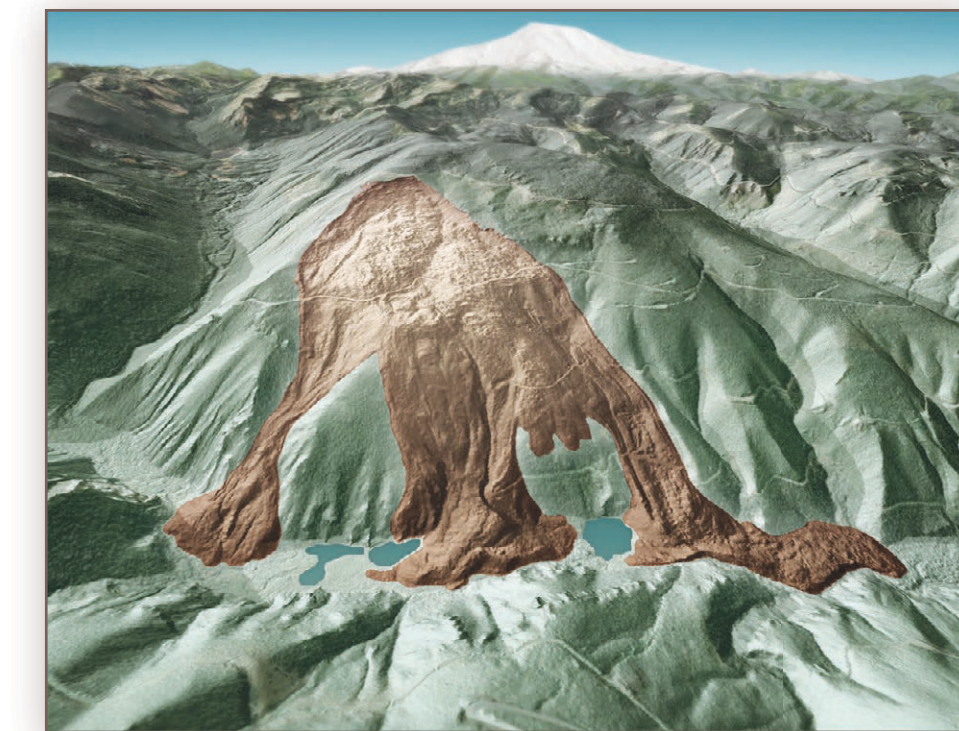


RAPID LANDSLIDE INVENTORIES FROM LIDAR: SIMPLIFYING THE INVENTORY PROCESS TO SHARE LANDSLIDE DATA QUICKLY

Stephen L. Slaughter, Katherine A. Mickelson • Washington Geological Survey • Landslide Hazards Program



Perspective-view lidar image of a large landslide above the Greenwater Lakes in northeastern Pierce County (Mount Rainier in the background).

Project Summary

In March 2016, the Washington Geological Survey's Landslide Hazards Program (LHP) began a pilot project that involved landslide inventory, susceptibility, and vulnerability mapping in Pierce County, Washington. The LHP developed a streamlined landslide mapping protocol (SLIP) to allow geologists to rapidly map landslide landforms from lidar, and tested this method in Pierce County. The intent of the simplification process is to rapidly map landslide deposits from high-quality lidar accurately and to omit the time-consuming process of recording tabular data. The SLIP approach allows geologists to quickly share a landslide inventory with counties, cities, state agencies, etc., to assist decision-makers in the prioritization of areas for future detailed landslide mapping. By implementing the SLIP method, the LHP and Pierce County were able to focus on critical areas for detailed landslide mapping. In areas where detailed mapping was unneeded, the SLIP landslide polygons will remain an effective tool for the county to identify mapped landslide hazards.

Why Simplify?

Eliminate previous false positives

- Washington State's amalgamation of previous landslide studies and reports contains thousands of mismapped and misidentified landslides.
- Previous, pre-lidar landslide mapping efforts encouraged geologists to remotely map indeterminate or questionable landslides to ensure that a field visit would be triggered. This has contributed to the large population of false positives.
- Remapping these areas using high-quality lidar will reduce the number of unnecessary geotechnical reports and landslide assessments.

