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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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Landslide Susceptibility and Risk Map, Ecola State Park Study Area, Oregon

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Open-File Report, O-25-02

Ecola State Park Landslide Risk Analysis, Clatsop County, Oregon

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PLATE 6

Introduction

Oregon's state parks are treasures that make Oregon an ideal place to live and explore. Ecola State Park (Ecola) is located on the northern Oregon Coast in Clatsop County between the cities of Seaside and Cannon Beach. Landslide hazards have plagued Ecola since its designation in 1932.

The purpose of this project is to evaluate the current and future landslide susceptibility and risk within and surrounding Ecola to assist the Oregon Parks and Recreation Department (OPRD) in making decisions to reduce landslide risk, with an emphasis on roadways. Landslide susceptibility is the relative likelihood of the landslide hazard occurring in a certain portion of the study area. Landslide risk is the possibility of damage or losses to assets (people, infrastructure, and the environment) by the hazard. To accomplish this goal, several tasks were performed:

- A new lidar topography dataset was collected in 2023.
- The distribution of landslides was mapped throughout the park.
- A new/updated geologic map of the park was created.
- Existing and future landslide susceptibility was analyzed.
- Recommendations for future risk reduction were provided.

Landslide susceptibility and risk were analyzed using several methods, including:

- Landslide inventory: an inventory of contemporary and historic landslide activity was created by examining the 2023 topographic lidar dataset.
- Serial lidar change analysis: landslide activity was identified by examining changes in the topography during a window of time using lidar datasets (2023 and 2009).
- Serial orthophoto change analysis: landslide activity was identified by examining changes in the vegetation and other visual details using multiple orthorectified aerial images spanning 1939 to 2022.
- Geologic mapping: geologic mapping data from the region was collected, corroborated and further investigated with several field days during this study, and combined to build a robust geologic map that can be used in the development of a landslide susceptibility map and provide additional understanding of landslide mechanisms.

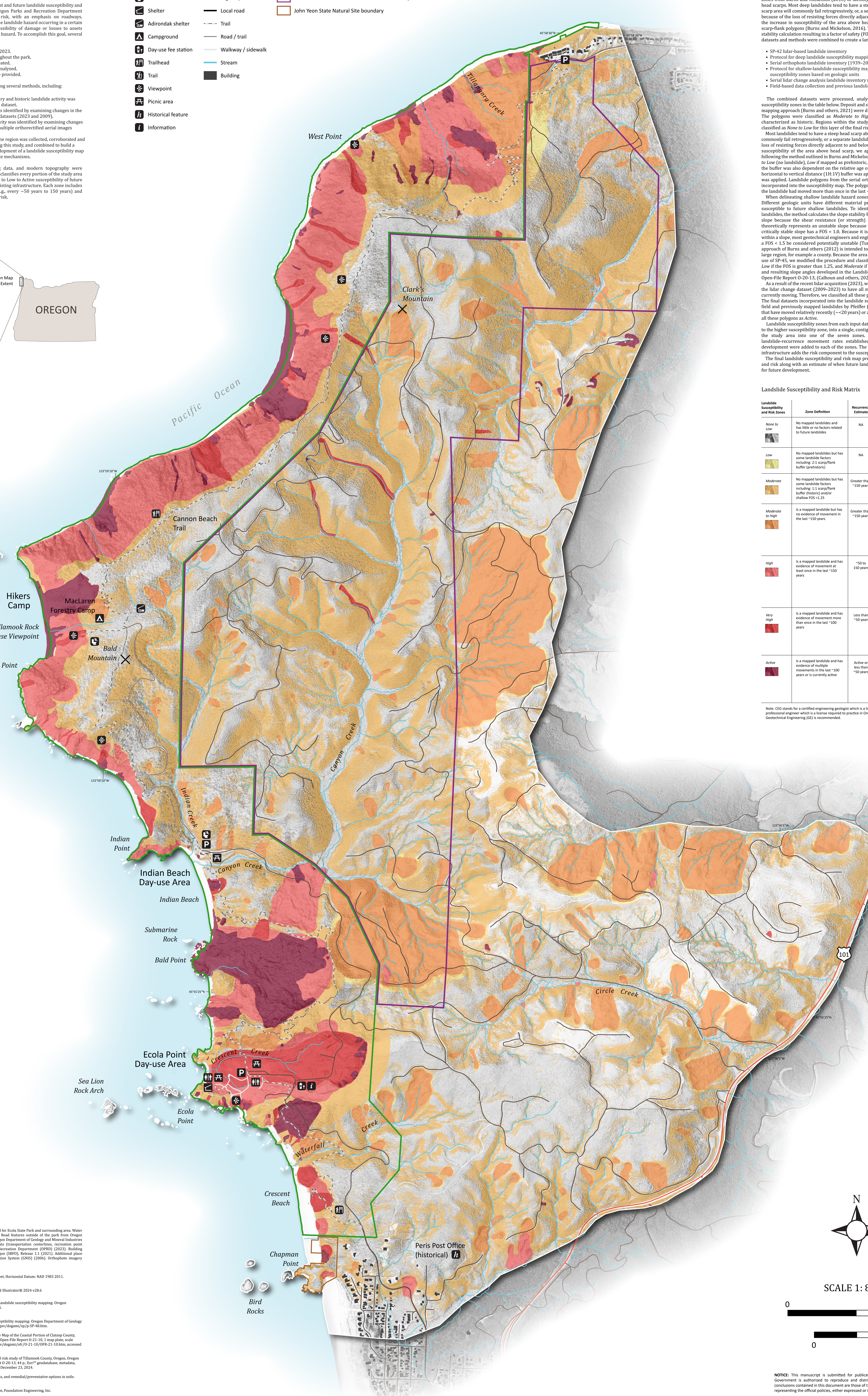
Finally, landslide inventories, geologic mapping data, and modern topography were combined to create a susceptibility and risk map that classifies every portion of the study area into one of the seven susceptibility zones, from None to Low to Active susceptibility of future landslide activity and risk of damage and losses to existing infrastructure. Each zone includes an estimate of past landslide-recurrence activity (e.g., every ~50 years to 150 years) and recommendations for future development to reduce risk.

