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MAKING PORTS AND HARBORS MORE RESILIENT TO EARTHQUAKE AND TSUNAMI HAZARDS

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INTRODUCTION

Over the past decade, the threat of very large earthquakes and tsunamis in the Pacific Northwest has been well documented by the scientific community. Such events pose significant threats to coastal communities, including a potential for significant loss of life and damage to public and private infrastructure and property. Damage could result from numerous earthquake-related hazards, such as severe ground shaking, soil liquefaction, landslides, and tsunami inundation. Because of their geographic location, ports and harbors are highly vulnerable to these hazards. This is problematic because ports are centers for much of the economic and social activity of coastal communities, and are also expected to be vital as post-event, response and recovery transportation links. Increasing the resiliency of port and harbor communities to earthquake and tsunami hazards is thus a high priority.

To address this issue, a collaborative, multi-year research, planning, and outreach initiative involving Oregon Sea Grant, Washington Sea Grant, the NOAA Coastal Services Center, and the USGS Center for Science Policy was begun in early 2000 to increase the resiliency of Pacific Northwest ports and harbors to earthquake and tsunami hazards. Two pilot demonstration projects, one in Yaquina Bay, Oregon and the other in Sinclair Inlet, Washington are almost concluded at this date. Specific products of this project include a regional stakeholder issues and needs assessment, a community-based mitigation planning process aimed at port and harbor resources, a GIS-based vulnerability assessment methodology, a regional data archive, and an educational web-site.

BACKGROUND

Historical and geological evidence suggest the Pacific Northwest has experienced catastrophic earthquakes in the past along the Cascadia Subduction Zone (CSZ), the 1000-kilometer fault located 60-80 km offshore northern California, Oregon, Washington, and British Columbia. Their magnitude and effects are similar to the great Alaska earthquake of Good Friday, 1964: severe ground-shaking lasting up to four minutes. Although no major events have occurred along this fault for over 300 years, available evidence suggests that we are now “in the window” for a very large earthquake along this fault.

A CSZ earthquake would generate a tsunami with a chain of waves up to 20 feet sweeping onshore approximately 20 minutes later at Newport, Yaquina Bay and persisting for up to eight hours. Robust tsunami modeling, validated by paleo-geologic evidence has enabled agencies to map maximum inundation lines along much of the Cascadia Coast and Strait of Juan de Fuca. Waves from the same event, while measurable inside Puget Sound, would be so attenuated as to be of negligible consequence by the time they reached Sinclair Inlet.

Other earthquake and tsunami sources, while likely less damaging, have greater probability of occurring in the short term. Large shallow earthquakes have occurred in the region in the past: in Oregon, the M 5.6 Scotts Mills, earthquake in 1993 and the M 6.0 Klamath Falls earthquake in 1996. An M7.2 event approximately 1,100 years ago on the *Seattle Fault* left evidence of major uplift on a surface fault near Sinclair Inlet in Washington and produced a tsunami that struck shore within minutes. On a decadal time scale deep intraplate (Benioff Zone) earthquakes in the subducting Juan de Fuca plate have been felt by almost everyone now living in the Puget Sound region; the last, an M 6.8 event near Nisqually caused $2 billion damage in 2001.

Submarine earthquakes occurring around the Pacific Rim produce tsunamis that reach the Pacific Northwest hours later with a succession of damaging waves. The 1964 Alaska earthquake was the most recent to inflict damage and loss of life in some coastal locations in Washington, Oregon and N. California, but other sources for *tele-tsunamis* including Chile, Japan and the Russian Kamchatka Peninsula are of concern. While measurable inside Puget Sound, tele-tsunamis would produce flooding only during the highest tidal levels.

APPROACH

Sustainable hazard mitigation is an emerging paradigm that challenges communities to plan for disasters over a longer time-span and to become more self-sustaining and resilient. It requires an assessment of risks, not only to populations and the built environment, but also to natural resources that sustain damage from the event as well as from the response and recovery operations, and from mitigation actions following it. The paradigm challenges communities to achieve these goals through a consensus-building, community-based approach involving all stakeholders (Mileti, 1999) .

The last point is particularly important for the design of our six-stage community-based planning model. Stakeholder involvement enhances traditional technical analyses with otherwise unattainable insight into the social, economic, political, and cultural systems of a community, thus incorporating multiple goals and motives into the process. (Wood, 2002)

SELECTING DEMONSTRATION COMMUNITIES

We identified two demonstration port and harbor communities, one each in Oregon and Washington that that were (1) representative of small to medium-sized ports, (2) faced a typical suite of seismic and co-seismic hazards, (3) had a defined and modeled tsunami risk, (4) had capacity to build a supporting Geographic Information System, (5) had local technical and planning capacity, and (6) evidenced local political support for hazard mitigation planning.

Yaquina Bay, Oregon was selected because it not only met these criteria, but had the additional advantages of local university marine research facilities and a familiarity to the Principal Investigator. The Cities of Newport and Toledo, and the Port of Newport comprise this community.

Sinclair Inlet in central Puget Sound, Washington was selected following a comprehensive and competitive review of interested small- to medium-sized ports in Puget Sound and along the Strait of Juan de Fuca. The Port of Bremerton, the municipalities of Bremerton, Port Orchard and Kitsap County comprise this community.

RESULTS

The six-stage planning process included: (1) getting started, (2) hazard-assessment and scenario-building, (3) vulnerability assessment, (4) mitigation options development, (5) plan development, and (6) implementation. Both Yaquina Bay and Sinclair Inlet are currently in stage 5—plan development, although some implementation activities are beginning. Principal activities and results for each stage are outlined below.

