WA State Cascadia Subduction Zone (CSZ) Tsunami Loss Estimate Study: Dataset Development Guide

July 30, 2025
Washington Emergency Management Division, Camp Murray, Washington

Background

In July 2021, Washington Emergency Management Division (WA EMD), of the Washington Military Department, hired John M. Bauer of Bauer GIS Solutions, Portland, Oregon, to conduct Hazus-based impact estimates for buildings and people in the Cascadia Subduction Zone tsunami zone, for all 15 Washington state coastal counties that will likely be significantly impacted by a tsunami.

This is a methods document, with the intent for WAEMD or others to duplicate the work we have done – either with the intent to refine the initial estimates provided by the contractor, or to adapt their usage for understanding earthquake impacts outside of the tsunami zone.

The tsunami inundation zone is defined by Washington Geological Survey's (WGS) detailed tsunami modeling of a Cascadia Subduction Zone (CSZ) Extended L1 M9.0 Tsunami (Washington Geological Survey, 2024) which has been quantified in raster format for all affected Washington counties.

This document describes the following:

- Development of a User-defined Facility (UDF) file for use in Hazus, one that specifically addresses the needs of this project, including:
    - Building replacement cost using 2021 US$ replacement cost
    - Landslide, liquefaction susceptibility using best available updated information from WGS
    - Seismic design levels reflecting the guidance of the Feb 9, 2017 Degenkolb memo based on year of construction
    - Permanent population using Census 2020 numbers
    - Temporary population estimates for a 2:00 AM id-summer weekend scenario
    - Distance-to-tsunami safety attributes used in the Hazus tsunami casualty model
- Development of a non-building lodging dataset, including locations and characteristics of all recreational marinas, campgrounds, and RV parks in the tsunami evacuation zone.
- Development of a tsunami evacuation zone polygon shapefile, one that for life safety reasons, may be more conservative than a simple polygon rendering of the WGS-supplied tsunami raster data.
- Development of a tsunami evacuation road network, one that is modified to factor in potential bridge failures
- Development of a Wave Arrival Time polygon overlay for use in the tsunami casualty model
- Exporting UDF Data for use in standalone Tsunami Casualty Spreadsheets
- Preparing tsunami grids for use in Hazus tsunami model

Assumptions

- Users have access to ArcGIS 10.8.1 (Advanced license, depending on the geoprocessing need), ArcGIS Spatial Analyst extension, Hazus 5.0, CDMS, and SQL Server Management Studio.
- Users are adept at making inquiries and database updates in the ArcGIS database and exporting out and summarizing tables for their own reporting purposes.
- Users can interpret some of the field calculator formulas herein, noting that some adjustments may be needed to run the formula successfully.
- Users can run python-formatted functions in ArcGIS field calculator.
- Users have training in FEMA CDMS and Hazus software and are aware of the terminology, tool limitations, and requirements.

UDF Starting Point

FEMA Region 10 staff compiled available UDF datasets for many Washington counties, imported them into CDMS in a UDF format, thereby assuring their Hazus compatibility (but not necessarily their accuracy in describing the building – including physical location and associated attributes). For the AEBM, the CDMS inventory included a "ShakeMap Beta" version. Note that for the deliverable, AEBM was not run, as earthquake-only results were not requested.

We replaced the standard issue Washington state inventory file with this very large `WA.mdf` in the `HazusData\Inventory\WA Hazus` folder, then proceeded to build out regions consisting of 3 to five coastal counties, then extracted out the UDF and AEBM points as individual feature classes for each coastal county. With such a large AEBM/UDF dataset for the entire state, Hazus would be unwieldy and unresponsive when trying to build a region at the full state level.

The UDF points were then examined/edited/updated in the manners discussed below. The end product was a UDF set representing buildings **in the tsunami evacuation zone** (which is more inclusive than the "tsunami zone"; discussed further below). We only adjusted UDF points within this tsunami evacuation zone. Sometimes points residing outside the tsunami evacuation zone that clearly represented the building, but were obviously misplaced, were moved to the building center (and thus, into the tsunami evacuation zone). Conversely, points outside of the tsunami evacuation zone were brought into the zone to represent the location of the designated building.

An earthquake model wishing to offer a complement to this study would remove all UDF/AEBM points in the tsunami evacuation zone, proceed to do the needed updates (as discussed below), then run the Hazus model and report only on buildings outside of the tsunami evacuation zone.

UDF Limitations

The datasets provided by FEMA during this study were a good starting point but had many limitations. The following is intended to provide insights into the database strengths and limitations, and to set reasonable expectations on what we delivered for the tsunami evacuation zone building dataset. The quality and usability of the Hazus results depend heavily on the quality of the data inputs, including the building dataset. Quality and coverage varied widely across counties; not surprising, considering the different individuals and methods involved in assembling the data.

Spatial representation: For Hazus flood and tsunami analysis, where the hazard varies widely across large tax lots, the UDF point need to represent the actual location of the building, and not at the tax lot centroid. We obtained the Microsoft Bing building footprints (available as a service and as a download), walked each coastline tsunami zone, and moved the UDF points to the building center where needed. Points outside the tsunami evacuation zone that did not map to a building inside the tsunami zone were ignored. For reference, a “Map Tips” option was used to display key attributes for the UDF point (Occupancy, Area, Building Type) and the Microsoft building footprint square footage.

Correcting Double Coverages: One can find cases where a building may have two or more records by spatially joining (one-to-one) a point file to itself and examining the `JOIN_COUNT` field. Normally, one expects just one join per record. We corrected such cases (removing one of the redundant records) where they occurred, which were normally only a handful within the tsunami zone per county. The major problem with the FEMA-compiled dataset was that **each building in Pierce County had two records.** We corrected the situation for points within Pierce County tsunami inundation zone but did not fix this for the entirety of Pierce County.

Incomplete Coverage: Fairly common situation. The town of Edison had less than 10 UDF points, severely undercounting the situation there. The town of La Conner had perhaps half the buildings with no data. To fill in these gaps, we manually placed UDF records, typically using a default RES1, 1970 year of construction, 1500 square foot, W1 (wood frame), foundation type of 5 (Crawl Space), 3 foot First Floor Height, one story. (A default set of attributes can be set up using ArcCatalog). Where the building square footage suggested otherwise (Microsoft Bing square footage estimate), the square footage was altered. Where the neighborhood was obviously newer, if available data suggested a group mean of a 1990 year of construction, then the year of construction was changed. We typically did not try to address minor outbuildings such as boat houses or detached garages. Again, the focus is on the impacts to people and the buildings in which they reside, and to large businesses.

Incorrect Attribution: By turning on labels for the UDF points, one can get a sense of building attributes, including area, building type, occupancy type. Obvious errors were corrected, such as the original data designating a building as a S1L when from street level imagery it is clearly a PC1 building type. In part of Skagit County, every barn was given an AGR1 (correct) 30,000 square foot attribute. The 30,000 square foot needed amending where appropriate.

One county had COM10 occupancy type representing surface parking lots. This is an understandable misinterpretation of the intent of this occupancy type, which should be limited to describing a multi-story parking structure. Such points were deleted (again, limited to those in the tsunami evacuation zone).

Compromise: In some areas, in interest of time only the largest buildings were represented. Such was the case with the Bremerton Puget Sound Naval Shipyard, which had no data in the original UDF file. Street-level imagery in a secured military area was limited; we relied on the oblique imagery from the Washington Shoreline Photo Viewer (https://apps.ecology.wa.gov/shorephotoviewer/Map/ShorelinePhotoViewer) and the Microsoft building footprints to assign building size, type, and function. In interest of time, many smaller buildings and outbuildings (typically less than 2000 square foot) were not represented.

The same situation occurred in the Commencement Bay industrial area (Tacoma). The original UDF dataset was lacking coverage for many large buildings. In addition, given the vintage of the UDF dataset for a particular county, we needed to represent newer construction – in Commencement Bay, this typically consisted of massive warehouses. Again, the focus was given to larger buildings, and guard houses and other smaller facilities were not included.

As noted in the “Incomplete Coverage” section, residential areas with many significant gaps were populated with points containing a default set of attributes. For tsunami casualty modeling, it is important to capture the presence of a building that houses people. But given the large numbers, time limits prevented thorough investigation into the number of stories, area, or first floor height for each building individual building.

For Phase 2 of this project we corrected mis-attributions, moving points to better represent the building relative to the natural hazard, and manually adding in UDF points where the situation warrants, keeping in mind the limited budget and the overall project needs: impacts to people and the buildings in which they reside, and to larger buildings used for commerce, manufacturing, education, government, and community resource purposes.

Guidelines for Modifying a UDF Dataset

Here we provide guidance on manually editing or updating key Hazus attributes, and where needed, provide new UDF records with this information. Auto-assignments of many of the other UDF attributes are discussed in subsequent sections. The key Hazus attributes with examples are:

- Occupancy Type (e.g. RES1, COM2)
- Square Footage
- Foundation Type (1 through 7)
- First Floor Height (generally, a decimal number greater than 0.0)
- Year of Construction
- Number of Stories
- Building Type (wood – e.g., W1, steel – e.g. S1L, etc.)

In addition, one needs to do:

- A reasonable attempt at filling in data gaps (e.g., obvious building is present; but no UDF record)
- Where UDF records already exist, move the point if needed to the building's centroid

For tsunami modeling purposes, populating the following two attributes is desirable. It can involve some internet queries or counting hotel room doors. Be reasonable in the amount of time devoted to researching these. If information is not readily available, leave the field blank (or null).

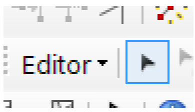
- N_Units_Man
  - For multi-family residential: number of individual housing units
  - For hotel/motel (RES4): number of rooms. TRY TO GET THIS WHERE POSSIBLE. Street-level imagery, web sites, etc.
  - For dormitories (RES5) and assisted living/nursing homes (RES6), number of beds. TRY TO GET THIS WHERE POSSIBLE. Web sites, etc.

- EMPE_Man
  - For large industrial buildings (>10,000 square feet): Employees on graveyard shift. Very large facilities may have such information for their 24/7 facilities. In the end, this was not researched; we used the Hazus defaults for 2:00 AM population.

