Training/Workshop on

Tsunami Evacuation Maps, Plans, and Procedures and the UNESCO-IOC Tsunami Ready Recognition Programme for the Indian Ocean Member States

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Guidelines for Establishing Tsunami Inundation Areas for Region Not Modelled or Low Risk

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Topics

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2 Guiding Principles

3 Recommended Steps

4 General Guidelines and recommended Process

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Background: Condition

- **Hazard:** is considered to be low based on historical occurrence of tsunamis, and no tsunami modeling exists or none is planned.
- **Risk:** is considered to be low due to its low vulnerability, i.e. small population and lower infrastructure vulnerability.
- Tsunami modeling does not exist but a **community wishes** to initiate planning and preparedness efforts.
- High level of uncertainty in the model simulation results, due to: limited knowledge of tsunami sources and/or poor resolution topographic and bathymetric data.

Guiding Principles

- Tsunami impact (loss of life and property damage) can be reduced by building communities resilient to tsunami disasters.
- Government Agencies have important a responsibility to these coastal communities and an important role in facilitating and helping communities in the assessment and mitigation of their risks.
- Tsunami inundation modeling provides scientifically based guidance to enable communities to address their tsunami risk and develop products for: planning, education, and training.
- Tsunami inundation map provides the information necessary for making tsunami evacuation maps and plans.

Guiding Principles

Example of situation/cases:

- If the estimation of tsunami inundation is not available due to no knowledge of tsunami sources and/or no topographic and bathymetric data available.
- It is recommended that government agencies (local level or national level) use the available guidance given, i.e. US National Tsunami Hazard Mitigation Program (NTHMP) Mapping and Modeling, to develop their evacuation maps and plans.
- Later, when required resources become available, the technical accuracy can be improved with modeling and their evacuation maps updated.

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Recommended Steps

1. Consult with scientists and emergency managers for advice on the coastal community hazard and risk.
2. Consider best practice for estimating the most hazardous areas.
3. When advised by experts, it is recommended to develop separate evacuation procedures for:
   - local tsunami scenario (felt events with only minutes to evacuate)
   - distant tsunami scenario (non-felt events with more time to evacuate).

- Reference: *Preparing Inundation Mapping for Evacuation Guideline (Draft, Aug 2016), p. 1 Your Community for Tsunamis – A Guidebook for Local Advocates*, Version 2.1, February 1, 2008, Laura Dwelley Samant, L. Thomas Tobin, Brian Tucker (see http://www.preventionweb.net/files/3984_PreparingYourCommunityforTsunamisV21.pdf)

General Guidelines and Recommended Process

1. **Apply historical inundation information**

a) Where information about historical tsunami events available: use maximum inundation evidence and add a safety buffer appropriate for the location. Inundation value can come from actual events:

- From geological evidence for past tsunami inundation, or from local experts. → The National Centers for Environmental Information / World Data Service (NCEI/WDS) Global Historical Tsunami Database can be accessed at http://www.ngdc.noaa.gov/hazard/.
- An alternative database developed by the ``Institute of Computational Mathematics and Mathematical Geophysics SB RAS, Tsunami Laboratory, Novosibirsk, Russia, is available at http://tsun.sscc.ru/tsunami-database/index.php.
- Regional tsunami catalogs are available in the literature as well.

