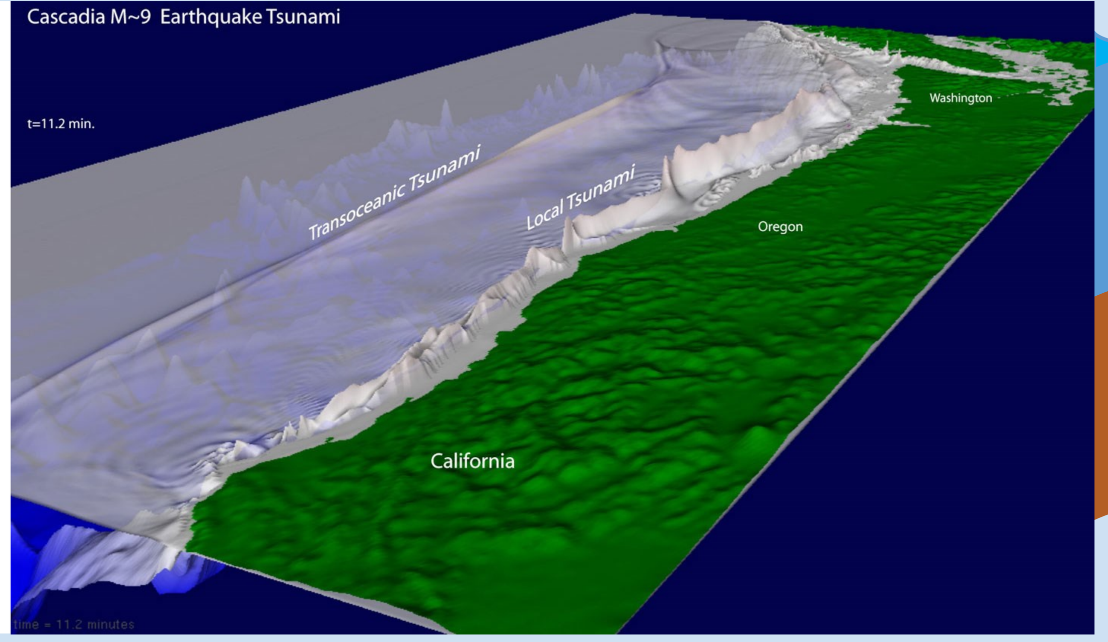

Civil and
Environmental
Engineering

SHOCK AND AWE
PREPARING FOR THE IMPENDING WAVES FROM THE *CASCADIA SUBDUCTION ZONE*

SOURCES:

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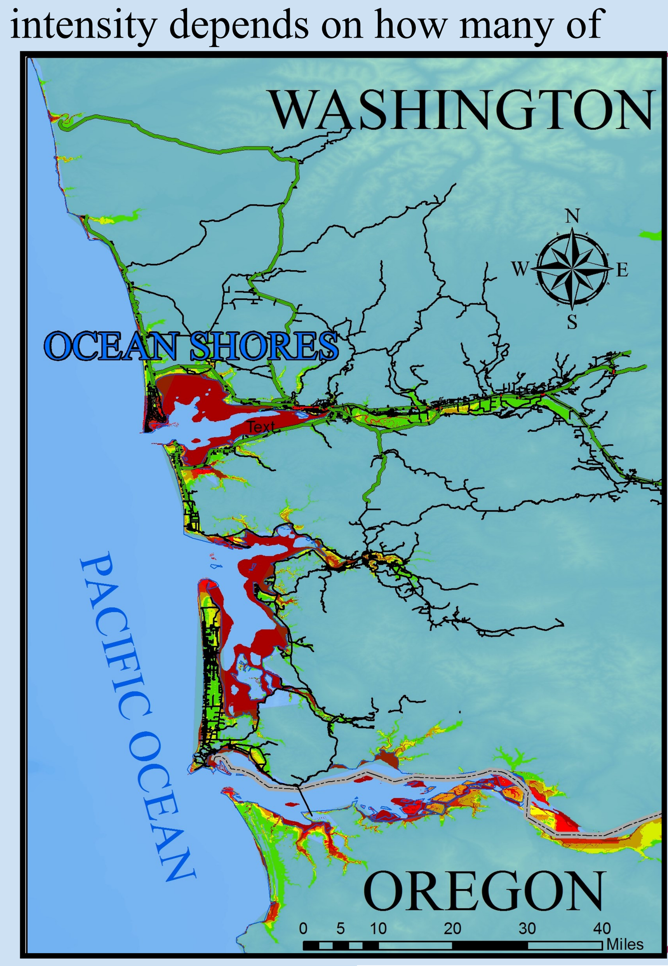
CARTOGRAPHER: COREY SNIDER
CEE-0187: GEOGRAPHIC INFORMATION SYSTEMS
PROJECTION: NAD_1983_UTM_ZONE_10N
DECEMBER 12TH, 2016

