Research Project Work Plan

for

ENHANCING LANDSLIDE INVENTORYING, HAZARD ASSESSMENT AND ASSET MANAGEMENT USING LIDAR

Submitted by

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for

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Research Unit

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Salem, Oregon 97301-5192

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1.0 Identification

1.1 Organizations Sponsoring Research

Oregon Department of Transportation (ODOT)
Research Section
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Salem, OR 97301-5192
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Federal Highway Administration (FHWA)
Washington, D.C. 20590

1.2 Principal Investigator(s)

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Co-PI, Michael J. Olsen, Assistant Professor
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Oregon State University
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Corvallis, OR 97331
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Co-PI, William Burns, Geologist
Oregon Department of Geology and Mineral Industries
800 NE Oregon Street, Suite 965
Portland, OR 97232
Phone: (971) 673-1555

1.3 Technical Advisory Committee (TAC) Members

Matthew Mabey, ODOT Research, *Chair*

Curran Mohney, ODOT GeoEnvironmental

Timothy Rogers, FHWA

1.4 Project Coordinator

Matthew Mabey, ODOT Research

1.5 Friends of the Committee

Joseph Wartman

Burak Tanyu

1.6 Project Champion

Curran Mohney, ODOT Engineering and Asset Management

2.0 Problem Statement

Landslides are frequent hazards that result in major economic, environmental and social impacts for operation, maintenance and construction of Oregon highways. Current databases of landslides in Oregon are limited and fragmented since they are based on a variety of inventories/geologic maps from various sources, and have been mapped sporadically over time. Often, when large landslides occur on Oregon highways, there is no information about whether it is a reactivated existing landslide or a new slope failure. Therefore, it is critical that a baseline inventory of landslide hazards occur so a baseline quantity, size, and location of existing landslides can be established - especially those of which are ongoing. Such knowledge is crucial to asset management, especially in the wake of significant rain events or seismic activity (e.g. Cascadia subduction zone event).

Despite their impact, inventorying and mapping existing landslides, often the areas at the highest risk of reoccurrence, is a challenging, time-consuming, and expensive process. Current landslide mapping techniques include roadside inventorying, photogrammetry and other surveying techniques to highlight regions of risk, which are likely also the areas that require more resources for maintenance. However, many of these techniques do not have sufficient accuracy, resolution or consistency for inventorying landslide deposits on a landscape scale. Fortunately, use of lidar digital elevation models (DEMs) provides sufficient accuracy to start inventorying regions subject to landslides surrounding Oregon highways. These DEMs can reveal the landscape beneath vegetation and other obstructions, highlighting landslide features, including scarps, deposits, and fans. Furthermore, such DEMs are scheduled to be available for the entire state of Oregon in coming years, with critical highways likely to be the first mapped areas. However, use of lidar for landslide inventorying, risk assessment, and management prioritization is primarily reliant on the subjective interpretation of individual geologists, which may provide improved manual landslide inventories, but introduces inconsistency and is limited by a pace that is not sufficient to accommodate ODOT's large network of managed right-of-way surrounded by a dynamic landscape. In order to improve large-scale asset management strategies in context of unstable slopes, it is desirable that a consistent and automated landslide inventorying approach be developed.

2.1 Background and Significance of Work

Figure 1 shows the extents of the proposed study area, consisting of State Highway 36 and State Highway 42, and a portion of Highway 101 between Port Orford and Bandon. These highways are critical to the economic and social well-being of coastal communities, but are often subject to road closures and repeated maintenance due to landslide activity. Much of this landslide activity stems from particular ongoing slope failures that require frequent maintenance, while there are numerous other historic, active landslides that have a high potential of affecting ODOT infrastructure function and safety. It is essential to not only inventory these past slope failures, but classify their mode of failure, activity, and proximity to valuable infrastructure enabling improved asset management decisions. This inventorying will be informed by detailed landslide inventorying and mapping by DOGAMI on an adjacent lidar BE DEM tile.

