SPR RESEARCH PROGRAM
SECOND-STAGE PROPOSAL SUMMARY

PROBLEM NUMBER AND TITLE

27-04: Phase 2: Leveraging Surface Monitoring to Guide Emergency Response and Long-Term Strategic Planning

PROBLEM SUMMARY

Conventional monitoring, site investigation, and assessment of landslides for mitigation often requires drilling along with installation of piezometers and inclinometers which is not always feasible due to the significant expense and safety risk of drilling on an active landslide, short lifespan of subsurface instruments, and difficult site access for drilling. **A continued critical need exists to expand the capabilities of near-real-time surface monitoring of ground movements** for (1) existing, surface monitored landslides to gather longer time-series of landslide response to variable wet seasons, (2) newly-monitored landslides that reflect uncharacterized climatic and geologic conditions to model the spectrum of landslide impacts to ODOT right-of-way, and (3) landslide events that occur that require rapid response and quantitative information for decision-making. Such data is key for evaluating highway safety, repair and mitigation needs, and strategies for reopening after failure. The absence of this information places critical infrastructure and travelers at risk.

ODOT OBJECTIVES

We propose expanded surface monitoring of landslides traversing critical ODOT lifelines that capture the variability of geologic and climatic settings together with the expansion of existing monitoring systems at problematic landslides to model the role of climatic variability as a driver of landslide movements. This approach would leverage ODOT's investment in surface monitoring technology, which has thus far been directly and indirectly used by ODOT to make decisions regarding highway closures, reopening, emergency response, and to observe the efficacy of mitigation efforts. Considering the success and utility of this monitoring approach thus far, we envision this research will advance surface monitoring operationalization for critical highway locations and enable prioritized deployment of this low-cost technology for ODOT.

BENEFITS

The data from this expanded monitoring would inform important ODOT planning activities and research questions. For planning purposes, this data has already demonstrated benefits for emergency response to landslide events, planning around mitigation plans and Goal 18 discussions, maintenance considerations, and reduced ODOT time for inspection of landslides. Expanding these efforts would further support ODOT's ability to monitor problematic slopes and make informed decisions regarding prioritization, planning, and sustaining mobility.

SCHEDULE, BUDGET AND AGENCY SUPPORT

Estimated Project Length: 42 months.
Estimated Project Budget: $485,000
ODOT Support: Susan Ortiz (State Geotechnical Engineer), Darin Neavoll (Region 3 Manager), Savanah Crawford (Region 2 Manager), Mike Nichols (State Surveyor)

FOR MORE INFORMATION

For additional detail, please see the complete STAGE 2 RESEARCH PROBLEM STATEMENT online at:
https://www.oregon.gov/odot/Programs/ResearchDocuments/27-04.pdf

SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2027

PROBLEM NUMBER AND TITLE

27-04: Phase 2: Leveraging Surface Monitoring to Guide Emergency Response and Long-Term Strategic Planning

RESEARCH PROBLEM STATEMENT

Landslides frequently affect right-of-way through slow movements that affect driver safety, result in road closures, or in some cases, accelerate towards collapse *(Figure 1)*. Much like any problem, evaluating the level of concern for landslide impacts requires monitoring and establishing a baseline for expected behavior. Unfortunately, conventional monitoring, site investigation and assessment of landslides for mitigation often requires drilling along with installation of piezometers and inclinometers but are not always feasible due to the significant expense of drilling, short lifespan of subsurface instruments, safety concerns about working on an active landslide, and difficult access. These restrictions result in only a small proportion of landslide-prone terrain having any level of characterization or monitoring.

Figure 1: Recent Landslide closing Hwy229 (ODOT)

Consequently, there is a continued critical need to expand the capabilities of near-real-time surface monitoring of ground movements for (1) existing, monitored landslides to gather longer time-series of landslide response to variable wet seasons, (2) newly-monitored landslides that reflect uncharacterized climatic and geologic conditions to extrapolate a spectrum of landslide impacts to ODOT right-of-way, and (3) landslide events that occur and require quantitative information for decision-making. Such data is key towards evaluating highway safety, need for repairs, approaches towards mitigation, and strategies for reopening after failure. The absence of this information places critical infrastructure and ultimately ODOT customers at risk.

Key advances in *in situ* GNSS surface monitoring technologies currently supported by ODOT have enabled near-real-time observation of ground movements, providing critical information regarding highway access, mitigation efficacy, and long-term landslide behavior at critical locations along ODOT lifelines. Along with an online interface for viewing near-real-time landslide movements (Figure 2; LandslideLink: landslidelink.github.io), ODOT professionals and planners have used this technology to strategize reopening at the Arizona Inn Landslide along US101, monitor movements and mitigation efficacy at US26 MP13 where ground movements have resulted in accidents and delays, monitor movements after the OR229 landslide, and provide information on the relative activity (or lack thereof) of eleven other landslides traversing lifelines across the state. Data from this monitoring investment is being used for discussion in Goal 18 exceptions along erosion-prone, unstable right-of-way at several landslide locations along US101. However, this strategic monitoring is (1) not yet at the scale to provide relevant data on many other problematic landslides traversing key lifelines in different geologic and climatic settings, (2) does not have sufficient time series to consider long-term changes in behavior from climatic variability, (3) has had limited testing

opportunities for rapid, emergency response (OR229 and Arizona Inn landslides only thus far), and (4) has not been incorporated into a simplified, but effective public-facing mechanism that can provide necessary data to planners inside and potentially outside of ODOT to justify mitigation strategies.

