Strengthening tsunami maritime response and mitigation through inclusive stakeholder engagement: Lessons learned in Washington State

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Abstract

Among the most vulnerable facilities to tsunami impacts are ports, harbours and marinas. The ability of maritime infrastructure to withstand a disaster and resume operations quickly plays a major factor in the recovery of the local community and economy in the short and long term. Despite this, little established guidance exists to assist the maritime community with addressing their tsunami risk in an actionable, site-specific manner. To close this gap and improve the resilience of its maritime community, Washington State has begun developing tsunami maritime response and mitigation strategies for major ports, harbours and marinas along its 3,200 miles of coastline. These strategies include detailed information about the location's specific tsunami risk, recommended guidance for vessel operators in the area, and tsunami mitigation and response recommendations ranked by their implementation feasibility for the maritime entity in question. Most importantly, the strategies are created through close collaboration with local key stakeholders, subject matter experts, local emergency management and state agencies

to ensure a final deliverable that is accurate, thorough and, above all, useful to the local maritime entity and its tenants and users. As this paper will discuss, the lessons learned during the planning and delivery of these strategies provide valuable insight for professionals in the maritime, business continuity and emergency management fields, including how to conduct effective and inclusive stakeholder engagement, identify gaps and opportunities in resilience planning, and establish a deeper understanding of tsunami maritime risk and hazards.

Keywords: maritime, emergency management, mitigation, response, stakeholder engagement, tsunami

INTRODUCTION

Tsunami risk to the maritime community

Ports, harbours and marinas are among the facilities most vulnerable to tsunami impacts. The ability of maritime infrastructure to withstand a disaster and resume operations quickly not only plays a major factor in disaster response, but also in the recovery of the local economy in the short and long term. While tsunamis are infrequent events when compared with other oceanic hazards, such as storm surge and coastal flooding from hurricanes, their unpredictability, limited warning time and potential to wreak widespread havoc across any strip of coastline makes tsunamis a low-probability, high-impact hazard for which the maritime community especially must prepare. In the past few decades, tsunamis have proven how deadly and costly they can be, even when compared with other major disasters. At the time of writing this paper, only the COVID-19 pandemic surpasses the 2004 Indian Ocean earthquake and tsunami as the deadliest disaster in modern human history, while only the COVID-19 pandemic and the Chernobyl nuclear disaster surpass the 2011 Japanese earthquake and tsunami as the costliest.[1]

In terms of damage, local tsunamis — those originating close to the shoreline that arrive within minutes to hours — pose the greatest threat to life and property due to their close proximity to the areas affected. Maritime communities in Indonesia and Japan suffered greatly in the wake of the 2004 and 2011 tsunamis,[2] respectively, due to a combination of factors, suffering direct fatalities, damage to maritime facilities, destruction of vessels, reduced import/export capabilities and environmental impacts. However, even distant tsunamis — those that originate far from the shoreline and arrive several hours later — carry risk for the maritime community. Although the waves from the 2011 Japanese tsunami lost energy in the 12 hours they took to cross the Pacific Ocean from Japan to the US west coast, vastly reducing their potential to cause widespread inundation, their impact to 27 of California's harbours still topped a total US$100m.[3] Likewise, the 2022 Hunga Tonga–Hunga Ha'apai volcanic eruption and subsequent tsunami caused an oil spill in Peru that is currently the country's greatest ecological disaster to date.[4]

Research proves that mitigating the impacts of natural hazards greatly reduces the costs of responding to those same hazards when they occur — sometimes saving an average of US$6 in response and recovery costs for every US$1 spent on mitigation projects.[5] Maritime-specific mitigation and response actions can greatly reduce the impact of tsunamis, lower the costs of response and recovery, and foster resilience in the maritime community. For example, while the 2011 Japanese tsunami caused US$20m worth of damage to the harbour in Santa Cruz, California,[6] the same harbour suffered damage in the region of US$6m due to the 2022 Tonga tsunami.[7] This reduction can in great part

be attributed to the post-2011 efforts to make California's major maritime infrastructure more resilient to tsunami hazards. This included increasing the height and size of pilings, along with planting them closer together into bedrock instead of the less steady upper soils of the sea floor, and updating dock materials and styles to better withstand the extreme forces of tsunami waves.

Tsunami maritime mitigation gaps and challenges

Despite the proven efficacy of maritime mitigation efforts, there is little established guidance to assist the maritime community and its stakeholders with addressing risk in an actionable manner. Existing research and guidance are often too limited, generic or highly technical to translate easily into practical steps for maritime entities. While tsunami modelling does exist, the resolution may not be high enough to capture site-specific impacts at the port or marina level. In addition, site-specific tsunami modelling and mapping for a particular port, harbour or marina can be cost-prohibitive for smaller entities. Given these challenges, it is understandable that many maritime entities lack robust tsunami plans that incorporate more tsunami-specific mitigation measures or robust tsunami emergency response plans. At the same time, however, when volume of critical infrastructure is being concentrated near, on and even under the ocean in the form of numerous oil refineries and over 869,000 miles of submarine cables,[8] the potential devastation caused by tsunamis cannot be ignored. This is especially true given that the maritime community will be impacted by, and potentially involved in, emergency response and recovery efforts.

