# Mapping Landslides on Mt. Baker-Snoqualmie National Forest with New LiDAR-based Contour Connection Method

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## Introduction

- Landslides are frequent hazards along the west side of the Cascade Mountains that result in major economic, environmental, and social impacts
- The Mt. Baker-Snoqualmie National Forest (MBS) has a heightened awareness of landslide risks and potential consequences, particularly since the catastrophic Oso Landslide of 2014
- Mapping of existing landslides, which tend to be the areas at highest risk of future instability, is a challenging, time-consuming, and expensive process
- Current landslide mapping techniques tend to be inconsistent due to subjective interpretation by individual geologists and most result in maps with insufficient resolution

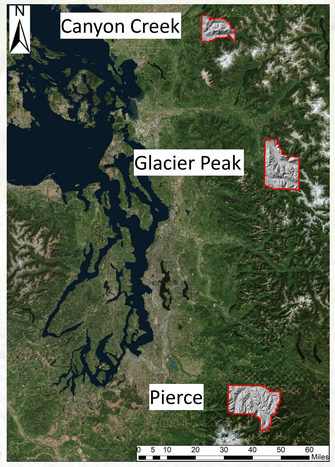


Figure 1: Map of areas that were studied

## Why LiDAR for detecting landslides?

- Light Detection and Ranging is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth
- LiDAR gives us the ability to see landslide scarps, deposits and more underneath vegetation
- The detection of scarps can be used as a way to initiate hazard mapping and shallowness of deposits as a way to terminate a search

## Objectives

The aims of this study are to:

- Use the CCM tool to inventory existing landslides within each study area of Mt. Baker-Snoqualmie National Forest
- Determine the degree of agreement between CCM results and the existing Department of Natural Resources (DNR) landslide inventory field data
- Assess the feasibility of using CCM for inventorying the entirety of MBS National Forest

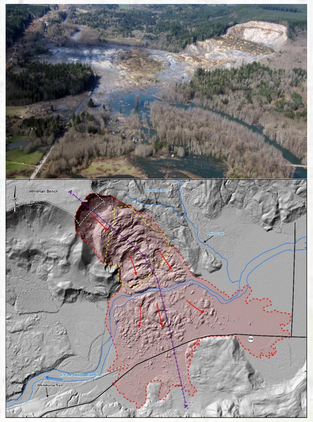

Figure 2: Images of the 2014 Oso Landslide from an aerial photograph (top) and an annotated LiDAR scan (bottom)

## Data

- Publically available data was gathered from the DNR LiDAR portal. Three datasets were selected from the MBS National Forest then clipped to areas where there is ongoing, or a high likelihood of, recreational or management activities:
  - Canyon Creek Watershed (North of Mt. Baker)
  - Glacier Peak
  - Pierce County (North of Mt. Rainier)

## Contour Connection Method

- This study uses a new mapping tool, the Contour Connection Method (CCM) that utilizes bare earth LiDAR, to automatically detect landslide deposits on MBS land
- The CCM approach requires less user input and focuses on general landslide geometry such as the slope of landslide scarps and deposits
- CCM provides an opportunity to evaluate very large areas within minutes or hours whereas the same areas, if evaluated based on field inventorying or manual interpretation high resolution DEMs (Digital Elevation Models), would take weeks or months
- The CCM approach follows a step-by-step workflow that takes the user from a DEM to a complete landslide inventory map

