21st Annual Technical Forum on Geohazards

April 9-11, 2024

Natural Bridge State Park
Rockbridge County, Virginia

Registration:

Please see the JMU Website at
https://www.jmu.edu/geology/cegga/forum.shtml

(through IRIS, or enter code GHF2024 if prompted)

Hotel reservations can be made at 540- 291-2121 (Code 040824GEO for public employees, Code 040824SPO for others.)

For meals, the Hotel Dining Room is open from 5:30 to 9:00 pm, and the Red Fox Tavern is open from 5:30 to 10:00. Both are on-site. Dining is also available in the nearby City of Lexington.

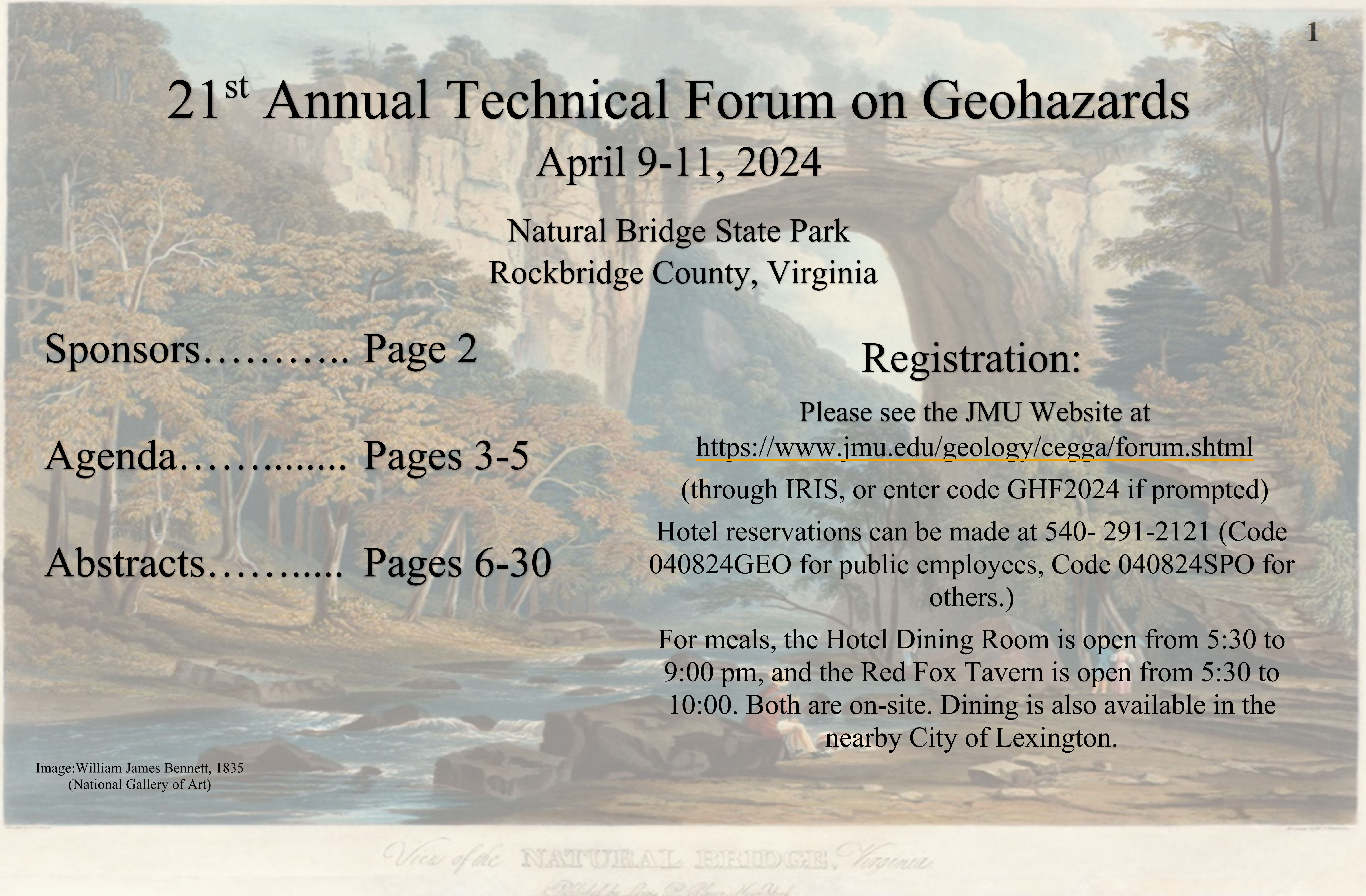

Image:William James Bennett, 1835
(National Gallery of Art)

Image: BRK

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Monday, April 8th, 2024 **Icebreaker**		
5:30 pm	~8:30	Icebreaker, Hotel Fox Lounge

Tuesday, April 9th, 2024 **All Day Vendor Exhibits Hotel Jefferson I** **Morning Session: Case Studies, Resilience, and Susceptibility** **Moderator: Anne Witt**					
7:00 am	8:30	Breakfast	Hotel Colonial Dining Room		
8:30	8:45	Welcome/Introduction	Hotel Jefferson II and III	Yonathan Admassu/Brian Bruckno	
8:45	9:15	Podium Sessions	Hotel Jefferson II and III	Jamal N. Tahat	***Session 1***: Evaluating Driven Pile Behaviors Using Machine Learning Through Case Study Experimental Pile Load Testing (PLT)
9:15	9:45			Lucas Martins	***Session 2***: Case Histories of Roadside Rockfall Barrier Applications
9:45	10:15			Anne Witt	***Session 3***: Preliminary Results of Recent Landslide Susceptibility Mapping in Albemarle and Nelson Counties, Virginia
10:15	10:45	Coffee Break	Hotel Jefferson II and III		
10:45	11:15	Podium Sessions	Hotel Jefferson II and III	Khalid Mohamed	***Session 4***: Overview of the Final Geohazards, Extreme Weather Events and Climate Change Resilience Manual
11:15	11:45			Ben Rivers	***Session 5***: The Road to Improving Transportation Resilience
11:45	12:30 pm	Podium and Demo Session	Hotel Jefferson II and III and Hotel Grounds	Introduction to Ground Penetrating Radar and Spider Rigs (VDOT and GSI)	
12:30	1:15	Lunch and Demo Session	Hotel Colonial Dining Room and Hotel Grounds		
Tuesday, April 9th, 2024 **Afternoon Session: Remote Sensing, Monitoring, and Forecasting** **Moderator: Yonathan Admassu**					
1:15	1:45	Podium Sessions	Hotel Jefferson II and III	Stuart Edwards	***Session 6***: Eye in the Sky
1:45	2:15			Christopher Markley	***Session 7***: Evolution of a System-Wide Landslide Monitoring Program for Pipelines Located in the Appalachian Region of the US
2:15	2:45			Yonathan Admassu	***Session 8***: Using High Resolution Topographic Data for Automated Mapping of Geohazards in the Valley and Ridge province
2:45	3:15			Brian Forsthoff	***Session 9***: Remote Ground Monitoring of Soil Slope Hazards Along Highways with Time Domain Reflectometry (TDR)
3:15	3:45	Coffee Break	Hotel Jefferson II and III		
3:45	4:15	Podium Sessions	Hotel Jefferson II and III	Nicholas Rebman	***Session 10***: Optical and Acoustic Televiewer Logging in Competent and Unstable Rock
4:15	4:45			Ritvick Bhalla	***Session 11***: The Move from Observations to Active Monitoring: The PROQIO Platform and Modern Data Synthesis
4:45	5:15			Atieh Hosseinizadeh	***Session 12***: Slope Instability Forecasting System Based on Precipitation Data
5:15	5:45			Alex Brown	***Session 13***: Regional Lidar Change Detection in Western Washington