To close this gap, the Washington State Emergency Management Division's (WA EMD) tsunami programme has begun developing tsunami maritime response and mitigation strategies for major ports, harbours and marinas along its 3,200 miles of complex coastline. Within the USA, Washington has the second highest earthquake risk[9] and one of the highest tsunami risks. Western Washington has dozens of active local crustal faults within its inner coastal waterways and the Cascadia Subduction Zone (CSZ) just off its outer coast (Figure 1). These faults, along with local landslides and distant earthquakes originating across the Pacific Ocean (ie Alaska, Japan, Chile), have the potential to generate dangerous tsunamis that could impact coastal communities along both Washington's outer Pacific coast and inland waters, including Puget Sound.[10] The maritime industry in Washington is a US$21.4bn industry contributing directly and indirectly to 5.8 per cent of jobs in the state.[11] Should a major tsunami disable Washington's major ports, harbours and marinas, the impacts would be felt across the nation, especially in states such as Alaska and Hawaii that rely on goods from Washington's ports.

Thanks to federal funding through the National Oceanic and Atmospheric Administration's (NOAA) National Tsunami Hazards Mitigation Programme (NTHMP),[12] WA EMD's tsunami programme has so far completed two such tsunami maritime strategies. The first, developed for the Port of Bellingham[13] on Washington's inner coast, was completed in 2021. The second, developed for Westport Marina, Port of Grays Harbor[14] on Washington's outer coast, was completed in 2022. A third strategy is currently in the works for the Guemes Channel area along Washington's inner coast, which includes the Port of Anacortes, to be completed in 2023. While the WA EMD tsunami programme intends to continue the projects for as long as funding remains available, the strategy document is also designed to act as a template for other

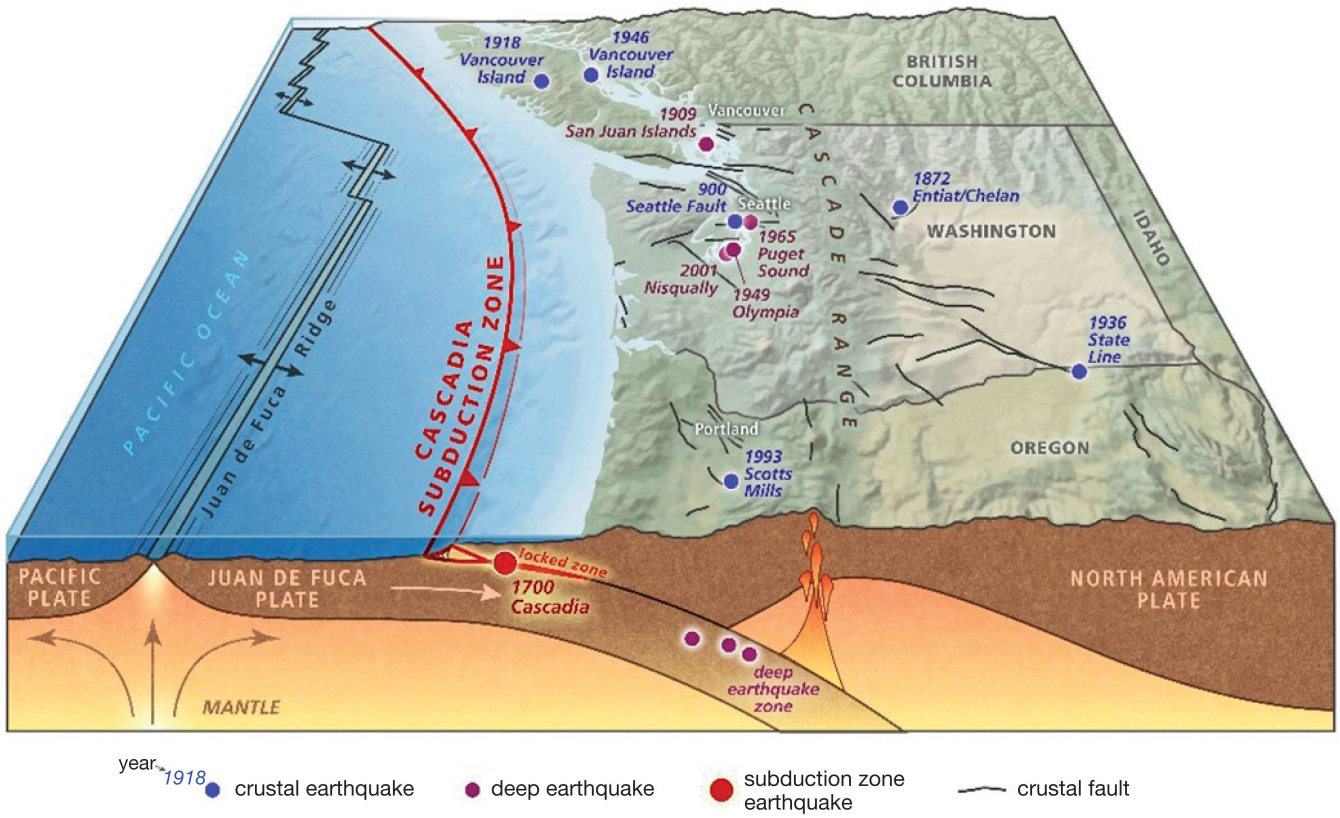

Figure 1 A diagram of Washington State showing major historical earthquakes and the geologic forces that created them. The Cascadia Subduction Zone drives much of this seismic activity and last ruptured back in 1700.
Source: WA Geological Survey (2023)

jurisdictions or maritime entities that wish to develop a strategy of their own.

The following sections of this paper outline the methods and steps of the Tsunami Maritime Response and Mitigation Strategy project planning, best practices for the inclusion of and delivery to stakeholders, and the lessons learned during the strategy development process.

