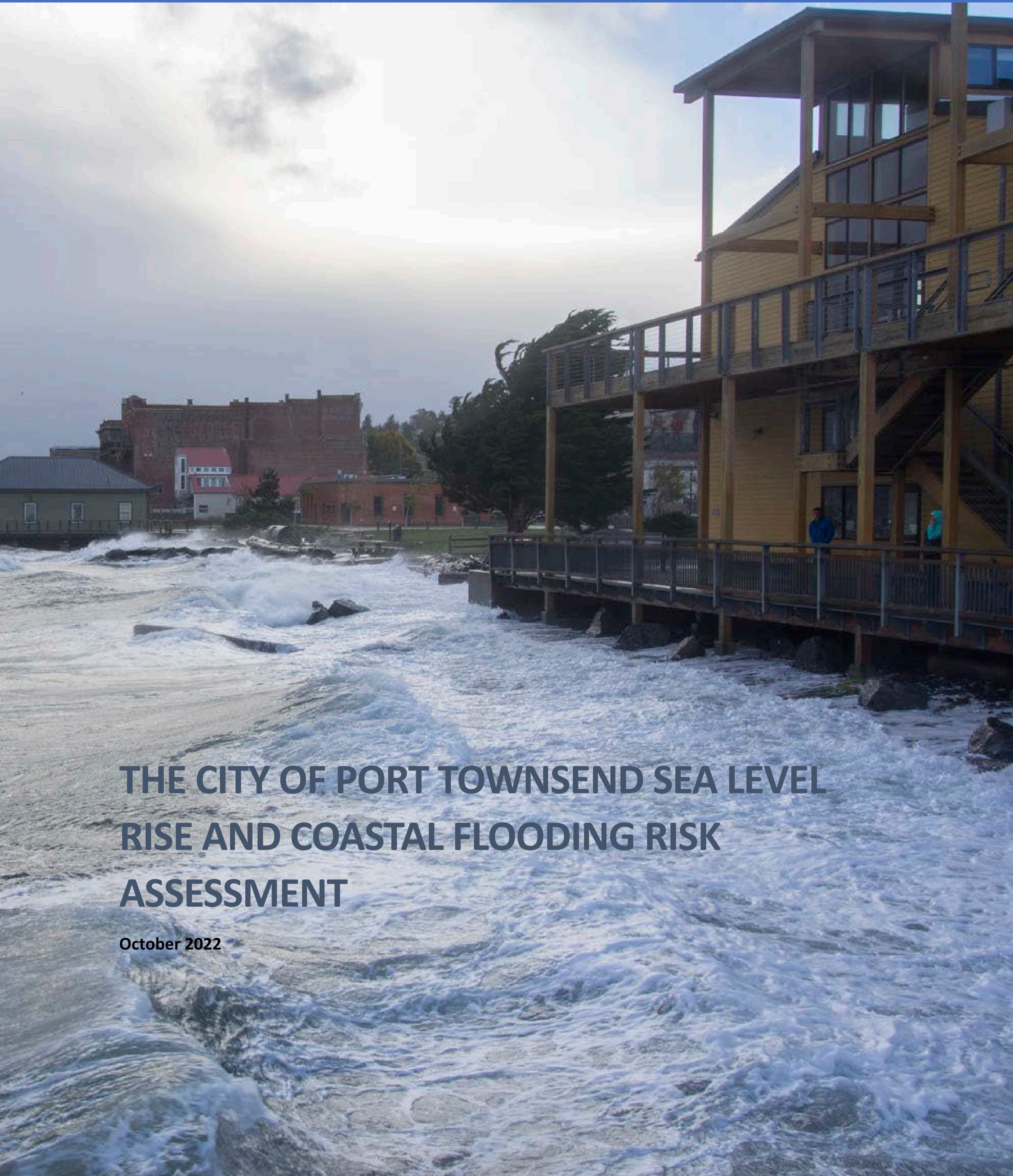

THE CITY OF PORT TOWNSEND SEA LEVEL RISE AND COASTAL FLOODING RISK ASSESSMENT

October 2022

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The City of Port Townsend thanks the North Olympic Peninsula Resource Conservation & Development Council for providing financial support for technical assistance.

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INTRODUCTION

Project Background

The North Olympic Peninsula Resource Conservation & Development Council (NODC) secured technical assistance funding to support four local jurisdictions across the North Olympic Peninsula to better prepare for the future impacts of climate change. Clallam County, the Jamestown S'Klallam Tribe, the City of Port Angeles, and the City of Port Townsend received funding for technical assistance to advance their climate resilience and mitigation planning. The City of Port Townsend used the support to identify asset risks from sea level rise and other coastal flooding impacts.

Figure 1. Map of the Olympic Peninsula in Washington State with location of Port Townsend.

The City of Port Townsend is the county seat of Jefferson County with a population of 10,148 (U.S. Census Bureau, 2021). Located on the Quimper Peninsula, the town is surrounded by water and many areas of the shoreline occur at low lying elevations and already experience coastal flooding from storm surge, wave run-up, and extreme high tides (**Figure 1**). This study examines sea level rise and coastal flooding risks to coastal assets in the City of Port Townsend, with the goals listed below.

- Model and map the extent of coastal flooding scenarios
- Analyze City of Port Townsend coastal asset exposure to coastal flooding
- Establish risk classifications to evaluate impacts of asset exposure to coastal flooding

Studies that share related goals are currently being conducted, such as the Jefferson County Sea Level Rise Study, which is currently underway in fall 2022. Both studies involve an analysis of sea level rise models and other scientific information, identification of areas exposed to future sea level rise, and an assessment of at-risk community assets and infrastructure. Additionally, the approach of the Port Townsend analysis was similar to the sea level rise matrix conducted as part of the City of Tacoma's Comprehensive Climate Adaptation Strategy.

FLOOD EXPOSURE AND MAPPING APPROACH

While much of the Port Townsend coast occurs along bluffs at high elevation many coastal areas of the city that are at much lower elevations are already susceptible to current coastal flooding. Rising sea levels due to climate change means that coastal inundation impacts will extend and intensify across many low-elevation areas of the City.

This study focuses on the impacts of coastal flooding that threaten city assets at low elevations. Mapping the relationship between assets and coastal inundation scenarios leads to a better understanding of the risks and vulnerabilities of key assets and resources to current and future exposure to coastal flooding, which will be exacerbated by sea level rise.

Coastal Flooding Probabilities and Projections

Coastal flooding probabilities and projections were developed using sea level rise projections and current coastal flooding impacts, such as storm surge, wave run-up, and 100-year floods. The subsequent sections discuss each impact.

Sea Level Rise Projections

The Washington Coastal Resilience Project (WRCP) developed community-scale sea level rise projections in 2018 across 171 locations along Washington's coastline based on global and regional sea level rise projections that account for vertical land movement (Miller et al. 2018). These projections are accompanied by an interactive website developed by the University of Washington's Climate Impacts Group that includes sea level rise data visualizations for each of the 171 locations. The sea level rise data is presented based on two global greenhouse gas emissions scenarios, a high emissions scenario and a low emissions scenario.[1] The analysis in this report uses sea level rise scenarios based on the RCP 8.5 scenario because it aligns with current the global emissions trajectory.

In addition to using different emissions scenarios, the 2018 sea level rise projections are based on probabilistic projections of sea level rise exceedance. The WRCP produced a report with recommendations for how to apply the projections, with guidance on applying the probabilistic projections (Raymond et al. 2020). These projection scenarios are listed below.

- ***High Probability Projections (>83%):*** This represents a lower rate of sea level rise with a high probability of occurring, meaning that it is very likely that the sea level will rise to the level associated with this projection. It suggests that there is an 83% chance that the sea-level rise will be greater than the identified rate with this threshold. The recommendation is to use this projection for risk-tolerant situations where infrastructure can accommodate sea level rise impacts or projects have flexibility or adaptability and where the consequences of flooding would be minimal.
- ***Low-Range Probability Projections (<17%):*** This represents a higher rate of sea level rise with a lower probability of occurring. It suggests that there is a 17% chance that the sea-level rise will be greater than the value identified for this probability, or amount of sea level rise. The recommendation is to use this level for assets that are risk-averse and where sea level rise will

[1] A high emissions scenario (RCP 8.5) assumes a global future in which we do not significantly reduce or limit emissions. It also assumes high population and lower income growth with moderate technological change and energy improvement, resulting in long-term to high energy demand and greenhouse gas emissions. A low emissions scenario (RCP 4.5) assumes a more aggressive global response to emissions reduction actions based on the 2015 Paris Agreement and limits mean global warming to less than 2°C and achieves net-zero greenhouse gas emissions by 2050. This scenario is considered politically challenging and would require concerted action by all countries to shift to lower emissions.

have substantial consequences. For example, using the estimated sea level rise associated with this probability should be used for critical infrastructure, such as sewage treatment plants or emergency response infrastructure, or others that would be seriously compromised by flooding and that the loss of that function would be a major disruption to the community.

- ***Extreme Low Probability Projections (0.1%):*** This represents the highest rate of sea-level rise with the lowest probability of occurring. This projection represents the physical upper limit for sea level rise and is a worst-case scenario for extremely conservative decisions. This level of sea-level rise is unlikely to change with future scientific updates.