Regulators typically don't care about the landslide details

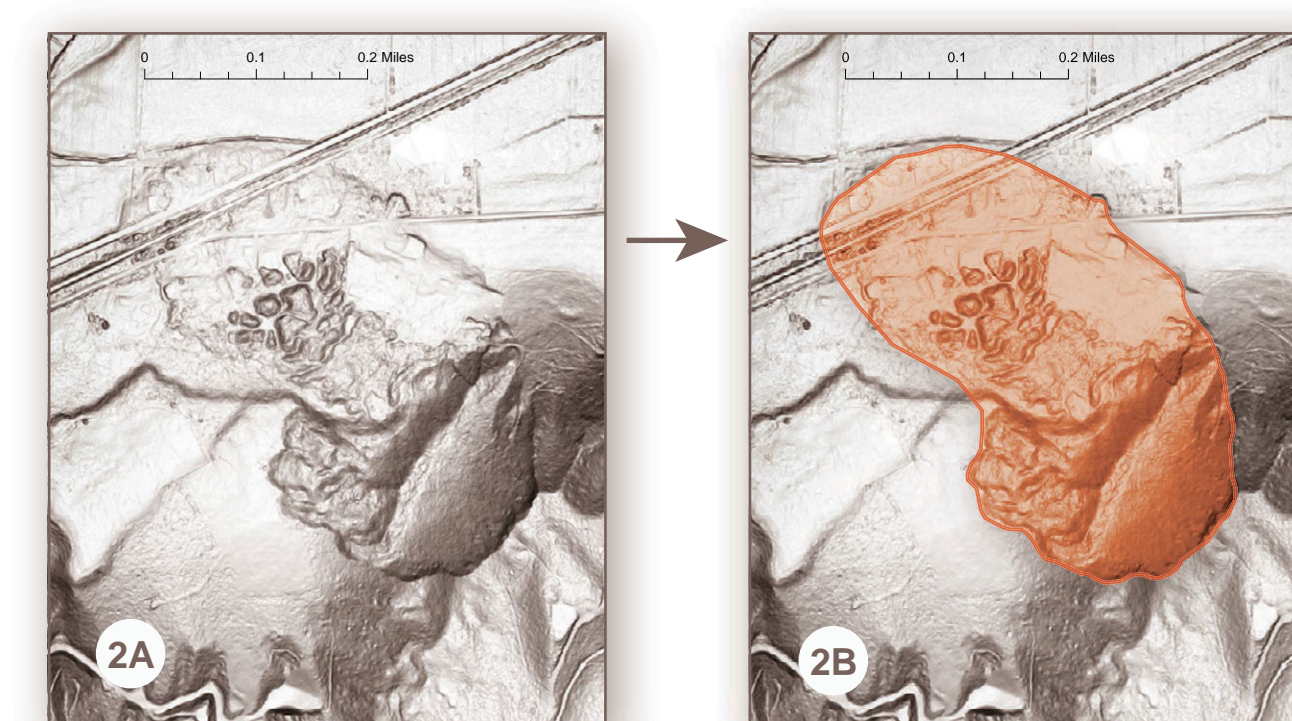
- In Washington, the burden of landslide proof is with the land manager/property owner. Regulators typically regulate with the landslide polygons, and most regulators lack the expertise (staff geologists) to understand the tabular data (landslide type, landslide material, age, geology, etc.).
- Washington's existing landslide database, used by many regulators, has more than 58,000 landslide polygons and more than half have incomplete or blank tabular data.