RESEARCH OBJECTIVES

We propose expanded surface monitoring of landslides traversing critical ODOT lifelines that capture the variability of geologic and climatic settings, and expansion of existing monitoring systems at problematic landslides to glean the role of climatic variability as a driver of landslide movements. This approach would leverage ODOT's investment in surface monitoring technology, which has thus far been directly and indirectly used by planners inside and outside of ODOT to make decisions regarding highway closures, reopening, emergency response and to observe the efficacy of mitigation. Considering the success and utility of this monitoring approach thus far, we envision deployment of this surface monitoring technology along other critical State highway locations. This expansion would be implemented for (1) existing, unmonitored slope failures in a variety of geologic and climatic settings, (2) expanded monitoring and upkeep of existing instrumentation at monitored, problematic landslides, and (3) creation of a suite of "go kits" for rapid, temporary emergency monitoring of slope failures that could guide reopening strategies and mitigation efficacy, such as that used for the OR229 landslide. These data would be processed through the cloud and immediately usable through development of an augmented version of LandslideLink, which would be modified to provide relevant monitoring data and early warning of movement.

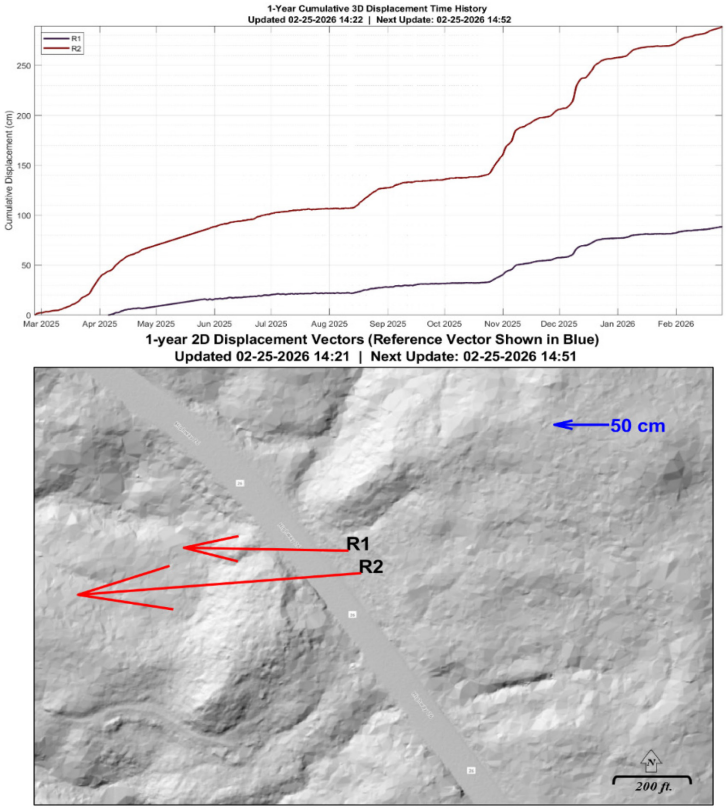

Figure 2: Hwy 26, MP 13. Top panel: 1-Year Cumulative 3D Displacement time series. Bottom Panel, displacement vectors.

Sustained and new monitoring would be directly used to create predictive tools to estimate timing and magnitude of ground movements given variability in weather conditions, different climatic regimes, different geologic settings, and considering the role of inter-annual variability in climate. The proposed expanded surface monitoring would provide quantitative characterization of similarities and differences as to how a diversity of landslide settings respond to disturbances. This directly useful as an index for evaluating landslide hazards in the diversity of unstable settings that are home to ODOT right-of-way, and empower planners to make decisions regarding near-real-time data or deploy instrumentation rapidly in the wake of a landslide emergency. This multi-faceted approach would leverage and expand on ODOT investments in near-real-time surface monitoring and enhance prioritization of ODOT resources, both for emergency management and long-term planning strategies.

WORK TASKS, COST ESTIMATE AND DURATION

The following tasks are envisioned for this research, which will leverage and expand on existing monitoring of slope failures from SPR808 and SPR878:

1. Review current approaches for monitoring landslide movements using GNSS systems surface monitoring systems and existing implementation for ODOT. Provide guidance on the appropriate application for monitoring existing and new failures, along with applications of technology for emergency monitoring.

