Agenda

1. Location / Background
2. Project Scope
3. Investigation / Analysis
4. Design
5. Construction
6. Summary
1 Project Location / Background

Project location

Background information
Project Location:
Amtrak’s Harrisburg Line Right-of-Way
MP 90.1 in West Donegal Township
Pennsylvania
• Rock slide December 31, 2013
• 3rd slide in 5 years within this section of track
• Both active tracks blocked
• Two rocks: ~ 10 and 50 tons
• 70' high cut (south side)
• Steep slopes ~ 2V:1H
• Constructed without controlled blasting techniques
• Signalized slide fence installed several years ago
• NE trending gullies observed on slopes
• Gullies may represent weak zones that are geologically controlled
• December 31, 2013 failure within a gully
South Slope:
Fracture/Joint Set slopes towards Track @ ~45°
2 Project Scope

Investigation and Analysis

Design

Construction
Project Scope

• Stage 1 - Investigation / Analysis
  ➢ Background study
  ➢ Site investigation
  ➢ Data processing / analyses
    ▪ Geological Data Summary Report

• Stage 2 - Design
  ➢ Development of remedial alternatives
  ➢ Plans and specifications for selected option

• Stage 3 - Construction
3 Investigation and Analysis

Investigation
- Surveying
- Geological Mapping
- Photogrammetry

Site Conditions

Analysis
Investigation and Analysis

**Topographic Survey**

- Laser scan and conventional surveying
- Conventional survey
  - Areas obstructed from laser scanner
  - Tie into geodetic
- 3D model combined with existing aerial photography
  - Profile sheets and top plan views
Investigation and Analysis

**Geological Mapping**

- Geological field mapping
- Orientation of geological discontinuities (joints, fractures, etc.) were measured in the field
- Rock sample collection for laboratory index testing
Investigation and Analysis

3D Photogrammetry

- Photographs used to generate 3D Models of the rock slope
- Data acquisition;
  - joint/fracture orientation and spacing
  - lithological mapping
  - distance and area calculations
  - slope profiles
Investigation and Analysis

3D Photogrammetry
Advantages

• Historical Issues
  • Access problem
  • Hazard problem
  • Overview problem
  • Time Consuming
  • Not reproducible
Investigation and Analysis

3D Photogrammetry

- Stantec’s System
  ShapeMetrix\textsuperscript{3D}

- Freehand picture taking
- No surveying of camera stations
- System concentrates on geological mapping / geotechnical engineering
Investigation and Analysis

**Site Conditions**

- Located within an intrusive diabase type rock
- Four principal discontinuity (joint/fracture) sets identified
- Discontinuity spacing ~1 to >10 feet
  - Large Blocks
- Localized shear zones
Investigation and Analysis

Site Conditions

Photographic Model

Wiremesh

Photographic Model with Structural Mapping Overlay

ShapeMetrix3D Survey Areas

Stereonet
Investigation and Analysis

Analysis

- Use of Steronets for evaluating kinematically possible failure modes
Investigation and Analysis

**Kinematic Analysis**

- South Slope

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**Potential Planar Sliding Zone**

Sliding on J1
Investigation and Analysis

**Kinematic Analysis**

- South Slope

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**Potential Wedge Failure Zone**

**J1 & J3 Wedge**
Investigation and Analysis

**Kinematic Analysis**

- South Slope

![Potential Toppling Failure Zone](image)
Investigation and Analysis

Analysis
- December 31, 2013 Failure
- Wedge Failure J1 and J3
Investigation and Analysis

Wedge Failures ➔ Gullies

Note: CL (CENTERLINE)
Investigation and Analysis

Analysis

- Area Prioritization
- Semi-quantitative risk assessment
4 Design

Development of remedial alternatives

Plans and specifications for selected option
Design / Specifications

Options

• **Option 1: Major slope cutting**
  - AMTRAK Specification No. 63
    - No steeper than 2H:1V
    - Rock cuts pre-split face
    - Catchment ditch at the base
  - Large scale excavation and blasting required

• **Option 2: Minor slope cutting & Stabilization / protection**
  - Scaling, blast scaling and trim blasting
  - Stabilization / protection measures (rock bolts, netting, etc..)
  - Will not meet Specification No. 63

• **Option 3: Stabilization / protection measures**
  - Scaling, rock bolts, netting, concrete buttresses, etc..

