Appendix F

THE NORTHWEST SEAPORT ALLIANCE
Gateway to Solutions

RESILIENT GATEWAY

NORTHWEST SEAPORT ALLIANCE VULNERABILITY ASSESSMENT

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RESILIENT GATEWAY PROGRAM

The Resilient Gateway Program supports NWSA's Key Initiative to develop a strategic resilience plan to ensure the long-term economic vitality of our region. This document presents the results of the NWSA's initial coordinated planning effort, building on prior efforts by the homeports. It was carried out by a core project team and subject matter experts that included staff from the Northwest Seaport Alliance, the Port of Seattle, and the Port of Tacoma.

The Vulnerability Assessment and Response Framework technical documents are designed to inform and support policy development and strategic decision-making, providing the framework for an Implementation Plan.

The Vulnerability Assessment looks at our exposure and vulnerability to potential hazards. The Response Framework describes how our ports may prepare for hazards through education and awareness, planning and preparation, and adapting and/or mitigating for hazards when investing in new facilities and upgrading existing facilities.

The Resilient Gateway Program considers risk both on-terminal and across the gateway to provide a framework for responding to resiliency goals, supporting policy development and strategic decision-making, and translating them into project design, prioritization, and asset management. **It does so by addressing the eight most likely and impactful hazards that could cause property damage or loss of life:**

- Coastal Flooding (includes sea level rise)
- Flooding (riverine, urban, groundwater)
- Severe Weather (cold, heat, rain, thunderstorms, wind, drought)
- Wildfires and Smoke
- Landslides (includes erosion and subsidence)
- Earthquakes
- Tsunamis
- Volcanic Activity

BACKGROUND

Our Gateway is critical infrastructure of national significance. The marine cargo operations provide significant jobs and revenue to Washington state, where 40% of the jobs are tied to trade. Cargo operations annually support tens of thousands of jobs, billions in business output and labor income, and genereate over one hundred million in state tax revenue. It serves as the 7th largest container gateway in the country, the 4th largest refrigerated container gateway overall, the 2nd largest refrigerated container export gateway, and the 4th largest warehousing and distribution cluster in the country.

The Tacoma harbor serves as strategic seaport for the nation's military, and both ports have a designated role as community lifelines during disaster recovery. In recognition of their role as critical infrastructure, the NWSA and both homeports have been engaged in various related planning efforts over the years.

Resilient Gateway builds on prior efforts which were limited in nature and typically focused on a single hazard, a single harbor, or the resilience aspects of a particular project. Recent examples include the Port of Seattle Resiliency Assessment, the Port of Tacoma All Hazard Mitigation Plan, and the Port of Seattle Climate Change Adaptation Plan.

Key Resiliency Terms

Adapted from FEMA

Resilience is the ability to prepare for threats and hazards, adapt to changing conditions, and withstand and recover from disruptions.

Risk is the potential for a negative outcome based on the combination of a hazard and potential areas of vulnerability.

Hazards are sources of potential danger or adverse conditions and are characterized in terms of their likelihood and magnitude.

Likelihood is the probability or frequency of a hazard occurring.

Scale is a measure of the severity of a hazard.

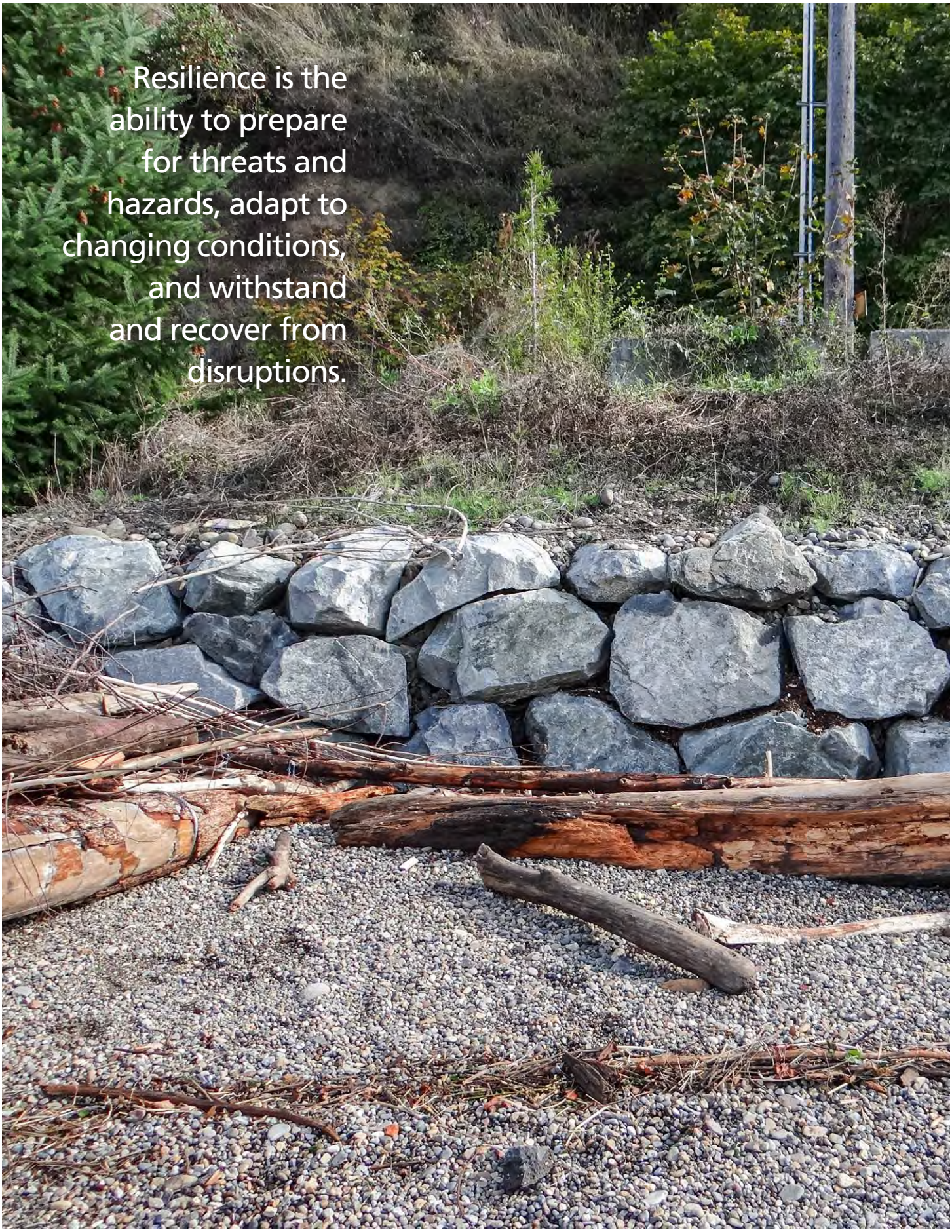
Vulnerability is impact or susceptibility to injury, harm, damage, or economic loss. It is characterized by what is exposed to a hazard and its sensitivity to the hazard.

Exposure is the potential geographic reach of a hazard that can harm people, property and anything else located in the hazard zone.

Susceptibility is the sensitivity of someone or something to a hazard.

Mitigation is any action to reduce risk by reducing one or more risk factors.

Adaptation is a type of mitigation action that focuses on adjusting to new climate conditions in order to reduce risk.


Resilience is the ability to prepare for threats and hazards, adapt to changing conditions, and withstand and recover from disruptions.

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NORTHWEST SEAPORT ALLIANCE VULNERABILITY ASSESSMENT

Assessing risk on terminals and across the Gateway

Understanding risk factors and ranking them can identify particular areas of vulnerability and help prioritize mitigation strategies to increase resilience.

VULNERABILITY ASSESSMENT APPROACH

The Northwest Seaport Alliance (NWSA) Vulnerability Assessment identifies the natural hazards likely to occur across the gateway, assesses their risk factors, and groups them according to their risk characterization. Each hazard has its own chapter within the Vulnerability Assessment and the hazards are organized by their hazard type: emerging hazards, chronic hazards, and shocks.

1) Hazard Identification
The hazards covered in Vulnerability Assessment are the natural hazards including geological and meteorlogical hazards that may affect our Gateway. The final list of hazards includes:

- Coastal Flooding (includes sea level rise)
- Flooding (riverine, urban, groundwater)
- Severe Weather (cold, heat, rain, thunderstorms, wind, drought)
- Wildfires and Smoke
- Landslides (includes erosion and subsidence)
- Earthquakes
- Tsunamis
- Volcanic Activity

The Vulnerability Assessment does not include human or technological hazards like cybersecurity issues, terrorism, infrastructure failures, or industrial fires. These were not included in this first phase of work since they are more closely aligned with the work functions of the homeport security teams and the individual terminal operators.

2) Risk Factors
Risk is the potential for a negative outcome based on the combination of a hazard and potential vulnerability. In breaking it down further, the hazard is measured by its likelihood and scale and the vulnerability is determined by exposure and susceptibility. The risk factors are assigned a low, moderate, or high ranking based on the best available scientific data, hazard literature review, and feedback from NWSA and homeport staff.

Since the ports can only function if cargo can get in and out of the terminals, the Vulnerability Assessment considers impacts on-terminal and across the Gateway. The Vulnerability Assessment includes risk factors for areas of susceptibility or impact to the NWSA including safety, operations, facilities, equipment, commerce, and the overall organization. RIsk factor rankings are also provided for impacts to the Gateway including roadways, railroads, waterways, utilities, industrial lands, community, and the environment.

Because risk levels change over time, each hazard is also ranked low, moderate, or high based on its risk outlook. This helps understand how risk levels change over time based on changes to a hazard likelihood, scale, exposure, or susceptibility. Understanding the outlook of a hazard is especially important for hazards which are greatly affected by changing climate conditions such as coastal flooding, flooding, severe weather, wildfires and smoke, and landslides. A hazard may also have changing risk levels if the level of exposure changes with development patterns or if actions are taken to reduce susceptibility to a hazard such as builder to more resilient design codes.

3) Risk Characterization

The hazards were divided into three hazard type categories to group hazards with similar risk profiles. Grouping hazards by type can help with identifying and prioritizing appropriate risk mitigation strategies.

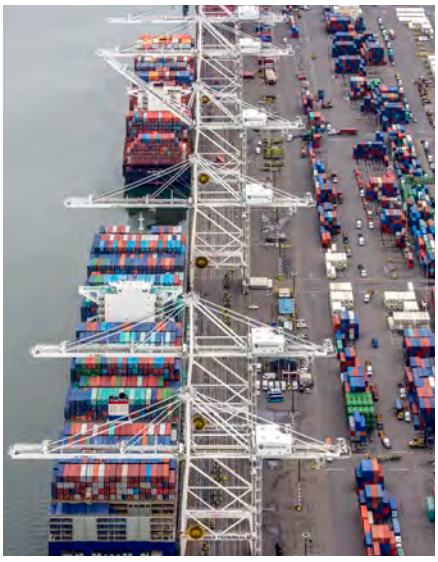
EMERGING THREATS The emerging threats category includes hazards which are not a major threat today but have greatly increasing risk levels over time and need to be considered over a longer planning horizon. The emerging threats category includes coastal flooding since it isn't a significant hazard to the Gateway now, but could be a major threat as sea levels rise if no adaptation measures are taken.

CHRONIC HAZARDS The chronic hazards are those which have a high likelihood of occuring but are typically smaller in scale and impact. These hazards are largely seasonal in nature since most of them are meteorlogical hazards. The chronic hazards include flooding, severe weather, wildfires and smoke, and landslides. These hazards typically occur multiple times a year across the Gateway during particular seasons.

SHOCKS Shocks are hazards which have a low likelihood of occurring but are typically larger in scale and impact. They can provide a major shock to the system and dramatically affect a large area. All of the shocks are geologic hazards and they include earthquakes, tsunamis, and volcanic activity. The only geologic hazard not included in shocks is landslides.

The NWSA has many terminals in each harbor that support cargo operations. Exposure to a hazard could affect terminal facilities and the workers, equipment, and cargo that are in the area at the time.

Infrastructure located along shoreline areas may be susceptible to emerging threats like coastal flooding from sea level rise without future adaptation measures.



Ports are water-dependent uses and both harbors are located in areas susceptible to shocks and emerging and chronic hazards.

The coastal waterfront is a dynamic environment with water levels that are always changing with the tides.

EMERGING THREATS

may not be a major threat today, but they have greatly increasing risk levels over time and need to be considered over a longer planning horizon.

COASTAL FLOODING

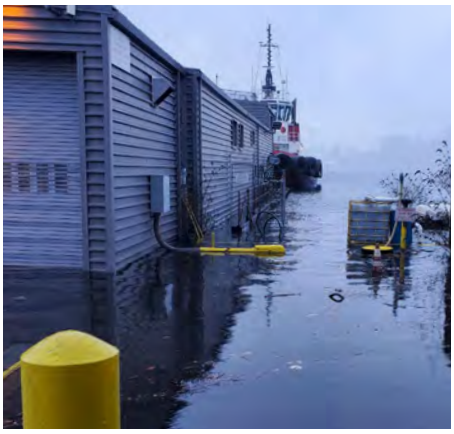
COASTAL FLOODING

Extreme high tides can damage waterfront facilities even if the water levels don't overtop the terminals. Many utilities hang on the underside of wharfs and can experience water damage before other parts of the terminal.

Tidal Range

The water levels are always changing as they move between high and low tides. The difference between typical high and low tides is over 11 feet.

Seattle Harbor	11.36 ft
Tacoma Harbor	11.77 ft



Extreme high tides have caused flooding at Pier 17 (shown above) and other terminals located in the 100 and 500-yr floodplain.

A HIGH-RISK DYNAMIC ENVIRONMENT

Coastal flooding is the saltwater inundation of land that is normally above water. As a result, it may pose a threat to life and property, potentially harming unprotected low-lying communities and infrastructure. This chapter focuses on coastal flooding hazards including sea level rise (SLR). Other sources of flooding including riverine, urban, and groundwater flooding are covered in the Flooding chapter.

The coastal waterfront is a dynamic environment with water levels that are always changing with the tides. Because of the great difference between low and high tide, coastal flooding typically occurs when there is storm surge or wave run-up during high tides. Flooding typically subsides during low tides but may re-occur with the following high tides if the storm surge and wave run-up are still present. Coastal flooding is exacerbated by SLR and can create or amplify other hazards including coastal eroision and landslides or inland flooding issues including riverine, stormwater, and groundwater flooding.

There are several factors that contribute to coastal flooding and total water levels including:

Astronomical Tide – Tides are dynamic and influenced by the gravitational effects of the alignment of the earth and moon.

Sea Level Rise – The height of the global sea level is increasing as a direct effect of climate change including the thermal expansion of warming waters and the melting of glaciers and ice sheets.

Storm Surge – Low pressure systems and wind can further increase water levels above the astronomical tide height.

Wave Run-Up – Wind can create waves, pushing water further up at shoreline areas, increasing coastal flooding.

Vertical Land Motion – Natural uplift or subsidence affects how an area experiences coastal flooding and SLR. Areas that are uplifting will notice less SLR than an area experiencing subsiding even though they both experience the same amount of SLR.

NWSA Harbor Sea Level Rise Projections

The Washington Coastal Resilience Project has developed SLR projections for all coastal areas in Washington. These projections account for the vertical land movement in different parts of the state and capture the relative change in sea level that a particular area will experience.

Time Period	Greenhouse Gas Scenario	Seattle Harbor Likely Range of SLR (ft)	Tacoma Harbor Likely Range of SLR (ft)
2050	Low	0.6 – 1.0	0.6 – 1.1
	High	0.6 – 1.1	0.7 – 1.2
2100	Low	1.3 – 2.5	1.5 – 2.7
	High	1.7 – 3.1	1.9 – 3.3
2150	Low	1.9 – 4.3	2.1 – 4.6
	High	2.7 – 5.4	3.0 – 5.7

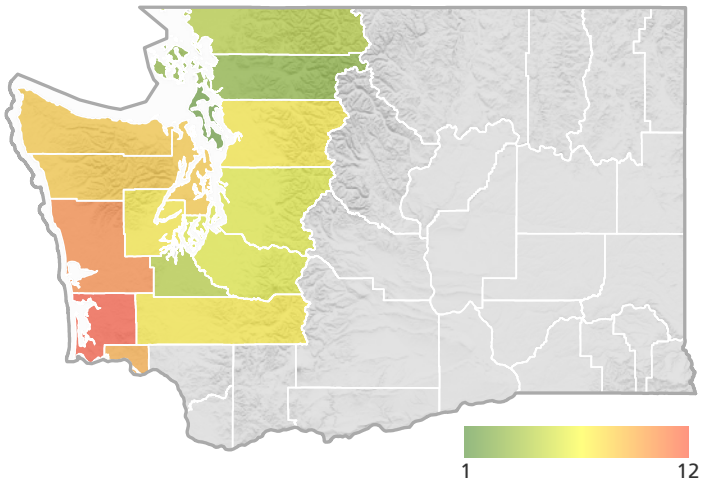
PAST EVENTS

Coastal flooding is a high likelihood hazard in Washington with many recorded events. Many of these flood events are smaller in nature compared to coastal flooding in other parts of the county that experience greater storm surge or hurricanes. In Washington, coastal flooding is more likely to occur in the winter months during the king tide season, when there are strong astronomical tides. Because SLR raises the overall water level, it has already increased exposure to coastal flooding. The sea level has already risen 8 to 9 inches globally since 1880 and additional SLR will make future high tides and coastal flooding events more severe.

Looking at coastal flooding events can be helpful for understanding how SLR will affect coastal areas. SLR will continue to increase the water level and normal high tides in the future could cause tidal flooding without adaptation measures.

Washington's Declared Coastal Flooding Disasters by County

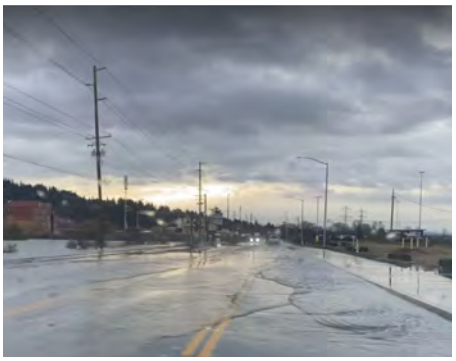
Coastal flooding is typically greater on the outer coast areas than the Puget Sound as seen by the number of declared coastal flooding disasters by county. Areas of the outer coast experience similar still water levels, but have greater potential for higher overall water levels and flooding when adding in wave run-up.



NWSA Harbor Extreme Water Level Events

Sea level rise and coastal flooding are an emerging threat with greater risk in future years. Both harbors are already seeing the impacts of rising water levels as both harbors experienced record water levels twice in 2022. What was previously thought to be a 5, 20, 50, or 100-yr high water event will be much more common in the future with SLR.

	Seattle Harbor		Tacoma Harbor	
Top 5 High Water Levels	Water Level (ft MHHW)	Date	Water Level (ft MHHW)	Date
1	3.76	2022-12-27	3.87	2022-12-27
2	3.16	2022-01-07	3.25	2022-01-07
3	3.12	1983-01-27	3.09	2012-12-17
4	3.12	2012-12-17	2.93	2016-03-10
5	3.10	1977-12-15	2.76	2003-01-03



The record tide in the **Tacoma Harbor** caused flooding on freight corridors including local roadways and rail. The high tides kept stormwater systems from draining, causing upland urban flooding issues.

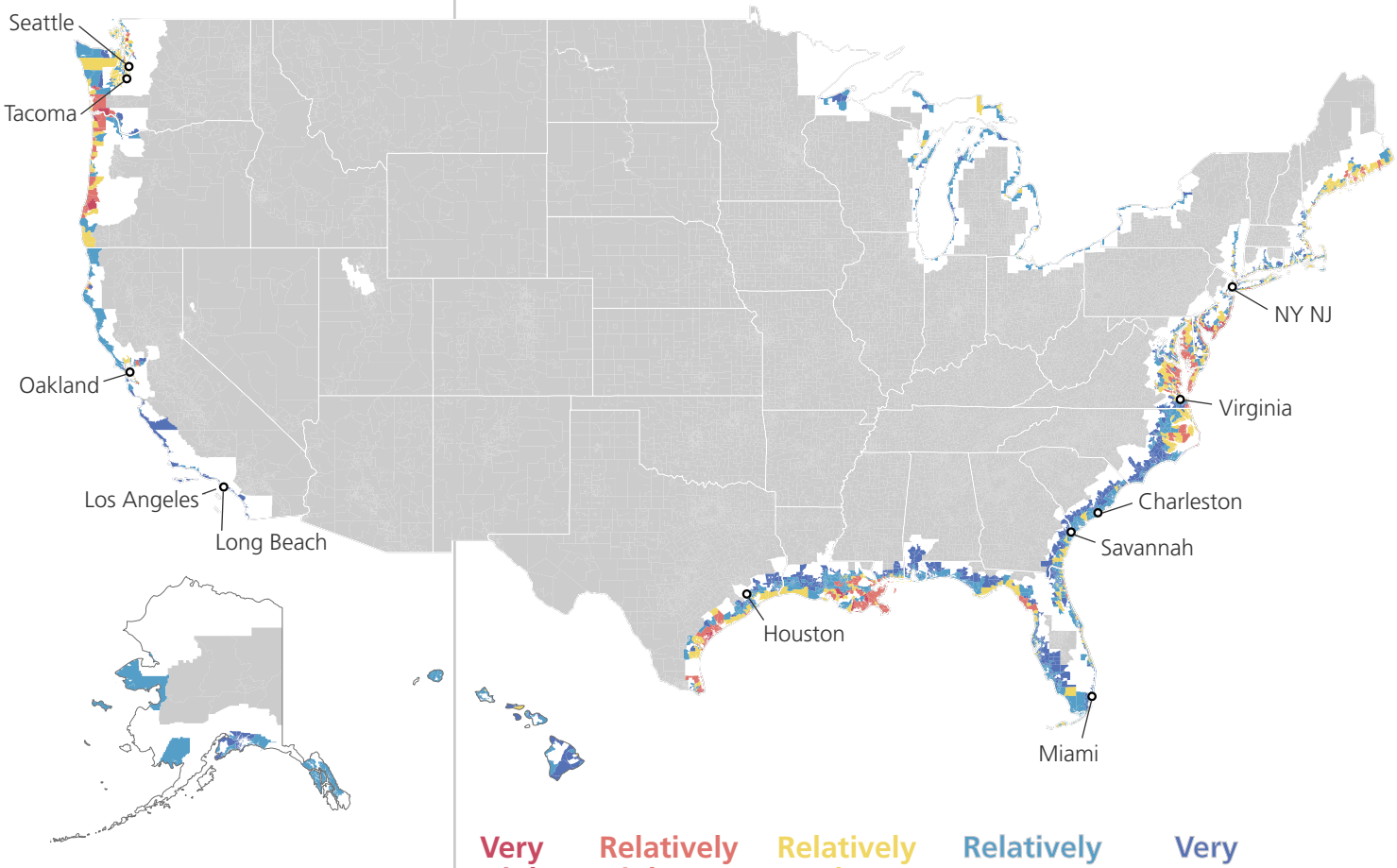
The record tide in the **Seattle Harbor** caused the Duwamish River to overtop its banks, flooding the South Park neighborhood in Seattle's Duwamish Manufacturing / Industrial Center.

Both harbors experienced record tide levels in December 2022 when king tides coincided with a low pressure system, heavy rain, and snowmelt.

- Top Container Port
- Very High
- Relatively High
- Relatively Moderate
- Relatively Low
- Very Low
- Not Applicable
- No Rating

COASTAL FLOODING RISK AT TOP 10 US CONTAINER PORTS

The Federal Emergency Management Agency (FEMA) has mapped and quantified the coastal flooding risk across the United States based on expected annual loss, social vulnerability, and community resilience. The coastal flooding risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties. This risk index does not account for future coastal flooding with sea level rise.



Very High	Relatively High	Relatively Moderate	Relatively Low	Very Low
NY NJ	NY NJ	Miami	**NWSA Seattle**	Long Beach
		NY NJ	**NWSA Tacoma**	Los Angeles
		Virginia	Charleston	
			Houston	
			Oakland	
			Savannah	

HAZARD CHARACTERIZATION AND IMPACTS

Sea level rise and coastal flooding hazard risk is based on hazard likelihood, scale, exposure, and areas of susceptibility. Hazards are characterized by their likelihood and scale and vulnerabilities are determined by exposure and susceptibility to the hazard. Coastal flooding and sea level rise is an emerging threat that doesn't pose a major risk today but will have significantly greater risk levels in future decades. The vulnerability scores below reflect a mid-century scenario and will be higher by end of century without adaptation.

COASTAL FLOODING HAZARDS

Likelihood	HIGH
Scale	MODERATE
Outlook	HIGH
Hazard Type	EMERGING

IMPACTS TO NWSA

Exposure	LOW
Safety	LOW
Operations	LOW
Facilities	LOW
Equipment	LOW
Commerce	LOW
Organization	LOW

IMPACTS TO GATEWAY

Exposure	LOW
Roadways	LOW
Railroads	MODERATE
Waterways	LOW
Utilities	LOW
Industrial	LOW
Community	MODERATE
Environment	LOW

Careful consideration of future sea levels in project design can ensure that cargo operations successfully continue in the face of rising tides.

Extreme high tides can pose operational challenges for roll-on/roll-off operations. The vessel may sit too high in the water relative to the wharf, making the cargo ramps too steep and temporarily inoperable.

The use of green infrastructure such as natural shorelines can help protect upland terminal areas from coastal erosion caused by coastal flooding and SLR.

HAZARD INFORMATION

LIKELIHOOD

HIGH

Likelihood of occurring on any given year

1. Sea level rise and coastal flooding is a high likelihood hazard.
2. Extreme still water levels resulting from storm surge are generally higher on the outer coast than the Puget Sound. The return frequency for extreme still water levels is between 2.2′ MHHW for a 2-yr flood event and 3.2′ for a 200-yr event in the Puget Sound and between 2.9′ MHHW and 4.0′ MHHW on the outer coast.
3. Extreme total water levels that include wave run-up are limited in the Puget Sound and less than 2.5′ additional feet above the still water level for a 2-yr event. Wave run-up on the outer coast can account for an additional 10′ above the still water levels for 100-yr events.
4. By mid-century, Washington is likely to experience 0.4′ - 0.8′ of absolute SLR in a low emissions scenario and 0.5′ - 0.9′ in a high emissions scenario. By end of century Washington is likely to experience 1.0′ - 2.2′ in a low emissions scenario and 1.4′ - 2.8′ in a high emissions scenario. These figures will vary locally depending on the amount of vertical land movement.

SCALE

MODERATE

Magnitude event with regional scale

5. SLR will increase the overall sea levels around the world. In Washington, this will making today's 100-yr flood event similar to a normal high tide by end of century. Coastal flood events in the future will be much greater in terms of their extent with SLR.
6. While sea level rise and coastal flooding has the potential to be devastating for coastal areas in future years without adaptation measures, impacts will be limited to coastal areas.
7. The amount of SLR that a particular area experiences is affected by the amount of vertical land movement. Areas that are subsiding will experience greater amounts of SLR compared to absolute SLR and areas that experience uplift will experience less SLR compared to the absolute SLR. The Puget Sound is estimated to generally experience subsidence while many areas of Washington's outer coast are expected to uplift.

OUTLOOK

HIGH

Level of increasing risk in future decades

8. There is an increasing amount of risk over time associated with SLR and coastal flooding. SLR has already been observed and will still occur despite efforts to reduce emissions. However, aggressive emissions reductions can help reduce the future amounts of SLR.
9. The rate of sea level rise (SLR) is generally slower in the near term but is expected to increase rapidly after mid-century, greatly increasing exposure to coastal flooding.
10. While there are policies that limit development in zones prone to coastal flooding, many coastal areas will be at risk in future decades as areas of coastal flooding expand.
11. Planning for SLR can help reduce exposure by limiting new development in areas that will flood in the future or designing new development to be compatible with future sea levels. Future adaptation measures will likely be needed to protect or relocate existing infrastructure located in areas that will be vulnerable.

EXPOSURE

LOW

NWSA exposure

1. Coastal flooding occurs in limited areas in both harbors during extreme coastal water level events. These typically occur when storm surge coincides with a high tide. Coastal flooding is more likely to occur during king tides in the late fall and winter months.
2. Only a few NWSA terminals are in FEMA-designated coastal flood zones and experience partial flooding during high tides and storm events.
3. In recent years tides have regularly reached 2'+ MHHW in both harbors and up to 3.76' MHHW in Seattle and 3.90' MHHW in Tacoma, causing minor flooding.
4. Both harbors experiences limited wave run-up compared to areas of the outer coast. A 2-yr storm event generally creates waves that are less than 2.5'.
5. The rate of sea level rise (SLR) is generally slower in the near term but is expected to increase rapidly after mid-century, greatly increasing exposure to coastal flooding in both harbors.
6. Both harbors are expected to see roughly 1' of SLR by mid-century and 3' of SLR by end of century. One foot of SLR is expected to slightly increase coastal flooding and three feet of SLR could greatly increase flooding, especially when combined with a storm event.
7. SLR can contribute to on-terminal flooding from multiple sources including tidal flooding, stormwater, and groundwater.
8. Tidal flooding can occur if the tide exceeds the terminal elevation and the water comes up over the shoreline or wharf. Tidal waters may also flood the terminal by traveling up the stormwater system if there aren't backflow prevention devices.
9. Higher sea levels may also cause on-terminal flooding if they impede stormwater conveyance. If the tides are higher than terminal outfalls, stormwater can't drain during tide cycles.
10. SLR can contribute to a rise groundwater levels and groundwater flooding.

SAFETY

LOW

Impact to safety and worker health

11. Flooding from SLR can create unsafe working conditions on terminals from standing water or wave run-up with chances of injury or drowning. Saltwater exposure to electrical infrastructure can also threaten life safety with potential for electrocution.
12. SLR is generally considered a low life safety concern since areas affected by higher water levels can generally be avoided by following the tides and flood watches. It could be a public safety concern for terminal operations if flooding affects emergency routes.
13. SLR may impact worker health if buildings are flooded and grow mold, causing or exacerbating respiratory disease. It may also increase exposure to pollutants if workers are in standing water.
14. Without future adaptation measures, SLR will have a greater negative impact on safety in the coming decades.

OPERATIONS

LOW

Impact to terminal operations

15. Coastal flooding currently has a minor impact on operations at several terminals during extreme water levels. Operations may be temporarily shut down in flooded terminal areas until the water recedes. Areas damaged by flooding may need to be shut down for repairs.
16. Some terminal operations may be especially susceptible to higher water levels even if flooding doesn't occur on the terminal. Roll-on/roll-off operations can be sensitive to high water levels since they raise vessels relative to the wharf. Cargo ramps may become temporarily inoperable if there is too large of an elevation difference between the vessel and the wharf.
17. Terminal productivity may go down as workers have to focus on repositioning cargo to keep it out of flooded areas or dealing with the floodwater, debris, and cleanup in the aftermath.
18. Terminal productivity may go down if the ability to get cargo to and from the terminal is affected by flooding or workers can't get to and from the site.
19. Without future adaptation measures, SLR will have a greater negative impact on operations in the coming decades as more areas become inundated semi-regularly.

FACILITIES

LOW

Impact to NWSA facilities

20. SLR has a low impact on facilities in the near-term with limited areas exposed to coastal flooding. Without future adaptation measures, facilities could be regularly inundated and damaged, limiting functionality, shortening their life expectancy, and increasing maintenance and repair costs. Saltwater is especially corrosive, further exacerbating the impact to facilities.
21. Waterfront structures like wharfs are durable and built to handle the harsh maritime environment, but their utility systems such as crane power, shore power, and water may be susceptible to damage from exposure to higher water levels and wave action. Many of the utilities are located under the wharf apron and will be exposed to higher water levels before water overtops the wharf and terminal areas.
22. Upland facilities like buildings and utility systems may be damaged if exposed to saltwater. Electrical and mechanical systems are especially vulnerable and may be damaged if exposed to floodwater above ground. Even underground infrastructure such as utilities in vaults or air systems for train operations may be damaged if water gets in the vaults.
23. Higher water levels may affect stormwater systems, which are tidally influenced and use gravity to drain. Without backflow prevention devices, saltwater can travel up pipes onto the terminal causing flooding. Pumping and storage systems may be needed to reduce on-terminal flooding and the amount of stormwater that bypasses treatment systems.
24. Stormwater treatment systems can be damaged if saltwater enters the stormwater system and fouls the treatment media.
25. Facilities can be damaged even if water doesn't flood the terminal since higher water levels can lead to greater wave action and scour, destabilizing terminal shorelines and compromising assets in the area.
26. As SLR leads to increases in groundwater levels, it can compromise subgrades and pavement, leading to areas of settlement. Rising groundwater levels can also affect the movement of contaminants at cleanup sites.

EQUIPMENT

LOW

Impact to cargo-handling equipment and fleet vehicles

(27) Terminal equipment is generally heavy duty and able to withstand the elements, but saltwater is especially corrosive. Equipment exposure to saltwater can damage the mechanical and electrical components and shorten life expectancy.

(28) In the event of coastal flooding, some equipment may be repositioned on the terminal to get it out of flood-prone areas if sufficient space is available.

(29) Transitioning to more electric-powered Cargo Handling Equipment (CHE) may require additional protective measures against SLR and coastal flooding. Electrified equipment relies on electrical cables or charging infrastructure which can be susceptible to saltwater exposure. Even though underground vaults for power infrastructure are typically designed to be water-tight, there can be issues with water penetration.

(30) SLR raises water levels and vessels relative to wharfs with ship-to-shore cranes and may create issues with vertical clearance or aerial draft between the vessel and crane booms. Terminals with shorter cranes are especially susceptible to higher water levels and may limit how many containers can be stacked on a vessel.

COMMERCE

LOW

Impact to business and cargo volumes

(31) Regular flooding on terminals from failure to adapt can make it hard to secure long-term leases for vulnerable terminals and disrupt revenue streams.

(32) Cargo may be damaged if exposed to floodwaters. Cargo that is on the ground is more susceptible to flooding than cargo that is stored in tanks or elevated off the ground. Other cargo such as autos and breakbulk may be damaged if water levels are high enough to damage sensitive components.

(33) As SLR increases and affects facilities, equipment, and operations, it increases the cost of doing business in the Gateway. More resources including money and workers' time would need to be invested in basic repairs to facilities and equipment, and operators may have to halt operations or adjust their operating hours around tide windows, potentially during more expensive shift times.

ORGANIZATION

LOW

Impact to organizational resilience

(34) Flooding is not expected to cause a major disruption to the organization. Flooding on or off-terminal could disrupt operations and business leading to a loss of revenue.

(35) Failure to adapt to future SLR could limit the ability to carry out the essential functions of the NWSA including moving cargo through port facilities.

(36) Coastal flooding and sea level rise could affect the NWSA and homeport office spaces in either harbor which are located along the shoreline or above the water. Coastal flooding has already affected office spaces in the Tacoma Harbor with shoreline erosion under the Administrative Building.

(37) Administrative staff that work indoors would be able to carry out their normal work duties either at one of the offices or from home in the event of coastal flooding. Staff that work in the field may be affected and have to adjust their work around tide windows.

(38) Future high-water levels may make it may be harder to get flood insurance to cover damage to facilities, equipment, and cargo. Current practice in writing terminal leases is to make the tenant responsible for flood damage to the cargo. SLR can be expected to change the view of prospective tenants who may still be interested in the lease, but only with risks shifted towards the NWSA and homeports.

IMPACTS TO **GATEWAY**

EXPOSURE

LOW

Exposure across the gateway

1. Coastal flooding occurs in limited areas during extreme coastal water level events. These typically occur when storm surge coincides with a high tide. Coastal flooding is more likely to occur during king tides in the late fall and winter months.
2. Many coastal areas across the state are in FEMA-designated coastal flood zones and experience flooding during extreme high tides and storm events.
3. Extreme still water levels resulting from storm surge are generally higher on the outer coast than the Puget Sound. The return frequency for extreme still water levels is between 2.2′ MHHW for a 2-yr event and 3.2′ for a 200-yr event in the Puget Sound and between 2.9′ MHHW and 4.0′ MHHW on the outer coast.
4. Extreme total water levels that include wave run-up are limited in the Puget Sound and less than 2.5′ additional feet above the still water level for a 2-yr event. Wave run-up on the outer coast can account for an additional 10′ above the still water levels for 100-yr events.
5. The rate of SLR is generally slower in the near term but is expected to increase rapidly after mid-century, greatly increasing exposure to coastal flooding in the gateway.
6. Washington's coastal areas are expected to see roughly 1′ of SLR by mid-century and 3′ of SLR by end of century. One foot of SLR is expected to slightly increase coastal flooding and three feet of SLR could greatly increase flooding.
7. SLR can contribute to additional tidal flooding, stormwater flooding, and groundwater flooding across the gateway.

ROADWAYS

LOW

Impact to truck travel on freight roadways

8. Only a few roadway locations are susceptible to minor coastal flooding today.
9. Most of the freight roadways are set back from shorelines and not expected to experience damage from rising waters that cause shoreline destabilization.
10. Major roadways like I-5 are generally located away from coastal flooding zones that will be affected by SLR, but certain areas like bridges over rivers and river deltas may be vulnerable if flooding affects bridge abutments.
11. Coastal flooding on roadways can slow travel or in severe cases, cause temporary shutdowns of roadway segments.

RAILROADS

MODERATE

Impact to rail travel on freight railroads

12. Rail corridors that follow shorelines are susceptible to coastal flooding and will be more vulnerable in future decades.
13. SLR and wave action may erode shorelines and compromise waterfront structures, damaging rail-beds, rail tracks, and rail bridges. Floodwaters can also lead to erosion of coastal bluffs adjacent to the tracks, potentially triggering landslides on rail corridors.
14. Inundation can compromise assets with saltwater corrosion and may impact electrical and mechanical components such as signals, switches, and interlockings. In extreme flooding events, floodwaters can damage rail locomotives and even railcars.
15. Inundation of rail corridors may impact operations, slowing or even halting train operations until floodwaters recede and damage is repaired.

WATERWAYS

LOW

Impact to vessel travel on navigable waterways

16. SLR can have a positive impact on the waterways by increasing their depth. This could create operational efficiencies for vessel movements by increasing their transit windows for moving to and from berths and the deep harbors.
17. SLR raises the waterways and vessels relative to fixed infrastructure like bridges, wharfs, and cranes. This can create issues with vertical clearance or air draft as vessels need to pass under crane booms and bridges.
18. SLR and higher wave action may erode and destabilize terminal shorelines enough to impede navigation if not maintained and repaired.

UTILITIES

LOW

Impact to gateway utilities

19. Initial impacts from SLR are likely to occur in systems that are influenced or by tidal elevations, such as stormwater or wastewater infrastructure and buried electrical system components, especially when terminations and splices are in a vault beneath the pavement surface.
20. Utility systems that are sensitive to tidal elevations may experience gradual loss of function over time depending on design, potentially leading to increased flood risk during coastal storm events.
21. Systems such as wastewater treatment plants and surface water infrastructure that rely on pump systems could become jeopardized if increased tidal elevations exceed design capacity or add more stress to system operations.

INDUSTRIAL

LOW

Impact to region's cargo support facilities

22. Most of the regional supply of industrial lands that support cargo operations are located away from shorelines and coastal flooding areas.
23. The industrial lands most at risk in future decades are those near terminal facilities within the Duwamish and Port of Tacoma Manufacturing/Industrial Centers (MICs).

COMMUNITY

MODERATE

Impact to gateway communities

24. Without future adaptation measures across the gateway, it will be difficult in the long term to protect the economic resilience of the region for communities and industries tied to the waterfront.
25. SLR could affect both coastal and inland communities as supply chains realign with trade lanes that have successfully adapted.
26. Failure to adapt would ultimately increase the cost of doing business in the gateway, increasing transport costs for exporters and consumers.
27. SLR could affect the ancestral lands of the Coast Salish Tribes in our Gateway and may also affect near-port and waterfront communities that are vulnerable to SLR.

EMPOWERMENT

LOW

Impact to organizational resilience

28. SLR and coastal flooding can affect cleanup sites in industrial areas that have legacy contamination. Higher, faster estuarine flows could compromise environmental caps. SLR and flooding may transport near-surface contaminants to other nearby properties. Rising groundwater levels can also affect cleanup efforts by altering subsurface contaminant plumes.
29. SLR can affect shorelines and riparian zones that are home to wildlife. Marsh and riparian vegetation may fail due to increased inundation periods or migrate upland. Fish fry and juvenile salmonids benefit from access to shallow, low-velocity habitat and SLR can increase the depth and velocity of these habitat areas.
30. SLR and coastal flooding can cause stormwater to bypasses treatment systems and go directly in the waterways, negatively affecting water quality.

Mean Higher-High Water
(0' MHHW)

The 0' Mean Higher-High Water (MHHW) line is representative of the typical high tide today but doesn't account for areas that may be inundated by wave runup.

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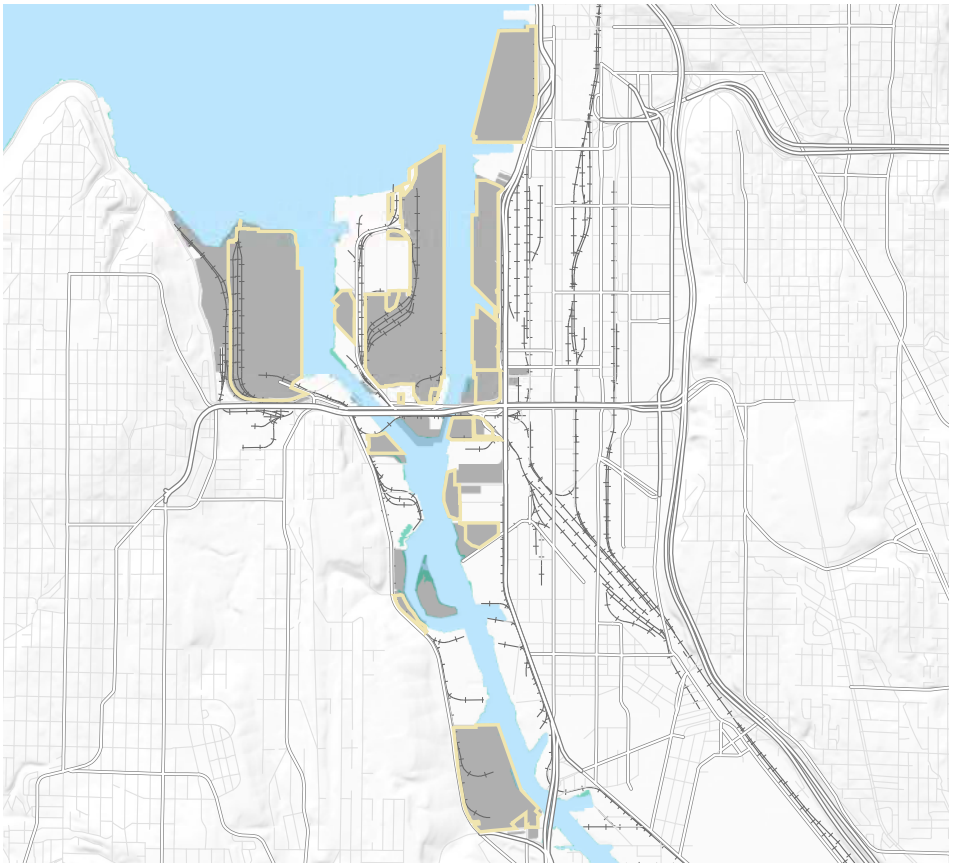
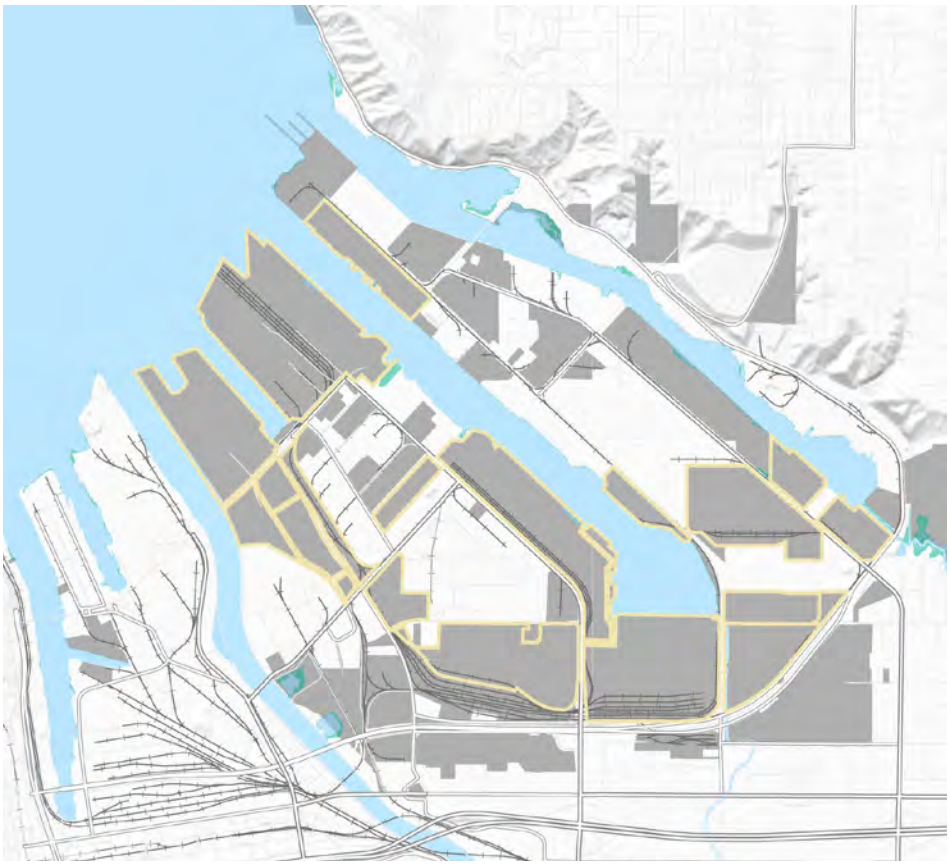
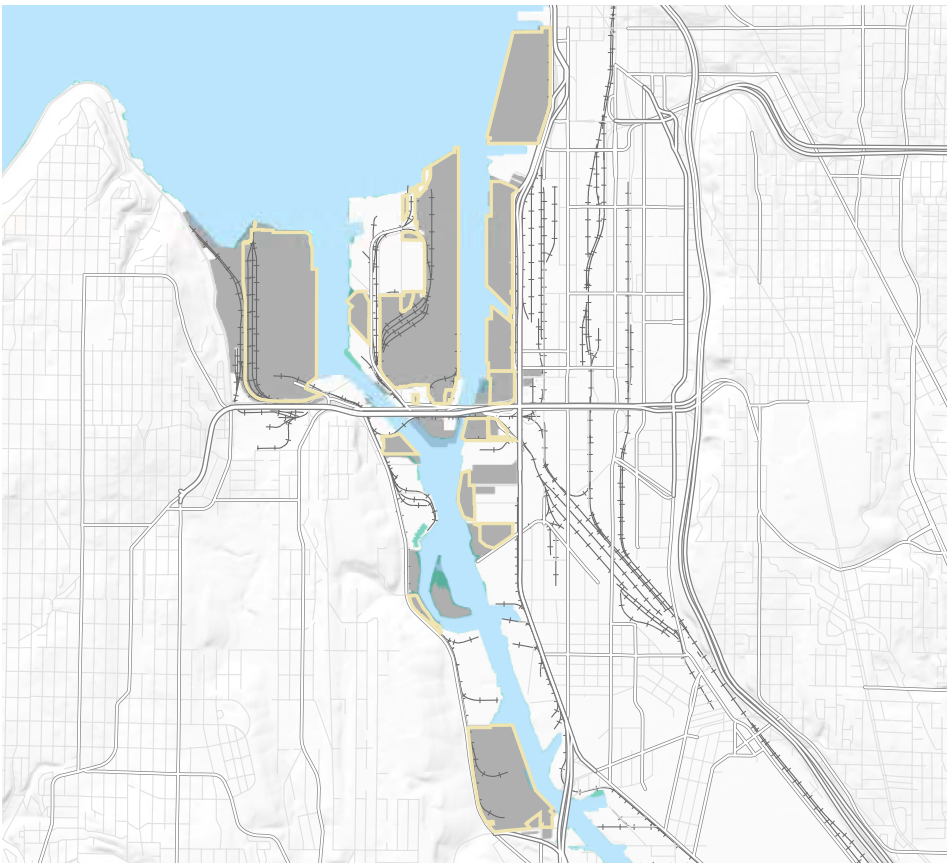
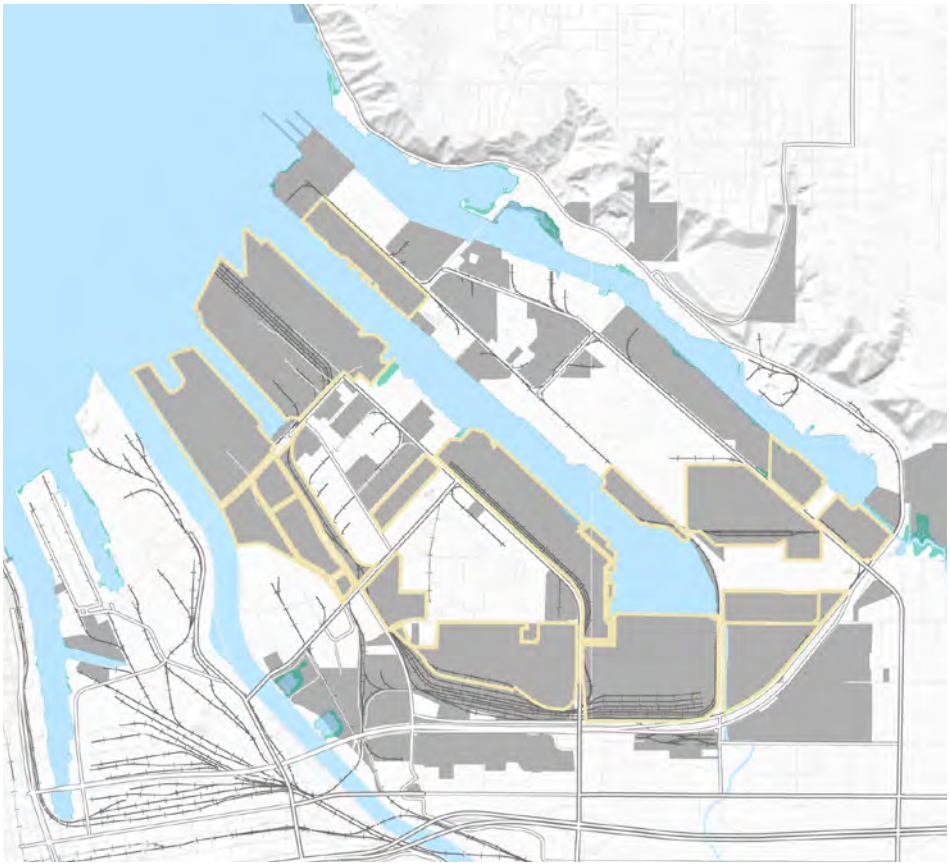
Inundated Areas









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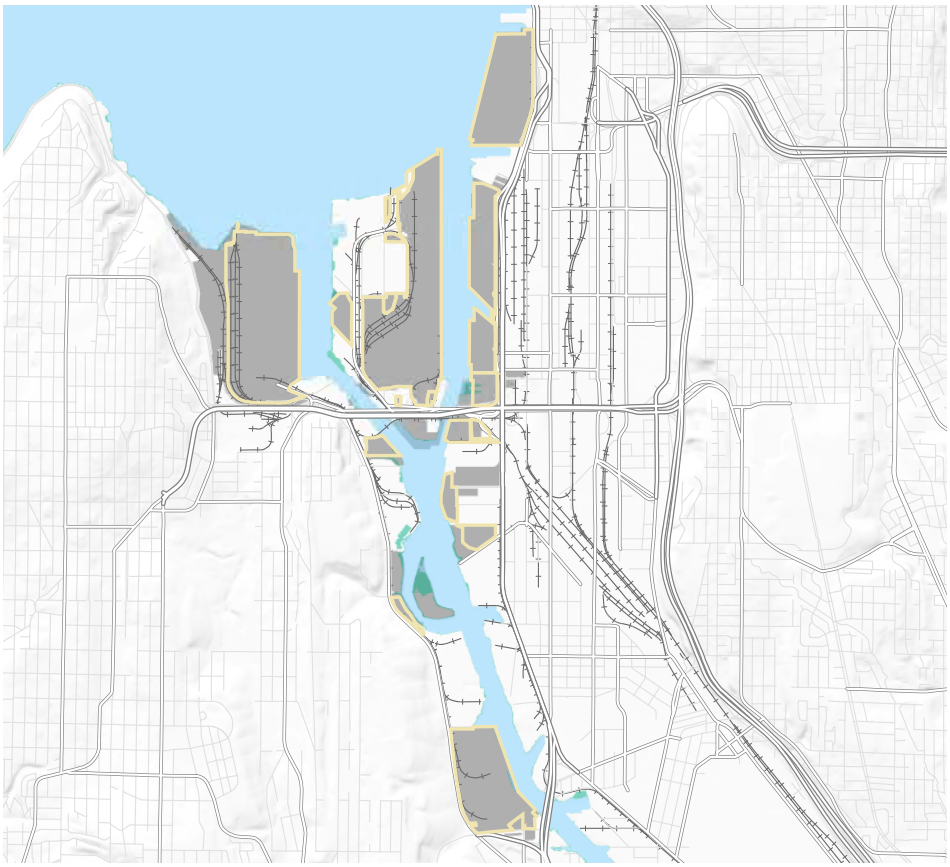