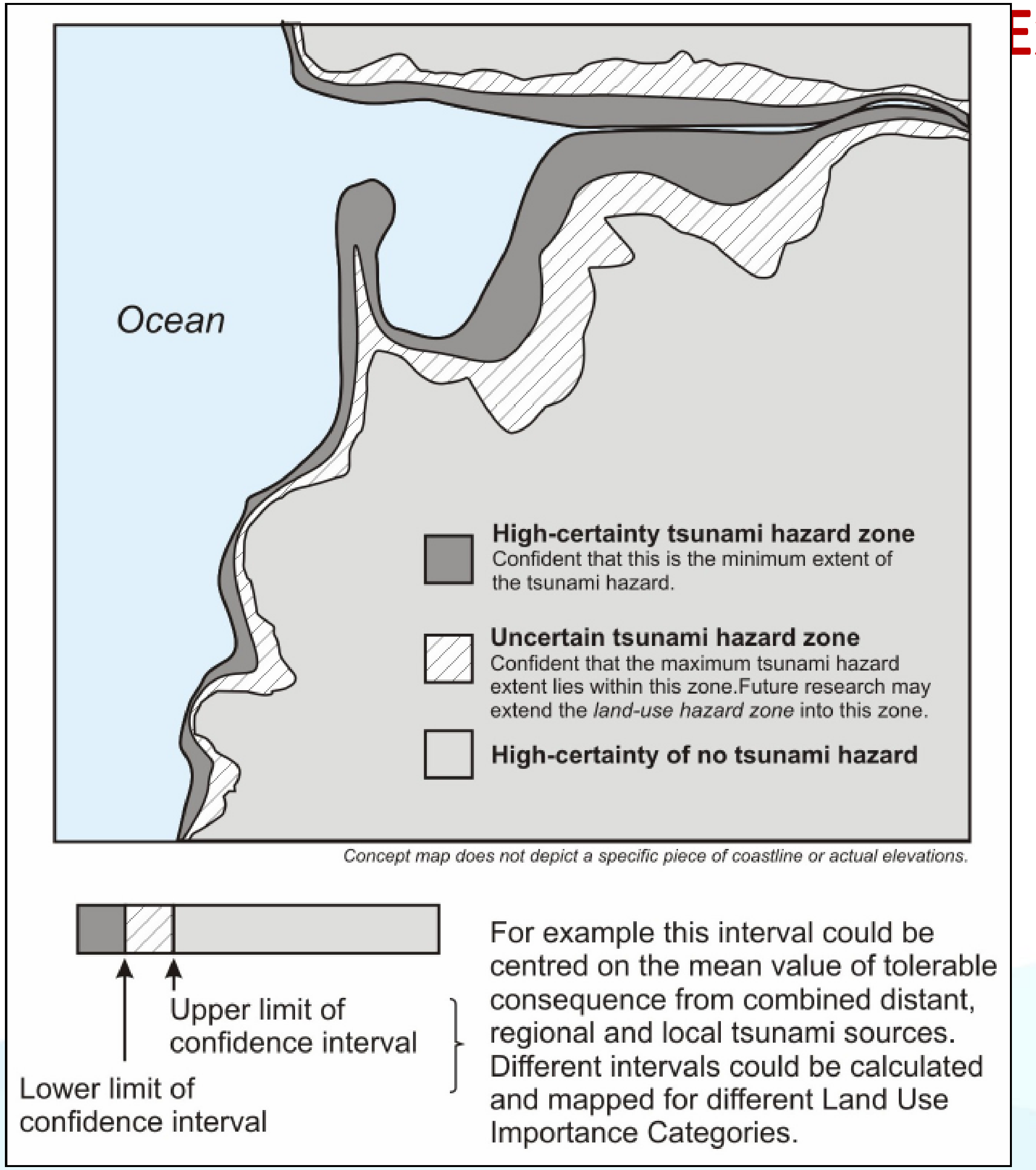
General Guidelines and Recommended Process

b) Safety buffer: should take into account potential storm surge and maximum tide level that would add to the historic event source(s) inundation, other known sources for local tsunamis, and local topography. → The US Guidelines recommended adding another 1/3 of the area corresponding to the historical maximum runup for safety.