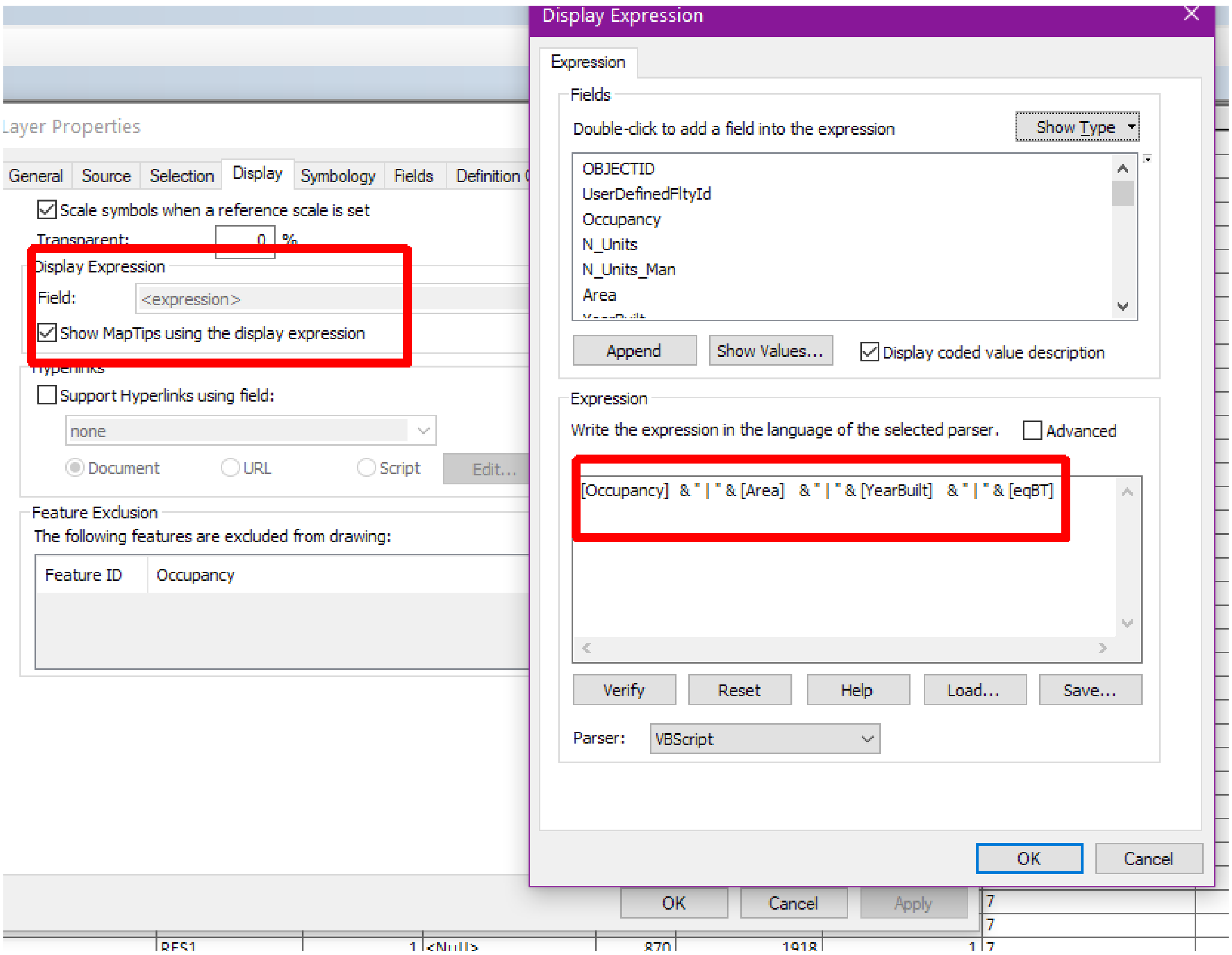
Spatial Adjustments

To aid in editing, turn off snapping.

When editing, only have the UDF layer selectable. Selecting a point can also be accomplished, when editing, with click-and-dragging the Editor arrow. It takes some practice:



Suggest that certain attributes be turned on as a guide when hovering over the UDF point:



Using the Microsoft building footprints and recent imagery (such as the NAIP 2017 series or the Washington state imagery services), select and move the UDF point, if needed, to inside the building footprint. Sometimes there can be outbuildings such as detached garages or sheds on the property that do not have a UDF point. That is fine; we want to focus on the important buildings that are costly to replace and that house people.

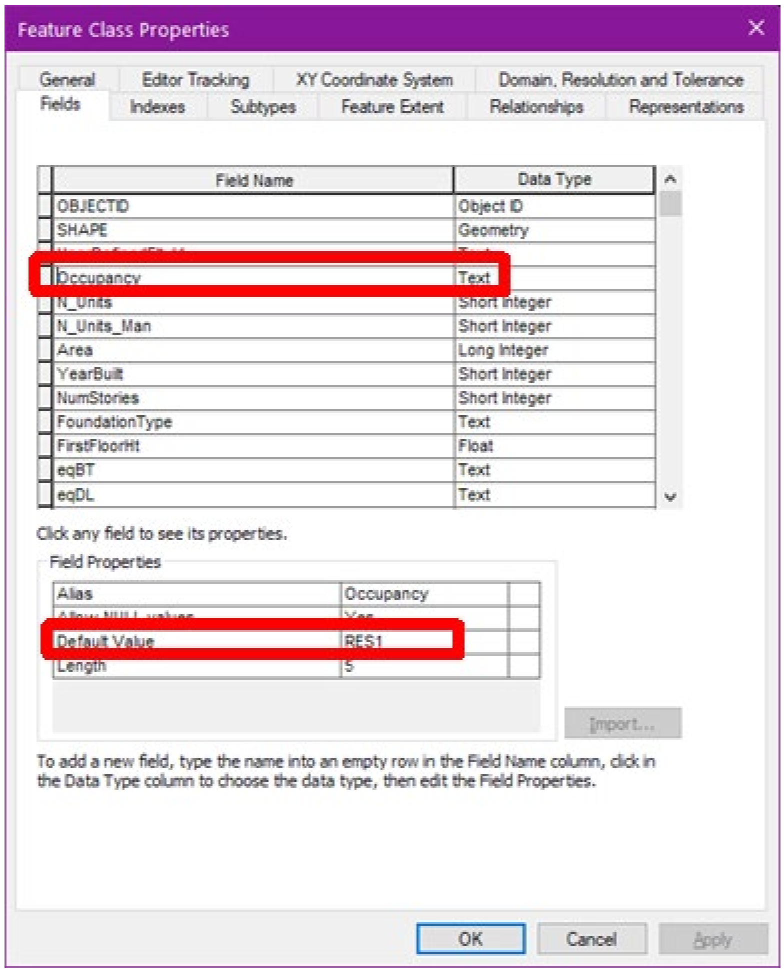
Limit the above activity to buildings within the tsunami evacuation zone. Sometimes a UDF point in the zone may be describing a building outside the tsunami evacuation zone. If that is the case, manually move the point to the building that is outside of the tsunami evacuation zone.

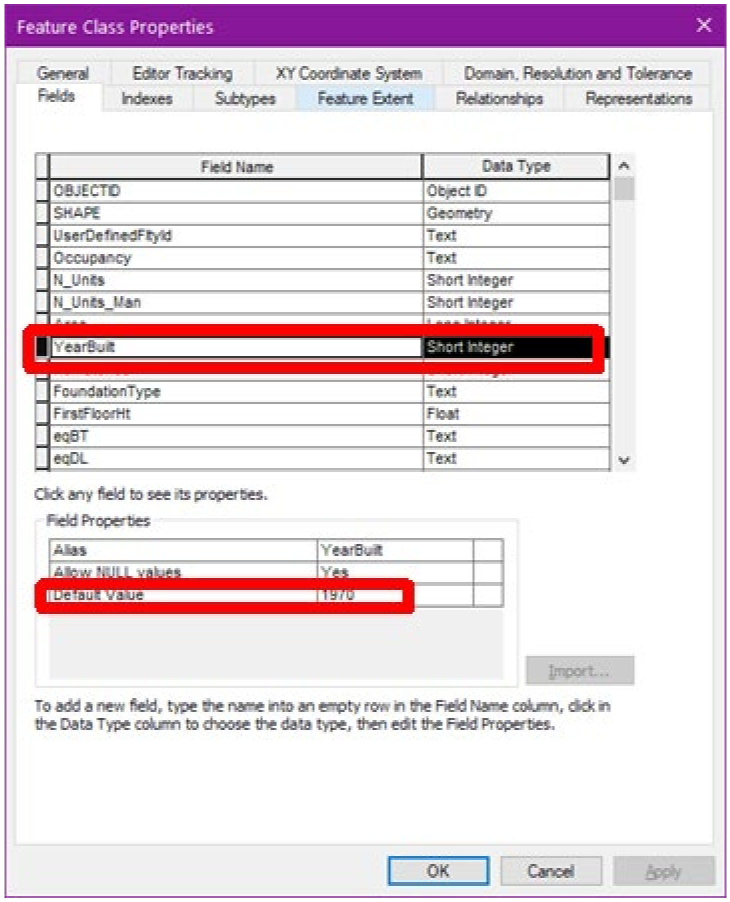
For a peculiar Hazus legacy modeling reason, occasionally a UDF point needs to be placed outside of the building footprint. This is due to a Hazus quirk wherein if a point is outside what it thinks is the terrestrial boundary, it will be ignored. So we did our best to capture the building tsunami impact yet still fitting into the legacy Hazus constraint. Below is such a case in Bellingham – the cyan point represents the building complex that is clearly in the tsunami zone (red zigzag line). Hazus' legacy terrestrial boundary is in pink. If the point is placed on the building, Hazus will ignore it, as it is not placed on what Hazus thinks is dry land. The compromise is to have it within the terrestrial zone and close to the building it is representing.

Missing Buildings

This will be the most significant task. Using imagery, with the building footprint as guidance, systematically inspect for missing buildings. Ignore small outbuildings, detached garages, boathouses, and non-building structures.

