Steeper is Cheaper, "*Danger Falling Rocks*!"

Geohazards Impacting Transportation in Appalachia
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The 10,000 Ft View

- Rock Slope Hazard Mitigation Challenges
- Innovative Rock Fall Mitigation Approaches
- Examples from Maryland and Tennessee

Challenges to Mitigate the Hazard

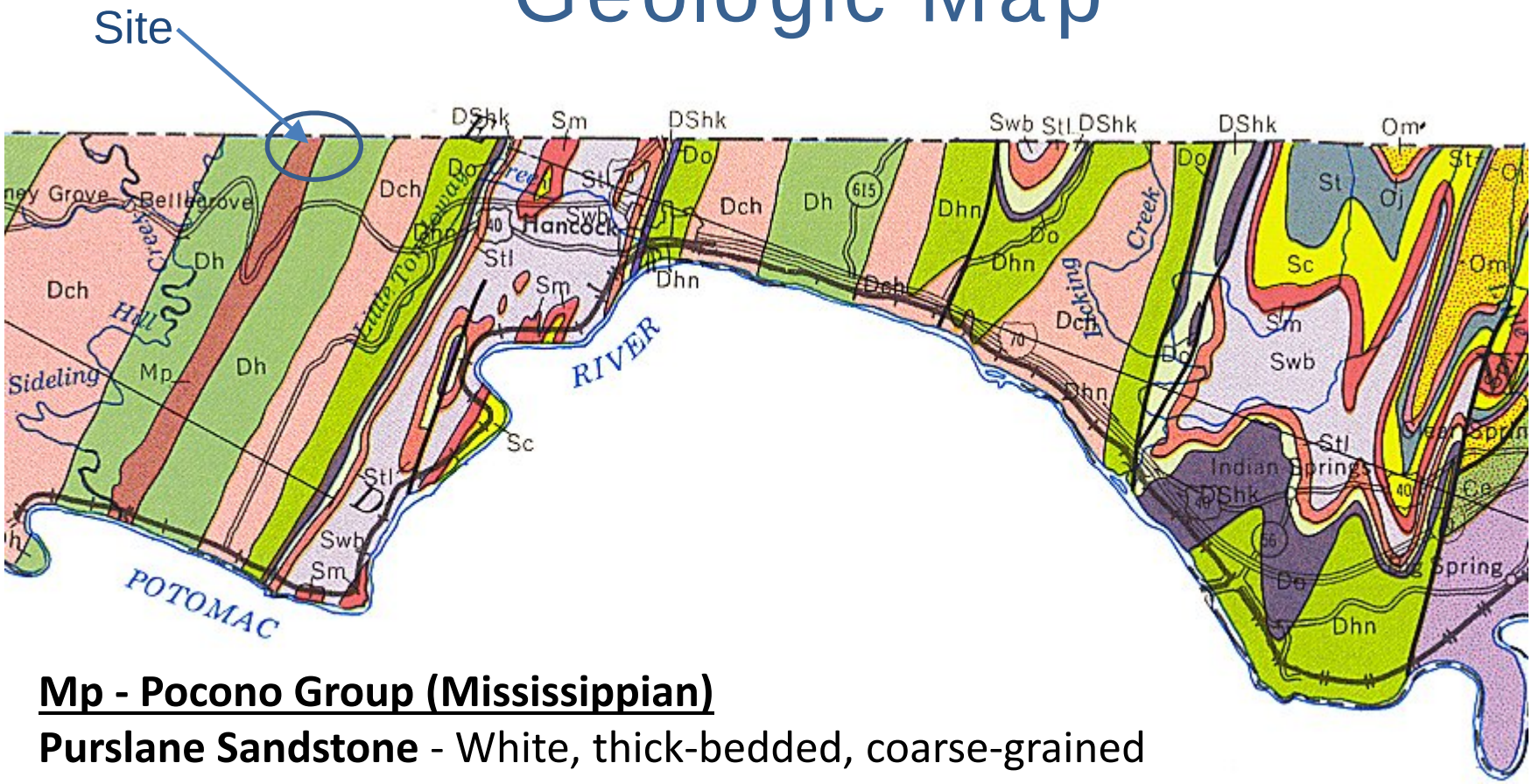
- Balancing Public Safety with Limited ROW, Construction Cost Control, Aesthetics, Institutional Design Philosophy, and O&M Accessibility/Cost
- Evaluating and Managing Risk
- Prioritizing Mitigation of the Greatest Rock Slope Hazards

Sideling Hill, Interstate 68 Maryland

- Construction in 1985
- Deterioration of Benches & Rock Falls
- Rock Slope Hazard Study and Mapping
- Develop Design Concepts for Hazard Mitigation


Thompson Township
Amaranth
Purcell
731
70
Thompson Rd
Big Cove Tannery
Dick Mountain
928
Silver Mills
Buck Valley
Stonybreak
Lashley
Plum Run
Inglesmith
Warfordsburg
Thompson Rd
Heavenly Acres Ridge Rd
S Clear Ridge Rd
Buck Valley Rd
522
Dogtown
Sideling Hill
68
Piney Grove
Old National Pike
SCENIC
40
National Pike
Western Pike
Hancock
E Main St
River Rd
National Pike
Hollow Rd
Bellegrove
Orleans Rd NE
E Nine Rd
Woodmont Rd
Exline
Potomac
Park
Ziegler Rd SE
Pearre Rd
Cohill
Pearre
9
Little Orleans
Lineburg
Berkeley Springs
Ridersville
Great Cacapon
New Hope
Cherry

Geologic Map



<u>Mp - Pocono Group (Mississippian)</u>

Purslane Sandstone - White, thick-bedded, coarse-grained sandstone and conglomerate with thin coal beds and red shales.

Rockwell Formation - Coarse-grained arkosic sandstone, fine-grained conglomerate, and buff shale; dark shale with thin coal beds near base.


LANE
ENDS
MERGE
LEFT

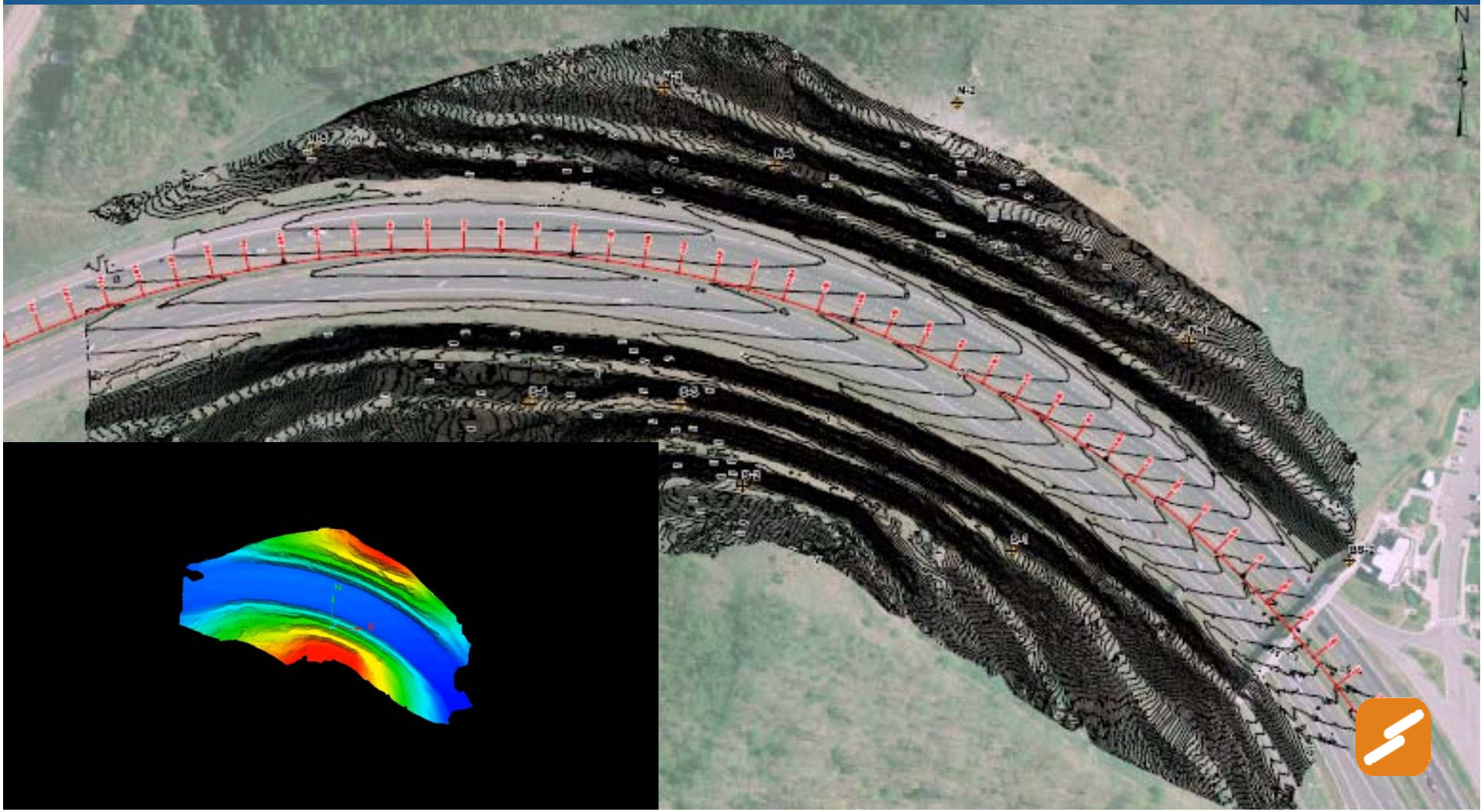
Cut Slope Construction

- Four benches on both sides
- Benches up to 80 ft high
- Bench slopes as steep as 0.25H:1V
- 20 ft wide benches
- Reverse sloped benches
- 38 ft wide catchment area
- Shallow V-shaped rockfall ditch

