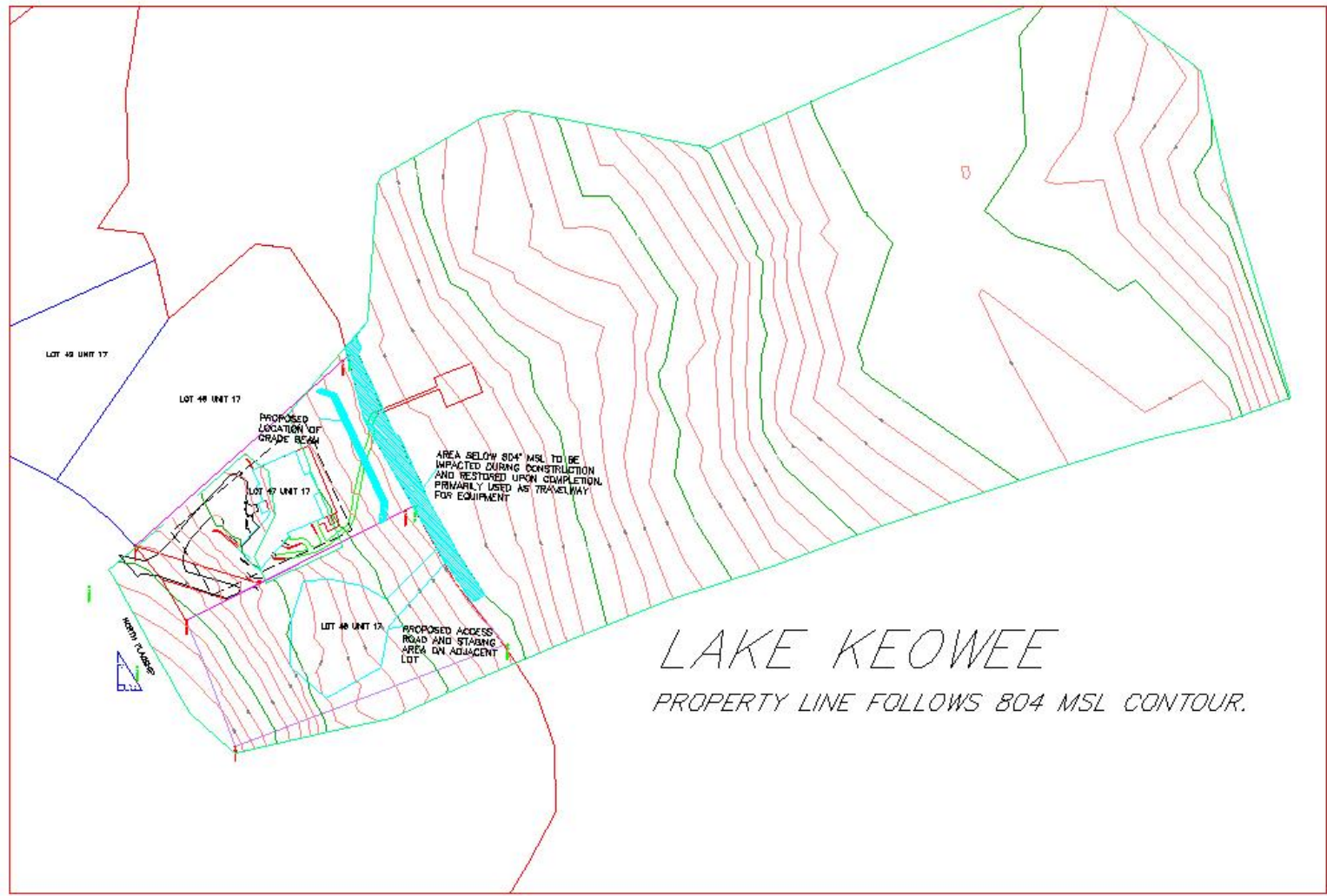
PLAT PREPARED FOR
DOUG CHAPPEL

THIS PLAT IS PREPARED FOR THE CITY OF KEOWEE, MICHIGAN, AND IS SUBJECT TO THE APPROVAL OF THE CITY ENGINEER AND THE STATE ENGINEER. THE CITY ENGINEER'S OFFICE IS LOCATED AT 1000 WEST 17TH AVENUE, KEOWEE, MICHIGAN 49753. THE STATE ENGINEER'S OFFICE IS LOCATED AT 1000 WEST 17TH AVENUE, KEOWEE, MICHIGAN 49753.