The National Oceanic and Atmospheric Administration (NOAA) also updated its sea level rise projections in 2022, which are based off extrapolated tide gauge record data, to reflect the most recent climate change scenarios (Sweet et al. 2022). NOAA's updated projects include 5 scenarios that generally correspond to a global climate model scenario (Low, Intermediate-Low, Intermediate, Intermediate-High, and High). The NOAA 2022 High Projection scenario was used as a visual reference layer in this spatial analysis, but the WRCP projections were used for the asset analysis since they are more locally tailored.

Current Coastal Flooding Processes

Sea level rise can exacerbate existing coastal flooding, which is affected by a variety of processes, events, and factors. This analysis uses storm surge, wave runup, and the FEMA 100-year flood zone to represent current drivers of coastal flooding, described below.

- ***Storm surge:*** Storm surge is a coastal phenomenon experienced in western Washington where the MHHW elevation level rises, due to a combination of high tide events, low atmospheric pressure, and wind-driven waves. Because of the intensified impacts of these events, this study additively combines storm surge with WCRP sea level rise projections. Storm surge for Port Townsend was estimated by examining the extreme water level historic data from the nearby Friday Harbor tide gauge and comparing it to MHHW levels. There is 1% chance of a storm surge event for any given year in Port Townsend that would raise the tide levels by an additional 3.1 feet (Petersen et al. 2015). For the purposes of this report, the 3.1 feet of water level rise attributable to storm surge was used to represent current flooding in Port Townsend.
- ***Wave runup:*** Wave runup is the height difference between the elevation of still water and the elevation that is reached by the uprush of a wave on beaches and shore barriers such as seawalls. At a local monitoring site (Salmon Club Boat Ramp, **Figure 2**) with a

Figure 2. Wave runup at a city park and the Salmon Boat Club ramp.

gently sloping shoreline, wave runup has been measured to increase tide levels by an additional 2.0 to 2.5 feet (Local 20/20 2018). For all inundation scenarios that were within 100 feet of the coast, an additional 2.5 feet was added to the total elevation to represent wave runup. In the case of this report, the purpose of evaluating wave runup was to better understand how properties along the shoreline are directly impacted due to wave action and serve as a planning tool for mitigation measures against wave runup.

- ***100-year flood:*** The National Flood Insurance Program provides geographic areas and subdivisions at risk of flooding and the associated base flood elevation. For this analysis, the base elevations of the 1% annual flood event—or a 100-year flood—for designated high-risk areas within Port Townsend were used. Depending on the subdivisions the base flood elevations ranged from 7 feet to 17 feet (FEMA 2019). These flood maps were included in the asset inundation analysis because it is representative of where historical flooding has occurred. However, the FEMA flood map does not consider future sea level rise.

Sea Level Rise and Coastal Flooding in Port Townsend

Sea level rise projections for the coastal area around the City of Port Townsend are summarized in **Table 1**. For the purposes of this analysis, we used WRCP's 17% and 1% probability of exceedance value with a planning horizon of 2100 (3-feet and 5-feet of sea level rise, respectively). We also mapped the NOAA 2022 High Projection scenario with a planning horizon of 2100 (6.52-feet of sea level rise) to compare across datasets. The sea level rise projections and current coastal flooding levels selected for this analysis are summarized on **Table 2**. To represent the impacts of current coastal flooding impacts in Port Townsend we used the FEMA 100-year coastal flood elevation, the observed tidal elevation from the 1% storm surge event (3.1 feet), and 2.5 feet of wave run-up.

Table 1. Projected Sea Level Change for Port Townsend (in feet).

Time period	Greenhouse Gas Scenario	Central Estimate (50%)	17% probability of exceedance	Higher magnitude, but lower likelihood possibilities			NOAA 2022 High projections
				10% probability of exceedance	1% probability of exceedance	0.1% probability of exceedance	
2050 (2040-2059)	**High**	0.8	1.0	1.1	1.5	2.1	1.47
2100 (2090-2109)	**High**	2.2	3.0	3.3	5.0	8.5	6.52
2150 (2140-2159)	**High**	3.7	5.2	5.9	10.2	18.8	16.2

This table summarizes the 2018 assessment projections from the WCRP projections and NOAA 2022 High Projection scenario for the City of Port Townsend. For the WCRP projections, projected changes are assessed relative to contemporary sea level, which WCRP defines as the average sea level over the 19-year period 1991-2009. For the NOAA 2022, projected changes are added on top of MHHW elevation. Projections highlighted in orange were used for this analysis and the projections highlighted in yellow was used as a reference.

Table 2. Scenarios and their associated elevations (feet).

Projection	Inundation Scenario	Feet of Sea-level Rise	Source
Washington State Unified projections	2100 Low-Range Probability Projections (<17%)	3 feet	Miller et al. 2018
Washington State Unified projections	2100 Low Probability Projections (1%)	5 feet	Miller et al. 2018
2022 NOAA Projection	2100 High projection	6.52 feet	Sweet et al. 2022
Storm Surge	100 Year Storm event	3.1 feet	Petersen et al. 2015
FEMA Flood Hazards	100-year Flood	Base elevations from 7-15 feet	FEMA 2019
Wave Run-up	Current observations	2.5 feet, on top of storm surge	Local 20/20 2018

Approach to Assess Future Coastal Flooding Levels in Port Townsend

This section outlines how we assessed future coastal flooding based on different sea level rise projections and coastal flooding scenarios.

Inundation Mapping for Future Water Levels

Tidal Datums

The National Oceanic and Atmospheric Administration (NOAA) maintains a tide gauge along Water Street near Point Hudson (Station ID: 9444900). **Table 3** details the tidal datums and their current elevations (feet) that the gauge tracks. For this analysis, MHHW (8.52 feet) was used as a reference base elevation with all inundation projections added on top of the 8.52 feet (in reference to Mean Lower Low Water, or MLLW).

Table 3. Tidal datums and their current elevations (feet) relative to MLLW.

Datum		Current Elevation
Mean higher high water	MHHW	8.52
Mean high water	MHW	7.84
Mean tide level	MTL	5.17
Mean sea level	MSL	5.00
Mean low water	MLW	2.50
Mean lower low water	MLLW	0.00

For instance, the 1% annual storm surge event was observed to increase the elevation of MHHW during low atmospheric events by 3.1 feet. Cumulatively, this would mean that the water level during a 1% storm surge event will be 11.62 feet (**Table 4**).

Table 4. Projected water level during 1% storm surge event (feet).

MHHW Elevation	1% Storm Surge Event Increase	Total Water Level During 1% Storm Surge Event
8.52	3.1	11.62

The total water level that accounts for sea level rise by 2100 was calculated by totaling MHHW with the elevation of WCRP sea level rise projections and storm surge. This would model not only the total water level increase brought on by sea level rise, but also the additional elevation driven by 1% storm surge events (**Table 5**).

Table 5. 2100 Total water level (feet) according to WRCP Washington State projections.

Projection	2022 MHHW Levels	1% Storm Surge	Sea Level Rise	2100 Projected Water Level
17% Likelihood SLR Event	8.52	3.1	3	14.62
1% Likelihood SLR Event	8.52	3.1	5	16.62

Because areas of the shoreline within proximity to the current water level would be additionally impacted by wave runup, the total water level for areas within 100 feet of the shoreline included an additional 2.5-feet of elevation that accounts for wave runup (**Table 6**).

Table 6. 2100 Projected (WRCP) total water level coupled with wave runup (feet).

Projection	2100 Projected Water Level	Wave Runup	2100 Water Level with Wave Runup
17% Likelihood SLR Event	14.62	2.5	17.12
1% Likelihood SLR Event	16.62	2.5	19.12

As a comparison, the 2022 NOAA High Projection scenario was 6.52-feet of sea level rise by 2100, which would place the total projected water level at 15.05 feet by 2100 (**Table 7**).

Table 7. Total water level (feet) in 2100 according to NOAA 2022 projections.

