Hazus Tsunami Pilot
FEMA Region 10

July 15th, 2015

NTHMP MES Summer Meeting

FEMA

Outline

- Background
- Objectives
- Assets at risk (Inventory)
- Hazard data
- Tsunami Analysis Prototype (TAP)
- Damage and Loss Assessment
- Results
- Observations and recommendations

Background

- Tsunami methodology was developed back in 2012-2013
- Though some validation efforts were carried out during development (based on tsunami damage data obtained from the historical 1964 Alaska EQ and the 2011 Tohoku EQ), no real pilots studies took place.
- This exercise provides a valuable opportunity to test out the methodology in greater depth.

Objectives

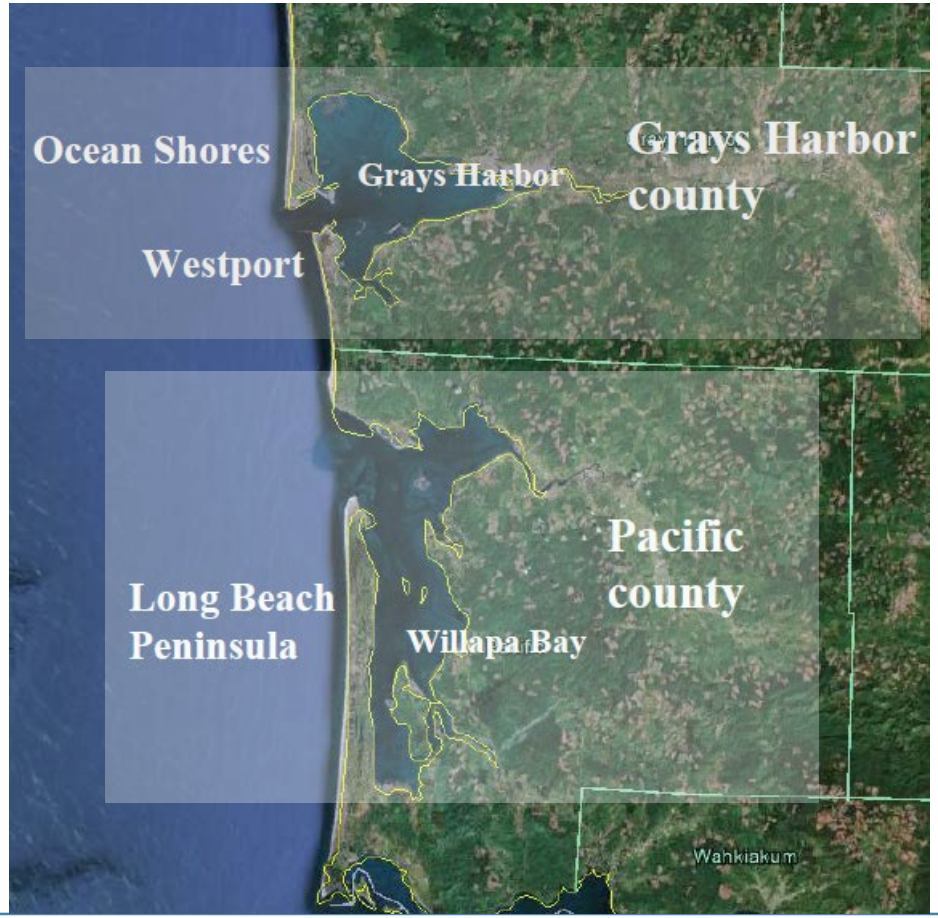
- Illustrate the application of the developed Tsunami methodology for coastal communities prone to tsunamis
  - Only building inventory at site-specific level considered in this exercise
- Assess the tsunami risk from two EQ events

Parameter	Scenario 1A	Scenario L1
Rupture length (km)	1,050	1,000
Rupture width (km)	70	83
Average slip (m)	17.5	13.0
Moment magnitude	9.1	9.0
Asperity location	47.324°N, 124.94°W	
Asperity Amplitude (m)	4.5	

- Share findings, identify areas in the methodology with potential enhancements and provide recommendations

Assets at Risk (Inventory)

- **Grays Harbor**
  - 2010 Population =72,797 (5,569 in Ocean Shores and 2,099 in Westport)
  - # Buildings = 33,727
  - All wood (43%W1, 3%W2, or 54%MH)
  - 28% pre-code and 72% moderate code
  - Building Value = 4.76 $B (of which about 1 $B allocated to structural elements)
  - Content Value = 3.43 $B
- **Pacific**
  - 2010 Population = 20,920 (1,573 in Ocean Park, 1,392 in Long Beach city)
  - # Buildings = 18,622
  - All wood (63%W1, 27%W2, or 10%MH)
  - 21% pre-code and 79% moderate code
  - Building Value = 1.51 $B (of which about 0.33 $B allocated to structural elements)
  - Content Value = 0.91 $B