Wednesday, April 10th, 2024 **All Day Vendor Exhibits Hotel Jefferson I** **Morning Session: Landslides, Rock Slopes, and Mass Movement** **Moderator: Arpita Nandi**					
7:00 am	8:30	Breakfast	Hotel Colonial Dining Room		
8:30	9:00	Podium Sessions	Hotel Jefferson II and III	Jeff Segar	***Session 14***: Landslide Repair on Top of a Bluff: Riverview Dr.
9:00	9:30			Jennifer Bauer	***Session 15***: The Multi-team Approach - Site Characterization and Conceptual Mitigation Design for a Landslide on SR32, Cocke County, Tennessee
9:30	10:00			Megan Palmer	***Session 16***: Landslide Susceptible Slopes and Tree Ring Pattern, a Case Study from East Tennessee
10:00	10:30	Coffee Break	Hotel Jefferson II and III		
10:30	11:00	Podium Sessions	Hotel Jefferson II and III	Arpita Nandi	***Session 17***: Probabilistic Rock Slope Hazard Assessment in Acid-Producing Roadway Corridors
11:00	11:30			Bryan Radabaugh	***Session 18***: US-340 Rockfall Mitigation Project – Wedged between 3 States, the Potomac River and the Blue Ridge Mountains
11:30	12:00			Christine Comuso	***Session 19***: State Route 46 Knowlton Township, New Jersey, and the Manunka Chunk Tunnels: Mitigating a Historic and Recent Mass Movement
12:00	1:00	Lunch	Hotel Colonial Dining Room		
Mentors Lunch in the Hotel Red Fox Tavern					
Wednesday, April 10th, 2024 **Afternoon Session: Data Management, Risk Management, Poster Sessions, and Natural Bridge** **Moderator: Ben Rivers**					
1:00	1:30	Podium Sessions	Hotel Jefferson II and III	Ross Cutts	***Session 20***: Geosetta
1:30	2:00			Evan W. Filion	***Session 21***: Leveraging Geophysics for Data Driven Decision-making: Geohazard Risk Assessment, Design-build, and Budgeting
2:00	2:30			Robert McSweeney	***Session 22***: A Multi-Stage Field and Modeling Approach for Inventory and Monitoring of Active Soil Slope Geotechnical Assets Along Tennessee Highways
2:30	3:00	Coffee Break	Hotel Jefferson II and III		
3:00	3:30	Poster Session	Hotel Jefferson II and III	Poster Authors	***Poster Session***
3:30	4:00	Podium Sessions	Hotel Jefferson II and III	Robert K. Denton Jr.	***Session 23:*** The Development of ASTM D8512-23, "Standard Practice for Preliminary Karst Terrain Assessment for Land Development"
4:00	4:30			Joshua Zimmermann	***Session 24:*** Identifying and Mitigating Subsidence Risk to Infrastructure from Abandoned, Underground Coal Mines
4:30	5:00			Skip Watts	***Session 25***: Special Session: The Geology of Natural Bridge and Its Unique Engineering Challenges
5:00	5:15	Closing Remarks/Field Trip	Hotel Jefferson II and III	Yonathan Admassu/ Skip Watts/ Brian Bruckno	
Board Meeting and Dinner in the Hotel Madison Room					

Thursday, April 11th, 2024 Field Trip				
Start	**End**	**Type**	**Location**	**Speaker and Subject**
7:00 am	8:30	Breakfast	Hotel Colonial Dining Room	
8:30	8:45	Travel to Natural Bridge State Park (Walk or Drive)		
8:45	9:00	Welcome/Introduction	Natural Bridge State Park Conference Room	Admassu/Bruckno
9:00	9:30	Podium Session	Natural Bridge State Park Conference Room	Park Ranger, History of Natural Bridge, Virginia
9:30	10:00			Susan Hammond, Plans for Natural Bridge's Future
10:10	10:15	Travel to the Arch (Walk or Bus)		
10:15	12:15pm	Field Trip	Natural Bridge State Park	Admassu/Watts, Demonstrations of UAVs for Remote Sensing of Geohazards
12:15	1:15	Box Lunch	Natural Bridge State Park Pavilion	
1:15	2:00	Open Session at Natural Bridge State Park with Rangers		
2:00	2:15	Travel to Natural Bridge State Park Conference Room (Walk or Bus)		
2:15	2:45	Podium Session	Natural Bridge State Park Conference Room	Admassu/Watts/Bruckno, Discussion of Data, Accuracy, Future Plans, and Adjourn

Session 1:

Jamal N. Tahat

EVALUATING DRIVEN PILE BEHAVIORS USING MACHINE LEARNING THROUGH CASE STUDY EXPERIMENTAL PILE LOAD TESTING (PLT)

Abstract:

Geotechnical engineers utilize soil properties for designing pile foundations, and pile load testing (PLT) is a crucial method to assess the pile-soil system. The behavior of driven piles, considering factors like skin friction, bearing capacity, and setup, is heavily influenced by subsurface soil characteristics. In a study conducted in Kilmore County, Indiana, the authors performed 99 pile load tests, covering lateral tension, axial compression, and tension, on derived piles of varying lengths at 33 locations. This research aimed to understand the effects of subsurface soil layers on pile behavior, providing valuable insights for pile installation and design criteria.