2022 MHHW Level	Sea Level Rise	2100 Projected Water Level
8.52	6.52	15.05

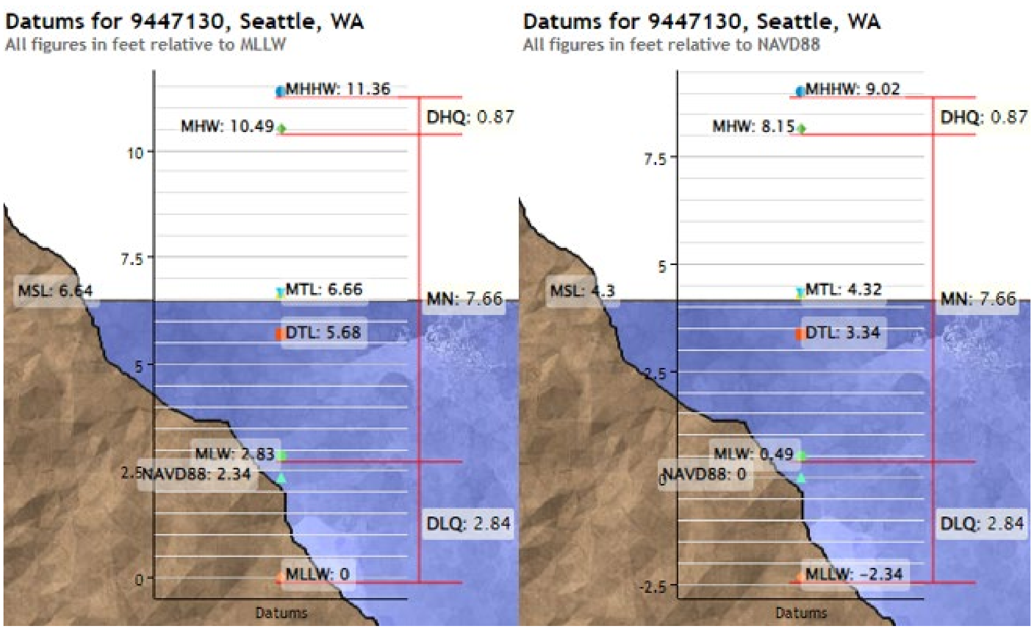
Vertical Datum Conversions

The Digital Elevation Model (DEM) for Jefferson County was obtained from the NOAA Sea Level Rise Viewer tool and downloaded into ArcGIS. The DEM used was in meters and had a spatial reference coordinate system of NAVD88. The DEM had a horizontal resolution of 3-meters and a 0.328 RMSE of vertical accuracy. Additionally, the elevation data source of the DEM met the standards of the USGS Quality Level 2 as defined by the Lidar Base Specification of the national interagency 3D Elevation Program. Using Online VDatum, the reference conversion from MLLW to NAVD88 for the Port Townsend area was calculated to be -1.1 feet. By applying this offset, water levels could be converted to NAVD88. For example, if MHHW of 8.52 feet was applied the conversion offset would have an elevation of 7.42 feet in reference to NAVD88 (**Table 8**). A visual representation of this offset illustrates how the conversion can be applied and can be seen in **Figure 3**.

Table 8. Water level (feet) in reference to MLLW and NAVD88.

Inundation Scenario	Elevation in reference to MLLW	Elevation in reference to NAVD88
MHHW	8.52	7.42
Storm Surge	11.62	10.52
17% Likelihood SLR Event	14.62	13.52
NOAA High 2022 Event	15.04	13.94
1% Likelihood SLR event	16.62	15.52

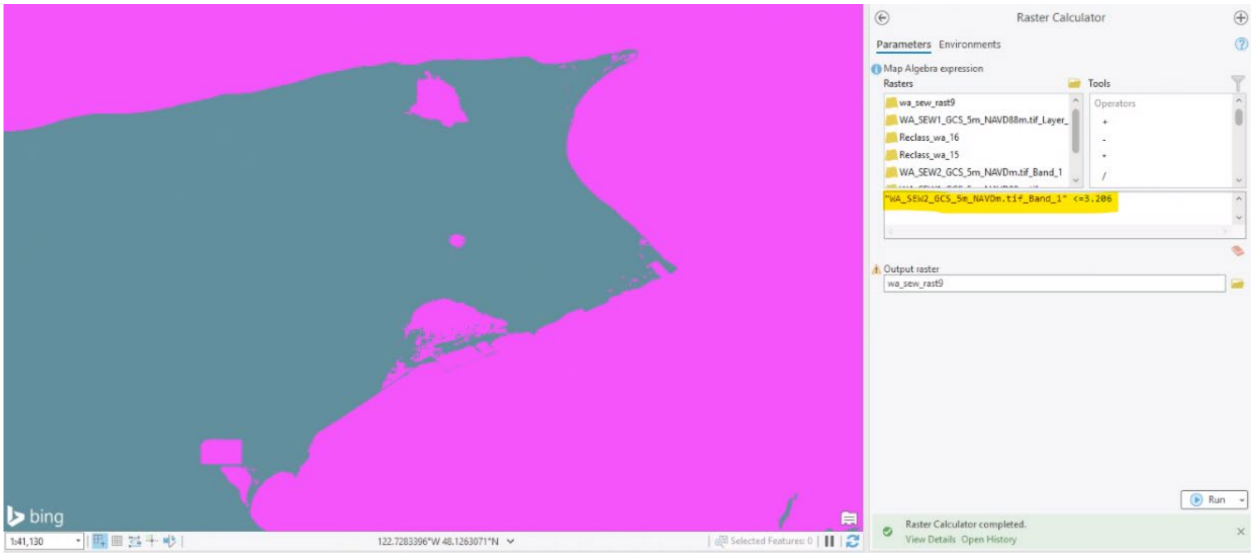
Figure 3. Tidal datum elevation offset in reference to MLLW and NAVD88.



Sea Level Rise and Storm Surge Mapping

This section outlines a case study of how these various models and data were used to estimate the total water level that accounts for sea level rise and storm surge within ArcGIS. To calculate storm surge, 3.1-feet was added on top of the MHHW (8.52 feet). This elevation of 12.62 feet was then offset by -1.1 feet to ensure total water elevation was based off the NAVD88 reference layer, leading to a total water level of 10.52 feet (in reference to NAVD88). This elevation was then converted from feet to meters (3.21). Finally, all areas of the DEM that were under 3.21 meters of elevation were selected using the Raster Calculate tool (**Figure 4**).

Figure 4. Example of how inundation layers were created using the Raster Calculate tool. In this scenario, the graphic depicts all areas equal to or below 3.21 meters (pink), which is the 3.1-feet storm surge scenario.



The Reclassify tool was used to replace the raster values that were over the specified elevation (3.21 meters) with “No Data” so that only the raster values representing sea level rise remained. The raster was then converted to a polygon using the Raster to Polygon tool to smooth the layer into simpler shapes and allow for further analysis.

Areas of the polygon that were under the elevation of water level that were not hydrologically connected to the coast or were deemed as “Areas unlikely to Flood”. These areas were eventually represented in a different color.

Wave Run-Up Mapping

The wave runup maps were calculated by adding total water level observation (Salmon Club Boat Ramp, Local 20/20 2018) and the NAVD88 offset and then subtracting the elevation from the tidal gauge observation (Point Hudson). Wave run-up height was modeled by adding an additional 2.5-feet of elevation for each inundation scenario.

The Erase tool was then used to delete all parts of the wave runup layer that overlapped with a corresponding inundation layer, leaving a layer that represents areas 2.5-feet higher than the given inundation scenario. Since wave runup only impacts shoreline areas, The Buffer tool was used to establish a zone of Port Townsend that was within 100 feet of the shoreline. Areas 2.5-feet higher than the given inundation scenario were attached to this 100-foot buffer zone using the Clip tool.

PORT TOWNSEND ASSETS AND FLOOD RISK

Asset Risk Assessment Methodology

Generally, climate vulnerability is defined as the climate risks and impacts moderated by the capacity to adapt and cope to those impacts. For example, the extent of coastal flooding impacts on sewer infrastructure is dependent on the location of sewer infrastructure in relation to expected sea level rise and whether the infrastructure can function with that inundation. A total of eighty-five (85) assets were identified through city documents and city staff consultation with an emphasis on coastal assets. For this assessment we focused on climate risks to coastal assets and categorized assets by various characteristics (**Table 9**).

Table 9. Asset type and characteristics.

Asset Type	Asset Characteristics
• Accommodations (Temporary Housing) • Dock or Marina • Education Facility • Fabrication or Working Boatyards • Financial Facility • Food, Restaurants, or Retail • Fuel • Offices and Buildings • Open Outdoor Spaces and Parks • Parking Lots • Power Structures • Residences (Housing) • Safety Facilities • Stormwater Infrastructure • Transportation • Wastewater Infrastructure • Water Infrastructure	• Ownership (e.g., City owned, privately owned, etc.) • Year Built • Expected Asset Lifespan • Estimated Cost (i.e., assessed parcel value or estimated replacement cost of public infrastructure)

We then looked at three components of risks to assets—exposure, sensitivity, and consequence—to assess sea level risk to these assets. These terms are further defined in subsequent sections.

Assessing Exposure

Exposure includes the physical factors that put assets in harm's way from sea level rise and coastal flooding. Extent of an asset's exposure to coastal flooding includes an asset's location, elevation, location, and whether it overlaps with anticipated future coastal flooding. We measured exposure by identifying the spatial locations of assets into ArcGIS Pro as points or polylines and overlayed with inundation layers. If an asset was within the boundary or intersected (partly within) with an inundation layer, it was deemed to be exposed to that flooding scenario.

We categorized asset exposure level as high, medium, or low based on the likelihood of that asset experiencing coastal flooding (**Table 10**). A high exposure asset would intersect with one of the current flooding risks (i.e., an asset overlapped with current wave run-up, storm surge, or 100-year flood). A medium exposure asset intersects with the 17% sea level rise threshold and a low exposure asset intersects with the 1% sea level rise threshold. We identified exposure for both private and public assets, however, only provide results for the public assets in this document.

Table 10. Exposure categories defined as high, medium, or low exposure levels.

