

Background Introduction to the Tsunami Provisions in ASCE 7-16 (and the International Building Code -2018)

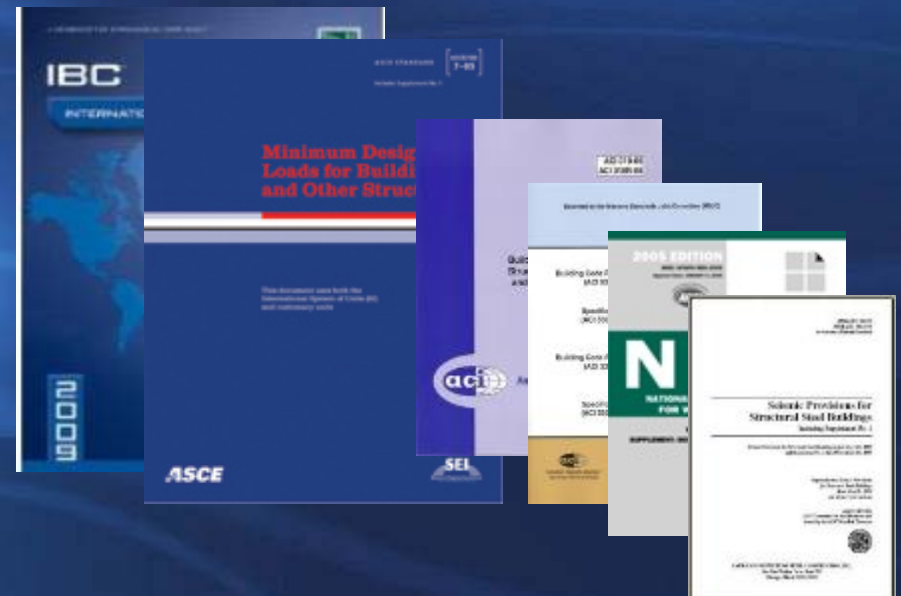
Gary Chock , S.E., F.SEI, F.ASCE, D.CE and Tsunami Loads and Effects Subcommittee
May 2015



Tohoku Tsunami photograph at Minami Soma by Sadatsugu Tomizawa

USA Codes and Standards

- International Building Code (IBC)
- ASCE 7 Minimum Design Loads for Buildings and Other Structures (ASCE 7) developed in an ANSI-accredited consensus process
- Other Standards:
 - Material specific design specifications
 - Non-structural installation standards
 - Testing and qualification standards



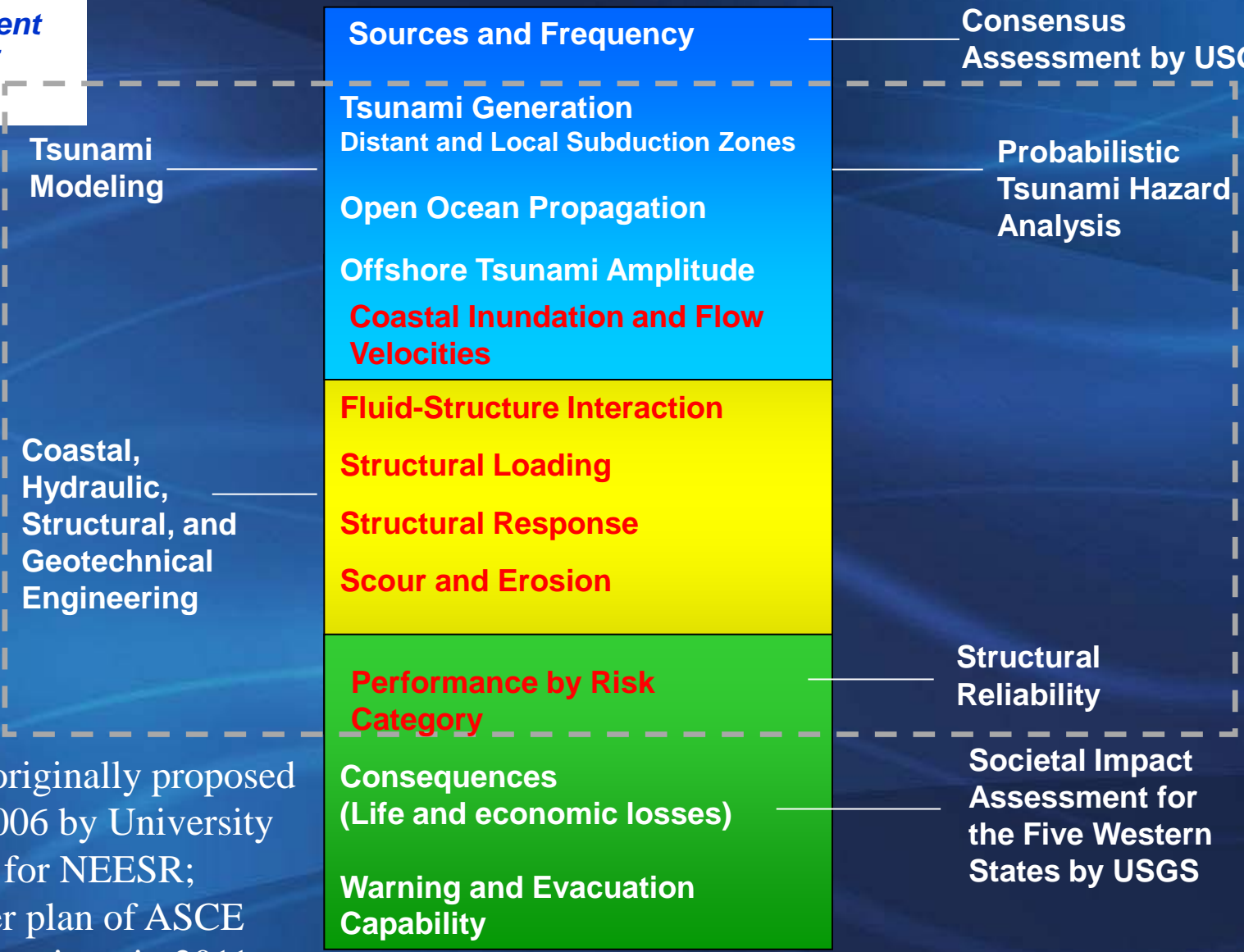
ASCE 7-16 Minimum Design Tsunami in the Five Western States

