Monitoring and Characterization of the Meadowview Lane Landslide: Boyd County, KY

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Appalachian Coalition for Geologic Hazards in Transportation

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UK
UNIVERSITY OF KENTUCKY
Kentucky Geological Survey

Outline

- Kentucky's landslides
- Meadowview Lane Landslide
  - Geology
  - Slide history
  - Objectives
  - Methodology
- Preliminary results
  - Boring logs/geotechnical data
  - Rainfall and groundwater
  - Slope movement
- Geophysics: Electrical resistivity
  - Surface
  - Borehole
- Geotechnical-Geophysical correlation
- Communicating with the geotechnical community

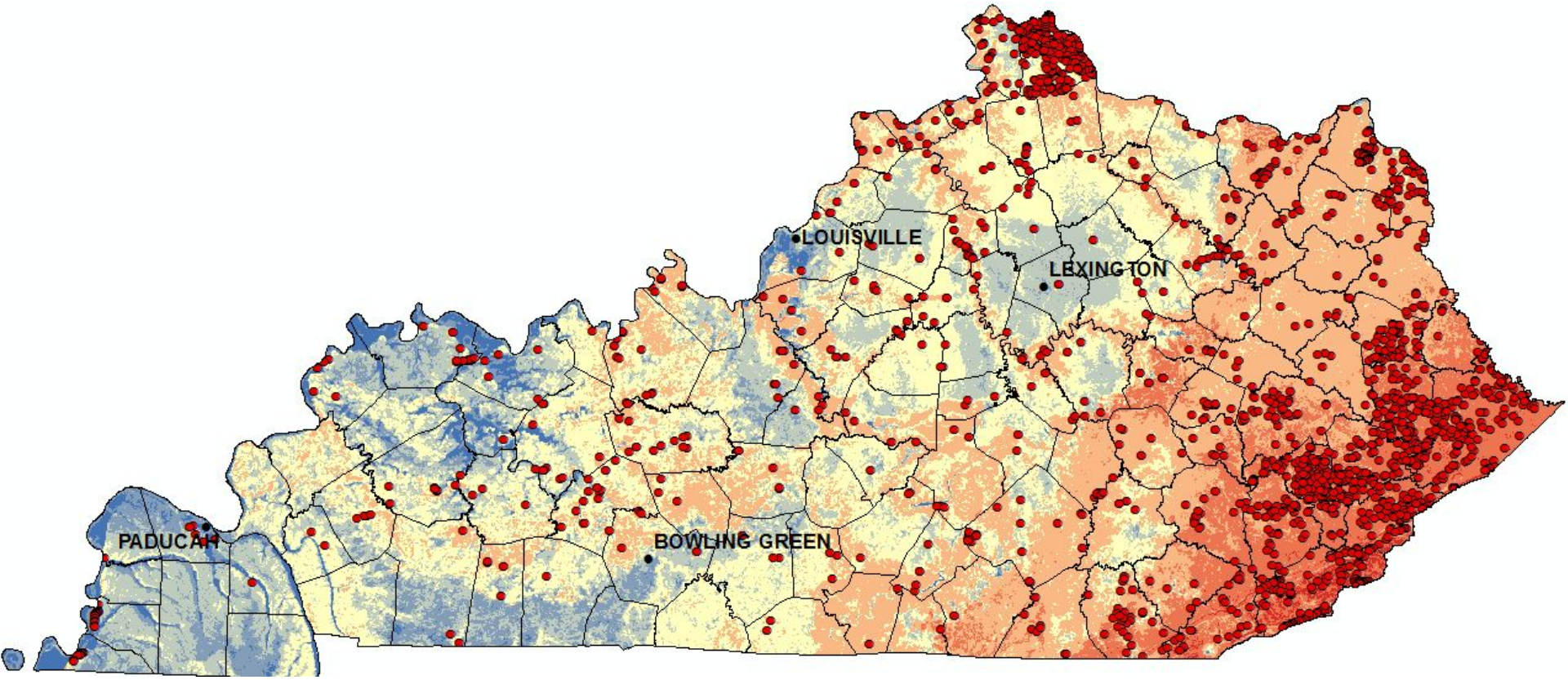
Acknowledgements

- Kentucky Geological Survey
- Francis Ashland – U.S. Geological Survey
- Chris Yohe and James Martin – Terracon, Lexington
- Junfung Zhu, Steve Webb, and Max Hammond – KGS

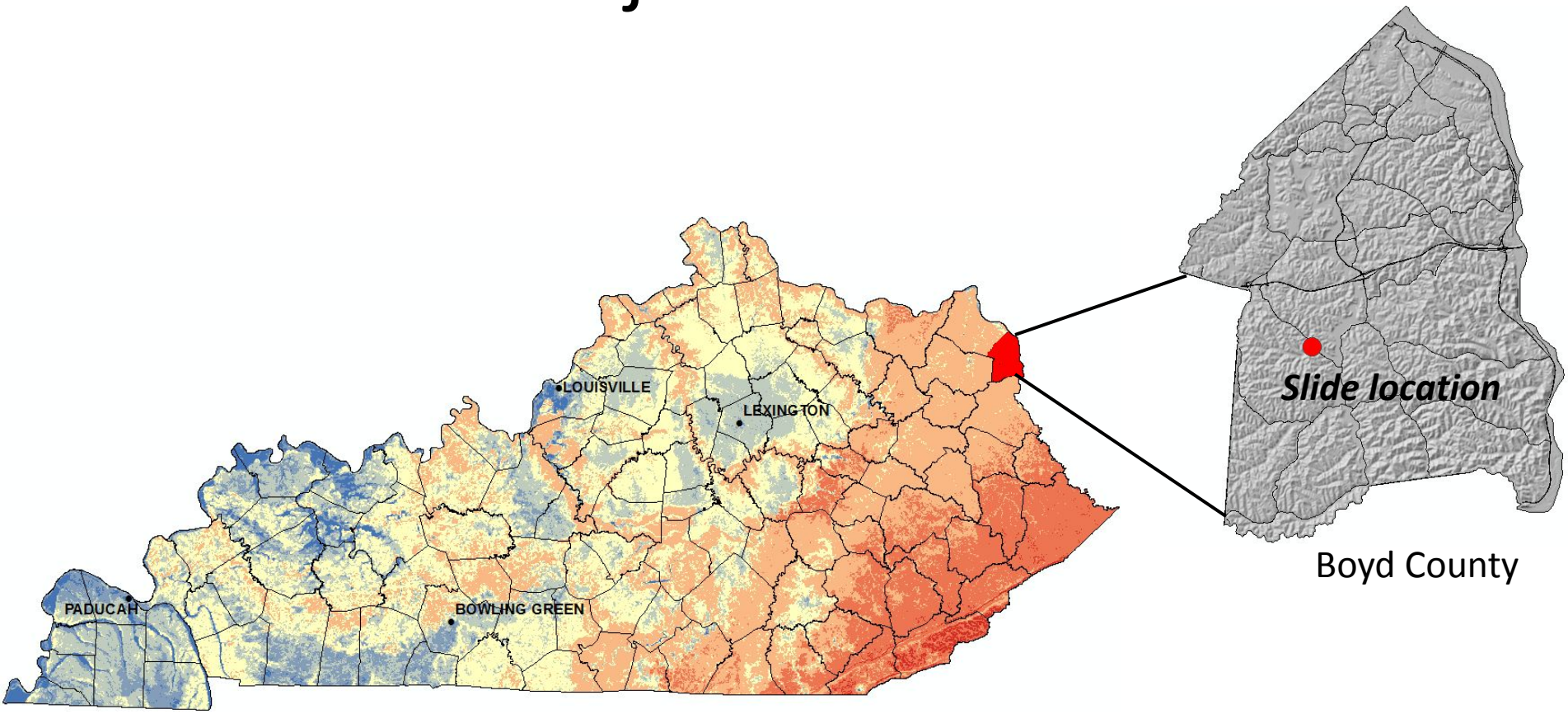
Kentucky Landslides

- 843 KYTC landslide geotech reports (1973-2013, unknown **$**)
- 2008-2009 KYTC spent $6.6 million on landslide and rockfall repair
- April-May 2011 storms caused ~50 slides, cost KYTC District 6 over $4 million
- KYEM-FEMA landslide mitigation projects ~ $5.3 million