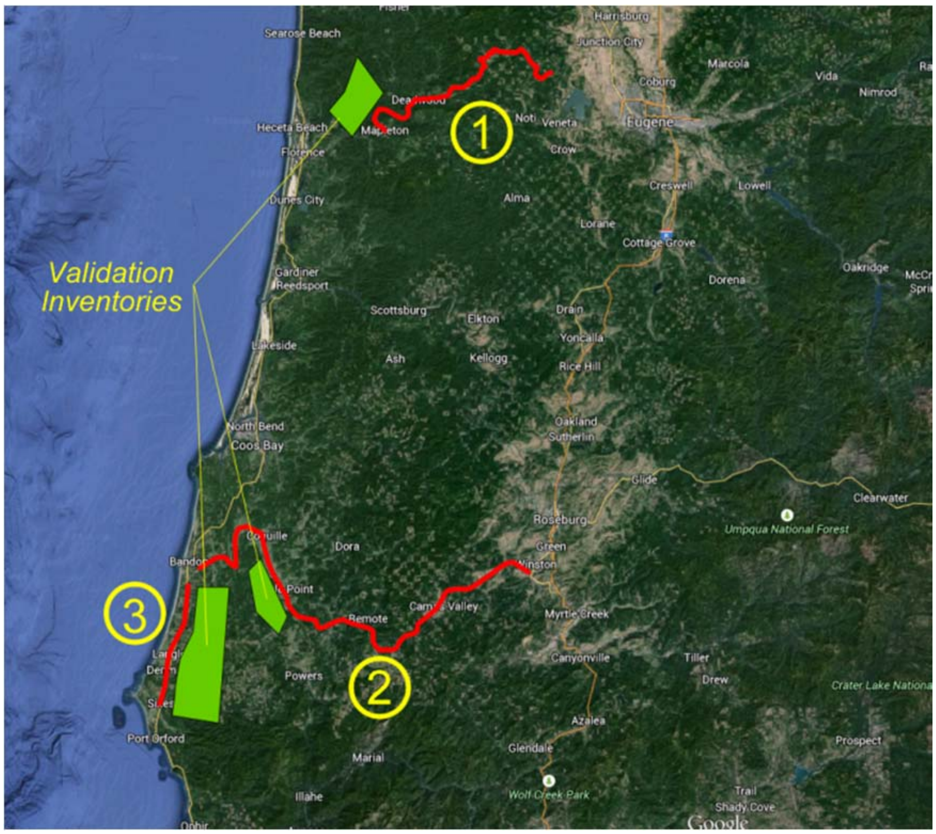

Figure 1 – Study areas.

3.0 Objectives of the Study

Lidar DEM's present the future of mapping landslides, but a level of automation is required to sufficiently and systematically inventory ODOT's large road network for improved allocation of resources, asset management, operations, and construction. Current automated approaches are extremely complex, and may require expensive mapping techniques and non-intuitive input parameters. A new algorithm, called the Contour Connection Method (CCM), utilizes any DEM, including bare earth lidar, to consistently detect landslide deposits on a landscape scale in an automated manner (Leshchinsky, Olsen and Tanyu, 2014). The CCM approach requires less user input than other mapping algorithms, and focuses on general landslide geometry - such as the slope of landslide scarps and deposits. This process not only highlights deposits, but it yields a unique signature for each landslide feature that may be used to classify different landscape features. Use of CCM also provides an opportunity to evaluate very large areas within matters of minutes or hours whereas the same areas, if evaluated based on field inventorying or manual interpretation of the high resolution DEMs, would have taken weeks or months. This tool can be developed and refined to expedite risk assessment and prioritization of assets by integrating transportation networks, landslide activity, soil and geology maps, and reliability-based approaches on a landscape scale.