Detailed landslide inventories are time-consuming

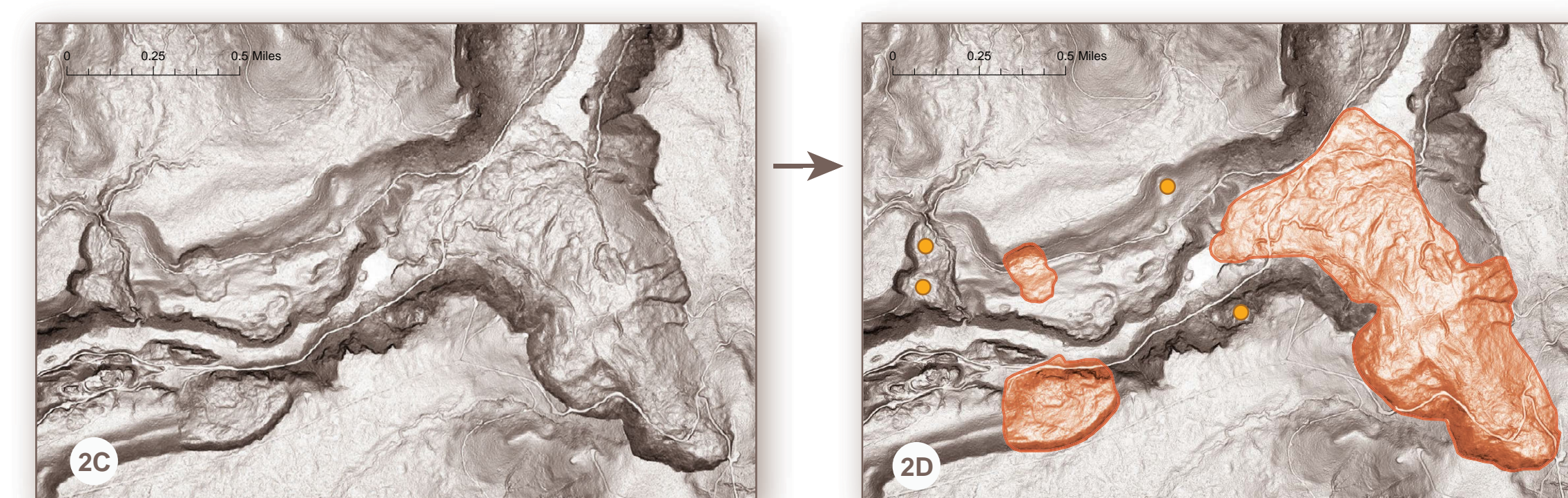
- An experienced landslide geologist can confidently digitize a landslide landform from high-quality lidar in less than a minute.
- Populating tabular data for each landslide may take several minutes or more and likely includes multiple datasets and interpretation.

Methods

- Each high-confidence landslide is mapped as an individual polygon that includes deposits, flanks, and scarp—the landslide-affected area.
- Lower-certainty landslides are identified as points and assigned an attribute of low or moderate confidence.
- No other attributes are recorded!



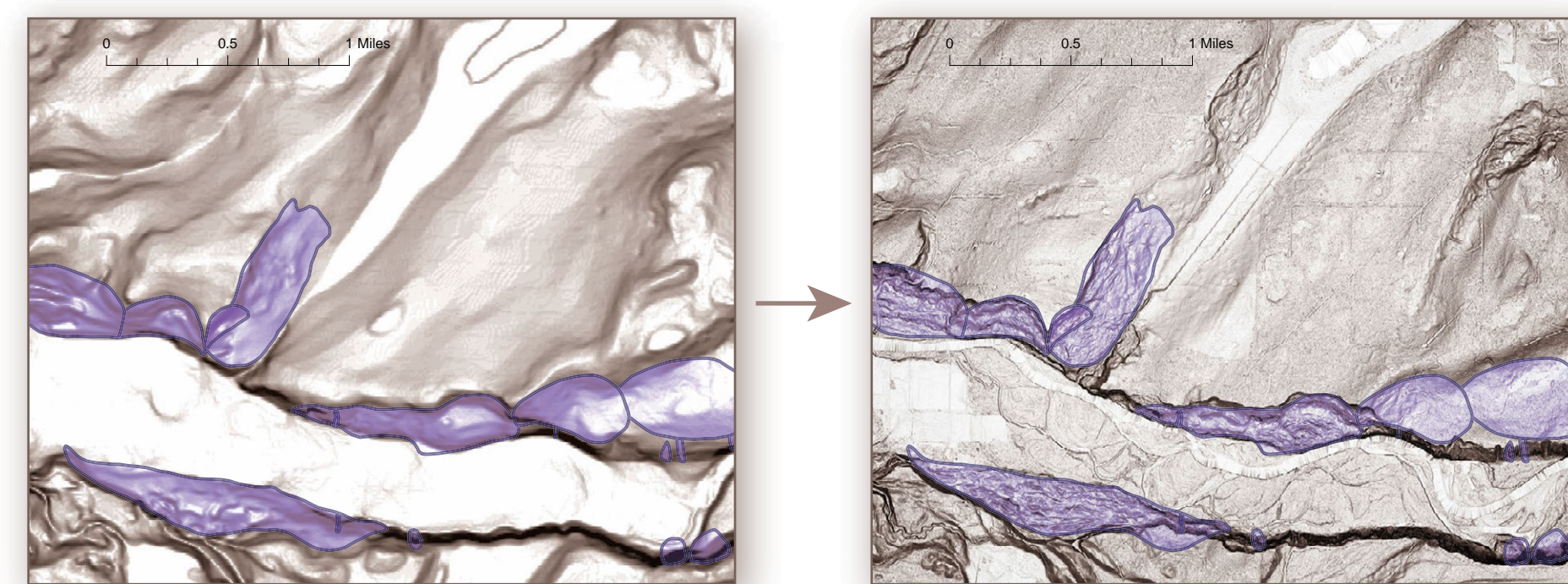
Lidar slope shade (2A) and polygon (2B) of a high-confidence landslide outlined and filled in orange that includes the landslide deposit, flanks, and scarp.



