PROCEEDINGS
2nd Geotechnical Asset Management Peer Exchange (GAMPE)
May 26, 2022
Asheville, North Carolina

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List of Acronyms

AUMIRA	Abandoned Underground Mine Inventory and Risk Assessment
CDOT	Colorado Department of Transportation
DOT	Department of Transportation
ESRI	Environmental Systems Research Institute
FAST	Fixing America's Surface Transportation
FHWA	Federal Highway Administration
GAM	Geotechnical Asset Management
GAMPE	Geotechnical Asset Management Peer Exchange
GHMS	Geohazard Management System
INDOT	Indiana Department of Transportation
LIMS	Lab Information Management System
LTRC	Louisiana Transportation Research Center
MAP-21	Moving Ahead for Progress in the 21st Century
MnDOT	Minnesota Department of Transportation
MSE	Mechanically Strengthened Earth
ODOT	Ohio Department of Transportation
TAM	Transportation Asset Management
TAMP	Transportation Asset Management Plan
TIMS	Transportation Information Mapping System
USMP	Unstable Slope Management Program
VE	Value Engineering
WisDOT	Wisconsin Department of Transportation
WSDOT	Washington State Department of Transportation

Preface

The **2nd Geotechnical Asset Management Peer Exchange (GAMPE)** was held at the Renaissance Hotel in Asheville, North Carolina on May 26, 2022 following the 71st annual Highway Geology Symposium and the TRB midyear committee meeting earlier in the week. These events brought together people interested in the deployment of Geotechnical Asset management (GAM) to improve safety and mobility on the nation's transportation corridors.

The first GAMPE was held at the headquarters of the College of Engineers and Surveyors of Puerto Rico in San Juan, Puerto Rico on August 27 and 29, 2019, and was organized by the Puerto Rico Highway and Transportation Authority and the Federal Highway Administration. Similar to the first exchange, the focus of the 2022 event was to increase awareness and knowledge of current GAM practices through real-world examples and lessons learned shared and discussed among participants. Discussions also included current trends, future plans, and resource needs for GAM implementation.

The GAMPE event was held from 8:00 AM to 4:00 PM, and involved introductory and closing remarks from the organizers, updates from several state transportation agencies regarding ongoing GAM efforts, and a mix of whole-group and breakout discussions. Representatives and spokespersons from the Federal Highway Administration (FHWA), state transportation agencies, and private engineering firms participated in the discussions.

Special Recognitions

This event's success was due to the efforts of the event organizers, contributions of the presenters and facilitators, and all that attended and participated in the discussions. We would like to express our sincere gratitude for the partnership and contributions made by the members of these committees:

- ASCE Geo-Institute Innovative Technologies & Tools in Geotechnical Engineering Committee
- TRB Committee on Geotechnical Instrumentation and Modeling AKG60
- TRB Geotechnical Asset Management (GAM) Section Subcommittee AKG00(1)

We would like to acknowledge and express our appreciation to the following individuals for facilitating and moderating discussions during the peer exchange:

- Silas Nichols, Principal Bridge Engineer, FHWA
- Scott Anderson, Principal Geotechnical Engineer, BGC Engineering
- Benjamin Rivers, Senior Geotechnical Engineer, FHWA
- Derrick Dasenbrock, Geotechnical Engineer, FHWA
- Darren Beckstrand, Engineering Geologist, Landslide Technology

Special thanks to John Pilipchuck and his staff at the North Carolina Department of Transportation for planning and coordinating the Peer Exchange. We also acknowledge the services of Jared Crenshaw of Schnabel Engineering for preparing these GAMPE proceedings.

And finally, we greatly appreciate the involvement of all those that attended, engaged in the lively discussions and shared their experiences to advance the practice of GAM.

Proceedings - Thursday, May 26, 2022

1.0 Introduction

The 2nd Geotechnical Asset Management Peer Exchange (GAMPE) began with remarks from Mr. Silas Nichols of the Federal Highways Administration (FHWA). After a short overview of the agenda, Mr. Nichols asked each participant to introduce themselves and state their goals for participating in the Peer Exchange. Mr. Nichols added that his purpose for attending the Peer Exchange was to take the temperature of the practice, and to identify what key steps should be taken to establish consistency across state agencies as it pertains to Geotechnical Asset Management (GAM).

Mr. Silas Nichols, Principal Bridge Engineer, FHWA

Mr. Scott Anderson (Principal Geotechnical Engineer; BGC Engineering), and TRB GAM Section Subcommittee AKG00(1) Co-Chair

Mr. Nichols introduced Scott Anderson. Mr. Anderson currently serves as a Principal Geotechnical Engineer with BGC Engineering, and as co-chair for the TRB section subcommittee on Geotechnical Asset Management AKG00(1). Mr. Anderson previously worked with Central Federal Lands and FHWA's Resource Center.

Mr. Anderson commented that he would like to see state transportation agencies more broadly accept the GAM concept. State governments are required to formally manage some of their assets such as pavements, bridges; however, there is currently no requirement to manage geotechnical assets. Mr. Anderson remarked that States possess more geotechnical assets than any other kind of asset. These geotechnical assets typically perform better and with less care than bridges and other structures; however, he noted, geotechnical assets should be managed and preserved proactively to best utilize federal dollars. Geotechnical asset management, opined Mr. Anderson, should be more predictable, and less crisis driven.

After Mr. Nichols and Mr. Anderson introduced themselves, each attendee introduced themselves and provided some information about their background and reasons for attending the peer exchange. In general, attendees were interested in sharing the information they had, learning about what other practitioners are doing, and finding innovative ways to contribute to the practice as a whole. A list of attendees is included in Appendix A.

At the conclusion of the introductions, Mr. Nichols challenged the group to consider the following questions:

- What are the funding challenges facing GAM?
- How should we manage overlapping assets such as subgrades?
- How do we incorporate resiliency?
- What are some external stressors or barriers to implementing GAM?
- Does our increasing awareness of geotechnical hazards expose us to more risk?
- Why don't we all manage our geotechnical assets now?
- How do we move past crisis reaction and into a proactive management strategy?
- How do we establish uniform performance metrics?
- How do we establish a common language with which to address GAM with transportation industry partners?
- How do we deal with the knowledge gap between the geotechnical engineering community and those who are involved with routine maintenance?

Mr. Nichols pointed out that we have a thousand times more geotechnical assets than other asset classes, yet there is not a perceived risk outside the GAM community that would drive a need to deal with geotechnical assets within the established Transportation Asset Management (TAM) system. Mr. Nichols noted that TAM is not a holistic process because it doesn't consider things we don't see, like bridge foundations, or geotechnical assets. To incorporate GAM into TAM, the current TAM models will need to be disrupted at significant cost. Mr. Nichols suggested that transportation industry leaders must be convinced that managing geotechnical assets will be worth the effort. This will be a difficult problem to overcome. We do not currently have uniform performance metrics which complicates implementation, affects how we think about GAM, and how we fund the work.

Mr. Nichols reported that the FHWA is generating a GAM implementation manual, a risk-based protocol for Mechanically Stabilized Earth (MSE) walls, and training materials that will be available to asset managers. He said that the FHWA will develop a series of videos to help others understand GAM. There will be a new landing page on the FHWA website for the GAM training course to be provided free of charge. The initial offering will include 10 workshops. Training materials will include a course designed to support GAM and develop GAM at state transportation agencies. Goals of the course will be to establish consistent definitions of GAM, what asset classes are, and how to collect and communicate data effectively.

Mr. Nichols also mentioned another GAM program recently developed for Federal Lands Management Agencies (FLMAs), the Unstable Slope Management Program (USMP), which has been implemented along some federally managed roadways and trails.

2.0 State DOT Presentations

Representatives from several state departments of transportation (DOT's) shared with the group the current state of their respective geotechnical asset management programs. The content of the presentations is summarized below. The presentation slides shown to participants are included in Appendix C through I.

2.1 Indiana Department of Transportation (INDOT)

Presented by: Mr. Aamir Turk, M.S. P.E., INDOT

Mr. Aamir Turk, Senior Engineering Manager, INDOT

INDOT has active asset management programs for bridges, drainage structures, traffic signs, and pavements. The department has recently initiated a geotechnical asset management program that prioritizes retaining walls and is just getting started with a landslide asset management program.

INDOT developed an Inspection Manual for retaining walls. In-house staff developed and utilized ArcGIS and Environmental Systems Research Institute (ESRI) applications to identify retaining walls, then worked with private consulting firms to perform field inspections on these assets. Inspectors prioritized state-owned structures that were visible to at least 5 feet above the ground surface. Inspectors entered the data shown below into a mobile application.

Figure 1. Retaining Wall Inspection Metrics (INDOT)

The retaining wall inventory revealed that most of INDOT's retaining walls are MSE walls and that most structures were in fair condition at the time of inspection. INDOT also found many structures for which no records were available. Design data for existing structures was only available for projects constructed within the past 15 years.

INDOT is in the initial phases of implementing a landslide asset management program. Private consultants with landslide experience are currently working to study landslides along five routes encompassing approximately 70 miles of roadway.

INDOT has used the information collected in the wall and landslide inventories to help generate budgets and schedule the repairs of these assets. Future plans include using new technology to assess potential slope problems and facilitate planning of needed repairs. INDOT also plans to develop a GAM program for invisible foundations through the use of geophysical testing applications.

The slides presented by Mr. Turk are included in Appendix C of this document.

2.2 Minnesota Department of Transportation (MnDOT)

Presented by: Mr. Derrick Dasenbrock, P.E. D.GE, F. ASCE, FHWA

Mr. Derrick Dasenbrock, who formerly worked at the Minnesota Department of Transportation (MnDOT) and is now with the FHWA, presented the following information in the place of John Siekmeier of MnDOT.

Mr. Derrick Dasenbrock, Geotechnical Engineer (FWHA)

Due to the passage of key legislation including Moving Ahead for Progress in the 21st Century (MAP-21; 2012), Fixing America's Surface Transportation (FAST; 2015), and INVEST in America (2021), future investments in transportation are to be guided by performance based, measured outcomes.

In 2021, Minnesota passed legislation that requires geotechnical asset management to be part of their statewide transportation plan to include, at a minimum, an inventory of geotechnical assets along with inventories of bridge, pavement, pedestrian, bicycle, and transit assets.

As part of the effort to assemble an inventory of geotechnical assets, MnDOT now requires contractors to provide information about the geotechnical assets on projects they constructed as part of the project closeout process. In addition to as-built plans, contractors are directed to enter information about the transportation assets they built on the MnDOT website.

The slides presented by Mr. Dasenbrock are included in Appendix D of this document.

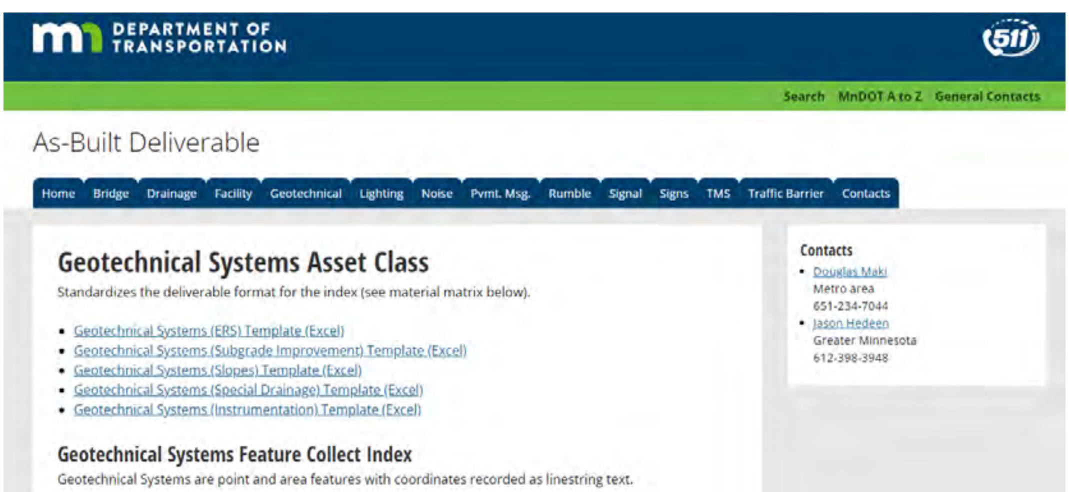


Figure 2. As-Built Deliverable Section of the MnDOT Website.

2.3 Washington State Department of Transportation (WSDOT)

Presented by: Mr. Marc Fish, WSDOT

Mr. Marc Fish, State Engineering Geologist, WSDOT

The Washington Department of Transportation has had an unstable slope management system to manage landslides, rockfalls, debris flows, and settlement for almost 30 years. The department has dedicated funding to mitigate unstable slopes. Slope selection is not based on a worst case first scenario. To be considered for mitigation or repair, unstable slopes must meet minimum programming criteria. The program manages costs through a cost benefit analyses. WSDOT has learned that partial mitigation is often more cost-effective compared to full-slope repairs.

In 2019, WSDOT moved towards a Geotechnical Asset Management Program (GAMP); however, the department has elected not to include geotechnical assets as part of the Transportation Asset Management Plan (TAMP) because of the reporting requirements of the TAMP.

WSDOT has a Geotechnical Asset Management Manual. A list of chapters and their topics is presented in Figure 3.

Chapter	Content
Chapter 1 – Introduction	Provides an overview of WSDOT's asset management framework, alignment with Practical Solutions, and overview of the TAMP content.
Chapter 2 – Objectives and Measures	Communicates asset management objectives, performance measures, and targets as well as a history of how WSDOT has measured geotechnical asset condition.
Chapter 3 – Inventory and Condition	Details total inventory, age, and condition of Geotechnical Assets.
Chapter 4 – Lifecycle Planning	Explains WSDOT's current geotechnical asset specific investment strategies to maximize asset life and condition at the lowest practicable cost.
Chapter 5 – Risk Management	Details WSDOT's risk framework, existing risk management practices, and recently conducted risk workshops.
Chapter 6 – Revenue and Financials	Summarizes WSDOT's financial sources and uses and aligns planned expenditures to Geotechnical Asset needs. Also provides an estimated replacement value for Geotechnical Assets.
Chapter 7 – Performance Scenarios	Discusses differences between target-based performance gaps and plan-based performance gaps. Also highlights WSDOT's efforts to develop a cross-asset resource allocation framework.
Chapter 8 – Investment Strategies	Aligns geotechnical asset specific investment strategies to various WSDOT plans and communicates how Geotechnical Asset Management informs our capital plans.
Chapter 9 – Implementation and Systems	Discusses various Geotechnical Asset Management efforts undertaken by WSDOT and work currently underway to enhance WSDOT's Geotechnical Asset Management practices. Also details systems used in support of Geotechnical Asset Management and future enhancements of those systems.

Figure 3. WSDOT GAM Manual Chapters

WSDOT currently performs routine slope inspections at 1, 3, and 5-year intervals based on past slope hazard ratings. Due to the large number of slopes, annual inspections for every slope is cost-prohibitive. If circumstances warrant, WSDOT may elect to partially mitigate a slope if the costs for a full-slope mitigation are determined to be unjustifiable based on the condition of the slope and the risk to surrounding infrastructure. Inspection costs are about $500,000 per year. Slope remediation costs are about $16 million per biennium.

As new technology emerges, WSDOT plans to adapt and streamline their inspection processes. Some inspections are currently being performed via mobile LIDAR survey which is very cost-effective but has some limitations. For example, the reliability of mobile LIDAR data can be adversely affected by the presence of vegetation along slopes. Mobile LIDAR also has limited utility in areas with high topographic relief.

The slides presented by Mr. Fish are included in Appendix E of this document.

2.4 Ohio Department of Transportation (ODOT)

Presented by: Mr. Andrew Jalbrzikowski, PG, ODOT

Mr. Andrew Jalbrzikowski, Field Exploration Manager, ODOT

The ODOT GAM program was initiated due to liability issues associated with abandoned underground mines. After a mine shaft under IR70 collapsed in 1995, ODOT began the Abandoned Underground Mine Inventory and Risk Assessment (AUMIRA) in 1998. The AUMIRA program consisted of cataloging and scanning Ohio Department of Natural Resources mine maps, creating an abandoned underground mine database, and building a GIS application for georeferencing mine locations. The program also included field inspections, which began in 2004 and concluded in 2008.

Building on the success of the AUMIRA program, ODOT added a Geotechnical Data Management System (GDMS) which is a document management system that includes a Lab Information Management System (LIMS) and a Geological Hazard Management System (GHMS).

ODOT performs geohazard inventory surveys along their State Highway System. Geohazards are assigned a rating within a 4-tier system, with higher tiers denoting higher risk. Inspection frequencies are established by tier. Detailed rating systems were established for each tier, so the higher the tier, the more detailed the inspection.

Much of the information within ODOT's GDMS is managed with Power BI software. Data presentation is available to the public on the Ohio Transportation Information Mapping System (TIMS) website. The TIMS site also features a portal for county managers, where they can access more detailed information that can be communicated to legislators and others who are involved in funding decisions and resource allocation.

The slides presented by Mr. Jalbrzikowski are included in Appendix F of this document.

