Tsunami Disaster Mitigation Research In The United States

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Outline

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- Joint Tsunami Runup Study
  - Plane Beach
  - Vertical Wall
  - Circular Island
- Corps Tsunami Disaster Mitigation and Research Facilities
- Tsunami Inundation Maps for Southern California
- Summary and Conclusions

Introduction

- **United States tsunami risk**
  - Alaska, California, Hawaii, Oregon, and Washington
  - East coast if Canary Islands or Puerto Rico trench
- **Historically concerned about far-field, tectonic tsunamis**
- **Co-seismic landslides potential realized**
- **Prior to 26 Dec 04, Corps of Engineers did not have formal tsunami design policy**
  - Coastal structure design based on storm levels and wave heights from models or measurements
  - Asia Tsunami will probably change that in future years
- **Corps main emphasis on mitigation**
  - Cooperation with other agencies
    - FEMA
    - Civil Defense
    - Office of Emergency Services
    - NOAA/PMEL
    - Academic institutions like USC
  - Support inundation mapping for West coast of U.S.
- **Coastal and Hydraulics Laboratory (CHL)**
  - More active in tsunami wave propagation and runup predictions in 1970's and 1980's
    - 27 reports, conference papers, journal articles
  - NSF Tsunami Runup Study in 1990's
- **Network for Earthquake Engineering Research (NEES)**
  - Oregon State University (OSU)

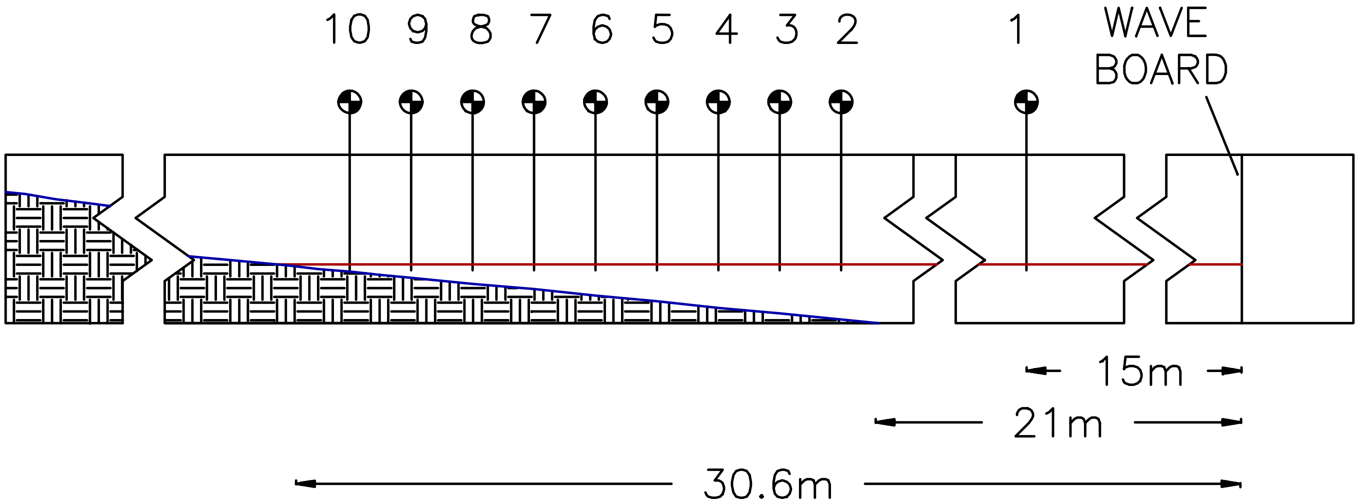
Joint Tsunami Runup Study

- **NSF**
  - 4 years in FY92
- **Purpose**
  - Integrated analytical, experimental, and numerical study of tsunami runup
- **Goals**
  - Better understanding
  - Experimental databases
  - Improve numerical models
- **Co-PI's**
  - Phil Liu, Costas Synolakis, Harry Yeh, George Carrier, & Mike Briggs
- **Advisory Committee**
  - Fred Raichlen, Howell Peregrine, Nobu Shuto, & Robert Street
- **WES Team**
  - Gordie Harkins, Debbie Green, Dave Daily

