Landslide Risk within Evacuation Areas after “The Big One” in Northern Aberdeen, Washington

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ABSTRACT:

Like many cities along the coastal Pacific Northwest, Aberdeen, Washington lies within an area of high risk in the event of an estimated 9.0 magnitude earthquake (“The Big One”) and Tsunami. A large shaking event such as this, followed by inundation increases the possibility of triggering landslides throughout the steep slopes that line the northern section of the city. This project focuses on the safety of evacuation areas and landslide risk along these northern slopes based on the city’s current evacuation map in the event of a natural disaster such as ”The Big One.”

RESEARCH QUESTION: Based on the current walking evacuation map of Aberdeen, Washington, are areas deemed “safe” for evacuation also at risk of landslides in the event of “The Big One”?

Figure 1: Location map of Aberdeen, Washington (Google Maps 2022).

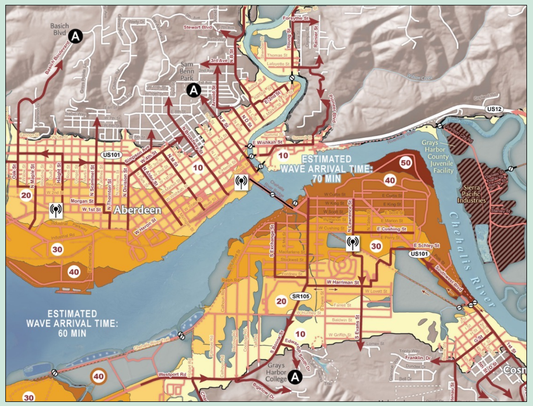

Figure 2: Walking evacuation map of Aberdeen, which shows suggested evacuation routes and areas (Washington DNR).

BACKGROUND & MOTIVATION:

The city of Aberdeen, Washington (Figure 1) is at high risk of incurring damage from a large earthquake and tsunami event, otherwise known as “The Big One.” This event will occur due to the converging plate boundaries of the the Juan de Fuca and North American tectonic plates. When this megathrust fault slips, an estimated 9.0 earthquake will occur, and a tsunami will inevitably follow with little time for citizens to prepare.

The Washington State Department of Natural Resources (DNR) has produced a walking evacuation map for the city of Aberdeen (Figure 2), outlining safe evacuation areas above inundation levels, and the accompanying walking speeds people will need to move to ensure they reach safety. What is not considered in this evacuation map is the risk that landslides within the northern area of the city (north of the Chehalis River) may pose to the suggested evacuation areas.

The Pacific Northwest Seismic Network (PNSN) has stated that,” Earthquakes of magnitude 4.0 and greater have been known to trigger landslides” and that “Strong earthquake ground shaking greatly increases the likelihood of landslides where landscape is susceptible to these types of ground failure” (PNSN). Considering “The Big One” is expected to be a 9.0 magnitude earthquake, landslides are a substantial concern. The power of these sweeping waves of inundation from the tsunami can further lead to slope failure, PNSN states “Slope material that becomes saturated with water may develop a debris flow or mud flow,” of which can lead to landslides that create blockages during evacuation (PNSN). Both earthquake tremors and tsunami inundation are factors that should be taken into consideration while planning for evacuation. This is to ensure that citizens have access to safe evacuation areas in such an event.

METHODS:

This study uses ArcMap to examine the relationship between the evacuation areas suggested by the DNR’s walking evacuation map and how much of a risk landslides are to highly populated areas within Aberdeen. GIS data was first gathered on the “Grays Harbor County GIS Download” website, including data on population, roads, city limits, and geologic units. A LiDAR (Light detection and ranging) topographic dataset with 1-meter resolution LiDAR data was collected from the Puget Sound Lidar Consortium. All data was synthesized into various maps using ArcGIS:

- Estimated 50ft inundation level overlayed with geologic units (Figure 3)
- Population density of Aberdeen (Figure 4)
- Lidar data calculated slopes >34° (Table 1) denoting areas at risk of landslide (Figure 5)
- Evacuation areas (based on DNR’s evacuation map) were overlayed with estimated inundation and landslide risk quadrants (Figure 6)

DATA MAPS:

Aberdeen Geologic Units

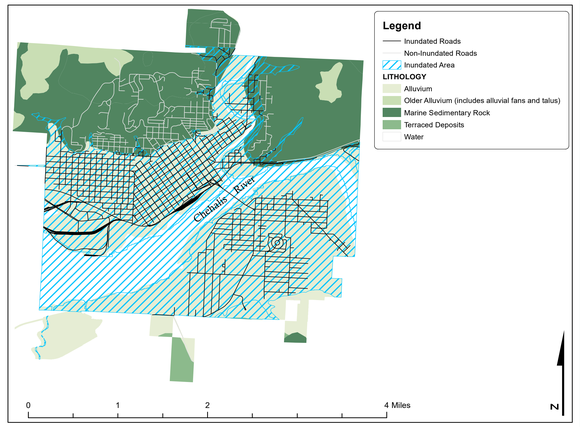

Figure 3: This maps shows Aberdeen’s geologic units and inundation levels once the tsunami has fully come inland. All alluvium deposits (old and new) and terraced deposits are from the Quaternary period. The marine sedimentary rock layers rang from the lower to upper Miocene.