Rock Slope Hazard Study

- LiDAR Survey
- Rock Structure Mapping
- Slope Stability Analysis
- Rockfall Hazard Analysis

Topographic Site Plan

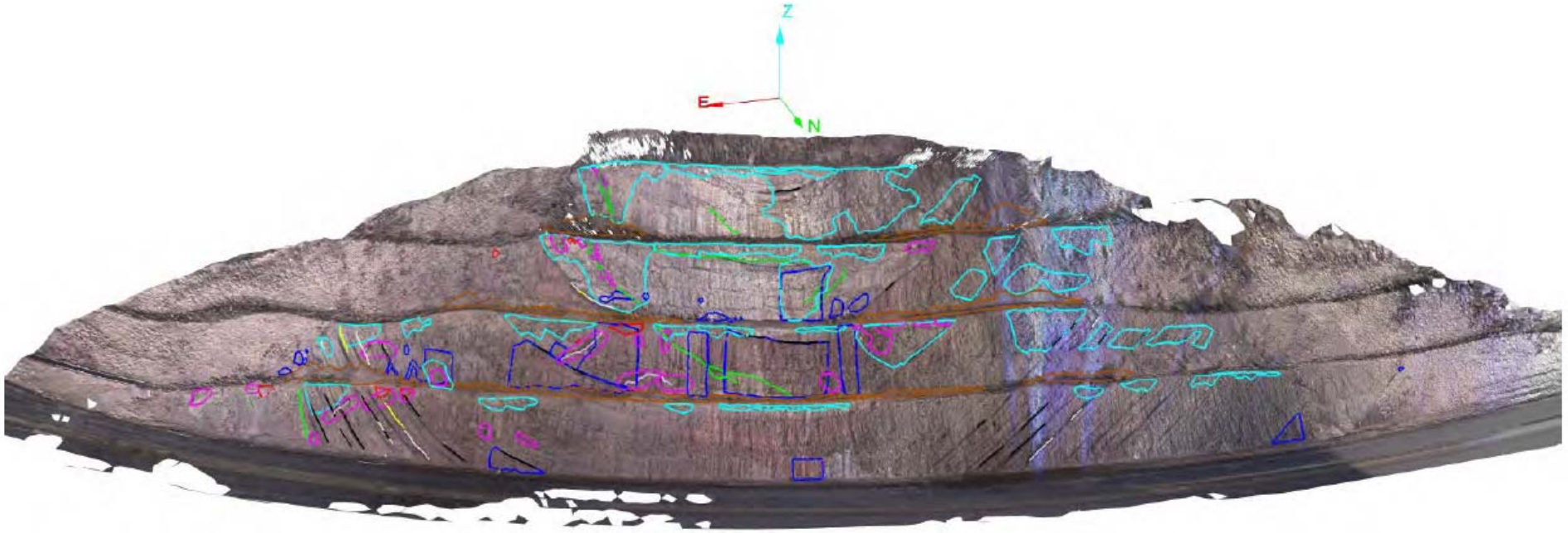


Field and Digital Mapping

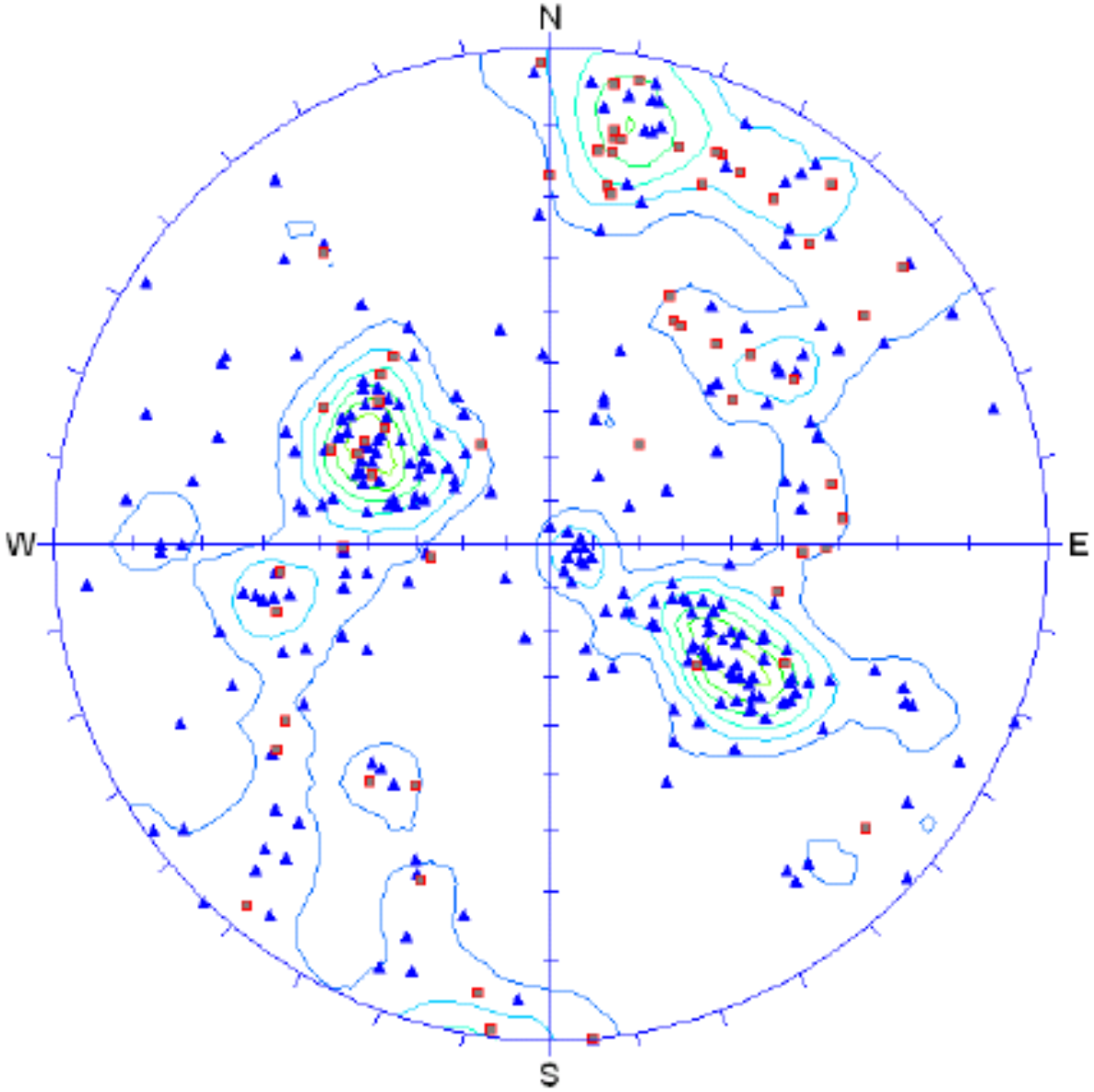
	FIELD	DIGITAL
Lithology / Engineering Geology Units	X	X
Areas of Loose Rock	X	X
Overhangs (>2 ft)	X	X
“Pop-outs”	X	X
Rockfall Debris Accumulations	X	X
Major Joints	X	X
Major Fractures and Faults	X	X
Potentially Unstable Blocks	X	X
Seepage Areas	X	X

