

THE NORTHWEST SEAPORT ALLIANCE
Gateway to Solutions

RESILIENT GATEWAY

VULNERABILITY ASSESSMENT AND RESPONSE FRAMEWORK SUMMARY

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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.

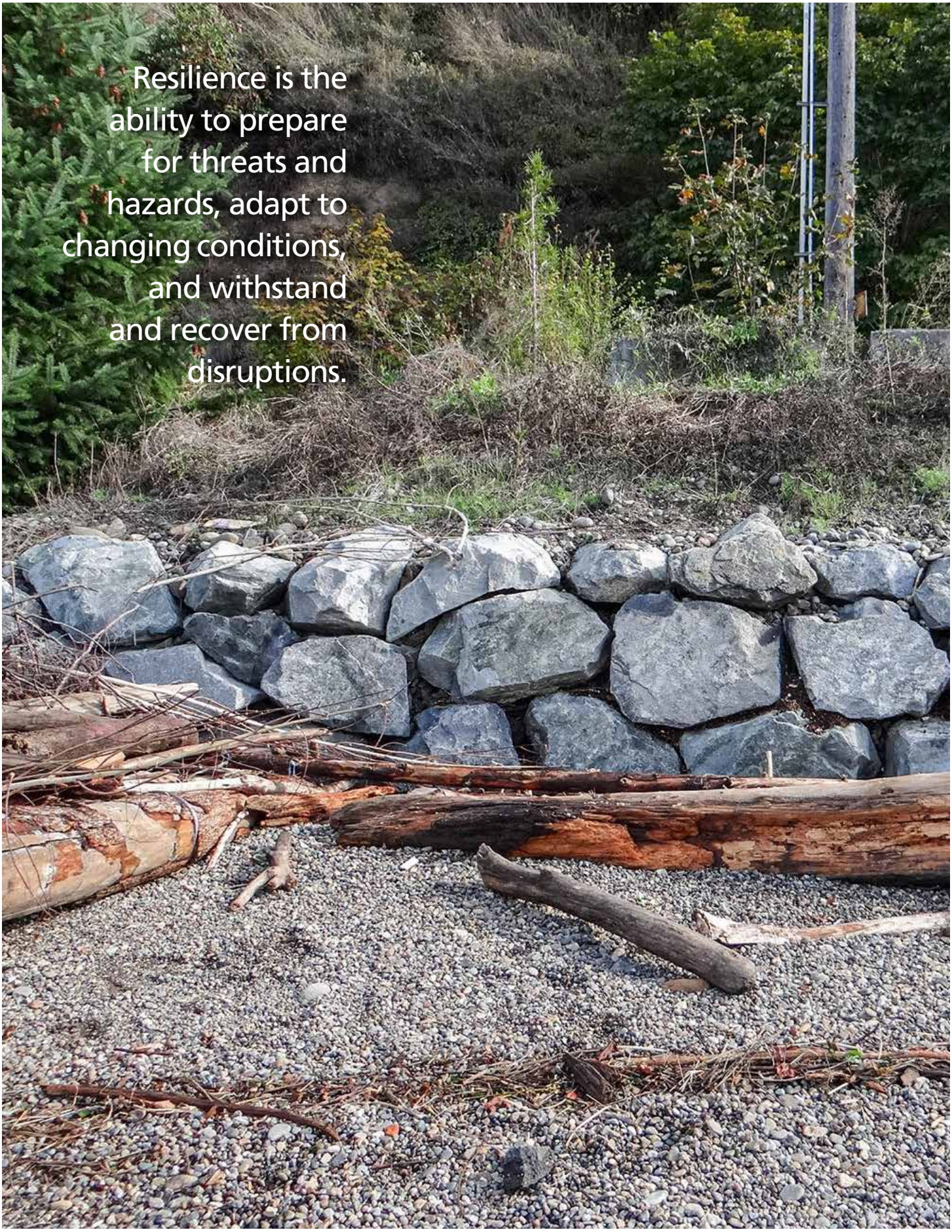
Vulnerability is impact or susceptibility to injury, harm, damage, or economic loss. It is characterized by what is exposed to a hazard and its sensitivity to the hazard.