Exposure Level	Short Description	Current Coastal Flooding Risk			Future Flooding Risk, related to SLR Projections	
		1% storm surge	Wave runup	FEMA 100-year flood	17% SLR	1% SLR
High	Assets that are already exposed to current flooding from storm surge, wave run-up, or 100-year floods.	*Any asset exposed to any current coastal flooding impact is considered to have high exposure.*				
Medium	Assets that will be exposed to future flooding due to SLR by 2100 at the 17% probability of exceedance.				X	
Low	Assets that will be exposed to future flooding due to SLR by 2100 at the 1% probability of exceedance or will experience no future flooding.					X

Assessing Sensitivity

Sensitivity is the degree to which the asset is affected by sea level rise and coastal flooding. For example, a new asset built with newer materials and built up to current design standards would be relatively less affected by temporary inundation as compared to infrastructure or assets that are built with older materials and to outdated design standards.

Within this analysis, sensitivity is defined as the asset age relative to expected design life. We identified less conservative and more conservative asset design life estimates using different sources related to asset types (**Table 11**). High sensitivity assets were assets whose current age exceeded less conservative design life estimates. We only identified sensitivity for public assets due to data availability and limitations.

Table 11. Design lifespan of key asset types.

Asset Type	Design Life (Less Conservative)	Design Life (More Conservative)	Source(s)
Accommodations (Temporary Housing)	30	100	Portland Cement Association (PCA), n.d. David and Sons, 2017
Dock / Marina	40	50	Michigan Sea Grant, 2015
Education	30	100	PCA, n.d. David and Sons, 2017
Fabrication / Working Boatyards	30	100	Eurostat, 2003
Financial	30	100	PCA, n.d. David and Sons, 2017
Food, Restaurants, Retail	30	100	PCA, n.d.

Asset Type	Design Life (Less Conservative)	Design Life (More Conservative)	Source(s)
			David and Sons, 2017
Fuel	20	30	ServoPro, 2021
Offices and Buildings	30	100	PCA, n.d. David and Sons, 2017
Open outdoor space and parks	20	50	City of Hamilton, Public Works, 2009
Parking lot	20	20	CA Department of Transportation, 2017
Power	50	50	Union of Concerned Scientists, 2017
Residences (Housing)	30	100	PCA, n.d. David and Sons, 2017
Safety	30	100	*No data found. Using lifespan of concrete structures as proxy.*
Stormwater	50	100	ASCE, 2021a
Transportation	10	100	Union of Concerned Scientists, 2017
Wastewater	25	50	ASCE, 2021b
Water	60	100	Union of Concerned Scientists, 2017

Assessing Consequence

High consequence assets represent assets that would affect key community functions if it failed due to coastal flooding. For this project, we identified high consequence assets using FEMA's definition of critical facilities — which includes assets, systems, networks, or functions that would have a debilitating effect on security or public health and safety if they were debilitated or incapacitated due to hazards — to identify critical infrastructure on the list of assets. Critical infrastructure was identified by the City of Port Townsend project staff. These assets were subsequently categorized as high consequence assets.

RESULTS

Summary of Coastal Flooding Risk to Key Assets

The eighty-five assets assessed in this study are categorized based on asset type, ownership, exposure, sensitivity, and whether it represents a high consequence asset (public assets are summarized on **Table 12** with the detailed asset descriptions for public and private assets in Appendix B). Of these 85 assets, forty (40) assets were publicly owned or owned by NGOs.

High Exposure

Of the 40 public assets, 32 were identified as having high exposure, meaning that those assets are already located within the 1% chance of storm surge (3.1 feet) area, wave runup (2.5 feet) area, and/or the FEMA 100-year flood zone. There highly exposed assets include assets within wastewater, water, transportation, stormwater, safety, marinas, housing, and business categories. Out of the 29 high consequence assets representing critical infrastructure (which include private assets), 23 are highly exposed to current coastal flooding.

These exposures represent current risk conditions and do not consider future sea level rise. The high exposure assets should be prioritized by the City for adapting to sea level rise as these are already known to experience coastal flooding during extreme high tide events and storm surge events and they will be the first assets to be affected by future sea level rise.

Highly Sensitive Assets

Out of the 40 public assets that were evaluated for sensitivity, six (6) are considered highly sensitive. That means their current age exceeds their anticipated design life, or the estimated length of time that asset is designed to function for. These assets are more likely to fail after a single or repeated flooding events because of their age in relation to their design life. Assets with high sensitivity to sea level rise should also be considered as priorities for the City as they will be the assets least equipped to deal with future coastal flooding worsened by sea level rise.

High Consequence Assets

The high consequence assets are assets that provide critical services – such as food, gas, shelter, power, and health services – to Port Townsend that also have high exposure and high sensitivity. The City will need to prioritize these assets in adapting to sea level rise to avoid failure of these critical facilities. High consequence assets include public and private assets. There are four (4) public assets that have been identified as high consequence assets.

Asset Values at Risk

Asset values were represented as either assessor's parcel value for private assets or represented as estimated replacement cost for public assets (included with detailed asset descriptions in Appendix B). We identified total costs at risk by different exposure levels for both public and private assets.

For public assets, the total estimated replacement costs for assets with high exposure where assets are already located within the 1% chance of storm surge, wave runup, or the FEMA 100-year flood zone is $179,200,000. The total estimated replacement cost for public assets with medium exposure, or where assets intersect with the 17% probability of exceedance, is $2,068,544. Finally, the total estimated replacement cost for assets with low exposure, or where assets intersect with the 1% probability of exceedance, is $12,771,167.

For private assets, the total assessed parcel value for assets with high exposure where assets are already located within the 1% chance of storm surge, wave runup, or the FEMA 100-year flood zone is $44,060,086. The total assessed parcel value for private assets with medium exposure, or where assets intersect with the 17% probability of exceedance, is $2,880,465. Finally, the total assessed parcel value for private assets with low exposure, or where assets intersect with the 1% probability of exceedance, is $1,231,924.

Table 12. Assets categorized by level of exposure and sensitivity and whether it represents a high consequence asset.

ID	Asset	Ownership	Exposure	Sensitivity	High Consequence
Wastewater					
WW- 1	Monroe Street Lift Station	City	High	High	Y
WW- 2	Gaines Street Lift Station	City	High	Low	
WW- 3	Kah Tai Nature Park Restrooms	City	High	Medium	

ID	Asset	Ownership	Exposure	Sensitivity	High Consequence
WW- 4	Wastewater Treatment Plant	City	Low	Medium	
WW- 5	Port Lift Station	City	Medium	Medium	
WW- 6	Point Hudson Lift Station	City	High	Medium	
WW- 7	Kearney Sewer	City	High	Low	
WW- 8	Boat Haven Sewer	City	High	Medium	
WW- 9	Downtown Sewer	City	High	High	Y
Water					
W- 1	Kearney Water	City	High	Low	
W- 2	Boat Haven Water	City	High	Low	
W- 3	Downtown Water	City	High	Low	
Transportation					
T- 1	Washington State Ferry Terminal	Washington State	High	Medium	
Stormwater					
SW- 1	Stormwater Lift Station	City	High	Low	
SW- 2	Kearney Storm	City	High	Low	
SW- 3	Boat Haven Storm	City	High	Medium	
SW- 4	Downtown Storm	City	High	High	Y
Safety					
S- 1	US Coast Guard	Federal	Low	Medium	
S- 2	Point Wilson Lighthouse	Federal	High	High	Y
Parking Lot					
PL- 1	The Back Alley	City	Low	High	
Power					
P- 1	Electric Sub-Station	City	Low	Low	
Open Outdoor Space and Parks					
OP- 1	Pope Marine Park	City	High	Medium	
OP- 2	Adams Street Park	City	High	Medium	
OP- 3	Tyler Street Plaza	City	High	Low	
OP- 4	Wave Viewing Gallery	City	High	Low	
Offices and Buildings					
OB- 1	City Hall	City	Low	Low	
OB- 2	Cotton Building	City	Low	Low	
OB- 3	Pope Marine Building	City	High	Low	
OB- 4	Port of Port Townsend	Port	High	Low	
Education					
E- 1	Marine Science Center- 1	NGO	High	Low	
E- 2	Northwest Maritime Center	NGO	High	Low	
E- 3	Marine Science Center- 2	NGO	High	Low	
E- 4	Marine Science Center- 3	NGO	Medium	Low	
Dock / Marina					

ID	Asset	Ownership	Exposure	Sensitivity	High Consequence
D- 1	Port of Port Townsend Maintenance	Port	High	High	
D- 2	Union Wharf	Public	High	Low	
D- 3	City Dock	Public	High	Low	
D- 4	Boat Haven Marina	Port	High	Low	
D- 5	Point Hudson (Port Property)	Port	High	Low	
Accommodations (Temporary Housing)					
A- 9	American Legion (Homeless Shelter)	NGO	High	High	

LIMITATIONS

While this report attempts to assess the coastal flooding risk of key assets, there are some limitations of this assessment, identified below.

- The inundation modeling was based off elevation data and does not account for the effects of seawalls or other fortification structures. Because of this, the hazard exposure analysis may have resulted in more conservative high estimations of flooding in certain areas.
- The elevation of assets (i.e., building height) was not considered and therefore may overrepresent flooding.
- Site specific variables of wave runup were not assessed.
- The effects of natural processes or human causes geomorphological changes that might lower or raise the sea level elevation are not sufficiently understood and therefore the model does not consider coastal geomorphological processes that might occur in the future.