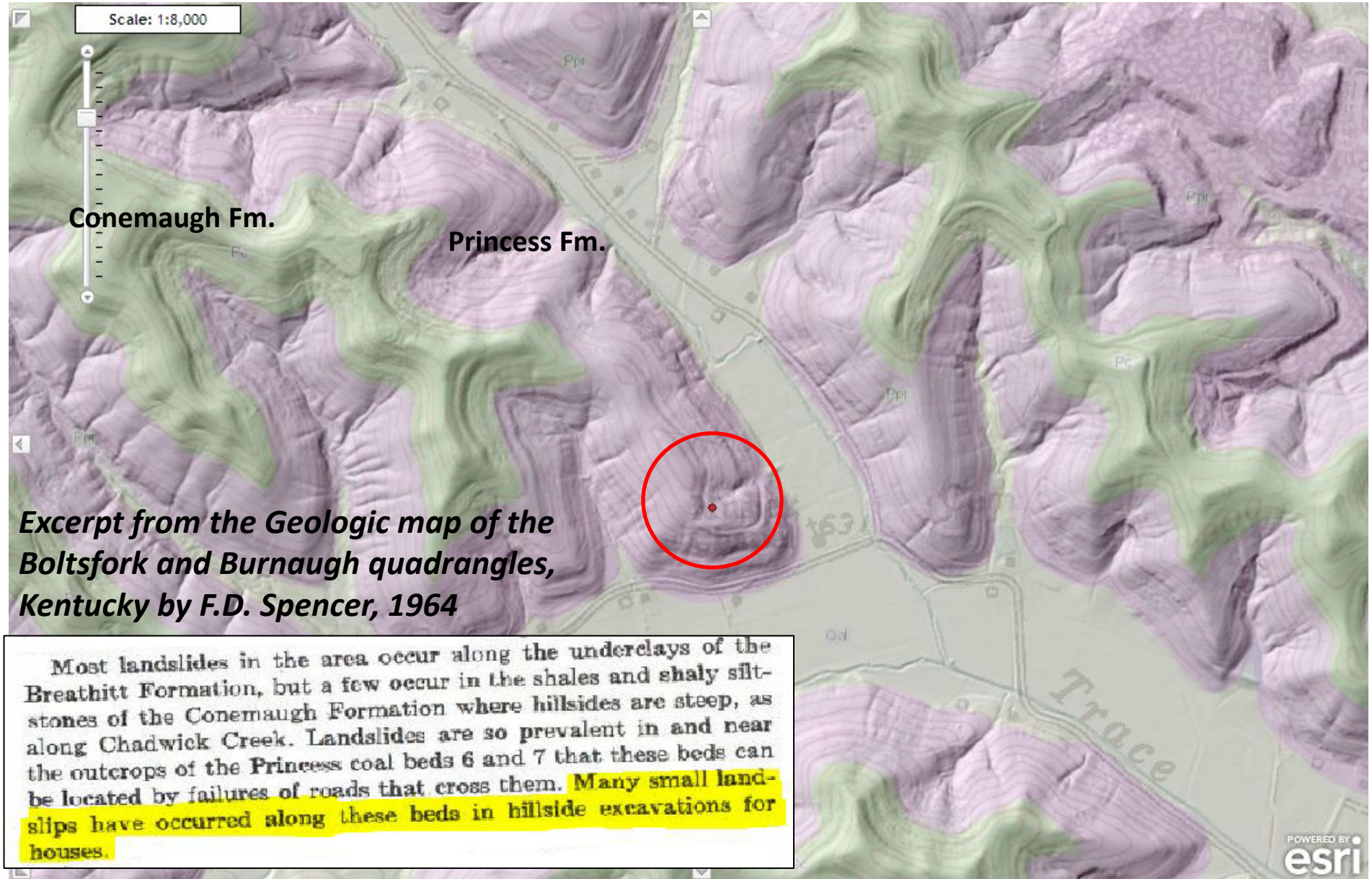
Landslide Inventory



Meadowview Lane Landslide: Project Location



Geology



Excerpt from the Geologic map of the Boltsfork and Burnaugh quadrangles, Kentucky by F.D. Spencer, 1964

Most landslides in the area occur along the underclays of the Breathitt Formation, but a few occur in the shales and shaly siltstones of the Conemaugh Formation where hillsides are steep, as along Chadwick Creek. Landslides are so prevalent in and near the outcrops of the Princess coal beds 6 and 7 that these beds can be located by failures of roads that cross them. Many small landslips have occurred along these beds in hillside excavations for houses.


MeadowView Ln
MeadowView Ln
MeadowView Ln
MeadowView Ln

Landslide Background

Trigger and Causes – Slide failed late April 2011. The Lawrence County precipitation monitoring station run by the Kentucky Mesonet measured over 8 inches of rain in April 2011. Causes are a complex interaction between bedrock, clayey colluvium, steep slopes, excess water, and slope modification.

Type – Shallow, roto-translational slide (upper rotation morphing into translational flow)

Material – Mixture of disturbed colluvial soil and bedrock derived from excavation of house and natural colluvial soils covering hillside.

Dimensions –

Width of displaced mass = ~220 ft

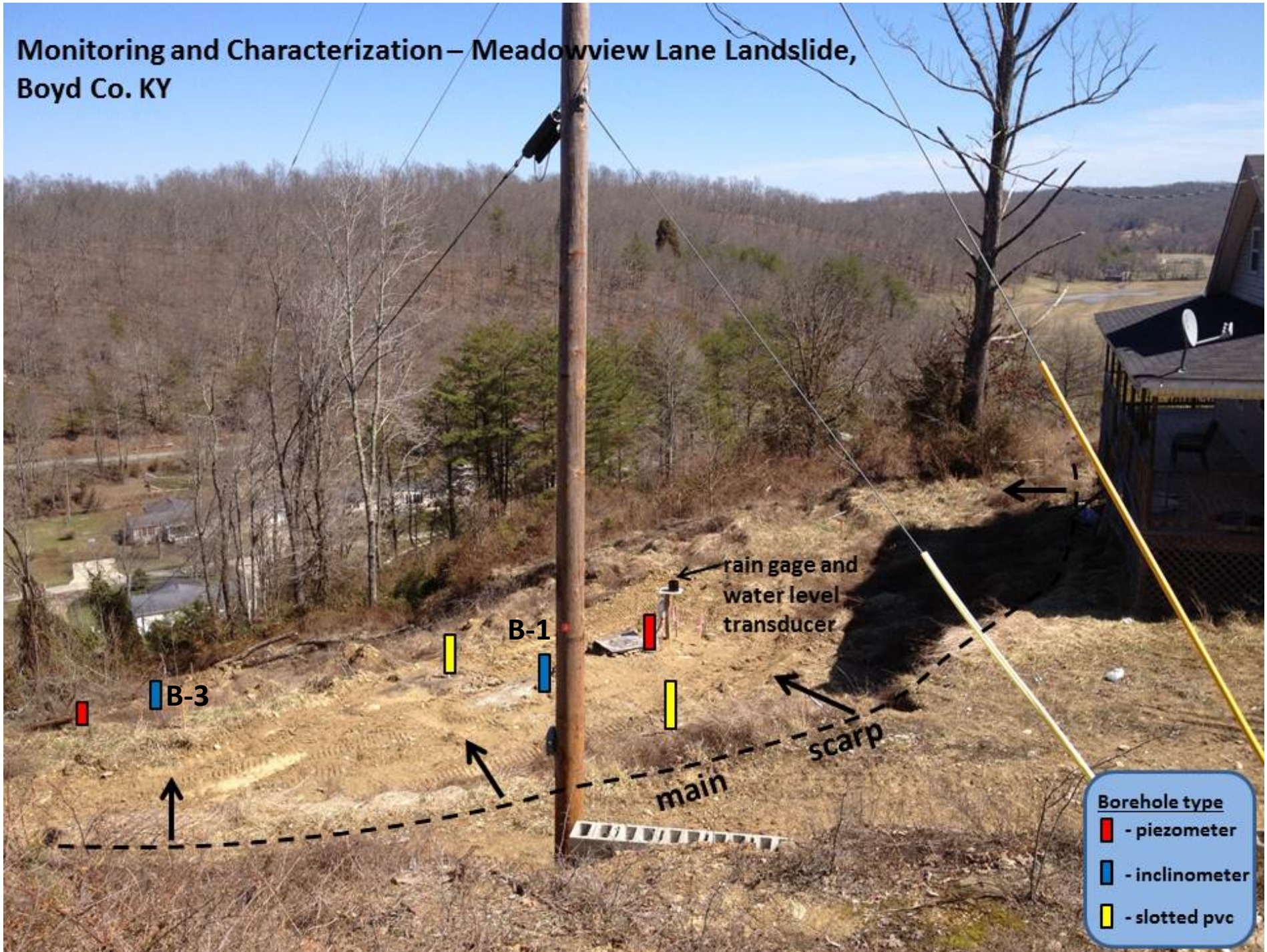
Length of displaced mass = ~140 ft

Project Objectives

- Determination of depth, shape, and velocity of the sliding mass
- Monitor groundwater conditions
- Correlate movement with increase in rainfall and pore pressures
- Measure electrical resistivity of the slide material to correlate with subsurface data
- Monitor site for approx. 1 year

Methodology

- Reconnaissance – geology, soils, aerial imagery, slope history
- Total Station monitoring (surface movement)
- Groundwater – 2 Standpipe piezometers
- Movement – 2 slope inclinometer boreholes
- Rain gage installation
- Surface and borehole electrical resistivity
- Geotechnical lab analysis – material index properties, Atterberg tests, and CU Triaxial shear tests


Monitoring and Characterization – Meadowview Lane Landslide, Boyd Co. KY
rain gage and water level transducer
B-1
B-3
scarp
main
Borehole type
- piezometer
- inclinometer
- slotted pvc

Preliminary Results: Boring Logs

BORING LOG NO. B-1

Page 1 of 1

PROJECT: Meadowview Lane Landslide

CLIENT: Kentucky Geologic Survey, Lexington, KY

SITE: Boyd County, Rush, Kentucky

LOCATION: See Exhibit A-2

Depth (ft)	Description	Recovery (in.)	Field Test Results	RQD %	Laboratory Torvane/HP (psf)	Strength Test: Test Type	Compressive Strength (psf)	Strain (%)	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits LL-PL-PI
0	**FILL - SANDY LEAN CLAY WITH GRAVEL (CL)**, light brown to orange and reddish brown, soft to medium stiff, sandstone fragments, shale fragments, some organics	9	2-3-2 N=5						12		
		8	2-2-2 N=4						14		36-20-16
4.0	**FILL - SANDY FAT CLAY (CH)**, with some cobbles and gravel, light brown, soft to medium stiff	9	0-1-42 N=43		2000 (HP)				21		
5		9	1-8-4 N=12						26		
		12	5-2-3 N=5						19		
9.0		9	2-2-2 N=4						32		
10	**FAT CLAY (CH)**, light gray, very stiff to hard, residual soil structure	12	3-8-10 N=18		4500 (HP)				15		
11.0	**CLAYSTONE**, light gray, completely to severely weathered, very soft, soil-like	18	3-18-32 N=50						8		37-21-16
13.5		10	38-50/6" N=50/6"						5		
	CLAYEY SHALE, light gray with some orange and reddish-brown, thinly laminated to laminated, completely weathered, very soft, trace thinly laminated interbedded sandy shale	12	35-45-50/5" N=50/5"						12		
15		6	37-50/4" N=50/4"						10		
20		51		13							
21.5	***Boring Terminated at 21.5 Feet***										
25											

