Maritime Tsunami Response Playbooks: Background Information and Guidance for Response and Hazard Mitigation Use

By Rick Wilson[1*], Patrick Lynett[2], Kevin Miller[3], Amanda Admire[4], Aykut Ayca[2], Edward Curtis[5], Lori Dengler[4], Michael Hornick[5], Troy Nicolini[6], and Drew Peterson[6]

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Funding by the Federal Emergency Management Agency, the National Tsunami Hazard Mitigation Program, and the National Oceanic and Atmospheric Administration

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4) Humboldt State University
5) Federal Emergency Management Agency
6) NOAA, National Weather Service

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California Maritime Tsunami Playbook Work Group

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Note: CGS and CalOES provide the following information on how maritime response Playbook plans were constructed, and guidance on how to use the Playbooks during future tsunami events. Evacuation and emergency response planning for future tsunamis is the responsibility of each maritime community, and these Playbook products are intended as internal emergency response and hazard mitigation planning tools for harbor/port authorities.

Contents

Overview

California's experience during 2010 Chile and 2011 Japan tsunamis has brought to light the desire by harbor/port authorities to obtain more detailed information on the estimated hazard and impact of tsunamis well ahead of their first wave surge arrival time (Wilson et al, 2012). The main issue is that there was no formal guidance for harbor/port authorities to use for in-harbor response and offshore evacuation activities. The primary post-tsunami recommendations by harbor/port authorities were for the California Tsunami Program to provide information regarding the following: 1) harbor-specific maps and other products about in-harbor tsunami hazards (currents and wave heights) and damage potential; 2) the minimum offshore safe depth for vessels to evacuate beyond during a tsunami; and 3) guidance for each harbor which can be tailored to future tsunamis of different size and damage potential.

To address these issues, the State tsunami program worked with research partners in academia and authorities in various maritime communities to analyze the potential tsunami hazards within harbors and ports, and develop the best format for guidance to help with harbor-specific tsunami response. Lynett et al (2014) established pilot projects in five harbors/ports (Crescent City, Santa Cruz, Ventura, Ports of Los Angeles and Long Beach, and northern San Diego Bay) which verified the accuracy of numerical tsunami models being used as well as established the relationship between tsunami currents and potential damage. Lynett et al (2014) also used model data to determine the appropriate minimum offshore safe depth for boats, which is 30 fathoms (180 feet) for any distant-source tsunamis.

This information was incorporated into maritime tsunami response "Playbook" plans to help harbors/ports respond to tsunamis of different sizes and distances from the California coast. "Playbooks" provide harbor officials with tsunami-specific maps and guidance about in-harbor hazards (strong currents, eddies, damage potential, potential for docks overtopping piles) and offshore safe areas for boats. Using a sports analogy, the Playbook approach provides the best defensive response "play" (or plan) against a tsunami of a particular size and source origin location.

The California Tsunami Program works with each of the harbors and ports to formalize their response activities for each scenario. Guidance is provided for both local and distant source tsunamis. For local or regional tsunamis where the arrival time is less than four hours, specific instructions are provided for safe and rapid response, especially where evacuation of waterfront areas may be needed.

For distant source events, where the arrival time exceeds 4 hours, the State and National Weather Service (NWS) will use the wave-height forecast from the National Tsunami Warning Center to recommend that each harbor use a specific MINIMUM Tsunami Playbook Plan for response actions. Harbors officials can refer to their Playbook document to find the applicable response map and associated set of instructions for the recommended Playbook Plan. Ultimately, each maritime community is responsible for determining and implementing tsunami evacuations and response activities.

In addition to using Playbooks for tsunami response, the California Tsunami Program, FEMA, and its partners encourage maritime communities to utilize this information to help mitigate damages and loss of life from future tsunamis. These products and plans should be used by maritime communities to pre-identify real-time response mitigation measures, determine where infrastructure enhancements should be initiated, and provide a mechanism for focused, pre-disaster hazard mitigation funding through additions to their Local Hazard Mitigation Plans (see the list of potential mitigation measures below).

Although these products, plans, and related mitigation efforts will not eliminate all casualties and damages from future tsunamis, they will provide a basis for greatly reducing future tsunami impacts on life-safety, infrastructure, and recovery in California maritime communities.

Introduction

The California Geological Survey (CGS), University of Southern California (USC), and the California Governor's Office of Emergency Services (CalOES) have created maritime response guidance documents called "Playbooks" which can aid emergency response activities for tsunamis of various sizes. These maritime products are similar to the tsunami evacuation Playbooks which help community emergency managers respond to tsunamis of various inundation amounts (Wilson et al., 2014). Both the maritime tsunami response and on-land evacuation Playbook products supplement the existing state-wide inundation maps and other products, which are available on the www.tsunami.ca.gov website, identifying inundation for multiple "worst-case" scenarios (Wilson et al., 2008; Barberopoulou et al., 2009).

The Maritime Tsunami Response Playbooks are intended for government and non-government entities responsible for emergency response planning and overall safety of harbors/ports. These are groups which are part of what is referred to as the "maritime community." These entities may include:

- Non-government – harbor masters, port captains, harbor patrol
- Federal Government– NOAA, Coast Guard, other military/Dept. of Defense, US Army Corp of Engineers, U.S. Geological Survey, and Federal Emergency Management Agency
- State Government – CalOES, CGS, and Department of Boating and Waterways
- Local Government – emergency management, police/fire, lifeguard, park rangers

During the typical tsunami alert, the National Tsunami Warning Center (NTWC) provides information about the tsunami in "bulletins" to the state and local jurisdictions. These bulletins include information about the tsunami source, typically an earthquake (location, depth, magnitude), and forecasts about the impending tsunami itself (alert level, first arrival, maximum amplitudes or wave height). There are four levels of "alert" that can be sent by the NTWC (from least to greatest significance):

- **Tsunami Information Statement** - Issued to inform and update emergency managers and the public that an earthquake has occurred, or that a tsunami Watch, Advisory or Warning has been issued elsewhere in the ocean.
- **Tsunami Watch** - Issued to alert emergency managers and the public of an event which may later impact the Watch area. May be upgraded to an Advisory or Warning - or canceled - based on updated information and analysis.
- **Tsunami Advisory** - Issued due to the threat of a tsunami which may produce strong currents or waves dangerous to those in or near the water; typically called when forecasted tsunami amplitudes between 0.3m and 1m (1ft and 3ft) above existing tidal

conditions are expected. Coastal communities are advised that beach and harbor areas could expect rapid, moderate tidal changes and strong currents.

- **Tsunami Warning** - Issued when a tsunami with significant widespread inundation is imminent or expected; typically called when forecasted tsunami amplitudes are equal to or greater than 1m (3ft). Coastal communities are advised to evacuate people from low-lying areas identified as vulnerable to tsunamis.

Tsunami Advisories and Warnings are situations where coastal emergency managers and harbor masters are recommended to take action to protect lives and property, including limiting access to beaches or waterfront areas to full evacuation of the local official evacuation zone identified in their emergency response plans.

Since the devastating December 26, 2004 Indian Ocean earthquake and tsunami, there has been a significant increase in tsunami awareness and preparedness world-wide. From 2004 to 2015, California had seven tsunamis large enough to cause "Advisory" or "Warning" alert levels requiring response by ports, harbors, or marinas in the State. Table 1 shows these seven events and the effects and damaged caused by the tsunamis.

Table 1 Notable "Warning" or "Advisory" level tsunami alerts in California since 2005.

Actionable Alert Tsunami	Alert Status and Location	Tsunami Effects and Damage Costs
2005 M7.2 Northern CA	*Warning: Statewide	No notable impacts
2006 M8.3 Kuril Islands	**Informal notice to Crescent City	Damage to docks in Crescent City approached $20M
2009 M8.1 Samoa	Advisory: Statewide	No notable impacts
2010 M8.8 Chile	Advisory: Statewide	Damage to 12 harbors approached $3M
2011 M9.0 Japan	Warning: North and Central CA Advisory: South CA	One fatality; damage to 27 harbors approached $100M
2012 M7.7 British Columbia	Advisory: North CA	No notable impacts
2015 M8.3 Chile	Advisory: South CA	No notable impacts

Sources for information include: the NOAA National Centers for Environmental Information (2016) Global Historical Tsunami Database; Barberopoulou et al, 2008; Dengler et al, 2009; Wilson et al, 2012a; and Wilson, 2015.

*At the time of the 2005 event, Warning Center protocol called for "Warning" alert for areas within a 2-hour travel time of a large earthquake. This has since changed.

**At the time of the 2006 event, Warning Center protocol did not include an "Advisory" alert level, which Crescent City would have received for this event.

Table 1 shows that tsunamis classified as "Advisories" or "Warnings" can cause varying degrees of damage, especially within harbors and ports. For example, tsunami Advisories in 2009, 2012, and 2015 caused no notable damage to harbors, whereas some areas under the tsunami Advisories and Warnings of 2010 and 2011 had moderate to major damage (Wilson et al., 2012a; Wilson, 2015). Not only did relatively minor increases in tsunami size make a difference in the amount of damage, the severity of damage varied from minor to significant between harbors because of the location, layout, and age of structures within the harbors.

Overall, harbor and port officials admitted they were not adequately prepared to respond to these tsunamis. This led to a request to the State tsunami program by many harbors to develop harbor-specific information that identifies in-harbor hazards, analyzes offshore safety during the tsunami, and provides tsunami-specific guidance for response. The result was a four-year project which included: 1) verification of tsunami numerical modeling accuracy; 2) analysis of the relationship between tsunami currents and damage to harbor structures; 3) assessment of the offshore safe depth for vessels; and 4) development of harbor-specific Maritime Tsunami Response Playbooks for real-time guidance for tsunamis of various sizes.

This report summarizes the background investigations which form the foundation of the Playbooks, and the creation of the Playbooks and how they can be used in real-time. The Playbooks can also be used for table-top and field exercises to help plan response to various size tsunami events.

Maritime Tsunami Planning Work Group and Playbook Production Process

To help develop and refine these products, CGS, USC, and CalOES formed an ad-hoc "Work Group" comprised of: tsunami specialists, modelers and engineers from USC and Humboldt State University; harbor officials from Crescent City, Santa Cruz, Ventura, the Ports of Los Angeles and Long Beach, and northern San Diego Bay; the four coastal NOAA-National Weather Service (NWS) Warning Forecast Office Warning Coordination Meteorologists (WCMs) in California (Eureka, Monterey, Oxnard, and San Diego); the National Tsunami Warning Center (NTWC) Director; representatives from the Federal Emergency Management Agency; and other relevant tsunami experts. A number of meetings where held with different individuals of the Work Group from 2011 to 2015. Workshops were held in each of the pilot project harbors/ports to get feedback on the Playbooks and associated products, and improve the process for developing and using these products during future tsunamis. Dozens of presentations and meetings have been held with members of the maritime community, including the U.S. Coast Guard, U.S. Army Corps of Engineers, and various harbor safety committees. Several presentations were also made at the annual meetings of the California Harbor Master and Port Captains Association to provide updates on the project. The format and content of the final Playbook products were vetted through the California Tsunami Steering Committee comprised of representatives from all 20 coastal counties. Draft Maritime Tsunami Response Playbooks were shared with each of the at-risk harbors and ports prior to finalizing the individual Playbooks. These products were also shared with members of the U.S. National Tsunami Hazard Mitigation Program (NTHMP) to gather feedback and develop guidance for other states to create and utilize maritime response products (NOAA-NTHMP, 2015).

Maritime Hazard Analysis and Associated Products

These guidelines and the associated Playbooks have been developed based on the tsunami response and planning experience of various maritime communities, the meetings and workshops discussed in the Work Group section above, and the results of detailed tsunami hazard analysis by the State tsunami program and its partners. Demonstration projects have provided valuable analyses of and practical solutions to tsunami hazards inside harbors. Where appropriate, these demonstration projects are referenced in the guidance.

In order to determine the appropriate tsunami mapping products and guidance for use by maritime communities, the tsunami hazards and potential types of damage that can occur should be understood to the extent possible. The following are examples of tsunami hazards and potential damage related to those hazards:

- Sudden and significant water-level fluctuations can cause boats and docks to hit bottom (grounded) as water levels drop, and docks to overtop piles as water levels rise;
- Strong and unpredictable currents can occur, especially where there are narrow passages, channels or harbor openings, or other natural or man-made structures that form constrictions;
- Tsunami-induced bores, seiches, and amplified waves can cause swamping of boats and damage to docks;
- Eddies/whirlpools can cause boats to break their moorings and float uncontrolled;
- Drag on deep draught boats can cause damaging forces to the docks they are moored to;
- Free floating boats, docks, and/or debris in the water can damage structures and infrastructures in the harbor;
- Dangerous tsunami conditions which may potentially last tens of hours after first wave arrival, can cause problems for inexperienced and unprepared boaters who may try to move their boats within harbors, take their boats offshore, or reenter the harbor during a tsunami;
- Sediment movement from both erosion and deposition can create hazards to navigation; and,
- Environmental issues with debris and contaminants in the water can slow/delay recovery efforts for long periods of time.

Most of the tsunami hazard analysis work is addressed in Lynett et al (2014) and Wilson and Miller (2014), and summarized below.

Numerical model validation

To ensure the accuracy of the numerical models to capture tsunami currents, modeled current velocity results were compared to currents observed during 2010 Chile and 2011 Japan tsunamis. Much of this data was gathered by Wilson et al (2012a, b) and Admire et al (2014) using both post-tsunami observation information and video interpretation. Five pilot project areas were selected based on the availability of observed and measured tsunami current data, the unique character of the harbor/port layout, and the susceptibility of the harbors to tsunami damage: Crescent City Harbor, Santa Cruz Harbor, Ventura Harbor, Ports of Los Angeles and Long Beach, and harbors in northern San Diego Bay.

