Research Project Work Plan

for

COASTAL LANDSLIDE AND BLUFF RETREAT MONITORING FOR CLIMATE CHANGE ADAPTATION AND TARGETED RISK ASSESSMENT

SPR 807

Submitted by

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1.0 Identification

1.1 Organizations Sponsoring Research

Oregon Department of Transportation (ODOT)
Research Section
555 13th Street NE
Salem, OR 97301 Phone: (503) 986-2700

Federal Highway Administration (FHWA)
Washington, D.C. 20590

1.2 Principal Investigator

Michael J. Olsen, Associate Professor
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1.3 Associate Investigator(s)

Ben Leshchinsky, Assistant Professor
College of Forestry
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1.4 Technical Advisory Committee (TAC) Members

Kira Glover-Cutter (ODOT), Chair; Curran Mohney (ODOT); Geoff Crook (ODOT); Katie Castelli (ODOT); Gary Pischke (ODOT); Mike Brinton (ODOT); and Adam Young (Scripps Institution of Oceanography)

1.5 Friends of the Committee

Bernie Kleutsch (ODOT, Geo/Hydro/Env Manager Region 2)
Jim Collins (ODOT, Geo/Hydro/Env Manager Region 3)

1.6 Research Coordinator

Kira M. Glover-Cutter, Ph.D., ODOT Research Coordinator, Phone: 503-986-2851

1.7 Project Champion

Curran Mohney, ODOT Geotechnical

2.0 Problem Statement

Rising seas and extreme coastal weather events pose significant risks for the safety, reliability, and effectiveness of ODOT infrastructure and operations along the coast. Coastal landslides and shore cliff erosion are particularly sensitive to climate drivers with sea-level rise, storm frequency and intensity, wave scour, and rainfall amounts influencing landslide movement and coastal bluff erosion. Coastal bluff retreat rate is also directly proportional to climate change effects and in many locations directly threatens disruption of ODOT's coastal infrastructure. Though landslides and coastal bluff erosion are common processes that affect coastal highways every year, bluff retreat and rate of movement are not well-characterized. In 2014, ODOT's Coastal Climate Change Vulnerability Assessment identified this limited information regarding coastal bluff retreat as an issue of concern.

Considering that ODOT is designated as a lead implementation agency for the Governor's climate change adaptation priority, together with the observation that at least 26 sites totaling nearly 20 miles along Hwy 101 have already been identified as areas of concern, the need to assess landslides and coastal bluff retreat in terms of both magnitude and rate of movement and retreat will become increasingly critical. The rate and magnitude of bluff retreat with respect to slope morphology and underlying geology are essential measures to be used in prioritizing highway segments situated upon those bluffs. These parameters would allow the agency to both prioritize sites for repair and financially plan for mitigation projects that are timed to maximize the utility of the existing facility. In this regard, the agency already knows which areas are impacted by bluff retreat, but without sufficient resources to address all of these locations at once; it becomes critical to determine which areas have the shortest lifespan so that they can be prioritized for repair. Research to directly address this concern is needed in order to optimize ODOT infrastructure planning, secure lifeline routes, and address the climate change adaptation focus of the Oregon Transportation Commission work plan.

2.1 Background and Significance of Work

Previous coastal landslide research for ODOT includes investigation of the Johnson Creek Landslide and Arch Cape site in Lincoln and Clatsop counties, respectively. The Johnson Creek Landslide research study focused on the relationships between coastal bluff retreat, precipitation, and groundwater using standard survey methods to evaluate select cross-sectional areas of the coastal bluff at the toe of the landslide. A separate, brief analysis of the coastal bluff morphology of the Arch Cape site evaluated the use of terrestrial lidar (Light Detection and Ranging) technology for change detection. Compared to standard survey methods, terrestrial lidar provides a more accurate and efficient way to map, visualize, and quantify changes in coastal bluff erosion. Figure 1 shows an example surface model that can be derived from ground-based lidar data. Figure 2 provides an example of a change analysis. Figure 3 shows an example analysis that can be completed using a GIS-based tool TopCAT developed by the PIs, which can be adapted as necessary for this research.

