Pedestrian evacuation modeling for tsunami hazards

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U.S. Department of the Interior
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2004 Indian Ocean earthquake and tsunami
M9.1 earthquake, 226,898 estimated deaths
Recent Catastrophic Tsunamis in the Pacific Basin

Figure modified from Atwater et al., 2005, Surviving a Tsunami—Lessons From Chile, Hawaii, and Japan, USGS Circular 1187
Exposure

How many and what kind of people are in hazard zones?

- Land cover
- Residents
- Employees
- Public venues
- Dependent-care facilities
- Community businesses
- Critical facilities

**Tsunami exposure reports available for Oregon, Washington, Hawaii, and California**
### Sensitivity

What demographic characteristics influence resilience?

**Age:** median age, % < 5 yrs, % > 65 yrs, # of nursing home residents per capita, % 25 or older with < 12 yrs education

**Employment:** % civilian labor force participation, % civilian unemployment, % employed in industry, farming, fishing, mining, and forestry, % employed in transportation, communication, and other public utilities, % employed in service

**Gender:** % of females, % households that are female headed and % female labor force participation

**Housing:** average # persons/household, % that are renter-occupied, % that are mobile homes, % in urban areas, % rural

**Race and ethnicity:** % Black or African American, % American Indian or Alaska Native, % Asian, % Hispanic or Latino, and % from international migration

**Socioeconomic status:** per capita income, % families earning > $100K, % persons living in poverty, % people receiving Social Security benefits, median home value, median rent

Figure adapted from Wood, N., Burton, C., and Cutter, S., 2010, Community variations in social vulnerability to Cascadia-related tsunamis in the U.S. Pacific Northwest, *Natural Hazards*, 52(2), 369-389
Adaptive Capacity

Can high ground be reached before wave arrival?

Figures adapted from Wood, N., and Schmidtlein, M., 2013, Community variations in population exposure to near-field tsunami hazards as a function of pedestrian travel time to safety, *Natural Hazards*, 65 (3): 1603-1628
Creating travel time maps

- 2009 NAIP Imagery
- eCognition boundary delineation
- Manual interpretation
- Ancillary data
  - Tax parcels
  - Roads (State of WA, OpenStreetMap)

- Land Cover and Speed Conservation Value (SCV)
  - Buildings - 0.00
  - Developed - 0.91
  - Light Brush - 0.83
  - Heavy Brush - 0.67
  - Unconsolidated - 0.56
  - Water - 0.0
  - Roads - 1.0
  (Soule and Goldman, 1972)

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Path Distance to Safety
Elevation vertical input = DEM
Friction = Inverse LC_SCV
Vertical Factor = Reverse Direction Inverse Slope SCV table
Origin = Safe Zone (non-hazard zone)

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Least Cost Path Surface

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Evacuation Time Surface

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Figure adapted from Wood, N., and Schmidtlein, M., 2013, Community variations in population exposure to near-field tsunami hazards as a function of pedestrian travel time to safety, Natural Hazards, 65 (3): 1603-1628
Incorporating population data

Figure adapted from Wood, N., and Schmidtlein, M., 2013, Community variations in population exposure to near-field tsunami hazards as a function of pedestrian travel time to safety, *Natural Hazards*, 65 (3): 1603-1628
Figure adapted from Wood, N., and Schmidtlein, M., 2013, Community variations in population exposure to near-field tsunami hazards as a function of pedestrian travel time to safety, *Natural Hazards*, 65 (3): 1603-1628
Risk reduction
Where could vertical-evacuation refuges be built?

Project Safe Haven:

Tsunami Vertical Evacuation on the Washington Coast

Information about Project Safe Haven

https://catalyst.uw.edu/workspac/wiserjc/19587/116498

http://www.facebook.com/ProjectSafeHaven
Risk reduction

How would each refuge change the evacuation landscape?

Risk reduction

Comparing potential benefits at each vertical-evacuation refuge

Risk reduction

Refuge-siting implications of prioritizing one group over others

Risk reduction

Post-disaster analysis of evacuation landscapes

Comparison of reported deaths with evacuation hotspots

Changes in population vulnerability due to post-disaster recovery decisions

Figure adapted from Wood, N., Schmidtlein, M., and Peters, J., 2014, Changes in population evacuation potential for tsunami hazards in Seward, Alaska, since the 1964 Good Friday earthquake, *Natural Hazards*, 70:1031-1053
Summary

- GIS has been instrumental in understanding variations in exposure, sensitivity, and adaptive capacity to tsunami hazards.
- Different vulnerabilities require different risk reduction efforts (education, evacuation training, and/or vertical refuges?)
- No one refuge can save everyone so difficult policy questions
- Continuing work – optimization, pathways, landscape preferences

For more information

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http://geography.wr.usgs.gov/science/vulnerability