PLANNING

To ensure the final strategies for the Port of Bellingham and Westport Marina, Port of Grays Harbor were comprehensive yet understandable and useful documents, the project team worked closely with stakeholders and subject matter experts throughout the life of the projects. These collaborators included key port and marina officials, city and county emergency management, emergency services, public utilities, other state agencies and subject matter experts. WA EMD's tsunami programme relied on existing connections, community meetings and the main port or marina stakeholders to identify those who should be part of the project. Kickoff meetings were held at the beginning of the projects to explain the goals and objectives, establish a project timeline, set out clear expectations and responsibilities, and coordinate next steps.

The project team lead was WA EMD's Inner Coast Tsunami Programme Coordinator, a full-time project position

funded each grant cycle through the NTHMP as part of the maritime task. This person acted as the project manager for the maritime strategy projects and was responsible for stakeholder engagement, meeting facilitation, timeline adherence, document compilation and editing, and final project deliverables. They also provided ongoing community outreach throughout the life of the project and beyond, as will be discussed in more detail in the delivery section. It is highly advised that any maritime entities intending to undertake a strategy on their own include a project manager role in their plans, either as a paid external resource or an internal resource with sufficient capacity to spare. Given the number of stakeholders and subject matter experts involved in such an endeavour, a project manager is vital to the overall success of the project.

Tsunami maritime response and mitigation strategy overview

The Washington strategies combine the best tsunami maritime and mitigation recommendations from across the world and their creation involved close collaboration with partners in California, Oregon, Alaska and others in the NTHMP.[15] The Washington strategies are intended for use by maritime stakeholders at all levels and provide practical guidance to assist the maritime community in reducing their tsunami risk. Stakeholders may include local community leaders, elected officials, concerned residents, business owners, employees, government workers and other community members. The strategies can be used to learn more about tsunami maritime risk, incorporate real-time response actions into standard operating procedures, determine and prioritise mitigation actions, and identify additional resources for implementing those changes. Response and mitigation actions highlighted in the strategy could greatly reduce the number of casualties and amount of damage from future tsunamis and reduce the time it takes for Washington's maritime communities to recover.

The main goal of Washington's tsunami response and mitigation strategies is to help reduce the maritime community's risk from tsunamis and save lives. To ensure a basic understanding of the tsunami hazard, especially as it pertains to the maritime community, each strategy includes a detailed overview of Washington's tsunami risk and the secondary hazards most dangerous for vessels and maritime infrastructure. Beyond this consolidation, the following components of the Washington strategies set them apart from general maritime tsunami resources: site-specific tsunami data, feasibility of maritime mitigation and response action recommendations, and protective action guidance for boaters.

Site-specific tsunami data

Washington's tsunami maritime response and mitigation strategies feature site-specific tsunami maps, graphs and other data provided by the Washington Geological Survey (WGS), University of Washington (UW) and NOAA's Pacific Marine Environmental Laboratory (PMEL) showing inundation, current velocity and drawdown for the tsunami scenarios most relevant to the selected port, harbour or marina. For the Westport Marina, Port of Grays Harbor strategy, these included a devastating M9.0 Cascadia Subduction Zone (CSZ) earthquake (combined CSZ Extended L1/ CSZ L1 model[16]) and tsunami and an M9.2 Alaska-Aleutian Subduction Zone (AASZ) megathrust earthquake and tsunami similar to the 1964 event.[17] Unlike the tsunami modelling completed for the rest of the state, this site-specific modelling was completed at a higher resolution and therefore provides a more detailed understanding of the

tsunami impacts both on land and in the water; this includes vital planning information such as the timing and depth of drawdown, timing of the first wave as well as the highest wave, and where the highest currents are anticipated. For example, Figure 2 shows a high resolution, site-specific map of Westport Marina indicating anticipated maximum current speeds from an M9.2 AASZ megathrust earthquake at mean high water. It depicts an area of strong currents near the simulated tide gauge which was not previously visible in more coarsely resolute tsunami modelling. This provides stakeholders with a better understanding of their tsunami risk, helping to determine more accurately the feasibility and priority of certain mitigation opportunities.

The creation of site-specific data for each strategy also allows some flexibility in what deliverables (ie maps, charts, tables, etc.) are included in the final product. Stakeholder input drives the generation of these figures based on what kind of information is most useful. For some, such as Westport Marina, this may mean a greater focus on comparing the two tsunami scenarios used to find overlapping opportunities for mitigation or response efforts. For others, as with the Port of Bellingham strategy, this may mean placing

