PRIORITIZATION OF AGING ROCK SLOPES ON I-77

HDR

Ryan Tinsley, PG

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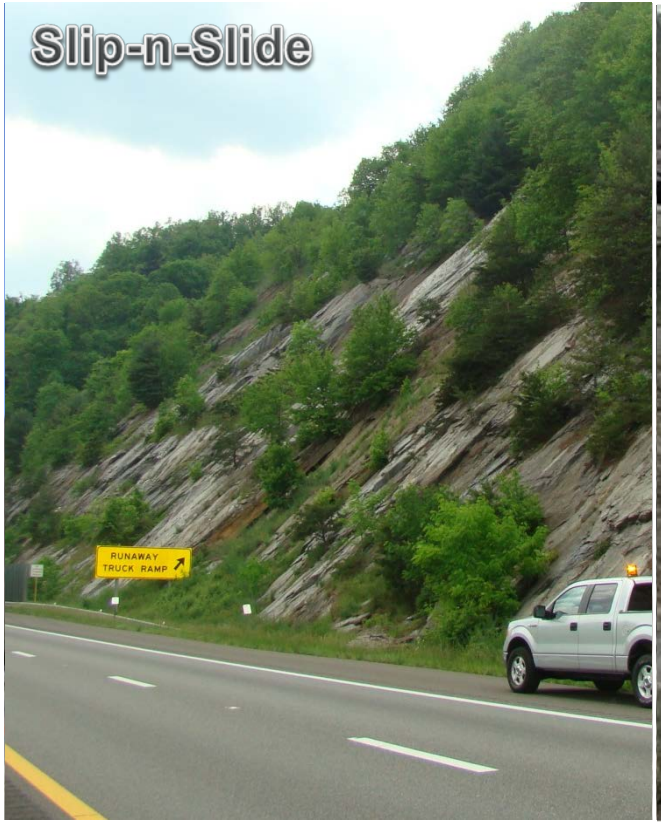
VDOT

David Lee, PE

Wade Pence, PG

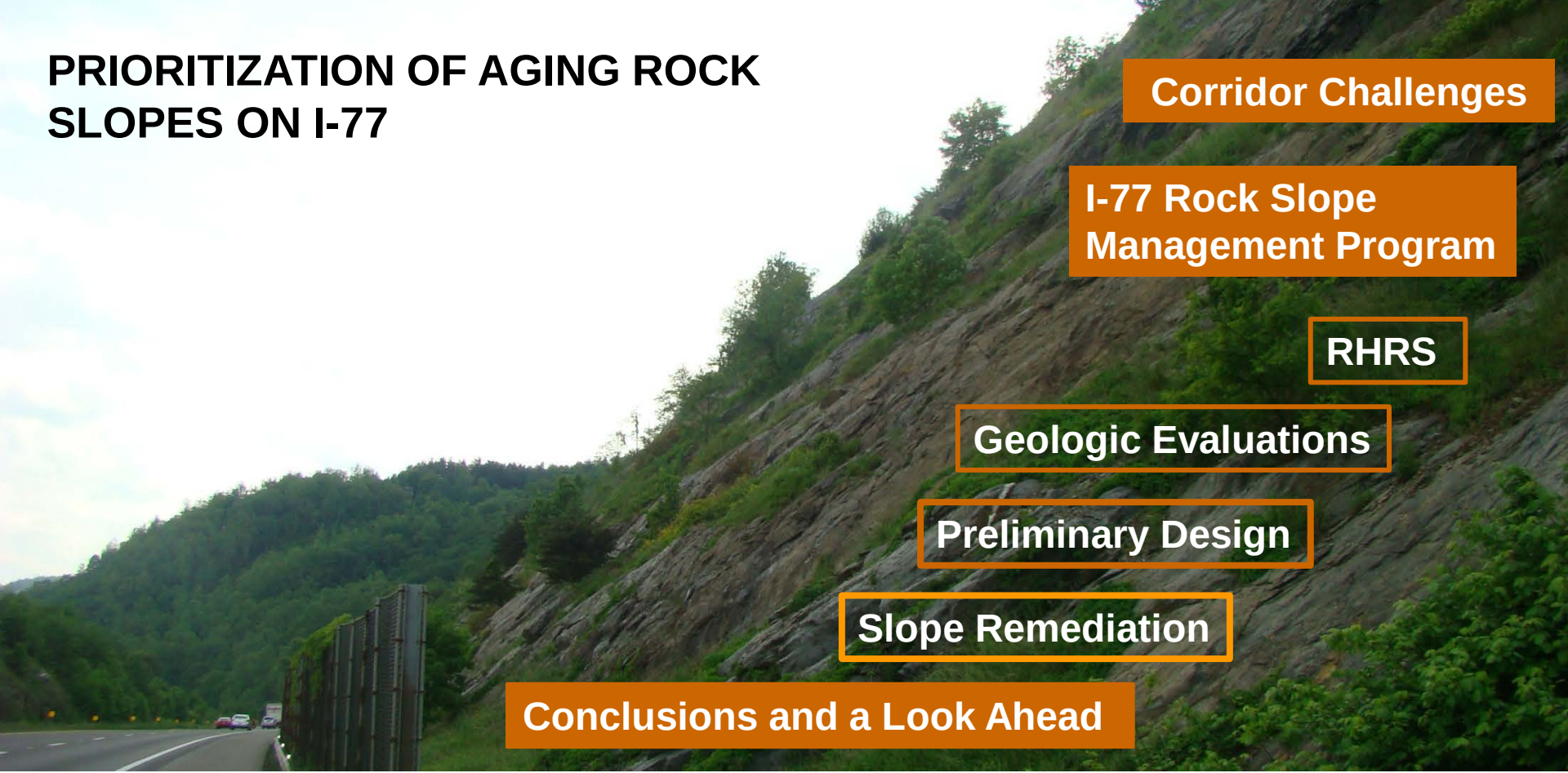
Travis Higgs, PE



JAMES MADISON UNIVERSITY.

EGAS
Center for Environmental, Geotechnical and Applied Sciences

PRIORITIZATION OF AGING ROCK SLOPES ON I-77



PRESENTATION OUTLINE

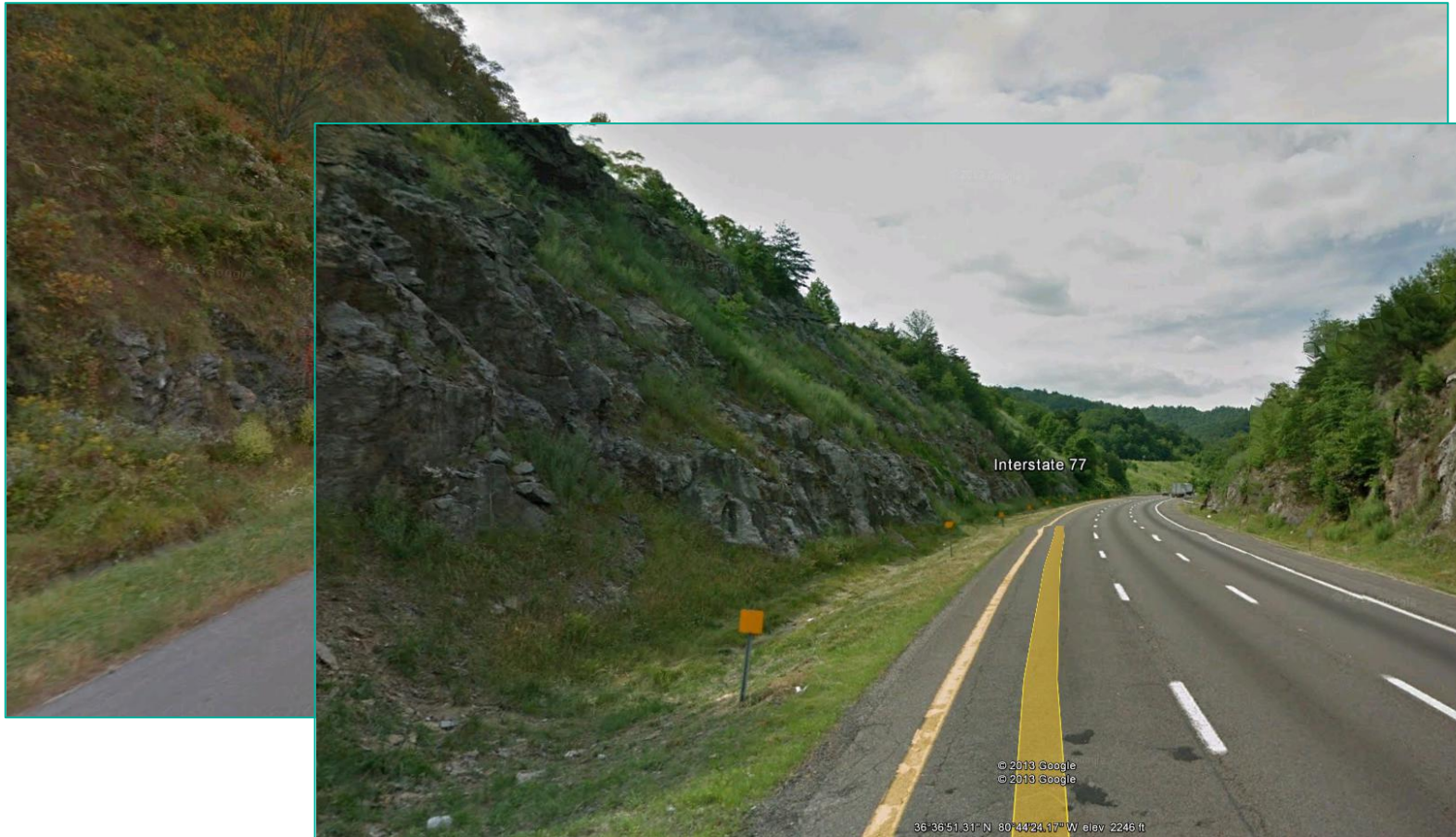
I-77 Rock Slope Evaluations| Carroll County, VA

