Assessment and Mitigation of I-40 Landslide, Rockwood TN

David Hannam PG, Lead Consultant, WSP, david.Hannam@wsp.com

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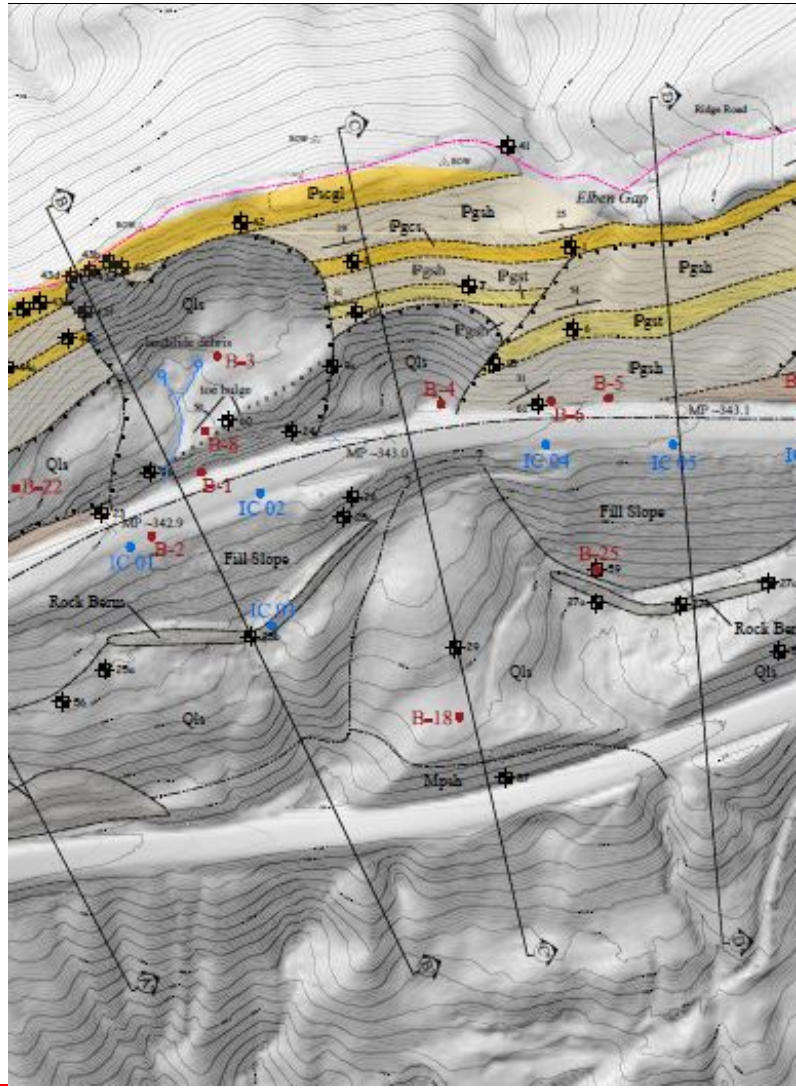
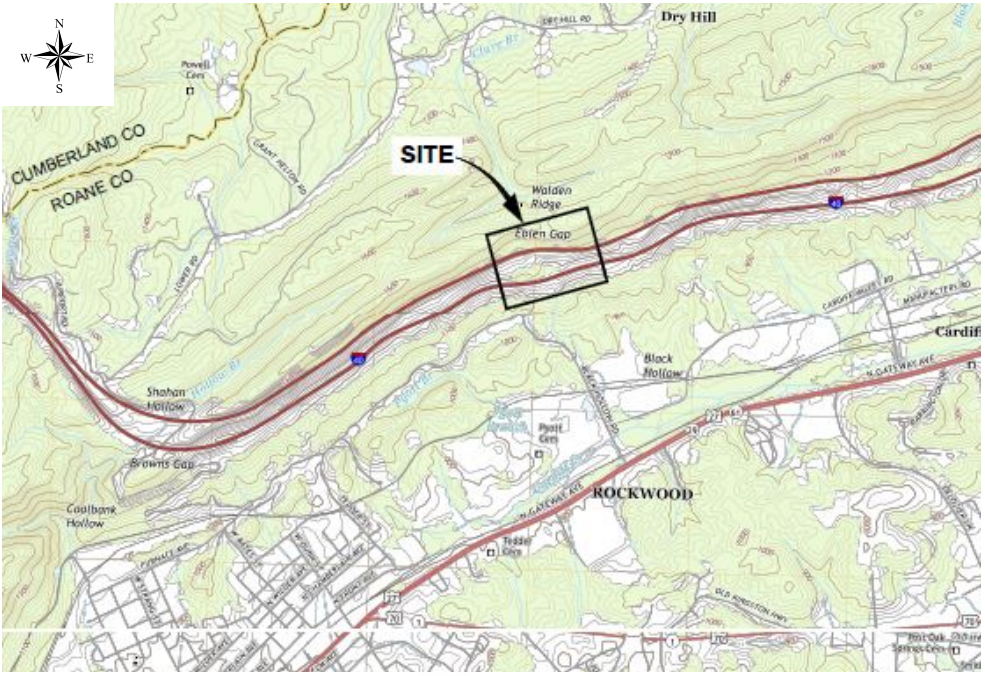
Content

