The United States and Washington State Tsunami Warning Systems & Tsunami Vertical Evacuation Strategies

From Education To Application

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Washington Emergency Management
NTHMP Mitigation & Education Subcommittee Co-Chair
First, some tsunami basics...

Water + EQ = Tsunamis
What is a Tsunami?

A tsunami is not a single wave, but a series of waves.
What causes a Tsunami?

Subduction Zone Earthquake
What causes a Tsunami?

Sudden submarine landslides or slumps

Local Landslides (above or below water)

Tsunami waves can be generated

Displacements of water
Local vs. Distant Tsunamis

- **DISTANT** Tsunamis:
  - Events with 2+ hours arrival time from around Pacific Rim
  - Time & capability to issue ‘official’ warnings
  - Much smaller than local tsunamis
  - NOAA Tsunami Warning Centers (TWCs), Dart Buoys provide useful data

- **LOCAL** Tsunamis:
  - Events with 5-30 min. arrival time & most casualties occur w/in 45 min.
  - Massive tsunamis with large inland penetration possible
  - People must be trained on life-safety protective actions & act immediately!
  - TWCs & buoys ineffective for initial life-safety actions

- **“The time’s, they are a changin’?”**
  - M8+ EQ in the next 50-years:
    - 10 – 14 % Northern CSZ (USGS)
    - 37 % Southern CSZ (C. Goldfinger)
Tsunami Warning System – What is it?

Acronyms
- NWS - National Weather Service
- EOC - Emergency Operations Center
- EMWIN - Emergency Managers Weather Information Network
- GTS - Global Telecommunications System
- FOS - Family of Services

Paul Whitmore, 2011
Tsunami Warning System History in the United States

Paul Whitmore, 2011

NOAA TSUNAMI WARNING SYSTEM AREAS OF RESPONSIBILITY
West Coast/Alaska Tsunami Warning Center (WC/ATWC) and Pacific Tsunami Warning Center (PTWC)

Paul Whitmore, 2011
The Tsunami Warning Process

The Tsunami Warning Centers provide:

- **Quick earthquake analysis**
  - Determine as fast as possible
    - Earthquake location
    - Magnitude
    - Depth
  - Issue initial message based on pre-set criteria

- **Analyze tsunami signal**
  - Forecast impact outside source zone
  - Issue supplemental messages as appropriate

- **Monitor until threat over**
  - Monitor coastal gages
  - Cancel alert when danger passed

Adapted from Paul Whitmore, 2011
Tsunami Warning Centers - Data Acquisition

• Seismic
  – Virtual network
  – Multiple data paths
  – Redundancy

Paul Whitmore, 2011
Tsunami Warning Centers - Data Acquisition

- Sea Level
  - Virtual network
  - Satellite data transmission
  - Many formats
  - Many instrument types
  - Coastal tide gages & DART
Tsunami Warning Centers - Data Processing

- Seismic
- Sea level
- GIS – Data bases
- Forecasting
- Message/graphic generation
Warning Process - Forecasting

- **Forecasting**
  - Assimilate observed tsunamis into models
  - Use forecast to dictate supplemental messages
  - Observations can also be compared with historical data to forecast impact
Warning Process – Performance

- Average response times by region for 2010-2011

<table>
<thead>
<tr>
<th>Region</th>
<th>Response Time (minutes)</th>
<th>Number of Events</th>
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<tbody>
<tr>
<td>U.S West Coast</td>
<td>3:22</td>
<td>38</td>
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<tr>
<td>British Columbia</td>
<td>3:49</td>
<td>4</td>
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<tr>
<td>Alaska</td>
<td>4:05</td>
<td>159</td>
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<tr>
<td>U.S/Canada East Coast/GOM</td>
<td>4:08</td>
<td>1</td>
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<td>Puerto Rico/VI</td>
<td>3:08</td>
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</table>
## WCATWC-Pacific