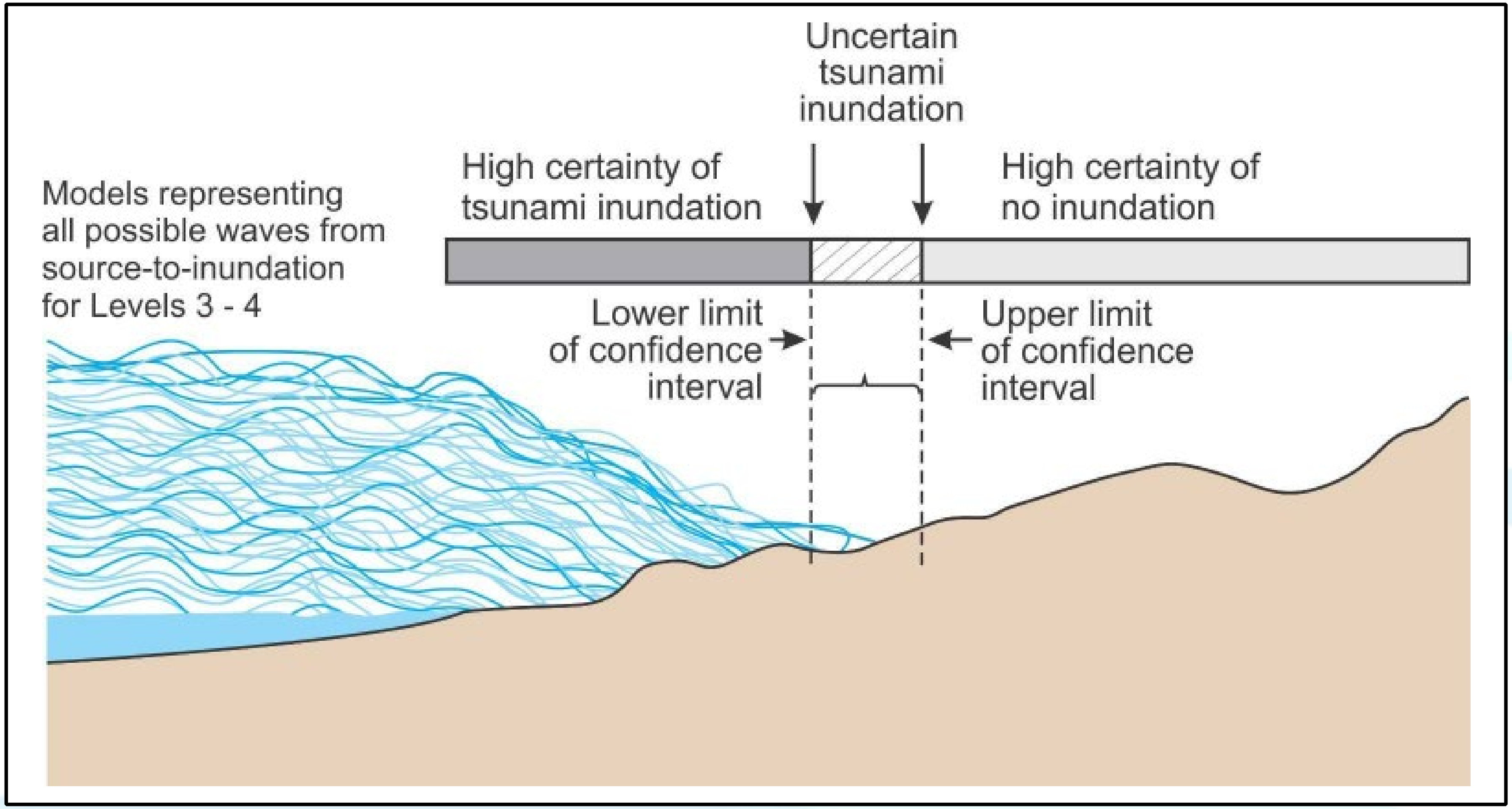
c) In situations where there is regional similarity in earthquake seismicity, source characteristics, tectonic regime, and off- and on-shore coastal morphology, using regional historical events as a proxy for country historical events is reasonable.