Plane Beach

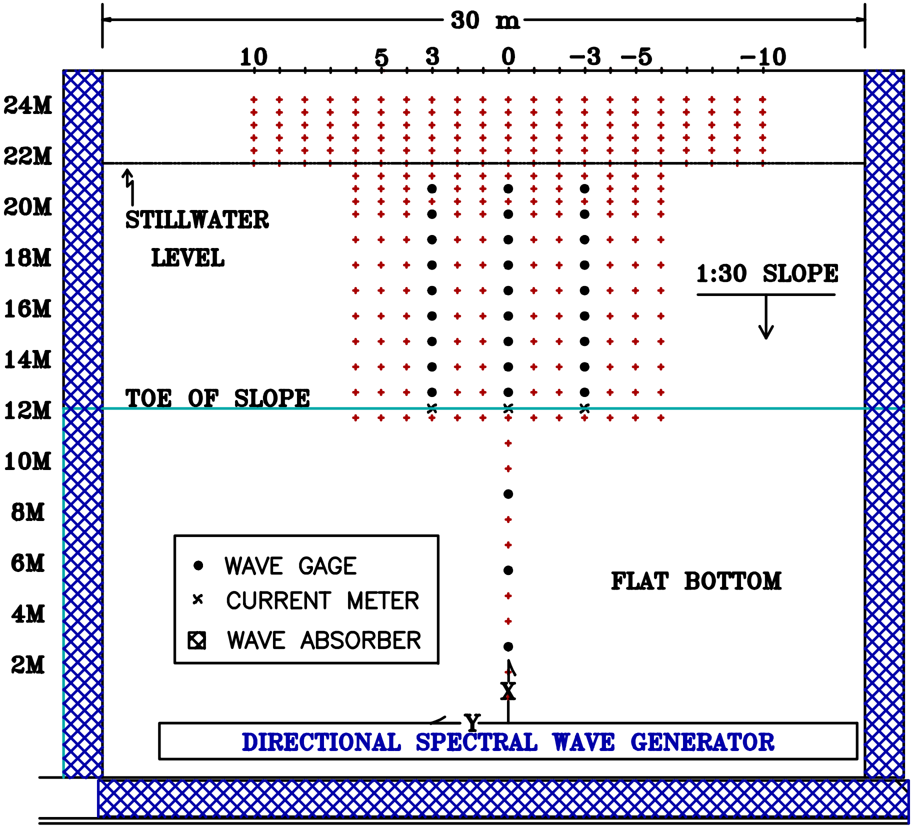
- **Study wave evolution, uniformity, runup, and wave kinematics over plane beach**
- **2D Flume & 3D Basin**
- **1 on 30 slope**
- **32 cm water depth**

Plane Beach Flume Study



- **Flume**
  - 42.4-m-long, glass-walled flume
  - Slope toe 21 m from wavemaker
- **Instrumentation**
  - 10 gages: 1m spacing for gages 2-10
  - Laser Doppler velocimeter

Plane Beach Basin Study

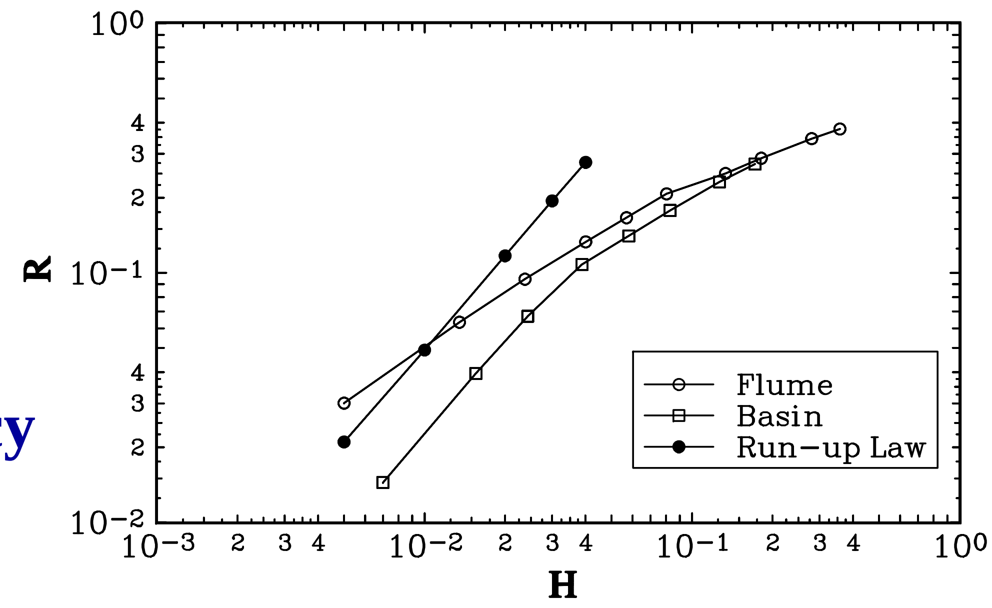


- **30m x 25m Basin**
  - Slope toe 12.4 m from DSWG
- **30 Wave gages**
  - 3 incident
  - 27 in 3 cross-shore transects, 1m spacing
- **8 Solitary wave cases**
  - **H**=H/d = 0.01 to 0.20
  - **S** Source length
  - $\mathbf{D_x}$=D_x/d & $\mathbf{D_y}$ eccentricity