Though aerial-based lidar surveys conducted by the U.S. Army Corps of Engineers and DOGAMI/Oregon LiDAR Consortium have been produced for coastal landscape-level

use, the resolution is insufficient for what is needed to accurately monitor coastal bluff retreat. These sources also do not sufficiently capture the steep or vertical bluff faces, the shape of which directly affects erosion rates and subsequent slope movements. Furthermore, these surveys are not conducted with a sufficient frequency to enable meaningful temporal resolution of coastal bluff degradation. This temporal and topographic resolution is of particular importance to better understanding the timing and behavior of successive movements of coastal slopes after large storms, rainfall and erosion events.

In summary, given the limited research on coastal landslide movement and bluff retreat with respect to changing climate drivers, an increasingly long-term and in-depth monitoring study with modeling potential is critical to enabling improved asset management decisions for ODOT, particularly in the face of climate change.

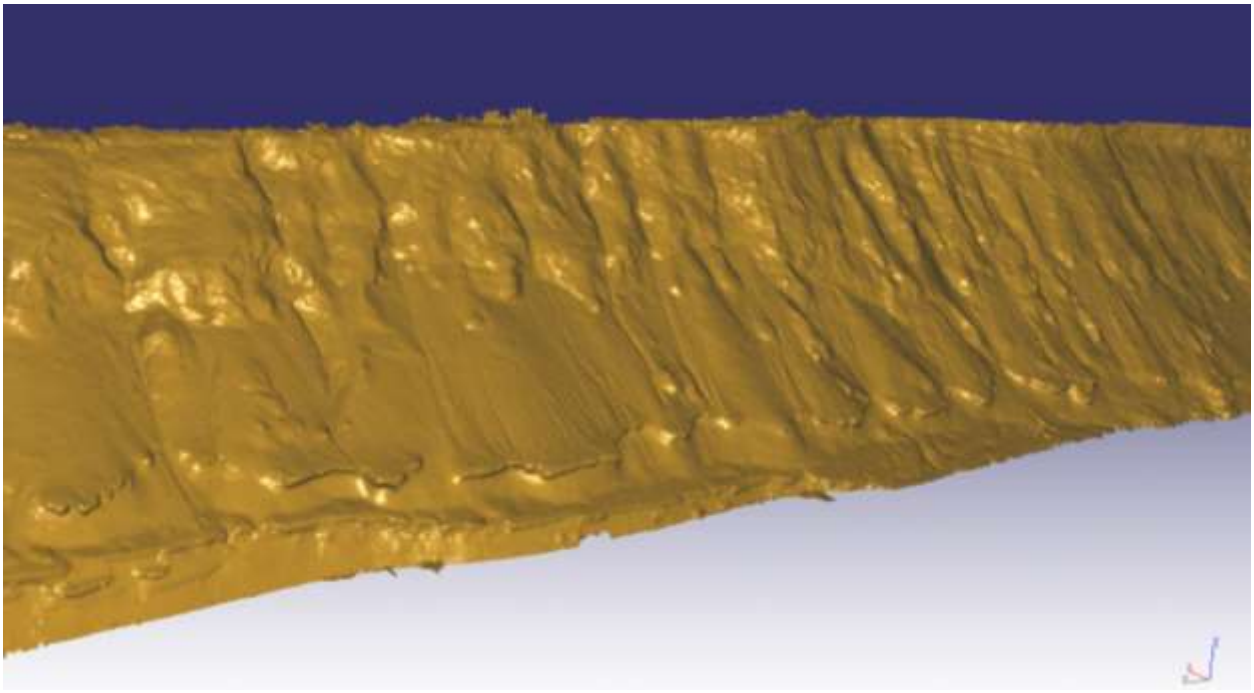

Figure 1. Example surface model with 5 cm resolution of seacliffs at Beverly Beach State Park derived with ground-based lidar.

