

# Rockfall in Ohio – An Update of the Rockfall Database Population

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*August 1, 2012*  
*Geohazards Conference*

One Team. Infinite Solutions



# ***Presentation Outline***

## ***Rockfall in Ohio – An Update of the Rockfall Database Population***

***I. Introduction***

***II. Site Identification***

***III. Site Tiers***

***IV. Field Data Collection***

***V. Database Population***

***VI. Results***

***VII. Remediation Cost Estimating***

# ***I. Introduction***

## ***ODOT Geohazards Management System (GHMS)***

- *Landslides*
- *Underground Voids*
- *Rockfall*
  - Manual for Rockfall Inventory (ODOT OGE, January 2009)
  - *From the manual: "...rockfalls constitute a major hazard along Ohio roadways, posing a risk to life, property and public safety."*
  - *Risk assessment process to prioritize rockfall prone sites*

# ***I. Introduction***

*Why was Rockfall process developed?*

- *Rockfall prevalent in Ohio, especially unglaciated areas*
- *Problems with past rockfall*
  - *Highway closures*
  - *Property damage*
  - *High repair costs*
- *A need to be proactive*
  - *Public Safety*
  - *Budgetary Mechanism*
  - *Informational Resource*

## ***II. Site Identification***

### *Site Criteria*

- *Natural or manmade slope with exposed bedrock, i.e. “rock slope”*
- *At least 10 feet tall (normally)*
- *Not longer than 1 mile*
- *Not crossing county lines*

### **III. Site Tiers**

#### *Determined by:*

- *Potential of rockfall occurrence*
- *Potential of rockfall reaching travelled lanes*

#### *Tiers:*

- *Tier 1 – low to moderate, low to moderate*
- *Tier 2 – moderate to high, moderate*
- *Tiers 3/4 – high to very high, high to very high*

# III. Site Tiers

## Preliminary Rating

| Potential of Rockfall Occurance | Potential of Rockfall Impacting the Traffic Lane |          |              |         |
|---------------------------------|--|----------|--------------|---------|
|                                 | Very High (10)                                   | High (8) | Moderate (4) | Low (1) |
| Very High (10)                  |  |          |              |         |
| High (8)                        |  |          |              |         |
| Moderate (4)                    |  |          |              |         |
| Low (1)                         |  |          |              |         |

A diagram showing a vertical arrow pointing down from the 'Moderate (4)' cell in the 'High (8)' row to the number '12' in the 'High (8)' row. A horizontal arrow points from the 'High (8)' cell in the 'High (8)' row to the number '12' in the 'High (8)' row.

# III. Site Tiers

## Tiered Approach to Data Collection

| <b>Preliminary Rating Score (PRS)</b>                                    | <b>Required Data Sections</b> | <b>Risk Assessment Criteria</b>  |
|--|-------------------------------|--|
| PRS = 2 to 5<br>(Tier 1 Sites)   | Preliminary Rating Only       | Preliminary Rating Only  |
| PRS = 8 to 11<br>(Tier 2 Sites)  | Part A Only                   | Site Location, General, and Interview Information; GPS Files                               |
| PRS = 12 to 16<br>(Tier 3 Sites)<br><br>PRS = 18 to 20<br>(Tier 4 Sites) | Part A, Part B, Part C        | Traffic, Maintenance, Accident, Geological, Slope, Hydrological, Rock Sampling Information |



# IV. Data Collection

## Field Equipment



## ***IV. Data Collection***

*(Performed by PSI – Columbus, Ohio)*

*Criteria Required for All Sites*

- *Beginning/Ending Mileage Point*
- *Orientation/Position of Rock Slope*
- *Lat/Long/Elevation*

# ***IV. Data Collection***

## *Tier 1 Sites*

- *Slope Configuration*
  - *Single-Angle*
  - *Multi-Angle*
  - *Single-Angle Benched*
  - *Multi-Angle Benched*
- *Slope Condition – vegetation cover, talus buildup, weathering, etc.*
- *Photographic Documentation*

# ***IV. Data Collection***

## *Tier 2 Sites*

- *Geometrics and Traffic Survey Data*
- *Additional Slope Information*
  - *Slope height*
  - *Overall face angle*
  - *Undercutting features*
  - *Jointing patterns*
  - *Catchment dimensions*
  - *Corrective actions and effectiveness*

