Tsunami Sign Placement Guidance
For the City of Alameda, Alameda County, California

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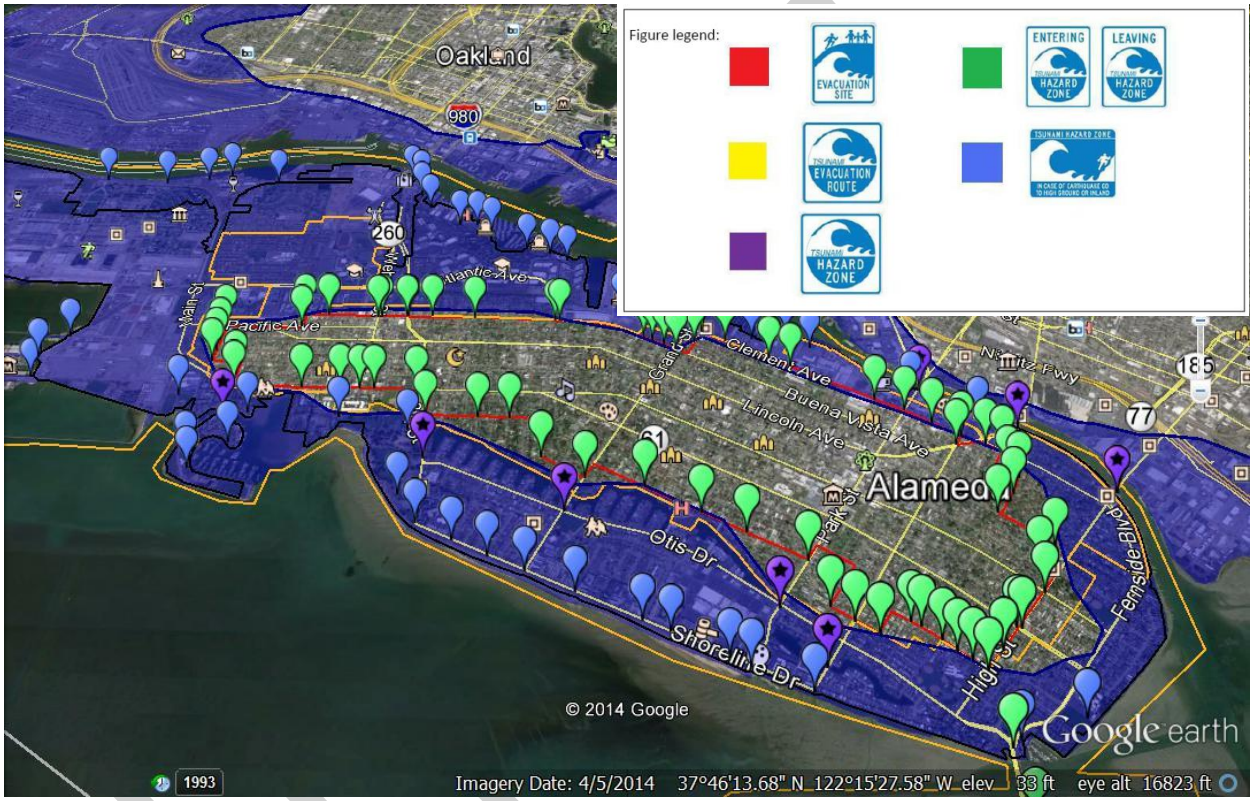

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Introduction

The California Geological Survey (CGS), the California Office of Emergency Services (CalOES), and the NOAA National Weather Service Warning Forecast (NWS) Office in Monterey provide the following information to the City of Alameda for consideration in their tsunami sign placement strategy. Studies have shown that tsunami signs are the most important tsunami education and preparedness tool that communities can use, especially for coasts with a large number of visitors like Alameda. This is one of the reasons CalOES will purchase tsunami signs upon request, and why these signs are considered important in the guidelines for communities to become designated *TsunamiReady* (NOAA-NWS). Funding for this program is provided by the National Tsunami Hazard Mitigation Program.