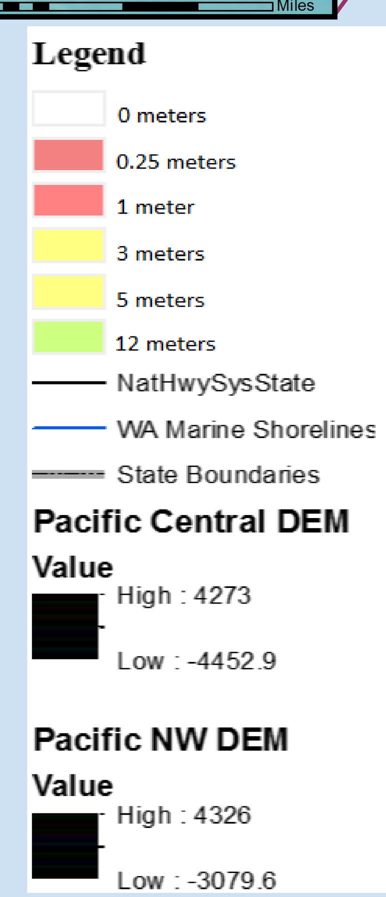
Background Information

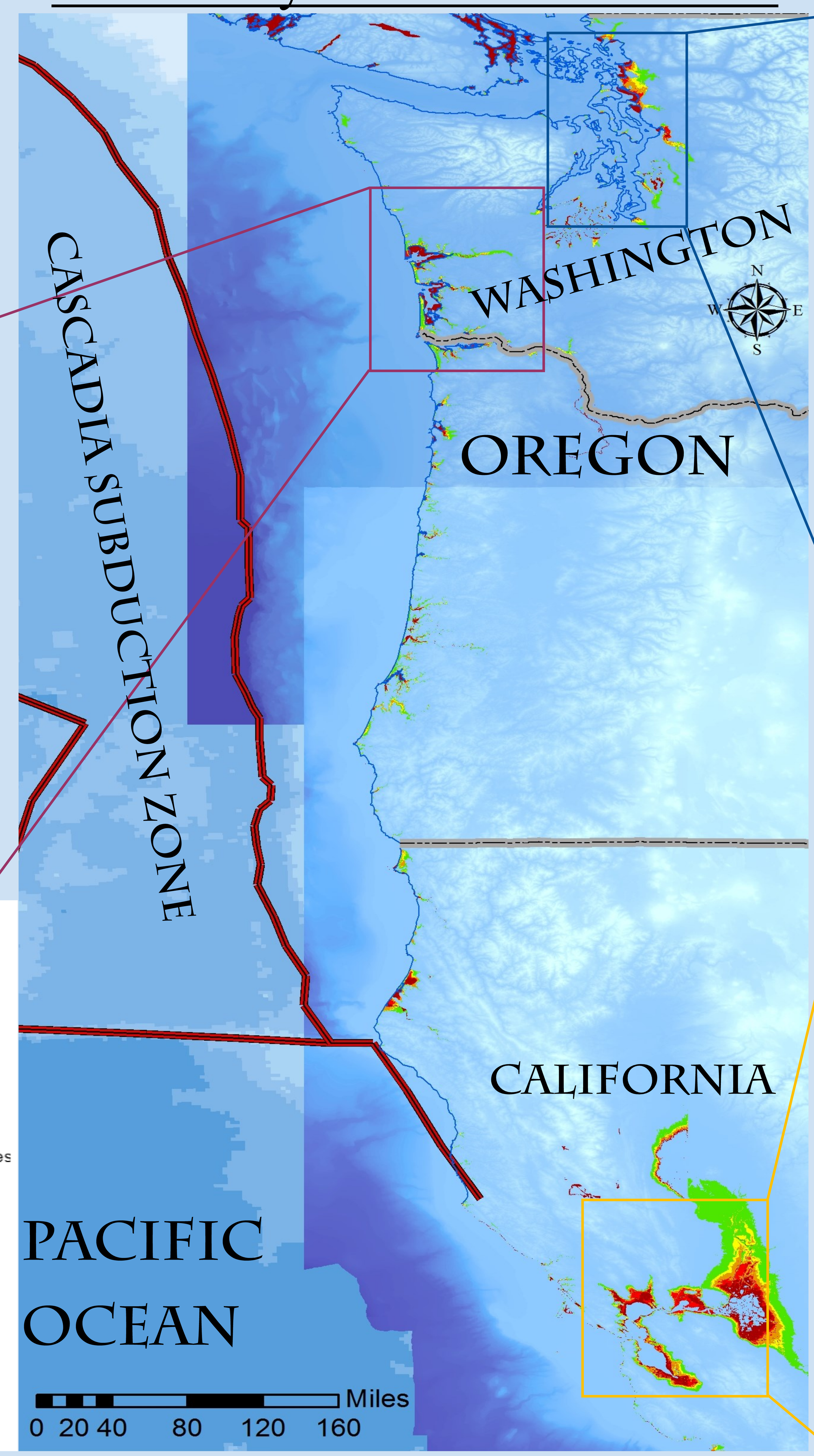
The Cascadia Subduction Zone (CSZ) is an approximately 1100-kilometer (683.5 miles) long fault created by a combination of the Explorer plate, the San Juan de Fuca plate, and the Gorda plate dipping below the North American continental plate. Over time, these plates' convergence causes smaller earthquakes as parts of the plate pass into the Transition Zone towards the mantle; adding more stress to the larger fault that remains in gridlock. When this gridlock finally is released, it produces displacement of several meters on land and shear waves powerful enough to generate devastating earthquakes and tsunamis. The degree of earthquake and tsunami intensity depends on how many of the CSZ's three regions slide under the continental plate at a given time. The CSZ periodically produces earthquakes with a moment magnitude greater than 8; it generated an earthquake with a moment magnitude of about 9 on January 26th, 1700, and was recorded by Japanese scribes.