CORRIDOR CHALLENGES

- High AADT
- Steep Grades
- Foggy Conditions
- Unfavorable Geology

I-77 CORRIDOR CHALLENGES: FOGGY CONDITIONS

TYPICAL SECTION – SOUTHBOUND/NORTHBOUND



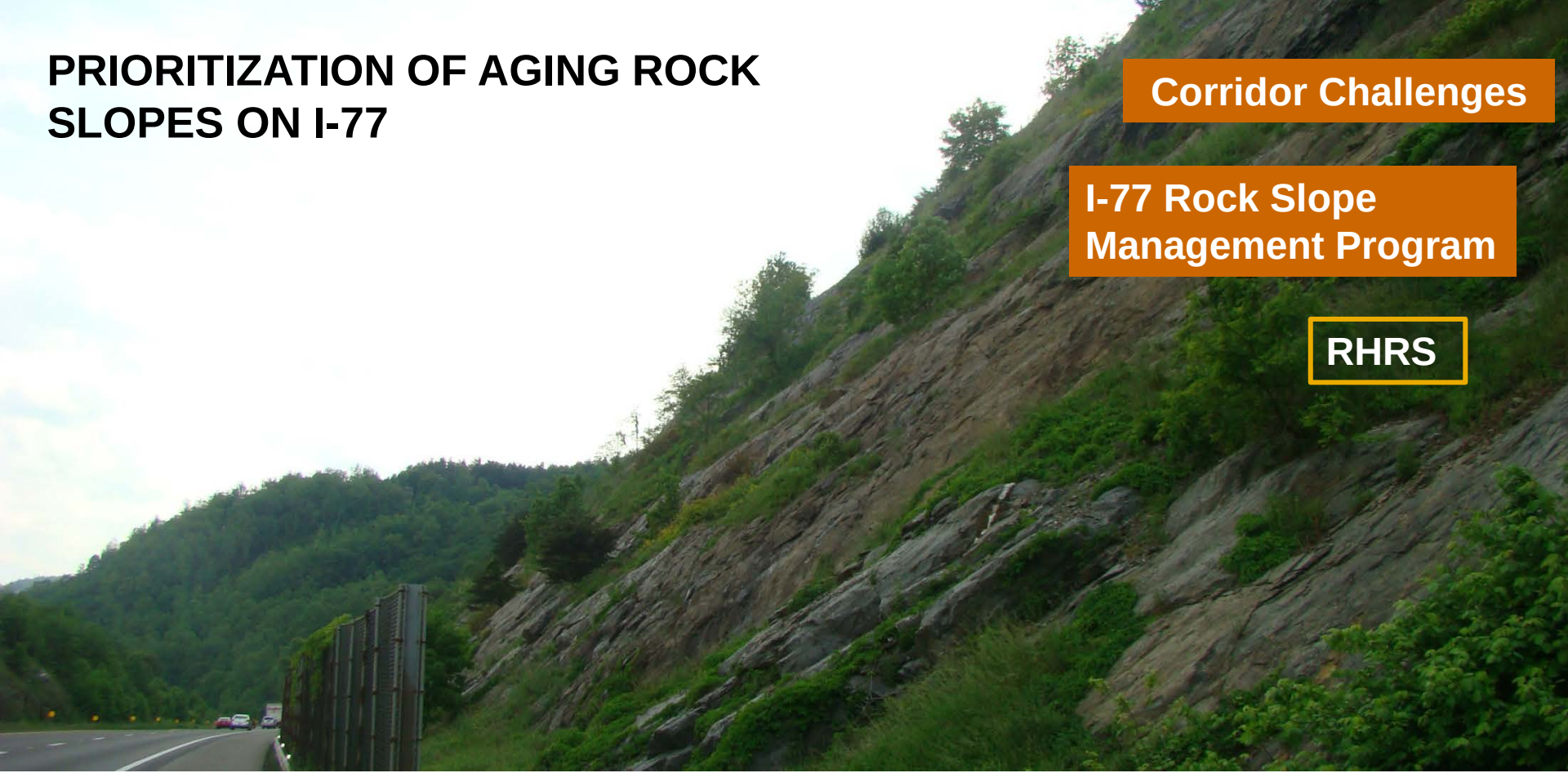
VDOT CHALLENGE: PRIORITIZATION OF AGING SLOPES

- Where are the problematic slopes along 32 Lane Miles
- What are the primary causes of the rockfall activity?
- What are feasible options?
- What are the probable construction cost estimates?

- Study Challenges
  - Significant slope height and length variability
  - No Existing Slope Inventory
  - No Survey
  - Limited Budget