The recommended tsunami sign placement plan is provided as an accompanying KMZ (GoogleEarth) layer. This sign plan was developed using the state tsunami inundation maps which considers inundation from both local and distant source tsunamis. Based on numerical tsunami modeling of a dozen large local and distant earthquake and landslide sources, tsunami run-up in the City of Alameda could reach a maximum of 18-foot elevation along the coastal zone (Wilson *et al*, 2008; State of California, 2009).

Distant source tsunamis can be generated by large subduction zone earthquakes (magnitude 8-9 range) along the entire rim of the Pacific Ocean. Tsunamis generated from sources along the Alaska-Aleutian Islands subduction zone are the most significant for the Alameda coastline (Wilson *et al*, 2008). These types of tsunamis can take anywhere from two (Cascadia) and five hours (Alaska), to over ten hours (Chile/Japan) to arrive in Alameda. Official warnings from the National Tsunami Warning Center will be provided ahead of the tsunami's arrival, providing local officials time to organize and implement evacuations, if needed.

Although locally generated tsunamis are less common than those created by distant sources, there are precedents for these types of events. In California, large offshore earthquakes capable of producing tsunamis have occurred at least seven times in the last 100 years (Dengler, 2009). In addition, the existing on- and offshore geologic conditions indicate that this is a very seismically active region capable of producing tsunamis that could strike the coastal areas of Alameda within 10 to 20 minutes (Wilson *et al*, 2010). Because of the short time for response, people located within the tsunami hazard zone need to be educated about this potential hazard because official warnings will not arrive in time to help. Basically, the earthquake ground shaking or the visible signs of a tsunami (rapid drawdown of ocean and/or large, frothy surge of water) are the "natural warning signs" that people must recognize to evacuate quickly.

Existing inundation modeling/mapping data (see Inundation Map references; Wilson *et al*, 2008), partial GIS analysis, and information from past field reconnaissance were used to provide the following sign placement guidance. In the appendix, we also provide guidance for developing/improving local evacuation plans by considering earthquake hazards (landslides, liquefaction, damage to structures, etc.) that might impact evacuation to safe locations. When

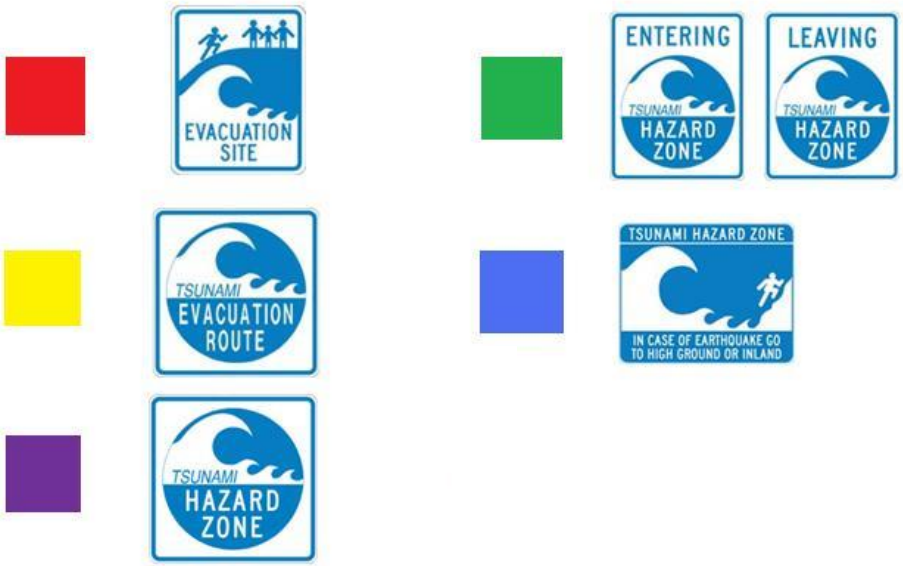
suggesting assembly sites (areas to evacuate to), also considered is the length of time for evacuation based on a general pedestrian evacuation speed of one-meter-per-second (3-feet-per-second), similar to Laghi and Cavalletti (2004) and Graehl (2008) for foot-traffic speed on paved surfaces. Potential assembly areas should be chosen based on the ability for egress after an earthquake in less than 10 minutes, which equates to travel distances of 600 meters or less (60 meters=60 seconds). For more detailed evaluation of evacuation times, additional information about the local population demographic, land-use and surface coverage, utility location, and anticipated structural damage, would be required (Laghi and Cavalletti, 2004).