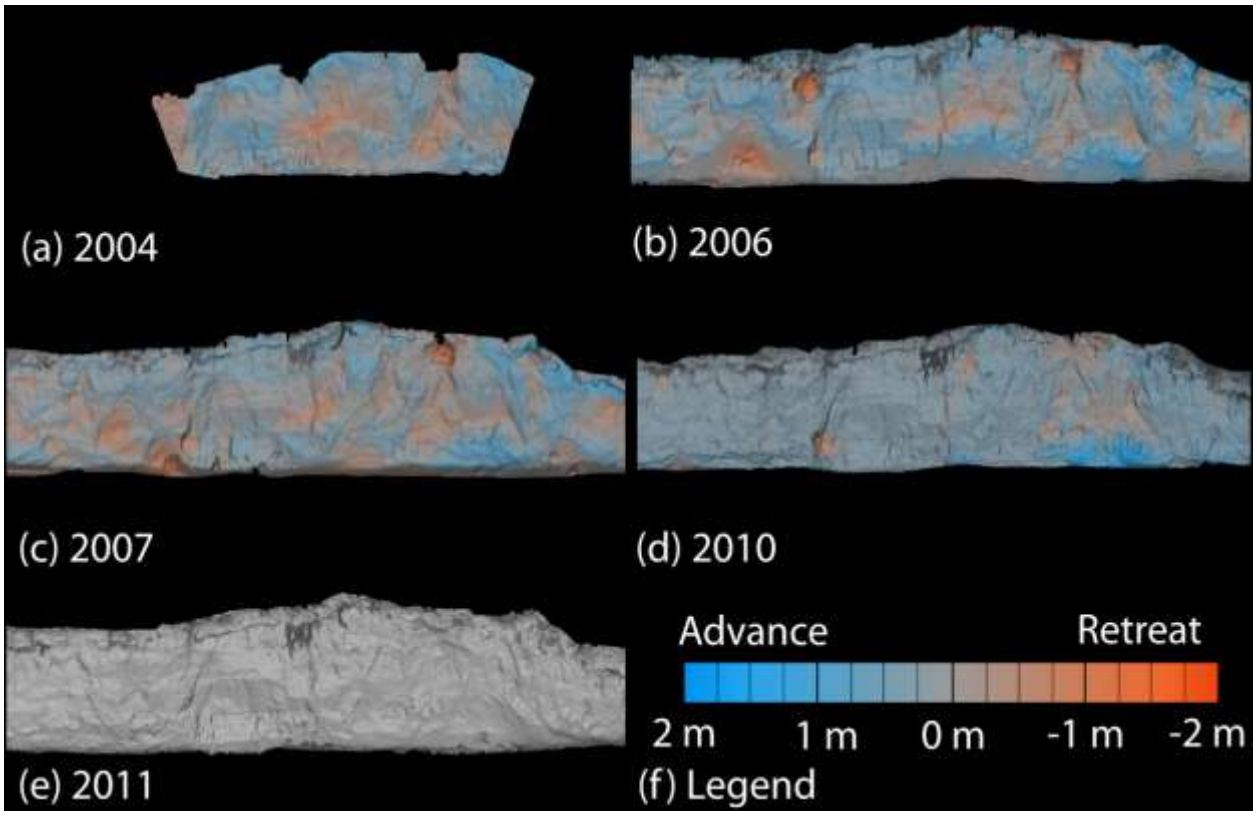

Figure 2. Sample change analysis of the Johnson Creek Landslide (using the 2011 surface as the reference) highlighting areas where erosion has outpaced landslide movement toward the ocean (retreat) and locations where landslide movement has outpaced erosion (advance).

