Lab 7

GEOG 451/551

Planning Principles & Practices for Resilient Communities

Proposed Vertical Evacuation Options in Ocean Shores East, WA Technical Report

Pedestrian Evacuation Analysis

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Executive Summary

This work focuses on proposing vertical evacuation options and analysing pedestrian evacuation to these safe zones for Ocean Shores East, a subsect of a community in Coastal Washington. Specifically, this work leverages the Pedestrian Evacuation Analyst Tool which is an ArcGIS extension that estimates how long it would take for someone to travel on foot out of a hazardous area. For the community of interest, it is calculated that currently the majority of the population will be unable to evacuate to higher ground within the threshold of time between a Cascadia Subduction Zone event's earthquake ground shaking and the first tsunami wave. These results underscore the need to design, site, and optimize vertical evacuation structures in order to save as many lives as possible. The following report presents proposed evacuation options and the processes guiding their initial selection. These frameworks are intended to support iterative decision-making, with the expectation that future work may refine priorities and criteria for identifying the most effective structure locations.

Link to the storymap product can be found here:
https://storymaps.arcgis.com/stories/65aa9193efe04091a66d3edb45d61a25/edit

Report Contents

Motivation

The Cascadia Subduction Zone describes the junction where the Juan de Fuca plate is slowly diving under the North American plate. A rupture in this zone has the potential to produce a megathrust earthquake and a subsequent large scale tsunami. This major fault runs about 70–100 miles offshore from Washington's coast and therefore poses a major risk for Washington's coastal communities. The earthquake will act as a warning sign for the incoming tsunami, the first wave of which is predicted to arrive about 15-20 minutes following the cessation of the shaking. It is imperative, therefore, to understand the vulnerabilities of these coastal communities with respect to the impending hazard, evaluate the current population capabilities to evacuate to safe (high) ground, and develop a plan for improving the resilience towards this risk.

The Washington Department of Natural Resources and National Oceanic and Atmospheric Administration have pages that provide additional information on this phenomena including some visualizations:

- Earthquakes and Faults (https://dnr.wa.gov/washington-geological-survey/geologic-hazards-and-environment/earthquakes-and-faults)
- Tsunamis (https://dnr.wa.gov/washington-geological-survey/geologic-hazards-and-environment/tsunamis)
- Cascadia Subduction Zone (https://www.noaa.gov/jetstream/tsunamis/tsunami-locations/jetstream-max-cascadia-subduction-zone#:~:text=Looking%20Ahead,30%20minutes%20in%20some%20locations.)

Assumptions

The following project assumptions are listed in Guide to Tsunami Vertical Evacuation Options on the Washington Coast – Volume 1: Pacific County, herein referred to as the PC Guide. In order to maintain consistency between recommendations listed herein and previous work, these assumptions are also made in this work.The assumptions in the PC Guide are divided into those made with respect to the (1) Tsunami Hazard, (2) Population Capabilities, and (3) Vertical Evacuation Tower Design + Construction.

Tsunami Hazard

1. The scenario event is a 9.0 magnitude subduction zone earthquake approximately 80 miles off the coast of the Long Beach peninsula.
2. The earthquake shaking could last five to six minutes and will create a tsunami.
3. Six feet of subsidence is expected.
4. The warning before the tsunami will be the earthquake.
5. There will be about 15 minutes between the cessation of shaking and arrival of the first tsunami wave.
6. Although tsunami models estimate that people will have approximately 20 minutes to get to high ground once the shaking begins, the preferred strategies contained within this study are based on people having only 15 minutes due to approximately 5 minutes of expected intense shaking. This reduced response time does not take into account the following challenges that people will face in getting to high ground: people not evacuating right away due to not understanding what is happening or what to do, looking for more information, contacting loved ones, finding pets, being injured, and grabbing supplies; poor road/evacuation route conditions resulting from landslides, liquefaction, downed power lines/trees, and traffic; and possible panic. People will have 15 minutes or less to get to high ground.
7. Tsunamis consist of multiple waves over a 12-24 hour or longer time period.The first wave is often not the highest wave.
8. Tsunami refugees will need to remain on the structure until it is safe to return to the ground. This could take 24-48 hours or longer.
9. Routes to high ground, including vertical evacuation structures will be available, accessible, and discernible after the earthquake and at night.
10. Those evacuating will walk/run to high ground, which includes the vertical evacuation structures. Travel by car will not be possible.
11. Communication will be limited.
12. Many of the bridges located in the study area, hazard area are assumed to be “out” following the shaking from the earthquake. This is reflected in the walk times for each community.

Population Capabilities

1. The majority of the population in the tsunami risk areas is physically mobile and can walk to the proposed tsunami evacuation sites.
2. The average fast walking speed of a typical individual is 1.52 meters/ second or 4,488 feet in 15 minutes and the average slow walking speed of a typical individual is 1.1

meters/second or 3,248 feet in 15 minutes. For the purposes of this analysis, the slow walking speed was used. Source: FHA (2009)

3. People on the beach have average to high physical mobility.
4. Residents and visitors understand the tsunami risk, know what to do to protect themselves, know where high ground is and how to get to it as quickly as possible.

Vertical Evacuation Tower Design + Construction

1. Vertical evacuation structures can be provided.
2. The margin of safety (distance between the height of the tsunami and the floor of the tower) is factored to be 30% of the height of the tsunami, plus 10 feet.
3. If the vertical evacuation structures are constructed on sites where wetlands are compromised, new wetlands will be developed or the compromised wetland will be mitigated in another way.
4. Each vertical evacuation structure will provide ten square feet of space per person (FEMA design standard minimum).

Link to the full PC Guide can be found here:https://mil.wa.gov/asset/618300c00353d

Methodology

The engine for our process was the Pedestrian Evacuation Analysis Tool (PEAT), an ArcGIS extension created by the United States Geological Survey (USGS) in 2017. PEAT can model a variety of hazard events such as tsunamis, floods, and volcanic lahar. A link to download can be found here, and a helpful user guide can be found here.

Additionally, our process is directly modeled off of the work from the University of Washington's Institute for Hazard Mitigation Planning and Research. In 2021, their team produced a potential VES assessment for communities in Pacific County.

Preparation

You will need the following: if it is not provided to you then you will need to download it:

1. Pedestrian Evacuation Analyst Tool (PEAT) User Guide and Tool
2. Study Boundary shapefile
3. DEM raster
   DEM data from the USGS (Washington 10-meter DEM) was used for this project, set to an analysis cell size of 3 (http://gis.ess.washington.edu/data/raster/tenmeter/byquad/index.html).
   Important note: All GIS data used or created for this project used the following coordinate system and projection:
   Coordinates: NAD_1983_HARN_StatePlane_Washington_South_FIPS_4602_Feet
   Projection: Lambert_Conformal_Conic
4. Hazard zone shapefile
5. Preliminary safezone shapefile
6. Land Cover Shapefile
   We will be updating the file used from the one used in the PC guide. The primary base layer is land classification data defined by the North American Land Change Monitoring System (NALCMS), set at 30 meters, with a publish date of **2020** (https://www.cec.org/north-american-environmental-atlas/land-cover-30m-2020/)
7. Water shapefile (aka impassable land)
8. Beach shapefile
9. Parcel shapefile
   From the Grays Harbor County website (https://www.graysharbor.us/departments/central_services/GISDataDownload.php)
   Download parcels, roads (and bridges). The PC guide states that the Grays Harbor County roads layer was augmented by OpenStreetMap. (https://download.geofabrik.de/north-america/us/washington.html)
   Download "washington-latest-free.shp.zip" file. Be sure to download the format description PDF as well.
10. Road shapefile (either with bridges already taken out or manually set to have bridges have a SCV of 0 later)
11. Wetland shapefile

Scroll halfway down the page and click on Download by State. Scroll down to Washington and download the gdb. Extract and save. (https://www.fws.gov/program/national-wetlands-inventory/data-download)

12. Residents in wetland shapefile
13. Flowdepth Raster “WGS_SouthwestWashingtonL1_flowdepth_feet_harn” raster file
14. CleanupSites and FacilitySiteInteractions shapefiles
    (To learn more about these files go to: Cleanup Sites- https://geo.wa.gov/datasets/waecy::cleanup-sites/about ; Facility Site Interactions- https://geo.wa.gov/datasets/waecy::department-of-ecology-facility-and-site-interactions/about)
15. School shapefile

Baseline Conditions

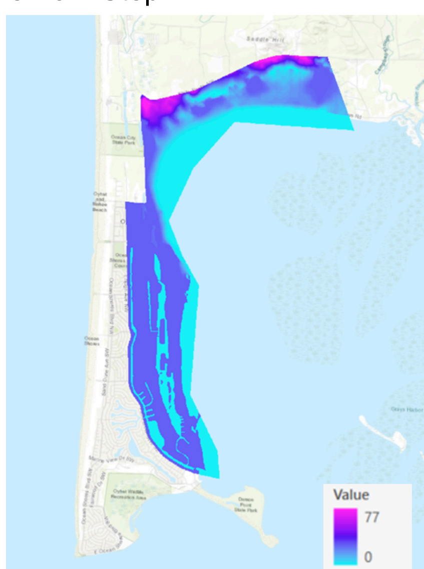
I. **<u>Set the community study boundaries.</u>**

For this work, the community of Ocean Shores is split into an East and West component for analysis. We are considering Ocean Shores East as our community of interest. Add a folder connection to where your data is housed (Catalog pane > Folders > right click and Add folder connection)

II. **<u>Pre-process digital elevation model (DEM) data.</u>**

In the Catalog pane, navigate to the PEAT Toolbox > Step1 Preprocessing > Step 1a: Preprocess DEM. Double-click to open the tool.