When preparing to move forward with this plan or a similar tsunami sign placement strategy, CalOES can provide examples from other communities of how to proceed upon request. This plan conforms to a similar evaluation performed for other communities in the San Francisco Bay Area (Wilson and Miller, 2010; Wilson *et al*, 2012).

Suggested Sign Usage

Locations are offered about tsunami sign placement to assist evacuation within each area evaluated. Existing light poles or sign poles should be used as sign locations if possible to minimize installation costs. Decals are available for some of these signs to also help minimize costs. The following legend (figure) shows the signs and color of symbols used on KMZ file to represent the standardized tsunami signs available from the state. Although the State of California has yet to adopt standard tsunami hazard signage, the signs described below are provided by the state tsunami program for use by local jurisdictions. These signs are available in different sizes and should be placed near the appropriate location and where plainly visible, considering the speed of the motorist/pedestrian. To see more details about the available dimensions and specifications for each sign, visit the following website: http://www.dot.ca.gov/hq/traffops/signtech/signdel/tsunami.htm.

Figure legend:



"Tsunami Hazard Zone – In case of earthquake go to high ground or inland" (blue on map)

These signs are the most commonly used and needed as they identify that our coast has both an earthquake hazard and a tsunami hazard, and that the two may be related. These signs should be placed in areas of heavy foot traffic at beaches, parking lots and areas where people gather along the coast. These signs come in various sizes. Decals of these signs can be placed on trash cans, on life-guard structures, and within existing public displays. These decals are very low cost alternatives to installing hard-backed tsunami signs.

"Tsunami Hazard Zone" (purple on map)

These signs may be placed anywhere within the zone that heightened awareness is desired. They can be placed at park entrances and areas accessing the beach. They are typically used along roads because lettering is large enough to be seen by drivers of passing cars. Decals of these signs are also available, and are very low cost alternatives to installing hard-backed tsunami signs. Based on the fact that the only primary area within the tsunami inundation area is the beach area and parking lots, no tsunami hazard zone signs were included in the tsunami sign plan.

"Entering/Leaving Tsunami Hazard Zone" (green on map)

These signs should be placed at or near the boundary of the tsunami evacuation zone along primary roads and highways. Where traffic is one way entering or leaving the tsunami inundation area, a single sign (entering or leaving) is needed to inform the public. At one location designated on the map where traffic is entering and leaving the parking lot on the south side of town, two signs should be placed on opposite sides of the street facing into traffic; "Entering" signs should be placed where traffic is descending into the tsunami zone, "Leaving" signs should be placed where traffic is leaving the zone. These signs are important in that they let the public know when they are entering a potential tsunami hazard zone, and when they are safely outside of the tsunami zone; the "Leaving" signs reduce the potential for extreme, over-evacuation, such as occurred during the March 11, 2011 tsunami in California at a number of locations (Wilson *et al*, 2011).

"Tsunami Evacuation Route" (yellow)

These signs should be placed along primary roads and highways to indicate the direction of egress out of the tsunami hazard zone and to potential evacuation sites. Evacuation route signs may be accompanied by arrows indicating the direction of egress. Though these signs were not included in the sign plan, the city may decide to use these signs if they think they are appropriate. Or, temporary evacuation route signs can be placed along roads to indicate where vehicle traffic should go during distant source events.