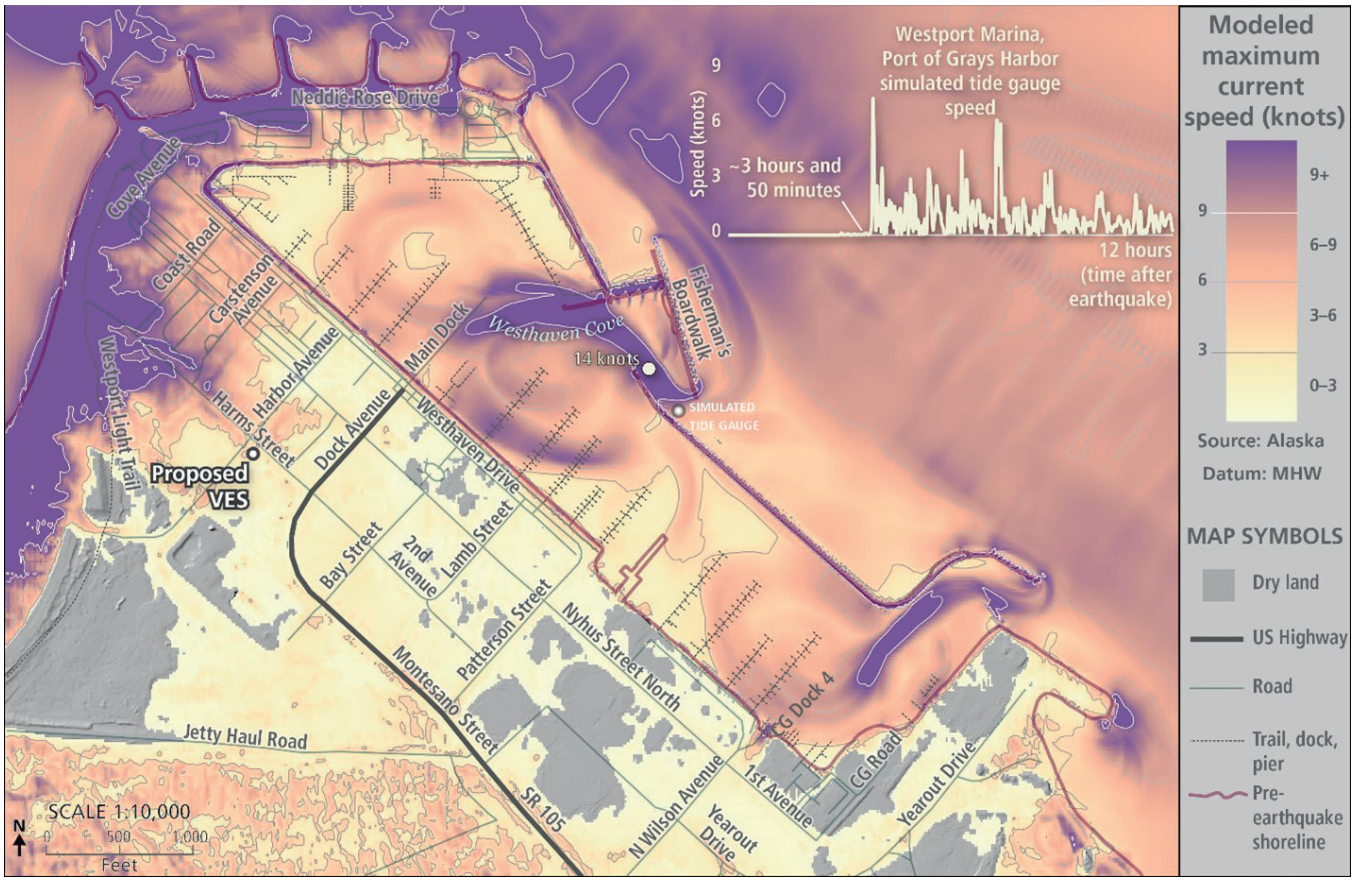

Figure 2 A high-resolution map of current speeds in Westport, WA during a modelled Alaska M9.2 earthquake and resulting tsunami. Knowing areas of particularly high currents within and near maritime infrastructure can assist in the planning process

Source: WA Geological Survey (2022)

a great emphasis on certain kinds of data, such as the depth and extent of tsunami drawdown. Ports or marinas located along complex water channels or high vessel traffic areas, such as Guemes Channel, may be most interested in graphs depicting wave arrival and amplitude over time. Including key stakeholders in the modelling and deliverable process from the very beginning, especially when determining the locations of the simulated tide gauges needed for such modelling, ensures the production of valuable data. Stakeholders are also likely to think 'outside the box' in terms of what can be done with this information, as they are coming to it with fresh eyes and may request deliverables the project team has not previously considered.

Thanks to the NTHMP's grant funding, the cost of the WGS' work has thus far been covered by WA EMD and is therefore completely free to project stakeholders. Should other maritime entities wish to undertake a project on their own, the bulk of the project cost would come from funding similar site-specific modelling and mapping. Depending on the location, currently available digital elevation models and agencies capable of performing the work, such deliverables can cost tens of thousands of dollars. Existing tsunami inundation and current velocity mapping may suffice in its place, if necessary, but the breadth and utility of the information to be gleaned from finer-resolution, site-specific modelling cannot be overstated.

Determining feasibility of maritime mitigation and response recommendations

Along with the site-specific modelling and mapping, sections on mitigation and response recommendations are at the core of Washington's maritime strategies. These recommendations are based on the selected site's specific risk and rated by feasibility to ensure stakeholders can easily identify which recommendations their port or marina should prioritise. This reduces time and money spent on efforts which may prove to either be impossible for the geographic area or too expensive to complete, as well as simplify future cost-benefit analyses for potential building or retrofitting efforts. It also provides justification and support for such projects as they move forward, especially if grant funding is pursued.[18] A fantastic example of the efficacy of mitigation efforts occurred during the Tonga tsunami of 15th January, 2022, when a camera in Ventura harbour caught the rise and fall of a tsunami wave that nearly overtopped a dock piling.[19] Had the waves been just 30 cm higher, the dock might have been ruined.