Plane Beach Runup

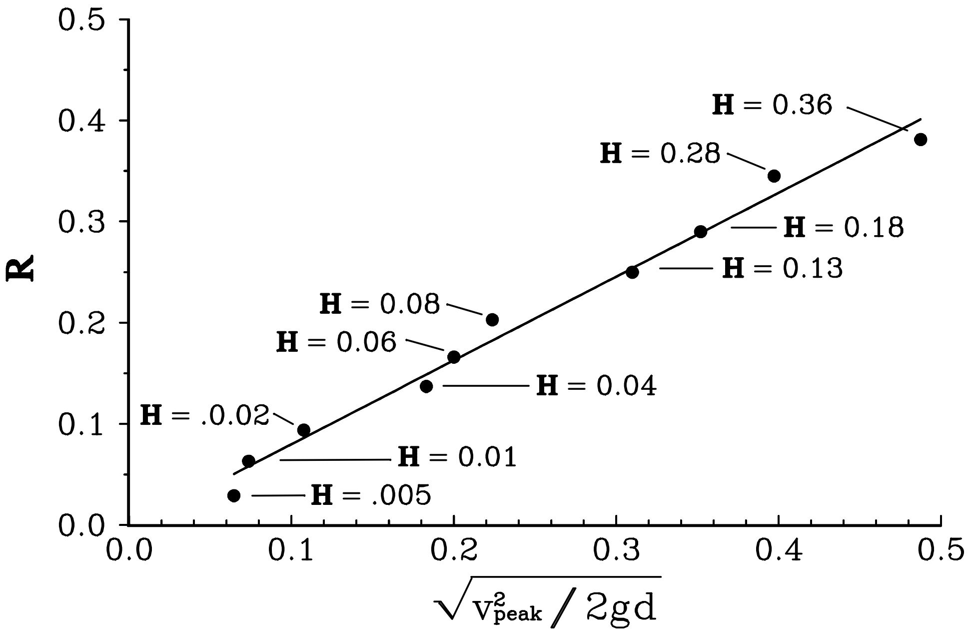
- **Normalized runup**
  - **R**=R/d vs. wave height **H**=H/d
- **Runup Law- earlier tests**

  $\mathbf{R}=2.83\ [\cot \beta]^{1/2}\ \mathbf{H}^{5/4}$
- **Breaking H**>0.04
- **2 Regimes**
- **Non-breaking discrepancy**
  - Source lengths
  - Cross-shore distances
  - Flume less dissipative



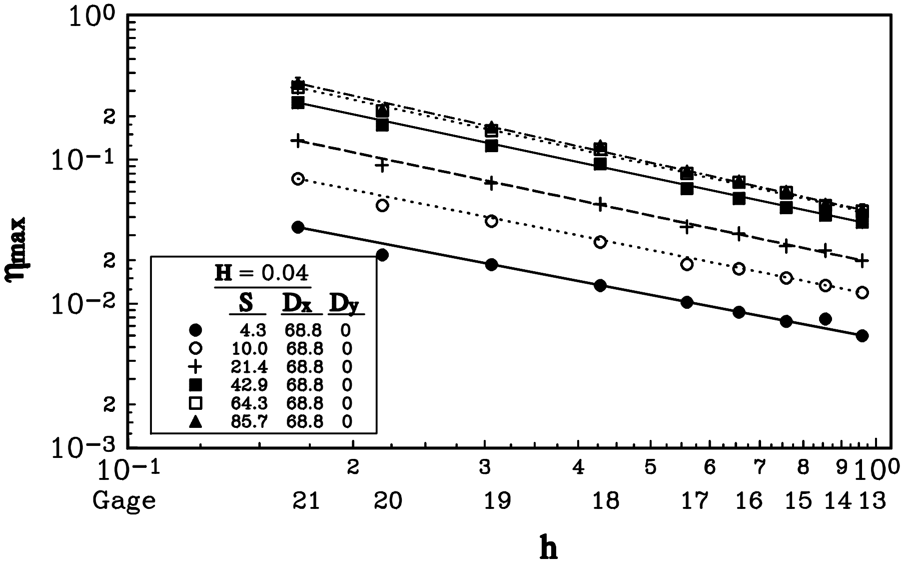
Flume Runup Velocity

- **Normalized vertical runup**
  - **R**=R/d vs. energy **V**=$[V^2_{peak}/2gd]^{1/2}$
- **Linear relationship to predict runup given peak horizontal velocity**
- **Consistent w/Runup Law**
  - Friction accounts for 20% losses during runup