Most common is a missing residential building. In ArcCatalog, using Properties, one can set default assignments for the needed attributes when creating a new point. Here, we specify a new record will be given RES1 for `Occupancy` and 1970 for `YearBuilt`. Other needed attributes can also be specified (e.g., `NumStories` = 1, `FoundationType` = 5 (crawl space), `FFH` = 3.0 `eqBT` = W1, **Area** = 1500)





Of course, the actual point may need further editing – for example, a commercial facility. Use the Hazus occupancy tables for guidance in terms of assigning occupancy type.

Square footage

This may need to be adjusted for existing buildings - but be reasonable in the time and effort. No need for high-resolution square footage. Use the Microsoft building footprint size, along with the number of stories for the building, to assign a square footage. Generally, the internal square footage of a building is about 90% of the building footprint outline.

Using street level imagery, if the building appears to be slab-on-grade, change the foundation type to 7 and the FFH to 1.0 feet.

Nearly all single-family residential properties in western Washington are wood frame. Assign “W1” or “W2”, depending on the building’s square footage (< 5000 square feet = “W1”, > 5000 square feet = “W2”). If the building type is unclear, use the [FEMA P-154 manual](), Table 3-1 (starting at page 118, going through page 127) for guidance.

Number of Stories

This can be obtained using street-level imagery. Oddities will arise with some complex buildings having portions at 1 story and portions at 2 stories. In such cases, choose the dominant case. Split-level residentials: Assign 2 stories.

Year of Construction

This can be a challenge to populate. Exact year is not needed; an approximate year is fine. Look at the neighborhood – does it look relatively new? Is the building similar to surrounding buildings that do have a Year of Construction? If so, use that value. If an industrial area, use the Google Earth historical imagery slider bar and see approximately what year it was constructed. If it is an older building, “1970” will do.

Oddities

Large decrepit or abandoned buildings defy an easy Occupancy assignment. For these, we suggest using “AGR1”. No permanent residents will be assigned to the building.

Buildings on piers: change the foundation type to ‘1’ and assign a generous first floor height. Typically, these buildings have their first-floor elevation well above the water line. In such cases, the first-floor height is the difference between the mean water line and the first-floor elevation.

We generally assigned “COM2” to large commercial shipping facilities – areas where goods are offloaded, stored, then moved onto trucks for distribution. These structures are very common in many Puget Sound ports.

Careful with the ‘GOV2’ assignment – this should be limited to facilities staffed 24/7, such as police/fire stations.

Workflow:

Save early, save often.

We suggest printing a paper map of the larger area, gridding it out, and systematically examining each grid cell, marking each cell off as you go, to not get lost or re-do an area. Given a focus on buildings within the tsunami evacuation zone, the map should include a representation of the tsunami inundation zone. Depending on the map scale, UDF points could also be included.

UDF Dataset Attributes: Simple Updates

The following assumes reasonable effort has been given to address the original UDF database deficiencies, described previously. Tsunami-specific updates that are not needed for an earthquake-only model are called out.

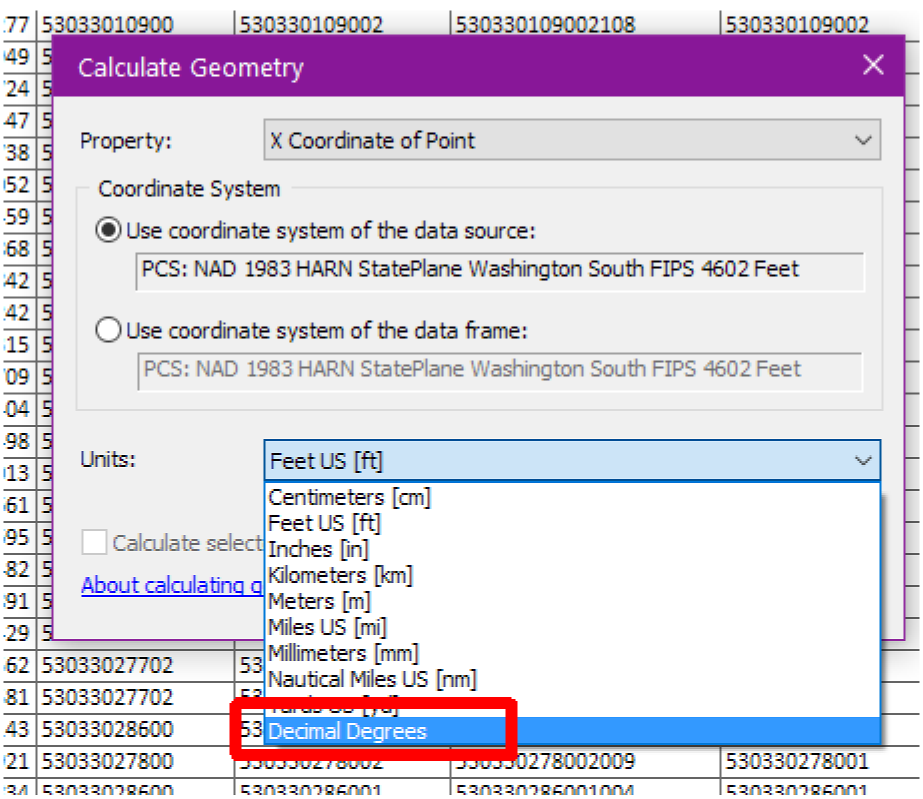
General Overlay/Simple Field Calculator Assignments

`CensusBlock, CensusTract, CBG` (Census Block Group): Hazus requires a CensusTract for earthquake and tsunami analysis, and as of Hazus 5.1, requires this to be the Census 2010 designation. Using the supplied Census 2010 geometry files, do the appropriate overlay, and update as needed.

`CBG_2020, CB_2020`: If 2020 census population numbers are desired (and they were for the tsunami casualty modeling purposes), use the geometries supplied with this release (feature class `CBG_2020_Pop_and_Housing_All`) to update these fields. For Hazus 5.1 there is no need to supply a Census 2020 tract.

`WAT`: Wave arrival time is only used for tsunami casualty modeling. Use the supplied `Wave_Arrival_Time` feature class as an overlay to assign WAT to all UDFs in the tsunami evacuation zone.

`Latitude, Longitude`: Update all records using the "Calculate Geometry". Specify Decimal Degrees:



`eqUdsClass`: Hazus requires this be assigned; unclear how it uses it. Assign all records with "UDFLT"

`CountyName`: Associate the COUNTYFIPS with an appropriate county table and assign all records with their correct counties. Do not include a "County" suffix. Field is used to easily summarize results at county level.

NEHRP: If you wish, this can be supplied, but it is ignored by the Hazus earthquake model when using a Shakemap scenario that has already factored in the site amplification. For completeness, and use in other earthquake situations, this should be populated but **is not needed** for the CSZ 2020 earthquake/tsunami analysis.

`LqfSusCat` (Liquefaction Susceptibility): Using the statewide liquefaction layer from WGS, do an overlay analysis and update all records with a value between 1 and 5. Data source:

https://www.dnr.wa.gov/publications/ger_portal_ground_response.zip

`LndSusCat` **(**Landslide Susceptibility): Initially, assign all records a value of 1 (low). Then using the "landslide deposit and fans" layers in the "post-2017 landslide inventory" from the WGS portal (also available as a service), assign a value of 10 to all UDF points that intersect a landslide fan **or** a landslide deposit. In practice, the number of UDF records that intersect fans/deposits are relatively few (less than 5%).

We also used the Landslide Compilation dataset and used the 24K polygons. In the end, relatively few UDFs have a high landslide susceptibility.

UF Attributes Requiring Custom Calculations

UserDefinedFltyId

Needs to be a unique identifier in Hazus. We attempted to retain the original ID that came from the FEMA compilation, even if we moved the point and/or updated some of its key Hazus attributes. However, for all points that were added and do not have an ID, the field needs to be updated with a legitimate, unique identifier. Select for such records, then using Field Calculation with Python, use the following expression:

```
"xx" + str(!OBJECTID!).zfill(6)
```

eqDL (Seismic Design Level)

We parsed Table 3 in the February 9, 2017 memo from Degenkolb[1] to develop conservative assignments for Hazus seismic design level, based on the Year of Construction. Note we do **not** include eastern Washington. Note, however, somewhat controversially, the memo identifies all W1 structures prior to 1976 to be classified as LC.

Puget Sound:

- Pre: < 1976
- Low: 1976-1977
- Moderate: 1978 – 1998
- High: > 1998

For “Puget Sound Region”, here is a Python field calculator expression that can be used that implements the above:

```
def eqdl_assign(yb, eqbt):
        if eqbt == 'W1':
                dl = "LC" if yb < 1976 else "LC" if yb < 1978 else "MC" if yb < 1999 else "HC"
        else:
                dl = "PC" if yb < 1976 else "LC" if yb < 1978 else "MC" if yb < 1999 else "HC"
        return dl

eqdl_assign(!YearBuilt!,!eqBT!)
```

Refer to the memo’s Figure 1 for an estimate of what constitutes “Puget Sound”, “Extended Puget Sound”, and “Coastal WA”. See notes below – Clallam must be done in parts:

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[1] Ash, C., Fisher, E., Goettel, K., 2017, Washington State Building Code History. Degenkolb Job Number B6616005.00, 23 p.

Extended Puget Sound (includes central portion of Clallam County, west of the Elwah Reservation, east of Clallam Bay):

- `Pre: < 1978`
- `Low: 1978– 1989`
- `Moderate: 1990 - 1998`
- `High: > 1998`

```
def eqdl_assign(yb, eqbt):
       if eqbt == 'W1':
              dl = "LC" if yb < 1978 else "LC" if yb < 1990 else "MC" if yb < 1999 else "HC"
       else:
              dl = "PC" if yb < 1978 else "LC" if yb < 1990 else "MC" if yb < 1999 else "HC"

       return dl
```

Coastal WA (Includes Clallam Bay and points to the west, including Wahkiakum Co):

- `Pre: < 1978`
- `Low: 1978– 1995`
- `Moderate: 1996 – 1998`
- `High: > 1998`

```
def eqdl_assign(yb, eqbt):
       if eqbt == 'W1':
              dl = "LC" if yb < 1978 else "LC" if yb < 1996 else "MC" if yb < 1999 else "HC"
       else:
              dl = "PC" if yb < 1978 else "LC" if yb < 1996 else "MC" if yb < 1999 else "HC"
       return dl
```

`eqAebmId [Only if you are pursuing an AEBM analysis!)`

Once the seismic design levels have been assigned, then update the `eqAebmId` field – if you are going to do an AEBM analysis. Note this uses the "relaxed betas", which should be used for earthquake scenarios.

```
eqAebmId = [Occupancy] & [eqBT] & [eqDL] & "-1"
```

Standardized Cost Basis

Assuming the square footage of all buildings in the UDF dataset are fully populated, the 2021 US $ replacement cost of a building is calculated as follows.

