Tsunami deposits and tsunami modeling of the 900 AD Seattle Fault event in northern Puget Sound: Thesis Proposal
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Problem to be Addressed and Hypothesis

Puget Sound is vulnerable to tsunamis that could cause catastrophic infrastructure and potential fatalities. About 1,100 years ago, an earthquake on the Seattle Fault generated a tsunami that flooded low-lying areas in at least six known sites in eastern Puget Sound, as far north as the Snohomish delta in Everett and as far south as Gorst near Bremerton (Adams, 1992; Atwater & Moore, 1992; Bucknam et al., 1992; Bourgeois & Johnson, 2001; Arcos, 2012) (Figure 1). These few paleotsunami field sites begin to illustrate the hazard posed by a rupture of the Seattle Fault, yet they do not define the extent of coastline inundated by that tsunami. Understanding the behavior of the 900 AD tsunami will provide significant knowledge that can be used in hazard planning throughout Puget Sound.

The goal of this project is to model the 900 AD tsunami for Puget Sound and validate the model based on observed tsunami deposit field sites. I will look for tsunami deposits at a new location, the Elger Bay marsh on Camano Island, because it lies between areas where evidence of inundation have and have not been found. A tsunami deposit, or lack thereof, will allow me to validate model simulations that predict where the tsunami still had the energy and size to inundate low-lying areas and leave a deposit. This project is a collaboration with the Island County Department of Emergency Management (ICDEM), who plans to use my results to evaluate and/or revise their current hazard mitigation plan and to add to their community outreach programs.
**Background and Previous Studies**

The Seattle Fault Zone (SFZ) is a series of three or more south-dipping blind-thrust faults that strike E-W (Figure 1) (Arcos, 2012). It extends ~70 km from the Hood Canal eastward to the Cascadia Range foothills (Nelson et al., 2003). The known faults that make up the SFZ are the Blakely Harbor Fault, the Orchard Point Fault and the Seattle Fault (Nelson et al., 2003). The only known rupture of the SFZ is the 900 AD event.

Tsunami deposits have been found at five sites south of my field area of Elger Bay and north of the Seattle Fault. The 5-15 cm thick sand deposit at Cultus Bay and the 4-6 cm thick deposit at West Point (Atwater & Moore, 1992) is testament of catastrophic flooding in these low-lying areas. The Snohomish delta experienced flooding that deposited a sand layer up to 5 cm thick (Bourgeois & Johnson, 2001). Bourgeois also completed fieldwork at Deer Lagoon and Priest Point that resulted in the discovery of tsunami deposits, though this information is unpublished. On the other hand, no tsunami deposits were found during extensive studies at Crescent Harbor and Dugualla Bay north of Elger Bay. Between the known tsunami deposits and Crescent Harbor is where the 900AD tsunami transitioned from onshore flooding of low-lying areas to being too small to breach the beach crest.

**Plan to Test Hypothesis**

I will use the GeoClaw code, a two-dimensional, shallow-water wave equation model (LeVeque et al., 2011), to simulate a tsunami from the known parameters of the 900AD Seattle Fault earthquake to locations known to contain and not contain the tsunami deposit. Parameters modified from Venturato et al., (2007) by Arcos (2012) will be used to model the earthquake. These parameters include fault segment length, width, dip, rake, strike, depth, and slip (Table 1).
The earthquake will be an input into GeoClaw along with bathymetry of Puget Sound. The tide also plays a major role in the areas inundated since the tides in Puget Sound vary by about 4 meters, thus the tsunami will be modeled at high and low tide levels.

My simulation area will cover northern Puget Sound, including sites with published and unpublished paleotsunami studies: West Point, Cultus Bay, Deer Lagoon, the Snohomish delta, Priest Point, Crescent Harbor, Dugualla Bay, and my new study area of Elger Bay (Figure 1). Tsunami deposits exist in the first five of these sites; no tsunami deposits occur in Crescent Harbor and Dugualla Bay. When I compare simulated tsunami wave heights to field-based observations of tsunami deposits, I can refine the model accuracy and develop a best-fit scenario by varying the fault parameters. With this best-fit model, I will predict if a tsunami flooded Elger Bay and further validate my simulations with additional fieldwork.