- Navigate to your project database, then for Elevation add the DEM.tif > Band_1 (potentially clipped to the study boundaries). For Study Area, input the Study Area Boundary file from Step 1.



- Click Run.

III. **Pre-process land use and land cover data.**

Open the tool for Step 1b: Preprocess Hazard.

- Navigate again to the project geodatabase, and for the Hazard Zone, find and add “SW_Washington_TsunamiHazard.shp”.
- Click Run.

Close that tool, and open the tool for Step 1c: Preprocess Safezone.

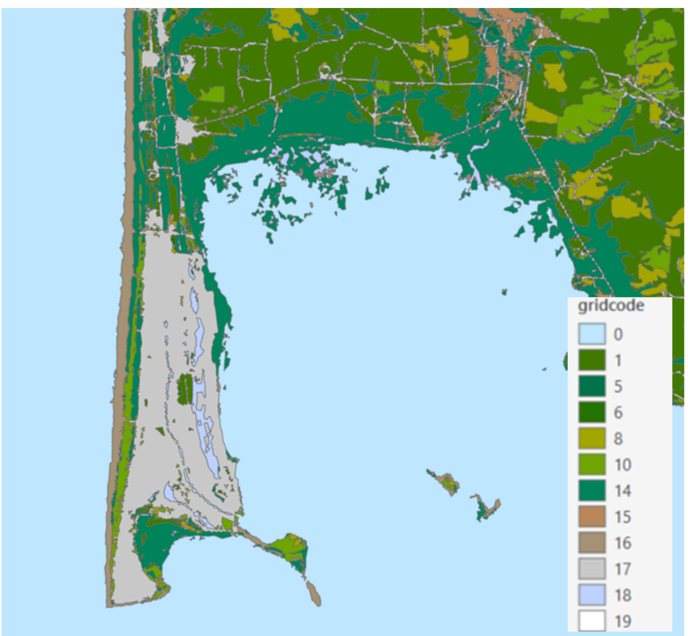
- Navigate to the project geodatabase for a third time. For the “Safe zone”, find and add the file “SW_wash_hazard_area_unclipped_prelim_safezone.shp”.
- Click Run.

In the Catalog > Folders, refresh the geodatabase and add both the “hazard” feature layer and the “safe_zone_polygon” to your map.

If you have questions or problems when running Steps 1a-1c, refer to the PEAT user guide first. ***Save the project.***

Open the tool for Step 1d: Preprocess Landcover.

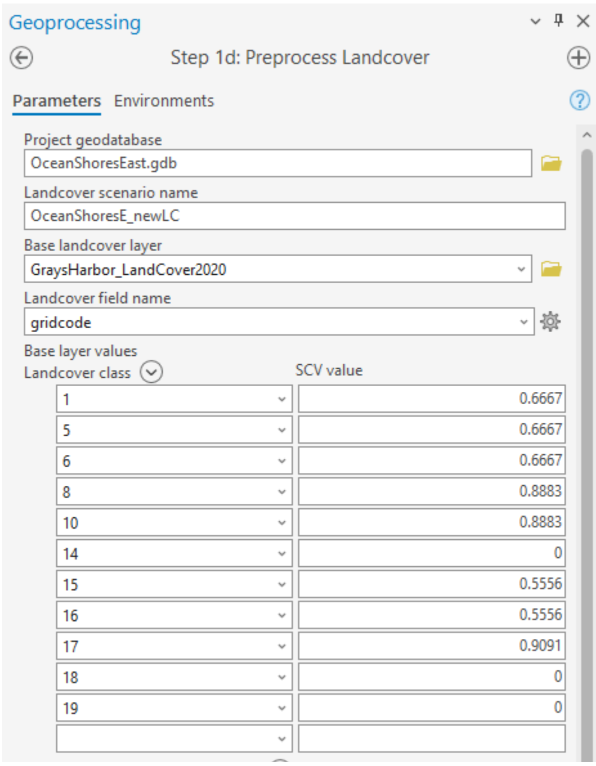
- Once again, navigate to the project geodatabase. For the base landcover layer, find and add the shapefile. For the landcover field name, use the dropdown menu and select “gridcode”.

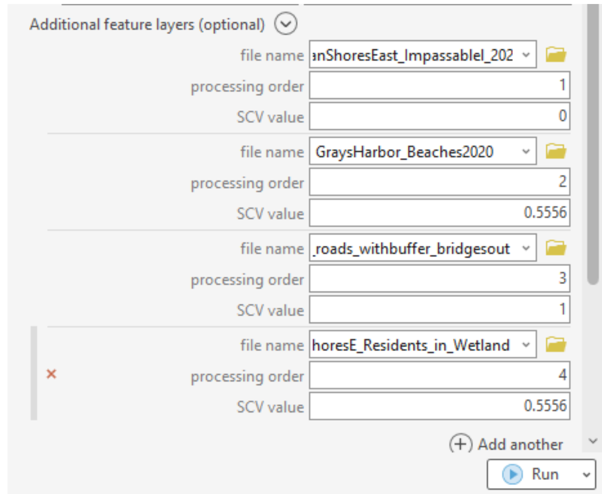


The complete list includes:

- Value 1, Temperate or sub-polar needleleaf forest (**.6667**)
- Value 2, Sub-polar taiga needleleaf forest
- Value 3, Tropical or sub-tropical broadleaf evergreen forest
- Value 4, Tropical or sub-tropical broadleaf deciduous forest
- Value 5, Temperate or sub-polar broadleaf deciduous forest (**.6667**)
- Value 6, Mixed forest (**.6667**)
- Value 7, Tropical or sub-tropical shrubland
- Value 8, Temperate or sub-polar shrubland (**.8883**)
- Value 9, Tropical or sub-tropical grassland
- Value 10, Temperate or sub-polar grassland (**.8883**)
- Value 11, Sub-polar or polar shrubland-lichen-moss
- Value 12, Sub-polar or polar grassland-lichen-moss
- Value 13, Sub-polar or polar barren-lichen-moss
- Value 14, Wetland, RGB (**0**)
- Value 15, Cropland, RGB (**.5556**)
- Value 16, Barren lands (**.5556**)
- Value 17, Urban, RGB (**.9091**)
- Value 18, Water, RGB (**0**)
- Value 19, Snow and Ice (**0**)

- Set the landcover classes and their SCV values manually per the instructions on pgs. 16-17 of the PC Guide.
- Add additional layers that aren’t part of the landcover and set their values—and importantly—their processing order. For precise guidance, refer to pgs. 8-12 of the PEAT User Guide and pgs. 16-17 of the PC Guide.





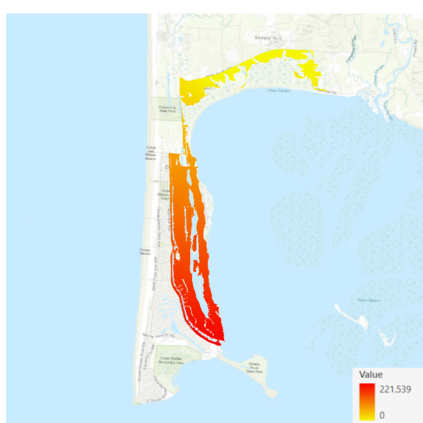
- Click run

Save the project

IV. **Create the Evacuation Surface.**

In the Catalog pane, open the tool for Step 2a: Create Evacuation Surface.

- Add the project geodatabase as you have previously.
- “Landcover scenario name” should have a dropdown menu; select the landcover scenario name that you created in the last step. This should be the only landcover scenario to select (unless you ran it multiple times).
- Travel speed value that Washington EMD is listed in the PC guide methodology and in our assumptions above. Use the recommended value that Washington EMD used: 1.1
- Click Run.