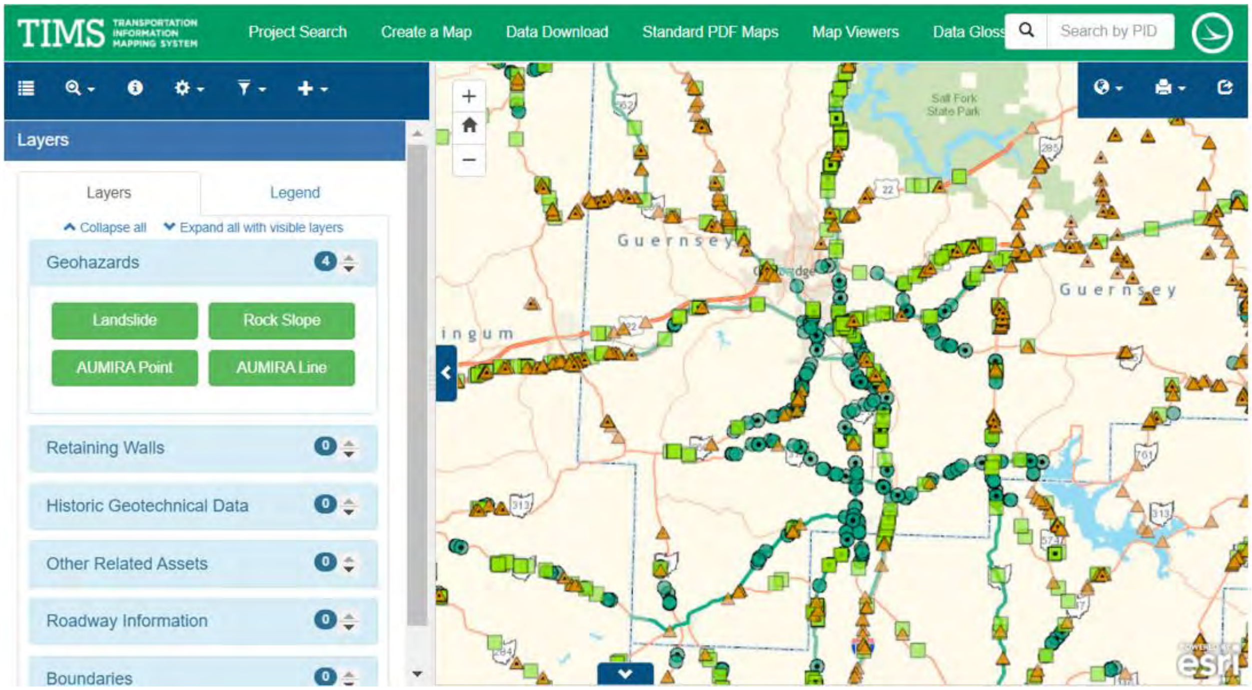


Figure 4. Ohio Transportation Information Mapping System (TIMS) website.

2.5 Louisiana Department of Transportation and Development (Louisiana DOTD)

Presented by: Mr. Gavin Gautreau, PE, M. ASCE, Louisiana Transportation Research Center (LTRC)

Mr. Gavin Gautreau, Geotechnical Research Engineer, LTRC

The Louisiana DOTD started their GAMP with an inventory of existing retaining walls along major highway corridors. Due to the state's relatively low natural topographic relief, most geohazards are associated with settlement and consolidation of soils beneath structures and roadways.

The inventory of geotechnical assets started with the identification of walls along highway corridors utilizing google maps. Key data points such as the wall size, type, length, face orientation, and condition were entered into a database in ArcGIS/ArcMap. Assets were rated utilizing assessment decision trees shown in Figures 5 through 7, then prioritized using the formula shown in Figure 8.

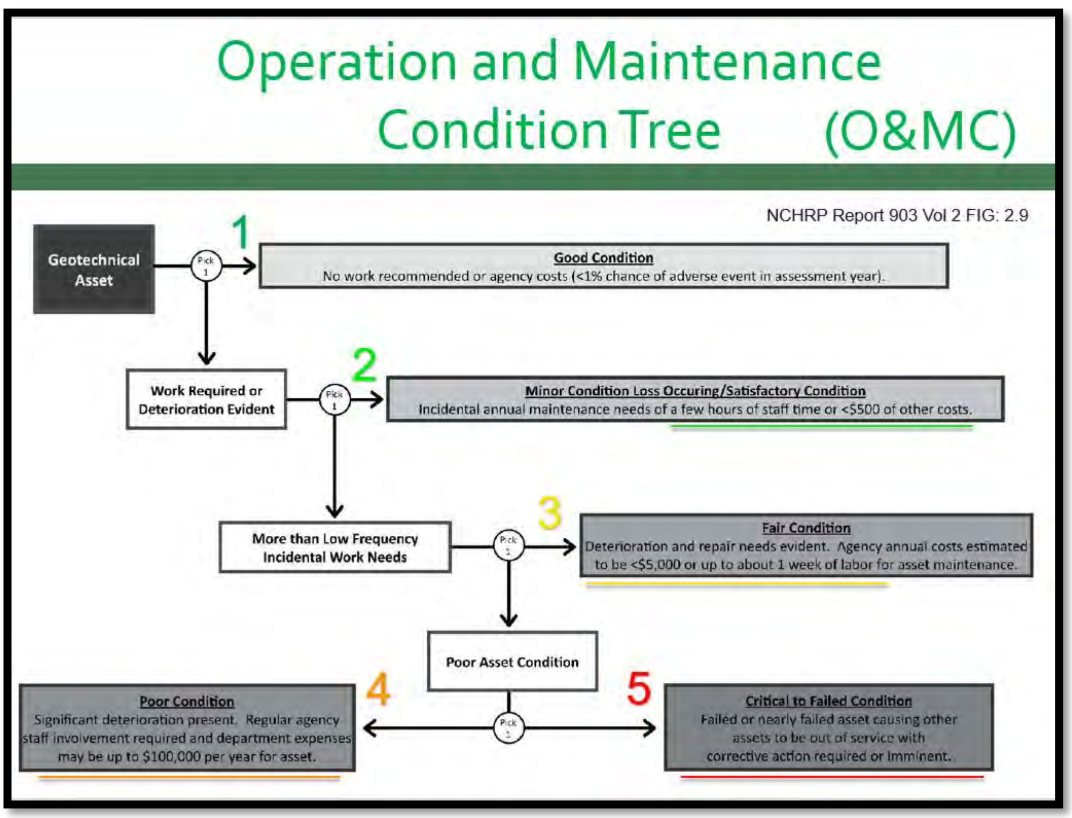


Figure 5. Louisiana DOTD's GAM Operation and Maintenance Condition Tree

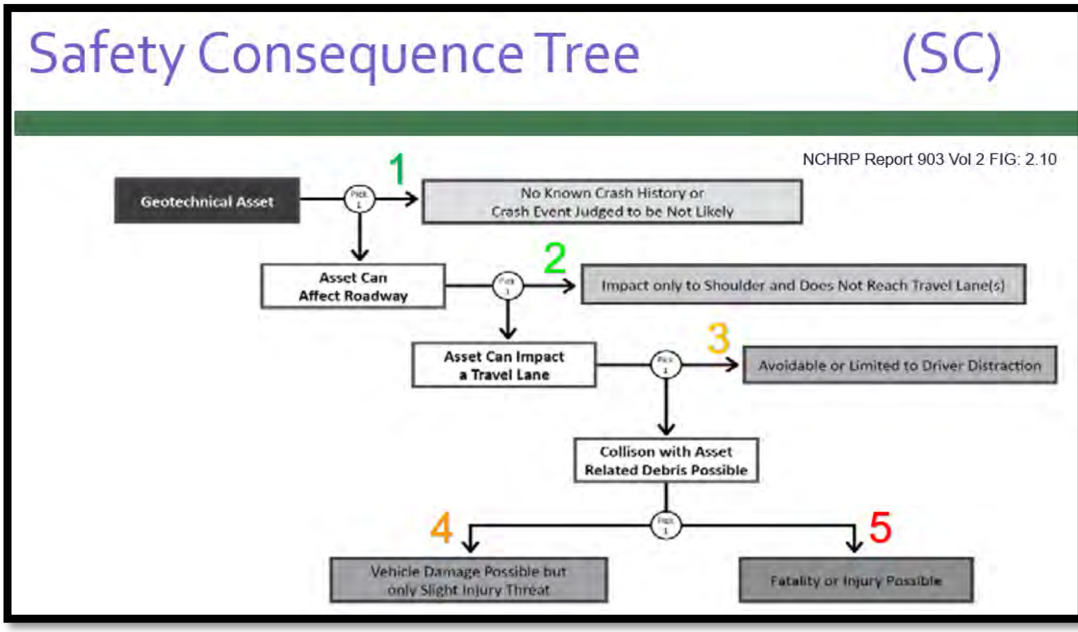


Figure 6. Louisiana DOTD's GAM Safety Consequence Tree

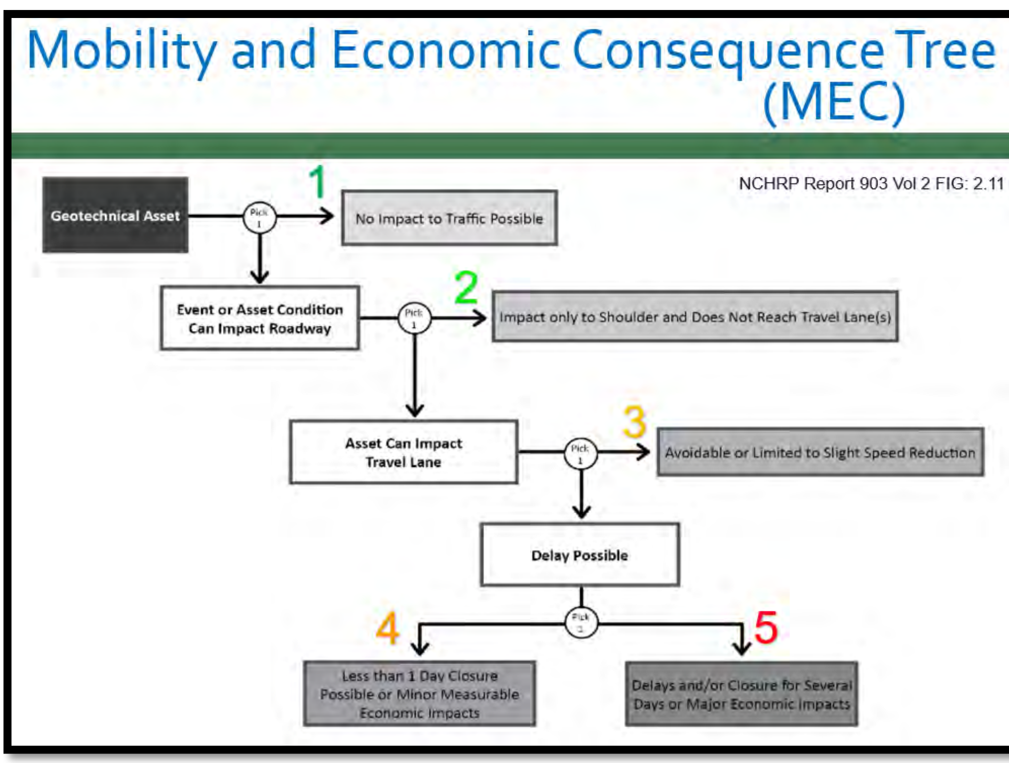


Figure 7. Louisiana DOTD's GAM Mobility and Economic Consequence Tree

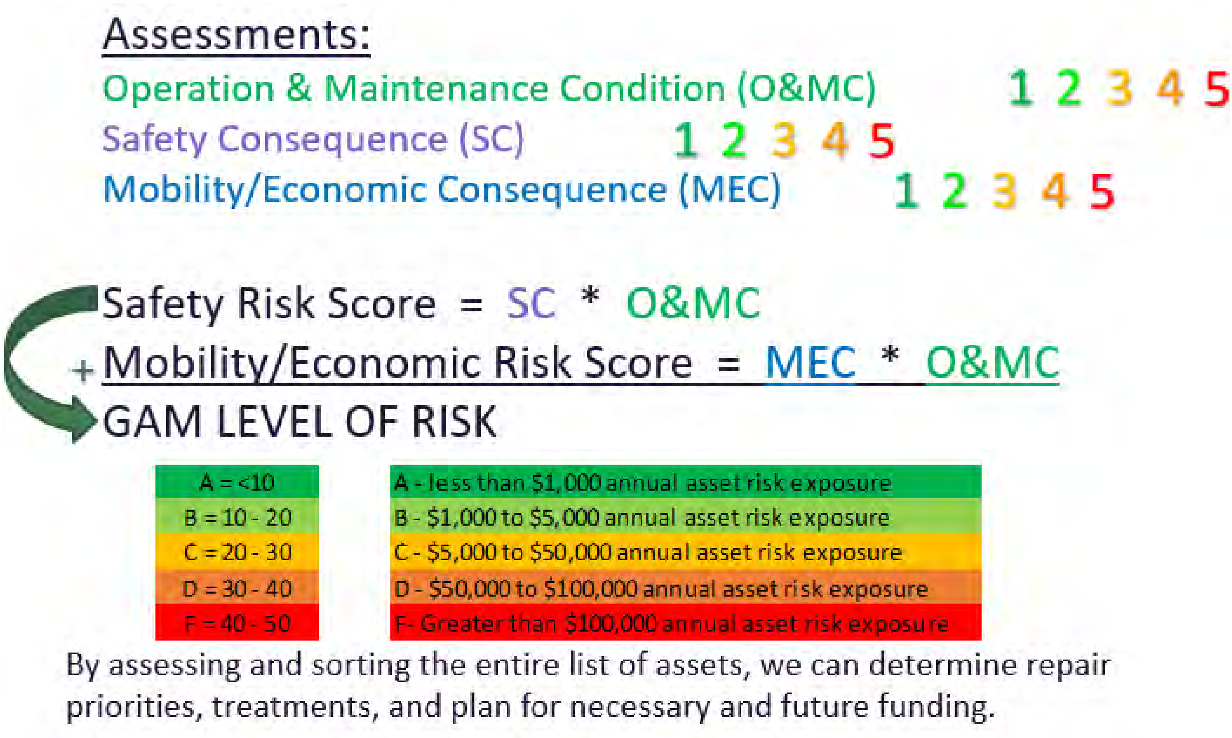


Figure 81. Louisiana DOTD's GAM Prioritization Formula

Moving forward, the Louisiana DOTD plans to integrate more data points into the geotechnical asset management system including designs and as-built plans for retaining walls, geotechnical boring information, and pile load test data. They also plan to add other asset types such as slopes and culverts, which will be integrated into a GIS database. Utilizing the database, the department can make informed decisions about resource allocation and prioritize their hazard mitigation efforts with a better understanding of the status of existing retaining walls and problematic slopes throughout the State of Louisiana.

The slides presented by Mr. Gautreau are included in Appendix G of this document.

2.6 Colorado Department of Transportation (CDOT)

Presented by: Mr. Matthew Tello, CDOT

Mr. Matthew Tello, Engineering Geologist, CDOT

The CDOT Geohazards program is funded by the CDOT TAM program. The geohazards group members are considered subject matter experts for the CDOT Resiliency Working Group.

CDOT's Geohazards Management Plan (GMP) measures and manages threats to CDOT owned highway corridors with respect to geohazards and systematically prioritizes corridor improvements. The plan involves the development and maintenance of the statewide Geohazard Management System (GHMS) and providing emergency services for geohazard related events.

CDOT evaluates and monitors rock falls, embankment failures, debris flows, and earth landslides. Key information about the safety threats a geohazard could pose to highway users, the mobility impacts a geohazard related event could have on the public, and the potential damage to other CDOT assets such as pavements, walls, culverts, and bridges are all documented.

Information about geohazard events is compiled into a database that is continually updated as new events occur. Geohazards are rated in terms of Level of Risk (LOR) using the general formula presented in Figure 9. Projects are then prioritized utilizing the approach shown in Figure 10.