# ***IV. Data Collection***

## *Tier 3/4 Sites*

- *Add'l Slope Geological Conditions such as:*
  - *Bench elevations and widths*
  - *Slope angles and elevations*
  - *Potential rockfall volume estimations*
  - *Talus accumulation information*
- *Hydrological conditions (springs, seeps, etc.)*
- *Slake Durability Index (SDI) testing*
- *Road slope and detour distance/time*

# V. Database Population

## Site Listing

|   | GlobalID                        | Insert Date | Name     | Dist. | Cty | RS/RN    | BMP    | Prel. Score | Raw Score  | ▲ Rank Score |
|---|---------------------------------|-------------|----------|-------|-----|----------|--------|-------------|------------|--------------|
| + | <a href="#">RF003838(1) (A)</a> | 2011-08-15  | Barr1    | 9     | LAW | US/00052 | 6.99   | 12          | <u>550</u> | <u>550</u>   |
| + | <a href="#">RF003833(1) (A)</a> | 2011-08-12  | Barr1    | 9     | LAW | US/00052 | 11.34  | 14          | <u>522</u> | <u>522</u>   |
| + | <a href="#">RF005200(1) (A)</a> | 2011-07-01  | Stantec1 | 10    | NOB | IR/00077 | 10.72  | 12          | <u>515</u> | <u>515</u>   |
| + | <a href="#">RF005700(1) (A)</a> | 2011-12-12  | Stantec1 | 11    | BEL | SR/00007 | 3.63   | 12          | <u>511</u> | <u>511</u>   |
| + | <a href="#">RF003870(1) (A)</a> | 2011-08-17  | Barr1    | 5     | COS | US/00036 | 27.82  | 12          | <u>502</u> | <u>502</u>   |
| + | <a href="#">RF005372(1) (A)</a> | 2011-07-19  | Stantec1 | 5     | GUE | SR/00022 | 6.84   | 20          | <u>492</u> | <u>492</u>   |
| + | <a href="#">RF003827(1) (A)</a> | 2011-08-11  | Barr1    | 9     | LAW | SR/00007 | 17.29  | 12          | <u>482</u> | <u>482</u>   |
| + | <a href="#">RF004282(1) (A)</a> | 2011-05-18  | Stantec2 | 10    | MOE | SR/00800 | 5.95   | 16          | <u>482</u> | <u>482</u>   |
| + | <a href="#">RF004286(1) (A)</a> | 2011-05-19  | Stantec2 | 10    | MOE | SR/00556 | 11.9   | 16          | <u>473</u> | <u>473</u>   |
| + | <a href="#">RF003934(1) (A)</a> | 2011-08-25  | Barr1    | 11    | JEF | SR/00007 | 13.97  | 12          | <u>470</u> | <u>470</u>   |
| + | <a href="#">RF003841(1) (A)</a> | 2011-08-15  | Barr1    | 9     | LAW | US/00052 | 4.45   | 12          | <u>469</u> | <u>469</u>   |
| + | <a href="#">RF004459(1) (A)</a> | 2011-05-26  | Stantec1 | 10    | MOE | SR/00255 | 11.7   | 12          | <u>464</u> | <u>464</u>   |
| + | <a href="#">RF003807(1) (A)</a> | 2011-08-09  | Barr1    | 10    | MEG | SR/00124 | 66.28  | 12          | <u>463</u> | <u>463</u>   |
| + | <a href="#">RF004299(1) (A)</a> | 2011-05-23  | Stantec2 | 10    | MOE | SR/00026 | 12.24  | 12          | <u>462</u> | <u>462</u>   |
| + | <a href="#">RF004451(1) (A)</a> | 2011-05-25  | Stantec1 | 10    | MOE | SR/00078 | 24.46  | 16          | <u>460</u> | <u>460</u>   |
| + | <a href="#">RF003958(1) (A)</a> | 2011-08-29  | Barr1    | 10    | HOC | US/00033 | 17.51  | 14          | <u>457</u> | <u>457</u>   |
| + | <a href="#">RF004293(1) (A)</a> | 2011-05-20  | Stantec2 | 10    | MOE | SR/00260 | 7.35   | 12          | <u>457</u> | <u>457</u>   |
| + | <a href="#">RF003818(1) (A)</a> | 2011-08-10  | Barr1    | 10    | MRG | SR/00669 | 11.107 | 16          | <u>456</u> | <u>456</u>   |