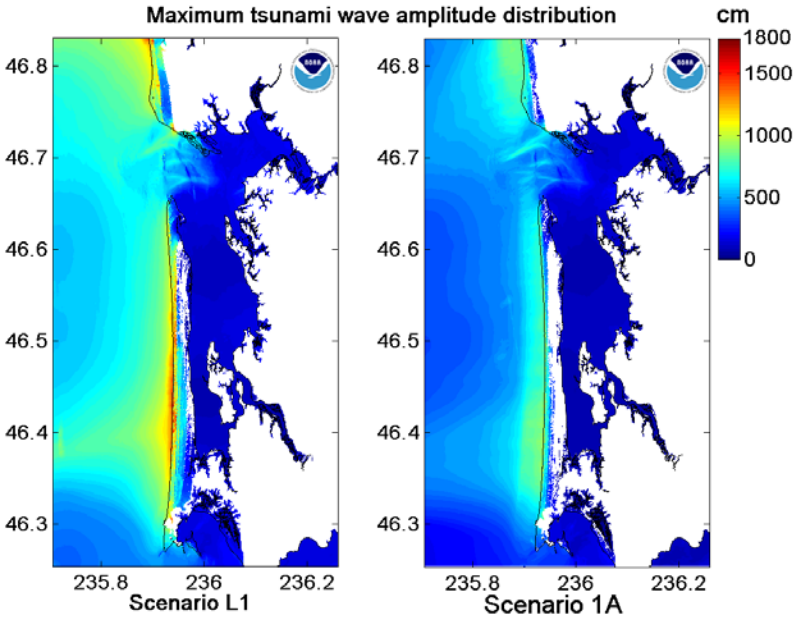


Hazard Data [1]

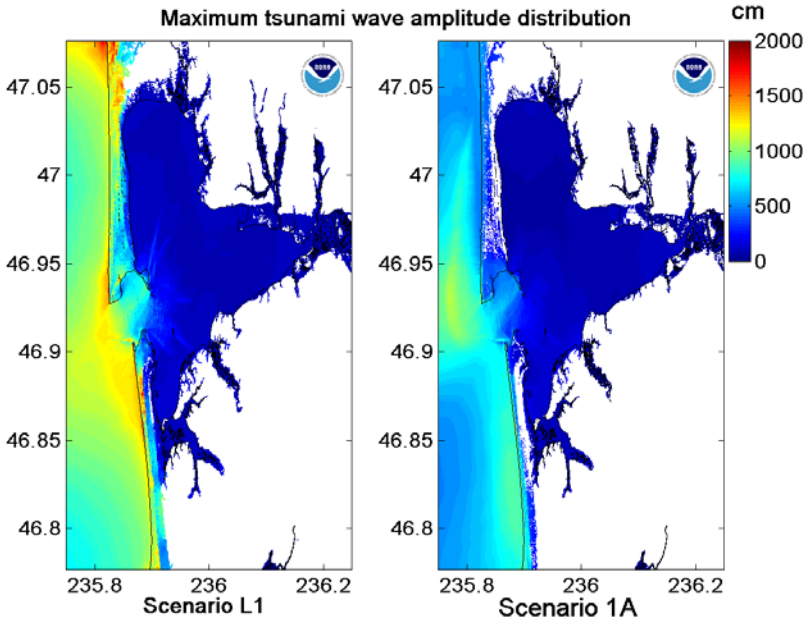
- PMEL provided Max H(x, y) and Max V(x, y) at grid point (x, y). Max H(x, y) is maximum amplitude and Max V(x, y) is maximum flow velocity
- Max $HV^2(x, y)$, which is the maximum flux was derived from Level 1 equation

$$f_f \, g \, R^2 \left(0.125 - 0.235 \frac{z}{R} + 0.11 \left(\frac{z}{R} \right)^2 \right)$$

Scenario	Grays Harbor	Pacific
1A	9.3 m (31 ft)	8.8 m (29 ft)
L1	18.8 m (62 ft)	15.5 m (51 ft)



Long Beach (Pacific)



Ocean Shore (G.H.)

Hazard Data [1]

Regarding Level 1 vs. Level 2 hazard data:

- In level 1,
  - All needed hazard parameters are equation-based, once seismic magnitude and epicenter are known. For example, Tsunami height is estimated based on the following equation:
    - where D is the distance to the earthquake epicenter in km, R is the tsunami height in meter, and Mw is the moment magnitude of the earthquake.
  - Max H(x, y), Max HV2(x, y), and Max V(x, y) at grid point (x, y) are calculated from the runup height R based on similar empirical equations
- In level 2,
  - Time histories for h(x, y, t), u(x, y, t) and v(x, y, t) at grid point (x, y) are provided. All needed parameters in the methodology are then derived from this data.
  - Alternatively, data for Max H(x, y), Max V(x, y), and Max HV^2(x, y) are provided.

In this exercise, the analysis is considered hybrid

Tsunami Analysis Prototype (TAP)

- When methodology was developed, TAP was designed to read time histories h(x, y, t), u(x, y, t), and v(x, y, t) which correspond to amplitude, velocity in horizontal direction and velocity in vertical directions, respectively. TAP would then compute Max H(x, y) and Max V(x, y), and Max HV^2(x, y) at each grid point (x, y).