Use a temporary text variable. Select all “RES1” buildings. Field Calculator the temporary text variable:

```
"RES1_2_"   & [NumStories]
```

Join the UDF table with this table, using the temporary variable and Key1 for keys. Verify the join.

```
Eq-Tsu Support.gdb\LUT_hzReplacementCost_RES1
```

Field calculator:

```
Cost = [Area] * LUT_hzReplacementCost_RES1.[AverageCost] * 1.17
```

Unjoin. Reverse the selection. Join the UDF file with

```
Eq-Tsu Support.gdb\LUT_hzReplacementCost_nonRES1
```

using [Occupancy] for the key. Verify the join. Field calculator:

```
Cost = [Area]* LUT_hzReplacementCost_nonRES1.[MeansCost] * 1.17
```

Unjoin.

[Note that the above does not factor in the per-county RSMeans ***cost adjustment factor****. If such refinement is needed (and we did as much for the tsunami buildings; variations are from 0.98 (Wahkiakum) to 1.06 (Island, Snohomish, Skagit, Whatcom). Consult the author if this is of interest.]*

[Lookup tables are a direct export of two SQL tables: Hazus SQL tables [dbo].[hzRes1ReplCost] for single-family residential; [dbo].[hzReplacementCost] for all other occupancy types.]

`ContentCost`

Per Hazus methods, `ContentCost` is proportional to the building replacement cost, and dependent on occupancy class. The following Python field calculator macro uses the standard Hazus multipliers. Use this to update the `ContentCost` field:

```
def ccost(OC,cost):

        Content_x_0p5 = ['RES1','RES2','RES3A','RES3B','RES3C','RES3D','RES3E','RES3F','RES4','RES5','RES6','COM10']

        Content_x_1p0 = ['COM1','COM2','COM3','COM4','COM5','COM8','COM9','IND6','AGR1','REL1','GOV1','EDU1']

        Content_x_1p5 = ['COM6','COM7','IND1','IND2','IND3','IND4','IND5','GOV2','EDU2']

        CMult = 0.5 if OC in Content_x_0p5 else 1.0 if OC in Content_x_1p0 else 1.5 if OC in Content_x_1p5 else 0

        bc = int(CMult*cost)

        return bc

ccost(!Occupancy!,!Cost!)
```

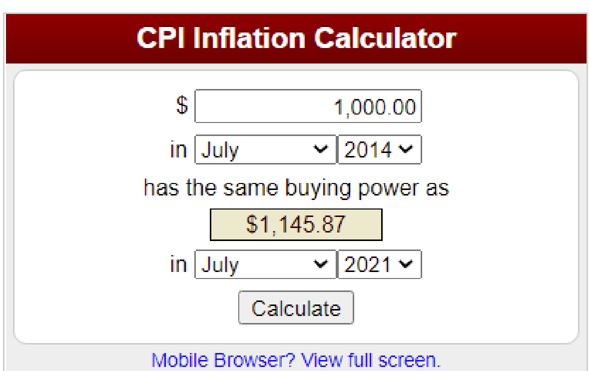
For this project, we did not report on business inventory, lost wages, rental income, or other economic factors. Standard Hazus UDF does not report on these. And the Hazus assumptions about recovery times for a major tsunami are recognized to be super-optimistic.

Construction cost index Background

https://www.enr.com/economics/historical_indices/construction_cost_index_history

2014 vs 2021 average: 11465/9806 = 1.17x

Consumer price index, https://www.bls.gov/data/inflation_calculator.htm



The choice of 1.17x was deemed reasonable, considering ongoing post-COVID cost adjustments.

Population Modeling

First, we populate three needed table attributes before running Python scripts which then populate the permanent and temporary resident fields. These table attributes are also handy for reference purposes.

Note that the Tsunami Casualty spreadsheet auto-populates the BOAT RV CAMP and RES4 (hotel/motel) facilities.

`CB_SRate`

[For tsunami casualty modeling purposes]

This is the US Census 2020 census **block** seasonal (actually, the vacant) housing rate. It is used by a script when calculating temporary population per vacation rental (discussed below).

Join the UDF with the `CensusBlock_2020_Pop_and_Housing_All` feature class, using `[CB_2020]` attribute. Assign `[CB_SRate]` with the table's `[VacantRatio]` attribute. Unjoin.

Query `[CB_SRate]` for -99 values. Reassign those to 0, using Field Calculator. These are infrequent, but do occur. The -99 values are for census blocks with no presumed housing units at all. Again, the situation occurs because of the at-times-imprecise geometries of the census block relative to the actual buildings. The number of non-RES4 residential buildings with -99 values should be minimal - but they do occur. That is the joy of working with census block geometries. For our assumption purposes, assign [CB_SRate] = -99 to 0. Once done, make [CB_SRate] into a fraction and divide it by 100.

PRPHU: Permanent Residents Per Housing Unit

[For tsunami casualty modeling purposes]

Join the UDF with the CBG_2020_Pop_And_Housing_All.

Assign PRPHU = [PeoplePerUnit]

Unjoin

[Note that this calculated average number of people per household for the census block group. We are applying peanut butter to all housing units. The reason it is done at the CBG and not the census block is that often the geometries of the census blocks are at odds with the actual building footprints, resulting in many populated census blocks with no UDFs, or absurd people per household values. Usage of the CBG smooths out these variations.]

O65Frac: Fraction of population 65 and older

[For tsunami casualty modeling purposes]

Join the UDF and the `CBG_2010_ACS2019_Age65Plus_Ratio` feature class/table using the `[CBG]` and `[GEOID10]` as keys. Note this is the ACS 2015-2019 which uses the 2010 geometries.

Assign [O65Frac] = [Age65Plus_Pct_Adj] (Note this is the age-adjusted ratio requested by WAEMD, where 20% of the under 65 were moved to the 65+ category to better model population with infirmities that limit their evacuation walking speeds).

Unjoin.

[The dataset was assembled in Excel by first downloading ACS table B01001 (Sex by Age) for ACS years 2015-2019, for all of Washington Census Block Groups. The numerous individual demographic attributes were then summarized into two fields: Under 65 and 65 and over. A simple ratio calculation was then made. The table was then joined to Census 2010 CBG geometries.]

Permanent Population Assignment (includes `N_Units` assignment)

Run the script `Population Assignment – Permanent Resident.py` that is in the scripts folder. Make the appropriate pointer changes to the right UDF file. Note how it uses the PRPHU and O65Frac values assigned above to assign a permanent population.

Note the assumptions for a square-foot-per-housing-unit for multi-family residentials (excepting the duplex type). The breakpoints are based on the information in Figure 2-2, DOGAMI Open-file Report O-20-10.

Temporary Population and Employee Assignment

> *[The following is applicable only for a "2 AM" Hazus tsunami casualty modeling exercise. If a daytime occupancy numbers are desired, consult the guidelines in Hazus Technical manuals which provides recommendations for daytime occupancy - Table 12.2 in the Hazus Earthquake Technical Manual October 2020 edition.]*

Based input from coastal community planners, our summertime temporary population estimates account for maximum occupancies of vacation rental properties. Often, local ordinances limit occupancy to two people per bedroom. Thus, for modeling single-family residential vacation rentals, it is necessary to calculate the number of bedrooms. Many county assessor databases have this information; however, given the tool chains and development history, the Bedroom count is not available in the FEMA-compiled UDF/AEBM library.

Our method also accounts for employees occupying non-residential buildings at 2:00 AM, following the guidance in the Hazus technical manuals. The assignment is based on occupancy and square footage. For example, an Emergency Operations Center ("GOV2") building has one employee for every 300 square feet (see Table 3.14 in the FEMA 2017 Hazus Tsunami Technical Guidance document).

For assigning temporary population to single-family residential buildings, we assume no bedroom information is available. The following field calculator uses assumptions specified in Figure 2-2, DOGAMI Open-file Report O-20-10 Note that Figure 2-2 in that report also specifies the Age < 65 ratio.

Recall `CB_SRate` attribute was previously populated (see above). Do a quality check, make sure CB_SRate is a fractional value between 0.0 and 1.0.