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.

VULNERABILITY ASSESSMENT

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.

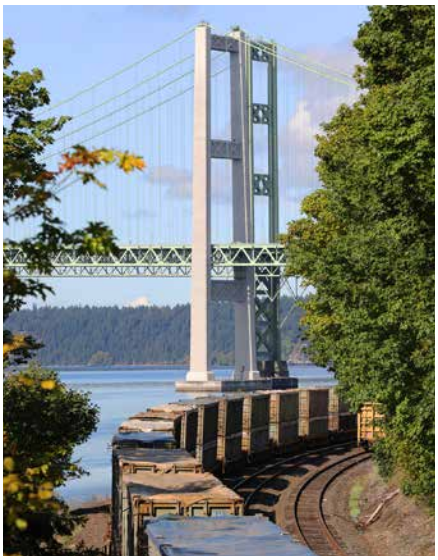
3) Risk Characterization

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.

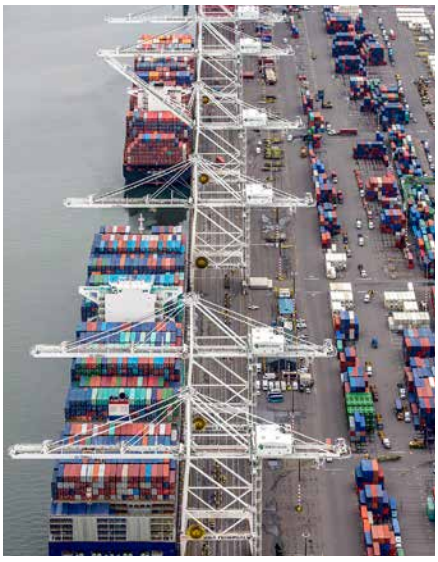
SHOCKS Shocks are hazards which have a low likelihood of occurring but are typically larger in scale and impact. They can provide a major shock to the system and dramatically affect a large area. All of the shocks are geologic hazards and they include earthquakes, tsunamis, and volcanic activity. The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



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



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.



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

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.