Safety Buffer

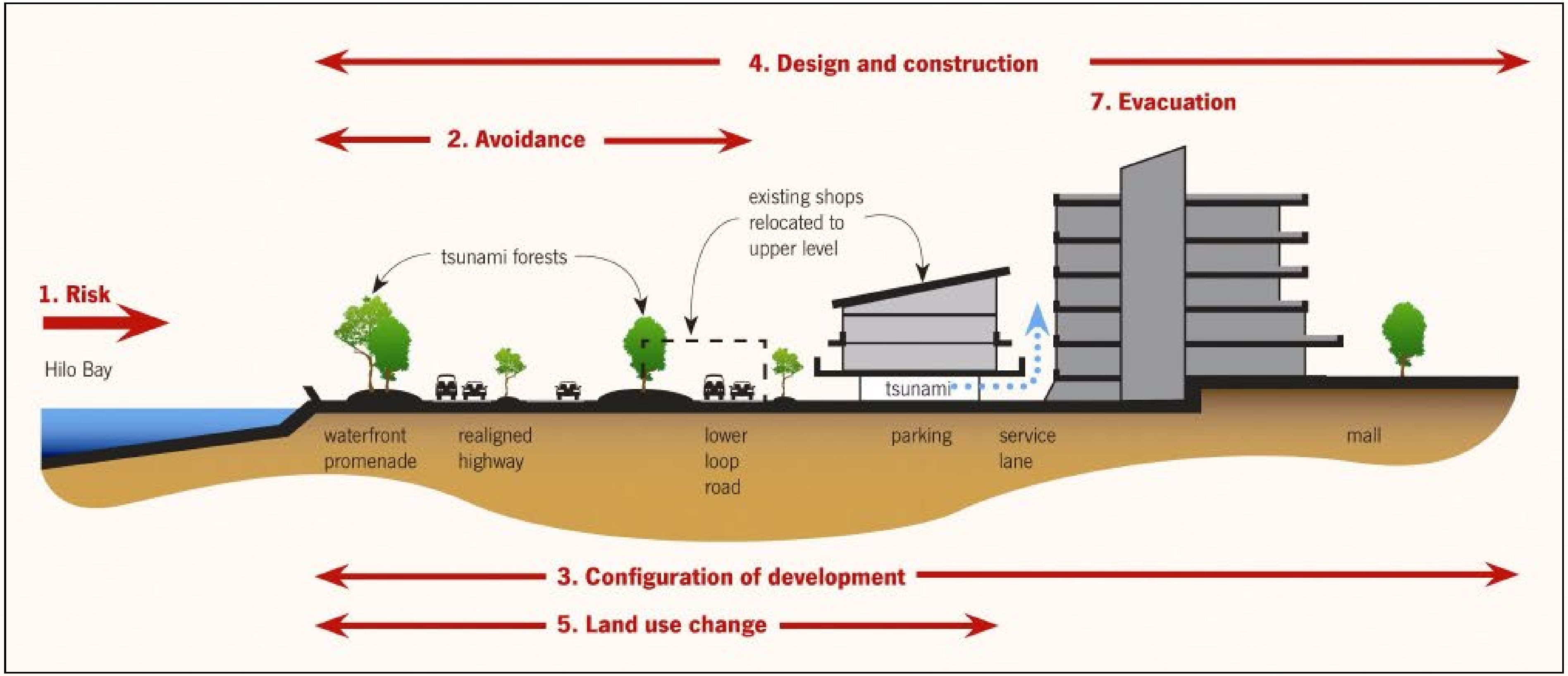
Example @ Hilo Hawaii



Safety Buffer
Example @ Hilo Hawaii



Use of Safety Buffer
Example @ Hilo Hawaii Development Planning



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General Guidelines and Recommended Process

2. Choose an elevation and distance from the shoreline keeping in mind the following:

a) Tectonic setting:

- Local tsunami sources typically generate larger tsunami waves along nearby coastlines than distant sources.
- Locations near subduction zones are more prone to large earthquakes, co-seismic subsidence, and thus larger tsunami waves.
- Establish the relative threat from local, distant, or both local and distant potential sources of tsunami.

b) Local topography:

- Consensus (US): coastal morphologies (e.g. shorelines, areas along bays, inlets, rivers with direct ocean outflow) that are below 10 m (~33 ft) in elevation are at risk of tsunami impact.
- In the absence of reference information, “reasonable” safe elevation in these areas should be at least 10 m

