Lower Columbia Watershed Tsunami and Flood Hazard Mapping Comparisons

CE 413 Final Project

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1 Introduction

There are two objectives of this project. The first objective is use ArcGIS to analyze the streams and streams flows throughout the watershed. This analysis will provide information on the length and flow of rivers and streams through the watershed, which will be used to provide context for the watershed analysis. The second objective of this project will compare the National Flood Hazard Layer (NFHL), Tsunami Evacuation Zones provided by the Oregon Department of Geology and Mineral Industries to flood inundation mapping done using ArcGIS tools. The flooding analysis for the watershed will only consider the part of the watershed in Oregon.

2 Site Description

The selected sire for this project as chosen as the Lower Columbia watershed. This watershed is located along the Columbia River and extends into both Oregon and Washington. The watershed includes the communities of Astoria and Warrenton on the Oregon side and Chinook on the Washington side of the river. The total watershed area is over 434,000 square miles (1756 square kilometers). Approximately 300,000 acres of the watershed lies in Oregon and the remainder is in Washington. A significant amount of the watershed area is surface water. This surface water is composed of the Columbia River, Youngs Bay and Grays Bay. A majority of the Oregon watershed area is coastal mountains, with elevations over 3,200 feet above mean sea level. This mountainous area is mostly forest, and these forests are frequently used for logging. Figure 1 below provides an aerial image of the watershed boundary.

Figure 1: Watershed Aerial Image

3 DATA

For analysis, the data was projected onto the NAD 1983 Oregon State Plan North coordinate system.

Watershed Boundary Dataset (WBD)

Description: The watershed boundary dataset provides the boundaries for all of the hydrologic units and the accompanying hydrologic unit codes (HUCs) which are used in watershed analysis. For this project, HUC-8, HUC-10, and HUC-12 boundaries are used.
Data Type: Vector
Source: USGS
Coordinate System: GCS_North_American_1983
Datum: D_North_American_1983

NHD Plus

Description: The National Hydrography Dataset (NHD) works with the WBD to provide geospatial datasets that map the surface water and information in the United States. This dataset shows streams, river, lakes, stream gages, and coastlines. The extended run-off method (EROM) extension from the NHD dataset is also used for analysis in this project.
Data Type: Vector
Source: USGS
Coordinate System: GCS_North_American_1983
Datum: D_North_American_1983

National Flood Hazard Layer (NFHL)

Description: This layer is provided by FEMA a part of the National Flood Insurance Program. It displays flood hazard information and is used for calculation of flood insurance rates in at risk areas.
Data Type: Vector
Source: FEMA
Coordinate System: GCS_North_American_1983
Datum: D_North_American_1983

SSURGO Web Soil Survey

Description: The SSURGO data displays information about soils that has been included over time. The main attribute in this analysis is the average water storage over the first meter of soil depth.
Data Type: Vector
Source: Natural Resources Conservations Services
Coordinate System: GCS_North_American_1983
Datum: D_North_American_1983

Oregon DEM 10 m

Description: This layer is a digital elevation model (DEM) raster layer for the whole state of Oregon. The cell size is 10 meters by 10 meters. This raster was masked to the project area prior to analysis.
Data Type: Raster
Source: USGS Geospatial Data gateway
Coordinate System: NAD 1983 Oregon Statewide Lambert
Datum: D_North_American_1983
Resolution: 10 m x 10 m

DOGAMI Tsunami Evacuation Zones

Description: This layer is provides information on local and distant tsunami evacuation zones. The local and distant tsunamis are using the worst-case earthquake event for each classification.
Data Type: Vector
Source: State of Oregon Department of Geology and Mineral Industries
Coordinate System: NAD 1983 HARN Oregon Statewide Lambert Conformal Conic
Datum: D_North_American_1983_HARN

4 GIS METHODS

4.1 WATERSHED CHARACTERISTICS

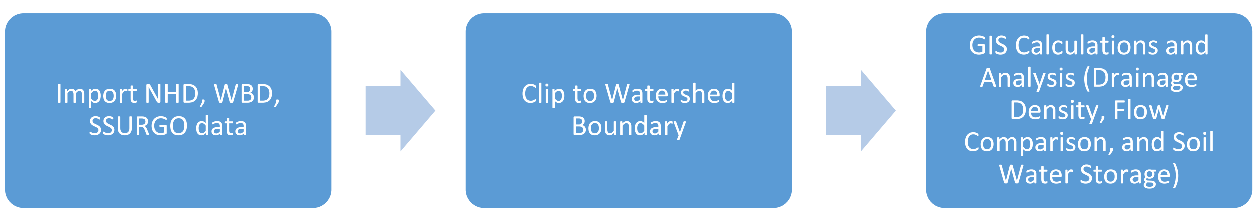

Figure 2: Watershed Characteristics Flowchart

This section of the GIS methods was comprised of simple vector calculations and functions to take the NHD, WBD, and SSURGO data and use it to analyze the watershed. All shapefiles were clipped to the watershed boundary. The drainage density was calculated using the total length of the NHD flow lines within each subwatershed and total area of the subwatersheds found in attribute tables. The soil water storage and flow comparison calculations used the attributes found in each layer.