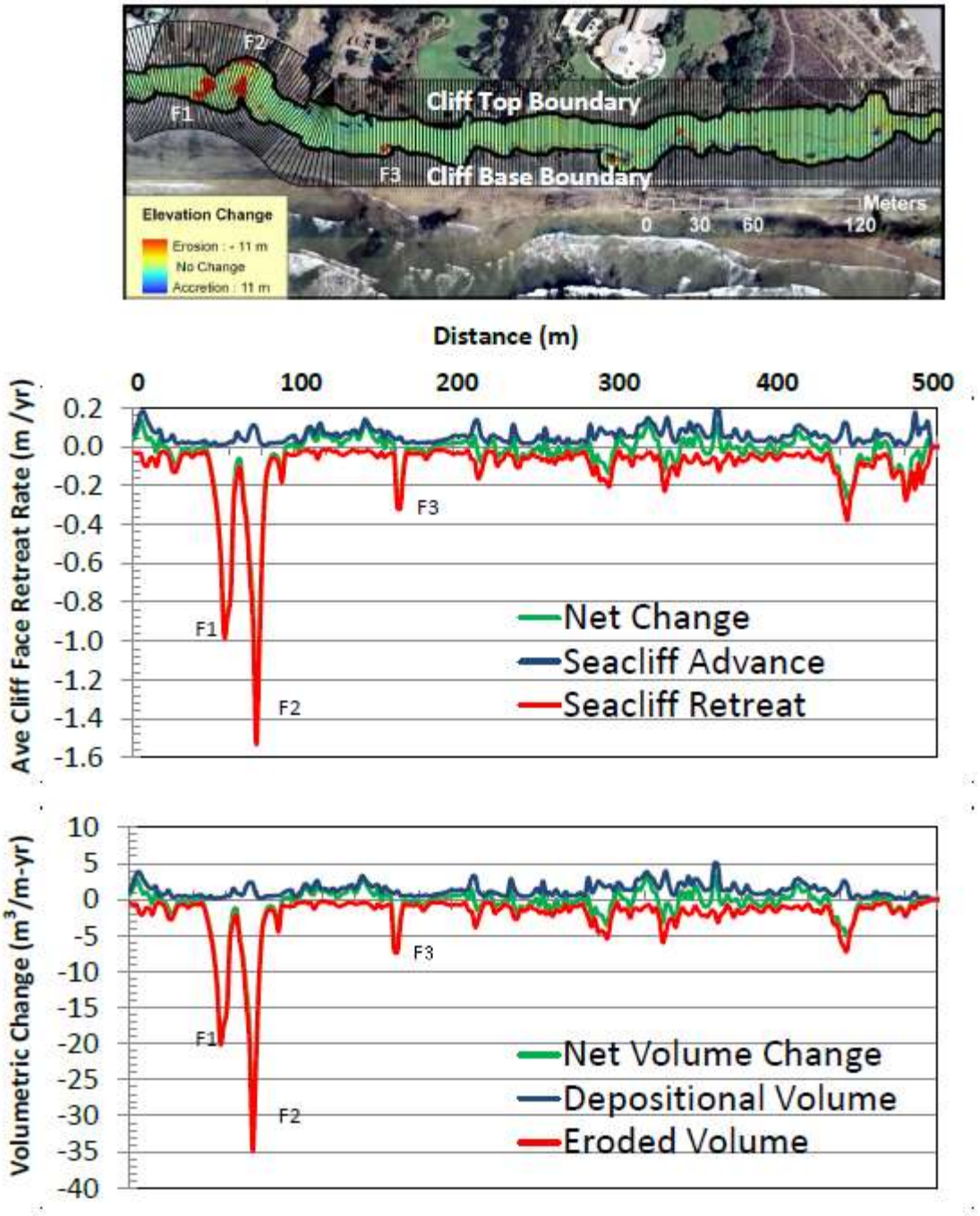

Figure 3 – Volumetric and topographic change analysis completed for Dog Beach, CA using the GIS-based tool TopCAT (Olsen et al. 2012).

3.0 Objectives of the Study

The goal of this research for ODOT is to develop a more comprehensive data-driven framework for prioritizing coastal asset management. This is new research for ODOT, building upon recent smaller-scale, foundational efforts and recommendations. The objectives of this project are to:

1) Evaluate five representative sites reflecting a combination of coastal geologic terrains, landslide types, and coastal bluff erosion activities.
2) Determine current geotechnical and hydrological data, as well as landslide and bluff geometry and movement using traditional and advanced 3D technologies (lidar and real-time remote in-place MEMS sensors).
3) Quantify changes in landslide movement, groundwater change, and bluff erosion rates over an extended 7 year timeline to fully capture the episodic nature of sea cliff erosion in the context of climate change events.
4) Develop GIS/LiDAR based management framework for targeted risk assessment and climate change adaptation planning including guidelines for future evaluations of coastal infrastructure sites.

