



September 2022

# COAST GUARD Additional Actions Needed to Improve Tsunami Emergency Planning in the Pacific Northwest

Accessible Version

# GAO Highlight

Highlights of [GAO-22-105220](#), a report to congressional committees

## Why GAO Did This Study

As the principal federal agency responsible for maritime search and rescue, Coast Guard deploys personnel across the United States. This includes deployments to 39 coastal units in the Pacific Northwest.

The Pacific Northwest is also home to seismic hazards, including the Cascadia Subduction Zone. This is a large fault 50-100 miles offshore known to produce large earthquakes and tsunamis that may necessitate the evacuation of Coast Guard personnel and dependents during a major event.

The National Defense Authorization Act for Fiscal Year 2021 provides for GAO to study Coast Guard efforts to plan for the evacuation of its personnel and dependents during a major Cascadia Subduction Zone event. This report addresses, among other things, the extent to which the Coast Guard developed tsunami evacuation plans and procedures for its personnel and dependents in the Pacific Northwest.

GAO reviewed Coast Guard guidance and policies; reviewed tsunami evacuation plans for 39 coastal units; interviewed Coast Guard officials from headquarters and 10 field units; and interviewed other federal, state, and local officials.

## What GAO Recommends

GAO is making three recommendations, including that Coast Guard ensure that coastal units in the Pacific Northwest develop and exercise tsunami evacuation plans for personnel and dependents, and provide guidance to assist units with planning efforts. DHS concurred with these recommendations.

View [GAO-22-105220](#). For more information, contact Heather MacLeod at (202) 512-8777 or [MacLeodH@gao.gov](mailto:MacLeodH@gao.gov).

September 2022

## COAST GUARD

### Additional Actions Needed to Improve Tsunami Emergency Planning in the Pacific Northwest

## What GAO Found

Among the 39 U.S. Coast Guard units on the Pacific Northwest coast, 19 had a written tsunami evacuation plan for unit personnel. Coast Guard does not ensure units in this seismically active region of the United States create tsunami evacuation plans. Rather, each unit's leadership determines whether to develop a plan. By ensuring coastal units in the Pacific Northwest develop evacuation plans, Coast Guard would have greater assurance that unit personnel are aware of local tsunami risks and are prepared to evacuate during a major tsunami event.

Coast Guard also does not provide guidance to units that create evacuation plans. As a result, the content of these written plans—where they exist—varies. For example, four of these 19 plans included a map or diagram with evacuation route information, and three included evacuation protocols for dependents. By providing tsunami evacuation planning guidance to its coastal units within the Pacific Northwest, Coast Guard could better ensure that unit-developed plans provide location-specific evacuation protocols for Coast Guard personnel and their dependents.

Leadership at the units GAO visited that had written tsunami evacuation plans did not know the feasibility of their plans because they had not exercised them due, in part, to the impact of COVID-19 on in-person gatherings. Further, officials were unaware of past attempts to exercise their unit's plan or the frequency, results, and lessons learned from exercises. These officials stated that personnel with such knowledge had rotated to new units—action which typically occurs every 3 to 4 years. By exercising tsunami evacuation plans, unit personnel would be better positioned to assess plan feasibility and make adjustments as needed.

#### Tsunami Evacuation Sign



Source: Betty Sederquist/stock.adobe.com. | [GAO-22-105220](#)

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**Abbreviations**

All-Hazards Plan	U.S. Coast Guard District 13 All-Hazards Contingency Response Concept Plan
CSZ	Cascadia Subduction Zone
DHS	Department of Homeland Security
FEMA	Federal Emergency Management Agency
NDA	William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021
NOAA	National Oceanic and Atmospheric Administration
VE	Vertical Evacuation

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September 07, 2022

The Honorable Maria Cantwell  
Chair  
The Honorable Roger F. Wicker  
Ranking Member  
Committee on Commerce, Science, and Transportation  
United States Senate

The Honorable Peter DeFazio  
Chairman  
The Honorable Sam Graves  
Ranking Member  
Committee on Transportation and Infrastructure  
House of Representatives

The U.S. Coast Guard, within the Department of Homeland Security (DHS), is the principal federal agency responsible for maritime search and rescue, among other missions. Coast Guard deploys personnel across the U.S., including to coastal units in the Pacific Northwest, a seismically active region known to produce large offshore earthquakes and tsunamis.<sup>1</sup> A major earthquake in this region could cause tsunamis with waves reaching up to 80 feet in height, which could reach the Pacific Northwest coast in 10 to 30 minutes. Thousands of Coast Guard personnel and their dependents are stationed or live within this tsunami inundation zone, and evacuation may be necessary to avoid loss of life.<sup>2</sup> Coast Guard contingency planning documents state that a major earthquake and subsequent tsunami is the worst-case scenario for units located in the region due to the potential for significant loss of life and damage to property and the environment.

The William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (NDAA) includes a provision for us to study Coast

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<sup>1</sup>The Pacific Northwest is a region of the United States consisting of Washington, Oregon, Idaho, and Montana. The states of Washington and Oregon are located on the Pacific Coast. For the purposes of this report, we refer to Coast Guard sectors, air stations, boat stations, and cutters as “units.”

<sup>2</sup>The tsunami inundation zone comprises the horizontal distance inland that a tsunami penetrates, generally measured perpendicularly to the shoreline.

Guard efforts to plan for the evacuation of its personnel and dependents at four locations on the Pacific Northwest coast in the event of a major tsunami.<sup>3</sup> This report addresses the following questions: (1) to what extent has Coast Guard developed tsunami evacuation plans and procedures for its personnel and dependents in the Pacific Northwest; and (2) what steps has Coast Guard taken to respond to a potential major tsunami on the Pacific Northwest coast?

To address both objectives, we met with Coast Guard officials from District 13, which oversees Coast Guard operations in the Pacific Northwest.<sup>4</sup> We also met with Coast Guard personnel from ten Coast Guard units in the Pacific Northwest. This included units located in Port Angeles, and Grays Harbor, Washington, and Yaquina Bay and Coos Bay, Oregon as well as the three sectors within District 13—Sectors Puget Sound, Columbia River, and North Bend.<sup>5</sup> Appendix II includes detailed tsunami evacuation planning information for the four unit locations described above.

We also reviewed Coast Guard guidance, policies, and requirements related to tsunami evacuation and response. These documents included Coast Guard's Emergency Management and Safety and Environmental Health manuals—which describe emergency management planning policy across all Coast Guard missions and contingencies—and District 13's All-Hazards Contingency Response Concept Plan (All-Hazards Plan), which describes response-related protocols for a variety of natural hazards, including tsunamis. Appendix I further describes our objectives, scope, and methodology.

We conducted this performance audit from May 2021 to September 2022 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that

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<sup>3</sup>Pub. L. No. 116-283, § 8438, 134 Stat. 3388, 4737. The locations identified in the Act include stations Port Angeles and Grays Harbor in Washington, and stations Yaquina Bay and Coos Bay in Oregon. For the purposes of this report, the term "dependents" refers to family members of Coast Guard personnel who live with them.

<sup>4</sup>Coast Guard districts are responsible for overseeing Coast Guard's missions within a specific geographic region.

<sup>5</sup>We met with senior leaders for four units co-located at Air Station Port Angeles. These units included the air station, the boat station, and the Coast Guard cutters *Wahoo*, and *Swordfish*.