Furthermore, we recommend expanding on this assessment in the future. These recommendations are also listed below.

- Assessing asset adaptive capacity or ability to cope with inundation is beyond the scope of this project. We recommend reviewing the identified asset list and focusing on assets that are highly exposed, highly sensitive, and would have a high consequence of failure to assess the ability of those assets to cope or withstand impacts of coastal inundation, especially repeatedly. In addition, identifying adaptive capacity of infrastructure and assets could result in policy and planning recommendations for how to adapt key assets. This process is identified in the Climate Action Committee’s Risk Screening Tool (2019) and follows the steps laid out in this project.
- Erosion along bluffs may be impacted by sea level rise and storm surge but is outside the scope of this study.
- Port Townsend’s identify is linked to its historic and cultural resources. The Comprehensive Plan encourages retention of significant buildings (Land Use Element Goal 17). We recommend reviewing US Department of Interior’s Guidelines on Flood Adaptation for Rehabilitating Historic Buildings.

- This study did not account for the tsunami inundation zone. Future expansion of this could include integration of assets exposed to tsunami-related flooding.

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APPENDIX A: FLOODING AND INUNDATION MAPS

This appendix section provides more detailed maps that depict coastal flooding and inundation of assets.

Figure 5. Infrastructure along Kearney Street that are exposed to different inundation scenarios. Storm water pipes are shown in pink, water systems are shown in orange, and sewer lines are shown in purple. Coastal flooding is show in blue, wave runup in green, and areas unlikely to flood in a crosshatch blue pattern for each inundation scenario.

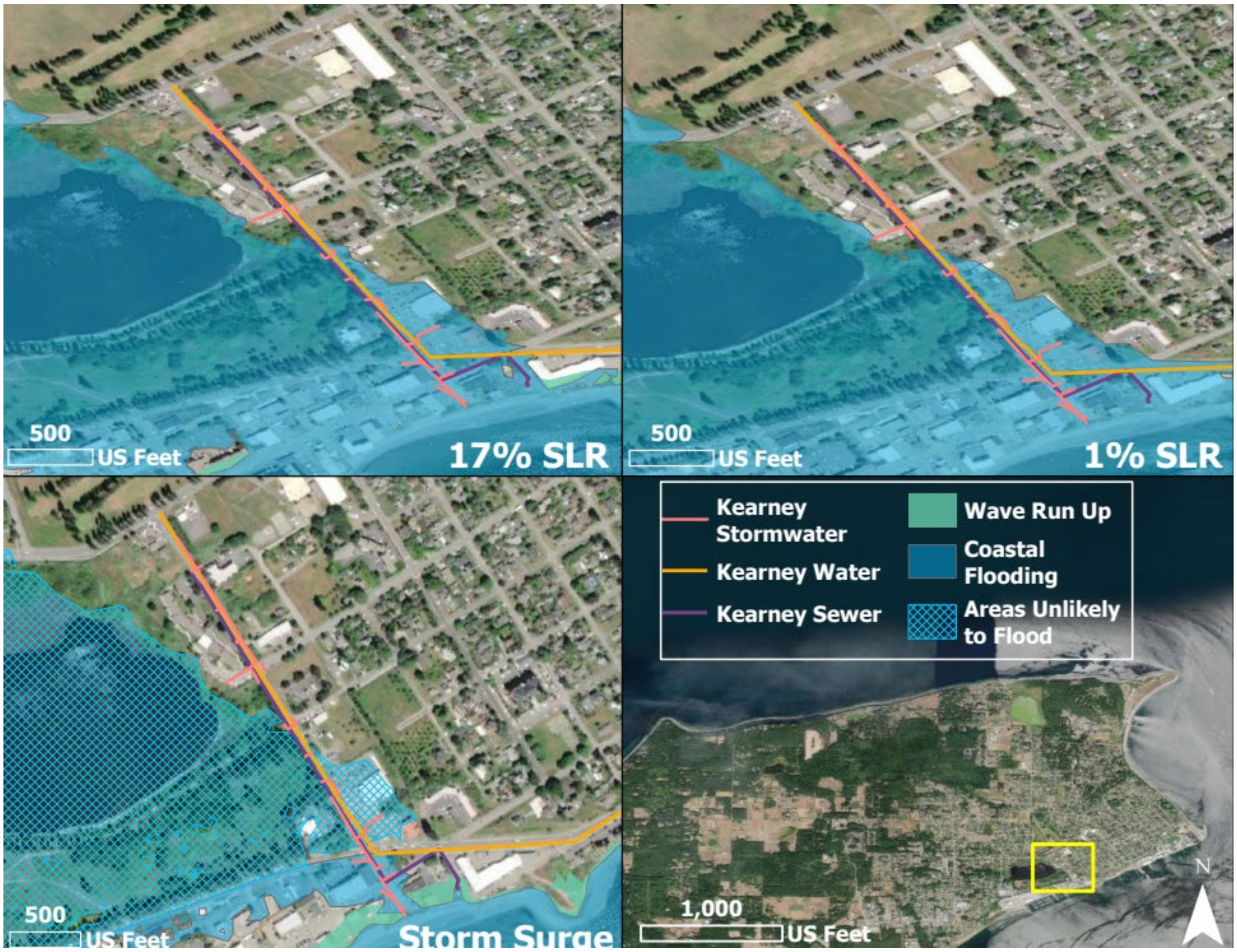

Figure 6. Boat Haven infrastructure exposed to different inundation scenarios. Storm water pipes are shown in pink, water systems are shown in orange, and sewer lines are shown in purple. Coastal flooding is show in blue, wave runup in green, and areas unlikely to flood in a crosshatch blue pattern for each inundation scenario.

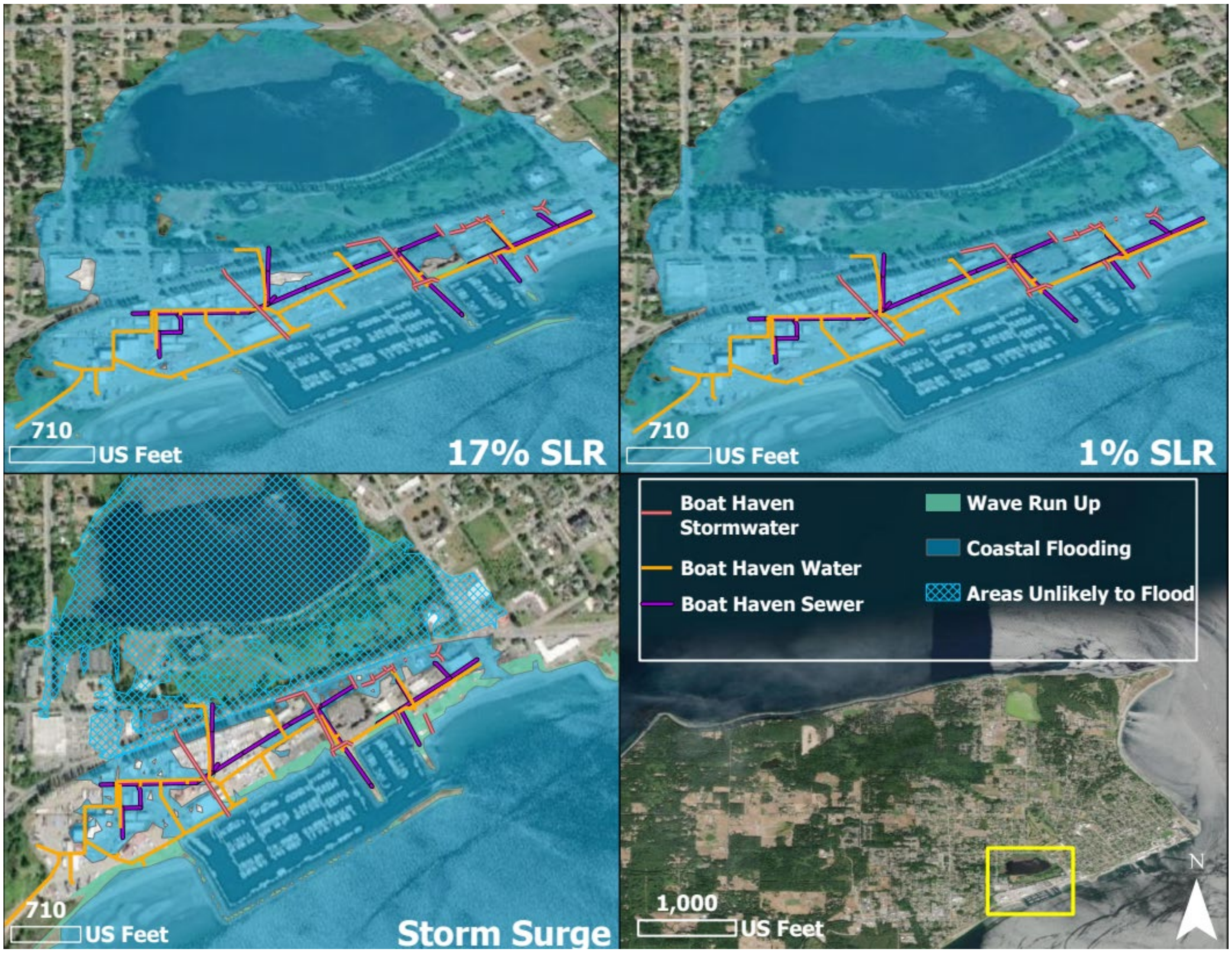

Figure 7. Downtown infrastructure exposed to different inundation scenarios. Storm water pipes are shown in pink, water systems are shown in orange, and sewer lines are shown in purple. Coastal flooding is show in blue, wave runup in green, and areas unlikely to flood in a crosshatch blue pattern for each inundation scenario.