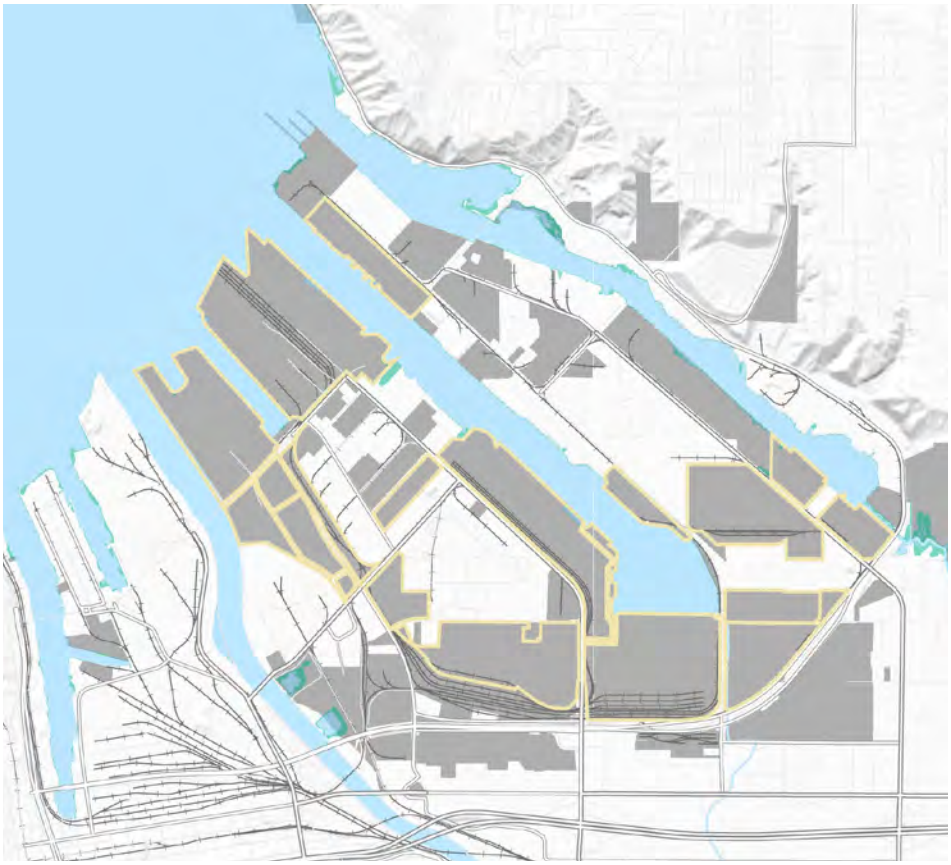

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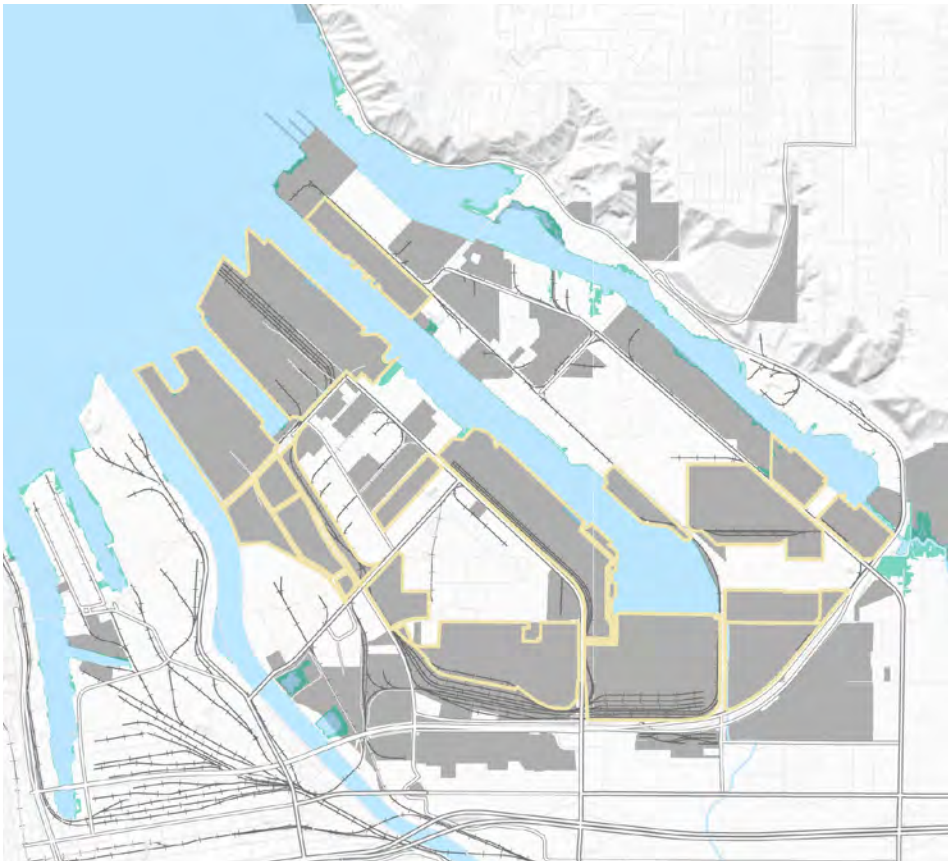

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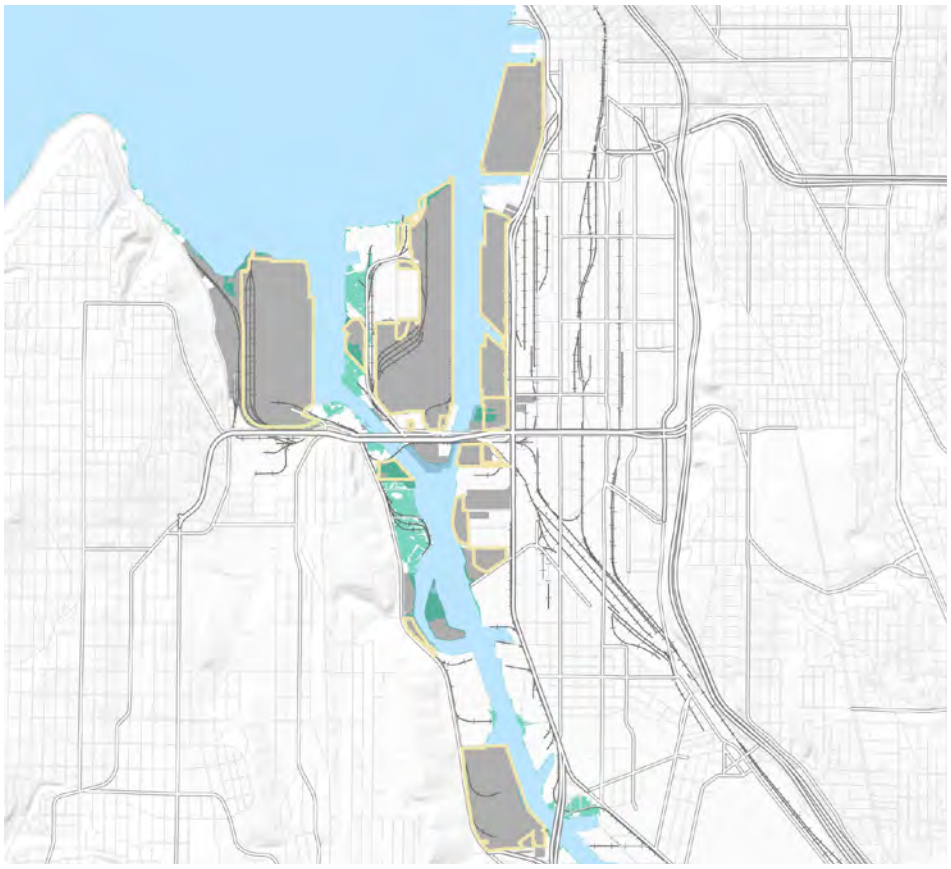

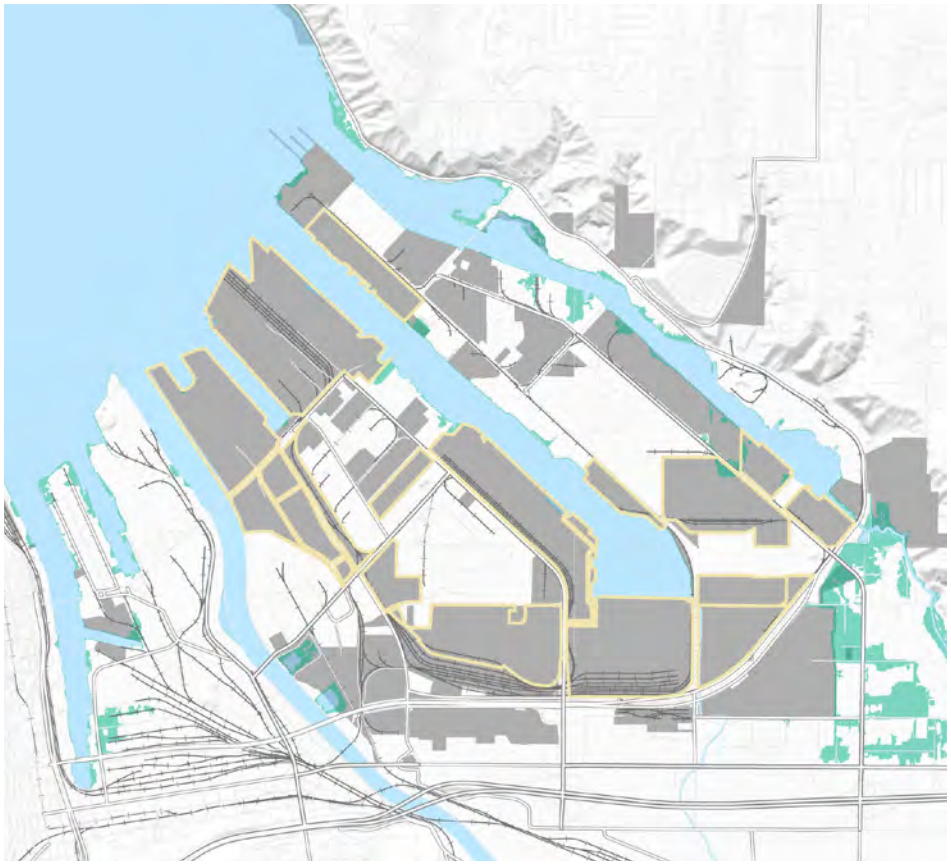

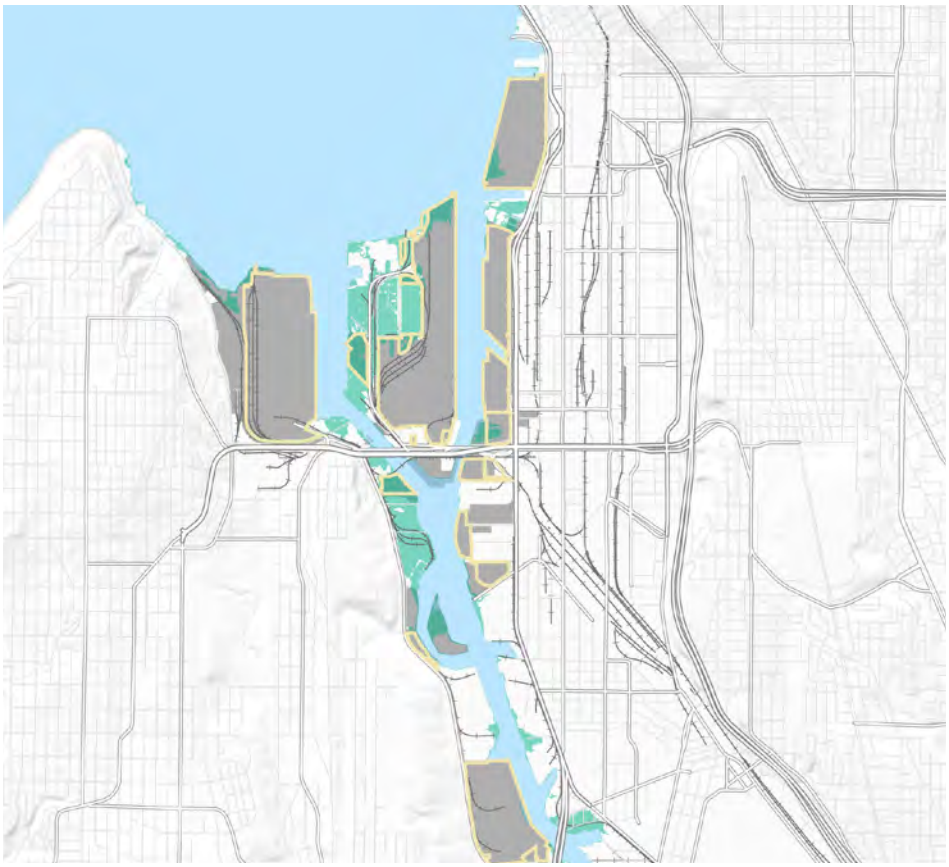

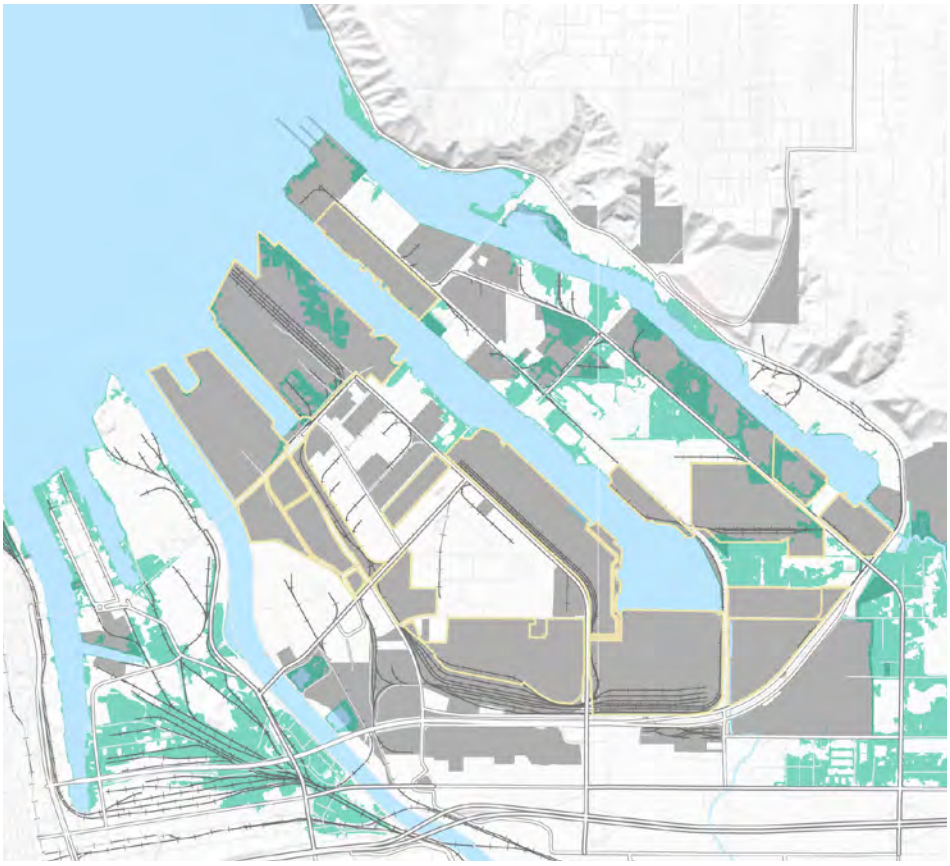

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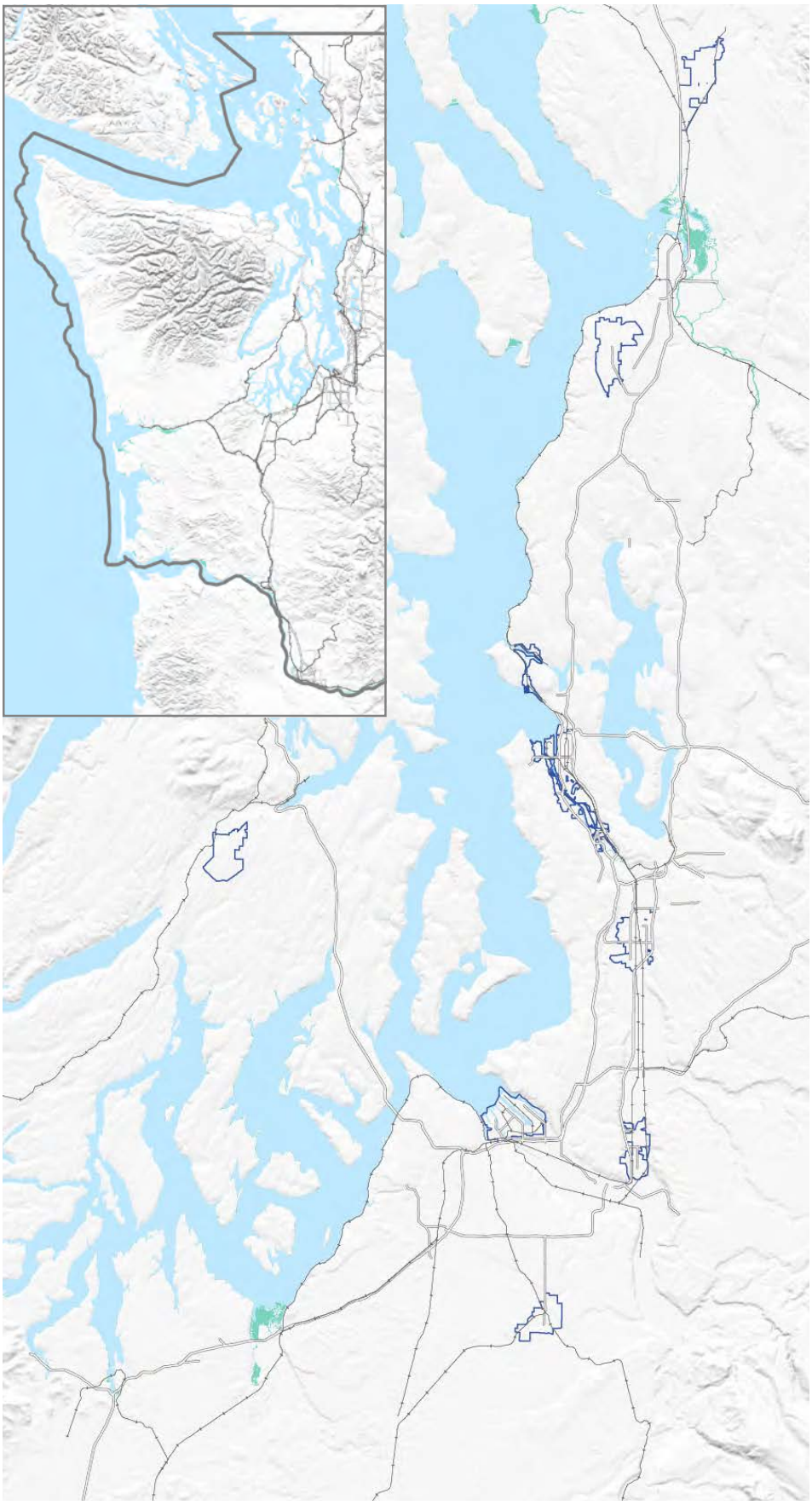

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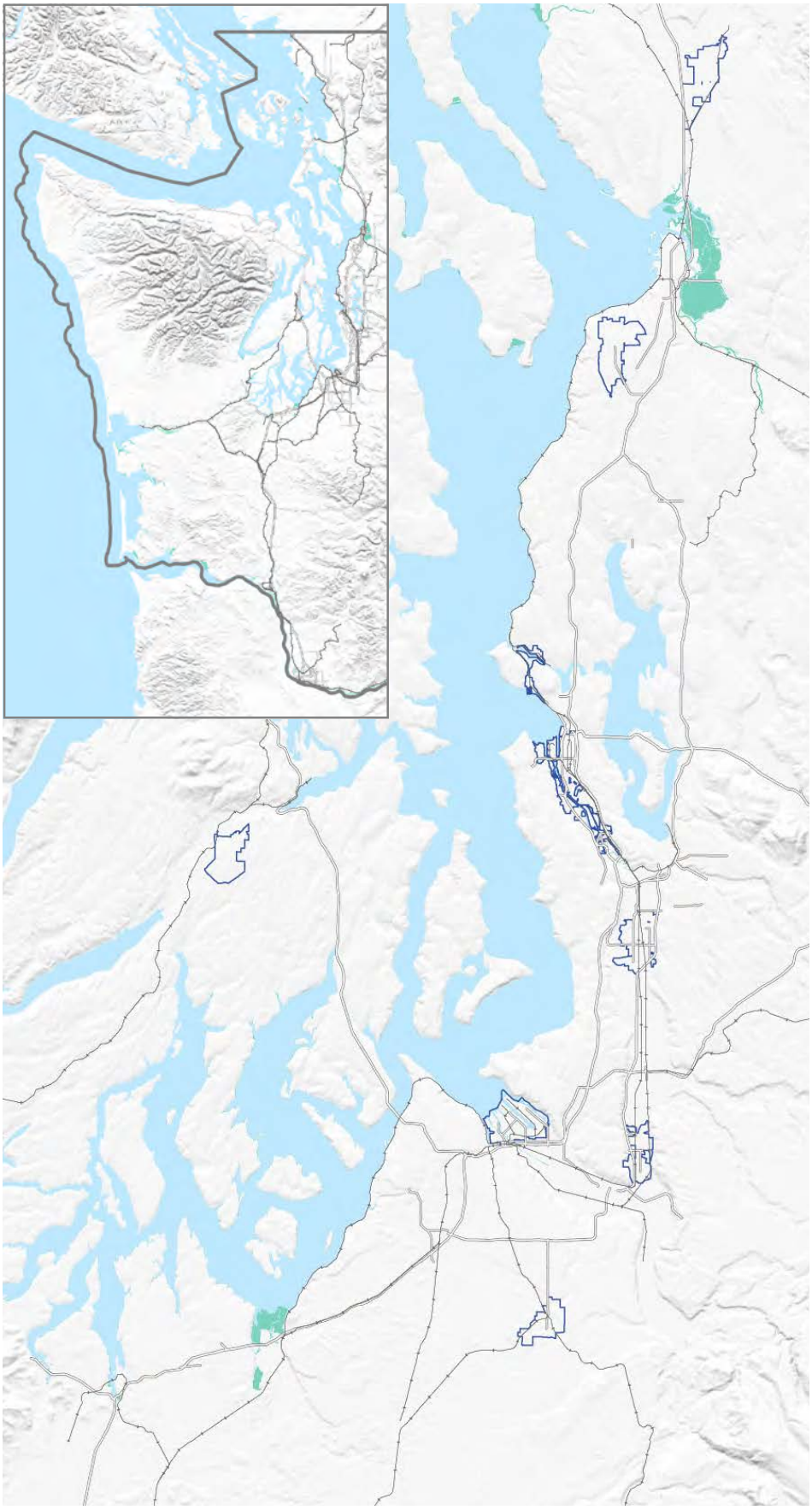

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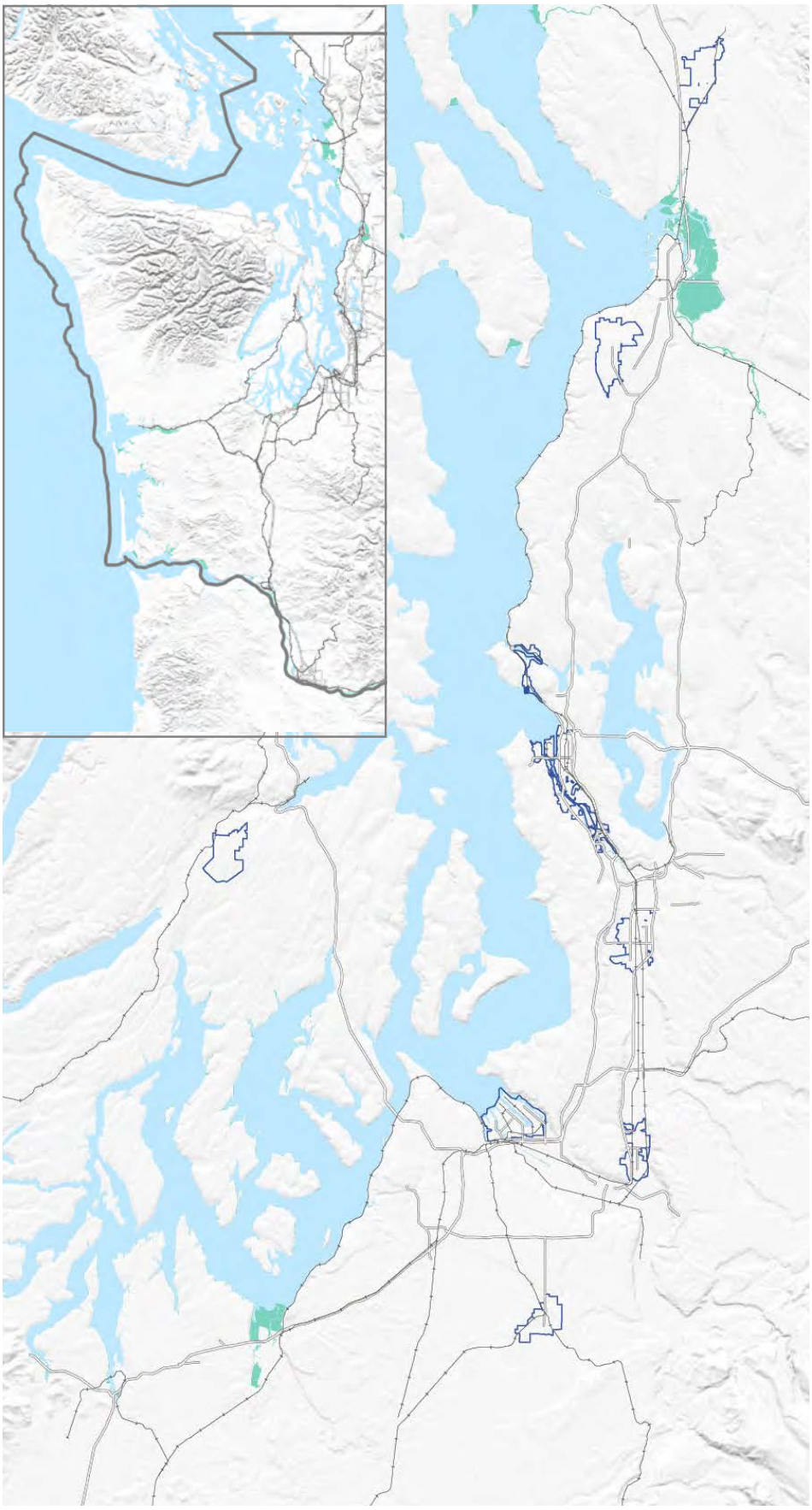

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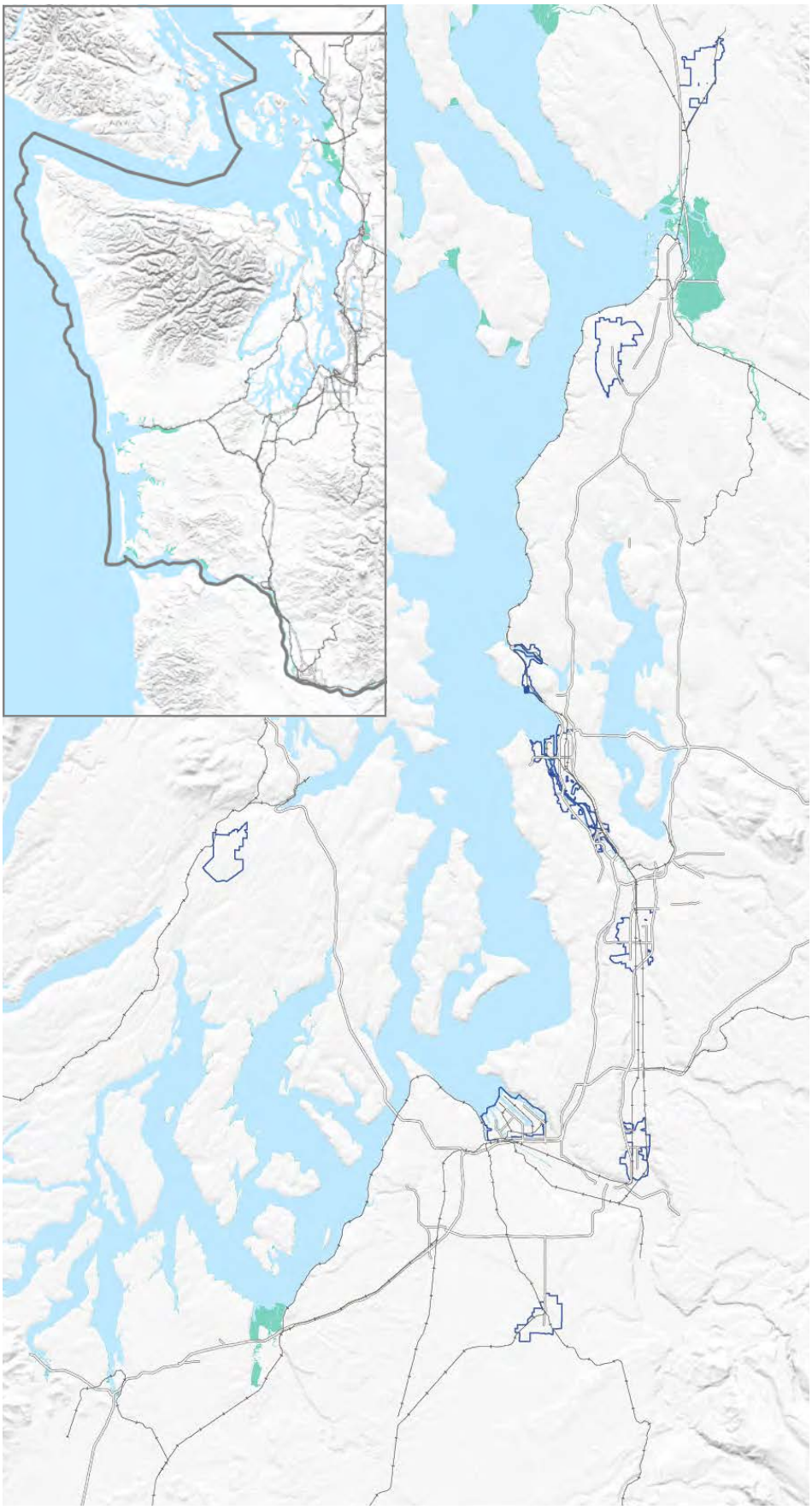

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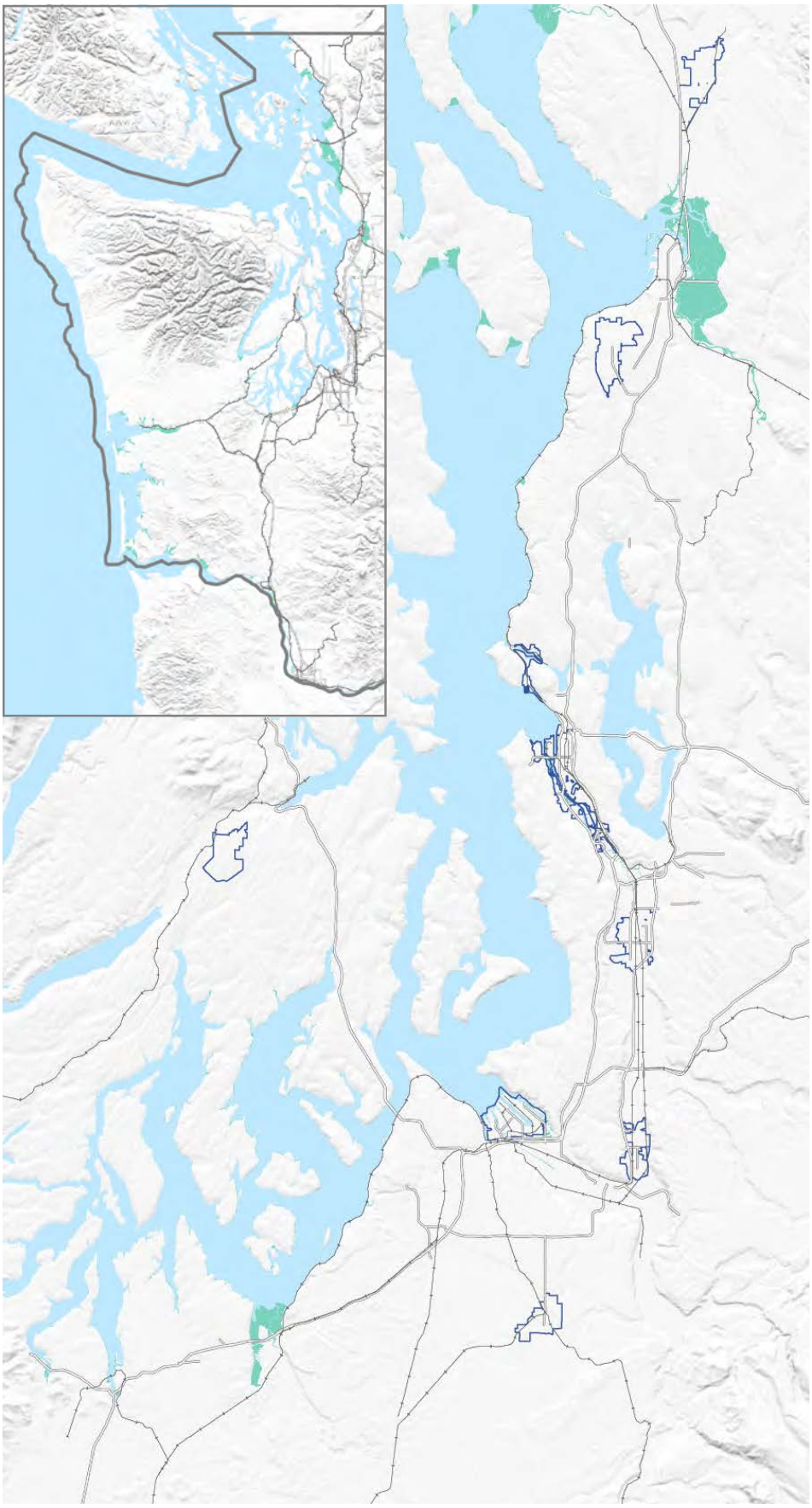

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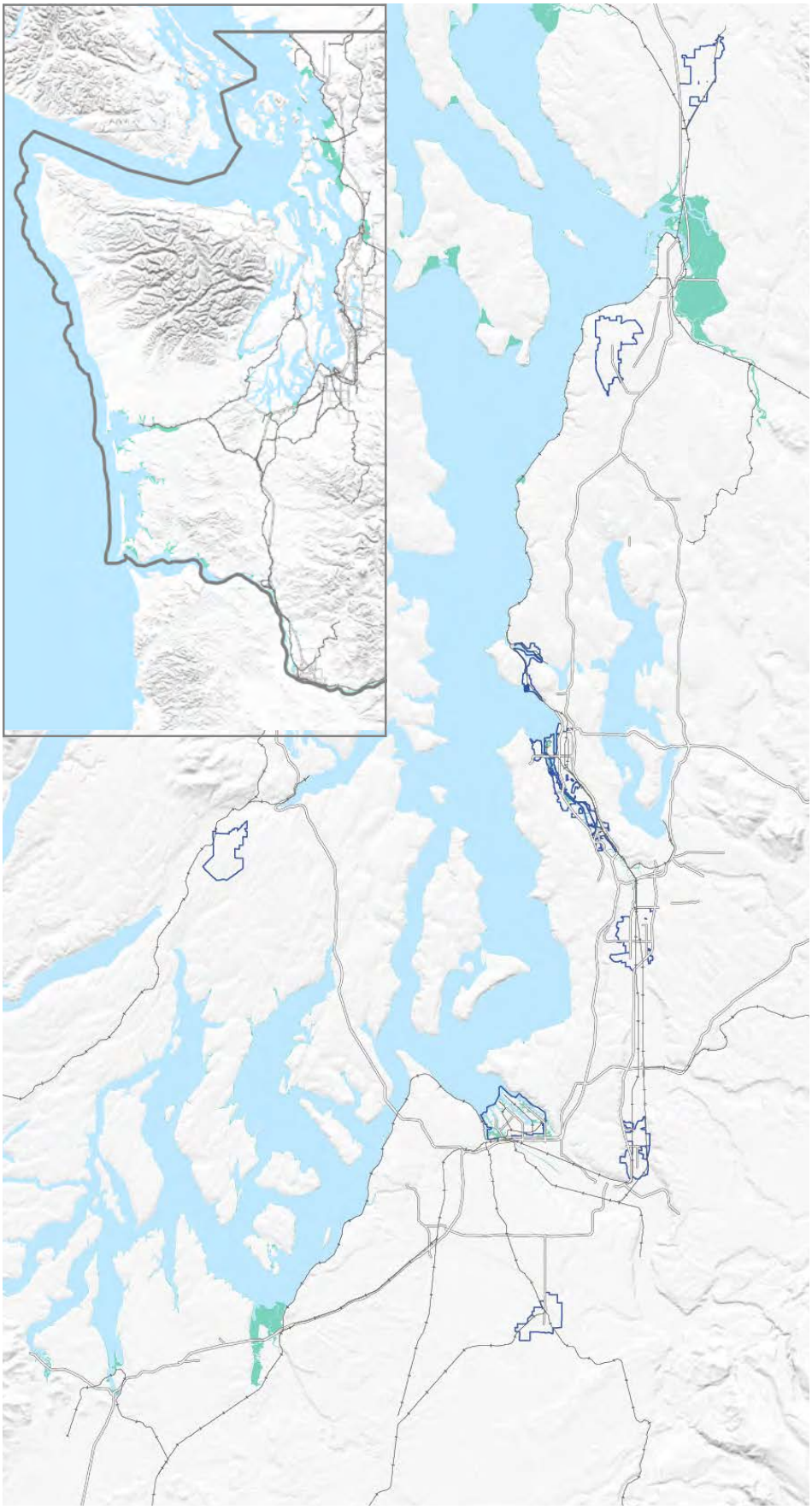

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Inundated Areas


Flooding is the most
frequent and expensive
natural disaster
in the United States.

CHRONIC HAZARDS

have a high likelihood of occuring but are typically smaller in scale and impact. They includes most of the hazards that are seasonal in nature.

FLOODING

SEVERE WEATHER

WILDFIRES & SMOKE

LANDSLIDES

While flooding is common in Washington, its overall flood risk rating is typically low compared to most of the country.

Bullfrog Junction Ditch (shown above) in the Tacoma Tideflats is a critical link between rail in the Tideflats and the mainlines. Urban flooding issues here have caused flooding on nearby properties and have the potential to disrupt rail operations.

A SEASONAL, HIGH LIKELIHOOD EVENT

Flooding is the inundation of land that is normally above water. As a result, it may pose a threat to life and property, potentially harming unprotected low-lying communities and infrastructure. This chapter focus on inland flooding hazards such as riverine, urban, groundwater, and infrastructure failure. Coastal flooding is covered in the Sea Level Rise chapter.

Flooding is the most frequent and expensive natural disaster in the United States. Since it is a meteorological hazard, it is seasonal in nature. It is typically brought about by heavy precipitation or snowmelt. In Western Washington, flooding is common during the wet winter months when there are large rainstorms. In Eastern Washington, flooding is more common in the spring and summer when there is rapid snowmelt or summer thunderstorms. Flooding may occur outside of the typical flooding seasons, especially if it occurs as a result of infrastructure failure or other natural hazards. Landslides can cause flooding if debris blocks rivers and streams and wildfires may also cause flooding since burned areas typically experience increases in stormwater runoff.

There are several types of flood hazards including:

Riverine – Excessive rainfall or or snowmelt may cause a river to exceed its capacity and overflow their riverbanks.

Urban – Flooding may occur when stormwater systems can't handle the amount of rain that occurs in a storm or when water pools in low-lying areas without drainage.

Groundwater – Rainfall may temporarily raise the water table above land, causing pooling of water at the surface.

Infrastructure Failure – Flooding may occur from failure of flood control infrastructure such as levee overtopping or a dam failure.

The 2007 flooding in Centralia and Chehalis (shown right) impacted communities and movement of goods through the region. Twenty miles of I-5 were closed for four days, resulting in a detour route that added 240 miles of driving per trip between Seattle and Portland. The road closure caused almost $50 million in losses from freight delays alone.

PAST EVENTS

Flooding is a high likelihood event in Washington with hundreds of recorded flood events. Many of these are smaller events, but a few stand out because of the extent of the flooding, number of casualties, and flood damage.

1894 Record flooding on the Columbia River wiped out Fort Cascade and the town of Cascade, WA. The town was never rebuilt.

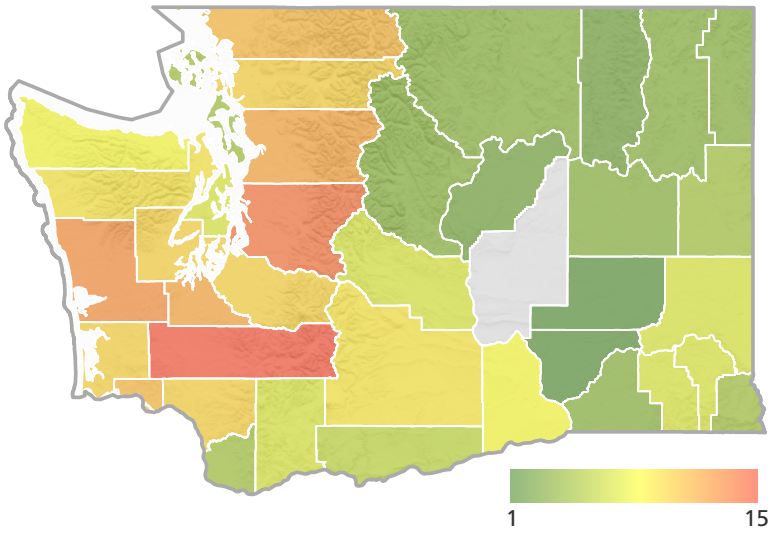
1948 Significant flooding occurred within the Columbia River Basin, damaging 5,000 homes, causing evacuations of 50,000 people, and $100 million in damage.

1996 Flooding occurred across the Pacific Norhtwest. Heavy rain and rapid snowmelt produced record and near-record flooding, mudslides, and avalanches. Flooding resulted in three fatalitites, damage to over 2,600 homes, destruction of dozens of bridges, and $120 million in damage.

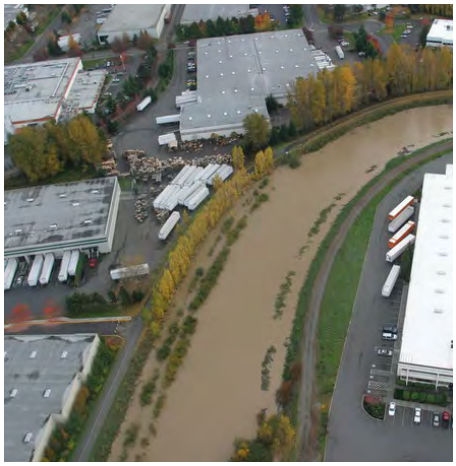
2006 This was the wettest November on record with 10-38" of rain in the Cascades and Olympics and 4-10" of rain in the Western Washington lowlands. There was widespread flooding in all of the Western Washington rivers and several rivers East of the Cascades flooded too. Flooding resulted in $70M in damage.

2007 Three rainstorms and melting snowpack caused record flooding in several areas of Western Washington.

Washington's Declared Flooding Disasters by County



The Green River flooded in 1959, devastating the Green River Valley including much of Kent. Earlier that year construction began on the Howard A. Hanson Dam. Today it continues to protect the valley from flooding, including many of the region's industrial lands.

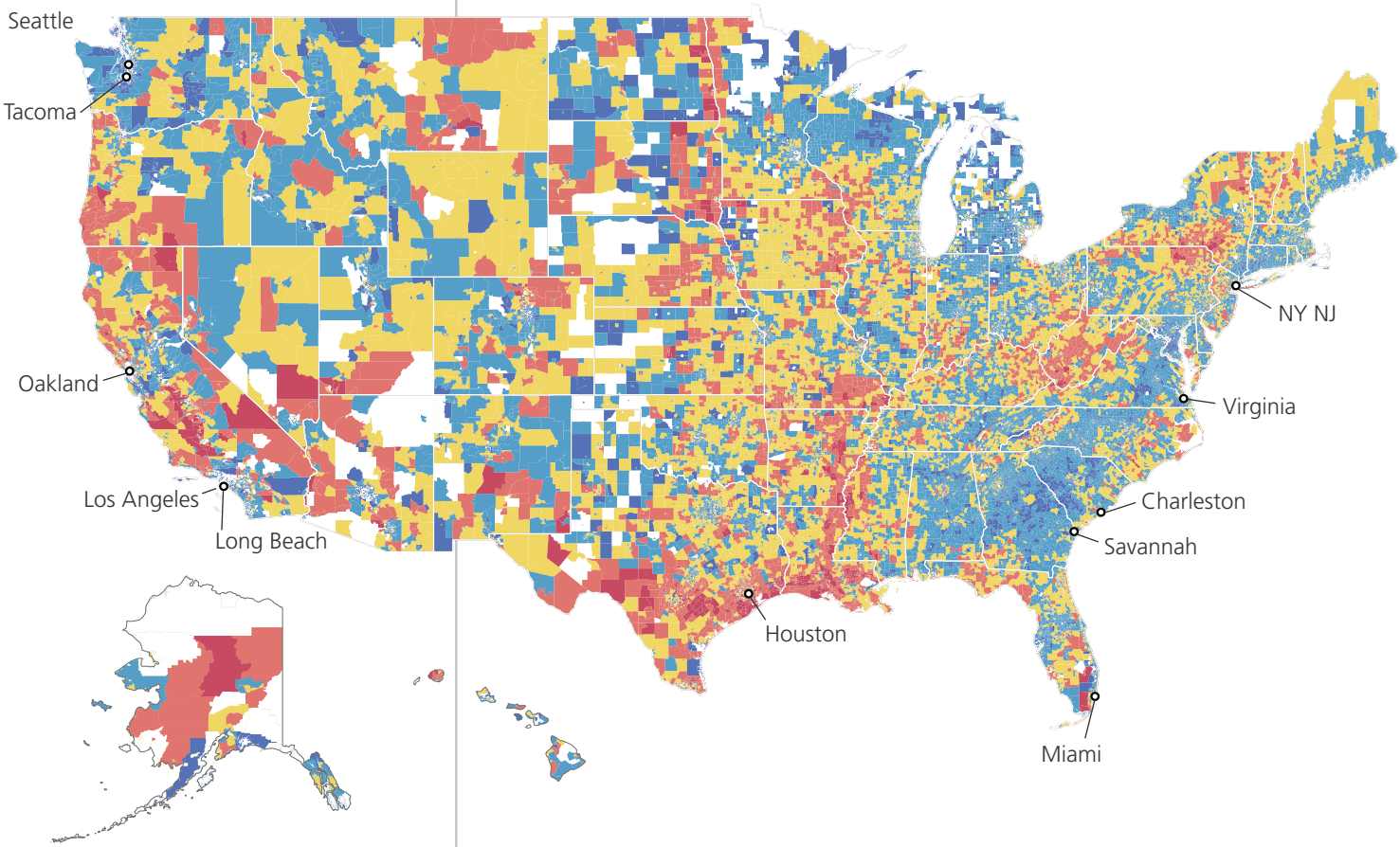


The construction of dams for flood control opened up river valleys for development. Today, many of the region's industrial lands are located along river floodplains such as the Duwamish (shown above).

Both NWSA harbors are located along rivers in areas that experienced regular flooding before flood control infrastructure was put in place.

RIVERINE FLOODING RISK AT TOP 10 US CONTAINER PORTS

The Federal Emergency Management Agency (FEMA) has mapped and quantified the riverine flooding risk across the United States based on expected annual loss, social vulnerability, and community resilience. The riverine flooding risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Very High	Relatively High	Relatively Moderate	Relatively Low
Houston	Oakland	Charleston	**NWSA Seattle**
Miami	NY NJ	Long Beach	**NWSA Tacoma**
		Los Angeles	Savannah
		NY NJ	NY NJ
		Virginia	

HAZARD CHARACTERIZATION AND IMPACTS

Flood hazard risk is based on hazard likelihood, scale, exposure, and areas of susceptibility. Hazards are characterized by their likelihood and scale and vulnerabilities are determined by exposure and susceptibility to the hazard.

FLOODING HAZARDS

Likelihood	HIGH
Scale	LOW
Outlook	MODERATE
Hazard Type	CHRONIC

IMPACTS TO NWSA

Exposure	LOW
Safety	LOW
Operations	LOW
Facilities	LOW
Equipment	LOW
Commerce	LOW
Organization	LOW

IMPACTS TO GATEWAY

Exposure	MODERATE
Roadways	LOW
Railroads	LOW
Waterways	LOW
Utilities	LOW
Industrial	LOW
Community	MODERATE
Environment	LOW

Widespread flooding across the Pacific Northwest in November 2021 caused significant damage to road and rail networks in the United States and Canada and delayed freight deliveries.

The November 2021 flood event was especially devastating for British Columbia, but it also affected goods movement in Washington. Damage to rail tracks caused the derailment of several railroad cars in Sumas, Washington.

The use of green infrastructure such as natural shorelines can help protect upland terminal areas from coastal erosion caused by coastal flooding and SLR.

HAZARD INFORMATION

LIKELIHOOD

HIGH

Likelihood of occurring on any given year

1. Flooding is a high likelihood hazard.
2. Each year there are typically multiple flood events with over an 80% chance of ten or more floods across Washington each year. There have been over 800 recorded flood events in Washington since the 1960s.
3. Many rivers in the western part of the state experience flooding every two to five years.
4. Urban flooding events are also common during heavy rain events and may cause ponding of water even when waterbodies like rivers are not experiencing flood conditions.
5. Areas identified in the 100-year floodplain have roughly a 1% annual chance of flooding. Areas in the 500-year floodplain have a 0.2% annual chance of flooding.
6. Flooding from infrastructure failure is a low likelihood event. There have been 22 recorded dam failures since 1918, but most have been small events.

SCALE

LOW

Magnitude event with regional scale

7. Small scale floods with minimal impact are most common, with large destructive flood events being much less common.
8. Even though the weather conditions that cause flooding can affect large areas at a single time, widespread flooding is not likely to cause major regional devastation.
9. Because Washington has great variation in terrain with mountains and river valleys, floodwaters have low-lying areas for the water to go. This reduces the overall floodplain as percentage of total area in comparison to other regions, and lowers the chances of experiencing a regionally devastating flood event.
10. Major floods caused large-scale devastation in the past, even wiping out entire towns. These triggered changes in development patterns with active efforts to reduce flood hazard exposure by limiting development in the floodplain.
11. Flood control infrastructure such as dams and levees have greatly reduced flooding and the potential for large-scale flood devastation.

OUTLOOK

MODERATE

Level of increasing risk in future decades

12. There is increasing amount of risk over time associated with flooding in the region.
13. While there are policies that limit development in the floodplain to reduce exposure to flooding, climate change is likely to increase their number and severity of flood events.
14. Warmer temperatures are expected to affect watersheds and when they experience peak streamflows that can cause flooding. This is because precipitation in winter months is less likely to fall as snow in the mountains and reduces the overall snowpack. This is likley to cause greater streamflows in the winter months and lower streamflows in the summer months.
15. Peak streamflows are expected to go up roughly 10-50% by mid-century and up to 70% or more depending on the rate of emissions. The floodplain may get larger in some areas in future years since the mapped floodplains today are based on historical streamflows and flood events.
15. Extreme precipitation is expected to increase across Washington which may increase flooding, especially urban flooding issues where stormwater systems aren't designed for larger rain events. Most areas are expected to see a 10-15% increase in rain during a 2-year storm by mid-century and up to almost 30% by end of century. There will also be more days in a year where precipitation values exceed one inch or more.

IMPACTS TO **NWSA**

EXPOSURE

LOW
NWSA exposure

1. There are only small areas in both harbors that are exposed to the mapped 100- or 500-year floodplain from riverine, urban, or groundwater flooding sources (coastal flooding covered in separate chapter). Several properties also have areas of flooding or water retention that aren't reflected in the mapped floodplain.
2. Terminals are most likely to experience urban flooding issues caused by low spots on the terminals or issues with the stormwater drainage such as clogs, high tides that impede drainage, or undersized pipes. Both harbors have reduced exposure to flood risk because of flood protection infrastructure such as levees and dams. The unlikely failure of this infrastructure such as failure of the Mud Mountain or Howard Hanson dam could inundate areas within both harbors.
3. Changing precipitation patterns with climate change could increase exposure to flooding.
4. Coastal flooding issues from extreme high tides or sea level rise can cause or exacerbate riverine, urban, or groundwater flooding. Higher tides can cause urban flooding issues by impeding stormwater conveyance if the tide gates are closed and stormwater cannot drain. The higher tides can also affect the river levels in the downstream areas that are near the ocean and increase the elevation of the groundwater table and over time cause groundwater flooding.

SAFETY

LOW
Impact to safety and worker health

5. Flooding is generally considered a low life safety concern since there is usually advance warning of which areas are at risk of flooding and workers can be kept out of hazardous areas.
6. Flooding can create unsafe working conditions on terminals from standing or flowing water with chances of injury or drowning. Water and electrical infrastructure can threaten life safety with potential for electrocution.
7. Flooding may impact worker health if buildings are flooded and grow mold, causing or exacerbating respiratory disease.
8. Flooding may increase exposure to pollutants if workers are in standing water.
9. The very unlikely event of dam failure and flooding could pose a threat to life safety.

OPERATIONS

LOW
Impact to terminal operations

10. Flooding is not expected to cause a long-lasting disruption to terminal operations.
11. When there are instances of flooding, workers may need to take measures to protect from floodwater intrusion and operations may slow down or temporarily shut down on terminal areas that are affected until the water recedes, debris is cleared, and facilities and equipment are repaired.
12. Severe flooding in the region could slow or halt terminal operations if workers are unable to get to the worksite or cargo can't be moved on and off terminal on flooded roadways or railroads.

IMPACTS TO **NWSA**

FACILITIES

LOW

Impact to NWSA facilities

13. Flooding could damage facilities that are not designed to withstand exposure to water such as buildings and utility systems, especially power.
14. Aging infrastructure and infrastructure failure can contribute to flooding, especially if the aging assets are stormwater or flood protection facilities.
15. Underground infrastructure such as utilities in vaults or air systems for train operations may be susceptible to flooding. Even watertight assets may experience water penetration which can damage assets or shorten their lifespan.
16. Flooding or water damage may occur outside of normal flooding events if there are low spots on the terminal or that collect water during rain events.
17. Many terminal buildings have flat roofs that are more likely to collect water and cause water damage inside the building during flood and heavy rain events.
18. Most terminal stormwater systems are tidally influenced and use gravity to drain. They might lose some functionality with future sea level rise and heavier rain events. Pumping and storage systems may be needed to reduce on-terminal flooding and the amount of stormwater that bypasses treatment systems.
19. Higher water volumes and higher speed currents on the waterways during floods could erode shorelines and drainage ditch banks, compromising upland facilities.
20. Floodwater debris could strike and damage structures or clog utility systems.

EQUIPMENT

LOW

Impact to cargo-handling equipment and fleet vehicles

21. Equipment, including cargo-handling eqipment, could be damaged by floodwaters if they reach sensitive electrical and mechanical components or other parts susceptible to water damage.
22. Mobile equipment may be moved out of flood-prone areas with advance warning.
23. Equipment used on the terminals is generally very durable. If floodwaters reach equipment, it may be easy to return to service with basic repairs if the floodwater is freshwater and not saltwater.
24. Electric-powered cargo-handling equipment may rely on underground cables in troughs. Most of these are designed to be water-tight, but may experience water penetration during flood events.

IMPACTS TO **NWSA**

COMMERCE

LOW

Impact to business and cargo volumes

25 Flooding may temporarily reduce cargo volumes, reducing revenue and labor income.

26 Cargo may be damaged if exposed to floodwater. Cargo stored on the ground is more susceptible to flooding than cargo stored in tanks or elevated off the ground. Autos and breakbulk may be damaged if water levels are high enough to damage sensitive components.

ORGANIZATION

LOW

Impact to organizational resilience

27 Flooding is not expected to cause a major disruption to the organization. Flooding on or off-terminal could disrupt operations and business and lead to a loss of revenue.

28 Limited areas of flooding on NWSA properties would likely be relatively easy to recover from in terms of ability to fund repairs and mobilize necessary resources. Flood damage at NWSA properties may be covered by flood insurance.

29 Flooding is not expected to have a large impact on staff's ability to perform essential work functions. None of the NWSA or homeport office spaces are in the floodplain.

30 Staff that live in or near the floodplain may be displaced from their homes. Others may not be able to access either of the harbors due to flooding and infrastructure damage on the transportation network.

31 Administrative staff may be able to carry out their normal work duties either from the office or from home to avoid flooded areas. Staff that work in the field would be most affected if flooding prevents them from getting to or around either of the harbors.