The test results were employed to analyze soil setup behavior and understand subsurface soil conditions. Various methods, including standard penetration tests (SPT) and laboratory tests on field samples like soil gradation, Atterberg limits, shear strength, and compressive strength, were used for this analysis. The study revealed a significant increase in skin pile resistance in clay soils compared to sandy soils. However, the toe bearing capacity remained relatively consistent over time for all tested piles. Machine learning techniques like artificial neural networks (ANN) and Random Forest (RF) were applied to model the complex nonlinear relationships between pile driving data and pile capacity. These data-driven methods improved prediction accuracy compared to traditional static analysis methods.

The study observed a linear trend with logarithmic time in pile installation rates, indicating a rise in the total resistance of the test piles over time. The authors selected two borings from different zones in the field, characterized by sandy lean clay and poorly graded sand soil types, for further evaluation and recommendations.

Session 2:

Lucas Martins

CASE HISTORIES OF ROADSIDE ROCKFALL BARRIER APPLICATIONS

Abstract:

Rockfall hazards pose a serious risk to transportation safety, with the potential to cause fatalities, infrastructure damage, and disruptions in transportation systems. For several decades, rockfall barriers have been a common technique to mitigate geohazards in the United States. Over the years, several of these safety systems have been tested and installed around the world. This study explores the unique challenges in implementing rockfall barriers in roadside applications, emphasizing specific infrastructure considerations that will lead to a comprehensive design of these systems.

Traditionally rockfall barrier systems' capabilities are measured according to their tested energy impact magnitude. The design of these systems should not only consider their maximum impact capabilities but should evaluate other key aspects such as limited barrier deflection, ease of installation and maintainability. This study will discuss how these critical site-specific considerations affect the design of cost-effective roadside rockfall barrier systems.
Three different case studies from different regions in the United States highlight successful installation of rockfall barriers alongside roadways. Emphasis is given on how the rockfall products unique design features and considerations aided in overcoming site-specific challenges and contributed to the success of these solutions.

Furthermore, this study showcases advancements in smartification of rockfall barriers, such as remote sensing and warning systems, to improve the overall effectiveness of rockfall mitigation systems. The integration of these new technologies with traditional rockfall barriers contributes to an integrated approach to geohazard mitigation and is essential for a continued improvement of roadway safety.

Session 3:

Anne Witt

PRELIMINARY RESULTS OF RECENT LANDSLIDE SUSCEPTIBILITY MAPPING IN ALBEMARLE AND NELSON COUNTIES, VIRGINIA

Abstract:
In 2018 and 2020, the Virginia Department of Energy was awarded Pre-Disaster Mitigation grant funds from the Federal Emergency Management Agency, through the Virginia Department of Emergency Management (VDEM), to complete a landslide inventory and susceptibility mapping in Albemarle and Nelson Counties. The eastern Blue Ridge of these counties were affected by Hurricane Camille in 1969 and a strong series of storms in 1995 which generated thousands of debris flows. Landslides from both storm events have been studied and mapped by the U.S. Geological Survey (1973, 1996, 1999), however recently available 1-meter resolution LIDAR has greatly improved the accuracy of mapping efforts . Inventory mapping of recent (1969-present) and ancient landslide features is complete and > 7900 recent landslides have been identified. Approximately 89% of these landslides occurred during Hurricane Camille and were primarily debris flows and slides. Initial susceptibility mapping for the western half of the study area was completed and delivered to VDEM in 2022. These maps show potential initiation areas for shallow, translational slope movements (i.e., debris flows) during a high-rainfall event as a color-coded map. This map was produced using a series of ESRI geoprocessing tools to calculate a weighted overlay raster. Parameter values for the raster were derived from topographic LIDAR data (curvature, slope), digital soil data (cohesion, soil depth), and geologic data. The final output raster was then assigned into three susceptibility zones (high, moderate, low) based on calculated parameter value ranges and known landslide occurrences. Parameter ranges were adjusted to maximize the number of landslide locations per unit area captured in high-hazard zones. High and moderate hazard zones from the susceptibility map, average debris flow width and length, and LIDAR topographic data were then used to produce areas of predicted debris flow pathways using hydrologic flow path tools in ESRI ArcPro. Additional feature classes indicate where public infrastructure (roads, railroads, etc.) intersect these pathways and may be at risk during a future rainfall event. Susceptibility mapping for the western study area has provided a "proof of concept" for the remaining eastern study area and will be delivered to VDEM in September 2024.

Session 4:

Khalid Mohamed

OVERVIEW OF THE FINAL GEOHAZARDS, EXTREME WEATHER EVENTS AND CLIMATE CHANGE RESILIENCE MANUAL

Abstract:
Impacts from geohazards on transportation infrastructure could be significant. These geohazards are generally defined as geological and climatic conditions that have the potential to cause damage to property, infrastructure, and the environment; loss of life; and economic losses. Types of geohazards include landslides, rockfall, debris flows, mine subsidence, sinkholes, expansive/collapsible soils, scour, and earthquake related phenomena. Geohazards occur in all geographic regions of the U.S. resulting from natural and human-induced factors and triggering processes. Evaluation of impact of climate change on the frequency, severity and intensity of geohazards is important for development of mitigation and adaptation methods for improved performance and a resilient transportation system.

The geotechnical section within the FHWA Bridge office worked with experts from federal agencies, State Departments of Transportation (DOT), contractors and academia in the development of a manual that provide the tools needed for developing geohazards protocols and programs. The manual discussed methods for incorporating climate factors in decision making for mitigation and avoidance of geohazards impact.

Session 5:

Ben Rivers

THE ROAD TO IMPROVING TRANSPORTATION RESILIENCE

Abstract:

Geohazards represents two sides of a resilience coin: On one side, they represent naturally occurring and potentially human-influenced disruptive events for which we can anticipate and prepare for and adapt to their accelerated occurrences as a result of changing weather patterns, durations of and periods between drought and precipitation cycles, and increasing frequencies and intensities of storm events. On the other side, geohazards represent occurrences having impacts to our transportation infrastructure and its system performance that can be, at least to some extent, managed. The Bipartisan Infrastructure Law (BIL) enacted in November of 2021 puts significant emphasis on improving resilience by providing contract authority of between $1.40B to $1.52B for Fiscal Years 2022 to 2026 under the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Formula Program. While this presentation does not attempt to cover the particulars of the PROTECT formula and competitive grant program, it does discuss elements under which vulnerability assessments of geohazards and solutions to improve system performance from their accelerated occurrences and impacts are possible.