"Tsunami Evacuation Site" (red)

These signs should be placed at predetermined, safe assembly areas, as a destination for public evacuating the coast. Because tsunami evacuations can last for over 24 hours, shelter and provisions should be made available at these locations until the "all clear" signal is given by officials. Since the city should designate the locations for safe evacuation, these signs were not included in the sign plan. Like the evacuation route signs, for distant source events, temporary evacuation site signs can be placed to indicate where vehicle traffic and the public can assemble.

Recommendations/Limitations for Use

The following should be considered when using this document for the development of tsunami evacuation plans and/or placement of tsunami hazard signage:

- This information is provided as recommendations to the local jurisdictions based on our reconnaissance work. These local jurisdictions, which are the responsible entities for evacuation planning, may utilize this information as they deem appropriate.
- Due to the reconnaissance nature of this evaluation, the State of California is not responsible for the accuracy of the information provided herein. Local site-specific knowledge of conditions and more advanced evaluation of evacuation may supersede the information provided. Detailed analysis of the hazards discussed will help determine the severity of those hazards for evacuation.
- The population at risk to tsunami hazards should be evaluated to determine if they require special assistance during evacuation.
- If areas within the tsunami hazard zone cannot be evacuated in a safe and timely manner from a locally generated tsunami, communities should consider vertical evacuation within an existing large, stable structure. Refer to FEMA, "Guidelines for design of structures for vertical evacuation from tsunamis" (FEMA, 2008) for more information.
- It is recommended that several important messages be made clear to the at-risk population:
    - After a strong earthquake people should immediately evacuate the beach, and if ground shaking lasts for more than 20 seconds, people in the potential tsunami hazard areas should evacuate within 10 minutes. People should remain away from these hazard areas until the "all's clear" message is issued by the local responsible agency.
    - All people evacuating tsunami hazard areas after an earthquake (local source tsunami) should do so ON FOOT. Numerous studies indicate people who evacuate by car are more likely to put themselves and others at higher risk of injury because roads may become damages and congested (Atwater *et al*, 1999).
    - Be careful when evacuating across roads or highways by foot. Drivers may be distracted by the effects from the earthquake and may not be looking for pedestrians.

General References

Atwater, B.F., Cisternas V.M., Bourgeois, J., Dudley, W.C., Hendley, J.W. II, and Stauffer, P.H., 1999, Surviving a tsunami: lessons from Chile, Hawaii, and Japan, USGS Circular 1187, 20 p.

Dengler, L.A., 2009, Frequency of tsunami alert bulletins in California: American Geophysical Union, Fall Meeting 2009, abstract #OS43A-1372.

FEMA, 2008, Guidelines for design of structures for vertical evacuation from tsunamis: Applied Technology Council (ATC) 64 project, FEMA P646, 158 p.

Graehl, N.A., 2008, Tsunami evacuation times for the community of Fairhaven, California: Humboldt State University, for NRPI 470 Intermediate GIS class, 31 p.

Laghi, M., and Cavalletti, A., 2004, Coastal risk analysis of tsunamis and environmental remediation: Evacuation Routes Tools ArcGIS toolbox, at the following web site: www.adpc.net/v2007/IKM/ONLINE%20DOCUMENTS/Default-DOCUMENTS.asp

Lander, J.F., Lockridge, P.A., and Kozuch, M.J., 1993, Tsunamis affecting the west coast of the United States 1806-1992: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NGDC Key to Geophysical Records Documentation No. 29, 242 p.

Wilson, R.I., Barberopoulou, A., Miller, K.M., Goltz, J.D., and Synolakis, C.E., 2008, New maximum tsunami inundation maps for use by local emergency planners in the State of California, USA: EOS Trans. American Geophysical Union 89(53), Fall Meeting Supplement, Abstract OS43D-1343.

Wilson, R.I., and Miller, K.M., 2010, Reconnaissance tsunami evacuation hazard analysis for Ventura County, California: Recommendations for tsunami evacuation from local earthquake source in higher risk areas; California Geological Survey and California Emergency Management Agency, California Tsunami Program Technical Report 2010-01, 29 p.