2. Install GNSS units to additional problematic landslides with ODOT site guidance. Particular focus will be

placed on sites that are affecting ODOT right-of-way and capturing a diversity of geologic and climatic settings that are not well-represented in current monitoring (Columbia River Gorge, Cascades, several portions of US101 and Valley-Coast lifelines). Further, create sets of rapidly deployable systems for emergency deployment on an *ad hoc* basis based on demand from ODOT projects and needs. This will enable both consideration of landslide behavior in various, uncharacterized geologic and climatic settings and characterization of post-event landslide response.
3. Expand and upgrade existing monitoring at existing, problematic landslides. This will expand the length and quality of time-series of landslide responses considering variability in climate at storm-, seasonal-, and inter-annual scales. This will enable improved predictive models for characterizing when landslides move, how much movement is expected, and uncertainties considering climatic forcing.
4. Tailor web tool for multiple audiences, public-facing systems guiding policy planning. Provide documentation for field application of supplementary surface monitoring techniques.
5. Host hands-on training course for ODOT professionals in the tools including sensor installation, monitoring, data analysis, and implementation for after the project ends.
Key Deliverables: Installation of surface monitoring on 8-10 problematic landslides. Expand monitoring network to span more climatic and geologic settings, providing key, near-real-time monitoring data to ODOT professionals about problematic landslides impacting highways.

- Development of 3-4 "go-kits" for emergency monitoring of ground movements. Work with ODOT professionals for deployment and capturing data critical to decision-making post-event.
- Sustaining monitoring and data collection from 15 existing stations, including those used to monitor recent, problematic landslides that have resulted in extensive maintenance costs and closures.
- Expansion of indices to characterize the timing and magnitude of landslide movements. Provide indices for response based on landslide size and geologic setting.
- Expansion of near-real-time webviewing for monitoring landslide movements on an online interface.

Estimated Project Length: 42 months.
Estimated Project Budget: $485,000

EXPECTED ODOT IMPLEMENTATION ACTIONS

Implementation includes (1) creation and sharing of landslide monitoring data through the existing webviewer and downloadable data hosted by ODOT or other public interfaces, (2) sharing of raw data with ODOT professionals at key times, (3) development of easy-to-use precipitation-movement indices to guide interpretation of landslide response in various Oregon geologic and climatic settings. Current systems are directly being used by ODOT professionals to make decisions about key landslides with respect to Goal 18 The surface monitoring systems, data, and workflow can be handed off to ODOT's Engineering Geology/Geotechnical team as well as Geometronics along with training and guidance as desired.

POTENTIAL BENEFITS

The data from this expanded monitoring would inform important ODOT planning activities and research questions. For planning purposes, this data has already demonstrated benefits for emergency response to landslide events, planning around mitigation plans and Goal 18 discussions, maintenance considerations, and reduced ODOT time for inspection of landslides. Expanding these efforts would further support ODOT's ability to monitor problematic slopes and make informed decisions regarding prioritization, planning, and sustaining mobility.

PEOPLE

ODOT champion(s): Susan Ortiz (State Geotechnical Engineer), Darin Neavoll (Region 3 Manager), Savanah Crawford (Region 2 Manager), Mike Nichols (State Surveyor)

Problem Statement Contributors: Ben Leshchinsky (OSU), Curran Mohney (Engineering Geologist Lead), Kira Glover-Cutter (Principal Research Analyst)

STAFF REVIEW PAGE

LITERATURE CHECK

TRID&RIP

☒ A review of TRID & RIP databases found no existing research that answers the research question

ODOT DECISION LENSES

Climate: This problem statement directly supports measurement and monitoring of natural hazards (landslides and coastal erosion) that are very sensitive to climate variability and are highly disruptive to ODOT infrastructure. These data have already demonstrated benefits for resilience, e.g. guiding reopening of Highway 101 after a landslide surge event, providing information on a problematic slope failure (and its mitigation) that has resulted in delays and accidents on HWY26 (a lifeline). It has also provided information to planners focusing on mitigation of erosion-prone parts of HWY101. Climate is inherently the driver of these ground movements, and this technology has thus far empowered ODOT and other relevant personnel to monitor numerous, hazardous sites with less personnel time.

Equity: This research is not focused on equity and will not include analysis of equity.

Safety: This research would expand and empower existing monitoring networks, the best available technology for precise and accurate near-real-time monitoring of ground movements, which have enabled planners to make decisions about road closures, speed limits, and delays. This benefits healthy and livable communities – particularly those dependent on singular lifelines, like coastal communities - by providing data behind reopening roads that when closed can turn a 30 minute trip to the doctor into a five-hour journey. The webviewer of this data has enabled communication to planners considering erosion mitigation options at vulnerable segments of Highway 101, which is critical for safe highway use and connectivity between coastal communities. These data, if public-facing, could provide opportunities for collaboration and communication between ODOT, other agencies, and the public, providing a means for justifying mitigation in strategic locations based on quantitative, real data. This work would leverage previous ODOT investments to expand on these results.

TECHNOLOGY & DATA ASSESSMENT

☒ No Identified T&D output

☒ At the end of this project, the implementing unit(s) within ODOT will need to coordinate the adoption of new technology or data in order to realize the full potential of this research.

CROSS-AGENCY IMPACTS

- List ODOT partners or impacted units. Geotechnical, Engineering Geology, Hazmat, Engineering Automation, Maintenance

- Identify any issues of concern raised by an ODOT partners. Note expected mitigation that addresses these concerns. No