4.2 DEM and HAND Generation

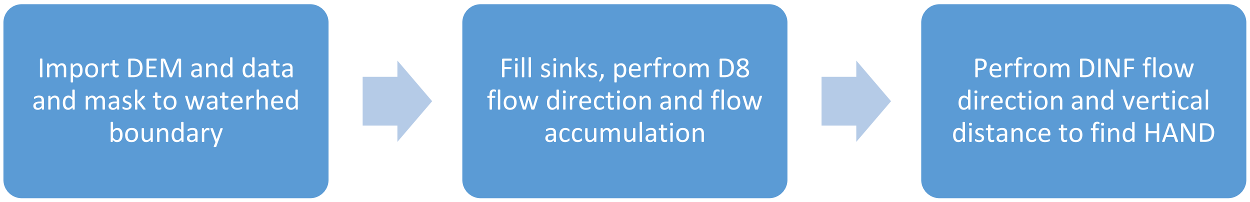

Figure 3: HAND Generation Flowchart

Generating the height above nearest drainage layer required the use of more complex GIS spatial analyst tools. Prior to processing the DEM, a layer is created showing the vertices of the NHD flowlines, showing the beginning of the streams. This point feature class is then converted to a raster with same cell size and processing extents of the DEM used for analysis. Once the DEM has been imported into ArcGIS, the spatial analyst tool of fill hydrologically conditions the DEM for processing. Then the D8 flow direction for the raster is found using the flow direction tool. Using the start raster as a weight raster, the flow accumulation is calculated using the D8 flow direction, and the Con tool creates a stream raster given the flow accumulation conditions based on the weighted raster. The flow direction tool is then used again to determine the d infinity (DINF) flow direction. Using the required, inputs the height above nearest drainage is calculated using vertical flow distance. The vector data for the national flood hazard layer and tsunami evacuation zones were imported into ArcMAP and compared to the HAND results.

5 Results and Discussion

5.1 Watershed Characteristics

Within the Lower Columbia Watershed (HUC 8 Watershed), there are five subwatersheds (HUC 10). One of the subwatersheds consists of the Columbia River and was not considered during analysis. Figure 4 below displays the HUC 10 subwatersheds with the flow lines from the NHD data. In order to provide context for the watershed it is important to analyze surface water and groundwater characteristics with the watershed. One characteristic of a watershed is drainage density. Drainage density is the measure of the total length of surface water streams and rivers divided by the total area of the basin. Table 1 displays the drainage density for each subwatershed. The Wallacut River subwatershed (the yellow area in Figure 4) has the highest drainage density with a value of 0.981 1/km. Drainage density is an important characteristic of flood analysis because drainage density is closely related to flood runoff. There is also a significant relationship between drainage density and groundwater properties (Carlston, 1963).

As part of the NHD data, there is an estimated stream flow calculation based on the extended run-off method. The USGS also maintains stream gages across the United States. Within this watershed, there are