Open the supplied python script

`Population Assignment – Temporary and Employee.py`

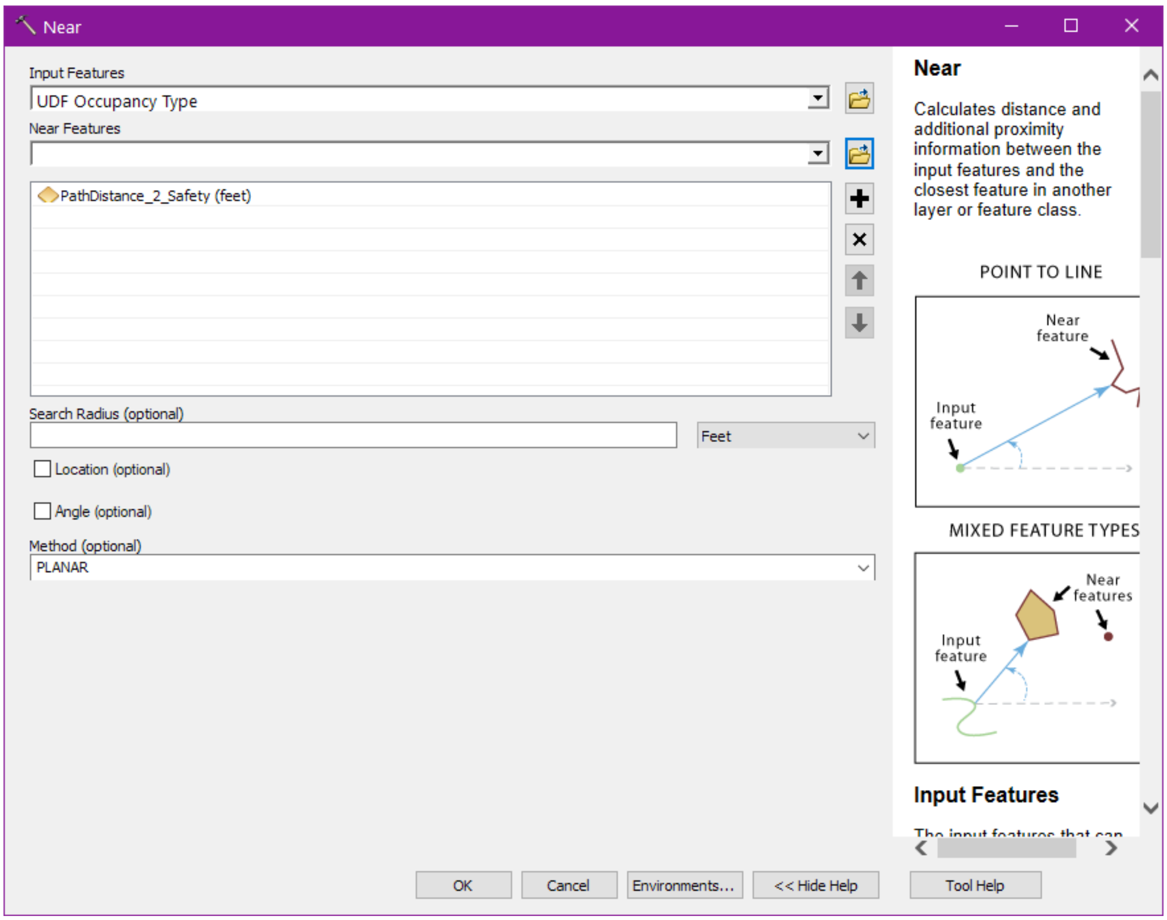
in a text editor, change the `UDFFile` pointer to point to the desired UDF file you want to process. Copy the entire contents of the script and paste it into an ArcMap python window, then hit [Return]. The following fields should now be populated:

- `TempRes` (total number of temporary residents at 2 AM, summertime, in the building)
- `TR_U65` (total number of temporary residents at 2 AM, summertime, in the building under 65 years of age)
- `TR_O65` (total number of temporary residents at 2 AM, summertime, in the building 65 years of age and older)
- `EMPE` (number of employees at 2 AM)

Path Distance to Safety, Path Distance to Partial Safety (PD_PS, PD_S)
[Applicable only for tsunami casualty modeling]

From the USGS Pedestrian Evacuation Analyst Tool (PEAT) output (discussed below), we assign the PD_PS and PS_S values. Note the feature classes `PathDistance_2_Safety_ft` `PathDistance_2_PartialSafety_ft` are in the accompanying file geodatabase.

Use the Near function (this requires an ArcGIS Advanced License) to assign `PD_S, PD_PS` per building in the tsunami evacuation zone. No other options are needed. Note that the Data Frame should be in a Projected Coordinate System with foot units for the following calculations to work properly.



Join the UDF with the path distance to safety feature class, using the NEAR_FID and the OBJECTID. Then assign PD_S as follows:

```
[UDF_File.NEAR_DIST] + [PathDistance_2_Safety_ft.gridcode]
```

[Note the units for the NEAR_DIST is based on the data frame's projection; hence the advice to make sure the data frame's units are feet. The NEAR_DIST accounts for the distance from the building to the evacuation network. Generally it is a small refinement to the overall distance to safety.]

Unjoin. Repeat using the `PathDistance_2_PartialSafety_ft` class to calculate `PD_PS`. Unjoin.

Next, a quality check. Due to some geoprocessing reasons in the PEAT and slight shifts between the two path distance files, occasionally the path distance to partial safety exceeds path distance to safety. Manual inspection usually indicates that there is not a problem, that the 50-foot difference is due to rounding errors. None the less, the Hazus tsunami casualty model requires `PD_PS` to be less than or equal to `PD_S`. Query the UDF for such cases, and for those records where this occurs, assign the `PD_S` value to the `PD_PS` value.

Evacuation Constrained Areas

These areas are hand-rendered polygons based on interpretation of the road network and the depth grids. If there is no viable means for occupants of the area to evacuate, then they are assumed to be a tsunami casualty, as there is no route to tsunami safety. Overlay the Evacuation_Constrained_Areas layer with the UDF file. Assign the PD_PartialSafety and PD_SSafety values in the Evacuation_Constrained_Areas to the UDF PD_PS and PD_S for the affected UDF records. Note how PD_Safety is always 10,000,000. This is one way to force the Hazus tsunami spreadsheet to bin the people into injury or fatality. The PD_PartialSafety, if 10,000,000 means all are in at least 6+ feet of water. If zero, they are in less than 6 feet of water, and the 50% injury/50% fatality modeling assumption will then apply.

UDF Attribution: Quality Checks

CDMS is slow. CDMS will take its time rejecting a file with even just one error – including an extra space, say, in Occupancy string. Time spent on the following prior to CDMS import is worth the effort. Many of these are to ensure smooth CDMS import; some are simple overall quality checks.

`UserDefinedFltyId`:

- Verify they are unique (Summary statistics can be of assistance here)
- Verify all are 8-characters and conform to Hazus standards (last 6 characters must be digits)

`Occupancy`:

- One of 36 predefined types. No spaces!
- COM10: check that these are not surface parking lots, but actual parking garages
- GOV2: Verify these are indeed EOCs, fire or police stations, guard stations, etc.

`Area`:

- Query `Occupancy like "RES1" and (area < 400 or area > 8000)` While not impossible, these should be pretty rare. It's likely the RES1 may be some other occupancy type**.**
- Query `Occupancy like "RES2" and (area < 400 or area > 4000` Such structures are uncommon. It would suggest a database problem. Note, however, that occasionally a large mobile home park is sometimes abstracted as a single UDF point that has the total park's square footage. While not ideal, it is an acceptable way to model the potential damage for earthquake. (Not for tsunami, however, as tsunami grids vary significantly across a large taxlot).

`NumStories`:

- For RES2, always 1.
- For RES1, between 1 and 3 (this is for RSMeans table lookup reasons). If a "RES1" has 4 or more stories, there may be an incorrect Occupancy assignment, or it could be real – a very large house. Reassign such cases to 3 stories.

`FoundationType`:

- A string value between 1 and 7. No spaces!

`Building Type`:

- Must be one of 33 predefined types. No spaces!
- For building types with a L/M/H suffix, verify L is for 1-3 stories, M for 4 to 7, H for 8 or more.
- All RES2 must be 'MH'
- Wood buildings: query for W1 and Area > 5000. Change those to W2. Likewise, query for W2 and Area < 5000. Change those to W1.
- Area: Query for buildings less than 200 square feet. Are they value-added; are they mistakenly attributed; should they be deleted?

`YearBuilt`:

- Sanity check – look at the range. All records should specify this between 1850 and 2021. CDMS will reject ‘0’ and other absurd values.

Seismic Design Level (`eqDL`):

- Verify all records are assigned to one of the following: PC, LC, MC, HC (special seismic design codes also allowed; we have no cases for those to date.) No spaces!

Liquefaction and Landslide Susceptibility:

- Verify Liquefaction is between 0 and 5 (0 is allowed) and Landslide is between 0 and 10.

If the above quality checks identify any problems, you may need to recalculate `Cost`, `ContentCost`, etc.

The UDF dataset should now be ready for importing into CDMS and into the Hazus tsunami casualty spreadsheet.

Non-building Lodging Data Development

To capture the large numbers of temporary visitors that may occupy the tsunami evacuation zone, we constructed a point file UDF-style feature class that represents recreational boat slips, camp sites, and RV sites. As with the building database, we assign a distance to safety and partial safety to each point. The dataset is then exported out for use in the Hazus tsunami casualty spreadsheet. "Occupancy" types are one of three types:

- BOAT
- RV
- CAMP

What this dataset does **not** capture:

- Merchant marines on commercial vessels
- Off-shore moorings
- People on ferries or cruise ships
- Individual docks or small docks with less than 5 boats

Individual camp sites and boat slips are typically not modeled as individual points, but rather a single point, one which is then attributed with a `N_Units` integer field that describes the total number of slips that point is representing. The placement of the point is intended to capture an overall ***mean*** distance to tsunami safety for all non-building entities represented by that point.

```
NonBldg_Lodging
```

Google map queries were made for campgrounds and RV parks on a per-county basis. In addition, during the manual adjustment of UDF points in the tsunami zone, we kept an eye out for such facilities. Internet queries were made for the number of sites; if provided, we used that for the `N_Units` field; otherwise, a rough count was made based on the aerial imagery.

Marinas were systematically queried using sites such as "marinas.com" and simple observations using aerial photography. Web queries on the individual marinas were made to obtain a boat slip estimate. If not provided, a rough count of the boat slips was made and assigned to `N_Units`.

Wave arrival time, Distance to safety, Distance to partial safety, and County name (`WAT, PD_S, PD_PS, County`) were assigned in a geoprocessing manner similar to the UDF point assignment (see previous section).

The `UDFID` is similar to UserDefinedFltyID, and provides a unique identifier, should one want to link the spreadsheet results back into a GIS. Python field calculator:

```
"NonB" + str(!OBJECTID!).zfill(4)
```

[Because the non-Building lodging is not run in Hazus, nor is it imported into CDMS, the UDFID need not conform to Hazus/CDMS standards.]

Quality checks:

- `Occ` must be one of BOAT, RV. CAMP
- `N_Units` must be >= 0. It can be zero, if the purpose is to say "I looked here and it should not be modeled" (e.g., offshore mooring)

- Distance to partial safety (`PD_PS`) must always be less than or equal to Distance to Safety (`PD_S`) (similar to the UDF assignment).