Session 6:

Stuart Edwards

EYE IN THE SKY

Abstract:
As one of the foremost geo-hazards, landslides are among the most difficult to anticipate and analyze. The fact that many if not most of them are re-activations of earlier slides that may still be slowly moving can provide some help in identifying a population of potential slide sites in a given area. The inventory can then be monitored by periodic inspections. This presentation introduces a new (to the geo-science community) space-based tool that can significantly reduce the level of effort required to monitor potential landslide locations, known as Interferometric Synthetic Aperture Radar, or InSAR. The technology is not new, and its ability to detect ground surface displacements on the order of millimeters/year has been appreciated for several decades. However the complexity of the data analysis had a chilling effect on its widespread adoption as a tool for geo-scientists. Only recently has there been an effort on the part of space agencies in Europe and the US to post-process InSAR data to a higher level where it can now be used by disciplines that lack an intimate knowledge of satellite radiometry. The general principles of InSAR are briefly presented and the workflow to produce a ground motion analysis is illustrated. Some examples of monitoring results at slow moving landslides are shown, followed by a look to the future opportunities that the 'Eye in the Sky' may represent for geo-scientists.

Session 7:

Christopher Markley

EVOLUTION OF A SYSTEM-WIDE LANDSLIDE MONITORING PROGRAM FOR PIPELINES LOCATED IN THE APPALACHIAN REGION OF THE US

Abstract:
Landslides have the potential to adversely affect the integrity of pipelines. The ability to properly identify, characterize, and if necessary, mitigate and monitor landslide hazards has become critical to the successful construction and operation of pipelines in the Appalachian Basin region of the United States. Natural geologic, geographic, and climatic conditions in this region combine to create a high occurrence of landslides. Pipeline construction within a hillside can often destabilize the slope, and the rapid expansion of pipeline construction and operation in the region, along with the ever-decreasing availability of preferred routing options, have resulted in increased landslide-related pipeline incidences, both during and post-construction. As such, there is an increasing need to identify, characterize, and closely monitor landslide hazards throughout the construction and operational lifespan of each pipeline system. This can prove challenging in an area with such a high incidence of landslides, and where new landslide hazards may develop on an annual basis. Typical site-specific landslide monitoring approaches (e.g., strain gauges, inclinometers, monitoring points, etc.) may not be economically feasible to use for all hazards when traversing long distances and steep terrain. Also, these monitoring methods likely do not address the need to identify new hazards that may develop over time (e.g., new or reactivated landslides).

With such a high density of landslides in the Appalachian Basin, it is necessary for a system-wide pipeline landslide monitoring program to be internally consistent in hazard classification and data collection/presentation, while also being dynamic enough to incorporate changes to the landslide condition which may increase or decrease pipeline integrity issues over time. It is essential to recognize new and emerging identification and monitoring techniques and to use complimentary technologies to balance out the relative strengths and weaknesses of each monitoring method. This presentation will provide an overview of monitoring approaches we have found useful for the long-term monitoring and assessment of high-density landslide areas at a system-wide scale, including the use of repeat LiDAR surveys (i.e., LiDAR Change Detection Analysis), interferometric synthetic aperture radar (InSAR) data, in-line inspection (ILI) inertial measurement unit (IMU) data, aerial patrol/reconnaissance, and ground patrol. While many of these methods can be applied to the entire pipeline systems, case studies from an anonymous pipeline company will be presented from the Appalachian Basin region, including how monitoring techniques were selected based on specific pipeline system configurations and individual operator objectives, and how they are being used to track existing hazards and to identify hazards as they develop.

Session 8:

Yonathan Admassu

USING HIGH RESOLUTION TOPOGRAPHIC DATA FOR AUTOMATED MAPPING OF GEOHAZARDS IN THE VALLEY AND RIDGE PROVINCE

Abstract:

High resolution digital elevation data has become more accessible now than ever before. Such data in the form of digital elevation models (DEMs) is now available for free download from various agencies. Through visual inspection of DEMs, one can easily identify geohazards such as sinkholes and landslides. However, visual inspection takes an enormous amount of time and therefore automating the process becomes necessary. For automated mapping of sinkholes, shape factors such as circularity, sphericity, and curvature of closed depressions, identified in ArcGIS, were used as variables to discriminate sinkholes from depressions that are not related to sinkhole. For landslides, we used surface various surface roughness measures including coefficient of elevation variation, Laplacian analysis, and eigenvalue analysis. Multivariate statistical analyses such as linear discriminant analysis, quadratic discriminant analysis, and logistic regression were used to produce predictive models that identify sinkholes and landslides at reasonably high accuracy. In addition to DEMs, we have explored using street level high resolution surface models for rockfall potentials from highway slope cuts.

Session 9:

Brian Forsthoff

REMOTE GROUND MONITORING OF SOIL SLOPE HAZARDS ALONG HIGHWAYS WITH TIME DOMAIN REFLECTOMETRY (TDR)

Abstract:
Unstable soil slopes are a major concern in regions with high topographic relief and extreme rainfall. Landslides pose a particular risk to infrastructure and public safety along major highways in eastern Tennessee, making slope monitoring an important aspect of geotechnical asset management (GAM). Traditional methods for slope monitoring, including inclinometers, tiltmeters, GPS surveys, and remote sensing, are labor-intensive, time-consuming, and expensive. Moreover, these generally do not provide real-time information on slope movements. Tennessee Department of Transportation (TDOT) actively monitors numerous slope hazards to anticipate failures and prioritize timely remediation projects. A recent low-cost technique for ground monitoring, time domain reflectometry (TDR), offers remote real-time slope monitoring. TDR measures borehole displacements via reflection of electric pulses along a grouted coaxial cable and, when paired with a remote data logger, delivers real-time monitoring of slope movements. To test the suitability of this method for future TDOT monitoring purposes, four TDR instruments were installed in two slow-moving soil landslides on I-40 in Roane County, TN. Boreholes were drilled in summer 2023, and in-ground monitoring instruments, on-site weather stations, and remote data loggers were installed. Ground monitoring instrumentation included TDR, vibrating wire piezometers, and soil moisture meters. Data were sent at 30-minute intervals via cellular uplink to a remote computer for processing and analysis. The result was "real-time" monitoring output of slope displacement metrics, groundwater levels, soil moisture, and rainfall and climate data. Initial results have indicated no active movements at either site. Future work includes the correlation of groundwater, rainfall, and slope movement data to train a predictive model for early warning of slope failures along Tennessee highways. This study marks the first application of TDR for soil slope monitoring in Tennessee.

