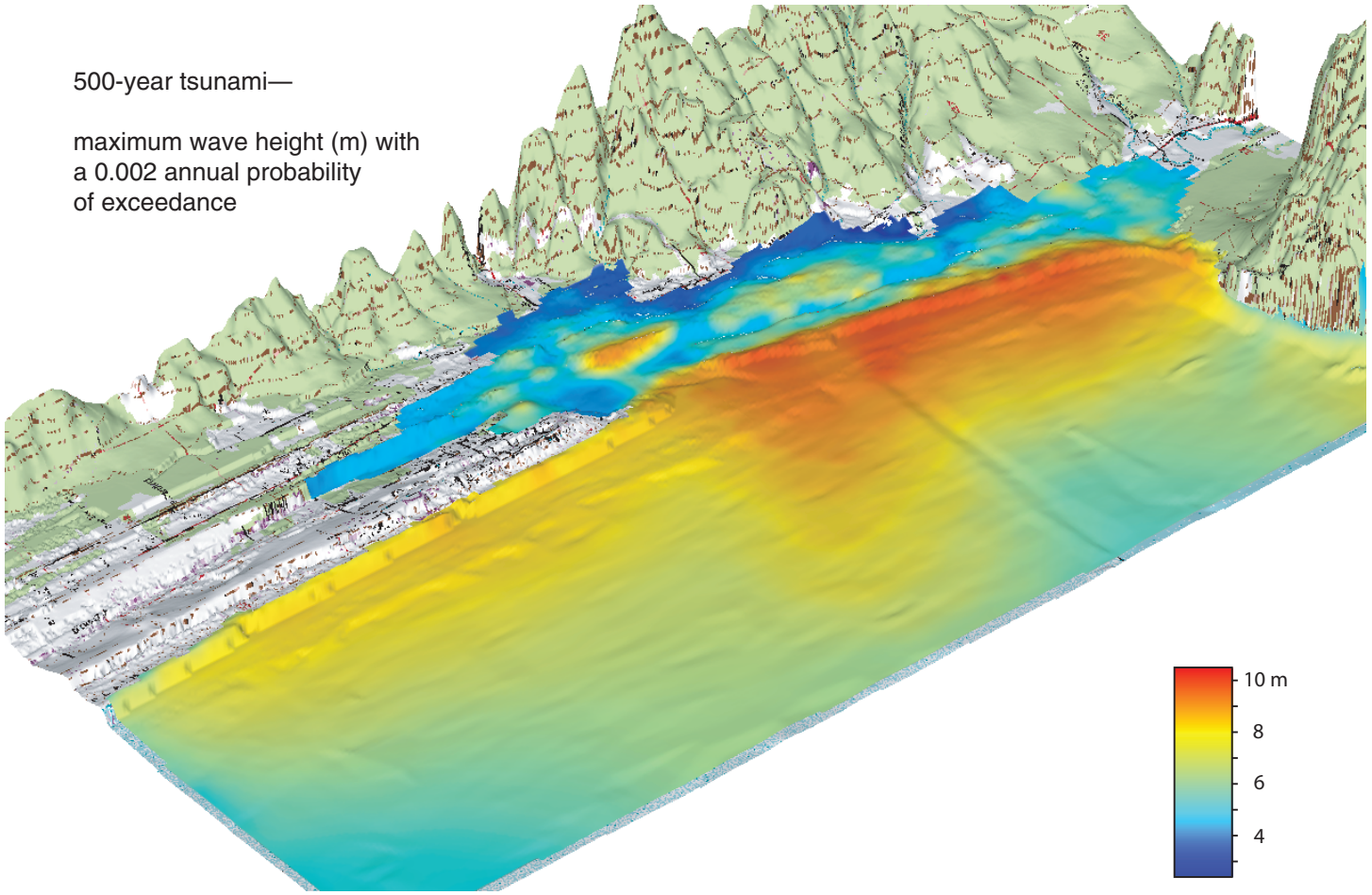
Seaside, Oregon Tsunami Pilot Study—Modernization of FEMA Flood Hazard Maps