# V. Database Population

## Preliminary Rating

Rockfall : PartA : RF003926 : Detail

close

Preliminary Rating

Site Location

General Info

Interview Info

GPS Files

### Preliminary Rating

Data Collection By Barr1 On 8/25/2011 9:36:45 AM

#### Description:

| Preliminary rating score | Required data sections | Data Section Instances  |
|--------------------------|------------------------|---|
| 2 <= Prel.Score < 8      | PartA only             | Preliminary Rating , Site Location Information , General Information , Interview Information , GPS Files  |
| 8 <= Prel.Score <= 11    | PartA , PartB , PartC  | Preliminary Rating , Site Location Information , General Information , Interview Information , GPS Files , Traffic Information , Maintenance Information , Accident Information , Geological Information , Slope Information , Hydrological Information , Info Source , Rock Sampling Information |
| 12 <= Prel.Score <= 20   | PartA , PartB , PartC  | Preliminary Rating , Site Location Information , General Information , Interview Information , GPS Files , Traffic Information , Maintenance Information , Accident Information , Geological Information , Slope Information , Hydrological Information , Info Source , Rock Sampling Information |

#### Probability of rockfall occurrence:

Low(1)
  Moderate(4)
  High(8)
  Very high(10)

#### Probability of rockfall reaching the traffic lanes:

Low(1)
  Moderate(4)
  High(8)
  Very high(10)

|                             |   |
|-----------------------------|---|
| Rating score:               | 16  |
| Sites Screening:            | <input type="radio"/> Rated <input type="radio"/> Not Rated |
| Associated Sites Screening: | <input type="radio"/> YES <input type="radio"/> NO          |
| Emergency Determination:    | <input type="radio"/> YES <input type="radio"/> NO          |

# V. Database Population

## Site Location

Rockfall : PartA : RF003926 : Detail

close

### Site Location Information

Data Collection By Barr1 On 8/25/2011 9:39:00 AM

#### Basic Information Roadway Information GPS Information

|                       |    |         |     |
|-----------------------|----|---------|-----|
| District:             | 11 | County: | JEF |
| No township / section |    |         |     |

|                  |  |
|------------------|--|
| Quadrangle Name: |  |
|------------------|--|

|               |                |               |       |
|---------------|----------------|---------------|-------|
| Route system: | SR-state route | Route number: | 00007 |
|---------------|----------------|---------------|-------|

|               |       |        |                |
|---------------|-------|--------|----------------|
| Jurisdiction: | State | NLFID: | SJEFSR00007**C |
|---------------|-------|--------|----------------|

|                            |          |
|----------------------------|----------|
| Classification of roadway: | Arterial |
|----------------------------|----------|

|                                     |            |                         |         |
|-------------------------------------|------------|-------------------------|---------|
| Slope Orientation:                  | 217 °      | Length(along the road): | 3168 Ft |
| Hazard width perpendicular to road: | Ft         | Toe to Shoulder Dist.:  | Ft      |
| BMP(SLM):                           | 5.04 Miles | Elev at BMP:            | Ft      |
| EMP(SLM):                           | 5.64 Miles | Elev at EMP:            | Ft      |
| Cardinal Direction:                 | NO         | Driving Direction:      | S       |
| Horizontal position:                | Right      | Vertical position:      | Above   |

Preliminary Rating

Site Location

General Info

Interview Info

GPS Files



# V. Database Population

## Basic Slope Information

Rockfall : PartA : RF003926 : Detail

[close](#)

Preliminary Rating

### General Information

Data Collection By Barr1 On 8/25/2011 9:40:42 AM

Basic Slope Information    Additional Information    Pic / Doc Information (Total:19)

|                         |                    |  |  |
|-------------------------|--------------------|--|--|
| Slope configuration:    | Multiple-angle(MA) |  |  |
| Estimated Slope height: | 160 Ft             |  |  |

Site Location

### Slope Condition

|                     |              |     |        |     |
|---------------------|--------------|-----|--------|-----|
| Vegetation Coverage | Shrub:       | 20% | Grass: | 10% |
|                     | Tree:        | 30% | Other: | %   |
|                     | Other Desc.: |     |        |     |

General Info

|                       |          |                |     |                            |                      |
|-----------------------|----------|----------------|-----|----------------------------|----------------------|
| Weathering condition: | Moderate | Talus buildup: | YES | General slope performance: | Potentially instable |
|-----------------------|----------|----------------|-----|----------------------------|----------------------|