General Guidelines and Recommended Process

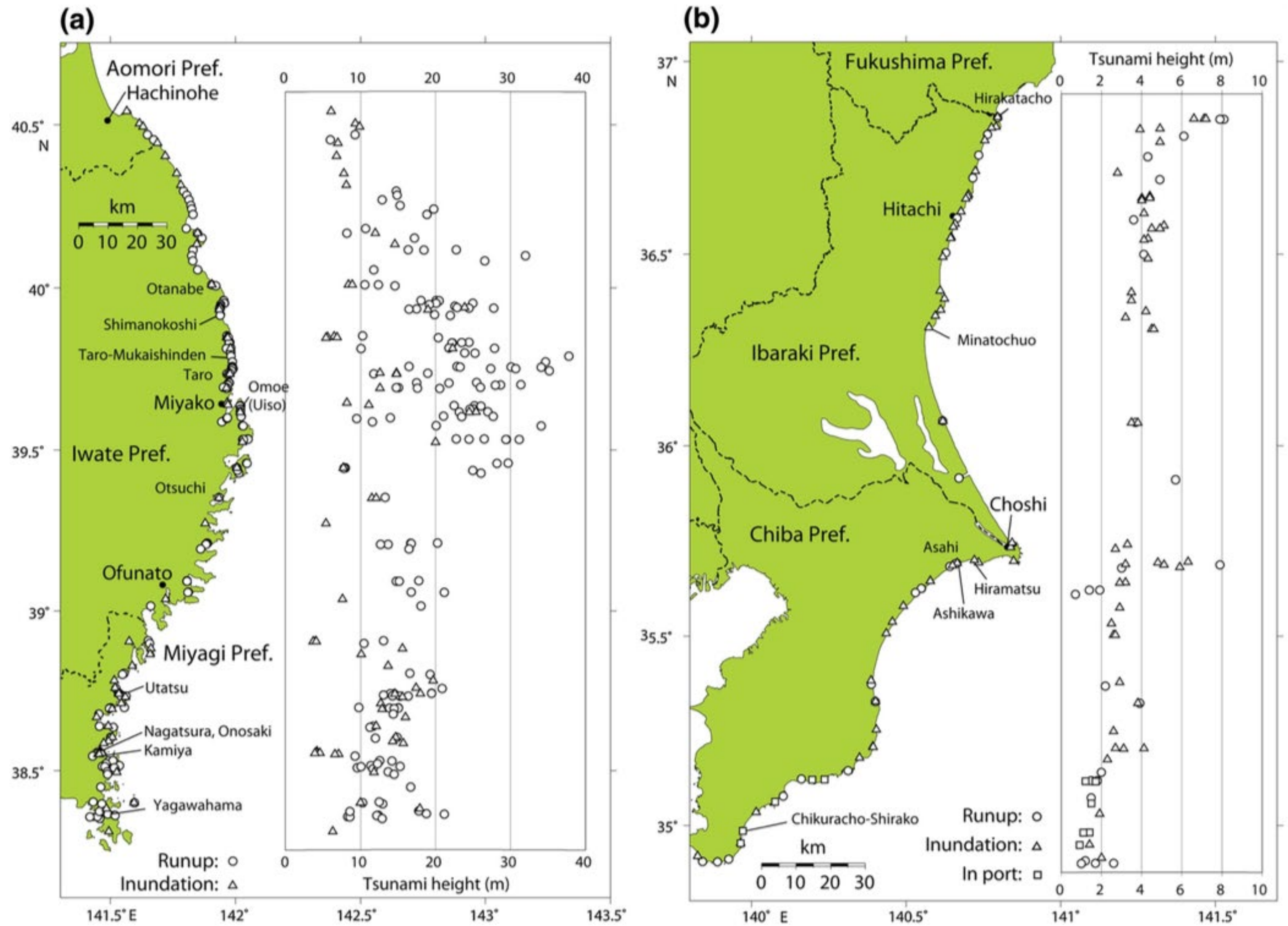
c) Local tsunamis :