IMPACTS TO **GATEWAY**

EXPOSURE

MODERATE

Exposure across the gateway

1. The Gateway has exposure to riverine, urban, and groundwater flooding hazards.
2. Flooding is common across Washington with late fall and winter flooding being more common in Western Washington and spring flooding more common in Eastern Washington.
3. Western Washington and has the greatest exposure to flooding with larger waterways that flood regularly and high levels of development near and sometimes in the floodplain.
4. Changing precipitation and snowmelt patterns with climate change are expected to increase areas of flood exposure across the Gateway and increase the frequency of events.
5. Coastal flooding issues from extreme high tides or sea level rise can cause or exacerbate riverine, urban, or groundwater flooding. Higher tides can cause urban flooding issues by impeding stormwater conveyance if the tide gates are closed and stormwater cannot drain. The higher tides can also affect the river levels in the downstream areas that are near the ocean and increase the elevation of the groundwater table and over time cause groundwater flooding.
6. There are typically limited areas of flooding in the region relative to other parts of the county. There is great variation in terrain within the region with the mountains and river valleys, so there are low-lying areas for the floodwaters to go. Other parts of the country that are more flat are more likely to experience widespread flooding that affects a larger area.
7. Much of the gateway is located downstream of dams. Many gateway support sites could be inundated in the very unlikely event of a dam failure.

ROADWAYS

LOW

Impact to truck travel on freight roadways

8. Flooding could cause temporary closures of key freight roadways until water recedes, debris is cleared, and repairs are made.
9. Flooding can damage roadways and roadway bridges. Floodwaters can erode riverbanks and carry large amounts of debris, potentially compromising upland roadway infrastructure from scour or debris strikes.
10. Much of the risk associated with roadway flooding has already been mitigated to an extent.

RAILROADS

LOW

Impact to rail travel on freight railroads

11. Flooding could cause temporary closures of key rail corridors until water recedes, debris is cleared, and repairs are made.
12. Flooding can damage railroads and railroad bridges. Floodwaters can erode riverbanks and carry large amounts of debris, potentially compromising upland railroad infrastructure from scour or debris strikes.
13. Much of the risk associated with railroad flooding has already been mitigated to an extent.

IMPACTS TO **GATEWAY**

WATERWAYS

LOW
Impact to vessel travel on navigable waterways

14. Flood events raise the water levels within the waterways with the potential for faster currents and debris.
15. Flood events may leave debris in the navigable waterways, such as logs that have washed down from upstream areas.
16. Vessel operations may be slowed or halted in areas affected by floodwater until conditions are safe for navigation and debris is cleared.

UTILITIES

LOW
Impact to gateway utilities

17. Stormwater culverts may be blocked by debris during flood events causing localized flood impacts.
18. Flooding may damage above ground utilities such as electrical infrastructure. Underground utilities may be damaged as soil is saturated during flood events and seeps into utility vaults.
19. Utility lines on bridges may be susceptible to damage if the bridge is damaged by floodwater.

INDUSTRIAL

LOW
Impact to region's cargo support facilities

20. A portion of the region's industrial lands that support cargo operations are in or near flood hazard zones from riverine, urban, or groundwater flooding, especially in the Puyallup and Duwamish/Green River Valley.
21. Several of the region's Manufacturing/Industrial Centers (MICs) are in the 100- or 500-year floodplain.
22. Any flooding at cargo support sites can damage structures and cargo, especially if cargo is stored at ground level.

COMMUNITY

MODERATE
Impact to gateway communities

23. Many communities in the region have been or could be affected by flood events that impact their homes or ability to carry out essential functions.
24. Several near-port communities are located in the floodplain or areas protected by flood control infrastructure.
25. Flooding could affect the ancestral lands of the Coast Salish Tribes and farmland in our Gateway.

EMPOWERMENT

LOW
Impact to organizational resilience

26. Flooding is a natural occurrence and can be beneficial to the environment when not occurring in developed areas.
27. Restoring and protecting floodplains near rivers can provide essential habitat for wildlife while reducing risk to nearby development.
28. Floodwaters in urbanized areas can cause pollutants to enter rivers and streams.

Flood Hazard

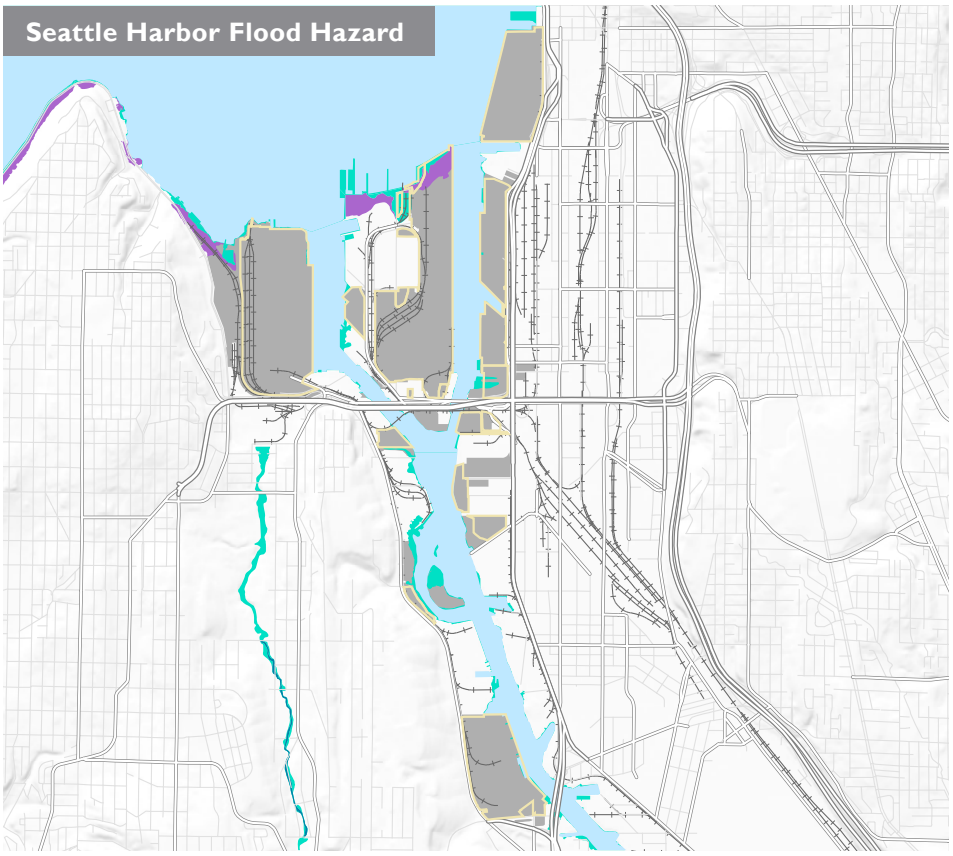
FEMA works with local jurisdictions to map out areas that are susceptible to flooding. These flood maps are used to support the National Flood Insurance Program by providing information about the level of flood risk and type of flooding that an area may experience.

Floodways are the river channels and nearby lands that are reserved to discharge a base flood, also known as a 100-year flood event. The 100-year floodplain includes areas that have a 1% annual chance of flooding and may also include coastal areas that are typically submerged outside of flood events. The 500-year floodplain includes areas that have a 0.2% annual chance of flooding. The flood hazard layer also shows areas that have reduced risk due to levees.

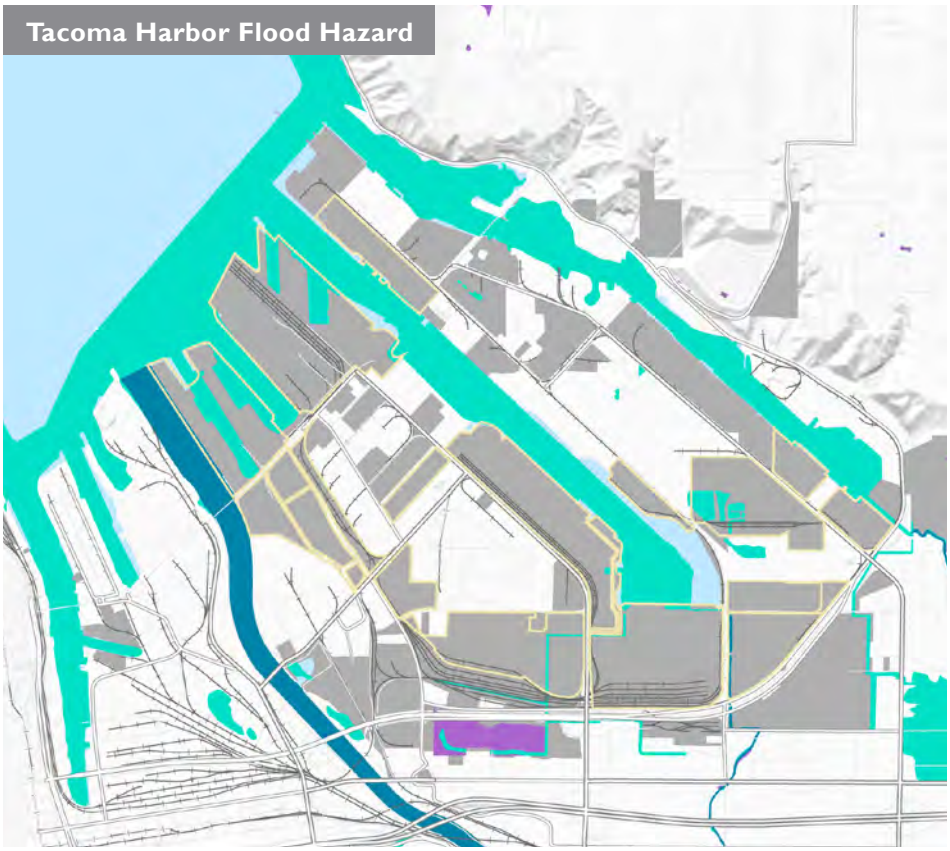
Both harbors are located on the coastal waterfront and have rivers and creeks that could flood. The flood maps are based on past flood events and may show areas as being in the floodplain that have since been filled and removed from the floodplain.

- **Floodway**
- **100-Year Floodplain (Flood Zones A, AE, AH, AO, VE)**
- **500-Year Floodplain**
- **Area with Reduced Risk Due to Levee**

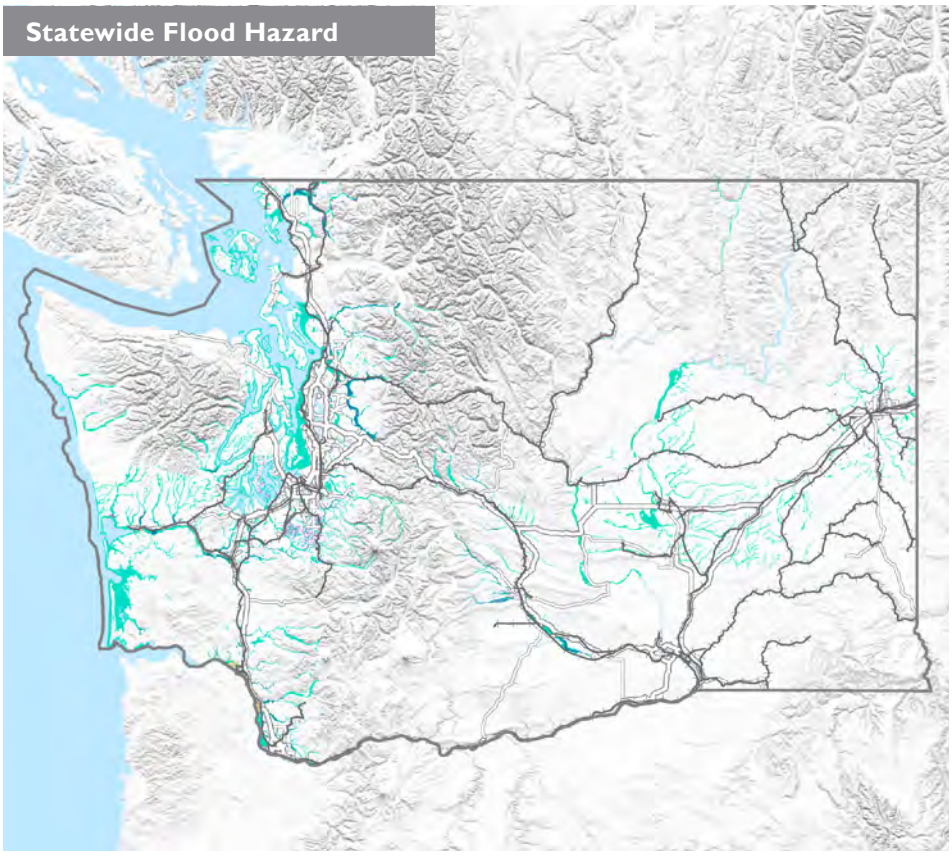
Seattle Harbor Flood Hazard



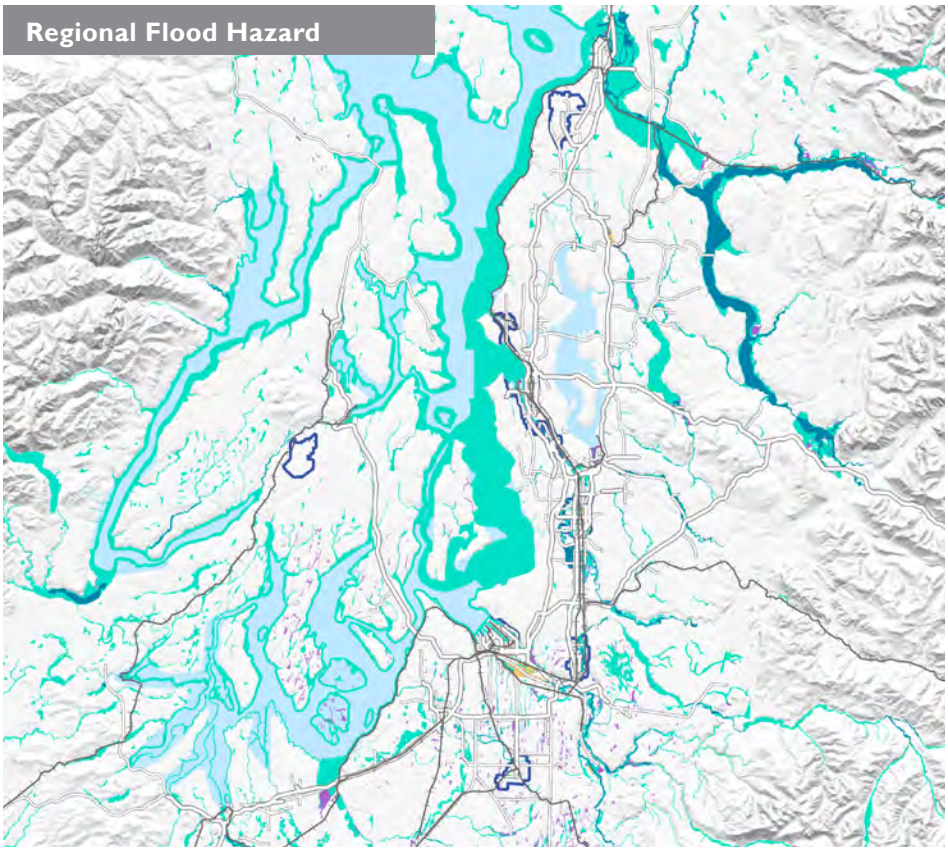
Tacoma Harbor Flood Hazard



Statewide Flood Hazard



Regional Flood Hazard



Flood Hazard

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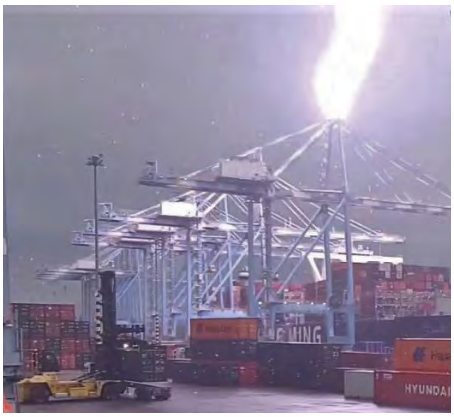
- **Floodway**
- **100-Year Floodplain (Flood Zones A, AE, AH, AO, VE)**
- **500-Year Floodplain**
- **Area with Reduced Risk Due to Levee**

Crane tie-downs and stowage pins can be used to safely secure a crane in the event of strong winds.

Protective measures have been put in place to protect heavy-duty equipment and their operators in the event of severe weather.



The lightning protection system on one of the port-owned cranes protected it from damage when struck by lightning.

A WIDE RANGE OF WEATHER EVENTS

Severe weather events are extreme meteorlogical conditions that may result in hazardous conditions. Examples of severe weather include atmospheric rivers, snow, ice, extreme heat, thunderstorms, severe wind, and hurricanes. Because the weather patterns vary greatly depending on the given location, what constitutes as severe weather is often relative to normal weather conditons for a given area.

The proximity to the coast and Olympic and Cascade mountain ranges play an important role in weather patterns in the state. Western Washington typically has a milder climate but more precipitation since water vapor is released as it moves over the mountains. Eastern Washington and inland areas are more arid but also experience more extreme hot and cold temperatures.

There is a wide range of severe weather events which may or may not be common in the Gateway including:

Atmospheric Rivers – Moving columns of water vapor in the atmosphere called atmospheric rivers can bring heavy amounts of rain and snow to an area.

Winter Hazards – The cooler seasons can bring cold waves and winter storm hazards such as snow, sleet, ice, or even avalanches.

Summer Hazards – The warmer seasons can bring heat waves and high temperatures such as extreme heat events.

Thunderstorms – The upward movement of moist, warm air can lead to thunderstorms that produce lightning and thunder. They are often accompanied by rain, wind, and hail. Severe thuderstorms may even cause tornadoes.

Severe Wind – Widespread damage can occur with higher speed winds. Severe wind can occur as a standalone windstorm or as part of a larger storm such as a thunderstorm or hurricane and doesn't have the rotation that is seen with tornadoes.

Tornadoes – Thunderstorms may create tornadoes, where a narrow air column rotates violently from a thunderstorm to the ground.

Drought – A drought is a period of unusually dry weather relative to the area.

Terminal operations continue in snowy conditions (shown right) as yard areas are cleared of snow.

PAST EVENTS

Severe weather and storms are high probability events in Washington, but many of these events are minor disruptions with minimal casualties and damage. A few weather events stand out as particularly notable in terms of their casualties, destruction, or magnitude.

1910 Wellington Avalanche – The deadliest avalanche in U.S. history occurred in the Stevens Pass area in the town of Wellington, since renamed Tye. A severe blizzard trapped two passenger trains in the area, which were then swept off the tracks into a ravine by a major avalanche, killing 96 people. This prompted the construction of a new rail tunnel through the mountains that continues to keep trains out of the high avalanche hazard areas to this day.

1950 Cold Wave – In January, the Puget Sound experienced a great snowfall and blizzard. Over 20" of snow fell in parts of the Puget Sound, making it the seond highest snowfall record in the area. The storm also brought winds up to 40 mph, creating blizzard conditions. The cold wave lasted roughly three weeks with temperatures dipping down into the single digits. The cold wave and storm resulted in 13 deaths.

1962 Columbus Day Windstorm – The strongest non-hurricane windstorm in the U.S. in the 20th century hit the northwest from northern California to British Columbia. The storm killed 46 people and caused $250 million in damage. Multiple cities in Washington reported wind speeds over 100 mph, even reaching as high as 150 mph before the power went out across much of the region.

1972 Tornado Outbreak and Thunderstorm – Three tornadoes hit Washington in one day ranging from significant to severe damage. The tornadoes killed 6 people and caused 300 injuries. There were also severe thunderstorms in eastern Washington with large hail and damaging winds.

2021 Heat Wave – A 1,000-year weather event with a week of extreme heat in the Pacific Northwest set 128 high-temperature records in Washington alone and a number of records elsewhere. The heat wave is estimated to have killed over 1,400 people including 126 Washingtonians, making it the deadliest weather-related disaster in Washington. It also damaged infrastructure, eco-systems, and disrupted events and commerce.

Thoughtful planning and design can reduce risk to severe weather hazards.

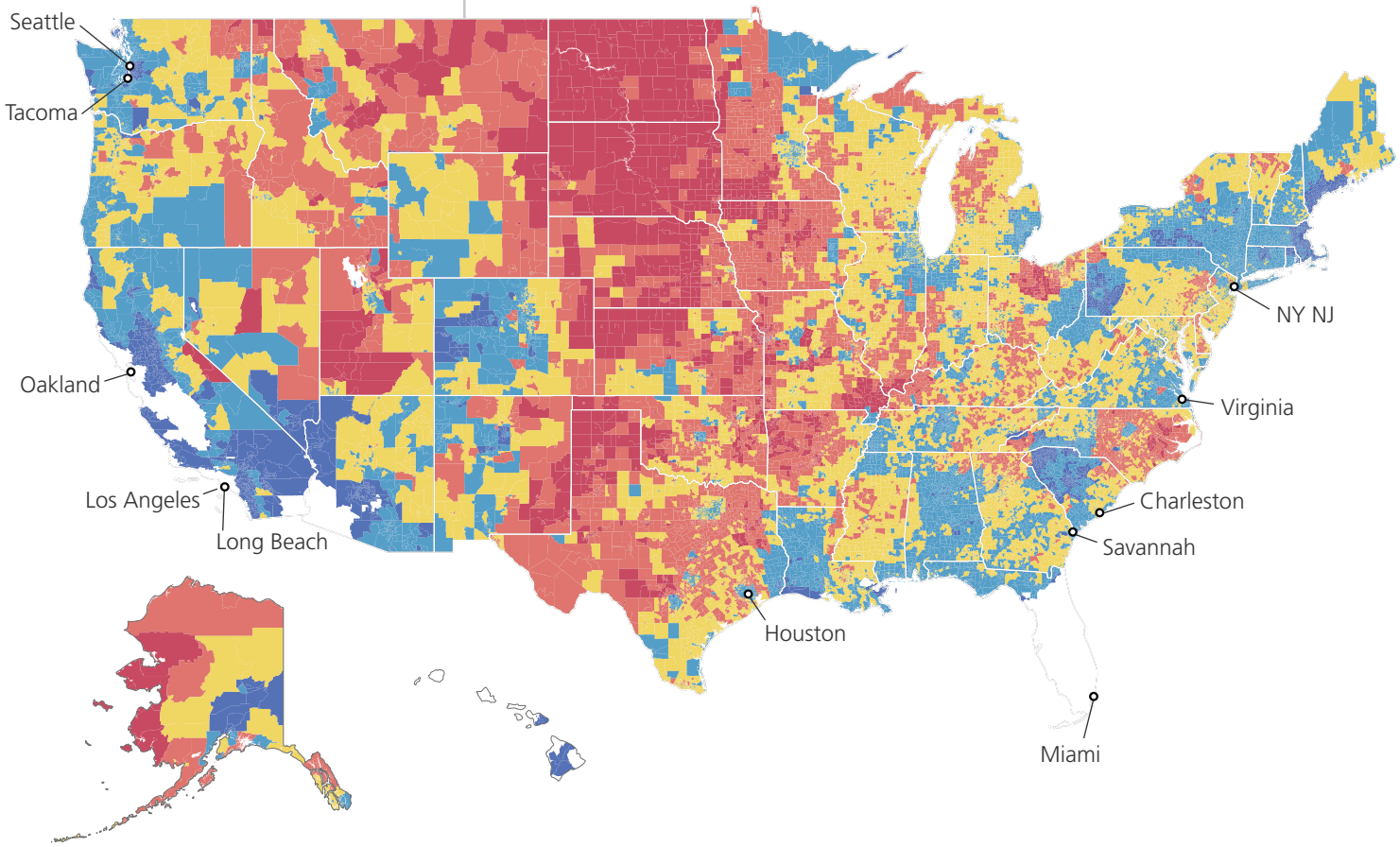
Mountain passes may temporarily close to clear snow and ice and perform avalanche control. The new I-90 avalanche bridges reduce road closures caused by avalanche threats.

The log export business began when the Columbus Day Windstorm (shown left) created major tree blowdowns in the region. Timber companies worked to salvage wood, but the sudden log supply was too big for the local mills and domestic markets. Ports played a critical role in exporting logs.

The devastating Wellington Avalanche led to the construction of the Cascade Tunnel. At 7.8 miles, it is the longest railroad tunnel in the U.S. and it continues to keep today's rail traffic out of avalanche hazard areas.

WINTER WEATHER RISK AT TOP 10 US CONTAINER PORTS

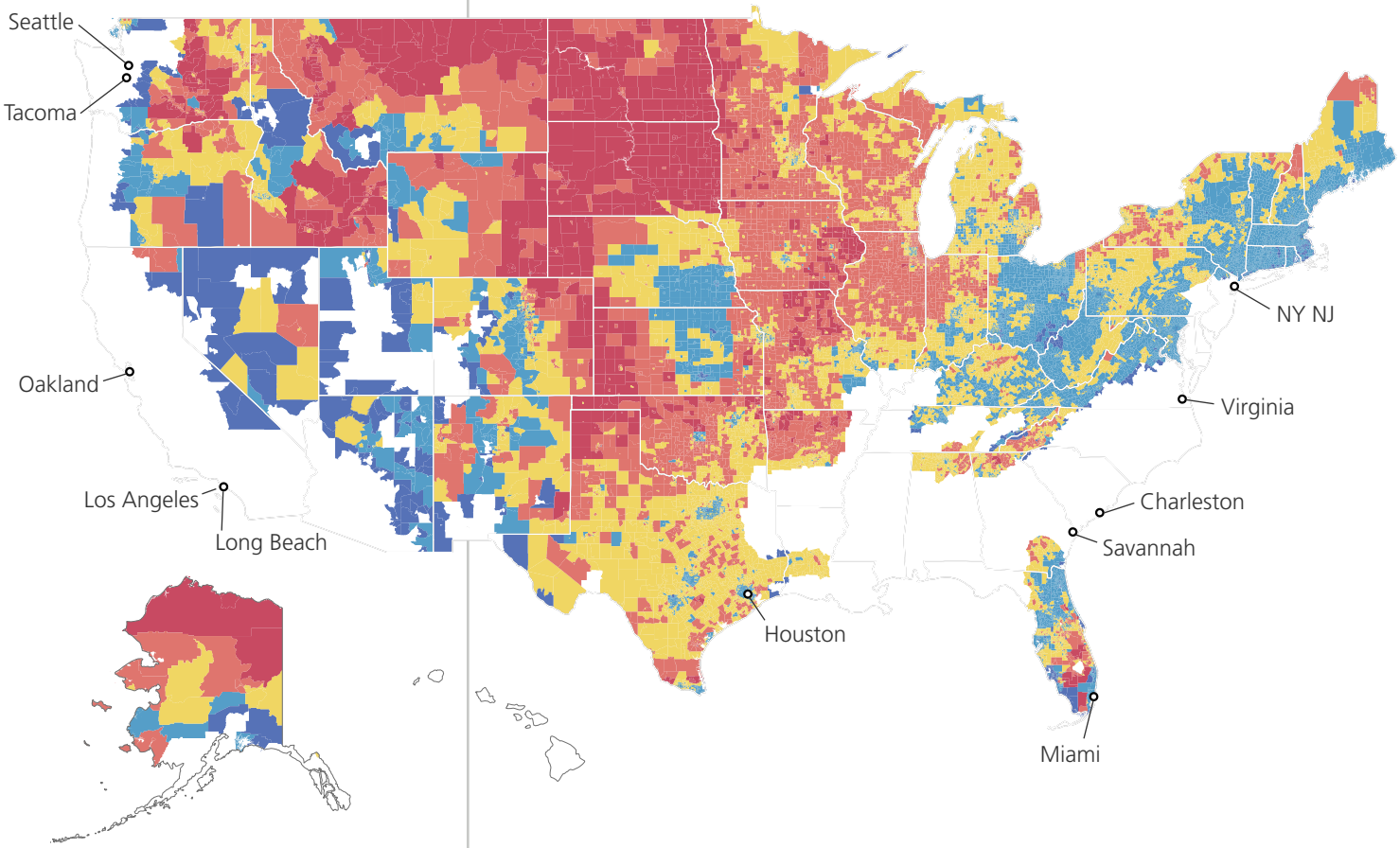
The Federal Emergency Management Agency (FEMA) has mapped and quantified the winter weather risk across the United States based on expected annual loss, social vulnerability, and community resilience. The winter weather risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Very High	Relatively High	Relatively Moderate	Relatively Low	Very Low	No Rating
Houston	NY NJ	Charleston NY NJ	**NWSA Tacoma** Long Beach Los Angeles Savannah Virginia	**NWSA Seattle** Oakland Virginia	Miami

COLD WAVE RISK AT TOP 10 US CONTAINER PORTS

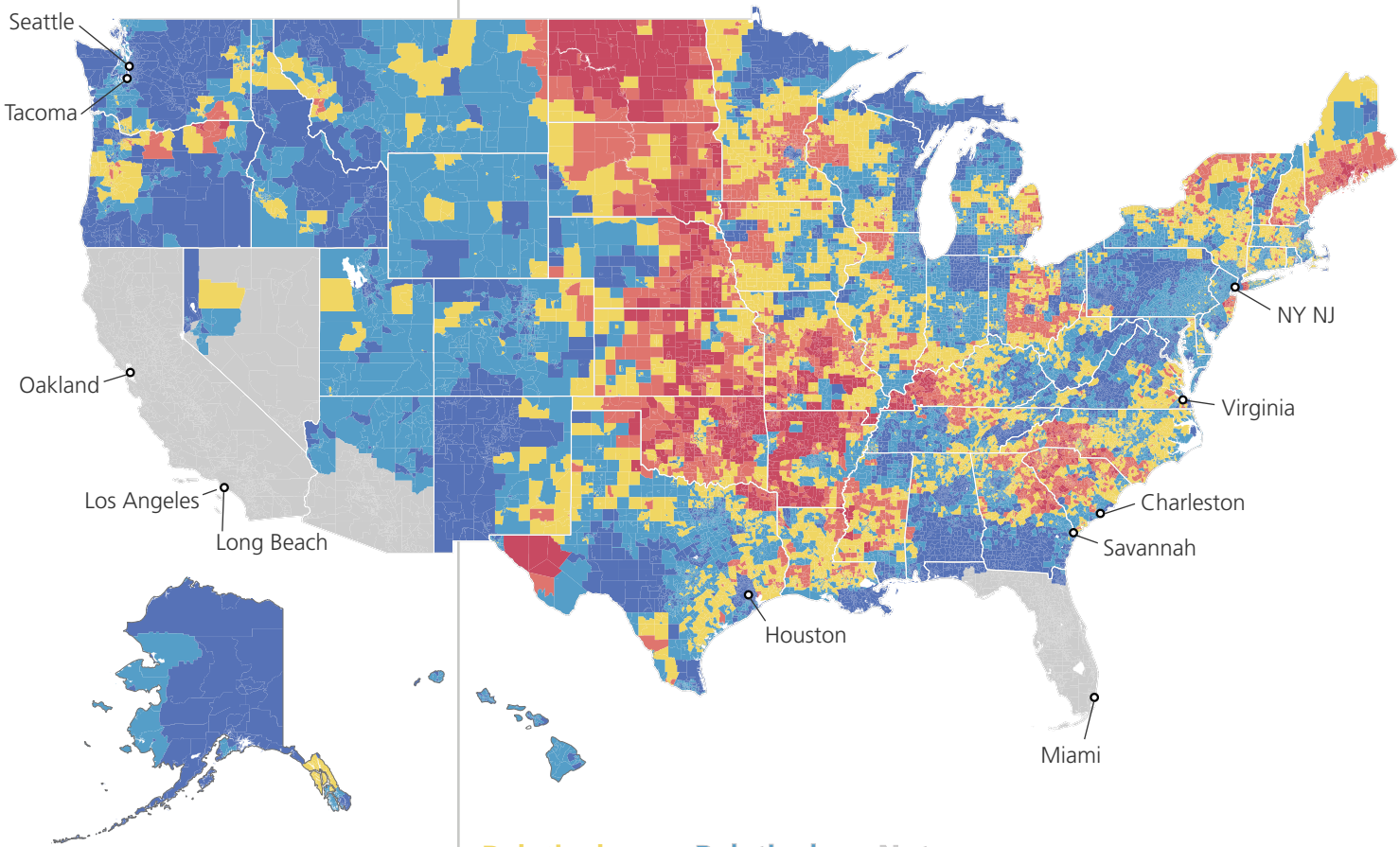
The Federal Emergency Management Agency (FEMA) has mapped and quantified the cold wave risk across the United States based on expected annual loss, social vulnerability, and community resilience. The cold wave risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Very High	Relatively High	Very Low	No Rating
Houston	Miami	**NWSA Seattle**	Charleston
		NWSA Tacoma	Long Beach
			Los Angeles
			NY NJ
			Oakland
			Savannah
			Virginia

ICE STORM RISK AT TOP 10 US CONTAINER PORTS

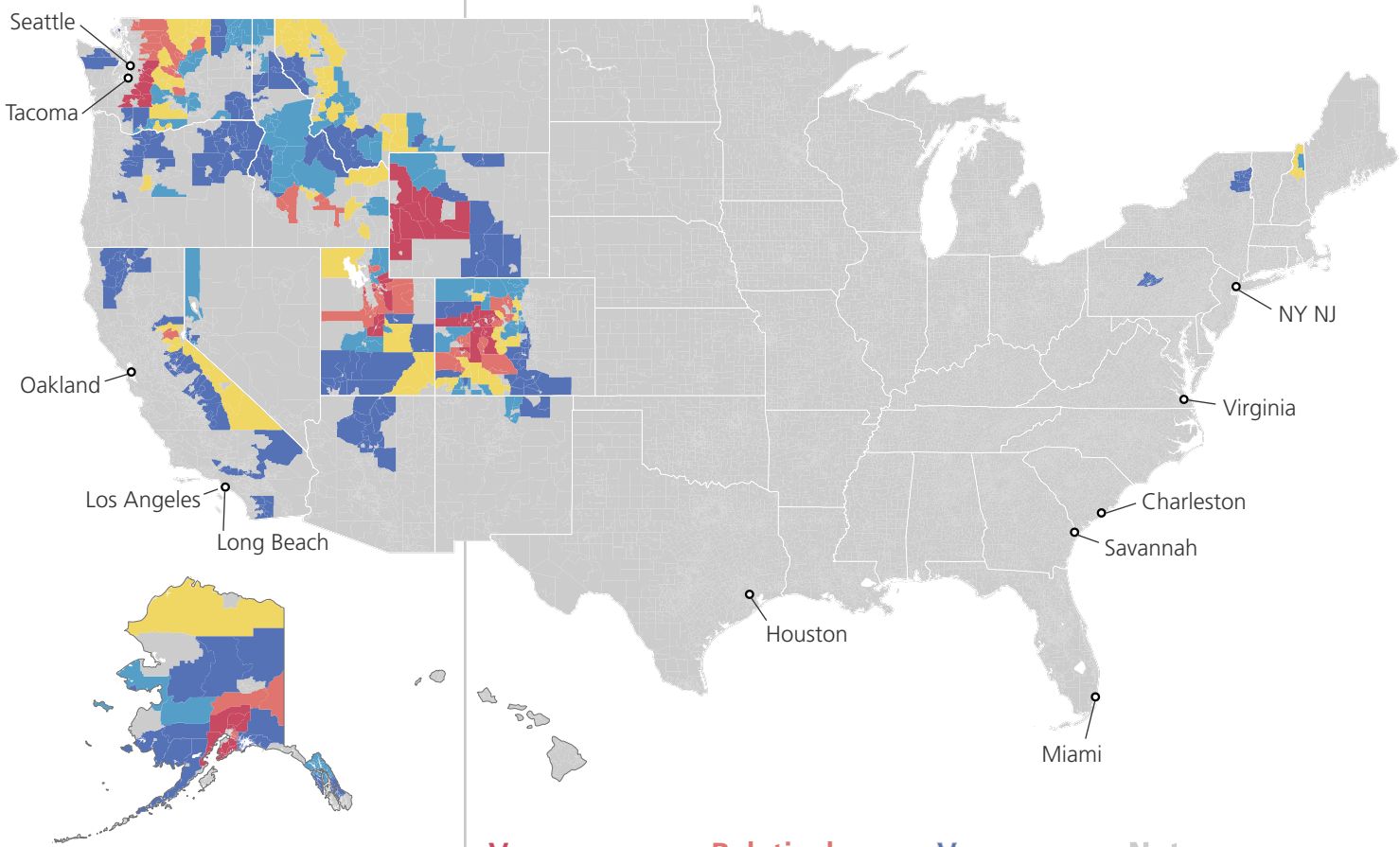
The Federal Emergency Management Agency (FEMA) has mapped and quantified the ice storm risk across the United States based on expected annual loss, social vulnerability, and community resilience. The ice storm risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Relatively Moderate	Relatively Low	Not Applicable
NWSA Seattle	Houston	Long Beach
NWSA Tacoma	Virginia	Los Angeles
Charleston		Miami
NY NJ		Oakland
Savannah		
Virginia		

AVALANCHE RISK AT TOP 10 US CONTAINER PORTS

The Federal Emergency Management Agency (FEMA) has mapped and quantified the avalanche risk across the United States based on expected annual loss, social vulnerability, and community resilience. The avalanche risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.

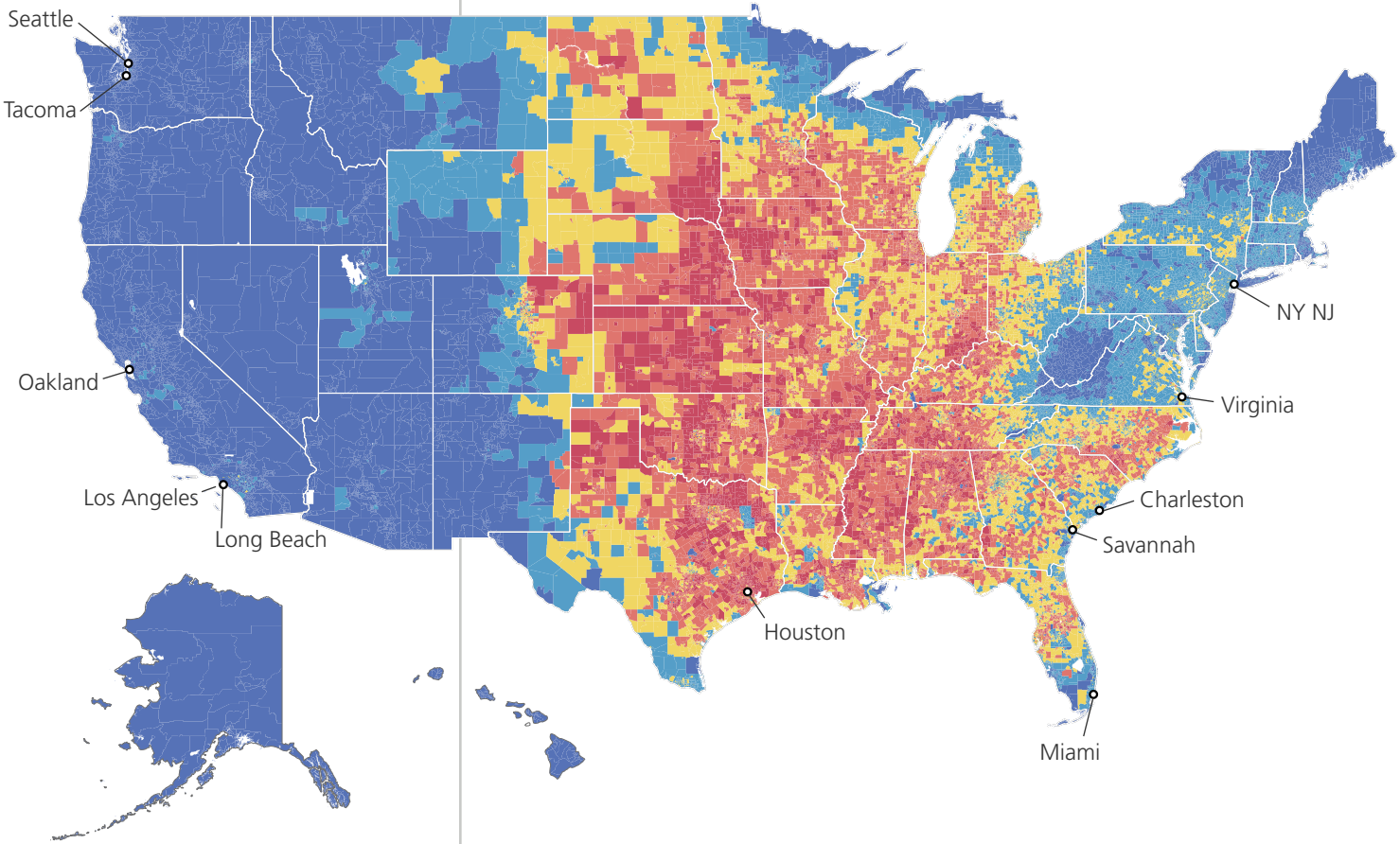


Very High	Relatively High	Very Low	Not Applicable
NWSA Tacoma	**NWSA Seattle**	Long Beach Los Angeles	Charleston Houston Miami NY NJ Oakland Savannah Virginia

- Top Container Port
- Very High
- Relatively High
- Relatively Moderate
- Relatively Low
- Very Low
- No Rating

TORNADO RISK AT TOP 10 US CONTAINER PORTS

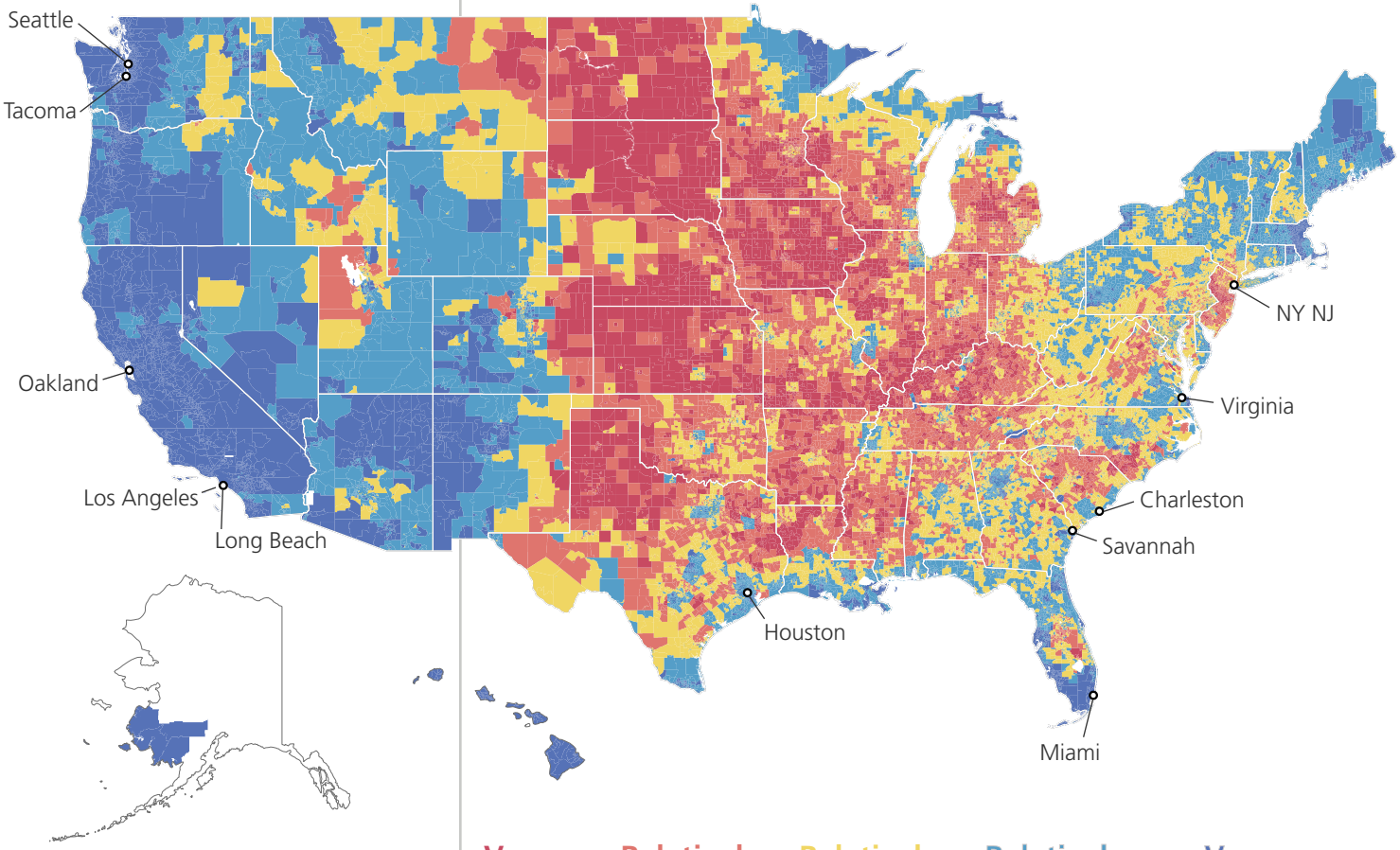
The Federal Emergency Management Agency (FEMA) has mapped and quantified the tornado risk across the United States based on expected annual loss, social vulnerability, and community resilience. The tornado risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Very High	Relatively High	Relatively Moderate	Relatively Low
Houston	Long Beach	**NWSA Seattle**	**NWSA Tacoma**
	Los Angeles	Charleston	Virginia
	Miami	NY NJ	
	NY NJ	Oakland	
		Savannah	
		Virginia	

STRONG WINDS RISK AT TOP 10 US CONTAINER PORTS

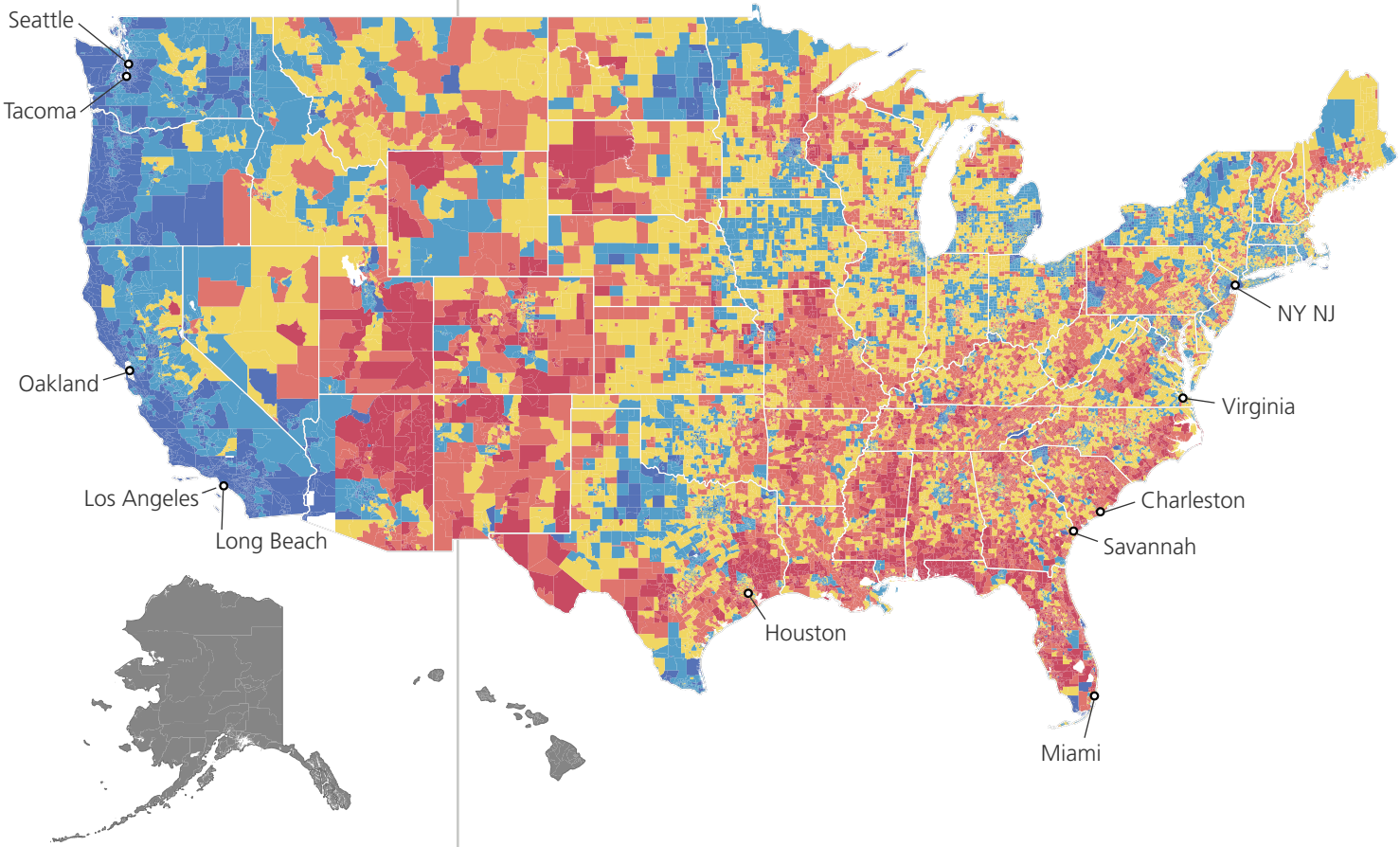
The Federal Emergency Management Agency (FEMA) has mapped and quantified the strong winds risk across the United States based on expected annual loss, social vulnerability, and community resilience. The strong winds risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Very High	Relatively High	Relatively Moderate	Relatively Low	Very Low
NY NJ	NY NJ Houston	Charleston Long Beach Los Angeles	Miami Savannah	**NWSA Seattle** **NWSA Tacoma** Oakland Virginia

LIGHTNING RISK AT TOP 10 US CONTAINER PORTS

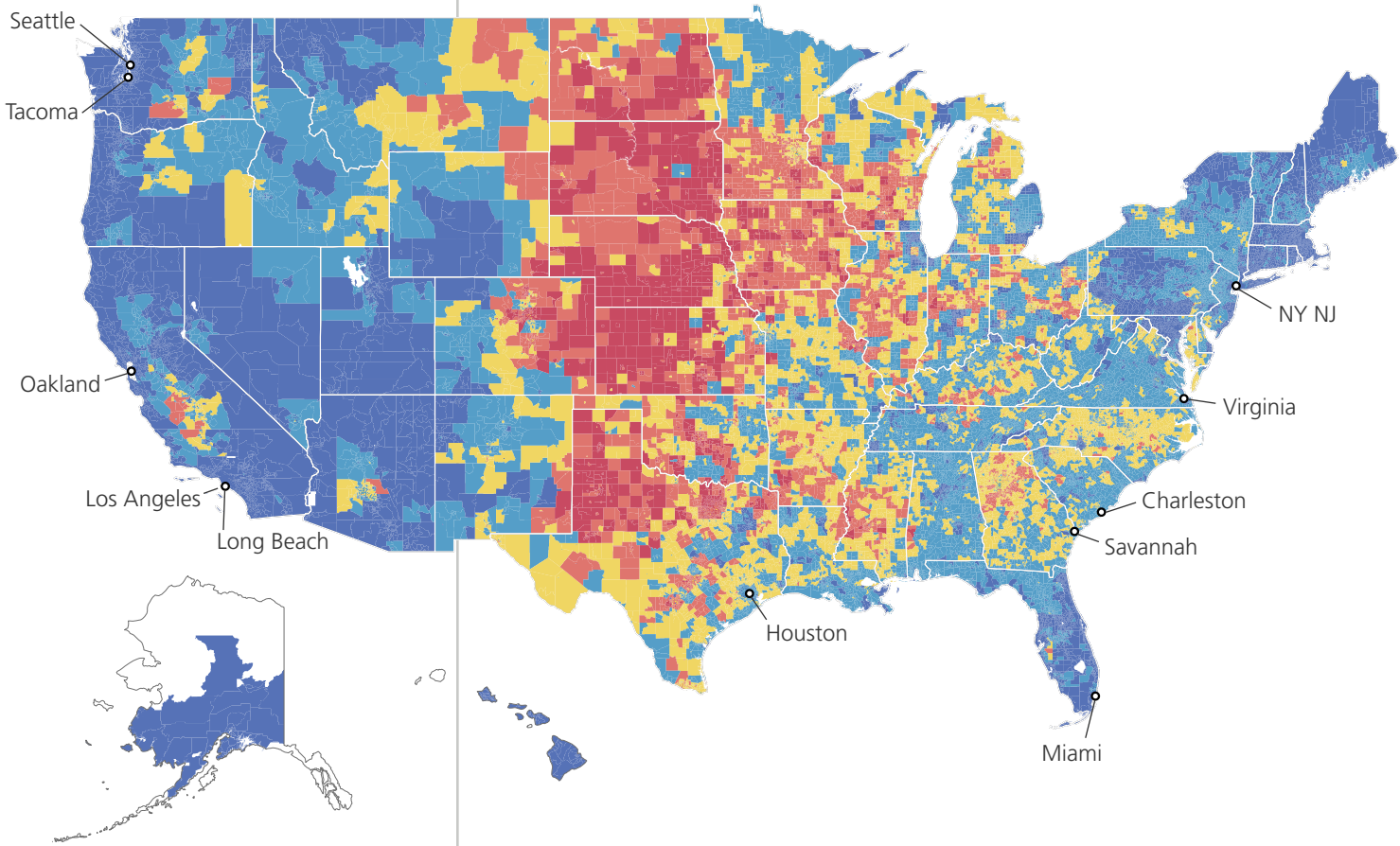
The Federal Emergency Management Agency (FEMA) has mapped and quantified the lightning risk across the United States based on expected annual loss, social vulnerability, and community resilience. The lightning risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Very High	Relatively High	Relatively Moderate	Relatively Low	Very Low
Houston	Charleston	**NWSA Seattle**	**NWSA Tacoma**	Oakland
Miami	Long Beach	NY NJ	NY NJ	
	Los Angeles	Virginia		
	Savannah			