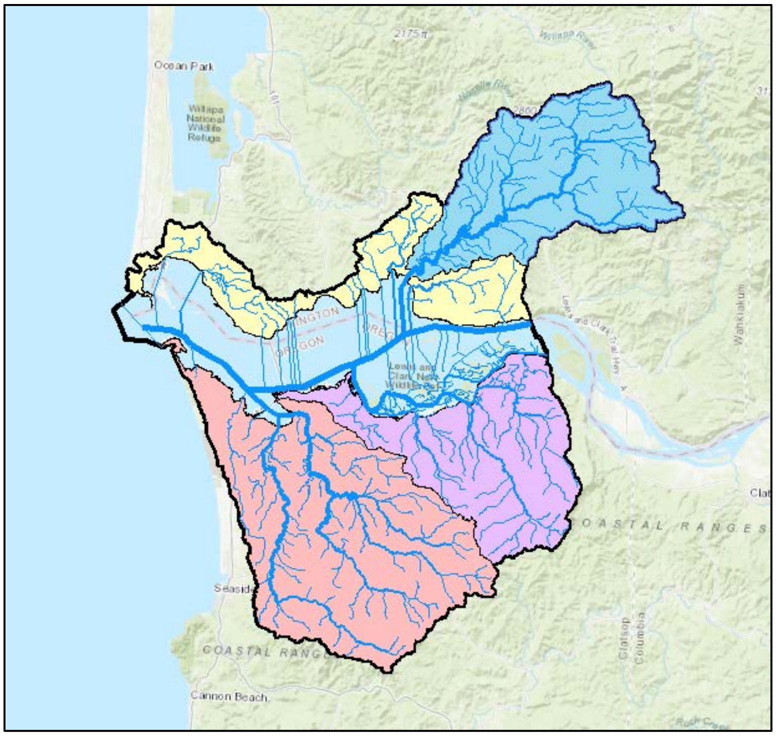

Figure 4: Subwatersheds and Flow Lines

Table 1: Subwatersed Drainage Densities

HUC 10	Name	Flow Length (km)	Drainage Area (km^2)	Drainage Density (1/km)
1708000601	Big Creek - Frontal Columbia River	218.72	302.05	0.724
1708000602	Youngs River - Frontal Columbia River	411.74	545.95	0.754
1708000603	Grays River	262.32	320.45	0.819
1708000604	Wallacut River - Frontal Columbia River	196.38	200.13	0.981

As part of the NHD data, there is an estimated stream flow calculation based on the extended run-off method. The USGS also maintains stream gages across the United States. Within this watershed, there are seven USGS operated stream gages. Figure 5 displays a map with the USGS stream gages. There are two different stream gages located at the junction of south fork of the Grays River. The differences between these gages is not distinguishable in Figure 5, but Figure 6 displays this clearly.