Recommended tsunami mitigation actions (Figure 3) range from the simple to complex. Simpler, less expensive examples include installing tsunami evacuation and hazard signage, increasing the size and stability of dock pilings, strengthening cleats and single point moorings, and other efforts that can facilitate evacuation or prevent vessels and docks from becoming dangerous debris. More elaborate and expensive methods include constructing floodgates or breakwaters, widening the size of the harbour entrance, and dredging channels near high-hazard zones. Depending on the size and shape of the port, harbour or marina in question, some options may not be viable; for example, while debris deflection booms can help protect vessels and docks from tsunami debris, they may take up too much space or block waterways in smaller marinas.[20] Evaluating the feasibility of each mitigation measure in the context of the infrastructure in question is therefore one of the most important aspects of the project. If projected building or retrofitting projects are planned, feasible recommendations can be worked into them over time to save

Mitigation actions	Feasibility for Westport Marina
Install tsunami signs	Yes
Increase size and stability of dock piles/increase height of piles to prevent overtopping	Yes
Reduce exposure of petroleum/chemical facilities and storage	Yes
Strengthen cleats and single point moorings	Needs review
Improve movement of dock along dock/pilings	Needs review
Acquire equipment/assets to assist in response activities	Needs review
Improve floatation portions of docks	Needs review
Fortify and armor breakwaters	Not feasible
Deepen or dredge channels near high hazard zones	Not feasible
Move docks and assets away from high hazard zones	Not feasible
Widen size of harbor entrance to prevent jetting	Not feasible
Construct floodgates	Not feasible
Construct breakwaters farther away from the marina	Not feasible
Increase flexibility of interconnected docks	Not feasible
Debris deflection booms to protect docks	Not feasible

Figure 3 Tsunami mitigation actions for Westport Marina, WA, ranked by feasibility. This ranking allows the marina to prioritise actions when planning improvement projects, requesting funding and other improvement ventures.
Source: WA EMD (2022)

money. Additionally, some mitigation recommendations may easily be incorporated in routine repair and ongoing maintenance of maritime infrastructure.

Regarding tsunami response recommendations (Figure 4), location is key. While some tsunami scenarios, such as a M9.0 CSZ earthquake and tsunami, leave little time to respond before the first waves arrive, response actions can sometimes take place before a distant tsunami arrives. Such actions not only reduce the chance of injuries but may also reduce the impact of the tsunami on maritime infrastructure. Some of the relatively simple response actions included in the recommendations are establishing a notification process for boat owners and individuals who live aboard their vessels; securing the moorings of docked vessels; shutting down marina infrastructure before the waves arrive; and removing or securing hazardous materials located in the mapped inundation zone. For example, in Westport Marina there is a port-owned chemical storage tank that can be capped if a tsunami is approaching.[21] Creating an emergency procedure to have Marina staff cap the storage tank

Distant source tsunami response actions	Feasibility for Westport Marina
Shut down marina infrastructure before tsunami arrives	Yes
Evacuate public/vehicles from waterfront areas	Yes
Secure moorings of marina owned vessels	Yes
Remove or secure hazardous materials	Yes
Informing and coordinating with key first responders during a tsunami	Yes
Personal floatation devices for marina staff	Yes
Identify boat owners/individuals who live aboard vessels and establish notification processes	Yes
Pre-identify personnel to assist in rescue, survey and salvage efforts	Yes
Activate incident command at evacuation sites	Needs review
Move vessels out of the marina	Needs review
Restrict traffic entering the marina by land and aid in traffic evacuation	Needs review
Activate mutual aid system as necessary	Needs review
Reposition ships within the marina	Needs review
Pre-stage emergency equipment outside affected area	Needs review
Remove small vessels from the water	Not feasible
Remove buoyant assets out of and away from the water	Not feasible
Restrict boats from moving and prevent ships from entering the marina during a tsunami	Not feasible

Figure 4 Distant source tsunami response actions for Westport Marina, WA ranked by feasibility. This ranking allows the marina to prioritise actions when updating response plans
Source: WA EMD (2022)

prior to the arrival of the first wave could potentially prevent the spill of hundreds of gallons of used oil that would otherwise compound existing debris and spill clean-up. Other response actions may only be applicable or feasible to larger ports or harbours; these include actions like removing small vessels and buoyant assets from the water prior to wave arrival, pre-staging emergency equipment outside the inundation zone, and restricting boats from moving and from entering the port, harbour or marina during the tsunami. Larger-scale efforts like these require more coordination and, in many cases, do not fall under the marine entity's direct authority.

Another feature that separates the Washington strategies from similar documents is the inclusion of tsunami response roles and responsibilities. Much of the collaboration between the project team and stakeholders involved documenting the existence of relevant emergency response plans, identifying which agencies and jurisdictions are responsible for specific response steps, and highlighting any gaps

that need to be addressed. This process demystifies tsunami response in general and not only empowers stakeholders at the local level to take response into their own hands, but to advocate for improved planning at higher levels. It also aligns response plans to reduce the chances of miscommunication, duplication of efforts and wasted time during an actual tsunami. Roles and responsibilities information is highlighted mainly in the response recommendations section, while links and other information relating to emergency response plans for other agencies are included in the appendices for easy reference.[22]

Protective action guidance for boaters

Along with information for the specific port, harbour or marina, each strategy includes protective action guidance for boaters with considerations vessel operators should take when making decisions during tsunamis (Figure 5). These recommendations include the kind of tsunami dangers vessel operators might encounter, actionable steps to take depending on the kind of tsunami warning received (natural warning signs versus official alerts), and easy ways to prepare for tsunamis specific to the maritime community. Providing such information is vital given the impact even