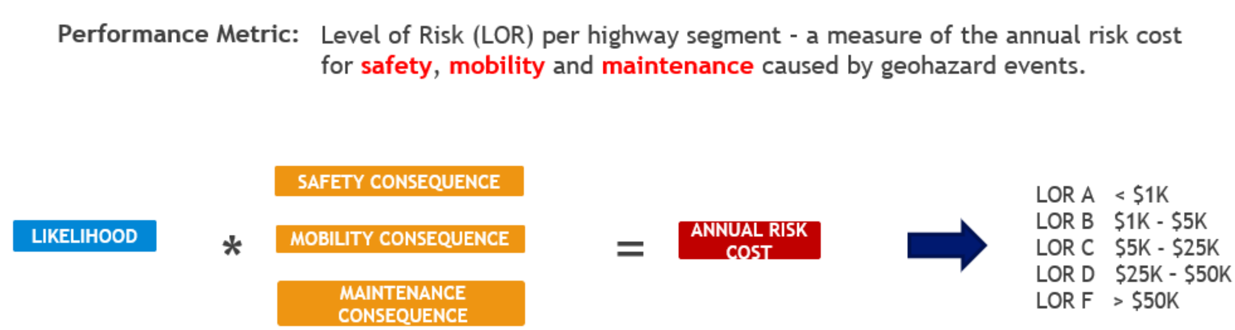


Figure 9. Level of Risk Formula (CDOT)

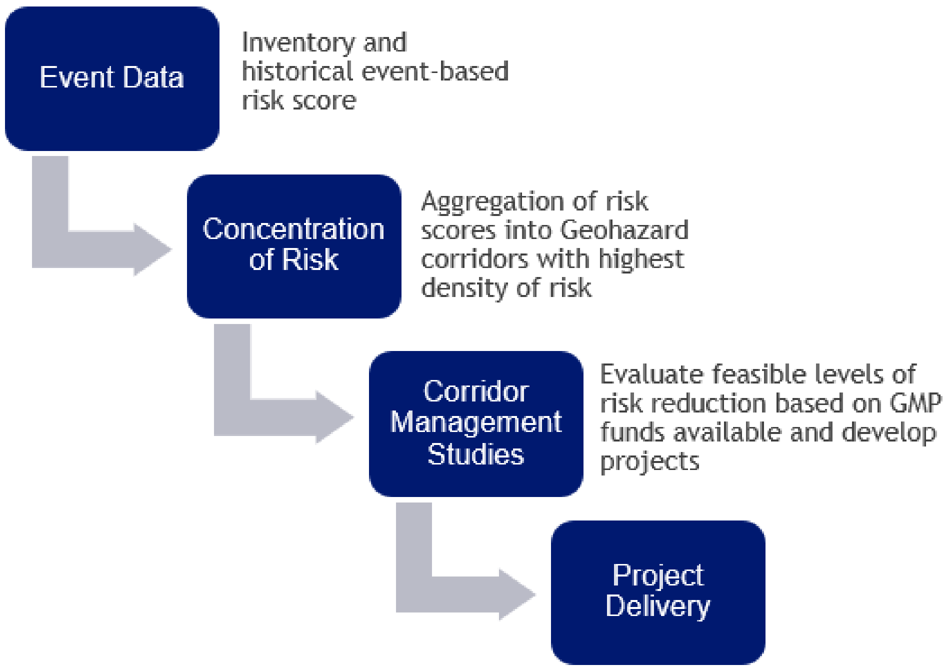


Figure 20. Project Prioritization Workflow Diagram (CDOT)

Going forward, CDOT would like to move away from an event-related model to a characterization-and-likelihood model that includes geohazards that have not yet generated a documented event. They plan to introduce a vulnerability metric which would improve the way the impacts of geohazard related events are estimated, and to integrate the potential risk to other assets such as walls, tunnels, pavements, bridges, and culverts. Other plans include introducing criticality and detour impacts, developing a realistic deterioration model for geotechnical assets, and enabling rapid assessments of change following geohazard related events.

The slides presented by Mr. Tello are included in Appendix H of this document.

2.7 Wisconsin Department of Transportation (WisDOT)

Presented by: Mr. David Staab, PE, LEED, AP, M. ASCE, WisDOT

WisDOT's GAM program is in its infancy and was initiated with a pilot program along a segment of STH-35 in Crawford County, in October of 2020. This corridor is important to tourism and is particularly vulnerable to slope failures. The pilot program is scheduled to conclude in 2022, when final reports presenting the findings of the program will be issued.

Mr. David Staab, Geotechnical Engineer, WisDOT

Future plans could be to integrate GAM into WisDOT's overall asset management program, and to expand the program into other parts of the state where slope stability issues have been documented.

The slides presented by Mr. Staab are included in Appendix I of this document.

3.0 The Past and Present State of Geotechnical Asset Management

The morning group discussion focused on the past and present state of GAM. In the interest of keeping the even on schedule, topics were discussed among all participants at once rather than breaking into small groups. A list of topics and questions to prompt discussion among participants are included on the GAM Peer Exchange Agenda in Appendix B.

3.1 Deployment of GAM and Incorporation into Transportation Asset Management

Mr. Ben Rivers facilitated a group conversation among all participants that focused on the threats to GAM implementation, and opportunities for improving GAM implementation.

To capture some of the ideas, idea boards were affixed to the wall upon which participants were encouraged to attach their thoughts using post-it notes. A graphic representation of the information collected is shown in Figures 11 and 12 below.

Mr. Benjamin Rivers, Senior Geotechnical Engineer (FHWA)

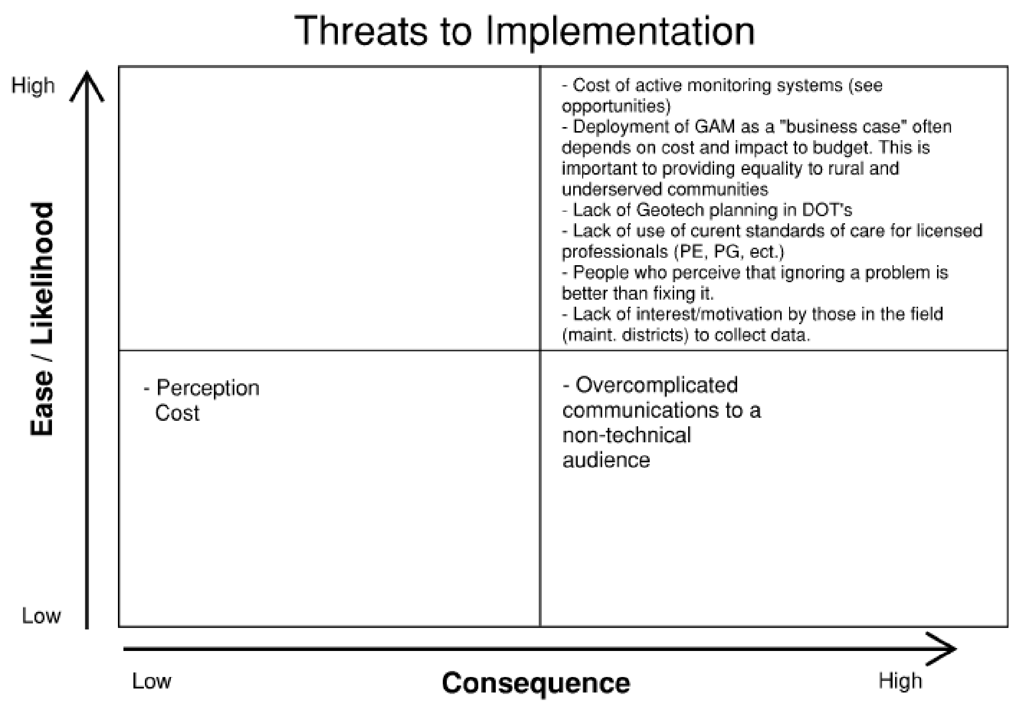


Figure 3. Threats to Implementation – Idea board

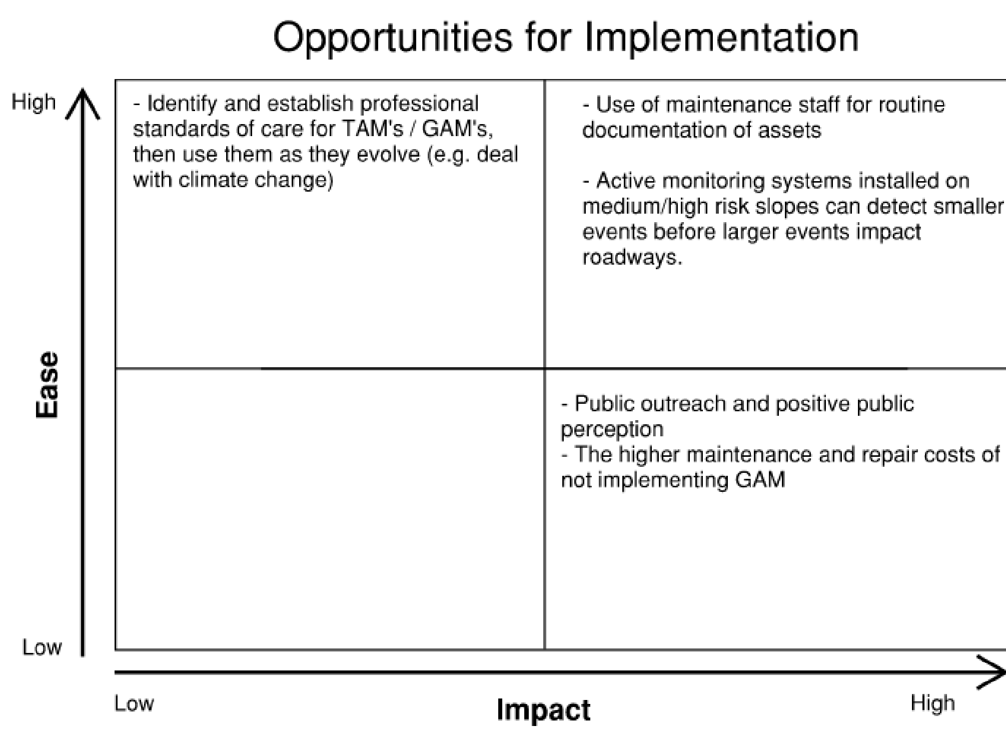


Figure 4. Opportunities for Implementation – Idea board

The group discussed some of the current obstacles to implementing GAM. Mr. Jalbrzikowski of the Ohio Department of Transportation stated that an obstacle within his state is the prevailing perception among higher level managers that GAM is overwhelming. Mr. Jalbrzikowski asserted that as policymakers are exposed to more information, they begin to understand the problems associated with geohazards and gain a level of comfort with GAM. With that perspective comes the recognition that GAM will lead to better asset performance and ultimately enhanced public safety.

Mr. Jalbrzikowski added that we are trying to quantify and gain a better understanding of risk exposure in the face of natural hazards not unlike other natural hazards such as climate change which policymakers are more committed to abating. A key element of GAM is the study and mitigation of risk to infrastructure including pavements, subgrades, and other traditional assets as they relate to geohazards. Mr. Jalbrzikowski made the point that we shouldn't need to fight for a seat at the table when we are trying to characterize geohazard risks to transportation assets.

Mr. Rivers commented that there is some confusion about what an asset is. Another attendee added that built geotechnical assets such as retaining walls are easy to identify and are more readily integrated into existing transportation asset management systems as built features that deteriorate over time. Other assets, such as unstable slopes that aren't as easy to recognize and quantify, could be separated out into a parallel management system.

Mr. Jody Kuhne of NCDOT commented that, to date, NCDOT has not evaluated the costs of a highway or roadway being closed. He noted that most of the conversation has been around the cost of materials and manpower to identify unstable slopes and perform slope repairs rather than the associated costs of responding to slope failures such as road closures. An obvious problem that NCDOT is beginning to quantify is the larger economic impact to the surrounding communities when a geohazard related event closes a primary travel route.

Mr. Jalbrzikowski commented that in order to help policymakers achieve a greater understanding of the situation, inventory and assessment metrics need to be translated into dollar amounts. The return on investment realized by performing proactive maintenance instead of disaster response could then be explained in terms of dollars. A potential conflict with this line of thought is that states are eligible to receive funding from the federal government for disaster relief. Perhaps there are ways to reimagine this current way of procuring funds if more is understood about risk exposure. Mr. Jalbrzikowski added that when prioritizing projects, the condition of an asset should be evaluated as well as the importance to the surrounding communities. For example, a slope in very poor condition on a low traffic corridor may be less of a priority than a slope in poor condition on a more frequently traveled route.

Ms. Jennifer Bauer of Appalachian Landslide Consultants commented that there could be issues associated with owning a slope that has the potential to fail. An intangible benefit of remediating and managing geohazards is the positive impact to public perception. Citizens of underserved communities often tend to feel that state and local governments aren't concerned with public safety in their area. In these situations, she noted, it is important to keep policymakers and the general public informed about the efforts of state agencies and the positive impacts those efforts are having on specific people.

Mr. Clay Elliot of NCDOT added that it can be difficult to fully capture the positive impacts of GAM in terms of dollars. He used as an example a recent incident in western North Carolina where a rock fall blocked access to an elementary school.

Mr. Michael Porter of BGC Engineering added that low frequency events are difficult to evaluate and explain to legislators. As part of public outreach, the notion that geotechnical assets are a primary source of risk should be explained to the public and policymakers.

3.2 Funding and Overlapping Assets of GAM Programs

Mr. Derrick Dasenbrock of FHWA lead the group conversation focused on overlapping assets by asking if anyone had experience with multiple entities each claiming a geotechnical asset as its own.

Mr. Nicholas Farny of FHWA commented that, in his experience, there has been a gray area when hydraulic features such as culverts are associated with debris flows. A contributing factor to the confusion is that the problem is both hydraulic and geologic in nature. Mr. Dasenbrock added that many design elements could be considered geotechnical assets such as wing walls at bridge abutments, approach slabs, roadway ditches, and subgrades. In these situations where assets could be managed by multiple parties, [the GAM specialists] could take the opportunity to leverage partnerships and relationships to achieve project goals.

3.3 Climate Change Impact on Geotechnical Assets and Incorporating Resiliency in Design

Mr. Darren Beckstrand, Engineering Geologist, Landslide Technology, and TRB GAM Section Subcommittee AKG00(1) Co-Chair

Mr. Darren Beckstrand lead the group in a discussion focused on climate change impacts to infrastructure and resiliency.

Mr. Beckstrand began by discussing opportunities for geo-professionals to get involved and increase their visibility by contacting their respective DOT's about GAM when natural hazards impact the infrastructure system. The current trend, he said, seems to be that officials contact geo-professionals after natural hazards impact the infrastructure to ask what could have been done to minimize the damage.

Several participants agreed that when communicating the importance of GAM as it relates to climate change, we should focus on the consequences of not being proactive, such as the potential for escalating maintenance costs associated with corridors more frequently impacted by slope failures and/or sea level rise. Another participant offered that a way to build resiliency into our transportation program is to update design standards to account for some of the changes brought about by climate change such as erosion, increasing sediment loads in debris flows and streams, and seasonal thawing in areas previously characterized by permafrost.

Ms. Jennifer Bauer of Appalachian Landslide Consultants commented that a component of public outreach should be making data about our work available to the public. Efforts to secure funding for GAM could be bolstered by earning the trust and support of the public by being transparent and telling the story about our successes and the financial cost savings realized by managing geotechnical assets.

A few participants discussed the merits of incorporating resiliency into design standards, commenting that we as an industry should also focus our efforts on building infrastructure in ways that achieve longer service life with geohazards in mind. Value engineering (VE) studies are often performed to realize construction cost savings; however, cheaper solutions may not necessarily be optimal when considering the anticipated service life of a design feature.

3.4 Risk Analysis – Management of Resources, and Prioritizing and Assessing Interventions

Mr. Silas Nichols asked members of the group how condition assessments of known geotechnical assets are being conducted. Participants discussed that, in general, personnel with the ideal skillset needed to conduct condition assessments are difficult to find. Within the industry there is a desire for departments of transportation to train consultants in how to conduct assessments.

Mr. Nicholas Farny of FHWA commented that some entities have used interns to collect data into standardized templates such as the Unstable Slope Management Program (USMP). When data was gathered utilizing field personnel with relatively little experience, a more qualified expert would review the data for consistency and accuracy.

The group discussed the opportunity of utilizing maintenance data such as when catchment ditches are cleaned out to identify areas that require more attention. Some states keep records of this information and use it as a guide, while others either do not using the data or not collecting it. The group recognized that geotechnical asset managers should engage with maintenance staff and county managers to gain an understanding of where effort is being expended and what projects should be prioritized.

The discussion concluded with the assertion that to better communicate the condition of geotechnical assets and to make our work more relatable to other asset classes, we should adopt the established lexicon and performance metrics used by professionals who are managing more traditional transportation assets.

4.0 Future of Geotechnical Asset Management

Following a lunch break, the participants resumed the peer exchange with discussions about the future of GAM in four small groups. At the conclusion of the break-out group discussions, representatives from each group reported summaries of the conversations held by their respective groups. A list of seed topics and questions to prompt discussion among participants are included on the GAM Peer Exchange Agenda in Appendix B.

Figure 5. GAM Peer Exchange Participants

4.1 Comparison of GAM Elements to Other TAM Feature Classes

Mr. Jared Crenshaw of Schnabel Engineering presented a summary of the first group's conversation to all participants. The questions addressed by this group during discussion of this seed topic were: *Inventory and beyond (including geohazards); how do we start, where and what do we do - and why? What are the business cases?*

The group generally agreed that establishing and communicating clear and succinct GAM goals to those who would be collecting the data is important for getting started. Asset classes should be made clear, and a common language should be developed so that priorities can be communicated to stakeholders. A few group members had successfully enlisted recent college graduates to collect unstable slope inventory data in the field. Data was reviewed by senior staff to ensure accuracy and uniformity. The recent graduates were mostly graduate-level geology students familiar with geologic features and associated terminology.

Mr. Jared Crenshaw, Project Geologist, Schnabel Engineering

After common goals and communication protocols are established, the easiest way to identify a starting point for inventorying geotechnical assets is to use experience as a guide, and to prioritize areas that have been historically problematic. Implementation should also include requiring contractors to supply as-built plans and geotechnical information on construction projects as part of the project close-out process.