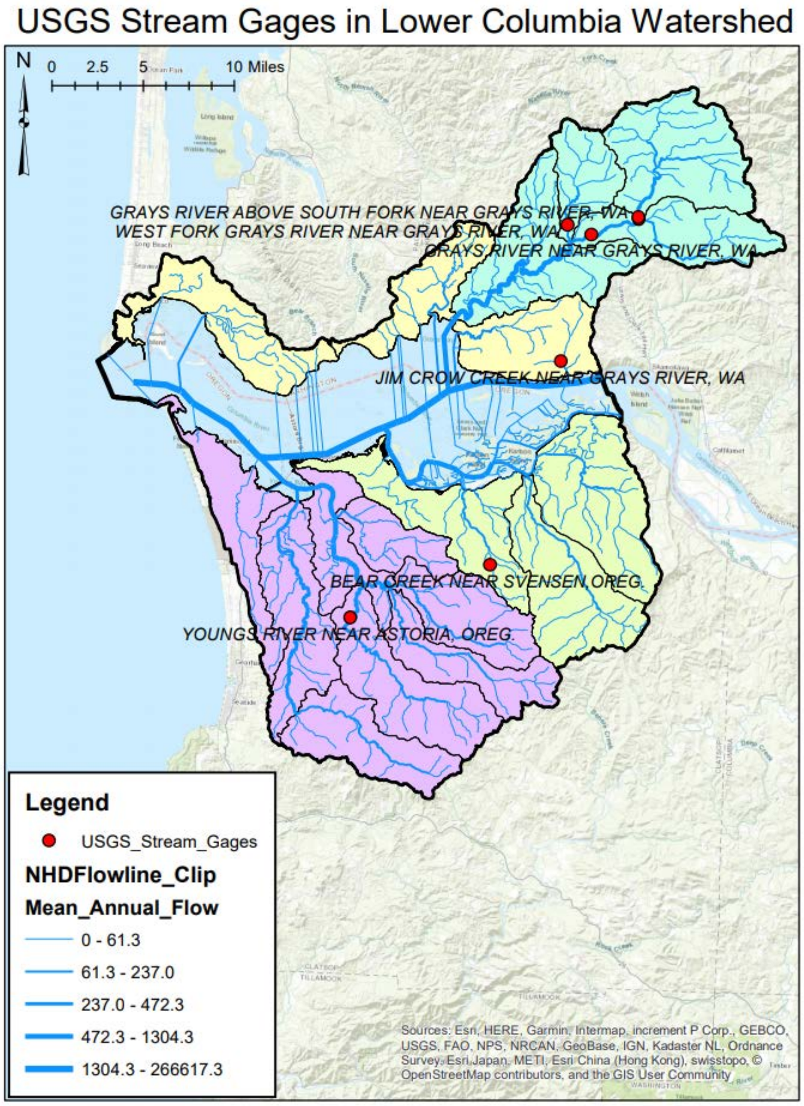

Figure 5: Map of USGS Stream Gages

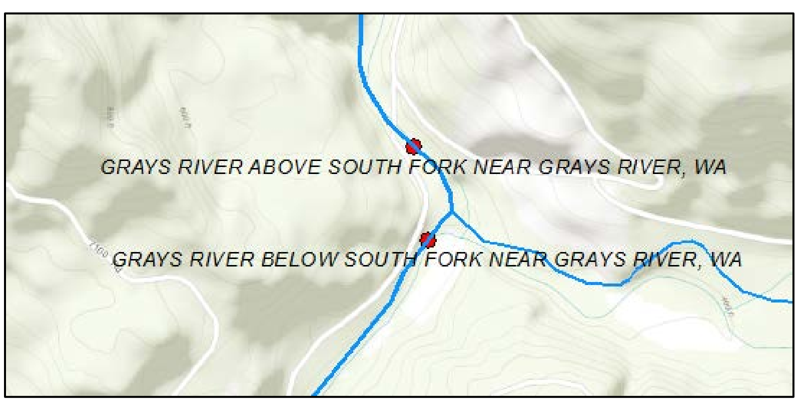

Figure 6: Stream Gages at Grays River South Fork Junction

Table 2 shows the USGS measured mean annual stream flow and the NHD calculated mean annual stream flow and the differences between the two. The differences between the two methods are significant at every stream gage except the Jim Crow Creek near Grays River, WA.

Table 2: Flow Measurements Comparison

Station Name	USGS Gage Flow (cfs)	EROM Flow (cfs)	% Difference
Grays River above South Fork near Grays River, WA	343.6	279.8	18.6%
Grays River below South Fork near Grays River, WA	526.9	431.5	18.1%
West Fork Grays River near Grays River, WA	124.0	119.7	3.5%
Grays River near Grays River, WA	554.6	465.5	16.1%
Jim Crow Creek near Grays River, WA	32.8	31.8	3.0%
Bear Creek near Svenson, OR	17.7	29.4	66.1%
Youngs River near Astoria, OR	178.4	266.5	49.4%

Groundwater storage is another important hydrologic condition of a watershed. Groundwater storage is very helpful when analyzing precipitation and flood runoff and resilience. Table 3 shows the available water storage in the top meter of soils and total water storage in the subwatersheds. Figure 7 is a map displaying the water storage within the whole watershed.

Table 3: Subwatershed Water Storage

HUC 10	Name	Average Available Water Storage Depth (cm)	Total Water Storage (km^3)
1708000601	Big Creek - Frontal Columbia River	21.64	0.0654
1708000602	Youngs River - Frontal Columbia River	20.66	0.1128
1708000603	Grays River	17.97	0.0576
1708000604	Wallacut River - Frontal Columbia River	19.72	0.0395