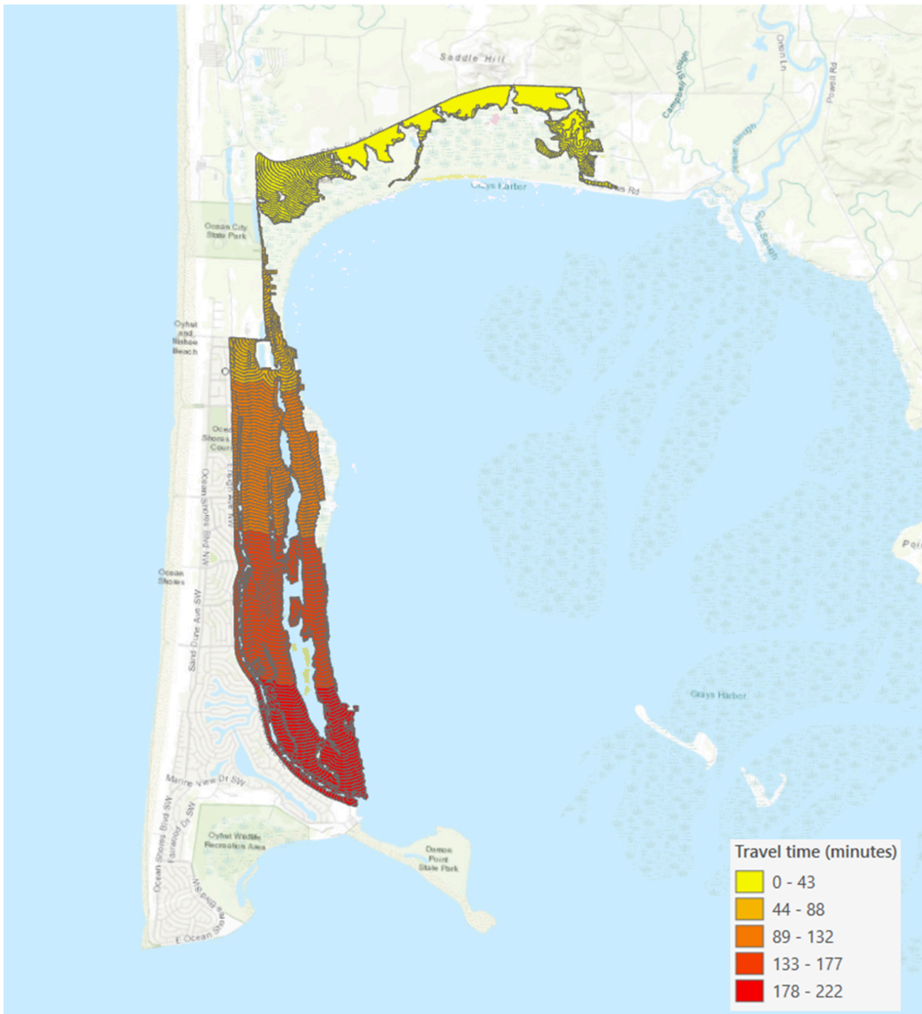


V. **Create the Time Map.**

Open the tool for Step 2c: Create Time Map.

- Add the project geodatabase, as in previous steps.
- Then same landcover scenario
- For “Evacuation surfaces”, use the dropdown menu to select the only evacuation surface there is: “evac_surface_XX_1p1”
- Leave “Buildings for fill” blank; this one really is optional!
- Click Run.

Go to your geodatabase in the Catalog pane > Folders and refresh. You should see a new item, XX_timemap. Expand this feature dataset and add the Time Map polygon to the map.



VES scenario

When considering how to select suitable placements for Vertical Evacuation Structures we heard some key criteria from WAEMD that includes the following:

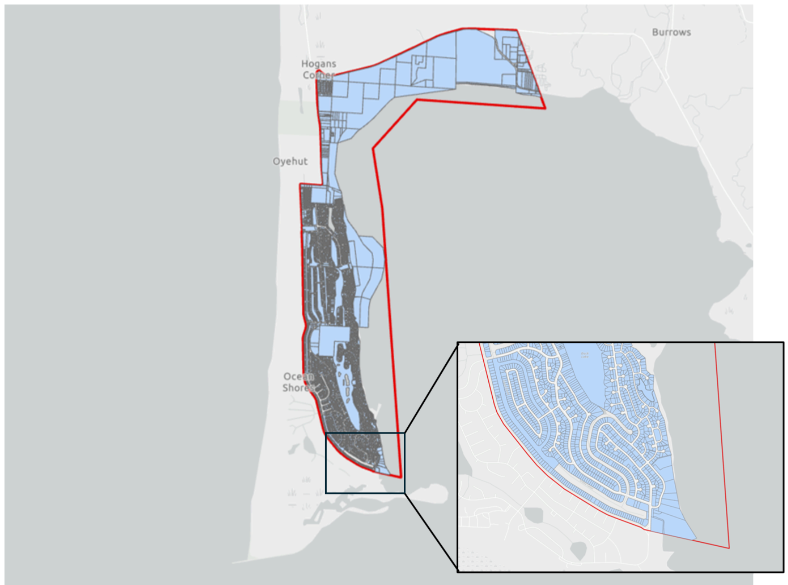
1. Located in the tsunami inundation area.
2. Publicly owned land (preference for local municipality but state, county)
    a. NOTE: we should NOT use federal property
3. Vacant, no buildings—but small outbuildings (sheds, etc.) that could be easily removed are okay.
4. On property where the VES could be shorter (e.g., the difference between inundation depth and elevation is positive and maximized).
5. The VES is not on a property with wetlands—though wetlands on the edges of property that would not be where the structure is might be okay.
6. The VES should not be located within 200 feet of the shoreline.
7. Properties and adjacent properties should not contain hazardous materials.
8. Properties and adjacent properties should not have items that could impede travel to the VES or the VES structural integrity (e.g., boat storage, powerlines, train cars).
9. Accessible from roads.
10. Close to schools.
11. Accessible to permanent residents
    a. NOTE: permanent residents are given higher priority because of the seasonal variability of visitor populations which may otherwise skew the analysis.

Now to apply this:

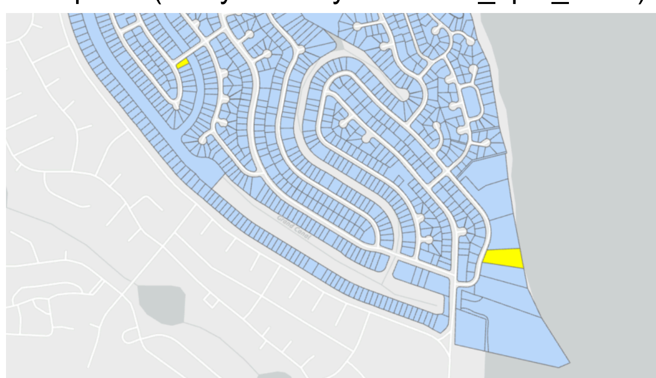
I. <u>Identify Vacant Lots.</u>

Add the parcel/ tax lot data to the map

- Add your study area boundary and your study area DEM to the map (from Lab4Data).
- Clip the parcel/tax lot feature layer to your study area boundary. Name the new feature layer “studyarea_parcels”.



- Next, let's add the VES locations for 'option 4' (the lean option) previously identified. Note that I only added opt 4 VES. You may find additional VES sites by looking the TEVO guide—we'll come back to this later. Add the previous VES locations shapefile (i.e. "yourstudyareaname_opt4_VES") to your map.

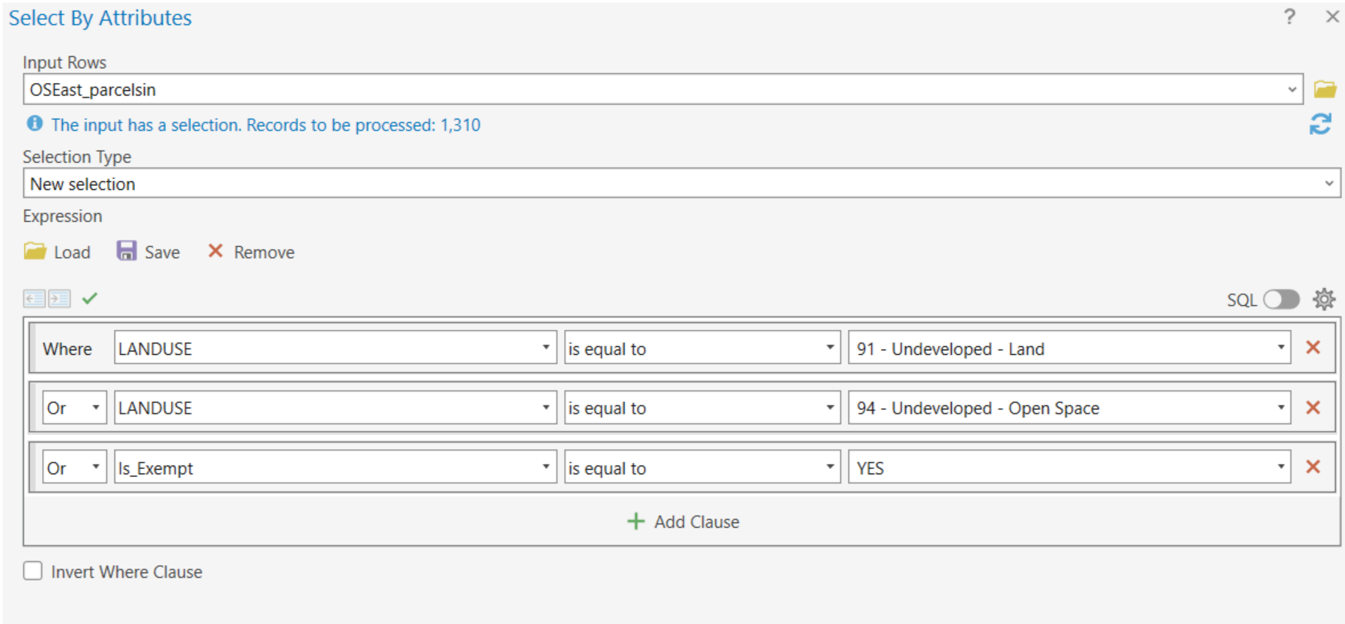


- Next, add the parcel/tax lot layer to your map.
- In the "studyarea_parcels" layer you just made, select all the same parcels (manually might be best—just double check that you got them all and didn't select any extra parcels).
    - Open the attribute table and add an attribute field (numeric, double) named "PreVES".
    - Give all these selected parcels a PreVES value of 2 and give all other parcels a value of 0. We are placing higher value to these sites that were previously identified because they reflect additional components that are not represented in this analysis and have potential likelihoods for improved buy-in.
    - Save Edits to the table (NOT Save Project – it's up in the contextual ribbon), then clear the selected features.