Interview Info

|               |   |                                    |                                    |                                    |   |
|---------------|---|------------------------------------|------------------------------------|------------------------------------|---|
| Exposed Rock: | <input type="checkbox"/> Anhydrite        | <input type="checkbox"/> Breccia   | <input type="checkbox"/> Chert     | <input type="checkbox"/> Claystone | <input type="checkbox"/> Coal                 |
|               | <input type="checkbox"/> Conglomerate     | <input type="checkbox"/> Dolomite  | <input type="checkbox"/> Fireclay  | <input type="checkbox"/> Flint     | <input type="checkbox"/> Gypsum               |
|               | <input type="checkbox"/> Halite           | <input type="checkbox"/> Ironstone | <input type="checkbox"/> Limestone | <input type="checkbox"/> Mudstone  | <input checked="" type="checkbox"/> Sandstone |
|               | <input checked="" type="checkbox"/> Shale | <input type="checkbox"/> Siltstone | <input type="checkbox"/> Underclay |                                    |   |

GPS Files

|        |  |
|--------|--|
| Other: |  |
|--------|--|

# V. Database Population

## Geologic Information

Rockfall : PartC : RF003926 : Detail

close

Geological

Slope

Hydrological

InfoSource

Rock Sampling

Multi-angle Bedding Information Joint Information Additional Information Pic / Doc Information (Total:1)

### Cut Slope Angle

YES  NO

#### Cut Slope Angle

#### Details For Angle1

Angle1

Angle2

Angle3

Angle4

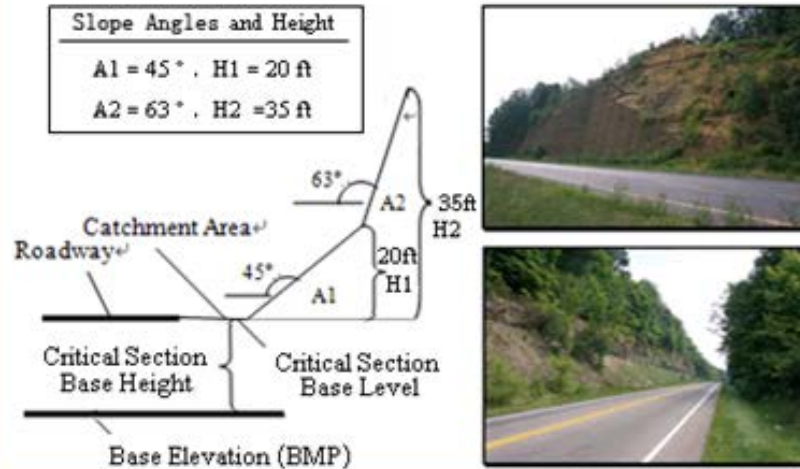
#### Typical Slope Diagrams:

Multi-angle Slope (MA)

#### Slope Angles and Height

A1 = 45° , H1 = 20 ft

A2 = 63° , H2 = 35 ft



|                         |        |
|-------------------------|--------|
| Angle ID:               | Angle1 |
| Cut Angle:              | 52 °   |
| Height from base level: | 16 Ft  |

# V. Database Population

## Joint Information

Rockfall : PartC : RF003926 : Detail

[close](#)

Geological

Slope

Hydrological

InfoSource

Rock Sampling

Multi-angle Bedding Information Joint Information Additional Information Pic / Doc Information (Total:1)

### Joint Information

YES  NO

#### Joint ID

Joint1  
Joint2  
Joint3  
Joint4

#### Details For Joint1

|                           |  |                         |        |
|---------------------------|--|-------------------------|--------|
| Joint ID:                 | Joint1   |                         |        |
| Type:                     | ORTH   | Joint Set Orientations: | 294 °  |
| Comp.Joint:               | <input checked="" type="radio"/> Yes <input type="radio"/> No  |                         |        |
| Avg.joint spacing - comp. | 7 Ft   | Avg.joint width - comp. | 0.1 Ft |
| Joint infilling - comp.   | 80 %   |                         |        |
| Incomp.Joint:             | <input type="radio"/> Yes <input checked="" type="radio"/> No  |                         |        |
| Infilling Type - Comp:    | <input checked="" type="radio"/> Yes <input type="radio"/> No  |                         |        |
| Infilling Type - compe.   | <input type="checkbox"/> Barite(Ba) <input type="checkbox"/> Clay(Cl) <input type="checkbox"/> Calcite(Ca)<br><input type="checkbox"/> Chlorite(Ch) <input type="checkbox"/> Iron Oxide(Fe) <input type="checkbox"/> Gypsum/Talc(Gy)<br><input type="checkbox"/> Healed(Hd) <input type="checkbox"/> Manganese(Mn) <input type="checkbox"/> None(No)<br><input type="checkbox"/> Pyrite(Py) <input type="checkbox"/> Quartz(Qz) <input checked="" type="checkbox"/> Sand(Sd)<br><input type="checkbox"/> Silica(Si) <input type="checkbox"/> Unknown(Uk) |                         |        |
| Infilling Type - Incomp.  | <input type="radio"/> Yes <input checked="" type="radio"/> No  |                         |        |