Rock Slope Management Program

PRIORITIZATION OF AGING ROCK SLOPES ON I-77



Corridor Challenges

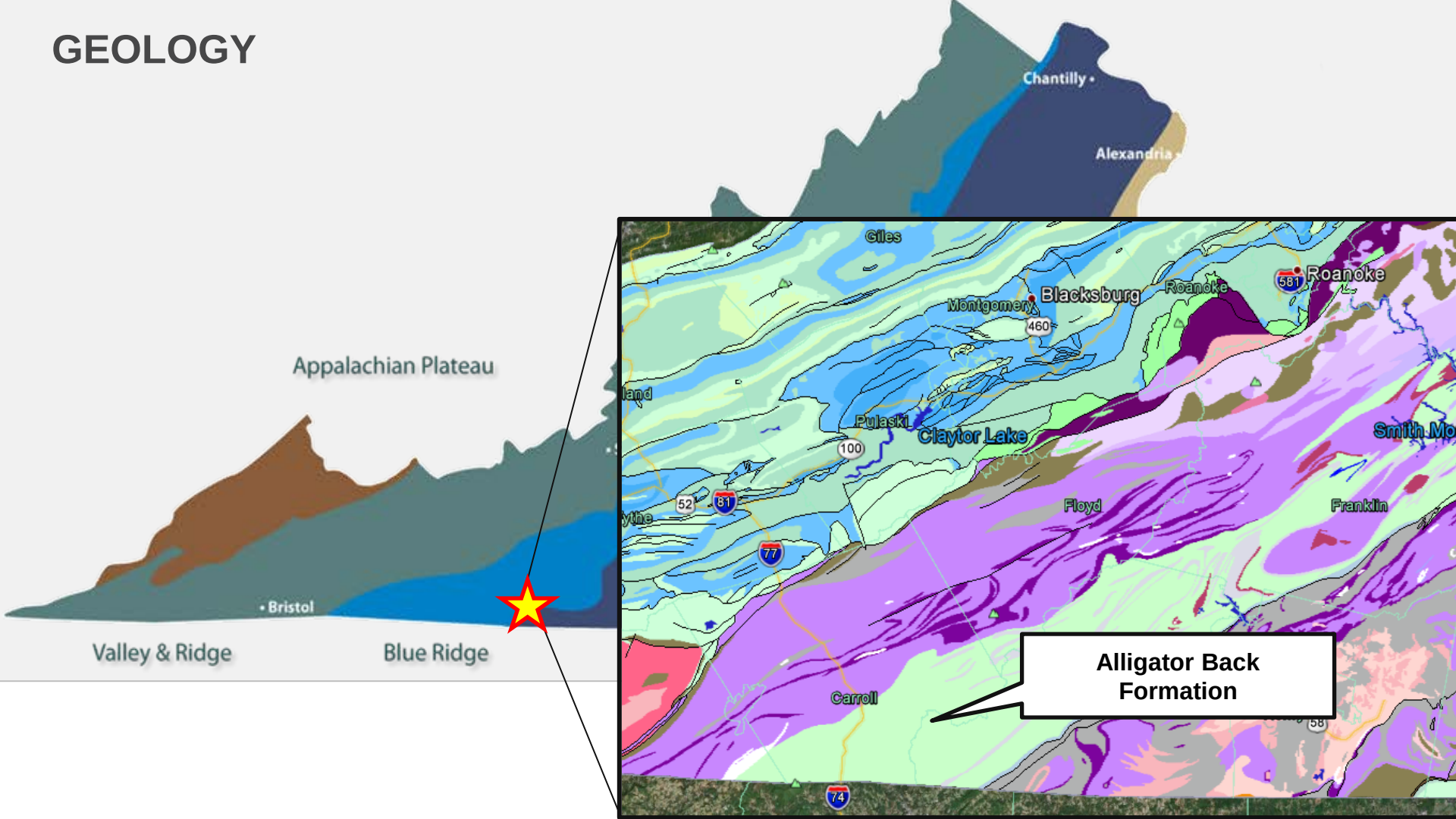
I-77 Rock Slope Management Program

RHRS

Rockfall Hazard Rating System

HDR

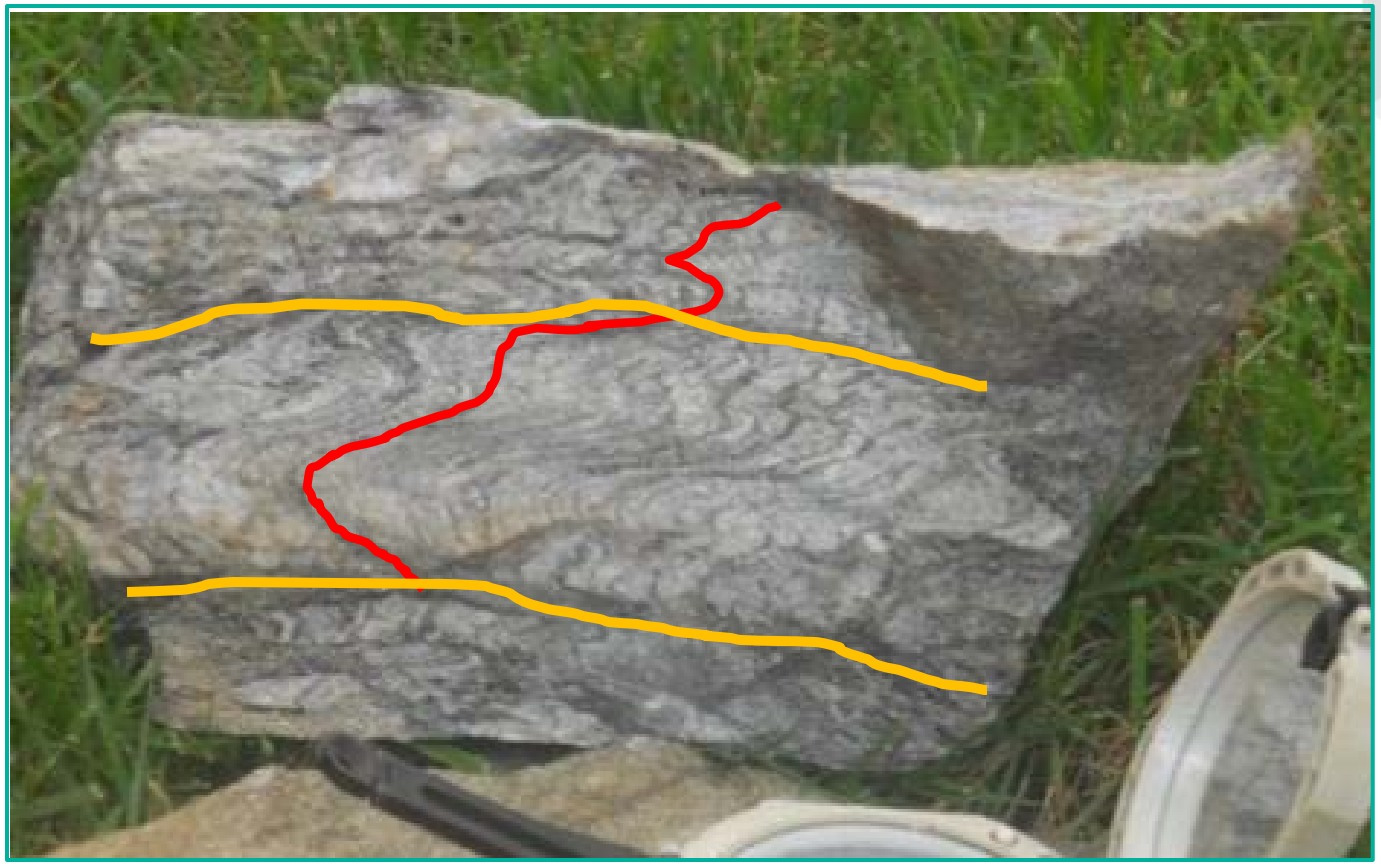
GEOLOGY


Chantilly
Alexandria
Appalachian Plateau
Bristol
Valley & Ridge
Blue Ridge
Giles
Blacksburg
Montgomery
Roanoke
Roanoke
460
581
Pulaski
Claytor Lake
100
52
81
77
Floyd
Franklin
Smith Mo
Carroll
58
74
Alligator Back Formation

GEOLOGY

- Alligator Back Formation – Proterozoic Z – Cambrian
- Complexly Deformed With at Least 2 Periods of Ductile Deformation with Isoclinal Folding
- Well-Developed Cleavage Dominates
- Rock Types:
  - Biotite Gneiss (Metagraywacke)
  - Mica-Biotite Schist and Amphibolite

GEOLOGY



RHRS IMPLEMENTATION

U.S. Department of Transportation
Federal Highway Administration

Publication No. FHWA SA-93-057
November 1993

NHI Course No. 130220

Rockfall Hazard Rating System
Participant's Manual

National Highway Institute

Innovation Through Partnerships

FINAL REPORT

IMPLEMENTATION OF THE ROCK SLOPE MANAGEMENT PROJECT AT THE VIRGINIA DEPARTMENT OF TRANSPORTATION

Edward J. Hoppe, Ph.D., P.E.
Senior Research Scientist

Derek H. Whitehouse, C.P.G.
Chief Transportation Geologist

Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

Charlottesville, Virginia

June 2006
VTRC 06-R23

2012 RHRS STUDY FOR INTERSTATE 77 – CUT SLOPE INVENTORY

- Initial Slope Inventory Using Plans and Aerial Photography
- Develop Sequential List of Cut Slopes in Each Lane Direction from South to North
- Field Verification of Cut Slopes Based on Preliminary RHRS Classes A, B, and C
  - Some Slopes Eliminated from Further Consideration and Rating
- Field Location of Class A, B, and C Slopes Using Hand-held Garmin and MP Designations

- What is a Class A, B, or C Slope?
  - ***Class A*** – High Potential for Rockfall on Roadway
  - ***Class B*** – Moderate Potential for Rockfall on Roadway
  - ***Class C*** – Low Potential for Rockfall on Roadway (Class C Slopes Not Rated)

Ultimately, Preliminary Class Designations are Subjective Based on Experience of Rater, But Provide a Means for Prioritizing Slopes!

2012 RHRS STUDY FOR INTERSTATE 77

NB/SB MP Marker
RHRS Preliminary Rating A
RHRS Preliminary Rating B
RHRS Preliminary Rating C
Historical Rockfall
Slope Length
SB MP Baseline
NB MP Baseline
NB/SB Median Slope Begin
NB/SB Median Slope End
NB/SB Outside Slope Begin
NB/SB Outside Slope End
NB/SB Begin/End Median Slope
NB/SB Begin/End Outside Slope
[364] 2012 RHRS Detailed Rating Score

A [565]
A [511]
B [349]
A [560]
A [506]
14-SB
13-SB/14-SB
12-SB
13-SB
12-SB (M)
10-NB (M)
0-NB
8-NB/9-NB
9-NB
12-NB (M)
11-NB
3-7-2011: MP 3.75
NB Median Slope

Note: 1. Slope Limits and Mile Posts are Approximate Only

Created by R. Roa
Checked by R. Tinsley

0 100 200 Feet
1 inch = 200 feet

Virginia Department of Transportation - Salem District
Interstate 77, MP 0.0 to MP 8.0 (Fancy Gap)
Slope Inventory and RHRS Slope Rating

Prepared by: HDR June 2012 Page 7 of 15

2012 RHRS STUDY FOR INTERSTATE 77

- RHRS Key Rating Criteria:
  - Slope Height
  - Ditch Effectiveness
  - AVR – Average Vehicle Risk
  - % Site Distance
  - Roadway Width
  - Geologic Characteristics
  - Block Size or Volume of Rockfall
  - Rockfall History (Historical and Observed)

TABLE 4.1: SUMMARY SHEET OF THE ROCKFALL HAZARD RATING SYSTEM

CATEGORY			RATING CRITERIA AND SCORE			
			POINTS 3	POINTS 9	POINTS 27	POINTS 81
SLOPE HEIGHT			25 FEET	50 FEET	75 FEET	100 FEET
DITCH EFFECTIVENESS			Good catchment	Moderate catchment	Limited catchment	No catchment
AVERAGE VEHICLE RISK			25% of the time	50% of the time	75% of the time	100% of the time
PERCENT OF DECISION SIGHT DISTANCE			Adequate sight distance, 100% of low design value	Moderate sight distance, 80% of low design value	Limited sight distance, 60% of low design value	Very limited sight distance 40% of low design value
ROADWAY WIDTH INCLUDING PAVED SHOULDERS			44 feet	36 feet	28 feet	20 feet
GEOLOGIC CHARACTER	CASE 1	STRUCTURAL CONDITION	Discontinuous joints, favorable orientation	Discontinuous joints, random orientation	Discontinuous joints, adverse orientation	Continuous joints, adverse orientation
		ROCK FRICTION	Rough, Irregular	Undulating	Planar	Clay infilling, or slickensided
	CASE 2	STRUCTURAL CONDITION	Few differential erosion features	Occasional differential erosion features	Many differential erosion features	Major differential erosion features
		DIFFERENCE IN EROSION RATES	Small difference	Moderate difference	Large difference	Extreme difference
BLOCK SIZE / VOLUME OF ROCKFALL/EVENT			1 Foot / 3 cubic yards	2 Feet / 6 cubic yards	3 Feet / 9 cubic yards	4 Feet / 12 cubic yards
CLIMATE AND PRESENCE OF WATER ON SLOPE			Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation or short freezing periods or intermittent water on slope	High precipitation or long freezing periods or continual water on slope	High precipitation and long freezing periods or continual water on slope and long freezing periods
ROCKFALL HISTORY			Few falls	Occasional falls	Many falls	Constant falls

2012 RHRS STUDY FOR

RHRS Detailed Rating Field Data Sheet CUT B-SB PHOTOS 70, 71, 72, 73, 74, 76

Date: 5-18-12 Rating: (A) / B Rater: L. ARTMAN, PG.

County/City	CARROLL	Start Latitude	36.602539	Start Longitude	80.736913
Route No.	I-77	End Latitude	36.605746	End Longitude	80.736360
Nearest Inter.	EXIT 1 (SB)	Start MP (est)	2.95	End MP (est)	3.15
ADT	18,000 (SB)	Speed Limit	65	Left / (Right) Heading N S E W	(S-SW)

Category		Remarks		Category Score	
Slope Geometry				**Slope Geometry**	
Slope Height	100 ft.	Slope Angle H.I.	½:1	Slope Height	81
Ditch Effectiveness	G M (L) N	Ditch Width	10'-15'	Ditch Effect.	27
Average Vehicle Risk	105 %	Section Length	1200'	AVR	100
Sight Distance % Decision S.D.	420 ft. 40 %	Sign Present	Yes / (No)	Sight Distance	81
Roadway Width	39 ft.			Roadway Width	6
Geologic Characteristics				**Geologic Characteristics**	
Case 1				*Case 1*	
Structural Condition	D (C) / F R (A)			Struct. Cond.	81
Rock Friction	R I (P) C-S			Rock Friction	27
Case 2				*Case 2*	
Differential Erosion Features	F O N M	N/A		Erosion Feat.	0
Difference in Erosion Rates	S M L E	N/A		Erosion Rates	0
Rockfall Characteristics				**Rockfall Characteristics**	
Block Size/Volume	>4 (ft) or yd³			Block Size	81
Rockfall History	F O M (C)			Rockfall History	81
				Total Score	565

Comments:
- MOST ROCKFALL OBSERVED ON SB SIDE,
- FREQUENT WEDGE/PLANAR FAILURES. JOINTS SEPARATED
- POISED BLOCKS HIGH ON SLOPE. MANY LARGE FEATURES.
- SPORADIC WATER
- SPARSE VEGETATION
- CHECKED SLIGHTLY DIFFERENT, MORE EXCAVATION AND WEATHERING.