Additionally, I want to see if these vacant properties are publicly owned and in the tsunami inundation area

- Select the study area parcels that are in the tsunami inundation area. Use the same inundation area you have used in previous labs for the PEAT analysis:
    - Select by Location
    - Input features = “studyarea_parcels”
    - Relationship = Intersect
    - Selecting features = SW_Washington_TsunamiHazard

    - Save selected features as new feature layer with the name “[studyarea]parcelsin”, e.g. “Westportparcelsin”.
    - Clear selected features.
- In this new layer, we can use Select by Attributes (in the Map ribbon) to further narrow it down.
- First let’s find vacant land. In Grays Harbor, the relevant attribute is LANDUSE: “Undeveloped – Land” and “Undeveloped – Open Space” (the latter may or may not be present in your study area). In Pacific County, look for the “Department” attribute.
- Exempt land may also be undeveloped, but not listed as such. Further, exempt land could also be government owned. Use the Boolean operator “OR” to include exempt land in this selection, as shown below (this example is for Grays Harbor, hence my use of the LANDUSE attribute). When finished, click Apply to select everything that fits this description.



Before doing anything else, review the attribute table. Then, carefully Select by Attributes again to get a smaller sub-selection using the OWNER attribute field to identify government property. There's all sorts of government property, so look carefully at the drop down in the Select by Attribute. Again, use the Boolean operator "OR" to include all municipal, county, state, and federal properties, schools, public utilities, etc. as shown on the next page.

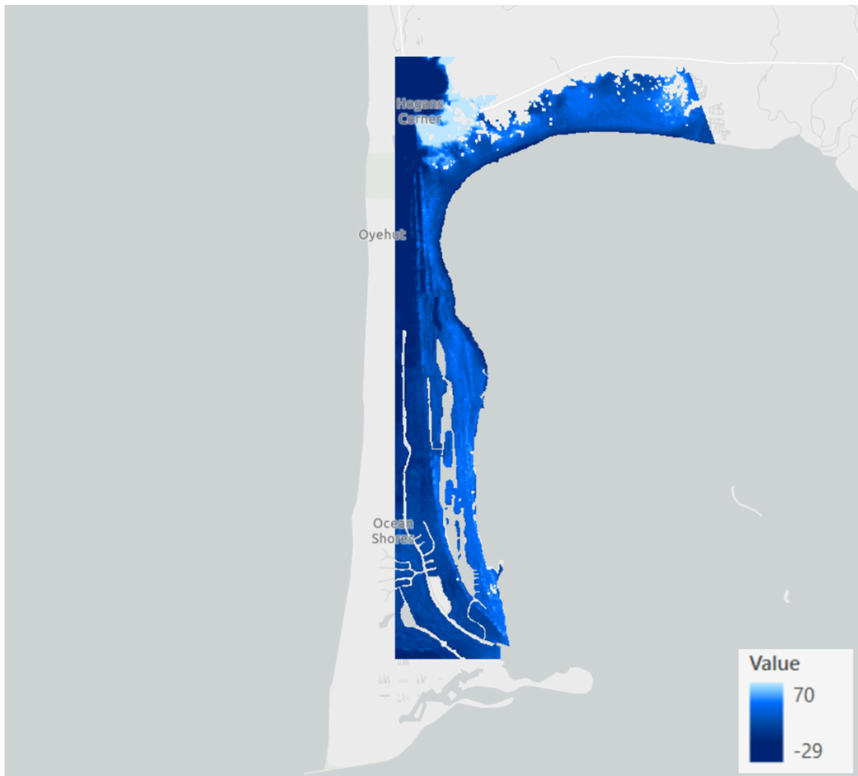
- Helpful hints:
  - Government property includes City, County, State, Schools, public utilities, etc. If you are not sure, include it - you can throw it out later if you need to. It is better to be inclusive at this stage.
  - Cities are listed as "City of…"
  - While an owner might have a city name in the title, it may not be public. For example, Westport LLC.
- For example:
  - CITY OF OCEAN SHORES
  - G H COUNTY
  - NORTH BEACH SCHOOL DISTRICT #64
  - OCEAN SHORES WATER DIST #3
  - PUBLIC UTILITY DISTRICT #1
  - STATE OF WASHINGTON
  - STATE OF WASHINGTON DEPT OF GAME
  - STATE OF WASHINGTON DNR

Export the selected features into a feature class named "[studyarea]_gov_vacant".

II. Assign Flow Depths.

Add flowdepth raster to map.

- Open the Raster Calculator and subtract your study area DEM from the flowdepth raster.
- Name the new raster file “[yourstudyarea]_heightaboveflowdepth”.
- Use the INT geoprocessing tool to convert the tiff Raster into an integer Raster. Use the same projected coordinates and the cell size as the input raster (Environments tab).
- Then, convert the new raster file into a polygon feature class “[studyarea]_heightaboveflowdepthpoly”. We’ll come back to this in a minute.

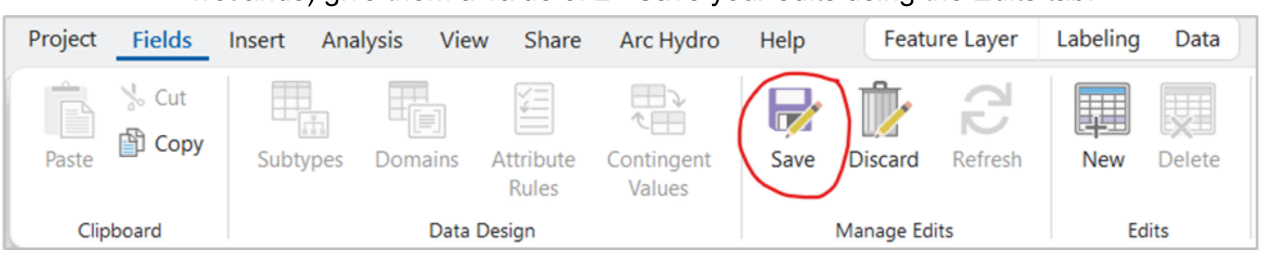


III. <u>Assign Wetland Features.</u>

Add the wetlands feature class (i.e. the 2020 data you downloaded) to your map.

- Use Select by Location to identify how many of the study area vacant government properties ([studyarea]_gov_vacant) intersect with wetlands.

- Since some of the properties are maybe okay as VES potential sites, we don't want to throw out any property right now, but want to instead designate it as a wetland property.
- Open the attribute table for [studyarea]_gov_vacant. Find the "Table" contextual tab at the top of ArcPro and use it to +Add a new attribute field (Data type = double; Number format = numeric) named "Wetlands". For the selected features (e.g., those that intersect with wetland properties) give the new Wetlands attribute a value of 1. For unselected features (e.g., do NOT intersect with wetlands) give them a value of 2. Save your edits using the Edits tab:

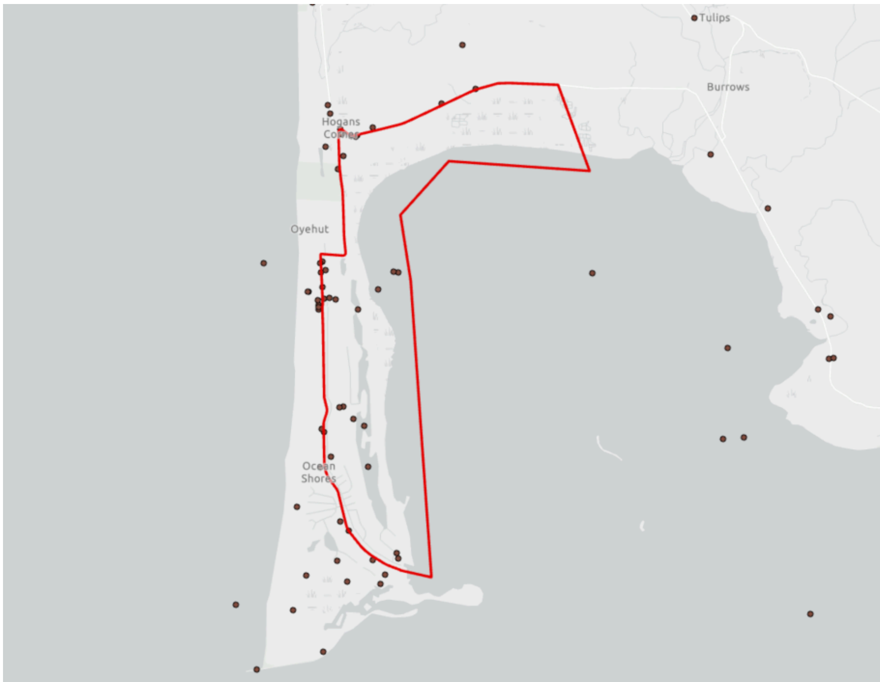


- HINT: I use the calculated field with the parcels selected so I can quickly add the values, then I switch the selection (e.g., those parcels not in wetlands) and calculate the other value.

Clear all selected parcels.

IV. <u>Identify Hazardous Materials.</u>

Add the CleanupSites and FacilitySiteInteractions shapefiles to your map. These are the two types of hazardous sites that may interfere with our options for VES placement. As we did with the Wetlands shapefile, we'll now identify how many of the government vacant properties intersect with each hazardous feature class respectively.