<table>
<thead>
<tr>
<th>Area</th>
<th>Bering Sea, Deep</th>
<th>Bering Sea, Shallow and Arctic Ocean</th>
<th>Outside AOR - Pacific</th>
<th>Outside AOR - Indian Ocean Basin</th>
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<tbody>
<tr>
<td>AK, BC, WA, OR, CA (Sections 6.1.1 and 6.1.2)</td>
<td>Within 50 km / 30 mi of the US or Canadian Coast</td>
<td>Notify: NADIN, NMC Line, NWWS, Internet, Email, QDOS Call: ECC, and ADHSEIM via AKWAS</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Message 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Except West of 156W (Kodiak))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Notify: NADIN, NMC Line, NWWS, Internet, Email, QDOS Call: NEIC and Associate States**</td>
<td></td>
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<tr>
<td></td>
<td>Within 150 km / 90 mi of the US or Canadian Coast</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Message 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Notify: NADIN, NMC Line, NWWS, Internet, Email, QDOS Call: NEIC and Associate States**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Within AOR or coastal state/province</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Message 5</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Notify: NADIN, NMC Line, NWWS, Internet, Email, QDOS Call: NEIC and Associate States**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TIS SEAK71 or SEUS71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Message 5</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Notification List #1 Flow Chart #3.2.1 (Including all inland quakes M&gt;=5.5 and 6.5 &lt;= M &lt; 7.6 deeper than 100 km) Monitor tide gauges for tsunami. Normally only one message issued, although a supplement can be issued if a tsunami is observed. If a significant tsunami is recorded, upgrade to warning.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Warning WEPA41/WEAK51</td>
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<tr>
<td></td>
<td>Message 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Notification List #1 Flow Chart #3.2.1 (Warning extending to first break points beyond 250 km — NO Watch Call Canadian Hydrographic Service and request tide gauge interrogation, if appropriate. Monitor tide gauges for tsunami. Coordinate future messages with PTWC)</td>
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<tr>
<td></td>
<td>Warning WEPA41/WEAK51</td>
<td></td>
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<td>Message 1</td>
<td></td>
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<tr>
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<td>Notification List #1 Flow Chart #3.2.1 (Warning to first break points beyond 1000km/Advisory to 1000km — NO Watch Monitor gauges for tsunami. (Call CHS) Coordinate future messages with PTWC)</td>
<td></td>
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<td>Warning WEPA41/WEAK51</td>
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<tr>
<td></td>
<td>Message 1</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Notification List #1 Flow Chart #3.2.1 (Warning for the Preliminary and Advisory to WEPA41/WEAK51. Note: This is a border area where the warning area will normally continue) Monitor tide gauges for tsunami. Coordinate future messages with PTWC)</td>
<td></td>
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<tr>
<td></td>
<td>Watch WEPA41/WEAK51</td>
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<td></td>
<td>Message 1</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Notification List #1 Flow Chart #3.2.1 (Watch for the Preliminary and Advisory to WEPA41/WEAK51. Note: This is a border area where the warning area will normally continue) Monitor tide gauges for tsunami. Coordinate future messages with PTWC)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**For earthquakes in Alaska, notify: ADHSEIM via AKWAS and call ENSCONC Command Center.**
Warning Process – Disseminate Information
Primary Contacts (simplified)
Tsunami Warning Centers – Disseminate Information

- Message Dissemination
  - Primary
    - National Warning System
    - NOAA Weather Wire
    - NWS gateway
    - FAA system
  - Secondary
    - Email
    - RSS
    - FAX
    - SMS messaging
    - Web site
    - USGS
< 30cm Amplitude Expected
Issued to prevent needless evacuations
OR to provide information on distant events

M>7.9 – Source > 2 hours away
Danger level not yet known

30cm-1 meter (3.2 feet) cm Amp.
Usually based on forecast
Automatic for 7.1-7.5 far offshore

> 1 meter (3.2 feet) Amplitude Expected
Issued based on forecast or automatically based on earthquake parameters

Paul Whitmore, 2011
Washington State Tsunami Warning Siren System:

- Integrated communications infrastructure developed to get the message to outdoors populations

- All-Hazards Alert Broadcast (AHAB) Sirens
  - 54 Sirens located along outer coast, Strait of Juan de Fuca, and Puget Sound
  - 2 additional sirens planned for installation this summer

- Regular, consistent testing regimen implemented in March 2009.
  - Tested on even numbered months from State EOC (satellite)
  - Tested on odd numbered months from local jurisdiction (DTMF tones)
Washington State Tsunami Warning Siren System:

- Federal-State-Local Partnership
- Deployed to at-risk Population Centers
- Primarily Located Along Outer Coast and Strait of Juan de Fuca

Siren Capabilities:
- 360-degree communications
- Multiple siren tones (chime, wail, steady, etc.)
- Public Address Functions:
  - Dynamic Digital Voice
  - Voice over Satellite Capability

Can be activated by:
- State EOC via satellite
- Local EOC via handheld radio or encoder
96 AHABs are needed along the outer coast for tsunami warning

Current: 54 tsunami, 8 lahar
Ok…but what warning systems exist for Local Tsunamis?