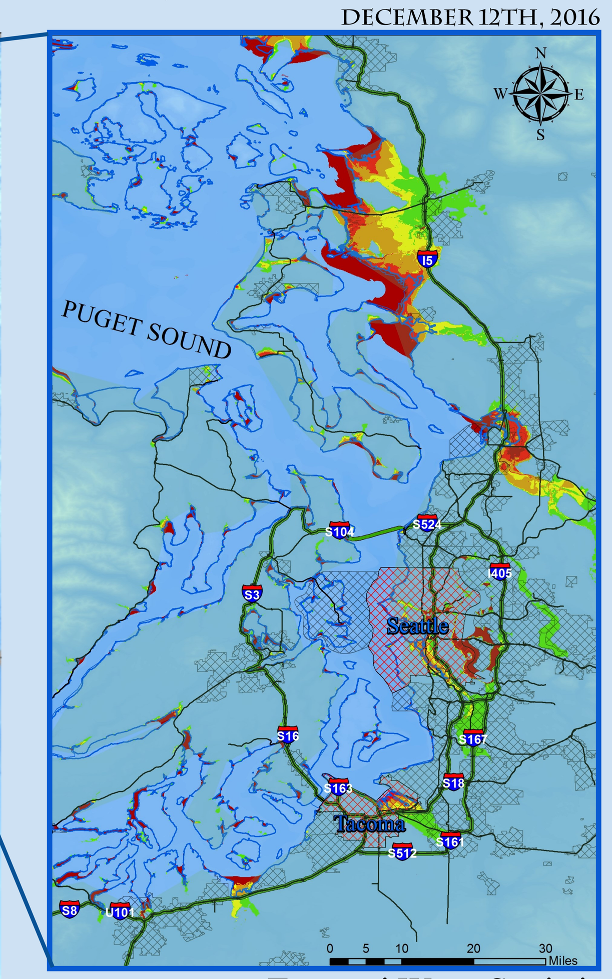
The last earthquake generated in the Cascadia Subduction Zone produced a ground acceleration of approximately 0.3g, which is comparable to the earthquake and subsequent tsunami that struck Japan on March 11th, 2016, that killed more than 15,000 people. In addition to the Japanese record of the last CSZ quake, geologists have determined that it caused liquefaction, deposited tidal sand inland, and killed redwood trees that remain to this day in "ghost forests". Native American oral traditions recount stories of the disaster from Vancouver Island to Northern California.

