SPR RESEARCH PROGRAM
SECOND-STAGE PROPOSAL SUMMARY

PROBLEM NUMBER AND TITLE
25-14: Proactive Strategy for Resilient Corridors: Landslide Prioritization, Planning, and Management Tool

PROBLEM SUMMARY
Landslides are frequent hazards that affect Oregon highway infrastructure, resulting in negative economic, environmental, and social impacts for Oregon communities. Goals from the Oregon Transportation Plan (OTP) include proactive preparation of lifeline routes to reduce possible hazards before events occur, starting with the strategy to map and assess multi-hazard threats to the transportation system. While ODOT's *Climate Adaptation and Resilience Roadmap* and *Climate Hazard Risk Map* identify resilience corridors to help prioritize investment, a higher resolution analysis to prioritize between sites along these corridors is needed for development of compelling business cases for investment and competitive funding opportunities. ODOT is already under financial strain reacting to landslide hazards as they happen. Given that these hazards are projected to increase in frequency/magnitude with climate change, reactive approaches for returning to site functionality will only exacerbate ODOT's fiscally constrained reality. High resolution landslide hazard site vulnerability analysis followed by site prioritization will provide planning and management teams practical science-based investment strategies aimed at improving safety, ensuring working emergency lifeline routes, preventing vulnerable community isolation, and reducing rising maintenance costs for hazard removal.

ODOT OBJECTIVES
This research will develop a corridor-wide landslide prioritization tool for optimized site selection for proactive intervention and investment, focusing on ODOT's resilience corridors. The prioritization matrix will include climate-driven landslide hazard and vulnerability assessments that incorporate economic and equity criteria, together with pre-disaster mitigation options to enable feasible management strategies. This work will leverage SPR808, which established a framework for evaluation of landslide susceptibility, hazard, and risk at large spatial scales under extreme events (seismicity and heavy precipitation), as well as SPR843, which developed a highway hazard vulnerability matrix for site prioritization. Tools from SPR808/SPR843 as well as landslide monitoring data from SPR807/SPR878 make validation and projections of landslide activity with climate change achievable through complementary modeling. Expected deliverables include: prioritization matrix and corridor site scores, interactive webGIS planning maps, and economic analyses of top sites.

BENEFITS
There are currently no means of prioritizing which landslides have the most potential for accelerated activity owing to climate change. Developing and expanding tools that enable assessment of potential landslide impacts from climate change and current conditions would enable prioritization of mitigation, project selection, emergency planning, and prevention of vulnerable community isolation. Tools developed from this research are anticipated to help position ODOT to take full advantage of funding opportunities as they arise by identifying corridor site locations at the highest risk of disruption from potential climate impacts.

SCHEDULE, BUDGET AND AGENCY SUPPORT
Estimated Project Length: **42** months. ***Estimated Project Budget:*** **$475,000.**
ODOT Support: **Curran Mohney (Eng. Geology Lead), Paris Edwards (Climate Policy Lead), Darrin Neavoll (Region 3 Manager), Savannah Crawford (Region 2 Manager**)

FOR MORE INFORMATION
For additional detail, please see the complete STAGE 2 RESEARCH PROBLEM STATEMENT online at:
https://www.oregon.gov/odot/Programs/ResearchDocuments/25-14.pdf

SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2025

PROBLEM NUMBER AND TITLE

25-14: Proactive Strategy for Resilient Corridors: Landslide Prioritization, Planning, and Management Tool

RESEARCH PROBLEM STATEMENT

Figure 1: Example of winter deep seated landslide failure and impact to road (Arizona Inn January 2023).

Landslides are frequent hazards that affect the operation, maintenance, and construction of Oregon highways, resulting in negative economic, environmental, and social impacts for Oregon communities. Deep-seated, slow-moving landslides driven by rainfall are more often the primary landslide-related delay for Oregon's traveling public, requiring continued maintenance, repair, and expense to manage as a negative transportation asset (Figure 1). The most problematic causative factor for these landslides stems from prolonged rainfall, particularly throughout the Oregon Coast, Coast Range, and Cascades. This problem is likely to worsen with increasingly wet winters, less snow and more rain, and more extreme atmospheric river events stemming from shifts in climate. Though most landslides are climate driven, quantitative projections of climate impacts on the activity of these landslides do not exist. Current methods for predicting landslide behavior rely on historic landslide behavior. What is unknown includes the relationship between a changing climate and the potential change in behavior of a landslide (magnitude, velocity, frequency of movements), as well as the potential impact to the community for each hazard site (delays, economy, evacuation options, community isolation). Though ODOT has identified resilience corridors that consider climate change, social disparity, and travel disruption potential[1], to achieve climate resilience, estimation of the least climate resilient landslides along a priority corridor is needed to build prioritized mitigation and management strategies. Without optimized mitigation and management strategies, climate and extreme weather impacts will increase, resulting in exorbitant compounding repair costs and potentially loss of route, isolation of vulnerable communities, economic decline, and in safety risks for the traveling public.