PLAT PREPARED FOR
DOUG CHAPPEL

COMMISSIONER OF PUBLIC SAFETY
NO. 10000
STATE OF MICHIGAN
MICHAEL L. EDMUNDSON, P.E. 10000

Recorded this _____ day of _____, 20____
at _____, Michigan, and Certified
Register of Deeds, County of _____



LAKE KEOWEE
PROPERTY LINE FOLLOWS 804 MSL CONTOUR.





FROEHLING & ROBERTSON, INC.

BORING LOG

Boring: B-4 (1 of 1)

Project No: 65M0144

Elevation:

Drilling Method: HSA

Client: Roger Keranen

Total Depth: 41.0'

Hammer Type:

Project: Keranen Residence Distress Evaluation

Boring Location: See Attached Figure 1

Date Drilled:

City/State: Lake Keowee, SC

Driller: Richmond, Va

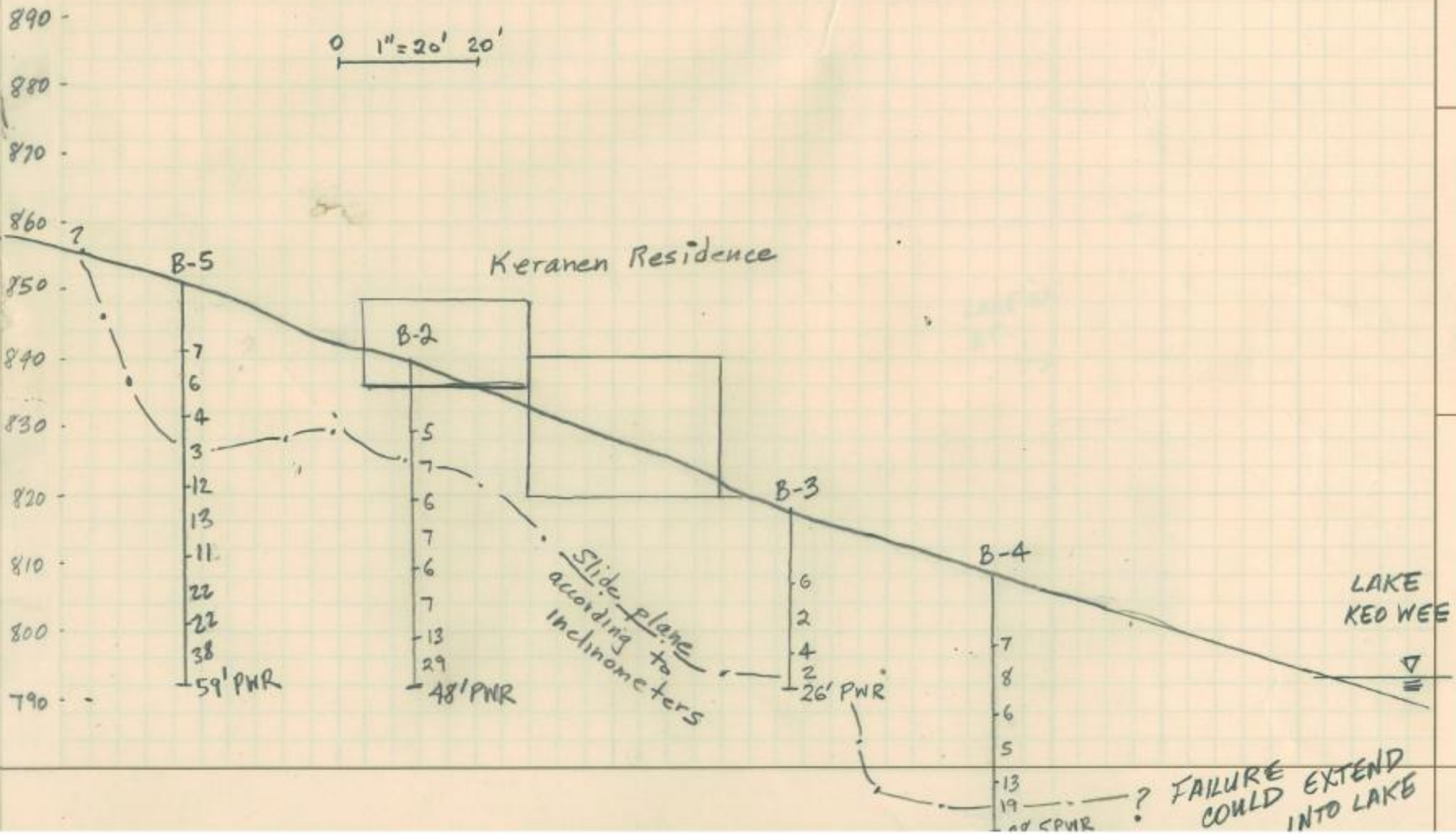
Elevation	Depth	Description of Materials (Classification)	* Sample Blows	Sample Depth (feet)	N-Value (blows/ft)	Remarks
		FILL - Soft to firm, moist, dark red clayey SILT (MH) with little sand	1-2-1	0.0		
			3-3-3	1.5	3	
			WOH-2-2	3.0	6	
	4.0	APPARENT RESIDUAL - Firm, moist, dark reddish brown clayey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