As part of making the business case to stakeholders for implementing GAM, the group agreed that asset owners should develop an understanding of the costs associated with uncontrolled deterioration and the benefits of investing in maintenance. For this reason, discussing the costs in terms of dollars is key to helping others to understand the return on investment of GAM. It was also discussed that a cost-effective approach recently pursued by WSDOT is to employ partial mitigation efforts that effectively reduce the risk without necessarily resulting in a comprehensive fix to completely eliminate risk.

4.2 Toward "Mature GAM Programs" in TAM: Prediction / Planning

Mr. Matt Mullen of NCDOT served as the spokesperson for the group that discussed prediction and planning related to GAM. The seed topics addressed by this group were: *Life cycle costs and project planning, in-service performance assessment, deterioration rates, projecting remaining service life, prioritizing, assessments, interventions (life-cycle extension activities); evolving from "worst first" or "ER' to a more proactive approach.*

Mr. Matt Mullen, Project Geological Engineer, NCDOT

The group discussed that those involved with GAM should understand and agree on what the associated classes of risks are. Furthermore, to facilitate prediction and planning, collectors and users of data need to agree on a common lexicon and reporting features to ensure that information is understandable and relatable. The group generally agreed that emerging technologies should be embraced if they can be utilized to manage costs and increase the usefulness of collecting data in the field.

Mr. Mullen offered his observation that stakeholders and geotechnical asset managers often use the term reactionary in a negative context. Leaders, he said, should understand that there will be a continuing need to respond to geohazard related events. A part of the planning process should be to ensure that adequate resources are available to react when infrastructure is impacted by geohazard related events.

In closing, Mr. Mullen remarked that assets should be rated in terms of their potential impacts to public safety, mobility, maintenance, and strength. Some members of the group opined that strength is inherent in the first three metrics. Mr. Mullen emphasized that stakeholders should prioritize projects by performing a cost-benefit analysis, and should also consider safety, mobility, maintenance, and infrastructure strength to capture the elements which may not be easily expressed in terms of dollars.

4.3 What Are the Missing Pieces (Other Than Money)

Ms. Jennifer Bauer of Appalachian Landslide Consultants provided a summary of the discussion focused on what is missing from GAM programs. Seed topics and questions for this break-out discussion were: *Pavement and Bridges are not the only TAM elements – how do we learn from our peers who inventory wetlands, sign-posts, guardrail, and other assets? Are there specific tools that would be helpful? Guidance documents? Organizational leads?*

Ms. Jennifer Bauer, Principal Geologist, Appalachian Landslide Consultants

Group members considered data-driven communication among asset managers, field personnel, and designers to be critical to program success and an element that is potentially missing from current efforts. They also discussed that geotechnical asset managers need to find ways to separate the escalation of risk associated with uncontrolled deterioration from the potential impacts of climate change and other disaster event scenarios.

Another element that appears to be missing is the involvement, education, and incentivization of maintenance staff who are in an excellent position to collect valuable data in the field. It would be helpful to educate these maintenance staff to better understand the GAM process and that the GAM information they collect will help manage geotechnical assets more effectively. Future efforts to bridge the gap between GAM specialists and maintenance personnel should include getting input from maintenance staff regarding problems they are finding in the field and what should be done to remedy them. Once information is obtained it must be integrated into the GAM inventory data set in a way that makes it easy to communicate and relate to other similar data.

As GAM best practices are advanced, taking advantage of emerging technology will be an important part of program development. Examples of newer observation and data collection technologies include Light Detection and Ranging (LIDAR), Interferometric Synthetic Aperture Radar (InSAR), 360-degree photographs of sites post-construction or during bridge inspection, and continuously reporting digital instrumentation. Another participant added that data management will be an increasingly important task as information comes from all of the different sources mentioned above.

4.4 Leveraging Resources and Interest Areas

Mr. Jody Kuhne of NCDOT presented notes from the group conversation focused on leveraging existing resources and relationships with others who share common interests. Seed topic for discussion by this breakout group was: *The benefits of building GAM into TAM through climate change, sustainability, equity, resilience, and other "funded" initiatives.*

Mr. Jody Kuhne, Regional Geological Engineer, NCDOT

Group members discussed the need for geotechnical asset managers to reach out to stakeholders to let them know that they are interested in working together. Some stakeholders currently assume that geotechnical asset managers are focused on fixing problems rather than building a resilient infrastructure system. In order to advance GAM, geotechnical professionals should help other transportation asset managers understand the benefits of GAM so that an overall plan which includes GAM can be established for the enhancement of overall infrastructure resiliency.

The group noted that in some states, existing resiliency programs are more focused on coastal issues where sea-level rise impacts communities and increasingly frequent storm events can inflict catastrophic damage to multiple communities at once. Many geotechnical asset managers are currently more focused on problems that tend to present themselves in mountainous regions, such as unstable slopes. Despite the varied nature of the problems we face, some of the tools such as the algorithms we use to rate and prioritize slopes could be shared. Developing a partnership by soliciting input as we're designing our management systems can help to solidify the bond between geotechnical asset managers and others who are involved in more traditional resiliency efforts.

As part of a follow-up conversation other participants added that the information collected on maintenance truck GPS systems, quantities such as the number of loads of material hauled away from a slope, maintenance activity logs, and other information we may have access to is a potential resource that needs to be mined.

5.0 Closing Remarks

Mr. Derrick Dasenbrock of FHWA led a closing discussion focused around the future of GAM and asked how participants visualize their successes over the coming decades. Several representatives from state DOTs envisioned the expansion and development of their GAM programs, particularly leveraging the enhanced information and insight available through advances in technology.

Mr. Silas Nichols remarked that he was encouraged by the creativity of the people in the room. As we move forward in implementing GAM, he said, it will be critical to our success to establish a common language with which to communicate the state of our assets as well as improving communication between those implementing GAM and those already enacting TAM for more established asset classes. He emphasized also that we should communicate with other asset management groups and data owners to seek out and gain access to any information that might help us better evaluate performance and thereby enhance our decision-making processes.

Mr. Nichols thanked the facilitators and all that were in attendance. He encouraged those that are working on GAM to get in touch if there are ways that the FHWA Resource Center can provide assistance.

Appendix A: GAMPE Attendee List

First Name	Last Name	Company Name
Mounir	Abouzakhm	Federal Highway Administration Eastern Federal Lands Highway Division
Kathryn	Aguilar	Bentley Systems
Scott	Anderson	BGC Engineering, Inc.
Catherine	Armstrong	GDOT
Maria	Arroyo	Puerto Rico Highway Authority
James	Arthurs	Federal Highway Administration
Brian	Banks	Schnabel Engineering
Jennifer	Bauer	Appalachian Landslide Consultants, PLLC
Darren	Beckstrand	Landslide Technology
Gordon	Box	NCDOT
David	Carpenter	Schnabel Engineering
Jared	Crenshaw	Schnabel Engineering
Derrick	Dasenbrock	FHWA
Jake	Davidson	IDS GeoRadar
George	Dunfield	Self
Christopher	Eddy	Haley & Aldrich
Clayton	Elliott	North Carolina Dept. of Transportation
Nicholas	Farny	Federal Highway Administration
Marc	Fish	WSDOT
Gavin	Gautreau	Louisiana Transportation Research Center (LTRC)
Orion	George	Federal Highway Administration
Jonathan	Herrera-Roldan	Federal Highway Administration Eastern Federal Lands Highway Division
Andrew	Jalbrzikowski	Ohio Department of Transportation - Office of Geotechnical Engineering
Karen	Kalbaugh	MD DOT SHA
David L	Knott	DiGioiaGray
Melissa	Landon	WSP Golder
Katherine	Marciniak	NCDOT- REU
Colin	Mellor	NCDOT
Silas	Nichols	FHWA
Yesenia	Perez Soto	Federal Highway Administration Eastern Federal Lands Highway Division
John	Pilipchuk	NCDOT
Michael	Porter	BGC ENGINEERING INC
Ben	Rivers	FHWA
Ricardo	Romero	Puerto Rico Highway Authority
Zac	Sala	BGC Engineering
Vernon	Schaefer	Iowa State University
R. Tyler	Smith	ECS Southeast, LLP
David	Staab	Wisconsin Department of Transportation
Cody	Stopka	GeoStabilization International
Matthew	Tello	Colorado Department of Transportation
Aamir	Turk	Indiana Department of Transportation
Mark	Vessely	BGC Engineering
Nancy	Whiting	National Academies, Transportation Research Board

Appendix B: GAM Peer Exchange Agenda

Start	End	Duration	Moderator	Theme	Geotechnical Asset Management State DOT Peer Exchange @ HGS in Asheville, NC (Thursday, May 26, 2022)
8:00	10:30	2:30	Nichols, Anderson	Shared Objectives	**Introductions/Lightining Round expectations and goals of the peer exchange** *The goal of this peer exchange is to increase awareness and knowledge of current GAM practices of participants through real-world examples and lessons learned.* - 5 min lighting presentations by IN, MN, WA, OH, LA, CO, and WI - Open forum for others to discuss their experiences
10:30	10:45	0:15		Networking	Break
10:45	11:50	1:05	Rivers, Dasenbrock, Anderson, Beckstrand	Group Session: Lessons from the Past	**Breakout Session Seed Topic A1: Deployment of GAM and incorporation into Transportation Asset Management – evaluating life cycle costs, deterioration rates, ….** What is the "business case" for GAM in TAM? What are the costs of not doing GAM? Why are States doing or not-doing GAM in TAM today? **Breakout Session Seed Topic A2: Funding and overlapping assets of GAM program. Discussion on managing the GAM program, funding projects, as well as opportunities to colloborate with other asset classes.** *What geotechnical feature would be of the greatest value to put into GAM/TAM first?* *Are there oppportunities to leverage efforts for other asset classes?* *What resources (people/budget) do you imagine that a GAM program would require?* **Breakout Session Seed Topic A3: Climate change impact on geotechnical assets and examples incorporating resiliency in design** *How to increase awareness of climate change impact on geotechnical features?* *How does managing assets impact resiliency?* *What are costs of not considering climate change?* **Breakout Session Seed Topic A4: Risk analysis – Management of resources, prioritizing interventions, assessment of interventions.** *Do we start with an Inventory and later move to a performance evaluation framework- or should these be done concurrently?* *How do you foresee geotechnical condition assessments being conducted?* *What resources (people/budget) do you imagine that a GAM program would require?* *How are interventions prioritized?*
11:50	12:00	0:10	Rivers	Listening and Amplifying	Closing Discussion from AM Group Discussion on Topics A1-A4
12:00	13:00	1:00		Eating	Lunch
13:00	13:15	0:15	Dasenbrock	Summary	Synopsis: The Past and the Present

Start	End	Duration	Moderator	Theme	Breakout Group 1	Breakout Group 2	Breakout Group 3	Breakout Group 4
13:15	14:15	1:00	Beckstrand Dasenbrock Rivers Anderson	4 Breakout Sessions: Planning for the Future	**Breakout Session Seed Topic B1: Comparison of GAM elements to other TAM feature classes:** *Inventory and beyond (including geohazards); how do we start, where do we do, what do we do- and why? What are the business cases?*	**Breakout Session Seed Topic B2: Toward "mature GAM programs" in TAM: Prediction/planning:** *Life cycle costs and project planning, in-service performance assessment, deterioration rates, projecting remaining service life, prioritizing, assessments, interventions (life-cycle extension activates); evolving from "worst first" or "ER" to a more proactive approach*	**Breakout Session Seed Topic B3: What are the missing pieces (other than money)?** *Pavement and Bridges are not the only TAM elements- how do we learn from our peers who inventory wetlands, sign-posts, guardrail, and other assets? Are there specific tools that would be helpful? Guidance documents? Organizational leads?*	**Breakout Session Seed Topic B4: Leveraging Resources and Interest Areas:** *The Benefits of Building GAM into TAM through Climate Change, Sustainability, Equity, Resilience, and other "funded" initiatives.*
14:15	14:30	0:15		Networking	Break			
14:30	15:30	1:00	Rivers	Listening and Amplifying	Report outs to the full group and discussion : B1-B4			
15:30	15:45	0:15	Dasenbrock	Summary	A forecast of a retrospective look from our participants in the future at the future: 10, 25, 66 years			
15:45	16:00	0:15	Nichols	Moving Forward	Summary of peer exchange - take aways, action items; Session adjournment			

Thanks to HGS and the steering committee for help in planning the peer exchange event. Addiitonal thanks to supporting and contributing partners:
TRB- GAM(0) GAM Subcommittee, AKG60 Geotechnical Instrumentation and Modeling Committee, ASCE-GI INN-C Innovation Committee

Appendix C: Indiana Department of Transportation - Slide Presentation

INDOT GEOTECHNICAL ASSET MANAGEMENT

Aamir Turk, M.S., P.E.
Geotechnical In-House Design & Asset Manager
Geotechnical Engineering Division
Indiana Department of Transportation

HGS 2022, Asheville, North Carolina
May 26, 2022

NextLevel INDIANA

Background

- INDOT asset management programs
- Active programs

  * Bridges

  * Drainage Structures

  * Traffic signs

  * Pavements
- New Programs

  * Geotechnical (Prioritized Retaining Walls + Landslides)

NextLevel INDIANA

Retaining Wall Asset Program

- Developed INDOT Inspection Manual for Retaining walls
- Using ArcGIS, ESRI application to input data (Developed in-house)
- Collected Inventory & Recorded Condition ratings (Through Consultants)
- Monitoring Program → Interface to Phase II

NextLevel INDIANA

Retaining Wall Asset Program

Considerations

- Structures that are visible above ground (> 5 ft)
- Priority
  - * State owned structures
- Finding retaining walls through Google Maps
- Searching one route at a time

Inventory challenges

- Many dated structures without any records
- Design Data available only for last 10-15 years
- Many structures and their locations was unknown
- Remaining asset life of such structures is unknown
- Physically searching undocumented structures

xtLevel
ANA

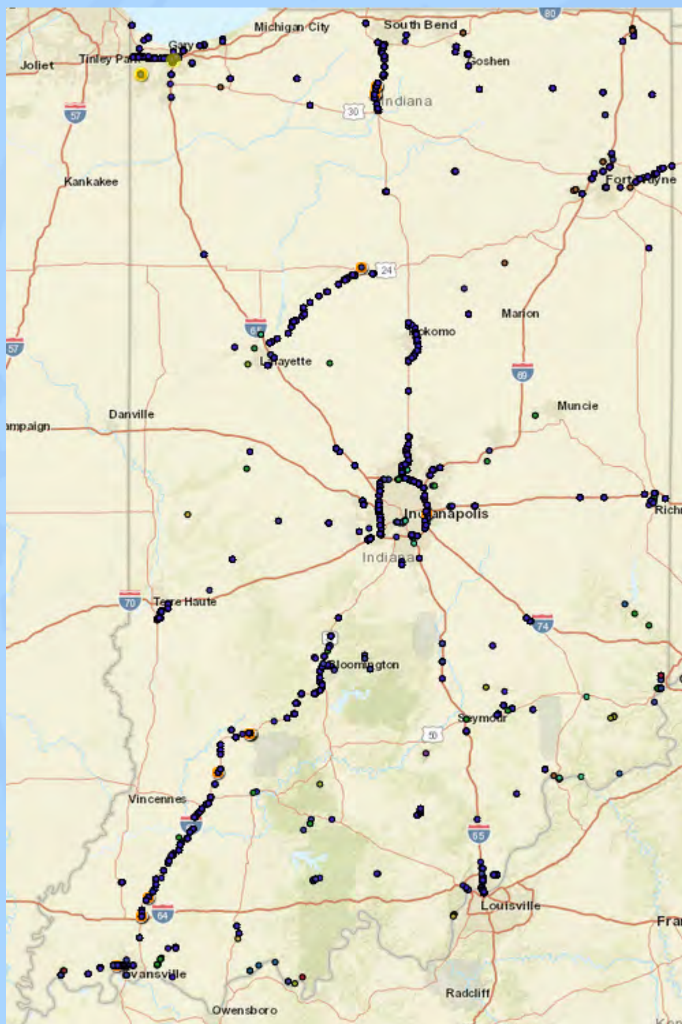
Retaining Wall Asset Program

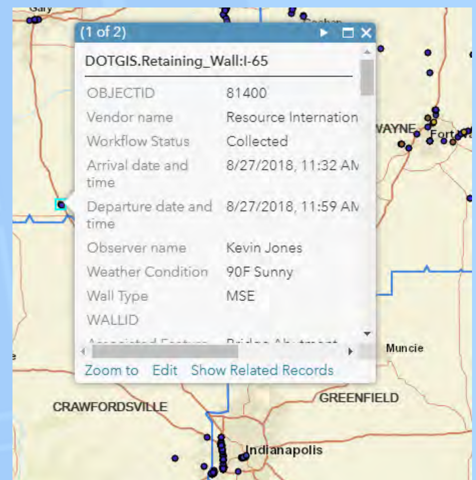
Fields for data input in app

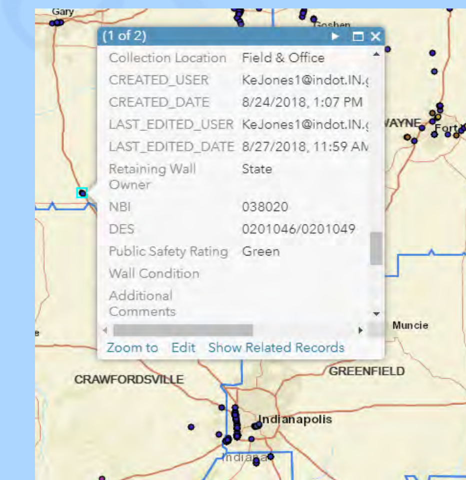
- Vendor name: CTL / RII / WSP
- Arrival date & time: 4/25/2018, 11:17 AM
- Departure date & time: 4/25/2018, 11:17 AM
- Observer name: xyz
- Weather Condition: Sunny 62°F
- Wall Type: MSE
- Associated Feature: Bridge abutment
- Incenteroid facing direction: West
- Wall Facing Type: Precast concrete panel
- Panel height: 5 ft
- Panel width: 10 ft
- Wall design method: LRFD
- Latitude: 41.06792471
- Longitude: -85.01113566
- Altitude: 235.2605231
- Wall height: 22ft
- NBI: 000000
- Des: 1234567
- Public Safety Rating: Green