- It is possible for large local tsunamis to flood land that is above the "reasonable" safe elevation, so careful consideration is needed in deciding on the elevation for evacuation, particularly in regions where no local historical tsunamis have occurred.
- See also: maximum local runups of 30-40 m were measured in M9.1 2004 Indian Ocean tsunami in Sumatra, Indonesia (*Runup Measurements of the December 2004 Indian Ocean Tsunami, Synolakis and Kong, 2006*) and 2011 Great East Japan tsunami in Tohoku, Japan (*National Field Survey of the 2011 Off the Pacific Coast of Tohoku Earthquake Tsunami, 2011 Tohoku Earthquake Tsunami Joint Survey Group, 2011*).

2011 Tohuku Tsunami Field Survey

Figure a: Circles and *triangles* indicate runup and inundation heights.

Figure b: Ibaraki and Chiba prefectures. *Circles*, *triangles*, and *squares* indicate runup heights, inundation heights, and tsunami heights in ports, respectively



- **Tsunami Heights along the Pacific Coast of Northern Honshu Recorded from the 2011 Tohoku and Previous Great Earthquakes**, Y. Tsuji, K. Satake, T. Ishibe, T. Harada, A. Nishiyama, and S. Kusumoto, Pure Appl. Geophys. 171 (2014), 3183–3215

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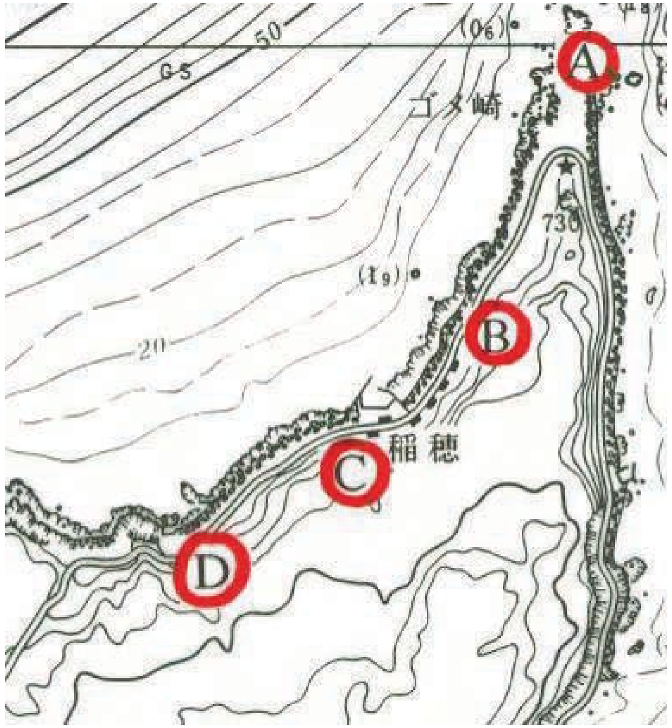