TLESC chair: Gary Chock <gchock@martinchock.com>

- A U.S. national standard for engineering design for tsunami effects does not exist. As a result, tsunami risk to coastal zone construction is not explicitly addressed in design.
- The Tsunami Loads and Effects Subcommittee has developed a new Chapter 6 - Tsunami Loads and Effects for the ASCE 7-16 Standard, which has been passed and is approaching approval.
- ASCE 7-16 to be published by March 2016
- Tsunami Provisions would then be referenced in IBC 2018
- State Building Codes of AK, WA, OR, CA, and HI ~ 2020
- ASCE will be publishing a design guide in 2015 with several types of design examples, and offering seminars.

Implementation of Tsunami-Resilient Engineering Design

Scope of development of ASCE 7 Chapter 6

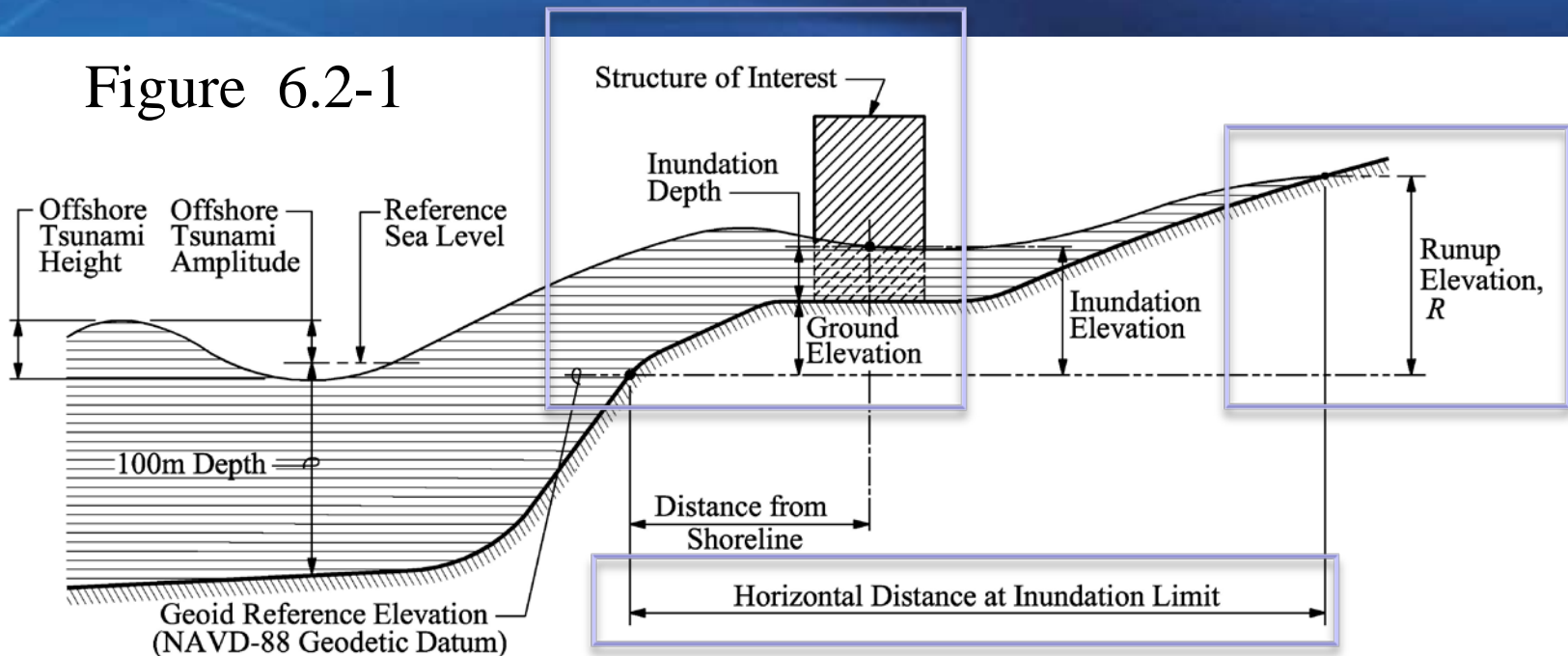


Concept originally proposed in 2005-2006 by University of Hawaii for NEESR; first master plan of ASCE provisions written in 2011