NextLevel INDIANA

Retaining Wall Asset Program







Legend

- Masonry
- RC Cantilever
- RC Counterfort
- Pre-stressed Concrete
- Cantilever Sheet Pile
- Anchored Bulkhead
- Diaphragm
- Bored Pile
- Soldier Pile
- Reinforced Earth
- MSE
- Timber
- Bin
- Wire

NextLevel INDIANA

Retaining Wall Asset Program

Retaining wall defects

- Abrasion/ wear (concrete)
- Freeze-thaw damage
- Masonry displacement
- Mortar breakdown
- Patched area masonry
- Rust stains
- Split/ spall masonry
- Settlement

- Backfill Leakage
- Damage
- Delamination/ Spall
- Erosion
- Exposed rebar/ fabric
- Efflorescence
- Graffiti
- Vegetation

- Bulging
- Corrosion
- Cracking
- Connection
- Distortion
- Horizontal rotation
- Separation
- Vertical rotation

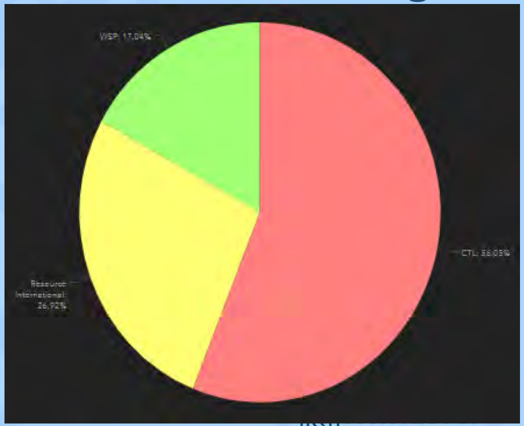
NextLevel INDIANA

Retaining Wall Asset Program

Wall Rating Codes

- Code 9- Excellent (Recently installed or recently repaired)
- Code 7- Good (No repairs needed, next inspection to be examined)
- Code 5- Fair (Significant defects, frequent inspections)
- Code 3- Poor (Structural issues, repair by qualified contractor)
- Code 1- Critical (Failing or failed, major mitigation or replacement)

Condition rating



Percentage of walls with condition rating

Public Safety Rating Codes

- Green flag- No danger of failure
- Orange flag- Repairs needed
- Yellow flag- Public safety issue, closure of lane/ traffic
- Red flag- Roads relying on wall for support are closed

Landslide Asset Program

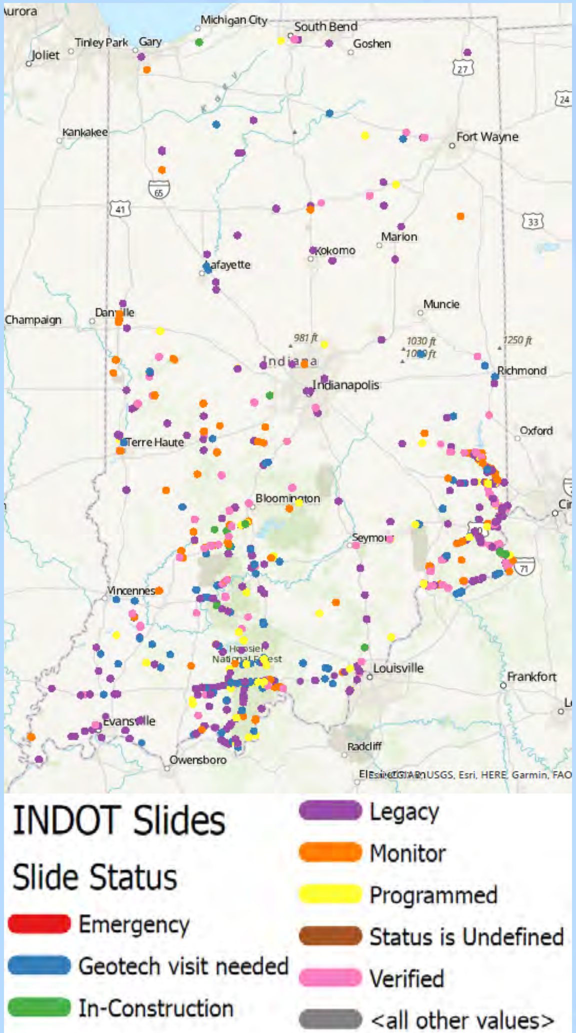
- Pilot program to collect landslides Inventory
- Route Assessment for potential landslides
- Hired consultants with landslide experience
- Currently, slope assessment along the routes are in progress

Five routes selected for assessment

Route	From	To	Miles
SR 262	US 50	SR 56	15.3
SR 1	US 50	I 74	15.3
SR 156	SR 250	SR 262	11
US 52	SR 101	SR 46	13.7
SR 62	SR 145	SR 66	14.5

NextLevel INDIANA

Landslide Asset Program



- Customized INDOT Template for Landslide Inventory Program
- Using ArcGIS, ESRI application to input data
- Condition ratings of landslides developed
- Transition to Phase II as a programming tool

Criteria for Landslide Inventory

- Landslide length
- Affected slope height
- Pavement affected length
- Pavement affected width
- Pavement lateral displacement
- Pavement vertical displacement
- Potential for additional slope failure

NextLevel INDIANA

Summary

Inventory:

State-Owned walls	2623
Statewide landslides	908

Asset Management:

Program walls repair for next 5 years using Open End Contracts statewide

Program slide corrections for next 5 years using Open End Contracts Statewide and project specific contracts

Annual Budget:

For wall repairs	$8 -10 millions
For Slide repairs	$20 -25 millions

NextLevel INDIANA

Future Plans

- Utilize new technology to assess potential slope problems ahead of time and program them accordingly
- Develop GAM for invisible foundations using more geophysical applications

- Considerations for Phase II
- Effective tool for planning
- Monitoring asset performance
- Risk Assessment
- Life cycle cost analysis
- Update inventory and condition assessments
- Program as a project
- Cost estimates for mitigation/ replacement

Appendix D: Minnesota Department of Transportation - Slide Presentation

DEPARTMENT OF TRANSPORTATION

Geotechnical Asset Update Minnesota

FHWA Peer Exchange
May 26, 2022

John Siekmeier P.E. M.ASCE
MnDOT Advanced Materials and Technology
Maplewood, Minnesota

Opportunity to Address National Priorities

MAP-21, FAST and INVEST are federal laws and bills that require transportation investments to be based on performance based measured outcomes.

- Moving Ahead for Progress in the 21st Century (2012)
- Fixing America's Surface Transportation (2015)
- INVEST in America (2021)
- Performance Based Professional Standards

  Federal Highway Administration

  American Association of State Highway Transportation Officials

  American Society of Civil Engineers

Code of Federal Regulations

A state asset management plan includes:

1. Summary of assets on NHS including condition;
2. Asset management objectives and measures;
3. Performance gap identification;
4. Lifecycle cost and risk management analysis;
5. Financial plan; and
6. Investment strategies.

23 U.S.C. 119(e)(4), MAP-21 § 1106

Opportunity to Address State Priorities

2021 Minnesota Statutes, 174.03, Subdivision 12

Trunk highway performance, resiliency, and sustainability.
(a) The commissioner must implement performance measures and annual targets for the trunk highway system in order to construct resilient infrastructure, enhance the project selection for all transportation modes, improve economic security, and achieve the state transportation goals established in section 174.01.
(b) At a minimum, the transportation planning process must include:
(1) an inventory of transportation assets, including but not limited to bridge, pavement, geotechnical, pedestrian, bicycle, and transit asset categories.

Geotechnical Asset Management Required

MnDOT Geotechnical Asset Website:
www.dot.state.mn.us/gisspec/methods/geotechnical.html

Grading and Base Manual, MnDOT, 2021

Other states and governmental agencies also include:

- Embankments and slopes
- Pavement subgrade, subbase, and base
- Stabilized full depth reclamation
- Edge drains and subcut drains
- Aggregate and quarry sites
- Geosynthetics, cement, and lime treated subgrade
- Storm water ponds

Geotechnical Asset Management, NCHRP, 2019

Geotechnical Asset Measures and Targets

Lag (resulting), and where practicable lead (predictive), performance measures, and annual targets that are:

- statewide and district-specific;
- for assets in each asset category specified in clause (1) for a period of up to 60 years; and
- identified in collaboration with the public;

Gap identification and an explanation of the difference between performance targets and current status.

Life cycle assessment and corridor risk assessment as part of asset management programs in each district of the department.

Geotechnical Asset Investment Plan

At a minimum, the ten-year capital highway investment plan in each district of the department must:

(1) be based on expected funding during the plan period;

(2) identify investments within each of the asset categories specified in paragraph (b), clause (1);

(3) recommend specific trunk highway segments to be removed from the trunk highway system; and

(4) deliver annual progress toward achieving the state transportation goals established in section 174.01.

Appendix E: Washington Department of Transportation - Slide Presentation

WSDOT's GAM Efforts

2022 Peer Exchange

Roger Millar, Secretary of Transportation

Amy Scarton, Deputy Secretary of Transportation

May 26, 2022

Prior to GAM at WSDOT

- WSDOT has had an Unstable Slopes Management System for almost 30 years
  - Landslides, rockfall, debris flows, and settlement
  - Dedicated funding to operate the program
  - Dedicated funding to mitigate unstable slopes
    - Not a worst case first scenario
    - Minimum programming criteria
    - Benefit cost analysis
    - Prioritize mitigation

GAM at WSDOT

- In 2019, WSDOT moved towards a GAMP
  - Not yet included in the TAMP and not reported upon

WSDOT Geotechnical Asset Management Plan

Chapter	Content
Chapter 1 – Introduction	Provides an overview of WSDOT's asset management framework, alignment with Practical Solutions, and overview of the TAMP content.
Chapter 2 – Objectives and Measures	Communicates asset management objectives, performance measures, and targets as well as a history of how WSDOT has measured geotechnical asset condition.
Chapter 3 – Inventory and Condition	Details total inventory, age, and condition of Geotechnical Assets.
Chapter 4 – Lifecycle Planning	Explains WSDOT's current geotechnical asset specific investment strategies to maximize asset life and condition at the lowest practicable cost.
Chapter 5 – Risk Management	Details WSDOT's risk framework, existing risk management practices, and recently conducted risk workshops.
Chapter 6 – Revenue and Financials	Summarizes WSDOT's financial sources and uses and aligns planned expenditures to Geotechnical Asset needs. Also provides an estimated replacement value for Geotechnical Assets.
Chapter 7 – Performance Scenarios	Discusses differences between target-based performance gaps and plan-based performance gaps. Also highlights WSDOT's efforts to develop a cross-asset resource allocation framework.
Chapter 8 – Investment Strategies	Aligns geotechnical asset specific investment strategies to various WSDOT plans and communicates how Geotechnical Asset Management informs our capital plans.
Chapter 9 – Implementation and Systems	Discusses various Geotechnical Asset Management efforts undertaken by WSDOT and work currently underway to enhance WSDOT's Geotechnical Asset Management practices. Also details systems used in support of Geotechnical Asset Management and future enhancements of those systems.

WSDOT new GAMP

GAMP

- Routine slope inspections, which look for change
  - Forms, photographs, and sometimes more advanced change analysis
- Incorporate slope maintenance activities
  - Fixing damaged fences and netting
- Still prioritize, but also risk-based programming

Issues

- Varied geology and climate
  - Determining slope degradation rates
  - Where is a slopes LLCC
- When do you reduce risk vs. fully mitigate slopes
- What's more important
  - Reduce risk
  - Fully mitigate slopes
  - Fix damaged fences and netting

Questions?

Appendix F: Ohio Department of Transportation - Slide Presentation

GEOTECHNICAL ASSET MGT. PEER EXCHANGE
MAY 26,2022

OHIO DEPARTMENT OF TRANSPORTATION

ODOT'S GAM BEGINNING

- Our GAM began with a liability
- 1995 Mine Collapse Closes IR70
- 1998 – Abandoned Underground Mine Inventory and Risk Assessment (AUMIRA)
- 2002-2004
    - Catalog and digital scan Ohio Department of Natural Resources mine maps
    - Create an AUM database
    - Build a GIS application for georeferencing
- Initial AUM Inventory
    - Began field inspections April 6, 2004
    - July 2008 initial AUM inventory and risk assessment complete

BUILDING THE SYSTEM

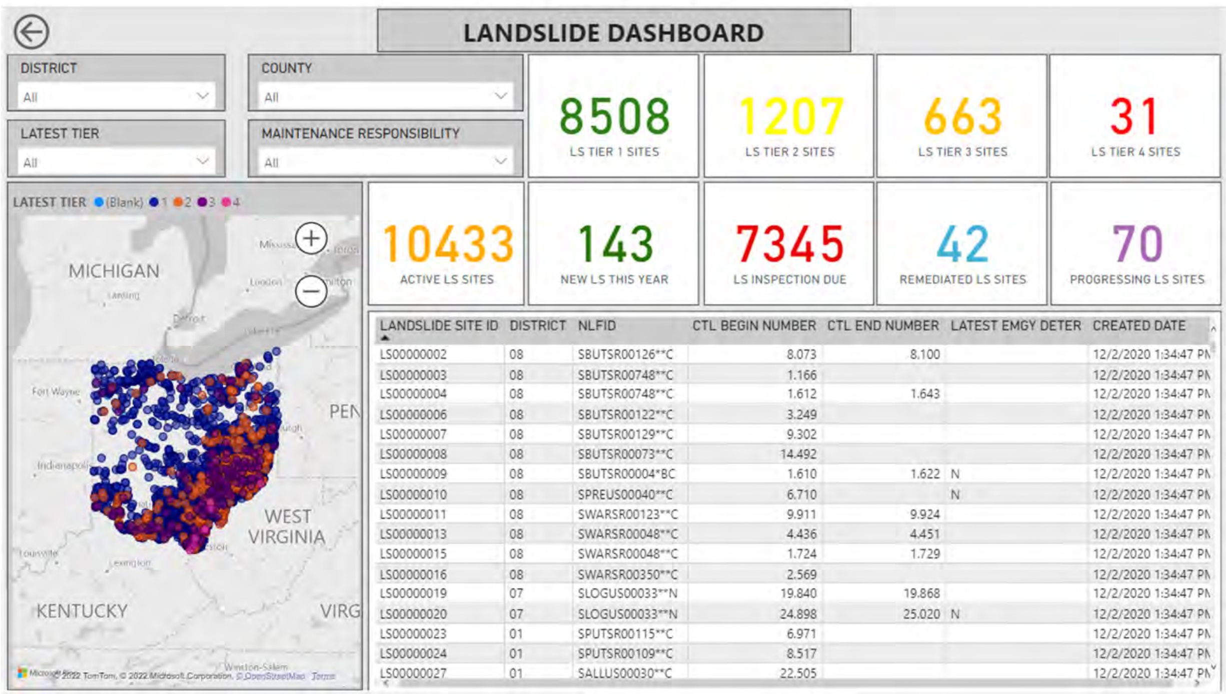
- Geotechnical Data Management System(GDMS)
  - Document Management System
  - Lab Information Management System (LIMS)
  - Geohazard Management System (GHMS)
- 2007-2019 GHMS (Inventory and Risk Assessment)
  - AUMIRA
  - Landslides
  - Rock Slopes (Rockfall)
- Created via Statewide Planning Research (SPR) Inventory via SPR funded consultant contracts
- Very little internal assistance

GEOHAZARD INVENTORY DETAILS

- State Highway System only
- All geohazards receive a Tiered Rating based on site characteristics
- 4 Tiers (higher the Tier = higher risk)
- Inspection frequency is based on Tier. Higher the Tier the more frequent the inspection.
- Detailed rating scores established for Tier 2, 3, & 4 sites (Tier 1 is non-rated)
- For Rock slopes and Landslides, Tier rating based on:
  - Likelihood of continued movement or rockfall
  - Likelihood road will be affected
- After a site is repaired - it is re-inspected to verify effectiveness
- Repaired sites are not retired; still need to periodically monitor for recurrence

GEOHAZARD INVENTORY DETAILS

- Data collection moved to ESRI Collector for ArcGIS in FY21, became Field Maps in FY22.
- Significant internal assistance to add Power BI reporting.
- Data is used by district for Geologic Site Management project funding