Goals from the Oregon Transportation Plan (OTP)[2] include proactive preparation of lifeline routes to reduce possible hazards before events occur, starting with the strategy to map and assess multi-hazard threats to the transportation system. ODOT's *Climate Adaptation and Resilience Roadmap*[1] and *Climate Hazard Risk Map*[3] identified priority resilience corridors for upkeep and investment using a three-tiered approach. Tier 1 ODOT priority corridors have the highest climate risk, highest social disparity, highest density of total historical events, and have a higher percentage of assets in poor or critical condition. The Tier 1 priority corridors account for 558 road miles and 593 vulnerable assets. While Tier 1 priority corridors have been highlighted for resiliency improvements, distinctions between landslide hazard impacts site-by-site are not available. Higher resolution analysis to prioritize between the most hazardous sites along these corridors is needed for planning, management, and development of compelling business cases for resilient investment and external funding. ODOT is already under financial strain reacting to landslide hazards as they happen. With the prediction that these hazards will likely increase in frequency and magnitude as Oregon's climate changes, reactive approaches for returning to site functionality will likely become both physically and fiscally constraining. Refined landslide hazard site prediction and vulnerability analysis followed by prioritization of sites that considers economic and equity impacts will provide planning and management teams viable and transparent science-based funding strategies to improve safety, ensure working lifeline routes for emergency scenarios, help prevent isolation of vulnerable communities, and reduce rising maintenance costs for hazard removal.

RESEARCH OBJECTIVES

This proposed research will develop a corridor wide landslide prioritization tool for optimized site selection for resiliency investment, focusing on ODOT's top resiliency priority corridors (Tier 1 and potentially Tier 2)[1]. The prioritization matrix will include climate driven landslide hazard and vulnerability assessments that incorporate economic and equity criteria, together with pre-disaster mitigation options to enable feasible management strategies. This work will leverage and expand on the success of SPR808, which established a framework for evaluation of landslide susceptibility, hazard, and risk at large spatial scales from extreme events such as heavy precipitation and seismic shaking, as well as SPR843, which developed a coastal highway hazard vulnerability matrix for site prioritization to build an initial prioritization strategy. Tools from SPR808 and SPR843 as well as landslide monitoring data from SPR807 and SPR878 will make validation and projections of landslide activity with climate change achievable through complementary modeling. Specifically, this research will develop a corridor-wide landslide assessment and resilience planning tool that (1) integrates seasonal hydrological conditions, historical rainfall data, groundwater modeling, and representative concentration pathway (RCP) scenarios for seasonal rainfall anomaly to characterize changes in landslide water balance, (2) uses large-scale inverse analyses and high-resolution lidar to analyze inventories of active, deep-seated landslides to provide realistic, spatially variable geotechnical and hydrological inputs for landslide activity, (3) uses forward projections of landslide movement considering back-analyzed geotechnical parameters and geometric properties, and (4) leverages highway fragility curves that describe acceptable thresholds of landslide movement in comparison to serviceability and impact to ODOT assets. Where available, use of remote sensing data, such as Sentinel-1 C-Band InSAR or lidar differencing would be used to supplement data on landslide activity. Through the completion of these tasks, tools that assess time-dependent likelihood of landslide movements traversing ODOT right-of-way will be implemented with traffic data and delay costs. Furthermore, a long-term map of projected changes in deep-seated landslide activity and associated impacts will be created for corridors with landslide inventories, enabling assessment of landslide impacts to (1) maintenance and repair costs and (2) impacts to connectivity for vulnerable communities under various climate change scenarios.

WORK TASKS, COST ESTIMATE AND DURATION

Expected project tasks include:

Task 1: *Data Review, Literature Review, and Development of a Research Methodology*. Build upon prior SPR research projects 807, 808, 843, the recently initiated surface monitoring project 878, together with current literature to develop and deliver the Research Methodology for creating a prioritization matrix for Tier 1 resilience corridors (and potentially Tier 2).

Task 2: *Create Technical Advisory Committee (TAC) and TAC Meeting Schedule*. Success of this research effort depends on input from an interdisciplinary TAC that includes geo professionals, planners, remote sensing professionals, climate professionals and Region representation. The TAC will meet at least yearly and will assist in implementation of the work if successful.

Task 3: *Expand inverse analyses of landslide inventories* to attain first order estimates of geotechnical properties for corridors throughout the Oregon Coast Range, Oregon Coast and Cascade Ranges. Corroborate inverse analyses with relevant geotechnical data from ODOT, prior SPR research products, and other relevant data sources. Preliminary back-analyses have been performed on several thousand landslides[4]. These landslide inventories are openly available (e.g. Statewide Landslide Inventory Database of Oregon, SLIDO, developed by DOGAMI), ODOT or through manual mapping performed by the research team on select corridors. These analyses could be performed for all landslide types (e.g. shallow- and deep-seated landslides), but deep-seated landslides will be a focus as their activity often results in frequent maintenance and highway serviceability issues.