- Since time histories were not provided, it was necessary to spend significant time to add another functionality to TAP that allows the use of the data in the format provided.

- TAP implemented most algorithms and logic of the various modules addressed in the methodology document.

Damage and Loss Assessment [1]

Tsunami methodology

- Use of lognormal damage probability functions to reflect uncertainty
  - Metric for structural damage ➔ Maximum flux
  - Metric for Non-structural damage ➔ Maximum flood depth
  - Metric for content damage ➔ Maximum flood depth
  - Metric for lifelines ➔ Maximum velocity
  - Building type and design level are important
- Economic loss ratios for different damage states are combined with damage state probabilities to estimate economic loss

Hazus Coastal flood methodology

- Economic loss ratios directly linked to hazard parameter
  - Building Loss ➔ Maximum depth
  - Content loss ➔ Maximum depth
- Building type is not important
- Design level is not important
- No differentiation between structural and non-structural losses
- No uncertainty is reflected

Results

Economic Impact

- **All results based on the use of 10-m (1/3 arcsec) DEM**

Impact Category	Grays Harbor County		Pacific County	
	Scenario 1A	Scenario L1	Scenario 1A	Scenario L1
# Buildings damaged	4,861	11,483	4,970	10,258
Structural Loss [$M]	37	99	31	61
Non-structural Loss [$M]	37	374	55	283
Content Loss [$M]	62	325	77	237
Building Loss [$M]	74	473	86	345
Total Loss [$M]	**137**	**798**	**162**	**582**

- Grays Harbor
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Sensitivity analyses [1]

- **Impact of DEM resolution – Grays Harbor County**

Impact Category	Scenario L1	
	30-m DEM	10-m DEM
# Buildings affected	5,402	11,483
Structural Loss ($M)	35	99
Non-structural Loss ($M)	143	374
Content Loss ($M)	124	325
Building Loss ($M)	178	473
Total Loss ($M)	**303**	**798**

Sensitivity analyses [2]

- **Use of Hazus damage functions for Coastal flooding**

Impact Category	Grays Harbor County		Pacific County	
	Scenario 1A	Scenario L1	Scenario 1A	Scenario L1
Building Loss [$M]	38	370	51	284
Content Loss [$M]	30	261	35	197
Total Loss [$M]	**68**	**631**	**86**	**481**

- **Tsunami Damage Function**

Content Loss [$M]	62	325	77	237
Building Loss [$M]	74	473	86	345
Total Loss [$M]	**137**	**798**	**162**	**582**

Sensitivity analyses [3]

- **Level 1 Approach vs Hybrid Approach (Max Velocity/Time History) – Grays Harbor County**

Impact Category	Scenario L1	
	Level 1	Hybrid
# Buildings affected	18,871	11,483
Structural Loss ($M)	113	99
Non-structural Loss ($M)	1,325	374
Content Loss ($M)	814	325
Building Loss ($M)	1,438	473
Total Loss ($M)	**2,252**	**798**

Observations and Recommendations [1]

- Tsunami methodology valuable in assessing tsunami risk and in providing planning scenarios for prone communities

  - Ocean Shores and Long Beach communities are definitely vulnerable to damaging tsunamis

- Methodology is most reliable when level 2 hazard data is available and used
  - Ideally, time histories enable deriving all hazard metrics needed in the methodology
  - At a minimum, data for maximum amplitudes and maximum velocities need to be available (which was the case in this exercise)
- Flux estimated from Level 1 equations seem to be very high
  - Need to look at flux derived from time histories (level II data) and compare
- Results are quite sensitive to DEM resolution
  - 1/3 arc sec (or better) is the desired resolution to use, especially for site-specific analyses

Observations and Recommendations [2]

- Level 1 tsunami methodology approach provides extremely conservative estimate at regional level
  - Eventually when implemented in Hazus, level 1 approach will be enhanced by constraining losses to inundated area (not study area)
- Flood coastal methodology provides losses generally comparable to those obtained by the tsunami methodology
  - This could be partly explained by the fact that all buildings were wood
  - Results would probably differ if other construction types were significantly present
- Earthquake damage, which may precede tsunami damage and may compromise building resilience, was not accounted for in these scenarios
  - Useful to assess in a future study, especially for EQ-vulnerable buildings
- Future study should also assess tsunami risk to some vital lifeline components such as bridges and roads
- Debris generated and casualty estimates also need to be looked at in a future study

Next Steps

- Similar Pilot currently out for RFP with FEMA Contractors.
  - Areas include Hilo, HI and Crescent City, CA
- Hauzs in going through a much needed update to the code (25 years old)
  - If we developed the code into the older program it would cost $1-1.5 Million currently.
  - If we developed in the new platform we would have to transfer over to the new program that could cost $2 million
- FEMA does still have higher level support in developing the module and we continue to integrate the development in the modernization of Hazus.