Case Study: West Virginia US Highway 19 "The Narrows" Rockfall Mitigation

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Frank Amend, Geobrugg North America, Rocky Mount, North Carolina

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Project Location

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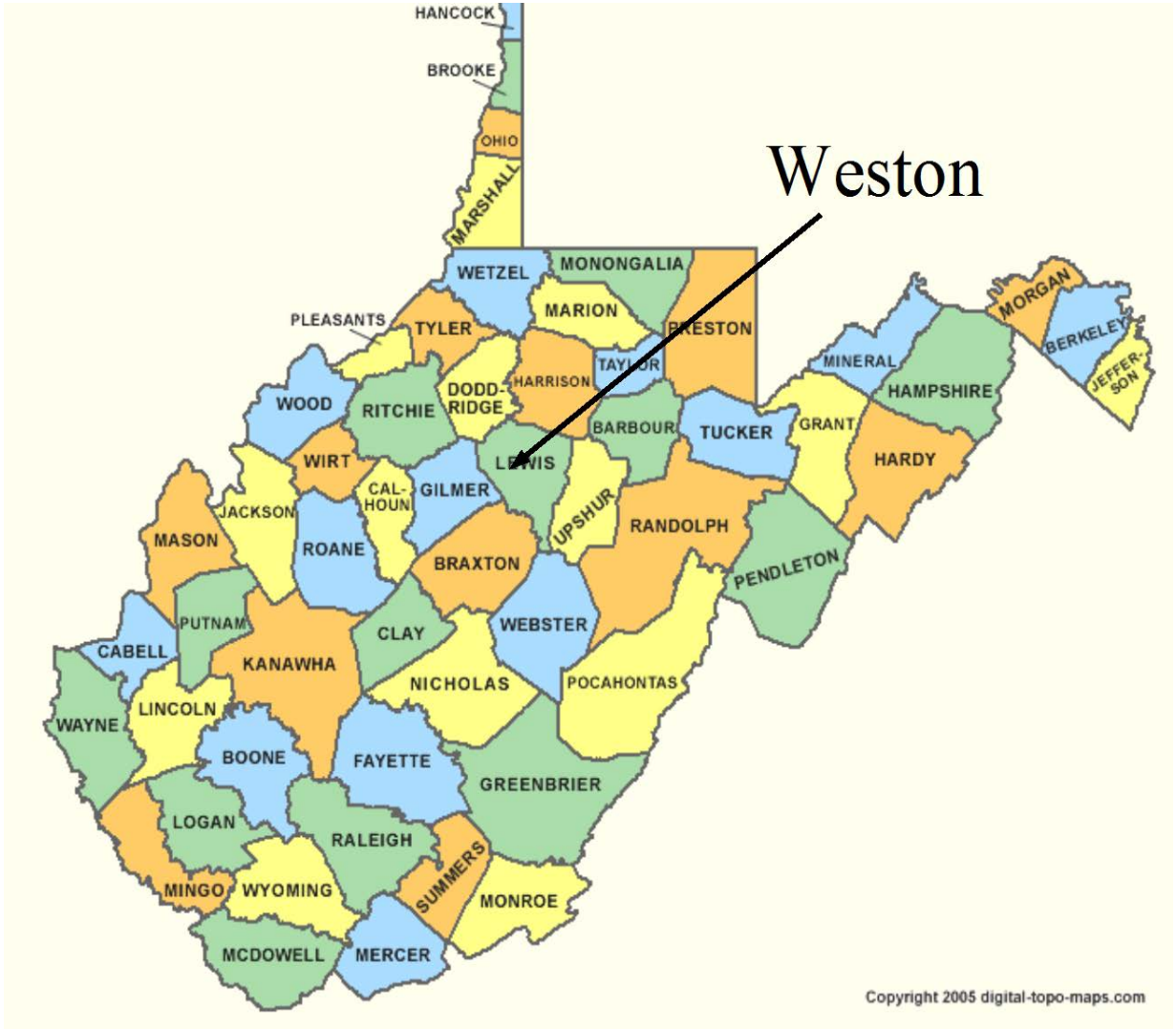