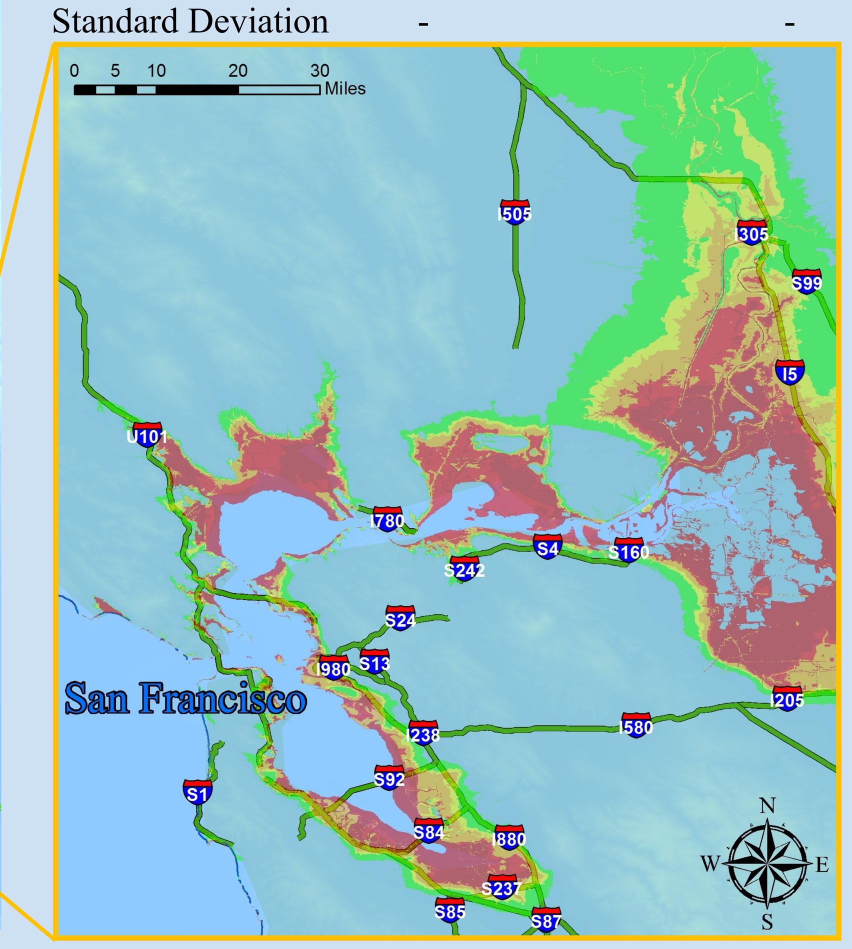
DEM analysis of areas inundated











Methodology

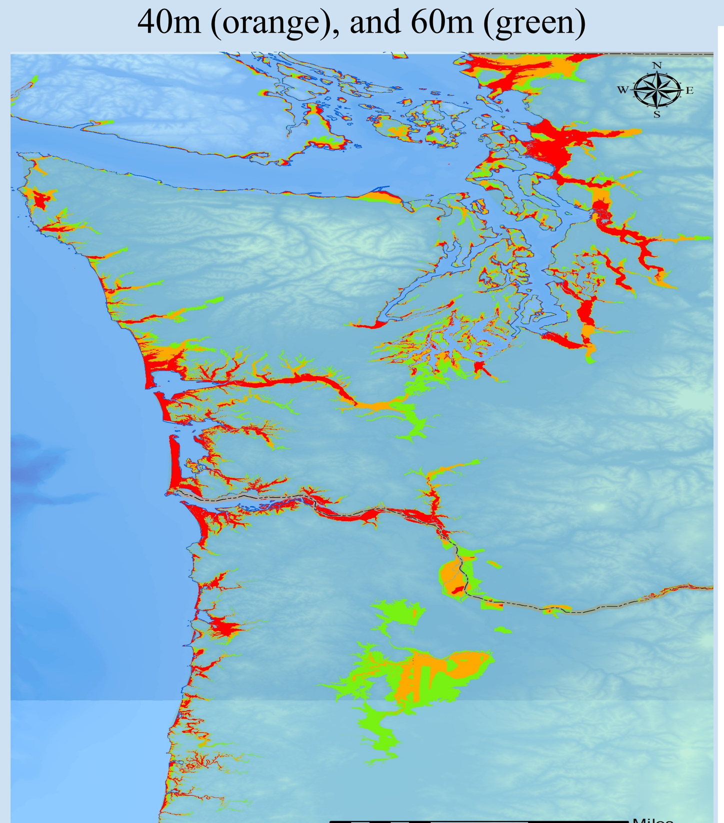
For this study, a risk assessment map was created by gathering information about the amplitude, velocity, and moment magnitude (M_w) of the next possible Cascadia Subduction Zone earthquake from research studies conducted on the effects of the one occurring on January 26th, 1700. This information was used to estimate the "run-up" height of a tsunami propagated by the earthquake in order to determine areas of inundation in coastal cities along the Western seaboard of a North America.