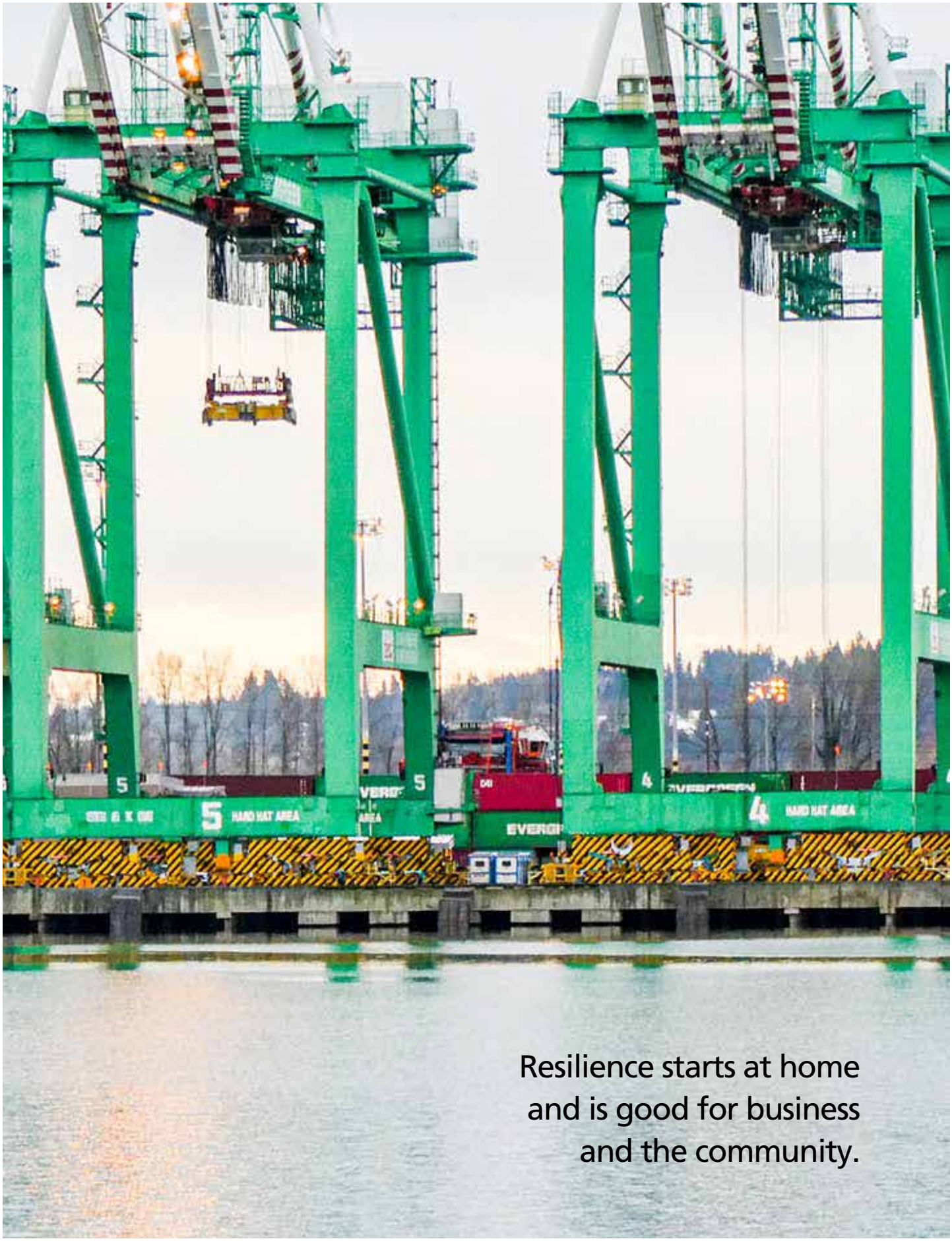
RESPONSE FRAMEWORK

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

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.

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.

USING THE SCORES TO PRIORITIZE ACTIONS

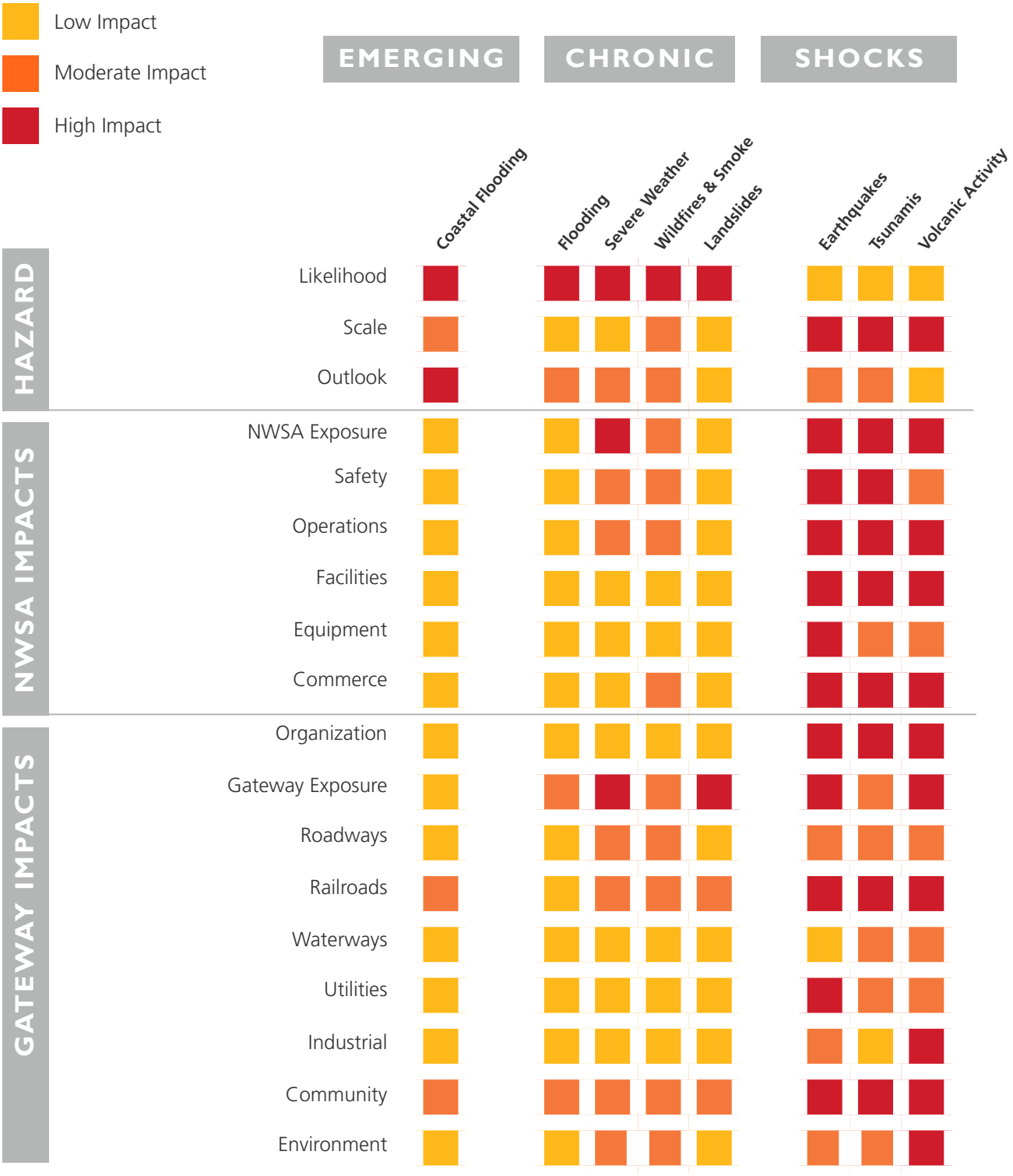
The risk factor scores are a helpful starting point for identifying areas to mitigate risk and adapt to changing climate conditions. They help show where the potential risks are both on-terminal and across the Gateway and make it easier to comprehend risk in terms of the big picture. There is no right 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