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method: 3.25" Hollow Stem Auger and NQ2 Coring

Abandonment Method:

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes: Boring converted to inclinometer, fully grouted from surface to 21.5' depth

WATER LEVEL OBSERVATIONS

4' While Drilling

Terracon

Boring Started: 3/13/2013 | Boring Completed: 3/13/2013

Drill Rig: | Driller: CSD

Project No.: N2135021 | Exhibit: A-3

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT GEO_LOG-DEPTH TO BOTTOM OF PAGE N2135021_BORINGS.GPJ TERRACON.2012.GDT 4/29/13

BORING LOG NO. B-3

Page 1 of 1

PROJECT: Meadowview Lane Landslide

CLIENT: Kentucky Geologic Survey, Lexington, KY

SITE: Boyd County, Rush, Kentucky

LOCATION: See Exhibit A-2

Depth (ft)	Description	Recovery (in.)	Field Test Results	RQD %	Laboratory Torvane/HP (psf)	Strength Test: Test Type	Compressive Strength (psf)	Strain (%)	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits LL-PL-PI
0	**FILL - SANDY LEAN CLAY WITH GRAVEL (CL)**, light brown and olive-brown, medium stiff, micaceous sandstone fragments	13	2-4-4 N=8		1500 (HP)				17		
2.0	**LEAN CLAY (CL)**, trace sand, brown to dark brown, stiff to very stiff, residual soil structure	14	3-5-6 N=11						16		
		13	4-5-7 N=12						13		27-19-8
5		15	9-7-17 N=24						11		
6.0	**CLAYEY SHALE**, olive-gray to dark gray, thinly laminated to very thinly bedded, highly weathered, very soft to soft	14	27-38-50/5" N=50/5"						6		29-20-9
		6	50/6" N=50/6"						7		
		5	50/5" N=50/5"								
10		23		7							
15.0											
15.5	**SHALE**, carbonaceous, black, thinly laminated, highly weathered, soft										
	Boring Terminated at 15.5 Feet										
15											
20											
25											

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method: 3.25" Hollow Stem Auger

Abandonment Method:

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes: Boring converted to inclinometer, fully grouted from surface to 15.5' depth

WATER LEVEL OBSERVATIONS

Water level not determined

Terracon

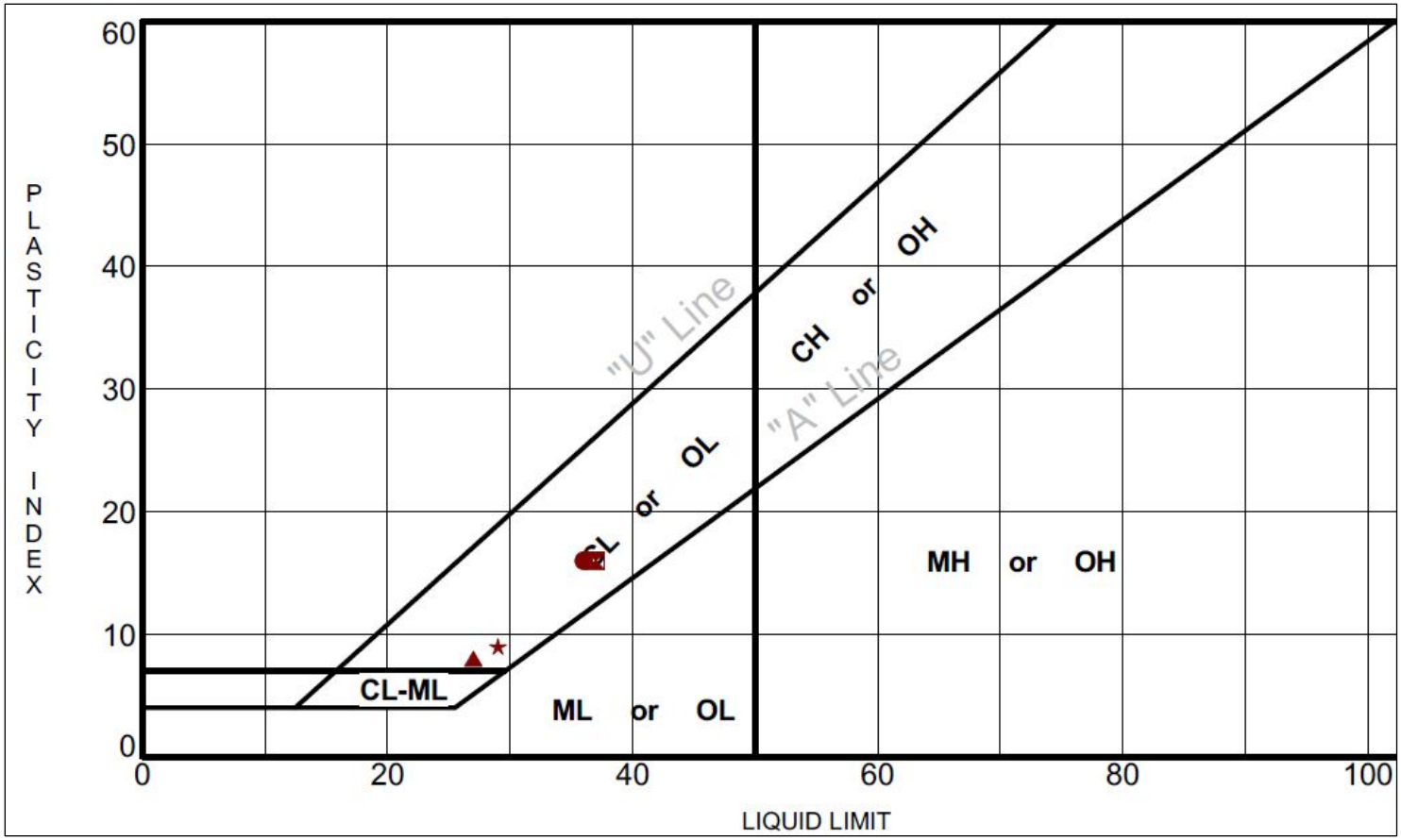
Boring Started: 3/16/2013 | Boring Completed: 3/16/2013

Drill Rig: | Driller: CSD

Project No.: N2135021 | Exhibit: A-5

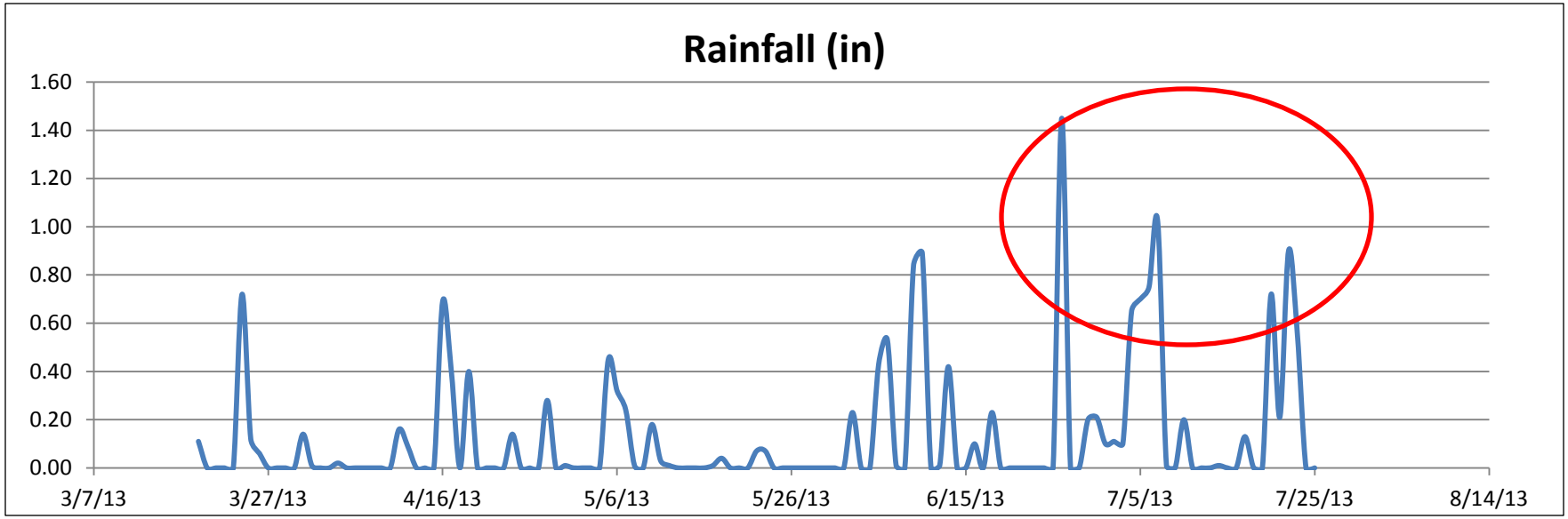
THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT GEO_LOG-DEPTH TO BOTTOM OF PAGE N2135021_BORINGS.GPJ TERRACON.2012.GDT 4/29/13