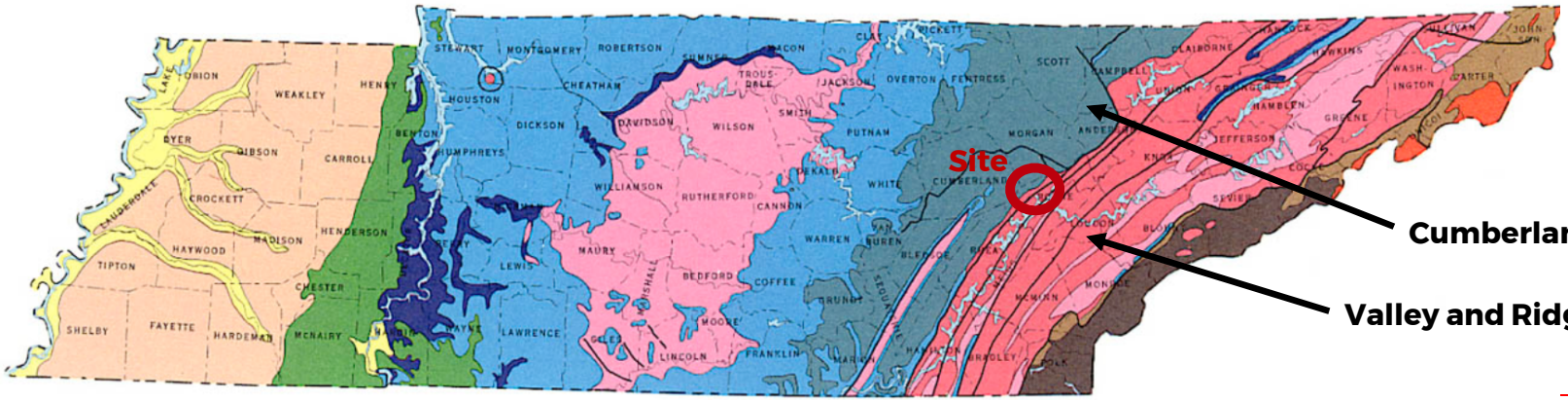




Background

Troublesome 5-mile section of I-40 known for landslides

- Location: 1,500 ft long section of westbound lane (WBL) I-40,
- 1.5 miles NE of Rockwood, TN. ~40 miles west of Knoxville
- Section of I-40 known for landslides
- Eastern Cumberland Plateau Escarpment, Pennsylvanian and Mississippian deposits
- Thick colluvial deposits
- 2019 arcuate cracks in WBL, TDOT requested Golder support on project.



Time Line

Based on TDOT archives and historical aerial photographs

1961

Pre-construction Landslides

Pre-construction historical USDA aerial photographs show landslides in the immediate area

1967

I-40 construction disturbs landslides

Scarps have formed in the immediate area, hummocky topography downlospe, fill on slide mass

1969

Road cuts in colluvium, large slump

Large slump in east of site, north of WBL has occured

1970

I-40 Slides investigated

5-mile section of I-40 slides investigated by Law Engineering. Tension cracks and subsidence reported 1975.

1994

Mitigation

Tension cracks and subsidence regular since 1975. Median fill removal and lined ditches as mitigation

2010

Retreating Scarps

Aerial images show retreating scarps above the WBL

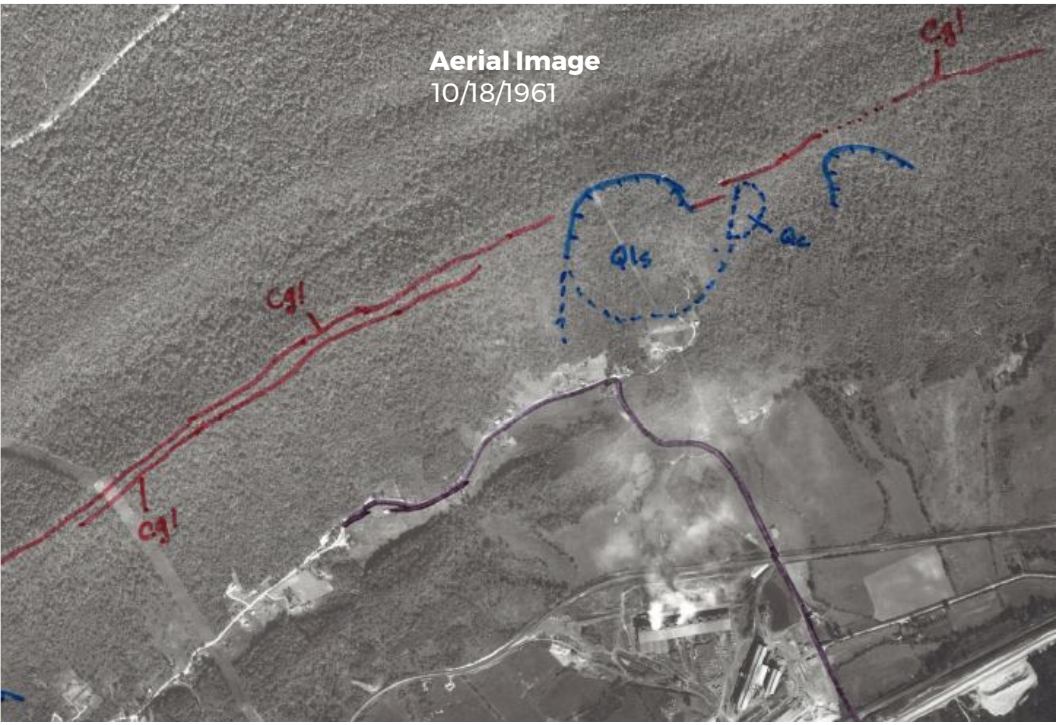
2019

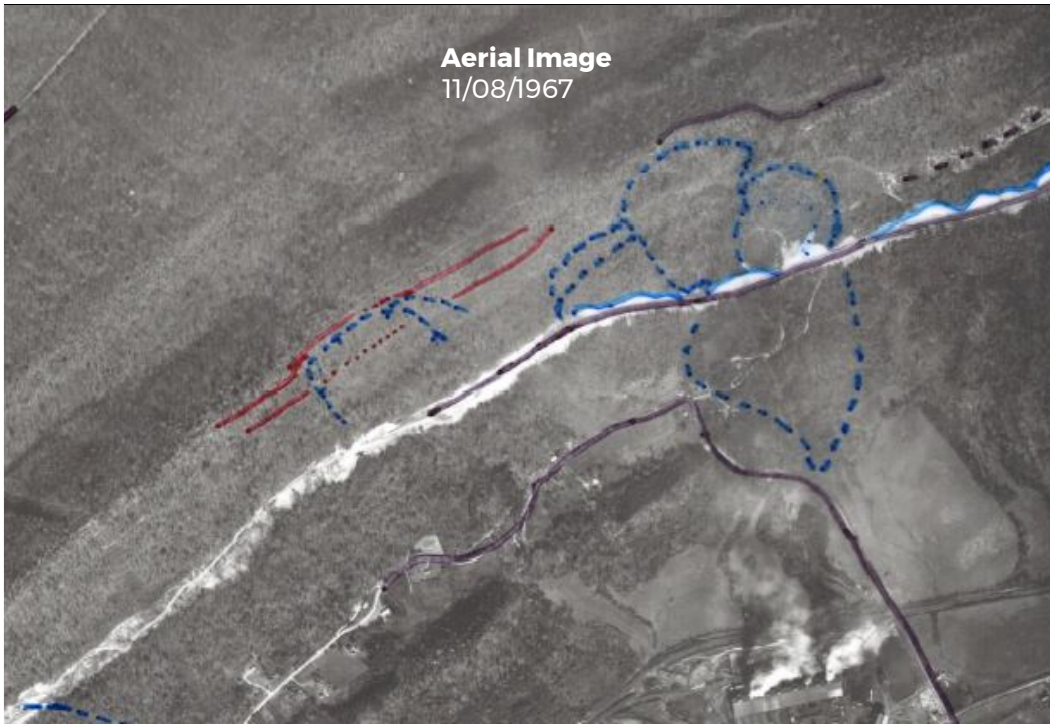
Arcuate cracks appear

TDOT identify arcuate cracks through WBL following heavy winter precipitation.