BORING LOG 65M0144 - KERANEN RESIDENCE.GPJ F&R.GDT 11/8/11

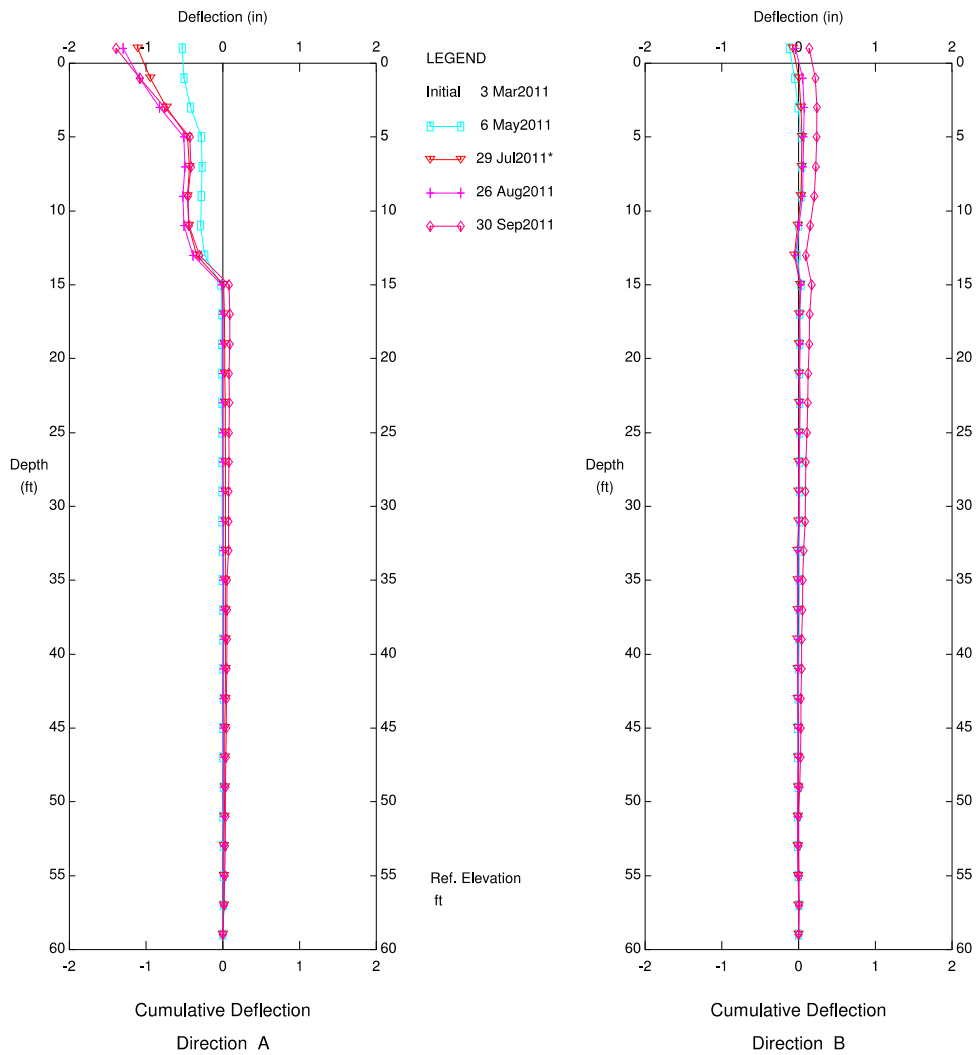
*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.

