F7: Coastal Mapping- Future Conditions & Sea Level Rise

Summary of Accomplishments for FEMA Region IX CCAMP Open Pacific Coast

RiskMAP
Increasing Resilience Together

ASFPM June 20, 2018

Welcome and Introductions

FEMA Region IX
Ed Curtis – Regional Engineer

Production and Technical Services (PTS) contractor: BakerAECOM
Darryl Hatheway – Technical Lead

Presentation Goals

- **Summary of Accomplishment for CA Coastal Analysis and Mapping Project Open Pacific Coast (CCAMP OPC)**
  - **CCAMP OPC – Overview**
  - **What's new**
  - **New Data Acquisition**
  - **New Detailed Analyses & Pilot Studies**
  - **Mapping Production**
  - **Challenges**

CCAMP OPC - Overview

Two Companion Large-Scale Efforts:

- San Francisco Bay Area Coastal Study
- Open Pacific Coast Study

Re-study flood risk along the open coast and inland bays of all California coastal counties

Re-map the elevation and inland extent of wave-induced coastal flooding

www.r9coastal.org

CCAMP OPC – Phases 1 & 2

Phase 1 (2010)
Ten Counties
Northern and Central
California Coast

Phase 2 (2012)
Five Counties
Southern
California Coast

Study Miles & Panels: Phase 1 No. CA (approx. 800 miles of coast)

Phase 1 County	Open Pacific Coast (study miles)	FIS Effective Date for Coastal Study	Pacific Coast Map Panels w/ Coastal Influence	Coastal-Riverine Flood Profile Confluence	Coastal SFHA (Sq. Miles)
Del Norte	50	09/26/08	15	1	20
Humboldt	160	02/08/99	38	5	81
Mendocino	110	06/16/92	14	1	2
Sonoma	60	09/06/06	5	1	0
Marin	100	05/05/97	28	5	27
San Francisco	15	n/a	2	0	2
San Mateo	60	08/05/86	13	5	9
Santa Cruz	40	03/02/06	27	10	2
Monterey	105	09/27/91	25	5	2
San Luis Obispo	100	02/04/04	32	9	3

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Study Miles & Panels: Phase 2 So. CA (approx. 535 miles of coast)

Phase 2 County	Open Pacific Coast (study miles)	FIS Effective Date for Coastal Study	Pacific Coast Map Panels w/ Coastal Influence	Coastal-Riverine Flood Profile Confluence	Coastal SFHA (Sq. Miles)
Santa Barbara	120	09/30/05	35	7	3
Ventura	50	09/03/97	18	2	2
Los Angeles	155	07/06/98	48	7	6
Orange	50	02/18/04	32	9	5
San Diego	160	09/29/06	50	13	4