R RATING = A

G = Good M = Moderate L = Limited N = None
D = Discontinuous C = Continuous F = Favorable R = Random A = Adverse
R = Rough I = Irregular U = Undulating P = Planar C-S = Clay-Slickensided
F = Few O = Occasional N = Numerous M = Major
S = Small M = Moderate L = Large E = Extreme
F = Few O = Occasional M = Many C = Constant

Near angle / Far angle / Distance between (see back of sheet)

Slope Heights:
25 to > 250 ft

Slope Height (ft)	25	50	75	100
Category Score	3	9	27	81

2012 RHRS STUDY FOR INTERSTATE 77

RHRS Detailed Rating Field Data Sheet CUT B-SB PHOTOS 70, 71, 72, 73, 74, 76

Date: 5-18-12 Rating: (A) / B Rater: L. ALTMAN, PG.

County/City	CARROLL	Start Latitude	36.602539	Start Longitude	80.736913
Route No.	I-77	End Latitude	36.605746	End Longitude	80.736360
Nearest Inter.	EXIT 1 (SB)	Start MP (est)	2.95	End MP (est)	3.15
ADT	18,000 (SB)	Speed Limit	65	Left / (Right) Heading	N S E W (S-SW)

Category		Remarks	Category Score
Slope Geometry			**Slope Geometry**
Slope Height	100 ft.	Slope Angle 1/2:1 H.I.	Slope Height 81
Ditch Effectiveness	G M (T) N	Ditch Width	Ditch Effect.
Average Vehicle Risk	105 %	Section Length 1280	AVR 100
Sight Distance	420 ft.	Sign Present Yes / (No)	Sight Distance 81
% Decision S.D.	40 %		
Roadway Width	39 ft.		Roadway Width 6
Geologic Characteristics			**Geologic Characteristics**
Case 1			*Case 1*
Structural Condition	D (C) / F R (A)		Struct. Cond. 81
Rock Friction	R I (P) C-S		Rock Friction 27
Case 2			*Case 2*
Differential Erosion Features	F O N M	N/A	Erosion Feat. 0
Difference in Erosion Rates	S M L E	N/A	Erosion Rates 0
Rockfall Characteristics			**Rockfall Characteristics**
Block Size/Volume	>4 (1) or yd³		Block Size 81
Rockfall History	F O M (C)		Rockfall History 81
			Total Score 565

Comments:
- MOST ROCKFALL OBSERVED ON SB SIDE.
- FREQUENT UNDERCUT/REMOVAL FAILURES. JOINTS SEPARATED
- POISED BLOCKS HIGH ON SLOPE. MOST LARGEST FEATURES.
- SPORADIC WATER
- STORMING VEGETATION
- GEOLOGY SIGNIFICANT DIFFERENCE, ANGLE OBLIGATION AND WEATHERING.

P. RATING = A

G = Good M = Moderate L = Limited N = None
D = Discontinuous C = Continuous F = Favorable R = Random A = Adverse
R = Rough I = Irregular U = Undulating P = Planar C-S = Clay-Slickensided
F = Few O = Occasional N = Numerous M = Major
S = Small M = Moderate L = Large E = Extreme
F = Few O = Occasional M = Many C = Constant

Near angle / Far angle / Distance between (see back of sheet)

Average Vehicle Risk:
AADT = 18,000
Slope Length = 1280 feet
Typical AVR Score :81-100

2012 RHRS STUDY FOR INTERSTATE 77

RHRS Detailed Rating Field Data Sheet CUT B-5B PHOTOS 70, 71, 72, 73, 74, 76.1

Date: 5-18-12 **Rating:** (A) / B Rater: L. ALTMAN, PG.

County/City	CARROLL	Start Latitude	36.602539	Start Longitude	80.736413
Route No.	I-77	End Latitude	36.605746	End Longitude	80.736360
Nearest Inter.	EXIT 1 (SB)	Start MP (est)	2.95	End MP (est)	3.15
ADT	18,000 (SB)	Speed Limit	65	Left / (Right) Heading N S E W	(S-SW)

Category		Remarks		Category Score	
Slope Geometry				**Slope Geometry**	
Slope Height	100 ft.	Slope Angle H.I.	½:1	Slope Height	81
Ditch Effectiveness	G M (L) N	Ditch Width	10'-15'	Ditch Effect.	27
Average Vehicle Risk	105 %	Section Length	1200	AVR	100
Sight Distance % Decision S.D.	420 ft. 40 %	Sign Present	Yes / (No)	Sight Distance	81
Roadway Width	39 ft.			Roadway Width	6
Geologic Characteristics				**Geologic Characteristics**	
Case 1				*Case 1*	
Structural Condition	D (C) / F R (A)			Struct. Cond.	81
Rock Friction	R I (P) C-S			Rock Friction	27
Case 2				*Case 2*	
Differential Erosion Features	F O N M	N/A		Erosion Feat.	0
Difference in Erosion Rates	S M L E	N/A		Erosion Rates	0
Rockfall Characteristics				**Rockfall Characteristics**	
Block Size/Volume	>4 (ft) or yd³			Block Size	81
Rockfall History	F O M (C)			Rockfall History	81
				Total Score	565

Comments:
- MOST ROCKFALL OBSERVED ON SB SIDE.
- FREQUENT WEDGE PLANAR FAILURES. JOINTS SEPARATED
- POISED BLOCKS HIGH ON SLOPE. MANY LARGE FEATURES.
- SPORADIC WATER
- STRONG VEGETATION
- GREATEST WEIGHT DIFFERENT, RIDGE ORIENTATION AND WEATHERING.

P. RATING = A

G = Good M = Moderate L = Limited N = None
D = Discontinuous C = Continuous F = Favorable R = Random A = Adverse
R = Rough I = Irregular U = Undulating P = Planar C-S = Clay-Slickensided
F = Few O = Occasional N = Numerous M = Major
S = Small M = Moderate L = Large E = Extreme
F = Few O = Occasional M = Many C = Constant

Near angle / Far angle / Distance between (see back of sheet)

% Decision Sight Distance:
Worst Case: 420 ft
% Decision S. D. Score = 81

2012 RHRS STUDY FOR INTERSTATE 77

RHRS Detailed Rating Field Data Sheet

CUT 8-SB
PHOTOS 70, 71, 72, 73, 74, 76!

Date: 5-18-12 Rating: (A) / B Rater: L. ARTMAN, PG.

County/City	CARROLL	Start Latitude	36.602539	Start Longitude	80.736919
Route No.	I-77	End Latitude	36.605746	End Longitude	80.736360
Nearest Inter.	EXIT 1 (SB)	Start MP (est)	2.95	End MP (est)	3.15
ADT	18,000 (SB)	Speed Limit	65	Left / (Right) Heading N S E W	(S-SW)

Category		Remarks	Category Score
Slope Geometry			**Slope Geometry**
Slope Height	100 ft.	Slope Angle 1/2:1 H.I.	Slope Height 81
Ditch Effectiveness	G M (L) N	Ditch Width 10'-15'	Ditch Effect. 27
Average Vehicle Risk	105 %	Section Length 1200-0	AVR 100
Sight Distance	420 ft.	Sign Present Yes / (No)	Sight Distance 81
% Decision S.D.	40 %		
Roadway Width	39 ft.		Roadway Width 6
Geologic Characteristics			**Geologic Characteristics**
Case 1			*Case 1*
Structural Condition	D (C) / F R (A)		Struct. Cond. 81
Rock Friction	R I (D) C-S		Rock Friction 27
Case 2			*Case 2*
Differential Erosion Features	F O N M	N/A	Erosion Feat. 0
Difference in Erosion Rates	S M L E	N/A	Erosion Rates 0
Rockfall Characteristics			**Rockfall Characteristics**
Block Size/Volume	>4 (B) or yd³		Block Size 81
Rockfall History	F O M (C)		Rockfall History 81
			Total Score 565

Comments:
- MOST ROCKFALL OBSERVED ON SB SIDE.
- FREQUENT HEADER/SPALLING FEATURES. JOINTS SEPARATED
- POISED BLOCKS HIGH ON SLOPE. MASS LAUNCH FEATURES.
- SPORADIC WATER
- SPARSE VEGETATION
- GREATEST SLIGHTLY DIFFERENT, ANGLE ORIENTATION AND WEATHERING.