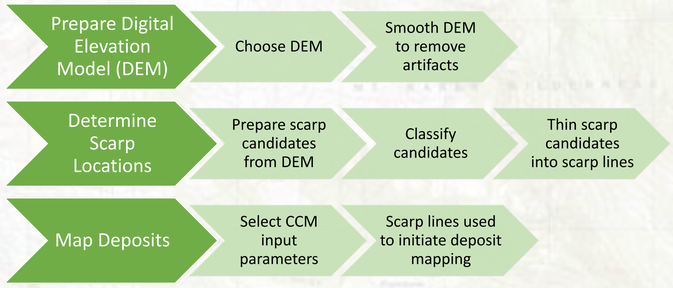


Figure 3: Basic workflow of CCM

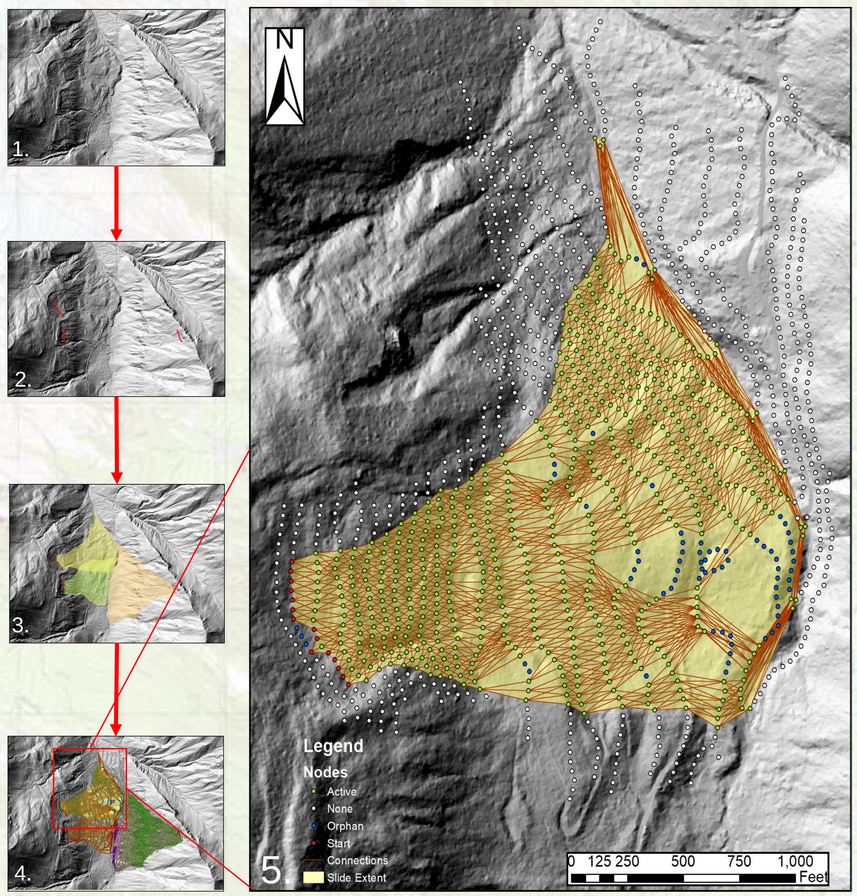


Figure 4: Visualization of the CCM process. 1) A DEM is selected and smoothed, 2) Scarps are drawn by tool based on a variety of metrics such as slope and curvature, 3) CCM draws flow of landslide with a series of algorithms, 4) Nodes are drawn along contours and connections are drawn based on set parameters, 5) final products are put into DEM as GIS layers

## Results

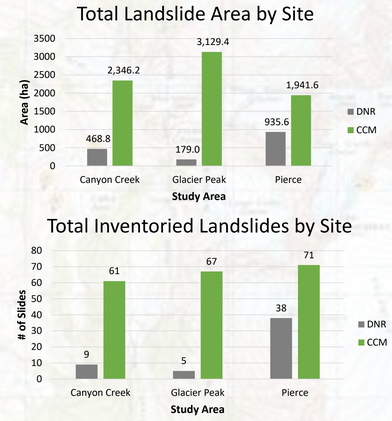


Figure 5: Comparing total number of slides and slide area between CCM maps and old DNR inventory maps

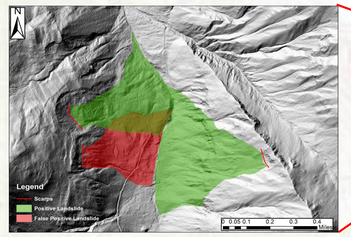


Figure 6: Ground-truth results from field excursion in Glacier Peak

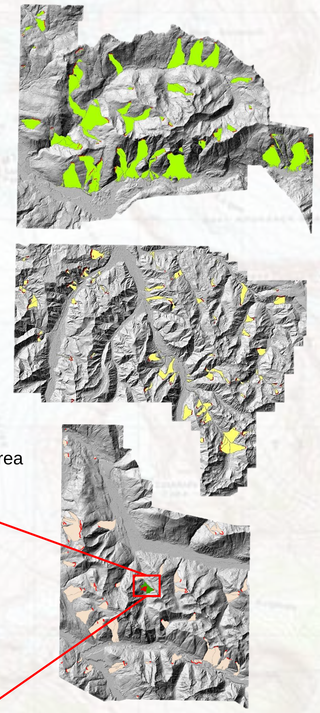

Figure 7: Final inventory maps produced by CCM. Canyon Creek (top), Pierce (middle), & Glacier Peak (bottom)

## Discussion

- In every study site, CCM produced landslide inventories that had significantly more landslides and total landslide area
- User defined inputs in scarp identification can significantly change the final scarp results
- Identifying false positive scarps is critical to minimizing CCM processing and maximizing positive results
- We must acknowledge the limitations of this study due to little time and resources to ground-truth results and an inability to access many remote areas
- Out of the landslides we were able to ground truth, two out of three were positive landslides

Figure 8: Taking observations of a landslide during a field assessment

## Conclusions

- CCM shows promise for landslide mapping the extent of MBS National Forest and other forests on a large scale
- This study points to a less expensive, consistent, and rapid framework for inventorying landslides and creating improved maps for designating activity avoidance areas and for designating landslide areas crossed by existing infrastructure
- Follow up studies with this tool ought to focus specifically on verifying CCM results in the field

## Acknowledgements

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