Rock Slope Hazard Map

South Face



Rock Structure Mapping



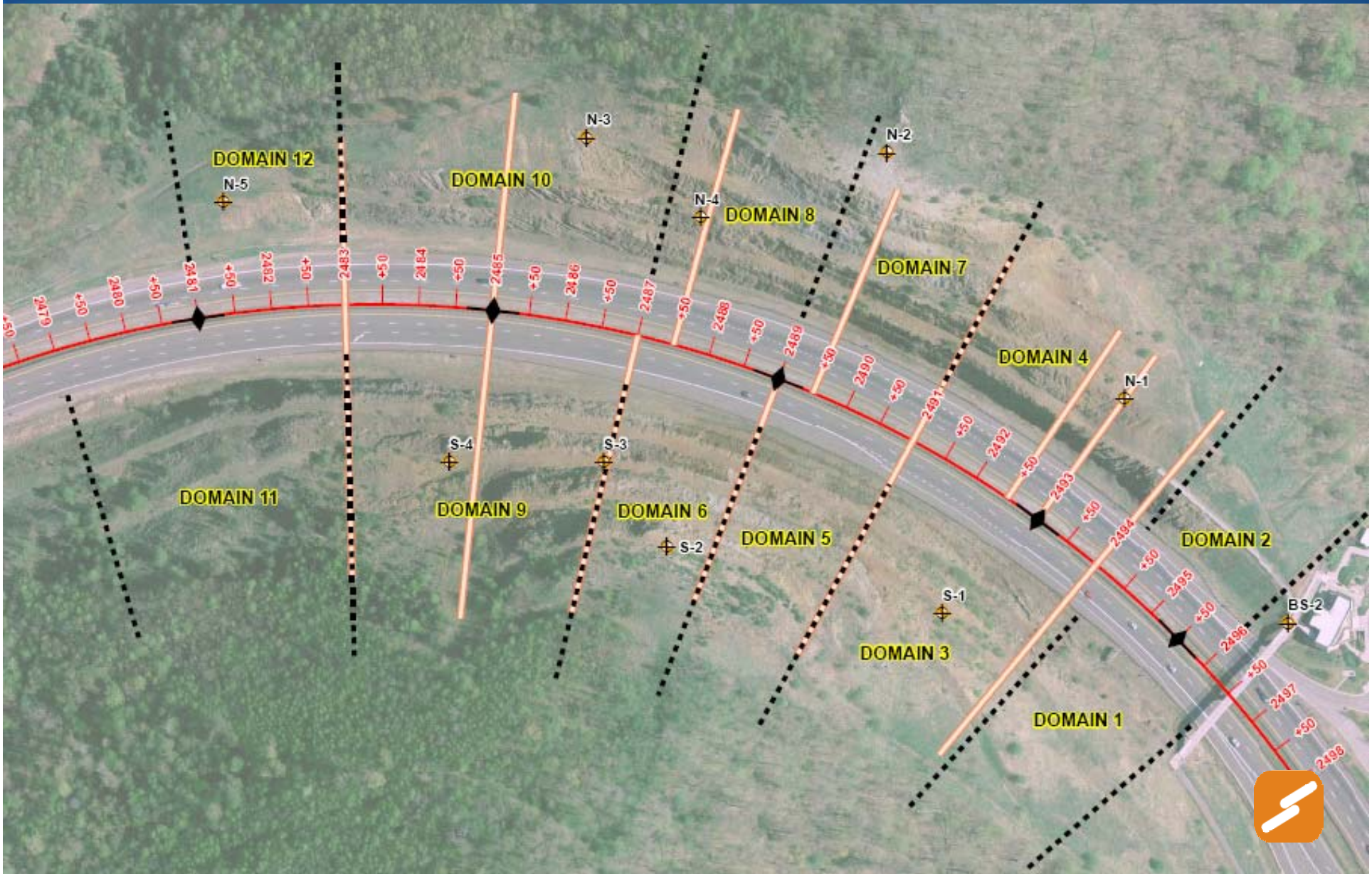
SOURCE

D [61]

F [255]

Equal Angle
Lower Hemisphere
316 Poles
316 Entries

Kinematic Analysis



Kinematic Analysis

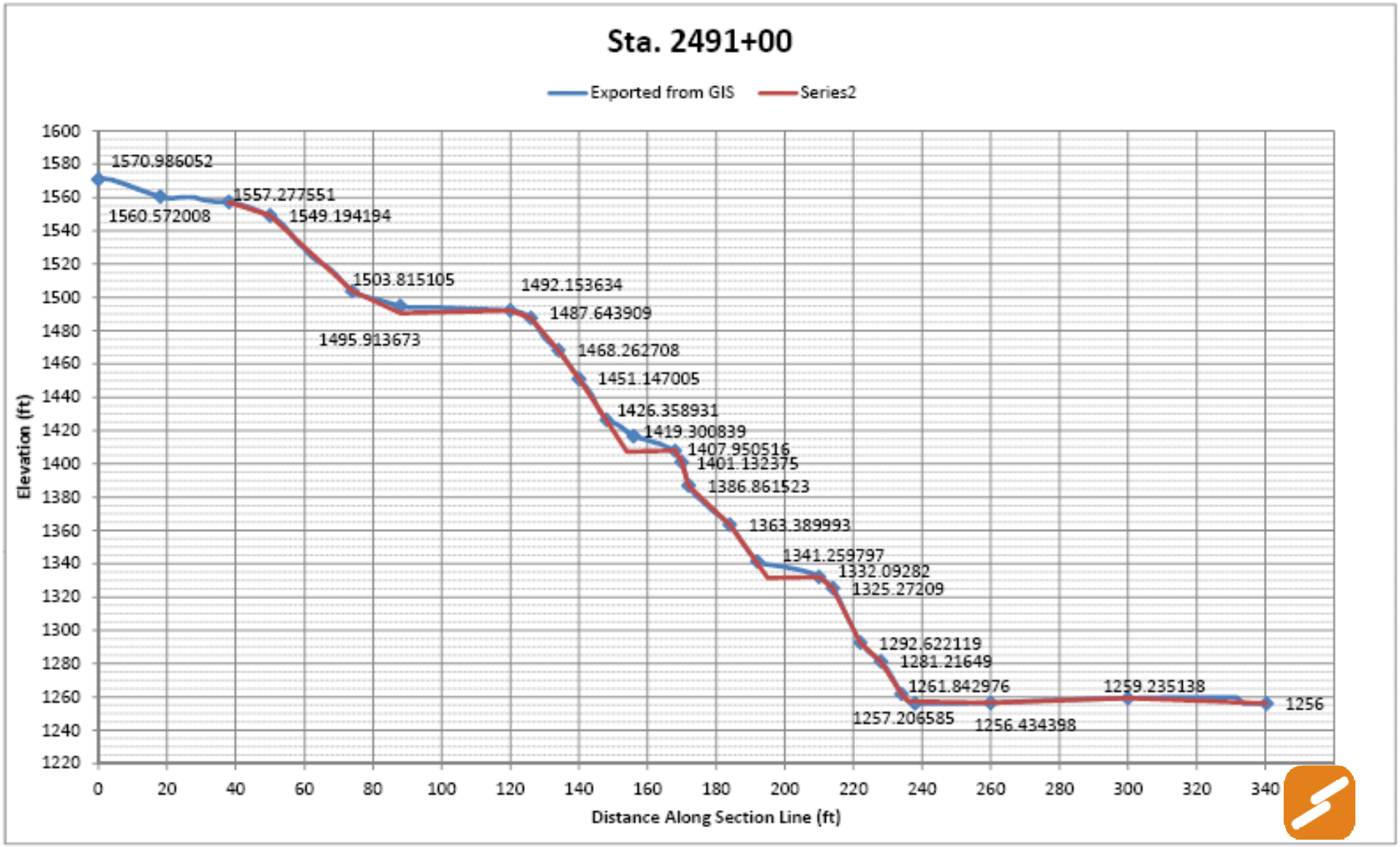
Summary

SLOPE	DOMAIN	FAILURE MODE
South	Domain 1	Planar Sliding (Major Joint)
North	Domain 8	Wedge Sliding (Bedding and Joint Set)
North	Domain 10	Planar Sliding (Major Joint)
North	Domain 12	Wedge Sliding (Bedding and Major Fracture)

Rockfall Hazard Analysis

- Inputs:
  - Profile (i.e., station)
  - Height (i.e., benches involved)
  - Debris on bench removed?
  - Block size (1ft, 3ft, 5ft)
  - Block shape
  - Analysis points

Rockfall Hazard Analysis



Rockfall Hazard Analysis

- Results:
  - Number passing
  - Percent passing
  - Maximum bounce height
  - Maximum energy