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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 infrastructue 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.

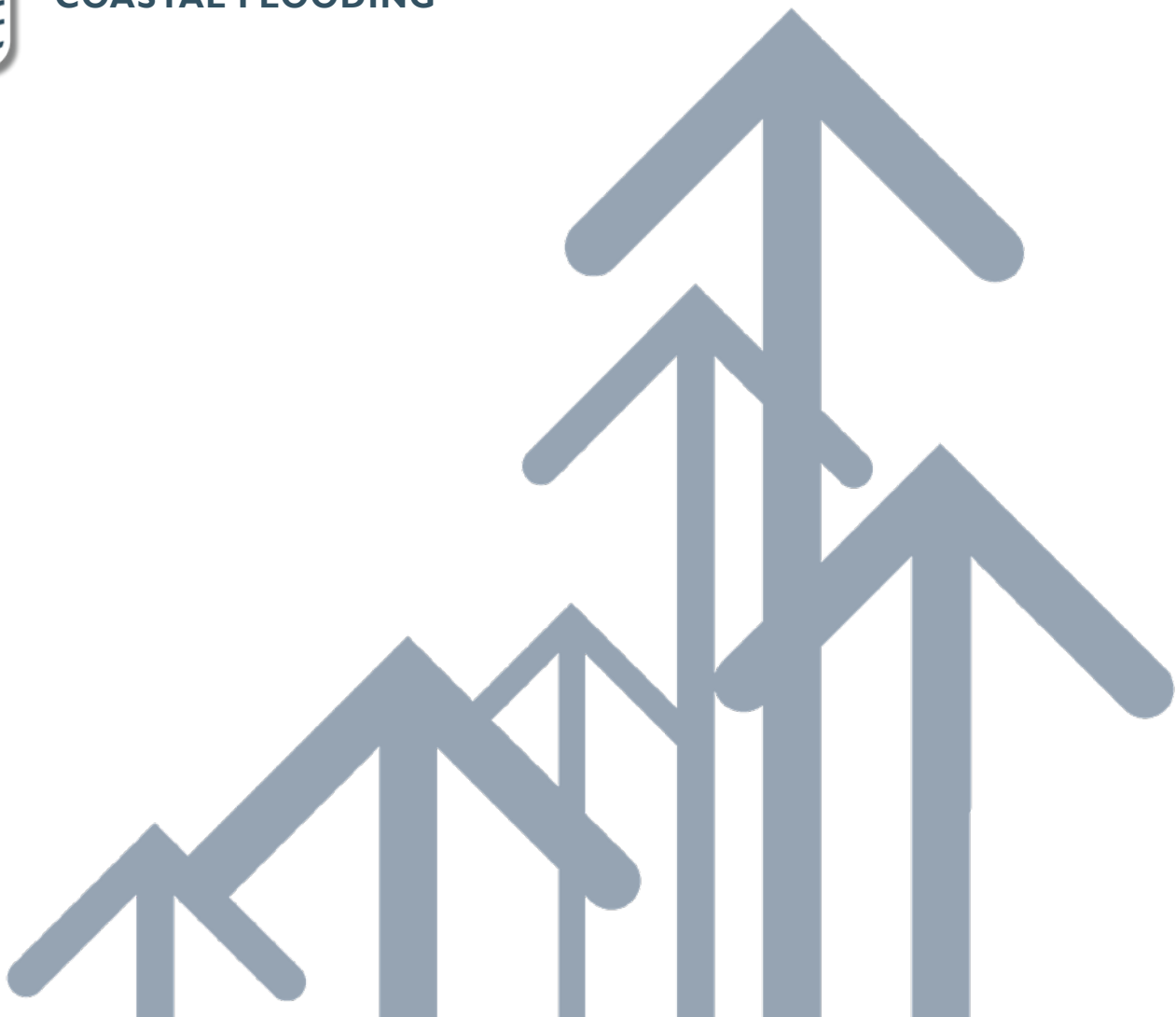
STRATEGY	POTENTIAL ACTIONS
I. Take climate action to reduce climate hazards	① **Implement the Northwest Ports Clean Air Strategy to reduce emissions and the impacts of climate change.** The NWSA and both homeports can implement the Northwest Ports Clean Air Strategy to phase out emissions and help limit 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.

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

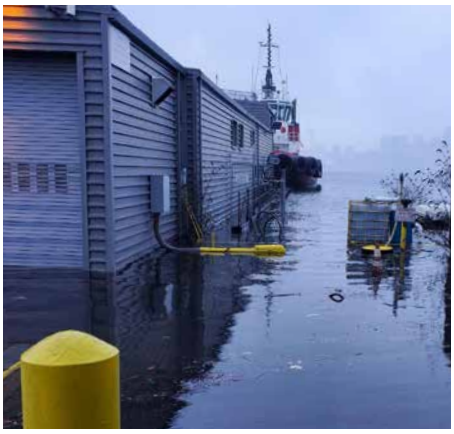


Extreme high tides can damage waterfront facilities even if the water levels don't overtop the terminals. Many utilities hang on the underside of wharfs and can experience water damage before other parts of the terminal.

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

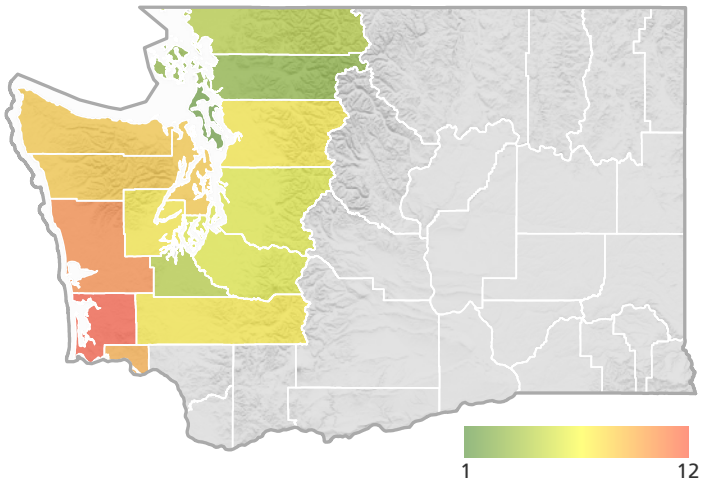
PAST EVENTS

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.