Historical Aerial Image Interpretation

Aerial images pre-construction and during construction show multiple triggered landslides





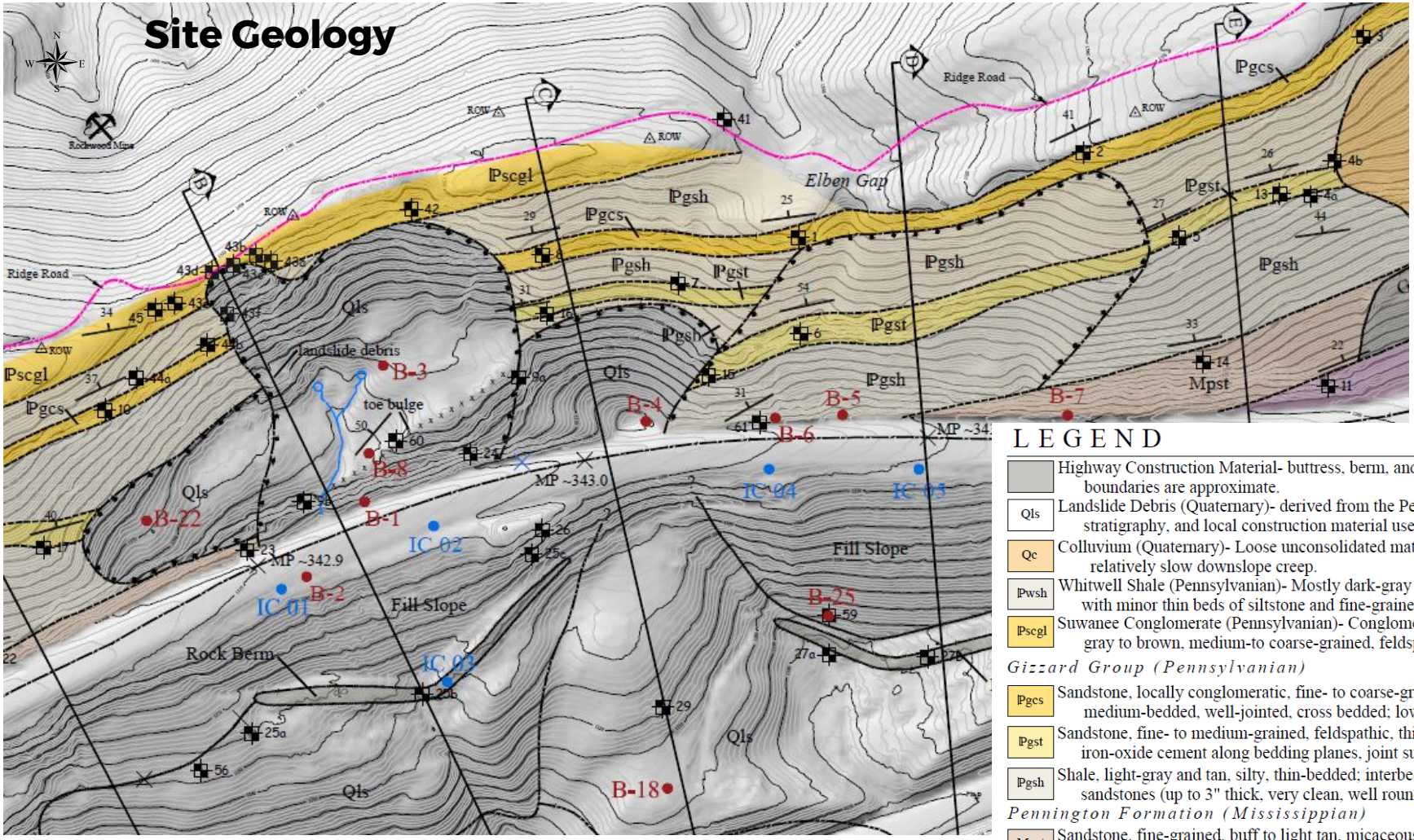
2019 Arcuate Cracks in Westbound Lane

Field Investigation

Early field mapping was fundamental to the project

- Geologic Mapping: Set up early model, informed all other investigation
- Drilling: Sonic and rotary core, 35 boreholes up to 300 ft deep.
- Geophysics: Three ERI Sections
- Installations: Inclinometers and piezometers

Site Geology



LEGEND

- Highway Construction Material- buttress, berm, and gabion wall material; boundaries are approximate.
- Qls — Landslide Debris (Quaternary)- derived from the Pennsylvanian and Mississippian stratigraphy, and local construction material used for highway fill.
- Qc — Colluvium (Quaternary)- Loose unconsolidated material deposited by relatively slow downslope creep.
- Pwsh — Whitwell Shale (Pennsylvanian)- Mostly dark-gray to light-brown shale, with minor thin beds of siltstone and fine-grained sandstone.
- Pscgl — Suwanee Conglomerate (Pennsylvanian)- Conglomeratic sandstone and sandstone, gray to brown, medium-to coarse-grained, feldspathic, thick-bedded, well jointed.