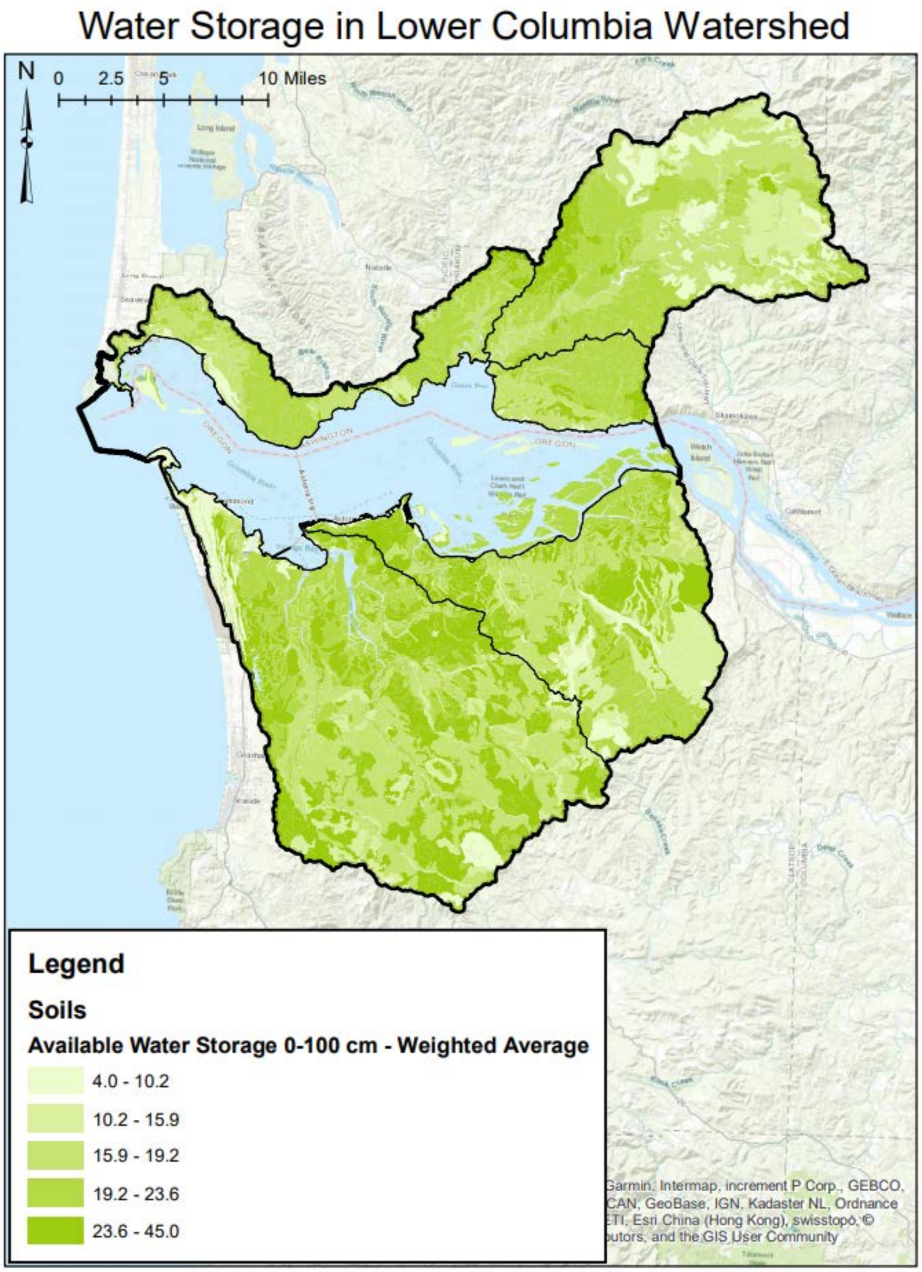

Figure 7: Map of Soil Water Storage

5.2 FLOOD MAPPING AND HAND ANALYSIS

The next part of the analysis is looking at different data provided that relates to flooding and tsunamis for this watershed. The first layer is the National Flood Hazard Layer provided by FEMA as part of the National Flood Insurance Programs. Figure 8 shows the National Flood Hazard Layer. Flood zone AE is the base flood plain. Flood zone A are areas with a 1% chance of flooding, which is equivalent to a 26% chance of flooding over the life of a 30-year mortgage. Flood zone D is area that needs more information. For this map, most of the flood zone D shown is the Columbia River. Flood zone VE is coastal area with 1% chance of annual flooding and a 26% chance of flooding over the life a 30-year mortgage. Flood zone X is area with minimal chance of flooding.