Fortunately, since 1995, Congress recognized the clear and present danger tsunami hazards pose to United States coastal communities (& all 95,471 statute miles of U.S. tidal shoreline) and did something about it:

The National Tsunami Hazard Mitigation Program (NTHMP)

Source: http://shoreline.noaa.gov/faqs.html
State tsunami programs, in collaboration with federal, state, and local researchers conduct:

- Scientific Studies and Workshops
- Tsunami Modeling for ‘Worst-case’ Scenarios to Ensure Life-safety
- Tsunami Inundation Mapping
- Evacuation Mapping
NEW Online Tsunami Evacuation Mapping Tool

www.dnr.wa.gov – Geologic Information Portal
“Community-based” Preparedness & Mitigation Efforts

State tsunami programs, in collaboration with federal & local partners to:

- Provide Tsunami Education
  - Incorporate ‘evidence-based’ social science approaches

  **Target Audiences:**
  - School Aged Children
  - Media Partners
  - Hospitality Industry
  - Local Businesses
  - Land Use Planners
  - Coastal Residents
  - Tourists
  - Maritime Community
  - First Responders

- Install Tsunami Signage

- Support Local Jurisdiction Needs
Tsunami Signage

- Pre-event Awareness
- Evacuation Routes
  - Driving & Walking
- Consistent Design & Message throughout U.S.
- Life Safety Signs
Warning Guidance

State tsunami programs in collaboration with federal, state, and local officials develop warning and response protocols:

- **NOAA:**
  - Tsunami Detection
  - Tsunami Bulletin Issuance

- **State & Local Warning Points**
  - Alert and Notification
  - Evacuation Orders
Project Safe Haven:
Tsunami Vertical Evacuation in Washington State
Tsunami Vertical Evacuation: Why Now?

Cascadia Subduction Zone
Local Earthquake!

Ah ha!

High ground: You CAN’T get there from here!

Bummer!
Guidelines for Design of Structures for Vertical Evacuation from Tsunamis

Vertical Evacuation from Tsunamis: A Guide for Community Officials

FEMA P646 / June 2008

FEMA P646A / June 2009

FEMA
Washington Tsunami Hazard Profile:

- Local Source - Cascadia
- ~30-40 minutes before arrival of first wave
- Extremely flat coastal topography coupled with long peninsulas
- Majority of Coastal Communities Likely to be Flooded
- Vulnerable Populations at Risk
  - Seniors
  - Children
  - Etc.
- Untrained Tourist Population that reaches 100k+ during summer
What’s at Risk on the Outer Coast of Washington State?

**Populations:**
- Residents: ~42,972
  - Most 65+ years in age, many renters
- Employees: ~24,934
- Tourists: 100K+ during summer months
- State Parks: ~17,029 people (daily average)
- Other populations:
  - Public venues and hotels
  - Dependent-population facilities (schools, day cares, etc.)

**Economy:**
- 33% of workforce in tsunami inundation zone
- Businesses focus on tourism, social services, and manufacturing

**Critical and Essential Facilities:**
- High number of police stations, fire stations, public-work facilities
- High number of banks, government offices, and markets

(Source: Wood & Soulard, 2008)
Hotspots of Evacuation Challenges

Ocean Shores, WA

Westport, WA

Long Beach Peninsula, WA

Grays Harbor

Pacific Ocean

Pacific Ocean

Travel time out of hazard zone (min)


Based on 1.1 m/s travel speed
Project Safe Haven:

- **Community-based, ‘top-down’ planning approach** (hint: the community is at the top)

- All options (buildings, towers, berms, etc.) are on the table for consideration by community participants

- Community members provide 100% of the input, experts are on hand to answer technical questions and facilitate the planning and design meetings.

  *After all, this is the community’s plan…*

Common Themes:

- School safety!!!
- Seniors and special needs populations
- More conservative travel times – 15 min. instead of 30 min.
- Requested more conservative estimates of elevations
Project Safe Haven Options (from FEMA 646):

Towers –
• Limited Space
• Blocks Views
• Few Options for Shelter

Buildings –
• Expensive
  • Better get it right the first time!
• Very Large, Likely to Block Views
• May require Private Development
  • Incentives for Height?