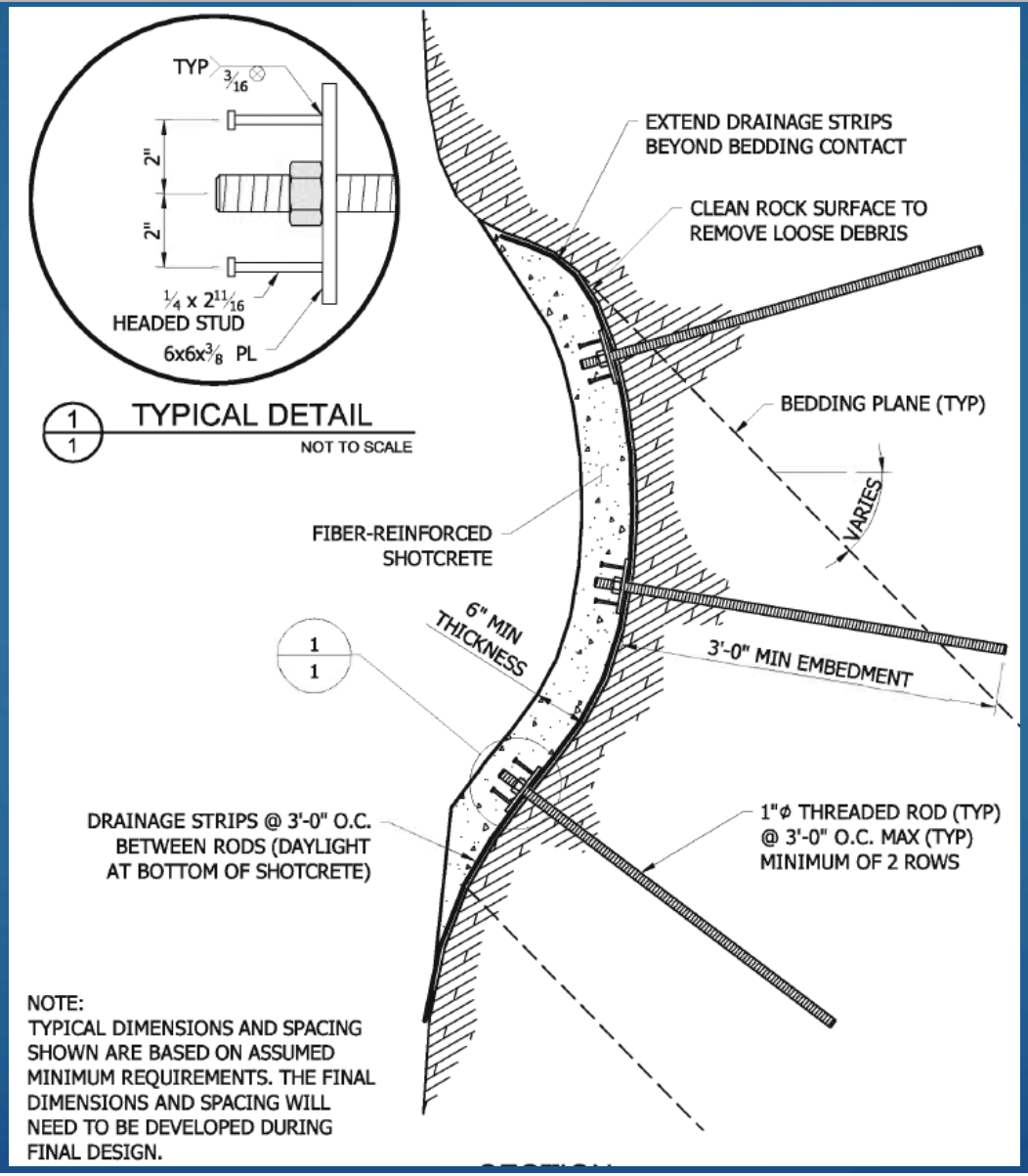
Conclusions from Hazard Study

- Emergency Action Not Required
- Bench-Scale Failures Not Indicated
- Small-Scale Rockfall Hazard
- Inadequate Catchment
- Debris Wedges
- Marginally-Stable Rock Blocks
- Overhanging Rock Ledges
- Vegetation

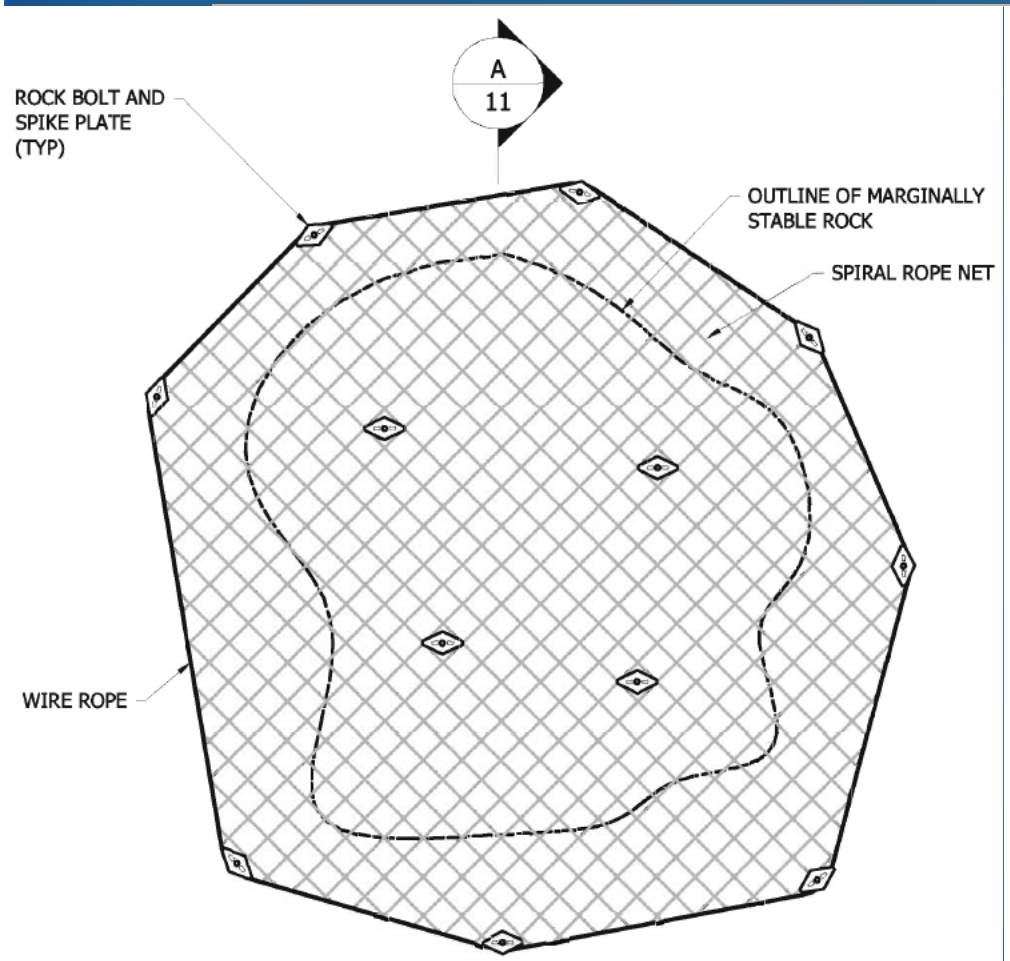
Option 1: Scaling and Bench Cleaning

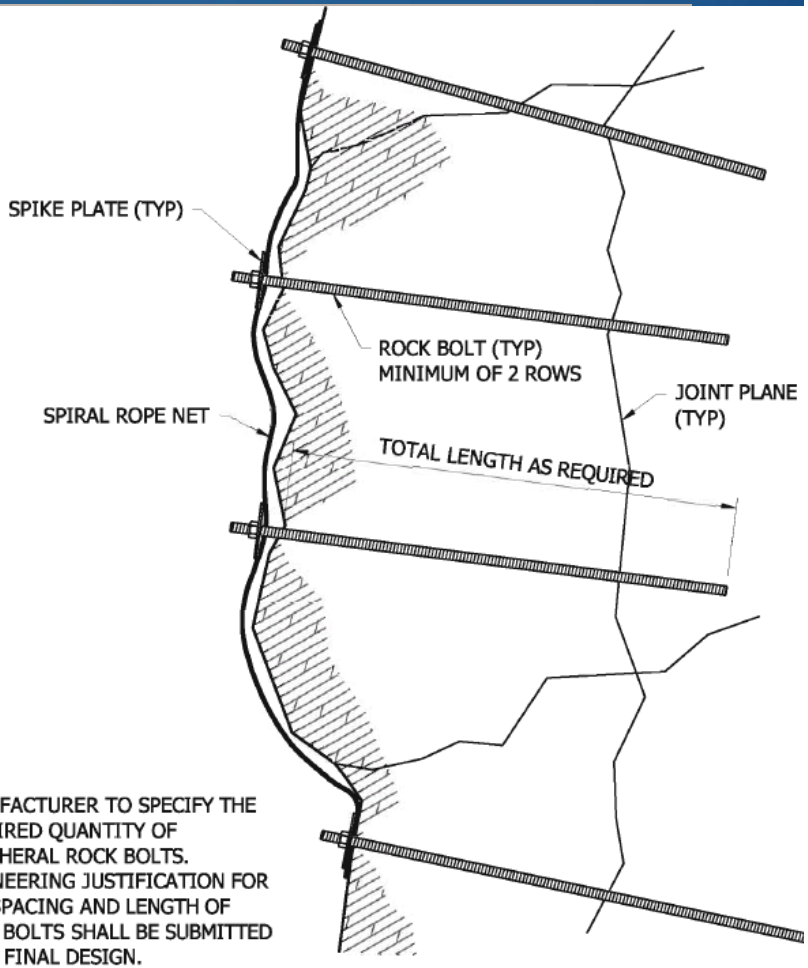
- “Routine” scaling
- Debris removal from benches and/or reshaping
- Reverse grade benches
- Periodic follow-up
- Shotcrete Surface Protection
- Spot Bolting and Anchored Mesh