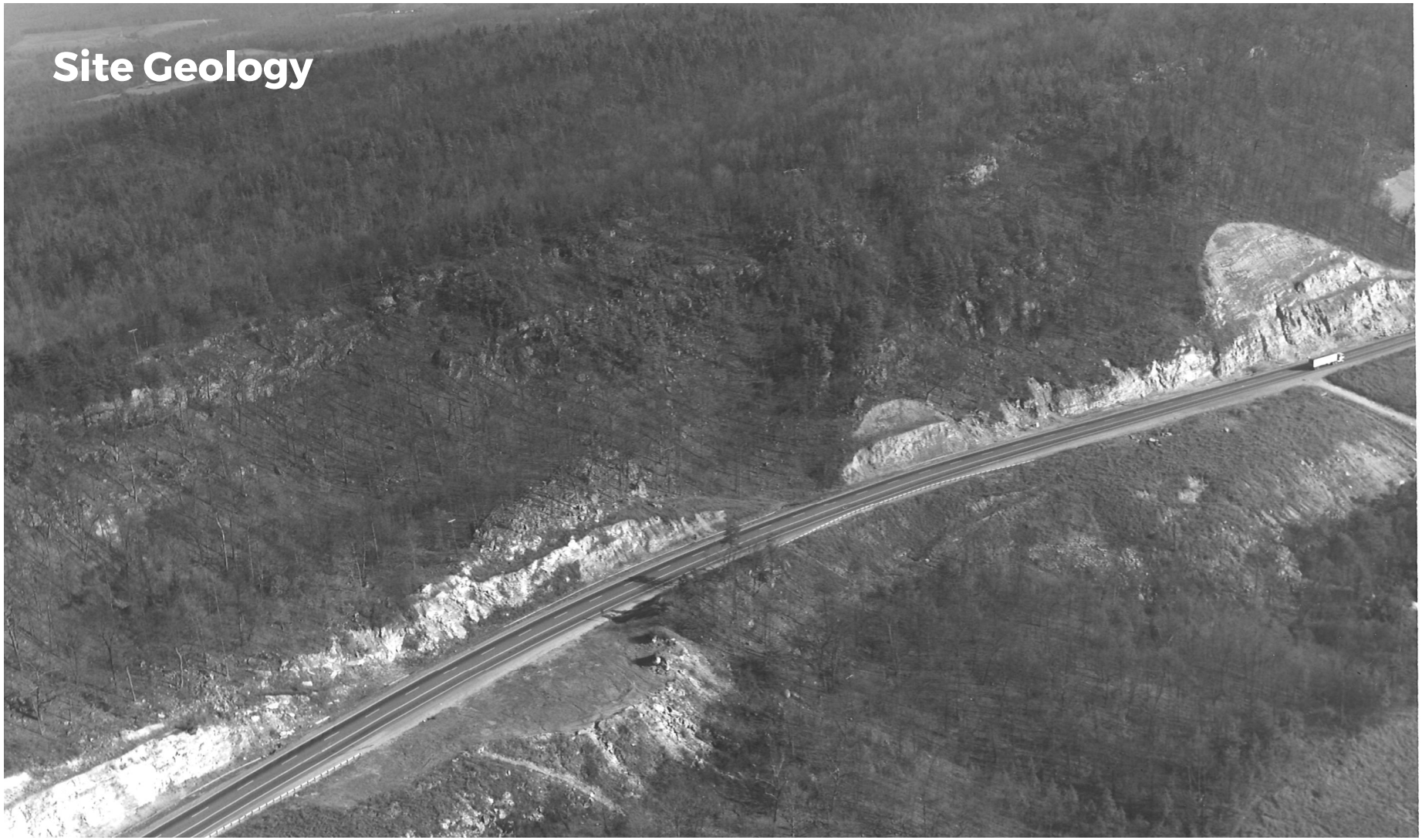
Gizzard Group (Pennsylvanian)

- Pgcs — Sandstone, locally conglomeratic, fine- to coarse-grained, feldspathic, medium-bedded, well-jointed, cross bedded; lower part is thick-bedded.
- Pgst — Sandstone, fine- to medium-grained, feldspathic, thin- to thick-bedded; contains iron-oxide cement along bedding planes, joint surfaces, and within the matrix.
- Pgsh — Shale, light-gray and tan, silty, thin-bedded; interbedded with thin sandstones (up to 3" thick, very clean, well rounded).

Pennington Formation (Mississippian)

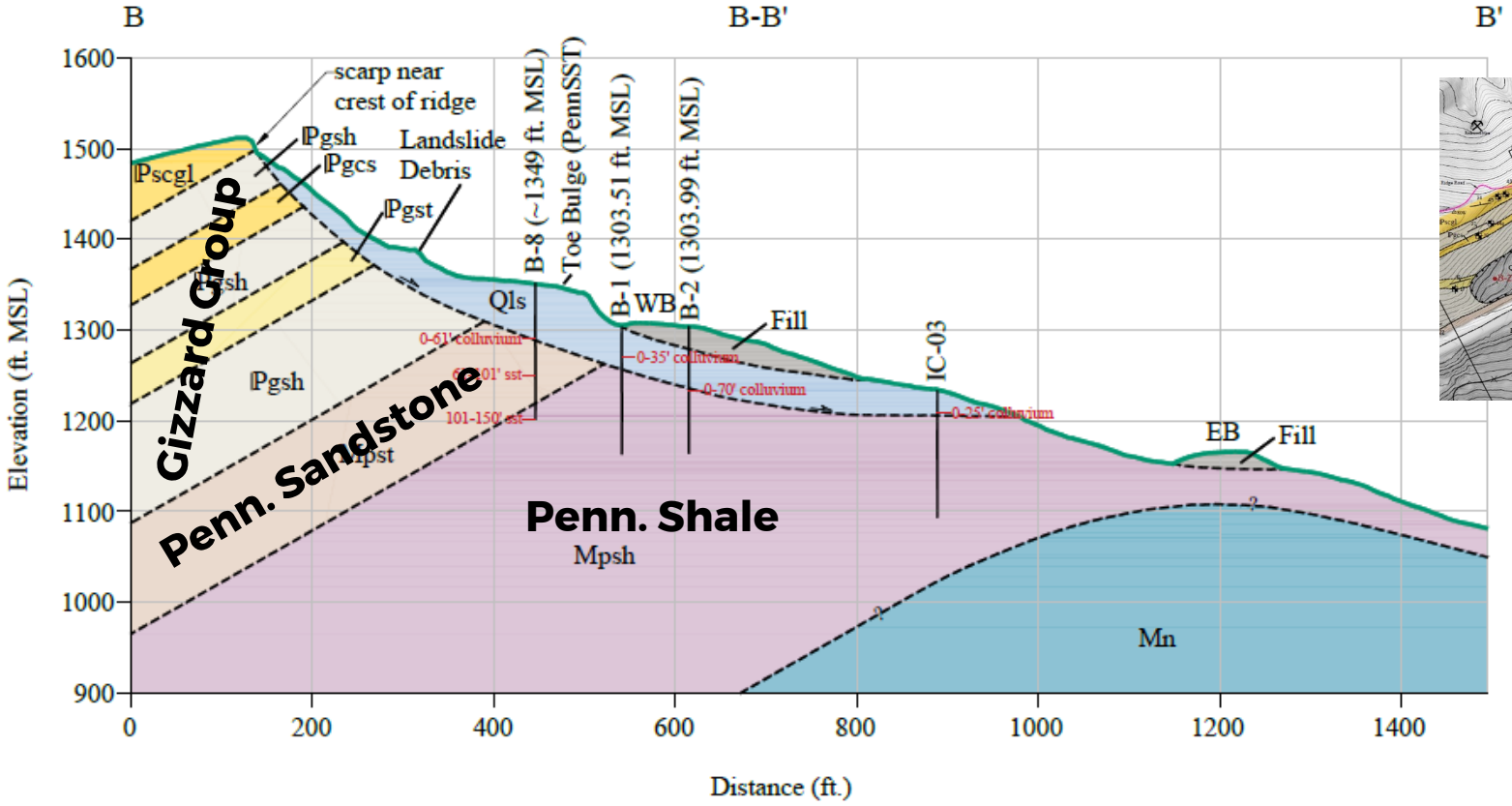
- Mpst — Sandstone, fine-grained, buff to light tan, micaceous, calcareous, cross bedded, contains symmetric ripples.
- Mpsh — Highly variegated clay shale, claystone, mudstone, and lesser gray and buff micritic limestone; all interbedded.