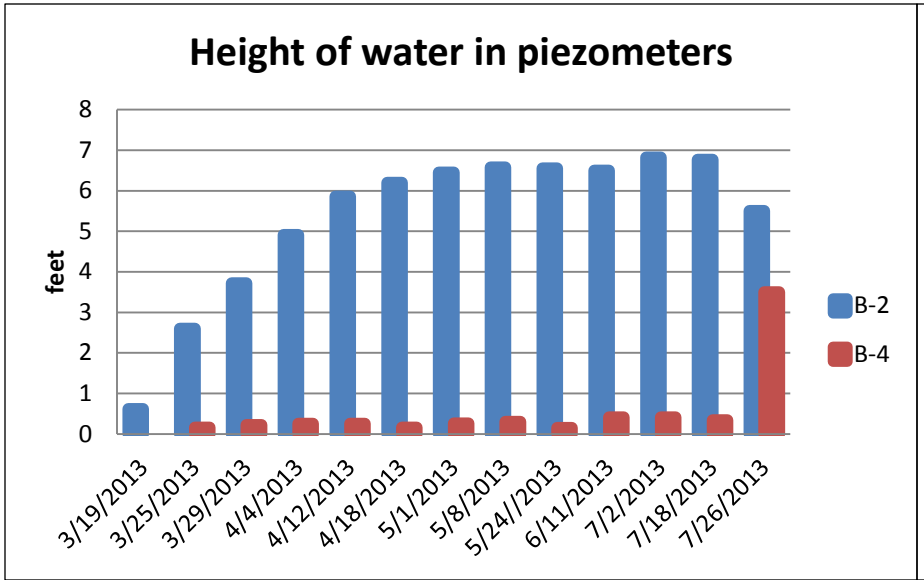
Geotechnical Data

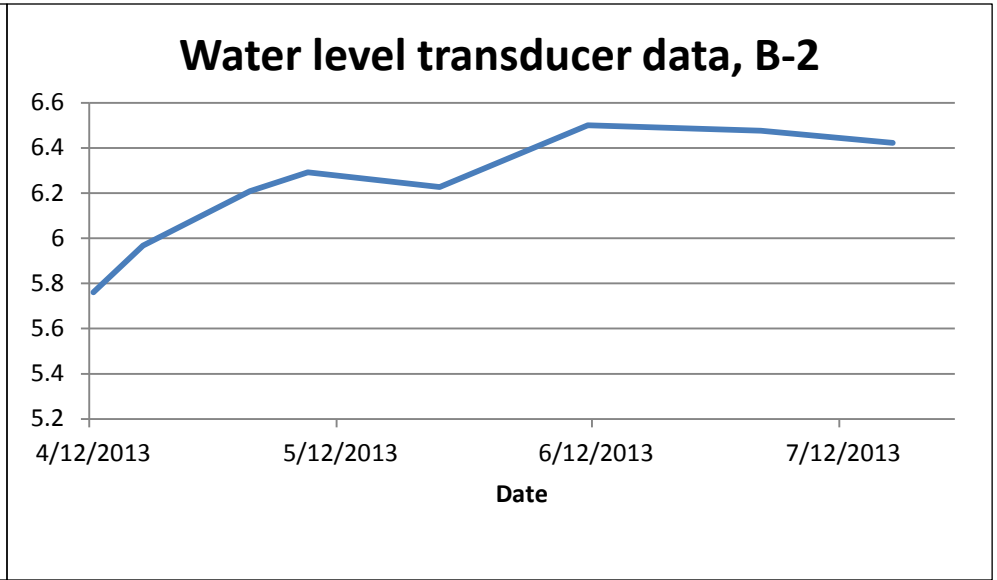


Effective stress parameters : CU with pore pressure
Sample from B-2, 4.5-6.5 ft., gray clay with weathered shale
$\phi' = 36.6^{o}$ $c' = 144psf$