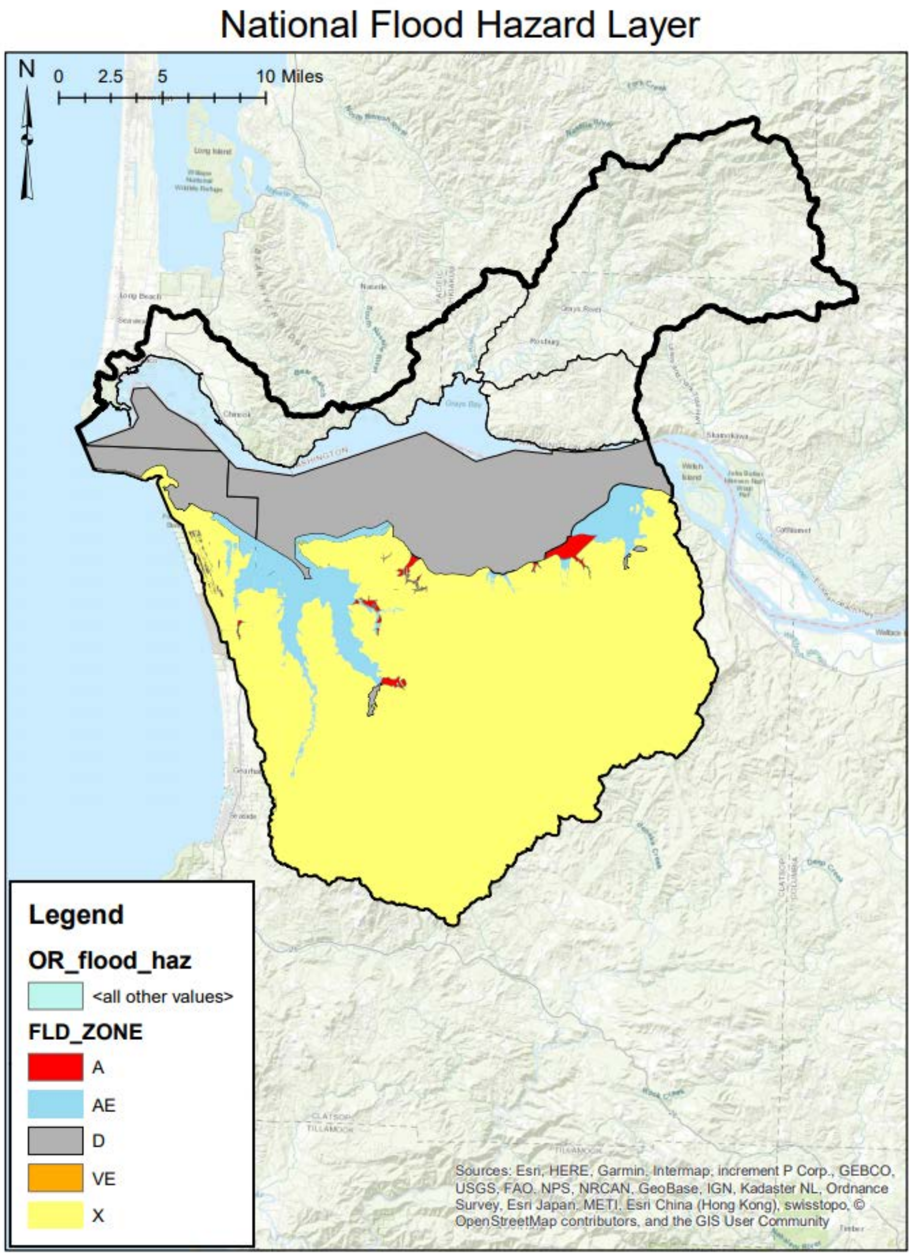

Figure 8: National Flood Hazard Layer

Figure 9 shows the tsunami evacuation zones in the watershed area developed by the Oregon Department of Geology and Mineral Industries. There are two different tsunami classes shown on the map, local and distant. A local tsunami is a caused by an earthquake in the Cascadia Subduction Zone. An earthquake elsewhere in the Pacific Ocean causes a distant tsunami. For both tsunami classes, the worst-case scenario tsunami was analyzed.

Tsunami Evacuation Zones

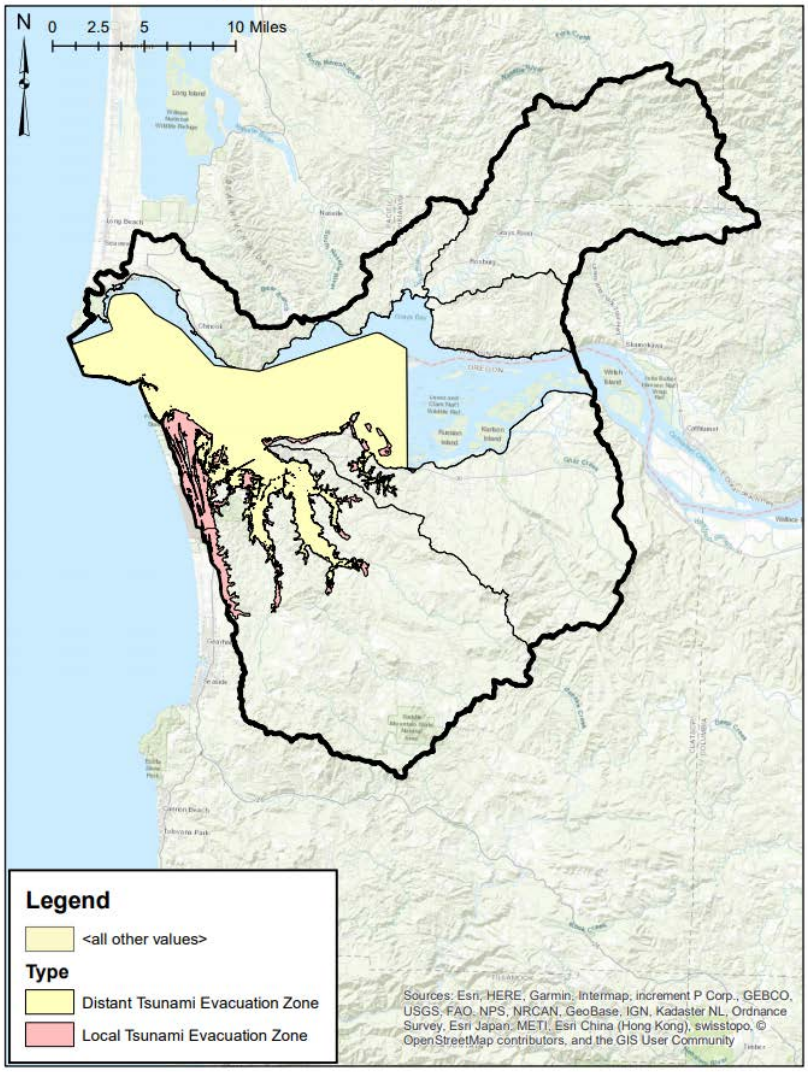

Figure 9: DOGAMI Tsunami Evacuation Zones

Figure 10 displays the height above nearest drainage (HAND) for the Oregon section of the Lower Columbia Watershed. Figures 11 and 12 show the DEM generated HAND layer overlaid on top of the flood hazard layer and tsunami evacuation zones respectively. These two figures display the disparity between the HAND layer and the different flood layers. In Figure 11, much of the base floodplain (AE flood zone) is not part of the HAND flood layer. This shows that the DEM generated HAND layer is very conservative compared to the NFHL. This limitation is probably due to the complexity of the watershed, given the width of the Columbia River at this location. Because the river is such a significant portion of the watershed, it shows the limits of the DEM calculations. This is also highlighted in Figure XXX where the drainage lines are straight lines through the river and the hand layer is very straight in areas. In Figure 12, it shows how the DEM generated HAND layer is also more conservative than the tsunami evacuation zones as well.