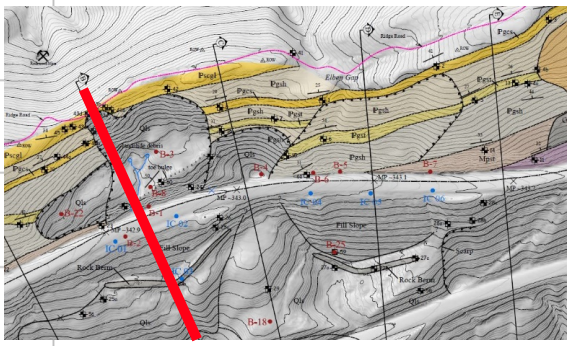
Site Geology



Site Geology

Geological Cross Sections





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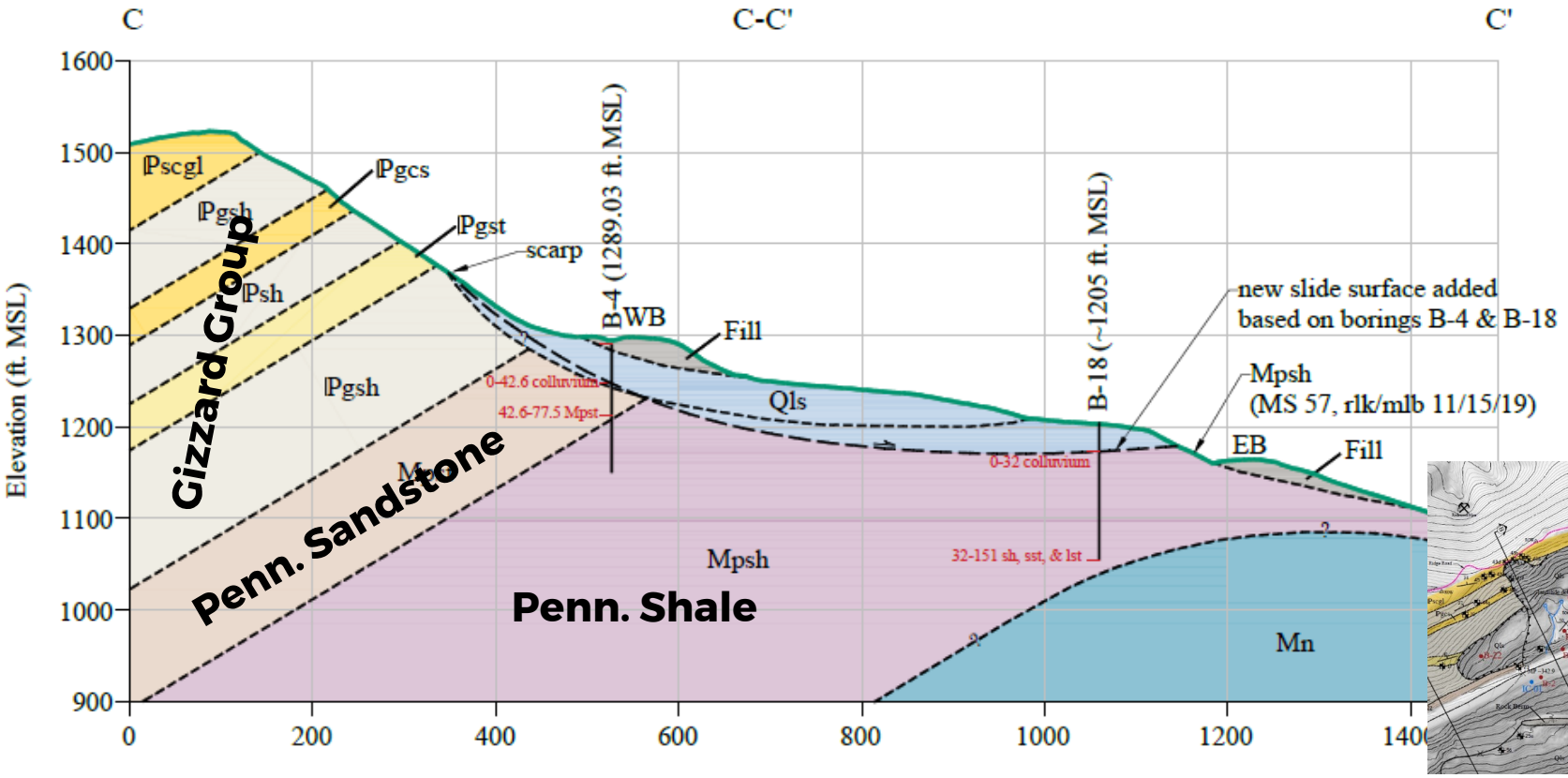
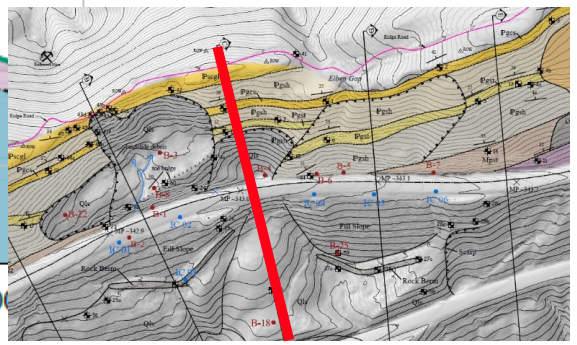
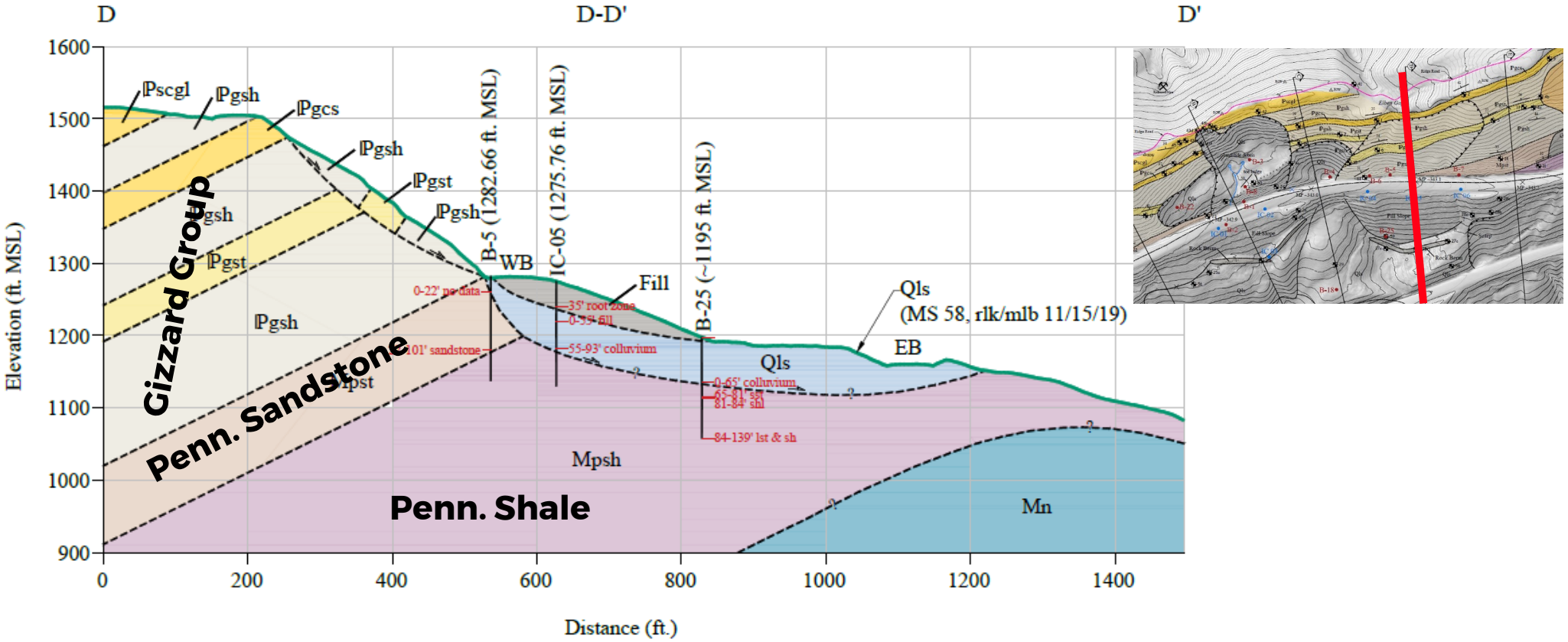