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.

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

FLOODING

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.

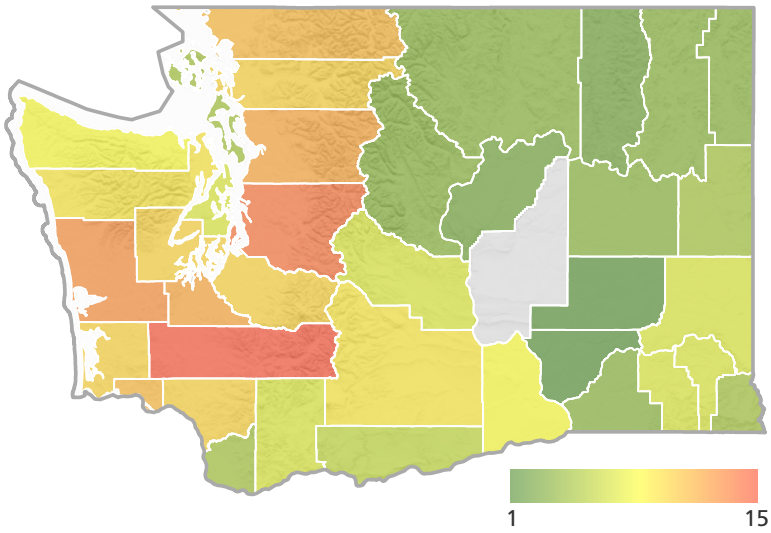
1948 Significant flooding occurred within the Columbia River Basin, damaging 5,000 homes, causing evacuations of 50,000 people, and $100 million in damage.

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.

ASSESSING RISK : FLOODING

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.



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.

ASSESSING RISK : SEVERE WEATHER

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.

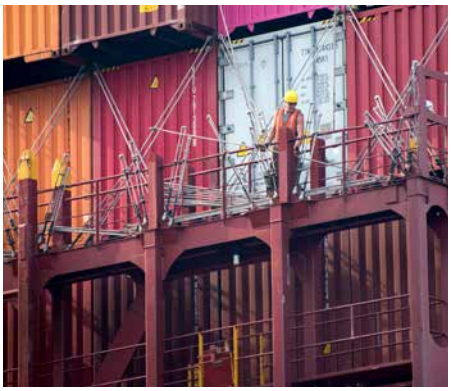


Smoky conditions and poor air quality at Seattle Harbor's Terminal 46 during the 2020 wildfire season.

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.

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.



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.

PAST EVENTS

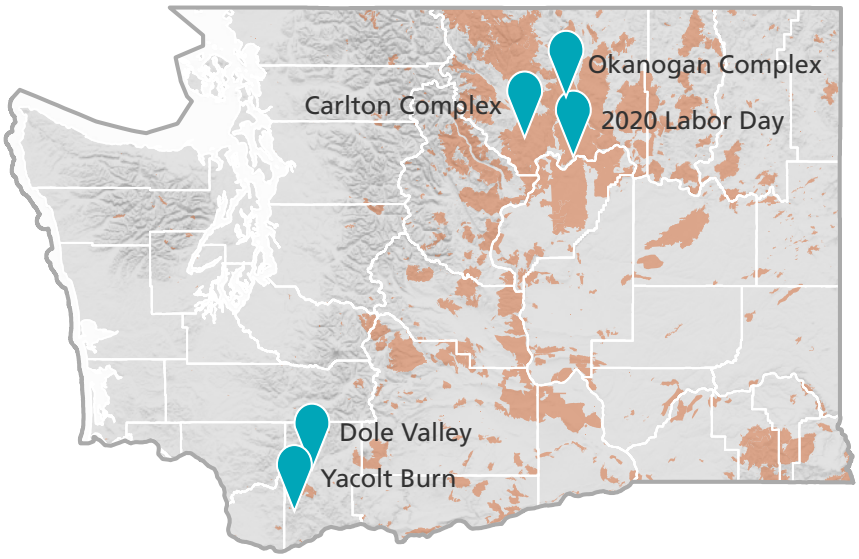
Wildfires are a high probability event in the western United States, with 21 recorded billion-dollar wildfire disasters since1980. There are typically over a thousand reported wildfires in Washington each year and most wildfires occur in eastern Washington where the climate is more arid.