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the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

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## Background

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### Key Federal Agencies Responsible for Disaster Response and Recovery

State and local entities are typically responsible for disaster response efforts. The Stafford Act establishes a process by which the Governor of the affected state or the Chief Executive of an affected tribal government may request a presidential major disaster or emergency declaration to obtain federal assistance.<sup>6</sup> If the President finds, among other things, that the incident is of such severity and magnitude that effective response is beyond the capabilities of the state or tribal nation, then the President may declare under the Stafford Act that a major disaster or emergency exists. The Secretary of Homeland Security is responsible for ensuring that federal actions are coordinated to prevent gaps in the federal government's efforts to respond to all major disasters, among other emergencies.<sup>7</sup>

- Within DHS, the Federal Emergency Management Agency (FEMA) is the lead agency for disaster response in the United States. FEMA coordinates incident management and response efforts, logistics planning, management and sustainment, mass care, emergency assistance, and disaster housing, among other efforts. FEMA also serves as the primary source of federal grant funding for state, local, tribal, and territorial investments in hazard mitigation—including tsunami hazard mitigation—to prevent future damage.
- The Coast Guard is an armed service that maintains multi-mission capabilities to support response efforts and help protect life, property, and the environment. As such, the Coast Guard serves as a first responder and humanitarian service provider that aids those impacted by natural and human-made disasters. Given its missions, the Coast Guard is uniquely positioned to respond to maritime emergencies. Its

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<sup>6</sup>42 U.S.C. § 5121 et seq.

<sup>7</sup>This responsibility is outlined in the DHS National Response Framework—a guide to how the federal government, states and localities, and other public and private sector institutions should respond to disasters and emergencies.

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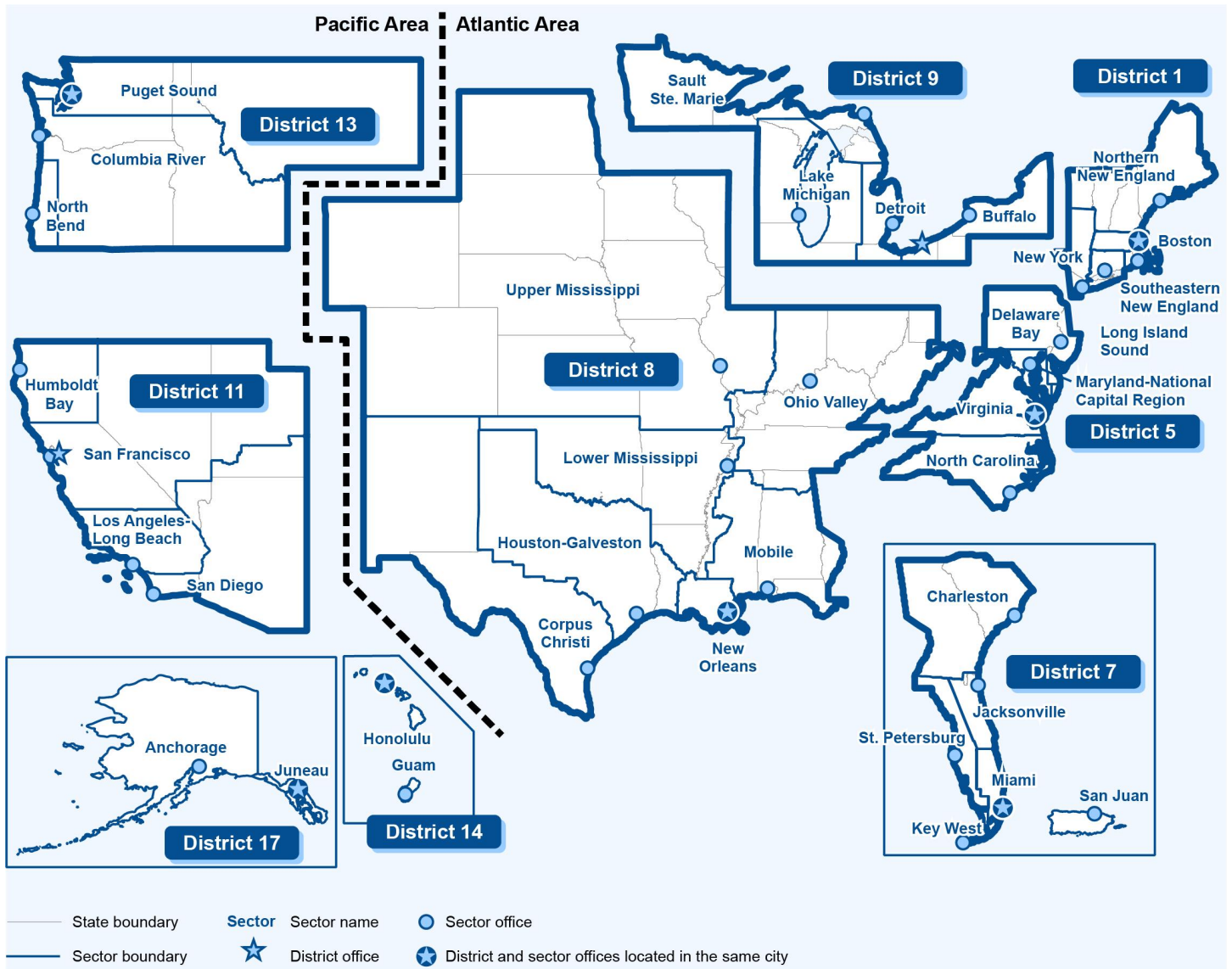
operations are split into two area commands—Atlantic Area and Pacific Area. Each area is further divided into districts, which are responsible for overseeing Coast Guard’s missions within a specific geographic region, as shown in Figure 1. District 13 is responsible for fulfilling the agency’s missions in the Pacific Northwest.<sup>8</sup> In total, District 13 oversees 39 coastal units, approximately 3,000 active duty and reserve members, and civilian employees, among others. Generally, active duty Coast Guard personnel rotate to a new unit every three to four years.

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<sup>8</sup>District 13 is further divided into three sectors—Sector Puget Sound, Sector Columbia River, and Sector North Bend—which manage sub-units in Washington and Oregon. In total, District 13 oversees 42 units. Among these, 39 are based on the coast.



