Montana Department of Transportation October 2017

RESEARCH PROGRAMS

Project Summary Report: FHWA/MT-17-008/8239-001

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Rockfall Hazard Process Assessment

http://www.mdt.mt.gov/research/projects/geotech/rockfall.shtml

Introduction

The Montana Department of Transportation (MDT) implemented its Rockfall Hazard Rating System (RHRS) between 2003 and 2005, obtaining information on the state's rock slopes and their associated hazards. The RHRS data facilitated decision-making in an informal process over the next several years. MDT applied the RHRS ratings in an informal process, reviewing ratings and comparing them to event occurrences, maintenance needs, and rockfall mitigation project selection in the decade since completion. MDT found the RHRS to be a valuable tool providing relative rankings between sites. After nearly a decade of using RHRS, MDT decided to develop a more comprehensive and updated Rock Slope Asset Management Program (RAMP), beginning in 2015, due to a combination of changed sites, a need for additional tools to aid in project selection, and a desire to incorporate principles of Transportation Asset Management (TAM) in managing rock slopes. The goal of the new research project is to assess changes in MDT's rock slope assets since 2003 and gather data that would allow MDT to develop an updated rock slope hazard assessment program with TAM-compatibility as an added benefit. The research project scope includes identifying rock slope condition and risk factors, determining critical sites, incorporating benefit/cost analysis, and forecasting future asset condition based on various budget scenarios. The objectives of the program are to 1) update rock slope rating criteria; 2) determine critical sites based on condition, risk, and cost/benefits using new decision support tools; 3) develop/ cost benefit scenarios; and 4) evaluate compatibility of the RAMP process with MDT's Transportation Asset Management program. Landslide Technology of Portland, Oregon, with team members Paul Thompson, DA Stanley Consulting, and Geographic Communications Systems, completed the project in 2017.

What We Did

The research team applied a multi-stage approach to update and assess MDT's existing rock slope management system in order to promote a more efficient use of resources. In addition to the final Research Report, separate reports were produced for each of the seven sub-tasks, all of which are available online at the above URL.

Following a literature review in Task 1, the project commenced Task 2 with 29 site visits throughout Montana that were constructed since the initial RHRS, had received mitigation work, or had changed significantly since the 2004 RHRS ratings. MDT's existing RHRS assessment was supplemented with four new rating approaches to these sites, but the individual detailed rating categories were not changed. Comparison of results explored different means of evaluating asset change, measured as a percent change in each method between the 2004 and 2015 ratings. Risk analyses focusing on mobility and safety impacts were incorporated as part of initial work on decision support tools.

For Task 3, the team developed a roadmap for creating performance measures for the RAMP that will help MDT meet its goals for this geotechnical asset class and integrate RAMP with MDT's transportation asset management (TAM) program in the future. The team developed different performance classes based on roadway functional classification, and proposed minimum standards for asset performance. As part of this work, Landslide Technology (LT) used rockfall activity survey responses from District 1 to develop risk assessment tools by correlating rock slope condition with the likelihood of a road-closing rockfall event.

After adding the new rating approaches and risk assessment tools to a revised rating spreadsheet, a second round of rock slope assessments was conducted in Task 4. Instead of re-rating all rated 869 slopes in the 2004 database, LT worked with MDT to select a smaller group. The final list of 362 slopes included all sites on the Interstate system, both those previously rated and those 'B' sites that did not receive a detailed rating in 2004. It also included all 'A' sites on highway segments with an AADT greater than 2,000 vehicles per day. The 2016 field work added 126 previously unrated sites along the Interstate routes to the RAMP database.

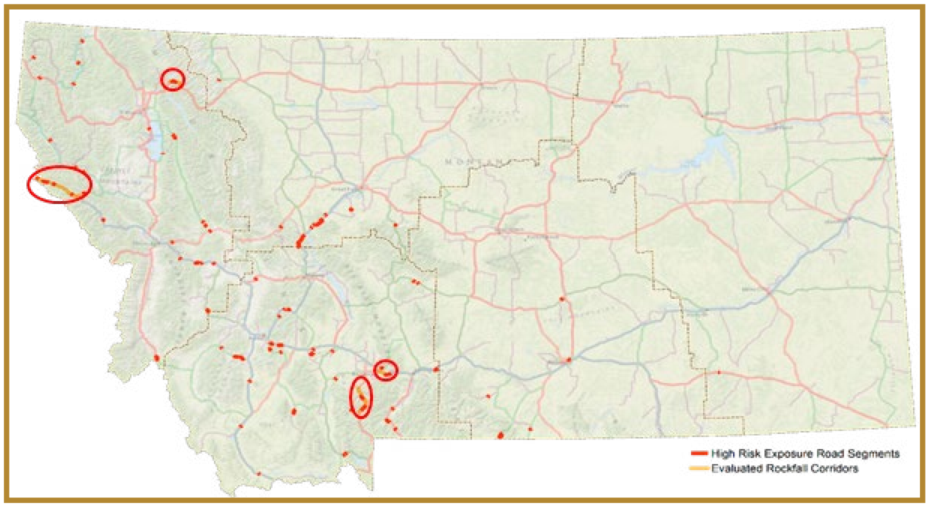

Figure 1: High-risk corridor segments.