Development of Tsunami Evacuation Zone Datasets

For the USGS PEAT to properly calculate a distance-to-safety, the boundary of the tsunami extent (and "partial safety zone" must be developed. One can, by default, use a polygon version of the tsunami depth raster data, but in discussions with others, the potential noisiness of that data and its propensity to create false "safe havens" need to be filtered out. Herein we discuss how the false "safe havens" can get filtered and also how we chose to add in extra conservatism in certain situations and thereby define a "tsunami evacuation zone" that may be more extensive than the simple "tsunami zone" itself.

We must emphasize that what is delivered for this project does not represent an official evacuation network or an official tsunami evacuation zone. It was developed for a statewide tsunami loss estimate study. Local emergency managers may make other route designations, including assumptions about potential bridge failures or other hazards that impede timely evacuation. The evacuation assumptions made below are not intended to circumvent local emergency management planning.

The "false safe haven" problem can be illustrated at Priest Point, just north of Everett, on the banks of the Puget Sound and a Snohomish River outlet (shown in the following figure). Some homes are inundated; others are not. Considering the uncertainties in the tsunami modeling itself, a conservative approach is to evacuate entire neighborhoods.

Priest Point (Snohomish County). Tsunami depth grid in light shade of blue; street (evacuation) network shown in red. Modeled conservative tsunami evacuation zone shown as a green outline.

In the case of La Conner (Skagit County), a large hill resides at the south end of the town. While this hill will likely be surrounded by water at maximum tsunami inundation, its elevation and size are such that this is a reasonable tsunami evacuation location, and that the residents of La Conner may only need to evacuate to this hill and not two miles east.

La Conner (Skagit County), showing road network in red, maximum tsunami inundation (shaded blue), and modeled evacuation zone (green outline).

In the Steamboat Island case (Thurston County), residents will likely be cut off from the mainland, due to the potential destruction of the access road itself and potential bridge failure. (Private boats are likely heavily impacted due to the tsunami, limiting their usage). While the island may be high enough to withstand a tsunami, this potentially isolated population may need food, water, and aid and may be without power. Therefore, we assumed the island should be vacated, and thus the tsunami evacuation zone was manually edited to reflect that.

Steamboat Island, Thurston County. Road network is red. Potential bridge failure is represented by the red dot. Tsunami depth grid in shades of blue. Conservative tsunami evacuation zone boundary shown in green.

One of the more challenging situations, using this approach, is the case of the Semiahmoo spit (Whatcom County). Should it be evacuated, or is the center of the island sufficient for a designated evacuation area? Will the residents be cut off due to washout, exacerbating delivery of food and water? For this modeling exercise, we assumed the sand island should be fully evacuated. Again, please see the above qualifier.

Semiahmoo Spit, Whatcom County, showing road network, tsunami depth grid (shades of blue) and modeled tsunami evacuation zone boundary (green)

To minimize the numerous false "safe haven" islands, we took a polygon version of the tsunami raster dataset, changed all values to 1 (integer), converted the integer raster to a polygon, clipped to a county boundary, buffered the county polygon dataset by 100 meters, dissolved the polygon dataset, then did a minus buffer of 100 meters. This has the geoprocessing effect of removing many small islands and slivers. While usually satisfactory, occasionally it produces some oddities. We optically scanned the boundary and resolved any discrepancies, and applied the above conservative guidelines where conditions warranted. The `HazardBoundary` shapefiles are available per-county, and in the PEAT_Input folder

In a similar manner, we developed a Fatality Boundary that is required by Hazus tsunami casualty model. We took the Hazus depth grid, multiplied by 0.666 to obtain a "median depth", then reclassified all points greater than 2 meters to 1 (integer), and reclassified all others as <null>, converted the raster to a polygon, and applied a +/- 100 meter buffer as described above to remove many of the islands. The per-county `FatalityBoundary` shapefiles per county are in the same PEAT_Input as the `HazardBoundary` shapefiles.

Development of Evacuation Road Network

Key to modeling distance-to-safety is an evacuation network wherein occupants of buildings and non-building lodging can proceed to tsunami safety.

This study does not represent an official evacuation network or an official tsunami evacuation zone. It was developed for a statewide tsunami loss estimate study.

Local emergency managers may make other route designations, including assumptions about potential bridge failures or other hazards that impede timely evacuation. The evacuation assumptions made below are not intended to circumvent local emergency management planning.

Depending on the county, we used as a starting point the Open Street Map (OSM) transportation data or the coarser road network available via Washington Department of Natural Resources. Roads were clipped using a 500-meter buffer of the tsunami zone. For Hazus modeling purposes, one only needs to have a route extending from the tsunami evacuation zone into the tsunami safety zone. It is important for the road to continue into the tsunami safety zone, otherwise the PEAT will not calculate the distance to safety correctly.

Next, the Washington Regional Resilience Assessment Program (RRAP) bridge datasets (both state and local bridges) were overlain on top of the clipped road network. Road networks that crossed a bridge with estimated Moderate, Significant, or Special damage from a CSZ earthquake were, for conservative reasons, assumed impassable. The road network was manually edited to disconnect the potential escape route.

Such an analysis can identify areas where it is impossible to leave via a hardened surface. For this analysis, we designed such areas as “Evacuation Constrained Areas”. These are hand-rendered polygons and are contained in the feature class `Evacuation_Constrained_Areas`. Often these are estuarine islands in agricultural use where likely no one will be at 2:00 AM. This situation does occur for some residential buildings. The `Evacuation_Constrained_Areas` was used to manually assign very large distance to safety numbers, so that the Hazus tsunami casualty model captured the potential situation.

For importing into PEAT, the road network must be in shapefile format. The format requirements can be challenging; no particular attribute was needed, but it seemed that the most successful approach (in terms of having Hazus properly digest the network) is to use the WGS_1984_UTM_Zone_10N projection.

Depending on the original source of the data, the road network for a given county may have minimal attributes or many attributes (the latter is the case when OpenStreetMap data were used as the starting point). Only one attribute is used by the USGS PEAT tool: [SCV], abbreviation for “Speed Conservation Value”. The USGS PEAT tool will apply the appropriate adjustment to the path distance, depending on the surface. For this study we confined evacuation to existing routes, making the rational assumption that people do not walk in a straight line through forests thick with underbrush or suburban yards with numerous fences, but limit their evacuation to roads and trails. More than 99% of these routes are assumed to be hardened (paved or not), with no speed adjustment needed.

The road network has only two assignments for SCV:

- 1: Hardened Surface. No SCV adjustment is to be made in PEAT. SCV assignment in PEAT is 1.0
- 2: Route is on a beach or other areas where evacuation will be impeded. In PEAT, the SCV=2 should be mapped to 0.5556. An example is the beach accessing the lighthouse on Dungeness Spit (Clallam Co).

Development of a Wave Arrival Time Polygon Overlay

Wave arrival time at the tsunami runup line is assigned on a per-building basis using a polygon overlay. This overlay was created from a wave arrival time raster developed by WGS, and by interpretation of animation videos published by WGS in 2020. A generalized polygon dataset was developed for overlay purposes, one which captured the information in that raster file. Sometimes the information was interpretive, and values assigned were from a nearby simulated tide gauge or developed in consultation with WGS.

Wave arrival time at shoreline is not of interest for tsunami casualty modeling. The people in the tsunami evacuation zone must arrive at or beyond the tsunami runup line prior to the wave arriving at that runup line.

Subsidence can produce leading waves preceding the main tsunami waves; while these waves are generally not considered life-threatening, they are important to bring to general awareness. Given a brief interactive review of the potential extents of the antecedent subsidence-driven wave(s), we determined these quick-arriving waves generated from the near-instant local subsidence would not be a major threat to life and thus will not be modeled from a casualty perspective.

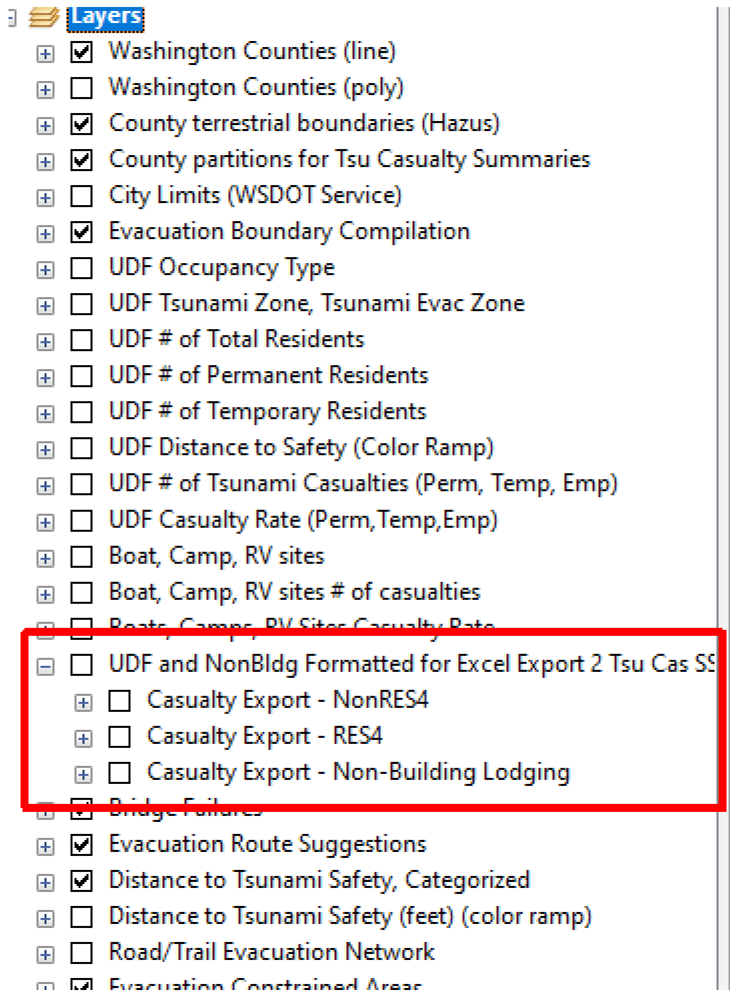
For purposes of life safety modeling, we assume the first tsunami wave would be the highest, even though it may not be the maximum wave. We understand that for messaging purposes, residents need to be told that a series of waves, some which exceed the previous, can happen, and that re-entering the tsunami zone prior to official clearance is to be avoided. This is a conservative modeling assumption.