Rainfall and Groundwater Measurements





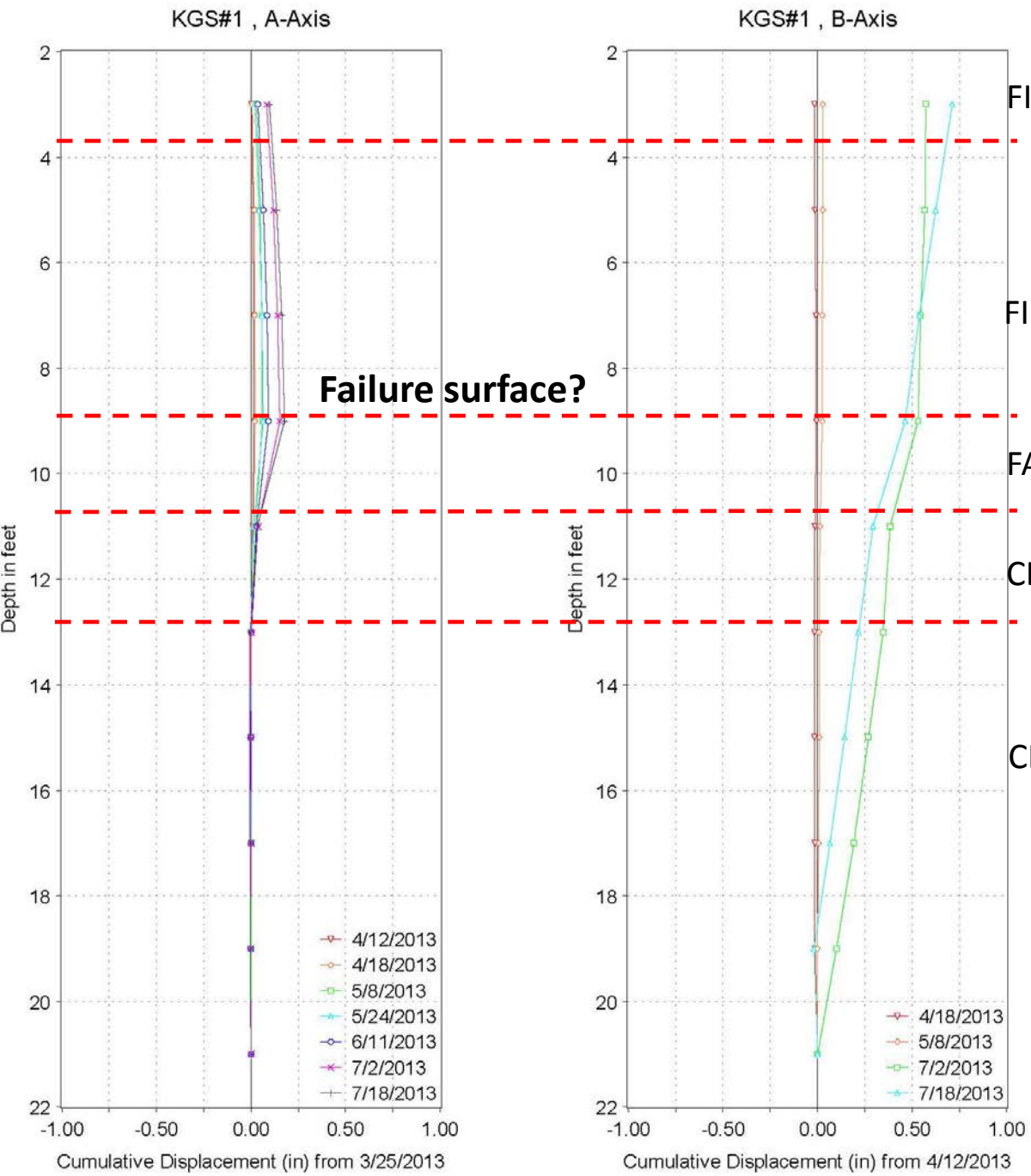


Inclinometer Data

- Biaxial probe – two perp accelerometers

- Readings spaced once a week for2 months, bi-weekly for 2 months, now monthly

B-1 (near scarp) cumulative



FILL - SANDY LEAN CLAY W/GRAVEL

FILL - SANDY FAT CLAY N=4

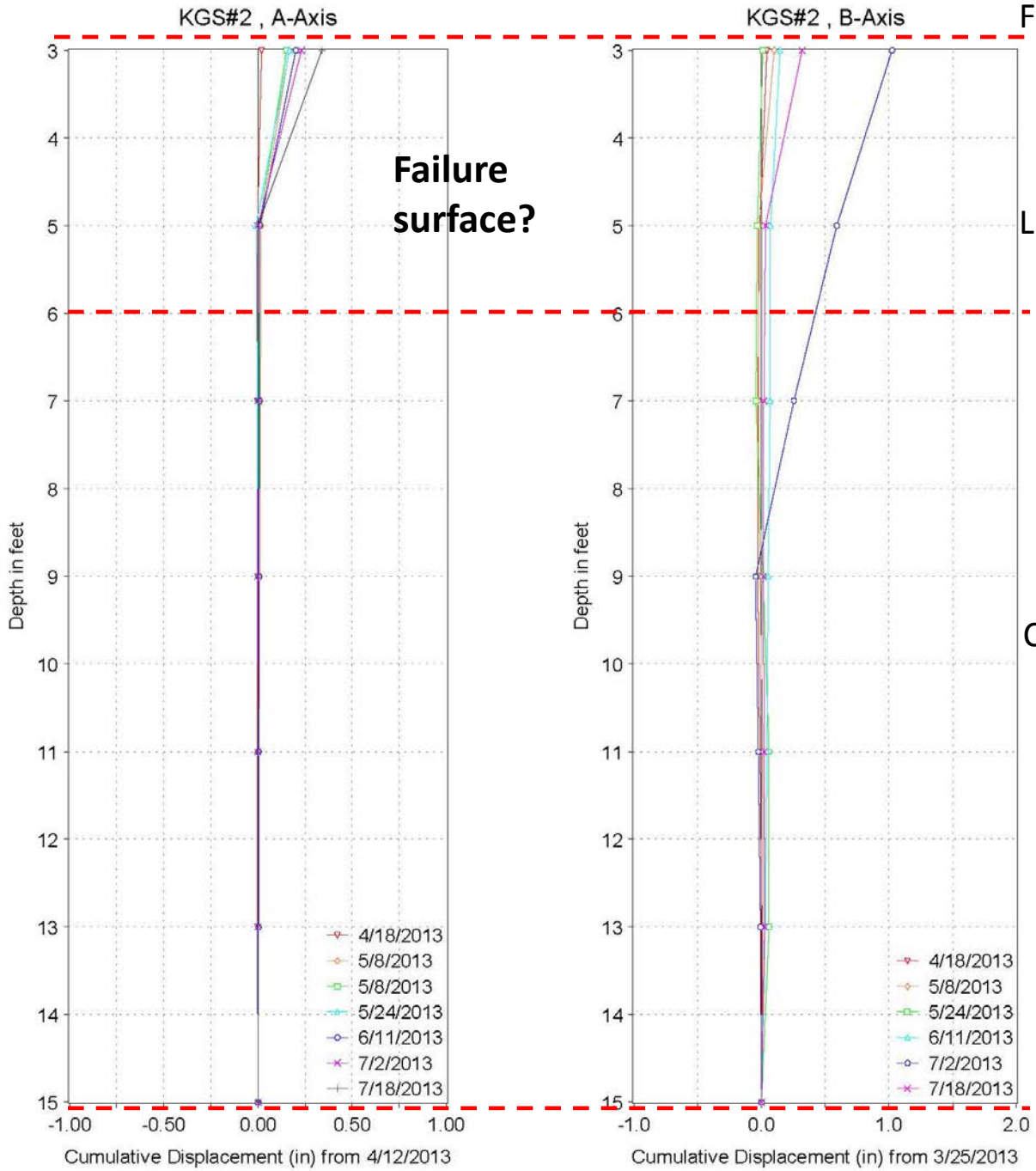
FAT CLAY (stiff) N=18

CLAYSTONE (weathered, soft)

CLAY SHALE (soft)

B-axis lines indicates horiz. directional movement. Recent measurements reflect increased rainfall and complex flow near toe of slide.

B-3 (near toe) cumulative

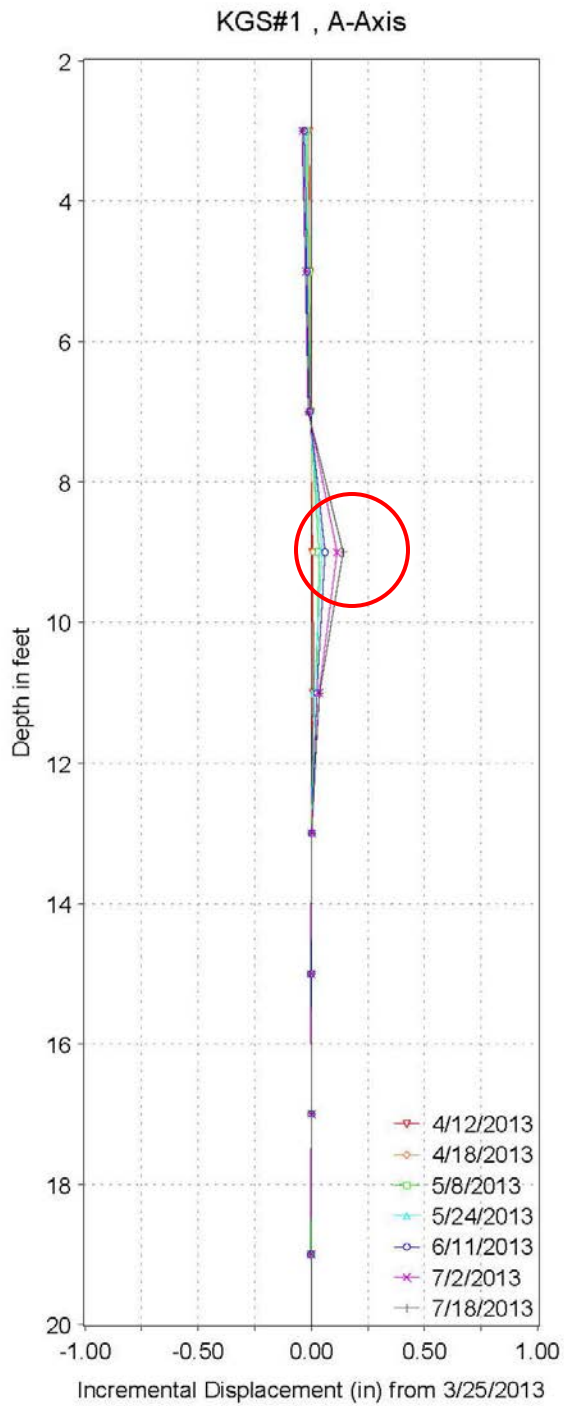


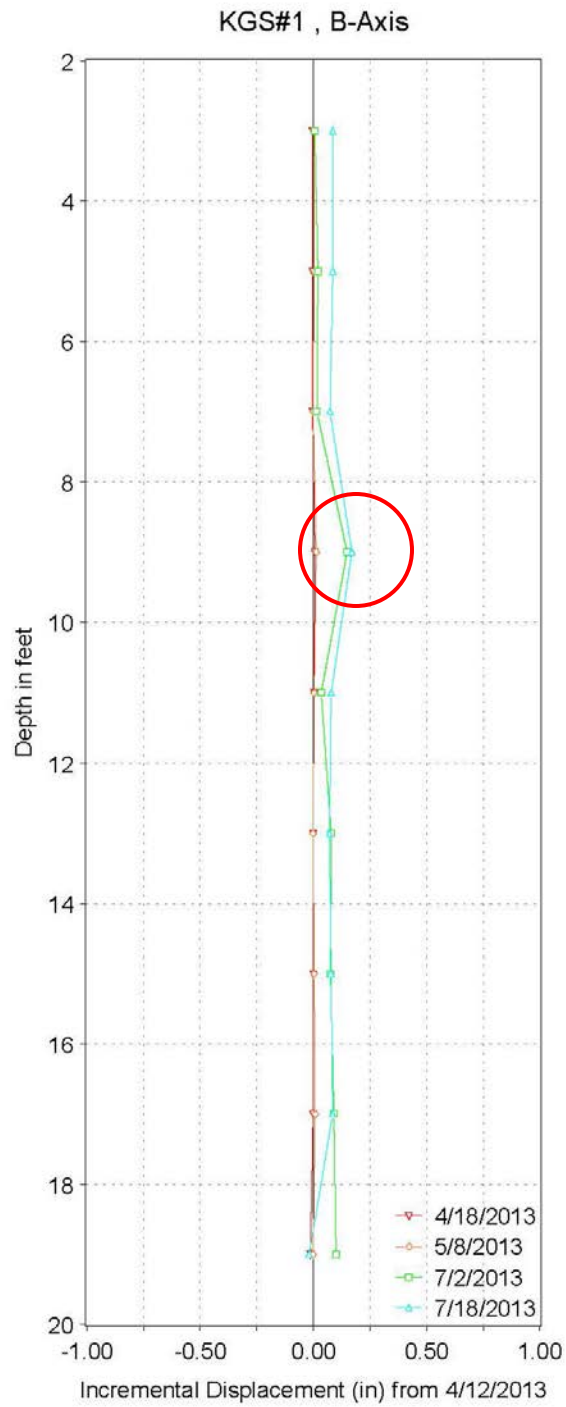
FILL - SANDY LEAN CLAY W/GRAVEL

LEAN CLAY (CL), stiff

CLAYEY SHALE (soft)

B-1 (near scarp) incremental





Slight increase in movement measured 7/2 and 7/18

Movement Summary

- Slow-moving, shallow landslide
- Complex hydrogeologic regimes including porous colluvial fill on top of impermeable clay shales creating perched water. This slide holds a lot of water!
- Potential failure location approximately 3 m below the surface coinciding with a sandy-clay colluvial fill and stiff clay interface.
- Rainfall collected to-date totals 16.5 in (419mm)
- Cumulative displacement to-date is approximately .25 inches in B-1 (near head scarp) and .30 inches in B-3 (toe)
- Slight acceleration recently correlates to a wet July and series of rain events
- Continued monitoring will reveal more correlations

Geophysics: Electrical Resistivity

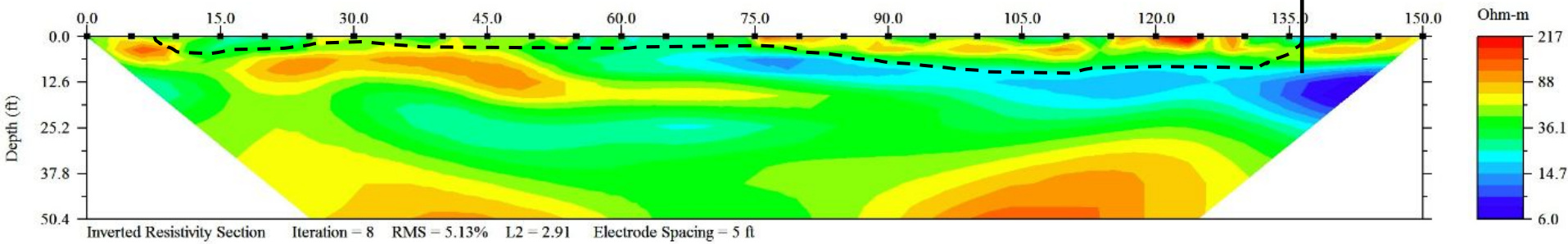
AGI Supersting 8-channel resistivity meter