P. RATING = A

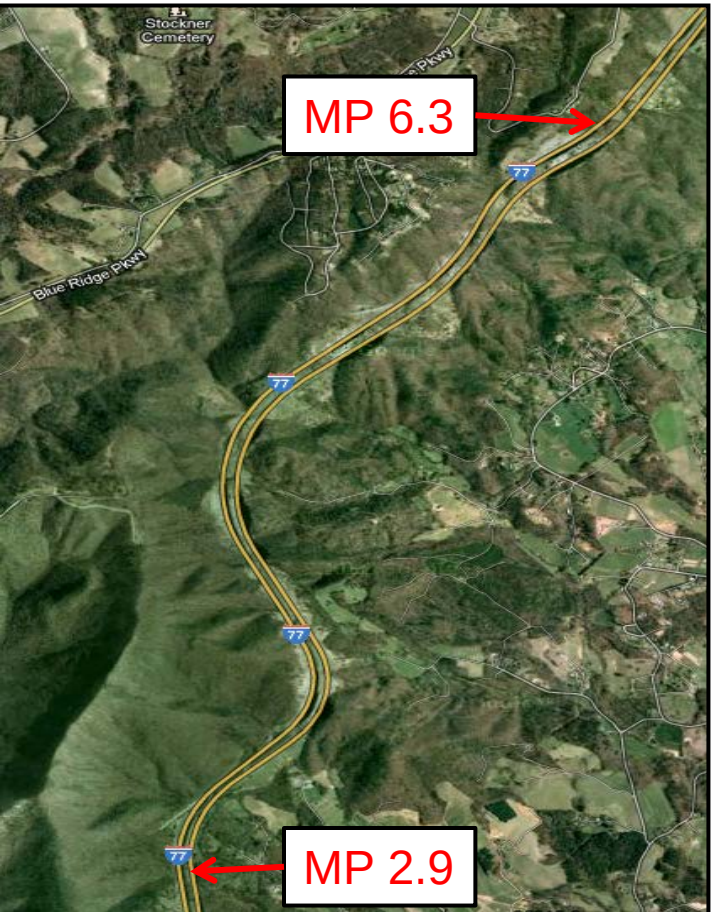
G = Good M = Moderate L = Limited N = None
D = Discontinuous C = Continuous F = Favorable R = Random A = Adverse
R = Rough I = Irregular U = Undulating P = Planar C-S = Clay-Slickensided
F = Few O = Occasional N = Numerous M = Major
S = Small M = Moderate L = Large E = Extreme
F = Few O = Occasional M = Many C = Constant

Near angle / Far angle / Distance between (see back of sheet)

Continuous and Adverse Orientation

Slopes Showing Their Age

2012 RHRS STUDY FOR INTERSTATE 77



- 64 Slopes Inventoried
- 28 Slopes – High Hazard (RHRS Score >300)
- MP: 2.9 to 6.3
- RHRS Scores: 319 to 565
- How to prioritize beyond the RHRS Ratings?

2012 RHRS STUDY FOR 77 - CUT SLOPE PRIORITIZATION LIST

Cut Slope Priority for Detail Evaluation	Cut Slope Designation	Begin MP	End MP	RHRS Detail Rating [2012]	Relevant Comments /Notes
1	8-SB	2.95	3.15	565	
2	14-SB	3.75	3.9	565	• Initial evaluation completed during I-77 Phase 1 Work (12/11/2011)
3	19b-SB	4.9	5	565	
9	23-SB	5.45	5.65	565	• Documented Rockfall History (Early 1990s) • **Existing Rockfall Barrier Fence**
	10-NB(M)	3.6	3.9	560	• Documented Rockfall History (3/7/2011) • Initial evaluation completed during I-77 Phase 1 Work (12/11/2011) • **Slope Remediation Completed (8/29/2012)**
	13-SB	3.6	3.75	511	• Sister slope to 14-SB • Initial evaluation completed during I-77 Phase 1 Work (12/11/2011)
2a	9-NB	3.7	3.85	506	• Initial evaluation completed during I-77 Phase 1 Work (12/11/2011)
4a	15d-NB(M)	5.05	5.15	506	• Documented Rockfall History (4/29/2008)
5	21-NB(M)	5.4	5.65	506	
6	16-SB	4.45	4.65	487	
10	33-SB	6.3	6.45	487	• Documented Rockfall History (12/25/1998) • **Existing Rockfall Barrier Fence**
7	13-NB(M)	4.45	4.65	482	
8	14-NB	4.45	4.65	482	• Documented Rockfall History (7/13/2011)
4b	15b-NB(M)	4.85	5	452	• Documented Rockfall History (4/29/2008)
4c	15a-NB(M)	4.75	4.85	362	

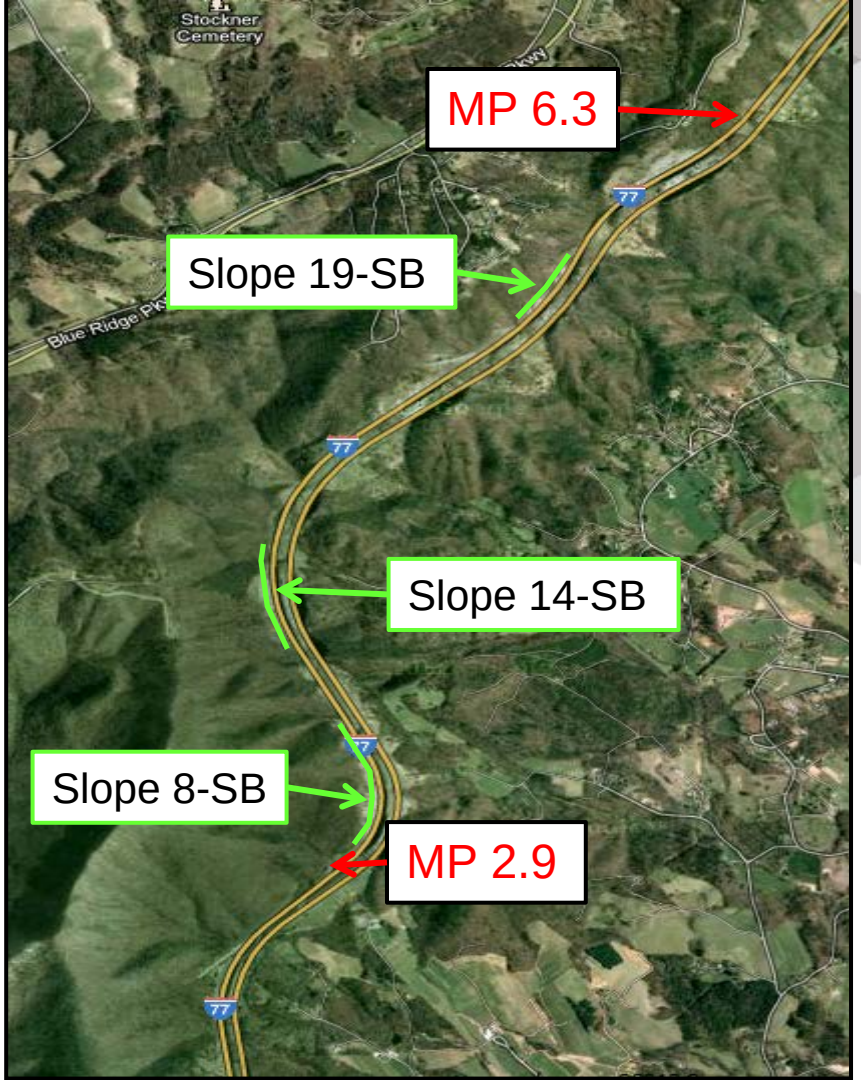
- RHRS Rating >500
- Actively Producing Rockfall
- Maintenance Records/ Rockfall Clean-up

PRIORITIZATION OF AGING ROCK SLOPES ON I-77

Geologic Evaluations

GEOLOGIC EVALUATIONS

- 3 Priority Slopes
- 4,500 LF of Slope
- MP: 2.9 to 5.7
- Goal:
  - Feasible Options
  - Probable Construction Cost Estimates



TEAM APPROACH

Key Factors:

- Client Input (Throughout Project)
- Understanding of Geologic Conditions
- Site Constraints
- Slope Access/ Construction Feasibility
- Product Applicability

PROJECT TEAM

VDOT

HDR

Ameritech Slope Constructors
Geotechnical Contractors

GEOBRUGG
BRUGG

HDR

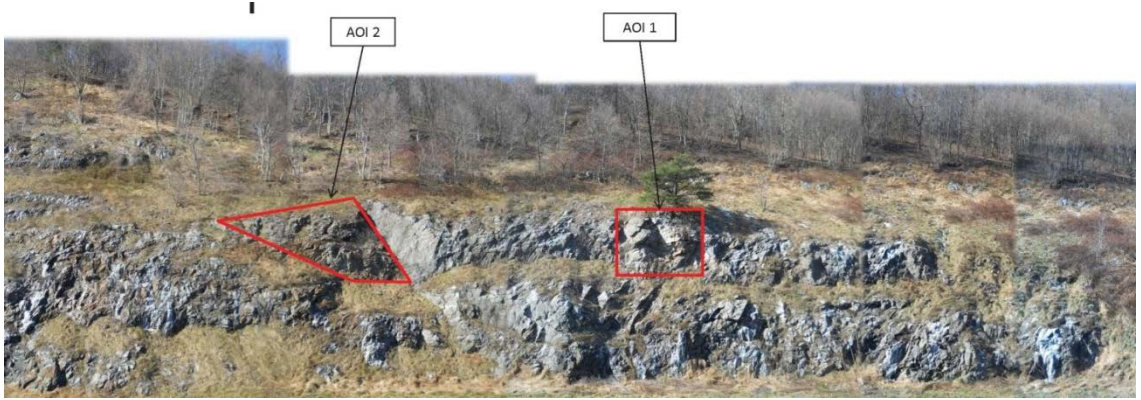
GEOLOGIC EVALUATIONS: STAGE 1 - ROAD LEVEL

Priority Slope Approach

- Establish Baseline
- Document Cut Slope Conditions
- Discontinuity Measurements
- Develop Slope Profiles for CRSP
- Identify Priority Slope Sections (AOI)
- Preliminary Kinematic Analysis