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.

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.

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.

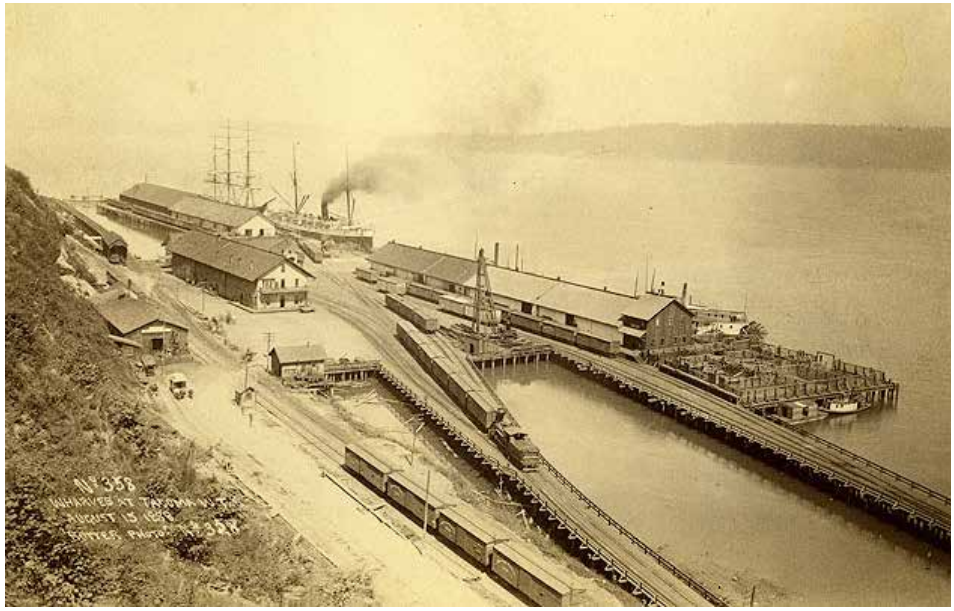
SMALL-SCALE, HIGH PROBABILITY EVENTS REQUIRING COORDINATION

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.

ASSESSING RISK : LANDSLIDES

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.



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.

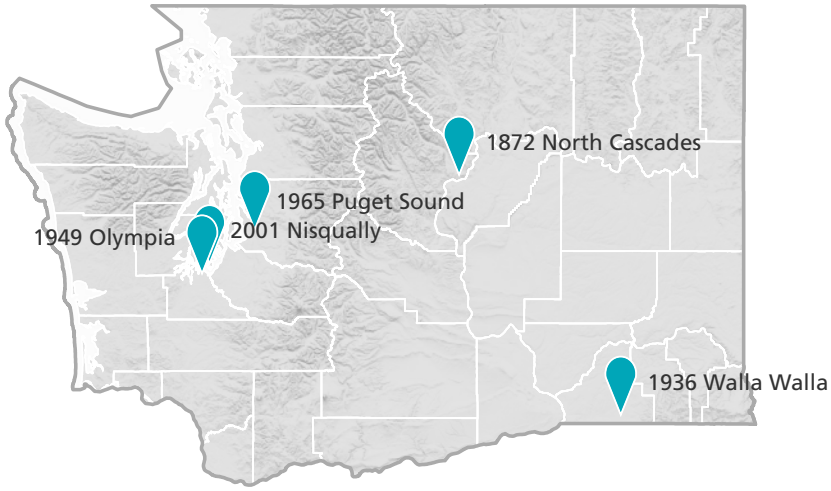
1936 A magnitude 6.1 earthquake that originated near Walla Walla affected a large area and caused significant damage with two minutes of shaking.

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.