Figure 8. Map of assets categorized by current flood exposure in Port Townsend. Storm surge is depicted in blue and wave runup in green. Areas that are below 1% storm surge event elevation but are hydrologically unconnected are labeled as "areas unlikely to flood" and are depicted in a crosshatch blue pattern. Assets are classified by their exposure types, high exposure assets are shown in red, medium exposure assets in yellow, and low exposure in green.

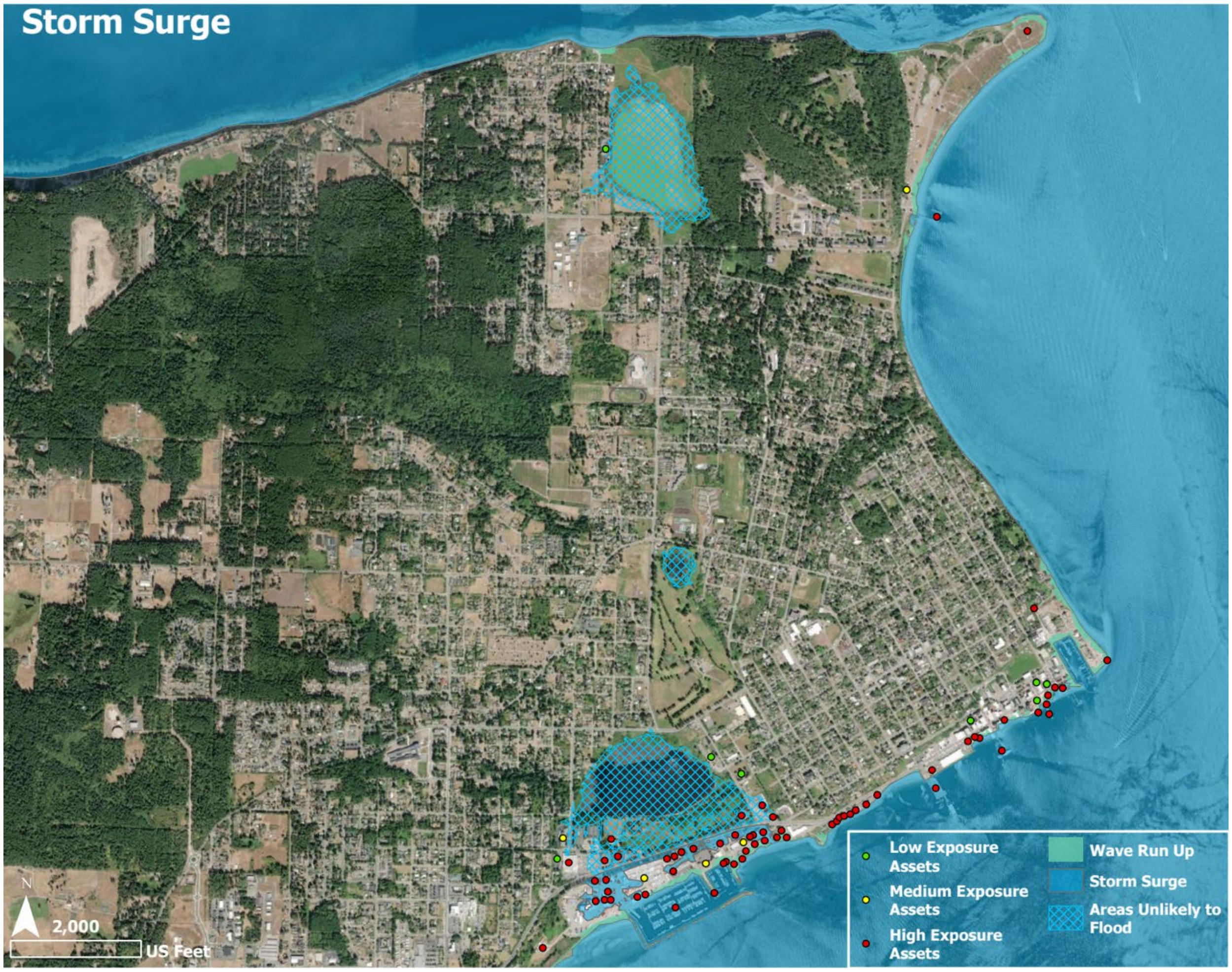

Figure 9. Map of assets categorized by future flood exposure in Port Townsend by 2100 under the 17% likelihood SLR event. Coastal flooding is depicted in blue, and wave runup in green. Areas that are below 17% SLR event elevation but are hydrologically unconnected are labeled as "areas unlikely to flood" and are depicted in a crosshatch blue pattern. Assets are classified by their exposure types, high exposure assets are shown in red, medium exposure assets in yellow, and low exposure in green.

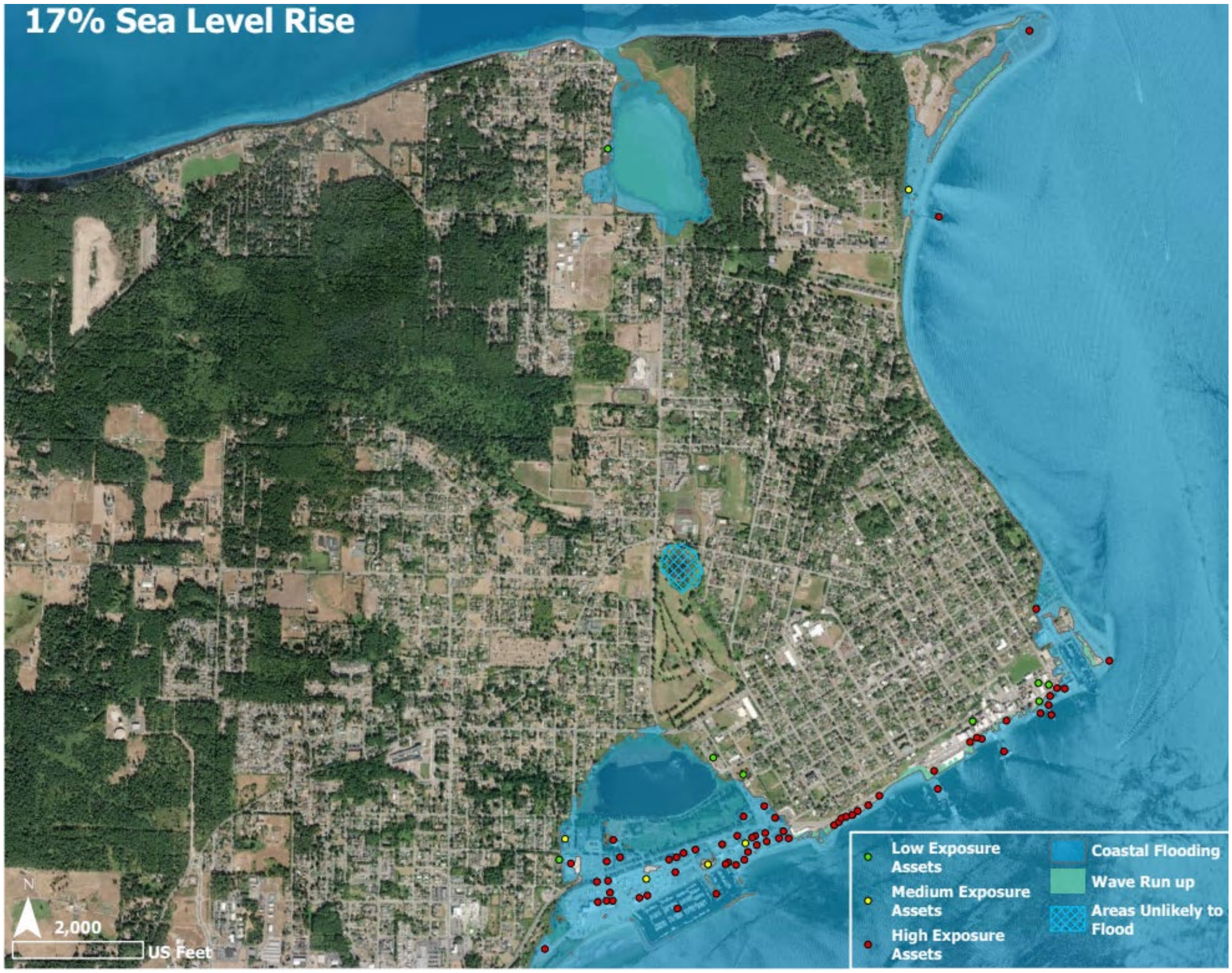

Figure 10. **Map of assets categorized by flood exposure in Port Townsend by 2100 under the 1% likelihood SLR scenario.** Coastal flooding is depicted in blue, and wave runup in green. Areas that are below 1% SLR event elevation but are hydrologically unconnected are labeled as "areas unlikely to flood" and are depicted in a crosshatch blue pattern. Assets are classified by their exposure types, high exposure assets are shown in red, medium exposure assets in yellow, and low exposure in green.