Shotcrete Surface Protection



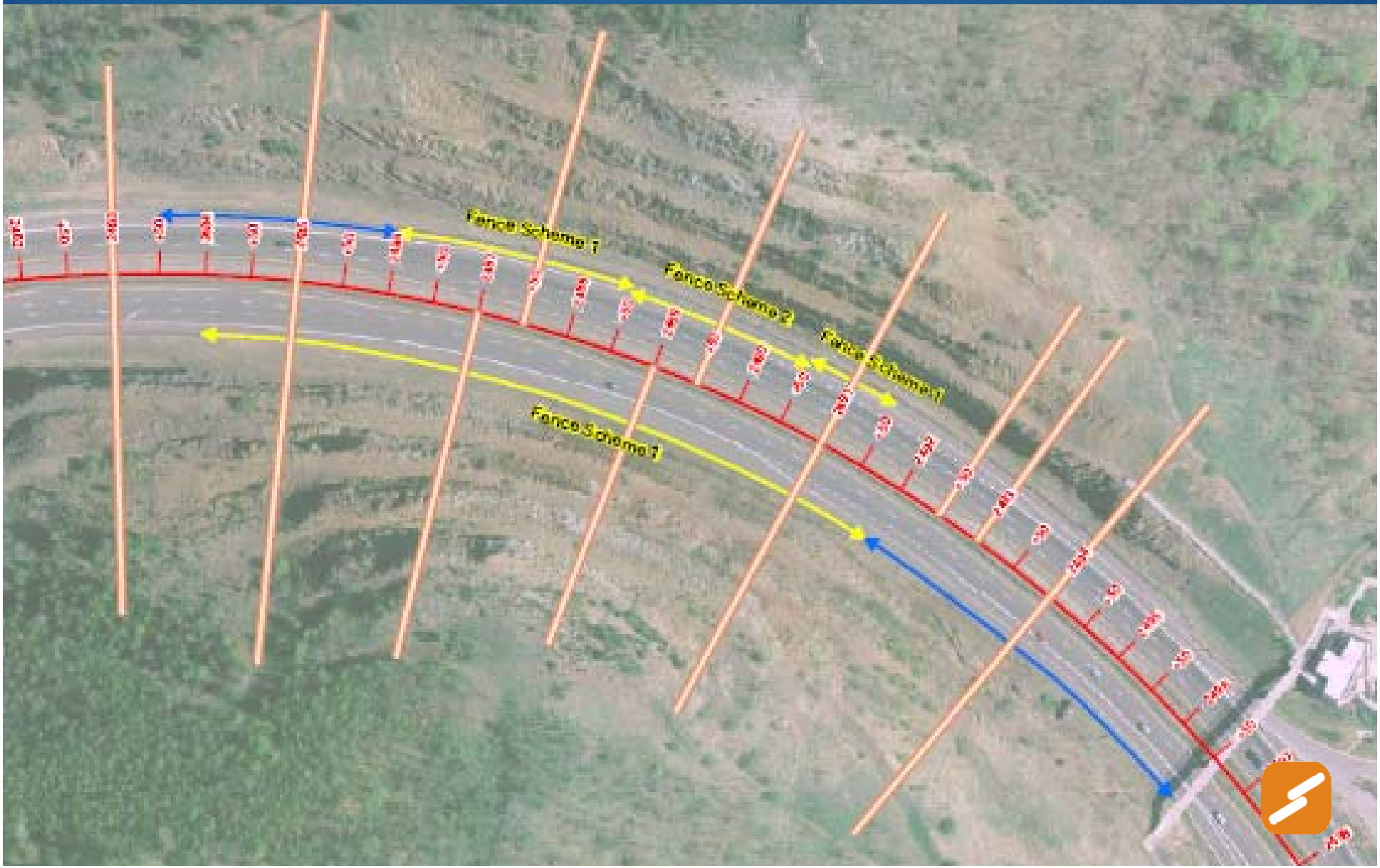
Spot Bolting and Anchored Mesh



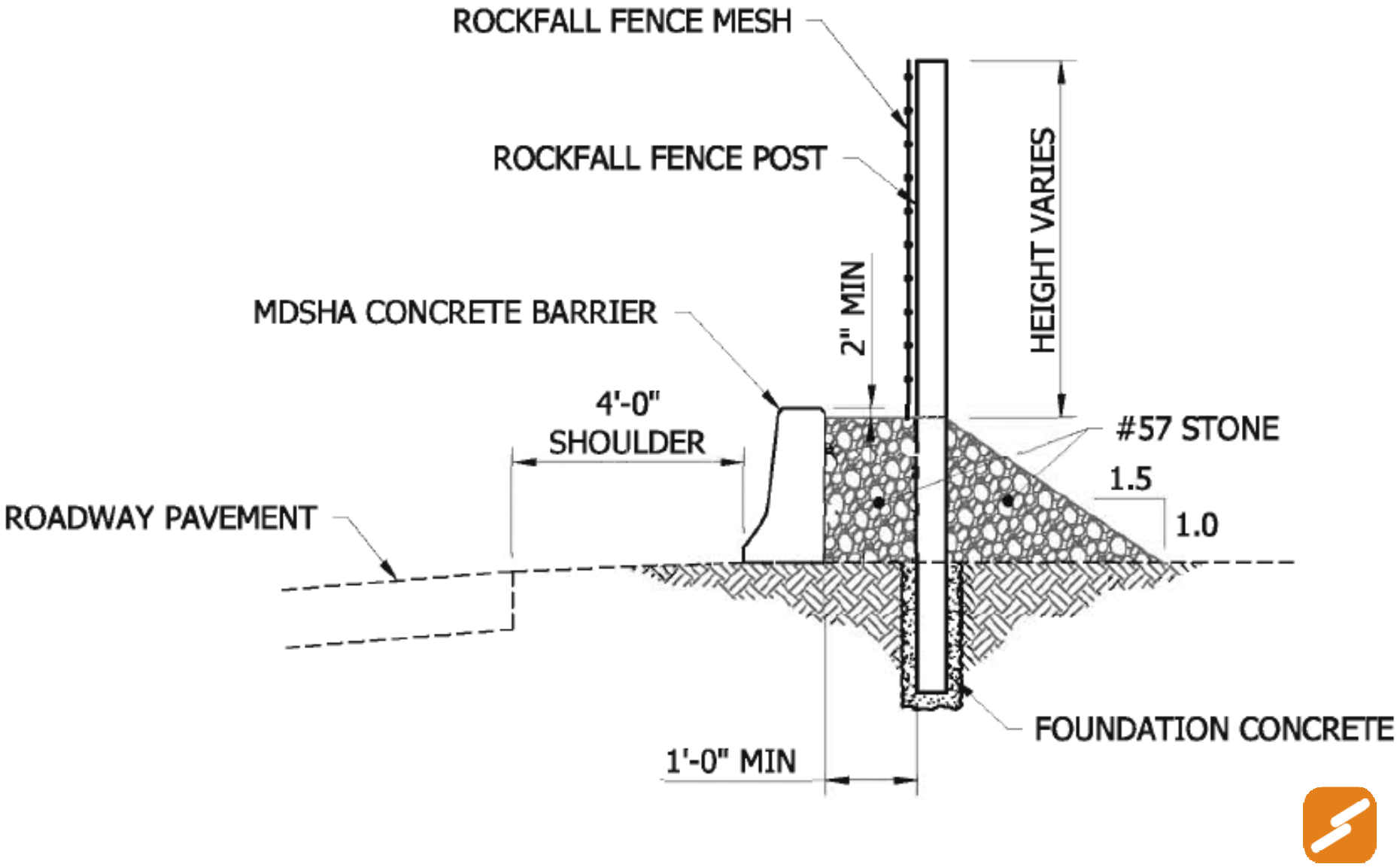


NOTES:
1. MANUFACTURER TO SPECIFY THE REQUIRED QUANTITY OF PERIPHERAL ROCK BOLTS.
2. ENGINEERING JUSTIFICATION FOR THE SPACING AND LENGTH OF ROCK BOLTS SHALL BE SUBMITTED WITH FINAL DESIGN.