Figure 1: Map of the U.S. Coast Guard Area Commands, Districts, and Sectors



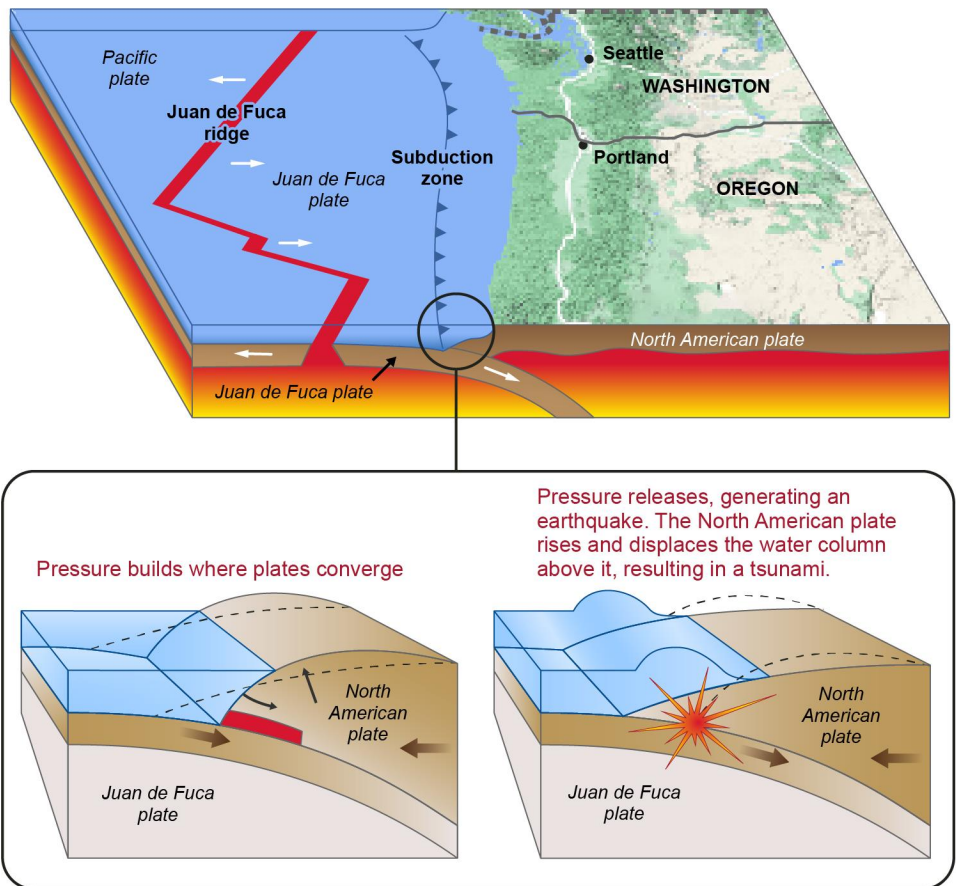
Source: GAO analysis of U.S. Coast Guard data. | GAO-22-105220

## Cascadia Subduction Zone

The Cascadia Subduction Zone (CSZ) fault is approximately 800-miles long and is located 50 to 80 miles off the coasts of Washington, Oregon,

Northern California; and British Columbia, Canada.<sup>9</sup> The CSZ, like other subduction zones, is created when one tectonic plate moves under another. Figure 2 depicts the CSZ in which the Juan de Fuca plate slides beneath the North American plate.

**Figure 2: The Cascadia Subduction Zone Hazard in the Pacific Northwest**



Source: GAO analysis of FEMA data; USGS; Google (map). | GAO-22-105220

According to FEMA planning documents, subduction zones produce some of the world’s largest earthquakes, which can exceed magnitude

<sup>9</sup>The CSZ fault is part of the “Ring of Fire,” a Pacific seismic belt known to generate approximately 90 percent of all earthquakes and 81 percent of the world’s largest magnitude earthquakes. The CSZ is the only significant fault line on the Ring of Fire that has not experienced a major earthquake in the last fifty years, according to FEMA documents.

9.0, generate large tsunamis, and produce aftershocks for months afterwards.<sup>10</sup> On average, a magnitude 9.0 CSZ event occurs approximately every 350 to 500 years.<sup>11</sup> According to FEMA documents, a full rupture of the CSZ fault may generate ground shaking up to five minutes and an initial tsunami wave of between three and 80 feet reaching the outer coast of Washington and Oregon within 10 to 30 minutes.<sup>12</sup> Tsunami arrival estimates along Washington's inner coast may exceed one hour from rupture. According to the Oregon Office of Emergency Management, scientists estimate there is a 37 percent chance that a magnitude 7.1 or greater CSZ event will occur in the Pacific Northwest within the next fifty years.

Seismic activity is difficult to predict and the CSZ fault could generate a major earthquake and tsunami without warning that would affect millions of people's lives, property, infrastructure, and the environment for years. According to FEMA planning documents, approximately 86,000 people in the Pacific Northwest live in the CSZ tsunami inundation zone. A full rupture of the CSZ fault would cripple communities in Western Washington and Oregon, Northern California; and British Columbia, Canada. FEMA also estimates that such an event may injure over 107,000 people, result in nearly 14,000 deaths, and severely damage approximately 620,000 buildings, 2,000 schools, 100 hospitals, and all seaports on the Pacific Northwest coast. FEMA also estimates that a CSZ event may cause \$134 billion in total economic losses.

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<sup>10</sup>Department of Homeland Security, Federal Emergency Management Agency, *Region 10 Cascadia Subduction Zone Earthquake and Tsunami Plan*, (Washington D.C., January 22, 2022). Recent subduction zone events include the 2004 Sumatra-Andaman earthquake and tsunami and the 2011 Tohoku earthquake and tsunami, which resulted in the deaths of approximately 280,000 and 15,800 people, respectively.

<sup>11</sup>According to FEMA planning documents, the last CSZ event occurred on January 26, 1700—322 years ago.

<sup>12</sup>A single magnitude 9.0 CSZ event may generate multiple tsunamis that last for approximately 10 to 12 hours after the initial earthquake. Aftershocks of magnitude 7.0 or greater may follow the initial earthquake and tsunami, generating additional tsunamis, according to FEMA documents.

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## Vertical Evacuation

Vertical evacuation (VE) structures are intended to be a possible solution for mitigating tsunami hazards in high-risk coastal communities.<sup>13</sup> A VE structure can be a standalone tower, incorporated into an existing or new building, or an earthen mound designated as a place of refuge in the event of a tsunami. These structures are designed and constructed to provide sufficient height to elevate evacuees above the tsunami inundation zone and resist tsunami load effects. According to a 2018 study by Washington State, VE structures may be appropriate in locations without immediate access to natural high ground and should generally be accessible to evacuees within fifteen minutes by foot.<sup>14</sup>

There are three completed VE structures in the Pacific Northwest. Two—Oregon State University’s Marine Science Center in Newport, Oregon and the Ocosta Elementary School in Westport, Washington—are incorporated into large buildings and designed to provide shelter for students and the nearby community. Safe Haven Hill, also in Newport, Oregon, is an earthen mound with multiple footpaths leading to the top. All three VE structures provide an evacuation area above the projected tsunami inundation zone and are equipped with emergency supplies. A fourth VE structure—currently under development by the Shoalwater Bay Tribe in Tokeland, Washington with a projected completion date in July 2022—will be a stand-alone tower. Figure 3 depicts these four VE structures.

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<sup>13</sup>Department of Homeland Security, Federal Emergency Management Agency, *Guidelines for Design of Structure for Vertical Evacuation from Tsunamis*, (Washington, D.C., August 2019).

<sup>14</sup>Washington State Emergency Management Division, *Manual for Tsunami Vertical Evacuation Structures*, (2018).

Figure 3: Vertical Evacuation Structures in the Pacific Northwest



1. Oregon State University's Marine Science Center's built-in VE structure (Newport, OR) opened in September 2020. Located on the roof of the building, the structure features a wide outdoor ramp to safely evacuate approximately 1,000 people. The roof is also equipped with emergency supplies.
2. Ocosta Elementary School's VE structure (Westport, WA), located on the roof of the school's gymnasium, was completed in 2016. The structure can accommodate 2,000 people, and is also equipped with emergency supplies.
3. Safe Haven Hill (Newport, OR) is an earthen VE structure that stands 70-90 feet above sea level, and was retrofitted in 2016. The structure can accommodate 2,000 people and is equipped with emergency supplies.
4. The Shoalwater Bay Tribe VE structure (Tokeland, WA) is projected to be completed in July 2022. When completed, it will stand approximately 50 feet above the ground with capacity to hold approximately 400 people. The Tribe plans to equip the tower with food and water supplies.