Berms –
• A Less Expensive Option
• Can be Multi-Purpose
• May be Placed to Limit View Blocking
Safe Haven Planning Process

- Kick off Meeting with Local Emergency Manager
- Community World Café Meeting (Gather initial community input)
- Alternatives Analysis (SWOT) By Community Members
- Community Development of Preferred Alternative
- Urban Design Charrette with Architects
- Community Ranking of Locations & Final Plan Development
1. City of Long Beach, WA

Preferred Strategy

- Five Berms Distributed Along Eastern Extent of Community

- Potential Public Building Development in Center of Town

- Permanent Residents Able to be Served by Structures

- Will accommodate tourists
2. Tokeland/North Cove, WA

Preferred Strategy

• Focus on towers that can be used for bird watching.

• Leverage casino facility uses and construct elevated parking structure.
## Evacuation Capacity Analysis

<table>
<thead>
<tr>
<th>Map Number</th>
<th>Structure Type</th>
<th>Location</th>
<th>Structure Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tower</td>
<td>Ocean City</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>Tower</td>
<td>Quinault Beach Resort</td>
<td>500</td>
</tr>
<tr>
<td>3</td>
<td>Berm</td>
<td>North Beach Junior/Senior High School</td>
<td>800</td>
</tr>
<tr>
<td>4</td>
<td>Parking Structure</td>
<td>Downtown</td>
<td>1700</td>
</tr>
<tr>
<td>5</td>
<td>Tower or Berm</td>
<td>Golf Course</td>
<td>350</td>
</tr>
<tr>
<td>6</td>
<td>Tower</td>
<td>Ocean Shores Airport</td>
<td>350</td>
</tr>
<tr>
<td>7</td>
<td>Tower or Berm</td>
<td>Ocean Shores Elementary</td>
<td>350</td>
</tr>
<tr>
<td>8</td>
<td>Tower</td>
<td>Ocean Shores Blvd &amp; Taurus Blvd SW</td>
<td>350</td>
</tr>
<tr>
<td>9</td>
<td>Tower or Berm</td>
<td>Blue Wing Loop SE &amp; Duck Lake Drive SW</td>
<td>350</td>
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<td>10</td>
<td>Tower</td>
<td>Cormorant St</td>
<td>350</td>
</tr>
<tr>
<td>11</td>
<td>Tower</td>
<td>Ocean Shores Blvd &amp; Marine View Drive SW</td>
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<tr>
<td>12</td>
<td>Tower</td>
<td>Emeritus Senior Living</td>
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<td>13</td>
<td>Tower</td>
<td>Wowona Ave SE &amp; Tonquin Ave SW</td>
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<tr>
<td>14</td>
<td>Tower or Berm</td>
<td>Spinnaker Park</td>
<td>500</td>
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<tr>
<td>15</td>
<td>Tower or Berm</td>
<td>Ocean City State Park Campground</td>
<td>350</td>
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<td>16</td>
<td>Tower</td>
<td>Between Lake Bay Loop SE &amp; Pearsall Street on Duck Lake Dr</td>
<td>350</td>
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<td>17</td>
<td>Tower</td>
<td>Trois Court &amp; Inlet Avenue NW</td>
<td>350</td>
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<tr>
<td>18</td>
<td>Tower or Berm</td>
<td>Ocean Lake Way &amp; N Port Loop</td>
<td>350</td>
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<tr>
<td>19</td>
<td>Tower or Berm</td>
<td>North Razor Clam Drive &amp; Butterclam St SW</td>
<td>350</td>
</tr>
<tr>
<td>20</td>
<td>Tower</td>
<td>Mt. Olympus</td>
<td>350</td>
</tr>
</tbody>
</table>
Step 2. Figure out what the community wants these things to look like!

OR
Safe Haven Berms
Safe Haven Berms
Safe Haven Towers

SAFE HAVEN
FIRE HOSE/TOWER/
TRAINING FACILITY

2.5% (tower)
200 (training)
450 - cap.
325

hose tower
training facility (conc.)

visitor center ex.
stairs

Long Beach

shelter option
Safe Haven Buildings

1,460+ cap.
1 roof
2 offices
3 observation fl. (2nd)

Safe Haven Resort
Building Component
36 cap.
1 roof
2 stair landings

Safe Haven Pool
Building Component

Service core
Elevator stair offices observation floor
Gambion

Stair core
Units
Office
Gambion (landscaped patio)
Step 3. Figure out what the cost is...