Task 4: *Integrate regional-scale hydrological models to constrain 30-year normal groundwater conditions and thereafter scale hydrological normal considering various RCP projections*. Tools, such as ParFlow, now enable simulation of variably saturated groundwater conditions necessary to evaluate hydrological forcing on these landslides and normalization of landslide activity. These data can be constrained in more populated regions with monitoring wells from the Oregon Water Resources Department or using remote sensing data.

Task 5: Advance landslide displacement analyses to integrate available landslide activity data mechanical properties, associated topography, landslide depth, and hydrological conditions to establish expected normal and projected climate change-driven movement for active, deep-seated landslides traversing ODOT right-of-way. Use fragility functions to establish implications of repair and maintenance costs, closure times and traffic impacts using TPAU and ODOT Unstable Slopes Database. Current and projected landslide activity and impacts will be used to evaluate the resiliency level of corridors. Suggested pilot corridors include Highway 20 (Coast Range and Cascades), Highway 30 (west of Portland), Highway 84, and Highway 101 (South Coast). Special emphasis will be placed on lifeline corridors (and priority Tier 1) with ODOT guidance.

Task 6: Create and deliver interactive webGIS maps that utilize the developed prioritization matrix for corridor wide assessment within an area of interest. Provide estimates of projected climate change-driven changes in deep-seated landslide activity along ODOT right-of-way. Using TPAU and fragility data, establish which hazard areas along corridors will be most impacted by climate change-driven landslide movements to enable planners and engineers with scenario-based data regarding resilience of selected ODOT corridors.

Task 7: Summarize and deliver tools, final report, and overview of models, methods and implications to ODOT geologists, engineers, and planners. Documentation and training materials will be developed to facilitate adaptation and implementation. Projected maps considering climate impacts will be provided in digital maps as well as digital datasets for ODOT use.

Key Deliverables: Prioritization matrix and site scores by corridor, interactive webGIS planning maps, and planning level mitigation overview and economic analyses of top sites.

Estimated Project Length: **42** months. ***Estimated Project Budget:*** **$475,000**

IMPLEMENTATION

Deliverables from this research will be used to help support and supplement implementation of the Climate Adaptation and Resilience Roadmap[1], the Climate Hazard Risk Map[3], and will be provided as GIS layers for ODOT's FACS STIP GIS tool for use by the Climate Office, Region Planners, District Managers, and the Unstable Slopes Program. Rollout of these tools will include an interactive workshop with key individuals from each group facilitated by collaboration of the Research Coordinator and the Climate Office. Findings will also be published as an ODOT Final Report with interactive Appendices and a public facing WebGIS tool. External peer-review publication and conference presentations for academic and applied research findings are also anticipated.

POTENTIAL BENEFITS

There is currently no means of prioritizing which deep-seated landslides have the most potential for accelerated activity owing to climate change. Developing and expanding tools that enable assessment of potential landslide impacts from climate change would enable more equitable prioritization of mitigation, project selection, and emergency planning. Tools developed from this research are anticipated to help position ODOT to take full advantage of funding opportunities as they arise by identifying corridor site locations at the highest risk of disruption from potential climate impacts. While this research effort will focus on top priority resilience corridors identified as Tier 1 and potentially Tier 2, the methods and tools developed can be subsequently applied to better evaluate potential resiliency impact infrastructure investments along Tier 3[1] priority corridors.

PEOPLE

ODOT champion(s): **Curran Mohney (Geo), Paris Edwards (CO), Darrin Neavoll (R3), Savannah Crawford (R2)**
Problem Statement Contributors: OSU B. Leshchinsky, ODOT: Curran Mohney, Kat Silva, Kira Glover-Cutter

REFERENCES

1-Climate Adaptation and Resilience Roadmap; 2-Oregon Transportation Plan (2023); 3-Climate Hazard Risk Map; 4-Alberti, S., Leshchinsky, B., et al. (2022). Nature Communications, 13(1), 6049.

STAFF REVIEW PAGE

Literature Check

TRID&RIP

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

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 stakeholders

- List ODOT partners or impacted units.

  GEEGH: Geotechnical Engineering, Engineering Geology, Hazmat (Highway Division, Eng. and Tech Services)
  Regions: Managers (2 and 3 especially), Geos, Planners, Maintenance Districts
  GIS (Planning, Data, Analysis Division)
  Geometronics (Highway Division, Eng and Tech Services)

- Identify any issues of concern raised by an ODOT partners. Note expected mitigation that addresses these concerns.

  Ensure Region TAC membership to inform/advice project team.