By Tsunami Pilot Study Working Group



Joint NOAA/USGS/FEMA Special Report

U.S. National Oceanic and Atmospheric Administration
U.S. Geological Survey
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Tsunami Pilot Study Working Group:

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Cover: Perspective view of 500-year tsunami in the Seaside/Gearhart, Oregon, pilot study area. Tsunami wave heights (m) with a 0.2% annual probability of exceedance. Wave heights include the effects of tides. Vertical exaggeration 10×; view looks southeastward.

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Also available from the National Technical Information Service (NTIS)
(`http://www.ntis.gov`)

Contents

Executive Summary

FEMA Flood Insurance Rate Map (FIRM) guidelines do not currently exist for conducting and incorporating tsunami hazard assessments that reflect the substantial advances in tsunami research achieved in the last two decades; this conclusion is the result of two FEMA-sponsored workshops and the associated Tsunami Focused Study (Chowdhury *et al.*, 2005). Therefore, as part of FEMA's Map Modernization Program, a Tsunami Pilot Study was carried out in the Seaside/Gearhart, Oregon, area to develop an improved Probabilistic Tsunami Hazard Assessment (PTHA) methodology and to provide recommendations for improved tsunami hazard assessment guidelines. The Seaside area was chosen because it is typical of many coastal communities in the section of the Pacific Coast from Cape Mendocino to the Strait of Juan de Fuca, and because State Agencies and local stakeholders expressed considerable interest in mapping the tsunami threat to this area. The study was an interagency effort by FEMA, U.S. Geological Survey, and the National Oceanic and Atmospheric Administration, in collaboration with the University of Southern California, Middle East Technical University, Portland State University, Horning Geoscience, Northwest Hydraulics Consultants, and the Oregon Department of Geological and Mineral Industries. Draft copies and a briefing on the contents, results, and recommendations of this document were provided to FEMA officials before final publication.

Methodology

The study methodology consisted of a number of important components, each of which was essential to successfully developing 100- and 500-year tsunami inundation products required by FEMA for Flood Insurance Rate Maps, including flooding depth and high velocity zones (V-zones). These components were:

- **Source Specification.** Review of literature; consultation with expert colleagues; development of a database of quantitative probabilistic models of local and far-field earthquake tsunami sources in the Cascadia Subduction Zone (CSZ), the Alaska-Aleutian Subduction Zone (AASZ) and the Peru-Chile Subduction Zone (PCSZ).
- **Data Acquisition.** Performance of a paleotsunami deposit mapping and interpretation study; acquisition of historical records and eyewitness reports.
- **Model Development, Testing, and Application.** Development of a high-resolution Digital Elevation Model (DEM) based on the latest available

topography, bathymetry, and tidal information; development of a state-of-the-art, site-specific tsunami inundation model; testing of the model with all available tsunami field observations, including paleotsunami data, historical records, and eyewitness reports; application of the model, using the source database, to generate the corresponding tsunami inundation database.

- **Probabilistic Computations.** Development of a systematic procedure to process the study data and compute the distributions of 0.01 and 0.002 annual rates of occurrence (100- and 500-year) quantities, including the effect of ocean tides; application of the procedure to create the site-specific tsunami hazard maps.
- **Study-Specific Database Development.** Development and documentation of a comprehensive, study-specific, GIS-compatible database that includes sources, DEM, model output, field observations, and other information relevant to the study; creation of web-based interface for database access.
- **Analyses and Interpretation.** Use of the GIS database for quality control and error-checking, and to analyze and interpret the primary study results; exploratory analyses and interpretation of various tsunami impact indices to generalize the concepts of tsunami hazard levels in general, and tsunami high-velocity flood zones (V-zones) in particular.