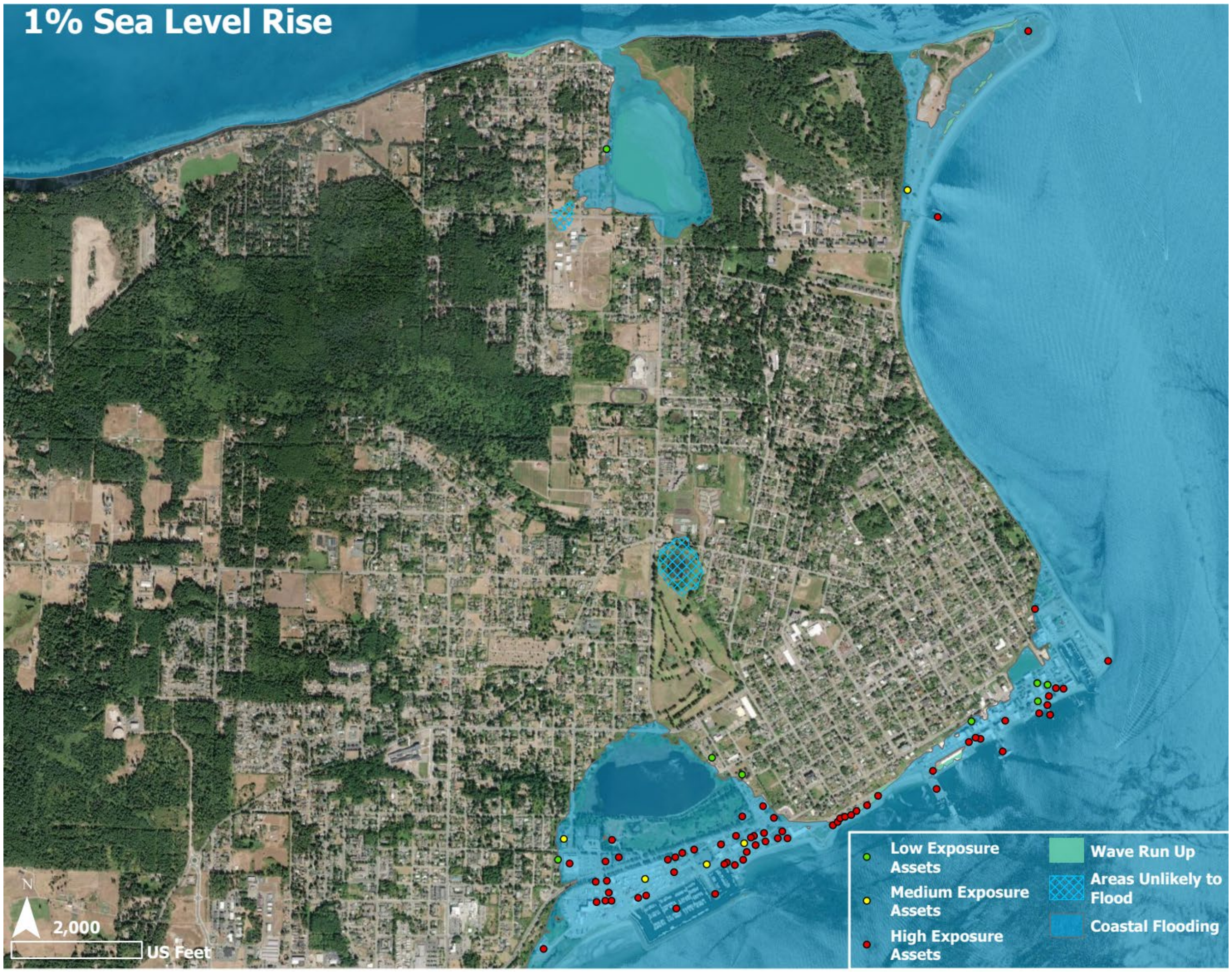

Figure 11**. Map of assets categorized by flood exposure in Port Townsend based on FEMA 100-year flood areas,** which represent historic flooding in Port Townsend (Shown in blue). Assets are classified by their exposure types, high-exposure assets are shown in red, medium-exposure assets in yellow, and low-exposure assets in green.

Figure 12**. Map of flooding impacts that would occur in 2100 under the 2022 NOAA High Projection scenario**. This was used as a reference layer.

APPENDIX B. DETAILED ASSET TABLE

The table below summarizes key assets, asset characteristics, and risk characteristics. Asset data was collected in summer 2022, and information was estimated when data was not explicitly available or accessible. These tables are based on the year 2022.

For a more detailed table that allows for regular updates, please visit https://docs.google.com/spreadsheets/d/15YVIpbCPVBIHBbgnCO5nbK7zZJHxVZyXkzFlzx-J4cw/edit#gid=0.

Detailed Asset Table

Asset	Description	Owned	Critical Facility	Year Built	Lifespan (years)	Value/Cost	Exposure		
							Current	17%	1%
Monroe Street Lift Station	Sewer Pump Station	City	Y	1960	62	$2,000,000	X		
Gaines Street Lift Station	Sewer Pump Station	City	Y	2022	0	$4,000,000	X		
Kah Tai Nature Park Restrooms	Restrooms	City		1993	29	$500,000	X		
Wastewater Treatment Plant	City's sewer plan on Kuhn Street	City	Y	1995	27	$75,000,000			X
Port Lift Station	Sewer Pump Station	City	Y	1985	37	$1,500,000		X	
Point Hudson Lift Station	Sewer Pump Station	City	Y	1990	32	$750,000	X		
Kearney Sewer	Wastewater line (Est. .25 miles)	City	Y	2005	17	$500,000	X		
Boat Haven Sewer	Wastewater line (Est. 1 mile)	City	Y	1990	32	$2,500,000	X		
Downtown Sewer	Sewer lines (Est. 2 miles)	City	Y	1950	72	$2,000,000	X		
Kearney Water	Water lines	City	Y	1975	47	$750,000	X		
Boat Haven Water	Water Lines	City	Y	TBD	TBD	$1,750,000	X		
Downtown Water	Water Lines	City	Y	TBD	TBD	$1,700,000	X		

Asset	Description	Owned	Critical Facility	Year Built	Lifespan (years)	Value/Cost	Exposure		
							Current	17%	1%
Washington State Ferry Terminal	Ferry Terminal	Washington State	Y	1990	32	$60,000,000	X		
Stormwater Lift Station	Stormwater Pump Station	City	Y	1995	27	$100,000	X		
Kearney Storm	Storm pump.... flooded pipes (Est. .25 miles)	City	Y	2000	22	$500,000	X		
Boat Haven Storm	Storm lines (est. .5 miles)	City	Y	1960	62	$1,250,000	X		
Downtown Storm	Storm lines (Est. 1 mile)	City	Y	1900	122	$5,000,000	X		
US Coast Guard	Coast Guard	Federal	Y	1960	62	$15,000,000	X		
Point Wilson Lighthouse	Lighthouse	Federal	Y	1914	108	$10,000,000	X		
Claridge Court	Apartments	Private		1989	33	$2,873,355		X	
Bay Vista II	Condominium	Private		1994	28	$2,531,400	X		
Bay Vista Condominium	Condominium	Private		1990	32	$1,177,343	X		
The Edgewater	Condominium	Private		TBD	TBD	$2,228,768	X		
Electric Sub-Station	Power	City	Y	1990	32	$5,000,000			X
The Back Alley	Public outdoor space	City		1950	72	$150,000			X
Pope Marine Park	Public outdoor space	City		1987	35	$500,000	X		
Adams Street Park	Public outdoor space	City		1993	29	$150,000	X		
Tyler Street Plaza	Public outdoor space	City		2017	5	$500,000	X		
Wave Viewing Gallery	Public outdoor space	City		2010	12	$750,000	X		
City Hall	Admin, Finance, Council, HR, Planning,	City	Y	2005	17	$20,000,000			X

Asset	Description	Owned	Critical Facility	Year Built	Lifespan (years)	Value/Cost	Exposure		
							Current	17%	1%
	Engineering and museum								
Cotton Building	Public gatherings	City		2010	12	$1,500,000			X
Pope Marine Building	Public gatherings	City		2010	12	$1,000,000	X		
Port of Port Townsend	Administrative Building	Port		2014	8	$5,000,000	X		
Jefferson Title	Title Company	Private		TBD	TBD	$568,544	X		
Port Townsend Yacht Club	Public gathering space	NGO		1986	36	$5,000,000	X		
Port Townsend Visitor Center	Information for tourists	Private		TBD	TBD	$568,544	X		
Safeway Gas Station	Gas Station	Private	Y	2001	21	$568,544	X		
The Food Coop	Grocery Store	Private	Y	1970	52	$2,626,938			
Penny Saver	Grocery Store	Private	Y	1989	33	$396,997			
Safeway	Grocery Store	Private	Y	1981	41	$8,560,966			
The Food Coop	Grocery Store	Private	Y	1988	34	$1,188,949			
Fast Shop	Grocery Store	Private	Y	2001	52	$568,544	X		
Bayview	Restaurant	Private		1978	33	$42,968	X		
123 Thai	Restaurant	Private		TBD	41	$912,327	X		
O'Reilly Auto Parts	Auto Parts	Private		TBD	34	$912,327	X		
PhoFilling	Restaurant	Private		1989	21	$680,467		X	
Pan d'Amore Bakery	Bakery	Private		TBD	44	$980,547	X		
Pourhouse	Pub with food service	Private		TBD	TBD	$851,675	X		
New Day Fisheries	Fish Processing	Private		TBD	TBD	$0 (Exempt based off parcel information)	X		
Sea J's Cafe	Restaurant	Private		TBD	33	$0 (Exempt based off parcel information)	X		