3.1 Benefits

ODOT needs a coordinated program to establish the system and tools needed to initiate, manage, and analyze data assessing coastal landslide and erosion risks. The findings from this project will enable ODOT to relate climate events to site conditions, changes and risk levels. Results from this project will also inform climate impacts to groundwater changes, their effects on landslide movement, and to differentiate these effects from those related to coastal erosion rates at the most vulnerable sites. Advanced methods for geotechnical investigation and monitoring of landslides used for this study would subsequently be adapted for common agency practice resulting in more accurate and efficient landslide monitoring and mitigation efforts, particularly from loss of coastal bluff support due to erosion.

4.0 Implementation

This research would be used by ODOT to inform project-level risk and decision making where coastal infrastructure is threatened by landslides and erosion. It will also inform planning and land-use at a policy-level regarding shoreline protection where infrastructure is threatened by future coastal bluff retreat. Improved projections of timing for infrastructure damage or loss provides ODOT with information needed to make informed decisions regarding shoreline protection planning of public property or adaptation strategies at the policy-level. Further, this research could be used by the agency to justify adjustments to land use goals and other environmental restrictions when proposing construction projects to protect infrastructure. This includes exceptions to Statewide Goal 18 (Beaches and Dunes) regulated by the Department of Land Conservation and Development and coastal permits issued through the Oregon Parks and Recreation Department.

5.0 Research Tasks

5.1 Task list

Task 1: Select representative coastal landslide and bluff sites for monitoring and develop instrumentation plan

Five high-risk coastal landslide sites will be selected that are susceptible to sea level rise, increasing rates of ground movement, and/or shore cliff retreat due to increased wave scour and higher, more intense precipitation events. Site preference will also be based on locations with historic data and available pre-instrumented locations such Arch Cape (US 101, MP 35.95), which is an example of an existing landslide within the coastal bluff where further erosion will undermine the slide itself. Other proposed sites of potential interest include Silverpoint slide (MP 31.8), Spencer Creek (MP 134), Arizona Inn (MP 312.3), and Hooskenaden (MP 344.1).

At the onset of the project, the PIs will visit each of these sites, evaluate their suitability for instrumentation, and provide recommendations for the types and configuration of instrumentation to be installed.

Time Frame: July- August 2016
Responsible Party: PIs
Cost: $10,000
Deliverable: Proposed instrumentation plans for selected sites.
TAC Action: Review and provide feedback on list of sites and instrumentation plan.
ODOT Action or Decision: Review TAC advice, discuss with PI, and if necessary direct PI to make changes to project documents.

Task 2: TAC Meeting #1

Project kick off meeting, discussion of sites to instrument, and instrumentation plan.
Time Frame: August 2016
Responsible Party: PI, ODOT Research Coordinator, TAC
Cost: $1,000
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes.
TAC Action: Review instrumentation plan. Review and understand project research problem statement, research question, limits of the proposed research, and the project schedule. Review site selection and instrumentation plan. Advise ODOT Research Coordinator regarding any critical issues with the project's scope or schedule. Advise PI's regarding related professional practices, standards, methods and context for the project. Discuss feasibility of drilling for soil sampling and instrumentation installation at selected sites.
ODOT Action or Decision: Review TAC advice, discuss with PI, and if necessary direct PI to make changes to project documents.

Task 3: Draft Literature Review

A brief literature review will be compiled and focus on the following elements:

- Geologic context of coastal erosion and landslide hazards in Oregon
- Coastal landslide monitoring techniques
- Gather relevant data from previously instrumented sites that are useful for current project. Use previous limitations, lessons learned, and research insights to help development of the draft research methodology.

Time Frame: May –August 2017
Responsible Party: PI
Cost: $5,000
Deliverable: Draft Literature Review.
TAC Action: Read Draft Literature Review and advise ODOT Research Coordinator regarding any gaps in the literature.
ODOT Action or Decision: Review TAC advice, discuss with PI, and if necessary direct PI to make changes to project documents.