In Task 5, the team worked with MDT to select critical sites for conceptual mitigation cost work. Application of proposed 'Minimum Acceptable Conditions' generated a list of 40 RAMP sites that did not meet any of the proposed minimum conditions. In addition, the event likelihood estimates developed for each rock slope as part of Task 3 work were combined with one-mile roadway segments provided by MDT. Again applying difference performance targets based on different roadway functional classifications, the research team identified 149 one-mile segments in Montana's transportation network where the likelihood of road closing events was greater than the conceptual risk targets (Figure 1). Combining these one-mile segments and site-specific minimum acceptable conditions, eleven high-risk corridors were identified as potential investment candidates. MDT selected four of these corridors (Table 1 and Figure 1), which allowed field personnel to visit 75 sites and develop site-specific conceptual mitigation costs. By also updating and incorporating the 100 conceptual mitigation cost estimates from the 2004 RHRS work, the research team created a mitigation cost dataset that correlated asset condition with a per square foot improvement cost.

What We Found

As part of the research project, the team developed cost and risk parameters for rock slopes that correlated with asset condition, as described in the Task 5 and 6 reports. Annual likelihood of both service disruptions and accidents were developed using survey responses from District 1. An average mitigation unit cost was developed by combining the 2004 and the 2016 conceptual mitigation work. Maintenance costs in dollars per square foot for rock slopes were estimated by reviewing annual costs for the two maintenance job codes (obtained from MDT) most likely to contain rockfall-related work. Maintenance section managers were surveyed on the average percentage of those codes actually spent maintaining rock slopes, and this was correlated with the percentage of rock slope-adjacent road miles in their sections. Combining this data with rock slope condition in each maintenance section enabled development of estimated maintenance costs based on asset condition. The various parameters are summarized in Table 2.

Table 1: Rockfall Mitigation Corridors Identified for Site-Specific Cost Estimates.

Location	No. sites below minimum acceptable conditions	Approximate 30 yr. risk exposure (millions)
Lookout Pass, West of St. Regis, I-90, MP 0-31	0	$17.7
Gallatin Canyon, Hwy 191, MP 50-63	3	$7.3
Rocky Canyon, East of Bozeman, I-90, MP 315	1	$2.4
East of West Glacier, US 12, MP 154-158.5	5	$2.3

In the Task 6 work, the research team first conducted an expert elicitation meeting with MDT personnel to gather observed and perceived deterioration rates of MDT's rock slopes. From these rates, the team developed an initial deterioration model, and used it to perform analyses resulting in decision-support tools, including:

- life-cycle cost model,
- return on investment model, and
- tradeoff analysis process.

All of which can be used to support MDT's long-term planning and budgeting in support of asset and performance management processes.

Applying these initial analyses via accepted asset management models, the researchers examined various funding scenarios and how they would affect network-wide rock slope conditions over the next 10 years. The researchers concluded that annual funding levels of approximately $28 million will maintain current conditions, as indicated by the yellow highlighted area on Figure 2. The researchers also concluded that if MDT continues its current method of funding rock slope management on a worst-first basis, the modeling indicates approximately $35 million per year would be required to maintain current conditions. These results suggest that MDT can save $7 million per year by taking a proactive approach to prevent excessive slope deterioration. Further, the research team conducted an analysis of return on preservation investment. This showed that MDT can

Table 2: Rockfall Mitigation Corridors Identified for Site-Specific Cost Estimates.

Condition/State	Annual Risk of Traffic Disruption per ft^2 Rock Face	Annual Risk of Accident per ft^2 Rock Face	Average Cost per ft^2 to Mitigate to Good Condition
1/Good	1.19E-08	5.94E-09	--
2/Fair	4.76E-08	2.38E-08	$8.20
3/Fair	3.91E-07	1.96E-07	$16.40
4/Poor	1.26E-06	6.31E-07	$24.60
4/Poor	2.02E-06	1.01E-06	$32.80

recoup every dollar spent on preserving rock slopes and also realize a benefit of an additional $1.14 for every dollar spent.

By monetizing the safety risks referenced in Table 2, the researchers also developed an incremental benefit/cost equation that is particularly useful when choosing how to best allocate funds with a given corridor or district on an annual basis, and applied it to the Task 5 conceptual mitigation sites as an example of how it could be used to choose sites from the group as a whole, or from within a particular target corridor.