The numerical model used in this evaluation and map production process is the 'Method of Splitting Tsunami' (MOST) numerical model (Titov and Gonzalez, 1997). The MOST model has been used extensively for tsunami hazard assessments in the United States and is currently in operational tsunami forecast use at the NOAA Pacific Marine Environmental Laboratory. Variations of the MOST model have been in constant use for tsunami hazard assessments and inundation mapping in California since the mid 1990's. In addition to comparisons with observed and measured current data, the MOST results are compared to numerical model results from COULWAVE, a high-order Boussinesq-type model developed over the past decade with the particular goal of understanding rotational flow in shallow water (Kim et al., 2009; Kim and Lynett, 2011; Son et al., 2011).

To fully understand the accuracy of modeling, the resolution of the digital elevation models (DEMs) to capture the current velocities accurately was evaluated. Lynett et al (2014) statistically compared modeled tsunami data at resolutions of 90m, 30m, 10m, and 5m to "ground truth" data (observed data and 5m COULWAVE modeling) from the 2010 and 2011 tsunamis to determine the relative current model accuracy and the appropriate DEM resolution for Playbook modeling. It was demonstrated that the MOST model captured the observed and COULWAVE currents, and the relative accuracy of DEMs starts to converge between 10m and 30m resolution. It was also found that the MOST model provides current estimates that are slightly greater than COULWAVE, and that the MOST predictions are assumed to be at least "conservative" for use on the Playbooks. Therefore, project partners agreed that the DEMs of at least 10m resolution will be used to capture details within enclosed harbors and ports, and that 30m resolution data could be used in open-water harbors in absence of 10m resolution data.

In 2015, a currents benchmarking workshop was held to address the adequacy of tsunami models to capture current velocities (NOAA-NTHMP, in press). This evaluation was accomplished by comparing model results to real tsunami velocity data from controlled wave-tank experiments, ADCP data, and video interpretation. Preliminary findings imply that models proposed for use by NOAA and NTHMP members were similar in their ability to identify areas of high currents, especially where jetting and eddies occur. However, the deficiencies of the models to capture currents in the areas where eddies form and are expected to migrate were a common problem. Guidance being developed by the NTHMP Mapping and Modeling Subcommittee (NTHMP, 2015) recommends that this issue might be addressed by: 1) running multiple models and combining the results to capture the maximum current velocities; 2) binning modeled current velocities into numerical categories related to damage potential, to reduce the reliance on the absolute accuracy of the velocity values; and/or, 3) identifying and encircling the areas where eddies are expected to be generated and migrate. Because MOST model results appear to be conservative compared to the higher order COULWAVE model (Lynett et al., 2014), the California project partners determined that binning modeled currents and encircling areas of eddy formation and movement would work best for the Maritime Tsunami Response Playbooks.

Relationship between tsunami currents and harbor damage

The data collected from the 2010 and 2011 tsunamis (Wilson et al., 2012a,b; Admire, 2014) was augmented by additional observations found in Lynett et al. (2012) and Borrero et al. (2013) to help understand the relationship between strong tsunami currents and harbor damage (Lynett et al., 2014). Typically, damage observations are accompanied by eyewitness estimates of the local current speed; however the accuracy of these estimates varies greatly, from low confidence estimates taken from distances greater than 10m from the water to those taken at or in the water by experienced boat captains. Furthermore, instrumental measurements of currents in the vicinity of damaged structures are rare, leaving select few datasets appropriate for model validation. However, with comparison to these measured field datasets in conjunction with experimental benchmarking, Lynett et al (2014) were able to use modeling tools to realistically estimate currents in ports and harbors.

To connect current speed with damage state, Lynett et al (2014) divided the damage state in to six indices, from no damage to complete damage (Figure 1). While the damage type and resulting index is subjective, a review of the observed types of damage suggests that these categories provide a reasonably complete coverage of tsunami impacts in harbors. Based on this damage categorization, Lynett et al (2014) plotted current speed versus damage index (Figure 1).

Damage Index:	Damage Type:
5	Complete destruction
4	Major dock/boat damage, large vessels off moorings
3	Moderate dock/boat damage, mid-sized vessels off moorings
2	1-2 docks/small boats damaged, large buoys moved
1	Small buoys moved
0	No damage

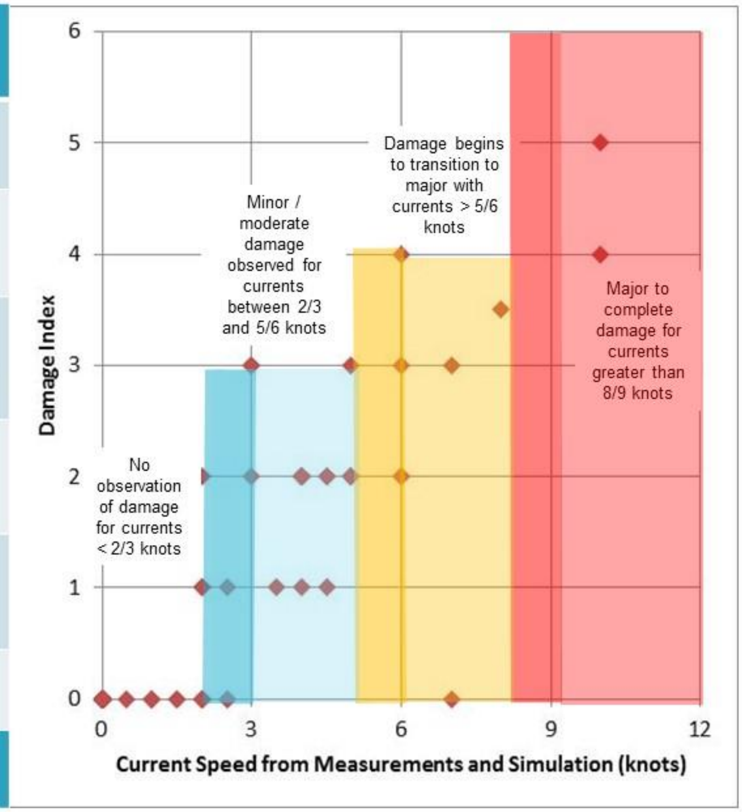

Figure 1 Graphic showing the relationship between strong tsunami currents and damage in a number of harbors and real events. The red points represent damage-current data from past events and tsunami modeling (modified from Lynett et al, 2014).

Although damage in harbors might vary based on the age and location of docks and boats, some generalities about the relationship between tsunami currents and damage were determined (Lynett et al, 2014). As expected, Figure 1 shows a general trend of increasing damage with increasing current speed. In this data, there is a noticeable threshold for damage initiation at ~3 knots (1.5 m/s). When 3 knots is exceeded, the predicted damage switches from no-damage to minor-to-moderate damage. Thus, in the simulated data, 3 knots represents the first important current velocity boundary. The second threshold where damage transitions from moderate to major occurs around 6 knots (3m/s). A third current speed threshold is less clear, but is logically around 9 knots (4.5 m/s), where damage levels move to the extreme damage category. Although it would be beneficial to have additional damage observations with correlated current speeds to better define these thresholds, these results are similar to the results from Suppasri et al (2014) and Muhari et al (2015) which evaluated post-2011 tsunami harbor and vessel damage in Japan. Therefore, in addition to encircling areas of potential eddy formation and movement, these three current divisions are used to categorize potential damage levels in the Maritime Tsunami Response Playbooks, as shown in the example for Ventura Harbor in Figure 2.

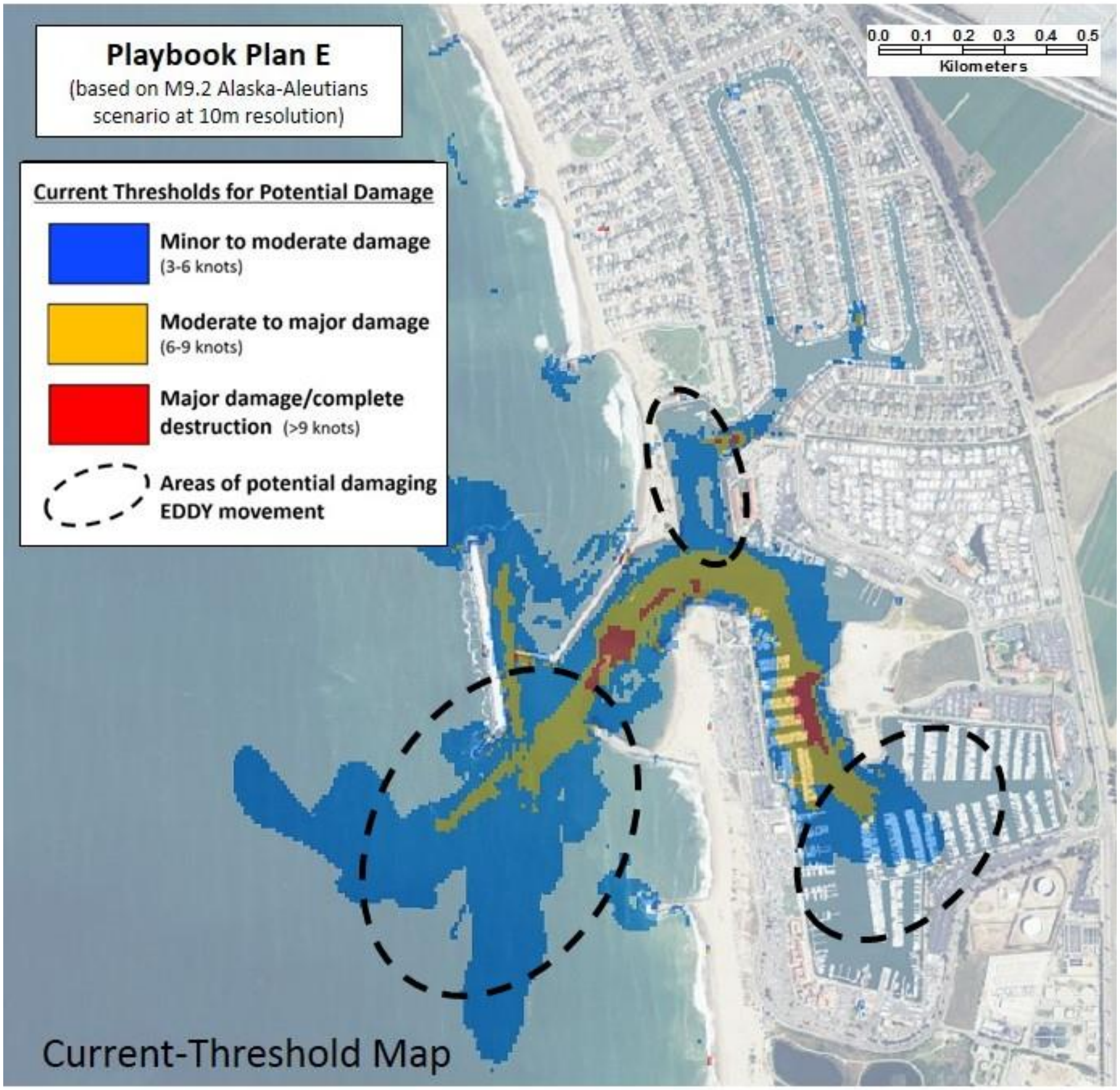

Figure 2 Tsunami current-threshold map for Ventura harbor. Colors represent potential current-damage bins and circles represent areas of tsunami eddy generation and movement.

Identification of timeframe for damaging currents

The duration of strong, damaging tsunami currents is of great importance to harbor masters and emergency managers for tsunami planning and response activities to enhance public safety for mariners as well as for vessel captains who may put out to sea. Kim and Whitmore (2013) demonstrated that tsunami signal duration can be estimated from maximum amplitude at locations, though the range of uncertainty is large. Lynett et al. (2014) captured the envelope of wave heights and current velocities decay in numerical models run for a 60-hour tsunami period at the five pilot project sites. Although the authors found little phase correlation between model results and measured data, this extended tsunami modeling information is nonetheless useful and can provide a general timeline of activity for specific strong currents. Therefore, this modeling information is included in the Maritime Tsunami Response Playbooks to indicate the “time threshold” for strong damaging currents, which equate to the velocity-damage bins for currents of 3-6 knots, 6-9 knots, and greater than 9 knots. Figure 3 shows the tsunami time-threshold information for the current-threshold bins in Figure 2 for Ventura Harbor.

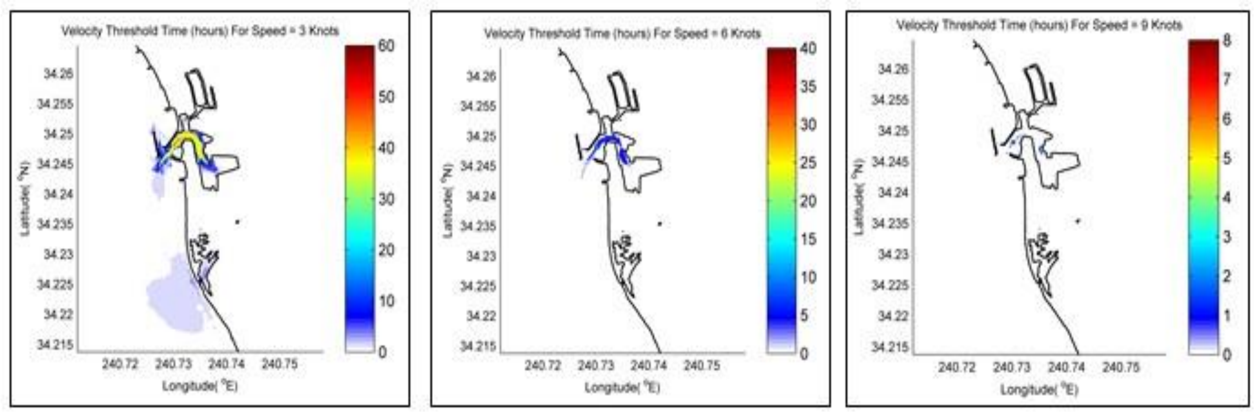

Figure 3 Tsunami current time-threshold maps for Ventura Harbor modeled currents shown in Figure 2. The color scales indicate the number of hours certain velocities could be active.