Task 4: Instrumentation of Sites

PIs will purchase instrumentation and procure services of contractor or contractors as needed to install instrumentation at the sites in coordination with, and with the assistance of, ODOT personnel. Obtain baseline readings at time of installation and ensure instrumentation is functioning properly. The specific sensors, quantity and arrangement for each site will be determined in Task 1. These sensors will likely include MEMs sensors for measure real-time landslide displacement and velocity in three dimensions, GNSS receivers to corroborate lidar data collection, porewater pressure transducer arrays to monitor increases in water table and excess porewater pressure buildup, in-situ seismometers to measure wave impacts, video cameras to record wave action, and rainfall gauges/weather stations to record precipitation.

Time Frame: August – December 2016
Responsible Party: PI, ODOT Research Coordinator, TAC
Cost: $250,000
Deliverable: Summary report of equipment installation.
TAC Action: Read summary report. Provide assistance with drilling contracting.
ODOT Action or Decision: Assess project potential for successful completion. If necessary direct PI to make changes to project documents. Provide formal acceptance of summary report of instrumentation.

Task 5: Draft Research Methodology.

Detailed, specific, standard operating procedures and business rules for systematic data acquisition, storage, processing, analysis, and potential model development will be provided and documented for review. These procedures will be completed after the first baseline surveys and readings are taken so that they can be developed to be specific to the data and locations of the project.

Time Frame: October 2016 - March 2017
Responsible Party: PI
Cost: $10,000
Deliverable: Draft Research Methodology Report Section.

TAC Action: Read Draft Research Methodology.
ODOT Action or Decision: Schedule TAC Meeting.

Task 6: Data Collection.

Collect data for analysis as identified in the Draft Research Methodology. Bi-annually collect data and monitor changes for each measurement for all sites. Additional interim measurements may be obtained at specific sites if substantial movement is observed or deemed likely (e.g. after large storms). Determine geotechnical and hydrogeological properties by hyperspectral imagery, lidar scanning, and instrumentation to measure groundwater pressure (e.g., pore pressure transducers), precipitation, wave impacts, and landslide movements throughout the landslide body.

Basic processing of the data will be completed as the data are collected, including lidar scan geo-referencing, inclinometer data analyses, precipitation data and wave impact measurements. This will enable systematic formatting of data and ensure that it is ready for archiving.

Records will be kept of data collection tools or methods and tool/method calibration. The design of any specialized data collection tools or algorithms will be documented and delivered to Oregon DOT at the conclusion of the project. The data will be stored in standardized formats.

Time Frame: October 2016 – March 2023
Responsible Party: PI
Cost: $236,337
Deliverable: Interim and final data will be made available via OSU's lidar server ftp. Organized data will be provided on hard drives to accompany the draft final report in March 2023. In addition to quarterly reports documenting data collection and overall project progress delivered to the TAC, ODOT will be alerted as soon as possible to monitoring data that indicates significant change as defined by the TAC in the first TAC meeting (Task #2). Significant changes in monitoring data will also be documented in the quarterly reports.
TAC Action: Review
ODOT Action or Decision: Review

Task 7: Interim Report

An interim report will document the progress to date, data acquisition summary, preliminary analyses of the data, risk framework model, project trajectory, and near-term or interim benefits and applications for ODOT.

Time Frame: April –September 2019
Responsible Party: PI
Cost: $15,500
Deliverable: Interim Report
TAC Action: Review interim report and discuss at TAC meeting #2.
ODOT Action or Decision: Review

Task 8: TAC Meeting #2

This TAC meeting will review the progress to date as described in the Interim Report delivered with Task 7.

Time Frame: September - October 2019
Responsible Party: PI, ODOT Research Coordinator, TAC
Cost: $3,000
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes, meeting agenda.
TAC Action: TAC review of Interim Report. Advise ODOT Research Coordinator regarding any critical issues with the project's research design. If possible, reach consensus regarding the content and methods contained in the draft research design. Advise ODOT Research Coordinator regarding project next steps. Provide PIs with necessary economic information to inform Data Analysis and Modeling (outlined in Task 9).
ODOT Action or Decision: Review TAC advice. Assess project potential for successful completion. If necessary direct PI to make changes to project documents. Provide formal acceptance of Interim Report. Authorize PI to proceed with subsequent steps, notify by memo or email.