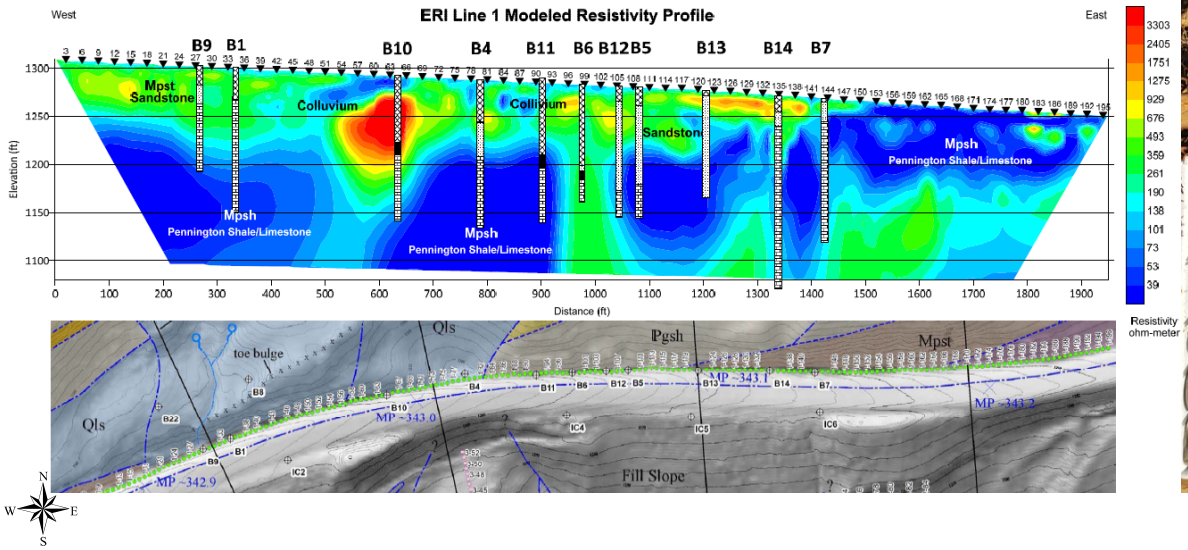
Site Geology

Geological Cross Sections



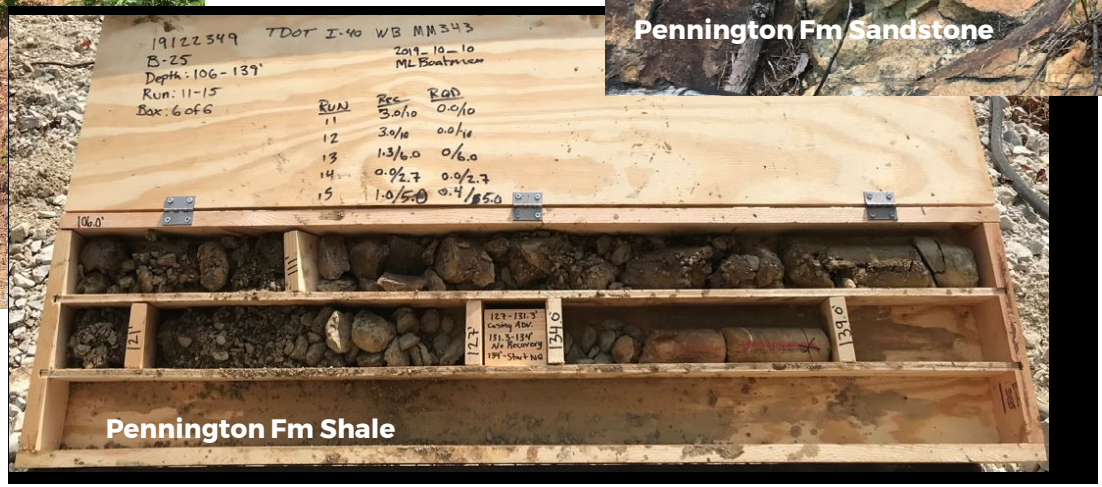
Site Investigation

Examples of borehole and geophysical interpretation



Site Geology

The rocks...