Terminology

- **RUNUP ELEVATION:** Difference between the elevation of maximum tsunami inundation limit and the (NAVD-88) reference datum
- **INUNDATION DEPTH:** The depth of design tsunami water level with respect to the grade plane at the structure
- **INUNDATION LIMIT:** The horizontal inland distance from the shoreline inundated by the tsunami

Figure 6.2-1



MCT and Tsunami Design Zone

- The Maximum Considered Tsunami (MCT) has a 2% probability of being exceeded in a 50-year period, or an inundation with ~2475 year average return period (1:2475 annual odds of exceedance).
- The Maximum Considered Tsunami is the design basis event, characterized by the inundation depths and flow velocities at the stages of in-flow and outflow most critical to the structure.
- The Tsunami Design Zone is the area vulnerable to being flooded or inundated by the Maximum Considered Tsunami. The runup for this hazard probability is used to define a Tsunami Design Zone map.

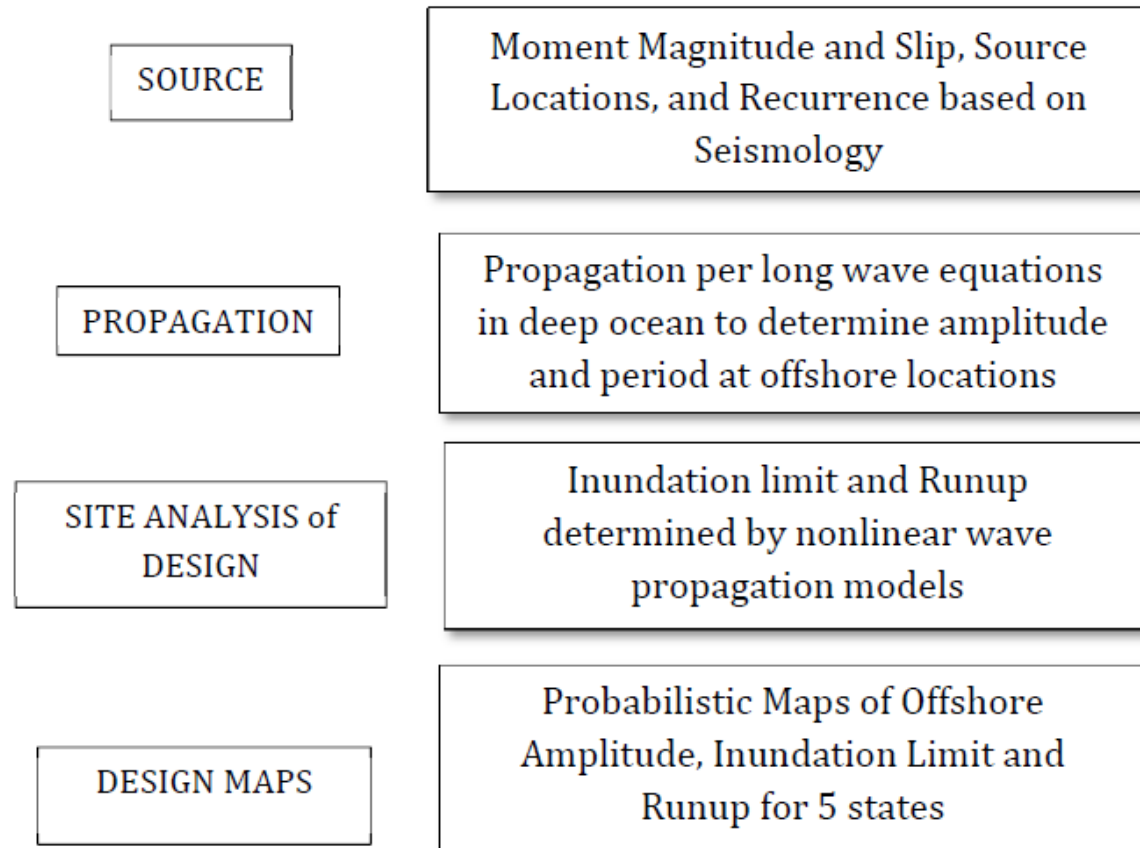
Probabilistic Tsunami Hazard Analysis (ASCE)

- Integration over a broad range of seismic sources with varying sizes and recurrence rates
- Formal inclusion of uncertainties through logic trees and distribution functions
- Probabilistic hazard is primarily expressed in the Offshore Tsunami Amplitude at 100m bathymetry offshore from the site of interest
- Source disaggregation of hazard for sites both near and far from those sources
- Source model characterization for probabilistic tsunami events

PTHA determines the Max. Considered Tsunami

- The ASCE PTHA procedure was peer reviewed by a broad stakeholder group convened by the NOAA National Tsunami Hazard Mitigation Program, and included independent comparative pilot studies. Subduction Zone Earthquake Sources are consistent with USGS Probabilistic Seismic Hazard model.