- First, for the CleanupSites, use the Select by Location function to identify how many of the [studyarea]_gov_vacant properties intersect with the CleanupSites layer.
- Just as you did before, open up the attribute table for [studyarea]_gov_vacant and add a new attribute field (numeric, double) named “CleanupSites”.
- For the selected features (those that intersect with the CleanupSites layer) input a value of 1. For unselected features (do NOT intersect with wetlands) input a value of 0 (yes you read that right). This is a binary yes/no attribute (i.e. is the feature a cleanup site, or not?). We use these often in raster datasets that we intend to later overlay with each other, as you will see.
- Save your edits using the Edits tab as above. Clear all selected parcels.

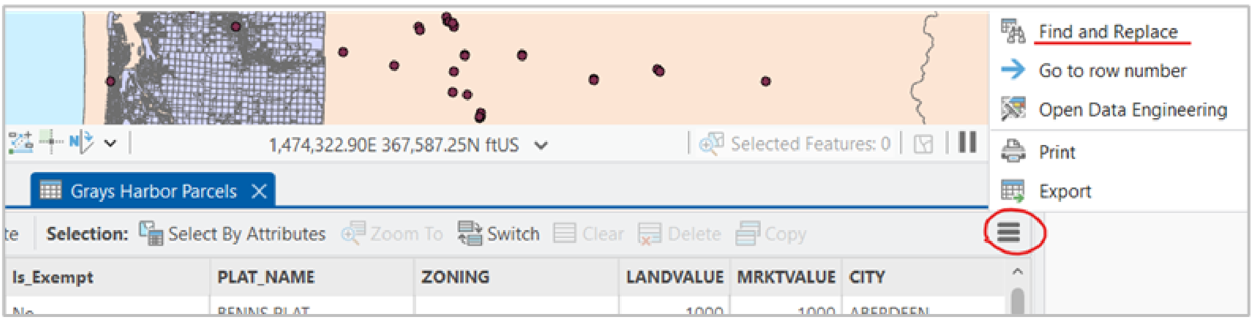
Next, we will do the same for facility sites. Use the Select by Location function to identify how many of the [studyarea]_gov_vacant properties intersect with the FacilitySiteInteractions layer.

- In the attribute table for [studyarea]_gov_vacant, add another new attribute field (numeric, double) named “FacilitySiteInteractions”. For the selected features, input a value of 1. For unselected features (e.g., do NOT intersect) input a value of 0.
- Save your edits using the Edits tab as above. Clear all selected parcels.

Next, we need to calculate a new attribute field named “AllHazards” that sums both the CleanupSites and FacilitySiteInteractions together.

- Make sure your [studyarea]_gov_vacant attribute table is open. Add another new field (numeric, double). Save your edits in the ribbon above. Then, go back to viewing the attribute table. Find the empty field you just made (all values therein should be zero), right-click on it and select Calculate Field. Do not change any parameters. Double-click on the names of layers and operators to create the equation “CleanupSites + FacilitySiteInteractions” and run. The new field should have sites with values of 0, 1, and 2.

- We now have a field where hazardous sites have a value of 2, and sites that didn’t overlap with either of the hazardous layers have a value of 0. But if you have been reading closely, you will notice that our criteria scale we used for the other layers (wetlands, etc.) typically goes the other way, with more desirable sites having higher scores.
- We can correct for this! Simply use Select by Attribute to select all the sites with AllHazards values equal to 1 or 2 (make sure you are ONLY viewing the selected records), then click the hamburger menu on the top right corner of the table view and select Find and Replace:

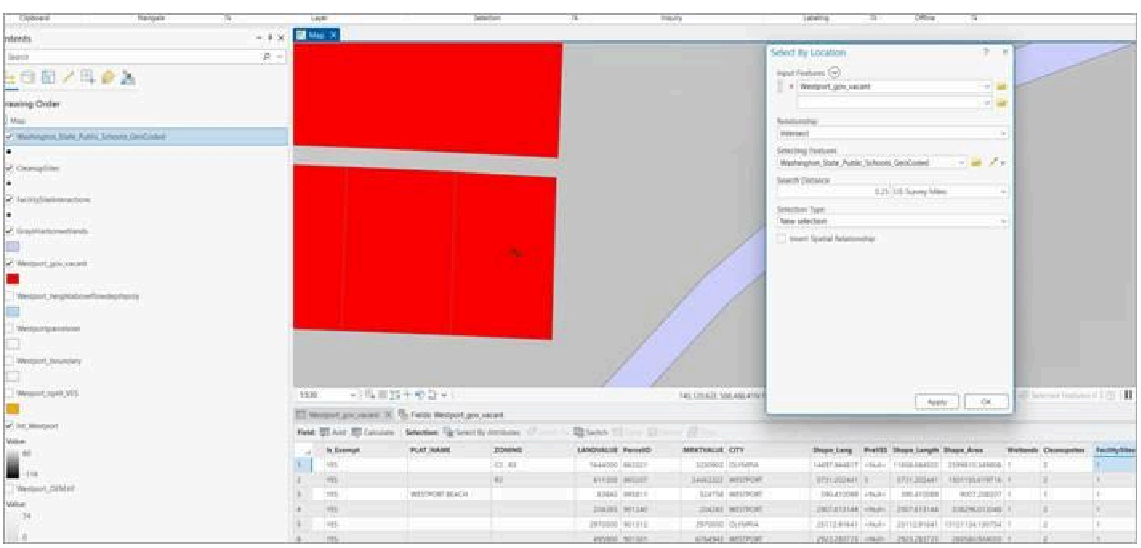


- Replace these values with 0.
- Clear selection and Select by Attribute again so that you are ONLY viewing the unhazardous parcels (i.e. sites with a CleanupSites value of 0 AND a FacilitySiteInteractions value of 0). Find and Replace so their AllHazards value is now 2, indicating that they are desirable building sites.

Then ***save your project.***

V. Identify Proximity to Schools.

Add the Washington_State_Public_Schools[…] layer to your map. Use Select by Location to select all [studyarea]_gov_vacant parcels that are within 0.25 mile of a school (see below, with example for Westport).



- To [studyarea]_gov_vacant**,** Add a new attribute field (numeric, double) named "Schools".
- For the selected features (e.g., within 0.25 mile of a school) input the value of 2.
- Clear selected features.

Perform a new Select by Location for a 0.50 mile distance. For any parcels not already given a value of 2 from the last selection, input a value of 1. Thus, all the sites within 0.25mi of a school will have a Schools value of 2 and those within 0.5mi of a school will have a Schools value of 1. When placing a VES, closer to a school is better.
For all remaining parcels, input a value of 0 – they are not close enough to a school to be worth considering. Save your edits and clear all selected parcels.

VI. Conducting a Visual Inspection

This is where things can really start to diverge. Just keep track of what decisions you make, it may be easier to keep record of what parcels you have chosen to delete at what steps.

- Visually inspect your [studyarea]_gov_vacant properties (change basemap to imagery) and use the Measure Distance tool (Map tab>Measure group) to verify if there are any properties that seem to be within that 200ft buffer. If you identify properties that are within that 200ft buffer and you don't think you would have adequate space to build a VES (50-100 feet) outside that buffer, record the site's unique identifier (i.e. PARCELATT for Greys Harbor, ASSESSOR for Pacific County), then remove that property from the feature layer.

Vacant Property:
Visually inspect the remaining [**studyarea]_gov_vacant** parcels. If there are clearly structures that could not easily be removed from the property (e.g., sheds), or there is not enough space for a VES on the remaining undeveloped area of the property, then remove these parcels from your dataset.

Impediments:
Visually inspect the parcels surrounding the [**studyarea]_gov_vacant** properties for large, heavy items that could impede or damage the VES (e.g., boats/car storage, train cars, powerlines, etc.). You can also open Google Street View and wander around if you are unsure of what an item is or whether it would impede on a VES site.

- To the [studyarea]_gov_vacant attribute table, Add TWO new attribute fields.
- The first attribute field (numeric, double) will be named "Impediments".
- The second will be TEXT and named "Impdes" (short for Impediment Description).
- Give properties with obvious impediments an "Impediments" value of 0. For their "Impdes", give a brief description of the impediment (e.g., "boats on adjacent property" "powerlines above").
- Give properties with no impediments an "Impediments" value of 2 field and leave the "Impdes" field blank.

- For properties that you are not sure or cannot tell, give them a value of 1 and explain the reason in the “Impdes” field.
- Save your edits to the attribute table, then clear any selected parcels.
- **Save your project** again – that was a lot of work!

Yours may be different but here is an example of some of the impediments I selected:

OBJECTID	Impediments	Description
43	0	Buoys/loose structures on site and adjacent
98	0	Shipping containers and tower onsite
106	0	Large obscured structure
22	1	Grid structure next to parcel
44	1	Densley wooded area, unsure
51	1	Densley wooded area, unsure
100	1	Densley wooded area, unsure

<u>Wetlands:</u>
Select By Attribute in the [studyarea]_gov_vacant table for sites that have a “Wetlands” value of 1 (e.g., those properties that intersected with the wetlands feature class). Manually inspect these properties using aerial imagery.

- For properties with clear wetlands over the majority of the property or areas that would leave little room for a VES structure, reclassify these properties with a “0” value in Wetlands.
- Save your edits to the table and clear any selected parcels.

<u>Roads:</u>
Add the Roads layer you used in Lab 4 for the PEAT analysis to your map and visually inspect it. Also inspect the basemap imagery and optionally inspect using Google Street View.