Session 10:

Nicholas Rebman

OPTICAL AND ACOUSTIC TELEVIEWER LOGGING IN COMPETENT AND UNSTABLE ROCK

Abstract:
Optical and acoustic televiewer geophysical logging is common in transportation projects to gather valuable information about subsurface conditions. Using these tools, engineers can assess the integrity and quality of rock masses, including discontinuities, such as fractures, faults, voids, and other features that may affect the stability and performance of transportation structures. These tools generate oriented images and can, therefore, provide the strike and dip of planar discontinuities, such as fractures, bedding planes, foliation, cleavage, etc.

This presentation will include case studies using acoustic and optical televiewers to assess discontinuities at proposed rock cuts and bridge abutments. Televiewer logging in unstable rock using a drilling/grouting/re-drilling technique will also be reviewed.

Bio:
Nick Rebman is an experienced practitioner in the field of near surface geophysics and has 10 years of experience with geophysical methods and instruments in the southeastern United States and Appalachia. Mr. Rebman routinely provides geophysical borehole logging services to assist clients with determining lithology, fracture orientations, and fluid flow in rock. He routinely conducts geophysical investigations in support of geotechnical investigations and environmental site assessment and remediation projects.

Session 11:

Ritvick Bhalla

THE MOVE FROM OBSERVATIONS TO ACTIVE MONITORING: THE PROQIO PLATFORM AND MODERN DATA SYNTHESIS

Abstract:
In the face of escalating geohazard risks, aging infrastructure, climate awareness, and the growing need for resilient infrastructure in transportation, tunnels, and bridges, this technical share presents our comprehensive approach to geohazard monitoring and management. Our focus extends beyond traditional monitoring, encompassing a broad spectrum of technologies that help us support assurance for the safety of civil infrastructure, the environment, and surrounding communities.

Geohazards, ranging from landslides and earthquakes to subsidence and erosion, pose significant threats to transportation networks, tunnels, bridges, and other corridor infrastructure. The complexity of these hazards necessitates a multidimensional monitoring strategy, integrating geotechnical, environmental, and remote sensing data.

PROQIO, the infrastructure data intelligence platform, is a central hub for this integration, combining data from ground-based geotechnical and environmental sensors, satellite imagery (including InSAR), BIM, UAVs, LiDAR, and more. This data aggregation provides a comprehensive view of the geohazard landscape, which is essential for accurate risk assessment and mitigation planning. Your location's Digital Twin, GIS layers, visualization tools, data analysis, and focused understanding methods help make this sustainable and offers a firm foundation for decision making support. The platform's advanced data intelligence capabilities are critical in analyzing the complex interactions between geohazards and infrastructure elements. PROQIO employs machine learning algorithms to interpret vast datasets, offering insights into potential risks and enabling predictive modeling, allowing for timely maintenance and reinforcement of transportation networks, tunnels, and bridges before disaster strikes.

In addition to predictive analysis, PROQIO enhances near real-time monitoring via its internal early warning systems and risk management, as this involves continuous surveillance and adaptive analysis of monitored areas, adjusting prediction models based on real-time data. It aids in designing resilient structures, planning effective maintenance schedules, and implementing emergency response strategies.

We will share the opportunity for emphasizing the importance of an integrated, intelligent approach to geohazard monitoring and management, particularly along transportation corridors, through tunnels, and over bridges. By leveraging comprehensive data aggregation and analysis capabilities, stakeholders can significantly enhance infrastructure safety, resilience, and longevity in the face of diverse geohazard challenges.

Session 12:

Atieh Hosseinizadeh

SLOPE INSTABILITY FORECASTING SYSTEM BASED ON PRECIPITATION DATA

Abstract:

Landslides, particularly those triggered by rainfall, pose substantial threats to lives and infrastructure, incurring significant economic damages. This research addresses the critical need for accurate prediction of rainfall-induced landslides, a complex challenge exacerbated by varying factors affecting slope stability. The study leverages advancements in precipitation-based datasets, high-resolution imagery, and soil mapping to enhance real-time prediction of landslide threats in partnership with Maryland Department of Transportation State Highway Administration (MDOT SHA), USDOT University Transportation Center-Safety 21 Program and Universities. The research aims to develop a comprehensive slope instability forecast system integrating precipitation data and physical landslide processes as part of geotechnical asset management of MDOT/SHA). The methodology employs the logit model to establish the relationship between slope instability and triggering factors. The machine learning model maps the relation of different factors and uses a learning process for prediction of future slope stability and enhance prediction accuracy in response to heavy rainfall events. Multiple data sources, including precipitation, soil condition, slope configurations, wind, visibility, pavement condition, and ground motion, are amalgamated using a routine transfer protocol. The resulting prediction provides real-time alerts to MDOT SHA, categorizing high-risk areas on a dynamic scale—three hours ahead, daily, and monthly. The project will also involve the development of a GIS-based software tool for seamlessly integrating data sources, visualizing highway slope features on a map, and providing alerts through a dashboard. This research is instrumental in mitigating the increased risk of slope instability, thereby reducing potential damages to transportation infrastructure and improving its resilience.

Session 13:

Alex Brown

Alex Brown

REGIONAL LIDAR CHANGE DETECTION IN WESTERN WASHINGTON

Abstract:

Understanding the location and movement history of recently active landslides allows engineers, planners, and scientists to make informed decisions related to development, conservation, and geohazard risk. High resolution topography data is a key resource in identifying landslides and their activity levels. States in the Appalachian region such as North Carolina and Kentucky are collecting these data with regularity, creating multi-temporal datasets containing a wealth of information on landslide deformation and sediment transport processes. However, unlocking this insight at scale has historically been a challenging and time-intensive task. Processing, aligning, and differencing thousands of square kilometers of lidar data to infer surface change required significant computational resources and was compounded by issues related to datasets of varying quality and resolution. BGC Engineering recently supported the Washington Department of Natural Resources in computing point-based change detection for approximately 6,000 km2 of overlapping high-resolution lidar datasets. BGC performed the change detection in six weeks by using an industry-leading workflow including point cloud alignment and GPU hardware acceleration. The results are 3D change vectors of the ground surface across change detection periods comparing 2006, 2013, 2014, and 2017. Using this process has allowed for the rapid identification of landslides and landslide activity in northwest Washington with movement of greater than 1-3 feet in the last 20 years. The purpose of this talk is to demonstrate the state of the science in regard to massive lidar change detection campaigns that can be undertaken wherever agencies have overlapping multi-temporal lidar acquisitions.

