Innovative Tsunami Preparedness, Response, and Recovery Planning Tools for California Communities

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Rick Wilson, California Geological Survey

Partners =

[Logos of various partners]
Recent Tsunamis in California

Evacuation & Response Planning

Maritime Planning

Land-Use & Construction Products
Issues following recent tsunami events:

1) Evacuation considered only maximum inundation (potential for over-evacuation);

2) Real-time forecasts didn’t consider impacts from tides or storm surge;

3) No planning products to help guide maritime communities;

4) No planning products to help with land-use planning and project-level evaluation of risk
Recent Tsunamis Activating California Emergency Response

Samoa Sept 2009

Chile Feb 2010

Japan March 2011

Haida Gwaii Oct 2012

SE Alaska Jan 2013

Chile April 2014

National Tsunami Warning Center
Initial State Response to: **WARNING** and/or **ADVISORY**

Focus on specific areas or locations of heightened concern based on:

<table>
<thead>
<tr>
<th>Start of Tsunami</th>
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</thead>
<tbody>
<tr>
<td>Wave Heights</td>
</tr>
<tr>
<td>Tide Conditions</td>
</tr>
</tbody>
</table>

**Actions:**

- Participate in calls with NOAA Tsunami Warning Center
- Activate state eoc’s (SOC/REOC)
- Conduct calls with emergency managers in 20 coastal counties
2011 Tohoku (Japan) Tsunami in California

- Large tidal fluctuations = 16 feet in Crescent City (largest surges at low tide)
- Strong currents/debris in harbors
- Potential dangerous tsunami conditions lasted for more than 48 hours (to 7 days).
- Impacts:
  - one fatality;
  - 27 harbors damaged;
  - Official = $50M; Total ~$100M

March 11, 2011 Tohoku, Japan, Tsunami in California; video at 11AM (about 3 hours after first arrival of tsunami) within Santa Cruz Harbor
Issues and Lessons Learned from Recent Real and Scenario Tsunamis

- **Evacuation Issues**
  - Inconsistent response actions statewide
  - What evacuation, if any, in a minor or moderate “Warning” alert at high/low tide?

- **Maritime Community Issues**
  - If/When/Where to move or evacuate boats?
  - Educate boat owners about tsunami hazards
  - Long-term recovery issues
  - What can be done to improve resiliency (mitigation and recovery)?

- **Land-Use and Recovery Planning**
  - Japanese experience pre- and post-tsunami development and tsunami recovery
  - Recovery issues in California in 2011
Tsunami Evacuation & Response Planning
Tsunami Warning Centers and Regional National Weather Service Forecast Offices

State Emergency Management Agencies, State Geological Surveys, and Academic Partners

National Tsunami Hazard Mitigation Program

Coordinating Committee
Mapping and Modeling Subcommittee
Mitigation and Education Subcommittee
Warning Coordination Subcommittee
Evacuation/Emergency response planning

www.tsunami.ca.gov
Evacuation Playbooks for Scenario Tsunami Events (less than “worst case” scenario)

- Project supported by NTHMP/NOAA
- Two types of tsunami evacuation playbooks:
  - Elevation-based Evacuation Playbooks (more than 4-5 hours until tsunami arrives)
  - Scenario-based Evacuation Playbooks (less than 4-5 hours until tsunami arrives)
- Guidance for use, consideration of FA-S-T-E-R decision-making approach

Draft tsunami evacuation “playbook” lines based on elevation for City of Imperial Beach
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 5-6 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)

\[
\text{FA} + \text{S} + \text{T} + \text{E} + \text{R} = \text{Height}
\]

\[
2.5\text{m} + 0\text{m} + (-1\text{m}) + 0.75\text{m} + 0.5\text{m} = 2.75\text{m}
\]

3m elevation below purple line below

Working example for March 11, 2011 event at Crescent City:
Secondary Evacuation Plans
Tsunami Evacuation Playbooks
Evacuation maps based on elevation using streets and landmarks

NOTE: Exploring use of evacuation Playbooks for other coastal flood events (King Tide; storm surge)

**Evacuation Playbooks for every community in state 2015-16**

www.tsunami.ca.gov   CGS Special Report 236
Maritime Response and Mitigation Planning Guidance and Implementation
Maritime Safety Products – FEMA RiskMAP

1. Create in-harbor hazard maps, based on current vs. damage
2. Create minimum offshore safety line/zone (30 fathoms=180 feet)
3. Provide statewide planning and response guidance (Playbooks)

Video and other analyses of currents used to validate currents from numerical models

March 11, 2011 tsunami in Santa Cruz; modified from Wilson and others, 2012, and Lynett and others, 2013
Tsunami Current Hazard Maps

Can we filter this information, create areas where certain levels of damage might be expected?