TCS

0 1" = 20' 20'



Froehling & Robertson - Sterling, VA

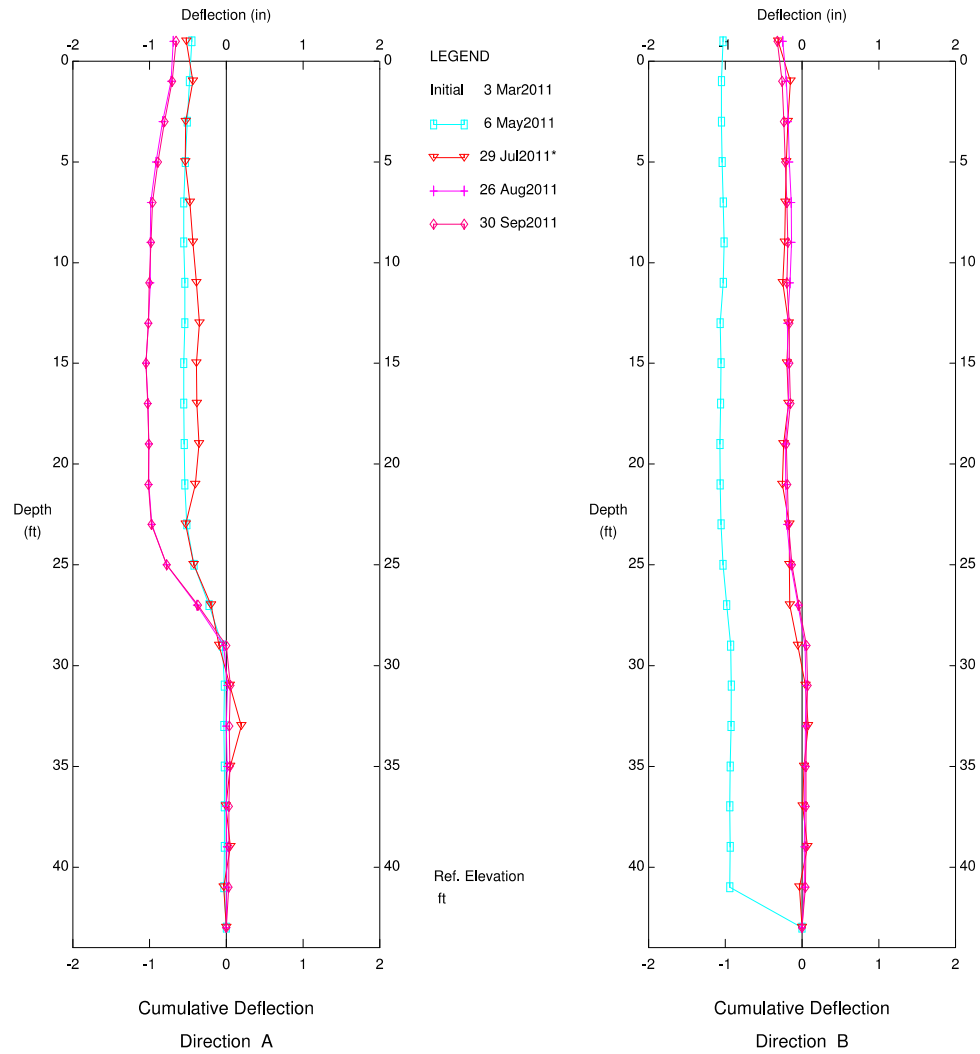


Keranen Residence, Inclinator K-2

Roger Keranen

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