Key objectives include:

1. Advance the CCM algorithm to include input from available soil and geology maps to improve landslide identification.
2. Associate identified landslides and their unique criteria with basic landslide types or modes of failure (e.g., rotational, translation, etc.) for classification of landslide age and activity. This will establish the first consistent and non-subjective framework for landslide classification.
3. Use existing geology and soil maps to enhance CCM inputs for inventorying in addition to manual input.
4. Provide ODOT with an easy-to-use landslide prioritization framework that uses a given DEM and CCM to map current landslides and problematic regions. The initial hazard maps and generalized process framework would directly assist in assessing hazards, asset management, and evaluating mitigation techniques of slope-related problems along ODOT right-of-way. Prioritization will be based off of identified landslide deposits, classified age, classified activity, size and proximity to the highway. Evaluation of the refined output and quantifying time and cost-savings due to CCM application will be used as metrics of the success of the new methodology.

3.1 Benefits

It is anticipated that this project will be of significant economic benefit to ODOT and the State of Oregon, including:

1. Cost savings by improving asset management decisions in context of landslide mitigation and prioritization.
2. Improved and consistent framework for a preliminary inventory of classified landslides throughout the state in an expedient and consistent framework.
3. Classification of and better understanding of the current, historic, and ancient landslides in proximity of Oregon highway systems so as to better manage their impacts on construction, maintenance and asset management.
4. Although the study will focus primarily on the coast range, the developed methodology should be applicable to other sections of Oregon.

4.0 Implementation

The products of this research project will include development of a risk and hazard mapping scheme for critical Oregon infrastructure based on a semi-automated landslide mapping algorithm and a framework for prioritizing landslide mitigation and management efforts. These deliverables will be provided in a geodatabase for GIS use as well as a webGIS geodatabase that will be compatible with smartphone and tablet devices for field reconnaissance for pilot map areas. Furthermore, a framework will be developed that uses publicly-available lidar data to inventory landslides on a landscape scale, including a classification system for landslide modes, activity and size. In collaboration with Curran Mohney, this deliverable will be developed for use by ODOT engineers.

5.0 Research Tasks

Landslide hazard mapping will be performed using geospatial data along aforementioned transportation corridors in Western Oregon. Analyzed information will be packaged in a GIS data format that can be readily accessed and utilized by ODOT personnel. Participation from personnel at DOGAMI will contribute significant landslide inventorying experience in Oregon, existing landslide surveys and bare earth lidar database to facilitate calibration of hazard and risk mapping. Furthermore, their current landslide inventorying framework is being adopted by many state geological surveys as well as DOTs nationwide. Development of CCM and integration as a framework for landslide hazard and risk mapping presents an opportunity for Oregon to be a pioneer in creating a consistent framework for landslide identification and classification.

The estimated duration of this project is 25 months. The estimated cost to accomplish the tasks outlined is $250,000. A final map will be produced at the end of the second year and will reflect a refinement of the maps and models.

5.1 Expected tasks:

The tasks involved in this project are as follows:

Task 1: Perform comprehensive literature review in consideration of Oregon landslide issues. Arrange and host a workshop involving the TAC to highlight major regional needs and potential obstacles for landslide hazard mapping.

The focus of this effort will be to determine the advantages and disadvantages to current methodologies for landslide inventorying and classification. The investigators will compile a list of relevant, available methodologies, strengths, weaknesses, and data requirements for refinement of CCM, including important topographic, geologic and soil criteria for landslide inventorying. These findings and recommendations will be presented to the TAC and other relevant personnel for feedback and discussion of next steps of action. Based on this task, strategies can be developed about refinement of CCM beyond simply topography.

Time Frame: November – December 2015

Responsible Party: Ben Leshchinsky (OSU), Michael Olsen (OSU)

Cost: $15,000

Deliverable: Brief summary of planned refinement strategy for CCM.

TAC Decision/Action: The TAC will help define the appropriate parameters for CCM refinement.