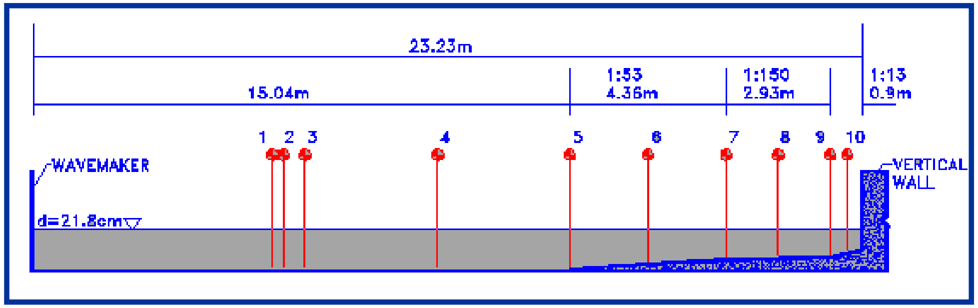
Basin Amplitude Evolution

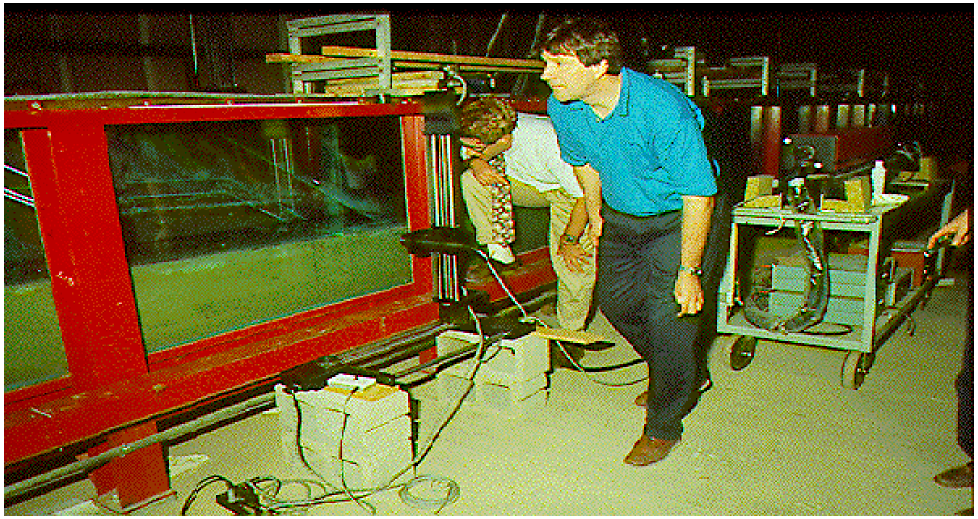
- **Normalized amplitude η_{max} vs. local gage depth h=**h/d
- **Parameters**
  - **H**=0.04
  - Source lengths **S**=S/d
  - Cross-shore distance $\mathbf{D_x}$=D_x /d
  - Longshore distance $\mathbf{D_y}$=D_y /d
- **Results**
  - η_{max} amplitude increases as **S** & h decrease
  - Excellent agreement with Green's Law



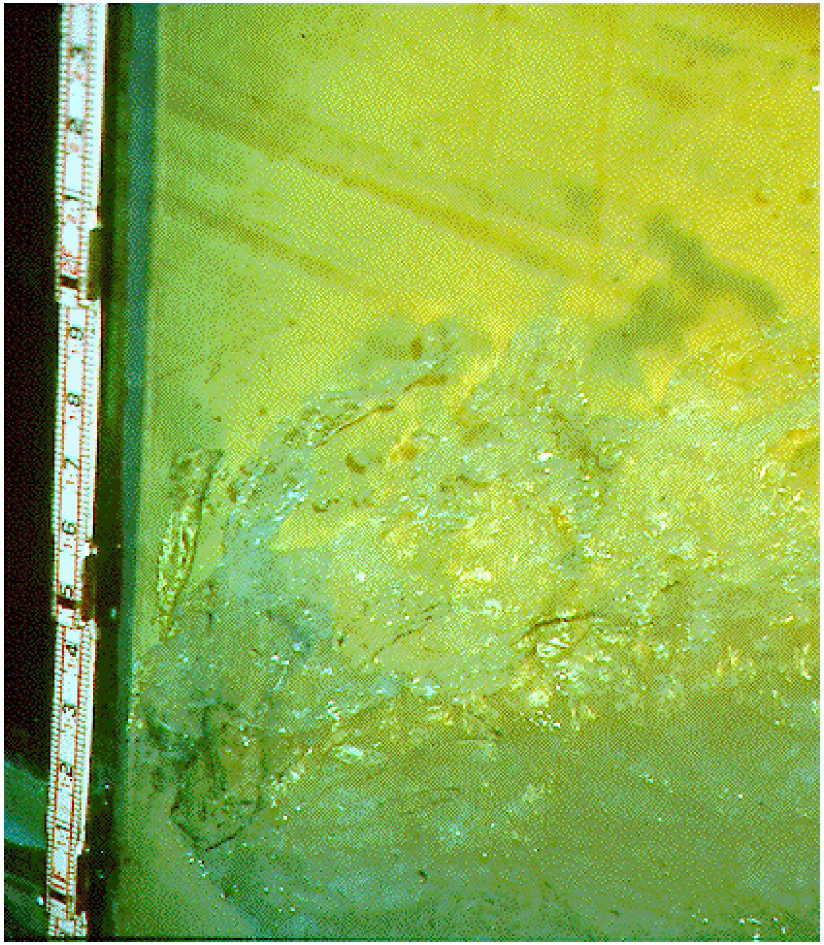
Vertical Wall

- **2D flume**
  - 23.2m x 45cm x 21.8cm
  - Compound slope
    - 1:53, 1:150, 1:13
  - Vertical wall
- **10 capacitance gages**
- **3 wave cases**
  - A: **H**=H/d=0.05
  - B: **H**=0.30
  - C: **H**=0.70