Wilson, R., Dengler, L., Borrero, J., Synolakis, C., Jaffe, B., Barberopoulou, A., Ewing, L., Legg, M., Ritchie, A., Lynett, P., Admire, A., McCrink, T., Falls, J., Rosinski, A., Treiman, J., Manson, M., Silva, M., Davenport, C., Lancaster, J., Olson, B., Pridmore, C., Real, C., Miller, K., and Goltz, J., 2011, The effects of the 2011 Tohoku tsunami on the California coastline: [abstract] Seismological Research Letters, 82(3), p. 459-460.

Wilson, R.I., Miller, K.M., and Strobin, M.H., 2012, Tsunami sign placement guidance for Marin County and portions of the Golden Gate National Recreation Area, California: California Tsunami Program Technical Report 2012-03, 12 p.

State Tsunami Inundation Map References (downloadable at www.tsunami.ca.gov)

State of California, 2009, Tsunami Inundation Map for Emergency Planning, Oakland West Quadrangle, Alameda County; produced by California Emergency Management Agency, California Geological Survey, and University of Southern California – Tsunami Research Center; dated July 31, 2009, mapped at 1:24,000 scale.

State of California, 2009, Tsunami Inundation Map for Emergency Planning, Oakland East Quadrangle, Alameda County; produced by California Emergency Management Agency, California Geological Survey, and University of Southern California – Tsunami Research Center; dated July 31, 2009, mapped at 1:24,000 scale.

State of California, 2009, Tsunami Inundation Map for Emergency Planning, San Leandro Quadrangle, Alameda County; produced by California Emergency Management Agency, California Geological Survey, and University of Southern California – Tsunami Research Center; dated July 31, 2009, mapped at 1:24,000 scale.

Appendix: Evacuation Planning Guidance (Local Source)

California Tsunami Hazard Mitigation and Preparedness Program

Guidance for Local Jurisdictions to Develop or Review Tsunami Evacuation Plans for a Post-Earthquake, Local-Source Tsunami

Purpose: This document provides local jurisdictions with guidance for assessing hazards after a large local earthquake that could inhibit safe evacuation from tsunami hazard areas.

Background: California's coastal region has many large active faults and unstable submarine slopes capable of producing destructive tsunamis. Examples where local earthquakes generated tsunamis in California include:

- January 26, 1700 - A magnitude 9 earthquake along California's north coast generated a major tsunami locally.
- December 21, 1812 - A local earthquake triggered a tsunami near Santa Barbara that so alarmed people in coastal villages that they retreated several miles inland closer to the Santa Barbara Mission.
- November 4, 1927 - A magnitude 7.1 earthquake off the coast of northern Santa Barbara County caused a six-foot-high tsunami along portions of the central coast.

For anyone in tsunami evacuation zones, strong ground shaking from an earthquake is the natural warning that a tsunami might be coming. People on the beach or in harbor areas should evacuate for any felt earthquake and, if strong shaking lasts for 20 seconds or more, all people within evacuation areas should move inland or to higher ground. However, strong earthquake shaking can also cause additional hazards, such as landslides or downed power lines, which can inhibit or prevent safe evacuation. Without analysis to identify these potential hazards along evacuation routes, evacuees might be routed through areas where they could become injured while moving away from potential tsunami inundation areas.

The state tsunami program provides assistance to jurisdictions that request help preparing or reviewing evacuation plans to address local-source tsunamis. However, for local jurisdictions that would like to evaluate these potential evacuation hazards using their own resources, the following step-by-step guidance is provided:

Step 1: Determine the areas vulnerable to tsunami hazards from all potential local tsunami sources. The state tsunami program has evaluated potential tsunami sources through their statewide inundation mapping project, which covers almost all populated, low-lying coastal areas in California (www.tsunami.ca.gov). Local jurisdictions have used this information and other data to compile evacuation zones. Although they address the combined tsunami hazard from both local and distant sources, these evacuation zones are the best starting point for this evaluation of potential evacuation hazards during a local earthquake. Consult the state program if you would like more detailed information about the local tsunami sources affecting your jurisdiction.