Session 14:

Jeff Segar

<u>LANDSLIDE REPAIR ON TOP OF A BLUFF: RIVERVIEW DR.</u>

<u>Abstract:</u>
Alton, IL, is a quaint river town with many blocks of Queen Anne Style houses and large bluffs that provide breathtaking views of the Mississippi River. The houses on Riverview Drive are perched on top of a 150 foot tall bluff and enjoy expansive views of the Mississippi river and the distant skyline of St. Louis beyond.

In July 2019 the road at the top of the bluff started showing signs of movement. Within three weeks a design build proposal was given to the city to stabilize the wall using soil nails. The proposal estimated two weeks to complete the installation. The city did not act on the proposal and the wall failed in January of the next year. The failure progressed about 18 feet into road and about 25 feet down the slope. The natural slope at the toe of the failure is about 65 feet long at a 55° angle to horizontal and then terminates at the 60 foot vertical limestone cliff.

The road was shut down for three years while the city procured FEMA funds, solicited designs, selected the design build contractor, and completed the repair.

Drones were flown over the area to get a lidar model that was used to determine the geometry of the failure. Using this information along with the geotechnical borings and inclinometer data, a repair was designed that used a system of soil nails to stabilize the slope, a geosynthetic confined soil wall (GCS) to rebuild the roadway, and micropiles to support the GCS and prevent it from loading and destabilizing the slope. Surface stabilization consisting of soil nails (pins) and high tensile mesh was installed on the slope below the wall by suspending drill rigs and workers on rappelling lines.

Session 15:

Jennifer Bauer

THE MULTI-TEAM APPROACH - SITE CHARACTERIZATION AND CONCEPTUAL MITIGATION DESIGN FOR A LANDSLIDE ON SR32, COCKE COUNTY, TENNESSEE

Abstract:
The slope at log mile 28.32 on Tennessee State Route 32 in Cocke County has a history of sliding dating back to the 1980’s or earlier. In July 2023, triggered by heavy rains, the north end of the site began to subside. After an unsuccessful attempt to reconfigure drainage and patch the pavement, Tennessee Department of Transportation (TDOT) Geotechnical Engineering Unit engineers decided that the entire length of the unstable slope needed mitigation. To protect the stable inside lane of the roadway while determining mitigation options, TDOT opted for a two-pronged approach: temporary shoring and long-term mitigation. The northern portion of the slope was shored up with a 14- to 16-foot high, three-tiered soil nail wall. Installation of the soil nails took place at the same time as the geotechnical investigation and instrumentation monitoring to determine the most feasible mitigation options.

Appalachian Landslide Consultants, PLLC (ALC) was the prime contractor that led a team of geologists and engineers from Landslide Technology and WSP Inc. The team conducted characterization of the site and landslide using remote sensing and aerial photography coupled with field observations, surface and subsurface soil and rock observations, and analyses of the slope inclinometer and vibrating wire piezometer data.

After the team recommended a variety of mitigation options, TDOT chose a soldier pile and lagging wall that is anchored into the underlying bedrock. They commissioned a second round of drilling operations to collect information that would provide the retaining wall contractor with a better understanding of the subsurface for anchor and pile installation. The ALC team presented these findings and recommendations for retaining wall design and specifications to be used by the contractor.

Session 16:

Megan Palmer

LANDSLIDE SUSCEPTIBLE SLOPES AND TREE RING PATTERN, A CASE STUDY FROM EAST TENNESSEE

Abstract:
Landslides are common along the rolling hills and escarpments of the Cumberland Plateau in East Tennessee and have impacted the roadway infrastructure, including State Route (SR) 116 in Anderson and Morgan counties, TN. Tennessee Department of Transportation (TDOT) continues to monitor and remediate unstable hillslopes along SR 116 for decades and will benefit from a landslide susceptibility map of the region. This study has predicted the locations of susceptible hillslopes using statistical models: forest-based classification and logistic regression in the New River Basin that encircles the SR 116. This study also evaluated the tree growth ring patterns in landslide susceptible areas. One hundred and ten landslide locations were identified with Tennessee LiDAR data, and 50% were field verified. Geomorphic variables used in the model preparation included annual rainfall, distance from streams, elevation, slope angle, bedrock geology, landcover, soil type, and topographic curvature. Forest-based classification indicated annual rainfall was the most important factor in landslide susceptibility, followed by distance to stream and bedrock geology, with 84.5% correctness in the model's performance. Logistic regression indicated all geomorphic variables except soil type, landcover, and curvature contributed to the landslide. The logistic regression model produced 73.6% overall correctness with a Receiver Operating Characteristic of 0.676. The study found areas of varying landslide susceptibility based on geomorphic factors. Additionally, from the landslide prone areas, nine bent trees were sampled through tree coring, the cores mounted, sanded, tree ring eccentricity was calculated and compared with the tree ring eccentricity from three trees in non-landslide areas. The percentage recovery rate for tree ring core extractions had a mean of 81.3%. All nine tree rings showed moderate to high eccentricity, hinting that tree ring eccentricity can provide meaningful information about hillslope movement. However, more extensive research is needed to study the effect of landslides on tree growth patterns.