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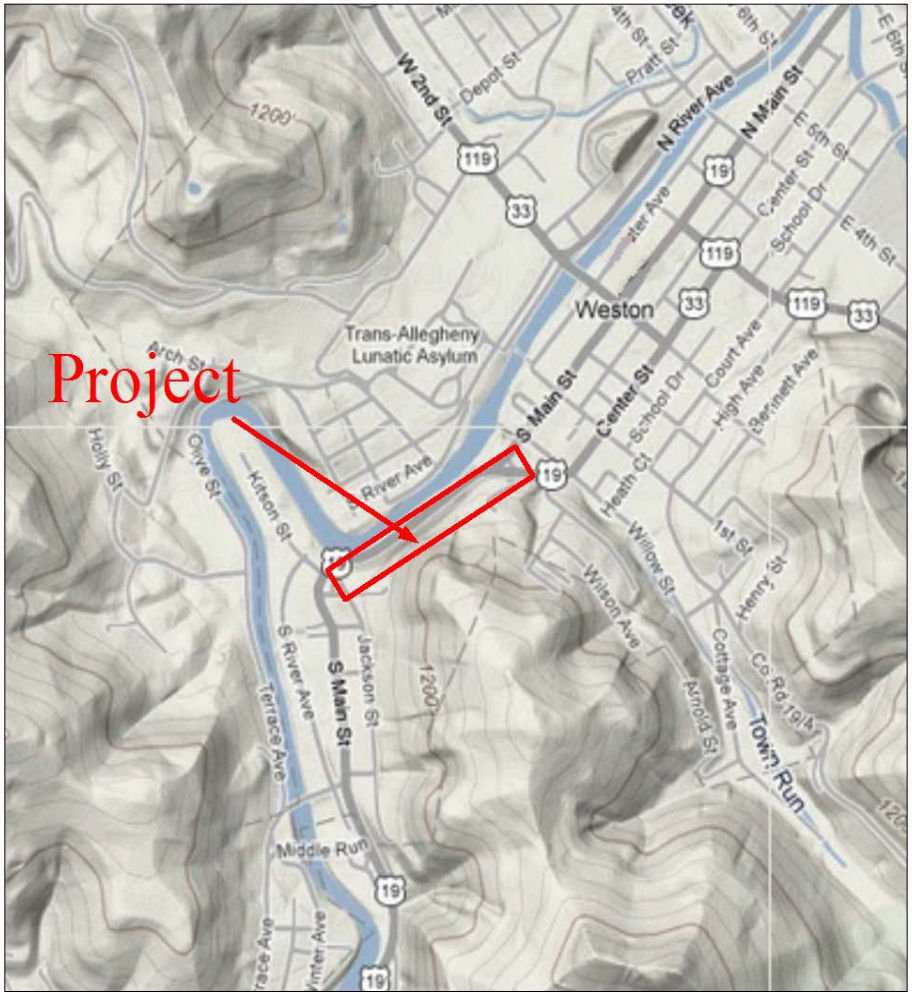
- U.S. Highway 19 connects Weston, West Virginia primarily as commuter route to neighboring counties
- Site parallels the New Fork River
  - Also known as “The Narrows”
- Along a cut-slope
  - approximately 900-ft long
  - On-going rockfall problem



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“The Narrows”

Participants

- Project was bid as a conceptual design with design-build aspects
  - Owner, West Virginia DOT
- Joint Venture
  - Ameritech Slope Constructors, Asheville, North Carolina
    - Contractor
  - Geobrugg North America, LLC, Algodones, New Mexico
    - Rockfall mitigation system manufacturer
  - KANE GeoTech, Inc., Stockton, California
    - Design engineer
- General Contractor-Orders Construction