HAIL RISK AT TOP 10 US CONTAINER PORTS

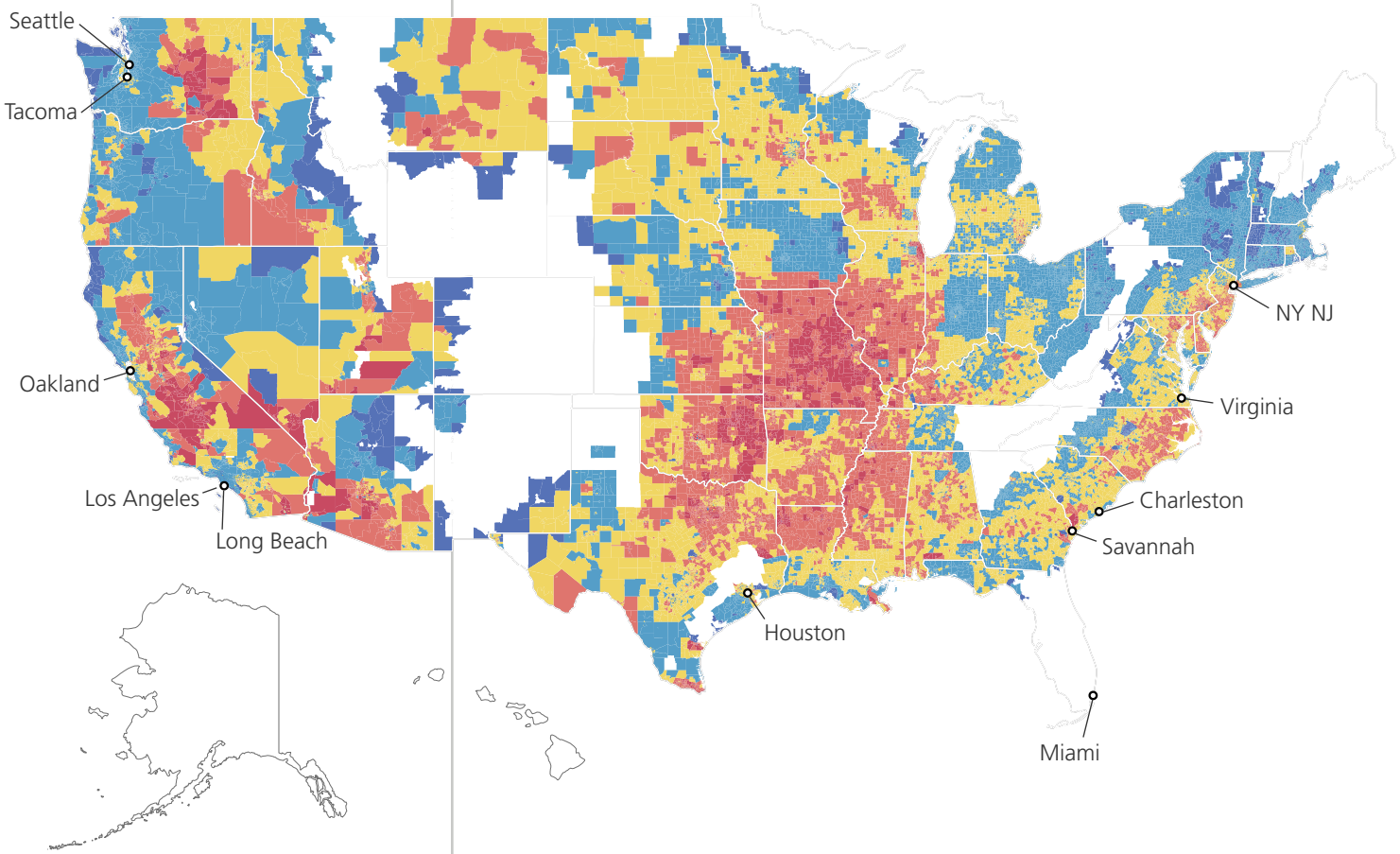
The Federal Emergency Management Agency (FEMA) has mapped and quantified the hail risk across the United States based on expected annual loss, social vulnerability, and community resilience. The hail risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Relatively Moderate	Relatively Low	Very Low
Houston	Long Beach	**NWSA Seattle**
	Los Angeles	**NWSA Tacoma**
	NY NJ	Miami
	Oakland	NY NJ
	Savannah	Virginia
	Virginia	

HEAT WAVE RISK AT TOP 10 US CONTAINER PORTS

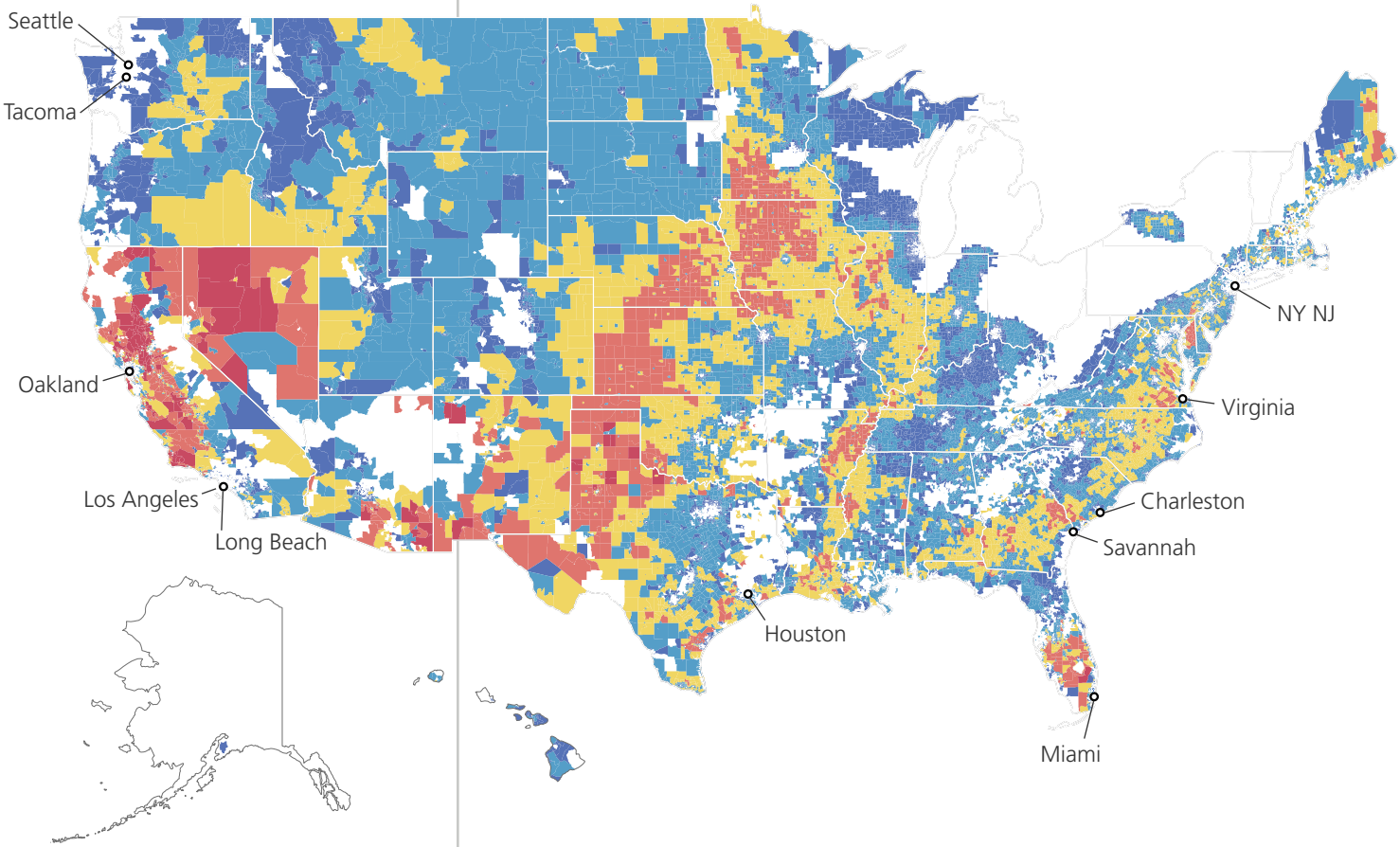
The Federal Emergency Management Agency (FEMA) has mapped and quantified the heat wave risk across the United States based on expected annual loss, social vulnerability, and community resilience. The heat wave risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Relatively High	Relatively Moderate	No Rating
Houston	**NWSA Seattle**	Miami
Long Beach	**NWSA Tacoma**	
Los Angeles	Charleston	
NY NJ	Oakland	
	Savannah	
	Virginia	

DROUGHT RISK AT TOP 10 US CONTAINER PORTS

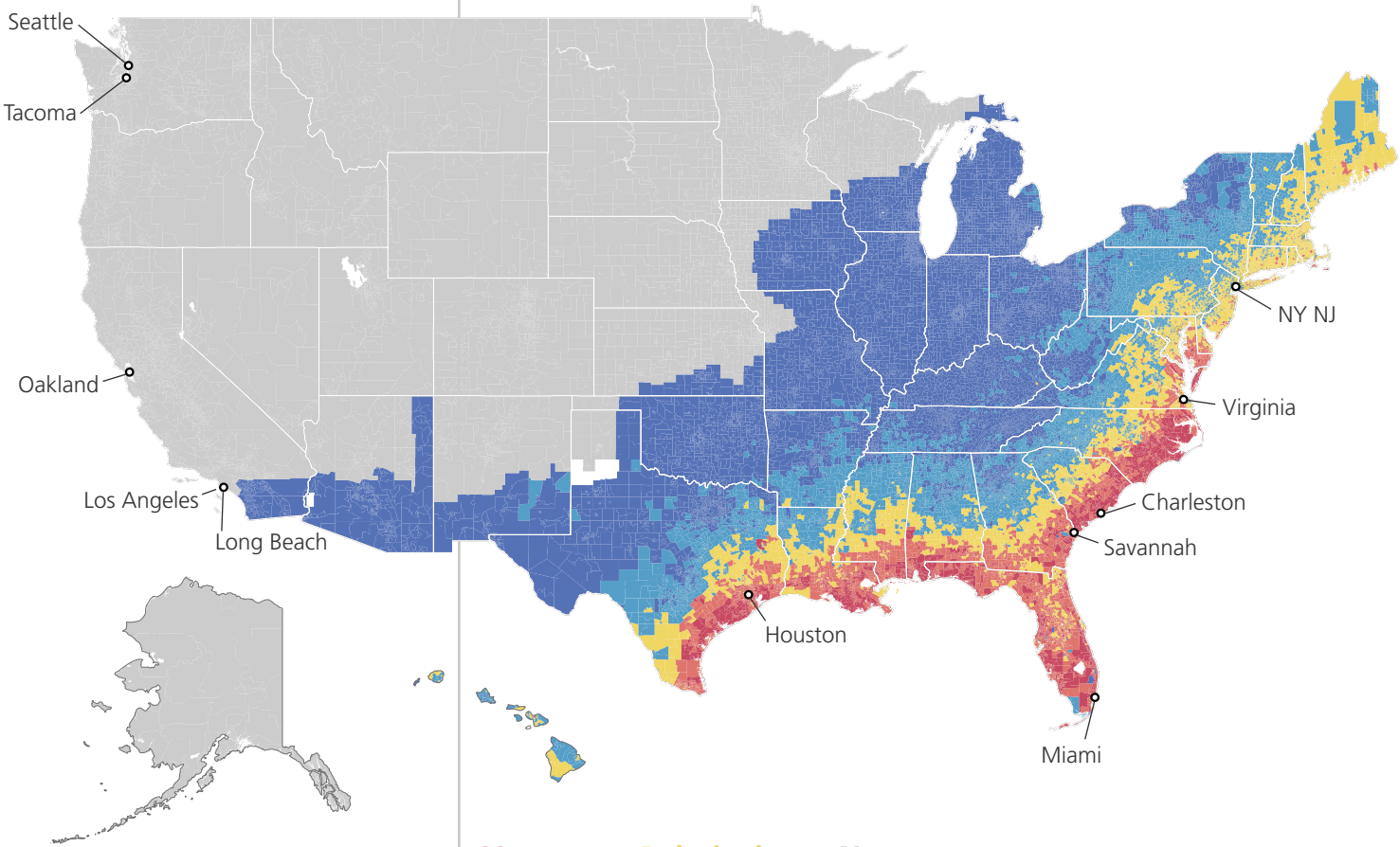
The Federal Emergency Management Agency (FEMA) has mapped and quantified the drought risk across the United States based on expected annual loss, social vulnerability, and community resilience. The drought risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Relatively High	Relatively Moderate	Relatively Low	Very Low	No Rating
Oakland	Houston Miami	Charleston Long Beach Los Angeles Savannah	**NWSA Seattle** **NWSA Tacoma** NY NJ	Virginia

HURRICANE RISK AT TOP 10 US CONTAINER PORTS

The Federal Emergency Management Agency (FEMA) has mapped and quantified the hurricane risk across the United States based on expected annual loss, social vulnerability, and community resilience. The hurricane risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Very High	Relatively Moderate	Not Applicable
Charleston	NY NJ	**NWSA Seattle**
Houston	Virginia	**NWSA Tacoma**
Miami		Long Beach
Savannah		Los Angeles
		Oakland

HAZARD CHARACTERIZATION AND IMPACTS

Severe weather risk is based on an aggregate of the types of severe weather across the Gateway and considers hazard likelihood, scale, exposure, and areas of susceptibility. Hazards are characterized by their likelihood and scale and vulnerabilities are determined by exposure and susceptibility to the hazard.

SEVERE WEATHER HAZARDS

Likelihood	HIGH
Scale	LOW
Outlook	MODERATE
Hazard Type	CHRONIC

IMPACTS TO NWSA

Exposure	HIGH
Safety	MODERATE
Operations	MODERATE
Facilities	LOW
Equipment	LOW
Commerce	LOW
Organization	LOW

IMPACTS TO GATEWAY

Exposure	HIGH
Roadways	MODERATE
Railroads	MODERATE
Waterways	LOW
Utilities	LOW
Industrial	LOW
Community	MODERATE
Environment	MODERATE

Extreme heat can create dangerous working condtions for outdoor workers such as farmworks and may also cause damage to crops.

Severe weather events place extra stress on the outdoor workers that keep cargo moving through our Gateway. Protecting everyone from the farmworkers to the longshoremen is critical to the Gateway's long-term viability.

Protective measures can be taken to protect workers in extreme conditions and reduce their risk.

HAZARD INFORMATION

LIKELIHOOD

HIGH

Likelihood of occurring on any given year

1. Severe weather events happen ever year in Washington and are often seasonal in nature. While there is a high likelihood of experiencing some form of severe weather event, not all forms of severe weather are common in the Gateway.
2. Every year there are summer hazards with periods of extreme heat. The warmest temperatures are more common in Eastern Washington than Western Washington. There are an average of 14 days a year with temperatures greater than 95°F in Eastern Washington and an average of 5 days a year with temperatures greater than 90°F in Western Washington.
3. Every year there are periods of cold weather with temperatures below freezing and winter hazards like snow, ice, sleet, and avalanches. There are typically colder temperatures in Eastern Washington with an average of 3.7 days a year with temperatures below 0°F. Western Washington has milder temperatures with an average of 3 days a year with temperatures below freezing.
4. Thunderstorms occur in Washington every year. Compared to the rest of the country, Washington has one of the lowest rates of annual mean thunderstorm days with 0-9 days a year. These storms may be accompanied by hail, strong winds, or tornadoes.
5. Droughts typically occur every few years.
6. Hurricanes do not occur in the Pacific Northwest.

SCALE

LOW

Magnitude event with regional scale

7. Compared to the rest of the nation, the severe weather events in Washington are generally pretty mild. They are smaller in scale than large severe weather hazards like hurricanes or the large tornadoes that occur elsewhere.
8. While weather systems generally have large areas of exposure and affect many areas at a time, most of the severe weather events in the Gateway are manageable and do not cause regional devastation the way that larger geological hazards do.

OUTLOOK

MODERATE

Level of increasing risk in future decades

9. Climate change is expected to increase the extent, intensity, and frequency of severe weather. Temperatures have risen 2°F since the early 20th century and are expected to continue rising, making summers hotter and winters warmer.
10. The average maximum temperature in the summer is expected to increase across Washington and Washington is expected to have an increasing number of hot days with temperatures over 100°F.
11. The combination of warmer temperatures and reduced snowpack will lead to more drought conditions and lower streamflows in the summer months.
12. The changing weather patterns are expected to cause more extreme precipitation events with greater amounts of precipitation coming down in shorter spans of time.
13. Warming temperatures are expected to contribute to an increase in thunderstorms across the region due to an increase in the Convective Available Potential Energy (CAPE).
14. Warming temperatures and reduced snowpack may lead to a reduction in winter hazards such as snow, ice, and avalanches.

IMPACTS TO **NWSA**

EXPOSURE

HIGH

NWSA exposure

1. While both harbors have large areas of potential exposure to severe weather, the magnitude and severity is generally less than other cargo gateways in the U.S.
2. Both harbors experience severe weather events like thunderstorms, strong winds, extreme heat, fog, drought, and winter storms. The harbors are not located in areas prone to hurricanes or tornadoes.
3. Severe weather events typically happen every year and are seasonal in nature.

SAFETY

MODERATE

Impact to safety and worker health

4. Severe weather can threaten the life safety and health of workers. Terminal operators can monitor the weather and adjust operations to protect workers.
5. Strong winds can make it unsafe to operate top-heavy cargo handling equptment and can knock over stacked containers around workers.
6. Thunderstorms can expose workers to hail and lightning. Operating tall equipment such as cranes can be especially dangerous during a thunderstorm.
7. Extreme heat can put outdoor workers at risk of hyperthermia and heat-related illnesses.
8. Snow, ice, or extreme cold can create unsafe working conditions if there is low visibility, the terminal is slick, or if workers are at risk of cold-related illness.
9. Fog and heavy rain may reduce visibility and make operations unsafe.

OPERATIONS

MODERATE

Impact to terminal operations

10. Severe weather events impact operations on a yearly basis, usually multiple times a year but for a limited duration.
11. Operations may need to slow down or stop during severe weather events to protect workers. Terminal operators may need to carry out operations at alternate shift times to make up for lost productivity, which is usually more expensive.
12. Some operations may be especially susceptible to certain types of severe weather events. For example, container operations are more susceptible to heavy winds than other operations since wind can cause containers to swing in the air when suspended by ship-to-shore cranes and can knock over stacks of containers.
13. Terminal productivity may go down during severe weather events as workers have to focus on prepping the site for safe operations such as snow and ice removal, secure empty containers against high winds, avoid work during periods of extreme heat, or clear debris from storms.
14. Terminal operations are susceptible to severe weather impacts off-terminal such as moving goods to and from terminals and access to utilities such as power and communications. This affects what happens at the terminal during the event and after as more cargo is pushed through the terminal all at once.
15. Severe weather events may have a greater impact on operations as they become more dependent on reliable and undisturbed electricity as cargo operations shift away from fossil fuels.

IMPACTS TO **NWSA**

FACILITIES

LOW

Impact to NWSA facilities

16. Greater variability in temperatures and their extremes can shorten the lifespan of facilities such as paved terminal surfaces, utilities, buildings, wharfs, and bridges.
17. Paved surfaces are susceptible to damage from extreme temperatures, hindering operations and compromising environmental caps. Warm asphalt becomes softer and more susceptible to damage from heavy loads. Precipitation and freezing temperatures can causing cracking and potholes.
18. Hotter weather places extra stress on electrical gear since there is more resistance and the electrical gear has to work harder.
19. Heavy rain can damage terminal buildings if they experience water intrusion.
20. Thunderstorms may damage facilities with impact from lightning strikes or hail.
21. Strong winds can damage facilities and blow objects like equipment, containers, or debris into them. They may also cause wave action that erodes terminal shorelines.
22. As terminal operations are more dependent on electricity to meet emissions reduction goals, there may be a need to install backup power systems to continue operations or carry out basic functions during severe weather events.

EQUIPMENT

LOW

Impact to cargo-handling equipment and fleet vehicles

23. Extreme heat and cold can impact temperature-sensitive components on equipment and damage them or make them temporarily inoperable.
24. Extreme temperatures can reduce the performance of terminal equipment. Battery-powered equipment may be more susceptible to reduced performance if the batteries have a harder time charging in the cold or overheat when the temperatures rise.
25. Strong winds can damage equipment by knocking it down, blowing it into other nearby objects, or striking it with windblown objects and debris. Some equipment like cranes have storm brakes and tie-downs to secure them in place during strong winds.
26. Thunderstorms may damage equipment with impact from lightning or hail. Tall equipment like cranes generally have lightning protection systems in place.
27. Port equipment like snowplows may be used to remove snow and debris from terminals.

IMPACTS TO **NWSA**

COMMERCE

LOW

Impact to business and cargo volumes

(25) Weather in the Pacific Northwest is mild compared to other parts of the county. Severe weather events are generally limited in nature and do not have a large impact on business.

(26) Even with climate change and increasing frequency and severity of severe weather, the Gateway is unlikely to lose cargo to other regions because of severe weather. It may even see an increase in cargo volumes as hurricanes become more intense and shift discretionary cargo away from the Gulf and East Coast during the hurricane season.

(27) Severe weather such as extreme heat, drought, and heavy rains could affect agricultural exports and reduce export volumes.

ORGANIZATION

LOW

Impact to organizational resilience

(28) Longer and more severe weather events may affect operations and commerce in the Gateway and could lead to loss of revenue for the NWSA.

(29) Staff that work indoors have flexibility in the event of severe weather and can carry out their work duties at home or at one of the offices. Staff that carry out work in the field may be affected and have to adjust how and when they carry out their outdoor work.

(30) The NWSA could have increased costs associated with shifting or halting work at NWSA-operated terminals during severe weather events.

(31) There could be increased costs to the NWSA in the future to upgrade facilities and equipment to better adapt to severe weather events.

IMPACTS TO **GATEWAY**

EXPOSURE

HIGH

Exposure across the gateway

1. All areas of the Gateway are affected by severe weather.
2. Winter hazards like snow, ice storms, and even avalanches can affect the Gateway especially in the mountain passes and cargo routes across the upper Midwest.
3. Warm weather hazards like extreme heat and heat waves are becoming more common across the Gateway.
4. The Gateway doesn't experience hurricanes unlike the Gulf and East Coast.
5. Strong winds do occur in the Gateway but are generally less severe than the strong winds experienced across the Midwest, Gulf, and East Coast. While tornados can and do occur in the Pacific Northwest, they are also more common in the Midwest, Gulf, and East Coast.
6. Thunderstorms and hail can affect the Gateway. The Gateway can experience drought conditions, but droughts are more likely to affect the Southwest, Midwest, Gulf, and East Coast.

ROADWAYS

MODERATE

Impact to truck travel on freight roadways

7. Severe weather may slow or halt vehicle travel if there are strong winds, low visibility, or slick conditions. Commercial trucks have an especially difficult time driving in heavy winds, rain, fog, snow, or ice.
8. Strong winds can knock trees or other debris onto roadways requiring clearing and repair prior to resuming travel and trucking operations.
9. Extreme heat can damage roadways through softening and expansion of materials, causing deformation and failure. It may also put increased stress on various roadway bridge components and shorten their lifespan.
10. Greater fluctuations in temperatures from climate change can accelerate roadway cracking from freeze thaw cycles.

RAILROADS

MODERATE

Impact to rail travel on freight railroads

11. Strong winds can knock trees or other debris onto the track and rail infrastructure requiring clearing and repair prior to resuming operations.
12. Extreme heat can cause the rail tracks to expand and buckle, known as "sun kinks," and may cause derailments. It may also put increased stress on various rail bridge components and shorten their lifespan.
13. Droughts can dry out soils beneath tracks, causing subsidence and misalignment.
14. Extreme winter conditions like ice and snow can affect rail operations. Snow drifts may make rail corridors impassable until the snow is cleared, and snow and ice can affect moving parts like switches, causing them to freeze in place.

WATERWAYS

LOW

Impact to vessel travel on navigable waterways

15. Strong winds may make navigation unsafe and slow or halt vessel transits in confined areas, especially with larger vessels.
16. Low-visibility conditions from heavy rain, fog, or snow may complicate navigation and slow or halt vessel transits.
17. Winds may knock debris and containers into the waterways and need to be cleared.
18. While drought conditions don't affect the navigable waterways that serve the Gateway, drought conditions in waterways that are fed by freshwater could be affected. Drought conditions at the Panama Canal have affected vessel operations with limits on vessel draft and number of authorized transits. This could affect shipping lanes and shift more trans-pacific trade back to West Coast ports from the Gulf and East Coast.

IMPACTS TO **GATEWAY**

UTILITIES

LOW

Impact to gateway utilities

19 Thunderstorms and strong winds can cause power outages. Extreme heat and winter storms may put excessive demand on the power system resulting in outages.

20 Heavy rainfall can overwhelm stormwater systems leading to backups and overflows.

21 Severe winter weather can freeze pipes for wet utilities.

Prolonged drought could affect hydropower generation and affect power supply in the region.

22 The utility companies have mitigated much of the severe weather risk for the utilities that serve the Gateway and disruptions to utility service are generally limited in duration.

23 The utilities may require additional adaptation measures to protect against future service disruptions with the changing climate.

INDUSTRIAL

LOW

Impact to region's cargo support facilities

21 All the region's industrial lands are in areas that could be affected by severe weather events.

22 Periods of extreme temperatures and severe storms can impact industrial lands and can lead to a loss in productivity.

23 Severe weather events are most likely to disrupt goods transport than they are to directly disrupt the cargo support locations. This can create busy periods at cargo support sites following severe weather events.

COMMUNITY

MODERATE

Impact to gateway communities

24 The stresses of severe weather can affect communities and the ancestral lands of the Coast Salish Tribes in our Gateway.

25 Increased frequency and severity of severe weather events may be especially harmful for vulnerable communities with less resources to adapt to weather events like extreme heat.

EMPOWERMENT

MODERATE

Impact to organizational resilience

26 While natural systems are generally resilient to severe weather, the greater frequency, variability, and intensity of these events from climate change may compromise these systems by altering their ecological balance.

27 Extreme heat events and droughts can threaten habitat areas by reducing food and water supply for plants and animals and overheating or burning them.

28 Warming water temperatures can be especially harmful for the well-being of aquatic life and eco-systems.

Severe Weather

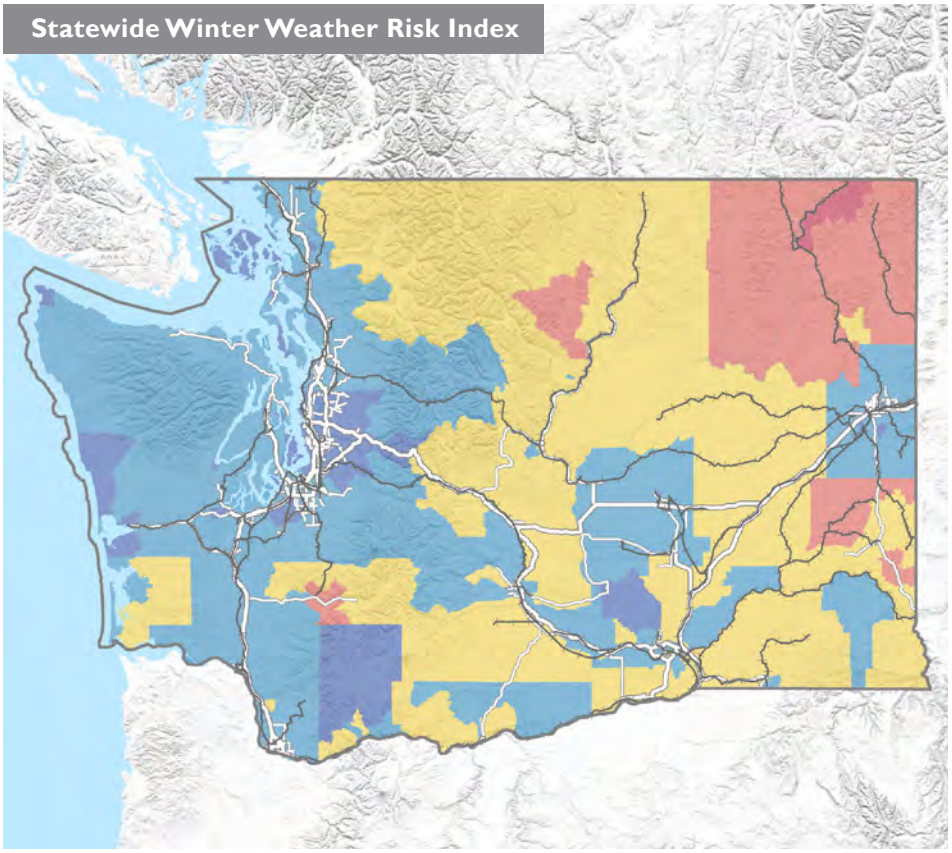
The FEMA National Risk Index has been used to provide a general overview of where these hazards may occur and their general level of risk. Severe weather is only shown at the statewide level since it affects a broader area than other natural hazards with a clearly defined hazard area.

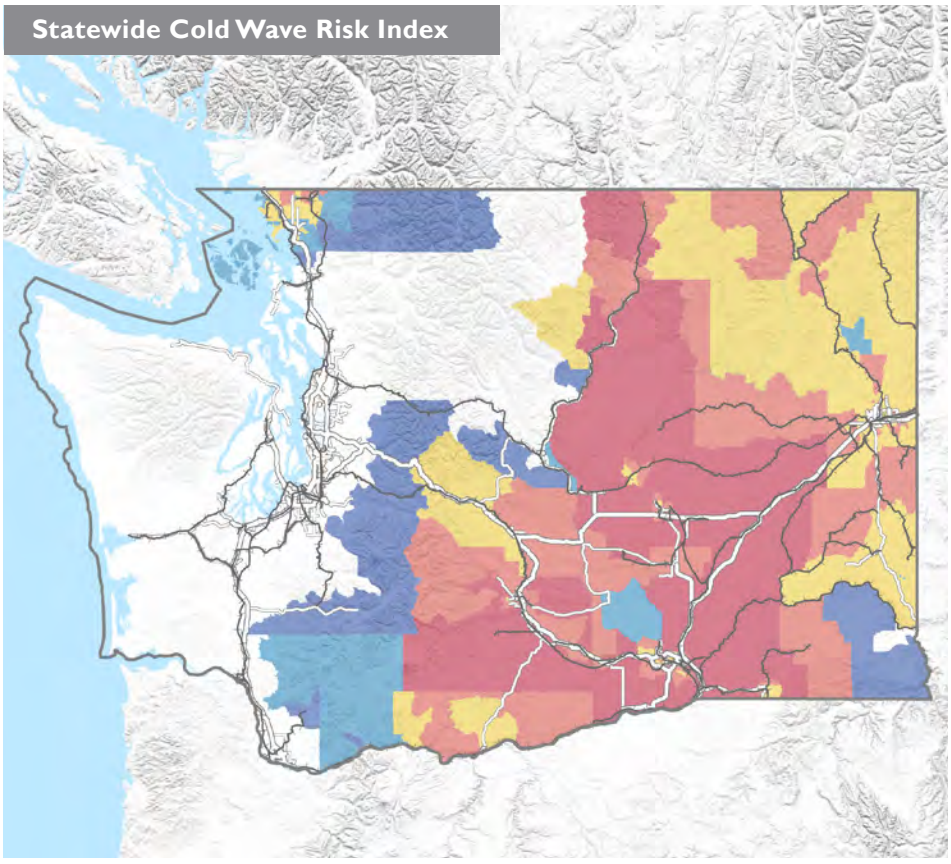
Winter Weather

Winter storm events such as snow, sleet, and freezing rain

Cold Wave

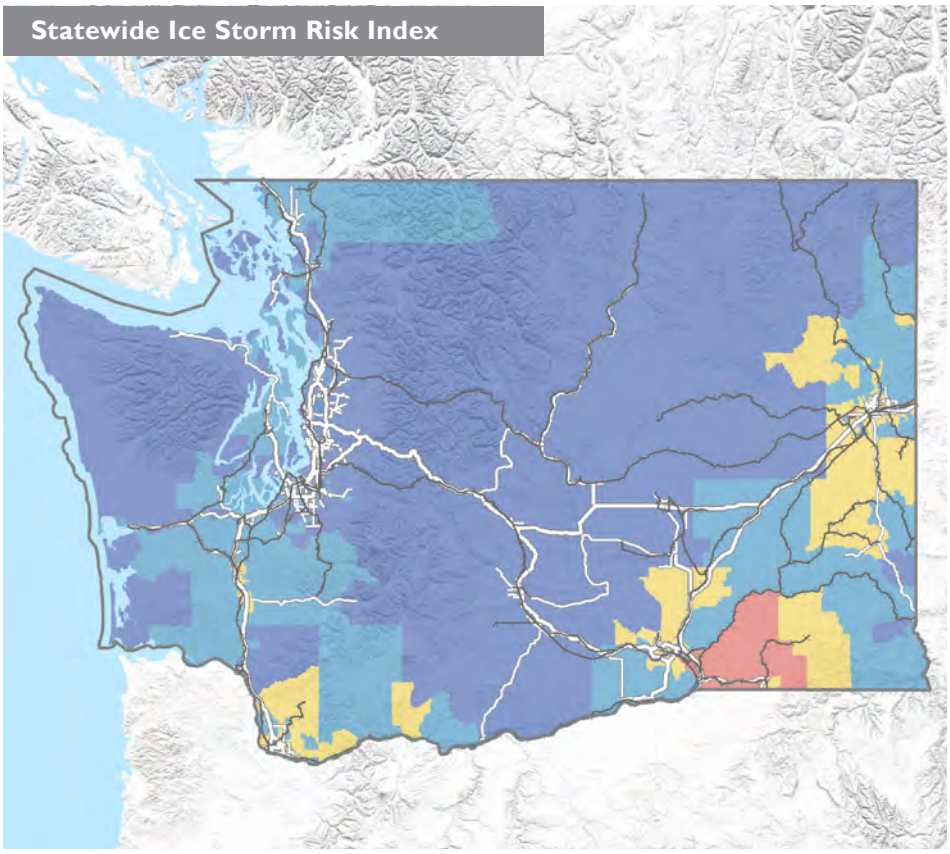
A rapid drop in temperatures followed by extreme low temperatures for an area for an extended period of time



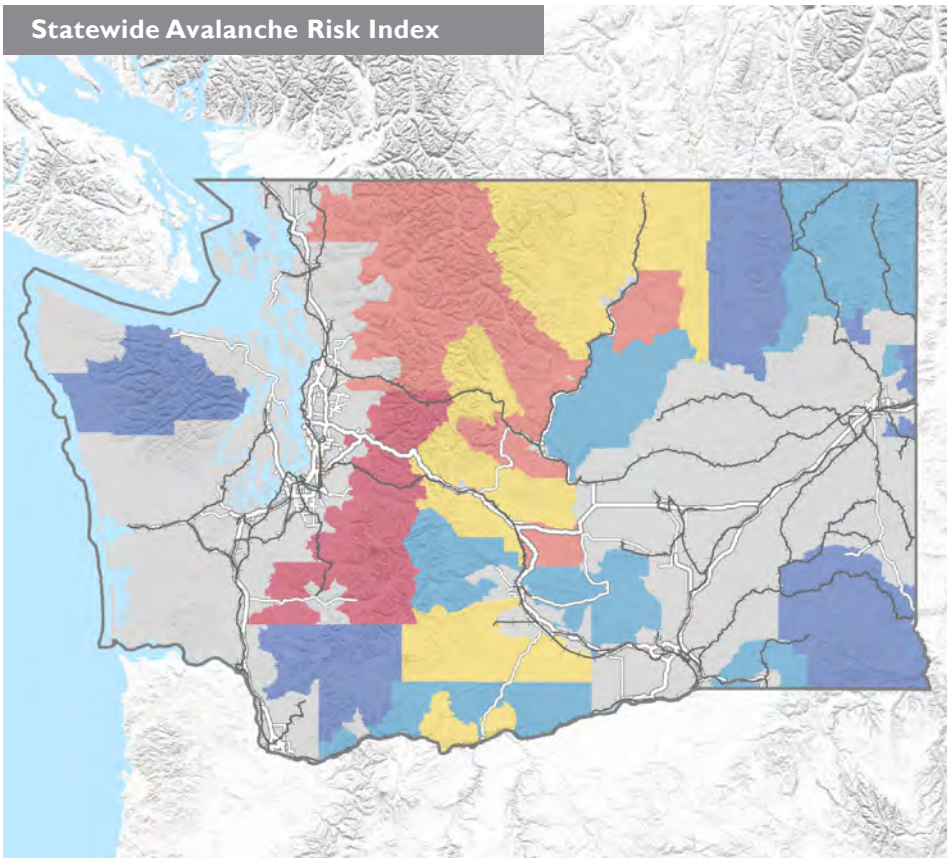


- Very High
- Relatively High
- Relatively Moderate
- Relatively Low
- Very Low
- Not Applicable
- No Rating

Statewide Ice Storm Risk Index



Statewide Avalanche Risk Index



Severe Weather

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Ice Storm

Freezing rain with significant ice accumulation

Avalanche

The rapid downhill movement of a mass of snow

- Very High
- Relatively High
- Relatively Moderate
- Relatively Low
- Very Low
- Not Applicable
- No Rating

Severe Weather

The FEMA National Risk Index has been used to provide a general overview of where these hazards may occur and their general level of risk. Severe weather is only shown at the statewide level since it affects a broader area than other natural hazards with a clearly defined hazard area.

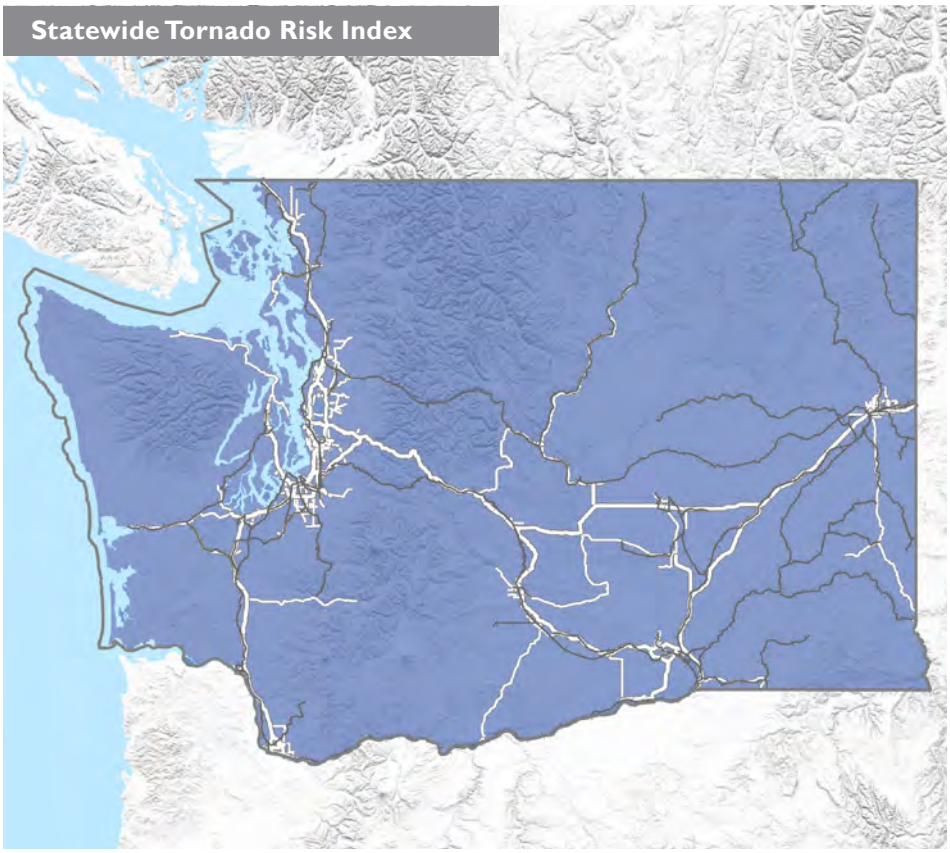
Tornado

A narrow air column that rotates violently from a thunderstorm to the ground

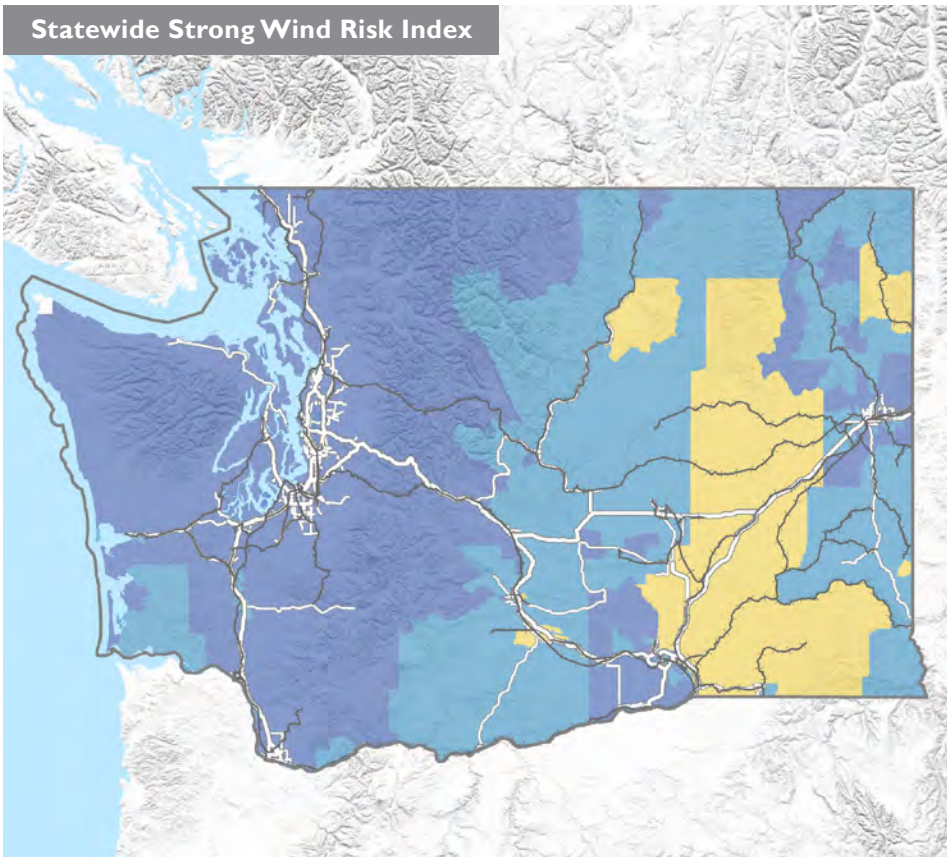
Strong Wind

Damaging winds over 58 mph and often result from thunderstorms

Statewide Tornado Risk Index

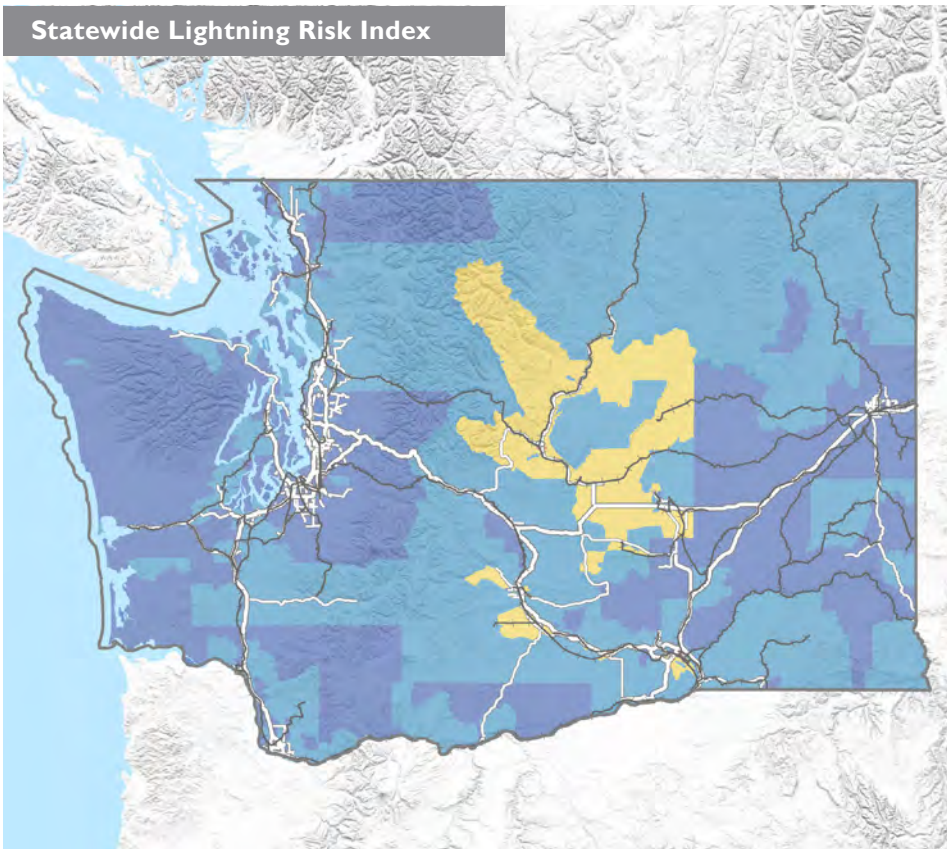


Statewide Strong Wind Risk Index

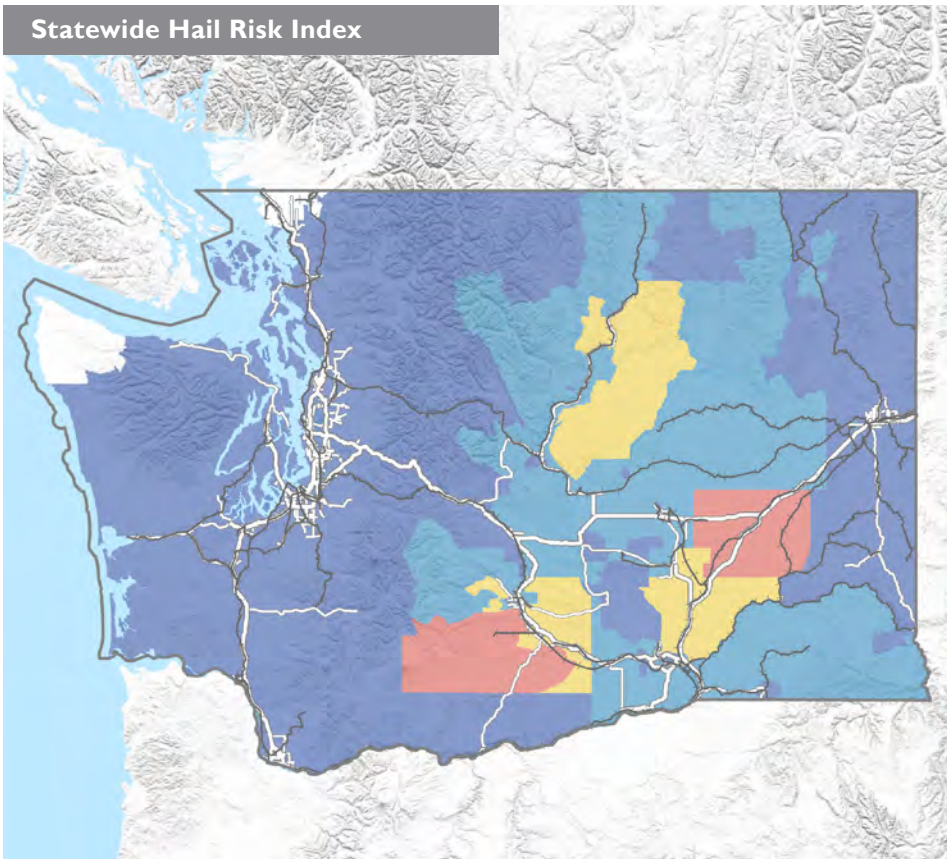


- Very High
- Relatively High
- Relatively Moderate
- Relatively Low
- Very Low
- Not Applicable
- No Rating

Statewide Lightning Risk Index



Statewide Hail Risk Index



Severe Weather

The FEMA National Risk Index has been used to provide a general overview of where these hazards may occur and their general level of risk. Severe weather is only shown at the statewide level since it affects a broader area than other natural hazards with a clearly defined hazard area.

Lightning

Visible electrical discharge between the air and ground often resulting from a thunderstorm

Hail

Frozen balls of ice that fall from the sky often resulting from a thunderstorm

- Very High
- Relatively High
- Relatively Moderate
- Relatively Low
- Very Low
- Not Applicable
- No Rating

Severe Weather

The FEMA National Risk Index has been used to provide a general overview of where these hazards may occur and their general level of risk. Severe weather is only shown at the statewide level since it affects a broader area than other natural hazards with a clearly defined hazard area.

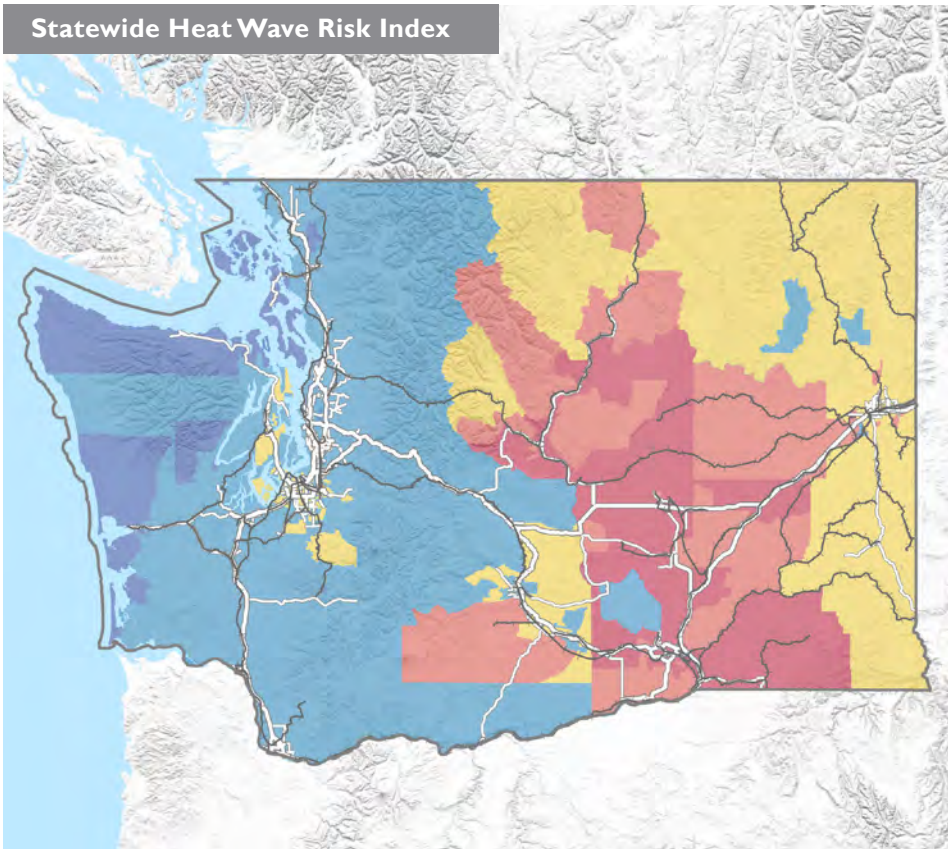
Heat Wave

A period of unusually hot and humid weather for an area lasting two or more days

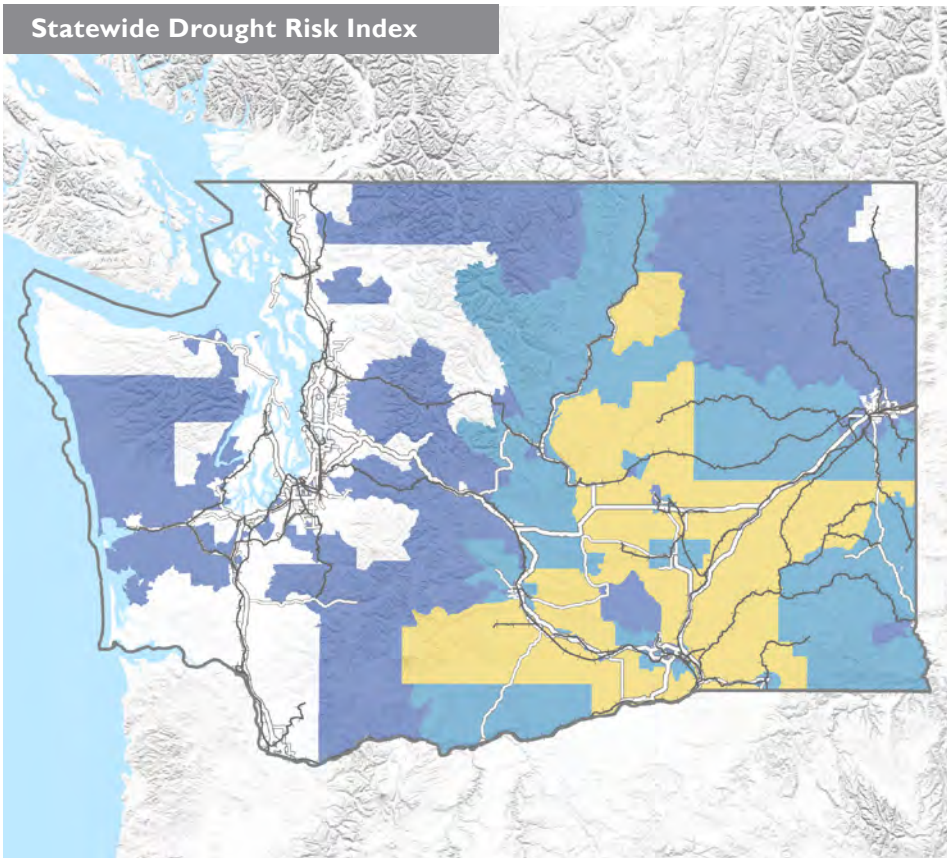
Drought

Lack of precipitation for an extended period of time leading to a shortage in water

Statewide Heat Wave Risk Index

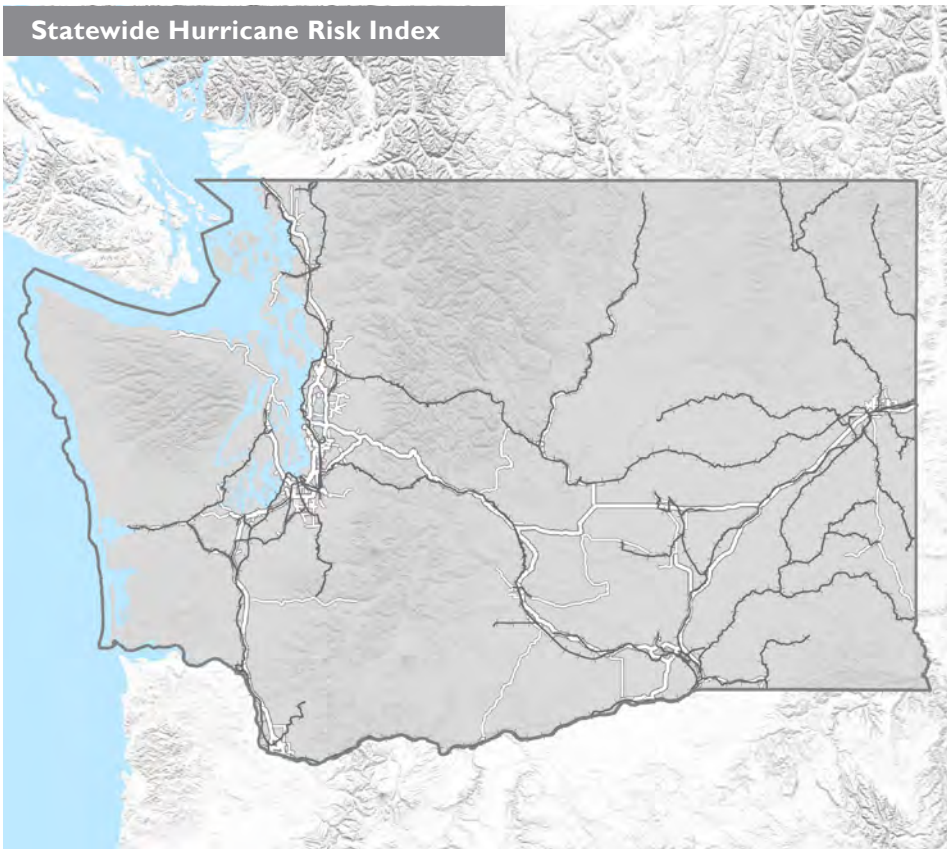


Statewide Drought Risk Index



- Very High
- Relatively High
- Relatively Moderate
- Relatively Low
- Very Low
- Not Applicable
- No Rating

Statewide Hurricane Risk Index



Severe Weather

The FEMA National Risk Index has been used to provide a general overview of where these hazards may occur and their general level of risk. Severe weather is only shown at the statewide level since it affects a broader area than other natural hazards with a clearly defined hazard area.