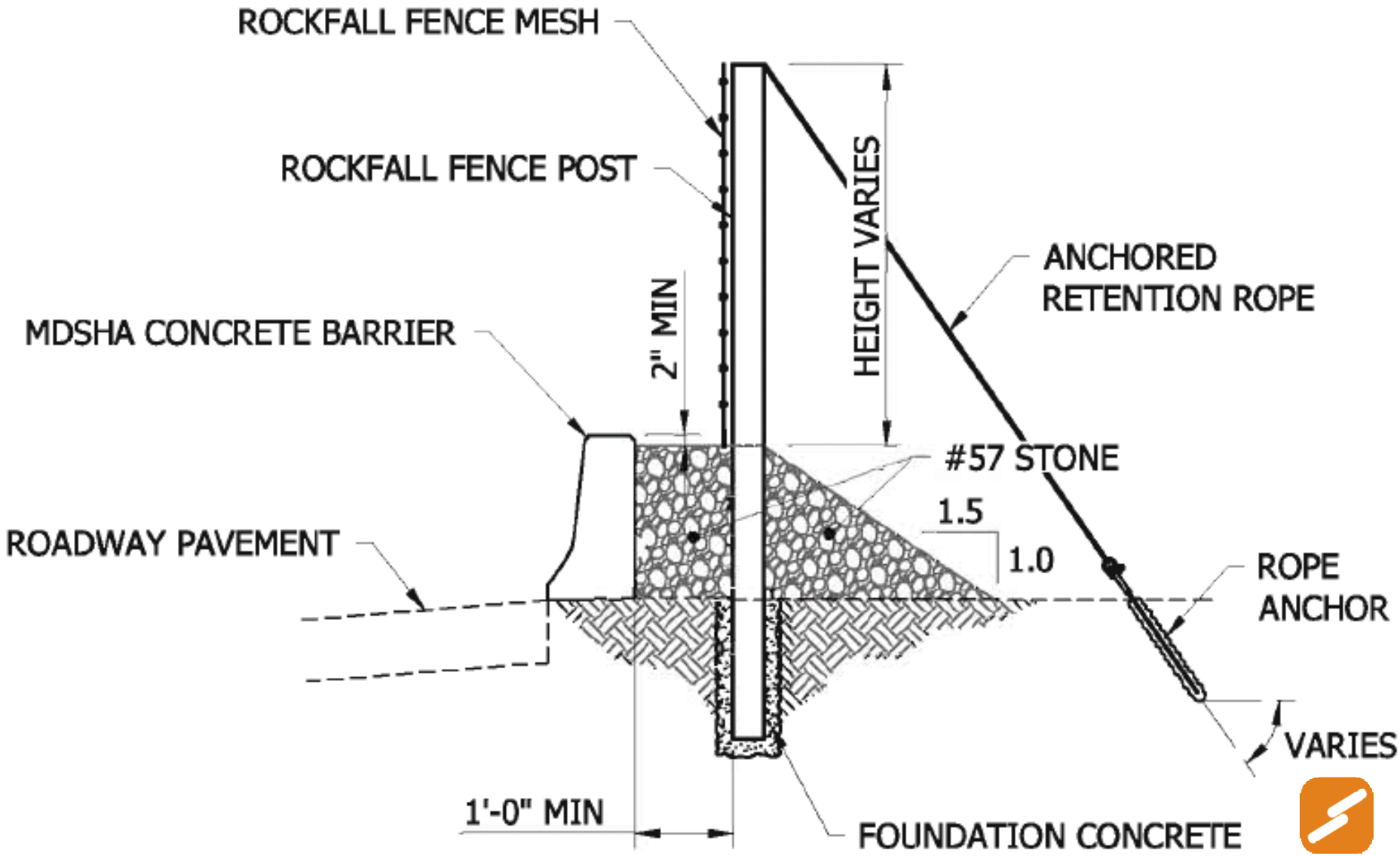
Option 2: Rockfall Barriers



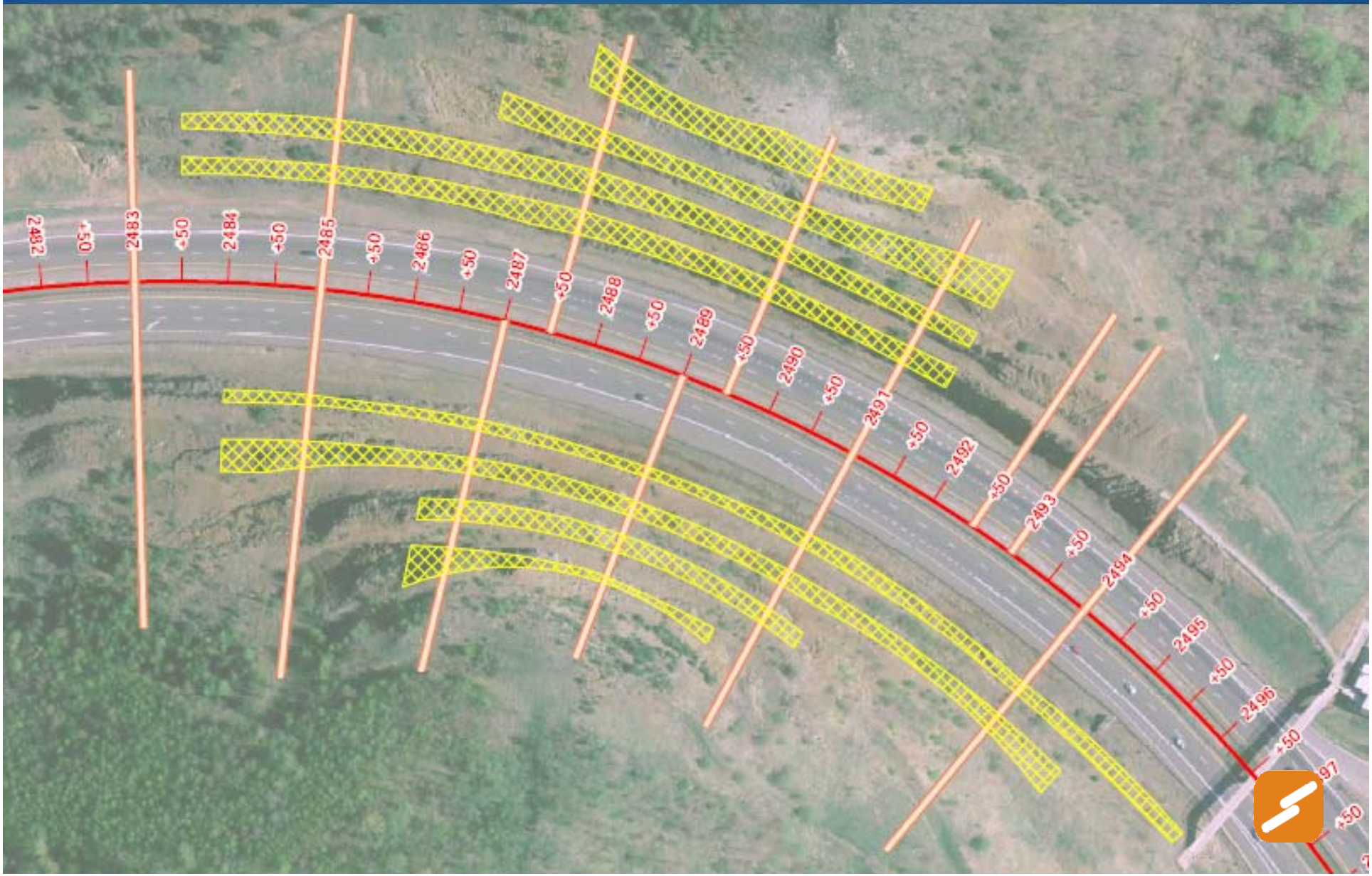
Option 2: Rockfall Barriers



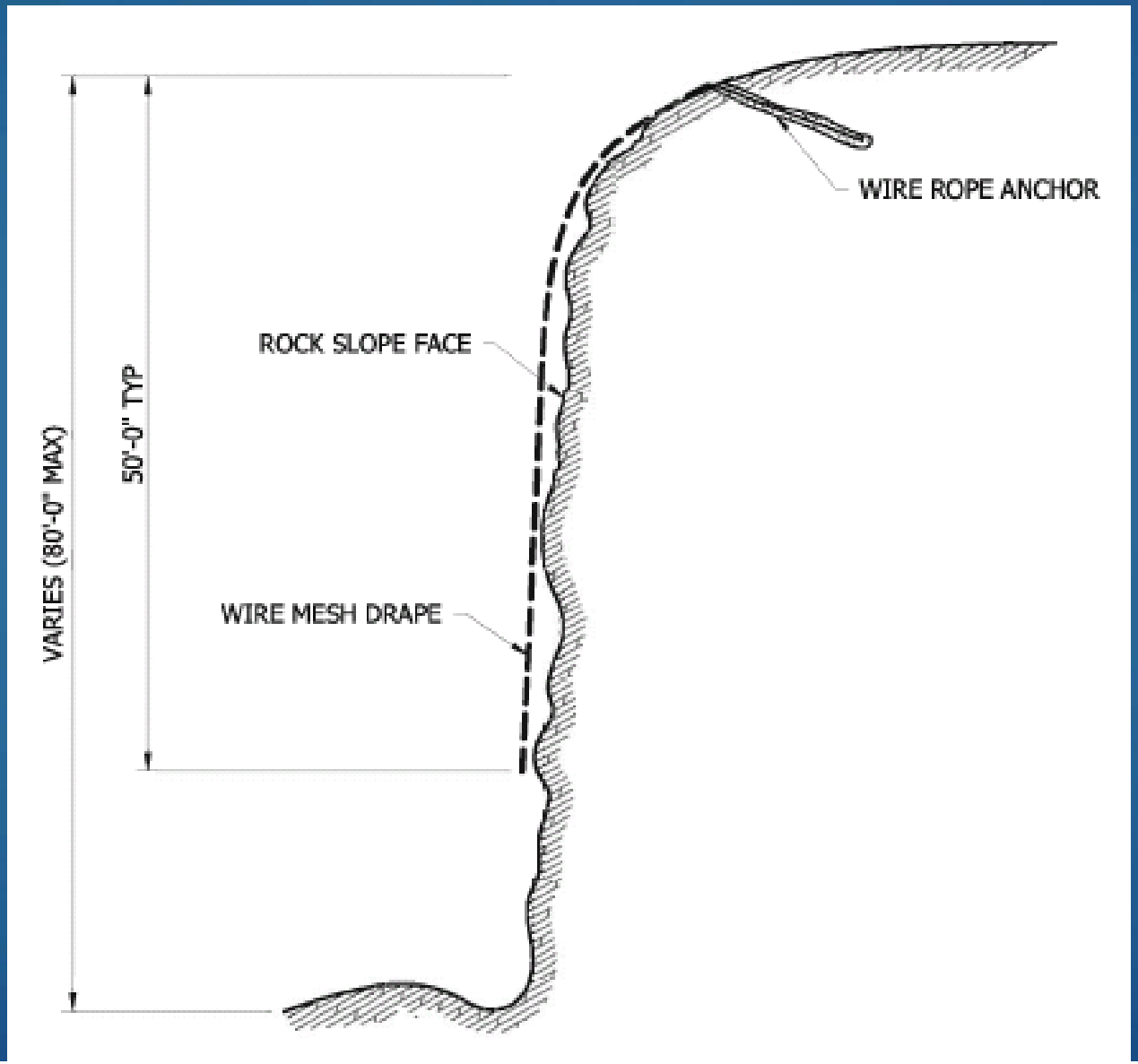
Option 2: Rockfall Barriers



Option 3: Rockfall Drapery



Option 3: Rockfall Drapery

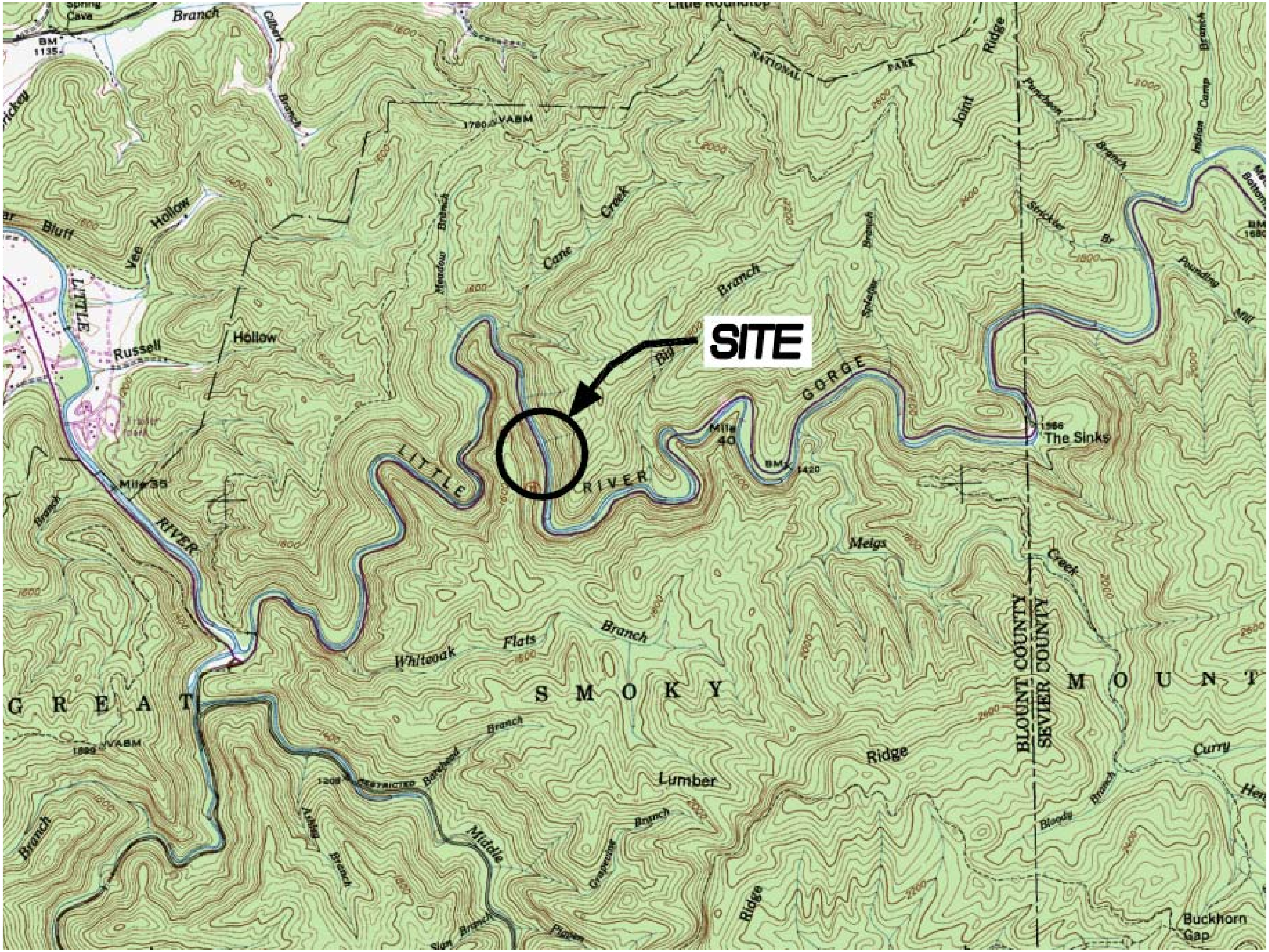