Analysis of pile overtopping using FASTER approach

Sudden large fluctuations in water levels during a tsunami can lead to a variety of hazards inside harbors. As the water level shallows, the keel of boats can be damaged by impact with the seafloor or may become stuck in muddy bottom sediment or debris. Vessels moored alongside docks and piers can torque and break mooring lines and/or collide with the docks themselves and cause damage. Boats can also float onto the top of docks and piers and docks could overtop piles if water levels rise suddenly. Relocating ships during an active tsunami is not recommended as large drops in water level could create very shallow conditions in navigation channels.

To address the issue of local flooding or floating docks overtopping piles, the State tsunami program developed an approach to calculate these flood conditions known as the “FA-S-T-E-R” method (Wilson and Miller, 2014). FASTER is an acronym that includes the following variables for calculating the most conservative, yet accurate run-up and flood elevation that the tsunami could reach at a particular location:

- **FA = <u>Forecasted Amplitude</u>** (wave heights) calculated and provided by the National Tsunami Warning Center during the first hours after a tsunami is generated;
- **S = <u>Storm</u>** surge or existing ocean conditions, predicted by the regional NOAA Weather Forecast Offices;
- **T =** Maximum **<u>Tidal</u>** height first 5 hours of tsunami, obtained from NOAA tidal forecast data;
- **E** = Forecast modeling **<u>Error</u>** potential, which has been calculated to be 30% of the forecast amplitude based on analysis of past events (Whitmore, 2003; Wilson et al., 2012a); and,
- **R =** Site-specific amplified **<u>Run-up</u>** potential, calculated from existing State tsunami modeling results.

Any other non-storm, non-tidal predicted anomalies will also be incorporated into the FASTER calculation. For most distant source tsunami events, the FASTER elevation value can be calculated for each maritime community prior to the arrival of tsunami. Figure 4 provides an illustration of how the FASTER water elevation value might be utilized in real-time to determine whether or not water level will be high enough for docks to overtop piles.

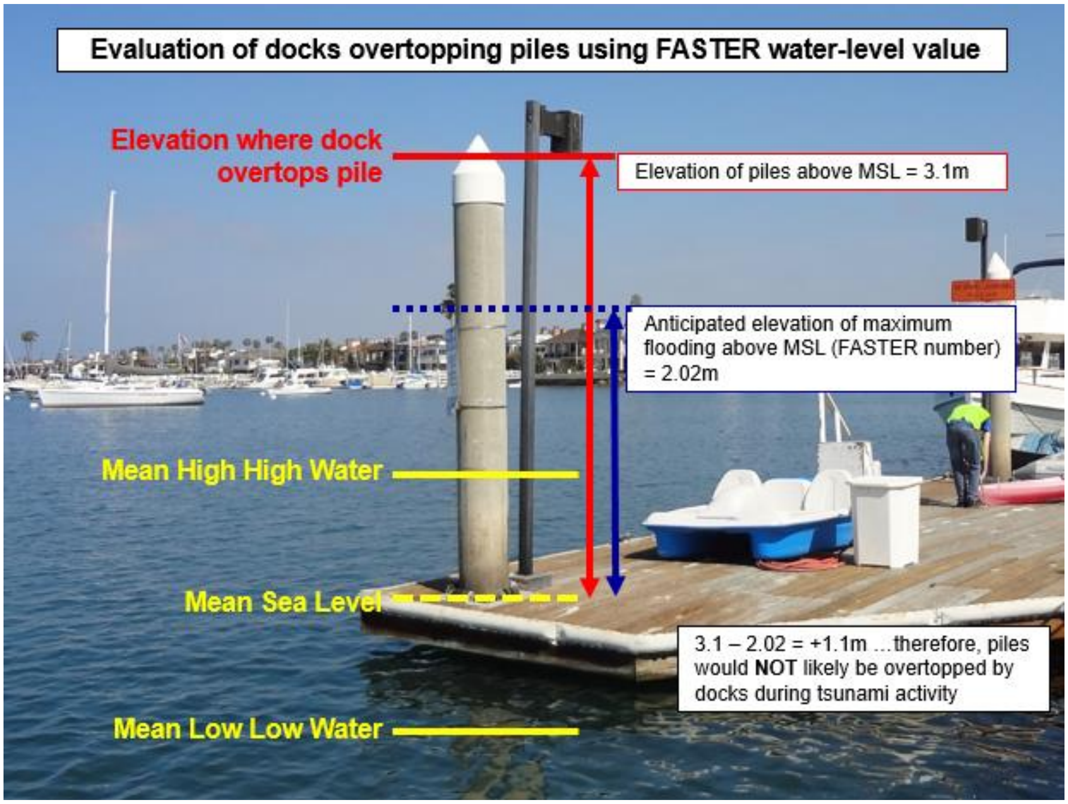

Figure 4 FASTER water-level value or elevation considers tsunami amplitude, tidal height, and storm surge level. It represents the potential maximum flood elevation during tsunami activity (different than tsunami amplitude by itself). The FASTER number can be compared to the absolute pile height to help determine if docks will overtop piles or tsunami flooding will inundate dry land around harbor (photo: Rick Wilson).

Evaluation of minimum offshore safe depth for boats

The general recommendation by the State tsunami program is that boat owners and ship captains should NOT be on their boats during a tsunami. However, if mariners have little options for getting to safety, are experienced boat handlers, and are prepared to remain at sea for up to a 24-hour period, they may attempt to take their vessel out of the harbor and transit offshore. In the event of a distant-source tsunami where there is sufficient time to safely move or evacuate vessels from a harbor, or in the event where vessels are already at sea during a local or distant source event, a “safe minimum depth” is needed.

There are a number of conditions that should be met in order for a depth to be recommended as "safe." Such conditions include no chance of vessel grounding, negligible wave steepness, and navigable currents. From observations of tsunami induced coastal currents in previous events, the dominant challenges to coastal navigation are due to both strong currents and currents that are rapidly changing. Whether or not there is enough time to reach a designated safe depth is a crucial decision trigger point for whether or not vessels should attempt to evacuate out to sea at all.

The general recommendation from NOAA has been to travel beyond a depth of 100 fathoms (600 feet). This guidance is generally considered to be overly conservative and, along some coastal locations, unrealistic. Analysis by Lynett et al (2014) at the five pilot harbors indicate that a 30 fathom (180 foot) depth is reasonable along the Pacific coast of North America following generation of a tsunami at a distant source. Figure 5 shows depth versus current velocity from the modeling results in Crescent City. Large variations in the possible maximum current exist to a depth of approximately 25 fathoms (150 feet), indicating that this is the greatest depth that large eddies or jets might extend to. Beyond 30 fathoms, currents are generally straight line, below the 3 knot (1.5 m/s) damage threshold discussed previously, and, therefore, should be navigable. The 30-fathom value has been verified by similar studies in the State of Oregon; however Oregon's work also indicated that if ships are already at sea during a local-source tsunami, they should travel beyond 100 fathoms to be safe from damaging currents. From this work, the California Tsunami Steering Committee established guidance of a minimum safe depth of greater than 30 fathoms for local-source tsunamis, and 100 fathoms for ships at sea during a local-source tsunami.

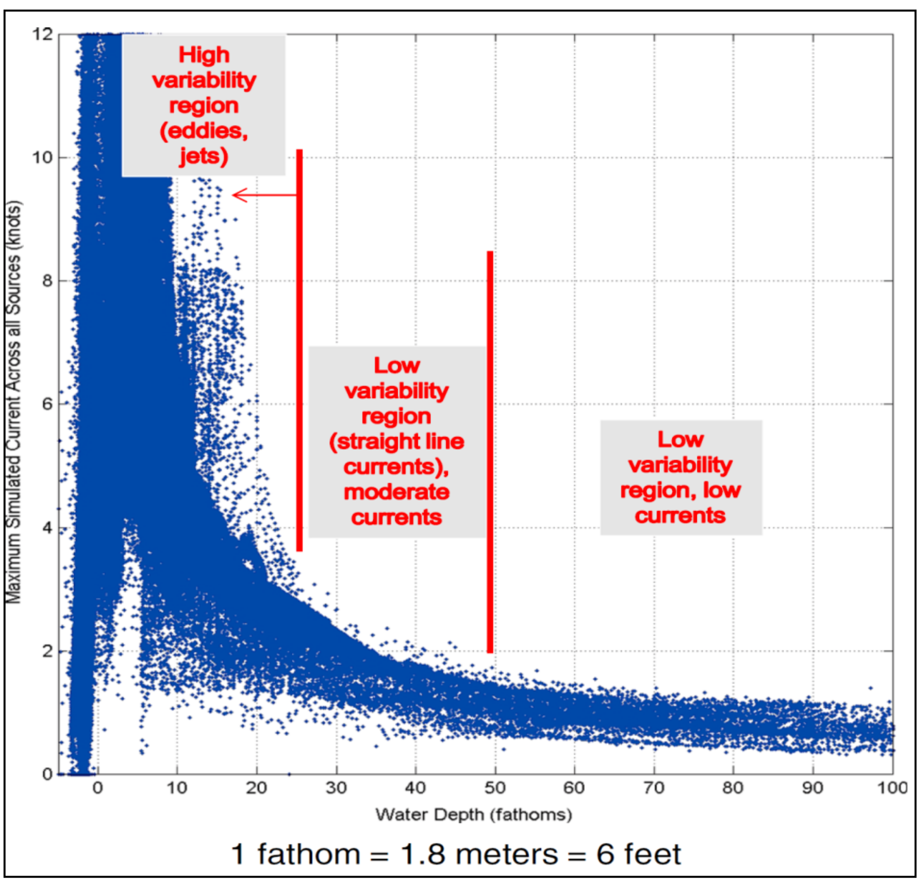

Figure 5 Scatter plot of maximum modeled current velocity versus water depth at Crescent City Harbor (Lynett et al, 2014).

Maritime Tsunami Response Playbooks

Based on feedback from maritime officials and the fact that damage from the 2010 and 2011 tsunamis varied statewide (Wilson et al, 2012a), harbor- and port-specific guidance will be more beneficial for tsunami response than general guidance, as it will better address:

- The characteristics unique to each harbor/port, especially size and layout related in relation to potential tsunami hazards;
- The harbor response to tsunamis of varying sizes and source locations; and,
- Identification of potential hazardous and non-hazardous areas within each harbor.

For this reason, Maritime Tsunami Response Playbooks have been completed for all ports, harbors, and marinas along the California coast susceptible to tsunami damage; the Playbooks and their areas of coverage are listed in Table 2. The response plans in the Playbooks should only be used if there is sufficient time for strengthening harbor infrastructure and relocating vessels. Playbooks are also consistent with the maritime product guidance developed by the NOAA-NTHMP (2015). These planning documents are essential to helping maritime officials assess the hazard for their harbor and develop appropriate response/mitigation strategies for their constituencies.

Appendix A provides an example of these Playbooks from Ventura Harbor. The Playbooks contain the following harbor-specific information: 1) actionable tsunami alert information; 2) notable historical tsunamis; 3) tsunami hazard potential maps based on current velocities and areas of eddy generation and movement; 4) recommendations on minimum safe depths for offshore evacuation; 5) tsunami evacuation maps/plans; and 6) real-time and permanent mitigation measures.

Playbook documents are 20-pages long and contain tsunami current and eddy hazard maps for five to six different scenarios that can be used for planning. The multi-scenario Playbook planning strategy relies on the direct relationship between tsunami amplitude and tsunami currents in harbors. Harbor-specific information helps harbor officials develop detailed response plans for these multiple scenarios in the Advisory to Warning-level range. Harbor officials can develop an action plan for each scenario and then reference the appropriate plan during future tsunamis.

To use the Playbooks in real-time, it is anticipated that once the National Tsunami Warning Center provides a forecast of tsunami wave height (amplitude), which may take one to three hours to calculate after the tsunami is first generated, the State and NOAA-NWS will determine and recommend the appropriate “minimum” Playbook Plan for each harbor to use. Because the process is completely automated, recommendations on the Plans should be immediate and verification should only take a few minutes. The State/NWS is making the recommendation on minimum response to help simplify the decision making process for each harbor.

The Playbook Plan recommendations will be directly shared with maritime officials via multiple (redundant) communication methods: emails, password-protected websites, etc. The State and NWS will provide further real-time support through conference calls, individual phone calls and other avenues to make sure the maritime officials understand what this recommendation means.

Recommendations will only be shared directly with harbor officials and not the public. The reasoning is that local harbor officials and emergency managers ultimately decide on and are responsible for all tsunami response activities. Each community will determine if and how to use and share the appropriate response plan and activities with their public.

Table 2 Maritime Tsunami Response Playbook for tsunami prone harbors in California.