(thank you, engineers)
<table>
<thead>
<tr>
<th>Type</th>
<th>Community</th>
<th>Site</th>
<th>Height (feet)</th>
<th>Capacity (# of people)</th>
<th>Estimated Cost</th>
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<tbody>
<tr>
<td>B1</td>
<td>berms</td>
<td>Long Beach N Place &amp; 41st Place</td>
<td>12</td>
<td>600</td>
<td>$644,095</td>
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<tr>
<td></td>
<td></td>
<td>Washington Avenue South &amp; 5th Street</td>
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<tr>
<td>B2</td>
<td>berms</td>
<td>Long Beach South</td>
<td>9</td>
<td>1000</td>
<td>$706,266</td>
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<td></td>
<td>Washington Avenue South &amp; 2nd Street</td>
<td></td>
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<tr>
<td>B3</td>
<td>berms</td>
<td>Long Beach South</td>
<td>12</td>
<td>400</td>
<td>$509,621</td>
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<tr>
<td>B4</td>
<td>berms</td>
<td>Long Beach 13th Street South &amp; Washington Avenue</td>
<td>9</td>
<td>700</td>
<td>$546,830</td>
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<td>B5</td>
<td>berms</td>
<td>Long Beach Q Street (Washington) &amp; 26th Street North</td>
<td>9</td>
<td>500</td>
<td>$440,540</td>
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<td>B6</td>
<td>berms</td>
<td>Ocean Park U Street &amp; 227th Place</td>
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<td>600</td>
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<td>Ocean Park SR 103 &amp; 210th Place</td>
<td>12</td>
<td>200</td>
<td>$375,147</td>
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<td>B8</td>
<td>berms</td>
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<td>16</td>
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<td>B9</td>
<td>berms</td>
<td>Ocean Park SR 103 &amp; 162nd Lane</td>
<td>25</td>
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<td>B10</td>
<td>berms</td>
<td>Ocean Park SR 103 &amp; Cranberry Road</td>
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<td>B11</td>
<td>berms</td>
<td>Ocean Park U Street &amp; 260th Street</td>
<td>20</td>
<td>800</td>
<td>$1,322,779</td>
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<td>B12</td>
<td>berms</td>
<td>Seaview N Place &amp; 37th Place</td>
<td>12</td>
<td>400</td>
<td>$509,621</td>
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<td>B13</td>
<td>berms</td>
<td>Ilwaco Ortelius Drive &amp; Scarboro Lane North</td>
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<td>T1</td>
<td>tower</td>
<td>Tokeland Kindred Avenue (Nelson Crab)</td>
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<td>100</td>
<td>$104,218</td>
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<td>T2</td>
<td>tower</td>
<td>Tokeland Tokeland Road &amp; Evergreen Street</td>
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<td>Tokeland Tokeland Road &amp; Pine Lane</td>
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<td>$105,929</td>
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<td>T5</td>
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<td>North Cove SR 105 &amp; Warrenton Cannery Road</td>
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<td>PK1</td>
<td>parking</td>
<td>Tokeland Shoalwater Bay Casino</td>
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<td>PK2</td>
<td>parking</td>
<td>Tokeland Shoalwater Bay Tribal Complex</td>
<td>19</td>
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<td>$414,201</td>
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Draft cost estimates for berm at Long Beach Elementary School *(1,000 person capacity)*

<table>
<thead>
<tr>
<th>Scope</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Utilities</td>
<td>$49,814</td>
</tr>
<tr>
<td>Excavation-Backfill</td>
<td>$289,512</td>
</tr>
<tr>
<td>Concrete</td>
<td>$153,951</td>
</tr>
<tr>
<td>Landscaping</td>
<td>$74,094</td>
</tr>
</tbody>
</table>

**Construction Totals** $567,370

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Fees (8%)</td>
<td>$45,390</td>
</tr>
<tr>
<td>General Conditions (10%)</td>
<td>$56,737</td>
</tr>
<tr>
<td>Contractor Fees, O&amp;P (15%)</td>
<td>$85,106</td>
</tr>
<tr>
<td>Construction Contingency (5%)</td>
<td>$28,369</td>
</tr>
<tr>
<td>Estimate/Design Contingency (10%)</td>
<td>$56,737</td>
</tr>
</tbody>
</table>

**Project Total** $839,708
Step 4. Deliver a community based plan...
And how do we know this will work here?
Because we’ve seen it work there
(Kesennuma, Japan)

From Stuart Frasier, GNS Science
We all have our faults...
There is NO SINGLE SOLUTION: Technological Solutions MUST dovetail with Preparedness Solutions to Achieve the Desired Outcome

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