# V. Database Population

## Slope Information

Rockfall : PartC : RF003926 : Detail

close

Geological

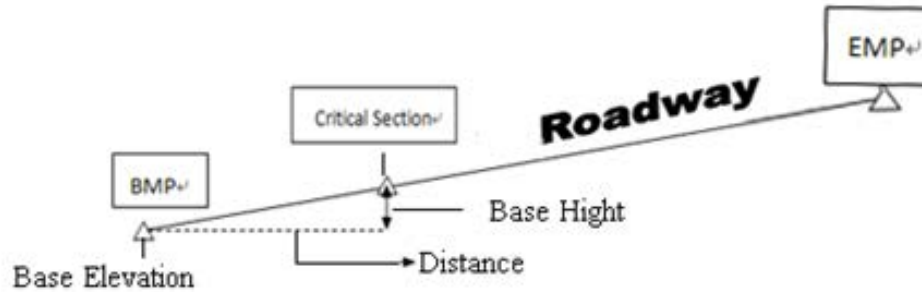
Slope

Hydrological

InfoSource

Rock Sampling

### Critical Section



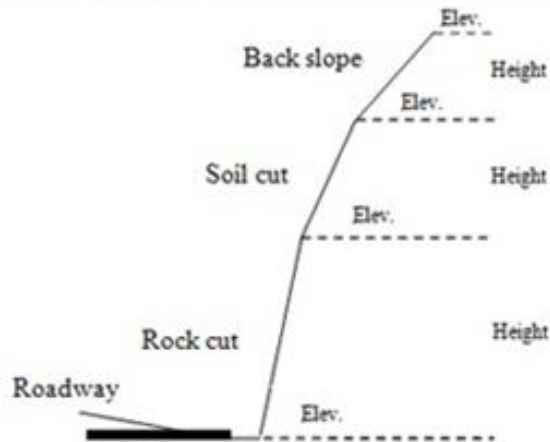
Distance from BMP to critical section:

Ft

Critical Section Base Height:

Ft

### Typical Cross Section of Slope:



Section Base Elevation:

1.25 Ft

Rock cut slope height:

124.83 Ft

Soil cut slope height:

0 Ft

Backslope height:

25 Ft

Rock cut elevation:

126.08 Ft

Soil cut elevation:

126.08 Ft

Backslope elevation:

151.08 Ft

# VI. Results

## Statewide Map

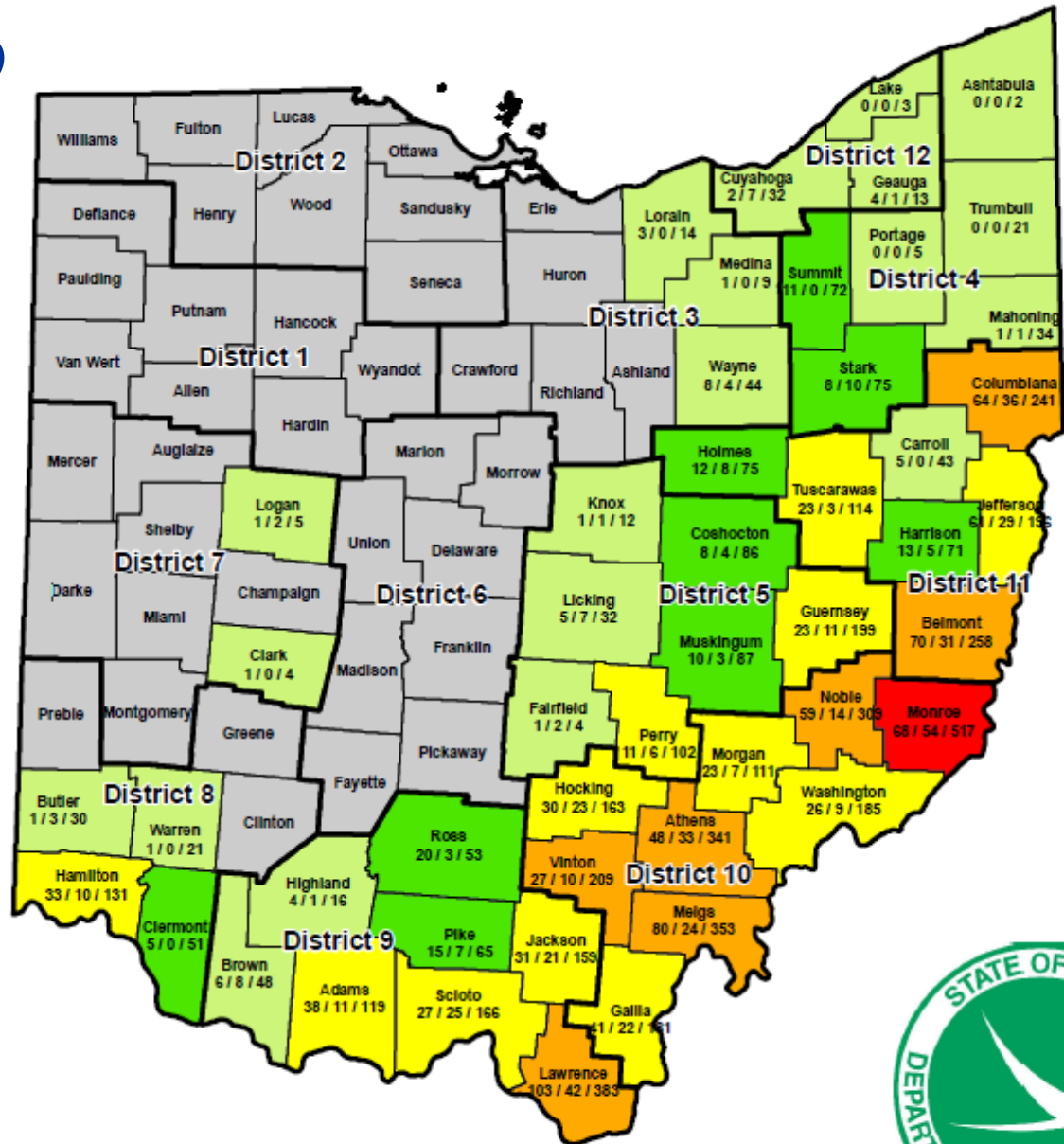
**RED**  
Rockfall Sites > 400

**ORANGE**  
Rockfall Sites > 200

**YELLOW**  
Rockfall Sites > 100

**GREEN**  
Rockfall Sites > 50

**LIGHT GREEN**  
Rockfall Sites > 0



# VI. Results

## Statewide Summary

|                     |       |      |
|---------------------|-------|------|
| # of Rockfall Sites | 5,540 | 100% |
| Tier 1              | 3,997 | 72%  |
| Tier 2              | 1,040 | 19%  |
| Tier 3              | 484   | 9%   |
| Tier 4              | 19    | 0.3% |