- Are the [studyarea]_gov_vacant parcels directly adjacent or close to roads? Let’s find out.
- Add a new attribute field called “Roads” (number, double).
- For properties with clear road access, input a value of 2.
    - I selected these as having a road within 20 ft.
- For properties with unclear or indirect access (e.g., the property is near a parking lot with road access, or there is no direct road access but a short road stem <500ft that could be easily built upon), input a value of 1.
- For properties with no direct road access (i.e. roads are more than 500 ft away), input a value of 0.

To recap, your **[studyarea]_gov_vacant** attribute table should include the following new fields (on the scale of 0-2, higher values are much more suitable for VES site locations):

- Previous VES (PreVES) (values 0 or 2)
- Wetlands (values 0-2)
- CleanupSites (values 1-2)
- FacilitySiteInteractions (values 1-2)
- AllHazards (values 0-2)
- Schools (values 0-2)
- Impediments (0-2)
- Impdes (text)
- Roads (0-2)

VII. <u>Assigning Height Values</u>

Height across each polygon might vary a lot. We'll look at the average, standard deviation, min. and max. heights across each [studyarea]_gov_vacant parcel.

- Summarize Within to find this information. Input polygons = your "[studyarea]_gov_vacant". The summary features = "heightaboveflowdepth", the Field = gridcode and you should add four different stats—mean, standard deviation, min and max. Name the output feature class "[yourstudyarea]_allcriteria".
- Sort the mean heights in descending order. Right-click on the attribute and click Explore Statistics. Note the interquartiles. Then Add a new attribute field (double, numeric) named Height, save edits, right-click on it and Calculate Field. Give any parcel in the first interquartile a score of 0, second and third quartiles a score of 1, and the fourth quartile (highest means) a score of 2.

VIII. <u>Applying Ranking Values</u>

We are now going to apply a rank-sum method to these criteria. We already have our most important criterion (hopefully accounted for)—vacant and government owned property. In our first iteration this is the criteria we imposed, it should be noted that after discussing with Maximilian and Dante, new rankings (e.g. roads ranked higher priority) are added. This brings about a point addressed in the future works that including community input may further change this ranking and so we have opted to keep this ranking the same in our project but acknowledge its value in future works:

Criterion	**Ranking**	**Inverse Ranking**	**Weight Inverse Rank/sum**
Height	1	7	7/28=.25
Previous VES	2	6	6/28=.21
Wetlands	3	5	5/28=.18

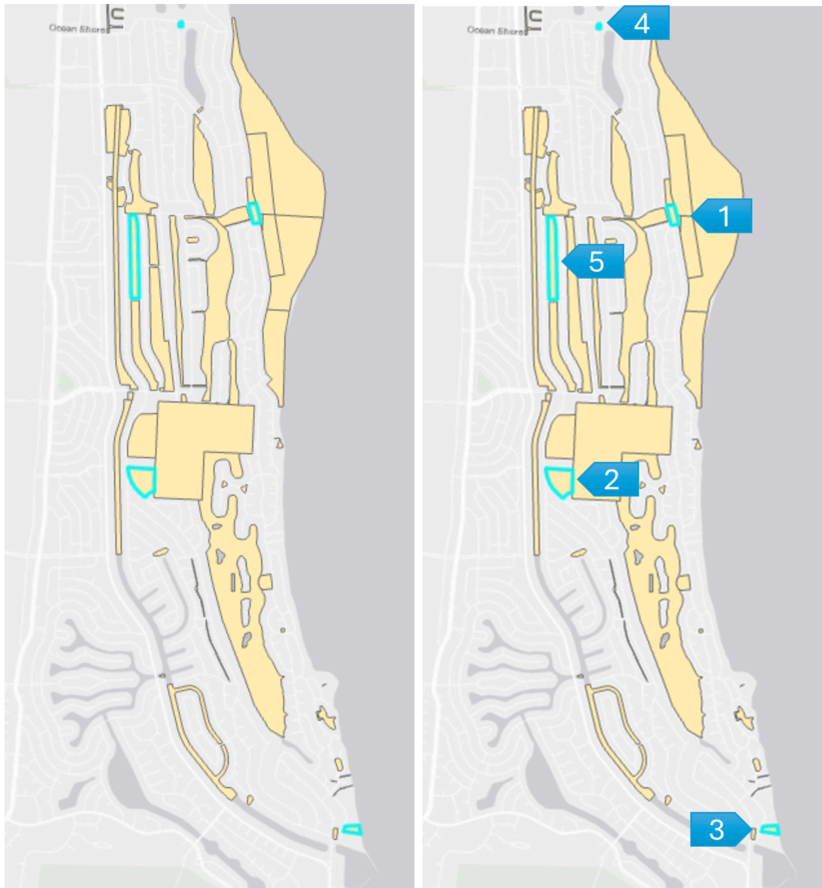
AllHazards	4	4	4/28=.14
Impediments	5	3	3/28=.11
Roads	6	2	2/28=.07
Schools	7	1	1/28=.04
		28	1.0

Add new attribute fields for each of these (i.e. wetlandsrank, hazardsrank, etc.) and Calculate them by multiplying the original attribute by its respective weighted rank.

Then Add and Calculate one more attribute field (**VESranksum**) that sums all the ranked attributes. Sort this field descending so the parcels with the highest ranking are first. Examine your results.

heightrank	previousVESrank	wetlandsrank	hazardsrank	impedimentsrank	roadsrank	schoolsrank	VESranksum
0.5	0.42	0.36	0.28	0.22	0.14	0	1.92
0.25	0.42	0.36	0.28	0.22	0.14	0.08	1.75
0.5	0.42	0.18	0.28	0.22	0.14	0	1.74
0.25	0.42	0.36	0.28	0.22	0.14	0.04	1.71
0.25	0.42	0.36	0.28	0.22	0.14	0	1.67
0.25	0.42	0.36	0.28	0.22	0.14	0	1.67
0.25	0.42	0.18	0.28	0.22	0.14	0.04	1.53
0.5	0	0.36	0.28	0.22	0.14	0	1.5
0.5	0	0.36	0.28	0.22	0.14	0	1.5

Now, Maximilian said that we should identify only half as many VES options as are listed under option 4 for each study community because of limited resources. While it seems like a reasonable approach to simply take the top ranked parcels, these parcels may all be clustered closely together, and that wouldn't be efficient or useful for the entire community. So be careful how you select the parcels—look for a good spatial spread across the populated areas (e.g., where houses/structures) of the community.



Note: If you like, you could add the **user_defined** and **non_bldg** layers back onto to your map to give you a better indication of where these population clusters might be.

Select your preferred parcels. Export them into a new feature layer.

IX. Manual VES Pre-processing Refinement

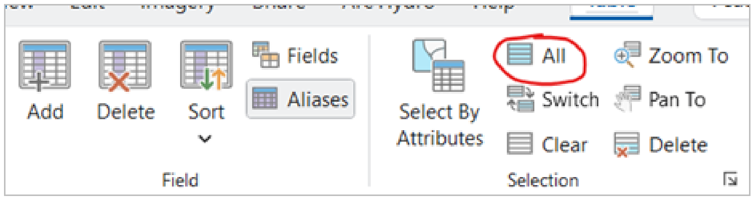
Since we want a bit more accuracy in terms of the size of the VES, convert this feature layer into a point layer (using the **Feature to Point** tool), but don't check the Inside box.

Visually inspect each point, and if necessary, manually move the points to be closer to the road and higher ground. You can do this with the Move To tool (Edit>Modify>Modify Features, the specifics of which are discussed on ESRI's Help page for the tool.)

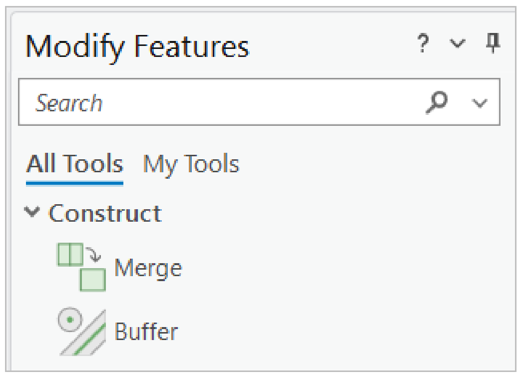
Hint: To visualize how close points are to roads and high ground, you can edit the visibility/transparency of various layers or even experiment with changing the basemap to Streets, Topographic, or USA Topo Maps – whichever works for you.

Next, search for and open the Buffer tool. Use it to add a 50-foot buffer around each point in the **selected** layer, and save it as **VESbuffer**.

Select all points (FYI, the easiest way to do this is in the Table contextual tab>Selection group).



Then, click on the Edit ribbon>Modify feature>Merge.



Make sure all points are selected, and merge. Then save.

We do this step because the PEAT tool by default wants to run a different analysis for each VES, rather than all of them together. However, we *want* to run them all together so that we can see which combinations give the most coverage and are the most cost-effective.

Keeping good records of the VES locations in each feature layer will be important, since this information disappears when you merge the points. Especially when you start working more with your group, I would advise keeping a table of the different VES scenarios you are running and the parcel ID of the potential VES site in each scenario. Since the PEAT tool uses a unique attribute field when it runs the vertical evacuation map, you could create a new attribute field and give it a unique number like 1026251 (Oct 26 2025, run1), 1026251 (Oct 26 2025, run2), etc. Whatever system works for you, just have a system!