Hurricane

A tropical cyclone with violent wind

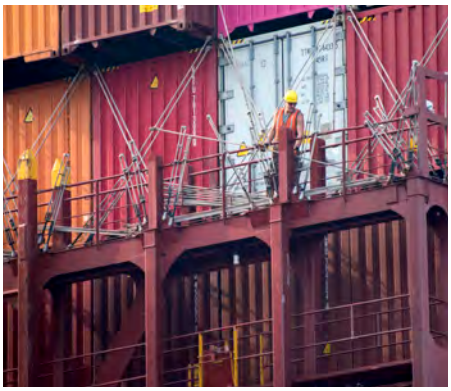
- Very High
- Relatively High
- Relatively Moderate
- Relatively Low
- Very Low
- Not Applicable
- No Rating

Smoky conditions and poor air quality at Seattle Harbor's Terminal 46 during the 2020 wildfire season.

Days of poor air quality

Seattle-Tacoma-Bellevue metropolitan area (2018-2022)

Hazardous	1
Very unhealthy	8
Unhealthy	21
Unhealthy for sensitive groups	42



Many outdoor jobs on the terminals are physically demanding and cannot easily be carried out with a mask on. Poor air quality may slow or halt terminal operations.

The 2022 Bolt Creek wildfire (shown right) had wide-reaching impacts on transportation in the gateway. It required community evacuations and caused temporary closures of US Highway 2 and Steven's Pass rail corridor, leading to delays on I-90.

WILDFIRE CHARACTERISTICS VARY GREATLY

Wildfires are unplanned and uncontrolled fires that burn forests, brush, crops, and grasslands. As they burn, they can wreak havoc on communities, destroying anyone and anything in their path. Wildfires are more prevalent in rural, undeveloped areas, but can also impact urban areas from the wildfire or resulting smoke. Neither NWSA harbor is located in a wildfire-prone area, but both experience poor air quality from wildfire smoke during the wildfire season that slow or halt terminal operations. Wildfires and smoke across the gateway can cause closures or delays on key freight corridors, affecting cargo operations.

Wildfire – Wildfires are a normal part of the ecosystem and are caused by human activity and natural causes. Natural causes include lightning strikes, coal seam fires, and volcanic activity. Human causes include recreational fires, smoking, fireworks, sparks from heavy machinery along roads or railroads, and downed powerlines. Wildfire characteristics can vary greatly depending on the type of fuel they are burning, the weather, and the topography. Weather conditions such as temperature, precipitation, humidity, and wind are significant determinants of fire behavior and how quickly it spreads. Climate change and decades of fire suppression resulting in build-up of wildfire fuels has created more favorable conditions for wildfires, resulting in longer, more severe wildfire seasons.

Smoke – Smoke is created as a wildfire consumes fuel and releases heat, water vapor, carbon dioxide, alongside other gases and particles. Ash and soot are the primary particles released in wildfire smoke and these particles negatively impact air quality and public health. Wildfire smoke can impact communities hundreds or even thousands of miles away from the wildfire source.

Post-Fire Debris Flows and Flooding – Areas that have been burned can become susceptible to other hazards such as debris flows and flooding. Burned areas can lose the ability to retain soil because the fire burns vegetation and leaves behind exposed, water-repellent soil. Rain events after a fire can trigger devastating flash floods and debris flows as the increased surface runoff flows downhill picking up the loose soil that is no longer anchored by vegetation. Any area downhill of a burn can be affected by landslides, flooding, and debris flows.

PAST EVENTS

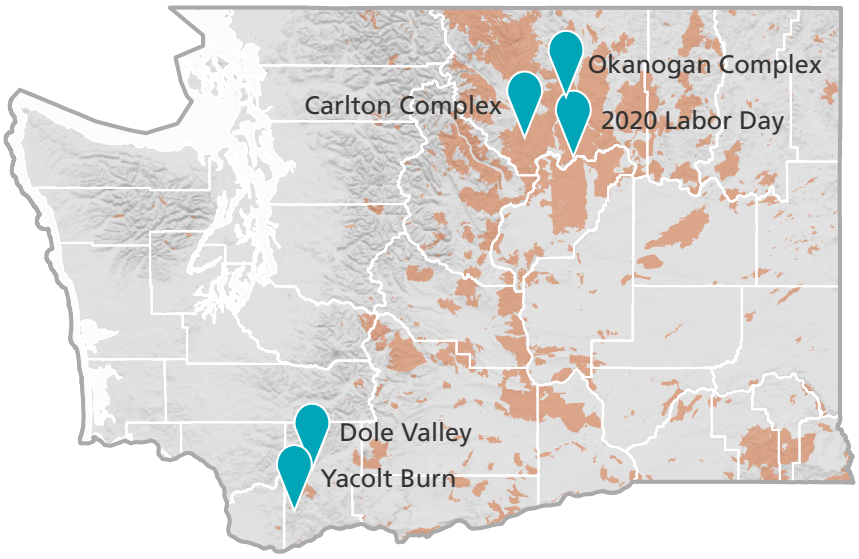
Wildfires are a high probability event in the western United States, with 21 recorded billion-dollar wildfire disasters since1980. There are typically over a thousand reported wildfires in Washington each year and most wildfires occur in eastern Washington where the climate is more arid.

The Yacolt Burn of 1902 was the largest recorded wildfire in Washington for over a century. The fire grew quickly because of limited firefighting capabilities at the time, causing many deaths and widespread property loss. Smoke from the fire even darkened the skies as far away as Seattle. The following year, the Washington Legislature established a state fire warden, beginning an era of organized fire protection in the state.

In 2014, the Carlton Complex surpassed the Yacolt Burn as the largest wildfire in Washington, a record which was broke the following year by the Okanogan Complex, and then again in 2020 during the Labor Day fires.

Top 5 Wildfires in Washington by Acres Burned

Major wildfires from 1980-2020 shown below in orange



Rank	Name	Year	Size (ac)
1	2020 Labor Day	2020	410,000
2	Okanogan Complex	2015	305,000
3	Carlton Complex	2014	256,000
4	Yacolt Burn	1902	239,000
5	Dole Valley	1929	227,000

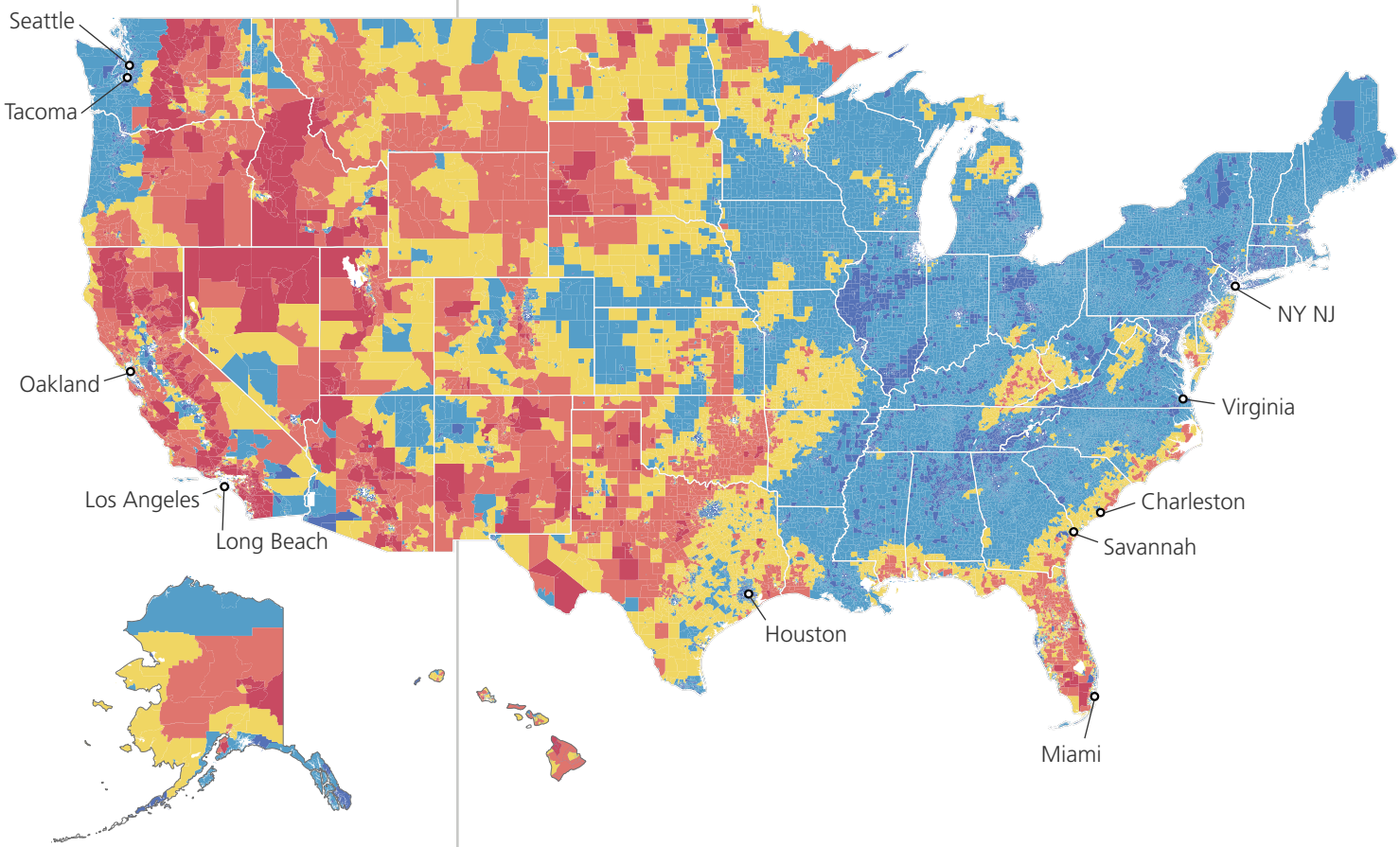
Thunderstorms caused mudslides and flooding in areas burned by the Carlton Complex fire, blocking two highways and damaging homes.

Climate change is causing longer, more severe wildfire seasons that affect cargo operations.

Our Gateway is an agricultural export hub. Wildfire smoke can affect crop quality and output and put agricultural workers and operations at risk.

WILDFIRE RISK AT TOP 10 US CONTAINER PORTS

The Federal Emergency Management Agency (FEMA) has mapped and quantified the wildfire risk across the United States based on expected annual loss, social vulnerability, and community resilience. The wildfire risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties. This risk index does not account for the risk associated with wildfire smoke.



Very High	Relatively High	Relatively Moderate	Relatively Low	Very Low
Long Beach	Miami	Charleston	**NWSA Seattle**	NY NJ
Los Angeles		Houston	**NWSA Tacoma**	Virginia
		Oakland		
		Savannah		

HAZARD CHARACTERIZATION AND IMPACTS

Wildfire and smoke risk is based on hazard likelihood, scale, exposure, and areas of susceptibility. Hazards are characterized by their likelihood and scale and vulnerabilities are determined by exposure and susceptibility to the hazard.

WILDFIRE & SMOKE HAZARDS

Likelihood	**HIGH**
Scale	**MODERATE**
Outlook	**MODERATE**
Hazard Type	**CHRONIC**

IMPACTS TO NWSA

Exposure	**MODERATE**
Safety	**MODERATE**
Operations	**MODERATE**
Facilities	**LOW**
Equipment	**LOW**
Commerce	**MODERATE**
Organization	**LOW**

IMPACTS TO GATEWAY

Exposure	**MODERATE**
Roadways	**MODERATE**
Railroads	**MODERATE**
Waterways	**LOW**
Utilities	**LOW**
Industrial	**LOW**
Community	**MODERATE**
Environment	**MODERATE**

Wildfires are a regular occurrence during the wildfire season. While NWSA and gateway areas of vulnerability are low to moderate, these could become higher in future decades with climate change.

Both BNSF and Union Pacific Class I railroads work to prevent and put out wildfires along their rail corridors with firefighting trains.

HAZARD INFORMATION

LIKELIHOOD

HIGH

Likelihood of occurring on any given year

1. Wildfires and smoke have a high likelihood of occurrence on any given year and there are typically over one thousand wildfires reported a year in Washington alone.
2. The 10-year average number of reported wildfires in Washington has increased from over 1,400 in 2005 to over 1,500 in 2022.
3. There has been an increasing number of days with poor air quality in the Puget Sound during the wildfire season in the last decade, especially as the wildfire season has become longer.

SCALE

MODERATE

Magnitude event with regional scale

4. Most wildfires on any given year are small in scale and extinguished before they become an acre in size.
5. Wildfires can spread and become much larger in size, burning tens to hundreds of thousands of acres with a single wildfire event.
6. There have been 15 wildfire events in Washington that burned over 100,000 acres since 1910.
7. The 10-year average of reported acres burned in Washington has increased from about 118,000 in 2005 to nearly 473,000 in 2022.
8. The impact of wildfire smoke on air quality in the region has been getting more severe, with more days during the wildfire season of unhealthy, very unhealthy, or hazardous air quality.

OUTLOOK

MODERATE

Level of increasing risk in future decades

9. Climate change is contributing to increased wildfire and smoke risk with longer wildfire seasons, an increasing number of wildfires, and more damaging events.
10. Factors that are contributing to the increased risk level include earlier snowmelt, increasing temperatures, drier summers, increased drought, lower soil moisture content, spread of insects such as the mountain pine beetle that kill or damage tree and plantlife, and increases in fuels from dead trees and plants.
11. Increased development and human-activity in wildfire-prone areas is likely to exacerbate wildfire and smoke activity and require more fire suppression efforts.
12. There will be an increased number of days a year with high fire potential relative to the 1971-2000 timeframe. Across the state there will be roughly 3-5 more days a year with high fire potential in the 2010-2039 timeframe and 6-9 more days a year in the 2040-2069 timeframe in a low emissions scenario. In a high emissions scenarios these numbers will increase to 4-7 more days a year in the 2010-2039 timeframe and 8-11 more days a year in the 2040-2069 scenario.

IMPACTS TO **NWSA**

EXPOSURE

MODERATE

NWSA exposure

1. The NWSA harbors are not in a wildland-urban interface zone and are not susceptible to wildfires.
2. Both NWSA harbors experience poor air quality from wildfire smoke during the wildfire season. There have been an increasing number of days with poor air quality each year as the wildfire season has been getting longer and more severe with climate change.
3. Both harbors may be exposed to ash from nearby wildfires.

SAFETY

MODERATE

Impact to safety and worker health

4. Wildfire smoke does not generally pose an immediate threat to life safety.
5. Worker exposure to wildfire smoke may cause or exacerbate health concerns such as respiratory illnesses and infection, asthma, hypertension, cancer, and chronic pulmonary diseases.
6. Many workers on the terminals have to work outside, often with labor-intensive jobs that are difficult to carry out with a mask on.
7. New regulations were put in place by the state that protect outdoor workers during periods of poor air quality from wildfire smoke. These rules apply to all the outdoor workers that support cargo operations on and off-terminal.

OPERATIONS

MODERATE

Impact to terminal operations

8. Wildfire smoke affects terminal operations by shifting work windows around or halting operations altogether when the conditions are not safe or healthy for workers due to poor air quality or reduced visibility on the terminal.
9. The shifts in operations to protect workers often go above and beyond the rules put in place by the state to protect outdoor workers.
10. While some jobs can be carried out indoors or inside equipment cabs with ventilated air, many of those jobs are tied to jobs that can't be relocated inside, resulting in shutdowns in most or all operations.
11. Wildfires and smoke can slow or halt on-terminal operations if key freight corridors are affected and goods can't get to or from the terminals. Disruptions to freight corridors can create surges of cargo coming through the terminals following a wildfire and smoke event.
12. Longer wildfire seasons can impact terminals for significant periods of time, reducing terminal production for the season.

IMPACTS TO **NWSA**

FACILITIES

LOW
Impact to NWSA facilities

13. Wildfire is not expected to impact facilities in either harbor but smoke and ash may affect facilities
14. Some terminal buildings may require improvements in order to provide a smoke-free healthy work environment. Terminal buildings may require additional upgrades, repair, or replacement of the HVAC system or particular components such as air filters. Some buildings may require improvements to the building envelope to prevent smoke from getting in the building.
15. Many of the terminal buildings are not designed to be air-tight and it would be cost-prohibitive to make the necessary upgrades to provide a some-free work environment, further affecting operations.

EQUIPMENT

LOW
Impact to cargo-handling equipment and fleet vehicles

16. Wildfire is not expected to impact equipment in either harbor.
17. Terminal equipment may require additional repair and replacement of components that are sensitive to smoke and ash.
18. Fine particulate matter from smoke and ash can foul air intakes and combustion systems, disrupt moving parts, corrode surfaces, and cause mechanical and electrical system failures.

COMMERCE

MODERATE
Impact to business and cargo volumes

19. Wildfires and smoke can have seasonal impacts to business in both harbors with seasons of reduced operations and terminal productivity.
20. Business could slow down during the wildfire season, especially if goods movement on key freight corridors is affected.
21. Wildfire smoke and ash are not expected to damage cargo on terminals. Smoke and ash in the region can affect agricultural products and operations, reducing export volumes through NWSA terminals.
22. Impacts to business are considered short-term following wildfire and smoke events and would be relatively easy to recover from due to minimal impacts to infrastructure.

ORGANIZATION

LOW
Impact to organizational resilience

23. Longer and more severe wildfire seasons that affect operations and commerce in the gateway could lead to loss of revenue for the NWSA.
24. Administrative staff that work indoors can carry out their normal work duties either at home or at one of the offices in the event of wildfire smoke. Staff that work in the field may be affected and may have to adjust their work around air quality conditions.
25. The NWSA would have increased costs associated with shifting or halting work at NWSA-operated terminals during seasons of poor air quality.
26. While there would be minimal cost to recover from wildfire and smoke events due to impact on facilities and equipment, there would be increased costs to the NWSA in the long-term if it upgrades terminal buildings or port-owned equipment to provide a smoke-free working environment.

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IMPACTS TO **GATEWAY**

EXPOSURE

MODERATE

Exposure across the gateway

1. There is greater exposure to wildfire smoke than wildfires across the gateway. Wildfire smoke can travel long distances and can result from wildfires within the gateway or travel to the gateway from outside.
2. The frequency of poor air quality days resulting from wildfire smoke is increasing and is now a recurring seasonal hazard.
3. Wildfire exposure in Washington is generally concentrated in rural areas in eastern Washington.
4. Much of the Gateway infrastructure and industrial lands are located in developed areas in western Washington where the risk of wildfires is low.
5. The Gateway is at a greater risk for wildfire smoke exposure which is widespread.

ROADWAYS

MODERATE

Impact to truck travel on freight roadways

6. Wildfires are not expected to have a significant impact on freight roadways in western Washington, except for any impacts from wildfire smoke. Roadways like I-90 that travel east are more exposed to wildfires and their impacts.
7. Wildfires could cause corridor closures during active fires. Severely burned areas may be closed following the fire if there is threat of post-fire flooding and debris flows.
8. Wildfire road closures may cause increased congestion on the remaining open freight corridors.
9. Roadways exposed to wildfire may experience damage to bridges, roadway surface, and other supporting infrastructure that require repairs to resume travel.
10. Poor visibility from wildfire smoke could slow roadway travel.

RAILROADS

MODERATE

Impact to rail travel on freight railroads

11. Wildfires are not expected to have a significant impact on the local rail network in western Washington. Rail corridors traveling to the east are more exposed to wildfires such as Stevens Pass, Stampede Pass, and the Columbia River Corridor.
12. Wildfires could slow or halt rail activity during active fires leading to service delays.
13. Railroads exposed to wildfire may experience damage to bridges, railroad ties, and other supporting infrastructure that require repairs to resume travel.

WATERWAYS

LOW

Impact to vessel travel on navigable waterways

14. Wildfires are not expected to impact the navigable waterways.
15. Poor visibility from wildfire smoke could impede vessel operations.

IMPACTS TO **GATEWAY**

UTILITIES

LOW
Impact to gateway utilities

16. Several utility systems that support Gateway operations are located in forested areas that could be susceptible to wildfires.
17. Utilities such as power are especially susceptible to wildfires since they are often sourced from further away and travel through wildfire-prone areas. Power infrastructure has also caused multiple wildfires.
18. Damaged utility systems could lead to temporary outages that impact operations.

INDUSTRIAL

LOW
Impact to region's cargo support facilities

19. Most of the region's industrial lands and Manufacturing/Industrial Centers (MICs) are located in developed areas with little wildfire potential.
20. Industrial lands are more likely to be affected by wildfire smoke. Building envelopes and HVAC systems may need to be upgraded to prevent smoke from getting into buildings and affecting operations.

COMMUNITY

MODERATE
Impact to gateway communities

21. Communities located in rural, forested areas are more susceptible to wildfires than those in urbanized population centers.
22. During wildfire episodes, air quality (as measured by the Air Quality Index, AQI) routinely gets to unhealthy levels, posing a significant public health risk for communities.
23. Wildfire smoke can exacerbate existing public health concerns for near-port communities and outdoor workers.

EMPOWERMENT

MODERATE
Impact to organizational resilience

24. Wildfires can alter habitat and harm biodiversity and wildlife populations.
25. Wildfires can impair water quality by altering nutrient cycling, infiltration, acidity, and turbidity.
26. Wildfire smoke results in poor air quality that can affect wildlife.
27. Elevated ozone concentrations resulting from wildfires can harm plant life.

Wildland Urban interface

The Washington Department of Natural Resources has mapped the Wildland Urban Interface (WUI) to show where human developments have potential fire risk because of their proximity to wildlands including forested and grassland areas.

Wildfires can break out in WUI and uninhabitated vegetated areas, but a wildfire is more dangerous and damaging when it occurs in developed areas. Urbanized areas are characterized by their dense development and lack of vegetation, which makes them less susceptible to wildfire. Both harbors are in urbanized areas that aren't susceptible to wildfires.

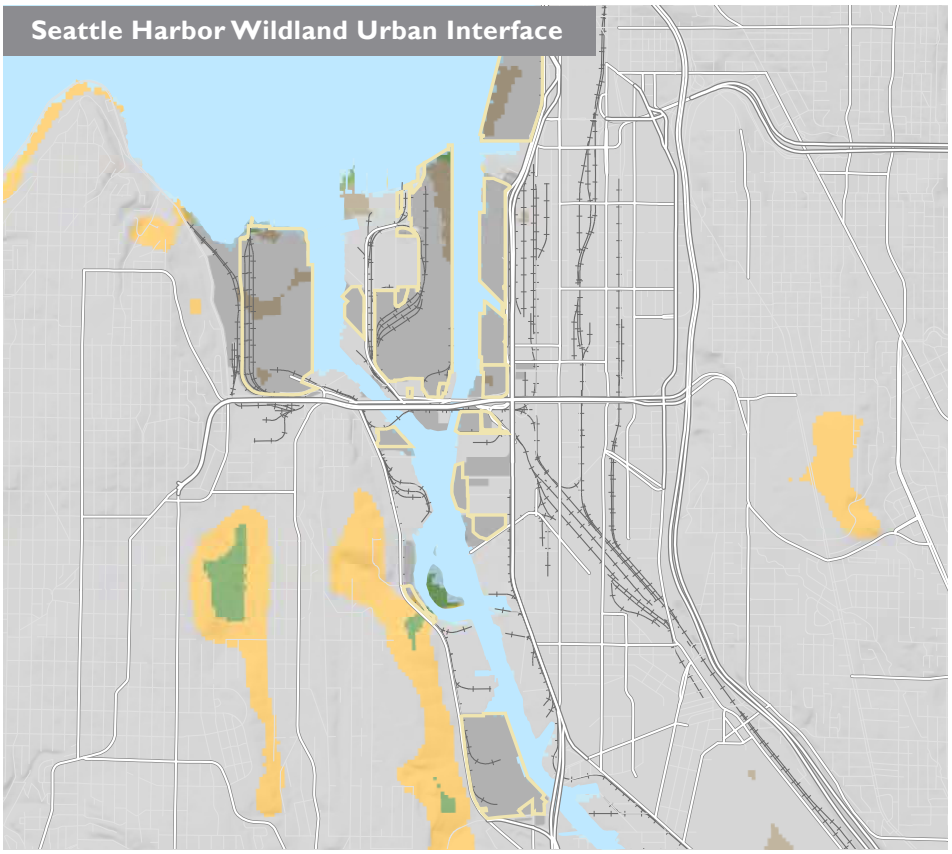
Vegetated Uninhabited
Undeveloped wildlands including forests and grasslands

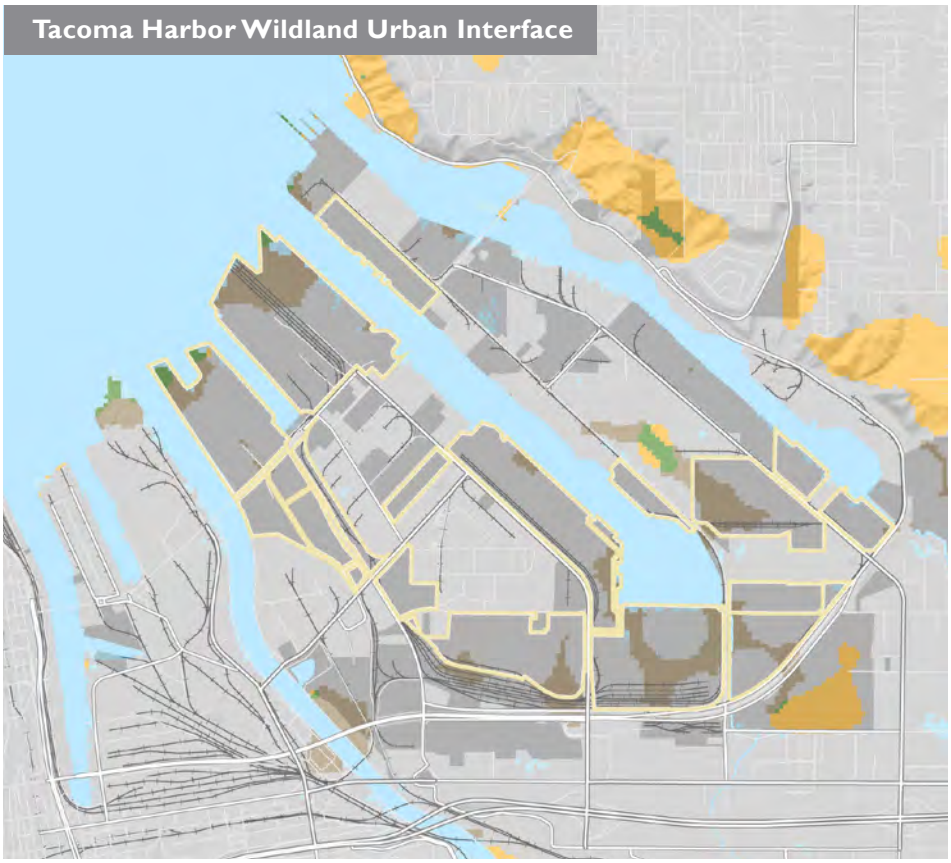
WUI Intermix
Development in or bordered by wildlands on two or more sides

WUI Interface
Development bordered by wildlands on one side

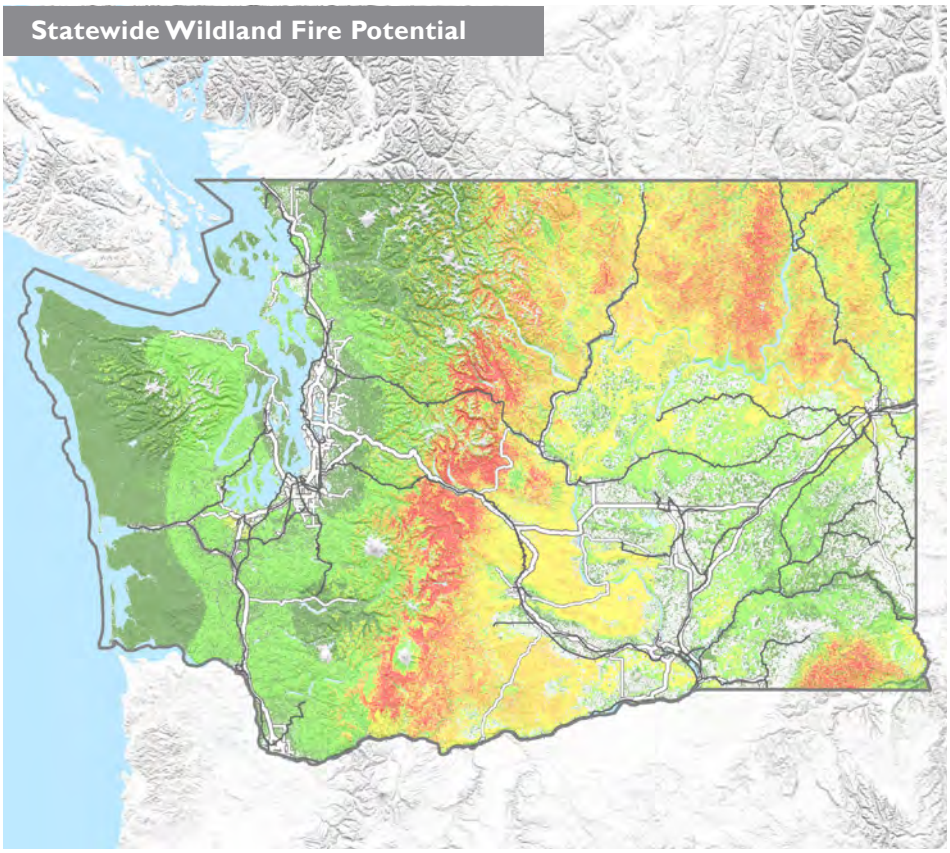
Non-Vegetated Inhabited
Developed area with less than 50% vegetation

Non-Vegetated Uninhabited
Uneveloped area with less than 50% vegetation

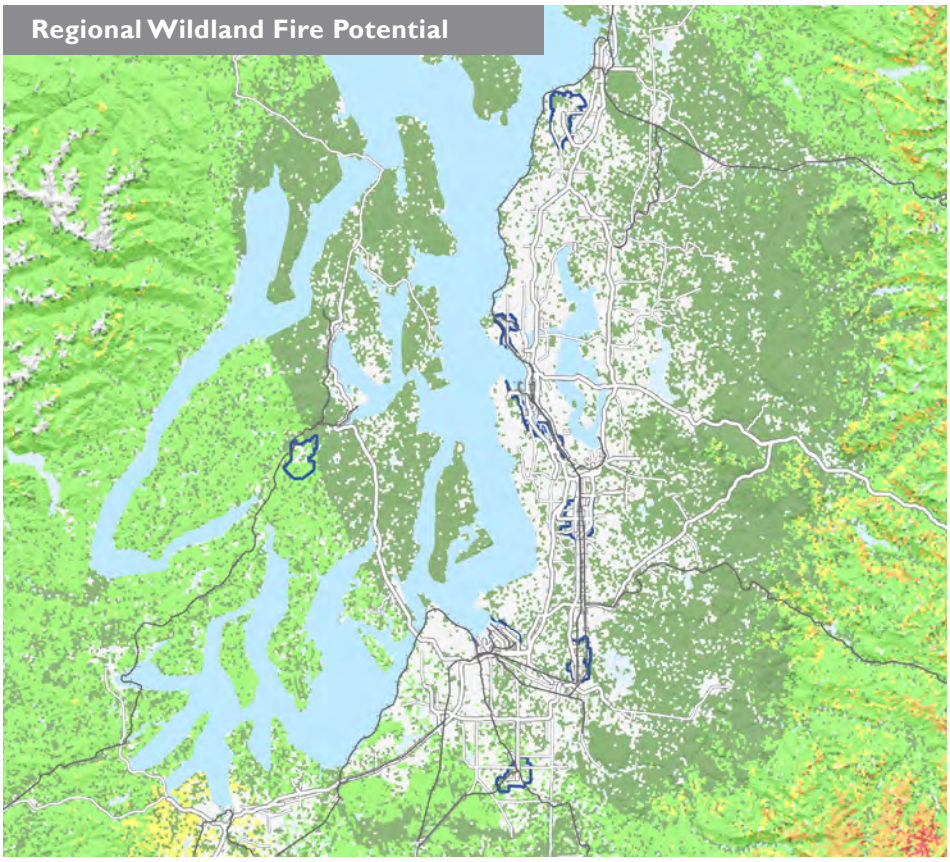




Statewide Wildland Fire Potential



Regional Wildland Fire Potential



Wildland Fire Potential

The US Department of Agriculture's Forest Service developed the wildfire potential map as a useful tool for assessing wildfire risk by better understanding where wildfires are likely occur and their potential intensity.

- Very Low
- Low
- Moderate
- High
- Very High
- Non-Burnable

Landslides are not common on NWSA properties, but the terminals are susceptible to shoreline erosion and subsidence.

Terminal 46 sinkhole (shown above)

Shoreline erosion at Pony Yard (shown below) required installation of a bulkhead to stabilize the slope and preventing damage to the upland environmental cap and stormwater system.

A submarine landslide along the Tacoma waterfront resulted in two deaths and destroyed Northern Pacific Railroad's freight docks shown above in 1894. Half a century later, a second submarine landslide occurred at the mouth of the Puyallup River.

SMALL-SCALE, HIGH PROBABILITY EVENTS REQUIRING COORDINATION

Landslides, erosion, and subsidence are common in Washington where the mountainous terrain, coastal bluffs, river valleys, and shorelines are susceptible to the downward movement of materials. There is a wide range of hazards associated with the downward movement of soil, rock, debris, or fill material. Landslides are the primary hazard assessed, but erosion and subsidence have been included because of their shared traits.

Landslide – A landslide is the downslope movement of earthen materials and common triggers include heavy preciptation, earthquakes, changes in water levels, and human development. They can be characterized based on the depth of the moving material and the type of movement. There are shallow events that are typically fast moving and include the surface materials of the slope whereas deep landslides are often slower moving and occur at depths greater than ten feet. Landslides are further characterized by their movement including flows, slides, falls, and topples. Slides are the downslope movement of earthen materials and are generally drier in nature, flows are like slides but with a slurry of water and earthen material, topples are the detachment of rock or soil from a slope with a forward rotation, and falls are like topples but with the material falling straight down instead of rotating outward. Landslides may also cause secondary hazards such as flooding or tsunamis.

Erosion – Surfaces such as hillslopes and shorelines may erode if water, wind, or ice can weather and loosen the materials at the surface. Unlike landslides which are more of a direct result of the force of gravity as opposed to general weathering. Strong erosion may eventually lead to slope destabilization and slope failures.

Subsidence – Ground may sink due to underground movement of materials such as water, natural gas, or mineral resources. Subsidence may occur naturally with earthquakes, soil compaction, or sinkhole formation or it may be triggered by human activity such as pumping, fracking, or mining.

PAST EVENTS

Landslides are very high probability events in Washington with hundreds to thousands of events each year. While most landslides are small-scale events with few if any impacts, there have been several notable landslides that were significant in terms of scale or impact.

Washington's Historic Landslides

Oso remains the deadliest landslide in U.S. history, claiming 43 lives.

Nile blocked SR 410, dammed the Naches River, and destroyed multiple homes.

Aldercrest-Banyon is the second costliest landslide in U.S. history and was the first landslide area that FEMA declared a disaster.

Mount St. Helens eruption triggered the largest recorded debris avalanche in the world, traveling 14 miles from its source iwth an average depth of 150'.

Lake Roosevelt landslides triggered tsunami waves reaching 65' high in nearby shoreline areas.

Tacoma Narrows landslide was triggered by the 1949 earthquake and triggered a tsunami wave at Gig Harbor and Sunset Beach.

Ribbon Cliffs landslide was caused by an earthuqake and blocked the Columbia River for multiple hours.

Bonneville landslide covered 6 square miles and temporarily dammed the Columbia River, creating a 150 mile-long lake before the water breached the landslide deposit, creating a new river alignment.

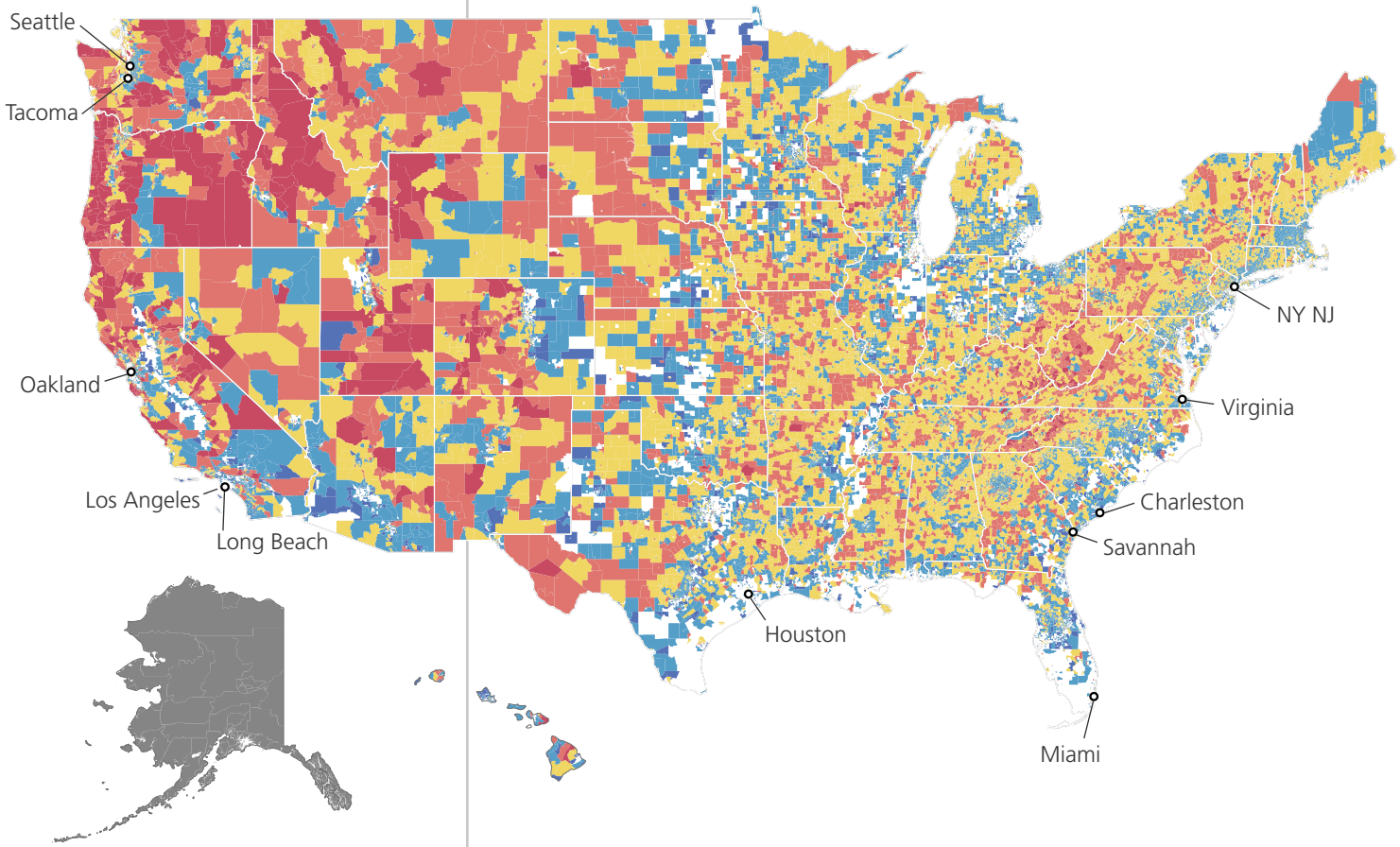
The 2014 Oso Landslide remains the deadliest landslide in U.S. history.

Landslides are common across Washington, but mitigation efforts can help reduce occurrence, impact, and recovery time to keep goods moving through the gateway.

The 1949 Tacoma Narrows Landslide was triggered by an earthquake that occurred several days prior.

LANDSLIDE RISK AT TOP 10 US CONTAINER PORTS

The Federal Emergency Management Agency (FEMA) has mapped and quantified the landslide risk across the United States based on expected annual loss, social vulnerability, and community resilience. The landslide risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Relatively High	Relatively Moderate	Relatively Low
NWSA Seattle	Houston	Charleston
NWSA Tacoma	Miami	Savannah
Long Beach	NY NJ	Virginia
Los Angeles		
Oakland		

HAZARD CHARACTERIZATION AND IMPACTS

Landslide risk is based on hazard likelihood, scale, exposure, and areas of susceptibility. Hazards are characterized by their likelihood and scale and vulnerabilities are determined by exposure and susceptibility to the hazard.

LANDSLIDE HAZARDS

Likelihood	HIGH
Scale	LOW
Outlook	LOW
Hazard Type	CHRONIC

IMPACTS TO NWSA

Exposure	LOW
Safety	LOW
Operations	LOW
Facilities	LOW
Equipment	LOW
Commerce	LOW
Organization	LOW

IMPACTS TO GATEWAY

Exposure	HIGH
Roadways	LOW
Railroads	MODERATE
Waterways	LOW
Utilities	LOW
Industrial	LOW
Community	MODERATE
Environment	LOW

Coordination and collaboration is needed to help solve regional problems like landslides along key freight corridors.

The 1997 Woodway landslide affected the railroad corridor between Seattle and Everett, derailing freight cars on a passing train and temporarily halting rail operations.

Frequent landslides along the coastal rail corridors between Seattle and Everett disrupted freight and passenger rail operations, leading partners to advance landslide mitigation projects.

HAZARD INFORMATION

LIKELIHOOD

HIGH

Likelihood of occurring on any given year

1. There are hundreds to thousands of landslide events in Washington each year.
2. Washington is one of the most landslide-prone states in the U.S.
3. There is almost a 50% chance that a major landslide will occur in a given year within the state.
4. Erosion and subsidence are common events that occur every year in Washington.

SCALE

LOW

Magnitude event with regional scale

5. Most landslides and incidents of erosion and subsidence are small in scale and go unnoticed because of their small size or remote location.
6. The 2014 Oso landslide in Snohomish County remains the deadliest landslide in U.S. history.
7. Seattle and Tacoma have both seen a significant number of landslides over the years but they've generally been small in scale.

OUTLOOK

LOW

Level of increasing risk in future decades

8. Climate change is expected to create more intense rain events, flooding, wildfires, and coastal erosion, all of which create favorable conditions for landslides.
9. Policies have been put in place to limit development in or mitigate the risk associated with building in landslide-prone areas.
10. While climate change may lead to an overall increase in number and scale of landslides, these are likely to occur mostly in low-consequence areas that do not have a major impact on cargo operations due to mitigation efforts to protect critical infrastructure.

IMPACTS TO **NWSA**

EXPOSURE

LOW
NWSA exposure

1. There is limited exposure to landslide hazard areas at NWSA terminals. Terminals are more likely to experience slope destabilization or subsidence.
2. NWSA terminals are primarily flat and located away from steep slopes that are susceptible to landslides, but several terminals are adjacent to landslide hazard areas and could have a landslide reach the terminal.
3. Terminals may be susceptible to slope destabilization along shorelines and other sloped areas such as creeks or drainage ditches. Destabilization could be caused from erosion or underwater landslides.
4. Subsidence can be an issue on the terminals because most of them are built on fill that can have areas of settlement.

SAFETY

LOW
Impact to safety and worker health

5. Landslides, slope destabilization, and subsidence do not pose a great risk to life safety or public health since most incidents are expected to be small-scale and only affect a limited area and number of workers.
6. Incidents may occur suddenly, but often appear slowly over time with the ability to keep workers out of unstable and unsafe areas.
7. Even areas with limited subsidence can pose a safety hazard for workers since many terminal operations need to be on flat surfaces, especially the container line of business.
8. Landslides, slope destabilization, and subsidence could impact remediation work and worker exposure to contaminants.

OPERATIONS

LOW
Impact to terminal operations

9. Landslides, slope destabilization, and subsidence would likely impact a limited area and not cause a major disruption to operations relative to gateway capacity.
10. Larger landslides on properties adjacent to the terminal could halt or slow operations at a terminal and require repairs and debris removal.
11. Slope destabilization and subsidence would likely impact a small area within a terminal. While this would make operations less efficient and may remove active terminal space, operations would likely be able to continue.
12. Water-dependent operations are more vulnerable than non-water dependent operations, especially if the wharf area is affected by slope destabilization.

FACILITIES

LOW
Impact to NWSA facilities

13. Landslides, slope destabilization, and subsidence could damage or destroy facilities located in compromised zones.
14. The transition point between the wharf and upland areas is one of the most susceptible areas on the terminal and is generally the main terminal area that operators prefer to have as flat as possible.
15. Terminal shorelines above and below water are engineered with geotechnical considerations in mind to minimize slope destabilization.

IMPACTS TO **NWSA**

EQUIPMENT

LOW

Impact to cargo-handling equipment and fleet vehicles

16. Landslides, slope destabilization, and subsidence could damage or destroy equipment located in compromised zones.
17. Equipment can generally be moved away from compromised zones when the area slowly becomes unstable over time.
18. Terminal equipment is designed to run over flat surfaces and operators generally avoid running equipment over areas with differences in grade from subsidence or slope failure.

COMMERCE

LOW

Impact to business and cargo volumes

19. Landslides, slope destabilization, and subsidence are not expected to cause a major disruption to long-term business or revenue streams.
20. The threat of landslides, slope destabilization, and subsidence are not expected to affect business attraction and retention.
21. Damage to cargo on terminals is expected to be minimal in the event of an incident. Landslides are not expected to greatly impact agricultural exports through the gateway.

ORGANIZATION

LOW

Impact to organizational resilience

22. A disruption to operations and business could lead to a loss of revenue at affected facilities. Impacts are typically smaller in scale and not expected to affect more than a few properties and businesses.
23. A landslide is not expected to affect a significant number of staff and their ability to perform work since there are typically alternative roadways or options for remote work.
24. A small-scale event would be relatively easy to recover from in terms of ability to fund repairs and ability to mobilize necessary resources.

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IMPACTS TO **GATEWAY**

EXPOSURE

HIGH

Exposure across the gateway

1. There is significant exposure to landslide prone zones across the gateway.
2. Major sources of landslide exposure are coastal bluffs, mountain passes, and river valleys.
3. Slope destabilization and subsidence may be found outside of landslide prone zones but they don't typically affect cargo operations across the gateway as much as landslides.
4. Slope destabilization can occur along shorelines areas and subsidence can be found across the state from vertical land movement due to natural or man-made causes.

ROADWAYS

LOW

Impact to truck travel on freight roadways

5. Freight roadways experience minor service disruptions from landslides somewhat regularly, especially in mountainous terrain during periods of intense rainfall.
6. Landslides typically impact roadway travel for short periods of time until debris is cleared, repairs are made, and the area is considered safe to travel.
7. Transportation providers have made landslide mitigation improvements along major freight corridors to reduce service disruptions.

RAILROADS

MODERATE

Impact to rail travel on freight railroads

8. Freight railroads regularly experience service disruptions from landslides where rail corridors follow coastal bluffs or mountainous terrain, especially during periods of intense rainfall. In rare cases, landslides have even caused train derailments.
9. Landslides typically impact rail travel for short periods of time based on debris removal, repairs or just weather conditions that make a landslide event likely.
10. Rail partners have made significant landslide mitigation improvements along the rail corridor between Seattle and Everett.

WATERWAYS

LOW

Impact to vessel travel on navigable waterways

11. Waterways have low susceptibility to landslides and have not affected vessel operations in the Gateway.
12. Underwater landslides or debris from unstable shoreline slopes could affect navigable channels and require repairs and dredging to resume vessel operations.

UTILITIES

LOW

Impact to gateway utilities

13. Many of the power lines within the Gateway go over steep slopes that could be susceptible to landslides.
14. Other utilities including water, sewer, natural gas, and communications infrastructure are also present in landslide prone areas and could experience service disruptions.

IMPACTS TO **GATEWAY**

INDUSTRIAL

LOW
Impact to region's cargo support facilities

⑮ Most of the region's industrial lands and Manufacturing/Industrial Centers that support cargo operations are on relatively flat terrain that are outside of landslide prone areas.

COMMUNITY

MODERATE
Impact to gateway communities

⑯ Landslides can be very destructive for affected communities and cause injury, loss of life, and property damage. Landslides may isolate communities from essential goods and services.

⑰ Significant efforts have been made to protect communities from landslides by reducing future development in landslide hazard areas.

⑱ Landslides could harm the ancestral lands of the Coast Salish Tribes in our Gateway, damaging cultural resources and affecting treaty-reserved fishing or other traditional practices.

EMPOWERMENT

LOW
Impact to organizational resilience

⑲ Landslides could destroy infrastructure and cause a release of pollutants, negatively impacting cleanup sites as well as air and water quality.

⑳ Landslides in hilly areas and along riparian zones could damage critical habitat areas.

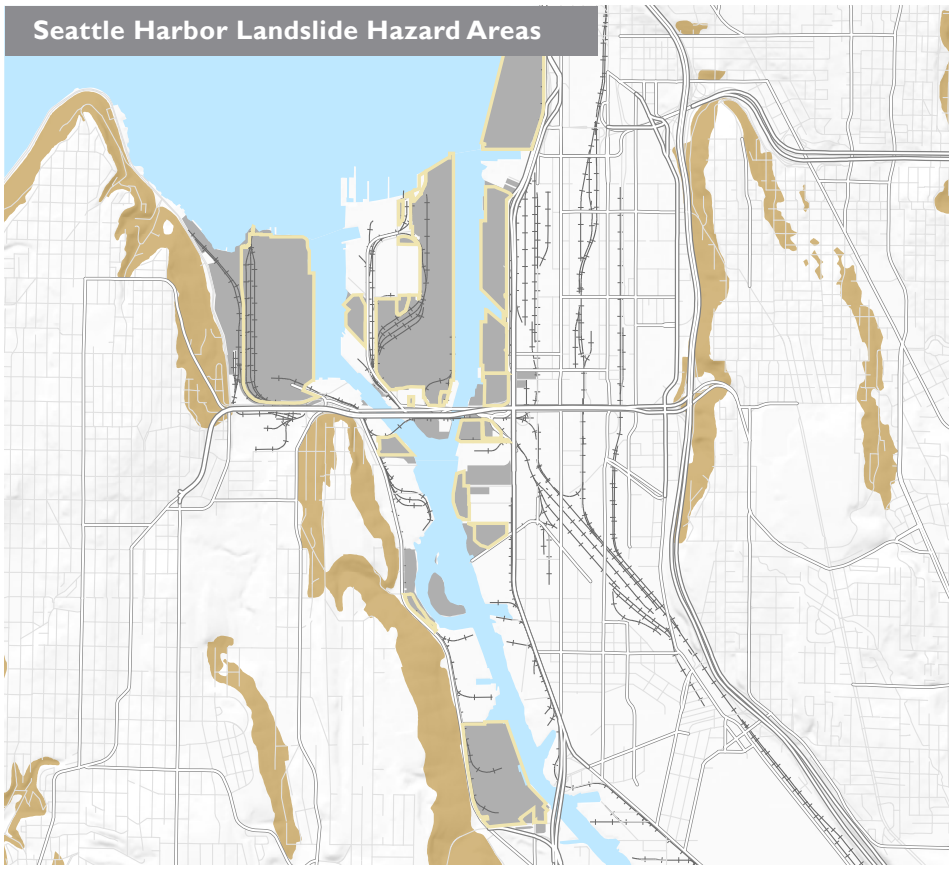
Landslide Hazards Areas

The Washington Department of Natural Resources and local jurisdictions map out landslide hazard zones to show areas that may be susceptible to future landslides. The Washington Growth Management Act requires cities and counties to adopt regulations to protect critcal areas including landslide prone areas. The areas have been identified by compiling the known locations of past landslides. Some areas may also be identified as landslide hazard areas if they have certain characteristics that make them more susceptible to landslides such as steep slopes.

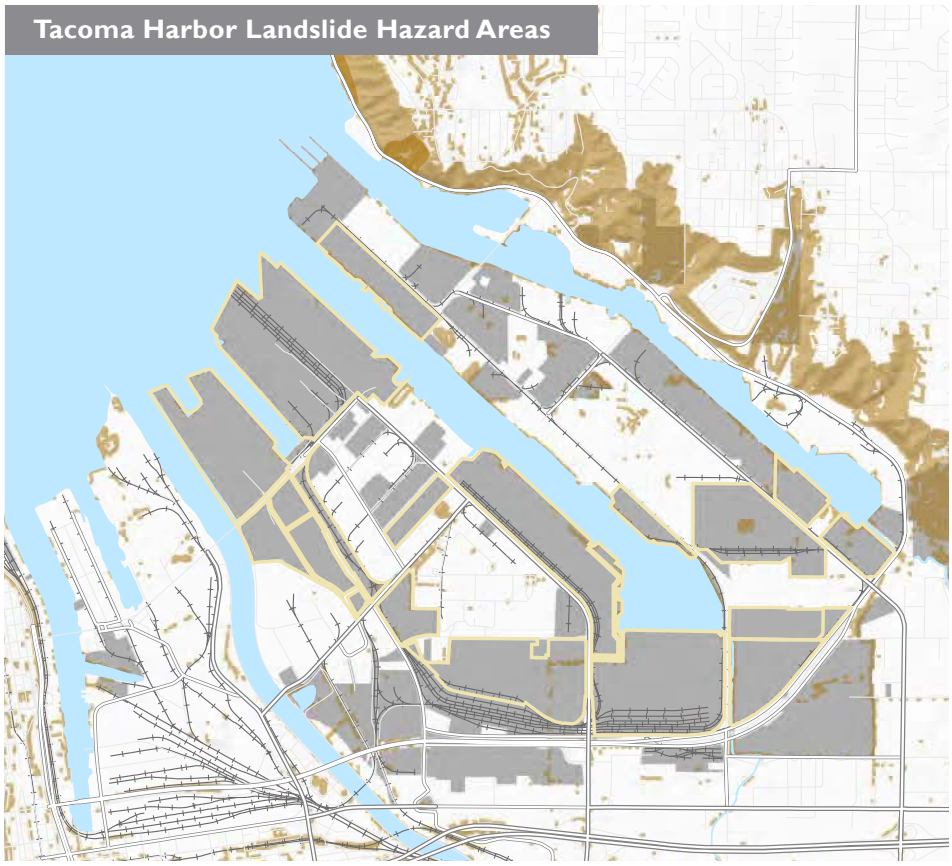
Both harbors are largely outside of landslide hazard areas but located near areas that could experience landslides.