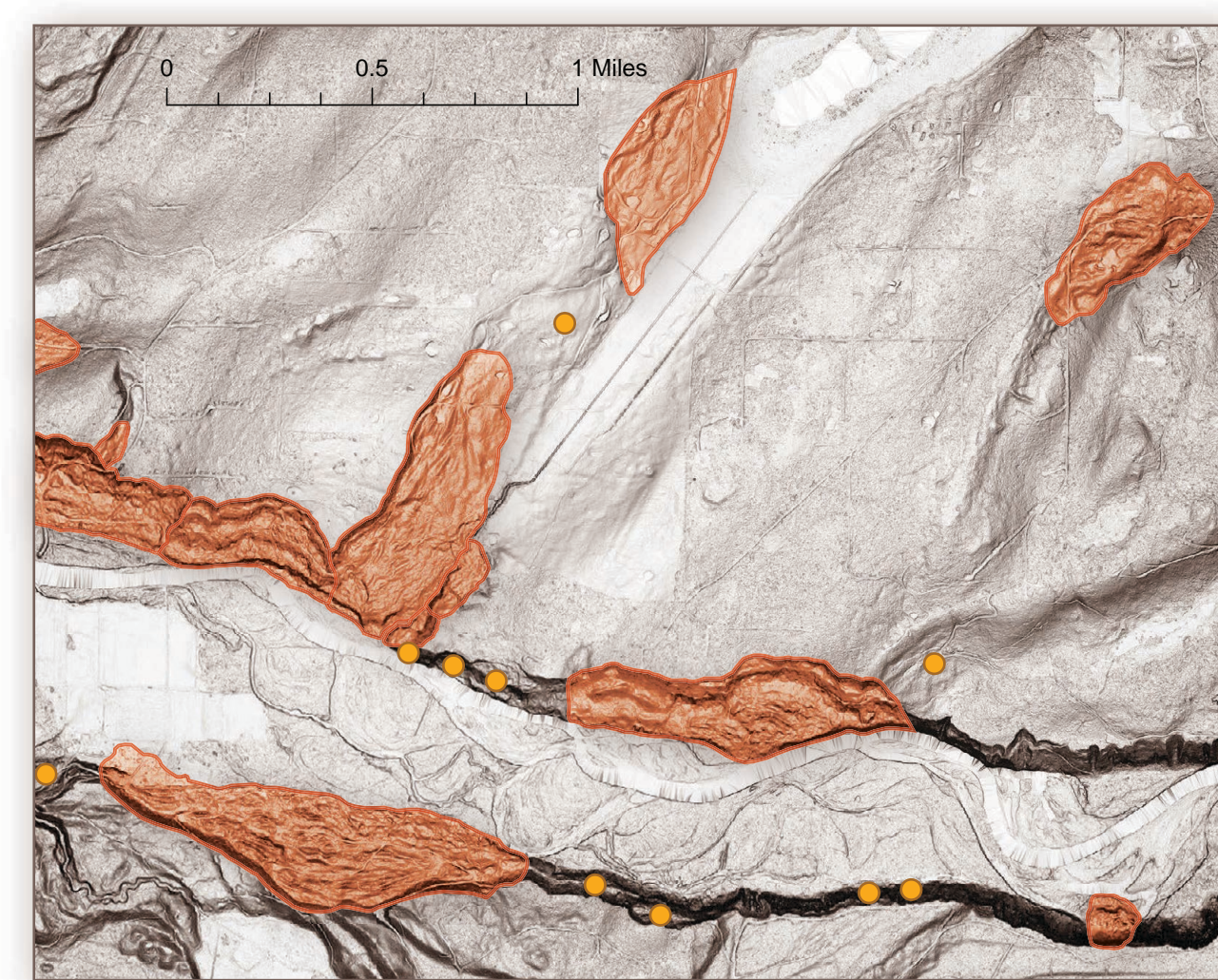
Lidar slope shade (2C) and high-confidence landslides (2D) filled in orange. Lower confidence landslides are marked with orange dots.