Playbook Number	**County(s)**	**Notable Ports, Harbors, and Marinas Covered by Playbook**
2015-DN-01	Del Norte	Crescent City Harbor
2015-Humb-01	Humboldt	Woodley Island Marina; other port/marinas in Humboldt Bay
2015-Mendo-01	Mendocino	Noyo Harbor; Dolphin Isle Marina
2015-Son-01	Sonoma	Spud Point Marina; other marinas in Bodega Bay
2015-Mar-01	Marin	Richardson Bay Marina; Clipper Yacht Harbor; Sausalito Yacht Harbor; Schoonmaker Marina; other marinas in Richardson Bay
2015-CC-01	Contra Costa	Port of Richmond; other harbors/marinas around the Port
2015-Alam-01	Alameda	Port of Oakland; other harbors/marinas around Alameda Island and near Oakland
2015-Alam-02	Alameda	Berkeley Marina; Emeryville City Marina; Emery Cove Marina
2015-SF-01	San Francisco	Port of San Francisco; piers/marinas in northern San Francisco
2015-SF-02	San Francisco	Port of San Francisco; piers/marinas in eastern San Francisco
2015-SM-01	San Mateo	Pillar Point Harbor
2015-SC-01	Santa Cruz	Santa Cruz Harbor
2015-Mont-01	Monterey	Monterey Harbor
2015-Mont-02	Monterey	Moss Landing Harbor
2015-SLO-01	San Luis Obispo	Morro Bay Marina; other marinas within Morro Bay
2015-SB-01	Santa Barbara	Santa Barbara Harbor
2015-Vent-01	Ventura	Ventura Harbor
2015-Vent-02	Ventura	Channel Island Harbor
2015-Vent-03	Ventura	Port Hueneme
2015-LA-01	Los Angeles	Port of Los Angeles; other marinas within the Port
2015-LA-02	Los Angeles	Port of Long Beach; other marinas within the Port
2015-LA-03	Los Angeles	King Harbor (Redondo Beach)
2015-LA-04	Los Angeles	Multiple marinas/harbors in Marina Del Rey
2015-LA-05	Los Angeles	Alamitos Bay Marina; other marinas within Alamitos Bay
2015-LA-06	Los Angeles	Avalon Harbor (Catalina Island)
2015-LA-07	Los Angeles	Two Harbors (Catalina Island)
2015-OC-01	Orange	Seal Beach Naval Base; Huntington Harbor; other marinas within Anaheim Bay
2015-OC-02	Orange	Multiple marinas/harbors in Newport Bay
2015-OC-03	Orange	Multiple marinas in Dana Point Harbor
2015-SD-01	San Diego	Multiple marinas/harbors in northern San Diego Bay
2015-SD-02	San Diego	Multiple marinas/harbors in southern San Diego Bay
2015-SD-03	San Diego	Multiple marinas/harbors in Mission Bay
2015-SD-04	San Diego	Oceanside Harbor; Marine Corps Base Camp Pendleton Harbor

Guidance for Use: Maritime Playbooks as Response Tool

"Playbooks" provide harbor officials with tsunami-specific maps and guidance about in-harbor hazards (strong currents, eddies, damage potential, potential for docks overtopping piles) and offshore safe areas for boats (beyond a depth of 30 fathoms/180 feet for distant source tsunamis). The State tsunami program works with each of the harbors and ports to formalize their response activities for each scenario in their Playbook document. The appendix contains a draft example of one of these Maritime Response Playbooks for the Ventura Harbor.

Before being used, harbor officials and response personnel need to become familiar with the Playbook maps and information. Certainly the tools described in this document must be approved, vetted, well understood, and then incorporated into local response and evacuation plans for testing in advance of application during a tsunami in real-time. Harbor officials should fill out the needed response plans and activities for each of the individual Playbook plan scenarios PRIOR to using the Playbook guidance document in an emergency. This step is very important so that the Playbook evacuation plans are tailored for each local maritime community. Misuse of these products could expose the emergency personnel and the public to life-threatening conditions by misunderstanding and miscalculating the tsunami hazard. Simulations and exercises using these materials will improve the effectiveness of evacuation activities and help ensure that emergency response is done correctly and conservatively.

Guidance is provided for both local and distant source tsunamis. For local or regional tsunamis where the arrival time is less than four hours, specific instructions are provided for safe and rapid response, especially where evacuation of waterfront areas is needed. This information is provided on page 5 of the Playbook document for each harbor (see appendix for example Playbook document).

For distant source events, where the arrival time exceeds 4 hours, the State and NOAA will use the wave-height forecast from the Warning Center to recommend that each harbor use a specific MINIMUM Tsunami Playbook Plan of response actions, such as the example provided for Santa Cruz Harbor (top left in Figure 6). Harbor officials can refer to their Playbook document (top right in Figure 6) to find the applicable response map and associated set of instructions for the recommended Playbook Plan (bottom in Figure 6). Ultimately, each maritime community is responsible for determining and implementing tsunami evacuations and response actions.

The following is a step-by-step summary on how to use the Playbook information when a tsunami alert for a community is generated. The steps discussed are simplified and directly related to the use of forecast tsunami amplitude and the Playbooks, and do not include many other response actions or activities for the harbor or port. **NOTE: It is very important for harbor officials to coordinate with appropriate city/county emergency managers to determine if evacuation of waterfront areas is needed**:

1. **"Quick" and "expanded" reference pages**: For use during an emergency, there are two different pages with directions which can be referenced dependent on the experience of the user. For emergency managers and harbor officials sufficiently familiar with the maritime Playbooks and this approach, the user can follow the instructions on the "Expanded

Reference" sheet. For those less familiar looking for a more simplified and direct approach, the user should follow the "Quick Reference" sheet.

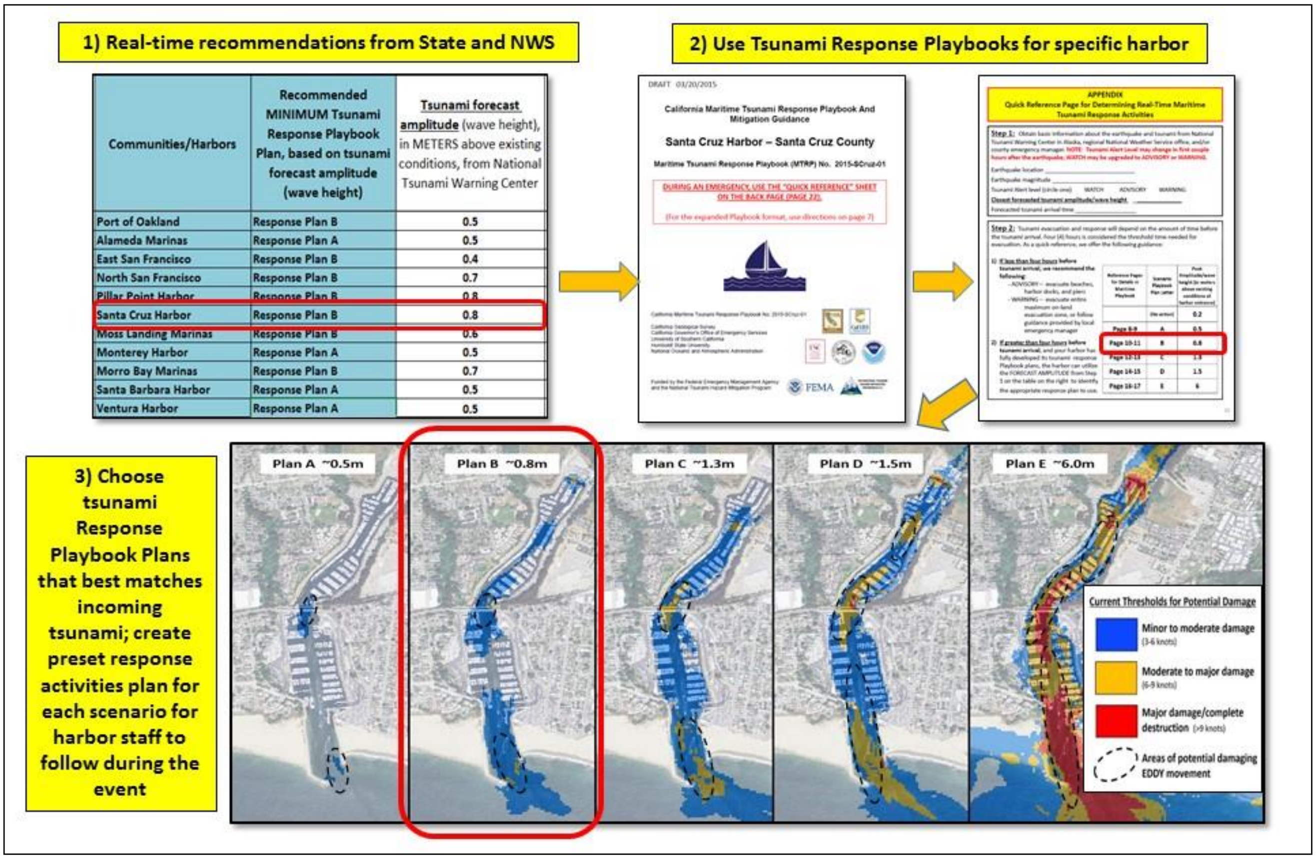

Figure 6 Diagram illustrates the three simplified steps from receiving the real-time Playbook recommendation to finding the appropriate Playbook plan to use during a tsunami (example from Santa Cruz Harbor).

2. **<u>Gather pertinent information on the potential tsunami event:</u>** Using the appropriate reference sheet, the first step is to gather information about the event. When the NTWC alert message is generated, coastal communities should determine what the tsunami "forecast" is for their jurisdiction. If a "Watch," "Advisory," or "Warning" alert level is forecasted for your area, review the rest of the alert message for information on the event (time of the earthquake, epicenter location, earthquake magnitude, and depth) and potential forecast information for your coastal area (tsunami arrival time and amplitude/wave height).

3. **<u>If the potential tsunami arrival time is less than 4 hours, actions must be taken immediately:</u>**
    a. If a large earthquake is felt along the coast, evacuation of coastal populations to high ground or inland should be immediate. The public should evacuate the maximum evacuation zone and should be rigorously educated as to where the boundaries of this zone are located.
    b. If the tsunami is generated by a large earthquake on a regional source (Cascadia for central and southern California) or an Alaska/Aleutian Islands source (>M8.5) where there are 4 hours or less before arrival, follow the recommendations provided with the NTWC Information Statement and/or the general response guidance on page 5 of

the Playbook for "Advisories" or "Warnings," depending on what is designated by the NTWC.

4. **<u>If the forecasted tsunami arrival time is more than 4 hours, acquire information on the appropriate "minimum" tsunami response Playbook plan recommended by the State/NWS for the harbor in question:</u>** As illustrated in Figure 6, the State and/or NWS will provide a recommendation for which Maritime Response Playbook plan should be used at a minimum. Harbor officials can always follow more significant plans if they wish. The State/NWS recommendation will be based on maximum forecasted tsunami amplitude provided by the NTWC. This forecast will be made approximately one to three hours after the tsunami is generated (e.g. the earthquake).

   The FASTER tsunami flood elevation number will also be provided to each harbor. As previously discussed, the FASTER number can be used to determine if the tsunami will be large enough to cause docks to overtop harbor pilings.

During a real event, resources will be available for community emergency managers to consult with state and federal experts on how the Playbook approach and FASTER number can be used to determine the appropriate tsunami response plan and activities. If a Warning alert is forecasted and there is uncertainty in using the Playbook plan document or the FASTER approach, it is recommended that coastal communities evacuate to their maximum evacuation line.

Use of Playbooks and Other Information for Tsunami Mitigation/Harbor Improvements

The State program encourages maritime communities to utilize all tsunami hazard map information within the Maritime Response Playbooks to help mitigate damages and loss of life from tsunamis. These products and plans should be used by maritime communities to pre-identify real-time response mitigation measures, determine where infrastructure enhancements are needed, and identify pre-disaster hazard mitigation funding through additions to their Local Hazard Mitigation Plans (see the list of potential mitigation measures in Table 3). Although these products, plans, and related mitigation efforts will not eliminate all casualties and damages from future tsunamis, they will provide a basis for greatly reducing future tsunami impacts on life-safety, infrastructure, and recovery in maritime communities. Therefore, we recommend the following steps/actions:

1. Review the maps within the maritime guidance documents to identify where strong currents and other tsunami hazards could potentially damage docks, structures, and/or infrastructure, especially where aging or run-down facilities exist.
2. Review the mitigation measures below for both real-time response actions, or "soft" mitigation, or permanent measures, or "hard" mitigation.
3. Incorporate these measures/actions into the community Local Hazard Mitigation Plan, and work with the community, the tsunami program of the state/territory/commonwealth, and/or FEMA to develop a strategy to request funding to implement these improvements.

Table 3 Potential harbor soft and hard mitigation measures for tsunami hazards.

Mitigation Measures for Reducing Impacts in Maritime Communities	
Real-time response ("soft") mitigation measures	**Permanent ("hard") mitigation measures**
Reposition ships within harbor	Increase size and stability of dock piles
Move boats and ships out of harbors	Fortify and armor breakwaters
Remove small boats/assets from water	Improve flotation portions of docks
Shut down infrastructure before tsunami arrives	Increase flexibility of interconnected docks
Evacuate public/vehicles from water-front areas	Improve movement along dock/pile connections
Restrict boats from moving during tsunami	Increase height of piles to prevent overtopping
Prevent boats from entering harbor during event	Deepen/Dredge channels near high hazard zones
Secure boat/ship moorings	Move docks/assets away from high hazard zones
Personal flotation devices/vests for harbor staff	Widen size of harbor entrance to prevent jetting
Remove hazardous materials away from water	Reduce exposure of petroleum/chemical facilities
Remove buoyant assets away from water	Strengthen boat/ship moorings
Stage emergency equipment outside affected area	Construct flood gates
Activate Mutual Aid System as necessary	Prevent uplift of wharfs by stabilizing platform
Activate of Incident Command at evacuation sites	Install debris deflection booms to protect docks
Alert key first responders at local level	Ensure harbor structures are tsunami resistant
Restrict traffic entering harbor; aid traffic evacuating	Construct breakwaters further away from harbor
Identify/Assign rescue, survey, and salvage personnel	Install Tsunami Warning Signs
Identify boat owners/live-aboards; establish phone tree, or other notification process	Identify equipment/assets (patrol/tug/fire boats, cranes, etc.) to assist response activities

The State program and its partners are also working on additional products to help harbors mitigate tsunami damage. Site-specific Harbor Improvement Reports are being provided to determine where infrastructure enhancements could be initiated, and a mechanism for pre-disaster hazard mitigation funding through additions to their Local Hazard Mitigation Plans and other grant/loan sources. The following types of analyses can be completed for individual harbors and summarized in the report:

- **Failure Potential Curves** will help identify areas of potential failure of cleats, pile guides, single point moorings, and other harbor structures during large tsunamis.
- **Pile Height and Vessel Grounding Analysis** will help determine if docks could overtop piles or keels of large ships could be grounded because of large water-level fluctuations during significant tsunami activity.
- **Sediment and Debris Movement Analysis** visualizes where sediment accumulation and scour will occur, where debris will be generated and travel, and if dredging can help reduce these hazards.
- **Multi-Hazard Evaluation** considers if and where other coastal hazards, such as El Nino storm flooding or long-term sea-level rise, could also impact harbor structures and infrastructures.
- **Cost-Benefit Assessments** will demonstrate how pre-disaster harbor improvements can greatly reduce post-tsunami damage and recovery costs and time.