Task 9: Data Analysis and Modeling

Analyze data collected in Task 6, primarily using methods anticipated in Task 5. Changes in landslide movement, groundwater data, and bluff erosion rates for each site will be quantified for the study period. Use existing three-dimensional slope stability analysis methods and remote sensing techniques merged with a GIS framework to compare and contrast sites to guide development of recommendations for prioritizing other coastal assets over a span of ODOT coastal highway

Revise as Draft Research Methodology to document deviations, and update the Draft Literature Review to support any methods of analysis not previously included in the literature review.

Time Frame: October 2021-September 2022
Responsible Party: PI
Cost: $90,000
Deliverable: Draft Analysis Report Section
TAC Action: Review and comment.
ODOT Action or Decision: Review.

Task 10: Draft Final Report

Create a publication-ready, draft final report in a prescribed ODOT format. (Formatting includes correct fonts, spacing, citations and graphics). Contents include: an updated abstract, acknowledgement, disclaimer, introduction, Updated Literature Review (Task 2), Final Research Methodology (Task 3), Draft Analysis Report Section (Task 9),

discussion of results, conclusions, and potential for future research, application, or technology transfer, and other sections as appropriate.

Time Frame: October 2022 - March 2023
Responsible Party: PI
Cost: $15,500
Deliverable: Draft Final Report using ODOT's report template
TAC Action: TAC review and feedback to the ODOT Research Coordinator
ODOT Action or Decision: Review and counsel prior to TAC meeting.

Task 11: TAC Meeting #3.

This TAC meeting will include a review of the Draft Final Report, and Draft Research Note prior to the TAC meeting, the TAC will offer advice on the content and clarity of these work products. The TAC will also advise on post research implementation within ODOT.

Time Frame: April to May 2023
Responsible Party: PI, assisted by the ODOT Research Coordinator, TAC
Cost: $3,000
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes
TAC Action: TAC review of Draft Final Report, and Draft Research Note. Advise ODOT Research Coordinator regarding any critical issues with the project's research design. Advise ODOT Research Coordinator regarding any required final edits to the Draft Final Report, and Draft Research Note.
ODOT Action or Decision: Review TAC advice. If necessary direct PI to make changes to project documents.

Task 12: Final Report

Edit the Draft Final Report to incorporate edits identified by the ODOT research Coordinator after the last TAC meeting.

Time Frame: May – July 2023
Responsible Party: PI
Cost: $10,000
Deliverable: Final Report.
TAC Action: None.
ODOT Action or Decision: Review. Provide formal acceptance of Final Report. Publish Final Report on ODOT's research website.

Task 13: Review Final Research Note

Review and edit provided ODOT Research Note draft prepared by Research Coordinator and select TAC members after final TAC meeting.

Time Frame: June 2023 - July 2023
Responsible Party: Research Coordinator, TAC, PI

Cost: $2,000
Deliverable: Final Research Note edits.
TAC Action: Review.
ODOT Action or Decision: Review. Provide formal acceptance of Research Note. Publish Final Report on ODOT's research website.

5.2 Reporting

All reports shall be produced in the standard ODOT Research Section report format provided to the Project Investigator by the Research Coordinator unless some other format is deemed to be more appropriate. The Project Investigators shall be responsible for submitting deliverables as professional-level, written composition equivalent to the writing standards of peer-reviewed journals. These writing considerations include grammar, spelling, syntax, organization, and conciseness.

The Project Investigator, in consultation with the TAC and Research Coordinator, shall deliver to ODOT in electronic format the data produced during the project. The Project Investigator shall ensure the data is labeled and organized to facilitate future access. ODOT shall warehouse the data.

5.3 Safety and Related Training

Prior to accessing ODOT right-of-way (ROW), all personnel who will work on ODOT ROW shall complete safety training appropriate to the work to be performed within the ROW. The Project Investigator shall notify Project Coordinator in writing (email accepted) prior to the first day of work within the ROW that all project personnel who will access ODOT ROW have been trained. Until all ROW work is completed, the Project Investigator shall notify Project Coordinator in writing (email accepted) annually that an active safety training appropriate to the work to be performed within the ROW has been completed by all personnel who will work on ODOT ROW.