Probabilistic Tsunami Hazard Analysis



6.1.1 Scope

The following buildings and other structures located within the Tsunami Design Zone shall be designed for the effects of Maximum Considered Tsunami including hydrostatic and hydrodynamic forces, waterborne debris accumulation and impact loads, subsidence, and scour effects in accordance with this Chapter:

- a. Tsunami Risk Category IV buildings and structures;
- b. Tsunami Risk Category III buildings and structures with inundation depth at any point greater than 3 feet, and
- c. Where required by a state or locally adopted building code statute to include design for tsunami effects, Tsunami Risk Category II buildings with mean height above grade plane greater than the height designated in the statute, and having inundation depth at any point greater than 3 feet.

Exception: Tsunami Risk Category II single-story buildings of any height without mezzanines or any occupiable roof level, and not having any critical equipment or systems need not be designed for the tsunami loads and effects specified in this Chapter.

Risk Categories of Buildings and Other Structures per ASCE 7

Not all structures within the TDZ are subject to the provisions

Risk Category I	Buildings and other structures that represent a low risk to humans
Risk Category II	All buildings and other structures except those listed in Risk Categories I, III, IV
Risk Category III	Buildings and other structures, the failure of which could pose a substantial risk to human life. Buildings and other structures with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure.
Risk Category IV	Buildings and other structures designated as essential facilities Buildings and other structures, the failure of which could pose a substantial hazard to the community.

- **The scope of the tsunami provisions targets the performance of Risk Category III and IV buildings and critical infrastructure**

Consequence Guidance on Risk Categories of Buildings Per ASCE 7

Risk Category I	Up to 2 persons affected (e.g., agricultural and minor storage facilities, etc.)
Risk Category II	Approximately 3 to 300 persons affected (e.g., Office buildings, condominiums, hotels, etc.)
Risk Category III	Approximately 300 to 5,000+ affected (e.g., Public assembly halls, arenas, high occupancy educational facilities, public utility facilities, etc.)
Risk Category IV	Over 5,000 persons affected (e.g., hospitals and emergency shelters, emergency operations centers, first responder facilities, air traffic control, toxic material storage, etc.)

Section 6.4 Tsunami Risk Categories

For the purposes of this chapter, Tsunami Risk Categories for buildings and other structures shall be the Risk Categories given in **Section 1.5** with the following modifications:

1. State, local, or tribal governments shall be permitted to include Critical Facilities in Tsunami Risk Category III, such as power-generating stations, water treatment facilities for potable water, waste water treatment facilities and other public utility facilities not included in Risk Category IV.
2. The following structures need not be included in Tsunami Risk Category IV and state, local, or tribal governments shall be permitted to designate them as Tsunami Risk Category II or III:
 - a. Fire stations and ambulance facilities, emergency vehicle garages
 - b. Earthquake or hurricane shelters
 - c. Emergency aircraft hangars
 - d. *Police stations that do not have holding cells, emergency call centers, or host central communications networks, and that are not uniquely required for post-disaster emergency response as a Critical Facility.*
3. Tsunami Vertical Evacuation Refuge Structures shall be included in Tsunami Risk Category IV.

Critical Facilities

- ASCE Board of Direction Policy Statement 518:

“Critical infrastructure includes systems, facilities, and assets so vital that their destruction or incapacitation would have a debilitating impact on national security, the economy or public health, safety, and welfare.”

- ASCE 7 Chapter 6 Definition:

CRITICAL FACILITY: Buildings and structures that provide services that are designated by federal, state, local, and tribal governments to be essential for the implementation of the response and recovery management plan or for the continued functioning of a community, such as facilities for power, fuel, water, communications, public health, major transportation infrastructure, and essential government operations.

Risk Category II Buildings

- The state or local government should determine a threshold height for where tsunami-resilient design requirements for Risk Category II buildings shall apply in accordance with the state or local statute adopting the building code with tsunami-resilient requirements.
- The threshold height would depend on the community's tsunami hazard, tsunami response procedures, and whole community disaster resilience goals. Considerations of evacuation egress time from a local community would also be a consideration.
- When evacuation travel times exceed the available time to tsunami arrival, there is a greater need for vertical evacuation into an ample number of nearby Category II buildings that are sufficiently tall.

