

## EXTENDED ABSTRACT – PROBABILISTIC TSUNAMI HAZARD ANALYSIS (PTHA) IN CALIFORNIA: PILOT STUDIES, MAP PRODUCTION, AND APPLICATIONS

By Rick Wilson, California Geological Survey (CGS), Chuck Real (CGS), and Kevin Miller, California Emergency Management Agency (Cal EMA)

Over the past two decades, tsunami hazard analyses have been performed using scenario-based, deterministic methods in order to develop tsunami inundation products for emergency response planning (Wilson et al, 2010; Barberopoulou et al, 2009). Knowing only the maximum possible run-up without information about probability of occurrence is an insufficient product to set engineering and land-use planning guidelines. Seismic hazard products for land-use and construction decisions are based on a probabilistic analysis, and for such applications information on the frequency of occurrence is similarly desirable for tsunami hazard products through a probabilistic tsunami hazard analysis (PTHA). Land-use tsunami hazard inundation maps and/or information should: 1) consider the lifetime of typical development projects, 2) incorporate likelihood in the quantification of tsunami hazard, 3) have a resolution appropriate for distinguishing individual land parcels, and 4) have a means for enforcement by local agencies.

To assist city and county land-use planning/building departments with enforcement of hazard information like this, the California Legislature authorized the California Geological Survey (CGS) to prepare tsunami hazard maps for incorporation into land-use plans through the Seismic Hazard Mapping (SHM) Act (Public Resources Code, sec 2690 et seq.). This State Law also contains provisions that require site-specific hazard evaluations and design mitigation plans to be completed prior to certain types of development within special designated hazard zones. CGS and the California Emergency Management Agency (Cal EMA) have received funding through the National Tsunami Hazard Mitigation Program (NTHMP) to initiate this work over the past several years and into Fiscal Year 2012-13. Because of this, the NTHMP Mapping and Modeling Subcommittee has recommended the work by California be considered a “national pilot” for PTHA mapping, and is currently working to integrate this project into the FY2013-2017 NTHMP Strategic Plan. Initial work included evaluation of several methodologies that have been and/or are being established for PTHA in California and along the west coast (Tsunami Pilot Study Working Group - Seaside, OR, 2006; Geist and Parsons, 2006; Uslu, 2011; Thio, 2010).

The California mapping team is working with other governmental, academic, and private entities on this project, to help supplement and enhance the state's work. The state team is partnering with URS Corporation, the Pacific Earthquake Engineering Research Center, and Caltrans on a PTHA project to develop tsunami hazard maps for the entire California coastline. The PTHA results will be initially used by Caltrans (a project sponsor for URS work) to evaluate the vulnerability of transportation facilities to the threat of tsunami inundation and wave loading. Tsunami hazard maps are also being developed with the intended use by local government agencies for land-use planning under the state SHM Act. In 2010, Dr. Hong Kie Thio, URS project manager of this effort, completed an initial phase of the project that focused on the development of a practical PTHA procedure that can be applied to a large region

while also utilizing nonlinear based wave propagation methods for estimating on-shore wave heights, current velocities, and inundation levels. This methodology, which is focused on tele-tsunami (distant) sources, is documented (Thio, 2010). The current phase of the project is to extend the sources considered in the overall PTHA to include the Cascadia Subduction zone and some smaller potential local sources off the southern and central California coast.

Another PTHA project being conducted by Dr. Frank Gonzalez of the University of Washington is being supported by coastal hazards consultant Baker/AECOM and FEMA. This project is focusing more specifically on Crescent City, using the PTHA methodology established in the Seaside, Oregon, study from 2006. The intent of the project would be to develop PTHA products that may eventually be incorporated into Flood Insurance Rate Maps (FIRM) as a coastal hazard analysis RiskMAP product.

Because both studies involve Crescent City, the parties have agreed to use this location as a PTHA “pilot” area to compare methods and results. The NTHMP has designated CGS to help facilitate this work by developing a review protocol for the PTHA results and establishing a tsunami-hazard policy group to determine the data/information needs of the planning community. These protocol/needs include: 1) selection of the appropriate tsunami return period for implementation, 2) determination of the data layers needed, such as tsunami flow depth, flow velocity, inundation area, modeled time series, and/or momentum flux, 3) deciding the appropriate resolution of the final data products, and 4) evaluating the utility of the SHM Act’s “zones of required investigation” for triggering site-specific analysis of tsunami hazard as part of the construction permit approval process, and for facilitating land-use development decision-making.

More recently, in addition to land-use planning, a number of other federal, state, and local uses for PTHA have been recognized creating a nexus for production of PTHA maps and products:

1. **FEMA RiskMAP** – FEMA’s RiskMAP products are useful for local jurisdictions to help mitigate hazards. Through a Collaborative Technical Partnership with FEMA, CGS and Cal EMA are developing tsunami hazard products for RiskMAP specifically for the maritime community in California.
2. **FEMA Flood Insurance** – FEMA’s National Flood Insurance Program is producing Flood Insurance Rate Maps that identify 100- and 500-year flood zones. California’s Tsunami Policy Work Group will help communities integrate this PTHA work into their coastal flood plans.
3. **FEMA HAZUS** – FEMA is developing a tsunami module for HAZUS that will be tested in various locations, including Crescent City. PTHA products of various tsunami risk levels (ie. “average return periods”) will be useful for determining the hazard/risk-levels faced by coastal communities.
4. **Local Hazard Mitigation Planning (FEMA/Cal EMA)** - PTHA products will help communities develop long-term, tsunami hazard mitigation plans more effectively, and will provide a platform for FEMA and Cal EMA to evaluate those plans more consistently.
5. **ASCE 7-15 tsunami loads/proposed building codes** – CGS and URS are members of a national ASCE subcommittee establishing a procedure for determining tsunami loads for coastal building

design standards. The design standards are being targeted for inclusion in the International/Uniform Building Codes by the year 2017.

6. **Inundation Mapping for emergency planning** – Although Cal EMA and CGS produced a set of “worst case” tsunami inundation maps in 2009, these maps cover sources with varying return periods that range from approximately 1,000 to 10,000 years. A PTHA will provide a consistent basis for comparing the tsunami inundation hazard for all sections of the California coast.
7. **State of California “My Plan” platform** – Cal EMA has developed a community mapping and data resource platform that can house and share the potential large data and GIS files produced from the PTHA. This is a web-service that can be easily accessed by community GIS departments.
8. **California Department of Water Resources (DWR) 200-year flood zone** – In accordance with state law, DWR is developing flood zones for 200-year events in fluvial settings. The proposal partners will work with DWR to provide support for incorporating appropriate tsunami inundation information into their analysis.

The review and validation of the PTHA process will be completed by the summer of 2013. If the methods are determined to be adequate for use in producing land-use planning products, initial maps should be available by the end of 2013. Maps for the rest of the low-lying, populated coast of California could be completed by early 2015.

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