In order to do this, several Digital Elevation Model (DEM) raster images were analyzed using logical operations such as (Greater Than, Less Than, Boolean AND) in order to produce geographic overlays within the range of desired inundation levels. These layers' true values were then "added" together in order to produce a stratified layer for varying levels of inundation. The levels of inundation measured ranged from 0 to 0.25 meters, 0.25 to 1 meters, 1 to 3 meters, 3 to 5 meters, and 5 to 12 meters above sea level.

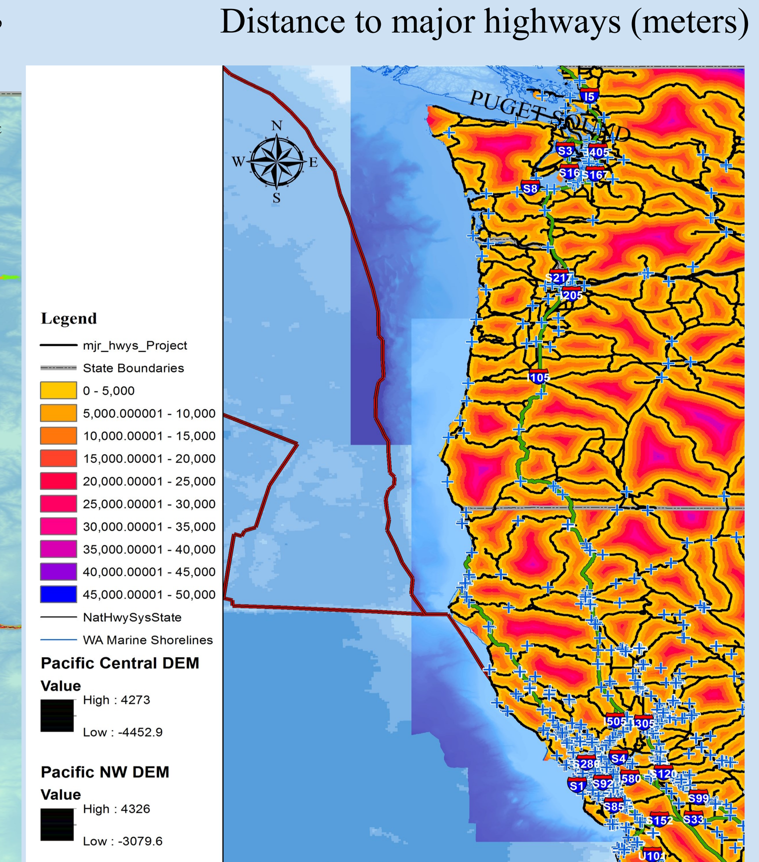
While it is not likely that areas far inland will receive inundation levels of 12 meters, there is the potential for the tsunami to produce a 30-meter-high Queen wave, therefore, it is taken into consideration for areas closer to the Pacific Ocean, such as Ocean Shores and Gray Harbor County, WA. San Francisco is not expected to receive the highest amplitude of waves from a CSZ tsunami, however, it has a large swath of land at low-elevation at risk from any tsunami's waves.