Source: GAO; GAO (photos 1-3); FEMA (photo 4). | GAO-22-105220

Washington State is developing plans for additional VE structures in populated areas on the coast. Specifically, in August 2021, Washington State issued a report that identified the need for between 56 and 85 VE structures, consisting of earthen berms, towers, and raised platforms,

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along the outer coast.<sup>15</sup> Among these is a proposed VE structure adjacent to Coast Guard Station Grays Harbor, in Westport, Washington, which is located within the tsunami inundation zone.

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## Half of the 39 Coast Guard Units Had Written Plans, but Their Content Varied and Plan Feasibility Is Unclear

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### About Half of Pacific Northwest Units Had Tsunami Evacuation Plans

Among the 39 coastal units in District 13 at risk of inundation during a CSZ event, 19 had a written tsunami evacuation plan for unit personnel as of May 2022. Coast Guard's Safety and Environmental Health Manual requires that all units develop emergency action plans.<sup>16</sup> These plans are to include emergency evacuation protocols for a variety of contingencies that could occur in the workplace and are relevant to the unit's geographic location, including tsunamis. Coast Guard guidance further states that unit contingency evacuation protocols should include a diagram or map identifying evacuation routes, the location of higher ground or other evacuation safe havens—such as a VE structure—and assembly areas, among other information. For example, Station Grays Harbor's tsunami evacuation plan directs personnel and dependents to the VE structure at Ocosta Elementary School, which may provide refuge during a CSZ event.<sup>17</sup>

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<sup>15</sup>Washington Emergency Management Division, *A Guide to Vertical Evacuation Options on the Washington Coast*, (Aug. 2021). According to the Washington State Emergency Management Division, VE structures currently proposed for Washington's outer coast range in cost from around \$800,000 to over \$10 million per structure. Washington State Emergency Management Division, *Project Safe Haven: Tsunami Vertical Evacuation on the Washington Coast*, (2016).

<sup>16</sup>Department of Homeland Security, U.S. Coast Guard, *Safety and Environmental Health Manual*, (Washington, D.C., February 27, 2019).

<sup>17</sup>Among the 19 coastal units in the Pacific Northwest with a written tsunami evacuation plan, Station Grays Harbor is the only unit that directs personnel and dependents to a VE structure. The remaining three VE structures are not located within a short walking distance from a Coast Guard unit and are not included in any unit plans. We describe Station Grays Harbor's tsunami evacuation plan in Appendix II.

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However, District 13 officials told us that they encourage coastal units in the Pacific Northwest, to develop tsunami evacuation plans, but do not ensure they do so. Instead, each unit's leadership determines whether to develop a tsunami evacuation plan for the unit. By ensuring coastal units in the Pacific Northwest develop location-specific evacuation plans, as required, Coast Guard would have greater assurance that unit personnel and their dependents are better informed and more prepared to evacuate in the event of a tsunami.

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### The Content of Pacific Northwest Unit Tsunami Evacuation Plans Varied

Among the 19 Pacific Northwest units with a written tsunami evacuation plan, we found that plan contents varied significantly. Coast Guard District 13 officials acknowledged variation in the contents of each plan and stated that neither District 13 nor its sectors have developed or provided tsunami-specific guidance or templates to units to ensure that unit-developed plans include consistent information. Our review of the contents of the 19 unit tsunami evacuation plans and relevant guidance showed:

- Fourteen plans included evacuation procedures for Coast Guard personnel for a major local tsunami event—the worst-case scenario for coastal units in the Pacific Northwest, according to District 13's All-Hazard Plan.<sup>18</sup>
- Three plans included local tsunami evacuation procedures for Coast Guard dependents—some of whom live in Coast Guard housing located within the tsunami inundation zone. However, according to District 13's All-Hazards Plan, unit personnel are required to alert dependents when issuing evacuation orders and transport them to a safe facility in the event of a natural hazard, including tsunamis.
- The timing for initiating evacuation procedures varied across unit plans. For example, seven plans direct personnel to evacuate upon detecting major seismic activity, whereas the remaining 12 direct

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<sup>18</sup>Department of Homeland Security, U.S. Coast Guard, *Thirteenth Coast Guard District All-Hazards Contingency Response Concept Plan*, (Seattle, WA: March 2018), which establishes contingency response protocols for units within District 13 that cover a variety of natural disasters, including tsunamis. In general, local tsunamis are generated by seismic activity near the impacted area, travel a short distance, and may reach the coast within minutes. Distant tsunamis are usually generated by seismic activity far from the impacted area and may take hours to reach the coast.

personnel to wait for an official tsunami warning before initiating evacuation procedures. However, National Oceanic and Atmospheric Administration (NOAA) officials responsible for operating the National Tsunami Warning System stated that evacuation procedures should begin upon detecting a major earthquake.<sup>19</sup> Specifically, NOAA officials explained that damage to communication infrastructure caused by the initial earthquake may inhibit units from receiving an official warning and any delay in evacuating the tsunami inundation zone may result in the loss of life. Table 1 provides summary information about the contents of the 19 unit plans.

**Table 1: General Summary of the Contents of 19 Cascadia Subduction Zone (CSZ) Tsunami Evacuation Plans for Coast Guard District 13 Units as of May 2022**

Unit	Plan Includes CSZ Evacuation Procedures	Plan Includes CSZ Evacuation Procedures for Personnel	Plan Includes CSZ Evacuation Procedures for Dependents	Plan Identifies Evacuation Assembly Area(s)	Plan Includes a Map or Diagram of Evacuation Route	Plan Directs Unit to Evacuate upon Detecting Seismic Activity
Station Cape Disappointment, WA	yes	yes	yes	yes	no	yes
<b>Station Grays Harbor, WA</b>	yes	yes	yes	yes	no	yes
Sector North Bend, OR	yes	yes	no	yes	no	yes
Station Chetco River, OR	no	no	no	no	no	no
<b>Station Coos Bay, OR</b>	yes	yes	no	yes	no	yes
Station Depoe Bay, OR	yes	yes	no	yes	no	yes
Station Siuslaw River, OR	no	no	no	no	no	no
Station Umpqua River, OR	yes	yes	no	yes	no	no
<b>Station Yaquina Bay, OR</b>	no	no	no	no	no	no
USCGC <i>Orcas</i> , OR	no	no	no	no	no	no
Air Station Port Angeles, WA	yes	yes	no	yes	no	no

<sup>19</sup>The Tsunami Warning System monitors for tsunamis, forecasts impacts, and issues tsunami warnings. According to Coast Guard officials, District 13 and NOAA test the interoperability of the system on a monthly basis.



Letter

Unit	Plan Includes CSZ Evacuation Procedures	Plan Includes CSZ Evacuation Procedures for Personnel	Plan Includes CSZ Evacuation Procedures for Dependents	Plan Identifies Evacuation Assembly Area(s)	Plan Includes a Map or Diagram of Evacuation Route	Plan Directs Unit to Evacuate upon Detecting Seismic Activity
Station Bellingham, WA	no	no	no	no	no	no
Station Neah Bay, WA	yes	yes	yes	yes	no	yes
<b>Station Port Angeles, WA</b>	yes	yes	no	yes	no	no
Station Quillayute River, WA	yes	yes	no	yes	no	yes
USCGC <i>Adelie</i> , WA	yes	yes	no	yes	yes	no
USCGC <i>Cuttyhunk</i> , WA	yes	yes	no	yes	yes	no
USCGC <i>Swordfish</i> , WA	yes	yes	no	yes	yes	no
USCGC <i>Wahoo</i> , WA	yes	yes	no	yes	yes	no
<b>Total</b>	<b>14</b>	<b>14</b>	<b>3</b>	<b>14</b>	<b>4</b>	<b>7</b>

Source: GAO summary of Coast Guard information. | GAO-22-105220

Note: We identified the above categories based on the contents of the plans we reviewed. Coast Guard has not identified best practices for tsunami evacuation or recommended plan elements. Twenty coastal units within District 13 did not have written tsunami evacuation plans and thus are excluded from this analysis.