Site Geology

More rocks...

Slumped Gizzard Group Shale

Symmetric ripples in Pennington Sandstone

Rotated blocks Gizzard Group Sandstone (see D-D')

Failure Mechanisms

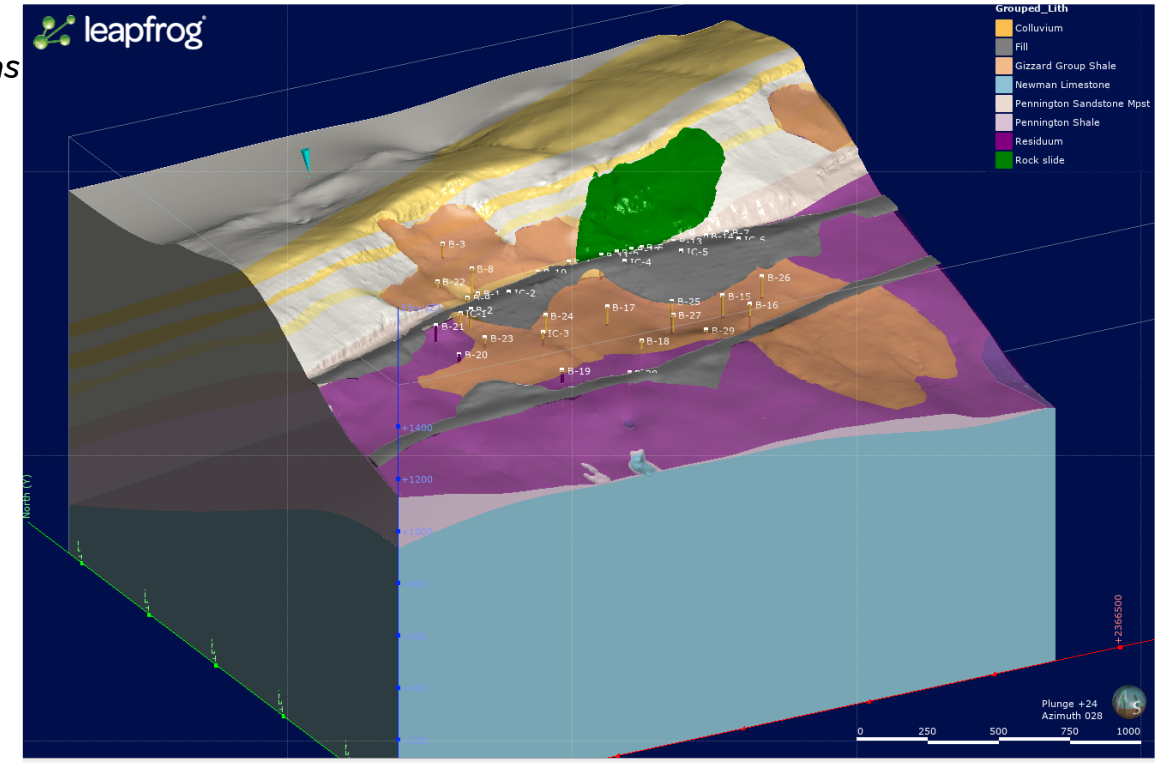
Multiple failure mechanisms across site

- Differential weathering
- Influence of the Pennington Fm Sandstone
- Accumulation of Colluvium
- Differing Permeabilities between Colluvium and underlying residuum
- Low shear strength of Pennington Fm Shale

3D Geological Model

Combine data sets in complex ground conditions

- 3D model important to project success
- Link between data collection interpretation and design
- Complex soils and critical depth of problem soils
- Model required good data and interpretation