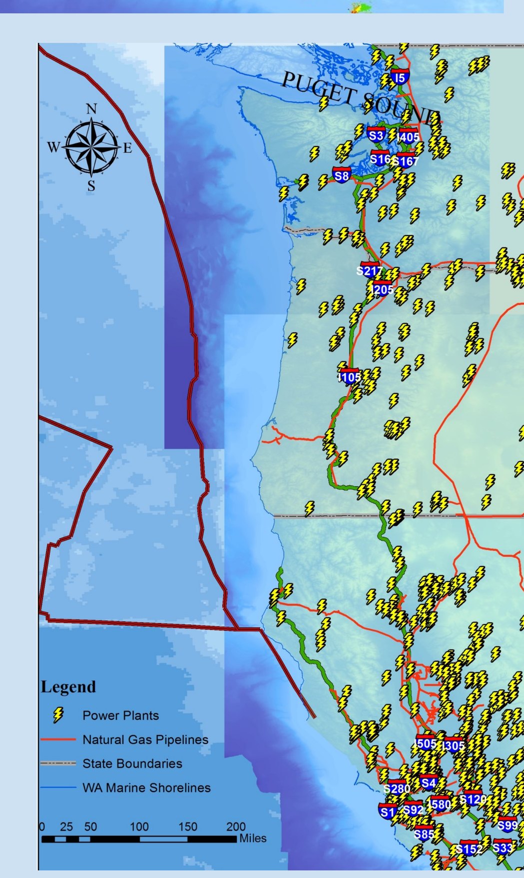
The first tsunami waves are projected to arrive on-shore in **less than 12 minutes** after the Magnitude 9 earthquake occurs. If warning systems do not notify you, animals such as dogs barking may be the only warning. In order to determine if you are in a dangerously isolated area of the coast, see the heat map indicating relative distance from major roadways near the western coastline.

Worst Case Scenario: Inundation at 20m (red), 40m (orange), and 60m (green)



Distance to major highways (meters)





Local Natural Gas & Power Plants

Limitations

Due to the variable changes and differences in stresses, subsurface temperatures and densities, coastal bathymetry, loss coefficients, tsunami wave propagation and amplitudes, and many other parameters, the following cause great experimental uncertainty and are outside of the scope of this study:

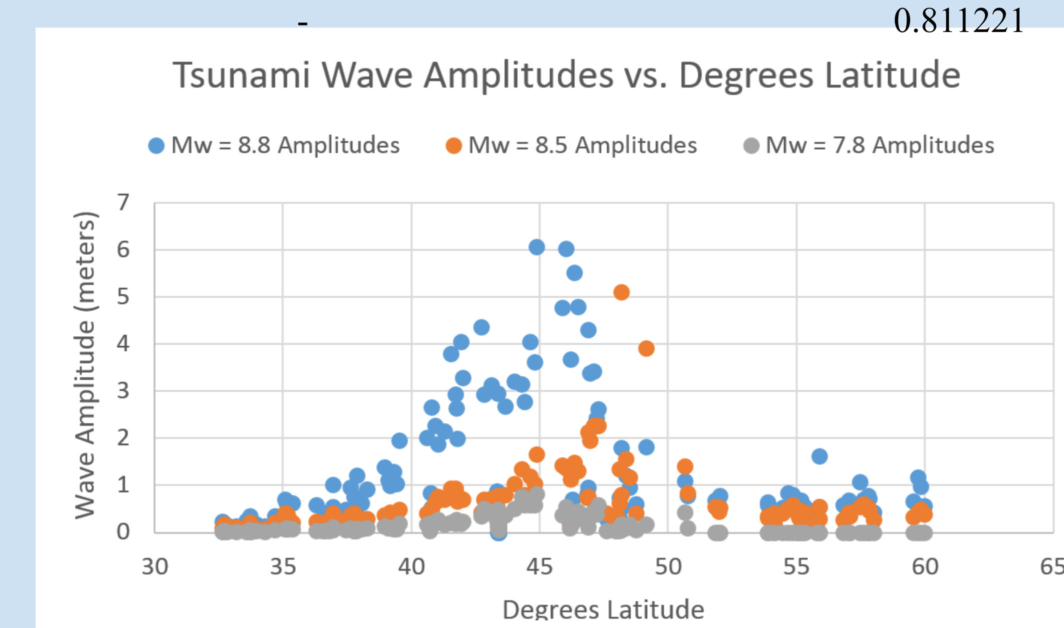
- predicting the intensity and areas of inundation by the next tsunami generated from the Cascadia Subduction Zone,
- predicting mass casualties or property damage from census datasets,
- predicting the time and conditions of the event,
- modeling the wave dynamics of the tsunami.