Froehling & Robertson - Sterling, VA

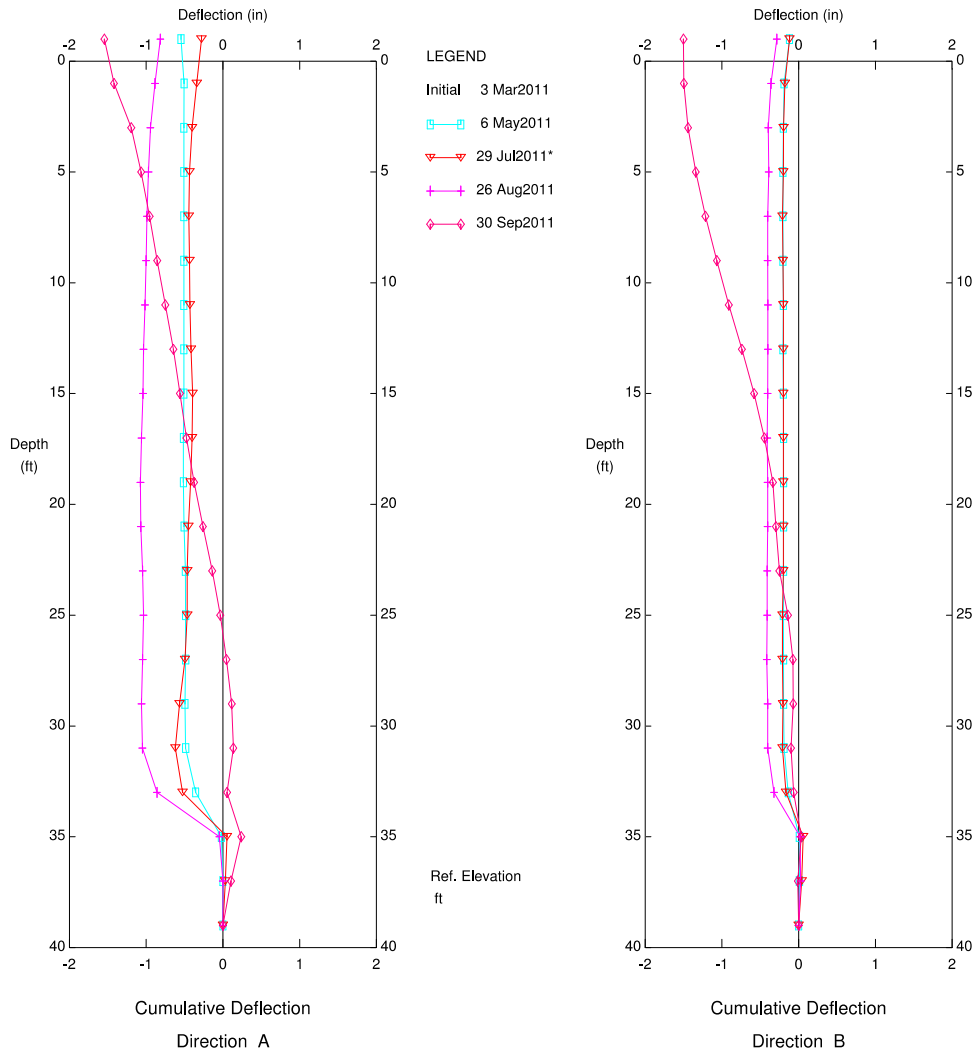


Keranen Residence, Inclinator K-3

Roger Keranen

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