Landslide Hazard Area

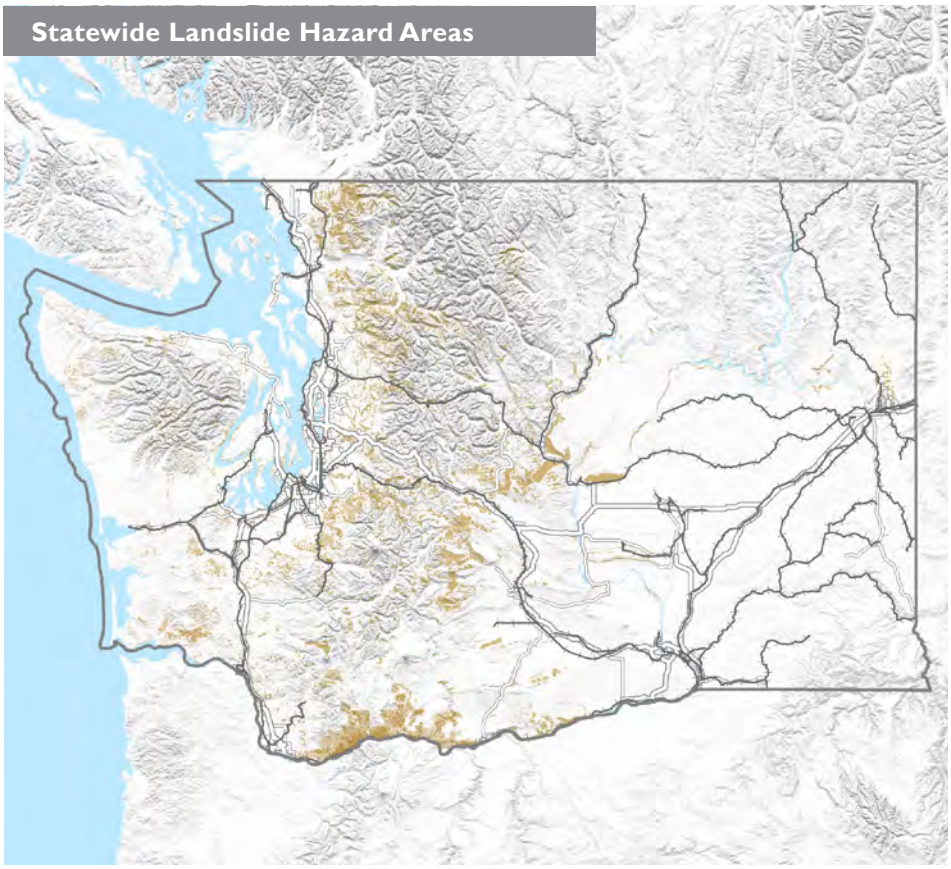
Seattle Harbor Landslide Hazard Areas



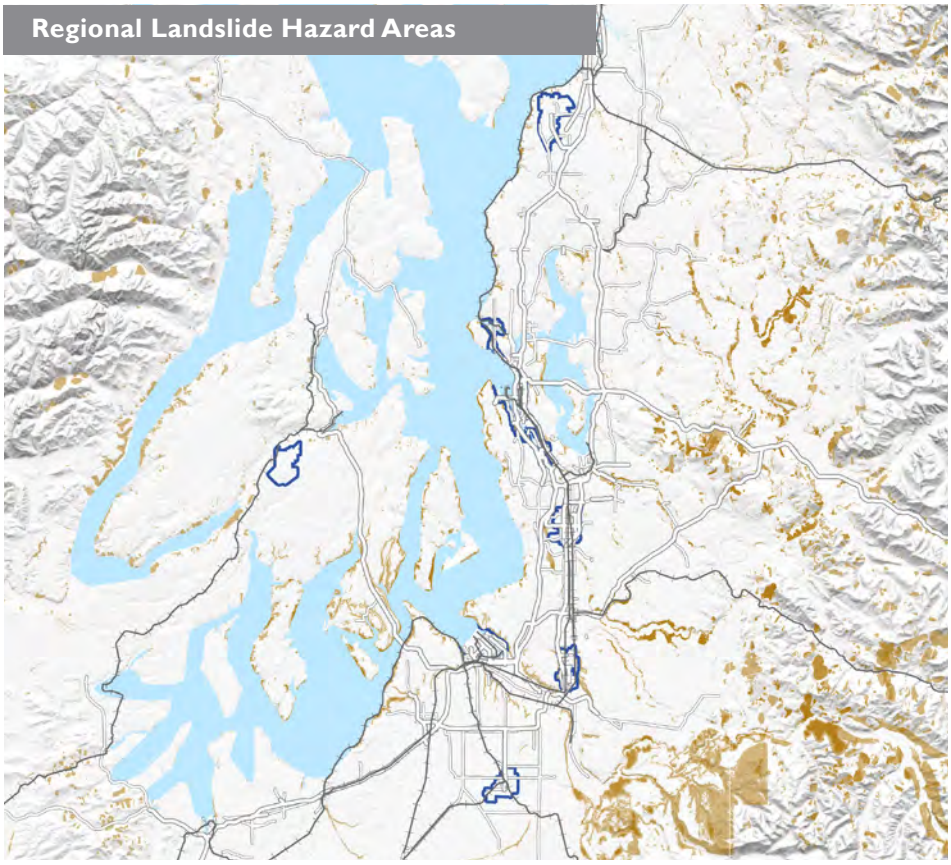
Tacoma Harbor Landslide Hazard Areas



Statewide Landslide Hazard Areas



Regional Landslide Hazard Areas



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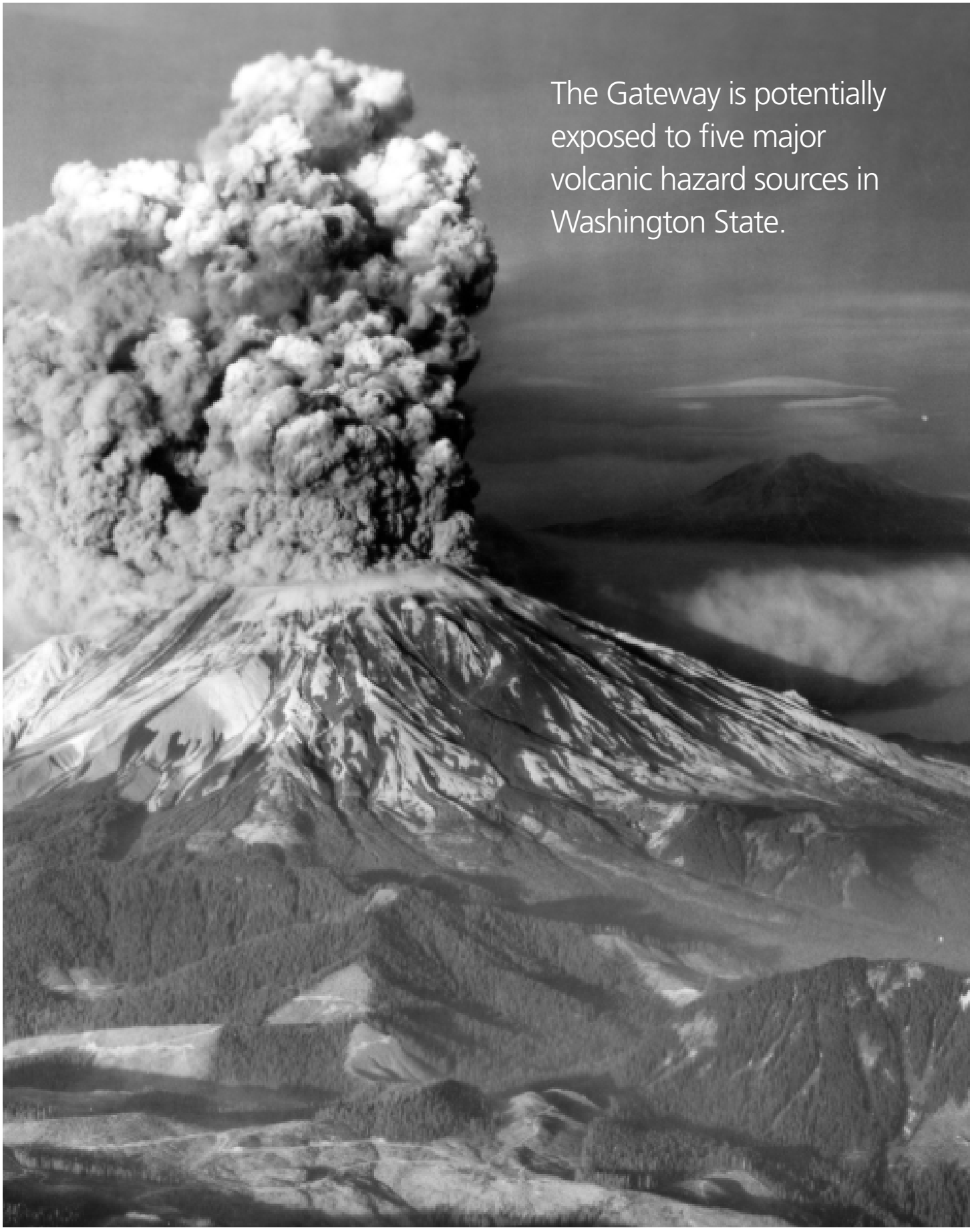
Landslide Hazard Area


The Gateway is potentially exposed to five major volcanic hazard sources in Washington State.

SHOCKS

have a low likelihood of occuring but are typically larger in scale and impact. They include most of the geologic hazards.

EARTHQUAKES

TSUNAMIS

VOLCANIC ACTIVITY

Local Earthquake Sources

Facts and figures by harbor

Cascadia Subduction Zone (M9.0)

Shaking Intensity

Seattle Harbor	Strong to Very Strong
Tacoma Harbor	Strong to Very Strong

Potential Damage

Seattle Harbor	Moderate
Tacoma Harbor	Moderate

Seattle (M7.2)

Shaking Intensity

Seattle Harbor	Violent to Extreme
Tacoma Harbor	Very Strong to Severe

Potential Damage

Seattle Harbor	Heavy to Very Heavy
Tacoma Harbor	Moderate to Heavy

Tacoma (M7.1)

Shaking Intensity

Seattle Harbor	Strong to Very Strong
Tacoma Harbor	Severe

Potential Damage

Seattle Harbor	Light to Moderate
Tacoma Harbor	Moderate to Heavy

Nisqually (M7.2)

Shaking Intensity

Seattle Harbor	Very Strong
Tacoma Harbor	Moderate

Potential Damage

Seattle Harbor	Very Strong
Tacoma Harbor	Moderate

SeaTac (M7.2)

Shaking Intensity

Seattle Harbor	Very Strong to Severe
Tacoma Harbor	Very Strong to Severe

Potential Damage

Seattle Harbor	Moderate to Heavy
Tacoma Harbor	Moderate to Heavy

Southern Whidbey Island (M7.4)

Shaking Intensity

Seattle Harbor	Very Strong
Tacoma Harbor	Moderate to Strong

Potential Damage

Seattle Harbor	Moderate
Tacoma Harbor	Very Light to Light

Concerns about seismic risk have led partners like WSDOT to invest billions of dollars in resilient transportation improvement projects such as the removal of the Alaskan Way Viaduct (shown right). WSDOT has made seismic retrofits on many bridges across the state and prioritized investment on Seismic Lifeline routes that are most critical to emergency response efforts.

LARGE QUAKES ARE LOW LIKLIHOOD EVENTS

Earthquakes are the ground shaking caused when rock in the earth's crust shifts or breaks rapidly, releasing stress and large amounts of energy in the form of seismic waves. Most earthquakes occur along faults where blocks of earth move along one another causing stress and fractures. The three main factors that determine the shaking experienced in an area are the magnitude (M) of the earthquake, the distance relative to the epicenter where the earthquake originated, and the local ground materials such as the soil and rock that affect the ground motion

Earthquakes cause damage from the ground shaking, which may lead to surface ruptures that cause land to move up, down, or laterally. Shaking may also result in liquefaction, which is the phenomenon where sandy soils liquefy and move. Earthquakes may also cause secondary hazards such as landslides, flooding, tsunamis, avalanches, infrastructure failures, and fires.

The three main types of earthquakes in the region include:

Subduction Zone Earthquakes – Subduction zone earthquakes, also known as megathrust earthquakes, occur where an oceanic plate moves under a continental plate. These large boundary areas between plates can build up extreme amounts of stress and cause the greatest earthquakes. The Cascadia Subduction Zone (CSZ) is located off the coast of Washington, Oregon, and British Columbia and is capable of producing magnitue 9.0 earthquakes that would affect large areas of the Pacific Northwest. An earthquake along the CSZ would also trigger a large tsunami wave that would affect coastal areas in the region.

Shallow Fault Earthquakes – Faults in the upper crust can produce up to magnitude 7.5 earthquakes. Because they originate closer to the Earth's surface, they generally affect a smaller area but with greater shaking intensity since the energy is concentrated in a smaller area. They can trigger tsunami waves that can be especially dangerous.

Deep Fault Earthquakes – Faults that occur where tectonic plates collide and one plate is forced beneath the other cause deep earthquakes. These earthquakes occur at depths of tens to hundreds of miles below Earth's surface. Because of their depth, their energy can spread to a larger area than a shallow earthquake but with less intense shaking. They do not typically generate tsunamis from the shaking alone but may trigger one if they genereate landslides near bodies of water.

PAST EVENTS

Major earthquakes are low likelihood hazards in region and are tracked on a geologic scale of tens to hundreds of years. In many cases, there is only geologic evidence to indicate past earthquakes along different faults and no modern records.

Major recorded earthquakes in Washington include:

1700 The last major earthquake along the Cascadia Subduction Zone.

1872 The largest earthquake recorded in eastern Washington originated near Lake Chelan and was also the most widely felt across the state. It was estimated to be a magnitude 6.5 to 7.5 event.

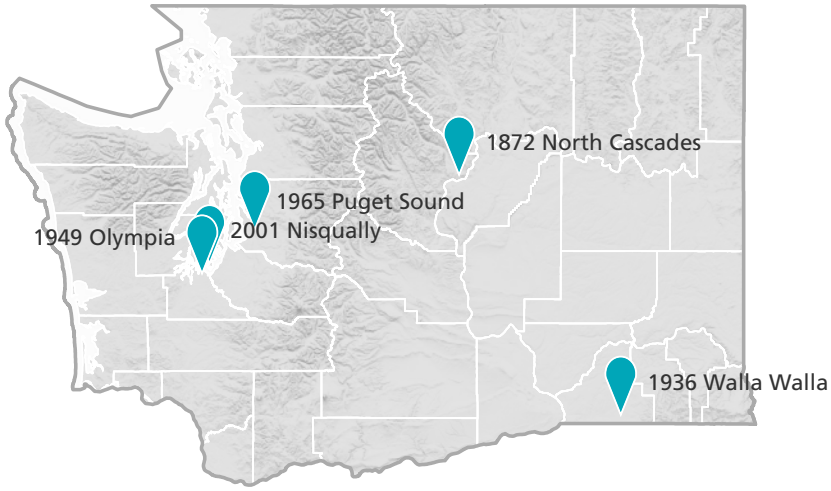
1936 A magnitude 6.1 earthquake that originated near Walla Walla affected a large area and caused significant damage with two minutes of shaking.

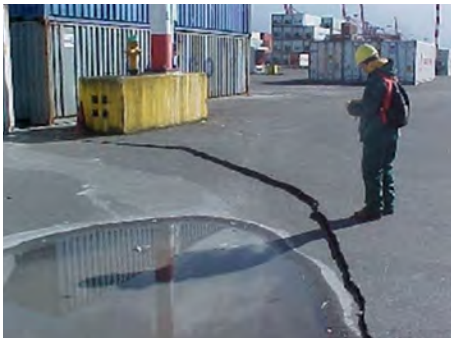
1949 A deep magnitude 7.1 earthquake near Olympia killed eight people and injured many more. The earthquake caused tens of millions of dollars of damage in Olympia, Seattle, and Tacoma and caused a large landslide that produced a tsunami wave in the Tacoma Narrows area. This earthquake also had a significant impact on Harbor Island, raising parts of it by 16 inches and droppping other parts by 12 inches.

1965 A second major earthquake originated in the Puget Sound area with a 6.7 magnitude event. The earthquake caused damage in similar areas as the 1949 Puget Sound earthquake and caused some areas along the East Waterway to move 12 inches closer to downtown Seattle.

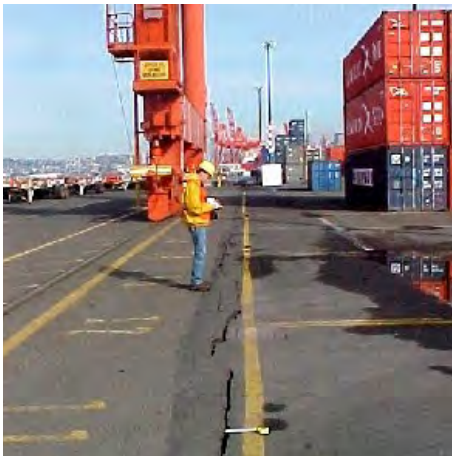
2011 The 6.8 magnitude Nisqually Earthquake was felt as far as Salt Lake City with most of the shaking concentrated in the river valleys along the I-5 corridor. Both NWSA harbors experienced damage with most of the damage in the Seattle Harbor where shaking and liquefaction caused ground deformation, cracking, and sand boils. The Port of Tacoma experienced pavement buckling and structural damage to several buildings.

Washington's Major Earthquakes since 1872





Shaking and liquefaction caused cracking in paved surfaces. Many of these areas also experienced sand boils where muddy water rose to the surface and flooded areas.

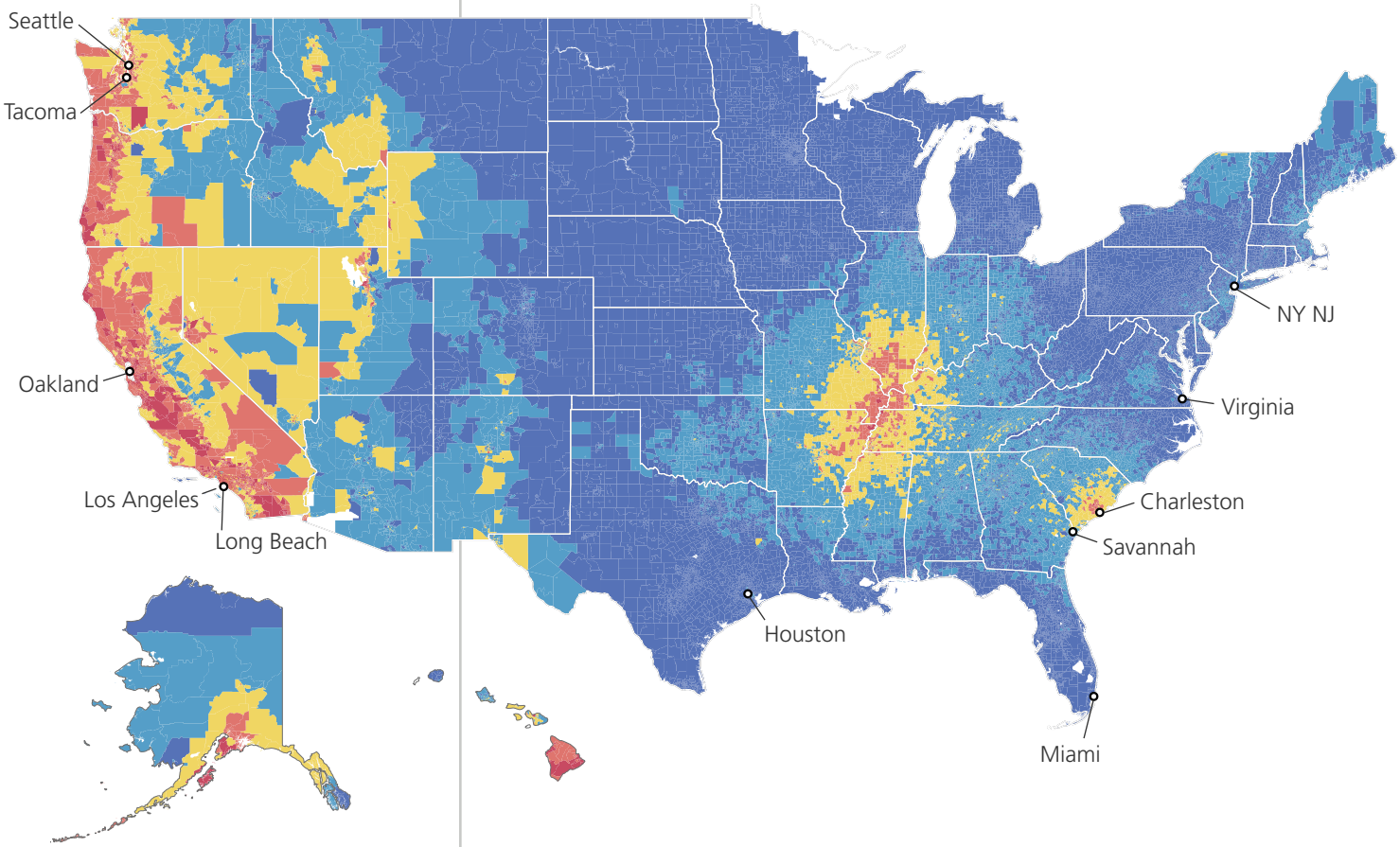


The Nisqually earthquake caused cracks to form at many of the terminals in the Seattle Harbor. Cracks were common where many of the wharfs connect with upland terminal areas and in areas with buried utility lines.

Both harbors are built on fill material in former river deltas. Their soil properties amplify shaking and they are prone to liquefaction.

EARTHQUAKE RISK AT TOP 10 US CONTAINER PORTS

The Federal Emergency Management Agency (FEMA) has mapped and quantified the earthquake risk across the United States based on expected annual loss, social vulnerability, and community resilience. The earthquake risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Very High	Relatively High	Relatively Moderate	Relatively Low	Very Low
NWSA Seattle	**NWSA Tacoma**	Savannah	Houst	Miami
Long Beach	Charleston		NY NJ	Virginia
Los Angeles				
Oakland				

HAZARD CHARACTERIZATION AND IMPACTS

Earthquake hazard risk is based on likelihood, scale, exposure, and areas of susceptibility. Hazards are characterized by their likelihood and scale and vulnerabilities are determined by exposure and susceptibility to the hazard.

EARTHQUAKE HAZARDS

Likelihood	LOW
Scale	HIGH
Outlook	MODERATE
Hazard Type	SHOCK

IMPACTS TO NWSA

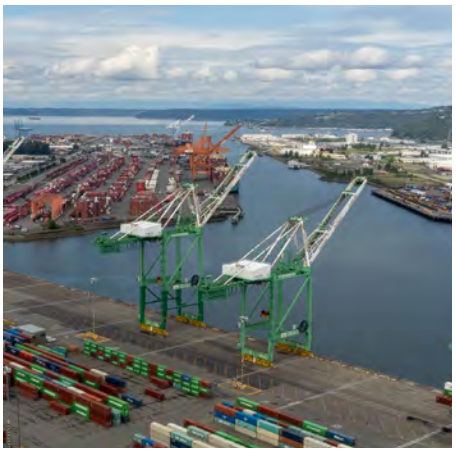
Exposure	HIGH
Safety	HIGH
Operations	HIGH
Facilities	HIGH
Equipment	HIGH
Commerce	HIGH
Organization	HIGH

IMPACTS TO GATEWAY

Exposure	HIGH
Roadways	MODERATE
Railroads	HIGH
Waterways	LOW
Utilities	HIGH
Industrial	MODERATE
Community	HIGH
Environment	MODERATE

Seattle Public Utilities and Tacoma Public Utilities have seismic plans in place to make their water systems more resilient against earthquakes.

Seismic planning efforts and improvements are reducing earthquake risk across the region.



The marine terminal operator at Pierce County Terminal raised several of their cranes and made seismic retrofits to them, allowing the terminal to accommodate larger vessels while also improving their resilience to earthquakes.

LIKELIHOOD

LOW

Likelihood of occurring on any given year

1. Washington is one of the most seismically active states in the country. While there are small earthquakes almost every day that go mostly unnoticed, large earthquakes with the potential to cause damage are low likelihood events.
2. There is less than a 20% annual chance that a major earthquake will occur in Washington.
3. The last Cascadia Subduction Zone (CSZ) earthquake and tsunami was in 1700 and their recurrence interval is 200-600 years. There is a 10-20% chance that a CSZ earthquake will occur in the next 50 years.
4. Shallow earthquakes along crustal faults are low likelihood events with a recurrence interval of hundreds to thousands of years. The last Seattle Fault earthquake was around 900-950 AD and there is no record of a past Tacoma Fault earthquake.
5. Deep earthquakes are more common in Washington but still low likelihood events. They have a recurrence interval of 30-50 years between events, with an 84% chance of a magnitude 6.5 or greater striking in the next 50 years.

SCALE

HIGH

Magnitude event with regional scale

6. Earthquakes can range from small-scale events that are not noticeable to high magnitude events that are regionally catastrophic.
7. Megathrust earthquakes, such as those on the CSZ, are the most powerful earthquakes in the world and the only source that can cause magnitude 8.5 or higher earthquakes.
8. The CSZ reaches from Northern California to British Columbia and can produce magnitude 9.0 or greater earthquakes. Given the length of the fault, the large area affected, and the anticipated devastation, it is referred to as the "Big One" in the Northwest.
9. Crustal faults can produce magnitude 7.0 and greater earthquakes and may also trigger a tsunami. While they are smaller magnitude events than CSZ earthquakes, they are some of the most damaging for urban areas of the Puget Sound. Their shallow depth focuses the shaking more intensely in a smaller area compared to other earthquakes. This can be especially devastating when they occur near major population centers such as an earthquake along the Seattle Fault.
10. Deep earthquakes can produce magnitude 7.0 and greater earthquakes. Because they occur deeper and further from the surface, their energy can spread to a greater area when they reach the surface but with less shaking intensity compared to a shallow earthquake. They do not typically generate a tsunami.

OUTLOOK

MODERATE

Level of increasing risk in future decades

11. There is an increasing amount of risk associated with earthquake hazards in the region given the continued growth of human development in earthquake hazard areas. This increases exposure and susceptibility if not paired with mitigation measures.
12. While climate change won't increase the likelihood or magnitude of seismic events, it can increase susceptibility and the overall risk of cascading hazards.
13. Waterfront areas may be more susceptible to shaking as sea level rise (SLR) also raises groundwater levels and increases the chance of liquefaction.
14. Earthquakes that trigger tsunamis will have greater inundation zones with future SLR. Landslides and flooding may also be more likely when earthquakes are paired with heavier rain events than experienced today.

IMPACTS TO **NWSA**

EXPOSURE

HIGH

NWSA exposure

1. Both harbors are susceptible to the three major earthquake sources in the region including earthquakes along crustal faults, deep intraplate earthquakes, and subduction zone earthquakes.
2. There are active crustal faults running through or near both harbors including the Seattle Fault Zone and the Tacoma Fault Zone. These could cause shallow earthquakes. Both harbors could also be affected by crustal earthquakes along the Southern Whidbey Island Fault.
3. Other sources of earthquake exposure for both harbors include deep intraplate earthquakes at Nisqually or SeaTac or an earthquake along the CSZ.
4. Earthquakes in the region are expected to cause very strong to severe shaking in both harbors because they are both built on fill material and are highly susceptible to liquefaction.

SAFETY

HIGH

Impact to safety and worker health

5. Earthquakes pose a significant threat to life safety and strike without warning. They are especially dangerous when combined with cascading hazards such as tsunamis, landslides, explosions, fires, and infrastructure failures, including electricity and communications networks.
6. Workers on terminals are in high-risk zones given their proximity to heavy equipment, stacks of containers, and other falling hazards. Workers could be struck or buried by falling objects or failing structures during the shaking event and aftershocks.
7. The release of contaminants and hazardous materials could affect the health of workers exposed to them.
8. Evacuation routes may be impassable due to damage and debris, interfering with evacuation and emergency response efforts.

OPERATIONS

HIGH

Impact to terminal operations

9. An earthquake would temporarily halt operations until it is safe to resume operations and the aftershocks and other potential cascading hazards like tsunami waves, hazmat release, and fires have passed.
10. Before resuming operations after an earthquake, facilities would need to be inspected and cleared for use.
11. Facility damage may leave some terminals inoperable until repairs are made, utilities and transportation routes are restored, and debris is cleared both on and off terminal.
12. Operations may be reduced or halted if terminals don't have the resources that they need to resume operations such as workers or fuels.
13. Cargo may be shifted around between terminals or harbors depending on the condition of the facilities and the anticipated recovery time.
14. In the event of a major earthquake within or outside the region, normal port operations may be disrupted if port facilities are used as staging area for emergency response and recovery efforts.

IMPACTS TO **NWSA**

FACILITIES

HIGH
Impact to NWSA facilities

15. Facilities could be damaged from shaking such as wharfs, buildings, pile foundations, riprap protected slopes, paving, and utility poles, especially if liquefaction occurs. Liquefaction may cause ground deformation such as slope destabilization, settlement, or lateral spreading, all of which can lead to significant facility damage.
16. Utilities like water, power, communications, drainage, sewer, and gas could rupture due to differential settlement and/or liquefaction.
17. Shaking and liquefaction could cause separation of water and landside infrastructure.
18. Portions of T5 and T18 in Seattle and Husky Terminal and EB-1 in Tacoma have seismically strengthened aprons. Other marine facilities may be vulnerable to slope failures or differential settlement.
19. On-terminal buildings are susceptible to differential settlements. Some of the newer buildings and retrofitted ones are built to modern codes and more resilient to shaking.
20. Facilities could be damaged if they are struck by cargo or equipment from the shaking.

EQUIPMENT

HIGH
Impact to cargo-handling equipment and fleet vehicles

21. Rail-mounted equipment such as ship-to-shore cranes or rail-mounted gantry cranes may be damaged due to lateral spreading of rails, especially if the two rails are not structurally connected along the entire length of the runway.
22. Top-heavy rolling stock like straddle carriers or rubber tire gantry cranes may tip over.
23. Ship-to-shore cranes crane legs, booms, trolleys, or other structural elements may be damaged from the stresses induced by shaking and differential settlement of waterside and landside crane beams.
24. Operating equipment on damaged terminal surfaces may result in equipment damage.
25. Equipment may be temporarily inoperable if power or fueling sources are disrupted.

COMMERCE

HIGH
Impact to business and cargo volumes

26. Earthquake impact on NWSA business depends on the magnitude of the shaking, cascading hazards, and total impact on facilities, operations, and workers.
27. Discretionary cargo could be lost to other ports and the Gateway could see a reduction in cargo volumes, jobs and labor income tied to cargo operations.
28. As terminals and Gateway infrastructure are repaired, cargo volumes would start to grow as the region focuses its efforts on bringing in goods needed for recovery.
29. A disruption to operations and business could lead to a short- or long-term displacement of tenants.
30. Cargo could be damaged from shaking and impact with other objects.

IMPACTS TO **NWSA**

ORGANIZATION

HIGH

Impact to organizational resilience

31 The NWSA and homeport office spaces are both located in seismic hazard zones that are prone to shaking and liquefaction. Employees may be injured in the event of shaking. If the earthquake triggers a local source tsunami, there may be little time and ability to evacuate employees from inundation zones.

32 If offices are destroyed, administrative staff may be able to carry out their work duties from home. Staff that work in the field would be most affected and the nature of their work would likely change during the recovery period.

33 Staff that live in areas that are greatly affected by an earthquake may be displaced from their homes. Others may not be able to access either of the harbors due to damage on the transportation network.

34 A disruption to operations and business would lead to a loss of revenue, making it more difficult to recover, especially if repairs aren't covered by insurance.

IMPACTS TO **GATEWAY**

EXPOSURE

HIGH

Exposure across the gateway

1. Washington is a seismically active state with the highest hazard areas in Western Washington and the lower hazard areas in Eastern Washington.
2. While roughly a quarter of the state is exposed to medium or higher earthquake hazards, the highest concentration of communities and infrastructure is in Western Washington where the earthquake hazard is higher.
3. Much of the infrastructure that supports cargo operations is in high hazard areas that are susceptible to liquefaction, especially between both harbors in the Kent and Puyallup River valleys.

ROADWAYS

MODERATE

Impact to truck travel on freight roadways

4. Major freight roadways pass through high hazard areas including both interstates, state highways, and local freight roads.
5. Shaking and liquefaction can cause roads to spread laterally and their pavement to crack at the surface, slowing or halting roadway travel.
6. Bridges and elevated roadways are the most vulnerable component of the roadway network and may experience structural damage.
7. Roadway operations are less susceptible to damage than railroad operations since there are more alternative routes and traffic can be detoured around limited areas of damage.

RAILROADS

HIGH

Impact to rail travel on freight railroads

8. Major freight rail corridors pass through high hazard areas that are susceptible to shaking and liquefaction.
9. Shaking and liquefaction can damage rail bridges and cause settlement and lateral movement of the ballast that supports rail tracks. This could make large portions of the railways or railyards inoperable until tracks are realigned and set to grade and bridges are repaired.
10. Railroad operations are highly susceptible to damage since there are limited alternative rail corridors and rail traffic can't be detoured around areas of damage.
11. Rail corridors pass through areas that may be susceptible to landslides from the shaking.

WATERWAYS

LOW

Impact to vessel travel on navigable waterways

12. Waterways are not expected to experience significant damage. They may become impassable in limited areas from debris and require dredging before vessel operations are restored.
13. Slope and structural failures near the waterways could deposit debris and shaking could cause equipment, cargo, or even facilities to fall into the waterways.

IMPACTS TO **GATEWAY**

UTILITIES

HIGH
Impact to gateway utilities

(14) Shaking and liquefaction may damage or cause outages in utility infrastructure that isn't adequately braced or secured to its foundation, is weak and inflexible, or is affected by differential settlement.

(15) Many utility systems span large areas from their supply source to their transmission, distribution, and ultimately their customer connections. Shaking and liquefaction at any part of the utility system can disrupt utility service.

(16) One of the larger potential utility risks from earthquakes is the outbreak of a fire from broken or damaged natural gas lines or downed electricity lines. This risk is further compounded if water service used for fire suppression is interrupted.

(17) Utilities may also be affected by earthquake-induced landslides.

INDUSTRIAL

MODERATE
Impact to region's cargo support facilities

(18) Many of the industrial properties that support cargo operations, including most of the Manufacturing/Industrial Centers (MICs) are in moderate to high shaking hazard areas. Most of these areas are also susceptible to liquefaction.

(19) There is a mix of older and newer industrial properties that are used for warehousing, transloading, and cold storage. The newer industrial properties that are constructed to newer building codes and more likely to better withstand a seismic event.

(20) Off-terminal container yards may be susceptible to differential settlement and liquefaction with potential for tipping over of container stacks.

COMMUNITY

HIGH
Impact to gateway communities

(21) An earthquake and other cascading hazards could cause local and regional devastation that would have a great impact on communities.

(22) Many of the near-port communities are in high-hazard and liquefaction-prone areas with the potential to suffer great loss.

(23) Infrastructure failure, including access roads and utility services, could cripple emergency response efforts and could isolate some communities from essential goods and services for extended periods of time.

(24) The gateway would be heavily impacted, but NWSA facilities may be able to aid in emergency response efforts and would eventually serve a critical role in the long-term recovery of the region.

EMPOWERMENT

MODERATE
Impact to organizational resilience

(25) Shaking and liquefaction could negatively impact environmental quality in the region.

(26) Shaking and slope failures along shorelines may increase sedimentation in the waterways and introduce contaminants if environmental caps are disturbed.

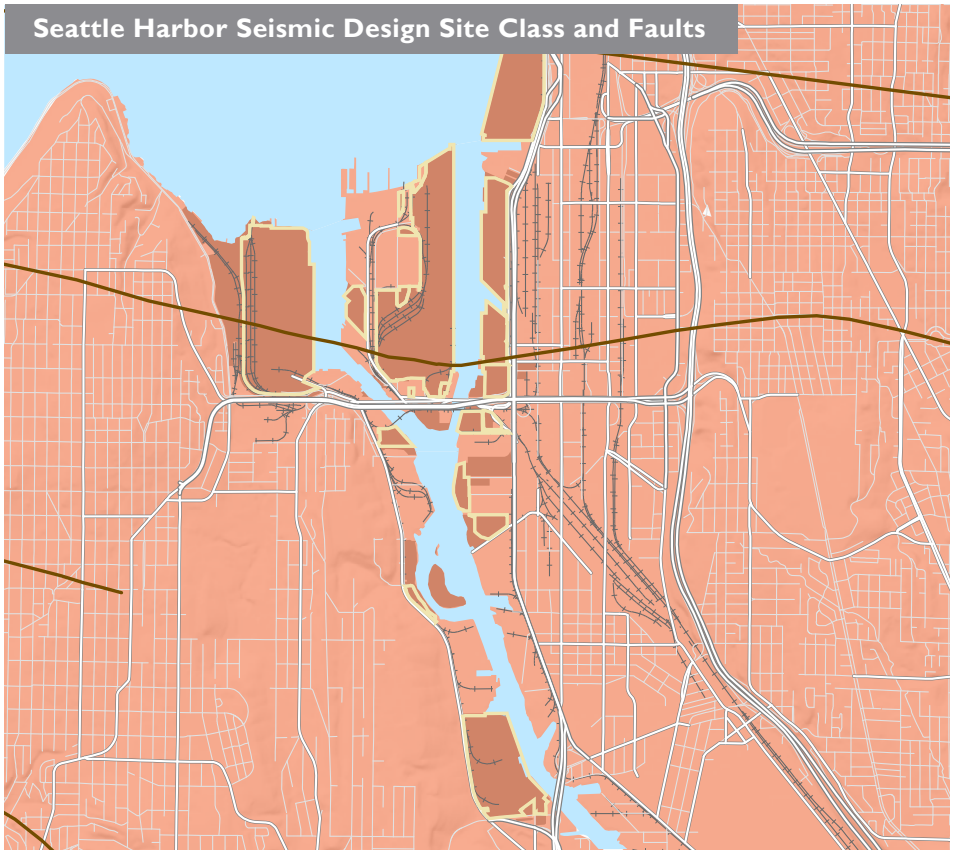
(27) Spills or leakage of oil, gas, or other organic chemicals can cause immediate harm to the ground on which they spill and could potentially leach into the groundwater supply or directly discharge to surface waters.

(28) Fires resulting from the shaking could temporarily impact air quality.

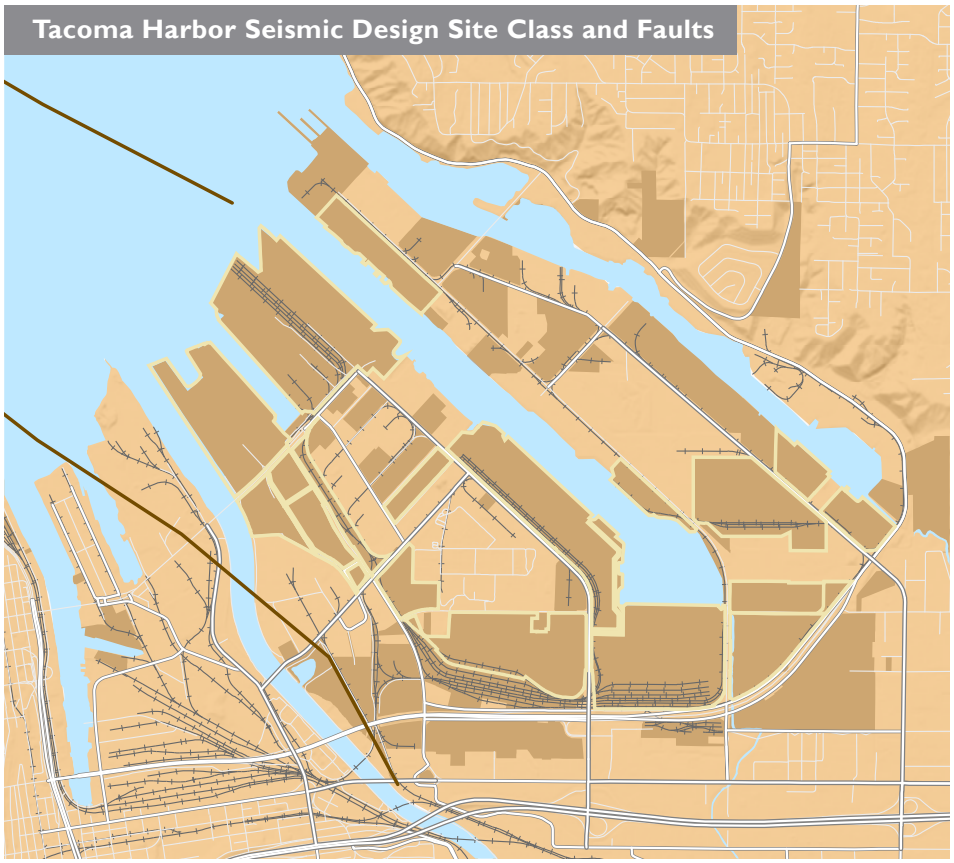
Seismic Design Site Class & Potentially Active Faults

Mapping out potentially active faults and the seismic design site class gives a general view of where faults are and the ground conditions and potential for amplified ground shaking when an earthquake occurs. The seismic design site class categories are used for determining the seismic resistance required for new buildings per building codes. wildfires.

Seattle Harbor Seismic Design Site Class and Faults

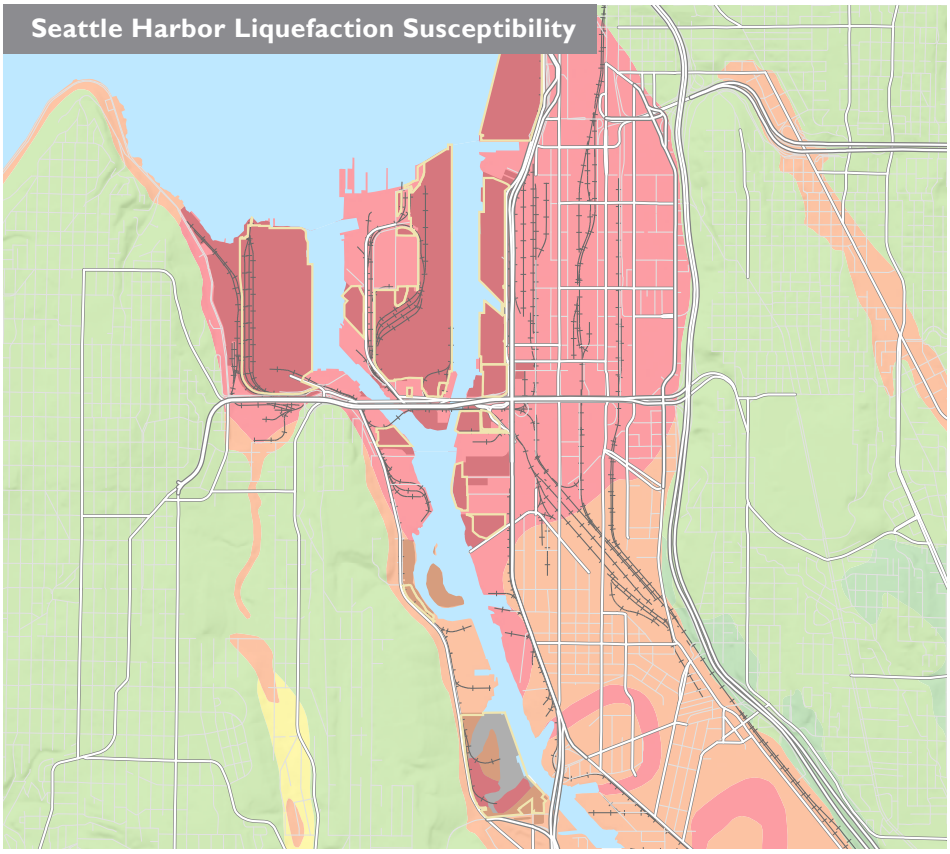


Tacoma Harbor Seismic Design Site Class and Faults

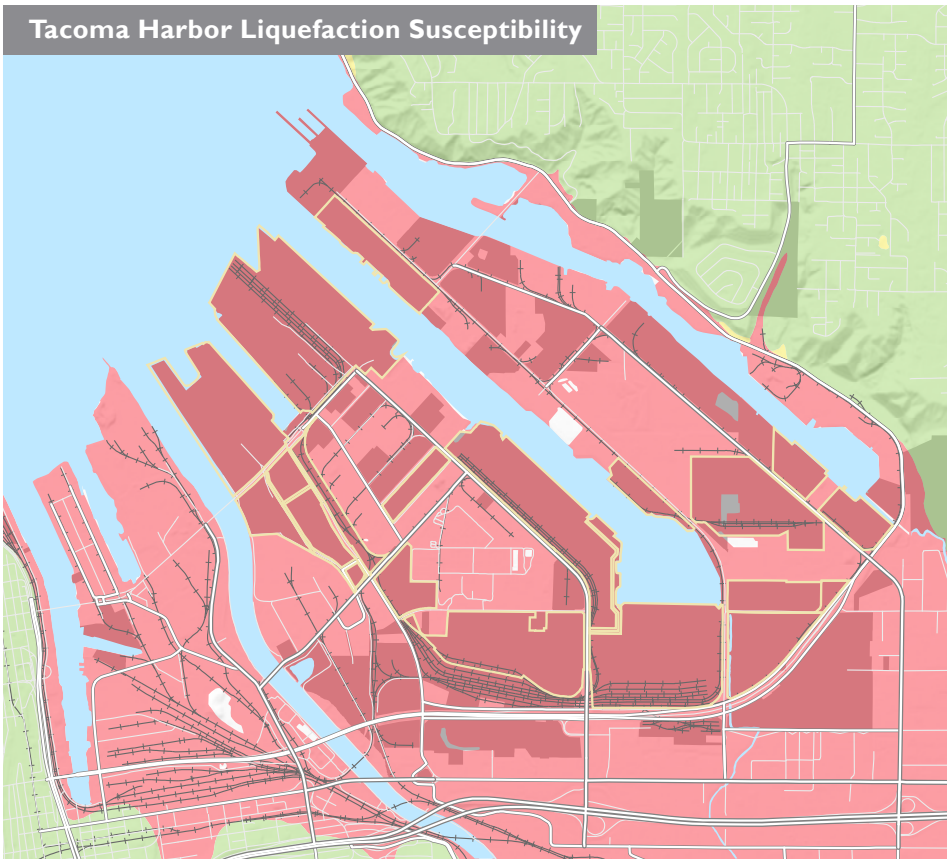


- **Potentially Active Fault**
- **Site Class E** Very High Hazard
- **Site Class D2** High Hazard
- **Site Class D1** High Hazard
- **Site Class D0** High Hazard
- **Site Class C** Moderate Hazard
- **Site Class B** Low Hazard

Seattle Harbor Liquefaction Susceptibility



Tacoma Harbor Liquefaction Susceptibility



Liquefaction Susceptibility

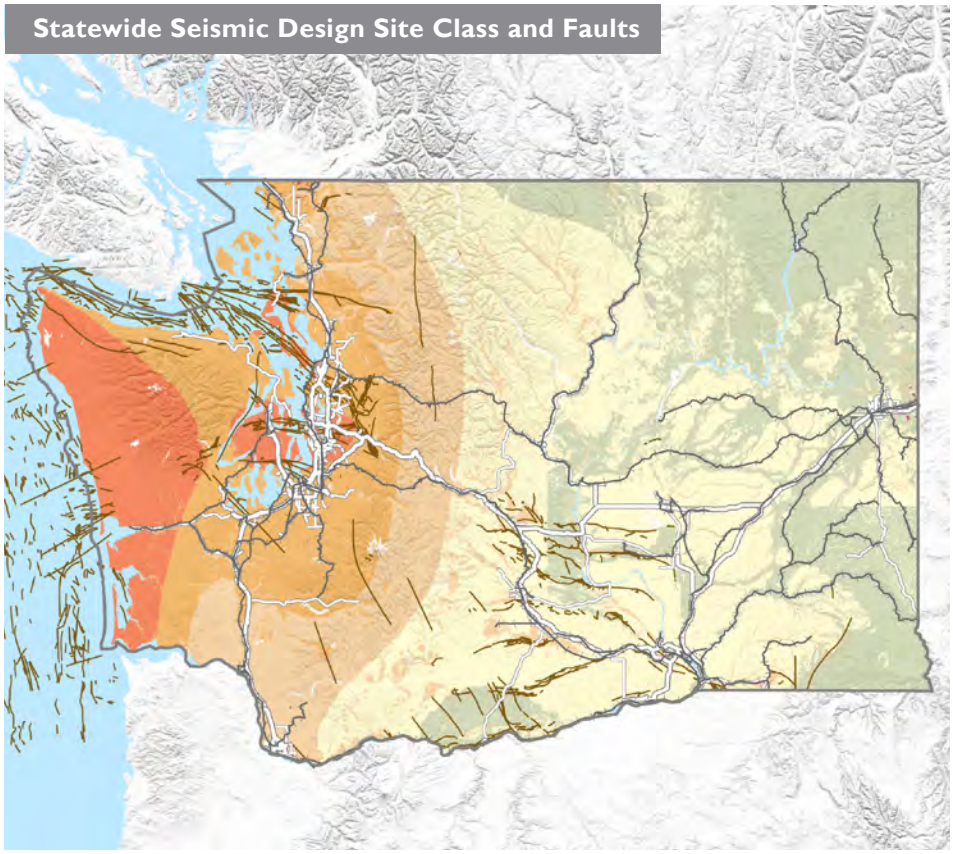
Mapping out areas that are susceptible to liquefaction shows which areas have water-saturated sandy soils that are likely to lose strength during shaking from an earthquake. Areas that are prone to liquefaction are more likely to experience damage when an earthquake occurs without mitigation measures in place. Both harbors are built on fill material that is prone to liquefaction.

- High
- Moderate to High
- Low to Moderate
- Low
- Very Low to Low
- Very Low
- Bedrock

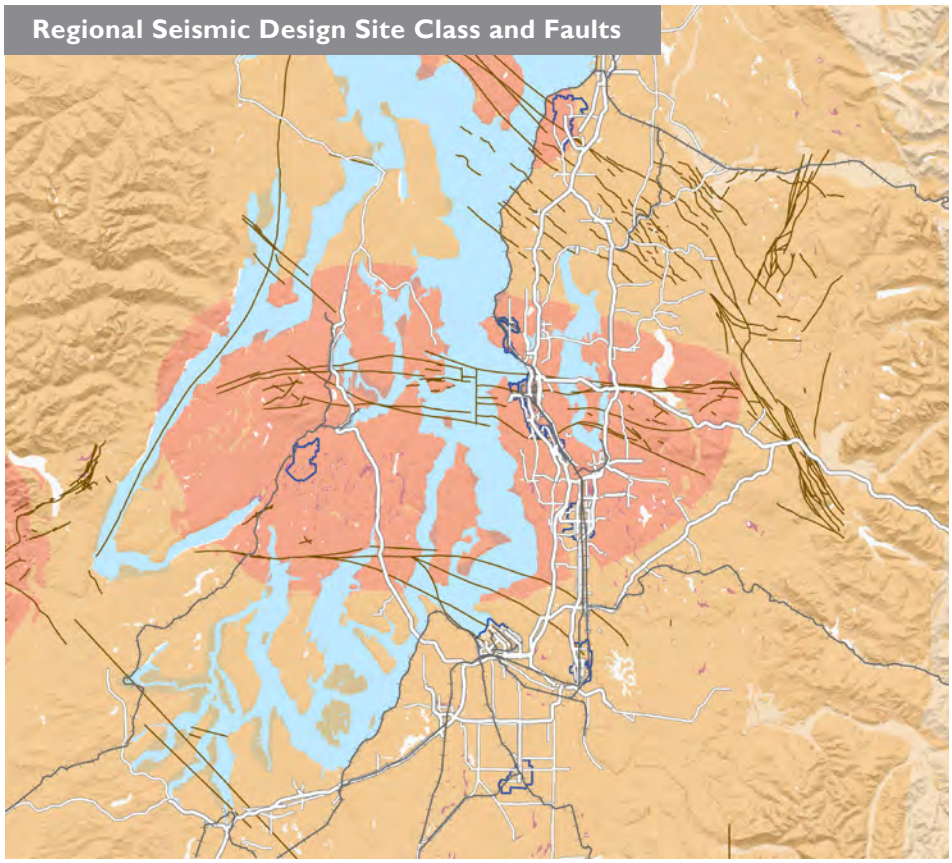
Seismic Design Site Class & Potentially Active Faults

Mapping out potentially active faults and the seismic design site class gives a general view of where faults are and the ground conditions and potential for amplified ground shaking when an earthquake occurs. The seismic design site class categories are used for determining the seismic resistance required for new buildings per building codes.

Statewide Seismic Design Site Class and Faults



Regional Seismic Design Site Class and Faults



- **Potentially Active Fault**
- **Site Class E** Very High Hazard
- **Site Class D2** High Hazard
- **Site Class D1** High Hazard
- **Site Class D0** High Hazard
- **Site Class C** Moderate Hazard
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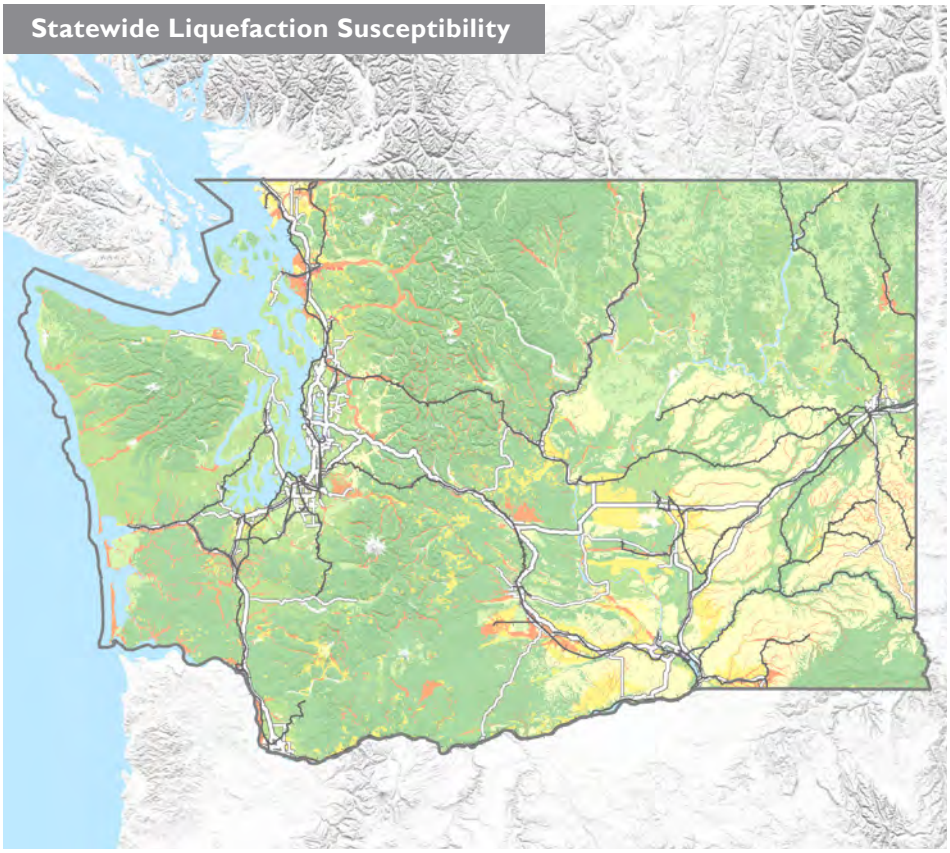
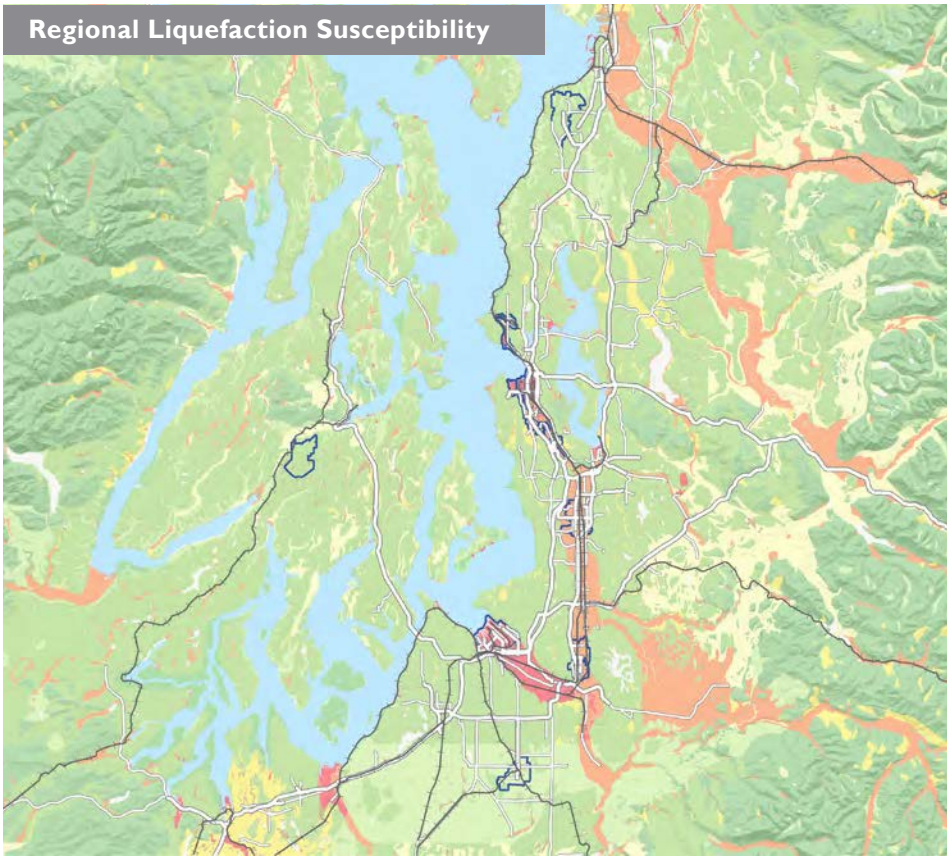
Statewide Liquefaction Susceptibility



Regional Liquefaction Susceptibility



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Mapping out areas that are susceptible to liquefaction shows which areas have water-saturated sandy soils that are likely to lose strength during shaking from an earthquake. Areas that are prone to liquefaction are more likely to experience damage when an earthquake occurs without mitigation measures in place. Both harbors are built on fill material that is prone to liquefaction.