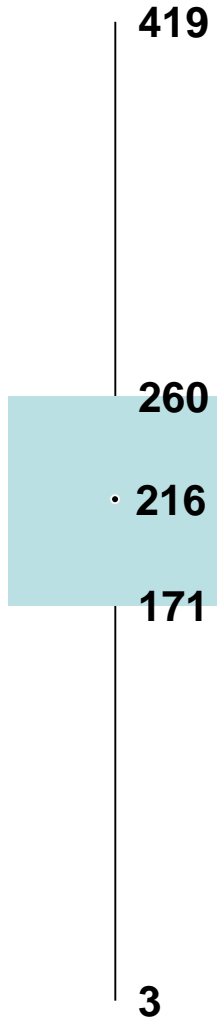
## Inventory Site Risk Score Worksheet

Inventory Site: RF003926

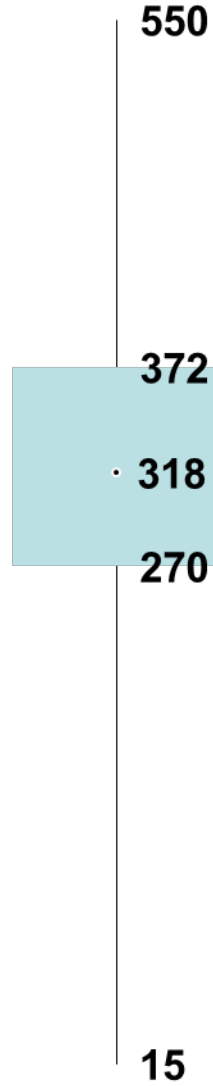
| Evaluation Parameter                        |                                       | Raw Value(RV)                  | Equation   | Max | Min | Weighting Factor | Result | Score |
|---|---------------------------------------|--------------------------------|--|-----|-----|------------------|--------|-------|
| Differential Weathering                     | Slake Durability                      | %                              | $130.273 - (2.2432 * RV) + (0.009455 * (RV^2))$                              | 81  | 0   | 1                | 0      | 66    |
|   | Max. Visible Undercut                 | 5ft                            | $0.378925 + (3.17826 * RV) + (1.97328 * (RV^2))$                             | 81  | 0   | 1                | 65.60  |       |
| Discontinuity Role                          | Discontinuity Extent/Orient.          | continuous adverse orientation | Not Applicable   | 81  | 3   | 1                | 81     | 81    |
|   | % Raveling of Slope                   | 22%                            | $(-1.23008) + (0.815122 * RV) + (0.0067726 * (RV^2))$                        | 81  | 0   | 1                | 19.98  |       |
| Block Size/Volume                           | Block Size                            | 1288ft <sup>3</sup>            | $(-1.18725) + (8.89329 * RV) + (0.582491 * (RV^2))$                          | 81  | 0   | 1                | 97777  | 81    |
|   | Volume                                | 49.2yd <sup>3</sup>            | $(-6.08308) + (5.48937 * RV) - (0.0767832 * (RV^2)) + (0.0003749 * (RV^3))$  | 81  | 0   | 1                | 122.7  |       |
| Hydrogeologic Conditions(seeps and springs) |                                       | 5%                             | $(-0.119188) + (1.08321 * RV) + (0.0023809 * (RV^2))$                        | 81  | 0   | 1                | 5.356  | 5     |
| Rock Slope Height                           |                                       | 124.8ft                        | $(-3.10851) + (0.394072 * RV) - (0.0004977 * (RV^2)) + (0.0000002 * (RV^3))$ | 81  | 0   | 1                | 38.71  | 39    |
| Catchment/Containment                       | Catchment Width(% of GB-3 Guidelines) | 66.33%                         | $144.997 - (2.06023 * RV) + (0.0060835 * (RV^2))$                            | 81  | 0   | 1                | 35.10  | 81    |
|   | Working Barrier                       | NO                             | Not Applicable   | 81  | 9   | 1                | 81     |       |
| Exposure Risk                               |                                       | 782.2                          | $(-0.676368) + (0.640534 * RV) - (0.021677 * (RV^2)) + (0.0002856 * (RV^3))$ | 81  | 0   | 1                | 12395  | 81    |
| %DSD  |                                       | 50.1%                          | $(112.91) - (3.30465 * RV) + (0.0334535 * (RV^2)) - (0.0001163 * (RV^3))$    | 81  | 0   | 1                | 16.69  | 17    |
| Rockfall History                            |                                       |                                | Not Applicable   | 81  | 3   | 1                | 0      | 0     |
| Accident History                            |                                       | No Accident                    | Not Applicable   | 81  | 3   | 1                | 3      | 3     |
| Site Score                                  |                                       |                                |  |     |     |                  |        | 454   |

# Score Summary

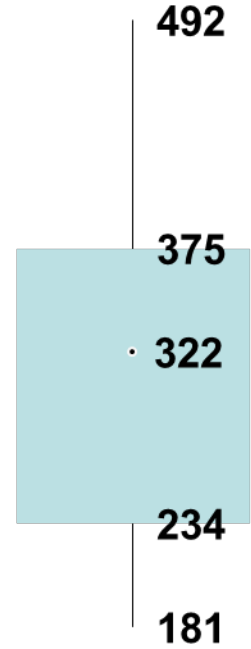
## Tier 2 Sites



## Tier 3 Sites



## Tier 4 Sites





## ***VII. Remediation Cost Estimating***

### *RCDA – Remediation Cost Database and Application*

- *Web-enabled cost estimating application developed by OSU*
- *Plan scenarios*
  - *Flatten the rock slope*
  - *Widen the catchment area*
  - *Placement of a New Jersey or modified D50 concrete barrier*
  - *Trim blasting of a rock overhang*
  - *Manually scaling the slope*