Benefits

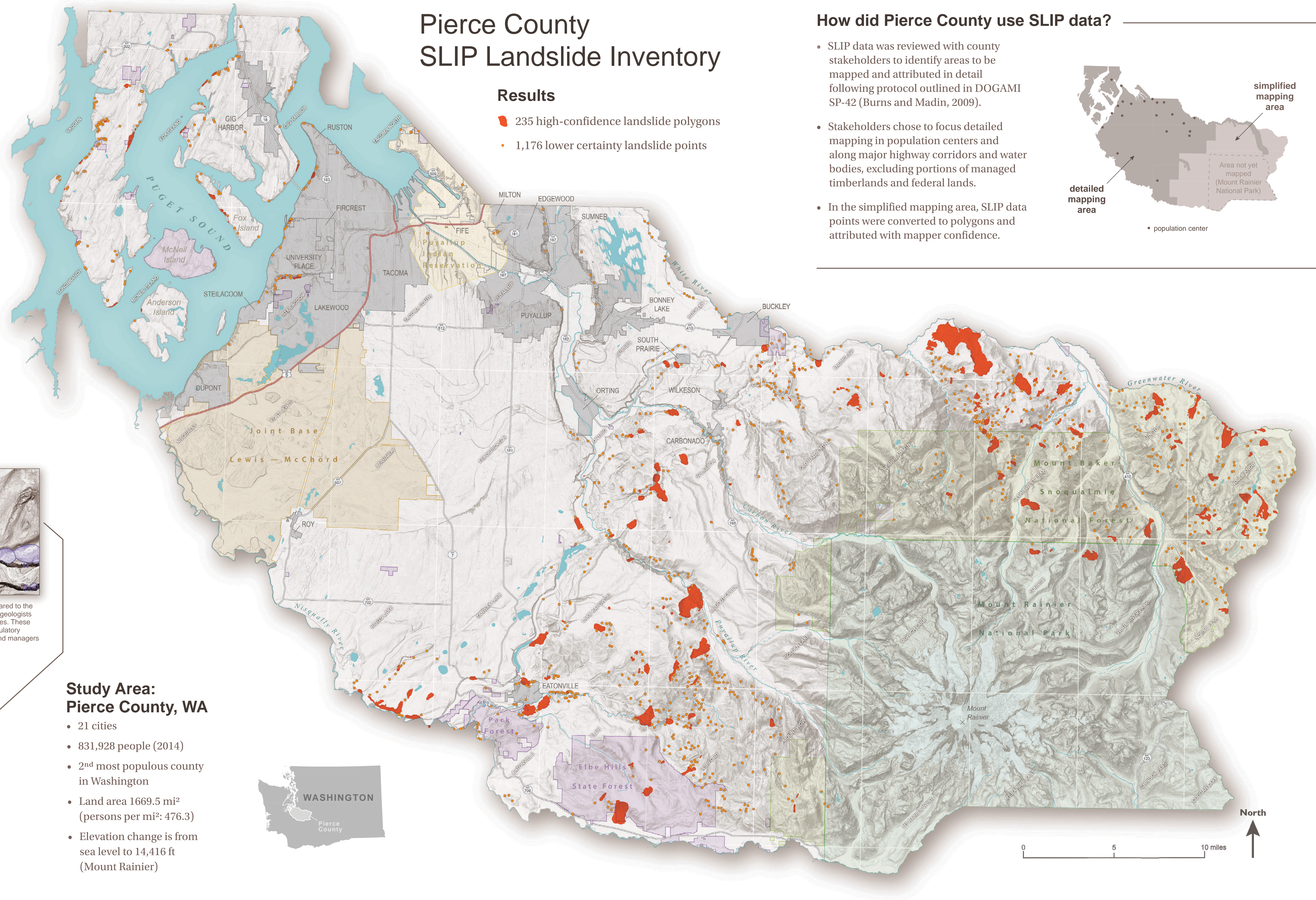
- Allows geologists to quickly share landslide data with stakeholders and decision-makers.
- Assists decision-makers in prioritizing areas for future detailed landslide inventory and susceptibility mapping following landslide-mapping protocols developed by Oregon Department of Geology and Mineral Industries (Burns and Madin, 2009; Burns and others, 2012; and Burns and Mickelson, 2016).
- Produces a basic landslide inventory map that is superior to all previous, systemic landslide mapping efforts.