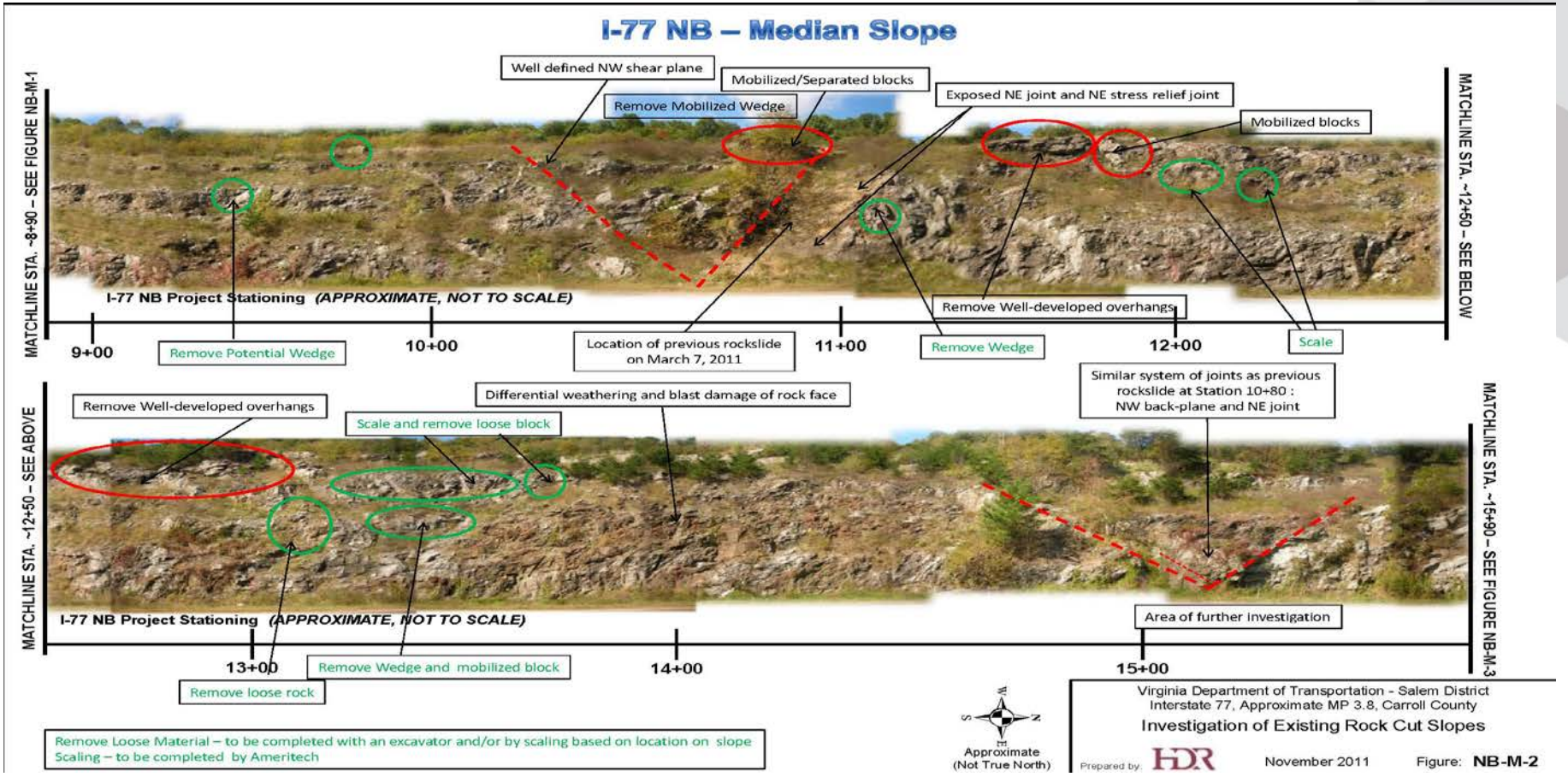
GEOLOGIC EVALUATIONS: STAGE 2 – ROPES ON THE SLOPE

- AOI Investigation
  - Geologic Investigation – potential failure mode(s)
  - Obscured slope sections
  - Stabilization requirements and option feasibility
  - Slope access



Ameritech Slope Constructors INC
Geotechnical Contractors

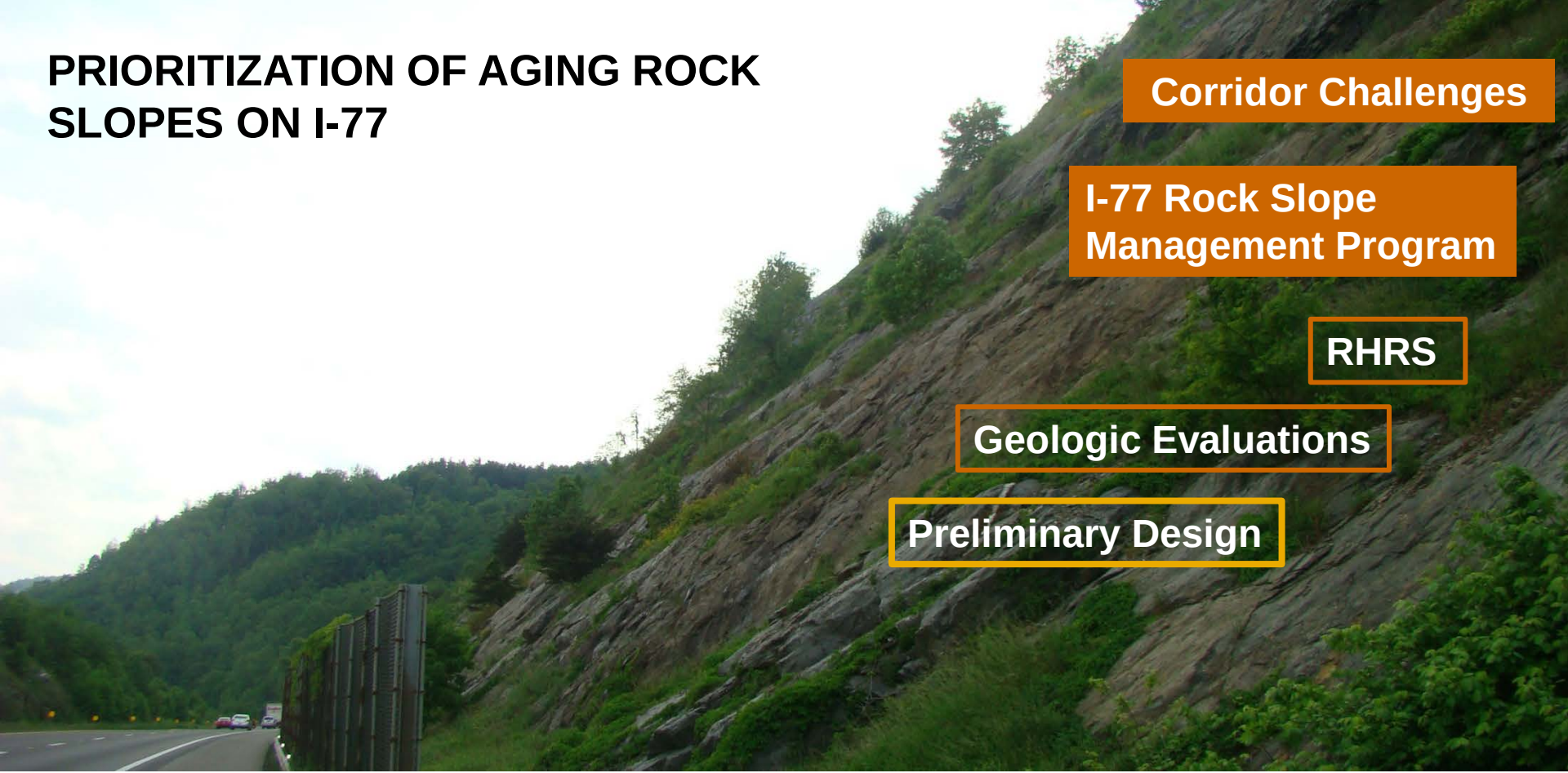
GEOLOGIC EVALUATIONS:



TECHNOLOGIES VS. SLOPE CONDITION

- Applicability
  - Maintain Existing Ditch
  - Scaling
  - Excavation
  - Rock Slope Drape
  - Attenuator Drape
  - Concrete Barrier
  - Flexible Rockfall Barrier
  - High Energy Barrier
  - Pinned Mesh
  - Rock Bolting

PRIORITIZATION OF AGING ROCK SLOPES ON I-77



PRELIMINARY DESIGN: CONSIDERATIONS FOR FEASIBLE OPTIONS

Subglobal Condition (Rockfall)

Height of Rockfall Generator

Maximum Bounce Height

Maximum Energy (kJ)