The State program is working with several harbors on the content and applicability of these products and should start completing reports for the first harbors in 2016.

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APPENDIX – Example Maritime Tsunami Response Playbook

NOTE: This example Playbook is only a draft and does not represent the final Maritime Tsunami Response Playbook for Ventura Harbor. The page numbers in the lower right corner (starting on the next page) and the discussion of page numbers in the Playbook text correspond to the pages within the Playbook, not the overall document.

DRAFT 06/16/2015

California Maritime Tsunami Response Playbook And Mitigation Guidance

Ventura Harbor – Ventura County

Maritime Tsunami Response Playbook (MTRP) No. 2015-Vent-01

DURING AN EMERGENCY, USE THE "QUICK REFERENCE" SHEET ON THE BACK PAGE (PAGE 22).

(For the expanded Playbook format, use directions on page 7)

California Maritime Tsunami Response Playbook No. 2015-Vent-01

California Geological Survey
California Governor's Office of Emergency Services
University of Southern California
Humboldt State University
National Oceanic and Atmospheric Administration

Funded by the Federal Emergency Management Agency and the National Tsunami Hazard Mitigation Program

Table of Contents – Tsunami Response Plan Playbooks

DURING AN EMERGENCY, USE THE "QUICK REFERENCE" ON PAGE 22 FOR GATHERING INFORMATION FOR RESPONSE ACTIVITIES.

PURPOSE: This Maritime Tsunami Response Playbook Guidance document will help members of the maritime community prepare, plan, and respond to strong currents and damage from future tsunamis. It has been developed with assistance from the maritime communities by the California Tsunami Program and principle funding from FEMA. **It is essential that harbor staff become familiar with this Playbook guidance document before use.** The information within the Playbook can also help the harbor develop and implement tsunami mitigation strategies through their Local Hazard Mitigation Plan, and receive potential mitigation funding if needed.

USE: This Playbook is primarily designed to help the maritime communities with tsunami response activities by providing detailed information about potential tsunami scenarios which can be used during an event.

Once this Playbook guidance document is received, **maritime communities should review the document and develop response plans for each of the scenarios in the Playbook**. The California Tsunami Program will work with the maritime communities to assist in developing these plans if requested. **Maritime communities should exercise the Playbook approach** on a regular basis to ensure it is understood by all emergency responders so that the plan works during an emergency.

When a tsunami is occurring, follow the steps outlined in either the Quick Reference guideline on the last page (Page 22) if the user is not as familiar with the Playbooks, or the Expanded Reference guideline on Page 7 if the user wants more detailed information. The harbormaster or emergency manager should **fill out information about the source earthquake and tsunami;** this information can be obtained from multiple sources, including the tsunami alert message from the National Tsunami Warning Center (NTWC) in Alaska, the city or county emergency manager, and/or the National Weather Service, Local Weather Forecast Office. Keep in mind that this information can change during the first hour or two after the earthquake occurs. **Compare the tsunami forecast amplitude (wave height) to the maximum tsunami amplitude on the scenario table on Page 7 or 22**. Choose the scenario (Pages 8-17) which best matches the forecast information. Follow the instructions on the page for that scenario. Each scenario Playbook may be accompanied by a digital file indicating the response and evacuation plans; this can be shared during an emergency with emergency responders in the field.

MITIGATION PLANNING

In addition to using these Playbooks for tsunami response, the California Tsunami Program, FEMA, and its partners encourage maritime communities to utilize this information to help mitigate damages and loss of life from future tsunamis. These products and plans should be used by maritime communities to pre-identify real-time response mitigation measures, determine where infrastructure enhancements should be initiated, and provide a mechanism for pre-disaster hazard mitigation funding through additions to their Local Hazard Mitigation Plans (see the list of potential mitigation measures below). Although these products, plans, and related mitigation efforts will not eliminate all casualties and damages from future tsunamis, they will provide a basis for greatly reducing future tsunami impacts on life-safety, infrastructure, and recovery in California maritime communities. Therefore, we recommend the following steps/actions:

1. **Review the maps within this Playbook guidance document to identify where strong currents could potentially damage docks, structures, and/or infrastructure, especially where aging or run-down facilities exist.**
2. **Review the Mitigation Measures below for both real-time response actions, or "soft" mitigation, or permanent measures, or "hard" mitigation.**
3. **Incorporate these measures/actions into the community Local Hazard Mitigation Plan, and work with the community, the state tsunami program, and/or FEMA to develop a strategy to request funding to implement these improvements.**

Mitigation Measures for Reducing Impacts in Maritime Communities

Real-time response ("soft") mitigation measures	Permanent ("hard") mitigation measures
Reposition ships within harbor	Increase size and stability of dock piles
Move boats and ships out of harbors	Fortify and armor breakwaters
Remove small boats/assets from water	Improve flotation portions of docks
Shut down infrastructure before tsunami arrives	Increase flexibility of interconnected docks
Evacuate public/vehicles from water-front areas	Improve movement along dock/pile connections
Restrict boats from moving during tsunami	Increase height of piles to prevent overtopping
Prevent boats from entering harbor during event	Deepen/Dredge channels near high hazard zones
Secure boat/ship moorings	Move docks/assets away from high hazard zones
Personal flotation devices/vests for harbor staff	Widen size of harbor entrance to prevent jetting
Remove hazardous materials away from water	Reduce exposure of petroleum/chemical facilities
Remove buoyant assets away from water	Strengthen boat/ship moorings
Stage emergency equipment outside affected area	Construct flood gates
Activate Mutual Aid System as necessary	Prevent uplift of wharfs by stabilizing platform
Activate of Incident Command at evacuation sites	Install debris deflection booms to protect docks
Alert key first responders at local level	Ensure harbor structures are tsunami resistant
Restrict traffic entering harbor; aid traffic evacuating	Construct breakwaters further away from harbor
Identify/Assign rescue, survey, and salvage personnel	Install Tsunami Warning Signs
Identify boat owners/live-aboards; establish phone tree, or other notification process	Identify equipment/assets (patrol/tug/fire boats, cranes, etc.) to assist response activities

3

There are a number of **TSUNAMI HAZARDS** that could directly affect boats/boaters:

- Sudden water-level fluctuations where docks and boats:
  - Hit bottom (grounded) as water level drops
  - Could overtop piles as water level rises
- Strong and unpredictable currents, especially where there are narrow entrances, narrow openings, and other narrow parts of harbor
- Tsunami bores and amplified waves resulting in swamping of boats and damage to docks
- Eddies/whirlpools causing boats to lose control
- Drag on deep draught boats causing damaging forces to the docks they are moored to
- Collision with other boats, docks, and debris in the water
- Dangerous tsunami conditions can last tens of hours after first wave arrival, causing problems for inexperienced and unprepared boaters who take their boats offshore

Tsunami Alert Bulletins: During tsunami alerts, the National Tsunami Warning Center provides information about the tsunami in "bulletins" to the state and local jurisdictions. There are four levels of "alert" that can be sent by the NTWC (from least to greatest significance; http://ntwc.arh.noaa.gov/):

Tsunami Information Statement - Issued to inform and update emergency managers and the public that an earthquake has occurred, or that a tsunami Watch, Advisory or Warning has been issued elsewhere in the ocean.

Tsunami Watch - Issued to alert emergency managers and the public of an event which may later impact the Watch area coastline. May be upgraded to an Advisory or Warning - or canceled - based on updated information and analysis.

Tsunami Advisory - Issued due to the threat of a tsunami which may produce strong currents or waves dangerous to those in or near the water; typically called when forecasted tsunami amplitudes are between 0.3m and 1m (1ft and 3ft) above existing tidal conditions are expected. Coastal communities are advised that beach and harbor areas could expect rapid, moderate tidal changes and strong currents.

Tsunami Warning - Issued when a tsunami with significant widespread inundation is imminent or expected; typically called when forecasted tsunami amplitudes are equal to or greater than 1m (3ft). Coastal communities are advised to evacuate people from low-lying areas identified as vulnerable to tsunamis.

ACTIONABLE TSUNAMI ALERT LEVELS

Tsunami **Advisories** and **Warnings** are the two actionable Alert levels for maritime communities.

Actions taken will depend on the Alert level and the forecasted tsunami wave height or amplitude for a particular harbor. For both Advisory and Warning level events, it is important that clear and consistent directions are provided to the entire boating community and waterfront or pier businesses.

If there is not sufficient time to use the Playbooks, consider the following general actions for your maritime communities for either Advisory or Warning level events:

GENERAL "WARNING" LEVEL RECOMMENDATIONS

All activities below should be completed no later than 30 minutes before forecasted tsunami arrival.

- Advise facility maintenance to shut off fuel to fuel docks, and all electrical and water services to all docks.
- Secure and strengthen all mooring lines throughout harbor, specifically areas near the entrance or narrow constrictions.
- Evacuate the public and harbor personnel from all structures and vessels in the water, as well as all land-ward areas identified in the mapped tsunami evacuation area (last page).
- Do not allow public to re-enter tsunami evacuation area until an official "all clear" message is provided by local emergency managers.
- Follow instructions for an Advisory if Warning is downgraded to Advisory level.

GENERAL "ADVISORY" LEVEL RECOMMENDATIONS

All activities below should be completed no later than 30 minutes before forecasted tsunami arrival.

- Advise facility maintenance to shut off fuel to fuel docks, and all electrical and water services to all docks.
- Secure and strengthen all mooring lines throughout harbor, specifically areas near the entrance or narrow constrictions.
- Evacuate the public from all structures and vessels in the water.
- Coordinate with local law enforcement to limit access of public along waterfront areas.
- While the tsunami is active, all personnel working on or near the water should wear personal flotation devices.
- Do not allow public to re-enter structures and vessels in the water until and official "all clear" message is provided by local emergency managers.

DIFFERENCE BETWEEN FORECAST TSUNAMI AMPLITUDE/WAVE HEIGHT AND FASTER TSUNAMI FLOOD HEIGHT

Forecast Tsunami Amplitude/Wave Height: Within the first couple hours after an earthquake and the generation of a tsunami, the National Tsunami Warning Center will provide an estimate, or forecast, of the potential amplitude/wave height of the tsunami for over 50 locations along the California coast. This amplitude is the height of the tsunami above existing ocean conditions and helps determine the official Tsunami Alert level for each region. **For the purposes of the Playbook, the forecast tsunami amplitude is used on the page 7 or 22 "Response Reference" to determine which Maritime Playbook Response Plan is appropriate to use.**

FASTER Analytical Tool: To determine the full impact of tsunami inundation, other variables such as tidal and storm conditions must be considered. An analytical method has been created which incorporates important variables that will impact the ultimate tsunami flood level. The simplified components of the calculation are shown to the right. **The FASTER calculation, which will be provided by the local jurisdiction or the regional NOAA NWS Weather Forecast Office to the harbor during a tsunami event, is used on Page 7 to determine if piles will be overtopped and inundation of dry land will occur.**

Working example: Formula for determining playbook evacuation line to use (FA-S-T-E-R):

FA: Forecasted Amplitude (Wave Height) from Warning Center

+

S: Storm surge or existing ocean conditions

+

T: Maximum tidal height (first 5 hours of tsunami)

+

E: Forecast error potential (30%; analysis of 2010-11 events)

+

R: Site amplified run-up potential (from existing modeling, unique to each location; applied if inundation expected)

= **Maximum tsunami run-up height**

= **Playbook elevation line**

RELATIONSHIP BETWEEN TSUNAMI CURRENT SPEED AND HARBOR DAMAGE: Analysis of recent tsunami damage indicates a relationship between current speed and harbor damage. The Damage Index (from Lynett and others, 2013) to the right has been used to determine the following relationship (see color codes here for blue, yellow, and red areas and on current threshold maps):

CURRENTS = DAMAGE

0-3 knots = No Damage

3-6 knots = Minor/Moderate Damage

6-9 knots = Moderate/Major Damage

>9 knots = Major/Complete Damage

Damage Index:	Damage Type:
0	no damage
1	small buoys moved
2	1-2 docks/small boats damaged, large buoys moved
3	Moderate dock/boat damage, mid-sized vessels off moorings
4	Major dock/boat damage, large vessels off moorings
5	Complete destruction

Expanded Reference Information for Determining Real-Time Maritime Response Activities

NOTE: It is important to review all sections of this Playbook prior to using it during a tsunami emergency. When a tsunami alert is issued by the National Tsunami Warning Center, fill out the Expanded Reference page below under Step 1. The State/NOAA will recommend a MINIMUM Playbook Response Plan for each maritime communities, and a FASTER number to determine the potential for piles to be overtopped during the tsunami.

Step 1: Obtain information about earthquake and tsunami from **National Tsunami Warning Center** in Alaska, regional NOAA-Weather Forecast Office, and/or county and state emergency managers. (e.g. www.tsunami.gov)

Earthquake location ___________________________

Earthquake magnitude _________________________

Tsunami Alert level (circle one) WATCH ADVISORY WARNING

Forecasted tsunami amplitude/wave height _____________ (this will be compared with Peak Amplitude in Step 2)

Forecasted tsunami arrival time __________________

Calculate/obtain FASTER tsunami run-up value in first 5 hours: _______

Calculate/obtain FASTER tsunami run-up value at highest tide _______

Height of shortest pilings above Mean Sea Level: _______________

Elevation of lowest land above Mean Sea Level: _________________

Compare FASTER value to pile heights and lowest land to determine if they will be overtopped.

Step 2:: Compare and match forecasted tsunami amplitude/wave height in Step 1 to "Peak Amplitude" in the table below (red box). Refer to associated Playbook page to determine actions for securing vessels and/or repositioning ships away from areas of expected damage to safe areas within the bay or offshore (Pg. 20).