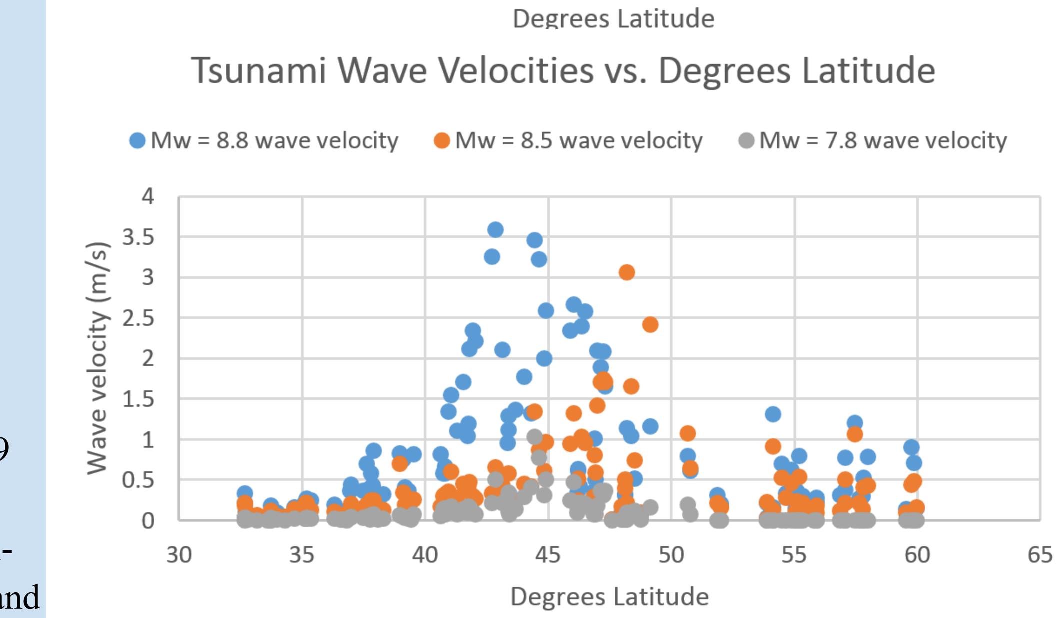
This study aims to determine the areas that could be at risk due to inundation, liquefaction, and vibration caused by a magnitude 9 earthquake at the Cascadia Subduction Zone. Run-up height has been estimated in varying studies on tsunami dynamics. If we estimate a run-up factor of 10, as in Japan's Tohoku tsunami, the inundation can be 10x the amplitude (~60 m in central Oregon).

Tsunami Wave Statistics simulated for a Moment Magnitude 8.8 earthquake occurring at the CSZ

Amplitude Statistics	Site	Latitude	Longitude	Amplitude (meters)
Maximum	Siletz Bay, OR	44.9	124	6.07
Mean	-	-	-	1.292824
Standard Deviation	-	-	-	1.370923

Velocity Statistics	Site	Latitude	Longitude	Wave Velocity (m/s)
Maximum	Cape Blanco, OR	42.85	124.55	3.59
Mean	-	-	-	0.759542
Standard Deviation	-	-	-	0.811221





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Data Results & Conclusions

An earthquake with a moment magnitude of 9 or greater from the Cascadia Subduction Zone has the potential to create a tsunami with waves having a "run-up" height ranging from a 1 to 3 meters in California and 12 to 60 meters in central Washington and northern Oregon.

If such a tsunami were to occur, places such as Ocean Shores, WA, Seattle, WA, and Astoria, OR, would face severe flooding. The large display of this study shows inundation ranging from only 0 to 12 meters across all regions. One study conducted by Whitmore recorded data of tsunami amplitudes and wave velocities which show a normal distribution when plotted against degrees latitude. The maximum wave amplitude simulated at Suetz Bay, Oregon, of 6.07 meters is disturbing considering that, with a run-up scale factor of 10, it would experience inundation of 60.7 meters above sea-level. However, the majority of coastlines along the Strait of San Juan de Fuca are at high elevations, where it may be expected that the wave amplitudes will decrease before reaching major cities such as Seattle, Tacoma, and Mt. Vernon, Washington. The tsunami is most threatening to places such as Ocean Shores, WA, and the Oregon coast, where long peninsular corridors prevent the possibility of evacuation to higher elevation before the tsunami strikes the coast. A few possibilities to consider for preparing for the tsunami and earthquake would be: ensuring that buildings are designed and/or braced such that they will withstand the earthquake loads from a magnitude 9 earthquake, attaching accelerometers and temperature probes to undersea communication cables, engineering gravity walls in the ocean that could reduce some of the wave force from an incoming tsunami.