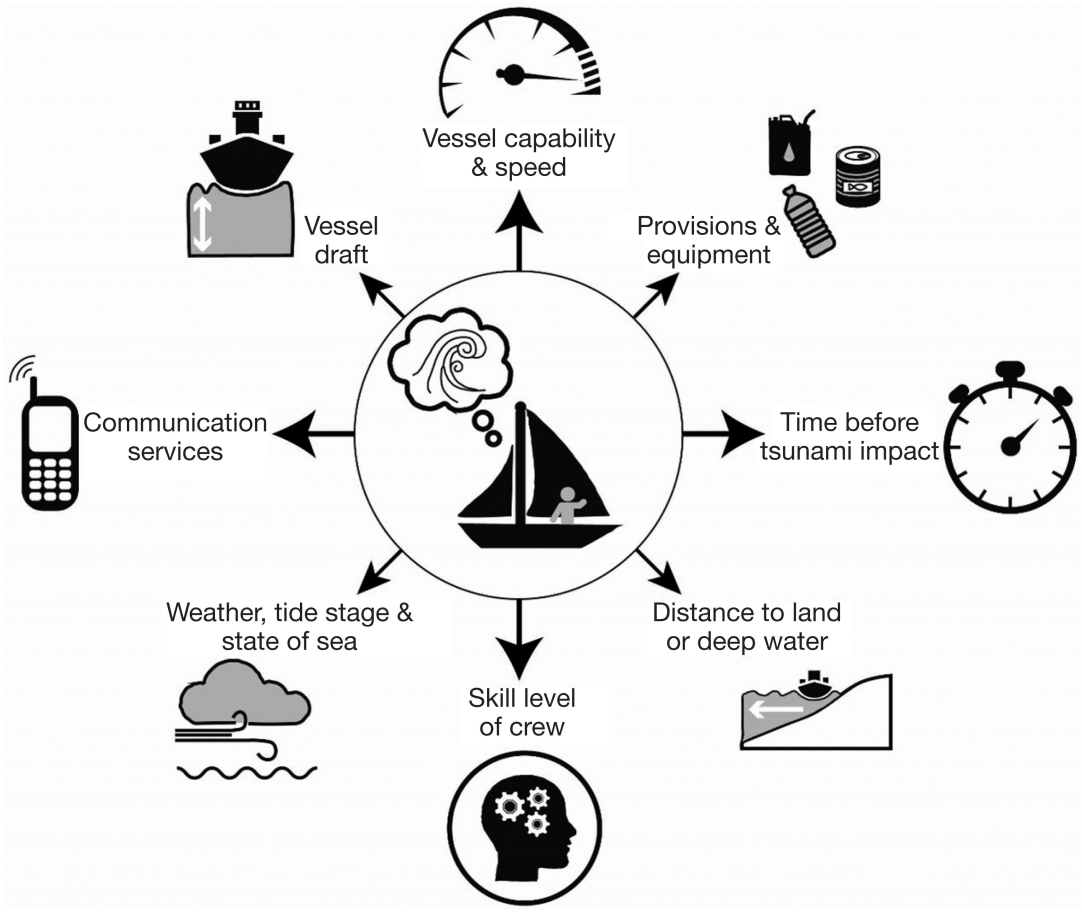

Figure 5 A diagram showing some of the many factors a vessel operator must take into consideration when on the water or attempting to go out onto the water during a tsunami
Source: WA Geological Survey (2021)

distant tsunamis can have on the maritime community, especially when many boaters intend to take their vessels out to deeper water when tsunamis approach. Indeed, as previous tsunami events have proven, some members of the public are tempted to head to the beach when an official tsunami alert is issued, not away from it. Both the 2011 Japanese tsunami's arrival in California[23] and the 2022 Tonga tsunami's arrival in Washington[24] provided examples of this risk-taking tendency. By providing clear guidance, the strategy arms boaters with the knowledge needed to make life and property-saving decisions before and during tsunamis.

DELIVERY

The polished draft of the strategy document compiled by the WA EMD tsunami programme undergoes extensive stakeholder review before completion. These rounds of review, editing and feedback involve all key stakeholders and ensure total buy-in on the final product. Once a strategy is given final approval by the project team, the final document is first sent to all team members and stakeholders who took part in the project. The document is then uploaded to WA EMD's tsunami website and the agency issues a press release and blog post about the project. Promotion may also include activity on social media, press interviews, and webinars or other public outreach to spread word about the project's successful completion and the new information available to the maritime community.

A completed tsunami maritime response and mitigation strategy represents a chance for the specific port or marina to commence the longer-term process of addressing the gaps and opportunities highlighted in the strategy. This will include further efforts to align and consolidate emergency response plans with local partners, develop new procedures and processes or strengthen existing ones, and in general endeavour to work tsunami awareness into their business practices in a holistic way that best reflects their needs. The strategy cannot address every issue or outline every step that should be taken, but it serves as a launch pad for future conversations, projects and collaborative efforts.

Ongoing outreach and education

Successful completion of a strategy does not signal the end of the WA EMD tsunami programme's work with the specific port or marina, nor the greater local community. Beyond the in-person presentations, webinars and other activities that may accompany the release of a strategy, the WA EMD tsunami programme continues providing education, resources and subject matter expertise as part of the strategy's implementation. This may include providing tsunami signage for installation, educational materials for staff, customers and visitors, and delivering tailored outreach through presentations and in-person events. The programme also facilitates meetings and stakeholder connections upon request to assist with the planning process. In this way, the WA EMD tsunami programme can ensure that the mitigation and response measures recommended in the strategy are as simple as possible for the port or marina to accomplish.