Reference Pages for Details in Maritime Playbook	Scenario Playbook Plan Letter	Historical Events and Modeled Scenarios	Earthquake Magnitude and Source Location	Peak Amplitude near Harbor (in meters, above existing conditions at harbor mouth)	Likely Tsunami Alert level	Tidal condition (during first 5hrs)	Peak Velocity from Modeling (in knots)	Damage Summary
	(No action)	2009	8.0 Samoa	~0.3	Advisory	High	-	Buoys moved
Page 8-9	A	Modeled Scenario	9.0 Cascadia	0.6	Advisory	High	4	-
Page 10-11	B	2010	8.8 Chile	0.8	Advisory	Low	7	$300-500k damage to docks in the Keys
Page 12-13	C	2011	9.0 Japan	0.9	Advisory	Low	8	$150k damage to docks/boats
Page 14-15	D	Modeled Scenario	9.4 Chile	1.5	Warning	High	10	-
Page 16-17	E	Modeled Scenario	9.2 Aleutians	3.2	Warning	High	>15	-

Playbook Plan A

(based on M9 Cascadia Scenario)

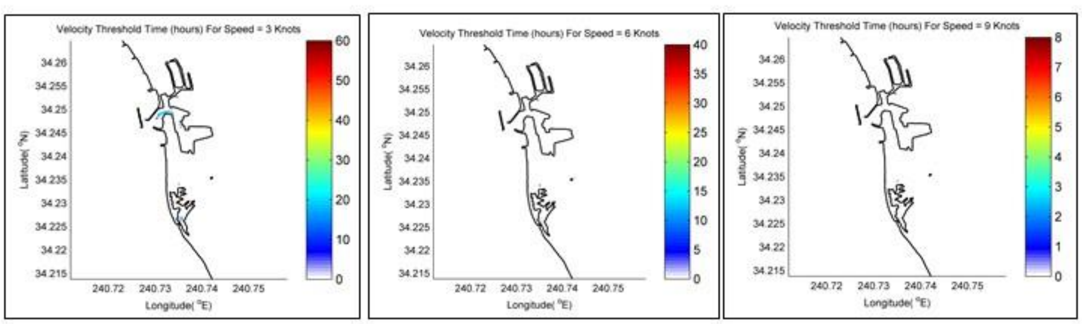
<u>Background Information:</u>
Alert level = Advisory
Peak Amplitude = 0.6 meters
Peak Velocity = 4 knots
Projected duration of strong currents (see location map below):
3-6 knots = 10 hrs; 6-9 knots = 0 hrs; >9 knots = 0 hrs

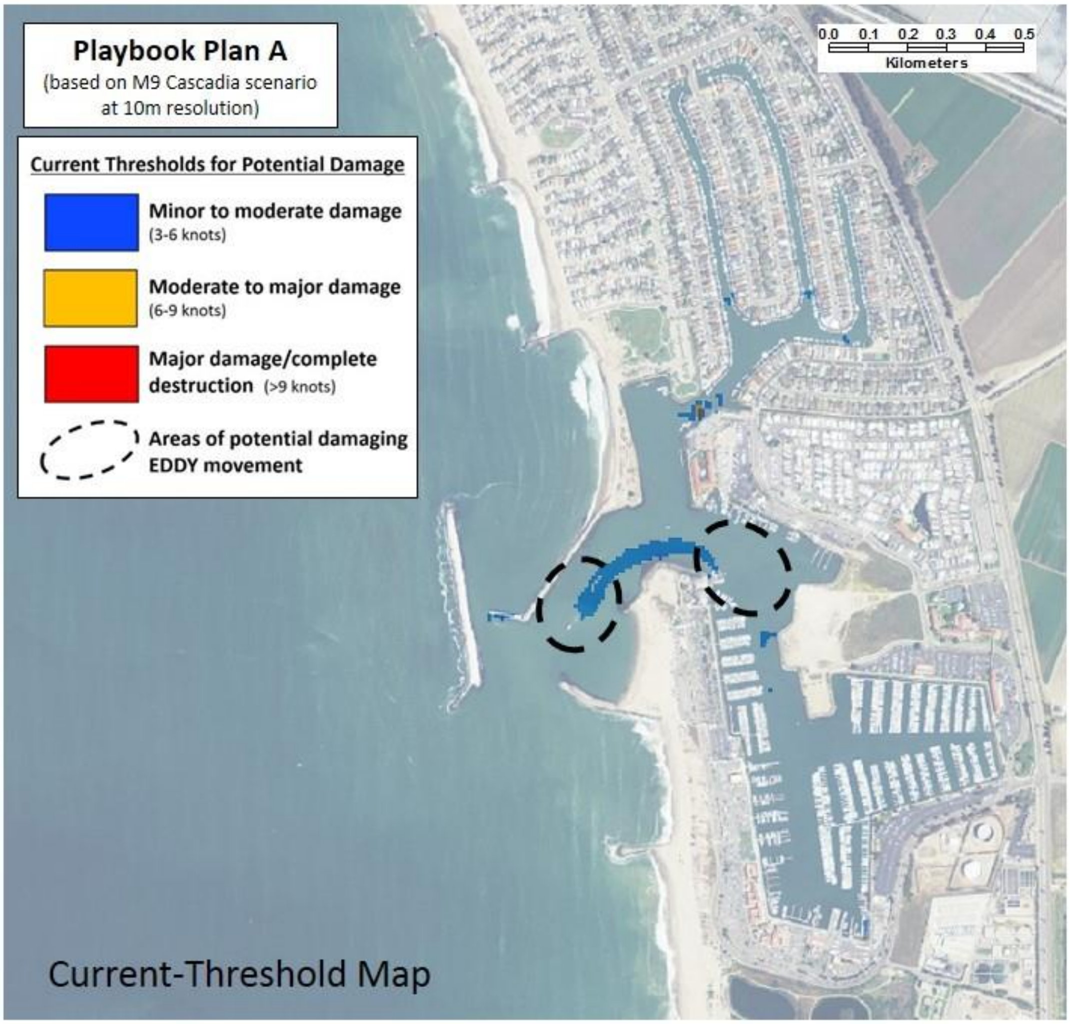
<u>Specific Instructions:</u>

- Follow general guidance for Advisory-level tsunamis (Page 5)
- Strong currents and potential scour are expected in areas identified in blue on the map to the right. Consider relocating vessels located within 100 meters (300 feet) of these areas.
- Specific areas where vessels should be relocated and docks secured:
  - Vessels can be moved to non-blue areas the southern portion of the harbor.
  - .... (completed with maritime community input)

<u>Safe areas for repositioning vessels within Ventura Harbor:</u>
..... (completed with maritime community input)

Time thresholds for currents >3 knots.......................>6 knots.....................................>9 knots
(Colors below represent HOURS of potential activity for blue, yellow, and red zones on opposite page)





Playbook Plan A
(based on M9 Cascadia scenario at 10m resolution)
Current Thresholds for Potential Damage
Minor to moderate damage (3-6 knots)
Moderate to major damage (6-9 knots)
Major damage/complete destruction (>9 knots)
Areas of potential damaging EDDY movement
0.0 0.1 0.2 0.3 0.4 0.5
Kilometers
Current-Threshold Map

Playbook Plan B

(based on 2010 M8.8 Chile Event)

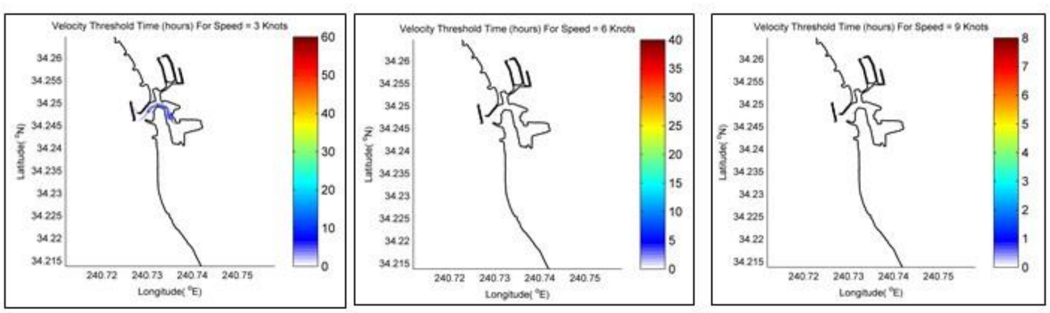
<u>Background Information:</u>
Alert level = Advisory
Peak Amplitude =0.8 meters
Peak Velocity = 7 knots
Projected duration of strong currents (see location map below):
3 knots = 10 hrs; 6 knots = 3 hrs; 9 knots = 0 hrs

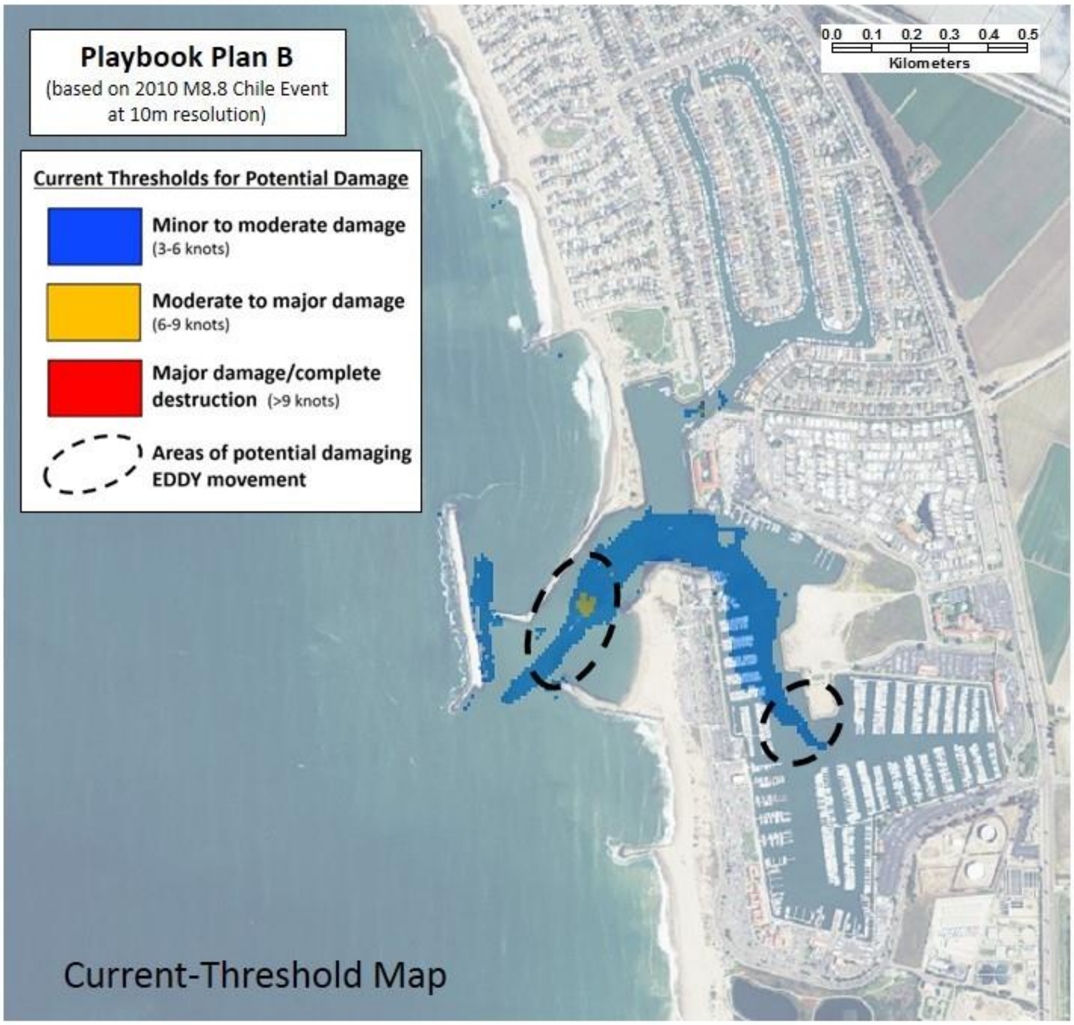
<u>Specific Instructions:</u>

- Follow general guidance for Advisory-level tsunamis (Page 5)
- Strong currents and potential scour are expected in areas identified in blue on the map to the right. Consider relocating vessels located within 100 meters (300 feet) of these areas.
- Specific areas where vessels should be relocated and docks secured:
    - Vessels can be moved to non-blue areas the southern portion of the harbor.
    - ..... (completed with maritime community input)

<u>Safe areas for repositioning vessels within Ventura Harbor:</u>
..... (completed with maritime community input)

Time thresholds for currents >3 knots.......................>6 knots......................................>9 knots
(Colors below represent HOURS of potential activity for blue, yellow, and red zones on opposite page)




Playbook Plan B
(based on 2010 M8.8 Chile Event
at 10m resolution)
Current Thresholds for Potential Damage
Minor to moderate damage
(3-6 knots)
Moderate to major damage
(6-9 knots)
Major damage/complete
destruction (>9 knots)
Areas of potential damaging
EDDY movement
0.0 0.1 0.2 0.3 0.4 0.5
Kilometers
Current-Threshold Map

Playbook Plan C

(based on 2011 M9 Japan Event)

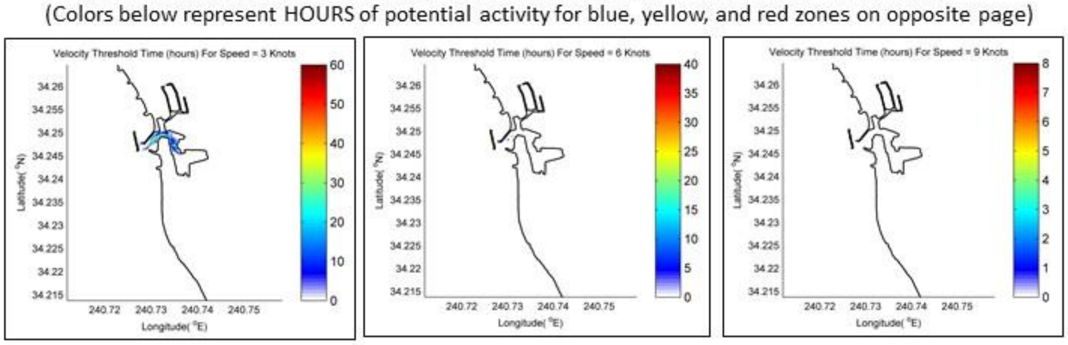
Background Information:
Alert level = Advisory
Peak Amplitude = 0.9 meters
Peak Velocity = 7 knots
Projected duration of strong currents (see location map below):
3-6 knots = 30 hrs; 6-9 knots = 10 hrs; >9 knots = 0 hrs