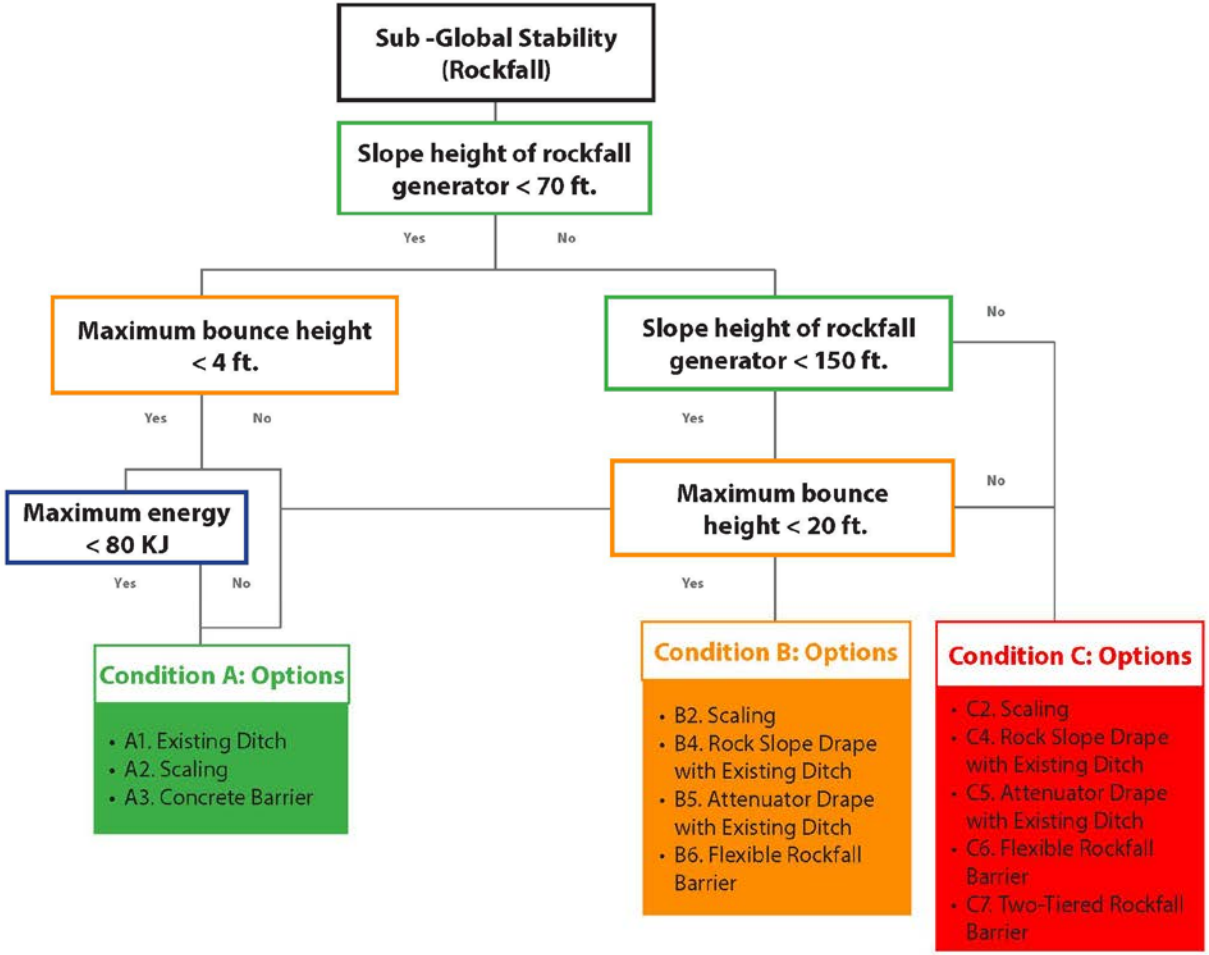
Slope Access/Site Constraints

Global Conditions (Planar, Wedge, Rock Mass)

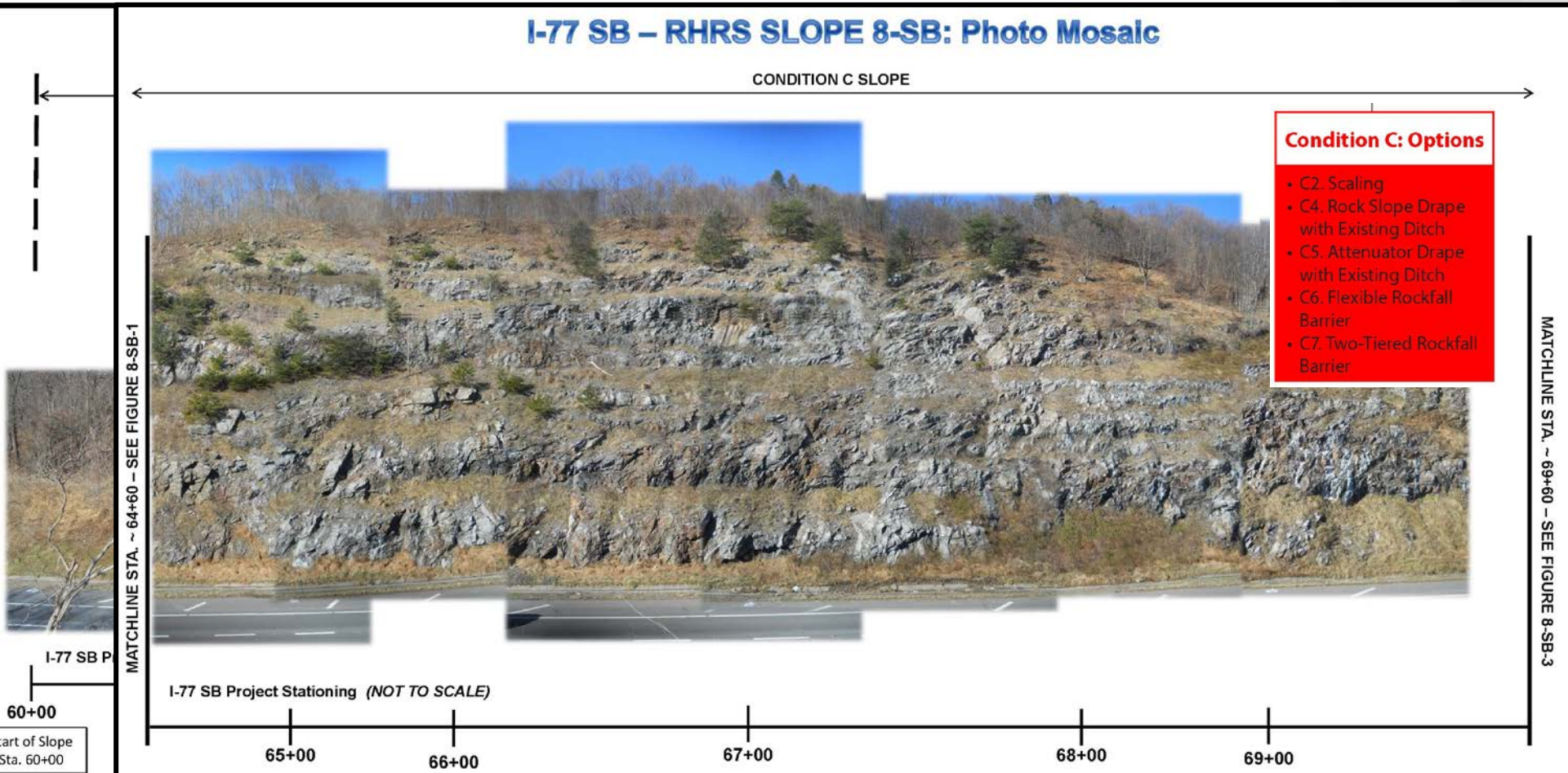
Height of Block Generator

Slope Access/Site Constraints

FEASIBLE SUBGLOBAL OPTIONS FOR SLOPE CONDITIONS



SLOPE CONDITIONS: A, B AND C



FEASIBLE GLOBAL OPTIONS FOR SLOPE CONDITIONS

Global Stability (Rock Mass, Toppling, Planar, Wedge Failures)

Slope height of rockfall generator < 50 ft.

Yes / No

Condition D: Options

- D2. Scaling
- D8. Excavation
- D9. Rock Bolts
- D10. Anchored Mesh
- D11. High - Energy Absorbing Device/Barrier with Existing Ditch

Condition E: Options

- E2. Scaling
- E9. Rock Bolts
- E10. Pinned Mesh or Nets
- E11. High - Energy Absorbing Device/Barrier with Existing Ditch

CLIENT INPUT: DRIVERS, IMPORTANCE FACTORS, & DRIVER RATING

1. Driver = Aspect or consideration of a feasible slope mitigation option during the selection process

2. Importance Factor = a weight assigned to each driver to determine relative importance amongst the drivers.

3. Driver Rating = relative assessment of each driver on a 1 to 5 scale

Driver	Importance Factor
Construction Cost	7
Effectiveness	10
Construction Complexity	6
Traffic Impacts	9
Aesthetics	3
Rockfall Maintenance	5
System Maintenance	8
Fog Impacts	7
Maintenance Experience	7
Environmental	3

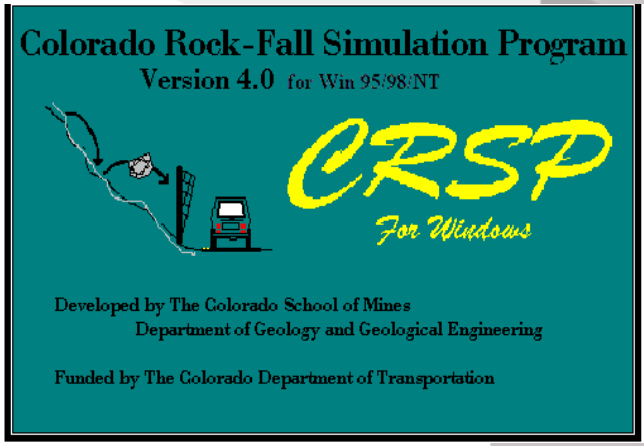
SCORED RELATIVE ASSESSMENT AND OPTION SHORTLIST

Total Option Score = Σ (Importance Factor X Driver Rating)

Driver Rating = 1 to 5 scale

Driver	VDOT Importance Factor (Weight)	Subglobal Condition C Options							
		C2: Scaling	Total Scaling Score	C4: Rock Slope Drape with Ditch	Total Rock Slope Drape with Ditch Score	C5: Attenuator Drape with Ditch	Total Attenuator Drape with Ditch Score	C6: Flexible Rockfall Barrier	Total Flexible Rockfall Barrier Score
Effectiveness	10	3	30	5	50	5	50	5	50
Traffic Impacts	9	1	9	2	18	2	18	4	36
System Maintenance	8	5	40	1	8	1	8	3	24
Construction Cost	7	2	14	1	7	1	7	2	14
Fog Impacts	7	5	35	5	35	5	35	1	7
Maintenance Perception	7	1	7	5	35	5	35	4	28
Construction Complexity	6	2	12	2	12	1	6	3	18
Rockfall Maintenance	5	1	5	3	15	3	15	3	15
Aesthetics	3	5	15	1	3	1	3	1	3
Environmental Impacts	3	4	12	2	6	2	6	5	15
Total			**179**		**189**		**183**		**210**

PRELIMINARY DESIGN



- VDOT Design Requirements (MOI, 2012)
  - Rockfall Simulation:

TABLE 3-12 -ALLOWABLE PERCENTAGE OF CLASTS ENTERING THE TRAVEL LANE

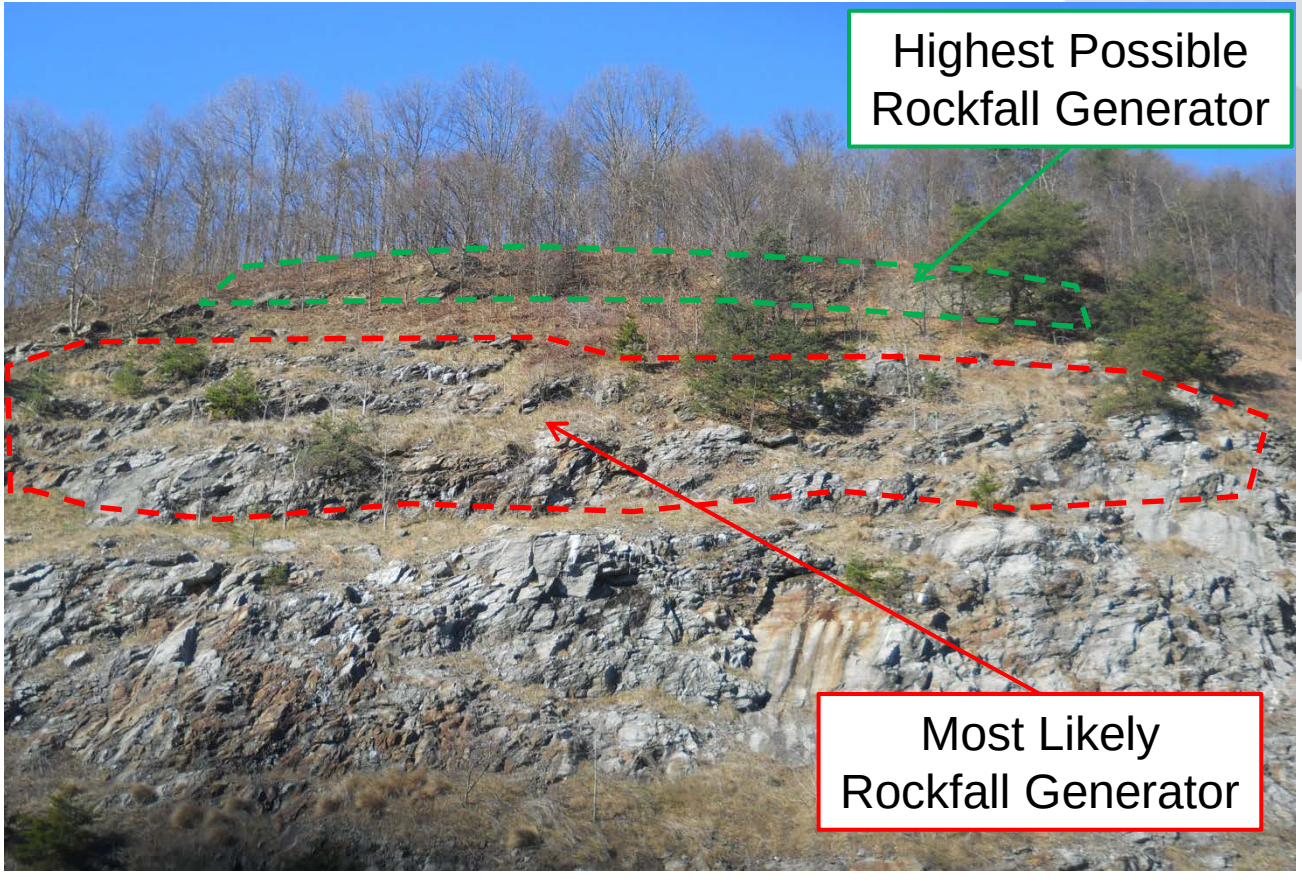
Alignment Type	Critical Rock Slope	Non-critical Rock Slope
Interstate	0%	N/A
Primary	0%	N/A
High-Volume Secondary	<1%	5%
Low-Volume Secondary	1%	5%

I-77 Priority Rock Slopes = Critical Rock Slope

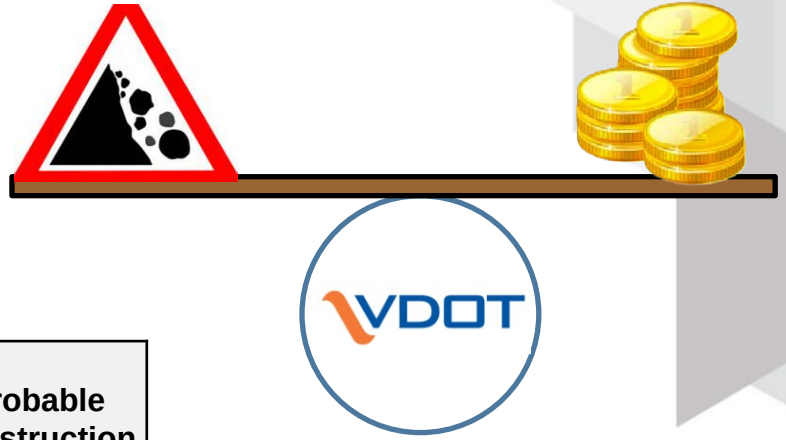
0% Design = Low Risk, but Higher $

PRELIMINARY DESIGN: ROCKFALL PROBABILITY

- Significant Variation in Slope Height/Angle
- Varying Degrees of Vegetation
- Changes in Geology/Weathering Susceptibility
- Multiple Rockfall Generators
- Multiple Launch Features



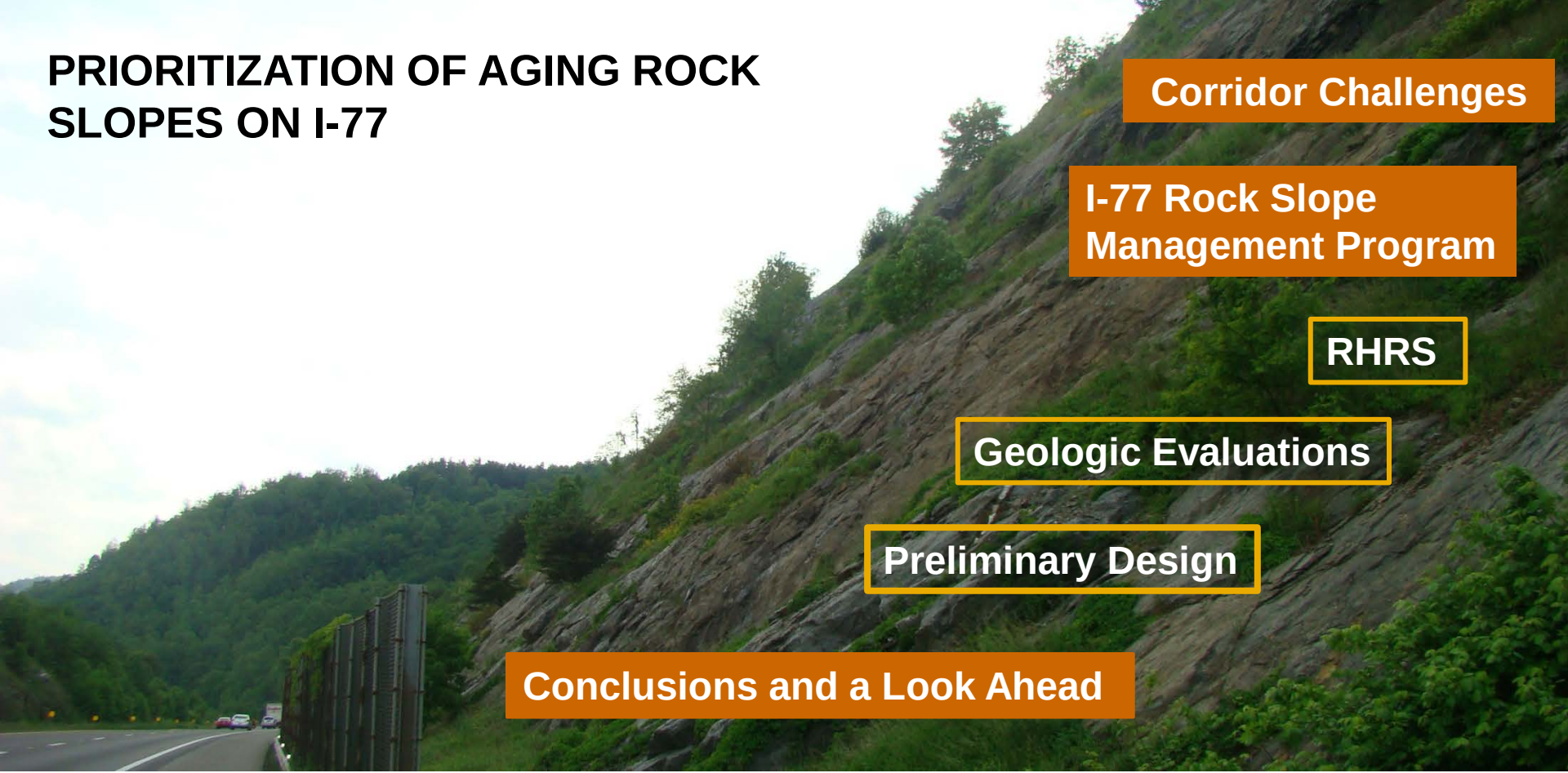
PRELIMINARY DESIGN APPROACH



- Design Criteria
  - Help Bracket Cost vs Rockfall Risk based on Probability of Occurrence:

Design Criteria	Percentage of Rockfall Entering the Travel Lane (%)	Probability of Rockfall Being Retained (%)	Rockfall Generator Location	Probable Construction Cost
1 (per MOI)	0	99.9	Highest Possible	Higher
2	5	95	Most Likely	Lower

PRIORITIZATION OF AGING ROCK SLOPES ON I-77



Conclusions and A Look Ahead

CONCLUSIONS

- Establishes Baseline (RHRS), Risk Assessment
- Geologic Evaluation
  - Aids in Further Prioritization of High Hazard Slopes
  - Involves all key players for reasonable construction cost estimates
  - Supports emergency response remediation of slopes sections
- Design Approach
  - Client input is very important
  - Design criteria allows for a relative Cost vs Risk assessment

A LOOK AHEAD

- Currently Conducting Preliminary Design and Developing Probable Construction Costs for each slope
- VDOT plans to utilize these costs for budgeting purposes for future final design and slope remediation
- Development of Contract Bid Documents
- Contract Advertisements for slope remediation as funding becomes available

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QUESTIONS……SLIP - SLIDE & ROCK-N-ROLL?