LANDSLIDE SITE ID	DISTRICT	NLFID	CTL BEGIN NUMBER	CTL END NUMBER	LATEST EMGY DETER	CREATED DATE
LS00000002	08	SBUTSR00126**C	8.073	8.100		12/2/2020 1:34:47 PM
LS00000003	08	SBUTSR00748**C	1.166			12/2/2020 1:34:47 PM
LS00000004	08	SBUTSR00748**C	1.612	1.643		12/2/2020 1:34:47 PM
LS00000006	08	SBUTSR00122**C	3.249			12/2/2020 1:34:47 PM
LS00000007	08	SBUTSR00129**C	9.302			12/2/2020 1:34:47 PM
LS00000008	08	SBUTSR00073**C	14.492			12/2/2020 1:34:47 PM
LS00000009	08	SBUTSR00004*BC	1.610	1.622	N	12/2/2020 1:34:47 PM
LS00000010	08	SPREUS00040**C	6.710		N	12/2/2020 1:34:47 PM
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LS00000013	08	SWARSR00048**C	4.436	4.451		12/2/2020 1:34:47 PM
LS00000015	08	SWARSR00048**C	1.724	1.729		12/2/2020 1:34:47 PM
LS00000016	08	SWARSR00350**C	2.569			12/2/2020 1:34:47 PM
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LS00000020	07	SLOGUS00033**N	24.898	25.020	N	12/2/2020 1:34:47 PM
LS00000023	01	SPUTSR00115**C	6.971			12/2/2020 1:34:47 PM
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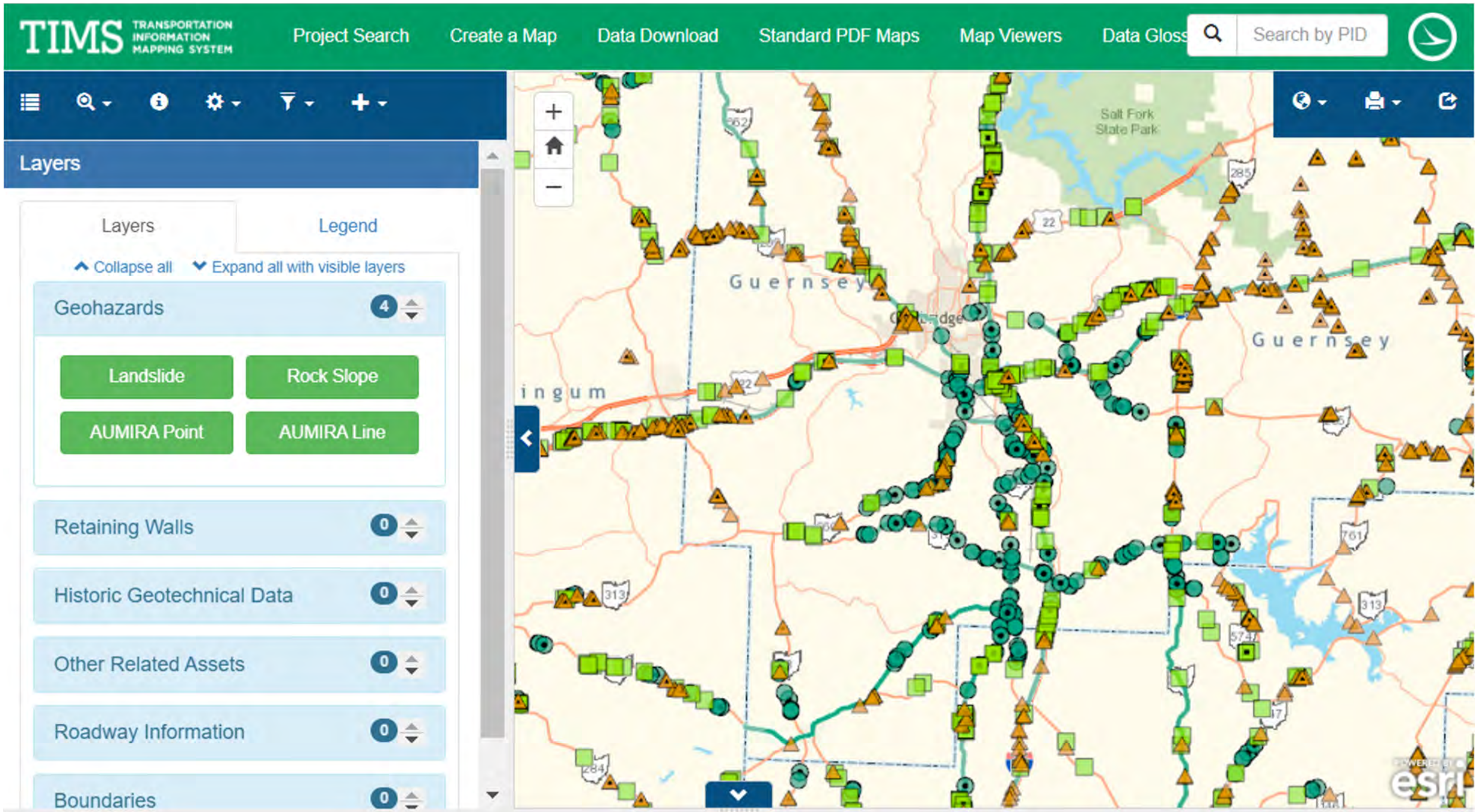
Ohio Department of Transportation

GAM OVERVIEW - TIMS



Ohio Department of Transportation

Appendix G: Louisiana Transportation Research Center - Slide Presentation

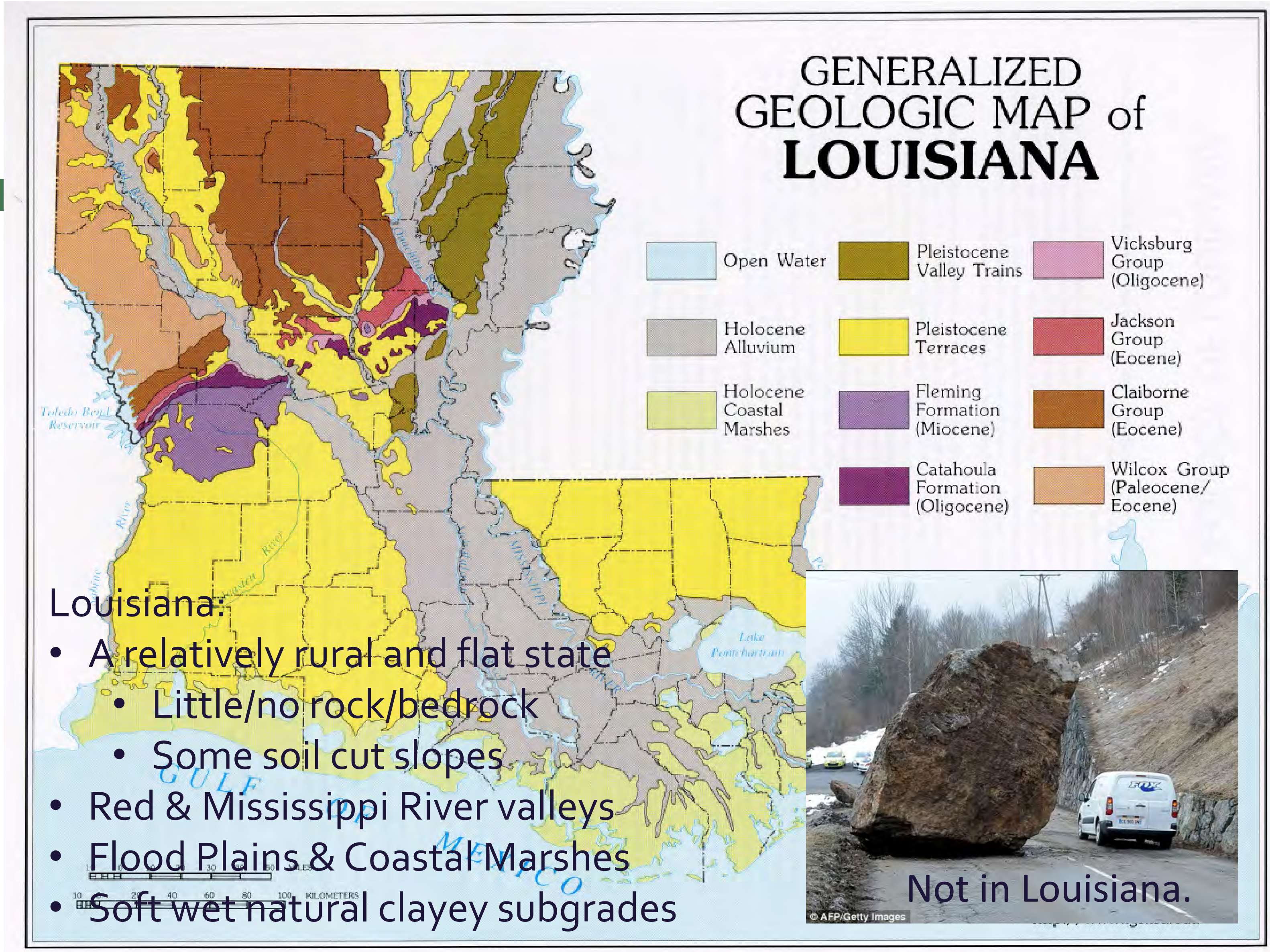
Highway Geology Symposium
Asheville, NC May 2022

Geotechnical Asset Management (GAM) for Louisiana

FHWA Peer Exchange
May 26, 2022

Gavin P. Gautreau, P.E., M.ASCE
LTRC Geotechnical Research Engineer
Louisiana Transportation Research Center (LTRC)

LTRC is Sponsored Jointly by the Louisiana Department of Transportation and Development (DOTD) and Louisiana State University (LSU)



Louisiana:

- A relatively rural and flat state
  - Little/no rock/bedrock
  - Some soil cut slopes
- Red & Mississippi River valleys
- Flood Plains & Coastal Marshes
- Soft wet natural clayey subgrades

Not in Louisiana.

Introduction/Objectives

- Why do the research?
  - Geotechnical Assets (Retaining Walls, Slopes, Culverts, etc.)
    - Research Problem Identification Committee – Priority.
    - Need to Inventory: How many, where, construction type, age, etc.?
    - Often overlooked after construction
      - …until emergency repairs are needed.

- What problem are we trying to solve?
  - The need for Geotechnical Asset Management.
    - Like Bridge Maintenance and Pavement Management. Performing (or not)?
    - Aging infrastructure with known/unknown design lives (start/end).
    - Condition and Consequences of Failure Assessments to … Manage Risks

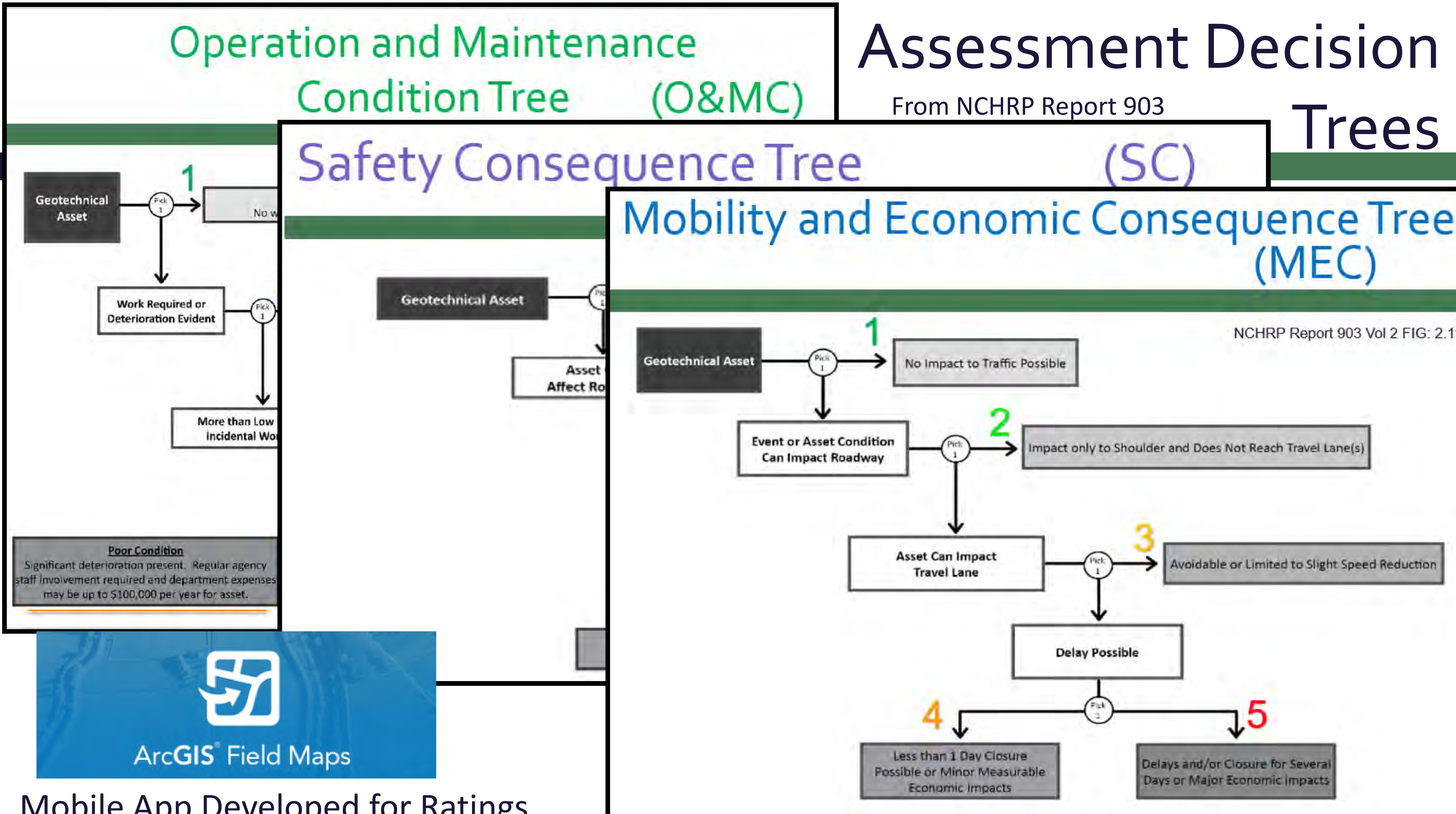
LOUISIANA TRANSPORTATION RESEARCH CENTER LTRC

Methodology - Inventory

- Google Earth & Maps
  - Fly-over scans of Major Hwys
  - Street and 3D views
    - Wall start/stop, types, facing
    - Quick and Safe info
      - From Office vs. Field Trips
- Drawn in ArcGIS/ ArcMap
- Segment breaks
  - Location, Purpose, Facing
  - Linear Referencing -LRS ID
  - Segments ➔ Continuous Walls

Assessment Decision Trees

From NCHRP Report 903



ArcGIS® Field Maps

Mobile App Developed for Ratings

GAM Planner Model - Risk Analysis

NCHRP Report 903

Assessments:

Operation & Maintenance Condition (O&MC) 1 2 3 4 5

Safety Consequence (SC) 1 2 3 4 5

Mobility/Economic Consequence (MEC) 1 2 3 4 5

Safety Risk Score = SC * O&MC

+ Mobility/Economic Risk Score = MEC * O&MC

GAM LEVEL OF RISK

A = <10	A - less than $1,000 annual asset risk exposure
B = 10 - 20	B - $1,000 to $5,000 annual asset risk exposure
C = 20 - 30	C - $5,000 to $50,000 annual asset risk exposure
D = 30 - 40	D - $50,000 to $100,000 annual asset risk exposure
F = 40 - 50	F- Greater than $100,000 annual asset risk exposure

By assessing and sorting the entire list of assets, we can determine repair priorities, treatments, and plan for necessary and future funding.

Walls in Shreveport, LA

Conclusions - Geotechnical Asset Management (GAM)

- GAM development and implementation:
  - will provide DOTD a logical, proactive, method to manage geotechnical assets.
  - will guide future decisions regarding condition, performance, repairs, and the consequences of risk.
- LTRC developed a GAM GIS database – Retaining Walls as Pilot Dataset
  - Provides geospatial locations, digital storage, and visual interfaces for retaining walls data.
  - Wall Inventory efforts utilized safe, efficient, and effective aerial photography, digital images, and GIS.
  - Continue to collect wall and other asset types. Possibly use LIDAR to inventory slopes.
- LTRC developed a mobile FieldMaps® application
  - Eases and speeds condition and consequence assessment data into the ArcMap GIS Database.
  - Other geotechnical assets (slopes/culverts/etc.) exist and can utilize this template as a guide.
- District asset information collection priorities:
  - GAM depends upon District Staff's insight and knowledge to characterize assets for risk calculations, and the full implementation of GAM. Operations & Maintenance to delegate assessments to Districts.

Thanks!