In Task 7, the research team evaluated the compatibility of the new RAMP with MDT's existing TAM program. The team concluded that MDT's well-developed TAM Plan, P3 Performance Programming Process and TranPlan21 provide the guidance needed for developing and incorporation of the RAMP rock slope management process. In addition, while federal law and guidance primarily focuses on bridges and pavement assets, the law supports and encourages inclusion of other assets in TAM plans, including geotechnical assets such as rock slopes. The path toward MDT incorporation of rock slopes and other assets into its 2015 TAM Plan is to develop a Geotechnical Asset Management Plan that is compatible with or part of MDT's TAM Plan.

In summary, we found the principal bottom-line conclusion of the research is that if MDT continues its current practices, maintaining rock slopes in current condition will cost $35 million per year. If the tools developed in this research are used to support decision-making based on life-cycle costs and other considerations, maintaining rock slopes in current condition will cost an estimated $28 million per year – a savings of $7 million per year for the same outcome. Taking advantage of the savings requires continued development of the decision-making tools, monitoring condition and costs of rock slopes and integration of the RAMP into or at least compatible with, MDT's TAM Plan.

What the Researchers Recommend

In order to maintain the quality of the current rock slope database, and ensure that it continues to provide useful information to the Department, the research team recommends that MDT take the following steps:

- Move forward to incorporate the RAMP into MDT's TAM Plan as soon as practicable. In the interim, continue development of RAMP processes and data collection in methods compatible with MDT's asset management and performance management processes.
- Integrate condition and risk assessments into budget allocation and department planning so rock slopes are considered as elements of projects early in the planning process or as stand-alone projects as warranted by risk, slope condition and other considerations.
- Develop a continuing STIP project for maintaining and improving the RAMP and for rock slope preservation projects.
- Utilize the Condition State approach for developing rock slope design goals.
- Update site data after mitigation/ repair work or construction of new slopes.
- Track rockfall events and rock slope specific maintenance costs, ideally as they occur
- Maintain licenses for online database to support collecting and storing rock slope data and enable communication of rock slope condition and cost.
- Conduct another large-scale site assessment in 5 years, consistent with other asset management standard of practice.

These recommendations, if undertaken, will help MDT improve the preliminary correlations, costs, and models developed in this research project at regular intervals. This will make the decision support tools more useful and budget-related planning more accurate, increasing Department benefit from the RAMP.

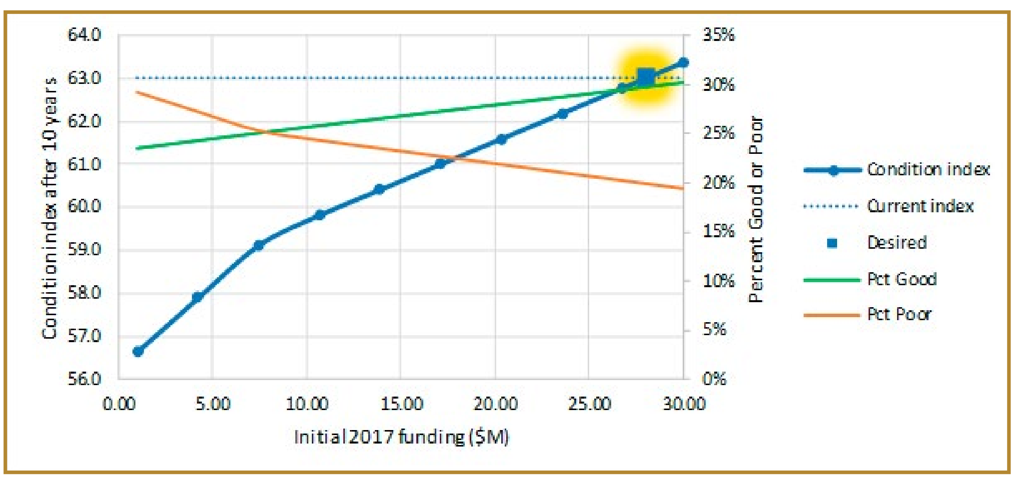

Figure 2: Network-Level RAMP Slope Condition Index versus Funding.

For More Details . . .

The research is documented in Report FHWA/MT-17-008/8239-001, http://www.mdt.mt.gov/research/projects/geotech/rockfall.shtml.

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To obtain copies of this report, contact MDT Research Programs, 2701 Prospect Avenue, PO Box 201001, Helena MT 59620-1001, mdtresearch@mt.gov, 406.444.6338.

MDT Implementation Status: October 2017

Eight implementation recommendations were made to MDT. These recommendations, along with MDT's response, are documented in the implementation report, which can be found at the above URL.