X. <u>Creating the Vertical Evacuation Map</u>

Open the PEAT toolbox and run Step 2d (Create vertical evacuation map) using the new data scenario and newdata timemap 1p1 base time map your group has collectively decided what new data scenario and newdata timemap 1p1 you should use. ALL members of the group should use the same data from these preprocessing steps onward. In order to do this, have the group member's data that you have decided to use send BOTH the peatdata gbd and raster folder (compress the folder that contains both of them) and send to your group. When you run step 2d, make sure you use the name of this gdb and map the correct landuse scenario and time map.

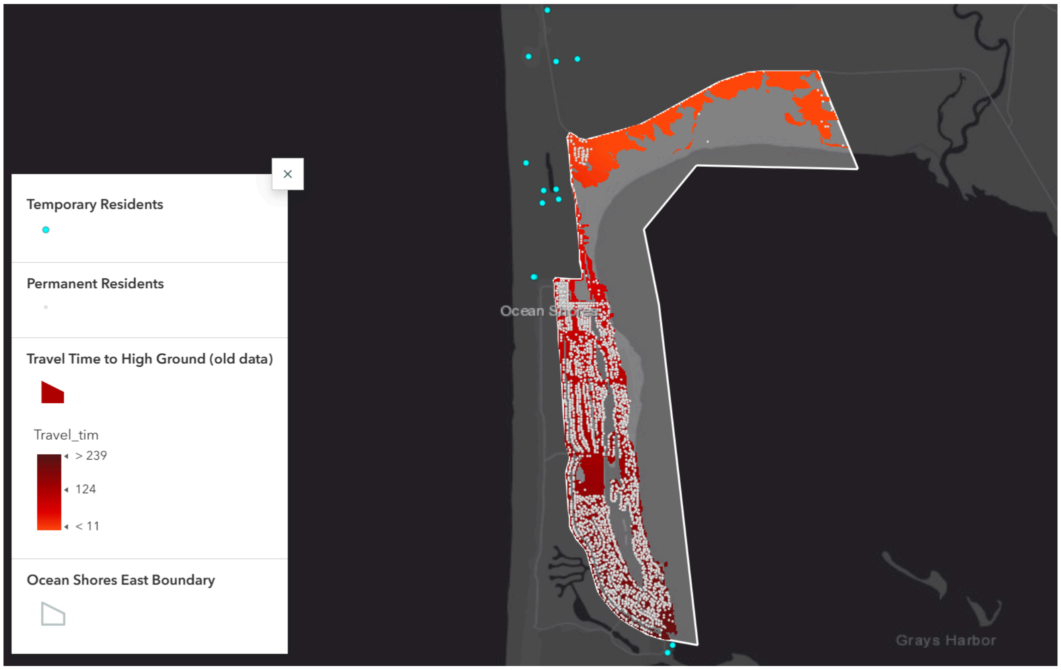
- The VE feature = "**VESbuffer**" and the unique VEnumberfield = **OBJECTID**. A new feature dateset should be named **"[scenarioname]_[uniquefield]_1p1"** (e.g., "timep_map_polygon_Westport_newLC_VES32144_1p1").
- Even though we are almost done, now is a good time to ***save your project!***
- Now, as in Labs 1 & 4, we are going to calculate total population types.
- Add both "User_defined" and "Non_bldg" (in the Population feature dataset for Lab4DATA) to your map.

Note: Ocean Shores East has no "non_bldg" points within the boundary but we will leave the directions in anyways in case this changes.

- Calculate the percentage of the Permanent, Temporary, and Worker (Empe) population, respectively, within 15 minutes of high ground (e.g., 0-15) and within 25 minutes (0-25).
- Repeat the three Summarize Within analyses (e.g., total, old data and new data) for the **NonBldg_Lodging** layer. For this layer, you should use the **N_Units** attribute field. **Assume two people per unit.**
- Lastly, calculate the percentage of the nonbuilding lodging population, respectively, within 15 minutes of high ground (e.g., 0-15) and within 25 minutes (0-25).

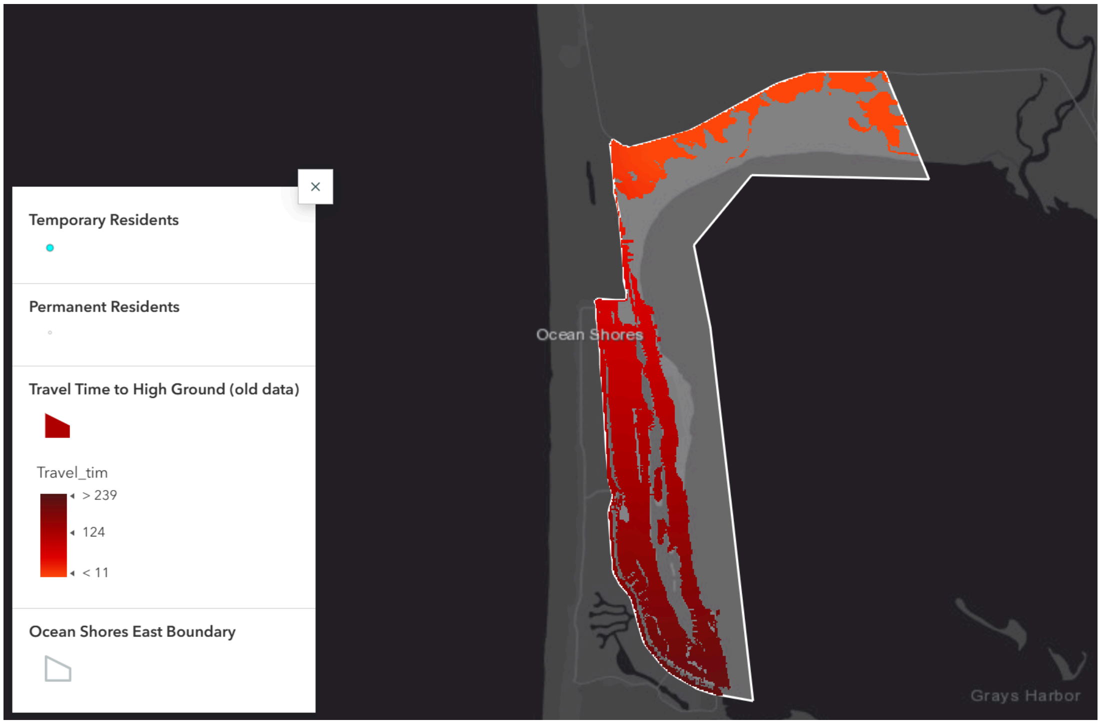
Results

Baseline Differences



Modeling based on the 2015 landcover and road network highlights the severe evacuation limitations within Ocean Shores East. <u>Nearly the entire study area falls below the 25-minute pedestrian travel threshold, with fewer than two percent of residents able to reach safety on foot under ideal conditions.</u> The evacuation surface shows a broad, continuous low-lying zone that extends across residential and commercial areas, bounded by the Pacific Ocean to the west and Grays Harbor to the east. These geographic barriers create a peninsula with only one narrow road corridor leading inland, effectively isolating the community during a local tsunami event. The extensive low-lying residential development and looping street network further constrain pedestrian mobility, as few direct routes connect to the nearest high ground. No temporary or visitor housing facilities were identified within the OSE boundary, meaning this exposure primarily affects permanent residents and local employees.

Overall, the 2015 data scenario underscores how the physical geography of Ocean Shores, not necessarily data accuracy, controls the community's evacuation vulnerability. Without vertical-evacuation structures or vehicle-based routes, the majority of residents would have no feasible means of escaping inundation during a short-notice tsunami.



The 2020 land cover and updated Grays Harbor road data produced only minimal improvements to modeled evacuation outcomes for Ocean Shores East. A few localized areas show slightly shorter modeled travel times, likely reflecting refined road alignments and updates to impassable-area mapping, but the overall evacuation pattern remains virtually unchanged from the 2015 scenario. Less than two percent of the total population can still reach high ground within 25 minutes, confirming that data improvements alone do not translate into meaningful increases in accessibility. The updated dataset better represents the existing infrastructure yet also illustrates how physical geography, not data precision, remains the dominant control on evacuation potential. The same extensive low-lying residential layout and limited road corridors that constrained mobility in the old data continue to isolate the community under the new model.

From a management perspective, these results emphasize that improving spatial data quality is not enough to alter the underlying vulnerability of Ocean Shores East. The peninsula's flat terrain, narrow connection to the mainland, and lack of nearby high ground restrict evacuation feasibility regardless of modeling detail. Increasing community safety will require structural and policy solutions such as constructing vertical-evacuation towers, maintaining clear signage, and expanding public preparedness programs, to provide residents with realistic options during a short-notice tsunami event.