Task 2: Modify CCM algorithm to account for existing lithological maps, soil maps, and existing statistical databases to refine semi-automated landslide mapping technique for DOT use.

For this task, we plan to implement findings from the literature review and feedback from the TAC in Task 1 into the next revision of CCM, which will use the same analysis (scarp and deposit gradients as input), but will have an additional stages that account for soil and lithology mapping, and potentially other factors, before performing the analysis. This technique will be tested on three manually inventoried tiles that represent different geologies or morphologies to enable a robust understanding of its performance in a variety of landscapes. Finally, for this task, we will evaluate the sensitivity of the models to the input data and assumptions needed for regional mapping. The TAC will be provided either a progress report or an update presentation regarding the accomplishments of this task. The TAC will choose between a report and a presentation in consultation with the project team.

Time Frame: December 2015 – December 2016

Responsible Party: Ben Leshchinsky (OSU), Michael Olsen (OSU)

Cost: *$71,000*

Deliverables: Update/Progress Report

TAC Decision/Action: Provide input on representative sites as well as the state and direction of progress.

Task 3: Work with DOGAMI and ODOT personnel to select regions of manually inventoried landslides representative of regional unstable geologies around Oregon, and calibrate algorithm to match inventories and slide classifications. Initial analysis will be done for State Highway 36, State Highway 42 and a select portion of Highway 101. Validation will be performed on select sections of these highways that do not currently have landslide inventories.

Selected inventories will have both refined landslide inventories as well as high-resolution LiDAR bare earth digital elevation models. ODOT personnel will help refine this selection based on infrastructure value, potential hazards, typical traffic loads, and data availability. Personnel from OSU will calibrate CCM analysis to capture existing landslide inventories to a satisfactory threshold.

Time Frame: August 2016 – April 2017

Responsible Party: Ben Leshchinsky (OSU), Bill Burns (DOGAMI), Curran Mohney (ODOT)

Cost: *$60,000*

Deliverable: Preliminary maps and statistics showing comparisons with manual landslide inventories.

TAC Decision/Action: The TAC will assist in selecting regions of concern for mapping and calibration based on DOGAMI landslide mapping to date. The TAC will also provide feedback regarding the maps and statistics.

Task 4: Work with personnel from ODOT to assign significance factors to landslide type/age, proximity to important infrastructure (e.g. highways, bridges, retaining structures), public safety, and emergency access (e.g. "Tier 1 Lifeline" Routes) to enable a prioritization scheme informed by refined landslide mapping and classification algorithm scheme. Use calibrated landslide inventorying scheme and ODOT prioritization metrics to create hazard and risk maps for pilot study of three selected Oregon highways.

ODOT personnel will recommend default importance factors for asset management concerns and proximity of landslide hazards to infrastructure. OSU personnel will implement a post-processing revision for the CCM algorithm that will consider these factors and provide risk mapping in consideration of synthesis of hazard mapping/classifications and asset protection. Using the results from the refined CCM analysis and landslide and asset management significance factors, the team will produce a hazard and risk map for selected highways three highway corridors (Highway 36, 42 and part of 101). This map will be organized as a GIS layer, such that it can easily be integrated with ODOT's asset management framework and in O-Help, OSU's open-access webGIS hazards explorer.

Time Frame: February – September 2017

Responsible Party: Ben Leshchinsky (OSU), Michael Olsen (OSU), Curran Mohney (ODOT)

Cost: *$33,000*

Deliverable: Risk and hazard maps for select Oregon highways (GIS geodatabase and WebGIS form).

TAC Decision/Action: The TAC will assist in defining asset management parameters of importance and provide suggestions for improvement. The TAC will also provide feedback on the quality and utility of the risk and hazard maps.

Task 5: Establish a guideline for application of CCM in context of the current DOGAMI landslide mapping framework, delivered as a publicly-available special publication.