Froehling & Robertson - Sterling, VA

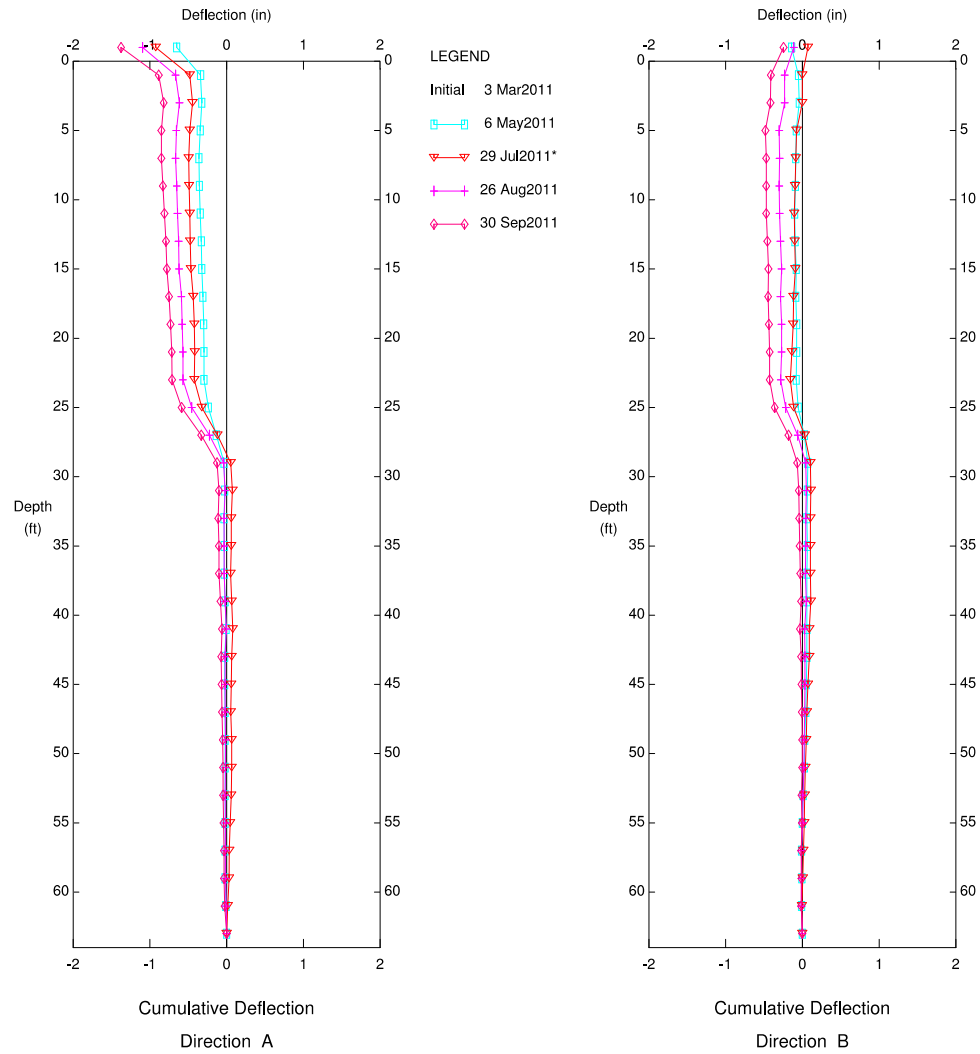


Keranen Residence, Inclinator K-4

Roger Keranen

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