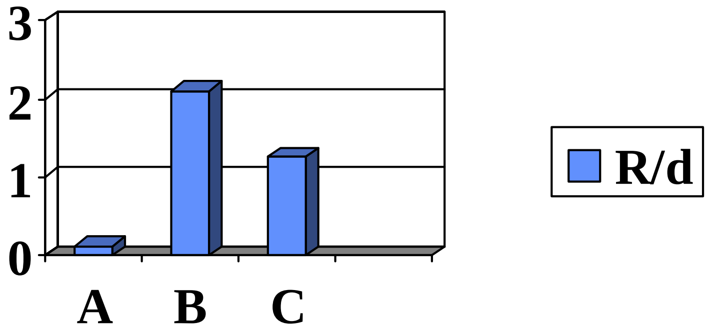




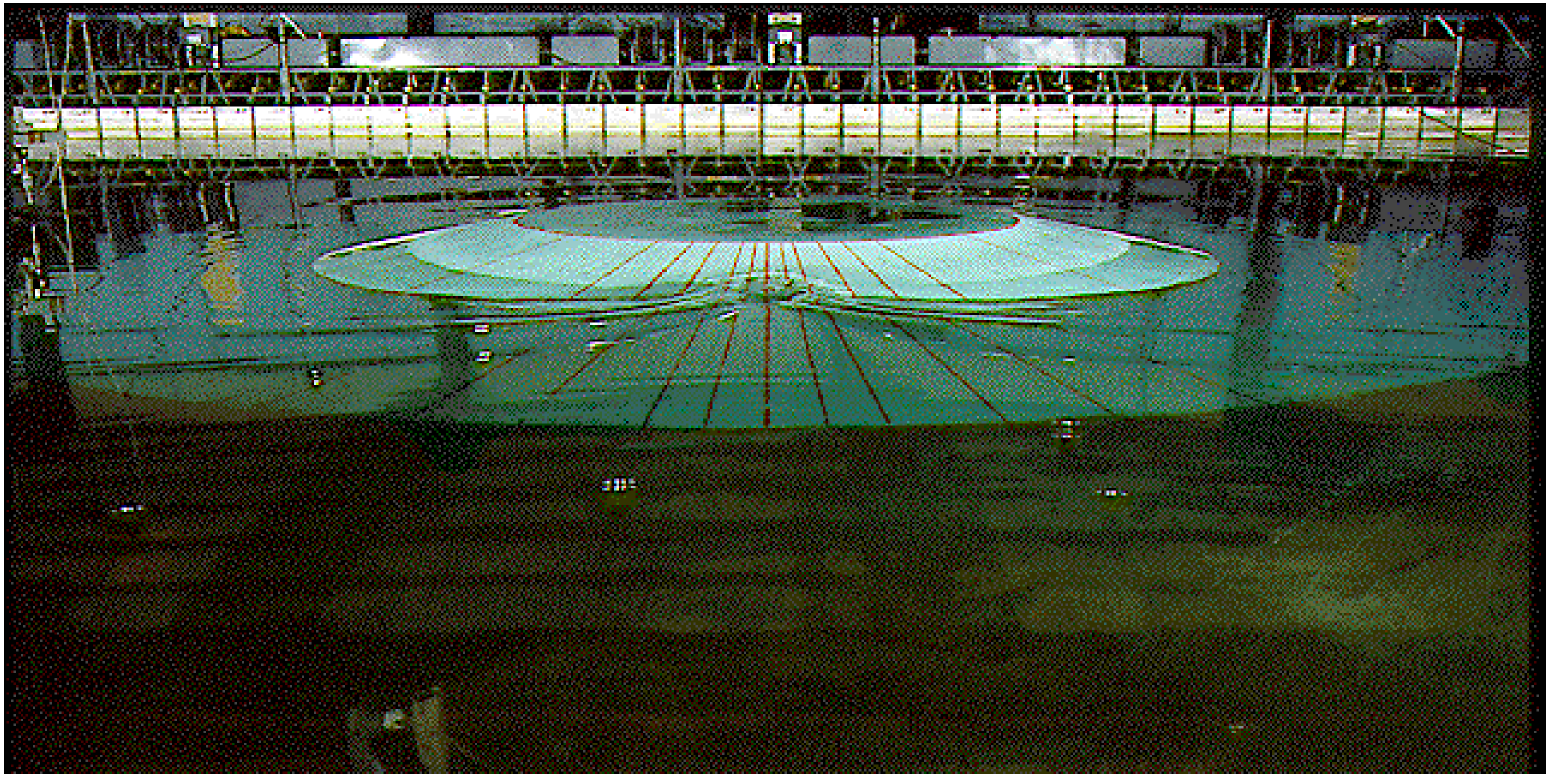
Runup Plume



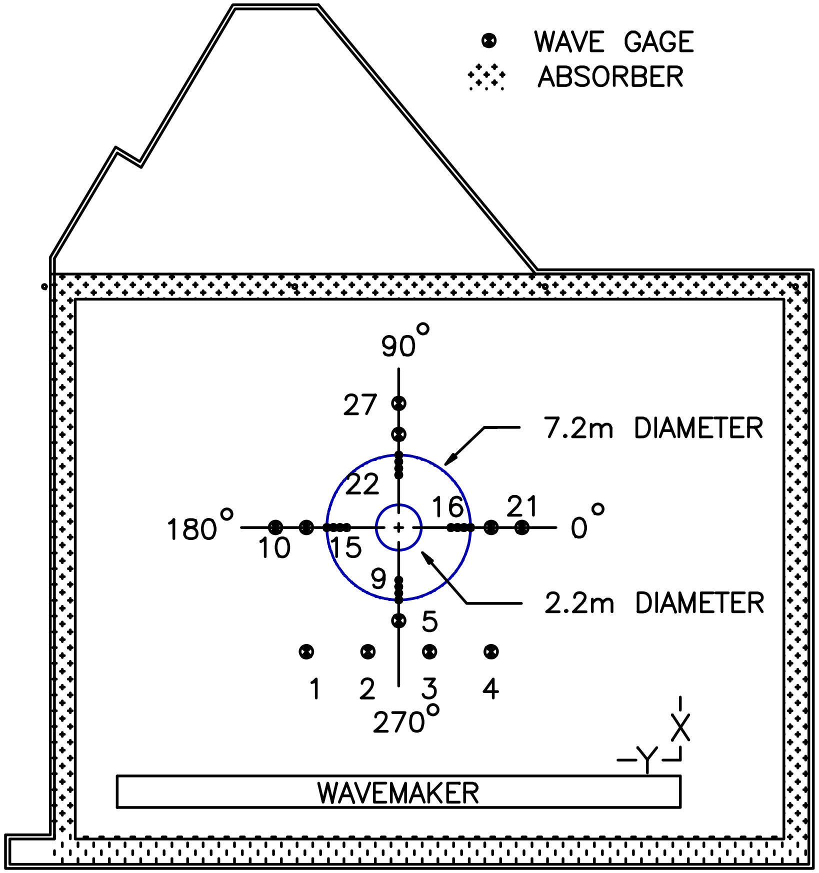
- A: No breaking
- B: Breaking at wall
- C: Breaking in nearshore