Surface ERT Image Profiles

Dipole-dipole arrays, 5 ft electrode spacing

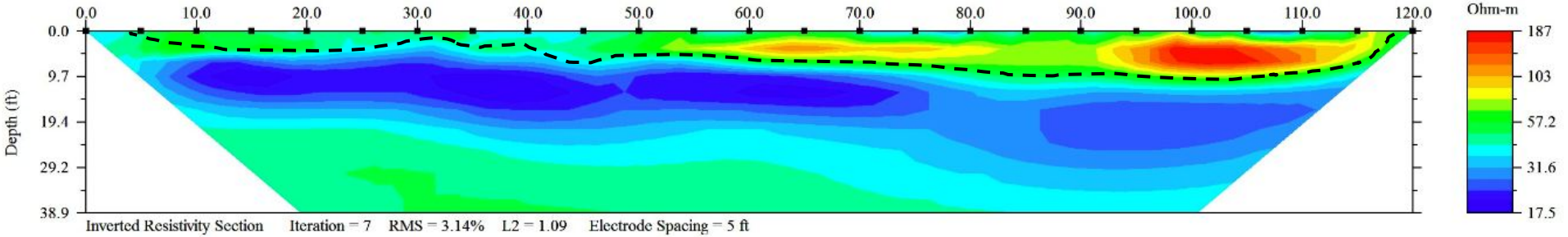
Head scarp?

toe



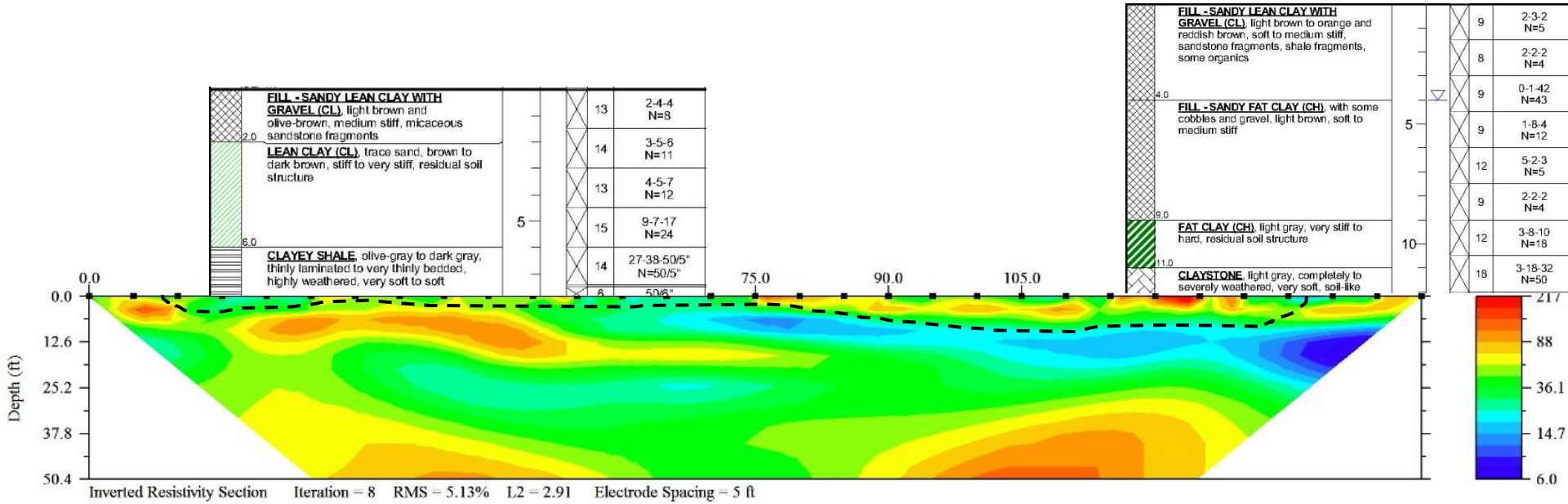
Parallel to slope

SE **NW**



Perpendicular to slope, near head scarp

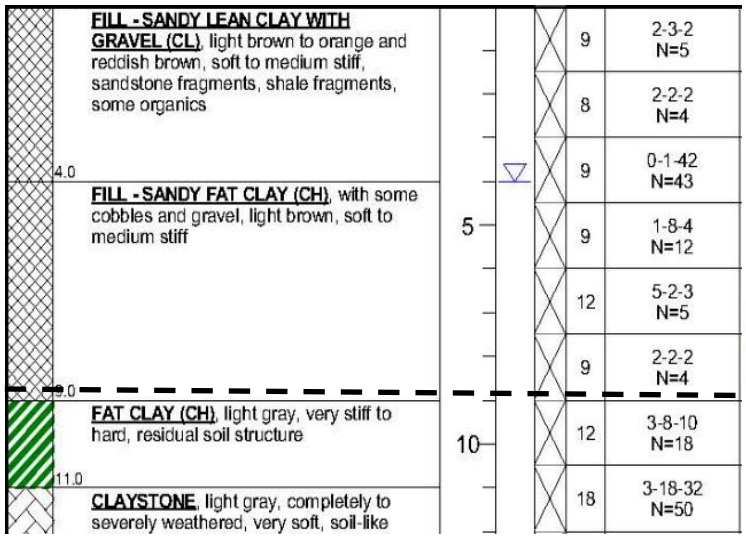
Surface ERT Image Profiles

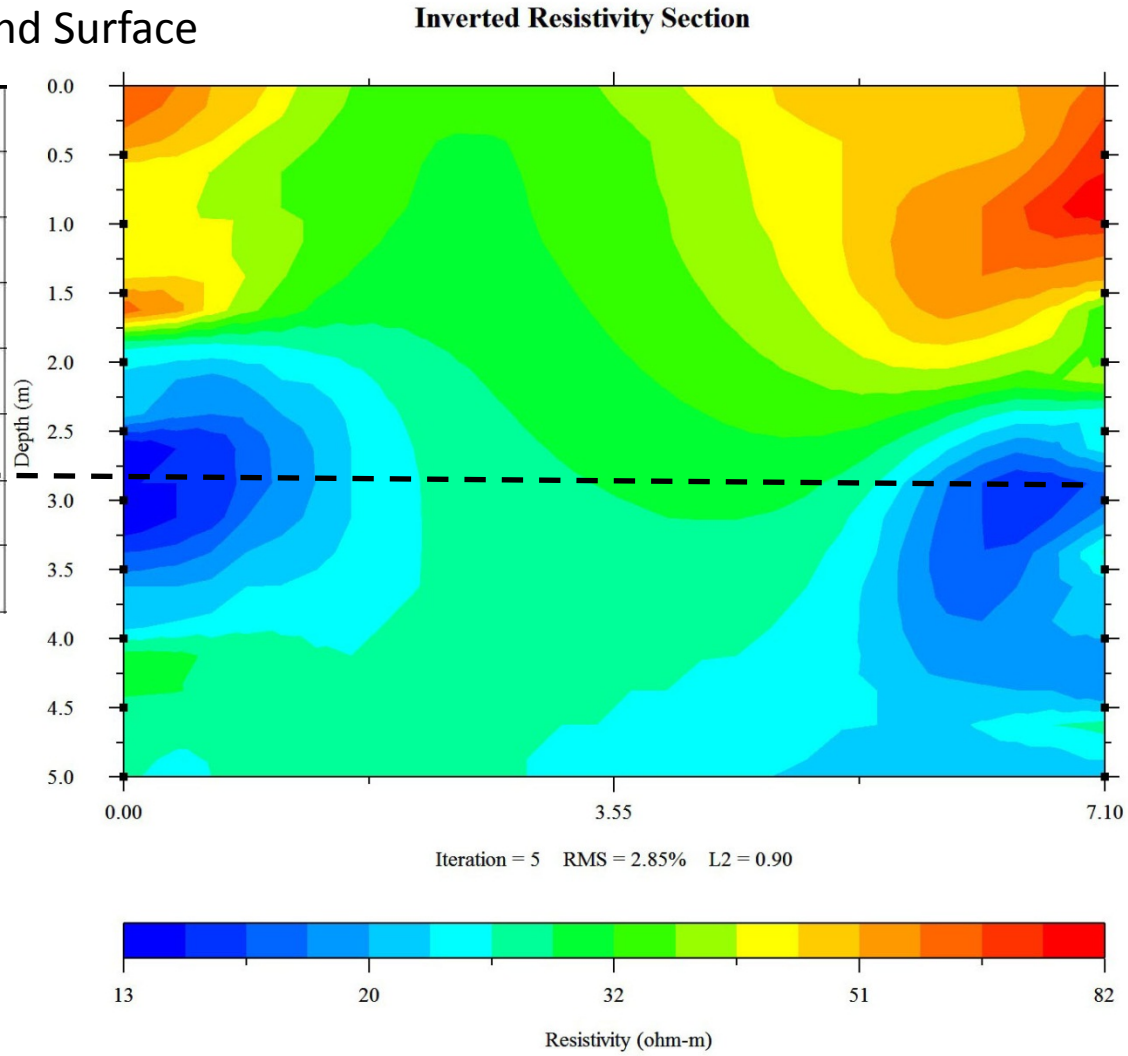


Parallel to slope

Borehole ERT

Ground Surface





Geotechnical-Geophysical Correlation

- ERT can detect landslide morphology, depth to slide plane, key lithologic interfaces and hydrogeologic regimes

- Thorough landslide investigations and slope stability assessments require additional parameters such as porosity, void ratio, and hydraulic conductivity used to assess shear strength.