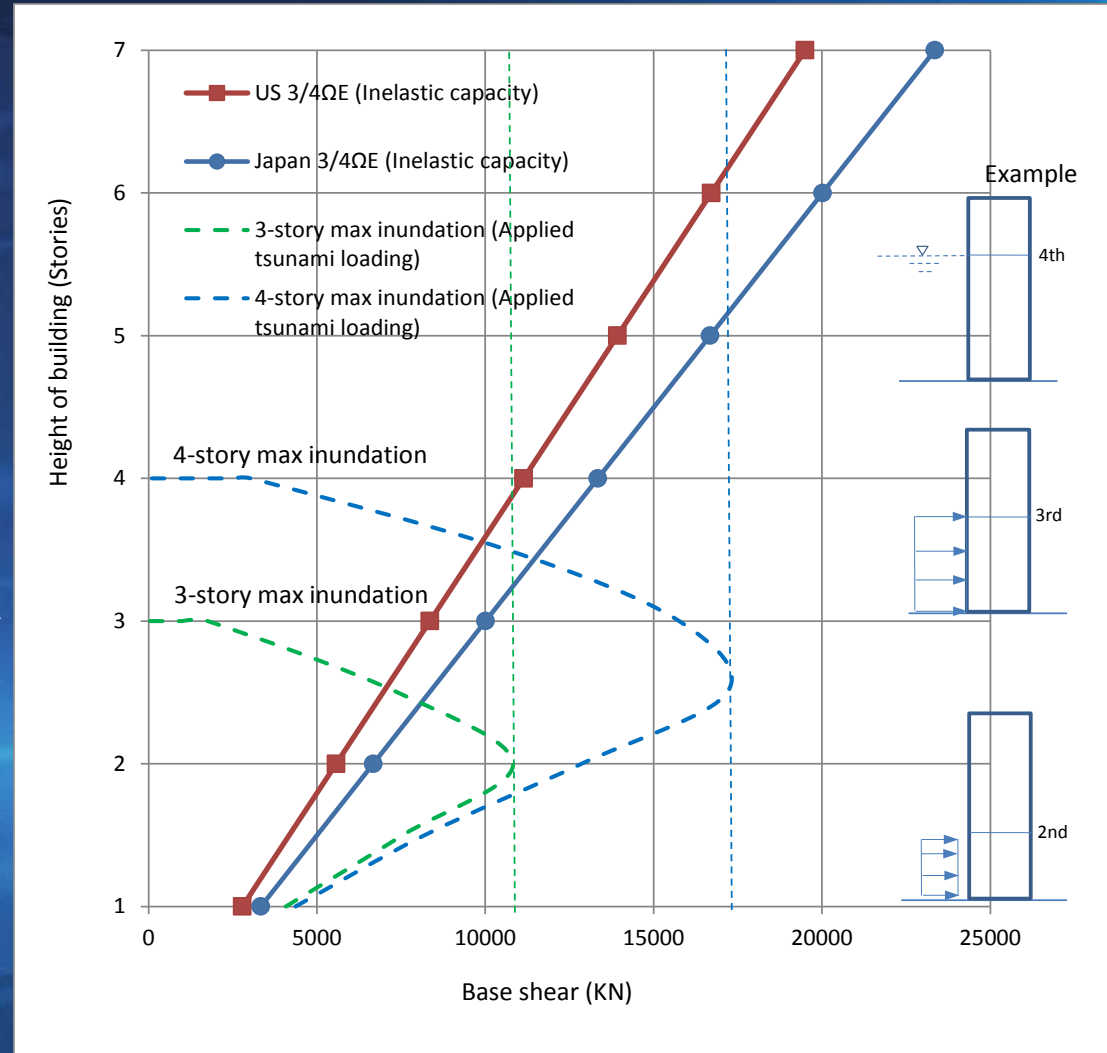
Tsunami Safety in Multi-Story Buildings

- *Tsunami Evacuation: Lessons from the Great East Japan Earthquake and Tsunami of March 11th 2011 (State of Washington sponsored investigation)*
- An example from the City of Ishinomaki (low-lying area similar to coastal communities at risk in the US) near Sendai
- “There was widespread use of buildings for informal (unplanned) vertical evacuation in Ishinomaki on March 11th, 2011. In addition to these three designated buildings, almost any building that is higher than a 2-storey residential structure was used for vertical evacuation in this event. About 260 official and unofficial evacuation places were used in total, providing refuge to around 50,000 people. These included schools, temples, shopping centres and housing.” (emphasis added)

Example of Comparing Minimal High-Seismic Design System @ 0.75 Ω Overstrength to Maximum Tsunami Loading

The technique demonstrated by Carden, et al (2015) can be used to evaluate the systemic level of tsunami resistance provided by the ASCE 7 seismic design requirements.

Past this point of structural system parity between tsunami and seismic demand, additional investment into the lateral-force-resisting system would become necessary for tsunami resistance.



Summary of Zoning Height Restrictions for Pacific Coast Communities in WA , OR & N. CA

Some of these heights may not be tsunami-resistant or safe

● Westport WA

- All residential – 35ft
- Commercial – 35ft (some areas allow 50ft)

● Long Beach WA

- OT Zone – 35ft limit (all structures)
- OTW zone – 45ft limit within 30ft of Ocean Blvd, 55ft limit elsewhere

● Seaside OR

- Residential - 35ft
- Commercial - 45ft

● Cannon Beach OR

- Residential – 24ft (flat roof), 28ft (sloped roof)
- Residential Motel – 32 ft
- Commercial – 32ft

● Florence OR

- All Residential/Commercial – 2 stories (30ft)

● Crescent City CA

- Single family residential – 35ft
- Multi-family residential – 35ft
- Office – 35ft
- Commercial – 40ft
- Light Industrial 45 ft
- Public Buildings – 40ft
- Agricultural - 35 ft