During June fieldwork at Elger Bay, I will train and supervise two teams of graduate and undergraduate field assistants to aid with mapping the stratigraphy from the Elger Bay channel, at the mouth of the marsh, to the uplands (Figure 2). Teams will use tidal channel banks to view the stratigraphy of the marsh and determine if a tsunami deposit is present. Tsunami deposits are typically characterized by normally graded sands, thin landward, and have laterally uniform thickness (Martin & Bourgeois, 2012). In the western and northern areas of the marsh, we will use a gouge core to map the stratigraphy. Elger Bay marsh covers a relatively small area of about 250 m$^2$. Throughout the 7 days in the field, I expect to take 40-50 cores. We will be describing stratigraphic layers, such as sand, gravel, peat, and mud, as well as creating stratigraphic columns to represent the stratigraphy. The sequence in which these deposits are found will enable reconstruction of the marsh through its history.
Google Earth images indicate dense driftwood covers approximately 40% of the marsh surface, making access challenging for core transects (Figure 2). Although Elger Bay is an ideal location for a paleotsunami study, the dense driftwood is the reason it has not yet been studied. I will use a DJI Phantom 2 quadcopter equipped with a GoPro camera that provides a live feed to a hand-held monitor to remotely search for paths of least resistance through the driftwood. Finding these paths is key to mapping the inland extent of the tsunami deposit for comparison to my model.

In the event that a tsunami record is not found, I will conduct extensive radiocarbon dating of organic materials found in the cut banks and cores to establish a detailed record of the age of the stratigraphy of the marsh. I will then compare the stratigraphic age record to relative sea level databases for the Puget Sound region to determine whether conditions at Elger Bay marsh were favorable for tsunami deposit preservation. If the elevation of the marsh were below sea level at the time of the Seattle Fault rupture, no tsunami deposits would be preserved due to the erosive nature of water. But, if the marsh is found to have been above sea level at that time then I can determine that the tsunami was not large enough to inundate the low-lying land at this location.

**ANTICIPATED RESULTS AND BENEFITS**

Using tsunami modeling combined with field validation, I anticipate being able to accurately simulate the flooding extent of the 900 AD Seattle Fault tsunami in northern Puget Sound. I am partnering with ICDEM to study the 900AD tsunami in northern Puget Sound because the northern extent of tsunami inundation is currently unknown. Compared to south of the Seattle Fault, the northern extent has enough field sites for effective model comparison. My
tsunami modeling best-fit results, validated by field observations, will provide valuable information for the ICDEM’s hazard mitigation mission, as well as all businesses and homeowners along eastern Puget Sound. The ICDEM can utilize the results of my work to help evaluate the hazards at population centers and locations with significant infrastructure. ICDEM hosts a number of events to promote awareness of the local hazards including hazard mitigation plan workshops and safety fairs. Hazard maps are readily available on their website as well as the “Where Are My Hazards?” app hosted by ArcGIS.com.
**SCHEDULE**

October 2014 – April 2016: Modeling

Spring 2015: Propose thesis, design field plan

June 13-20, 2015: Field work at Elger Bay Marsh

Summer-Fall 2015: Analyzing field data

February 2016: First draft of thesis complete

Winter-Spring 2016: Edit thesis

Spring 2016: Defend thesis

**BUDGET**

CWU Van rental: $414

Per diem (5-7 people): $1500

Lodging: $1500

AMS radiocarbon dates: $1674

Bulk radiocarbon dates: $458

TOTAL: $5546
Figure 1. Study area, tectonic setting, and location of sites for comparison to tsunami models of the 900 AD Seattle Fault event. DB = Dugualla Bay, CH = Crescent Harbor, EB = Elger Bay, PP = Priest Point, SN = Snohomish delta, DL = Deer Lagoon, CB = Cultus Bay, WP = West Point. Modified from Arcos, 2012.
**Figure 2.** Google Earth image of Elger Bay.

**Table 1.** Parameters of the Seattle Fault earthquake modified from Venturato (2007) (Arcos, 2012).

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<th>Width (km)</th>
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<th>Rake</th>
<th>Strike</th>
<th>Depth (km)&lt;sup&gt;f&lt;/sup&gt;</th>
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REFERENCES