Froehling & Robertson - Sterling, VA



Keranen Residence, Inclinator K-5

Roger Keranen

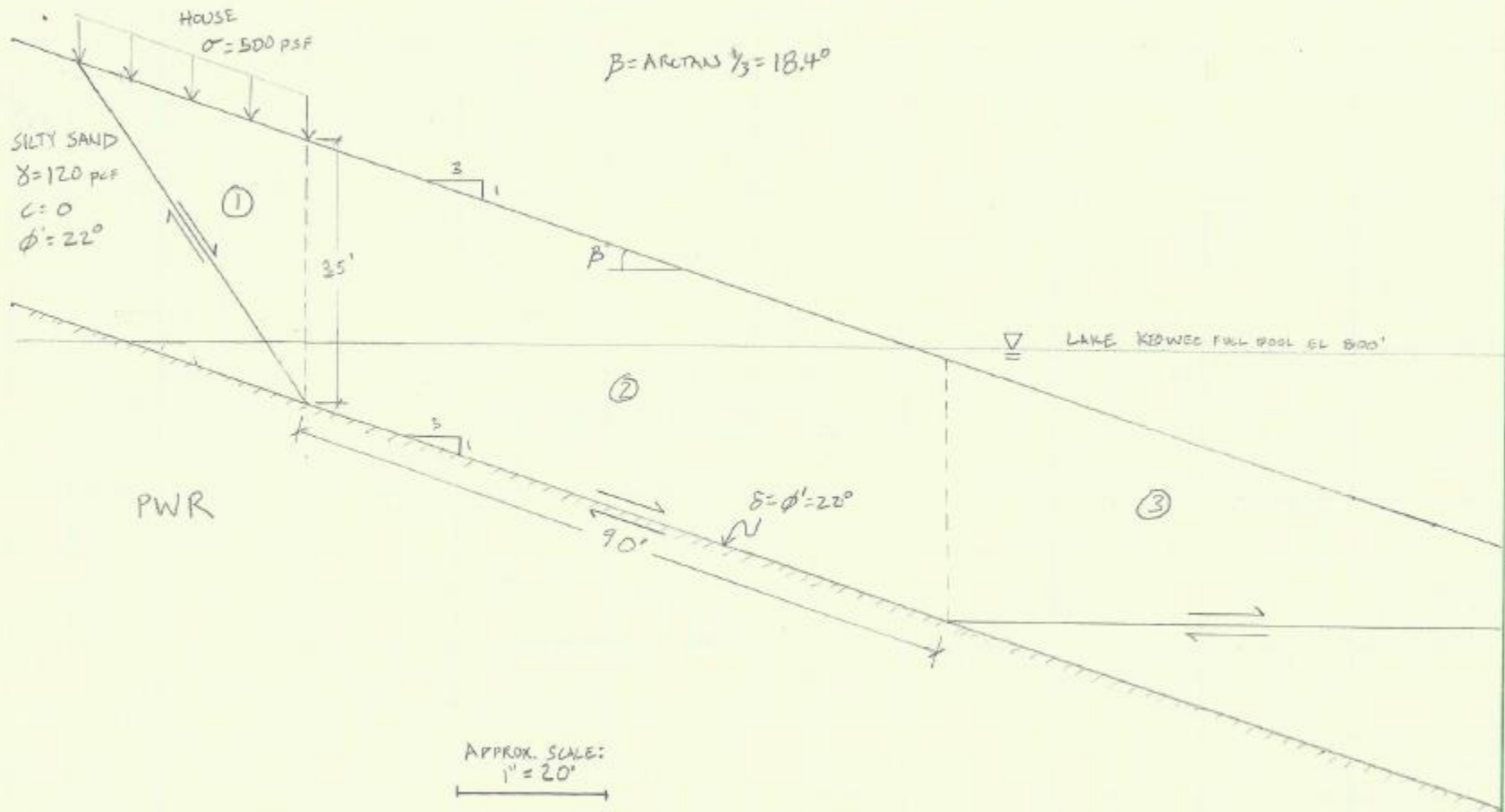
Sets marked * include zero shift and/or rotation corrections.

11-0110
KIRANBAI RES.