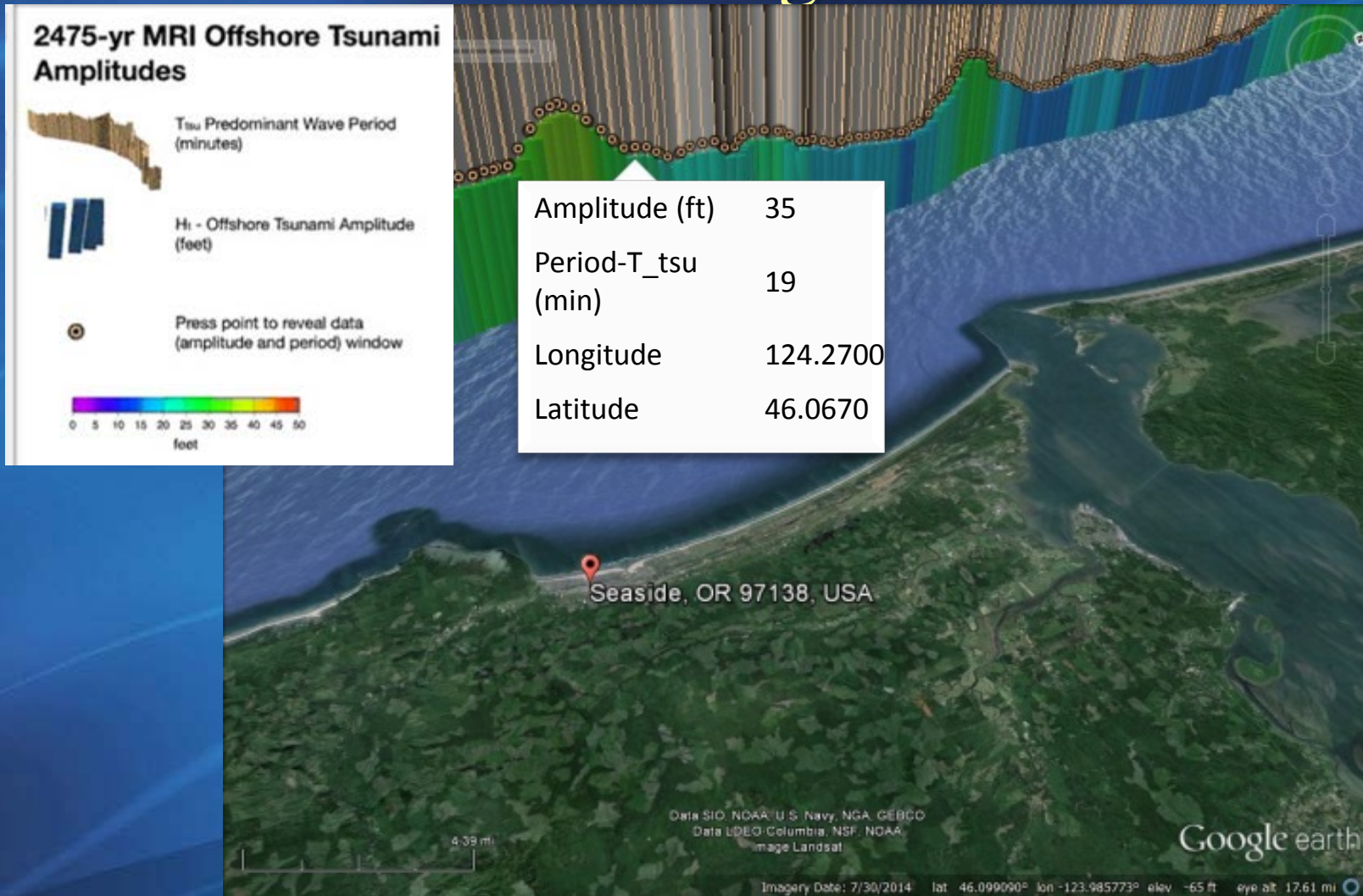
● Eureka CA

- Single family residential – 35ft
- Multi-family residential – 75ft
- Office – 100ft
- Other Commercial – 35ft
- Downtown commercial – 100
- Waterfront commercial – 100
- Service commercial – 100 ft
- Hospital – 75ft
- Other medical - 25
- Industrial – 35