1A. Existing landslide inventory mapped primarily from 10-m digital elevation models (DEM), 7.5-minute USGS quadrangles, stereo aerial imagery, some field work, and (or) other methods. Purple polygons are landslides. The hillshade is derived from a 10-m DEM.
1B. Existing landslide inventory compared to the 3-ft lidar DEM. Experienced landslide geologists will recognize falsely mapped landslides. These false positives are still considered regulatory triggers and must be addressed by land managers and property owners.



1C. The LHP landslide inventory (orange outlines and fill) identifies landslide affected areas using the 3-ft lidar DEM. Points show locations where geologists are less confident of landslide existence and are digitized near the centroids of the potential landslide landforms.



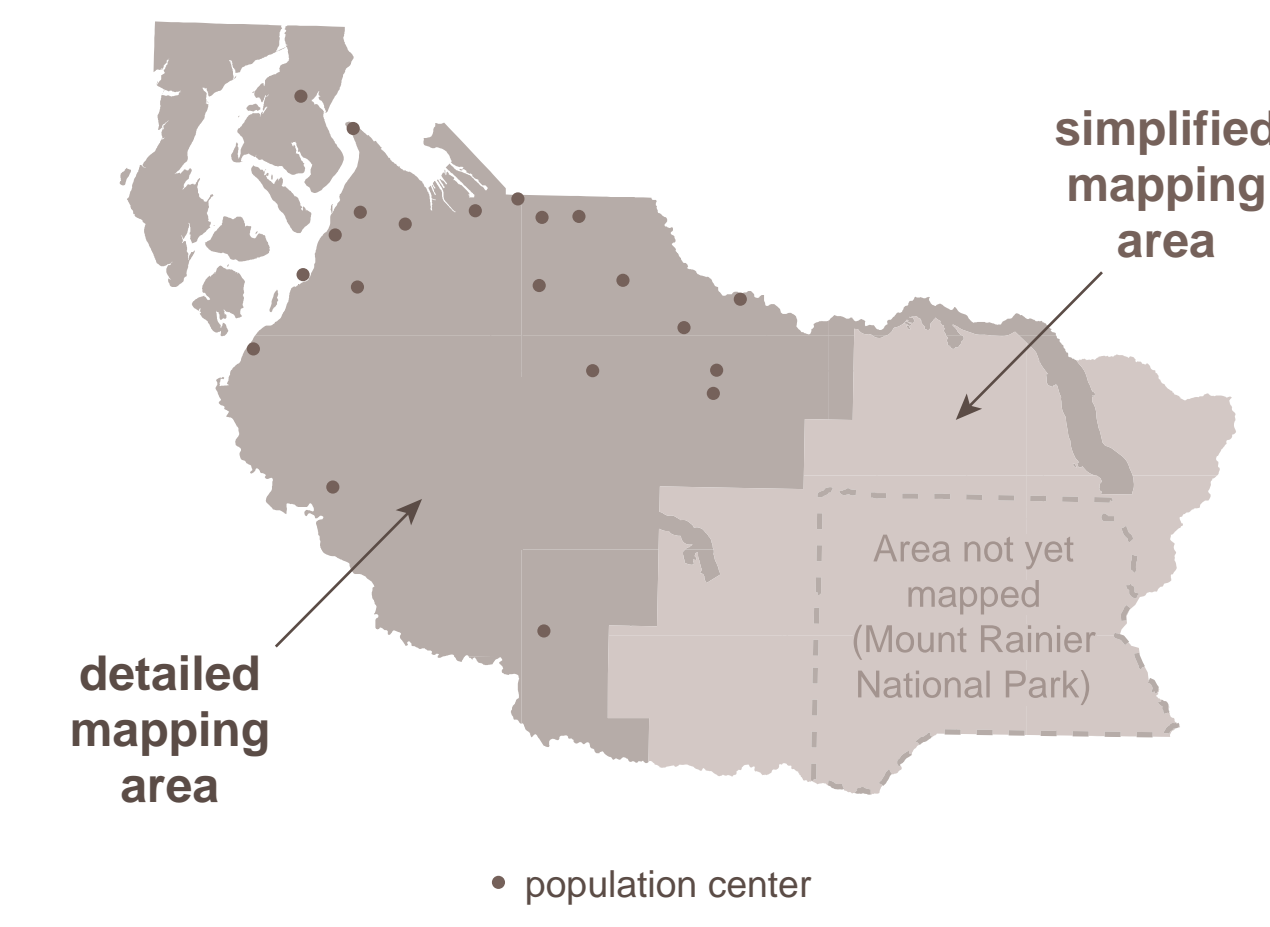
Pierce County SLIP Landslide Inventory

Results

- 235 high-confidence landslide polygons
- 1,176 lower certainty landslide points

How did Pierce County use SLIP data?