- Attempt to further interpret ER and correlate it with laboratory geotechnical data and extrapolate the necessary parameters to improve slope characterization and advance ability to quantify landslide hazards.

- Can ER data in shallow, heterogenous colluvial slides be interpreted beyond moisture content and key boundaries to establish relationships with hydraulic conductivity, porosity, and void ratio?

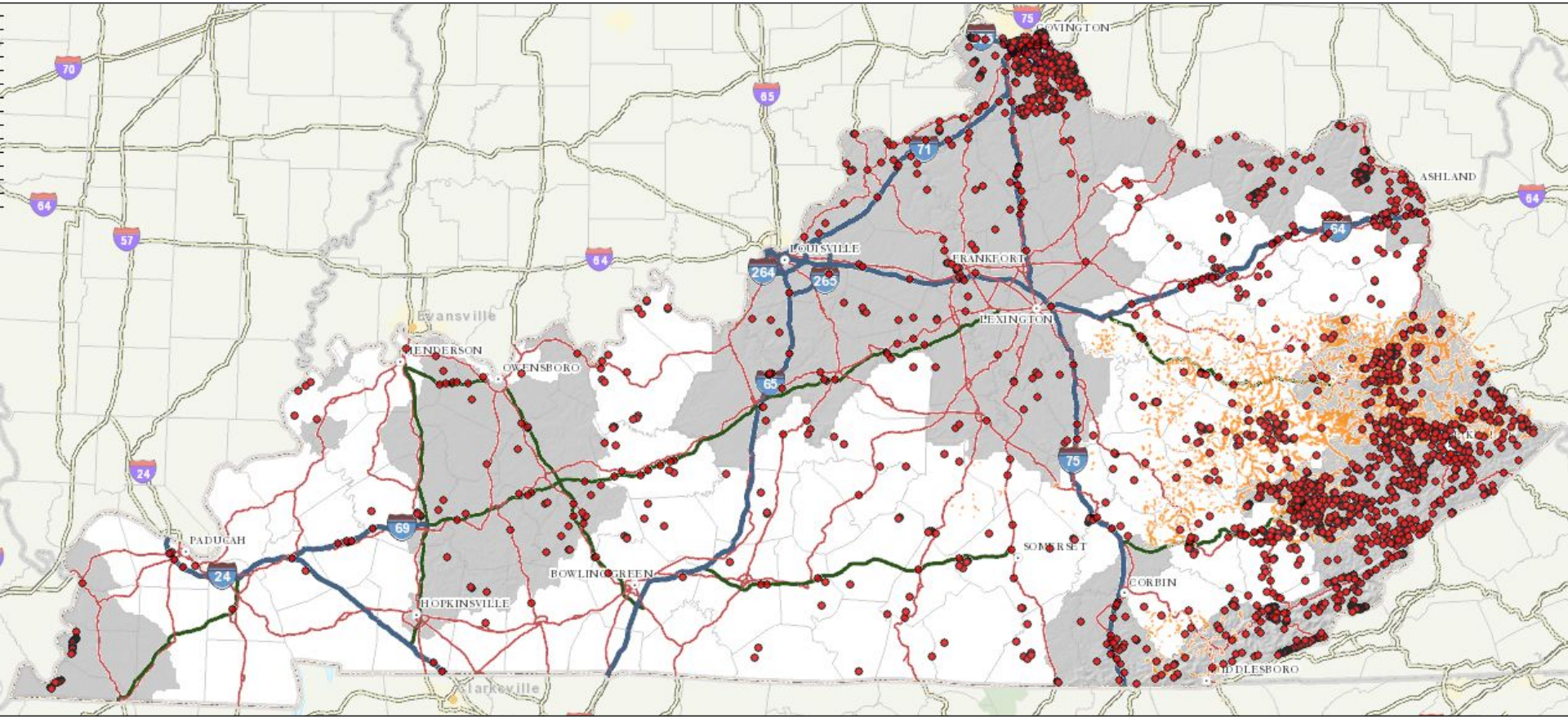
ω, *k*, Θ >>>>> n, matrix suction >>>>> μ >>>>> c'

- If so, can these parameters then be connected and put into unsaturated soil mechanics shear strength models?

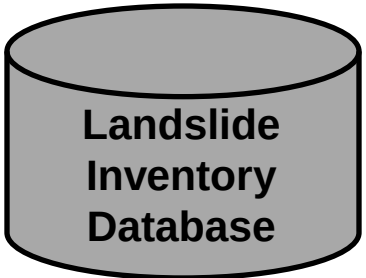
Conclusions

- KGS is gathering landslide monitoring data in order to characterize the Meadowview Lane Landslide
- Potential failure location approx. 9 ft (3 m) below the surface coinciding with a sandy-clay colluvial fill and stiff clay interface.
- Cumulative displacement to-date is approx. .25 inches in B-1 (near head scarp) and .30 inches in B-3 (toe)
- Continue to monitor movement, groundwater levels, and rainfall. Attempt will be made to correlate and geotechnical properties
- Apply information to other parts of Kentucky susceptible to landslides

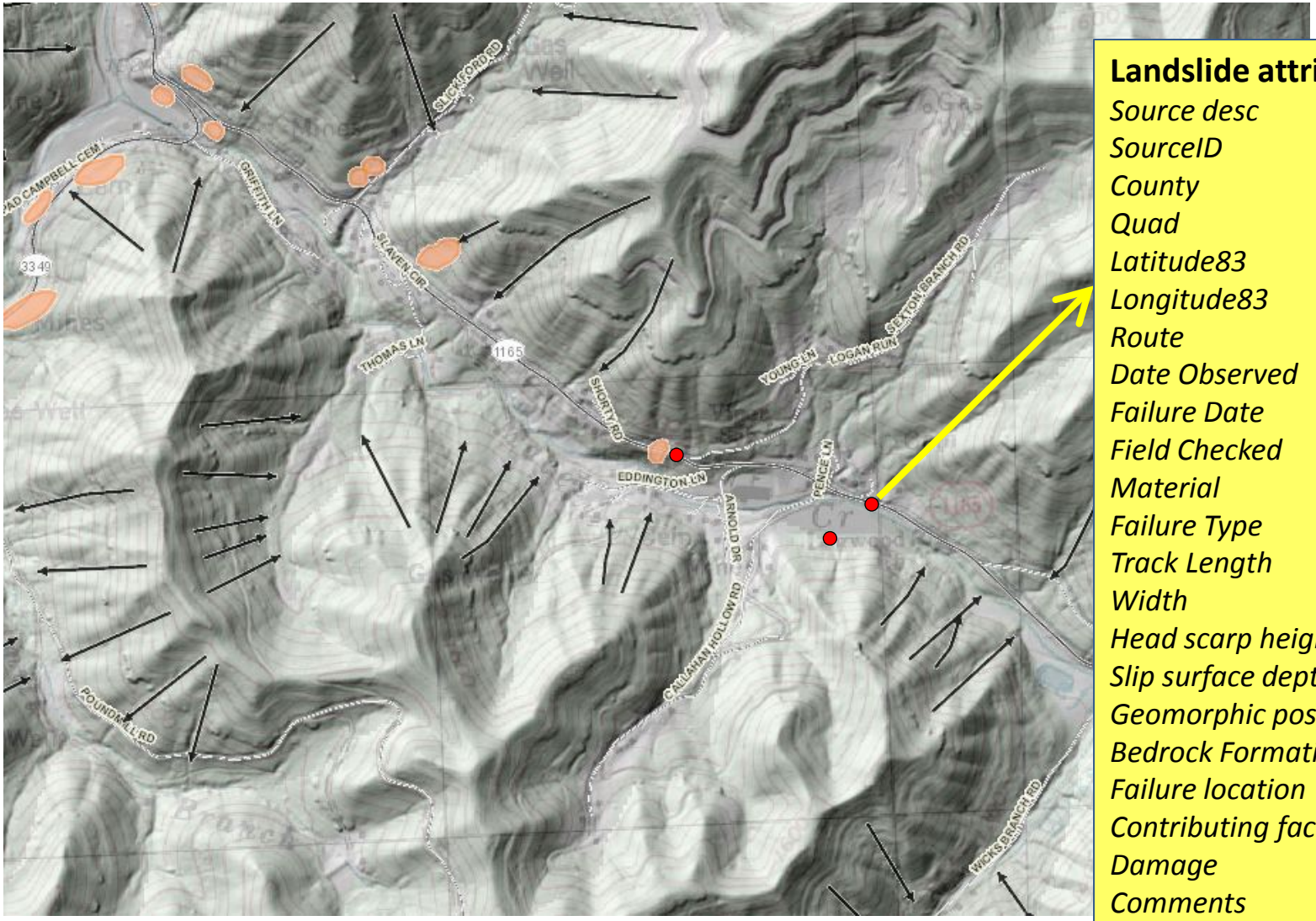
Communicating with Geotechnical Users: KGS Landslide Information Map



- Known landslide locations
- Areas susceptible to debris flows
- Landslides located from LiDAR and aerial photography
- LiDAR hillshade layer (where available)



Landslide Information Map Service (cont.)