Circular Island

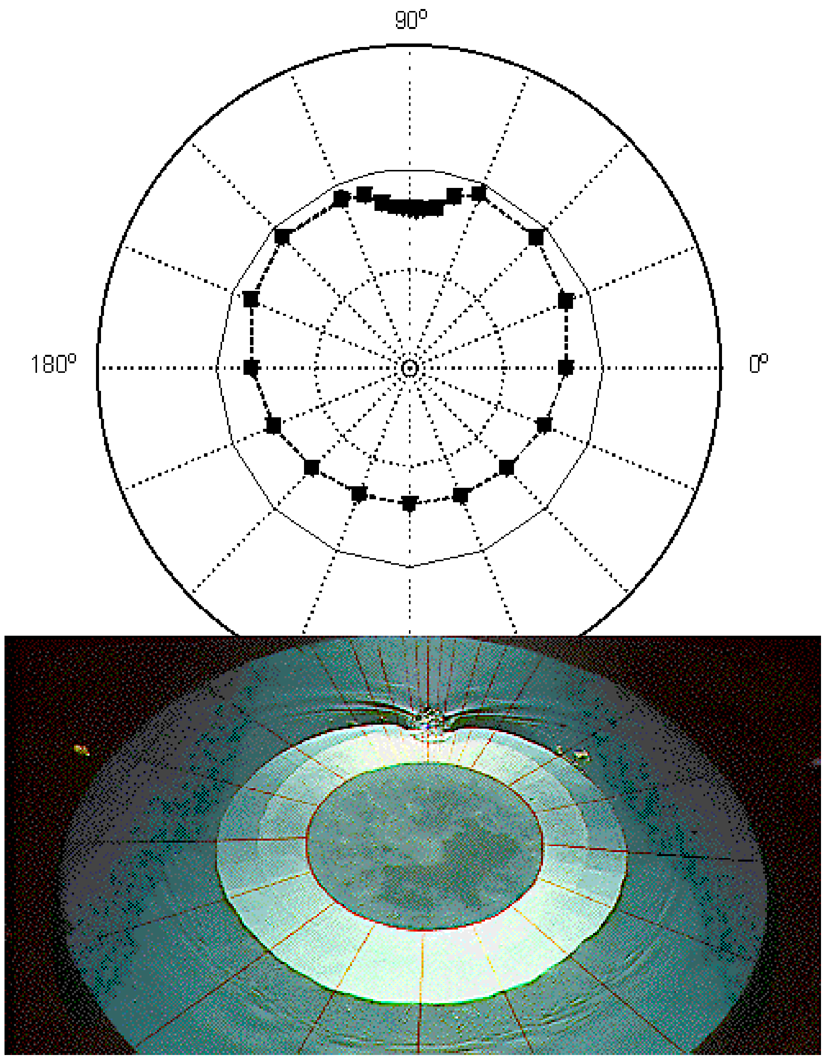


Circular Island Parameters



- **Circular island**
  - D=7.2m at toe
  - Slope = 14 deg
- **Water depth** d
  - d=32 cm (47 cases)
  - d=42 cm (66 cases)
- **Solitary waves, H=**H/d
  - 32 cm: 0.05, 0.10, 0.20
  - 42 cm: 0.05, 0.08, 0.10
- **Source lengths S**
  - Symmetric
  - Eccentric

Vertical Runup Measurements



- **Max runup value**
  - Rod & transit
  - 20 transects
    - 16 @ 22.5 deg
    - 4 @ 2.5 deg centered @ 90 deg (back side)
- **Runup time series**
  - 1 gage
  - 1 m length
  - 32 rods, 1 cm min spacing

Joint Research with Japan

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RUNUP OF TSUNAMIS WITH TRANSIENT WAVE PROFILES INCIDENT ON A CONICAL ISLAND

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Based on the linear long wave theory, analytical solutions are obtained for the propagation of tsunamis with an arbitrary incident wave profile around a conical island. The validity of the theory is verified through comparisons with two laboratory datasets. Effects of incident wave profile on the distribution of runup height and on the maximum runup height along the coastline of an island are discussed on the basis of this theory.

Keywords: Conical island, trapping, tsunami runup, wave refraction, transient wave analysis.