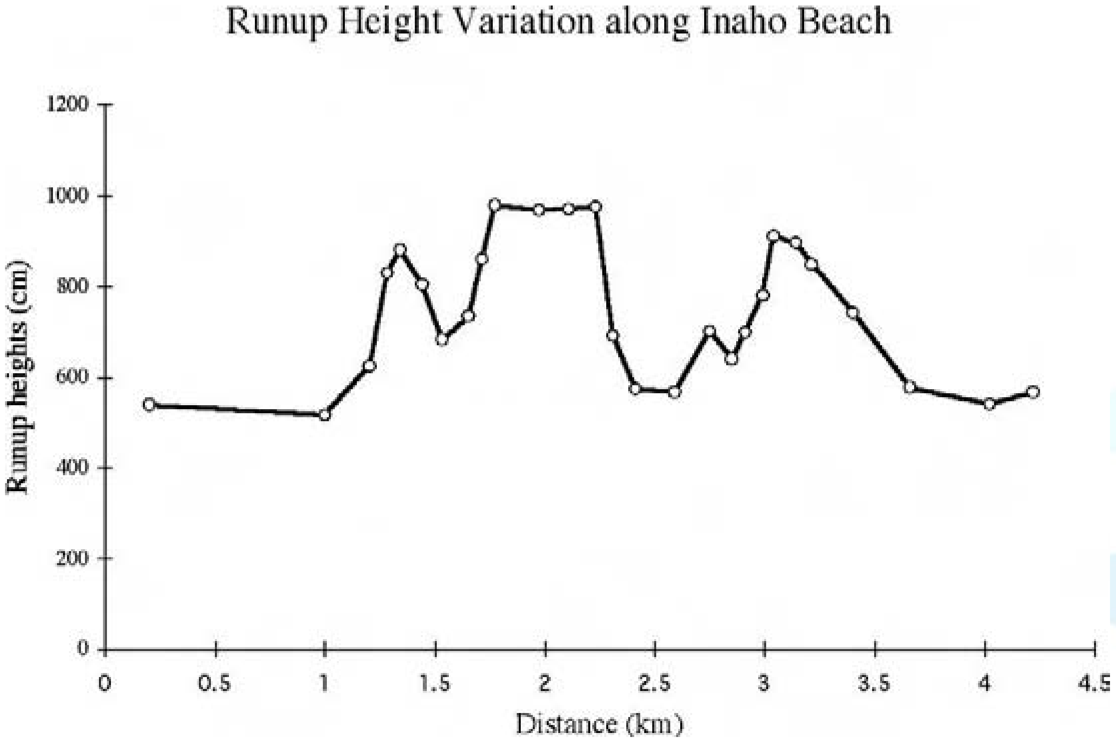

Measured runup heights of the 1993 Okushiri tsunami along Inaho Coast, demonstrating that runup height varies significantly between neighboring areas

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General Guidelines and Recommended Process

d) Distance from the shoreline:

- Low-lying areas along rivers or channels that connect to the ocean should be designated as tsunami inundation zones.
- For large, flat coastal rivers, the zone should be at least three kilometers inland and up to ten kilometers inland (Sendai plain inundation was 8 km in the 2011 Great East Japan tsunami).
- The US Guidelines noted that most local tsunamis would no longer be destructive by 3 km (~ 2 miles) inland, and most distant tsunamis generally affected beaches and waterfront areas within ~1.6 km (1 mile) of the open coast.

e) Once the elevation or distance from shoreline is reached, this will determine the potential inundation/evacuation zone.

General Guidelines and Recommended Process

3. **Use tsunami modeling for nearby areas:**
   a) In situations where there are regionally-similar earthquake, tectonic, and coastal regimes, and numerically-acceptable inundation modeling has been conducted for other nearby locations:
      - Define inundation based on maximum modeled inundation in nearby / bounding areas.
      - If available, use low resolution, regional simulations to estimate the relative amplification of tsunamis by offshore bathymetric effects.
      - Consider behavior of tsunamis of similar size for terrain analogous to that of the target area, even for tsunamis from other parts of the world.

General Guidelines and Recommended Process

b) Take a conservative approach if using lower-resolution tsunami model results by adding a safety buffer to estimates of both inundation and evacuation zones:

- US Guidelines require a minimum grid resolution of 3 arc-sec (90 m at latitude of Equator) for inundation modeling and 10 m for determination of tsunami currents.
- If modeling has been completed at a lower resolution, it is advisable to apply a safety factor to both inundation and runup.
- Account for the behavior of tsunamis of similar size for terrain analogous to that of the target area, even for tsunamis from other parts of the world.