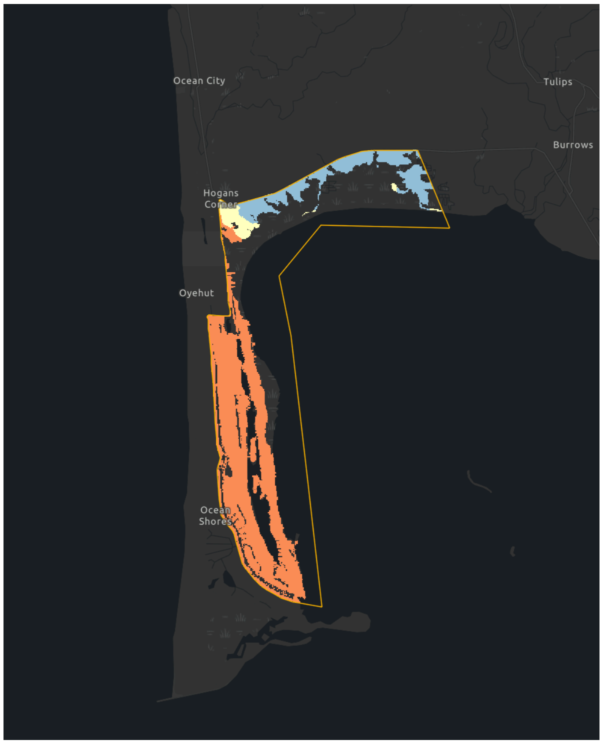
Proposed VES sites

Group member	Scenario name	Population within 15 minutes of high ground (0-15 minutes)				Population within 25 minutes of high ground (0-25 minutes)				Individual VES Parcel ID(s)	Parcel Ownership	Individual VES Height	Individual Previous VES	Individual Ranksum
		Perm.	Temp	Emp	Nonbdg	Perm.	Temp	Emp	Nonbdg					
Dunford, Clark	Dunford_S1	52.05%	41.71%	85.71%	N/A	81.30%	73.22%	100.00%	N/A	94900900100	CITY OF OCEAN SHORES	6.686036	2	1.7
										95101300000	CITY OF OCEAN SHORES	1.129918	2	1.71
										617121014001	NORTH BEACH SCHOOL DISTRICT #64	-1.136816	2	1.75
										92900060102	QUINAULT LAND & TIMBER ENTERPRIS	7.575774	2	1.74
										94700118200	DELU CAROL F & TAMMY A	0.961702	2	1.67
										94700500100	HOLZ MARK	5.641254	2	1.67
Lattig, Mckenzie	Lattig_S1	46.79%	35.98%	14.29%	N/A	69.86%	57.86%	32.14%	N/A	94900900100	CITY OF OCEAN SHORES	6.686036	2	1.7898
										95101300000	CITY OF OCEAN SHORES	1.129918	2	1.57
										181118410010	STATE OF WASHINGTON DNR	8.245191	0	1.36
										94500109100	CITY OF OCEAN SHORES	3.711059	0	1.36
										90500079700	CITY OF OCEAN SHORES	-2.088232	2	1.2898
										94701400000	CITY OF OCEAN SHORES	4.753251	0	1.1898
Marroquin, Anthony	Marroquin_S1	17.80%	17.80%	10.70%	N/A	27.80%	27.90%	17.90%	N/A	90500079201	CITY OF OCEAN SHORES	8.18	0	1.5
										90500079300	CITY OF OCEAN SHORES	12.48	0	1.5
										94701400000	CITY OF OCEAN SHORES	-11.21	0	0.82
										617121011003	CITY OF OCEAN SHORES	2.93	0	1.4
										617121014001	NORTH BEACH SCHOOL DISTRICT #64	2.77	2	1.75
Miller, Emmaline	Miller_S1	11.92%	6.77%	14.29%	N/A	32.47%	20.71%	25%	N/A	91900061500	OCEAN SHORES COMMUNITY CLUB	52.973712	2	1.31
										90500030901	CITY OF OCEAN SHORES	22.73026	0	0.78
										91100007400	CITY OF OCEAN SHORES	34.706945	0	1
										94900900100	CITY OF OCEAN SHORES	79.53904651	2	1.45
										94500108700	CITY OF OCEAN SHORES	125.377867	0	1.5
Meselhe, Amina	Meselhe_S1	48.00%	34.00%	86.00%	N/A	72.00%	62.00%	100.00%	N/A	90500079700	CITY OF OCEAN SHORES	-2.087387	2	1.67
										92900060102	QUINAULT LAND & TIMBER ENTERPRIS	7.60262	2	1.74
										94900900100	CITY OF OCEAN SHORES	6.685009	2	1.92
										95101300000	CITY OF OCEAN SHORES	1.128893	2	1.71
										181118410010	STATE OF WASHINGTON DNR	8.241879	0	1.5
										617121014001	NORTH BEACH SCHOOL DISTRICT #64	-1.13678	2	1.75
Varga, Jeffrey	Varga_S1	42.03%	34.70%	21.43%	N/A	71.68%	63.85%	28.57%	N/A	90500079401	CITY OF OCEAN SHORES	-9.461941	0	0.71
										94500108700	CITY OF OCEAN SHORES	15.144357	0	1.5
										94701400000	CITY OF OCEAN SHORES	11.207349	0	1.07
										94901700000	CITY OF OCEAN SHORES	13.339895	0	1.07
										94901800000	CITY OF OCEAN SHORES	3.628609	0	1.25
										617121011003	CITY OF OCEAN SHORES	9.370079	0	0.68
Varga, Jeffrey	Varga_S2	54.08%	52.28%	92.86%	N/A	90.35%	90.26%	100.00%	N/A	90500079401	CITY OF OCEAN SHORES	-11.922571	0	0.71
										91900057600	CITY OF OCEAN SHORES	2.381889	0	1.25
										94500108700	CITY OF OCEAN SHORES	15.144357	0	1.5
										94701400000	CITY OF OCEAN SHORES	11.076116	0	1.07
										94901800000	CITY OF OCEAN SHORES	3.628609	0	1.25
										617121011002	CITY OF OCEAN SHORES	-5.459318	0	0.86
Meselhe, Amina	Meselhe_S2	55.35%	41.93%	85.71%	N/A	82.74%	74.63%	100.00%	N/A	90500079700	CITY OF OCEAN SHORES	-2.087387	2	1.67
										92900060102	QUINAULT LAND & TIMBER ENTERPRIS	7.60262	2	1.74
										94701400000	CITY OF OCEAN SHORES	4.779278	0	1
										94900900100	CITY OF OCEAN SHORES	6.685009	2	1.92
										95101300000	CITY OF OCEAN SHORES	1.128893	2	1.71
										617121014001	NORTH BEACH SCHOOL DISTRICT #64	-1.13678	2	1.75

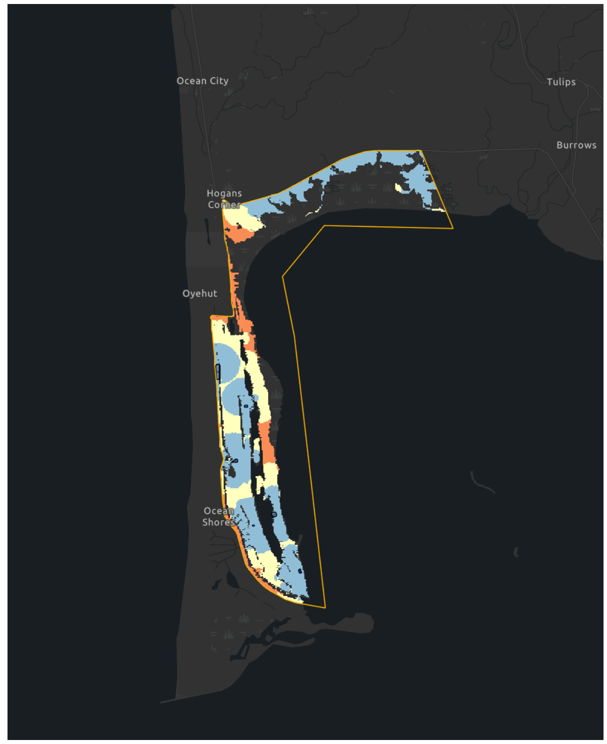
Highlighted above is the selected scenario. Time map results of this scenario are shown in the section below.

Selected VES Sites

The highlighted scenario in the above section was selected since it presented the greatest percentage of populations that would be saved within the threshold times. Below is a visualization of the time maps for the current scenario, or baseline, compared to the time maps using Varga_S2.



Baseline (No VES)



Selected VES Scenario

The following table describes the population breakdown within threshold times of evacuation to either high ground or a vertical evacuation structure. This breakdown is helpful for characterizing the impact on permanent, temporary, and shift workers respectively.

	Population Type	**Within 15 minutes**	**Within 25 minutes**
Baseline (No VES)	*Permanent*	0%	2%
	Temporary	0%	1%
	Workers	0%	4%
Selected VES Scenario	*Permanent*	54%	90%
	Temporary	52%	90%
	Workers	93%	100%

Data Complications
Throughout this project, our group hit several minor yet notable speedbumps. To start, we had issues utilizing a shareable geodatabase (gdb). Some group members were unable to use the shared gdb, so they created their VES time maps using their own gdbs. This resulted in slightly different results, but we simply chose the proposed VES sites that would benefit the largest number of people. Additionally, PEAT incorrectly identified some areas as impassable.

Individual vs Combination
Our methodology evaluated the performance of certain combinations of VES sites, not individual VES sites themselves. It is therefore difficult to identify the single most effective site (or sites). This being said, there was some agreement on certain sites (such as Ocean Shores Elementary School) across our scenarios. In the future it will be helpful to use PEAT to evaluate the performance of specific sites.

Redefine OSE boundaries?
While OSE is defined as the portion of the city to the east of Point Brown Avenue, there is a narrow strip of homes within OSE that are to the west of a sizable canal (running parallel to Point Brown Avenue). Because they are on the opposite side of the canal, the population here are significantly isolated from the rest of OSE and are therefore poorly served by all of our VES scenarios. This being said, it is plausible that the population here may be within a 15 or 25 minute walking distance from the VES sites selected by the Ocean Shores West (OSW) team. Future analysis should incorporate/annex this strip of homes into OSW to avoid a ‘False Positive’ situation.