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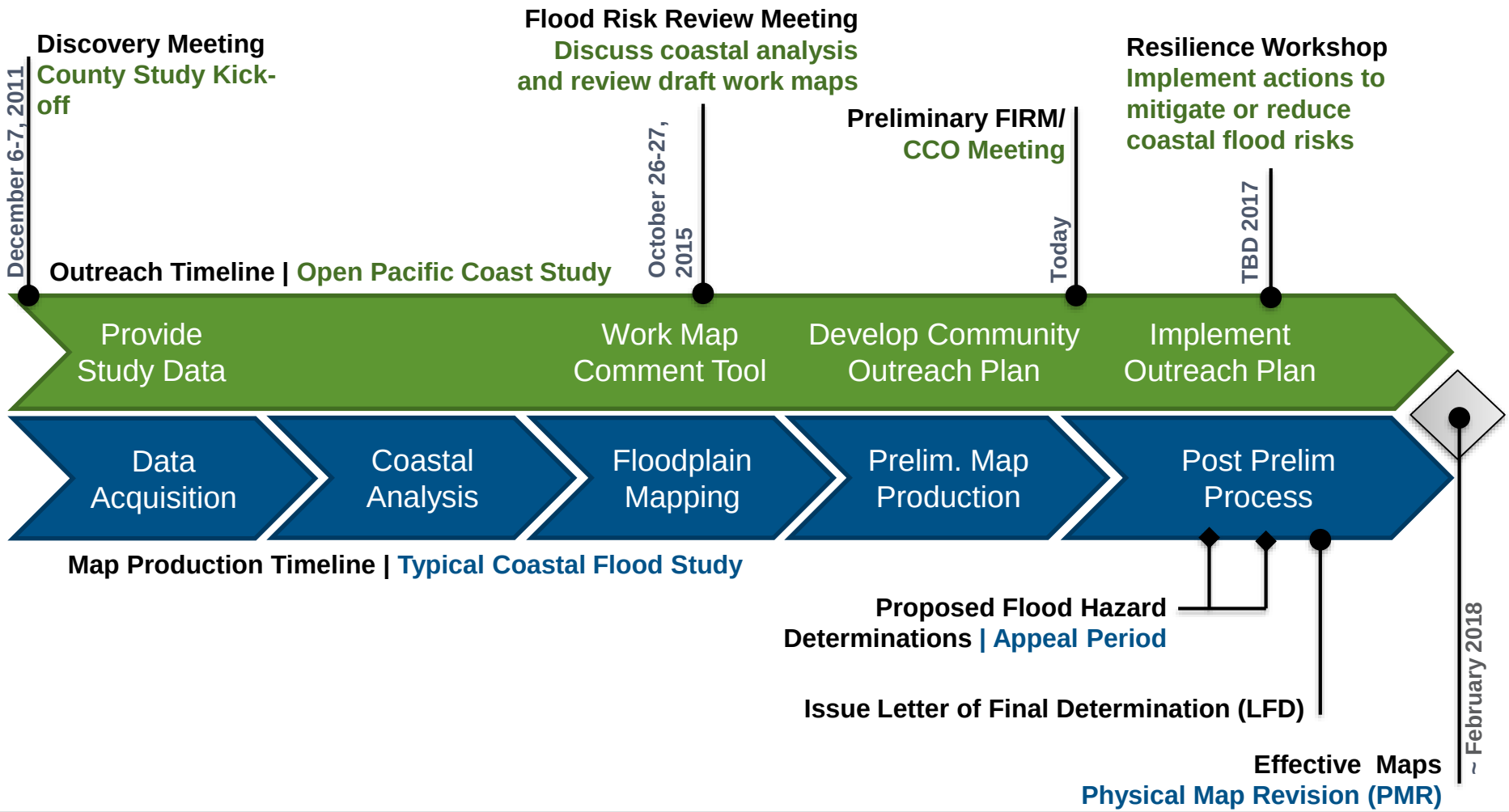
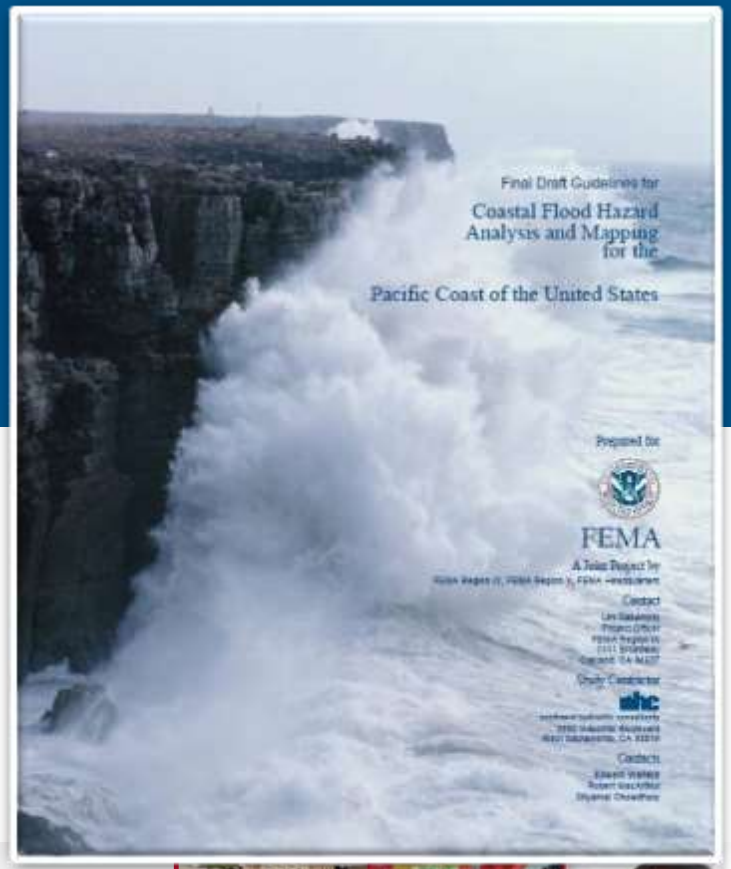
What is Different – New Processes