Developed relationship between tsunami currents and damage

Based on previous observations of damage, and numerical hindcast & direct speed measurements at the damage location

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

From Lynett and others (2013)

Damage begins to transition to major with currents > 5/6 knots

Minor / moderate damage observed for currents between 2/3 and 5/6 knots

No observation of damage for currents < 2/3 knots

Major to complete damage for currents greater than 8/9 knots
Maritime Tsunami Response Playbooks
Maps are FEMA RiskMAP Products

**Draft Maritime Playbooks for entire state in June 2015**
Mitigation Planning Using Maritime Response Playbooks

- Identify areas prone to tsunami hazards using historical information, tsunami current maps, and other products

- REAL-TIME MITIGATION - Determine where planning for pre-tsunami vessel movement and infrastructure controls/shut-down can reduce damage

- LONG-TERM MITIGATION - Develop strategy for replacing or hardening docks, piers, piles, etc.

- Consider mitigation measures that address multi-hazard (tsunami, earthquake, storm, sea-level rise, etc.) impacts

- Incorporate reasonable and achievable mitigation measures into Local Hazard Mitigation Plans

Scenario-Based Failure Probability for cleats, moorings, docks, boats, etc., based on strength and direction of tsunami currents.

**First Multi-Hazard Maritime Mitigation Reports available in 2015**
Land-Use Planning and Construction Products

Hilo 1946  Hilo 1946  Hilo 2015
Production and Uses for Maps based on Probabilistic Tsunami Hazard Analysis (CA Work Group)

Our concept: Produce **single set** of risk maps/products for multiple uses

- **Real-estate disclosure and Project-level assessment** (CGS-Seismic Hazard Mapping Act)

- **Land-use planning** (Coastal Communities, CA Coastal Commission)

- **Standardized hazard analysis for evacuation planning** (Cal-OES)

- **Building design and construction, essential/critical facilities** (ASCE, Uniform/ International Building Code, Nuclear Regulatory Commission)

- **Flood protection and insurance** (FEMA, Risk MAP, CA-Dept. of Water Resources)

- **Input for consistent risk analysis and damage estimates** (HAZUS)

*URS Consultants (AECOM), 2013 for Caltrans/PEER/CGS
Probabilistic Tsunami Hazard Analysis in Crescent City; blue line is 2009 state inundation map line*
**Probabilistic Tsunami Hazard Analysis maps available in 2016**

<table>
<thead>
<tr>
<th>Risk levels (ARP)</th>
<th>Annual rate of exceedance</th>
<th>Seismic Hazard Mapping Act Zones</th>
<th>FEMA</th>
<th>Evacuation planning</th>
<th>Evacuation design</th>
<th>DWR Flood Zones (equivalent)</th>
<th>ASCE – IBC</th>
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<tbody>
<tr>
<td>100</td>
<td>50% in 50yr</td>
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<td>yes</td>
<td></td>
<td></td>
<td></td>
<td>in potential future version</td>
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<tr>
<td>200</td>
<td>25% in 50yr</td>
<td></td>
<td>yes</td>
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<tr>
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<td>10% in 50yr</td>
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<tr>
<td>1000</td>
<td>5% in 50yr</td>
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<td>ASCE 7-16; IBC 2018</td>
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RISKMAP

**Table 2. Potential applications for various PTHA risk-levels.**
Conclusion:

- Mission is public safety, property & environment protection.
- We are in the business of developing scientifically vetted, consistent tsunami hazard information.
- Goal is getting the right info into the hands of decision-makers:
  - Emergency Managers
  - Harbor Authorities
  - Community Planners
  - Building Industry
Thank you!

www.TsunamiZone.org
www.tsunami.ca.gov