ASSESSING RISK : EARTHQUAKES

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

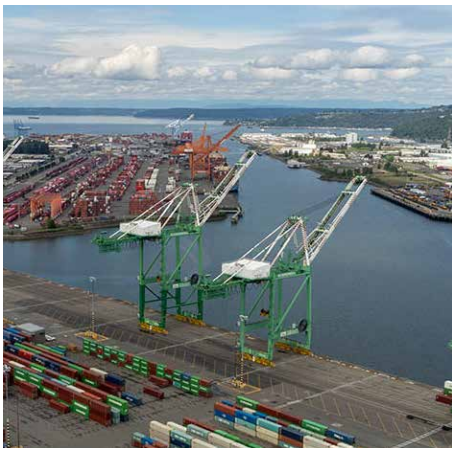
IMPACTS TO GATEWAY

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.

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.

ASSESSING RISK : TSUNAMIS

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

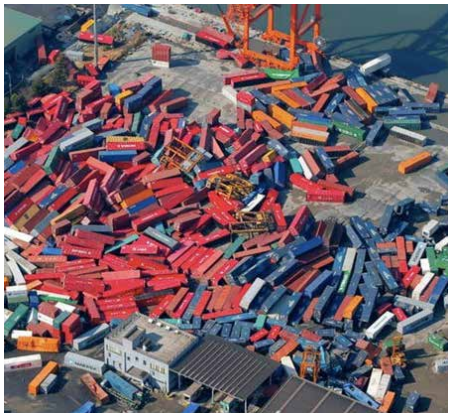
Likelihood	LOW
Scale	HIGH
Outlook	MODERATE
Hazard Type	SHOCK

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.

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.

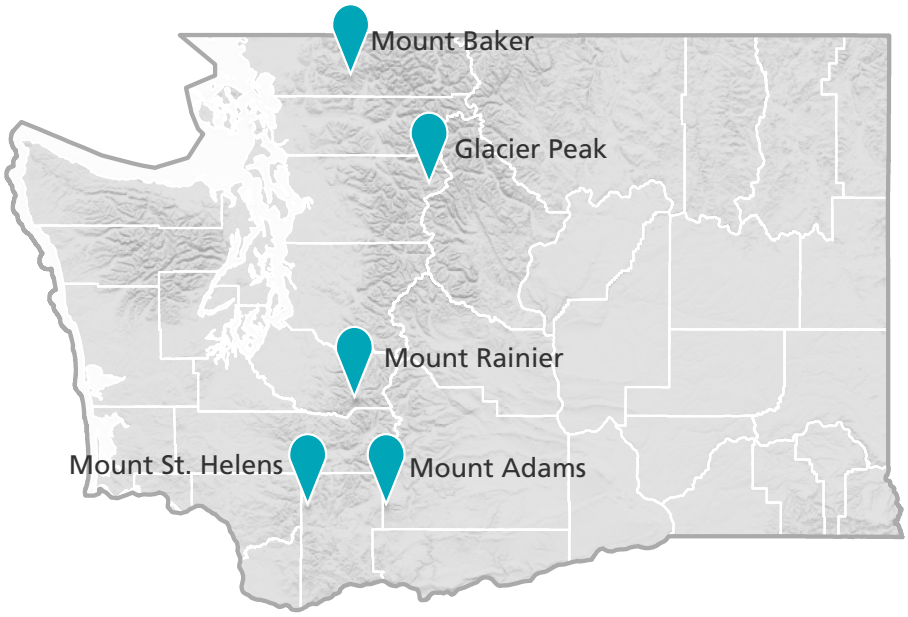
Mount St. Helens is the most frequently active volcano in the Cascades. During the past 4,000 years, it has produced many lahars and a wide variety of eruptive activity, from relatively quiet outflows of lava to explosive eruptions much larger than that of May 18, 1980.

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.

ASSESSING RISK : VOLCANIC ACTIVITY

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.

APPENDICES: REFERENCES

Please see the full NWSA Vulnerability Assessment report for a list of references and credits.

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.

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.

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.

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.

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	MODERATE	HIGH
No or minimal short-term or localized impact to environmental quality with ease of recovery without outside intervention	Moderate impact to environmental quality. May recover on its own over time or with limited intervention to restore functionality.	Major impact to environmental quality. Recovery requires significant intervention to restore functionality.


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