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TECHNICAL SUMMARY

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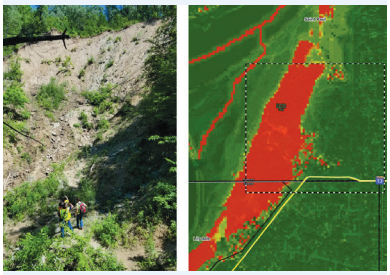
$247,849



The new GIS model indicated that this Dakota County slope had experienced significant erosion.

New GIS Model Assesses and Maps Slope Failure Vulnerability

Researchers developed a model for assessing slope failure risks near roadways in 44 Minnesota counties. The model, which can be used in MnDOT's existing GIS platform, maps slope vulnerability based on slope characteristics and proximity to risk factors. It then generates PDFs and physical maps of slopes that are color-coded according to risk levels.

What Was the Need?

Annual precipitation levels in Minnesota continue to climb, and heavy rainfalls have become more frequent. This precipitation, in combination with flooding, frost action and geological instability, creates geohazards for slopes near state roadways. Various slope failures may result, including a translational slide (a cohesive land mass that slides down a slope), a rotational slide (a portion of a slope that breaks and rotates downhill), or a rockfall or rock topple (rocks that tumble down a slope).

Slope failures may result in millions of dollars in damage and cleanup costs along Minnesota roadways. These events threaten property and lives, damage environments and force lengthy road detours. Local knowledge of slopes helps officials predict those that may be vulnerable to certain failures, but relying on visual inspections to effectively assess risks remains difficult.

What Was Our Goal?

Researchers sought to identify slope failure risks along state trunk highways in several MnDOT districts. Using geographic information system (GIS) modeling, researchers would identify, map and rank slopes along highways according to failure vulnerability and then develop a method for MnDOT to quantify failure risk for asset and emergency management planning. In a second phase of the project, researchers would refine the model and expand mapping to a total of five MnDOT districts.

What Did We Do?

In Phase I, a review of MnDOT's slope failure records suggested the need for a probabilistic model based on geostatistics and geomorphology—the study of landscape evolution and function that draws on hydrology, geology, soil science and climate science.

The research team selected software that would integrate with MnDOT's GIS platform, and analyzed terrain and landforms associated with slope failures. Then they designed a model that uses elevation and GIS data to highlight areas with geomorphic features characteristic of failures. The model also draws on state and national geological data to identify vulnerability factors in the vicinity of modeled slopes.

Team members refined the model with a sensitivity analysis and mapped county slopes. In Phase I, they visited three field sites in the Metro District and in Districts 6 and 7 to inspect actual failure types and vulnerabilities, validate GIS model findings, and identify model strengths and areas for improvement. After further refinements to the model, investigators applied a risk estimation framework to it, generated vulnerability assessment maps and ensured the model worked with MnDOT's GIS platform.

In Phase II, researchers refined the model further, expanded application to Districts 4 and 8, focused on failure modes specific to these areas, visited two more sites (another in District 7 and one in District 8) and mapped the districts.

continued

"As far as we know, this model is the first of its kind. While most models test for one type of slope failure, this model evaluates over a dozen types of failures."

—Jen Holmstadt,
Senior Project Manager, WSB

"This is a planning-level model meant to trigger further investigation and point us to areas that require site-specific analysis."

—Andrew Shinnefield,
Field Operations Supervisor, MnDOT Geotechnical Engineering

The new GIS model identifies and maps slopes at high risk, like this ditch washout on U.S. Highway 169 in Belle Plaine.

What Did We Learn?

Investigators identified several geomorphic characteristics as keys to determining risk. In Phase II, they expanded the considered factors to include the hydrology of ravines and bluffs to match the new terrains to be mapped. Risk factors from both studies include terrain curvature, slope angles, proximity to streams, and rain- and flood-related deepening of waterway beds. The main catastrophic slope failures identified in site inspections from both phases were rotational slides, translational slides and rockfalls. Sensitivity analysis showed that 10-meter elevation data resolution works well and that slope failure mapping should be provided in half-mile buffers from roadways.

The model calculates risk probabilities of slopes in 10-by-10-meter resolution based on past slope failures, slope shape and physical characteristics, and proximity to other risk factors. For example, the calculated risk increases if a stream is close, but is reduced if the slope angle is low.

In Phase I, researchers mapped the entire trunk highway system of the 12 counties in the three districts. In Phase II, they mapped another 32 counties covering the Metro District and Districts 4, 6, 7 and 8. Maps illustrate vulnerability at four proposed risk levels for over 100,000 proposed management areas:

- **High** (red): A site visit and/or action is recommended.
- **Moderate** (orange): Further evaluation is required.
- **Low** (yellow): The area should be monitored.
- **No action required** (green).

What's Next?

The model and maps identified 1,674 high-risk management areas within a half-mile of highways in 44 counties that would require field verification and possible failure-mitigation efforts if the areas and risk levels were recognized as proposed. Color-coded maps that illustrate slope vulnerability are available as 20-by-30-inch wall posters and as PDFs that can be accessed and updated within MnDOT's GIS platform.

In further study, researchers will expand mapping to all 87 counties, considering bedrock depth and similar geomorphic features. Maps will help MnDOT minimize the impacts of slope failures, lower the threats to public safety and reduce the need for expensive, post-failure mitigation.

This Technical Summary pertains to Report 2019-12 "MnDOT Slope Vulnerability Assessments," published March 2019, and Report 2019-28, "MnDOT Slope Vulnerability Assessments—Phase II," published July 2019. Full reports can be accessed at mndot.gov/research/reports/2019/201912.pdf *and* mndot.gov/research/reports/2019/201928.pdf.

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