Recommendations – Geotechnical Asset Management (GAM)

- Coordinate Bridge / Geotechnical/ Operation and Maintenance/District Communications
  - Add Subcontractor wall designs and details (As-builts) to DOTD Digital Files – Link to Database.
  - Manage geotechnical assets like Bridge Maintenance, and Pavement Management.
- Continue to Inventory Assets (350+ wall segments so far)…building GIS database.
  - GIS location, Age, ADT, Project #s, Wall type, Verify with Districts (edits, missing, new, etc.)
  - Slopes, Culverts, Other Assets, Hazards (salt domes, etc.). Link to Geotechnical Database GIS.
- Conduct Assessments with District forces – Field Maps Application
  - Operation & Maintenance Condition / Safety Consequences / Mobility & Economic Consequences… (1-5)
- Calculate Risk Scores (A to F); Review Treatments (Checklists & Inspection Frequency)
- Utilize the GAM tools from this research as part of the GAM implementation:
  - **GIS database**
  - **Field Maps app**
  - **GAM guide**

… to manage these assets, plan for repair priorities, and allocate necessary staff & funding.

Thanks!

Appendix H: Colorado Department of Transportation - Slide Presentation

COLORADO
Department of Transportation

Efforts to Quantify the Benefits of Implementing Resilience Measures for Geologic Hazards in Colorado

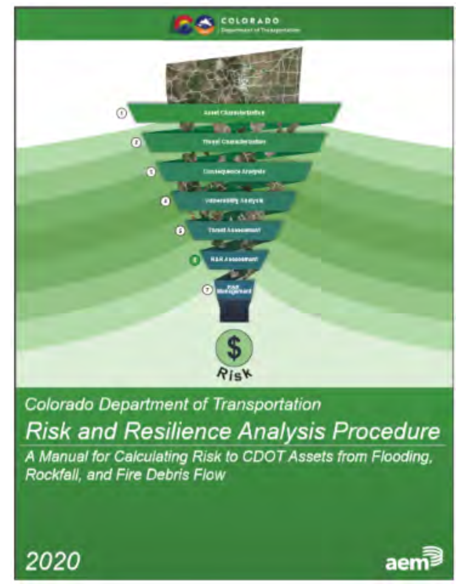
Background

Transportation Resilience
The ability to keep our roads open and functional in the face of unexpected events and challenges

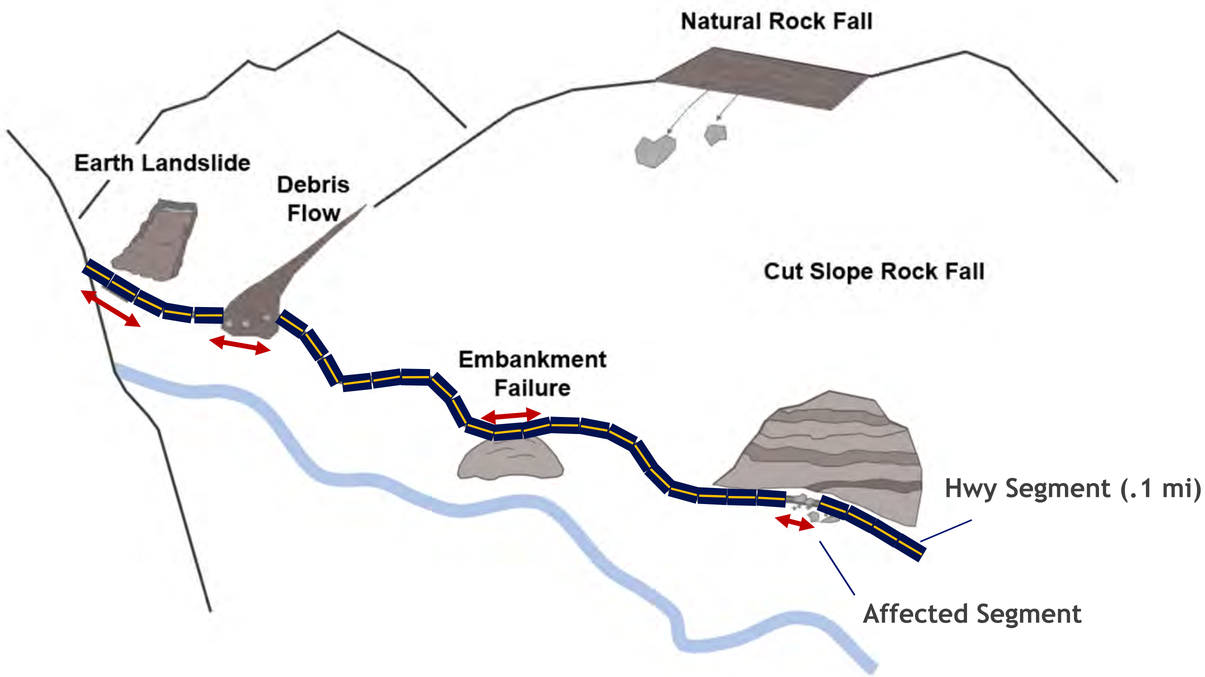
Policy Directive 1908.0 (2018)
"Building Resilience into Transportation Infrastructure and Operations"

CDOT Resiliency Group
- **I-70 Risk and Resiliency Pilot Study**
- **Project Planning Tools**

CDOT Geohazards Program
- **Funded by CDOT TAM**
- **Subject Matter Experts for the CDOT Resiliency Working Group**
- **Geohazards Management Plan (GMP)**
    - **Measures and manages threats to CDOT performance from geohazards**
    - **Systematic prioritization for corridor improvements**
    - **Risk of hazard impacts versus cost of greater system resilience**



Geohazards Overview



Why Geohazards are important:

Geohazards pose safety and mobility threats to users and direct costs to CDOT

SAFETY threats: Property damage, injury and fatalities can and have resulted from rockfall and debris flows

MOBILITY impacts: Frequent source of highway closures and delays. Significant impacts to user costs have been observed.

OWNER impacts: Damage to pavement, walls, culverts, bridges, and ITS assets, as well as demands on Maintenance crews

Performance Metric

Performance Metric: Level of Risk (LOR) per highway segment – a measure of the annual risk cost for **safety**, **mobility** and **maintenance** caused by geohazard events.

LIKELIHOOD * SAFETY CONSEQUENCE / MOBILITY CONSEQUENCE / MAINTENANCE CONSEQUENCE = ANNUAL RISK COST →

LOR A	< $1K
LOR B	$1K - $5K
LOR C	$5K - $25K
LOR D	$25K – $50K
LOR F	> $50K

Two Examples of Implementing Resiliency

1) SH 550 Corridor Investment Study
Statewide Risk Reduction

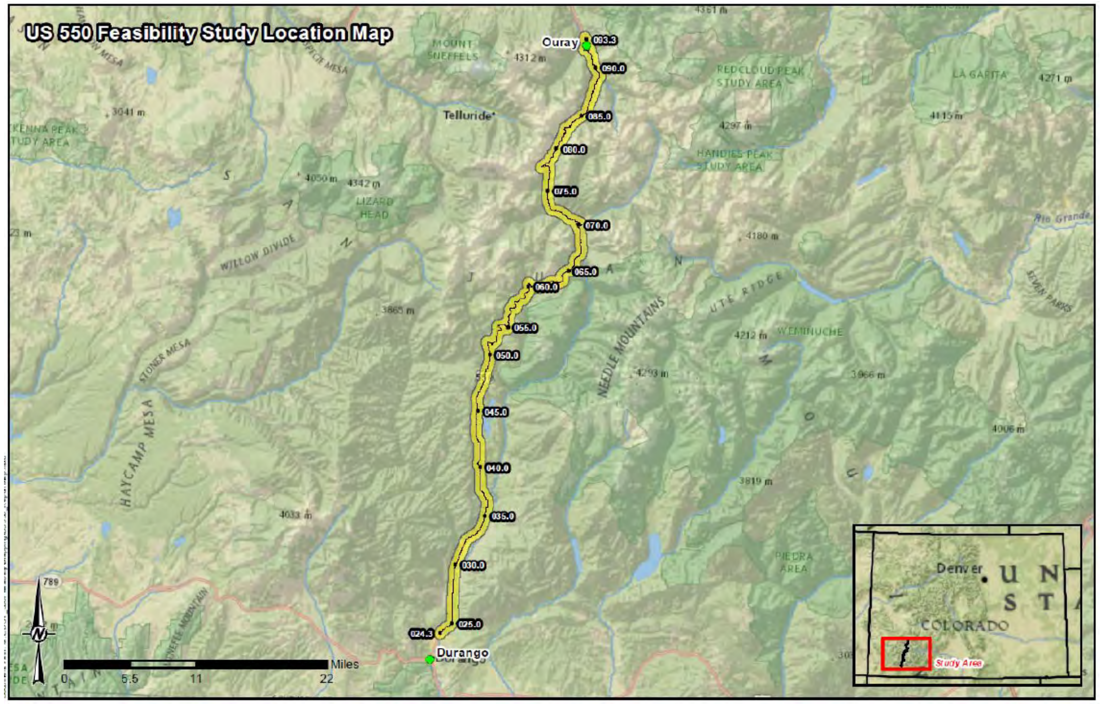
2) Glenwood Canyon Debris Flows
Emergency Relief Risk Reduction

550 Corridor Investment Study

US 550 MM24.3-MM93.3 (Ouray to Durango)

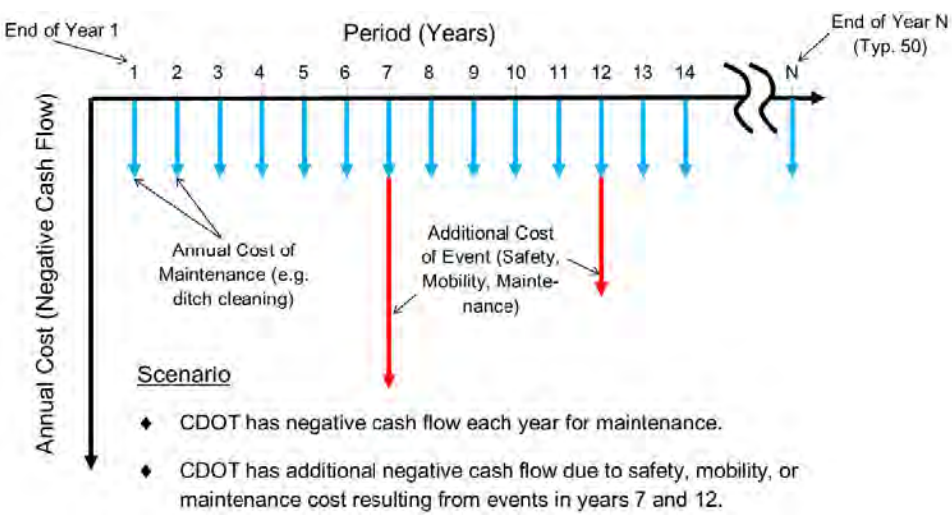
Risk Exposure
- **125 Priority 1 and 2 sites evaluated**

Conceptual Mitigation Development
- **35 hazard sites selected (28 Rockfall and 7 Debris Flow)**
- **11 Embankment Sites**

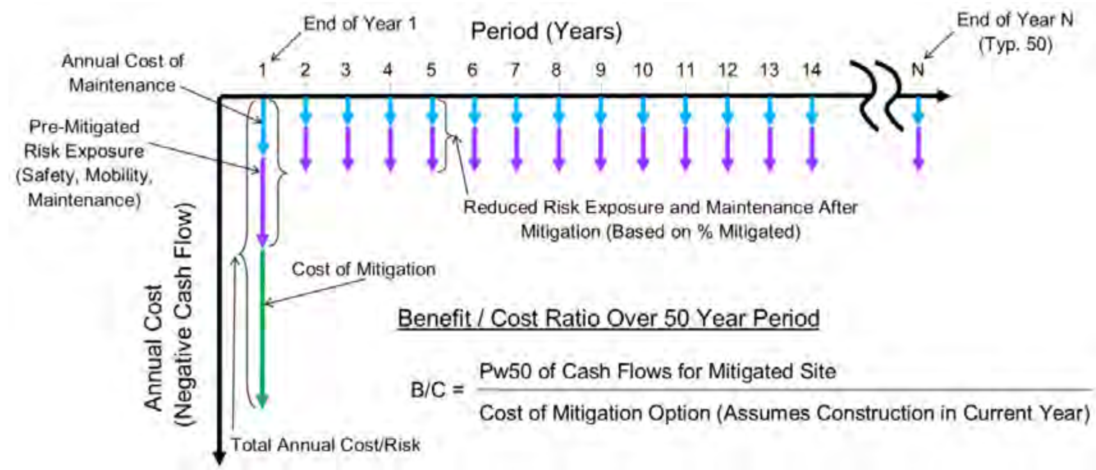


Benefit Cost Analysis

Do Nothing

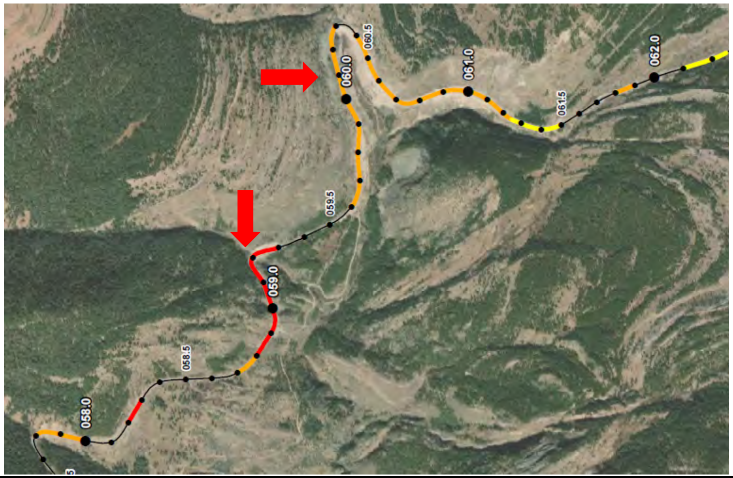


Mitigation Benefit



Project Selection Process

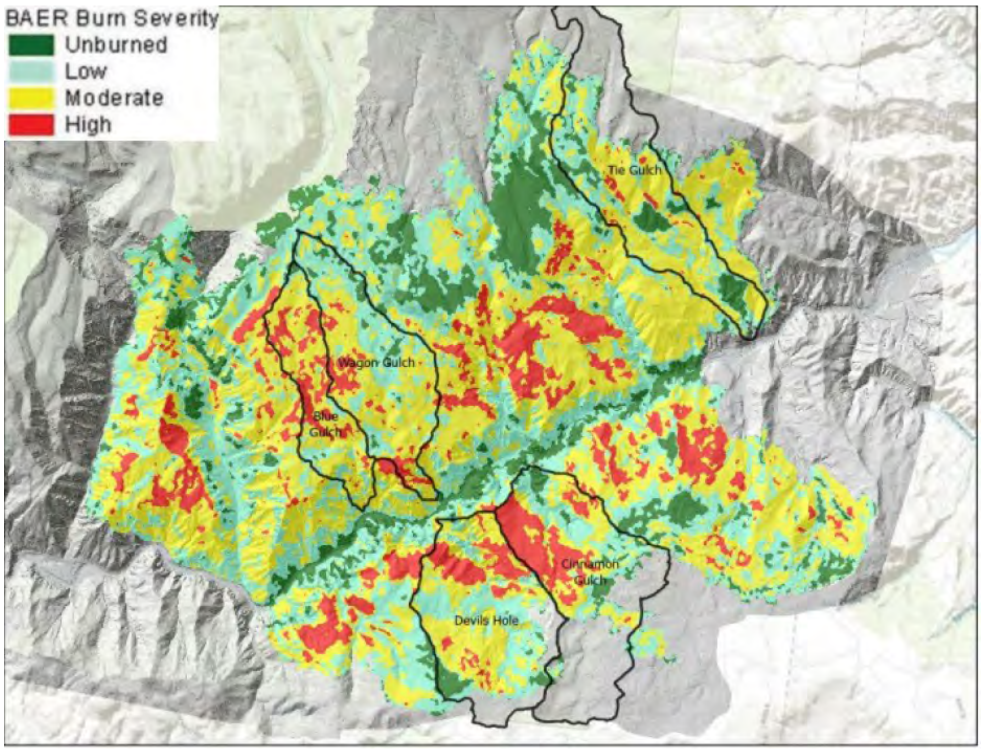
Projects and mitigation methods are prioritized based on risk to performance objectives and on cost-benefit evaluation