WA EMD tsunami boaters' guide

In addition to the maritime strategies, in 2022 the WA EMD tsunami programme also released a separate brochure geared toward Washington's maritime community as part of these efforts. 'Tsunamis! What Washington's Boaters Need to Know'[25] condenses much of the tsunami maritime information included in the strategies into a handy trifold brochure with easy, actionable recommendations. The brochure

includes an overview of tsunami hazards and risks for boaters; official tsunami alert-level meanings and actions to take; natural warning signs and actions to take; and a tsunami preparedness checklist. Quick response (QR) codes lead directly to WA EMD web pages that are continually updated as new information, maps and other resources become available.

As part of the process to streamline and simplify the oftentimes confusing guidance for boaters, the WA EMD tsunami boaters' guide breaks down recommended actions first by the type of tsunami warning received (awareness of a natural warning sign in the area versus receipt of an official tsunami alert) and then by location (on land/tied up at dock/nearshore versus far out on the water). This arms boaters with the knowledge necessary to make an informed decision if they encounter a tsunami while near or on their vessel. While some of these nuances may be less important for boaters in areas where the geography is simpler and deep water can be reached in a small amount of time, with Washington's extensive inner and outer coasts it is necessary to provide more thorough guidance. WA EMD's tsunami boaters' guide does not list minimum safe water depths for boaters to reach for this reason; in many parts of the state, reaching the generally recommended minimum depths[26] for either a distant tsunami (30 fathoms) or a local tsunami (100 fathoms) may prove impossible or still not ensure a vessel's safety. Instead, the WA EMD boaters guide recommends those who cannot return to the dock in time head to 'the deepest water possible'. This represents a departure from guidance in other jurisdictions[27] by simplifying the messaging for increased understanding.

WA EMD's tsunami programme has already distributed almost 7,000 of these brochures to local jurisdictions eager to deliver them to their maritime stakeholders through distribution at preparedness events, mailers like marina or utility bills, and making them available in port and marina offices.

LESSONS LEARNED

With two tsunami maritime response and mitigation strategies completed and a third in progress, the WA EMD tsunami programme has gathered many valuable lessons to improve the success and versatility of future projects. Aside from assigning a project manager for the completion of the strategy and securing project funding, engaging with stakeholders that are embedded in the fabric of their communities and well-connected with key decision makers in implementing mitigation and response actions is essential. It is equally important to engage with stakeholders at the right time and simplify the overall data collection process as much as possible. These lessons are outlined in more detail below.

Onsite champions are vital

The success of a strategy hinges on the engagement, passion and expertise of the port, marina or harbour stakeholder helming the project on the entity's behalf. While a disengaged or ineffective onsite champion will not necessarily prevent a project from being completed, this key stakeholder facilitates connections between the project team and the right subject matter experts to produce accurate and robust recommendations. An engaged and proactive onsite champion will bring the right people to the table from the beginning and ensure port or marina leadership have eyes on the project. A disengaged or passive champion, on the other hand, can cause delays throughout the life of the project and result in a final product missing vital information and feedback.

For example, when determining if a mitigation action such as increasing the dock piling heights in a marina above expected wave height is feasible, the champion should consult with their engineering team. Likewise, to determine if this same mitigation action can be funded, the entity's financial team should be consulted to determine if the measure would need outside funding or whether existing funding is in place to implement the mitigation action. If these parties are not fully utilised, the final feasibility recommendation may not be accurate.

A positive working relationship with the onsite champion should be established early through site visits by the project team. Not only do site visits provide an excellent opportunity to take pictures of infrastructure to include in the strategy, but they also provide a chance to meet face-to-face and talk candidly about project goals. In turn, having an onsite champion who is vested in the fabric of the community can bring in more stakeholders who might not typically get involved in the planning process.

Engage the right stakeholders

No tsunami maritime response and mitigation strategy can be successful without the right stakeholders onboard. Aside from those leading the project and providing tsunami modelling data, anyone who utilises the selected port, harbour or marina or has a tsunami alerting or response duty in the area should be invited to take part. This may include government agencies like county, tribal and city emergency management, local fire and police departments, the US Coast Guard, and local or state departments of transportation, public works, and parks and recreation. Port, marina or harbour staff in charge of infrastructure, safety and other operations will play a vital role in the project, especially when determining the feasibility of the recommended mitigation and response measures. Finally, private businesses in the area, especially those who are tenants, own major infrastructure, or operate large vessels and equipment in the inundation zone, should be encouraged to take part as well.

With a proactive onsite champion onboard, stakeholders who would otherwise be unknown to the project team can easily be identified and brought into the project at the right time. For instance, in the Guemes Channel there is a ferry terminal located within a high tsunami impact area, so onsite champions invited the captain of the vessel to be part of the response conversations directly. This kind of stakeholder engagement secures the unique perspectives of those 'in the field' that will have to navigate emergency response, helping strengthen overall planning assumptions and decisions typically made only at the director or executive level. Without this vital insight, stakeholders who should be involved are likely to be forgotten or engaged too late to provide sufficient feedback. This can lead to inaccurate and inadequate information in the final document; worse, the stakeholders in question may take the omission as a purposeful snub.

As WA EMD's tsunami programme continues its maritime strategy projects, it seeks to increase the scale of stakeholders involved. Past strategies have brought mainly emergency management and local government to the table; for ongoing and future projects, the programme plans to renew efforts to bring in private sector stakeholders as engaged participants from the beginning. So far in the development of the Guemes Channel strategy, private business owners have been invited to take part in the emergency planning and response discussions not only because of their interests and relationship with Port of Anacortes staff, but because some

have flat-bottom vessels that might be the only operable vessels available to use for emergency response post-tsunami. By having them directly work with port and emergency management staff, more robust community response and problem solving can take place to better protect people in the Anacortes area.