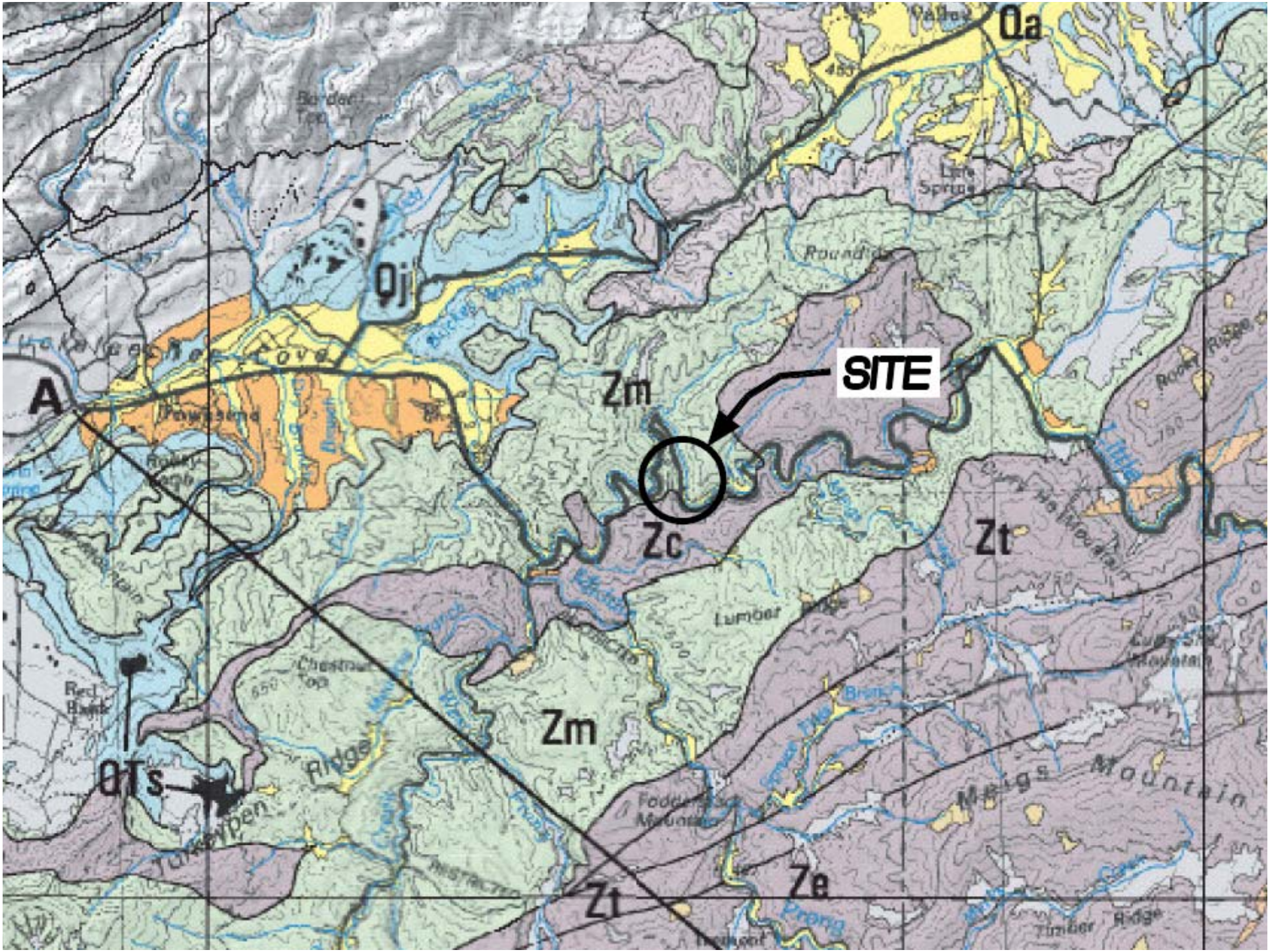
Periodic Monitoring and Maintenance

- Debris removal (2 yrs.)
- LiDAR survey and engineering geologic evaluation (4 yrs.)
- Slope monitoring plan
- Qualified engineering geologist or geological engineer should be present during slope maintenance