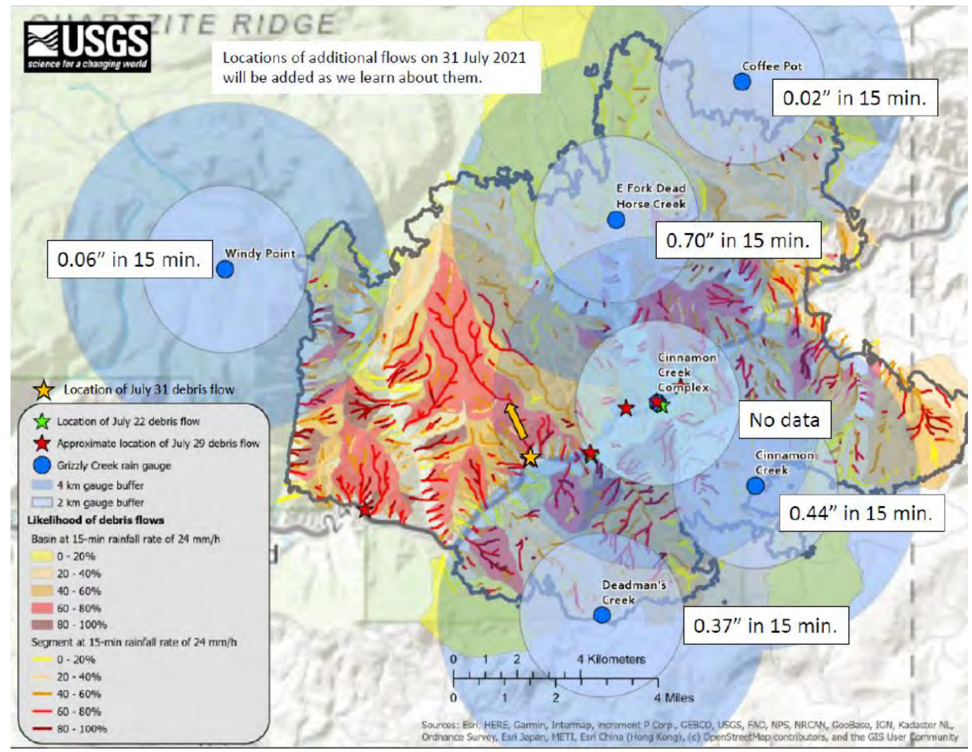


BMP	EMP	% Mitigated Benefit (PW 50)	Mitigation Option	RR %	B/C	Option Cost	Performance
59.65	60.27		Do Nothing	0		$5,982,260.00	D
		$5,384,034.00	Attenuator/Hanger	90	0.55	$9,871,428.00	B
		$5,683,147.00	Midweight Drape Mesh	95	6.36	$893,664.00	B
60.37	60.52		Do Nothing	0		$5,977,937.00	F
		$5,679,040.00	Drape Mesh	95	11.19	$442,400.00	C
		$5,380,143.00	Attenuator	90	2.97	$1,580,000.00	C
		$5,858,378.00	Drape + Ditch Improvement	98	10.96	$466,100.00	B
		$5,858,378.00	Pinned Mesh	98	1.59	$3,207,400.00	B

Glenwood Canyon Debris Flows

Glenwood Canyon Debris Flows





GWC Debris Flows




Metric

LIKELIHOOD * OWNER CONSEQUENCE = RISK COST (5yr)

$$\text{Benefit / Cost} = \frac{\text{RISK COST (5yr)}}{\text{COST OF MITIGATION}}$$

Owner Costs


Maintenance
Barriers and Rails
Culvert
Retaining Wall
Pavement
Buried Fiber Optic
Pedestrian Path

Mile Post 120.0 Earthwork Example

Small Event (Annual Likelihood Assuming 20% Decrease Annually)					Medium Event (Annual Likelihood Assuming 20% Decrease Annually)					Extreme Event (Annual Likelihood Assuming 20% Decrease Annually)				
1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2	1.6	1.2	0.8	0.24	0.5	0.4	0.3	0.2	0.06	0.04	0.032	0.024	0.016	0.008

Item Number	Description	Units	Unit Cost	Damage Caused Per Small Event	Damage Caused Per Medium Event (2 Yr)	Damaged Caused Per Extreme (25 Yr Event)
202-00210	Removal of Concrete Pavement	SY	$30	5	10	30
202-00217	Removal of Concrete Pavement (Planing Special)	SY	$40	5	10	15
202-01140	Removal of Guardrail Type 4	LF	$150	10	10	100
203-00000	Unclassified Excavation	CY	$40	10	1000	5000
203-00066	Embankment Material CIP R40	CY	$35	0.01	10	500
203-01550	Dozing	HR	$180	0.1	5	80
203-01565	Hydraulic Excavator	HR	$160	8	24	80
203-01590	Front End Loader (Rubber Tire)	Hour	$160	8	24	80
203-01594	Combination Loader	Hour	$160	0	0	80

MP 120.0 Earthwork	
1 Year ER Cost (No Mitigation)	$342,007
5 Year ER Cost (No Mitigation)	$1,007,788.06
1 Year ER Cost (With Mitigation)	$29,797
5 Year Cost (With Mitigation)	$87,824
MP 120.0 Earthwork Cost	$183,330.00
B/C: 1 Year	**1.60**
B/C: 5 Year (Lifecycle)	**3.72**

Benefit Cost Ratio Analysis

ITEM	Mitigation	Cost PR Mitigation	ER Cost with Mitigation	ER Cost No Mitigation	B/C Ratio
Tier 1 Locations					
MP 119.9	Earthwork, gabion, culvert protection	$ 334,425.00	$ 103,787.89	$ 1,120,423.87	2.56
MP 120.0	Earthwork, culvert protection	$ 183,330.00	$ 87,823.76	$ 1,007,788.06	3.72
MP 120.23	Rockfall Fence	$ 259,250.00	$ 39,889.72	$ 604,438.23	2.02
MP 123.4 Blue Gulch	Rockfall Fence	$ 555,200.00	$ 254,941.63	$ 1,289,431.91	1.59
MP 124.4 Wagon Gulch	Earthwork, gabion	$ 748,755.00	$ 323,779.18	$ 1,852,887.64	1.73
MP 126.16	Pier Protection	$ 64,050.00	$ 1,769.75	$ 158,118.83	2.40
MP 126.5	Pier Protection	$ 253,300.00	$ 28,315.94	$ 158,118.83	0.56
MP 126.6	Pier Protection	$ 253,300.00	$ 1,769.75	$ 158,118.83	0.62
MP 126.85	Pier Protection	$ 928,650.00	$ 1,769.75	$ 158,118.83	0.17
MP 126.95	Earthwork, culvert protection	$ 235,900.00	$ 72,889.98	$ 1,324,746.78	4.29
MP 126.96	Pier Protection	$ 56,000.00	$ 1,769.75	$ 158,118.83	2.74
MP 127.25	Pier Protection	$ 45,500.00	$ 1,769.75	$ 158,118.83	3.35
MP 129.06 Tie Gulch	Earthwork	$ 657,965.00	$ 87,823.76	$ 1,007,788.06	1.35

ER Cost No Mitigation	$ 18,217,576
PR Project Cost	$ 6,419,640
ER Cost with Mitigation	$ 3,149,333
Savings	$ 8,648,603
Benefit to Cost	1.90

Thank You

CDOT Geohazards Program

CDOT Resiliency Group

CDOT Region 3 Engineering

WSP (Formerly Golder)

BGC Engineering

USGS

Appendix I: Wisconsin Department of Transportation - Slide Presentation

Geotechnical Asset Management (GAM) for Slopes

David Staab, PE, LEED AP, M. ASCE

Geotechnical Engineer – WisDOT Bureau of Technical Services

Highway Geology Symposium - GAM Peer Exchange

May 26, 2022

WISCONSIN DEPARTMENT OF TRANSPORTATION

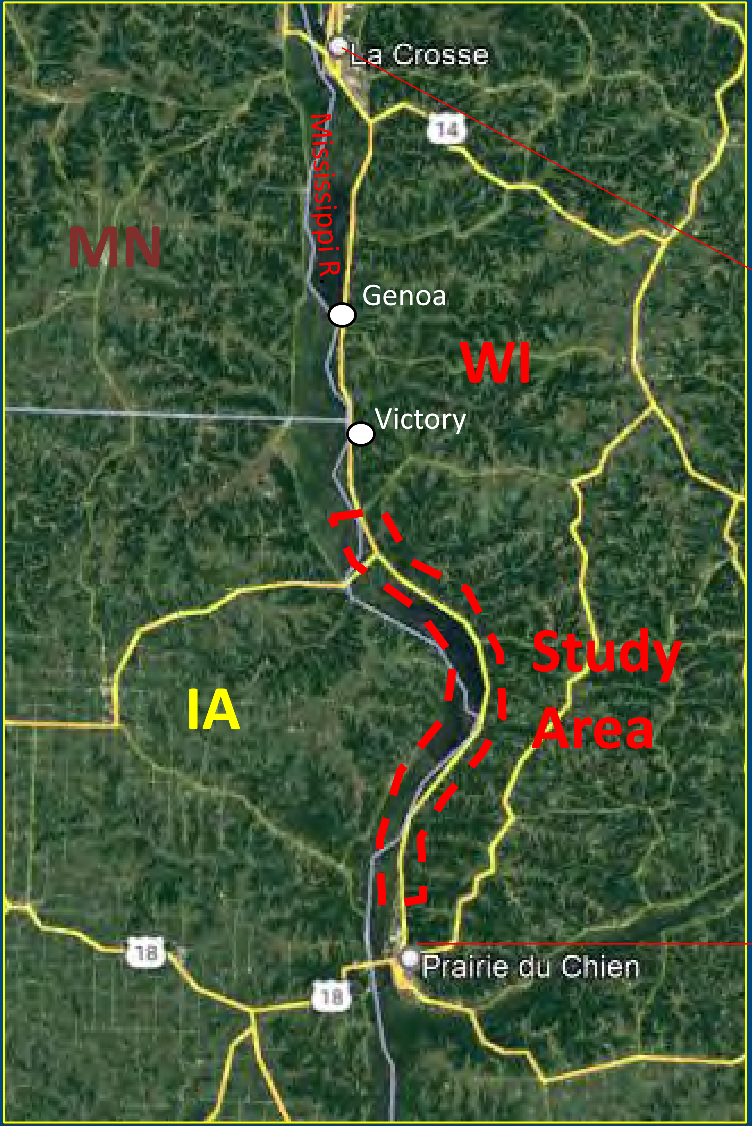
WHRP Project G21-06 – Geotechnical Asset Management (GAM) for Slopes

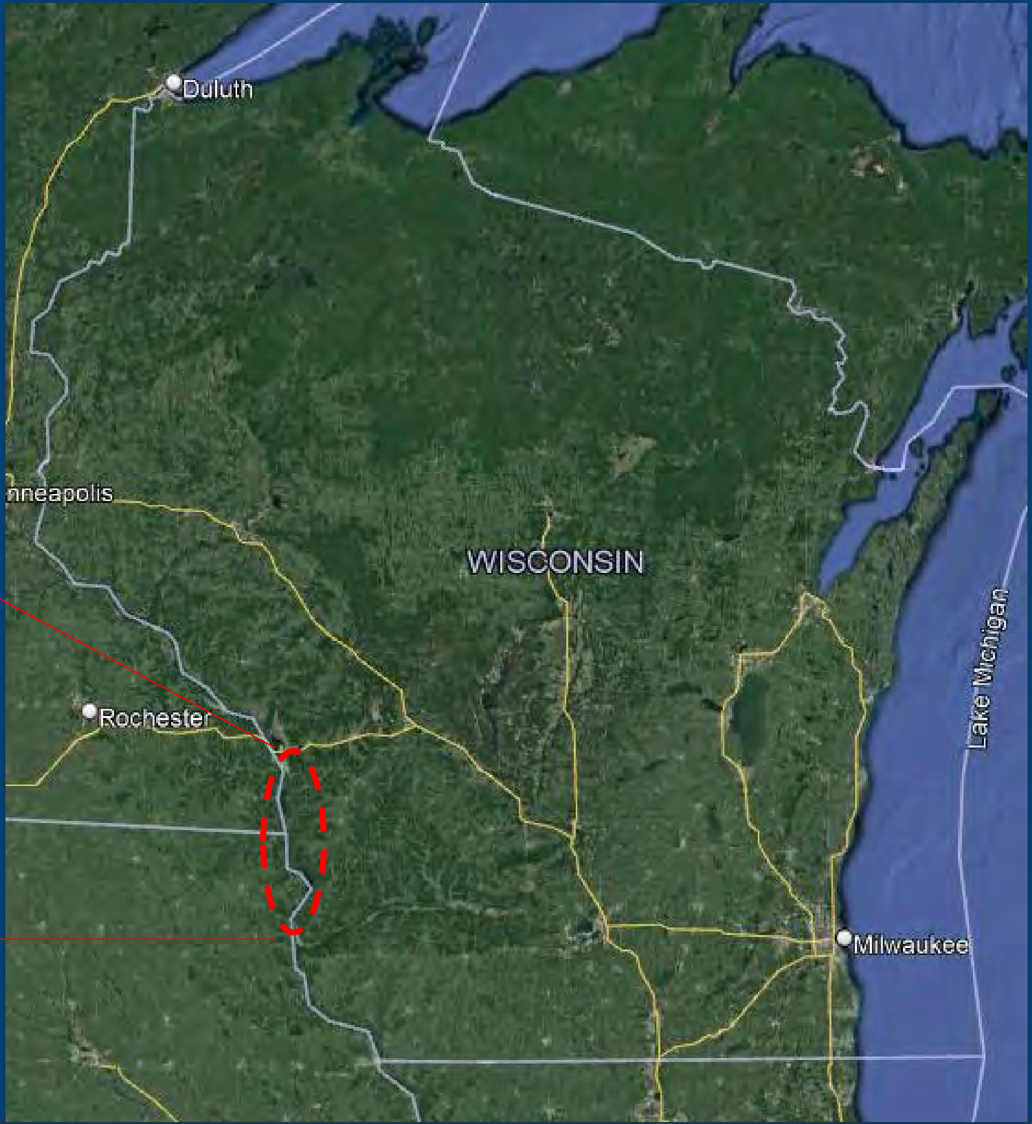
- Develop GIS-based Geotechnical Asset Management (GAM) for Slopes framework to categorize slope failure risk potential along STH 35 segment (Crawford County)
- GAM-Slopes framework expandable elsewhere (with appropriate local adjustments)
- Potentially use to prioritize and plan future projects and maintenance

WHRP Project G21-06 – Geotechnical Asset Management (GAM) for Slopes

- 11 research team proposals submitted
- BGC Engineering, Inc. (PIs: Scott Anderson and Mark Vessely)
- Schedule: 2 years – Oct. 2020 – Sept. 2022
- Budget: $150,000

STH 35 – Crawford County



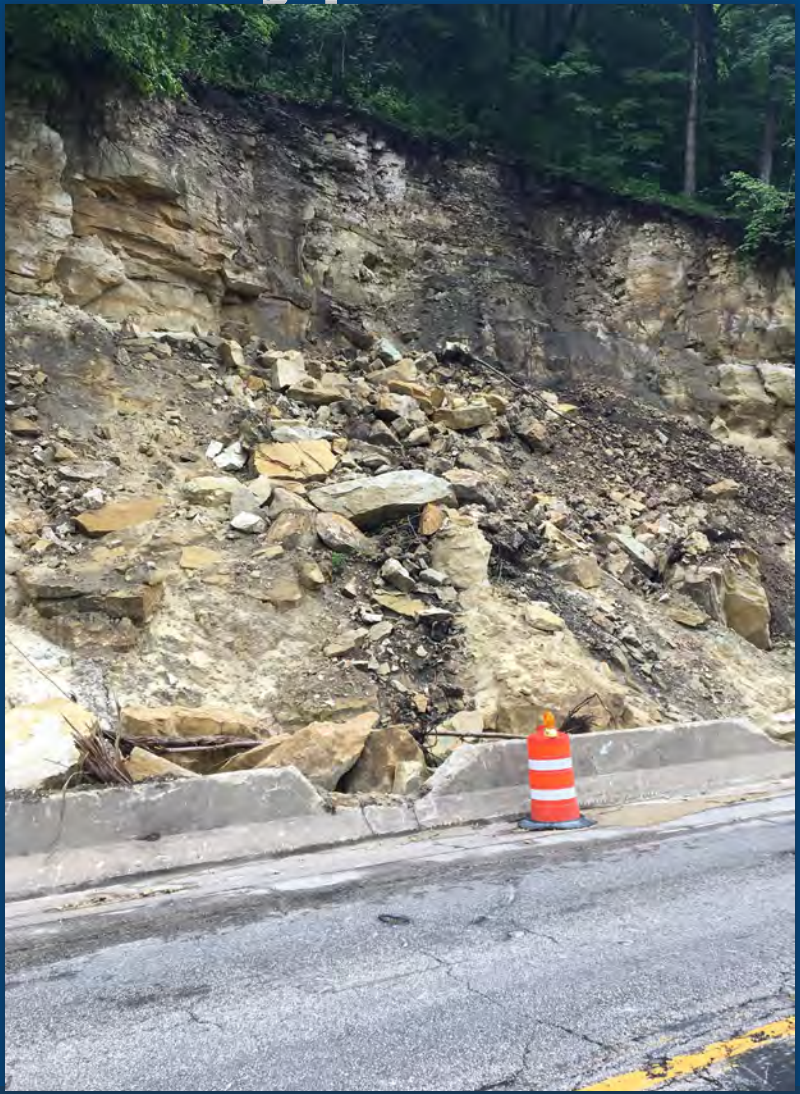


Study area ~20 miles

Sources: Google Earth; wigrr.com

STH 35 - Geology

STH 35 – Typical Slide Event



FUTURE STEPS - PROJECT

Project Specific

- Final report preparation and researcher presentation
- Project completion: September 30, 2022 (currently ahead of schedule)

FUTURE STEPS - DEPARTMENT

Department Specific

- Incorporate GAM-Slopes into overall asset management program?
- Expand to other parts of the state with historic slope stability issues?