Coast Guard provides units with contingency planning templates that include explicit procedures for emergency evacuation for various natural hazards, including earthquakes, hurricanes, and wildfires, but has not done so for tsunamis.<sup>20</sup> For example, there is no guidance addressing whether a unit’s plan should account for a major local tsunami or identify evacuation procedures for personnel or dependents. Instead, Coast Guard officials stated that sectors may share external resources with units—including state-developed tsunami evacuation and inundation maps—and may provide some planning assistance to those units that choose to develop a written tsunami evacuation plan, when requested. Coast Guard officials stated that most small units do not have planning departments or personnel with extensive planning experience, which may affect the level of detail and quality of plans developed by small units. Coast Guard officials also stated that tsunami evacuation planning

<sup>20</sup>These templates include instructions for developing unit evacuation procedures as well as for identifying primary and secondary evacuation routes and designated assembly areas.

guidance would be helpful to ensure consistency and quality across unit plans.

Coast Guard's Emergency Management Manual requires that districts and sectors provide direction to subordinate units for all preparedness planning.<sup>21</sup> Specifically, the manual calls for districts to provide planning support and oversight to subordinate units, and for the sectors to review and approve subordinate units' planning documents for completeness on an annual basis. However, without specific evacuation planning guidance for tsunami hazards and the evacuation of Coast Guard personnel and dependents, the Coast Guard is at greater risk of loss of life if such an event occurred.

By providing tsunami evacuation planning guidance to coastal units within the Pacific Northwest, Coast Guard could better ensure that unit-developed plans account for relevant tsunami scenarios, including a CSZ event, and provide location-specific evacuation protocols for its personnel and their dependents. Guidance would help to standardize tsunami evacuation planning and help ensure unit plans' contents are consistent, such as including evacuation routes to locations above the inundation zone and assembly areas, as applicable. Further, tsunami evacuation planning guidance could better ensure that unit plans account for both Coast Guard personnel and their dependents residing in Coast Guard housing within the inundation zone.

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### Unit Tsunami Evacuation Plan Feasibility is Unclear

Among the ten units we visited, eight had written tsunami evacuation plans. However, the feasibility of these eight plans was unknown to Coast Guard personnel located at these units because the units had not exercised their plans to assess feasibility, according to unit leadership.<sup>22</sup> These officials explained that they had not exercised their unit's plans due, in part, to the impact of COVID-19 on in-person gatherings. These officials further stated that they were unaware of any past attempts to exercise their unit's plans, or the frequency, results, and lessons

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<sup>21</sup>Department of Homeland Security, U.S. Coast Guard, *Emergency Management Manual*, Vol. I (Washington, D.C., December 07, 2020)

<sup>22</sup>While individual units have not exercised their evacuation plans, Coast Guard has participated in national-level response and recovery exercises, which we address later in this report.

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learned—if any—since the personnel with such knowledge had rotated to new units.<sup>23</sup> Officials we met with at these eight units expressed an intent to exercise their evacuation plans in light of loosening of COVID-19 restrictions; however, none reported having a strategy or timeframe in place for doing so.

According to Coast Guard’s Emergency Management Manual, emergency management exercises are a cornerstone of overall preparedness and allow Coast Guard personnel and community stakeholders to test and assess the feasibility of their contingency plans, and identify gaps and areas of improvement.<sup>24</sup> Specifically, the manual states that written plans designed for emergencies that can be reasonably anticipated to occur within a unit’s area of operation—which can include tsunamis—must be exercised and reviewed to continually evaluate plan effectiveness. It further states that each level of Coast Guard holds responsibility for the development and maintenance of emergency management exercises, and specifies that written plans for natural disaster emergencies, including tsunamis, must be exercised on an annual basis.

By regularly exercising tsunami evacuation plans, unit personnel would be better positioned to assess plan feasibility during a potential CSZ event, validate the process and resources needed for a timely evacuation, and make adjustments to their unit plan as needed. Further, by providing opportunities for dependents to participate in such exercises, unit personnel would have greater assurance that dependents are familiar with relevant evacuation protocols. Lastly, by exercising tsunami evacuation plans on a regular basis, Coast Guard would better ensure that personnel and dependents new to a unit are familiar with tsunami evacuation protocols on a timely basis.

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<sup>23</sup>Coast Guard personnel typically rotate from one unit to another every three to four years, often leaving little institutional knowledge in place after a few years when the personnel at a unit has completely changed over.

<sup>24</sup>Department of Homeland Security, U.S. Coast Guard, *Emergency Management Manual*, Vol. I and III (Washington, D.C., 2020, 2022).

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## Coast Guard Improved Its Tsunami Preparedness, but Key Actions Remain

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### Coast Guard Has Taken Steps to Improve Tsunami Preparedness and Response

Coast Guard has taken steps to improve its tsunami preparedness by developing contingency plans, purchasing emergency equipment, and participating in emergency response exercises, but additional actions would better prepare it for a major tsunami event. Some key steps the Coast Guard has taken include:

- District 13's development of the All-Hazards plan, which includes protocols for responding to a variety of natural hazards, including a CSZ event. According to the plan, District 13 would continue to fulfill its statutory missions following a major tsunami event and would give priority to: (1) maritime search and rescue; (2) ports, waterways, and coastal security; (3) marine environmental protection; and (4) marine transportation system recovery. However, according to Coast Guard officials, since personnel in the Pacific Northwest would likely be among the victims and survivors, responsibility for response efforts would likely extend beyond District 13 and include Coast Guard personnel from non-affected regions.
- District 13's purchase of emergency communications equipment—such as satellite phones and mobile communication systems—that each sector can utilize if a major natural hazard, including a CSZ event, damages communications infrastructure.
- Coast Guard's involvement in Cascadia Rising 2016, a national level exercise, involving federal, state, and local emergency management officials enabled Coast Guard to test and communicate its post-event response capabilities.<sup>25</sup> Specifically, Coast Guard personnel from Pacific Area, District 13, and its three sectors participated in a four-day national-level exercise to test response and recovery capabilities following a major CSZ event. However, given the exercise's focus on response and recovery, personnel from coastal units within District 13

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<sup>25</sup>The exercise involved various federal agencies, including FEMA, as well as military commands, state, tribal, and local partners, and private sector and non-governmental organizations in Washington, Oregon, and Idaho.