Landslide attributes

Source desc
SourceID
County
Quad
Latitude83
Longitude83
Route
Date Observed
Failure Date
Field Checked
Material
Failure Type
Track Length
Width
Head scarp height
Slip surface depth
Geomorphic position
Bedrock Formation
Failure location
Contributing factor
Damage
Comments

Landslide Information Map

This map shows the locations of known landslides and areas susceptible to landslides in a geologic and geomorphic context. The purpose of the map is to provide an overall view of landslide hazards across the state. There are several landslide data layers represented as points, lines, and polygons. Locations come from Kentucky Geological Survey research, published maps, state and local government agencies, the public, and the media, thus making attributes and spatial accuracy highly variable. Most all landslide types, sizes, and states of activity are represented. This map can be used to identify preexisting landslide locations and serve as a basis for landslide hazard assessment and risk reduction. It is not intended for site specific investigations. The absence of landslides in an area does not infer that a landslide does not exist or that the ground is stable. A professional geologist or geotechnical engineer should be consulted for planned construction at identified landslide locations or in identified landslide areas. A professional geologist or geotechnical engineer should also be consulted for control and mitigation efforts of existing slides.

The full extent of the Landslide Information Map shows landslide points, landslide areas, counties, and roads. The "areas susceptible to debris flows" become visible when zoomed in. The light gray areas are a LiDAR hillshade layer (5ft) and are not present in all parts of the state. The LiDAR layer can be adjusted for varying amounts of transparency in the Data Layers list. If LiDAR is not present, the 30ft DEM hillshade draped with topographic maps are visible when zoomed in.

Landslide Map Layer Descriptions

Five layers are contained within the "KGS Landslide Data" layout. Their descriptions are as follows:

- **KGS landslide inventory data**
  This map layer contains known landslide locations (points) across Kentucky compiled in a landslide inventory database. The locations come from Kentucky Geological Survey research, state and local government agencies, and the public. Many of the points represent larger landslide features that have not been mapped in detail and may fall within different parts of the slide area (crown, head scarp, middle, or toe). The landslides are active or have historically been active. Slide locations are collected at different times and contain varying amounts of attributes. The inventory does not capture work by private industry or other agencies that document landslides but do not make them available. Many attribute values are "Null" and data is only present if the slide was visited or could be collected another way. Landslide inventory points that fall within a landslide polygon layer represent the centroid of that polygon so it could be catalogued in the inventory database.

The SourceDesc field describes the source of the landslide location. KGS=Kentucky Geological Survey, KY EM = Kentucky Emergency Management, KYTC = Kentucky Transportation Cabinet, DNR-DMRE = Division of Natural Resources-Mine Reclamation & Enforcement, NRCS = Natural Resource Conservation Service, NKAPC = Northern Kentucky Area Planning Commission, NKU = Northern Kentucky University, AML = Abandoned Mine Lands.

1:24,000 geologic map landslides
These landslide locations (polygons) were mapped on the 7.5-minute, 1:24,000-scale geologic quadrangles published jointly by the Kentucky Geological Survey and US Geological Survey from 1960 to 1978. Attributes include original map symbol and formation name, as well as county, quadrangle, and Area Development District. Landslides were not mapped on all quadrangles. Search source data on the KGS publications search page: http://kgs.uky.edu/kgsweb/PubsSearching/PubsSimpleSearch.asp.

Landslide areas derived from LiDAR
These landslides (polygons) were mapped using 1 m resolution (horizontal) Light Detection and Ranging (LiDAR) data. Using hillshade digital elevation models, potential landslide locations were identified and digitized. Locations were field verified, where possible. Comments included are notes and observations taken during the mapping of these slides. For more information regarding these landslides and LiDAR see KGS RI_24_12. http://kgs.uky.edu/kgsweb/PubsSearching/MoreInfo.asp?titleInput=17614&map=0.

Landslide areas derived from aerial photography
This layer (polygons) represents mapped landslides including earthflows, debris slides, and slumps. The data come from a series of published Landslide and Related Features Maps and Landslide Potential Maps that cover most of southeastern and south-central Kentucky. Landslides were interpreted from aerial photographs and historical records. The features digitized (polygons) depict generalized slope conditions as they existed at the time of field checking (1977-1981). Slope stability may decrease by excavation, loading, and changes in drainage conditions. The data are from preliminary type maps and are suited for general planning purposes only. Search source data on the KGS publications search page: http://kgs.uky.edu/kgsweb/PubsSearching/PubResults.asp?pubtype=Landslide+Map&searchtype=typeofpub.

Areas susceptible to debris flows
This layer (lines) represents debris flow deposits or areas susceptible to debris flows. Primarily these areas are shallow, narrow ravines containing variable accumulations of colluvium. The data come from a series of published Landslide and Related Features Maps and Landslide Potential Maps that cover most of southeastern and south-central Kentucky. The features were interpreted from aerial photographs and historical records. The debris flows digitized (lines) depict generalized slope conditions as they existed at the time of field checking (1977-1981). Areas of thick colluvium are susceptible to rapid movement during intense rainfall. The data are from preliminary type maps and are suited for general planning purposes only. Search source data on the KGS publications search page: http://kgs.uky.edu/kgsweb/PubsSearching/PubResults.asp?pubtype=Landslide+Map&searchtype=typeofpub.

Landslide Basics

Landslides are the downslope movement of rock, soil, or both under the influence of gravity. A combination of steep slopes, excessive pore water levels, geology, and slope modification are the main causes of landslides. Landslides types (translational, rotational, etc.) vary by the rate of movement, type of material involved, and structure of the failure plane. Increased population, rapid urbanization, and development will likely cause an increasing trend in landslide activity.

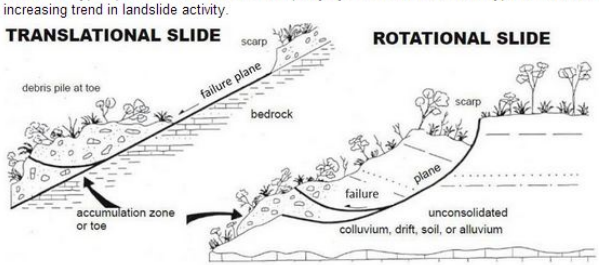


Diagram modified from Potter, P.E., 2007, "Exploring the geology of the Cincinnati/northern Kentucky region", Kentucky Geological Survey, Special Publication 8, 128 p.

Causes

General causes of landslides include water, steep slopes, easily weathered rock, natural erosion, and artificial slope modification. These causes when combined with certain triggers create areas susceptible to sliding.

Triggers

Intense rainfall or rapid snowmelt	Excavation of toe slopes (steepening)
Groundwater level changes	Loading extra material on top of the slope
Poor drainage	Leakage from pipes
Vegetation removal	Earthquakes

Map explanation

Communicating with Geotechnical Users

- Why are landslide inventories important?
  - Planners/engineers
  - Transportation officials
  - Emergency managers
  - The public

- How can we best communicate with the geotechnical and other audiences? COOPERATION

- Most planners or local gov officials do not adequately address landslide hazards…do not have the appropriate resources to id hazards.

- Users can minimize activities that cause landslides (poor road construction, construction on hillsides, poor drainage practices, etc.) by taking advantage of this information. They have the means…geotech site analysis, design, regulations, zoning, and disclosure to address the hazard

Communicating with Geotechnical Users

KYTC District 9 @KYTCDistrict9 7 Mar

@matt_m_crawford KGS landslide map's an awesome tool! Copying link to our engineers today. Thanks! kgs.uky.edu/kgsmap/kgsgeos...

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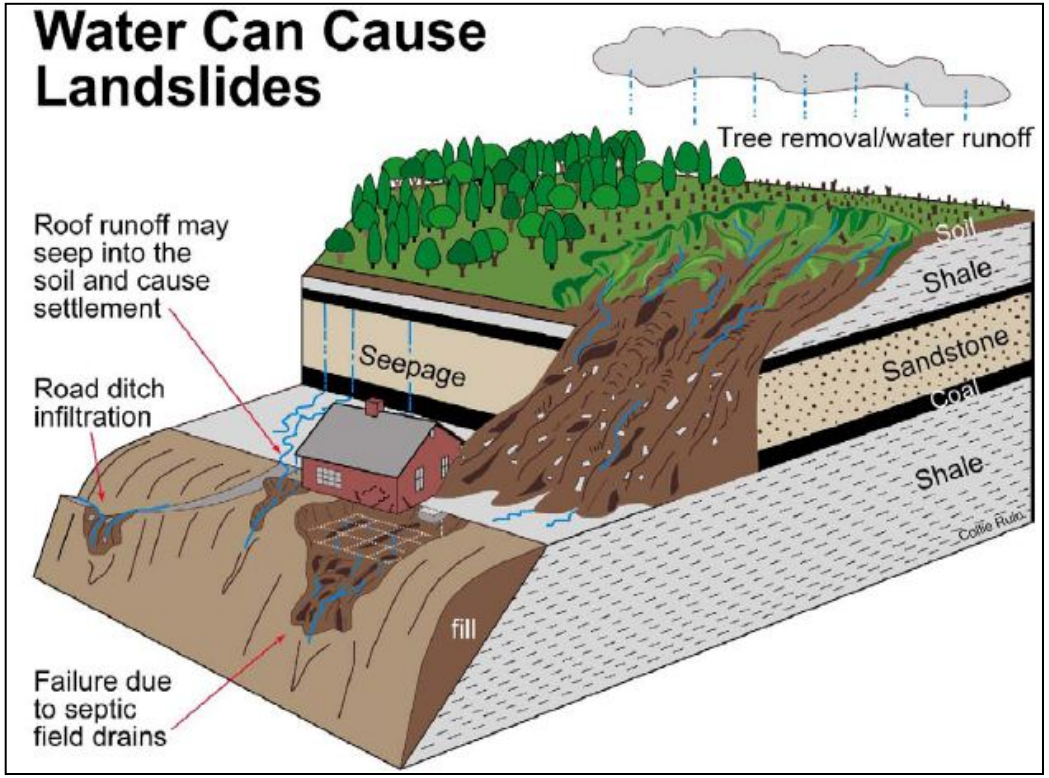

Thanks!

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