- High
- Moderate to High
- Low to Moderate
- Low
- Very Low to Low
- Very Low
- Bedrock

Local Tsunami Sources

Facts and figures by harbor

Cascadia Subduction Zone

Wave Arrival Time

Seattle Harbor	2 hr 20 min
Tacoma Harbor	2 hr 40 min

Maximum Inundation

Seattle Harbor	4.4 ft
Tacoma Harbor	3.5 ft

Maximum Currents

Seattle Harbor	>9 knots
Tacoma Harbor	<9 knots

Seattle Fault

Wave Arrival Time

Seattle Harbor	<3 min
Tacoma Harbor	<3 min

Maximum Inundation

Seattle Harbor	44 ft
Tacoma Harbor	6 ft

Maximum Currents

Seattle Harbor	25 knots
Tacoma Harbor	13 knots

Tacoma Fault

Wave Arrival Time

Seattle Harbor	N/A
Tacoma Harbor	10 min

Maximum Inundation

Seattle Harbor	N/A
Tacoma Harbor	10 ft

Maximum Currents

Seattle Harbor	N/A
Tacoma Harbor	3 knots

A SECONDARY, LOW LIKELIHOOD HAZARD

A tsunami is a series of extremely long waves generated by the sudden displacement of a large volume of water. They radiate outward in all directions from the point of origin and can move across entire oceans causing coastal flooding and powerful currents that can last several hours or days. All tsunamis are a secondary hazard generated by a primary hazard such as an earthquake, landslide, volcanic activity, or oceanic impact of a near earth object such as a meteorite. Tsunamis trigger additional hazards such as fires and infrastructure failures.

The four main types of tsunamis in the region include:

Cascadia Subduction Zone – The Cascadia Subduction Zone (CSZ) is located off the coast of Washington, Oregon, and British Columbia. An earthquake along the CSZ would trigger a large tsunami wave that would be felt across the coastal areas across the region.

Local Source – Local source tsunamis are those which are generated within the region and include those which are triggered by local earthquakes. In the Puget Sound, these include tsunamis triggered by earthquakes along the Seattle Fault or Tacoma Fault.

Distant Source – Distant source tsunamis are those which are generated far from the region and cross major bodies of water before they arrive. Examples of potential sources of distant tsunamis that could reach the region are Alaska and areas on the other side of the Pacific Ocean.

Landslide-Triggered – Large landslides may trigger tsunamis in coastal areas and in lakes. These can also be triggered by underwater landslides.

The Great Alaskan Earthquake of 1964 remains the largest recorded earthquake in North America and the ensuing tsunami wave destroyed all cargo docks in south-central Alaska except for in Anchorage. This ultimately shifted cargo away from commercial hubs like Seward (destruction shown right) to Anchorage, which remains the main marine cargo hub for the state and is a key domestic trade partner for the NWSA.

PAST EVENTS

Tsunamis are a low likelihood hazards in region. Major tsunamis caused by local earthquakes are tracked on a geologic scale of hundreds of years. Smaller tsunamis resulting from landslides or volcanic activity are more common and have occurred in coastal areas and inland near lakes in recent decades.

Cascadia Subduction Zone – The last major tsunami recorded was in 1700 when the Cascadia Subduction Zone last ruptured.

Local Source – Geologic evidence indicates that there was also an earthquake along the Seattle Fault around 900-950 AD that would have also caused a tsunami.

Distant Source – The only recorded distant source tsunami of major significance to reach the region was the Great Alaska Earthquake and Tsunami of 1964. The wave traveled as far as California. While there have been other distant source tsunamis that have reached the region, they've been small in size and not had a significant impact on communities in Washington.

Landslide-Triggered – Most tsunami events in recorded Washington history have been triggered by landslides. These landslides were either standalone landslide events or resulted from earthquakes or volcanic eruptions.

Washington's Tsunami Events

Name	Year	Cause
Spirit Lake	1980	Volcanic Eruption and Landslide
Puget Island	1965	Landslide
Tacoma Narrows	1949	Earthquake and Landslide
Lake Roosevelt	1944	Landslide
Commencement Bay	1894	Landslide
Hat Island	1820s	Landslide
Cascadia Subduction Zone*	1700	Earthquake
Seattle Fault	900-950	Earthquake

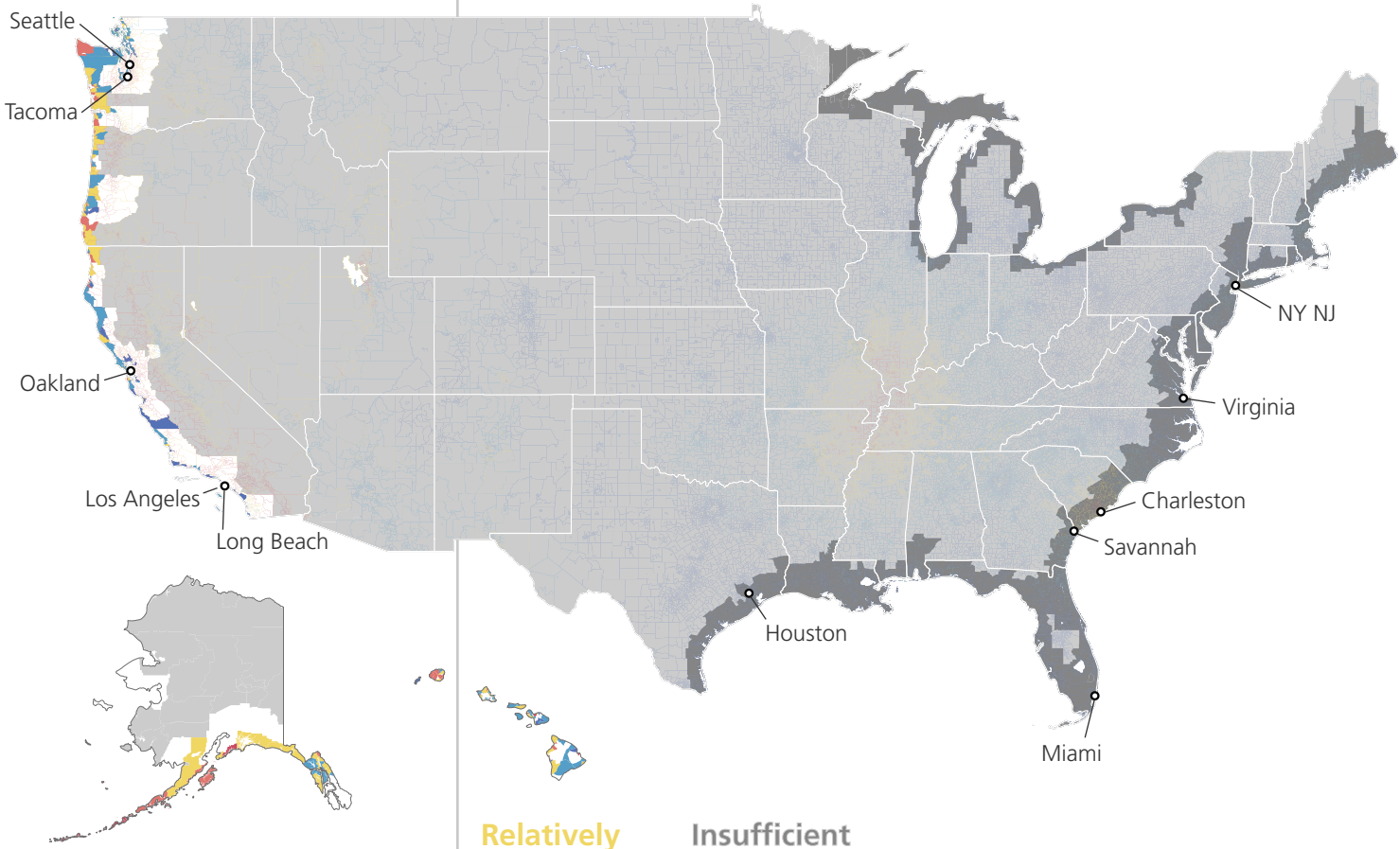
*Cascadia Subduction Zone tsunami not mapped.

Distant source tsunami waves from the Great Alaskan Earthquake destroyed a bridge on the Washington outer coast.

The last Cascadia Subduction Zone (CSZ) earthquake in 1700 created a tsunami that reached Washington, Oregon, California, British Columbia, and Japan. Ghost forests and tsunami deposits in Washington and Oregon reveal just how widespread a CSZ event can be.

TSUNAMI RISK AT TOP 10 US CONTAINER PORTS

The Federal Emergency Management Agency (FEMA) has mapped and quantified the tsunami risk across the United States based on expected annual loss, social vulnerability, and community resilience. The tsunami risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties.



Relatively Moderate	Insufficient Data
NWSA Seattle	Charleston
NWSA Tacoma	Houston
Long Beach	Miami
Los Angeles	NYNJ
Oakland	Savannah
	Virginia

HAZARD CHARACTERIZATION AND IMPACTS

Tsunami hazard risk is based on hazard likelihood, scale, exposure, and areas of susceptibility. Hazards are characterized by their likelihood and scale and vulnerabilities are determined by exposure and susceptibility to the hazard.

TSUNAMI HAZARDS

Likelihood	LOW
Scale	HIGH
Outlook	MODERATE
Hazard Type	SHOCK

IMPACTS TO NWSA

Exposure	HIGH
Safety	HIGH
Operations	HIGH
Facilities	HIGH
Equipment	MODERATE
Commerce	HIGH
Organization	HIGH

IMPACTS TO GATEWAY

Exposure	MODERATE
Roadways	MODERATE
Railroads	HIGH
Waterways	MODERATE
Utilities	MODERATE
Industrial	LOW
Community	HIGH
Environment	MODERATE

The Tohoku earthquake and tsunami was devastating and deadly, with more deaths attributed to the tsunami than the earthquake. The tsunami hit the Port of Sendai,destroying many facilities and equipment in the port complex.

The Tohoku earthquake and tsunami showed how disruptive natural disasters can be to global supply chains.

The Tohoku earthquake and tsunami affected many electronics and auto manufacturing facilities, causing temporary facility shutdowns outside of Japan because businesses couldn't get the goods they needed.

HAZARD INFORMATION

LIKELIHOOD

LOW

Likelihood of occurring on any given year

1. Tsunamis are generally low likelihood events. Local and distant tsunamis from earthquakes are very low likelihood events. Tsunamis from local landslides are more common, but still low likelihood events.
2. The last Cascadia Subduction Zone earthquake and tsunami was in 1700 and their recurrence interval is 200-600 years.
3. The Seattle Fault and Tacoma Fault are both crustal faults that can cause a tsunami wave in the Puget Sound. The last Seattle Fault earthquake was around 900-950 AD and there is no record of a past Tacoma Fault earthquake. Crustal faults typically have a recurrence interval of hundreds of years.

SCALE

HIGH

Magnitude event with regional scale

4. Tsunamis can range from small-scale events that are barely noticeable to high magnitude events that are regionally catastrophic.
5. The Cascadia Subduction Zone and the Seattle Fault earthquakes have the most potential to create regional devastation from a tsunami.
6. The Cascadia Subduction Zone earthquake and tsunami will have the largest impact on the outer coast areas but could also affect most of the Puget Sound inner coast.
7. An earthquake on the Seattle Fault or Tacoma Fault could create a very destructive tsunami and could be especially dangerous given the limited amount of time there would be to evacuate hazard areas.
8. Distant source tsunamis could be a threat to coastal communities or even the Puget Sound, but would not be as devastating as local source tsunamis resulting from earthquakes.
9. Local tsunamis resulting from landslides are typically small scale events that affect a limited area and are not expected to cause the same devastation of a local tsunami from an earthquake.

OUTLOOK

MODERATE

Level of increasing risk in future decades

10. There is an increasing amount of risk associated with tsunami hazards in the region on account of sea level rise. Future rates of sea level rise will increase the total water level that the tsunami waves affect and increases exposure by increasing the overall inundation area.
11. Human development continues in tsunami hazard areas, increasing exposure and susceptibility in the event of a tsunami if not paired with mitigation measures.

IMPACTS TO **NWSA**

EXPOSURE

HIGH

NWSA exposure

1. Both harbors and most NWSA terminals are in inundation zones from several local tsunami threats including earthquakes along the Cascadia Subduction Zone, Seattle Fault, and Tacoma Fault.
2. Exposure to local tsunami threats is greatest for terminals closest to Elliott Bay and Commencement Bay where inundation depths and currents are generally greatest.
3. Either harbor could be exposed to a local tsunami generated by landslides.
4. A distant source tsunami from Alaska or across the Pacific Ocean could potentially reach both harbors, but these are less likely to enter the Puget Sound since they would have to enter the Puget Sound at the right angle.
5. Tsunami wave run-up depends on the tide at the time of the event. Future sea level rise could increase exposure to tsunami hazards as it increases the overall water levels and wave run-up.

SAFETY

HIGH

Impact to safety and worker health

6. Tsunamis can pose a significant threat to life safety and public health, especially if preceded by an earthquake. They can also trigger dangerous secondary hazards including fires, hazmat release, or infrastructure failure.
7. Wave inundation can cause injury or death due to drowning or impact injuries from being knocked against cargo, equipment, buildings, or other large objects.
8. The amount of time to evacuate before the tsunami arrives depends on the tsunami source, with wave arrival times ranging from as little as several minutes for some local sources to several hours for distant sources.
9. Evacuation of inundation zones around the terminals can be challenging with the high number of workers, limited areas of ingress and egress, high number of trucks, and potential for rail blockages. Evacuation can be further complicated by infrastructure damage and debris if the tsunami was triggered by an earthquake.

OPERATIONS

HIGH

Impact to terminal operations

10. The extent of disruption to port operations would depend on the location and extent of the waves and impact to the workforce, facilities, equipment, and off-terminal freight system.
11. Tsunamis could greatly reduce or even halt terminal operations if significant resources are needed to repair facilities and equipment or to replace lost workers.
12. In the event of a large tsunami, gateway capacity may be reduced permanently.
13. Cargo may be shifted around between terminals, NWSA harbors, or even other ports depending on the condition of the facilities and anticipated recovery time.
14. Even small tsunamis can temporarily impact operations if tsunami advisories or warnings are issued and workers are evacuated out of hazardous areas.

IMPACTS TO **NWSA**

FACILITIES

HIGH

Impact to NWSA facilities

15. Damage to facilities depends on the magnitude and source of the tsunami and cascading effects of other hazards.
16. Port structures such as wharfs and buildings could be damaged from the loads placed on them from waves or collision with vessels, equipment, or cargo. Tsunamis can also damage structures near the shoreline if scour compromises their foundations.
17. On-terminal utility systems above and below ground could be compromised if exposed to saltwater or damaged by impact. Even if they are not damaged, they may need to be cut off for safety reasons.
18. None of the port facilities have been designed in accordance with the newly released tsunami design criteria included in the new building code.

EQUIPMENT

MODERATE

Impact to cargo-handling equipment and fleet vehicles

19. Cargo-handling equipment located in inundation zones could be damaged and need repairs or even require complete replacement.
20. Equipment could be damaged if it collides with other objects in the area such as other equipment, cargo, or buildings.
21. Electrical and mechanical components on equipment are especially susceptible to damage from exposure to saltwater and other pollutants released during the tsunami.

COMMERCE

HIGH

Impact to business and cargo volumes

22. Tsunami impact on NWSA business depends on the location and extent of the waves and its impact on workforce, facilities, operations, equipment, and off-terminal freight system.
23. Discretionary cargo could be lost to other ports and the gateway could see a reduction in cargo volumes, jobs and labor income tied to cargo operations.
24. As terminals and gateway infrastructure are repaired, cargo volumes may start to bounce back as the region focuses its efforts on bringing in goods needed for recovery.
25. Cargo in inundation areas would likely be damaged from collisions or exposure to saltwater.

IMPACTS TO **NWSA**

ORGANIZATION

HIGH

Impact to organizational resilience

26 A tsunami could reach the NWSA and homeport office spaces in either harbor. There may be little time and ability to evacuate employees in the event of a local source tsunami which may lead to staff injuries and fatalities.

27 If offices are destroyed, administrative staff may be able to carry out their work duties from home. Staff that work in the field would be most affected and the nature of their work would likely change during the recovery period.

28 Staff that live in areas affected by the tsunami or an earthquake that triggers a tsunami may be displaced from their homes. Others may not be able to access either of the harbors due to dame on the transportation network.

29 A disruption to operations and business would lead to a loss of revenue, making it more difficult to recover, especially if repairs aren't covered by insurance.

30 Staff that live in areas affected by the tsunami or an earthquake that triggers a tsunami may be injured, killed, or displaced from their homes. Others may not be able to access either of the harbors due to dame on the transportation network.

IMPACTS TO **GATEWAY**

EXPOSURE

MODERATE
Exposure across the gateway

1. The gateway exposure is limited to low-lying coastal areas on the outer coast and the Puget Sound. Most of the exposure areas that are expected to impact cargo operations are in the Puget Sound between Everett and Nisqually.
2. Primary exposure areas outside of the cargo terminals include several key freight corridors that the gateway relies on.
3. Future sea level rise could increase exposure to tsunami hazards across the gateway.

ROADWAYS

MODERATE
Impact to truck travel on freight roadways

4. Many of the local roadways around both harbors are in inundation zones as are several state highways and portions of I-5.
5. Tsunamis can damage roadway bridges and roads located along shorelines. The damage can be compounded by cascading hazards.
6. Floodwaters and debris may knock down or compromise the electrical and mechanical components in streetlights.
7. Once floodwaters recede, there would be significant amounts of debris left in the streets and stormwater systems that would need to be removed.

RAILROADS

HIGH
Impact to rail travel on freight railroads

8. Key freight rail corridors in coastal areas are located in inundation zones as are a number of rail facilities including railyards.
9. The high currents and wave action may erode and destabilize shorelines and waterfront structures, causing damage to rail-beds, rail tracks, and rail bridges.
10. Inundation can deposit large amounts of debris and compromise electrical and mechanical components such as signals, switches, and interlockings.

WATERWAYS

MODERATE
Impact to vessel travel on navigable waterways

11. Vessel operators will be some of those first affected by the tsunami as the water recedes before the tsunami waves arrive.
12. The highest currents will typically be found in constrained navigation channels with less of an impact in deeper waters.
13. Vessels in the constrained navigation channels and at berth are at greatest risk. Even if a vessel is secured at berth, the tsunami can cause mooring lines to break.
14. The currents and waves could lead to vessel drifting, grounding, or collisions with infrastructure or other vessels.
15. Tsunamis can impede waterways if scour damages the waterfront facilities and leaves debris that needs to be removed to restore vessel operations.

IMPACTS TO **GATEWAY**

UTILITIES

MODERATE
Impact to gateway utilities

16. A tsunami would likely affect key utility systems in the gateway and could require temporary shutoffs until repairs are made.
17. The oil and gas pipelines in inundation areas would likely need to be shut off to reduce fire risk and prevent explosions. If fueling facilities are damaged, it may be difficult to get the necessary fuels to carry out cargo operations.
18. The region's larger power generation sites are not in inundation zones, but a tsunami could damage power connections to affected areas.
19. Water, wastewater, stormwater, communications, and electrical systems could be damaged, especially if preceded by an earthquake. Damage to the water and communications systems could complicate emergency response efforts including fire suppression and communications needed to effectively respond to affected areas.

INDUSTRIAL

LOW
Impact to region's cargo support facilities

20. The majority of the region's industrial lands that support cargo operations are outside of tsunami hazard areas with near-terminal facilities close to the waterfront being most susceptible.
21. Several of the region's Manufacturing/Industrial Centers (MICs) are located in inundation zones including the Port of Tacoma, Duwamish, and Ballard-Interbay MIC.

COMMUNITY

HIGH
Impact to gateway communities

22. A tsunami could cause local and regional devastation, directly affecting the communities and industries that are hit by the tsunami and other cascading hazards. Communities may be isolated from essential services.
23. Coastal and inland communities may be affected as supply chains realign to route goods through areas in or outside of the region that have the infrastructure, equipment, and labor force to handle the cargo and get it to its destination.
24. Realigned supply chains could hurt regional exporters and consumers if it is more expensive to move cargo through the gateway or cargo must come through another port.
25. The gateway would be heavily impacted, but NWSA facilities may be able to aid in emergency response efforts and would eventually serve a critical role in the long-term recovery of the region.
26. A tsunami could harm the ancestral lands of the Coast Salish Tribes in our gateway, damaging cultural resources and affecting treaty-reserved fisheries.

EMPOWERMENT

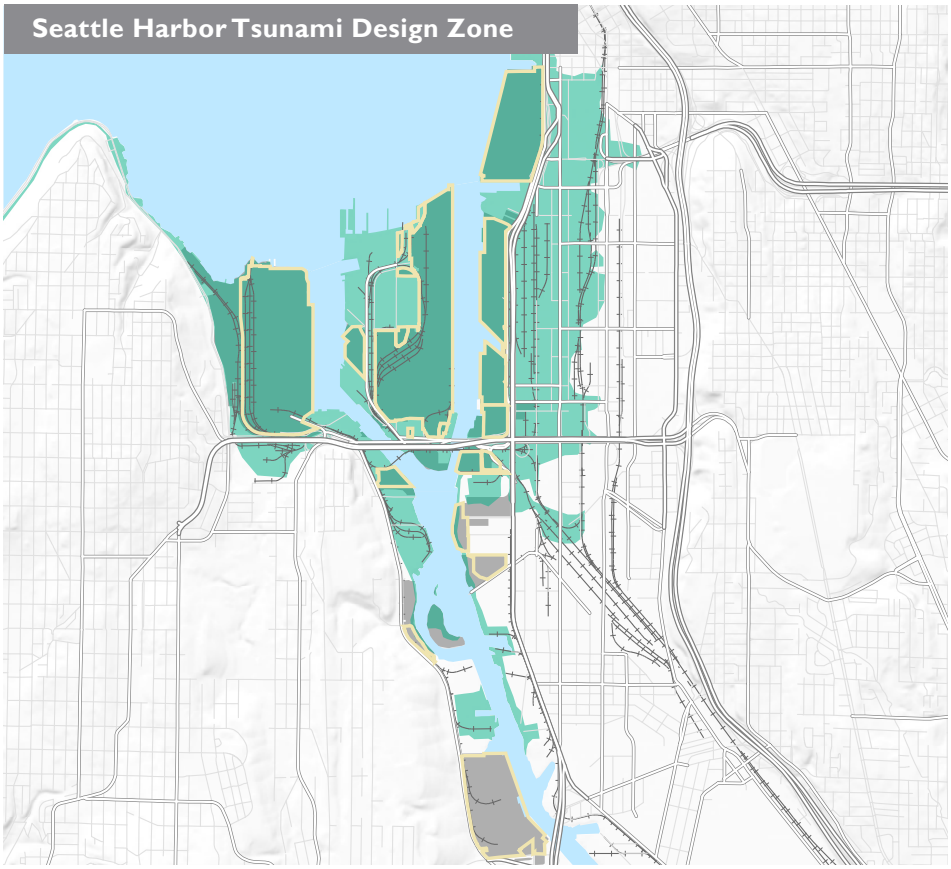
MODERATE
Impact to organizational resilience

27. Tsunamis can be damaging to the environment, especially if they occur in urbanized areas where there is a lot of development. They can be especially harmful to the environment when they occur in industrial areas where there is a high presence of hazmat.
28. Tsunami flooding can spread pollutants and saltwater across a wide area of land, compromising remediation sites and contaminating freshwater sources.
29. Debris and pollutants from a tsunami can choke up rivers and creeks, harming critical habitat that fish and other wildlife rely on.

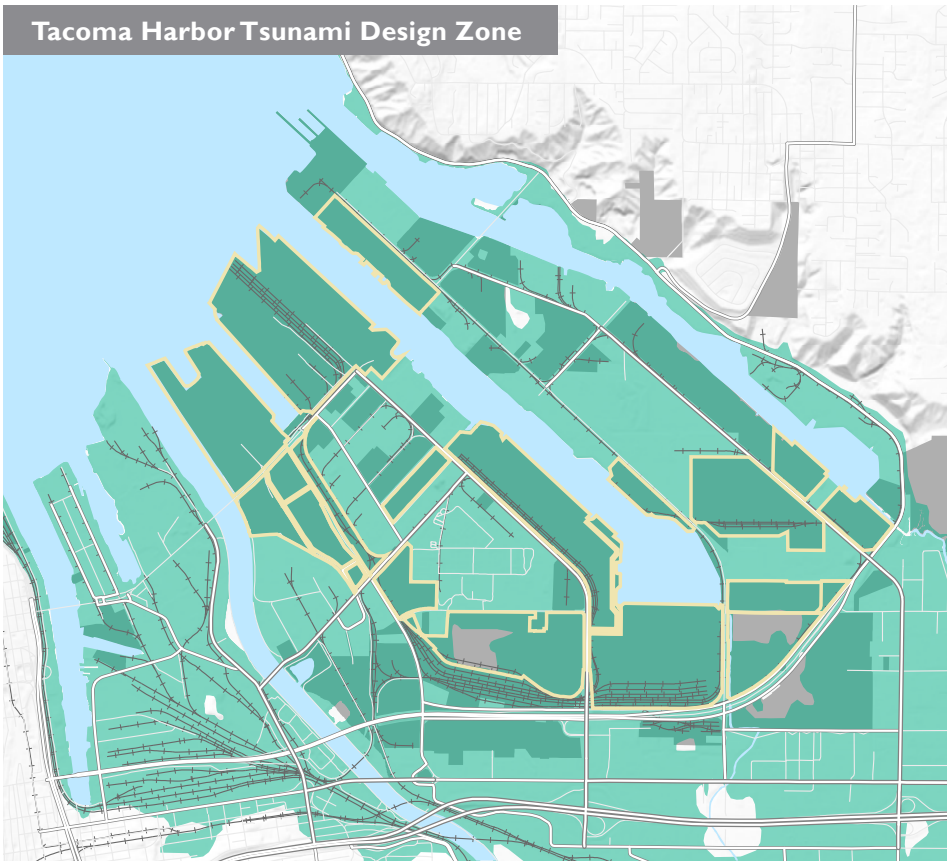
Tsunami Design Zone

The mapped Washington Tsunami Design Zone shows areas that could be inundated by a tsunami. The mapped inundation areas are reflective of the maximum inundation areas from all potential tsunami sources. This map is not reflective of the inundation from any single tsunami such as one resulting from an earthquake along the Cascadia Subduction Zone or along either the Seattle or Tacoma Fault. New structures built within the Tsunami Design Zone may have special design requirements to withstand tsunami loads. Both harbors have terminals within the Tsunami Design Zone.

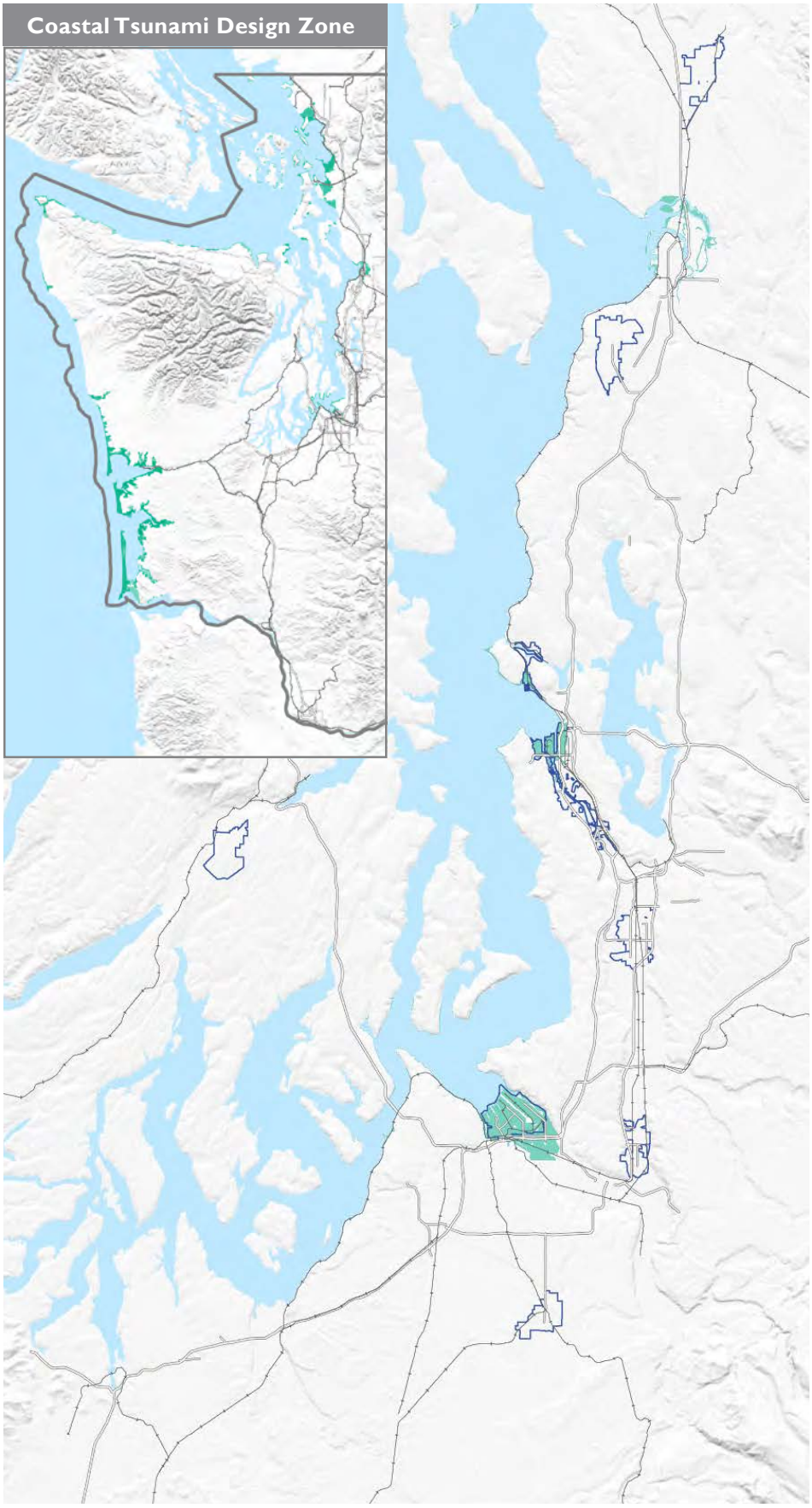
Seattle Harbor Tsunami Design Zone



Tacoma Harbor Tsunami Design Zone



Tsunami Design Zone



Tsunami Design Zone

The mapped Washington Tsunami Design Zone shows areas that could be inundated by a tsunami. The mapped inundation areas are reflective of the maximum inundation areas from all potential tsunami sources. This map is not reflective of the inundation from any single tsunami such as one resulting from an earthquake along the Cascadia Subduction Zone or along either the Seattle or Tacoma Fault. New structures built within the Tsunami Design Zone may have special design requirements to withstand tsunami loads. Shoreline areas may also be affected by tsunami waves but may not appear in the tsunami design zone.

Tsunami Design Zone

VOLCANIC ACTIVITY

A UNIQUE VERY LOW PROBABILITY HAZARD

Volcanoes are openings in the earth's crust where hot material below the surface can escape the magma chamber. There are five major volcanoes in Washington state including Mount Rainier, Mount St. Helens, Mount Baker, Glacier Peak, and Mount Adams. These are some of the highest threat volcanoes in the US due to their type, explosivity, and rate of occurrence alongside exposure factors such as population density, land use, and critical infrastructure in the hazard zone.

The volcanoes in the region are all part of the Cascade volcanoes family that is formed by the Cascadia Subduction Zone and stretch from northern California to British Columbia. They are unique from other types of volcanoes and are known for their explosive nature.

There is a wide range of volcanic hazards associated with Cascade volcanoes and some of the hazards may occur with or without an eruption:

Eruption Column – When an eruption occurs, it creates an eruption column with a large cloud of volcanic material such as ash. This ash can travel far distances, with some eruptions depositing ash over 10,000 miles away from the eruption.

Lava Flows – When molten rock reaches the surface of the Earth during an eruption, it may form molten rivers that travel downhill.

Pyroclastic Flows – Ash, rock, and gas mixing together following an eruption may form a hot pyroclastic flow that can travel long distances and be very destructive.

Lahars – When water from melted snow and ice mixes with volcanic ash and rock on a volcano, it can form a type of mudflow that is likened to rivers of concrete. They are especially dangerous since they can occur with or without an eruption with little notice.

Landslides – Volcanoes are often made of loose, weak rock that can be susceptible to landslides. They may also occur during an eruption if areas of the volcano collapse.

Volcanic Gas – Volcanoes may emit gas during eruptions and between eruptions. Most of the gas is steam, but there can also be release of dangerous gases.

U.S. Volcano Threat Ranking

How Washington volcanoes rank

Mount St. Helens	#2
Mount Rainier	#3
Mount Baker	#14
Glacier Peak	#15
Mount Adams	#34
Total U.S. Volcanoes	161

There are Pierce County AHAB sirens located throughout the port that were installed as a lahar warning system. They now serve as an all-hazards warning system.

An eruption at Mount Rainier could be regionally devastating, with lahars potentially reaching heavily populated areas and the Tacoma Tideflats.

PAST EVENTS

Volcanic eruptions and lahars are a very low probability event in region and their likelihood of occurrence is tracked on a geologic scale of centuries to thousands of years. There has been an average of one to two eruptions per century at Cascade volcanoes the last 4,000 years.

Mount Rainier has produced at least four eruptions and numerous lahars in the past 4,000 years. It is capped by more glacier ice than the rest of the Cascade volcanoes combined, and parts of Rainier's steep slopes have been weakened by hot, acidic volcanic gases and water. These factors make this volcano especially prone to landslides and lahars.

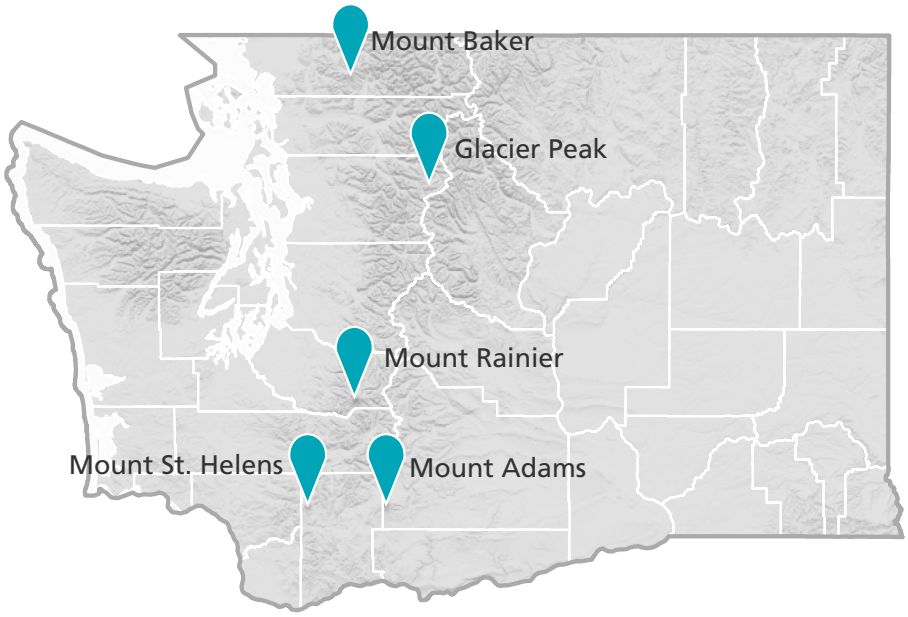
Mount St. Helens is the most frequently active volcano in the Cascades. During the past 4,000 years, it has produced many lahars and a wide variety of eruptive activity, from relatively quiet outflows of lava to explosive eruptions much larger than that of May 18, 1980.

Mount Baker erupted in the mid-1800s for the first time in several thousand years. Activity at steam vents near the summit increased in 1975 and is still active, but there is no evidence that an eruption is imminent.

Glacier Peak has erupted at least six times in the past 4,000 years. About 13,000 years ago, an especially powerful series of eruptions deposited volcanic ash as far away as Wyoming.

Mount Adams has produced few eruptions during the past several thousand years. This volcano's most recent activity was a series of small eruptions about 1,000 years ago.

Washington's Cascade Volcanos



Ash from Mount St. Helens destroyed about $100 million worth of crops. This amounted to roughly 7% of the typical crop value in the affected area.

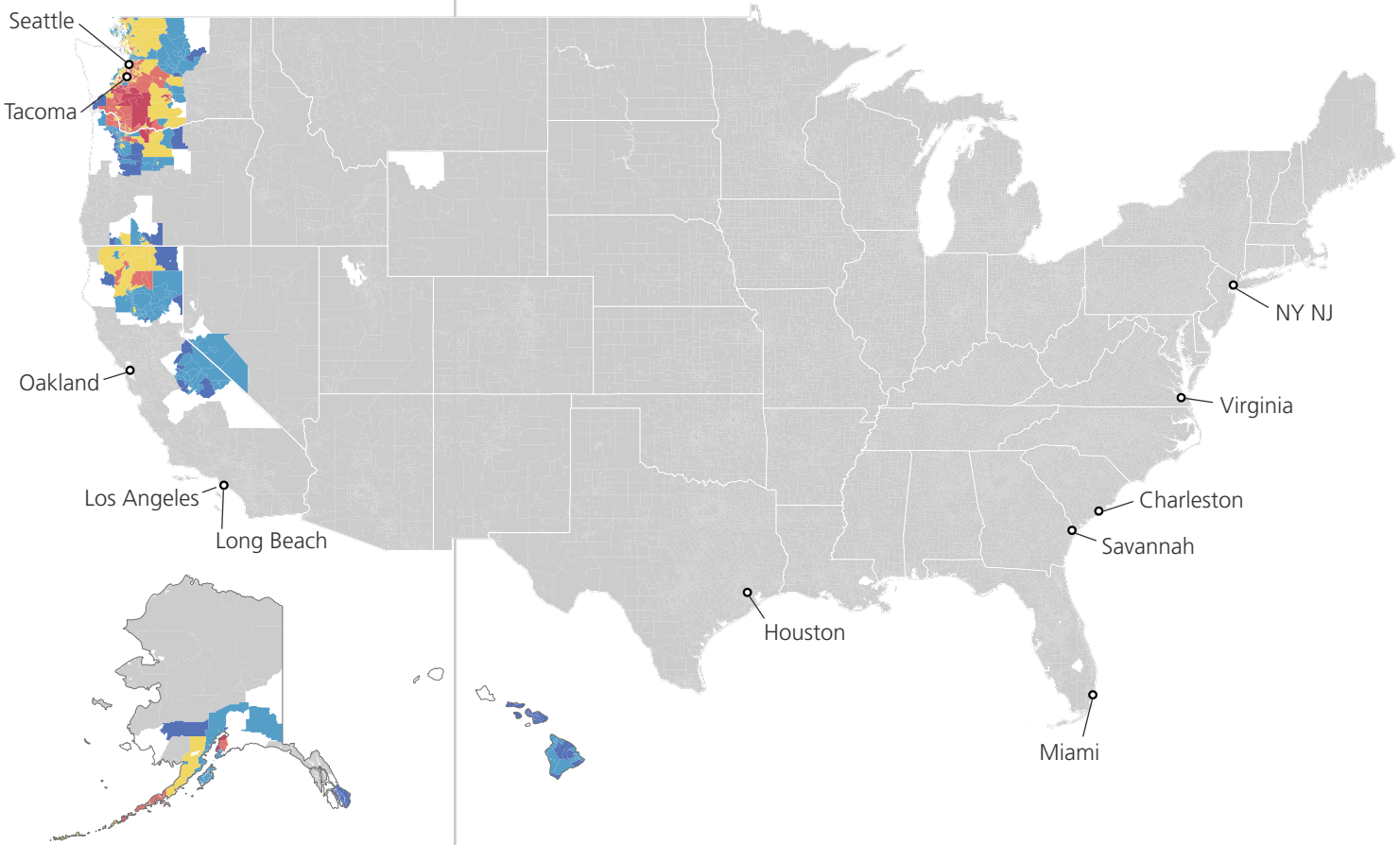
The eruption of Mount St. Helens remains one of the world's costliest volcanic eruptions to this day.

The Mount St. Helens eruption caused a mudflow that reduced the navigable channel depths of the Columbia River from 40 feet to 15 feet, grounding one vessel and stranding 31 vessels upstream. Emergency dredging shown above.

- Top Container Port
- Very High
- Relatively High
- Relatively Moderate
- Relatively Low
- Very Low
- Not Applicable
- No Rating

VOLCANIC ACTIVITY RISK AT TOP 10 US CONTAINER PORTS

The Federal Emergency Management Agency (FEMA) has mapped and quantified the volcanic activity risk across the United States based on expected annual loss, social vulnerability, and community resilience. The volcanic activity risk index map below shows the risk rating at the census tract level. The map includes the location of the top 10 US container ports by TEUs based on 2022 cargo volumes. The risk index score for the top 10 US container ports is also included below at the county level to show how the ports compare. Some ports may have several risk index scores if their terminals are located in multiple counties. This risk idex reflects the risk for volcanic hazards but does not account for the risk posed by volcanic ash.



Very High	Not Applicable	
NWSA Seattle	Charleston	NY NJ
NWSA Tacoma	Houston	Oakland
	Long Beach	Savannah
	Los Angeles	Virginia
	Miami	

HAZARD CHARACTERIZATION AND IMPACTS

Volcanic hazard risk is based on hazard likelihood, scale, exposure, and areas of susceptibility. Hazards are characterized by their likelihood and scale and vulnerabilities are determined by exposure and susceptibility to the hazard.

VOLCANIC ACTIVITY HAZARDS

Likelihood	LOW
Scale	HIGH
Outlook	LOW
Hazard Type	SHOCK

IMPACTS TO NWSA

Exposure	HIGH
Safety	MODERATE
Operations	HIGH
Facilities	HIGH
Equipment	MODERATE
Commerce	HIGH
Organization	HIGH

IMPACTS TO GATEWAY

Exposure	HIGH
Roadways	MODERATE
Railroads	HIGH
Waterways	MODERATE
Utilities	MODERATE
Industrial	HIGH
Community	HIGH
Environment	HIGH

Volcanic eruptions and lahars are very low likelihood events that are sudden shocks to the region. They can be large scale events that can affect multiple states.

The eruption of Mount St. Helens sent a cloud of ash 15 miles up into the sky that reached the central United States.

HAZARD INFORMATION

LIKELIHOOD

LOW

Likelihood of occurring on any given year

1. Volcanic hazards are very low likelihood events.
2. There is a 1-2% chance that at least one Cascade volcano will erupt in any given year in Washington.
3. There is a 0.001% annual chance that a large lahar could be triggered by Mount Rainier, Mount Baker, Mount Adams, or Glacier Peak.
4. There is a 0.002% chance that portions of King and Pierce Counties will receive at least 4 inches of volcanic ash as a result of a Cascade volcano eruption.

SCALE

HIGH

Magnitude event with regional scale

5. Small scale volcanic hazards are more common than large scale events.
6. Smaller scale events may be isolated to the areas immediately around the volcano and may not reach heavily populated areas below.
7. Large scale volcanic events can reach from the volcano all the way to the Puget Sound and Columbia River, affecting much larger areas. These sorts of events can be regionally devastating.

OUTLOOK

LOW

Level of increasing risk in future decades

8. There is an increasing amount of risk associated with volcanic hazards in the region on account of the increasing population and human development in potential hazard zones.
9. Volcanic hazards like eruptions and lahars are geologic hazards that are minimally affected by climate change. Shrinking glaciers and reduced snowpack from climate change may result in smaller lahars.

IMPACTS TO **NWSA**

EXPOSURE

HIGH

NWSA exposure

1. Both harbors are located in Mount Rainier volcanic hazard zones.
2. The Tacoma Harbor is in a lahar zone and the Seattle Harbor is in a post-sedimentation flooding zone.
3. Ash from any of the volcanoes in the region could post a threat to both harbors, but prevailing weather patterns would likely blow ash to the east.

SAFETY

MODERATE

Impact to safety and worker health

4. Volcanic hazards can be a threat to life safety and worker health.
5. Lahars can destroy almost anything in their path and could result in fatalities or injury to those in the lahar or flooding zones.
6. Cascade volcanoes typically show early signs that they are about to erupt and hazard areas can be evacuated in advance of the eruption and lahar.
7. In the event of a lahar from Mount Rainier, there would be just under two hours to evacuate workers from hazard zones before the lahar arrives at Commencement Bay.
8. Volcanic ash can irritate eyes and making breathing difficult for workers, potentially causing wheezing, coughing, respiratory irritation, and asthma attacks.

OPERATIONS

HIGH

Impact to terminal operations

9. Operations could be temporarily halted in hazard zones such as the Tacoma Tideflats leading up to an eruption. If the lahar and flooding reach either harbor, they could be halted for an extended period of time until repairs are made and the area is cleared to resume operations.
10. Cargo may shift from inoperable terminals to the remaining functional ones. In the event of a lahar from Mount Rainier reaching the Tideflats, Tacoma Harbor cargo operations may be shifted to the Seattle Harbor.
11. Volcanic ashfall could create unsafe working condition on terminals due to associated health issues, reduced visibility, and slick surfaces.
12. Operators would have to spend significant resources managing debris from any of the volcanic hazards, whether from a lahar, ashfall, or post-sedimentation flooding.
13. The extent of damage on terminals and across the gateway would greatly impact on-terminal operations. If key freight corridors, utilities, and industrial lands are inoperable or at reduced capacity, it will affect the ability to move cargo through port terminals.
14. If facility damage is extensive, there may be an overall reduction in gateway capacity even after recovery.

IMPACTS TO **NWSA**

FACILITIES

HIGH

Impact to NWSA facilities

15. A large lahar from Mount Rainier could reach the Tacoma Harbor, burying or even destroying nearly all of the facilities in its path and infiltrating underground utility systems.
16. Post-sedimentation flooding could also damage facilities in both harbors and leave debris on the terminals.
17. Volcanic ash could damage port facilities in both harbors if the weight of the ash overloads structures or the ash gets into sensitive components such as electrical and mechanical systems and stormwater treatment media.

EQUIPMENT

MODERATE

Impact to cargo-handling equipment and fleet vehicles

18. Equipment in volcanic hazard zones could be damaged or destroyed from the lahar or flooding.
19. Volcanic ash can damage sensitive components such as electrical and mechanical systems like engines and moving parts on equipment. They can also clog air filters and scratch and corrode surfaces

COMMERCE

HIGH

Impact to business and cargo volumes

20. Impact to commerce would depend on which volcano erupts or releases a lahar and the extent of the devastation on the terminals and across the region.
21. An eruption or lahar from Mount Rainier may cause a reduction in cargo volumes and loss of discretionary cargo to other ports.
22. Lines of business based primarily out of the Tacoma Harbor would be most affected by a Mount Rainier lahar, such as domestic containers, breakbulk, and autos, especially if there is no alternate site that could support those operations.
23. Cargo could be damaged from the lahar, flooding, or volcanic ash.
24. Agricultural exports through the Gateway could be damaged or destroyed if volcanic ash falls on farmlands.
25. Cargo mix would change as the gateway helps bring in goods for recovery effort.
26. The gateway could see an increase in cargo volumes if another volcano in the region impacts cargo operations at other ports.

IMPACTS TO **NWSA**

ORGANIZATION

HIGH

Impact to organizational resilience

27 A lahar could reach the office spaces in the Tacoma Harbor. While there should be several hours to get staff out of the hazard zone, the offices may be destroyed.

28 If the offices are destroyed, administrative staff may be able to carry out their work duties from home. Staff that work in the field would be most affected and the nature of their work would likely change during the recovery period.

29 Staff that live in lahar zones may be displaced from their homes. Others may not be able to access either of the harbors due to damage on the transportation network.

30 A disruption to operations and business could lead to a loss of revenue, making it more difficult to recover, especially if recovery functions aren't covered by insurance or government assistance. Recovery efforts would be complicated by the extent of damage across the region.

IMPACTS TO **GATEWAY**

EXPOSURE

HIGH

Exposure across the gateway

1. The Gateway is potentially exposed to five major volcanic hazard sources in Washington including Mount Rainier, Mount St Helens, Mount Baker, Mount Adams, and Glacier Peak.
2. Both harbors rely on infrastructure and industrial lands within volcanic hazard areas including lahar and post-sedimentation zones.
3. Volcanic ash can travel far from the source and can pose risk within and beyond state borders depending on the weather.

ROADWAYS

MODERATE

Impact to truck travel on freight roadways

4. Major freight roadways pass through lahar and post-sedimentation zones such as I-5 and other state and local freight routes in the Puyallup and Duwamish/Green River Valleys.
5. Lahars and flooding can damage roadways, bridges, and the electrical and mechanical systems that support roadway operations. Debris could bury the roadways.
6. Truck operations may need to stop in areas with volcanic ash to prevent damage to trucks and avoid unsafe operating conditions due to reduced visibility and slick roadway conditions.

RAILROADS

HIGH

Impact to rail travel on freight railroads

7. Major rail corridors pass through lahar and post-sedimentation zones including corridors in the Puyallup, Duwamish/Green, Nisqually, and Columbia River Valleys.
8. Lahars and post-sedimentation flooding can damage railroad structures and surfaces, electrical and mechanical systems, and bury rail corridors.
9. Rail operations may need to stop in areas with volcanic ash to prevent damage to the locomotives and avoid unsafe operating conditions due to reduced visibility. Ash may need to be cleared to fully resume operations.

WATERWAYS

MODERATE

Impact to vessel travel on navigable waterways

10. Lahars could reach Commencement Bay, filling the Blair, Hylebos, and Sitcum Waterways with debris and sediments. Post-sedimentation flooding could also bring debris to the West, East, and Lower Duwamish Waterways.
11. Vessel operations may need to stop in areas with debris or volcanic ash to prevent damage to vessels and avoid unsafe operating conditions due to reduced visibility and navigational impediments from debris. Dredging may be needed to fully resume vessel operations.

IMPACTS TO **GATEWAY**

UTILITIES

MODERATE
Impact to gateway utilities

(12) Many utility systems supporting gateway functions are located in lahar and post-sedimentation zones.

(13) Power supply in the Gateway could be disrupted from a lahar, post-sedimentation flooding, and volcanic ash impacts to power generation and transmission infrastructure.

(14) Debris and volcanic ashfall could affect buried and above ground utility systems such as water, gas, wastewater, and communication.

INDUSTRIAL

HIGH
Impact to region's cargo support facilities

(15) Lahars, post-sedimentation, and volcanic ash could affect the region's industrial areas. Many of the Manufacturing/Industrial Centers (MICs) are located in lahar or post-sedimentation zones.

(16) These sites could experience burial or damage to facilities and equipment.

COMMUNITY

HIGH
Impact to gateway communities

(17) Communities could be devastated by a lahar or post-sedimentation flooding with threats to life safety, public health, and overall livability.

(18) Ash could greatly affect daily life and require extensive cleanup efforts.

(19) A lahar and post-sedimentation flooding could harm the ancestral lands of the Coast Salish Tribes in the gateway, damaging cultural resources and affecting fish that are part of their treaty rights.

EMPOWERMENT

HIGH
Impact to organizational resilience

(20) Lahars and volcanic ash could threaten ecosystems and biodiversity due to excess debris, erosion, and sedimentation.

(21) Water quality and aquatic ecosystems can be affected by increased turbidity, acidity, and changes in water temperatures.

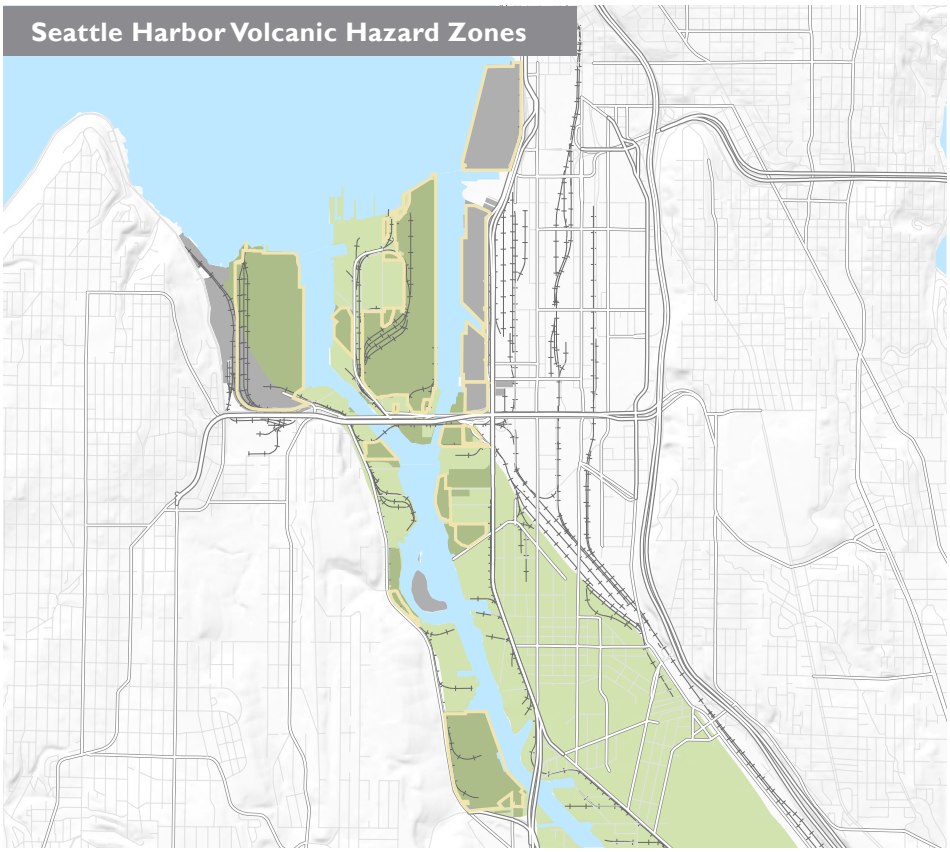
(22) Air quality could be negatively impacted by volcanic ash.

(23) Lahars and post-sedimentation flooding could release hazmat and spread contaminants.