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generally did not participate, and tsunami evacuation of personnel and dependents at these units was not assessed.<sup>26</sup>

- Following the Cascadia Rising 2016 exercise, Coast Guard developed and submitted after-action reports documenting lessons learned, best practices, and recommendations for improvement. Coast Guard uses after-action reports to generate recommended actions to mitigate a deficiency or challenge identified through exercises. These recommended actions are entered into a Coast Guard database—the Contingency Preparedness System.<sup>27</sup>

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## Key Actions Remain to Address Known Evacuation and Response Gaps

While Coast Guard has taken steps to improve its preparedness, it has not addressed known evacuation and response gaps identified through its participation in Cascadia Rising 2016. Specifically, District 13 and its sectors documented after-action reports resulting in 71 recommended actions. However, our analysis of Coast Guard recommended action data identified that Coast Guard had not resolved 65 percent (46 of 71) of the recommended actions associated with the Cascadia Rising 2016 exercise within agency-established timeframes. As of May 2022, Coast Guard had addressed 25 of the 71 (35 percent) recommended actions from the exercise, falling well below its internal goal of resolving 80 percent of after-action report recommendations within 18 months.<sup>28</sup>

In 2021, we analyzed other after-action reports and recommended actions from 2007 through 2020 and found that Coast Guard lacked a process to track, update, and resolve recommended actions in line with program goals.<sup>29</sup> We identified similar challenges in this review. By resolving recommended action items in line with program goals, Coast

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<sup>26</sup>According to Coast Guard officials, personnel were unable to assess the feasibility of unit tsunami evacuation plans for personnel and dependents as part of the exercise.

<sup>27</sup>The Contingency Preparedness System is Coast Guard's data system for managing after-action information.

<sup>28</sup>Coast Guard officials reported this 80 percent goal during prior work in which we reviewed the agency's performance in resolving recommended actions. GAO, *Coast Guard: A More Systematic Process to Resolve Recommended Actions Could Enhance Future Surge Operations*, [GAO-21-584](#), (Washington, D.C.; September 21, 2021).

<sup>29</sup>[GAO-21-584](#).

Guard could better ensure that personnel are prepared for a real life event.<sup>30</sup> Coast Guard could also ensure that it fully benefits from its participation in future exercises. As a result, in 2021 we recommended that the Commandant of the Coast Guard establish a more systematic process for ensuring that assigned recommended actions are tracked, updated, and resolved in line with Coast Guard's resolution rate and timeliness goals. The Coast Guard agreed with this recommendation, but as of July 2022, the agency had not yet taken actions to implement this recommendation. We will continue to monitor Coast Guard's efforts to implement this recommendation.

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## Conclusions

A major tsunami in the Pacific Northwest could have devastating impacts on the region, cause \$134 billion in economic losses, and endanger thousands of people, including Coast Guard personnel and their dependents. Given the predicted risks and probability of a CSZ event in the Pacific Northwest, Coast Guard action is merited. However, over half of the Coast Guard units in this region have not documented tsunami evacuation plans. Further, where plans existed, many did not include critical detail—such as an evacuation route or assembly area—that would be necessary to facilitate an effective unit evacuation during a major tsunami event. By ensuring that each unit develops a location-specific evacuation plan, Coast Guard would better position its personnel and their dependents to survive a major tsunami event. Additionally, by providing units with tsunami evacuation planning guidance, Coast Guard could better ensure that the contents of these unit-developed plans account for relevant tsunami-related scenarios and are location-specific.

It is also unclear if the existing tsunami evacuation plans developed by units in the Pacific Northwest are feasible because unit personnel have not exercised these plans. By conducting tsunami evacuation exercises, Coast Guard units could better determine the feasibility of their tsunami evacuation plans, validate plan processes and needed resources, and make adjustments as needed. These efforts would help ensure that

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<sup>30</sup>For example, multiple recommended actions from the 2016 exercise identified that many units lacked sufficient emergency supplies, such as food and water. However, six years later, we found that coastal units in the Pacific Northwest generally do not maintain the recommended amount of emergency supplies for a major tsunami event. We are planning to undertake future work to examine Coast Guard's emergency supply policy and its implementation at Coast Guard units.

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personnel and dependents stationed at coastal units in the Pacific Northwest are better prepared for an emergency evacuation.

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## Recommendations for Executive Action

We are making the following three recommendations to the U.S. Coast Guard:

The Commandant of the U.S. Coast Guard should ensure that coastal units in the Pacific Northwest develop location-specific evacuation plans. (Recommendation 1)

The Commandant of the U.S. Coast Guard should ensure that coastal units in the Pacific Northwest are provided with tsunami evacuation planning guidance that includes protocols for personnel and dependents. (Recommendation 2)

The Commandant of the U.S. Coast Guard should ensure that coastal units in the Pacific Northwest assess the feasibility of their tsunami evacuation plans through regular exercises that provide participation opportunities for Coast Guard personnel and dependents. (Recommendation 3)

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## Agency Comments and Our Evaluation

In July 2022, we provided a draft of this report to the Department of Homeland Security (DHS) and the Department of Commerce for review and comment. DHS and the Department of Commerce provided technical comments, which we have incorporated into the report as appropriate. In addition, DHS provided written comments, which are reprinted in appendix III. In its letter, DHS stated it concurred with our three recommendations and provided steps and time frames for addressing them. However, Coast Guard does not anticipate developing written tsunami evacuation plans and providing guidance to units for plan development until December 31, 2025. It also does not anticipate that units will exercise their plans until December 31, 2026. Given the potential risks to Coast Guard personnel and their dependents at these units, more timely completion of plans, guidance, and exercises may be warranted.

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We are sending copies of this report to the appropriate congressional committees, the Secretaries of Homeland Security and Commerce, and other interested parties. In addition, the report is available at no charge on the GAO website at <https://www.gao.gov>.

If you or your staff have any questions about this report, please contact me at 206-654-5574 or [MacLeodH@gao.gov](mailto:MacLeodH@gao.gov). Contact points for our

Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix IV.

A handwritten signature in black ink, appearing to read "H MacLeod". The signature is stylized and cursive.

Heather MacLeod  
Director, Homeland Security and Justice



## Appendix I: Objectives, Scope, and Methodology

The William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (NDAA) includes a provision for us to study Coast Guard efforts to plan for the evacuation of its personnel and dependents at four locations on the Pacific Northwest coast in the event of a major tsunami.<sup>1</sup> This report addresses the following questions: (1) to what extent has Coast Guard developed tsunami evacuation plans and procedures for its personnel and dependents in the Pacific Northwest; and (2) what steps has Coast Guard taken to respond to a potential major tsunami on the Pacific Northwest coast?

To address both objectives, we met with officials from Coast Guard District 13, which oversees Coast Guard operations in the Pacific Northwest. We also met with Coast Guard personnel from ten Coast Guard units in the Pacific Northwest. These units included stations located in Port Angeles, and Grays Harbor, Washington, and Yaquina Bay and Coos Bay, Oregon—which are identified in the Act—as well as the three sectors within District 13—Sectors Puget Sound, Columbia River, and North Bend.<sup>2</sup>

We also reviewed Coast Guard guidance, policies, and requirements related to tsunami evacuation and response. These documents include Coast Guard’s Emergency Management and Health and Environmental Safety manuals—which describe emergency management planning policy across all Coast Guard missions and contingencies—and District 13’s All-Hazards Contingency Response Concept Plan (All-Hazards

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<sup>1</sup>Pub. L. No. 116-283, § 8438, 134 Stat. 3388, 4737. The locations identified in the Act include stations Port Angeles and Grays Harbor in Washington, and stations Yaquina Bay and Coos Bay in Oregon. For the purposes of this report, the term “dependents” refers to family members of Coast Guard personnel living with them.

<sup>2</sup>We met with senior leadership at four units co-located at Air Station Port Angeles. These units include the air station, the boat station, and the Coast Guard cutters *Wahoo*, and *Swordfish*.