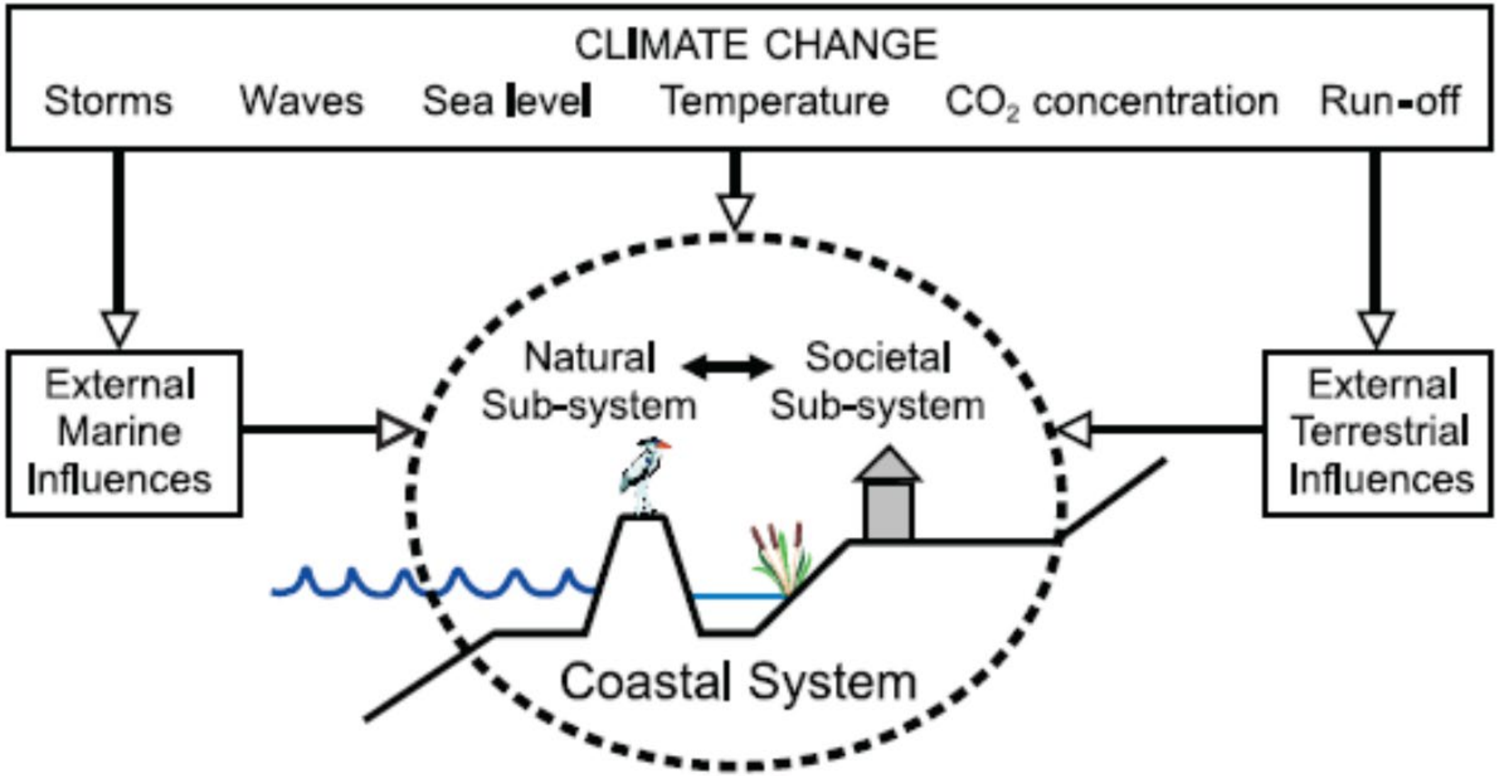
c) In the absence of other tsunami hazard information, and where Hurricane Storm Surge Maps are available

- storm surge inundation may be considered as a proxy, in consultation with scientists, for tsunami evacuation planning.

General Guidelines and Recommended Process

d) If inundation modeling shows that inland areas will not be affected, but strong offshore currents are possible, consider developing safety and response procedures for recreational areas (e.g., 'clear the beaches') and port facilities.

New Trend: Consider Climate Change Impact to Tsunami Inundation Map



Integrate Tsunami with Climate Change Impacts on Coastal Flooding.
i.e. Global Sea level rise, Wind waves, Severe storms, ENSO, Cyclones
Coastal Flooding , Coastal erosion

Thank you