1. Introduction

Recently, tsunamis have struck several islands around the world and caused heavy damages. The characteristics of a tsunami, including wave trapping and amplification, are thought to be a major cause of this damage. Thus, the mechanism of

- **Coastal Engineering Journal paper**
- **Runup of tsunamis with transient profiles incident on a conical island**
- **Fujima, Briggs, and Yuliadi**
- **Verify analytical solutions for propagation of tsunamis and the distribution of maximum runup heights around the island**

Corps Tsunami Disaster Mitigation and Research Facilities

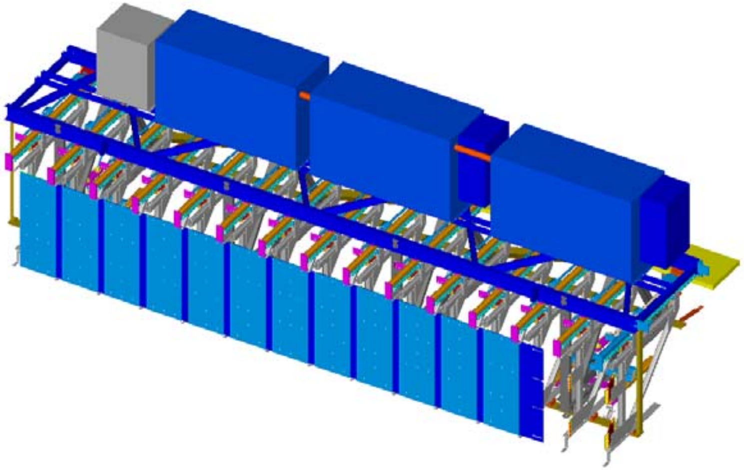
- **TeleEngineering Operations Center (TEOC)**
  - **Respond to disaster mitigation relief efforts**
  - **Asia Tsunami 26 Dec 2004**
  - **Estimates of runup and inundation to determine safety of roads and bridges**
- **Physical modeling facilities**
  - **7 Flumes**
  - **2 Stability Basins**
  - **5 Harbor Basins**
  - **Port of Los Angeles and Long Beach (LALB) distorted model**
  - **Directional spectral wave generator (DSWG)**

Los Angeles/Long Beach Physical Model

- **Distorted-Scale Model**
  - 1:100 Vertical
  - 1:400 Horizontal
  - Time and frequency 1:40
  - Largest harbor model
- **30 wave gages**

Directional Spectral Wave Generator

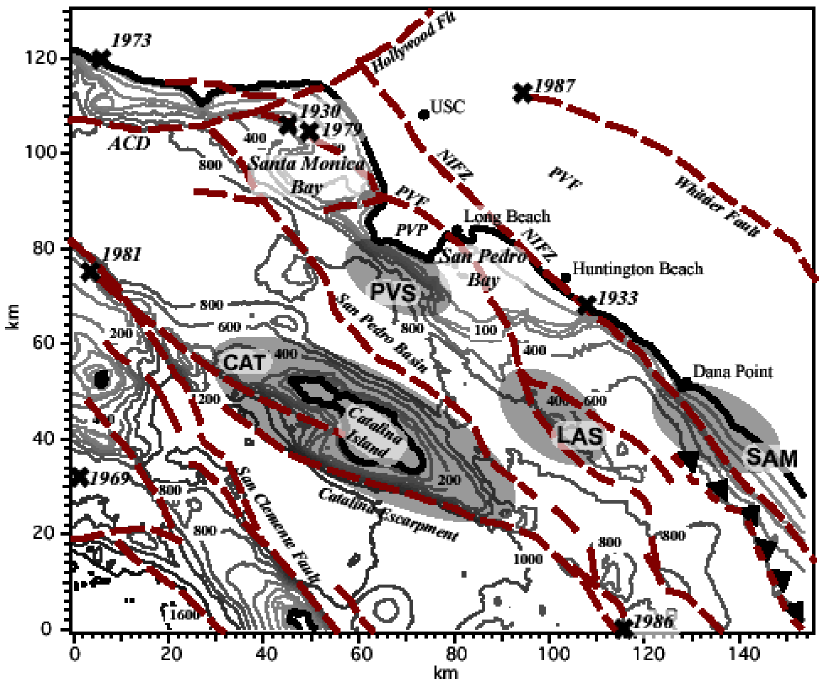
- **DSWG Basin**
  - Passive wave absorber frames
  - Active wave absorption
  - PC-based controls, data acquisition, and analysis
  - Max stroke = ± 36 cm
  - Max wave height = 48 cm
  - GEDAP software for wave generation and analysis
  - Gate for model construction