6.0 Time Schedule

The table below shows the anticipated schedule for the project. It is divided into segments for clarity given the 7 year duration of the project.

Task	2016				2017								2018			
	FY17				FY18											
	Jul - Sep		Oct - Dec		Jan - Mar		Apr - Jun		Jul - Sep		Oct - Dec		Jan - Mar		Apr - Jun	
1 Site Selection & Inst. Plan		*														
2 Tac Meeting 1		*														
3 Draft Lit Review										*						
4 Instrumentation at Sites				*												
5 Draft Research Methodology						*										
6 Data Collection																
Tasks 7-14 (Future)																

Task	2018				2019				2020			
	FY19				FY20							
	Jul - Sep		Oct - Dec		Jan - Mar		Apr - Jun		Jul - Sep		Jan - Mar		Apr - Jun	
Tasks 1-5 (Completed)														
6 Data Collection														
7 Interim Report									*					
8 Tac Meeting 2										*				
Tasks 9-14 (Future)														

Task	2020				2021				2022			
	FY21				FY22							
	Jul - Sep		Oct - Dec		Jan - Mar		Apr - Jun		Jul - Sep		Jan - Mar		Apr - Jun	
Tasks 1-5 (Completed)														
6 Data Collection														
Tasks 7-8 (Completed)														
9 Data Analysis and Modeling														
Tasks 10-14 (Future)														

Task		2022						2023						
		FY23												FY 24
		Jul - Sep			Oct - Dec			Jan - Mar			Apr - Jun			Jul
	Tasks 1-5 (Completed)													
6	Data Collection									*				
	Tasks 7-8 (Completed)													
9	Data Analysis and Modeling			*										
10	Draft Final Report									R				
12	TAC Meeting 3											*		
13	Final Report													F
14	Review Final Research Note													F

*Deliverables
R - Draft report submitted for ODOT review.
F - Revised report submitted to ODOT for publication. End of contract.

7.0 Budget Estimate

An itemized budget for the project is included below showing expenditures for each task by fiscal year and in total.

Task	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Total
1 Site Selection & Inst. Plan	$10,000	$0	$0	$0	$0	$0	$0		$10,000
2 Tac Meeting 1	$1,000	$0	$0	$0	$0	$0	$0		$1,000
3 Draft Lit Review	$1,000	$4,000	$0	$0	$0	$0	$0		$5,000
4 Instrumentation at Sites	$250,000	$0	$0	$0	$0	$0	$0		$250,000
5 Draft Research Protocols	$2,000	$8,000	$0	$0	$0	$0	$0		$10,000
6 Data Collection	$33,857	$33,857	$37,065	$34,280	$44,577	$33,886	$18,815		$236,337
7 Interim Report	$0	$0	$7,500	$8,000	$0	$0	$0		$15,500
8 Tac Meeting 2	$0	$0	$0	$3,000	$0	$0	$0		$3,000
9 Data Analysis and Modeling	$0	$0	$0	$0	$0	$65,000	$25,000		$90,000
10 Draft Final Report	$0	$0	$0	$0	$0	$0	$15,000		$15,000
11 TAC Meeting 3	$0	$0	$0	$0	$0	$0	$3,000		$3,000
12 Final Report	$0	$0	$0	$0	$0	$0		$10,000	$10,000
13 Review Final Research Note	$0	$0	$0	$0	$0	$0		$2,000	$2,000
Total for tasks (Contract amount)	$297,857	$45,857	$44,565	$45,280	$44,577	$98,886	$61,815	$12,000	$650,837
Support/management (ODOT completes)	$8,000	$4,000	$4,000	$6,000	$4,000	$4,000	$7,000	$5,000	$42,000
Total for ODOT (ODOT completes)	**$305,857**	**$49,857**	**$48,565**	**$51,280**	**$48,577**	**$102,886**	**$68,815**	**$17,000**	**$692,837**
Task	**FY17**	**FY18**	**FY19**	**FY20**	**FY21**	**FY22**	**FY23**	**FY24**	**Total**