• **Option 4: Protection Barrier**
  - Protection barrier at toe of slope
Design / Specifications

Options Selected

• Option 2: Minor slope cutting & Stabilization / protection
  • Scaling, blast scaling and trim blasting
  • Stabilization / protection measures (rock bolts, netting, etc..)
  • Will not meet Specification No. 63

• Option 3: Stabilization / protection measures
  • Scaling, rock bolts, netting, concrete buttresses, etc..
Option 2

- Trim Blasting/Scaling
- Rock Bolts
- Netting
- Drain holes
Option 3

- Scaling
- Rock Bolts
- Concrete Buttress
- Netting
- Drain holes
Design / Specifications

Design Options
- Prioritized Work Plan

<table>
<thead>
<tr>
<th>Zone</th>
<th>Area</th>
<th>Category</th>
<th>Stantec Recommended Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1, A2</td>
<td>III</td>
<td>Option 3</td>
</tr>
<tr>
<td>2</td>
<td>B3, B4</td>
<td>IV</td>
<td>Option 3</td>
</tr>
<tr>
<td>3</td>
<td>B6, B7, B8, B9</td>
<td>III</td>
<td>Option 3</td>
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<tr>
<td>4</td>
<td>C10, C11, C12, C13</td>
<td>IV</td>
<td>Option 3</td>
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<tr>
<td>5</td>
<td>D14, D15, E16, E17</td>
<td>III</td>
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<td>6</td>
<td>E18, F19, F20, F21, G22, G23, G24, H25, H26</td>
<td>I</td>
<td>Option 2</td>
</tr>
<tr>
<td>7</td>
<td>H27</td>
<td>III</td>
<td>Option 3</td>
</tr>
</tbody>
</table>

Diagram showing zones and areas with color-coded categories and recommended options.
Design / Specifications

• **Communication with Client/Owner**
  - design philosophy
  - design limitations

• **Estimating quantities**
  - notoriously difficult to estimate accurately during design stage

• **Site conditions during construction**
  - conditions will likely be encountered requiring field assessment and potential design modifications.
  - quantity estimates should accommodate this philosophy

• **Contractual language**
  - to allow change in quantities without incurring penalties or cost premiums
Design / Specifications

- **Speciality contractors**
  - Unique nature of work and field assessment requires speciality contractors

- **Site inspection**
  - Full-time site inspection and review by a rock slope design professional

- **References**
  - National Transportation Research Board
    “Rockfall Characterization and Control”
5 Construction

Scaling
Rock Bolts
Concrete Buttress
Netting
Construction

Schedule
• May to October 2015
• Client requirements – firm schedule

Considerations
• Maintaining track operations
• Active Track
  • Safe work environment
  • Work stoppages » Planning

Sequence
• Scaling
• Rock Bolts
• Concrete Buttress
• Netting
Construction
Rock Bolts
Construction
Concrete Buttress
Construction Netting
6 Summary

Technical Design

Construction
Summary

• **Technical**
  
  • Rock slopes » hazards along transportation corridors
  
  • 3D Photogrammetry advantages
    • Safe, Accurate, Fast
  
  • Geological model defines failure modes
  
  • Failure modes determine design
  
  • Risk assessment » priority areas
Summary

- Design
  - Communication with Client/Owner
    - Design philosophy
    - Design limitations
    - Design options
  - Quantities are difficult to estimate accurately
  - Expect design modifications during construction
Summary

• **Construction**
  
  • Restrictions/limitations » Transportation corridors
  • Specialty contractors required
  • Full-time engineering site inspection
Acknowledgments

Stantec Team

- Maureen Matthew
- John Nichols
Acknowledgments

Stantec appreciates the opportunity to serve the National Railroad Passenger Corporation (AMTRAK) on this project.
thank you

questions?