1. Conceptual plans developed by WVDOT
2. Preliminary investigation prior to slope clearing
   - Review and assess the original conceptual plans
3. Initial analyses and 90% design
4. Preliminary construction drawings
5. Slope was cleared of all vegetation
6. Construction began
7. Second phase of investigation
   - Optimize design and refine approach
8. Engineer was present during the entire construction process
   - Ensured conformance to plans
   - Made any necessary changes as construction progressed
   - Provided technical support to the contractor as necessary

Site Description

- Located within the Appalachian Mountain range
- Continental climate
  - Hot, humid summers
  - Cool to cold winters
- About 45-50 inches of precipitation annually

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- Mostly of flat lying Pennsylvanian Age strata
  - Inter-bedded sandstone
  - Shale
  - Coal
  - Differential weathering of the shale and coal layers beneath massive sandstone beds
  - Cantilevered sandstone beds
    - Relatively resistant sandstone beds become vertical cliffs
    - Relatively weak shale beds form recessed slopes
    - Create rockfall hazard

Site Conditions

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- Cut slope
  - Approximately 900-ft long
  - Vertical slope heights varying from approximately 20-ft to 65-ft
- Upper slope was composed of a 20-ft thick massive sandstone bed
- Directly underneath the sandstone was a 35-foot thick layer of black to brown shale with coal seams and lenses
- Just beneath the shale layer was a 5-ft section of massive sandstone
- Massive rockfall
  - Large joint spacing in the sandstone
  - Combined with rapid weathering of the underlying shale and coal layers

Large, cantilevered, sandstone blocks

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- Project divided into three sections
  - Nature of the hazard
  - Relative risk of rockfall
- Sections 1 and 3 had Geobrugg Rolled Cable Net (RCN) with a secondary chain link mesh backing
- Section 2 was to have 76 pattern rock bolts
  - Secure large, massive sandstone blocks at the highest portion of the cut
  - Draped over the entire cut slope with RCN and conventional chain link mesh

- Conducted prior to construction
- Verify original WVDOT conceptual mitigation plan
- Collect data
  - Analyses
  - Design
  - Prepare working drawings
- Evaluate existing global slope stability
- Further evaluate potential rockfall hazard

Data collection

- Slope was densely covered with vegetation
  - Difficult to get a good picture of conditions
  - Data collection was difficult and time-consuming
- Standard field data collection procedures were used
  - Slope height and angle
  - Geology
  - Potential rockfall sizes and shapes
  - Surface conditions
  - Rockfall run-out data
  - Soil properties
  - Photographs and notes
- Large outcrops in Section 2 were measured for size