- SLIP data was reviewed with county stakeholders to identify areas to be mapped and attributed in detail following protocol outlined in DOGAMI SP-42 (Burns and Madin, 2009).
- Stakeholders chose to focus detailed mapping in population centers and along major highway corridors and water bodies, excluding portions of managed timberlands and federal lands.
- In the simplified mapping area, SLIP data points were converted to polygons and attributed with mapper confidence.

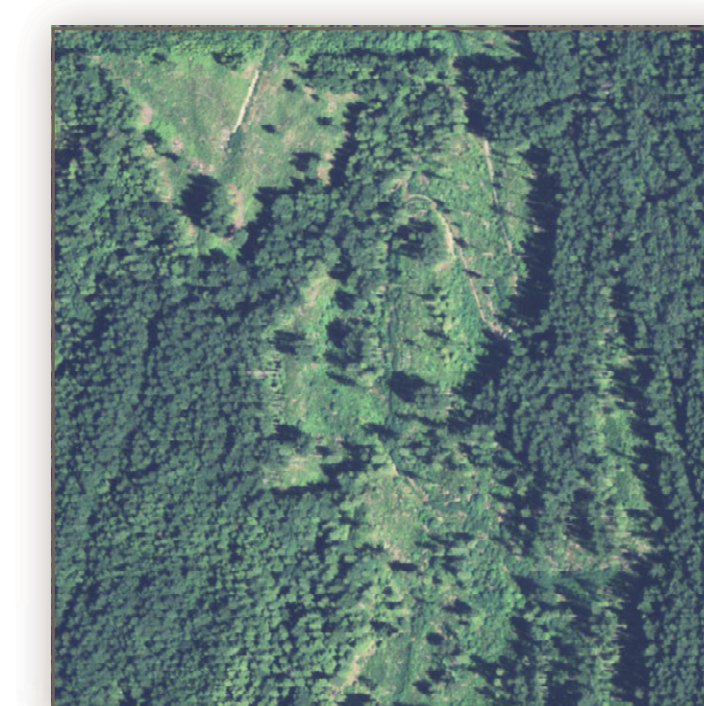


Study Area: Pierce County, WA

- 21 cities
- 831,928 people (2014)
- 2nd most populous county in Washington
- Land area 1669.5 mi² (persons per mi²: 476.3)
- Elevation change is from sea level to 14,416 ft (Mount Rainier)

Requirements

- High-quality lidar
- An experienced landslide hazards geologist
- Acceptance that more data isn't necessarily better



3A. 2013 3-foot resolution orthophoto.



3B. 2006 3-foot resolution lidar DEM shaded relief.



3C. 2013 3-foot resolution lidar DEM shaded relief.

What is our opinion of high-quality lidar?

Western Washington has very dense temperate forests, so to collect sufficient ground returns in a forested environment, lidar should be flown at >16 points/m² and must be collected during leaf-off conditions. An orthoimage (3A) and two lidar hillshades from the same area (3B and 3C) with differing lidar quality near Bellingham, Washington. Areas that lack sufficient ground returns poorly model the earth's surface and are called noisy, or "TIN-y", and look similar to a faceted mineral surface (3B). Note the significant detail missing between hillshades 3B and 3C, including stream channels and the forest road that is apparent in 3C.

References:

- Burns, William J.; Madin, Ian P., 2009, Protocol for inventory mapping of landslide deposits from light detection and ranging (LIDAR) imagery: Oregon Department of Geology and Mineral Industries Special Paper 42, 30 p.
- Burns, William J.; Madin, Ian P.; Mickelson, Katherine A., 2012, Protocol for shallow-landslide susceptibility mapping: Oregon Department of Geology and Mineral Industries Special Paper 45, 32 p.
- Burns, William J. and Mickelson, Katherine A., 2016, Protocol for deep landslide susceptibility mapping: Oregon Department of Geology and Mineral Industries Special Paper 48, 69 p.