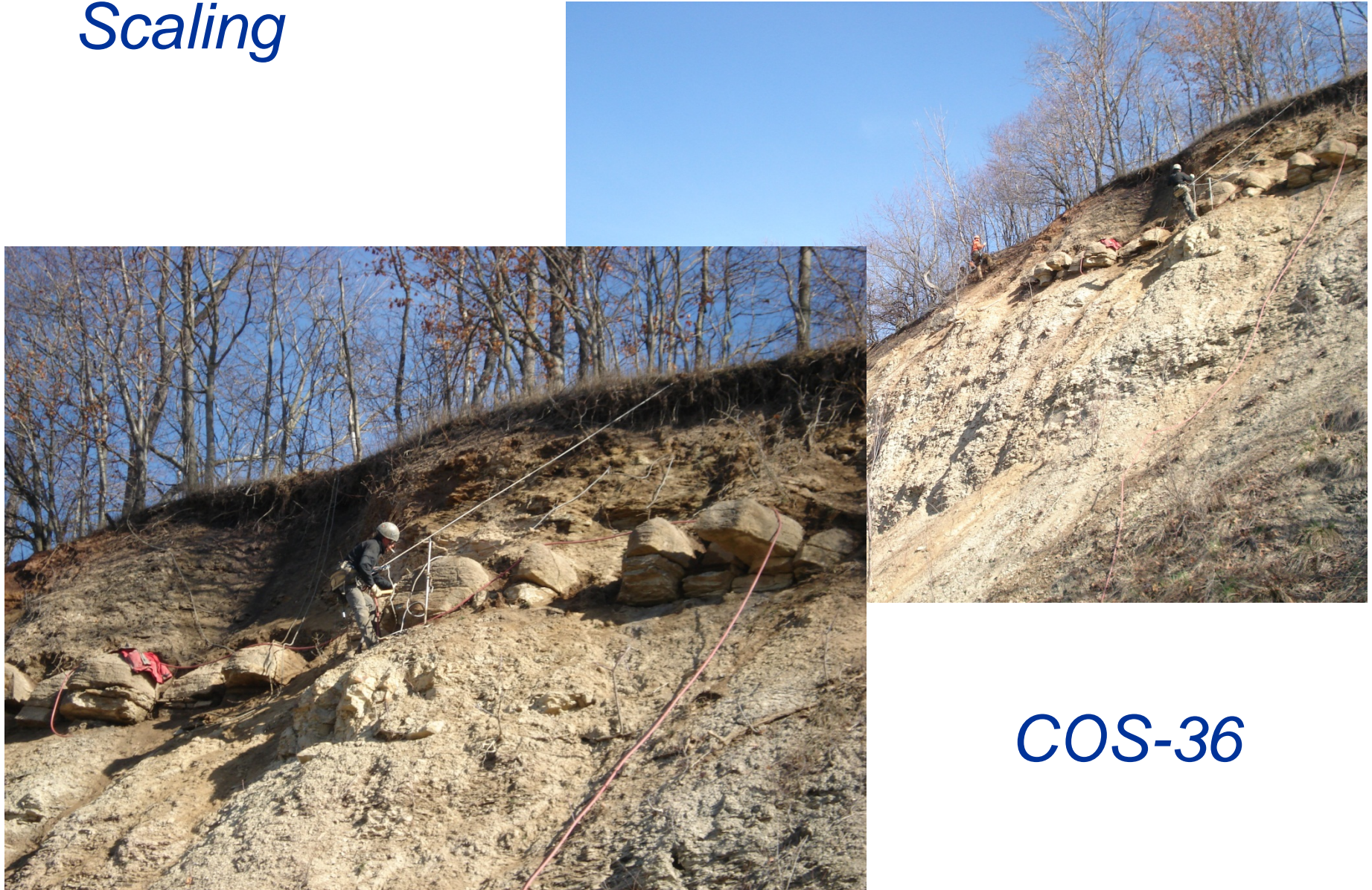
# ***VII. Remediation Cost Estimating***

## ***Statewide Average Remediation Costs***

| <b>Remediation Scenario</b>        | <b>Cost (\$) / Foot Site Length</b> |
|------------------------------------|-------------------------------------|
| New Jersey Barrier                 | 87                                  |
| Modified D50 Concrete Barrier      | 101                                 |
| Scaling                            | 164                                 |
| Trim Blasting                      | 240                                 |
| Flatten Slope                      | 1,885                               |
| Flatten Slope with Added Catchment | 2,392                               |

# VII. Remediation Cost Estimating

## Scaling



COS-36

# **VII. Remediation Cost Estimating**

## *Trim Blasting*



*Before*

*GUE-22*

*North Slope*

*After*



# VII. Remediation Cost Estimating

## *Trim Blasting/Draping*



*Before*

*GUE-22*

*South Slope*

*After*



# Closing



- *Ohio (esp. southeast Ohio) contains rockfall-prone bedrock formations.*
- *ODOT has established a risk-based inventory for rockfall-prone sites.*
- *ODOT is utilizing the inventory to systematically remediate the highest risk sites.*
- *Questions?*