Slope clearing and beginning construction

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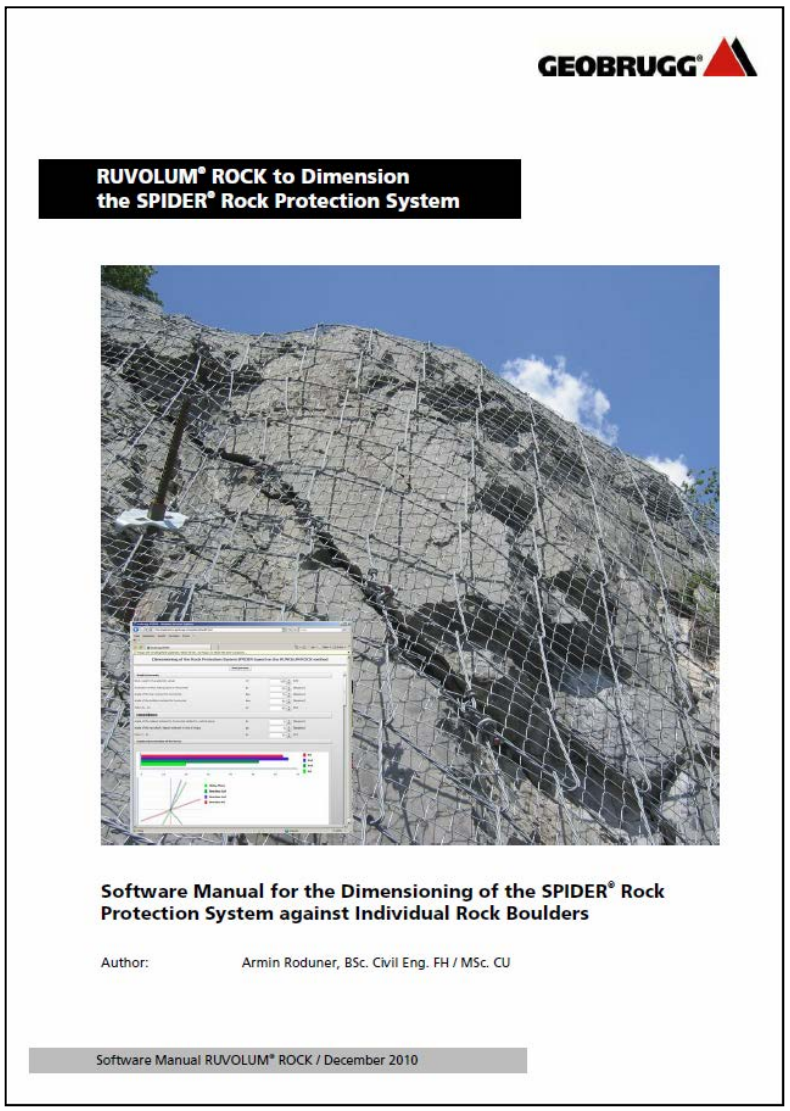
- Slopes were analyzed for kinematic global slope stability
- Decision to consider anchored tensioned mesh system in Section 2
  - Replaced rock dowels and drapery system
- Because of the unknown depth of the large jointed sandstone blocks WVDOT specified that the SPIDER anchors be drilled 25-ft into the sandstone
  - Anchored the tensioned mesh
  - Anchors served as rock dowels

RUVOLUM® ROCK software



- Used to design tensioned wire mesh, rock block stabilization systems
  - Geobrugg SPIDER S4-230 mesh
- Utilizes limiting equilibrium analyses
  - Determine force vectors necessary to restrain a large block onto a slope face
  - Program output
    - Pattern of anchors around the block
  - Necessary tensioning forces to achieve a specified factor of safety.
- Drapery and SPIDER anchor depths
  - Determined and checked using the Post-tensioning Institute (PTI) guidelines

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Phase 2 site evaluation

- Conducted after brush cleared and construction begun
- Refine drapery layout and anchor locations
- Landslide hazard revealed
  - Loose soil and colluvium and additional loose material removed
- Phase 2
  - Provided much additional insight into the project design