For this statewide study, detailed “walk-sheds” or “evacuation-sheds” were generally not done in a rigorous manner; instead a conservative (i.e. lower) WAT was assigned even though the WAT may vary between tsunami safety arrival points. The peculiar situation at Long Beach peninsula, specifically in the Long Beach City area, required some interpretation of “evacuation-sheds”. This WAT polygon development effort was semi-quantitative and should not be considered authoritative for evacuation mapping purposes.

Exporting Data from UDF File for Use in Tsunami Casualty Spreadsheet

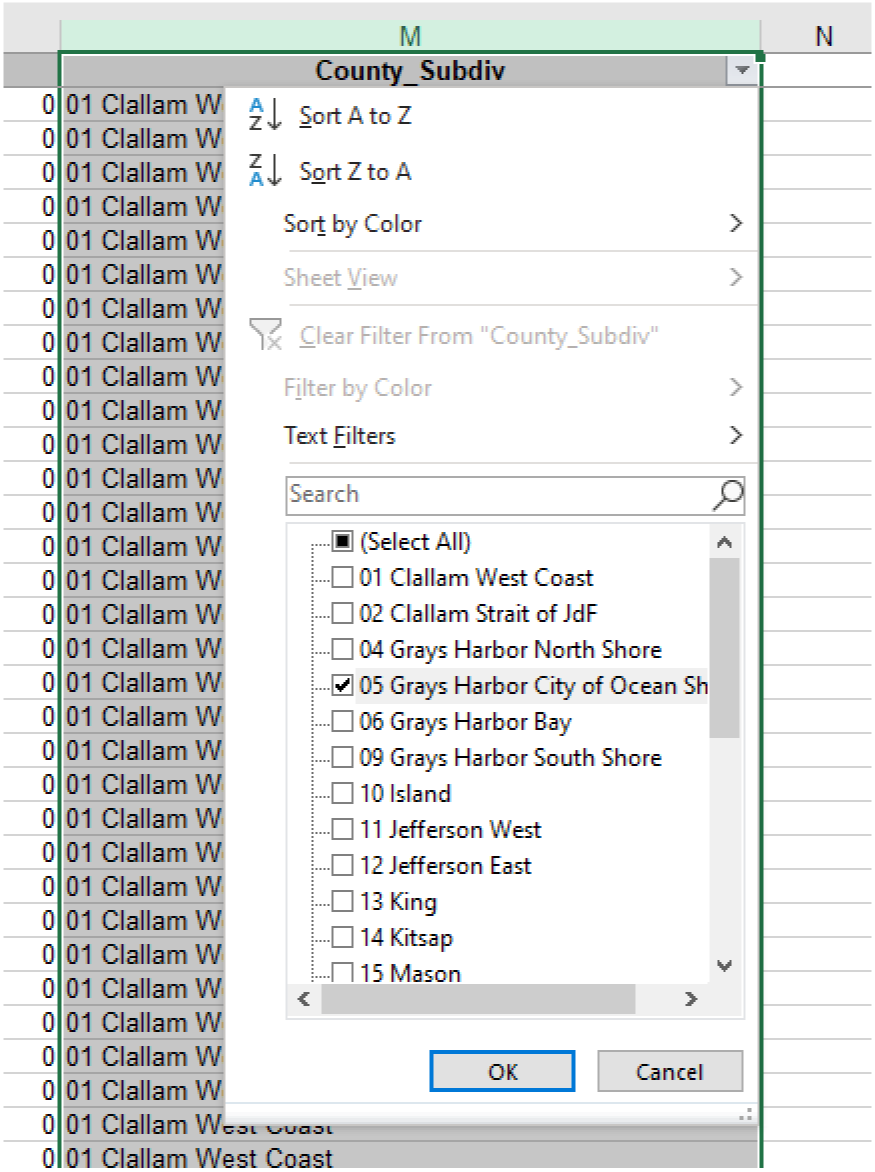
Currently, the process for populating the tsunami casualty spreadsheets is manual, with copy and paste actions required by the user.

Export to three separate Excel files these three layers:

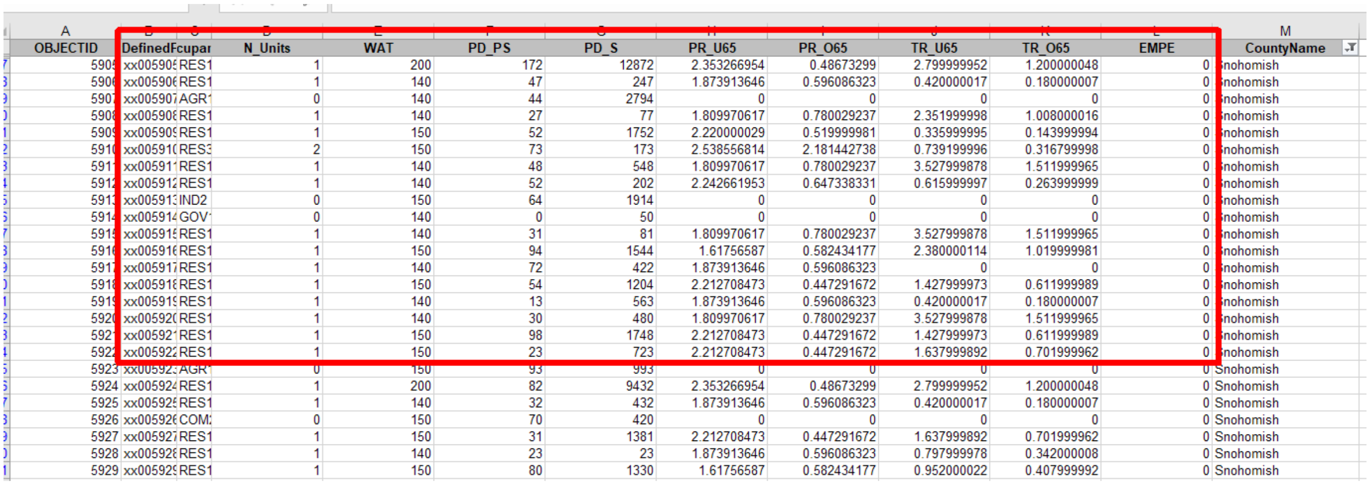


Open the exported files (one by one) in Excel, and open the Hazus Tsunami Casualty spreadsheet *for the particular county you want to update*. Start with `Casualty Export – NonRES4.xls` This information will populate the *Buildings* worksheet. In Excel, apply a filter to the `County_Subdiv` column, then select the county or county subunit you are working with:

Here, we are selecting Grays Harbor City of Ocean Shores:


M
N
County_Subdiv
Sort A to Z
Sort Z to A
Sort by Color
Sheet View
Clear Filter From "County_Subdiv"
Filter by Color
Text Filters
Search
(Select All)
01 Clallam West Coast
02 Clallam Strait of JdF
04 Grays Harbor North Shore
05 Grays Harbor City of Ocean Sh
06 Grays Harbor Bay
09 Grays Harbor South Shore
10 Island
11 Jefferson West
12 Jefferson East
13 King
14 Kitsap
15 Mason
OK
Cancel
01 Clallam West Coast

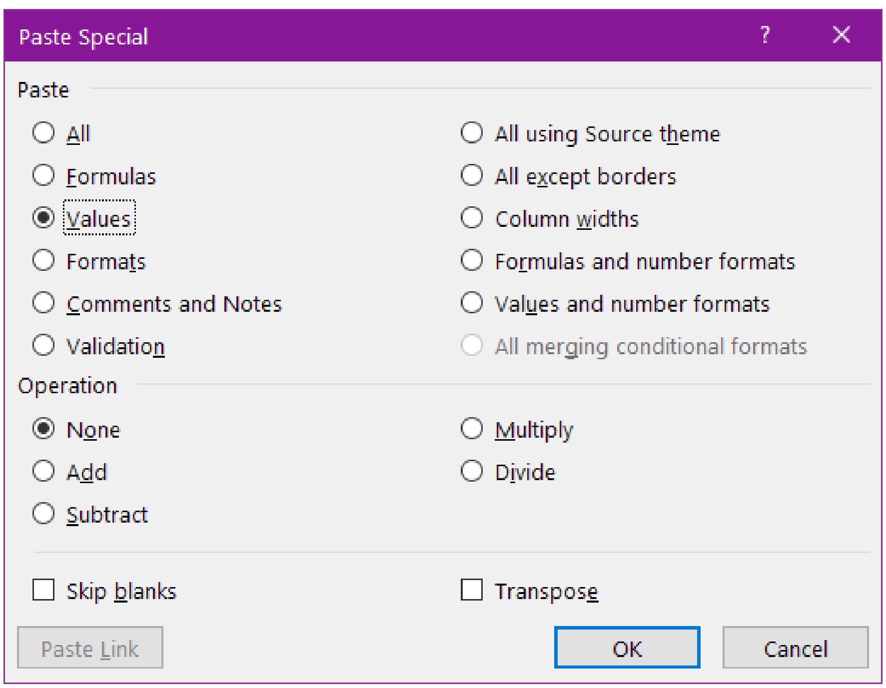
Copy all populated rows in these columns (the red box only captures a portion of the records):