Stage 1: Getting Started

This stage included meetings with port-harbor community leaders and governing bodies to build support and understanding of project goals. Staff activities included defining the study area; identifying preliminary GIS design questions, associated data needs, and data availability; identifying and getting commitments of support from technical advisors; and developing a flexible task and local workshop timetable.

Stage 2: Assessing Hazards and Developing Scenarios

One-day technical workshops were conducted with key local advisors and technical experts in both communities, resulting in scenarios that formed the basis for hazards analysis and vulnerability assessment. For *Yaquina Bay*, two scenarios—a distant earthquake-generated tsunami (the 1964 Alaskan event served as the model) and a local CSZ event were selected to guide planning. For *Sinclair Inlet*, three scenarios were identified: a CSZ event, a Benioff event (similar to the 2001 Nisqually earthquake), and a Seattle Fault event. The last is most problematic for Sinclair Inlet, given the fault's location in the local area and its significant potential to generate tsunami.

In both communities, based on respective scenarios, coseismic and secondary hazards were identified and evaluated, including groundshaking amplification, liquefaction and lateral spreading of unconsolidated soils, landslides adjacent to shorelines, land level changes, and potential damage from fires and hazardous material spills. Deaths, injuries and psychological trauma, isolated populations, economic dislocation and business failures, and severe environmental damage are the expected outcomes of these hazards.

Step 3: Assessing Community Vulnerability

Two-day Vulnerability Assessment workshops, combining classroom and field exercises and aided by GIS hazards maps were held in each community. First grouped geographically, then by "function," stakeholder working groups identified high priority community vulnerabilities. Technical advisors with scientific and engineering expertise were included in each working group to interact with local stakeholders, who were seen as local area "experts". The *product* of this effort included vulnerability issues of local concern and preliminary mitigation suggestions.

Step 4: Developing Mitigation Options
At a one-day Mitigation Workshop, using the Vulnerability Workshop results as starting point, stakeholders reviewed key issues and fleshed out preliminary mitigation options identified earlier. Each community assigned high priority to similar issues: life safety; uncoordinated port and harbor response capacities; community-wide infrastructure (especially bridges, water and gas lines, sewage systems); navigational infrastructure (channels, jetties, aids to navigation); port infrastructure (docks, wharves, bulkheads); recreational marinas; vessels afloat; shoreside structures; shoreside businesses. The *product* of this workshop was a framework for a Port and Harbor Mitigation Plan.

Step 5. Preparing The Mitigation Action Plan
Staff work was undertaken to complete research and findings on key issues, and to evaluate mitigation options at preceding workshops. Small-group meetings are being held with potential implementing entities to refine mitigation actions in the draft plan, and staff are making presentations to business groups such as Chambers of Commerce meetings, luncheons. The ultimate *product* is a final Mitigation Action Plan (MAP), along with implementation suggestions. An example issue from the Yaquina Bay MAP illustrates the results of this stage.

Issue: Navigation Infrastructure
Damage to jetties, alteration of navigation channel configuration and depth, blocked channels, and lost or displaced navigation aids would disrupt important transportation lifelines and severely hamper response and recovery efforts.

Mitigation Objective
To quickly restore navigation infrastructure and water access to ports, and government and private facilities on Yaquina Bay following an earthquake and/or tsunami.

Mitigation Actions—Existing or planned
The north jetty at Yaquina Bay entrance was recently repaired and strengthened, but not for seismic stability.

Mitigation Actions—Short term
Model the effectiveness of the current jetty system in dampening the impact of tsunami events, for example, in the new tsunami laboratory at Oregon State University.
Implementation: Port of Newport promote tsunami modeling studies at O. H. Hinsdale Wave Laboratory, OSU Department of Civil, Construction, and Environmental Engineering.

Mitigation Actions—Long Term
Develop a post-event navigation maintenance plan, considering likely impacts to existing infrastructure and needs for post-event navigational access.
Implementation: Ports of Newport and Toledo in collaboration with the US Army Corps of Engineers, Portland District; seek federal assistance through local Congressional offices.

Step 6. Implementing The Mitigation Action Plan

This stage has yet to be carried out, but it is envisioned to include local governmental adoption of MAP actions (port, city, county); individual and enterprise adoption of MAP actions (households, firms, vessel owners, associations); other agency adoption of MAP actions (federal and state geology, marine science/management, and emergency management agencies); and periodic assessment of progress/updates (community officials, stakeholder groups, enterprises and individuals).

LESSONS LEARNED

Stakeholder Involvement: Stakeholder input elevated vulnerability assessments from individual exposure to community-wide vulnerability. Interactions with technical advisors built a cadre of knowledgeable local "experts."

Involving the business community: Small business owners were reluctant to devote time to 1- and 2-day workshops, but were appreciative of and engaged by team presentations to business groups—Kiwanis breakfasts, Chamber of Commerce luncheons, etc.

GIS as a vulnerability assessment tool: GIS maps of composite hazard, resources, and vulnerability hot-spots are an effective tool to reveal the complex nature of natural hazards and their destructive interactions with the built, social and natural environments.

Dual Vulnerability Assessment Methodology: Assessments from both *geographic* and *community function* viewpoints resulted in a robust representation of community-wide vulnerability issues.

Implementing Mitigation Actions: Mitigation options developed during stakeholder workshops required much refinement by staff and will need further review by community leaders and key stakeholders before they can be implemented.

Scientific uncertainty about hazards: Where hazards are not adequately defined and quantified (e.g. uncertain tsunami inundation depths and run-up distances) scientists seem powerless to help stakeholders develop appropriate responses.

Stakeholder skepticism: For seismic hazards with long, irregular, or unknown recurrence intervals (e.g. a Seattle Fault event) stakeholders are reluctant undertake structural mitigation measures, or support prohibition of development – especially single family homes – in shoreline areas.

LITERATURE CITED

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