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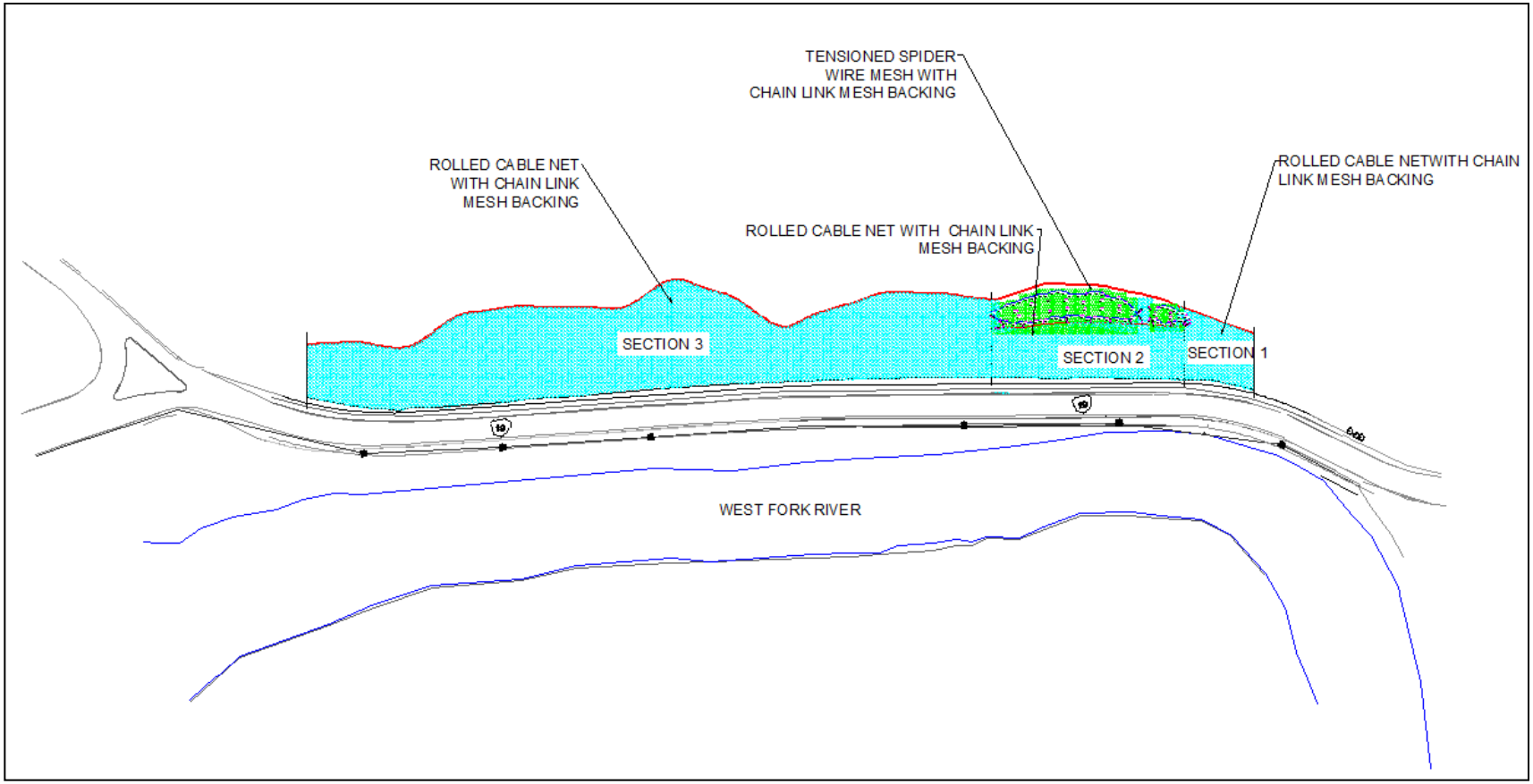
- Final mitigation plans for each section were completed
- Final layout and anchor plan was developed



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Value of two-phase evaluation

- Detailed calculations and plans from Phase 2
- Finalized change from a rock bolt and draped slope at the top of the middle section to a tensioned SPIDER system
  - Design was more effective for the purpose of full retention of the outcrops in Section 2

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1. Initial rockfall project designs should be open to changes

- Once slopes are cleared of vegetation, rockfall conditions can be quite different than initially thought
- Initial designs should be general enough to allow for modification
  - But specific enough to allow a realistic bid process

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2. Consider design-build

- Sometimes in-house personnel lack rockfall analyses and design experience
- Owners should consider design-build concepts by joint ventures between contractors, manufacturers, and engineers
- Specialty professionals have a great deal of experience and expertise that they can bring to bear on projects

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3. Require engineered designs

- Many projects in the past were designed and built using on-the-fly solutions
- Methodologies for investigation have evolved as the discipline has developed over the years
- Many tools, based on sound engineering and scientific principles are available to provide well-engineered designs

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4. Retain the original design engineer for construction oversight and require that the contractor use the manufacturer's representative

- Rockfall mitigation systems are not that commonplace
- Inexperienced inspectors generally are not able to identify problems or irregularities during construction, or ensure conformance to the original design concepts
- Retention of the design engineer for at least periodic inspections is essential to prevent large problems at the end of the project
- Reputable manufacturers supply a certain amount of technical assistance with the sale of the products


THE END
Thanks for your attention!