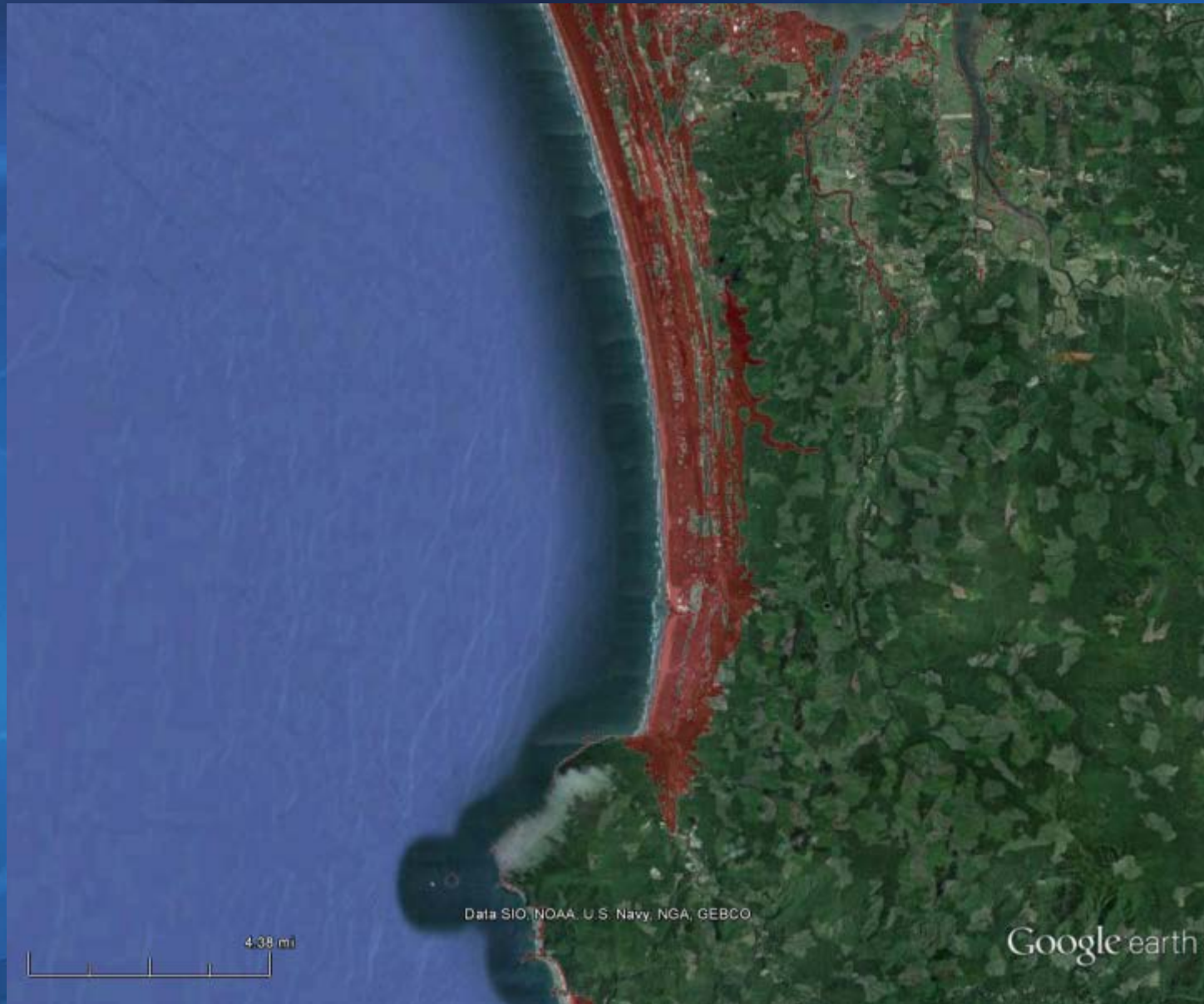
ASCE 7-16 Tsunami Design Zone Geodatabases

- Digital delivery
- Offshore Tsunami Amplitude with Predominant Period in kmz format
- Disaggregated hazard source contribution figures
- Probabilistic Subsidence Map
- Runup in kmz format and GIS point data format
- Tsunami Design Zone in kmz format
- Organized by state
- Metadata to include a final report of documentation, suitable as an accompanying technical manual

Offshore Tsunami Amplitude and Period for the Maximum Considered Tsunami at Seaside, Oregon