Session 17:

Arpita Nandi

PROBABILISTIC ROCK SLOPE HAZARD ASSESSMENT IN ACID-PRODUCING ROADWAY CORRIDORS

Abstract:

The first step in geotechnical asset management is to create an inventory of unstable slopes along major transportation corridors. Rock slope stability problems are common along the most traveled roadway corridors in Great Smoky Mountains National Park (GRSM), often initiated in highly weathered, fractured metasedimentary rocks. This study used the Unstable Slope Management Program for Federal Land Management Agencies protocols to create an unstable rock slope inventory and evaluate hazards and risks for 285 rock slopes along 243.67 km of roadway. To identify unstable slope hotspots, Kernel Density Estimation was used, and fourteen sites were chosen for site-specific investigations to evaluate potential impacts of discrete unstable slopes along major roadways. Two-dimensional probabilistic rockfall simulations and Acid Base Accounting tests were used to predict rockfall pathways and evaluate the acid-producing potential of rocks. Simulations revealed that rock material would likely enter the roadway at all fourteen sites. Acid Base Accounting test results indicate that the influence of Acid Rock Drainage on rockfall outcomes is generally confined to slaty rocks of the Anakeesta Fm. and graphitic schist of the Wehutty Fm. This research presents an approach for prioritizing areas for site-specific investigations with the aim of improving safety in GRSM. Mitigation strategies for rockfall can be developed by widening ditches, installing barriers, and encapsulating acidic rockfall material.

Session 18:

Bryan Radabaugh

US-340 ROCKFALL MITGATION PROJECT – WEDGED BETWEEN 3 STATES, THE POTOMAC RIVER AND THE BLUE RIDGE MOUNTAINS

Abstract:
The US 340 Rockfall Mitigation project, located in Jefferson County, WV, addressed critical rockfall challenges in the Loudoun Heights region of Harper's Ferry National Historical Park. This high-traffic (>24,000 VPD) 2 lane corridor serving local, commuter, and truck traffic from and through West Virginia, Virginia, and Maryland. The corridor faces rockfall hazards due to cut slopes from 1950s construction and natural erosion along the Shenandoah River. The existing conditions pose threats to public safety, impeding emergency response times and requiring continuous maintenance by the West Virginia Division of Transportation (WVDOT). Additionally, the Loudon Heights includes a trail network and overlook at the top of the slope with access from the Appalachian Trail. Agency collaboration between WVDOT, VDOT, MDOT, FHWA, and NPS were vital to the project planning and successful construction.
The project included a 22-mile detour involving routes in WV and VA as well as impacting traffic flows into MD. Access Limited Construction (ALC), a geohazard mitigation specialist, collaborated with Triton Construction, WVDOT, HDR Engineering (WVDOT's engineer of record), Ice Engineering (WVDOT's inspection Team) and Infinite Consulting and Engineering, respectively, to implement comprehensive rockfall protection and stabilization measures. ALC incorporated safety and maintenance scaling techniques and constructed advanced rockfall protection systems provided by GeoBrugg North America LLC on three slopes along US-340. Access Limited teamed with Infinite Engineering, LLC. to complete final design of rockfall systems. Rockfall slope drape, rockfall attenuator barrier, rockfall barrier, rock overhang removal and localized rock bolting were strategically deployed to stabilize slopes and mitigate the risk of potential rockfalls. The integration of technology, including horizontal drain installation, added an extra layer of protection. The ALC and Triton Construction team ensured a seamless integration of geohazard expertise and construction proficiency. ALC completed approximately ½ mile of rockfall mitigation measures up to 300 feet above the roadway complimenting Triton's efforts to resurface the project limits, complete sign replacements and pavement markings all in less than 90 days. ALC successfully mitigated rockfall risks along the vital US 340 corridor on an accelerated schedule to enhance public safety.

Session 19:

Christine Comuso

STATE ROUTE 46 KNOWLTON TOWNSHIP, NEW JERSEY, AND THE MANUNKA CHUNK TUNNELS: MITIGATING A HISTORIC AND RECENT MASS MOVEMENT

Abstract:
In July of 2023, after several days of heavy rain, a mass movement was triggered along State Route 46 in Knowlton Township, New Jersey at the historic Manunka Chuck Railroad Tunnels. Both lanes of Rt 46 were closed and nearby dwellings experienced significant property damage. In addition to that, the adjacent Delaware River reached flood capacity, causing enhanced flooding which affected neighboring communities and roadways. Mitigation efforts commenced immediately following the slope failure, and included the removal of soil, rock, and debris from the failure zone, laying the slope back to a 2H:1V, and overlaying the slope with riprap. Additionally, the New Jersey Department of Transportation (NJDOT) designed a gabion basket wall on each side of the cleared slope to buttress the overburden and aid in minimizing future washout at the toe of slope.

After further investigation, evidence of a historic slope failure was discovered at this site. A desk top study provided additional insight on the Warren Railroad, which opened in the mid-1800s, as a means to transport freight and passengers along the western side of New Jersey to Pennsylvania and Delaware. A major flooding event in 1913 subsequently damaged the rail system, and caused the freight station and operator tower, along with portions of the slope, to collapse. The Warren Railroad officially closed in 1948 due to additional damage to the remaining rail and tunnels. Both the historic and July 2023 mass movement will be discussed in detail along with the local geology and the emergency response efforts that were performed to remediate this slope.

Session 20:

Ross Cutts

GEOSETTA

Abstract:

This presentation will delve into the opportunities and strategies available to Departments of Transportation (DOTs) once their public data is organized within Geosetta. We will explore how the digitization and analysis of previously inaccessible geotechnical logs can significantly enhance infrastructure planning and decision-making. This advancement not only improves current project management but also opens avenues for future data management strategies. A key aspect of our discussion will be the implementation of the DIGGS standard, a critical element for consistent and accurate data exchange. This standard signifies a move towards a more collaborative and unified approach in tackling infrastructure challenges, particularly geohazards. Our session is designed to highlight how Geosetta, empowered by DIGGS, provides DOTs with effective tools for geohazard mitigation. We will emphasize the vital role of integrated geotechnical data in boosting infrastructure safety and enhancing resilience against geohazards.

Session 21:

Evan W. Filion

LEVERAGING GEOPHYSICS FOR DATA DRIVEN DECISION-MAKING: GEOHAZARD RISK ASSESSMENT, DESIGN-BUILD, AND BUDGETING

Abstract:
Unknown geohazards often result in unanticipated costs during construction and can present unforeseen failures post-development. One of the most difficult tasks for site development and construction planning at locations with higher geohazard risk is adequately characterizing potential geohazards and responsibly allocating costs for addressing these hazards early in the project development phase. Failure to address these hazards early on may lead to complications or structural failure during construction or after final site development. An efficient way to reduce or eliminate many site development unknowns is through measuring and interpreting the material properties of the subsurface through the use of non-invasive geophysical surveying. ARM Geophysics has developed a specialty for integrating geophysical survey results with those from traditional invasive geotechnical analyses (i.e., soil borings and rock cores). This combination of datasets enables us to determine the character and spatial distribution of geohazard risk and to identify localized subsurface features that may require further investigation or specific mitigation efforts. This technical presentation will outline the workflow of leveraging geophysical survey results for data-driven decision making and risk evaluation to support design, construction, and budget estimation. We will discuss recent project examples where this workflow proved critical to timely decision making for unique geohazards encountered in the design phase, construction phase, and post-development phase (i.e., structural failure).