Step 2: Select a team representing local emergency planners and responders, and local/regional earthquake and tsunami experts to identify local, collateral earthquake hazards. In addition to the group typically selected for evacuation plan preparation (primarily emergency managers), engineers, geologists, and Geographic Information Systems (GIS) personnel from the jurisdictions at risk should be consulted to determine what additional hazards exist and where they are located. Regional earthquake alliance or tsunami work groups will also have the needed breadth and expertise to oversee such efforts. This group should work with the state tsunami program in the hazard identification effort.

Step 3: **Using a GIS platform, identify and map out potential collateral hazards and obstacles, and consider any special needs of the communities in the tsunami hazard areas.** First determine if previous earthquake scenarios have been developed for the area, including HAZUS assessments. For areas with significant coastal hazards, detailed analyses to determine the severity of those hazards may be required. The first focus should be on areas of potential isolation. The following variables should be considered during the evaluation:

- **Areas of isolation:** islands, peninsulas, cliffs, and other natural/man-made areas of isolation.
- **Geologic hazards:** ground shaking intensity, liquefaction, lateral spreading, subsidence, landslides, fault rupture, and other types of ground failure hazards.
- **Utility hazards:** above ground power lines/poles/towers (pictured right), buried gas/oil pipelines, buried electric lines, electrical boxes and structures, and other utilities.
- **Man-made obstacles:** fences, locked/electronic gates, walls, buildings, bridges, overpasses, berms, vegetation, and other structures.
- **Population at risk:** number of people, age and mobility, and other factors affecting the personal egress of the population.

Step 4: **Visit each location identified as having potential collateral hazards during evacuation.** Determine the impact and severity of potential hazards on evacuation in each area, including the combined effects from multiple hazards (for example: fires sparked by downed power lines over disrupted, leaking gas pipelines). Evacuation should always be ON FOOT. Identify pedestrian paths of egress with the fewest hazards and walk those routes to determine if evacuation can be safely done within 10 minutes, the time it typically takes a tsunami from a local source to arrive on shore. Without obstacles, the average person should be able to walk approximately 2000 feet (600 meters) in 10 minutes, a rate of about three feet (one meter) per second. If obstacles exist or the evacuees have mobility problems, the distance they can travel will be less. If certain man-made hazards or obstacles cannot be overcome, address these issues with the land/utility owners and the resident evacuees. Vertical evacuation options should be considered in this case (for more information, see FEMA document P646, "Vertical Evacuation from Tsunamis: A Guide for Community Officials" http://www.fema.gov/library/viewRecord.do?id=3808). This is also a good opportunity to identify locations to place tsunami hazard signs; make sure signs represent evacuation for both local and distant tsunami events (visit http://www.dot.ca.gov/hq/traffops/signtech/signdel/tsunami.htm for sign specifications).

Step 5: **Develop evacuation plans based on the pathways with the fewest hazards and obstacles.** Consider using a GIS for digital representation of evacuation plans that can be overlain on different base maps, and can be readily updated as needed. Discuss potential utility and obstacle (fence/locked gate) hazard issues with utility/property owners and determine if evacuation problems can be mitigated. Some areas may have no reasonable evacuation solution; discuss what messaging to use for those areas. Consult with representatives from adjacent jurisdictions to develop consistent evacuation plans across jurisdictional boundaries.

Step 6: **Share evacuation plans with communities at risk.** Present the results of the evacuation plan at public meetings in each community. Educate the communities about both earthquake and tsunami hazards that might impact them. Recommend that the communities practice their evacuation plans through drills, perhaps during "Tsunami Awareness Week" (held in March each year). Discuss possible sign placement options with the community leaders to get their assistance and input. Gather feedback from the communities.

Step 7: **Make adjustments to the evacuation plans as needed.** Review the tsunami evacuation plan every several years in case significant changes occur to the community population or evacuation pathways. Integrate community inputs as needed. The state can help provide localized public outreach materials.