Results

Although Seaside suffered inundation and damage as a result of the tsunami generated by the Great 1964 Prince William Sound earthquake, little inundation is indicated by the 100-year tsunami hazard map. The interpretation of this result is that, on the 100-year time scale, Seaside is threatened primarily by tsunamis generated by far-field earthquakes that are not generally as destructive as those generated locally. In contrast, on the 500-year time scale, Seaside is threatened by large, destructive tsunamis generated locally by great earthquakes on the Cascadia Subduction Zone, which lies just offshore. As a consequence, the 500-year tsunami hazard map reflects very large regions of Seaside inundated to significant depths.

Details of the methodology developed during the course of this project, a discussion of older tsunami assessment methods, data sources, literature references, results, and other recommendations are provided in the body of the report.

Recommendations

Some important factors influenced our recommendations, as follows. First, the methodology for probabilistic tsunami hazard assessment (PTHA) developed by this study, while preliminary, is nonetheless a major advance over previous methods, and should therefore be applied to upgrade assessments

in other coastal areas. However, considerable work remains to improve the methodology, and these follow-on studies should also be designed to refine and improve the methodology, as discussed in the report. Also, truly disastrous local events will inevitably devastate U.S. coastal communities near known subduction zones, such as the Cascadia and the Alaska-Aleutian Subduction Zones; though infrequent, the impact of such events are so catastrophic that they must somehow be taken into account. Time limitations did not allow development of a "Credible Worst Case" methodology during the course of this study. However, our results lay the groundwork for the development of this method which, essentially, answers two fundamental questions: *"What is the scientifically defensible and credible worst case scenario?"* and *"What is the probability of occurrence of this scenario?"* This simple concept has great intuitive appeal and should have very high practical value as an actuarial tool. Finally, adequate PTHA for all U.S. coastlines is a long-term, challenging effort that requires an integrated, sustainable national approach, including the establishment and maintenance of Federal agency partnerships, in collaboration with State agencies, academic, and other institutions. Our specific recommendations are therefore grouped as Scientific/Technical and Policy/Programmatic, as follows.

Scientific/Technical Recommendations

- Include all reasonable epistemic and aleatory sources of uncertainty in each Probabilistic Tsunami Hazard Assessment, using the best available science.
- Utilize tsunami hydrodynamic models that meet NOAA standards, to ensure consistency of Federal agency products.
- Test all earthquake and tsunami models by extensive field studies to gather and exploit all possible paleogeography and paleotsunami data, historical tsunami measurements, eyewitness reports, and other types of field observations.
- Develop and maintain a comprehensive GIS database of all field data, model results, and a comprehensive site- and source-specific tsunami/earthquake bibliography for the region as an essential and invaluable analysis and product development tool.
- Publish a report for each PTHA project that documents procedures, data sources, and results, that includes a bibliography, and that is reviewed for consistency with FEMA standards.
- Publish PTHA results either as a separate Federal Insurance Rate Map, or include PTHA information as separate, tsunami-specific items on FIRMs. In either case, include: (a) the 100-year and 500-year events, (b) tsunami-specific V-zones, (c) measurements available for the worst case historical and/or paleotsunami events, and (d) the "Credible Worst-Case Scenario" event.

Policy/Programmatic Recommendations

- Establish a formal FEMA/NOAA/USGS partnership to address national needs for tsunami hazard assessment products in a federally consistent and cost-effective manner.
- Apply PTHA to additional Cascadia Subduction Zone communities as NOAA inundation models are completed.
- Conduct pilot studies to adapt PTHA to other tsunami regimes in the Pacific, Caribbean, Atlantic, and Gulf, using a preliminary assessment of uncertainty.
- Apply PTHA to additional Pacific, Caribbean, Atlantic, and Gulf communities as the corresponding pilot studies and NOAA inundation models are completed.
- Establish a systematic maintenance and improvement program to integrate scientific and technical advances into the PTHA methodology.