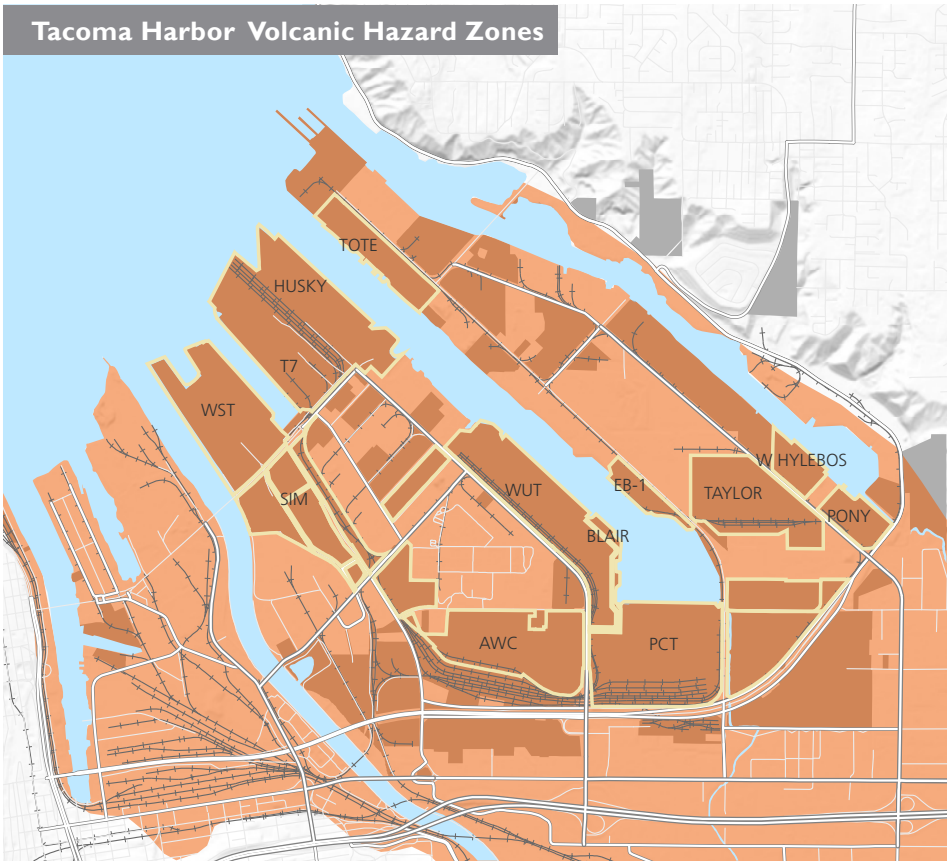
Volcanic Hazard Zones

The volcano hazard zones show areas that could be affected by an eruption at one of Washington's five volcanoes. The map is based on the extent of past events and so the extent of any single eruption would likely be smaller than areas shown in the map. While volcanic ash is also a hazard, it can't be mapped since its area of impact depends on many factors including the direction of the wind. Both harbors are in volcanic hazard areas.

Seattle Harbor Volcanic Hazard Zones



Tacoma Harbor Volcanic Hazard Zones



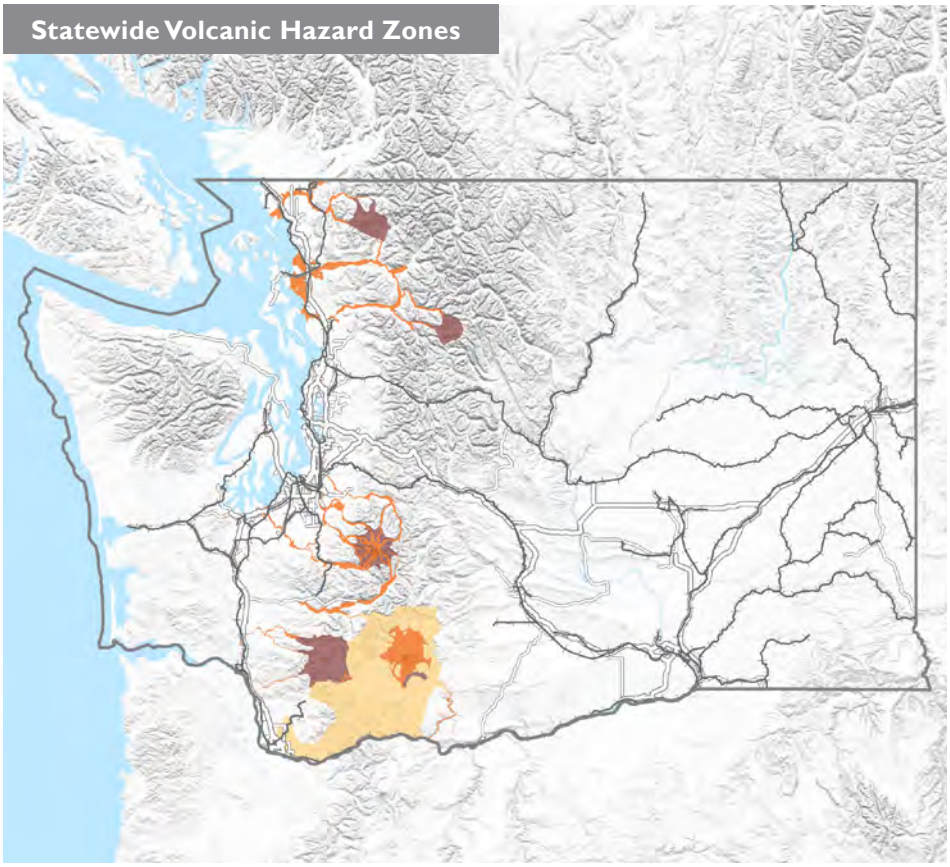
Near-Volcano Hazards
Includes the explosive blast zone, lava, pyroclastic flows and tephra

Regional Lava Flows
Areas which may experience lava from nearby lava vents

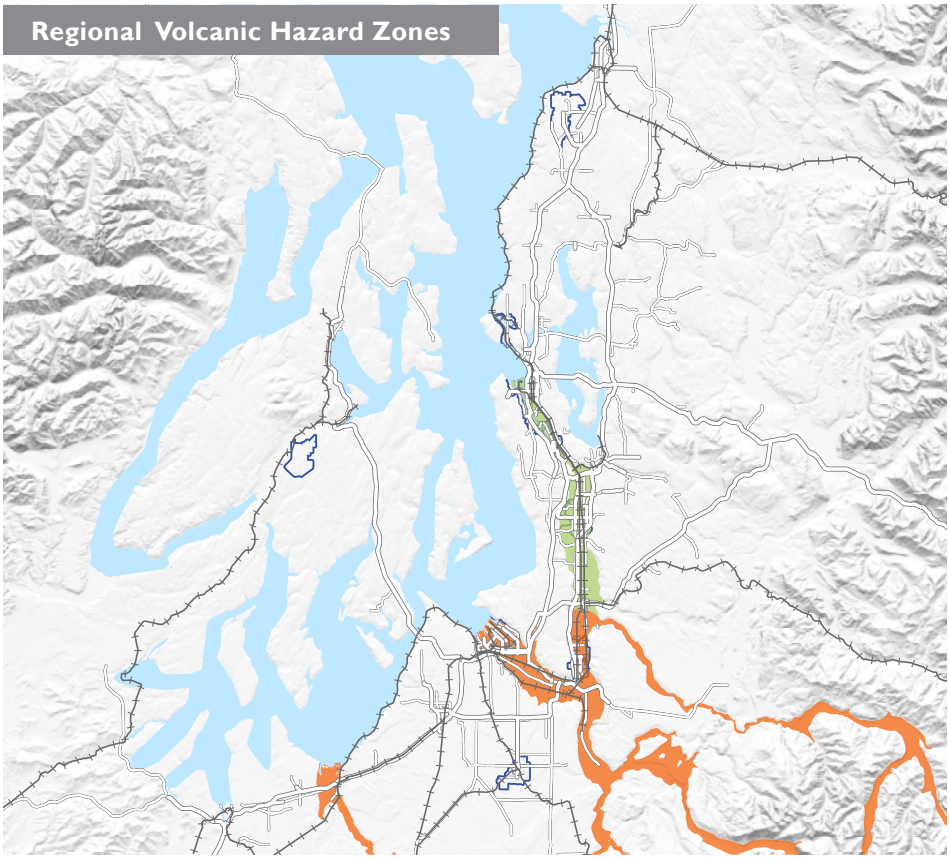
Lahars
Far-reaching mudflows in drainage valleys below the volcano

Post-Sedimentation Flooding
Areas which may flood as debris fills low-lying areas

Statewide Volcanic Hazard Zones



Regional Volcanic Hazard Zones



Volcanic Hazard Zones

The volcano hazard zones show areas that could be affected by an eruption at one of Washington's five volcanoes. The map is based on the extent of past events and so the extent of any single eruption would likely be smaller than areas shown in the map. While volcanic ash is also a hazard, it can't be mapped since its area of impact depends on many factors including the direction of the wind.

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Far-reaching mudflows in drainage valleys below the volcano

Post-Sedimentation Flooding
Areas which may flood as debris fills low-lying areas

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United States Geological Survey

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Washington State Department of Natural Resources, 2016. Simplified Volcanic Hazards. Available at: dnr.wa.gov/programs-and-services/geology/publications-and-data/gis-data-and-databases

APPENDIX: **HAZARD** RISK RANKING CRITERIA

LIKELIHOOD: the likelihood of the hazard occuring

LOW
Likely to occur within hundreds to thousands of years. These are typically major geohazards.

MODERATE
Likely to occur within tens of years. These are typically small magnitude geohazards or large magnitude meteorological hazards.

HIGH
Likely to occur at least once in any given year. These are typically seasonal meteorological hazards.

SCALE: the scale of the hazard

LOW
Small, isolated hazard.

MODERATE
Limited duration or mostly localized hazards.

HIGH
Large region-wide catastrophe.

OUTLOOK: how a hazard's risk changes over time

LOW
Decreasing risk or minimal changes to level of risk.

MODERATE
Modest increase in level of risk.

HIGH
Great increase in level of risk.

APPENDIX: **NWSA** IMPACT RANKING CRITERIA

The impact of a hazard to the NWSA or its vulnerability is characterized by its exposure and susceptibility. The NWSA exposure score is a measure of all the NWSA-licensed terminals in both harbors and provides a high level overview of where a hazard could affect NWSA properties. The vulnerability scores for safety, operations, facilities, equipment, commerce, and the organization reflect the hazard's overall impact to the NWSA and consider both the exposure and the susceptibility. This is an important distinction to make since a hazard with low exposure could greatly affect a small area, but the overall impact to the NWSA could still be relatively low.

NWSA EXPOSURE

The NWSA exposure risk ranking considers where hazards may occur on NWSA terminals and what is exposed, including workers and assets. Having two harbors in our Gateway provides redundancy and resilience in the port system. In the event of a hazard, having two harbors diversifies the geographic risk and reduces the chances of harmful exposure on all of the NWSA terminals.

LOW
Minimal exposure to workers and assets with few if any terminals affected (roughly 20% of less).

MODERATE
Moderate exposure to workers and assets with multiple terminals affected in both harbors or the majority of terminals affected in one harbor (roughly 20%-80%).

HIGH
High exposure to workers and assets with most terminals affected in both harbors (more than 80% of terminals).

SAFETY

The safety risk ranking considers how hazards may impact exposed workers from a life safety and public health perspective. The waterfront can be a risky work environment under normal working conditions and hazards can increase the chance of injury or fatalities. Outdoor workers are at increased risk of exposure to hazards and hazardous conditions, which makes heavy labor and equipment operations more risky. Evacuating either harbor in the event of a major disaster can be complicated by the potential for rail blockages of evacuation routes, the large number of trucks leaving an area, and the limited areas to exit terminals.

LOW
Potential for minor injuries and impacts to public health. Fatalities are not anticipated but could be possible, especially with particularly vulnerable populations.

MODERATE
Serious impacts to public health and potential for multiple injuries or fatalities, especially for particularly vulnerable populations.

HIGH
Serious impacts to public health and potential for many injuries and fatalities.

OPERATIONS

The operations risk ranking considers how hazards impact cargo operations in terms of adjusting or canceling work shifts, shifting cargo to other terminals or harbors, reducing terminal productivity, or halting operations altogether. The impact to operations is highly dependent on how the hazard affects both the terminals and the larger Gateway. Terminal need workers, safe working conditions, functional facilities, utility service, and functional equipment to operate in addition to working waterways, roadways, railroads, and industrial lands like warehousing. Having two harbors makes operations more resilient since it increases the chances of having some operational terminals following a disaster.

LOW

Recovery is rapid and requires few resources. Operators may shift operations to other work windows or cancel one or more work shifts. Minor impact on overall terminal productivity. Impacts are limited to a short period of time (less than a week).

MODERATE

Recovery is challenging. There is reduced ability to accommodate typical cargo operations. Operators may need to make significant adjustments to their operating hours, cancel many work shifts, or even shift operations to another terminal or harbor within the Gateway. Potential drop in overall terminal productivity. Impacts last for a moderate amount of time (1 week to months).

HIGH

Recovery is highly challenging. Operators have limited or no ability to accommodate cargo operations. Significant loss of terminal productivity and cargo shifts outside of the Gateway to other ports. Impacts typically last for an extended period of time (months to years).

EQUIPMENT

The equipment risk ranking considers how hazards impact the functionality of exposed equipment such as cargo-handling equipment (CHE), container cranes, or fleet vehicles. There is a large inventory of equipment used in both harbors for cargo operations. Each terminal relies on different types of equipment to move cargo. Equipment is generally resilient to hazards because it is heavy-duty and terminals often have multiples of their CHE, cranes, or fleet vehicles. Even if equipment is exposed to a hazard, there is a high chance that some equipment will remain functional. Equipment may be functional but temporarily inoperable if there are disruptions to power supply including electricity or fuels.

LOW

Minimal damage to equipment. Ability to move most equipment out of hazard-prone areas or minimal damage to exposed equipment. Repairs of equipment are relatively easy and can typically be handled with in-house maintenance crews. Low repair or replacement costs relative to value of overall equipment fleet.

MODERATE

Moderate damage to equipment. May or may not be able to move equipment out of hazard-prone areas. Significant repairs are required for exposed equipment. Moderate repair or replacement costs relative to value of overall equipment fleet.

HIGH

Significant damage to equipment. Largely unable to move equipment out of hazard-prone areas. Extensive repairs or even replacement required for exposed equipment. High repair or replacement costs relative to value of overall equipment fleet.

NWSA IMPACT RANKING CRITERIA

COMMERCE

The commerce risk ranking considers how hazards may damage cargo and impact overall cargo volumes, lines of business, and market share. The redundancy in harbors reduces the chance of experiencing a major disruption that results in a long-term loss in cargo volumes, discretionary volumes, and market share.

LOW
Event is easy to recover from with minimal impact to cargo operations and cargo volumes. There are no significant impacts to terminals or lines of business. There is potential damage to small amount of cargo.

MODERATE
Event is challenging to recover from and reduces cargo operations and cargo volumes. There are significant impacts to terminals and lines of business and potential damage to cargo. The event may result in loss of discretionary cargo and market share.

HIGH
Event is extremely difficult to recover from and there is a potential for a significant disruption to cargo operations and cargo volumes. There are long-term impacts to terminals and lines of business and potential damage to significant amounts of cargo. There is long-term loss of discretionary cargo to other ports and loss in market share.

ORGANIZATION

The organization risk ranking considers how hazards impact the NWSA's financial sustainability, leadership, staff, and ability to carry out essential functions. Remote capabilities and redundancy in office and public meeting spaces makes it easier to carry out essential functions in the event of a hazard.

LOW
Minimal impact to revenue and financial sustainability, staff, and ability to carry out essential functions. Disruptions are relatively easy to recover from within a matter of days.

MODERATE
Moderate impact to revenue and financial sustainability, staff, and ability to carry out essential functions. Disruptions are challenging to recover from and last days to weeks. May require significant operational adjustments for staff and leadership to perform their work functions. Outside funding assistance may be need to help cover costs such as relief funding or insurance claims.

HIGH
Major impact to revenue and financial sustainability, staff, and ability to carry out essential functions. Disruptions are challenging to recover from and last over a month. Major operational adjustments are needed for staff and leadership to perform their work functions. Long-term recovery requires funding assistance to help cover costs such as relief funding or insurance claims.

APPENDIX: **GATEWAY** IMPACT RANKING CRITERIA

EXPOSURE

Where these hazards may occur across the Gateway and what is exposed (workers and assets).

LOW
Minimal or no exposure across the Gateway.

MODERATE
Potential for limited areas of exposure across the Gateway.

HIGH
Potential for widespread exposure across the Gateway in coastal and inland areas.

ROADWAYS

How these hazards impact travel on key truck corridors.

LOW
No or minimal short-term impact to truck operations. May experience delays and congestion from temporary route closures during hazardous conditions. Minimal if any damage to infrastructure with no loss of functionality.

MODERATE
Disruption to truck operations. May experience delays and congestions from closures that last several days or more. Delays and closures are likely driven by a combination of hazardous travel conditions such as weather and infrastructure damage. Functionality restored after hazardous travel conditions pass and infrastructure is repaired.

HIGH
Major disruption to truck operations. Loss of key truck routes for extended periods of time with limited or no alternative routes. Major damage to roadways with loss of functionality.

RAILWAYS

How these hazards impact travel on key rail corridors.

LOW
No or minimal short-term impact to rail operations. May experience delays and congestion from temporary route closures during hazardous conditions. Minimal if any damage to infrastructure with no loss of functionality.

MODERATE
Disruption to rail operations. May experience delays and congestion from closures that last several days or more. Delays and closures are likely driven by a combination of hazardous travel conditions and infrastructure damage. Functionality restored after hazardous travel conditions pass and infrastructure is repaired.

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HIGH
Major disruption to rail operations. Loss of key rail corridors for extended periods of time with limited or no alternative routes. Major damage to railroads with loss of functionality.

GATEWAY IMPACT RANKING CRITERIA

WATERWAYS

How these hazards impact travel on key navigable waterways.

LOW	MODERATE	HIGH
No or minimal short-term impact to vessel operations. May experience vessel delays during hazardous travel conditions. Minimal if any damage to infrastructure with no loss of functionality.	Disruption to vessel operations. May experience delays and congestions from closures that last several days or more. Delays and closures are likely driven by a combination of hazardous travel conditions and infrastructure damage. Functionality restored after hazardous travel conditions pass and infrastructure is repaired.	Major disruption to vessel operations. Loss of navigable waterways for extended periods of time with no alternative routes. Major damage to waterways with loss of functionality.

UTILITIES

How these hazards impact utility services.

LOW	MODERATE	HIGH
No or minimal short-term or localized impact to utility infrastructure and service. Minimal loss of functionality in isolated areas.	Moderate disruption to utility infrastructure and service. Moderate loss of functionality across the region.	Major disruption to utility infrastructure and service. Severe loss of functionality across the region.

CARGO SUPPORT

How these hazards impact the region's industrial lands and their operations.

LOW	MODERATE	HIGH
No or minimal short-term or localized impact to region's industrial lands a nd cargo support activities. (20% or less).	Moderate impact to region's industrial lands and cargo support activities. (20% to 80% affected)	Major disruption to region's industrial lands and cargo support activities. (80% to 100% of total industrial land supply

COMMUNITY

How these hazards impact neighboring communities.

LOW	MODERATE	HIGH
No or minimal short-term or localized impact to community and daily life.	Moderate impact to community with ability to resume day to day activities in a short period of time.	Major impact to community with difficulty carrying out life-essential activities.

ENVIRONMENT

How these hazards impact the environment (air, water, land, habitat).

LOW
No or minimal short-term or localized impact to environmental quality with ease of recovery without outside intervention

MODERATE
Moderate impact to environmental quality. May recover on its own over time or with limited intervention to restore functionality.

HIGH
Major impact to environmental quality. Recovery requires significant intervention to restore functionality.


THE NORTHWEST
SEAPORT ALLIANCE
Gateway to Solutions

THE NORTHWEST SEAPORT ALLIANCE
Gateway to Solutions

RESILIENT GATEWAY

NORTHWEST SEAPORT ALLIANCE RESPONSE FRAMEWORK

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RESILIENT GATEWAY PROGRAM

The Resilient Gateway Program supports NWSA's Key Initiative to develop a strategic resilience plan to ensure the long-term economic vitality of our region. This document presents the results of the NWSA's initial coordinated planning effort, building on prior efforts by the homeports. It was carried out by a core project team and subject matter experts that included staff from the Northwest Seaport Alliance, the Port of Seattle, and the Port of Tacoma.

The Vulnerability Assessment and Response Framework are designed to inform and support future policy development and strategic decision-making, providing the framework for a future Resilient Gateway Implementation Plan.

The Vulnerability Assessment looks at our exposure and vulnerability to potential hazards and the Response Framework describes how our ports may prepare for hazards through education and awareness, planning and preparation, and adapting and/or mitigating for hazards when investing in new facilities and upgrading existing facilities. The Resilient Gateway Program considers risk both on-terminal and off-terminals and provides a framework for responding to resiliency goals, support policy development and strategic decision-making, and translating them into project design, prioritization, and asset management. **It does so by addressing the eight most likely and impactful hazards that could cause property damage or loss of life:**

- Coastal Flooding (includes sea level rise)
- Flooding (riverine, urban, groundwater)
- Severe Weather (cold, heat, rain, thunderstorms, wind, drought)
- Wildfires and Smoke
- Landslides (includes erosion and subsidence)
- Earthquakes
- Tsunamis
- Volcanic Activity

BACKGROUND

Our Gateway is critical infrastructure of national significance. The marine cargo operations provide significant jobs and revenue to Washington state, where 40% of the jobs are tied to trade. Cargo operations annually support tens of thousands of jobs, billions in business output and labor income, and genereate over one hundred million in state tax revenue. It serves as the 7th largest container gateway in the country, the 4th largest refrigerated container gateway overall, the 2nd largest refrigerated container export gateway, and the 4th largest warehousing and distribution cluster in the country.

The Tacoma harbor serves as strategic seaport for the nation's military, and both ports have a designated role as community lifelines during disaster recovery. In recognition of their role as critical infrastructure, the NWSA and both homeports have been engaged in various related planning efforts over the years.

Resilient Gateway builds on prior efforts which were limited in nature and typically focused on a single hazard, a single harbor, or the resilience aspects of a particular project. Recent examples include the Port of Seattle Resiliency Assessment, the Port of Tacoma All Hazard Mitigation Plan, and the Port of Seattle Climate Change Adaptation Plan.

Key Resiliency Terms

Adapted from FEMA

Resilience is the ability to prepare for threats and hazards, adapt to changing conditions, and withstand and recover from disruptions.

Risk is the potential for a negative outcome based on the combination of a hazard and potential areas of vulnerability.

Hazards are sources of potential danger or adverse conditions and are characterized in terms of their likelihood and magnitude.

Likelihood is the probability or frequency of a hazard occurring.

Scale is a measure of the severity of a hazard.

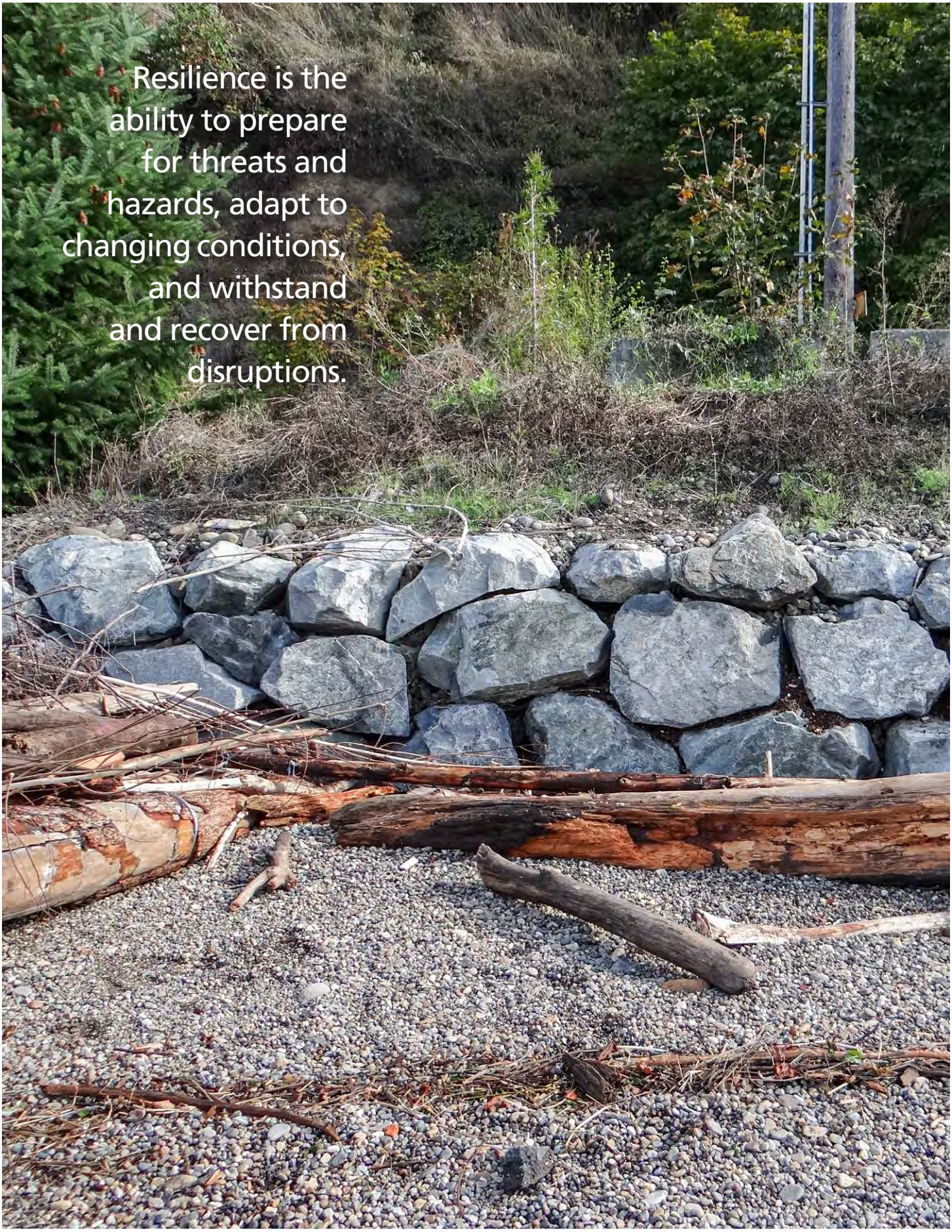
Vulnerability is impact or susceptibility to injury, harm, damage, or economic loss. It is characterized by what is exposed to a hazard and its sensitivity to the hazard.

Exposure is the potential geographic reach of a hazard that can harm people, property and anything else located in the hazard zone.

Susceptibility is the sensitivity of someone or something to a hazard.

Mitigation is any action to reduce risk by reducing one or more risk factors.

Adaptation is a type of mitigation action that focuses on adjusting to new climate conditions in order to reduce risk.


Resilience is the ability to prepare for threats and hazards, adapt to changing conditions, and withstand and recover from disruptions.

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NORTHWEST SEAPORT ALLIANCE RESPONSE FRAMEWORK

Opportunities to mitigate risk by increasing resilience

RESPONSE FRAMEWORK

Ports play an important role in the larger freight sytem and rely on a multi-modal network to keep goods moving to their destination.

PREPARING FOR CHANGE AND DISASTER

The purpose of Resilient Gateway Program is to prepare for natural hazards and changing climate conditions so that we can better withstand and recover from disruptions. In planning for a Resilient Gateway, we can protect the safety and health of workers, the critical infrastructure needed for cargo operations, and support sustainable prosperity for the long-term success of our region. The Response Framework builds on the Vulnerability Assessment and is designed to inform and support future policy development and strategic decision-making.

The Vulnerability Assessment identified the eight natural and climate hazards that are the biggest threat to our Gateway. Each hazard is unique in how it impacts the Gateway, and understanding their risk factors including their likelihood, scale, and outlook can help inform our approach for mitigating risk. The most effective approach for addressing risk is unique to the hazard and whether it is an emerging threat, chronic hazard, or shock. The NWSA Vulnerability Assessment also looks at how a hazard affects cargo-operations both on-terminal and across the Gateway. Identifying these potential areas of vulnerability helps highlight which areas have the greatest risk and helps prioritize actions to mitigate that risk.

The Cascadia Rising exercise at the Port of Tacoma brings together government agencies to test the state's Cascade Subduction Zone earthquake and tsunami plan.

RESILIENCE PRINCIPLES

There are standard principles used in the resilience planning field for developing strategies and actions to reduce risk. These overarching resilience principles can be used to help promote resilience before a hazard occurs and to help recover more quickly and smoothly. Resilience strategies and actions should be in line with one or more of these principles.

Plan and Prepare – Develop risk management and/or emergency management plans and preparedness procedures before a hazard occurs. Having a plan in place before a hazard occurs reduces uncertainty and can help protect life safety and public health, promote operational procedures that protect against property damage, and reduce overall risk.

Maintain and Manage – Keeping facilities and equipment in a state of good repair can help them better withstand hazardous events and changing climate conditions. Proactively monitoring facilities and equipment can identify issues and problem areas early on so that they can be fixed.

Strengthen and Protect – Strengthen infrastructure to better withstand hazards and adapt to changing climate conditions. Use design standards and the best available science to build more resilient facilities. The driver for these infrastructure hardening measures can be a standalone resiliency project or they can be added on as part of a larger project such as a rehabilitation or modernization effort.

Enhance Redundancy – Identify and reduce single points of failure by providing alternatives. This principle builds on the notion that "two is one and one is none." Promoting redundancy in our systems protects against complete shutdown when a hazard takes down part of the system.

Recover – Develop plans for post-event response and recovery. The more quickly service is restored, the more quickly resources can be deployed to support emergency response efforts and the long-term recovery of the region if needed.

Retreat – Relocate or abandon facilities in extremely vulnerable areas. This resilience principle is less applicable to both harbors where most facilities and operations are located in hazard zones and can't feasibly be relocated.

Planning for a Resilient Gateway helps ensure that we can continue to deliver and receive goods from across the world and meet community needs.

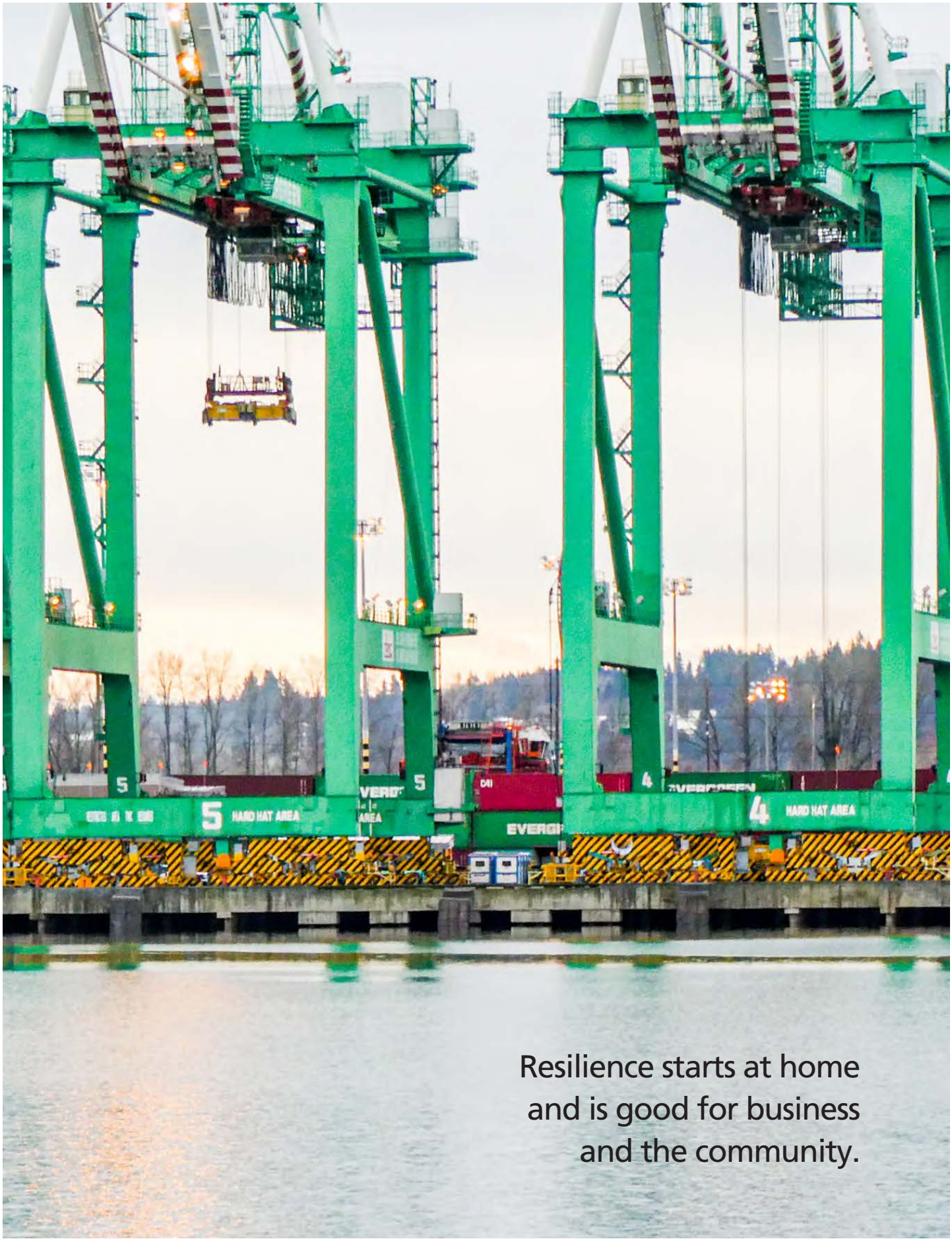
Newer facilities such as the new ILWU worker breakrooms at Terminal 5 are built to newer codes and are more resilient.

Promoting resilience before a hazard occurs will help recovery proceed more quickly and smoothly.

KEY TAKEAWAYS

Looking at the NWSA Vulnerability Assessment findings, there are some key takeaways to consider moving forward:

1. **Planning for resilience is more important now than ever.** We are globally connected and disruptions to the Gateway can have large implications beyond our immediate region.
2. **It is impossible to eliminate all risk,** but we can take action to fare better in the face of hazards and changing climate conditions.
3. **Our cargo operations rely on critical infrastructure** across the Gateway that needs to be resilient and adapt to changing conditions.
4. **The working waterfront is already a risky place.** It is important to prioritize life safety and public health to protect our essential workers.
5. **If we go it alone, we will become islands.** Our harbors are one part of the larger freight system and we must coordinate with our regional partners to protect the long-term viability of our cargo Gateway.
6. **Resilience is good for business and the community.** Many resilience improvements that benefit goods movement also benefit the general public and vice versa.
7. **Resilience starts at home and in our communities.** No amount of resilient infrastructure and equipment can keep cargo moving through the Gateway if workers can't meet their essential needs at home or get to work.
8. **There is no one-size fits all solution to mitigating risk.** A mixture of different types of mitigation measures is often the best approach to reducing risk. Focusing on one aspect alone such as emergency planning or strengthening infrastructure is not as effective as an integrated approach that brings different actions together.
9. **We can take climate action to reduce our risk.** Cutting emissions will improve the outlook for hazards that are influenced by changing climate conditions and make us less vulnerable in future years.
10. **We have little to no control over the natural hazards** that affect our Gateway. Natural hazards are regular processes and we cannot stop geologic or meteorlogical hazards.
11. **If we wait to adapt, we will be too late.** Emerging threats may not be a major threat today, but delaying action until after issues arise will result in regular disruptions to operations and costlier adaptation improvements later.
12. **It is impractical and infeasible to fortify the Gateway to be wholly resilient** against major shocks, but we can still take action to meet priority goals like protecting life safety.
13. **Resiliency is an ongoing process.** We are never done mitigating risk and will need to adapt to changing conditions to stay viable in the long-term.



Resilience starts at home
and is good for business
and the community.

TURNING FINDINGS INTO ACTION

COMPARING HAZARDS BY RISK FACTORS

The NWSA Vulnerability Assessment looked at the eight natural and climate hazards that are the biggest threat to our Gateway and assigned each risk factor a low, moderate, or high score. After assigning scores, the hazards were divided into three different hazard types based on their risk profile: emerging threats, chronic hazards, and shocks. This helps in better understanding how to plan for and manage the risk associated with each hazard based on their likelihood, scale, and outlook. Breaking out the hazards by type is also helpful because it shows that hazards within the same grouping having similar impact scores based on exposure and susceptibility. The emerging threat category has one of the lowest number of moderate and high impact scores, shocks have the most high and moderate impact scores, and chronic hazards fall in the middle.

Hazards were divided into three different types based on their risk profile: emerging threats, chronic hazards, and shocks.

Areas that score low may need mitigation action to stay low impact in the future.

USING THE SCORES TO PRIORITIZE ACTIONS

The risk factor scores are a helpful starting point for identifying areas to mitigate risk and adapt to changing climate conditions. They help show where the potential risks are both on-terminal and across the Gateway and make it easier to comprehend risk in terms of the big picture. There is no right way to assess risk and prioritize mitigation action, but the risk factor comparison table is an easy resource to refer to in prioritizing mitigation work.

It is helpful to look at the table in several ways. Look top to bottom for each hazard and notice any risk factors that stand out. Think about the hazard likelihood and scale in relation to its impacts to the NWSA and Gateway. Then consider the outlook. How will the outlook change over time and how would that affect the other risk factor scores? If the outlook is high, the other risk factors scores will likely go up in the future without mitigation or adaptation whereas low outlook scores will have less change in future years. Then look left to right for each risk factor to see which hazards are low, moderate, and high. Are there any risk factors that are especially high across multiple hazards?

It should also be noted that looking at the risk factor scores alone isn't enough to determine where and how to mitigate risk. For example, areas that score high might not be the best place to focus limited resources to increase resiliency and areas that score low may need mitigation action to stay low impact in the future.

RISK FACTOR COMPARISON TABLE

Below is a high level summary of the the 2023 NWSA Vulnerability Assessment. Please refer to the Assessment for details and more information as there are many nuances to these results that should not be implemented out of context.

MITIGATION APPROACH BY HAZARD TYPE

Emerging Threat – The emerging threat category includes coastal flooding because it is the one hazard that is not a major threat today but has greatly increasing I was risk levels over time with future sea level rise. We have a great ability to plan for and adapt our infrastructure to future sea level rise with thoughtful planning that considers sea level rise projections and infrastructure lifespan. Because adaptation will be expensive, it is recommended to begin planning for adaptation now at the areas most vulnerable to coastal flooding and sea level rise. This will spread the adaptation work over a longer planning horizon and make it more manageable.

Chronic Hazards – The chronic hazards have a high likelihood of occurring but are typically smaller in scale and impact. They are largely seasonal in nature since most of them are influenced by weather. The chronic hazards include flooding, severe weather, wildfires and smoke, and landslides. Because they typically occur multiple times a year, mitigation actions here can have a very high return on investment in terms of improving the Gateway's resilience.

Shocks – Shocks have a low likelihood of occurring but are typically larger in scale and impact. They can provide a major shock to the system and dramatically affect a large area. All of the shocks are geologic hazards and they include earthquakes, tsunamis, and volcanic activity. The only geologic hazard not included in the shocks category is landslides. Because these are low likelihood events, it is important to prioritize work here to maximize return on investment. It is impractical and infeasible to fortify the Gateway to be wholly resilient against major shocks. However, we can come up with actions to address our high priority goals like protecting life safety in the event of a disaster. This can help us be more strategic about where and what facilities we upgrade to be more resilient against disruptions.

Key Resiliency Terms

Adapted from FEMA

Resilience is the ability to prepare for threats and hazards, adapt to changing conditions, and withstand and recover from disruptions.

Risk is the potential for a negative outcome based on the combination of a hazard and potential areas of vulnerability.

Hazards are sources of potential danger or adverse conditions and are characterized in terms of their likelihood and magnitude.

Likelihood is the probability or frequency of a hazard occurring.

Scale is a measure of the severity of a hazard.

Vulnerability is impact or susceptibility to injury, harm, damage, or economic loss. It is characterized by what is exposed to a hazard and its sensitivity to the hazard.

Exposure is the potential geographic reach of a hazard that can harm people, property and anything else located in the hazard zone.

Susceptibility is the sensitivity of someone or something to a hazard.

Mitigation is any action to reduce risk by reducing one or more risk factors.

Adaptation is a type of mitigation action that focuses on adjusting to new climate conditions in order to reduce risk.

RESILIENCE STRATEGIES AND ACTIONS

RESILIENCE STRATEGIES

The following is a list of resilience strategies that the NWSA can follow to increase resilience both on-terminal and across the Gateway. Each strategy has its own subset of potential actions listed on the following pages.

A. Administer the Resilient Gateway Program to mitigate risk

B. Partner with stakeholders to make the Gateway more safe and resilient

C. Be stewards of port assets to protect their long-term viability

D. Identify the most at-risk facilities to help prioritize resiliency improvements

E. Build a resilient workforce and workplace to increase organizational resilience

F. Use nature-based solutions to reduce vulnerability to hazards

G. Leverage data-sharing partnerships to manage risk across the supply chain

H. Protect critical infrastructure for national defense and emergency response

I. Take climate action to reduce climate hazards

RESILIENCE STRATEGIES AND ACTIONS

STRATEGY	POTENTIAL ACTIONS
A. Administer the Resilient Gateway Program to mitigate risk	① **Dedicate staff time and resources to promoting the Resilient Gateway Program.** Champion resiliency across the Gateway by developing a Resilient Gateway Program to help coordinate and align related resiliency planning efforts. ② **Develop a Resilient Gateway Implementation Plan.** Build on the Vulnerability Assessment and the Response Framework to develop a Resilient Gateway Implementation Plan. This will provide direction about which mitigation strategies the NWSA should pursue and be used to develop a budget request to implement the work. ③ **Update leadership and staff with hazard and climate communications.** Provide briefings on Resilient Gateway to leadership and staff. Forms of communication could include briefings, end of year program reports, summaries of impact to tenants following a hazardous event, or seasonal hazard outlook and wrap-up summaries. ④ **Track resiliency funding opportunities and apply for relevant grants.** Continue to track grant funding opportunities that support the work of the Resilient Gateway Program. Seek outside funding opportunities to help build more resilient infrastructure that can better withstand hazards and adapt to changing climate conditions. Planning funding may also also be helpful to build capacity for hazard and adaptation planning.

STRATEGY	POTENTIAL ACTIONS
B. Partner with stakeholders to make the Gateway more safe and resilient	① **Participate in resilience and climate adaptation efforts across the Gateway.** Coordinate with regional partners on their related resilience efforts. Identify and collaborate on opportunities to make Gateway infrastructure more resilient and better able to support cargo operations in the event of a hazard or with changing climate conditions. ② **Develop and maintain a FEMA-approved Hazard Mitigation Plan.** Work with FEMA, Pierce County, and King County to develop and update FEMA-approved Hazard Mitigation Plans for both harbors. The plans are similar to Resilient Gateway in that their goal is to reduce risk to lose of life and property by lessening the impact of disasters. Having a FEMA-approved Hazard Mitigation Plan is a requirement for applying to many federal grant opportunities for mitigation work. The Port of Tacoma has a current FEMA-approved Hazard Mitigation Plan but there is not one that covers the Seattle Harbor. ③ **Maintain up-to-date evacuation plans for multiple hazard scenarios and update as appropriate.** Update evacuation plans for a range of hazards to account for changing conditions on the transportation network. Work with transportation partners and emergency responders to identify vulnerable parts of the evacuation network that may be susceptible to failure in the event a hazard. Identify alternate routes or improvements to the network that could improve the ability to evacuate hazard zones. ④ **Develop hazard disclosure language to incorporate into new lease agreements.** Notify tenants and potential tenants of the hazard zones that their lease area is in. Encourage tenants to develop their own safety plans in the event of a hazard.

B. ***continued***

5. **Develop hazard outreach program with tenants and customers.** Provide notice to tenants when a hazard or hazardous conditions are emerging. Follow up with tenants and customers to gather information about impacts to the site, worker safety, operations, facilities, equpment, and business following a hazardous event. Collecting this data can be helpful in idenitfying problem areas and coming up with strategies to address them.

6. **Pursue StormReady Designation with National Weather Service.** Partner with government agencies and the community to pursue StormReady designation through the US National Weather Service. This program promotes severe weather preparedness by helping participants develop their capabilities to prepare for and respond to a severe weather event.

7. **Pursue TsunamiReady Designation with the National Weather Service.** Partner with government agencies and the community to pursue TsunamiReady designation through the US National Weather Service. This program promotes tsunami preparedness by helping participants develop their capabilities to prepare for and respond to a tsunami event.

STRATEGY	POTENTIAL ACTIONS

C. Be stewards of port assets to protect their long-term viability

1. **Develop resilient design guidelines for port facilities.** Incorporate resiliency into port facilities to protect their long-term functionality in the face of hazards and changing climate conditions. Work with homeports to develop a guidance document for incorporating resiliency considerations into projects on port property including port-led projects and tenant improvements.

2. **Implement asset management programs to protect port investments.** Maintain port assets including facilities and equipment in a state of good repair to reduce emergency shutdowns of critical facilities and maximize return on public investments. Develop a programmatic way to understand asset inventory, needed repairs, and life-cycle costs to maintain assets in a cost-effective manner. Effective asset management can help avoid costly repairs and service disruptions by identifying and addressing issues early.

3. **Ensure that stormwater infrastructure protects against flooding hazards.** Proper planning, design, and maintenance of stormwater infrastructure is essential for reducing flood risk to port facilities,equipment, and cargo. Port properties are at risk of different flooding sources including coastal flooding, riverine flooding, urban flooding, and groundwater flooding. With rising sea levels and increasing extreme precipitation events, it is especially important to maintain stormwater infrastructure in good condition and adapt stormwater systems to changing conditions.

4. **Review maintenance matrix responsibilities in lease agreements.** The ports own most of the facilities on any given terminal, but existing practices make most terminal maintenance activities a tenant responsibility. Ensure current maintenance practices in lease language support the long-term stewardship of port facilities.

5. **Explore smart technologies to monitor changing conditions and identify potential threats to port assets.** Use technology to better track assets and manage them over time. Smart technology applications may be especially useful in monitoring sites and areas that are hard to reach. For example, installing water-detection sensors in underground utility vaults may help identify water intrusion from events like groundwater flooding that may otherwise go unnoticed.

6. **Review and update risk management and insurance practices and policies.** Regularly coordinate with the homeports to review risk management practices and update insurance policies based on existing risk levels, the insurance market, anticipated changes in level of risk, and availability of FEMA Public Assistance Program funding to support recovery efforts.

RESILIENCE STRATEGIES AND ACTIONS

STRATEGY	POTENTIAL ACTIONS
D. Identify the most at-risk facilities to help prioritize resiliency improvements	① **Survey facilities including buildings, wharfs, and utilities to assess their condition and potential risk.** Identify potential safety hazards and critical infrastructure on terminals and develop strategies to address safety issues and protect critical infrastructure. Regularly monitor facilities to assess changes in conditions. ② **Maintain up-to-date floodplain maps.** FEMA-approved floodplain maps are a helpful tool to mitigate flood hazard risk. The floodplain maps show legacy flood hazards on some port properties where the site has since been modified and is no longer in a floodzone. Work with FEMA to update outdated areas and develop a systematic way to regularly update the maps as port projects are completed that affect the floodplain. ③ **Assess facilities and equipment located in the 100-year floodplain and determine their vulnerability.** Perform survey of facilities and equipment that are in the floodplain. Identify critical infrastructure located in the floodplain that needs protective measures to avoid critical damage. Develop operational procedures to prevent or reduce floodwater intrusion on the site and damage to facilities and equipment. ④ **Perform a high-level screening of terminal buildings for potential seismic hazards.** Develop a better understanding of seismic risk for buildings by performing a rapid visual screening in accordance with FEMA P-154. Buildings that are identifed as potentially hazardous should be further evaluated by an engineer for their seismic risk.

STRATEGY	POTENTIAL ACTIONS
E. Build a resilient workforce and workplace to increase organizational resilience	① **Maintain up-to-date emergency response plans.** Develop and maintain emergency response plans for various hazards and hazardous working conditions. Include coverage area for both offices and NWSA-operated terminals. Allow for coodination and collaboration with stakeholders. ② **Train staff on hazard plans and procedures.** Use emergency response plans to create a staff safety plan in the event of hazards. Use this safety plan to share key hazard and emergency response procedures to staff. Train staff on these procedures through organized safety drills and trainings such as the annual Great ShakeOut drill or Prepare in a Year. ③ **Incorporate hazard mitigation into standard operating procedures at NWSA-operated terminals.** Review standard operationg procedures for NWSA-operated terminals and incorporate best hazard mitigation practices where feasible. An example includes following the Standards of Care outlined in the Puget Sound Harbor Safety Plan. ④ **Develop and maintain an up-to-date Continuity of Operations Plan.** Develop and maintain a Continuity of Operations Plan to identify the organization's Essential Functions and plan for their continuation or quick recovery after a disruption. ⑤ **Keep remote work capabilities in place.** Maintaing remote work capabilities can help administrative staff carry out their work from home if needed. In the event of hazardous conditions at the offices or on commute routes, staff can carry out their essential work duties from home.

E. ***continued***

6. **Protect information by backing up data outside of the region.** Review IT policies with homeports to ensure that the NWSA and homeports' information is backed up at an alternate site. Having backed up data greatly reduces the chance of losing important records.

7. **Offer Community Emergency Response Team (CERT) training to staff.** Create a more resilient workforce by teaching staff how to prepare for disasters and help with basic disaster response at the workplace or at home.

8. **Train staff on incident management and command systems.** Identify key staff that need to be trained on the National Incident Management System (NIMS) and the Incident Command System (ICS). This will empower staff to plug into and participate in response efforts in the event of an incident.

9. **Create resilient lines of communication with staff.** Enroll employees phone coverage plans used for public safety officials. This will increase capabilities for notifying staff of hazards and maintaining contact with them following a major disaster.

STRATEGY	POTENTIAL ACTIONS

F. **Use nature-based solutions to reduce vulnerability to hazards**

1. **Use green infrastructure to capture stormwater and reduce urban flooding issues.** Terminals require stormwater infrastructure to move water off the terminals and reduce urban flooding issues. While most terminals use traditional stormwater infrastructure, green infrastructure may be appropriate in some instances.

2. **Develop habitat sites that support the ecosystem while increasing flood storage capacity.** Both homeports have habitat sites near NWSA terminals and other critical infrastructure that supports cargo operations. Many of these existing sites help reduce flood risk by storing stormwater. As new habitat sites are developed by the homeports, continue to explore alternatives that also reduce flood risk.

3. **Protect shorelines from coastal flooding and erosion using natural hardening methods.** Coastal flooding and erosion can compromise terminal shorelines and their upland facilities. Nature-based solutions can help reduce wave action, decrease water velocity, or prevent waters from overtopping the shoreline and getting on the terminal.

4. **Increase tree and vegetative cover where appropriate to reduce urban heat island effect.** Industrial areas can experience the urban heat island effect because of the large amount of paved area and limited tree canopy and vegetation. Context-sensitive design can help identify appropriate areas to increase tree canopy and vegetation without reducing sightlines and creating safety hazards in industrial areas.

RESILIENCE STRATEGIES AND ACTIONS

STRATEGY	POTENTIAL ACTIONS
G. Leverage data-sharing partnerships to manage risk across the supply chain	① **Provide real-time weather and water level data through PORTS.®** Sharing real-time data to the Puget Sound Pilots and ship masters on weather and water level conditions supports safe and cost efficient navigation. Partner with the National Oceanic and Atmospheric Administration (NOAA) to deploy the Physical Oceanographic Real-Time Systems (PORTS®) to support safe vessel loading and vessel transits while avoiding groundings and collisions. ② **Use precision navigation for safe and efficient vessel operations.** Work with the National Oceanic and Atmospheric Administration (NOAA) and maritime partners to integrate real-time data about ocean and weather conditions into navigational procedures and tools. Providing vessel operators information about rapidly changing local conditions helps inform their navigational decisions, improving safety, operational efficiencies, and reducing environmental risk. ③ **Coordinate incident and congestion management for safer and more efficient goods movement.** Coordinate data and communications with the Seattle Area Congestion Management Joint Operations Group (SAJOG) and the Tacoma Area Congestion Management Joint Operations Group (TAJOG), or similar entity engaged in traffic incident management. This coordination aims to manage incident-generated congestion, and mitigate regional impacts after an incident has been cleared. ④ **Implement the Port Community System to provide supply chain visibility.** Develop a digital platform with stakeholders to share real-time data and provide visibility into different parts of the port system and supply chains. Data sharing across the system can help optimize the performance of the system under normal conditions and can be a helpful tool adjusting operations in the event of a disruption, ultimately making operations and supply chains more resilient. ⑤ **Develop a digital twin of the Gateway to reduce risk across the system.** Digital twins are useful planning tools for understanding the complex relationship between physical assets and their system performance. They can be used to optimize performance under normal conditions as well as test how disruptions like hazards and changing climate conditions affect the overall goods movement system. This information can be helpful in identifying and prioritizing solutions to reduce risk to people, assets, and business across the Gateway and minimize service disruptions.

STRATEGY	POTENTIAL ACTIONS
H. Protect critical infrastructure for national defense and emergency response	① **Maintain Port of Tacoma's status and capabilities as a Strategic Seaport.** The Port of Tacoma is a Strategic Seaport and part of the National Port Readiness Network. The Port of Tacoma must be ready to make the port and its facilities available to support the deployment of military forces. ② **Support JBLM's role as a Power Projection Platform.** The Joint Base Lewis McChord (JBLM) is a Power Projection Platform in the region and needs to be able to quickly deploy resources for defense operations. The Port of Tacoma is a Sea Port of Embarkation for the JBLM. The Power Projetion Platform Route between JBLM and the Port of Tacoma must to be able to support national emergency deployments which often move military equipment in a convoy. ③ **Partner in emergency response efforts and exercises across the Gateway.** Join emergency managers in planning for and exercising emergency and disaster response to test and improve response capabilities. In the event of a major disaster like an earthquake and tsunami or volcanic activity, port facilities may be used to support emergency response and recovery efforts across the region. An example is participation in the Cascadia Rising Exercise to simulate a major earthquake along the Cascadia Subduction Zone and the ensuing tsunami. ④ **Support efforts to improve the resilience of lifeline routes.** The Washington State Department of Transportation has identified Seismic Lifelines that are priority routes to reopen following a major earthquake. These roadways will support post-disaster emergency response efforts including bringing life-saving and life-sustaining resources to affected communities and include major corridors like I-5 and I-90. Making these corridors more resilient and better able to withstand earthquakes will improve community resilience and also minimize damage to key freight corridors in the event of an earthquake.

STRATEGY	POTENTIAL ACTIONS
I. Take climate action to reduce climate hazards	① **Implement the Northwest Ports Clean Air Strategy to reduce emissions and the impacts of climate change.** The NWSA and both homeports can implement the Northwest Ports Clean Air Strategy to phase out emissions and help limit global temperature rise to 1.5° Celsius. Limiting emissions and climate change will improve the outlook for hazards with risk levels that are greatly influenced by changing climate conditions such as coastal flooding created by sea level rise, increasing flooding with more extreme precipitation events, extreme heat, and increased wildifres and smoke. ② **Explore resilient energy solutions to avoid disruptions to operations.** Efforts to meet emissions reduction goals will involve a mixture of electrification and transition to renewable fuels. As cargo operations across the Gateway rely more heavily on electricity and battery storage, explore options to provide backup power in the event of a power outage.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