Engage stakeholders early and often

Along with engaging the right stakeholders, engaging stakeholders early and often throughout the life of the project both informs the creation of the final product and ensures buy-in from all groups involved. Most of the stakeholders involved in informing key aspects hold full-time positions with demanding schedules. Some are directors of emergency management with limited staff support, others oversee operations for ports, are chiefs of fire and police for large jurisdictions, or have otherwise demanding jobs. Establishing time to facilitate in-depth discussions can be a challenge, especially when attempting to organise recurring meetings that fit into all stakeholders' schedules. Setting clear expectations and scheduling out meetings to collect information and review project goals is essential for success. For example, months in advance of formally initiating the start of a tsunami maritime strategy, the WA EMD tsunami team organises a kickoff meeting with key stakeholders to introduce project goals and establish expectations. This provides an opportunity to elevate the significance of the project, discuss preliminary tsunami maritime risk in the community and gather interest for future project engagement.

It is also important to be flexible in communication platforms. With a diverse stakeholder group across a variety of professions, it is vital to keep communication efficient and streamlined. Having regularly scheduled check-ins with the identified onsite champion allows for updates on the project timeline to be shared and challenges, successes and next steps to be discussed. The regular cadence of these meetings provides for more in-sync communication that helps the project manager navigate unexpected changes and ensure consistent communication with all stakeholders.

Simplify data collection and stakeholder feedback

One area where WA EMD's tsunami programme identified an opportunity to reduce the overall project timeline is by streamlining data collection and stakeholder feedback using stakeholder workshops. In past projects, reviewing the feasibility of mitigation actions and response plan opportunities was conducted over the course of the project through a series of check-ins with the onsite champion and other primary stakeholders. This typically required many meetings where the onsite champion would have to consult others to collect the needed information, resulting in significant delay. The project team identified that while the check-ins were valuable for organising and tracking the project's development, they should not be the sole avenue for inclusive discussion on the feasibility of mitigation and response actions. As a result, for the Guemes Channel project, the WA EMD tsunami programme implemented a series of hands-on workshops that welcomed a broader group of stakeholders to discuss not only response and mitigation action feasibility, but to review tsunami risk directly with representatives across local government, emergency management and private business stakeholders. The goal was to yield more fruitful discussion, highlight gaps and collect information directly from the subject matter experts, tenants and employees in the field over

a much shorter timeframe. Hosting workshops ensures a more intentional, thorough data collection process that at the same time is also more accessible. This establishes a stronger familiarity within the entity's community to initiate iterative conversation on mitigating their tsunami risk, implementing more robust response procedures and increasing the knowledge base of tsunami maritime impacts. Additionally, more in-depth review and research can be achieved in the development of the overall strategy, which in turn could allow for more steadfast completion of subsequent projects.

At the time of writing this paper, one response workshop has been held for the Guemes Channel project and the mitigation workshop is scheduled to follow soon. Feedback from attendees and the wealth of information collected during the workshop give an initial impression that the workshop format is more engaging than previous data collection methods and saves both time and energy for the project team and stakeholders. It also provided a valuable opportunity to get stakeholders in the room together to brainstorm, identify areas of interest and collaborate in ways they had not in the past. As WA EMD continues its tsunami maritime response and mitigation strategy initiative in the future, it will build on this workshop format to provide stakeholders with as collaborative an experience as possible. The newest project, with the Port of Neah Bay and the Makah Indian Tribe, has already completed a highly successful kickoff meeting and aims to get its first workshop on the calendar in the coming month. Over 30 stakeholders attended the Port of Neah Bay strategy project kick-off meeting, including members of tribal council, tribal police, tribal and county emergency management, and federal agencies.

CONCLUSION AND NEXT STEPS

With the completion of a strategy, stakeholders have actionable next steps and an easy way to prioritise mitigation efforts over time as ports, harbours and marinas undertake new infrastructure or remodelling projects. Where funding may be lacking, entities can consider pursuing grant funding through local, state or federal channels to offset some or all of the costs. The Federal Emergency Management Agency's Building Resilient Infrastructure and Communities grant programme,[28] for example, provides funding for hazard mitigation projects that aim to reduce a community's risk to natural hazards and may therefore be a good funding source for maritime mitigation efforts. Where tsunami maritime mitigation projects also coincide with a reduction in risk associated with sea-level rise and other coastal hazards, grant programmes through the NOAA or state and federal departments of ecology may also be fruitful. Lastly, the recently passed Community Disaster Resilience Zones Act 2022[29] seeks to provide additional federal funding and support to the nation's highest-risk communities, many of which are located along coastlines. Ports, harbours and marinas located in these zones (to be identified later in 2023) may have more funding avenues available to them in the coming years.

Despite maritime infrastructure's high vulnerability to tsunami hazards, much can be done both before and during a tsunami to reduce the impact to a port, harbour or marina through the creation and implementation of tsunami maritime response and mitigation strategies. Strategies that are detailed, actionable and site-specific empower ports, harbours and marinas of all sizes to take tsunami risk reduction into their own hands. They also bring varied stakeholder groups together in a collaborative effort

where all partners have a stake in the final product. This ultimately benefits not just the maritime entity itself but the geographic region as a whole, as it contributes to a statewide and nationwide culture of resiliency.

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