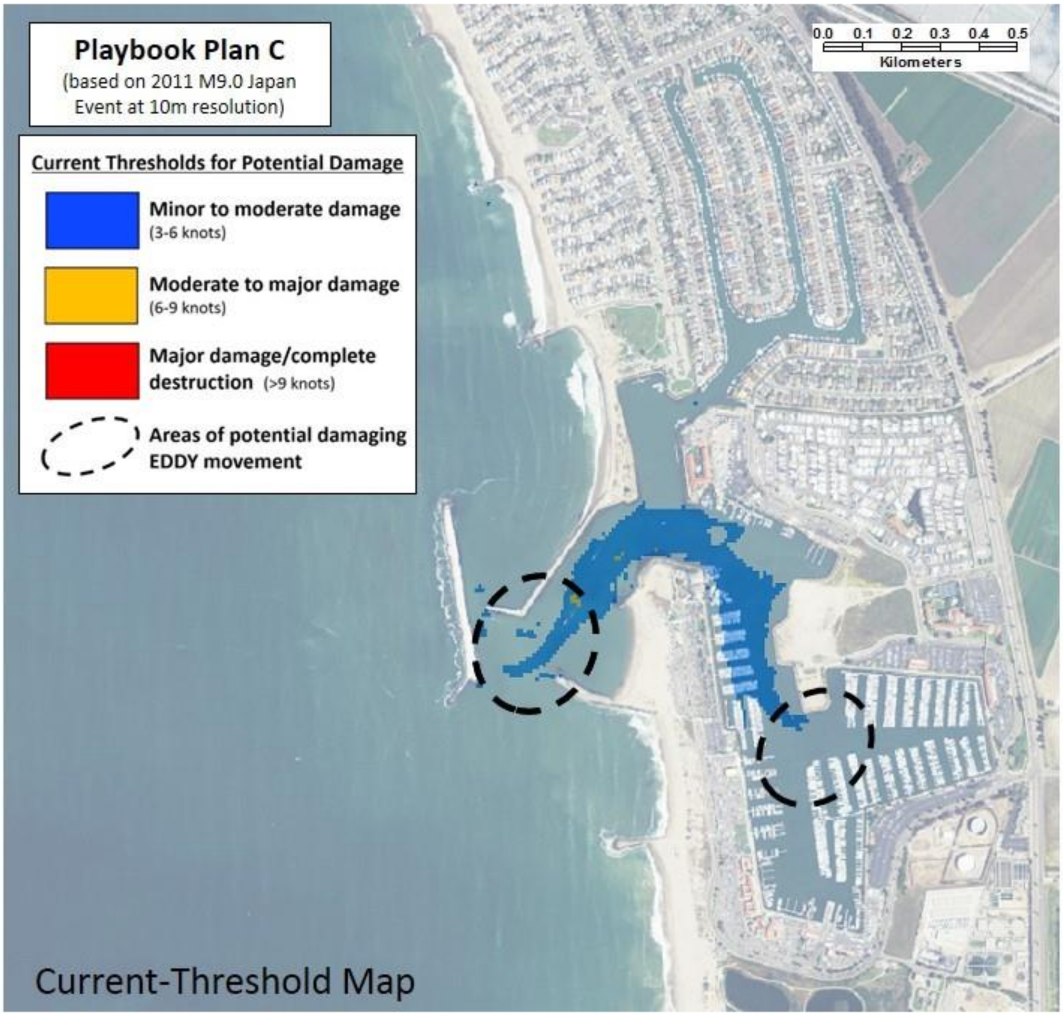
Specific Instructions:

- Follow general guidance for Advisory-level tsunamis (Page 5)
- Strong currents and potential scour are expected in areas identified in blue and gold on the map to the right. Consider relocating vessels located within 100 meters (300 feet) of these areas.
- Specific areas where vessels should be relocated from and docks secured:
    - Vessels can be moved to non-blue areas the southern portion of the harbor.
    - ...... (completed with maritime community input)

Safe areas for repositioning vessels within Ventura Harbor:
.....(completed with maritime community input)

Time thresholds for currents >3 knots......................>6 knots.....................................>9 knots
(Colors below represent HOURS of potential activity for blue, yellow, and red zones on opposite page)




Playbook Plan C
(based on 2011 M9.0 Japan Event at 10m resolution)
Current Thresholds for Potential Damage
Minor to moderate damage (3-6 knots)
Moderate to major damage (6-9 knots)
Major damage/complete destruction (>9 knots)
Areas of potential damaging EDDY movement
0.0 0.1 0.2 0.3 0.4 0.5
Kilometers
Current-Threshold Map

Playbook Plan D

(based on M9.4 Chile North Scenario)

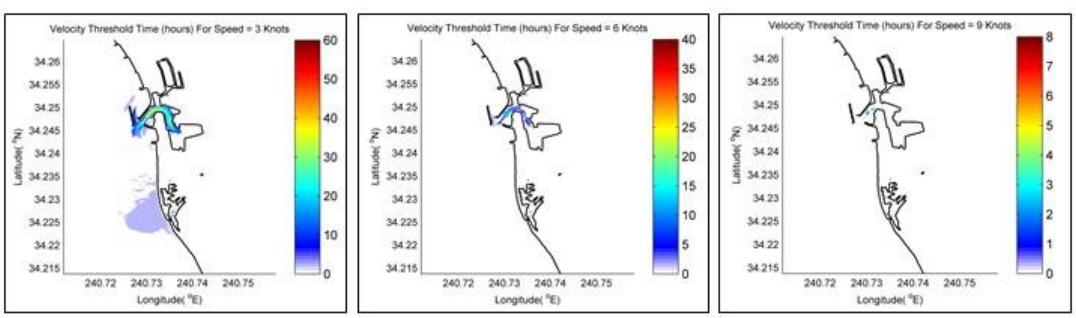
Background Information:
Alert level = Warning
Peak Amplitude = 1.5 meters
Peak Velocity = 10 knots
Projected duration of strong currents (see location map below):
3-6 knots = 40 hrs; 6-9 knots = 15 hrs; >9 knots = 3 hrs

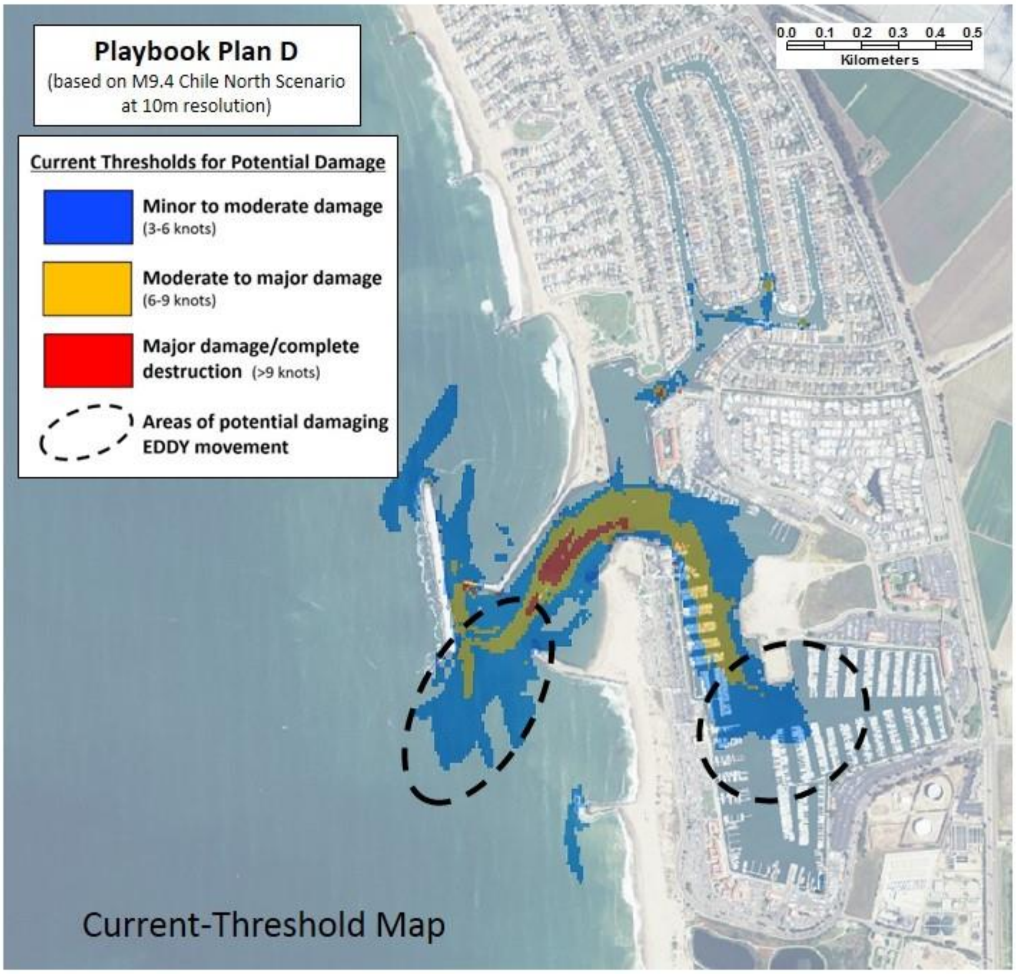
Specific Instructions:

- Follow general guidance for Warning-level tsunamis (Page 5)
- **Inundation of dry land could occur in this scenario**
- Strong currents and potential scour are expected in areas identified in blue and gold on the map to the right. Consider relocating vessels located within 100 meters (300 feet) of these areas.
- Specific areas where vessels should be relocated from and docks secured:
    - Vessels can be moved to non-blue areas the southern portion of the harbor.
    - ...... (completed with maritime community input)

Safe areas for repositioning vessels within Ventura Harbor:
.....(completed with maritime community input)

Time thresholds for currents >3 knots.......................>6 knots......................................>9 knots
(Colors below represent HOURS of potential activity for blue, yellow, and red zones on opposite page)





Playbook Plan D
(based on M9.4 Chile North Scenario at 10m resolution)
Current Thresholds for Potential Damage
Minor to moderate damage (3-6 knots)
Moderate to major damage (6-9 knots)
Major damage/complete destruction (>9 knots)
Areas of potential damaging EDDY movement
0.0 0.1 0.2 0.3 0.4 0.5
Kilometers
Current-Threshold Map

Playbook Plan E

(based on M9.2 Eastern Aleutian-Alaska Scenario)

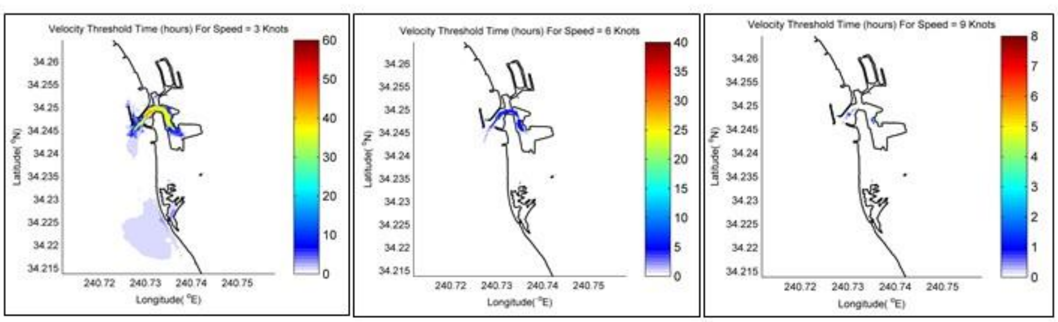
Background Information:
Alert level = Warning
Peak Amplitude = 3.2 meters
Peak Velocity = 15+ knots
Projected duration of strong currents (see location maps below):
3-6 knots = 50 hrs; 6-9 knots = 20 hrs; >9 knots = 5 hrs

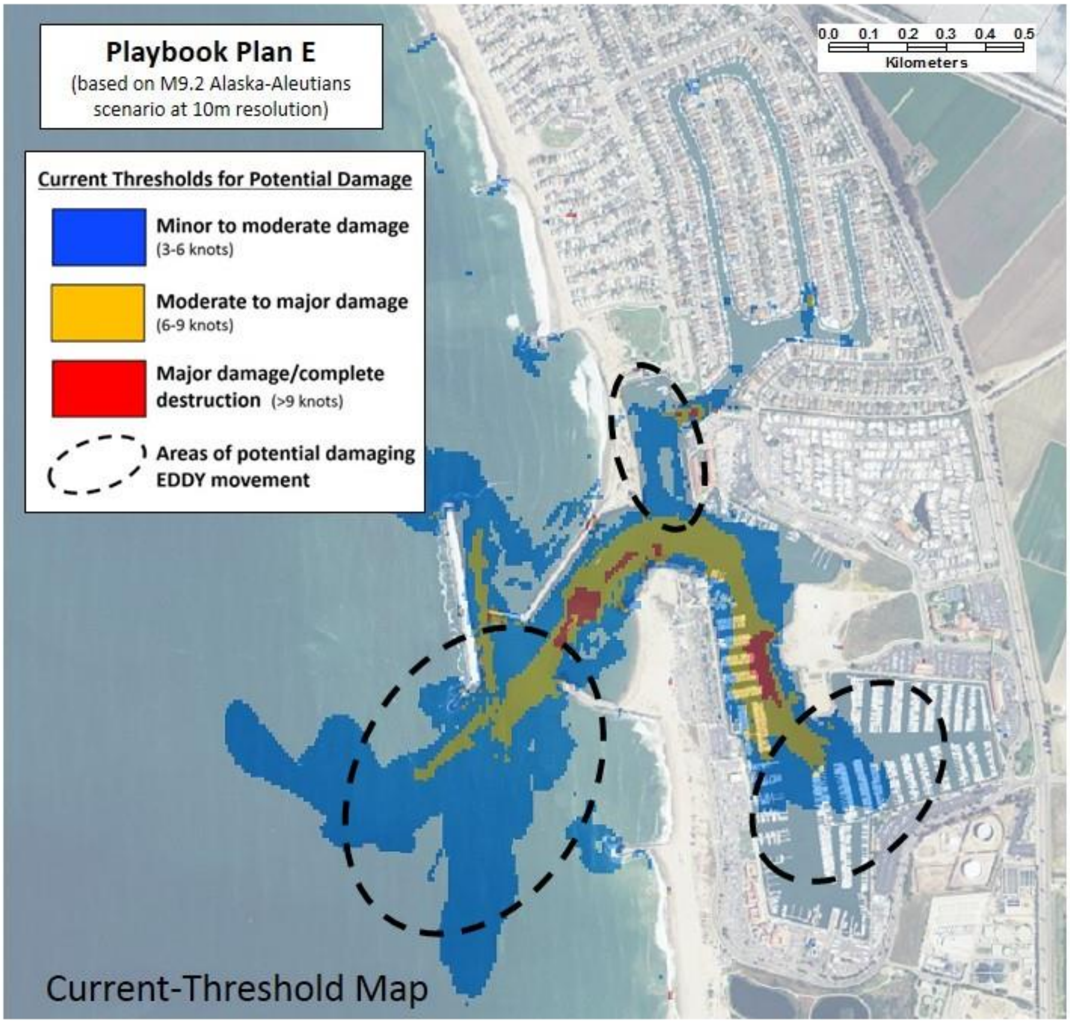
Specific Instructions:

- Follow general guidance for Warning-level tsunamis (Page 5)
- **Inundation of dry land will likely occur in this scenario**
- Strong currents and potential scour are expected in areas identified in blue – yellow-red on the map to the right. Consider relocating vessels located within 100 meters (300 feet) of these areas.
- Specific areas where vessels should be relocated from and docks secured:
  - NONE (completed with maritime community input)

Safe areas for repositioning vessels within Ventura Harbor: NONE
(completed with maritime community input)

Time thresholds for currents >3 knots……………………>6 knots…………………………………>9 knots
(Colors below represent HOURS of potential activity for blue, yellow, and red zones on opposite page)




Playbook Plan E
(based on M9.2 Alaska-Aleutians scenario at 10m resolution)
Current Thresholds for Potential Damage
Minor to moderate damage (3-6 knots)
Moderate to major damage (6-9 knots)
Major damage/complete destruction (>9 knots)
Areas of potential damaging EDDY movement
0.0 0.1 0.2 0.3 0.4 0.5
Kilometers
Current-Threshold Map

Notable Historical Tsunamis: The following table provides very basic information about historical tsunami events; not all tsunamis are represented, especially minor or small tsunamis. Note that the largest, most damaging tsunamis in Ventura County history have come from large earthquakes in the Alaska-Aleutian Islands and Chile regions as distant tsunami sources and a potential submarine landslide as a local source. Although the potential for local tsunamis exists, they are much less frequent than distant source tsunamis.

Notable Historical Tsunamis in Ventura County

Run-up amplitude, in feet, above normal tide conditions

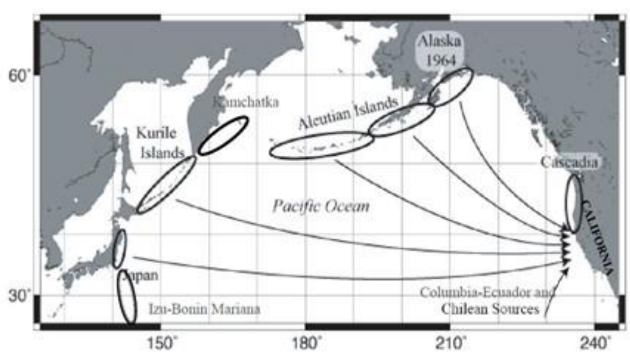
OBS = observed tsunami activity

NR = No damage or severe conditions reported

- Distant Source - Tsunamis without felt earthquakes

- Local Source - Earthquake and tsunami together

Date	Magnitude-Source area	Tsunami location	Run-Up/Amp	Remarks
12/21/1812	Local M7 earthquake triggered potential submarine landslide	Ventura	7 ft	Tsunami damage to San Miguelito Chapel
4/1/1946	M8.8 – Aleutian Islands	Ventura	OBS	Single wave to the high-water mark
		Port Hueneme	3 ft	Minor berthing problem for ship
		Ormond Beach	5ft	Sand swept over railroad tracks near beach
11/4/1952	M9.0 - Kamchatka	Port Hueneme	2 ft	NR
3/9/1957	M8.6 - Aleutian Islands	Port Hueneme	2 ft	High run-up occurred 6 hours after first wave
3/28/1964	M9.2 Alaska	Ventura	OBS	Tide dropped eight feet
		Oxnard	OBS	Large swells reported
9/29/2009	M8.0 – Samoa	Ventura	OBS	Several buoys moved near mouth of harbor
2/27/2010	M8.8 – Chile	Ventura	3 ft	Over 20 docks damaged ($300-500k)
		Oxnard	3 ft	Damage to docks from large boat wake
		Port Hueneme	4 ft	NR
3/11/2011	M9.0 - Japan	Ventura	4 ft	Damage to dock and several boats ($150k)
		Oxnard	4 ft	Minor damage to docks
		Port Hueneme	5 ft	NR



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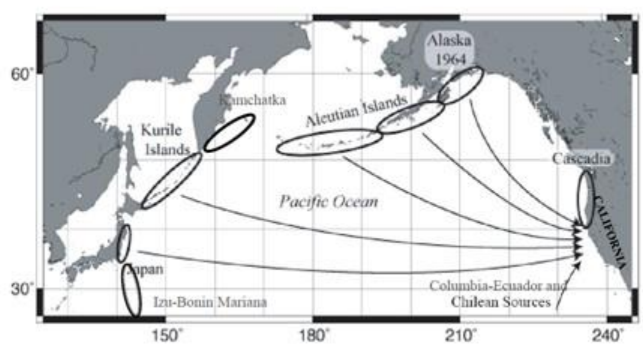
<u>Modeled Tsunami Scenarios</u>: Because very large tsunamis are infrequent and the likelihood that the largest potential tsunamis have not yet occurred in Ventura County, the state tsunami program developed a suite of maximum credible tsunami scenarios as part of their tsunami inundation mapping project for local evacuation planning. The general tsunami wave height for key locations from these scenarios are provided below. As identified in the historical tsunami table, the largest tsunamis could occur from large earthquakes in the Alaska-Aleutian Islands or Chile regions, or from a large submarine landslide offshore.

Tsunami Source Scenario Model Results for Ventura County

Near shore tsunami heights (flow depths) for both local and distant sources scenarios, in feet above Mean Sea Level

	TSUNAMI SOURCES	Approximate Travel Time	Punta	Pitas Point	Dulah	Ventura River	Pierpoint	Ventura Harbor	Oxnard Mandalay	Ox Hbr Entrance	Ox Hbr Channel	Port Hueneme	Oxnard Pier	Point Mugu	Solromar
Local Sources	M7.2 Anacapa-Dume Fault	10-15min		3	4	4	3	4	4		2				
	M7.5 Channel Isl. Thrust Ft	10-15min	8	7	8	6	7	7	6	6	3	4	5	3	5
	M7.1 Santa Monica Fault	15-20min		2	3	3	3	2	3		2				
	M7.7 Catalina Fault	20-30min							2	2	2	3	3	3	5
	Goleta 1 Landslide	10-15min	12	22	6	12	10	5	7		2				
	Goleta 2 Landslide	10-15min	16	9	8	12	11	8	12		2				
Distant Sources	M9 Cascadia-full rupture	1hr		4	4	4	4	5	4		2				
	M9.2 Alaska 1964 EQ	5hr	7	7	7	7	7	8	6	5	5	5	5	4	5
	M8.9 Central Aleutians I	5hr	5	5	5	5	5	5	6	5	8	4	4	3	3
	M8.9 Central Aleutians II	5hr		4	4	4	4	4	3		2				
	M9.2 Central Aleutians III	5hr	10	9	10	9	10	10	10	9	10	7	7	5	6
	M9 Kamchatka 1952 EQ	9hr							3	5	5	3	3	3	3
	M8.8 Kuril Islands II	9hr		3	3	3	3	3	2		2				
	M8.8 Kuril Islands III	9hr		3	3	3	3	3	3		2				
	M8.8 Kuril Islands IV	9hr		3	3	3	3	3	3		2				
	Japan II	10hr		3	3	3	4	4	3		2				
	Chile 1960 EQ	13hr		4	4	4	4	4	4		2				
	Chile North	13hr	7	6	8	6	6	7	7	7	2	5	5	4	4
	Maximum Runup - Local Source		16	22	8	12	11	8	12	6	3	4	5	3	5
	Maximum Runup - Distant Source		10	9	10	9	10	10	10	9	10	7	7	5	6



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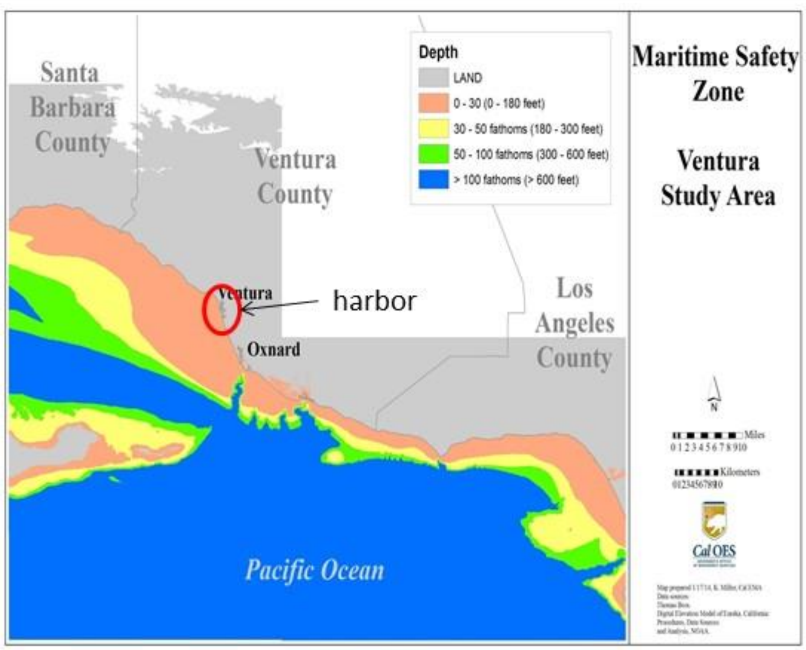
PLAN FOR OFFSHORE EVACUATION OF BOATS

NOTE: The safety of the boating public should outweigh the benefit of saving boats and harbor property during a tsunami.

- For most harbors in California, it is safer to keep boats docked during a tsunami because most tsunamis are relatively small.
- On the rare occasion when a large, damaging tsunami and associated strong currents are expected and there are no safe areas within the harbor, the boat owner may be considering taking their boat offshore.
- There are a number of factors that should be considered prior to recommending boats evacuate offshore prior to the arrival of the tsunamis, including:
  - (1) the SIZE of the tsunami;
  - (2) is there sufficient TIME to get to the 30 fathom depth (180 feet), which has been evaluated as safe depth for boats during distant source tsunamis (map below);
  - (3) the PREPAREDNESS of the boat and its captain to stay at sea over 24 hours;
  - (4) the WEATHER at sea could be as dangerous as the tsunami itself; and,
  - (5) if significant damage occurs within the harbor, boaters should have enough fuel and supplies to travel to a non-damaged harbor.

Note for trailer boat owners: Expect congested boat ramps and remember that you have to get your boat to the trailer, out of the water, and out of the tsunami zone before the tsunami arrives.



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TSUNAMI EVACUATION ZONE MAP FOR VENTURA HARBOR AREA

This tsunami evacuation map was prepared to assist cities and counties in identifying their tsunami hazard. It is intended for local jurisdictional, coastal evacuation planning uses. The red area represents the maximum considered tsunami inundation from a number of extreme, yet realistic, tsunami sources. In other words, people within the red-colored zones could get wet; people uphill or inland from these areas should be safe during any tsunami. **This map, or the local tsunami evacuation map/plan, should be used for evacuation from a Warning-level tsunami event unless otherwise directed by local emergency management officials.**

For digital copies of tsunami inundation maps for other portions of California, visit **http://www.tsunami.ca.gov**

APPENDIX
Quick Reference Page for Determining Real-Time Maritime Tsunami Response Activities

Step 1: Obtain basic information about the earthquake and tsunami from National Tsunami Warning Center in Alaska, regional National Weather Service office, and/or county emergency manager. **NOTE: Tsunami Alert Level may change in first couple hours after the earthquake; WATCH may be upgraded to ADVISORY or WARNING.**

Earthquake location ___________________________

Earthquake magnitude _________________________

Tsunami Alert level (circle one) WATCH ADVISORY WARNING

Closest forecasted tsunami amplitude/wave height _____________

Forecasted tsunami arrival time __________________

Step 2: Tsunami evacuation and response will depend on the amount of time before the tsunami arrival. Four (4) hours is considered the threshold time needed for evacuation. As a quick reference, we offer the following guidance:

1) **If less than four hours before tsunami arrival, we recommend the following:**
   - ADVISORY – evacuate beaches, harbor docks, and piers
   - WARNING – evacuate entire maximum on-land evacuation zone, or follow guidance provided by local emergency manager
2) **If greater than four hours before tsunami arrival**, and your harbor has fully developed its tsunami response Playbook plans, the harbor can utilize the FORECAST AMPLITUDE from Step 1 on the table on the right to identify the appropriate response plan to use.

Reference Pages for Details in Maritime Playbook	Scenario Playbook Plan Letter	Peak Amplitude near Harbor (in meters, above existing conditions at harbor mouth)
	(No action)	~0.3
Page 8-9	A	0.6
Page 10-11	B	0.8
Page 12-13	C	0.9
Page 14-15	D	1.5
Page 16-17	E	3.5