The application of the framework will be documented in context of the current DOGAMI landslide inventorying framework. This will be disseminated in the form of a DOGAMI special publication that is available to the general public, as well as other agencies. Bill Burns will compile this publication and framework in context of the current landslide mapping framework.

Time Frame: March – September 2017

Responsible Party: Ben Leshchinsky (OSU), Michael Olsen (OSU), Bill Burns (DOGAMI)

Cost: *$61,000*

Deliverable: DOGAMI special paper (draft) documenting consistent workflow for using CCM to inventory and classify landslides.

TAC Decision/Action: Review of the CCM framework.

Task 6: Deliver technical report and pilot hazard/risk maps for ODOT use based on landslide activity and proximity to important infrastructure.

The report for the project will be continually developed and refined throughout the entire project duration, as each task develops a key component of the final report. Additional literature review will be ongoing throughout the project. The draft final report will be delivered to ODOT along with supporting GIS geodatabases and other data files. The project team will also compose a Research Note that summarizes the project in language for a general audience. Following TAC review and a meeting with the project team with the TAC, the report and note will be revised and submitted in the ODOT Research Section's report format. The final report sections of this report will also be further developed by the students for publication as theses and peer-reviewed journal papers. This research will fund one PhD student and partially fund a second graduate student. However, it is anticipated that the thesis and journal paper publications will require additional time beyond the project cycle to complete. We will also give presentations to ODOT personnel, as directed by the

TAC, including a lunchtime informational seminar for ODOT employees discussing landslides in Oregon.

Time Frame: July to October 2017.

Responsible Party: Ben Leshchinsky (OSU), Michael Olsen (OSU)

Cost: $*10,000*

Deliverable: Final Report to ODOT, presentation to TAC, informational seminar to ODOT personnel.

TAC Decision/Action: The TAC will assist in setting up the presentations and review the report and note for final approval.

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. This format includes having all tables be tables and not images. All figures are to be of clarity, quality, and resolution suitable for publication. The Project Investigator shall be responsible for submitting deliverables as professional-level, written compositions 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 data or arrange to have the data warehoused.

5.3 Safety and Related Training

Due to the nature of this project, it is not anticipated that any work will be taking place in ODOT right-of-way (ROW). If any such work arises, 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 Schedule

Project Tasks	FY2016				FY2017				FY2018	
	Qtr. 1 July-Sep	**Qtr. 2** Oct-Dec	**Qtr. 3** Jan-Mar	**Qtr. 4** Apr - June	**Qtr. 1** July-Sep	**Qtr. 2** Oct-Dec	**Qtr. 3** Jan-Mar	**Qtr. 4** Apr - June	**Qtr. 1** July-Sep	**Q2** Oct
Task 1: Literature Review/Workshop Deliverable: Meeting/Presentation										
Task 2: Modify CCM Algorithm Deliverable: Progress Report										
Task 3: Calibrate CCM Algorithm Deliverable: Preliminary Maps										
Task 4: Assign significance factors Deliverable: Risk Maps										
Task 5: DOGAMI Special Paper / Framework and Documentation Deliverable: CCM plug-in										
Task 6: Dissemination and ODOT Workshop Deliverable: Final report										

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

Task	FY2016	FY2017	FY2018	Total
1: Literature Review and Workshop	$15,000			$15,000
2: Customize CCM Model	$41,000	$30,000		$71,000
3: Calibration of CCM Model		$60,000		$60,000
4: Develop Classification Scheme		$25,000	$8,000	$33,000
5: Develop CCM Guidelines		$52,000	$8,000	$61,000
6: Technical Report and Maps			$10,000	$10,000
Total for tasks (Contract amount)	**$56,000**	**$167,000**	**$27,000**	**$250,000**
Support/management (ODOT completes)	$6,000	$7,000	$7,000	$20,000
Total for ODOT (ODOT completes)	**$62,000**	**$174,000**	**$34,000**	**$270,000**