Little River Road
Great Smokey Mountains, Tennessee

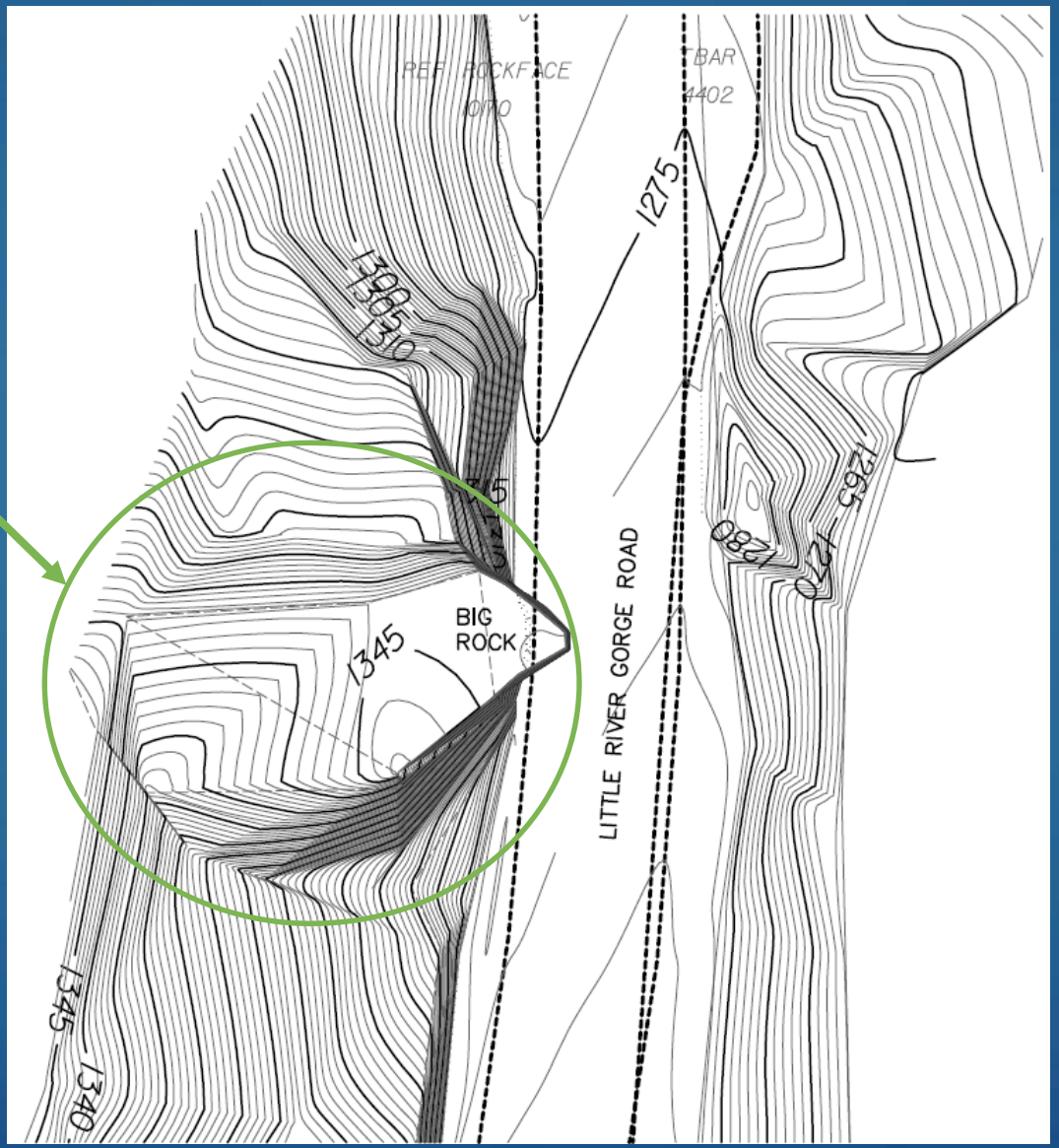
- Response to Large Rock Fall from ‘Big Rock’
  - Up to 7 ft. rock slabs on Little River Gorge Road During Storm
- Preservation of Natural Appearance of Iconic Rock Outcropping a Key Requirement
- Provide Assessment and Concept Remedial Design


SITE
LITTLE RIVER
GORGE
Mile 40
Mile 35
The Sinks
Big
Branch
Cane Creek
Meadow Branch
Russell
Hollow
Vee Hollow
Bluff
Meigs Creek
Whiteoak Flats Branch
GREAT SMOKY MOUNT
Lumber Ridge
BLOUNT COUNTY
SEVIER COUNTY
Joint Ridge
NATIONAL PARK
Buckhorn Gap
Middle
Indian Camp Branch
Pounding Mill
Curry
Bloody Branch
Grapeyard Branch

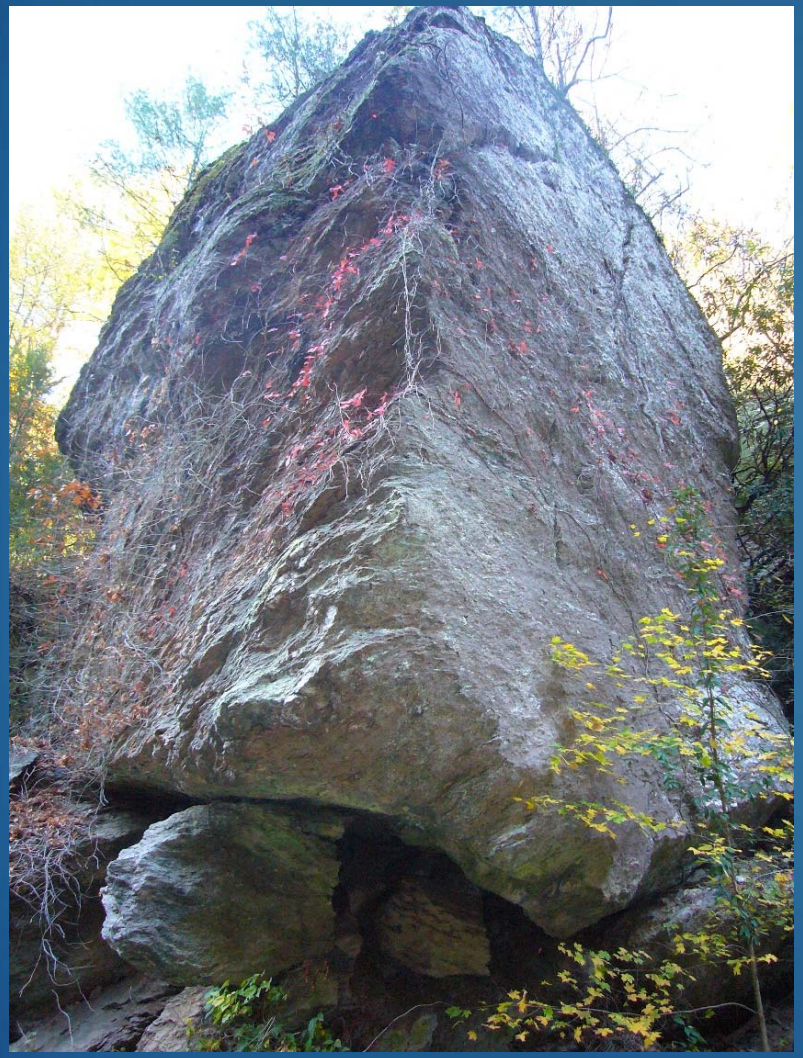

Qa
Qj
SITE
Zm
Zc
Zt
Zm
Zt
Ze
QTs
A

Topographic Site Plan

Big Rock



Little River Road
Great Smokey Mountains, Tennessee



- Rock Structure Mapping
  - Weathered and Fractured Mylonitic Phyillite with Strong Foliation
  - Fault Gouge Zone at Base
  - Potential Planar Sliding Along Foliation
- Boulders at Base (‘Key Block) ‘holding up’ Big Rock as Overhang ‘Rotates’ Toward Road
- Options: 1) Remove the Iconic ‘Big Rock’; or, Preserve In-Place

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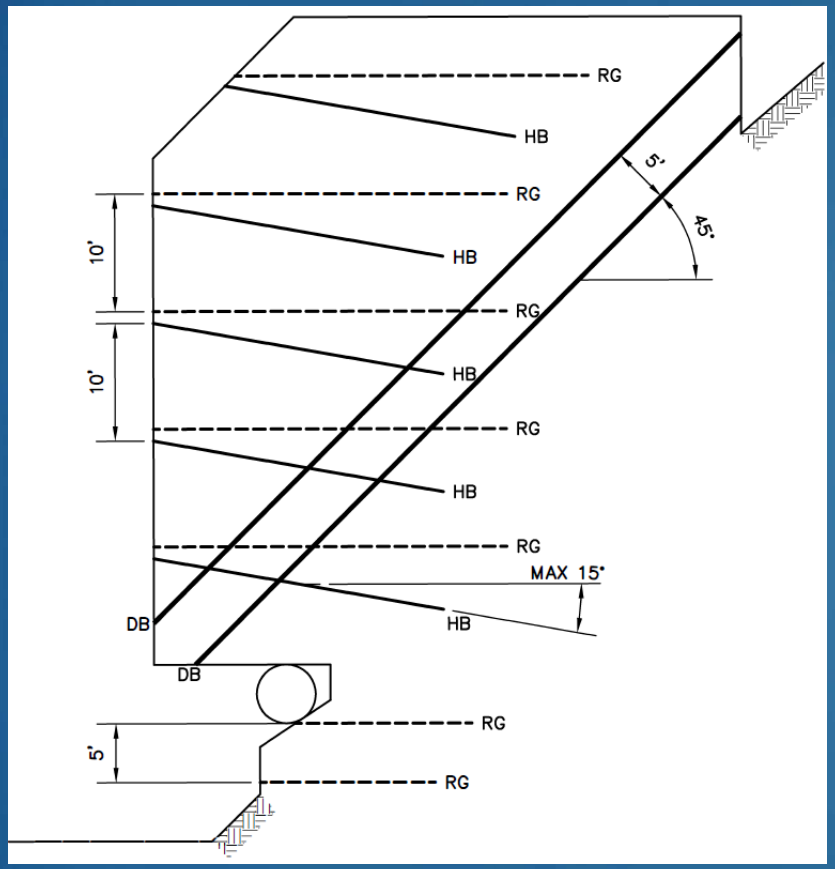
Great Smokey Mountains, Tennessee



- Mitigation Design Intent
  - Resist Planar Sliding Potential
  - Reduce Tensional Forces within Overhanging Rock Mass to Resist 'Rotation' onto Key Block
  - Stabilize Key Block and Base of Overhang by Grouting
- Design Features:
  - 'Rock Gluing' of Overhanging Rock Mass using PUR
  - Horizontal and Diagonal Passive Rock Bolts through Overhang
  - Grouting and Drainage around Key Block at Base

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