OBJECTID	DefinedFcupar		N_Units	WAT	PD_PS	PD_S	PR_U65	PR_O65	TR_U65	TR_O65	EMPE	CountyName
5905	xx005905	RES1	1	200	172	12872	2.353266954	0.48673299	2.799999952	1.200000048	0	Snohomish
5906	xx005906	RES1	1	140	47	247	1.873913646	0.596086323	0.420000017	0.180000007	0	Snohomish
5907	xx005907	AGR1	0	140	44	2794	0	0	0	0	0	Snohomish
5908	xx005908	RES1	1	140	27	77	1.809970617	0.780029237	2.351999998	1.008000016	0	Snohomish
5909	xx005909	RES1	1	150	52	1752	2.220000029	0.519999981	0.335999995	0.143999994	0	Snohomish
5910	xx005910	RES3	2	150	73	173	2.538556814	2.181442738	0.739199996	0.316799998	0	Snohomish
5911	xx005911	RES1	1	140	48	548	1.809970617	0.780029237	3.527999878	1.511999965	0	Snohomish
5912	xx005912	RES1	1	140	52	202	2.242661953	0.647338331	0.615999997	0.263999999	0	Snohomish
5913	xx005913	IND2	0	150	64	1914	0	0	0	0	0	Snohomish
5914	xx005914	GOV1	0	140	0	50	0	0	0	0	0	Snohomish
5915	xx005915	RES1	1	140	31	81	1.809970617	0.780029237	3.527999878	1.511999965	0	Snohomish
5916	xx005916	RES1	1	150	94	1544	1.61756587	0.582434177	2.380000114	1.019999981	0	Snohomish
5917	xx005917	RES1	1	140	72	422	1.873913646	0.596086323	0	0	0	Snohomish
5918	xx005918	RES1	1	150	54	1204	2.212708473	0.447291672	1.427999973	0.611999989	0	Snohomish
5919	xx005919	RES1	1	140	13	563	1.873913646	0.596086323	0.420000017	0.180000007	0	Snohomish
5920	xx005920	RES1	1	140	30	480	1.809970617	0.780029237	3.527999878	1.511999965	0	Snohomish
5921	xx005921	RES1	1	150	98	1748	2.212708473	0.447291672	1.427999973	0.611999989	0	Snohomish
5922	xx005922	RES1	1	150	23	723	2.212708473	0.447291672	1.637999892	0.701999962	0	Snohomish
5923	xx005923	AGR1	0	150	93	993	0	0	0	0	0	Snohomish
5924	xx005924	RES1	1	200	82	9432	2.353266954	0.48673299	2.799999952	1.200000048	0	Snohomish
5925	xx005925	RES1	1	140	32	432	1.873913646	0.596086323	0.420000017	0.180000007	0	Snohomish
5926	xx005926	COM	0	150	70	420	0	0	0	0	0	Snohomish
5927	xx005927	RES1	1	150	31	1381	2.212708473	0.447291672	1.637999892	0.701999962	0	Snohomish
5928	xx005928	RES1	1	140	23	23	1.873913646	0.596086323	0.797999978	0.342000008	0	Snohomish
5929	xx005929	RES1	1	150	80	1330	1.61756587	0.582434177	0.952000022	0.407999992	0	Snohomish

Paste these columns into the Hazus tsunami casualty spreadsheet, worksheet *Buildings*, using Paste Special – Values (alt-e-s-v). They can go into cell B1. (The header can be restored from the *Header Reminder* worksheet)

The assumption here is that you have cleared whatever entries were already present in the Hazus tsunami casualty spreadsheet, or you are starting with a fresh spreadsheet.



xxcount	serDefinedFltyId	ccupancy	_Units	AT	D Partial Safety	D Safety	R_U65	R_O65	R_U65	R_O65	mployees	xx1	Pct_U65_GT_2M_Good	Pct_U65_in_TZone_Good	Pct_O65_GT_2M_Good	Pct_O65_in_TZone_Good	Perm_Fatal_U65_Good
1	MA000424	IND2	0	270	65	415	0.0	0.0	0.0	0.0	3.0		0.0%	0.0%	0.0%	0.0%	0.00
2	MA000630	RES2	1	270	761	761	2.2	0.6	0.0	0.0	0.0		0.0%	0.0%	0.0%	0.0%	0.00
3	MA000919	RES1	1	270	6	206	2.2	0.6	2.8	1.2	0.0		0.0%	0.0%	0.0%	0.0%	0.00
4	MA000960	RES1	1	270	158	158	2.2	0.6	0.8	0.3	0.0		0.0%	0.0%	0.0%	0.0%	0.00
5	MA000961	RES1	1	270	251	251	2.2	0.6	0.3	0.1	0.0		0.0%	0.0%	0.0%	0.0%	0.00
6	MA000965	RES1	1	270	190	190	2.2	0.6	0.8	0.3	0.0		0.0%	0.0%	0.0%	0.0%	0.00
7	MA000987	RES1	1	270	309	309	2.2	0.6	0.5	0.2	0.0		0.0%	0.0%	0.0%	0.0%	0.00
8	MA001091	RES1	1	270	0	0	2.2	0.6	0.6	0.2	0.0		0.0%	0.0%	0.0%	0.0%	0.00
9	MA001129	RES1	1	270	150	150	2.2	0.6	0.5	0.2	0.0		0.0%	0.0%	0.0%	0.0%	0.00
10	MA001912	RES1	1	210	731	1,731	1.5	0.6	2.2	0.9	0.0		0.0%	0.0%	0.0%	0.0%	0.00
11	MA001918	RES1	1	210	693	1,693	1.5	0.6	1.6	0.7	0.0		0.0%	0.0%	0.0%	0.0%	0.00
12	MA001962	RES1	1	210	632	1,632	1.5	0.6	1.1	0.5	0.0		0.0%	0.0%	0.0%	0.0%	0.00
13	MA001969	RES1	1	210	519	1,519	1.5	0.6	2.2	0.9	0.0		0.0%	0.0%	0.0%	0.0%	0.00

Next, take the two temporary lodging files (RES4 and the Non-building lodging), and do the same export to Excel, apply the County filter, and copy and paste into the `TempLodging` worksheet. Except here, you only populate the first six columns. The spreadsheet populates the permanent and temporary residents based on user-supplied settings. Again, copy all populated rows, and use Paste-special.

xxcount	UserDefinedFltyId	Occupancy	N_Units	WAT	PD Partial Safety	PD Safety	PR_U65	PR_O65	TR_U65	TR_O65	Employees
1	MA023817	RES4	3	160	57	57	0.0	0.0	3.1	2.0	0.0
2	MA025945	RES4	9	210	33	133	0.0	0.0	9.2	6.1	0.0
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	27.5	18.4	0.0
4	NonB0130	BOAT	68	220	600	650	6.8	6.8	61.2	61.2	0.0
5	NonB0173	RV	31	160	26	276	0.6	5.6	5.6	50.2	0.0
6	NonB0174	CAMP	2	180	125	225	0.1	0.0	5.3	0.6	0.0
7	NonB0175	BOAT	5	180	419	619	0.5	0.5	4.5	4.5	0.0
8	NonB0176	BOAT	7	180	311	361	0.7	0.7	6.3	6.3	0.0
9	NonB0177	RV	73	210	0	850	1.5	13.1	13.1	118.3	0.0
10	NonB0178	CAMP	70	210	7	1,007	1.9	0.2	187.1	20.8	0.0
11	NonB0179	RV	1	210	43	43	0.0	0.2	0.2	1.6	0.0
12	NonB0181	BOAT	14	220	701	851	1.4	1.4	12.6	12.6	0.0

Remember to do the copy and paste for **both** the RES4 (hotel/motel) and the Non-Building Lodging spreadsheets.

Preparing Tsunami Depth and Velocity Grids for Use in the Hazus Tsunami Model

Two continuous grids modeling tsunami maximum depth and maximum velocity grids for the entire state of Washington were provided for use in this project by WGS. These grids are compilations (mosaics) of several individual tsunami studies, each quantifying a Cascadia Subduction Zone (CSZ) Extended L1 M9.0 Tsunami. For details on the lineage of a particular study in a particular area, please consult with WGS.

Hazus Level 2 tsunami modeling accepts and expects units as Maximum. They may be expressed in meters or feet. The data provided by WGS is in meters.

Table 6-1 Hazus Tsunami Data Requirements

	Hazard Data Required	Input Data Files and Formats
Level 1	Runup Only - Mean Sea Level (MSL)	Maximum Runup height grid in raster format ---AND--- DEM raster (download option for USGS provided)
Level 1	Quick Look - Single Maximum Runup	DEM raster and single maximum runup value (MSL)
Level 2	Depth Above Ground Level (AGL) and Velocity	Maximum Depth grid and Velocity grid in raster format ---OR--- Maximum Depth and Velocity NetCDF NOAA SIFT (.nc) files
Level 3	Depth AGL (ft) and Momentum Flux (ft3 sec2)	Median Depth grid in raster format ---AND--- Median Momentum Flux grid in raster format

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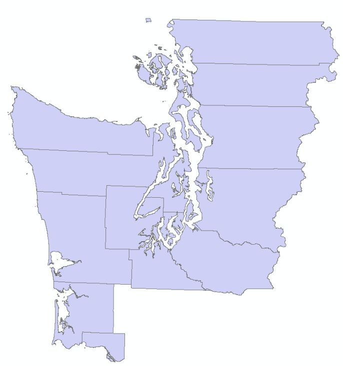
The Hazus tsunami module slows down considerably when working in any region larger than a county. Hence, all grids were extracted out to a particular county.

For an extraction layer, use a county boundary dataset for Washington State that is terrestrial-only. An example is shown here:



Buffer each county by 500 meters. Store the buffered county as a temporary feature class. In the PEAT folder, these are called the "StudyArea_*countyname*.shp"

Using Spatial Analyst, Extract by Mask two grids (one for depth, one for velocity) using the selected county (buffered version).

The county buffer removes lots of open water raster data provided by WGS that, while certainly important for maritime guidance and analysis, is not needed for evaluating impacts to terrestrial buildings – thereby saving processing time and file size.

There is no need to reproject or re-sample the raster data. The Hazus tsunami tool will do its own reprojections.

For convenience, we have supplied the Hazus-ready tsunami grids in the file geodatabase for all counties:

```
geodata\TsuGrids_by_County.gdb
```

Appendix A. Acronyms used in this report

AEBM	Advanced Engineering Building Module (Hazus)
CSZ	Cascadia Subduction Zone
Hazus	Hazards of the United States
HIFLD	Homeland Infrastructure Foundation-Level Data
OSM	Open Street Map
PEAT	USGS Pedestrian Evacuation Analysis Tool
PDS	Probability of Damage States
UDF	User-defined Facility (Hazus)
WA EMD	Washington Emergency Management Division
WGS	Washington Geological Survey