Location Map

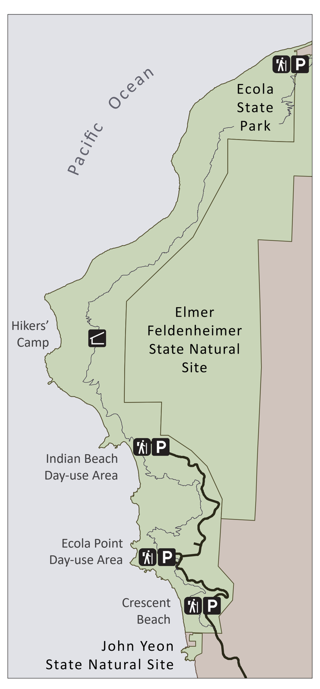
- City
- Highway
- Project Area
- State Park
- Oregon
- Pacific Ocean

General Legend

- Modern restroom
- Pit restroom
- Shelter
- Adirondak shelter
- Campground
- Day-use fee station
- Trailhead
- Trail
- Viewpoint
- Picnic area
- Historical feature
- Information
- Summit
- Highway
- Local road
- Trail
- Road / trail
- Walkway / sidewalk
- Stream
- Building
- Ecola State Park boundary
- Elmer Feldenheimer State National Site boundary
- John Yeon State Natural Site boundary



Park Boundary Map



- Ecola State Park Road
- Oregon Coast Trail
- State Park
- Oregon
- Pacific Ocean

The Landslide Susceptibility and Risk Map Data and Methods

To make the landslide susceptibility and risk dataset, we combined several datasets and selected appropriate portions of published landslide susceptibility methods. The two methods we used are Burns and Mickelson (2016) and Burns and others (2012). We used the retrogression zones from Burns and Mickelson (2016) to identify susceptible regions upslope of deep landslide head scarps. Most deep landslides tend to have a steep head scarp above the failed mass. The head scarp area will commonly fail retrogressively, or a separate landslide will form above the head scarp because of the loss of resisting forces directly adjacent to and below the head scarp. To account for the increase in susceptibility of the area above head scarp, we applied a buffer around the head scarp-flank polygons (Burns and Mickelson, 2016). We also used a portion of the shallow landslide stability calculation resulting in a factor of safety (FOS) from Burns and others (2012). The following datasets and methods were combined to create a landslide susceptibility map of the study area:

- SP-42 lidar-based landslide inventory
- Protocol for deep landslide susceptibility mapping, Special Paper 48, retrogression zone
- Serial orthophoto landslide inventory (1939–2022)
- Protocol for shallow-landslide susceptibility mapping, Special Paper 45, shallow landslide FOS susceptibility zones based on geologic units
- Serial lidar change analysis landslide inventory (2009–2023)
- Field-based data collection and previous landslide studies

The combined datasets were processed, analyzed and classified into one of the landslide susceptibility zones in the table below. Deposit and scarp-flank polygons created following the SP-42 mapping approach (Burns and others, 2021) were directly incorporated into the susceptibility map. The polygons were classified as *Moderate to High* if characterized as prehistoric and *High* if characterized as historic. Regions within the study area with no mapped landslide deposit were classified as *None to Low* for this layer of the final risk map.

Most deep landslides tend to have a steep head scarp above the landslide body. The head scarp area will commonly fail retrogressively, or a separate landslide will form above the head scarp because of the loss of resisting forces directly adjacent to and below the head scarp. To account for the increase in susceptibility of the area above head scarp, we apply a buffer around the scarp-flank polygons following the method outlined in Burns and Mickelson (2016). We classified the buffer zones as *None to Low* (no landslide), *Low* if mapped as prehistoric, and *Moderate* if mapped as historic. The size of the buffer was also dependent on the relative age of the landslide. If classified as prehistoric, a 1:1 horizontal to vertical distance (1H:1V) buffer was applied and if classified as historic, a 2H:1V buffer was applied. Landslide polygons from the serial orthophoto landslide inventory were also directly incorporated into the susceptibility map. The polygons were classified as *Very High*, which indicates the landslide had moved more than once in the last ~150 years.

When delineating shallow landslide hazard zones, one of the main factors is steepness of slope. Different geologic units have different material properties, and thus, will have different slopes susceptible to future shallow landslides. To identify areas more susceptible to future shallow landslides, the method calculates the slope stability FOS. A FOS > 1.0 theoretically represents a stable slope because the shear resistance (or strength) is greater than the shear stress. A FOS < 1.0 theoretically represents an unstable slope because the stress is greater than the shear strength. A critically stable slope has a FOS = 1.0. Because it is impossible to know all the conditions present within a slope, most geotechnical engineers and engineering geologists recommend that slopes with a FOS < 1.5 be considered potentially unstable (Turner and Schuster, 1996; Cornforth, 2005). The approach of Burns and others (2012) is intended to delineate shallow landslide susceptibility for a large region, for example a county. Because the area in this study is much smaller than the intended use of SP-45, we modified the procedure and classified slopes within the geologic units as *None to Low* if the FOS is greater than 1.25, and *Moderate* if the FOS is less than 1.25. We used the strength and resulting slope angles developed in the Landslide Hazard and Risk Study of Tillamook County, Open-File Report O-20-13, (Calhoun and others, 2020).

As a result of the recent lidar acquisition (2023), we consider the landslide polygons mapped using the lidar change dataset (2009–2023) to have all moved relatively recently (~<20 years) or to be currently moving. Therefore, we classified all these polygons as *Active*.

The final datasets incorporated into the landslide susceptibility map were the data collected in the field and previously mapped landslides by Pfeiffer (2016). Because all these data are of landslides that have moved relatively recently (~<20 years) or are currently moving (2016–2024) we classified all these polygons as *Active*.

Landslide susceptibility zones from each input dataset were combined, with the precedence going to the higher susceptibility zone, into a single, contiguous GIS layer, which classifies every portion of the study area into one of the seven zones. The zones were defined and estimates of landslide-recurrence movement rates established. Additionally, recommendations for future development were added to each of the zones. The addition of the recommendations and the park infrastructure adds the risk component to the susceptibility.