Asset	Description	Owned	Critical Facility	Year Built	Lifespan (years)	Value/Cost	Exposure		
							Current	17%	1%
Port Townsend Garden Center	Plant retail	Private		TBD	TBD	$678,055	X		
Goldstar Marine	Marine Service	Private		TBD	TBD	$0 (Exempt based off parcel information)	X		
Sunrise Coffee Company	Coffee Shop	Private		TBD	TBD	$0 (Exempt based off parcel information)	X		
Key City Fish	Grocery - seafood	Private		TBD	TBD	$0 (Exempt based off parcel information)	X		
Port Townsend Brewing Company	Pub	Private		TBD	TBD	$1,287,369	X		
Blue Moose Cafe	Restaurant	Private		TBD	TBD	$1,417,070	X		
Admiral Ship Supply	Marine Service	Port		TBD	TBD	$1,417,070	X		
Shipwright's Co-op	Marine Service	Private		TBD	TBD	$1,287,369	X		
Better Living Through Coffee	Coffee Shop	Private		TBD	TBD	$1,051,583	X		
Henry Hardware	Hardware store	Private		1991	TBD	$1,872,103	X		
Chase	Bank	Private		1984	31	$568,544	X		
Kitsap Credit Union	Credit Union	Private		1992	38	$987,877			X
US Bank	Bank	Private		1975	30	$1,124,141		X	
Wells Fargo	Bank	Private		1977	47	$1,370,471	X		
Kitsap Bank	Bank	Private		1975	45	$1,025,197	X		
Anderson Machine Shop	Machine shop	Private		TBD	TBD	$0 (Exempt based off parcel information)	X		
Armstrong Consolidated Inc.	Boat Manufacturer	Private		TBD	TBD	$1,274,890	X		
Marine Science Center- 1	Interactive museum	NGO		2021	1	$10,000,000	X		

Asset	Description	Owned	Critical Facility	Year Built	Lifespan (years)	Value/Cost	Exposure		
							Current	17%	1%
Northwest Maritime Center	Education facility and gather space	NGO		2009	13	$25,000,000	X		
Marine Science Center-2	Interactive museum	NGO	Y	2010	12	5,000,00		X	
Marine Science Center-3	Interactive museum	NGO		2010	12	$5,000,000	X		
Port of Port Townsend Maintenance	Marine Service	Port		1950	72	$2,000,000	X		
Union Wharf	Public outdoor space	Public	Y	1996	26	$1,500,000	X		
City Dock	Public outdoor space	Public		1990	32	$5,500,000	X		
Boat Haven Marina	Port of Port Townsend	Port	Y	1997	25	$5,000,000	X		
Point Hudson (Port Property)		Port	Y	1990	32	$4,000,000	X		
Life Care Center	Convalescent Center	Private		1980	42	$2,409,149			X
Harborside Inn	Hotel	Private		1990	32	$5,338,062		X	
The Tides Inn-1	Hotel	Private		TBD	TBD	$481,924	X		
The Tides Inn-2	Hotel	Private		TBD	TBD	$902,358	X		
The Tides Inn-3	Hotel	Private		TBD	TBD	$902,358	X		
The Tides Inn-4	Hotel	Private		TBD	TBD	$428,232	X		
The Tides Inn-5	Hotel	Private		TBD	TBD	$428,232	X		
Aladdin Inn-	Hotel	Private		1989	33	$1,651,831	X		
American Legion	Homeless Shelter	NGO	Y	1950	72	$2,500,000			X

Detailed Asset Table, by Exposure

Assets that were partially within an inundation layer are denoted with an asterisk. While spatial analysis may not categorize these as at-risk assets, real life ground truthing confirmed that some assets would still be partially or completely flooded despite their asset only partially overlapping an inundation later.

Asset ID	Asset	Current Coastal Flooding Risk			Future Flooding Risk, related to SLR Projections	
		1% storm surge	Wave run-up	FEMA 100-year flood	17% SLR	1% SLR
1	Monroe Street Lift Station		X		X	X
2	City Hall					X
3	Cotton Building					X
4	Pope Marine Building	X	X*	X	X	X
5	Gaines Street Lift Station	X	X*		X	X
6	Kah Tai Nature Park Restrooms			X	X	X
7	Wastewater Treatment Plant					X*
8	Port Lift Station				X	X
9	Pope Marine Park		X	X	X	X
10	Adams Street Park		X*	X*		X
11	Stormwater Lift Station	X		X	X	X
12	The Food Coop			X	X	X
13	Penny Saver			X	X	X
14	Chase			X	X	X
15	Life Care Center					
16	Electric Sub-Station					
17	Safeway			X*	X	X
18	McDonald's			X	X	X
19	Claridge Court				X	X
20	Kitsap Credit Union					X*
21	Safeway Gas Station	X*		X*	X	X
22	Fast Shop			X*	X	X

Asset ID	Asset	Current Coastal Flooding Risk			Future Flooding Risk, related to SLR Projections	
		1% storm surge	Wave run-up	FEMA 100-year flood	17% SLR	1% SLR
23	Port of Port Townsend	X*			X	X
24	Harborside Inn				X*	X
25	US Coast Guard	X*	X*	X*	X	X
26	Point Wilson Lighthouse			X	X	X
27	Point Hudson Lift Station			X	X	X
28	US Bank		X*		X*	X
29	Bayview	X*	X*		X*	X*
30	Bay Vista II	X*	X*	X*	X*	X*
31	Bay Vista Condominium	X*	X*		X*	X
32	The Tides Inn-1		X*		X*	X
33	The Tides Inn-2		X*		X*	X
34	The Tides Inn-3		X*	X*	X*	X*
35	The Tides Inn-4		X*		X*	X
36	The Tides Inn-5		X*		X*	X
37	Wells Fargo		X*			X
38	The Edgewater	X*	X	X	X	X
39	123 Thai	X		X	X	X
40	O'Reilly Auto Parts	X		X	X	X
41	Kitsap Bank	X		X	X	X
42	PhoFilling				X	X
43	Aladdin Inn	X*	X		X	X
44	Pan d'Amore Bakery		X		X	X
45	Pourhouse		X	X*	X	X
46	Jefferson Title	X	X*	X	X	X
47	New Day Fisheries		X		X	X
48	Sea J's Cafe		X	X*	X	X
49	Port Townsend Yacht Club	X	X*	X	X	X
50	Port Townsend Garden Center	X		X	X	X

Asset ID	Asset	Current Coastal Flooding Risk			Future Flooding Risk, related to SLR Projections	
		1% storm surge	Wave run-up	FEMA 100-year flood	17% SLR	1% SLR
51	Port Townsend Visitor Center	X*		X	X	X
52	Anderson Machine Shop	X*		X	X	X
53	Armstrong Consolidated Inc.	X	X*	X	X	X
54	Goldstar Marine	X	X*	X	X	X
55	Sunrise Coffee Company	X		X	X	X
56	Key City Fish	X			X	X
57	Port Townsend Brewing Company	X		X	X	X
58	Blue Moose Cafe	X		X	X	X
59	Admiral Ship Supply	X		X	X	X
60	Shipwright's Co-op	X		X	X	X
61	Port of Port Townsend Maintenance			X	X	X
62	Better Living Through Coffee	X	X*	X	X	X
63	Marine Science Center	X*	X*	X*	X*	X
64	Tyler Street Plaza		X*		X	X
65	Northwest Maritime Center		X	X*	X	X
66	Marine Science Center				X	X
67	Marine Science Center	X		X	X	X
68	Washington State Ferry Terminal	X		X	X	X
69	Henery Hardware			X		X
70	The Back Alley					X
71	Wave Viewing Gallery	X		X	X	X
72	Union Wharf	X		X	X	X
73	City Dock	X		X	X	X

Asset ID	Asset	Current Coastal Flooding Risk			Future Flooding Risk, related to SLR Projections	
		1% storm surge	Wave run-up	FEMA 100-year flood	17% SLR	1% SLR
74	Boat Haven Marina	X		X	X	X
75	American Legion					X
76	Point Hudson (Port Property)	X	X	X	X	X
77	Kearney Sewer	X		X	X	X
78	Kearney Storm	X	X	X	X	X
79	Kearney Water	X		X	X	X
80	Boat Haven Sewer	X	X	X	X	X
81	Boat Haven Storm	X	X	X	X	X
82	Boat Haven Water	X	X	X	X	X
83	Downtown Storm	X	X	X*	X	X
84	Downtown Sewer	X	X	X*	X	X
85	Downtown Water	X*	X	X*	X	X