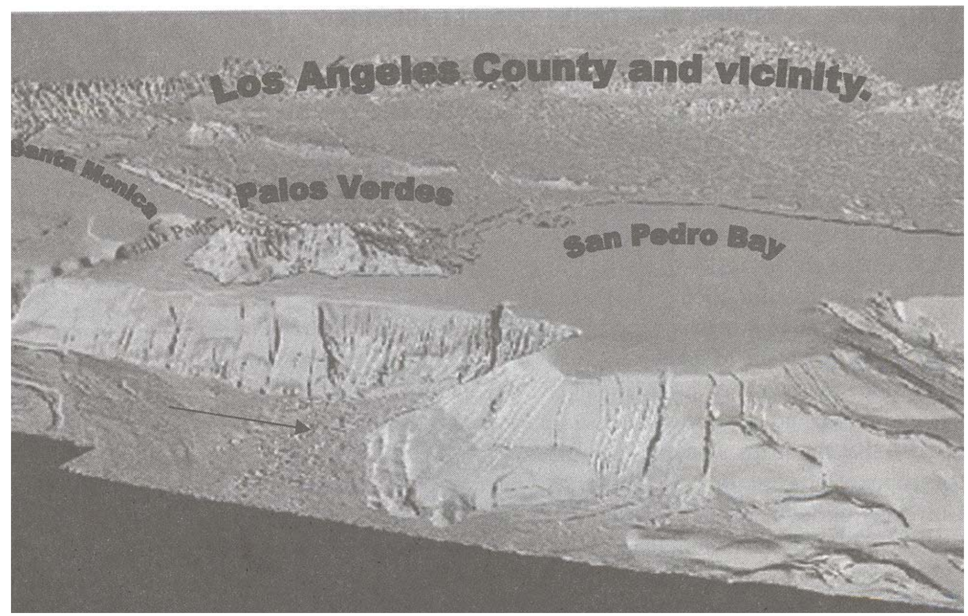


Tsunami Inundation Maps for Southern California

- **Houston and Garcia (1974, 1978) and Houston (1974, 1980)**
  - **FD and FE predictions of tsunami inundation in Southern California**
  - **100-yr and 500-yr runup heights**
- **Borrero (2002) and Synolakis et al (2002)**
  - **100-yr adequate**
  - **500-yr dominated by local landslide potential**
- **U.S. National Tsunami Hazard Mitigation Program (NTHMP)**
  - **1996 develop inundation maps for 5 states**
    - **Alaska, California, Hawaii, Oregon, and Washington**
  - **California maps begun in 1998**
  - **MOST model (Titov and Gonzalez 1997)**
  - **Maximum penetration from relocating worst case scenarios rather than particular event**

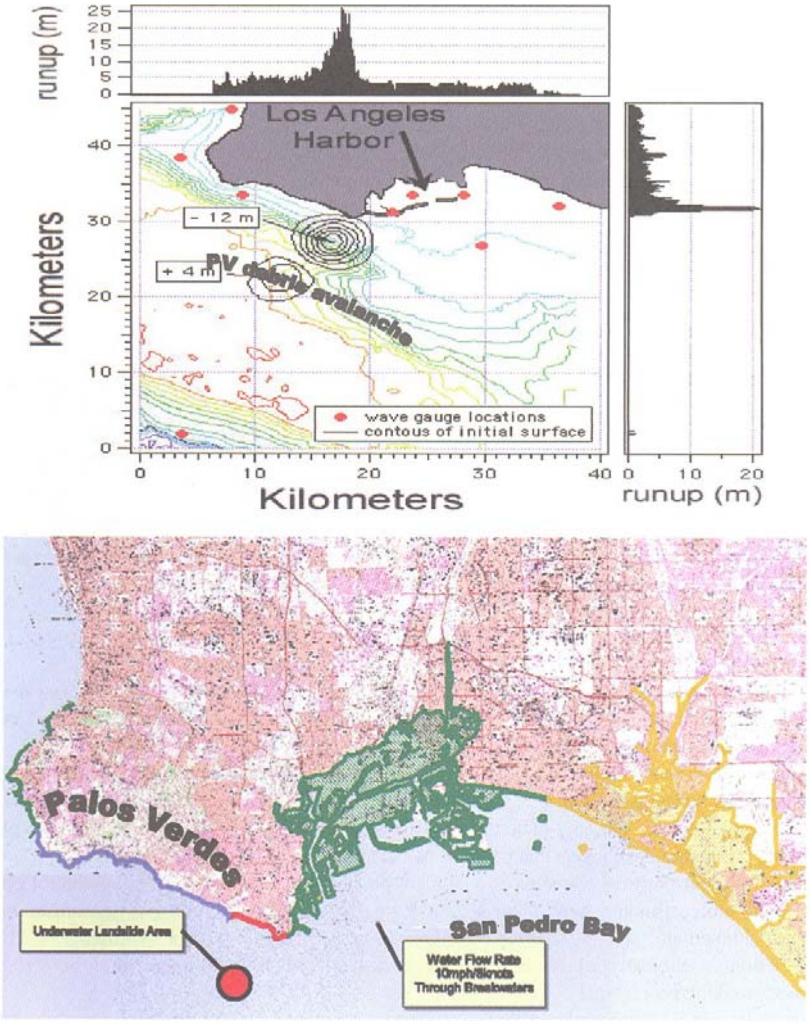
Ports of Los Angeles and Long Beach





- **Ports of Los Angeles and Long Beach (LALB) located on San Pedro Bay**
- **Adjacent to Palos Verdes Debris Avalanche (PVS)**
- **Could be triggered by strong earthquake producing disastrous landslide-generated tsunami in harbor**

Effect of Landslide on LALB



- **Borrero et al. (2002)**
  - **Broad San Pedro Bay Shelf**
  - **Attenuates travel time, but focuses tsunami**
  - **Projected losses of $4.5B**
  - **Disruption of port would effect global economies**

Summary and Conclusions

- **Corps does not currently have a formal tsunami design policy for coastal structures**
- **Joint Tsunami Runup Study**
  - **Plane Beach**
  - **Vertical Wall**
  - **Circular Island**
- **Corps Tsunami Disaster Mitigation and Research Facilities**
- **Tsunami Inundation Maps for Southern California**