Session 22:

Robert McSweeney

A MULTI-STAGE FIELD AND MODELING APPROACH FOR INVENTORY AND MONITORING OF ACTIVE SOIL SLOPE GEOTECHNICAL ASSETS ALONG TENNESSEE HIGHWAYS

Abstract:
Recent improved tools and methods for geotechnical asset management (GAM) indicate a need for updated slope hazard management practices along highways. Statewide slope asset inventories can benefit from mobile GIS tools and standardized workflows based on the 2019 federal Unstable Slope Management Program (USMP). In this project, current best practices were reviewed for hazard and risk assessment protocols, mobile GIS inventory tools, and slope monitoring with unmanned aerial systems (UAS). The findings were applied in developing a comprehensive approach to statewide soil slope management for use by Tennessee Department of Transportation (TDOT). The study objectives were to (i) adopt a soil slope rating system modified for Tennessee roadways based on the federal USMP, (ii) create and test a digital mobile USMP survey form with Survey123, and (iii) perform one-year UAS monitoring and limit equilibrium analysis for selected hazardous slopes. The resulting Tennessee USMP scheme calculates hazard and risk ratings for soil slopes assets according to 55 user input criteria. The Survey123 USMP form was coded to automatically generate scores and create GIS records in an Esri cloud database appended with site data, photos, field notes, and hazard and risk ratings. A field trial of the system generated twenty-two slope ratings with USMP scores ranging from 369 (Fair) to 1104 (Poor). Six high-risk sites were selected for UAS monitoring with data collection flights performed in leaf-off conditions in 2023 and 2024. These produced a one-year time series of digital elevation models (DEMs), orthoimages, and raster derivatives, which were compared to existing 2016 LiDAR to identify slope movements and map emergent landslide features. Elevation profiles were extracted from DEMs to produce cross-sections for limit equilibrium modeling of predicted slope failures. This project presents a feasible and effective multi-step approach for improving slope assessment, inventory, monitoring, and GIS data management for soil slope assets along Tennessee highways.

Session 23:

Robert K. Denton Jr.

THE DEVELOPMENT OF ASTM D8512-23, "STANDARD PRACTICE FOR PRELIMINARY KARST TERRAIN ASSESSMENT FOR LAND DEVELOPMENT"

Abstract:

As a result of increased public interest and concerns regarding sinkholes, karst assessments began to be required by planning boards and zoning commissions as part of the process for approval and permitting of residential and commercial development in potential karst terrain. However, the manner in which these studies were conducted, and the necessary qualifications of the investigators, were typically not specified. Karst "assessments" ranged in nature from cursory sinkhole inventories and rudimentary geophysical subsurface investigation (often without any interpretation) to geologically detailed and highly technical "all-inclusive" investigations, none of which would assist municipal planners, regulators and/or developers in making well-informed decisions. Frequently the lack of any obvious surface karst features (e.g., sinkholes or caves) would result in a finding by the investigator(s) that there were "no karst issues" at a site. In contrast, investigators might recommend lengthy and detailed follow-up studies where none were warranted. Errors and misstatements of this sort made karst studies misleading and often useless for responsible development and land planning.

In response to this, a movement towards a karst assessment "standard practice" began to take form in the first decade of the 21st century. Notable examples were the Virginia Sinkhole Classification Scheme for Land Use Planning (Orndorff, et al, 2001), Kentucky Model Karst Ordinance (Currens, 2009), the Clarke County Virginia Sinkhole Ordinance (Code of Clarke County, 1997) and Karst Plan Requirements (Teetor, 2004), and Chapter 6 of the Loudoun County Virginia Facility Standards Manual – Limestone Overlay District (2010). Nevertheless, a national or international karst assessment standard practice was lacking.

Thus, the new ASTM standard practice D8512-23, embodies a set of basic elements that should be included in any karst site characterization. It must be emphasized that this approach is not to be considered the exclusive requisite elements in a karst assessment, but the essential starting points for a basic (preliminary) evaluation. Karst assessments will vary according to the needs of the user(s), the requirements embodied in local ordinances and the scope and nature of the proposed development. However, if performed in accord with this protocol, and reported accurately, the assessments should allow even a non-technical stakeholder to make informed decisions regarding the relative karst risk, the need for further studies, and potential corrective actions that site development may entail.

Session 24:

Joshua Zimmerman

IDENTIFYING AND MITIGATING SUBSIDENCE RISK TO INFRASTRUCTURE FROM ABANDONED, UNDERGROUND COAL MINES

Abstract:

There are an estimated ~240,000 abandoned coal mines across the United States dating back to the early 18th century. Many of these mines are underground, and in the Appalachian region, the surrounding communities have developed homes, roads, utilities, and other infrastructure in the overlying areas. Every year, the supports of these mines continue to degrade, weakening the overlying bedrock. As degradation of the rock progresses, it can result in sudden subsidence or sinkhole events at the ground surface, which can be dozens of feet wide and deep and induce slope stability issues in the surrounding area. This poses a huge safety risk to the overlying communities and can significantly damage transportation corridors, resulting in long-term closure, injury, or death to residents. Dozens of these events occur yearly and are often poorly understood by local governmental bodies, which are frequently ill-equipped to address the problem on a large scale.

This presentation presents historical approaches that have been used to analyze, assess, and mitigate the subsidence risk from these abandoned mines and how modern investigation and mitigation techniques have improved the detection and mitigation of these risks on a site-by-site basis. This includes the discussion on subsurface geophysics, exploratory drilling programs, laboratory testing, innovative infilling design, and the utilization of Geographic Information Systems to determine mine extents and potential hazard areas/levels of risk.

Session 25: Special Session

Skip Watts

THE GEOLOGY OF NATURAL BRIDGE AND ITS UNIQUE ENGINEERING CHALLENGES

Image: William James Bennett, 1835
(National Gallery of Art)