Plan), which describes response-related protocols for a variety of natural hazards, including tsunamis.<sup>3</sup>

To address our first objective examining tsunami evacuation plans and procedures for Coast Guard personnel and dependents in the Pacific Northwest, we reviewed existing unit tsunami evacuation plans. We then compared the number of District 13 units with written tsunami evacuation plans against Coast Guard's Safety and Environmental Health Manual, which requires that all units develop emergency evacuation protocols for natural hazards, including tsunamis. We also reviewed Coast Guard guidance for contingency planning and examined the contents of each unit evacuation plan for consistency. To illustrate the variation across these plans, we identified categories based on the contents of each plan we reviewed. We also discussed plan development and reviewed Coast Guard guidance, tsunami risk information, or other resources utilized during plan development. In general, these resources included Washington and Oregon state-developed information on tsunami risk in the Pacific Northwest, including tsunami risk analyses and inundation maps. Lastly, during our visits to Coast Guard units, we discussed each unit's written tsunami evacuation protocols and observed established tsunami evacuation routes and assembly areas.

To assess the feasibility of the tsunami evacuation plans for the four units identified in the Act, we met with senior leadership at these units to discuss their efforts to assess the feasibility of their plans through exercises. We then compared these efforts against Coast Guard's Emergency Management Manual. For context, we also met with dependents associated with the four units to obtain their perspectives on tsunami risk and Coast Guard's efforts to inform dependents about local natural hazards and evacuation protocols. To further assess plan feasibility at the four units, we developed tsunami evacuation maps. To do so, we incorporated tsunami wave arrival and inundation data produced by Washington and Oregon state agencies, images from Google Maps, and information within each unit's tsunami evacuation plan. During our site visits, we observed vertical evacuation structures on the Washington and Oregon coasts and discussed the extent to which Coast Guard personnel may utilize these structures to evacuate the tsunami inundation zone.

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<sup>3</sup>Department of Homeland Security, U.S. Coast Guard, *Emergency Management Manual*, Vol. I and III (Washington, D.C., 2020, 2022) U.S. Coast Guard, *Safety and Environmental Health Manual*, (Washington, D.C., Feb. 27, 2019).

We also interviewed emergency management officials from Washington and Oregon, including Clallam and Grays Harbor counties in Washington, and Lincoln and Coos counties in Oregon. During these interviews, we discussed the extent to which Coast Guard has communicated its local tsunami evacuation protocols. Further, we met with Coast Guard officials as well as officials from the National Oceanic and Atmospheric Administration (NOAA) to review Coast Guard's interconnectedness with NOAA's National Tsunami Warning System. During these meetings, we reviewed how Coast Guard receives tsunami warnings and then transmits them to units on the coast, as well any back-up communication systems that may be utilized during a major tsunami event.

To address our second objective examining Coast Guard's efforts to prepare for a major tsunami event, we reviewed District 13's All-Hazards Plan. During our site visits, we also discussed tsunami response at the units. We also analyzed Coast Guard's After-Action Reports from the Cascadia Rising 2016 national level exercise, which tested federal, state, local, and tribal tsunami response capabilities across the Pacific Northwest.

To further assess Coast Guard's tsunami response planning efforts, we met with leadership from ten units—including the four units identified in the Act—as well as the three sectors, two cutter units and District 13. During these meetings, we discussed Coast Guard's efforts to communicate its response capabilities to federal, state, and local emergency management authorities. We also interviewed state and local emergency management officials to discuss how, if at all, Coast Guard participates in regional tsunami response planning efforts.

We conducted this performance audit from May 2021 to September 2022 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

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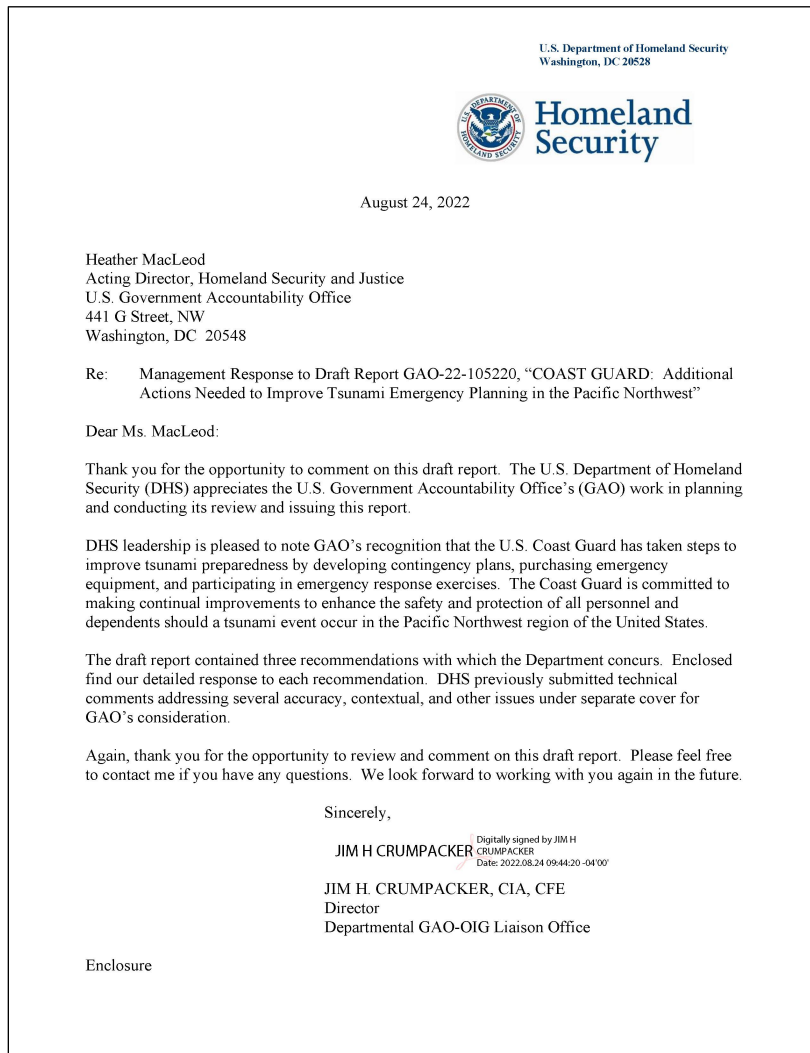
## Appendix II: Tsunami Evacuation Plans at Four Coast Guard Units in the Pacific Northwest

The William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 includes a provision for us to study Coast Guard efforts to plan for the evacuation of its personnel and dependents at four locations on the Pacific Northwest coast in the event of a major tsunami.<sup>1</sup> These locations include: stations Port Angeles and Grays Harbor in Washington, and stations Yaquina Bay and Coos Bay in Oregon. This appendix includes basic information about each Coast Guard location, including the units present, assets, as well as our analysis of each unit's tsunami evacuation plan. To visually display each unit's tsunami evacuation plan, we developed maps identifying evacuation routes described in the plan and the tsunami inundation zone Coast Guard personnel would need to clear before tsunami wave arrival.

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<sup>1</sup>Pub. L. No. 116-283, § 8438, 134 Stat. 3388, 4737. For the purposes of this report, the term "dependents" refers to family members of Coast Guard personnel living with them.