Aberdeen Population Density

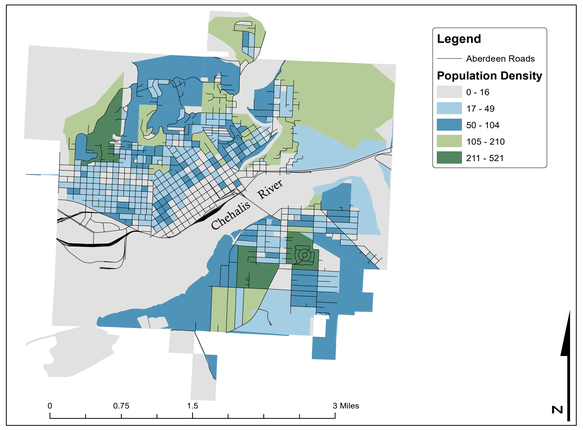

Figure 4: Population density of Aberdeen

Slopes and Populated Areas Most at Risk of Landslide

Figure 5: Slopes likely to fail in an earthquake or tsunami event and populated areas at risk

State of Sand:	Failure Angle:
Sand (Dry)	34°
Sand (Water Filled)	15-30°
Sand (Wet)	45°

Table 1: Sand angle of repose based on liquid saturation (Beakawi et al.).

RESULTS:

Aberdeen Hazard Areas

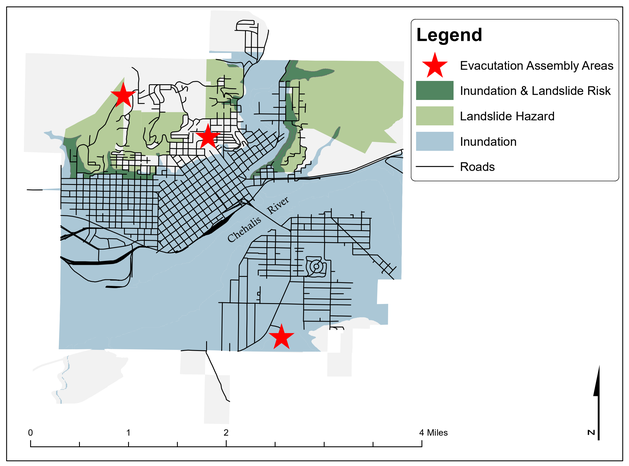

Figure 6: Suggested evacuation areas and hazard areas including landslide and Inundation. Generally, any area above the inundation zone is considered safe from evacuation by the DNR, assembly areas allow people to gather during or after the event.

	Population	Population %
Total Population:	18,122	100%
Inundation & Landslide Risk	1,387	7.7%
Landslide Hazard	1,651	9.1%
Inundation	15,287	84.4%

Table 2: Hazard events and the percent of Aberdeen's population it would affect.

When summing all the population data that are within areas that are at risk of landslide, inundation, or both the resulting product is Table 2.

- Over 80% of *inundated* geologic units are made of alluvium deposits, areas with “high risk” slopes are made of marine sedimentary rock.
- Majority of non-inundated density plots range from 58-521 people; these are also areas with greater risk of slope failure.
- Majority of “high risk” slopes are above inundation levels. These slopes are within or are near suggested evacuation/assembly areas.
- 2/3 evacuation assembly areas suggested by the DNR are within an area at risk of either landslide or inundation, 1/2 evacuation areas in North Aberdeen are at risk.
- All areas most at risk of slope failure are within evacuation zones (above inundation)

DISCUSSION:

- Slopes based on the angle of repose for dry sand, which fail at a slope of ~34° (Table 1).
- Areas densely populated and within landslide risk will become increasingly populated as people flee to higher ground. This increases the danger for current residents and citizens evacuating.
- 1/2 evacuation areas are at risk of landslide in North Aberdeen, people evacuating should have access to safe evacuation zones in an earthquake, tsunami, or landslide.
- Landslides may decrease or block evacuation zones and assembly areas, leaving less places for people to evacuate to within the higher grounds of the city.

CONCLUSION:

- Large portions of North Aberdeen that have been deemed “safe” for evacuation and assembly are shown to be at risk of slope failures based on the generalizations on the stability of dry sand sized grains.
- One of two assembly areas suggested by the DNR in North Aberdeen are within risk of landslide; the re-evaluation of these assembly and evacuation areas will be pertinent to the safety of evacuating citizens in the event of an earthquake, tsunami, or landslide.
- Southern Aberdeen (South of the Chehalis River) was not considered in this project due to minimal slope failure hazard.
- Future research:
  - Range of slope failures (different ground material) seeing if areas at risk change.
  - Investigate outer-city limits in southern Aberdeen to identify safe evacuation areas/landslide risk.

SOURCES:

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