Tsunami Design Zone - Seaside



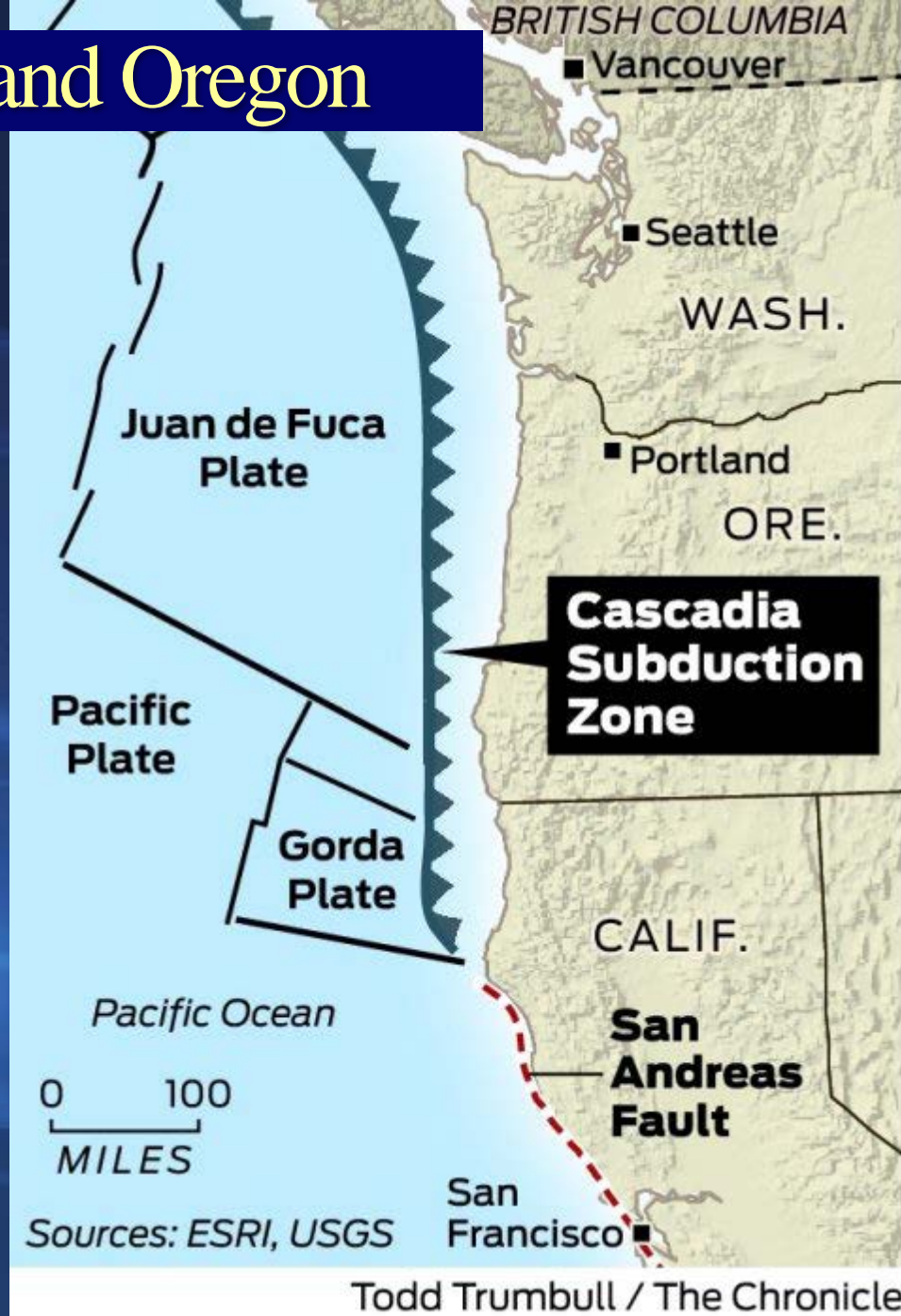
Tsunami Design Zone – Vicinity of Ocosta, WA

- At sites with overwash, reference points of inundation depth are given



CSZ and Washington and Oregon

- 30 minutes to first wave arrival
- Extremely flat coastal topography sometimes with long peninsulas; insufficient time for evacuation
- Majority of communities will be inundated:
 - WA: 45,000 residents plus another 20,000+ tourists
 - OR: 25,000 residents plus another 55,000+ tourists
- Critical and Essential Facilities:
 - High number of police stations, fire stations, and public-works facilities
 - High number of banks, government offices, and essential goods



Summary of Design Basis

- PTHA-based design criteria - The method of Probabilistic Tsunami Hazard Analysis is consistent with probabilistic seismic hazard analysis in the treatment of uncertainty.
- Maximum Considered Tsunami – 2475-year MRI
- The tsunami design provisions utilize probabilistic Offshore Tsunami Amplitude maps and Tsunami Design Zone inundation maps
- Procedures for tsunami inundation mapping are based on using these probabilistic values of Offshore Tsunami Amplitude

Tsunami Design Zone Maps for a Local Code

- Higher-resolution bathy-topographic data should be used with a validated inundation modeling of Hazard-Consistent Tsunami whenever possible to produce higher-resolution Tsunami Design Zone maps for an individual region, provided it is done in compliance with the provisions of the ASCE 7 Standard.
- **HAZARD-CONSISTENT TSUNAMI SCENARIO:** One or more surrogate tsunami scenarios generated from the principal disaggregated seismic source regions that replicate the offshore tsunami waveform characteristics for the site of interest, taking into account the net effect of the probabilistic treatment of uncertainty into the offshore wave amplitude of the scenario(s).

Tsunami Disaster Resilience by Design

- Maps and design criteria in the ASCE 7 design standard are based on engineering risk analysis and reliability targets, rather than deterministic scenarios
- The ASCE 7 tsunami provisions applies to design for community planning and resilience before a tsunami event.
- After a tsunami, it will have even more significance as means to plan, site, and design what (and where) is appropriate and necessary in reconstruction, to enable Building Back Better.
- This is a new accomplishment that directly provides a means to effectively influence community resilience and the reliability of critical infrastructure.

Recommendations

- The ASCE 7 provisions constitute a comprehensive means of improving tsunami resilience when adopted as part of a mandatory building code. It then makes tsunamis a required consideration in planning, siting, and design.
- The ASCE 7 tsunami provisions have general applicability and can be adapted elsewhere as a standardized methodology for risk-based engineering. Its specified parameters have been validated in a reliability analysis.
- In order to achieve the appropriate reliabilities for community resilience, Probabilistic Tsunami Hazard Analysis produced in accordance with the ASCE 7-16 Standard Chapter 6 specifications should be the basis for the development of Tsunami Design Zone maps.
- It is important to apply the mapping procedure strictly in order to maintain consistency among the 5 western states.