## Appendix III: Comments from the Department of Homeland Security



**Enclosure: Management Response to Recommendations  
Contained in GAO-22-105220**

GAO recommended that the Commandant of the U.S. Coast Guard ensure that coastal units in the Pacific Northwest:

**Recommendation 1:** Develop location-specific evacuation plans.

**Response:** Concur. The Coast Guard's Office of Emergency Management and Disaster Response (CG-OEM) identified the Thirteenth Coast Guard District's Preparedness Branch as responsible for development of contingency plans and policies for all hazards responses, to include evacuation plans, coordination of preparedness activities, and input into Federal Emergency Management Agency (FEMA) and Coast Guard's Integrated Preparedness Planning Workshop (IPPW) process, as described in COMDTINST M3010.11E, "Emergency Management Manual," dated December 7, 2022.<sup>1</sup>

Accordingly, the Thirteenth Coast Guard District will charter a workgroup to develop a Tsunami Evacuation Template for coastal units to use when building evacuation, contingency, and other plans, as appropriate. Further, the Thirteenth Coast Guard District will lead a seminar titled, "Natural Disaster Contingency," tentatively planned for the fourth quarter of Fiscal Year 2023, that will contribute to develop of this template, as the seminar will to bring together subject matter experts for three planning meetings as well as the actual seminar to develop overall objectives centered on the risk to human life from a tsunami impact on the coastal zone. In addition, to ensure location-specific plans, the workgroup will be composed of subject matter experts from Thirteenth Coast Guard District, as well as Coast Guard Sector and coastal units. The U.S. Coast Guard believes that these efforts will effectively develop a template that allows flexibility to be used across all units along the Washington and Oregon coasts.

However, it is important to note that the current Coast Guard cycle for plan development is a lengthy process, and addressing this recommendation using the seminar approach will take approximately 1.5 to 2 years, especially as seminars have three meetings (initial, mid-term, and final) plus the actual seminar, followed by a period of time to complete the final product. This length of time is predicated on identifying subject matter experts from across the District, Sector, and coastal units to ensure the template aligns with guidance, command structure, and local community evacuation plans already in place. Additionally, the estimated time reflects that Sectors and coastal units are primarily first responders for lifesaving and port, waterways and coastal safety and security, which may require directing resources away from this effort periodically. Estimated Completion Date (ECD): December 31, 2025.

<sup>1</sup> [https://media.defense.gov/2021/Mar/05/2002593952/-1/-1/0/CIM\\_3010\\_11E.PDF](https://media.defense.gov/2021/Mar/05/2002593952/-1/-1/0/CIM_3010_11E.PDF)

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**Appendix III: Comments from the Department  
of Homeland Security**

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**Recommendation 2:** Are provided with tsunami evacuation planning guidance that includes protocols for personnel and dependents.

**Response:** Concur. As CG-OEM identified the Thirteenth Coast Guard District's Preparedness Branch as responsible for the development of contingency plans and policies for all hazards responses, the previously described seminar. Design and objectives shall address that the template and subsequent plans include protocols that both active duty personnel and their dependents are evacuated to safety. Further, the workgroup will ensure that the guidance aligns with State and local evacuation plans already in place, and adheres to established civil evacuation corridors and muster sites at any disaster shelter/structure that may already exist for evacuees.

As previously noted, completion for these efforts are impacted by the current Coast Guard cycle for plan development using a seminar, as well as the competing priorities faced by Sectors and Coastal units, which are primarily first responders for lifesavings and port, waterways and coastal safety and security. ECD: December 31, 2025.

**Recommendation 3:** Assess the feasibility of their tsunami evacuation plans through regular exercises that provide participation opportunities for Coast Guard personnel and dependents.

**Response:** Concur. Once complete, evacuation plans based on the template under development by the Thirteenth Coast Guard District's Preparedness Branch shall be exercised periodically for their feasibility, and adjusted as prescribed in COMDTINST M3010.11E. Coast Guard currently anticipates completing these plans by June 2026, and scheduled exercises shall include participants, both members and dependents. ECD: December 31, 2026.

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## Text of Appendix III: Comments from the Department of Homeland Security

August 24, 2022

Heather MacLeod  
Acting Director, Homeland Security and Justice  
U.S. Government Accountability Office  
441 G Street, NW  
Washington, DC 20548

Re: Management Response to Draft Report GAO-22-105220, "COAST GUARD:  
Additional Actions Needed to Improve Tsunami Emergency Planning in the Pacific  
Northwest"

Dear Ms. MacLeod:

Thank you for the opportunity to comment on this draft report. The U.S. Department of Homeland Security (DHS) appreciates the U.S. Government Accountability Office's (GAO) work in planning and conducting its review and issuing this report.

DHS leadership is pleased to note GAO's recognition that the U.S. Coast Guard has taken steps to improve tsunami preparedness by developing contingency plans, purchasing emergency equipment, and participating in emergency response exercises. The Coast Guard is committed to making continual improvements to enhance the safety and protection of all personnel and dependents should a tsunami event occur in the Pacific Northwest region of the United States.

The draft report contained three recommendations with which the Department concurs. Enclosed find our detailed response to each recommendation. DHS previously submitted technical comments addressing several accuracy, contextual, and other issues under separate cover for GAO's consideration.

Again, thank you for the opportunity to review and comment on this draft report. Please feel free to contact me if you have any questions. We look forward to working with you again in the future.

Sincerely,  
JIM H. CRUMPACKER, CIA, CFE  
Director  
Departmental GAO-OIG Liaison Office



Enclosure

Enclosure: Management Response to Recommendations Contained in GAO-22-105220

GAO recommended that the Commandant of the U.S. Coast Guard ensure that coastal units in the Pacific Northwest:

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However, it is important to note that the current Coast Guard cycle for plan development is a lengthy process, and addressing this recommendation using the seminar approach will take approximately 1.5 to 2 years, especially as seminars have three meetings (initial, mid-term, and final) plus the actual seminar, followed by a period of time to complete the final product. This length of time is predicated on identifying subject matter experts from across the District, Sector, and coastal units to ensure the template aligns with guidance, command structure, and local community evacuation plans already in place. Additionally, the estimated time reflects that Sectors and coastal units are primarily first responders for lifesaving and port, waterways and coastal safety and security, which may require directing

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As previously noted, completion for these efforts are impacted by the current Coast Guard cycle for plan development using a seminar, as well as the competing priorities faced by Sectors and Coastal units, which are primarily first responders for lifesavings and port, waterways and coastal safety and security. ECD: December 31, 2025.

Recommendation 3: Assess the feasibility of their tsunami evacuation plans through regular exercises that provide participation opportunities for Coast Guard personnel and dependents.

Response: Concur. Once complete, evacuation plans based on the template under development by the Thirteenth Coast Guard District's Preparedness Branch shall be exercised periodically for their feasibility, and adjusted as prescribed in COMDTINST M3010.11E. Coast Guard currently anticipates completing these plans by June 2026, and scheduled exercises shall include participants, both members and dependents. ECD: December 31, 2026.

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## Appendix IV: GAO Contacts and Staff Acknowledgments

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### GAO Contact

Heather MacLeod, 202-512-8777 or [MacLeodH@gao.gov](mailto:MacLeodH@gao.gov)

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### Staff Acknowledgments

In addition to the contact above, Dawn Hoff (Assistant Director), Bruce Crise (Analyst-in-Charge), David Matthew Curtis, Dominick Dale, Michele Fejfar, Eric Hauswirth, David Hooper, Tracey King, Melissa Lefkowitz, Katrina Pekar-Carpenter, and Joshua Timko all made key contributions to this report.

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