The final landslide susceptibility and risk map provides definitions of each level of susceptibility and risk along with an estimate of when future landslide activity may occur and recommendations for future development.

Landslide Susceptibility and Risk Matrix

Landslide Susceptibility and Risk Zones	Zone Definition	Recurrence Estimate	Recommendations
None to Low	No mapped landslides and has little or no factors related to future landslides	NA	Acceptable to develop under general direction from a CEG or PE.
Low	No mapped landslides but has some landslide factors including: 2:1 scarp/flank buffer (prehistoric)	NA	Acceptable to develop under general direction from a CEG or PE.
Moderate	No mapped landslides but has some landslide factors including: 1:1 scarp/flank buffer (historic) and/or shallow FOS <1.25	Greater than ~150 years	Acceptable to develop under direction from a CEG or PE. Detailed local slope stability analysis should be performed prior to development. Development should be done so that there is greater stability post development.
Moderate to High	Is a mapped landslide but has no evidence of movement in the last ~150 years	Greater than ~150 years	Caution should be taken if considering development in these areas. Develop only under direction from a CEG or PE. Detailed local slope stability analysis should be performed including proposed development prior to development. Development should be done so that post development ensures greater stability. Development in these areas is very likely going to require slope stabilization measures. Consider development with minimal infrastructure (e.g. trails) to reduce risk.
High	Is a mapped landslide and has evidence of movement at least once in the last ~150 years	~50 to 150 years	Caution should be taken if considering development in these areas. Develop only under direction from a CEG or PE. Detailed local slope stability analysis should be performed including proposed development prior to development. Development should be done so that post development ensures greater stability. Development in these areas is very likely going to require slope stabilization measures. Consider development with minimal infrastructure (e.g. trails) to reduce risk.
Very High	Is a mapped landslide and has evidence of movement more than once in the last ~100 years	Less than ~50 years	Great caution should be taken if considering development in these areas. Develop only under direction from a CEG and PE. Detailed local slope stability analysis should be performed including proposed development prior to development. Development should be done so that post development ensures greater stability. Development in these areas is going to require slope stabilization measures.
Active	Is a mapped landslide and has evidence of multiple movements in the last ~100 years or is currently active	Active or less than ~50 years	Great caution should be taken if considering development in these areas. Develop only under direction from a CEG and PE. Detailed local slope stability analysis should be performed including proposed development prior to development. Development should be done so that post development ensures greater stability. Development in these areas is going to require slope stabilization measures.

Note: CEG stands for a certified engineering geologist which is a license required to practice in Oregon. PE stands for a professional engineer which is a license required to practice in Oregon. For landslide evaluation and mitigation design a Geotechnical Engineering (GE) is recommended.

SCALE 1: 8,000

0 0.5 Miles

0 0.5 Kilometers

Source Data:
Oregon Lidar Consortium (OLC) one-meter digital elevation model for Ecola State Park and surrounding area. Water features from USGS National Hydrology Dataset (NHD) (2017). Road features outside of the park from Oregon Department of Transportation (ODOT) (2015) or digitized by Oregon Department of Geology and Mineral Industries (DOGAMI) from 2022 orthophotos. Park infrastructure GIS data (transportation centerlines, recreation point locations, transportation structures) from Oregon Parks and Recreation Department (OPRD) (2023). Building footprints from DOGAMI Statewide Building Footprints for Oregon (SBFO), Release 1.1 (2021). Additional place locations from US Geologic Survey, Geographic Names Information System (GNIS) (2006). Orthophoto imagery (2022) from Oregon Statewide Imagery Program (OSIP).

Projection:
Oregon Statewide Lambert Conformal Conic, Unit: International Feet, Horizontal Datum: NAD 1983 2011.

Software:
Esri ArcGIS® ArcPro v3.3.1, ArcGIS® ArcMap v10.7.1, and Adobe® Illustrator® 2024 v28.6

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