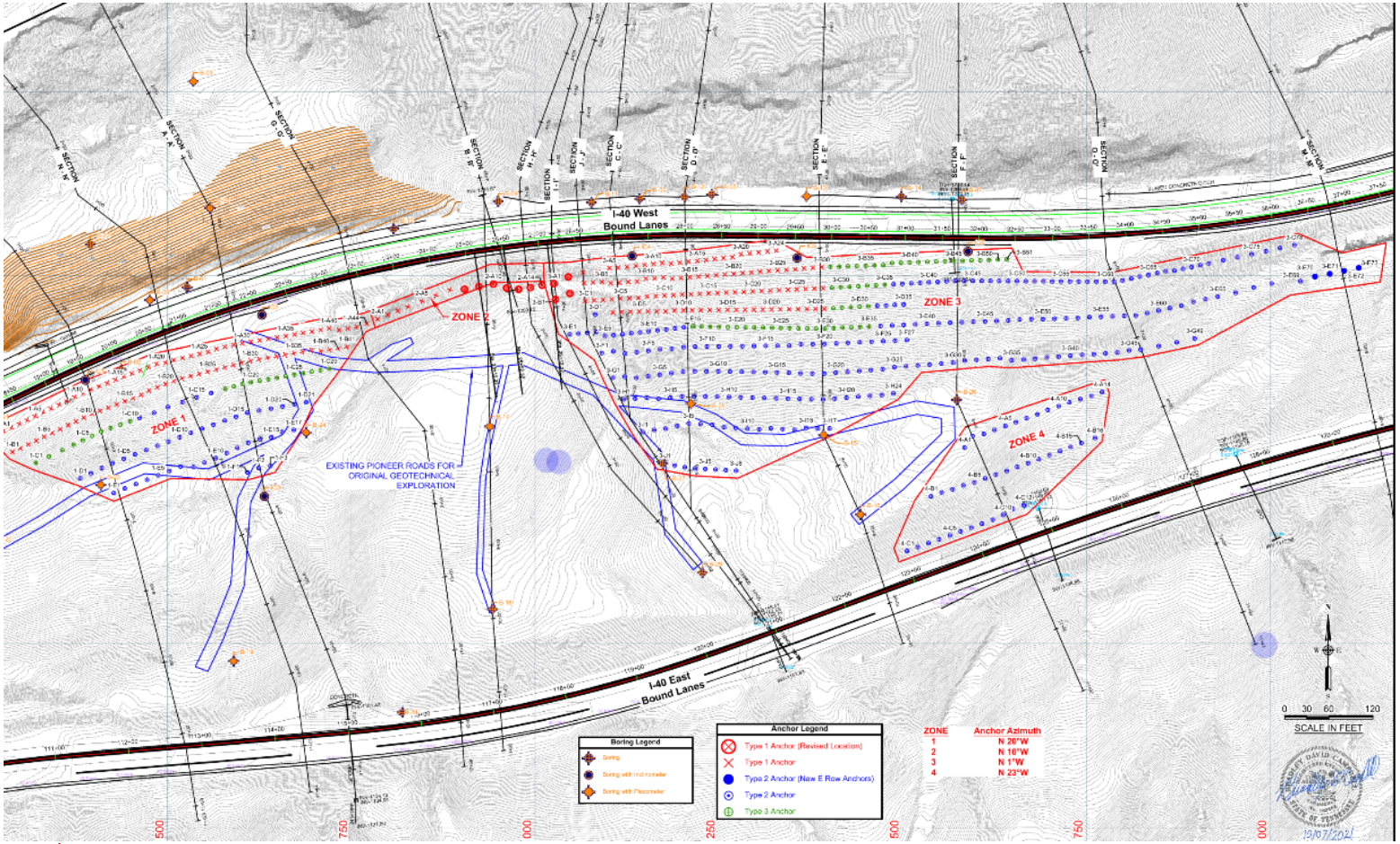
3D Geological Model

Solutions Using 3D Geological Model

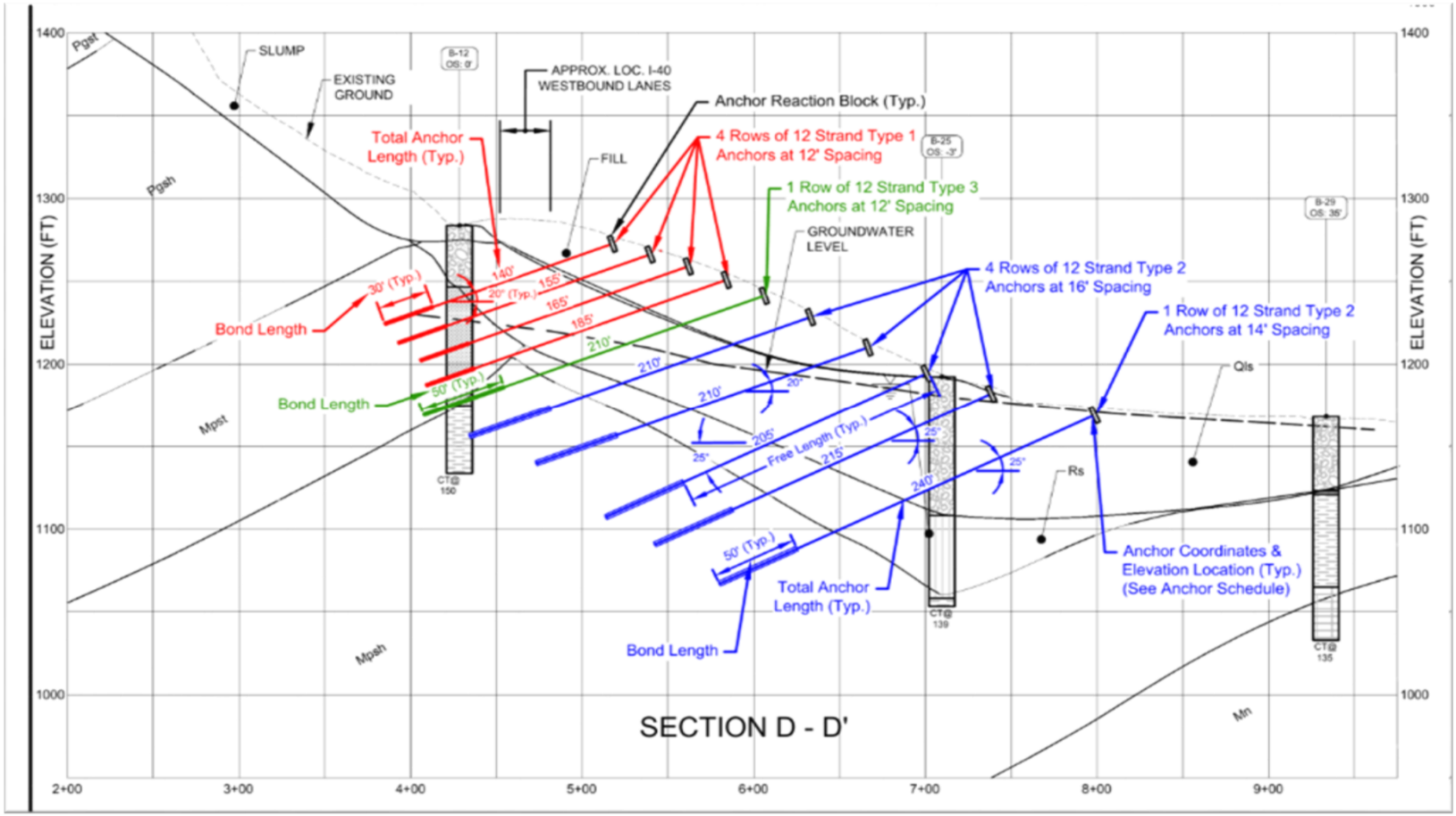
Problem	Solution by Using 3D Model
Variable of data sets, (e.g., borings logs, linear ERI profiles geological mapping, groundwater)	Multiple data sets could be combined to understand spatial relationships
Difficult interpretation between data points	Data combined into single model for interpretation between data points
Large complex geometry with critical depths	Geological interpretations improved by 3D visualization.
Multiple sections along linear structure	Can rapidly cut multiple sections and surfaces to import into other computer programs
Additional data collection	3D modelling program designed for iterative approach

Engineering Mitigation

Geological Model Combined with Engineering Design



Engineering Mitigation



Ground anchors

Extend below slip surface into Pennington Shale or higher up into Pennington Sandstone

Model surfaces directly imported into CAD for design

3D Geological model critical for bonded and unbonded anchor length, orientation and load

Setting Anchor Blocks

Anchor Drilling

Anchor Load Tests

Anchor Installation Progress

Completed Anchor Blocks

Conclusions

Early field mapping was fundamental to the project

- Early geological field mapping key to project success.
- Historical and archive document review supports interpretation
- 3D modeling is an excellent tool for large complex landslides, with multiple data sets
- 3D modeling forms a link between geological interpretation and design and can accelerate design stage.

Thank you

Thanks to:

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