SKETCH FOR HAND CALC.
BLOCK STABILITY ANALYSIS

DY: DSG
DATE: 1/5/2012

checked by: TCS



W_x

$$W_x = W \sin \beta = 298.6 \sin 15.4^\circ$$

$$W_x = 78.5 \text{ k/ft}$$

 F

$$F = N \tan \phi' = 235.9 \text{ k/ft} \tan 22^\circ$$

$$F = 95.3 \text{ k/ft}$$

FS WITH HOUSE LOAD

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

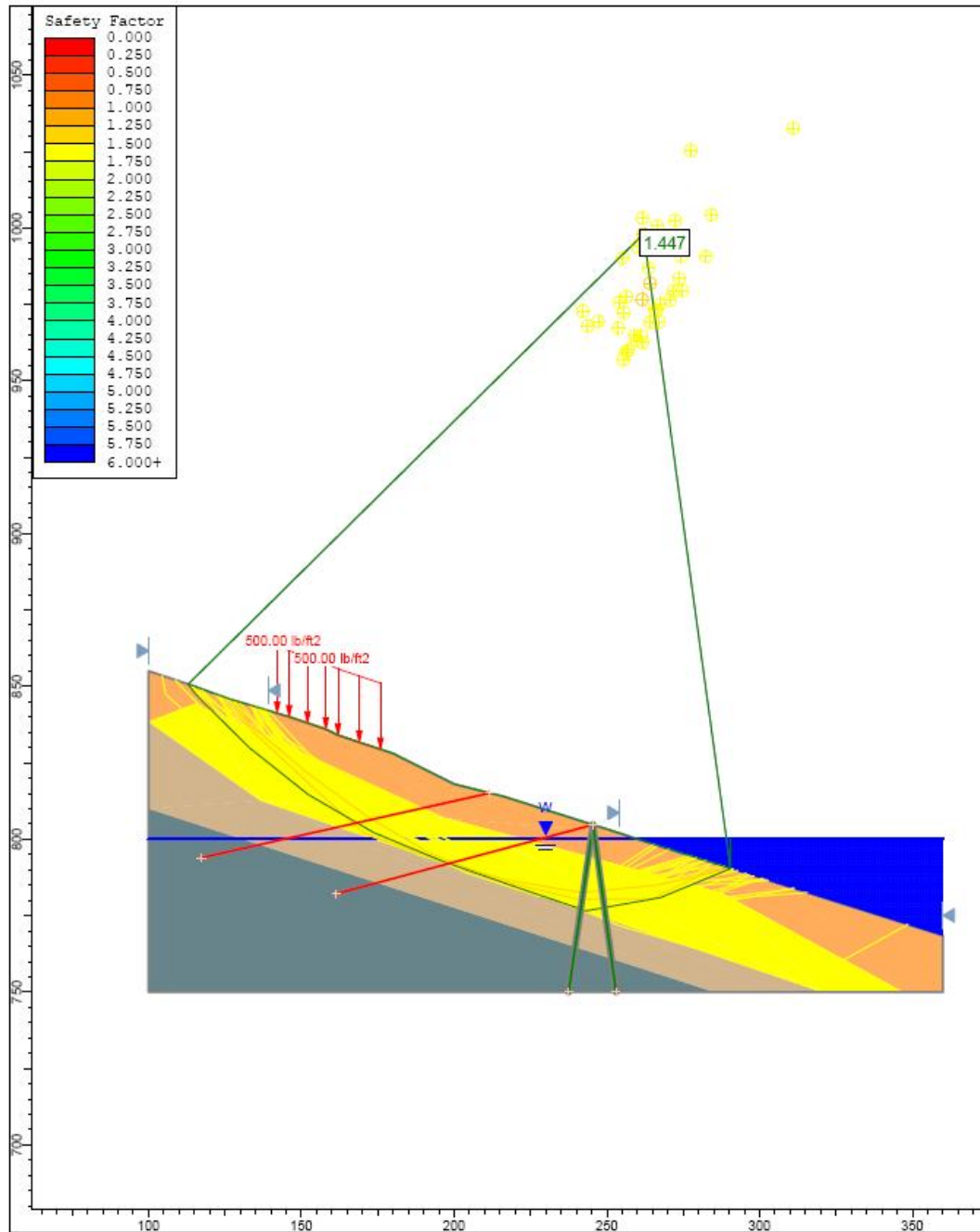
$$FS = 1.00$$

FS WITHOUT HOUSE LOAD

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

$$FS = 1.09$$

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.







1170

High Pressure
Air Rentals

03/19/2012 14:54



03/19/2012 15:23



03/19/2012 15:00

















05/10/2012 12:18



05/10/2012 12:24

Conclusions/Additional Questions

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Conclusions/Additional Questions

- Does geology have anything to do with location of slides?
- What effect does the lake have on these slides?
- Apparent similarities between these slides?
- Could the susceptibility of these sites to landslide movement be assessed?