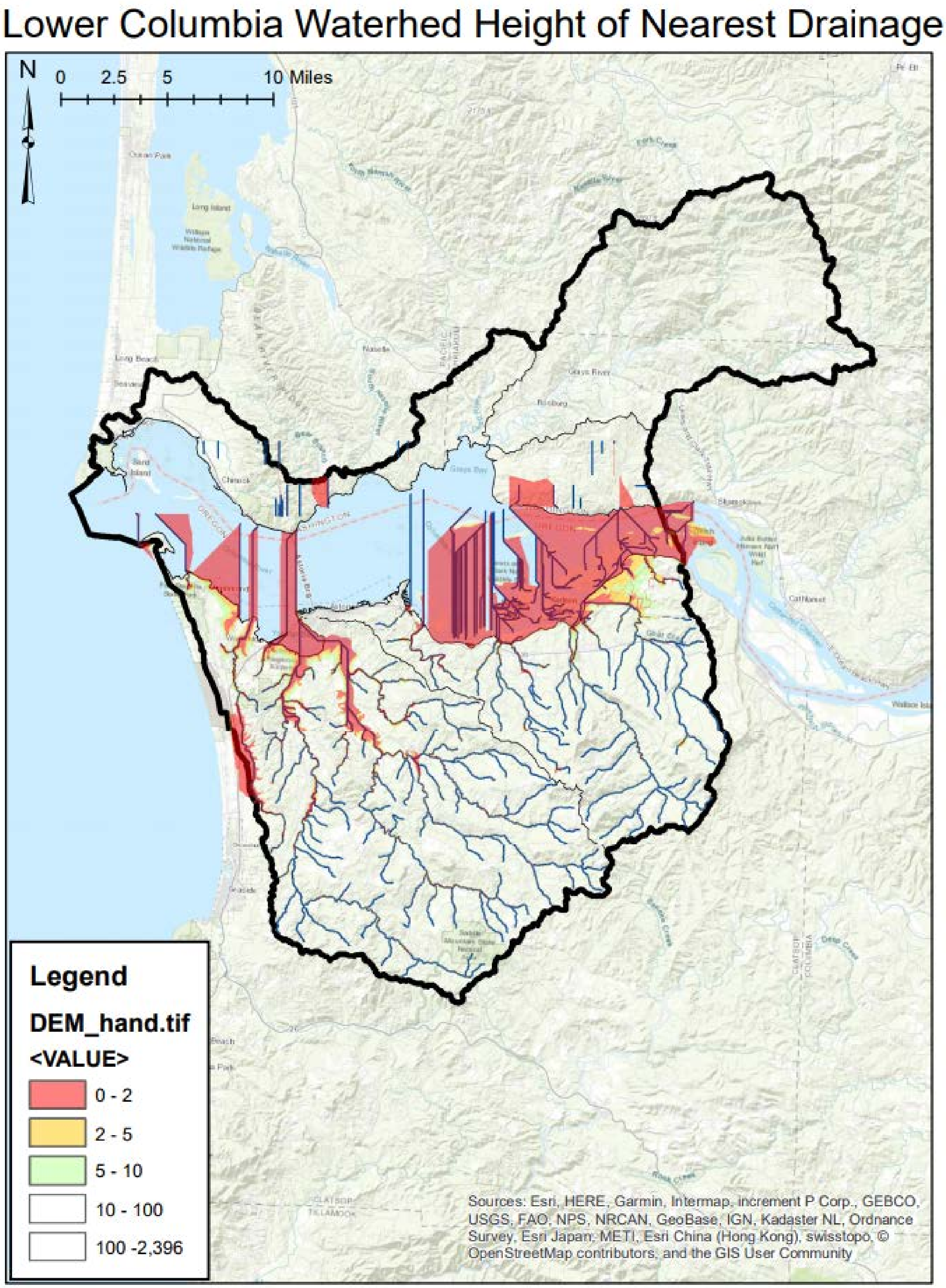

Figure 10: DEM Generated Height Above Nearest Drainage

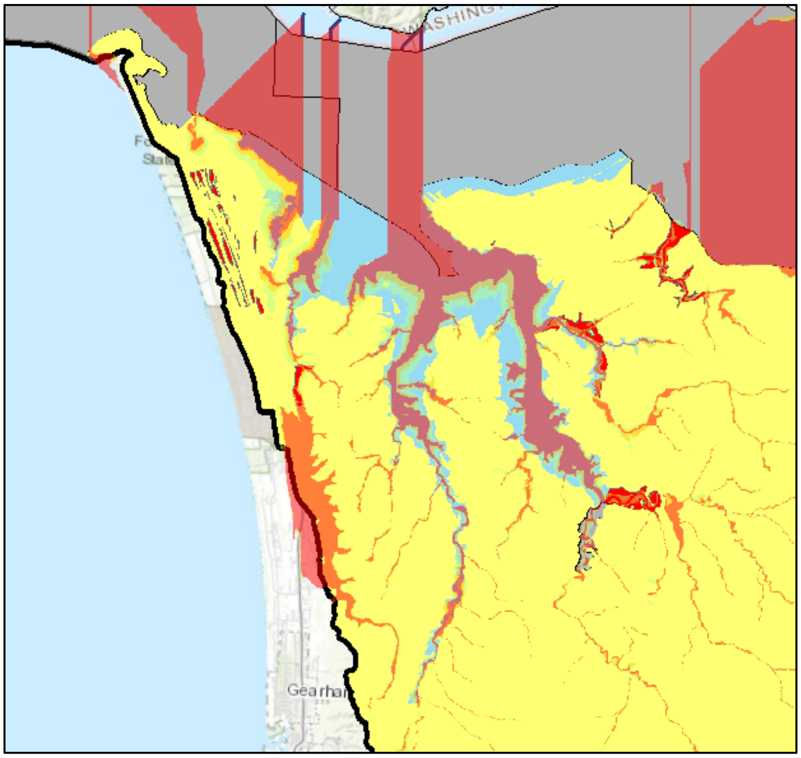

Figure 11: HAND Overlay with NFHL

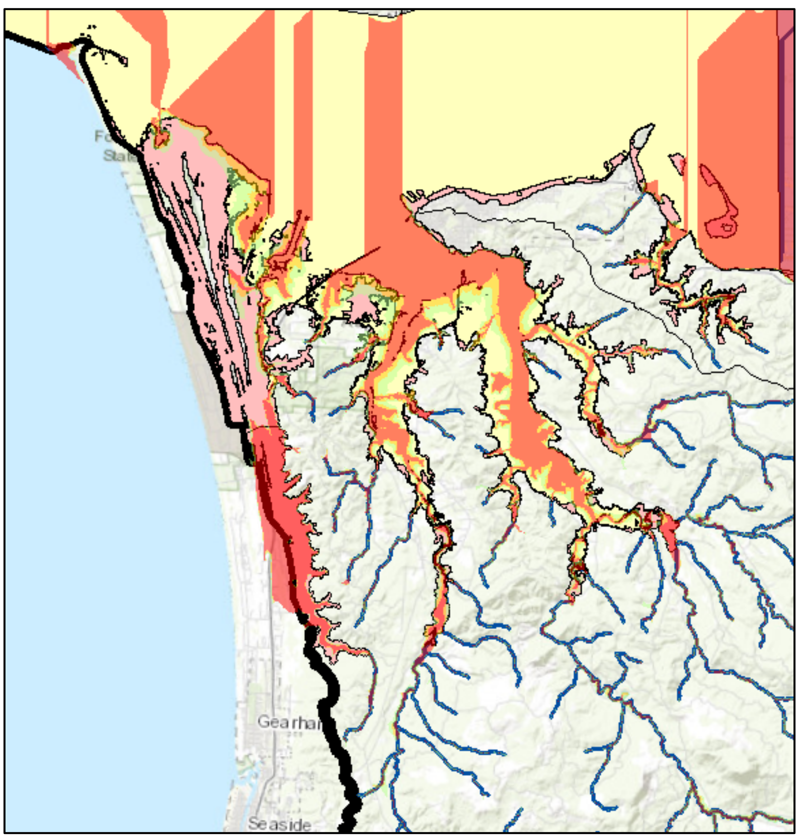

Figure 12: HAND Overlay with Tsunami Evacuation Zones

From these observations, for future analysis it is important to be aware of the limitation of the height above nearest drainage when dealing with larger bodies of water. This same principle may apply hen looking at coastal infrastructure and watersheds. Because the drainage line is assumed to be a single cell wide, or 10 meters, when in reality the Columbia River is miles wide and the junctions from the smaller rivers in the Columbia are thousands of feet wide, it makes the DEM generated model more conservative and inaccurate compared to the provided flood map and tsunami evacuation zones. In the upper part of the watershed, where the slopes are steeper in the mountains and the rivers and streams are smaller, the DEM generated method seemed to provide more accurate results.

6 REFERENCES

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