New Pacific Guidance

Apply "Final Draft Guidelines for Coastal Flood hazard Analysis and Mapping for the Pacific Coast of the United States"(dated Jan. 2005)



- **Developed by FEMA with help from 50 Coastal Experts**
- **First Wide-Scale Implementation in CCAMP OPC**

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New Data Acquisition

1,355 miles of new LIDAR from CA OPC

↓

10,000 oblique images (CA Records Project)

↓

Offshore Wave 50-yr Hindcast from OWI (1960-2010)

↓

Nearshore Waves 50-yr Hindcast from Scripps (CDIP)

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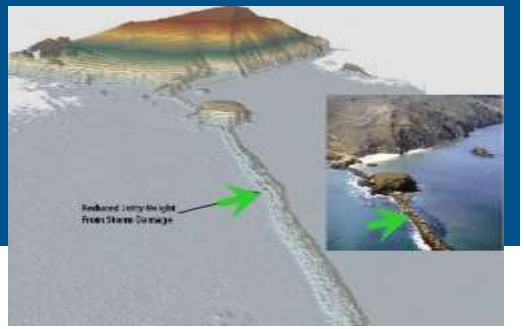
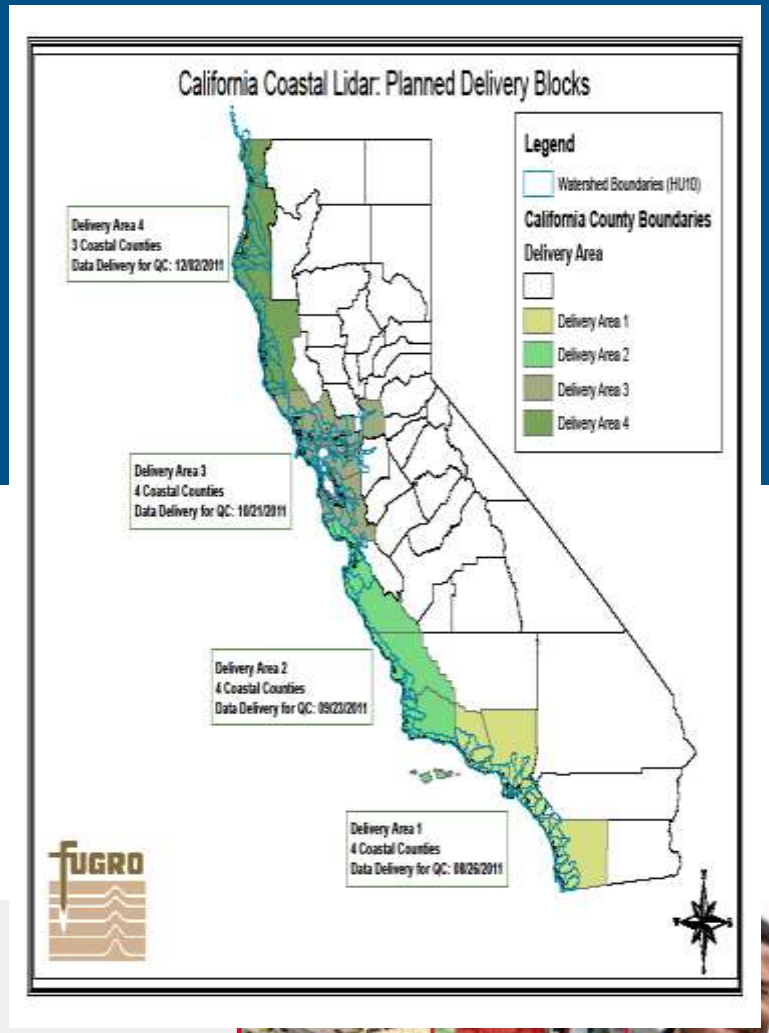
Tide Frequency Analysis from NOAA Gage Data

↓

CDIP Wave Transformation to MOP for hourly tide/wave data

Coastal Data: LIDAR (CA OPC)





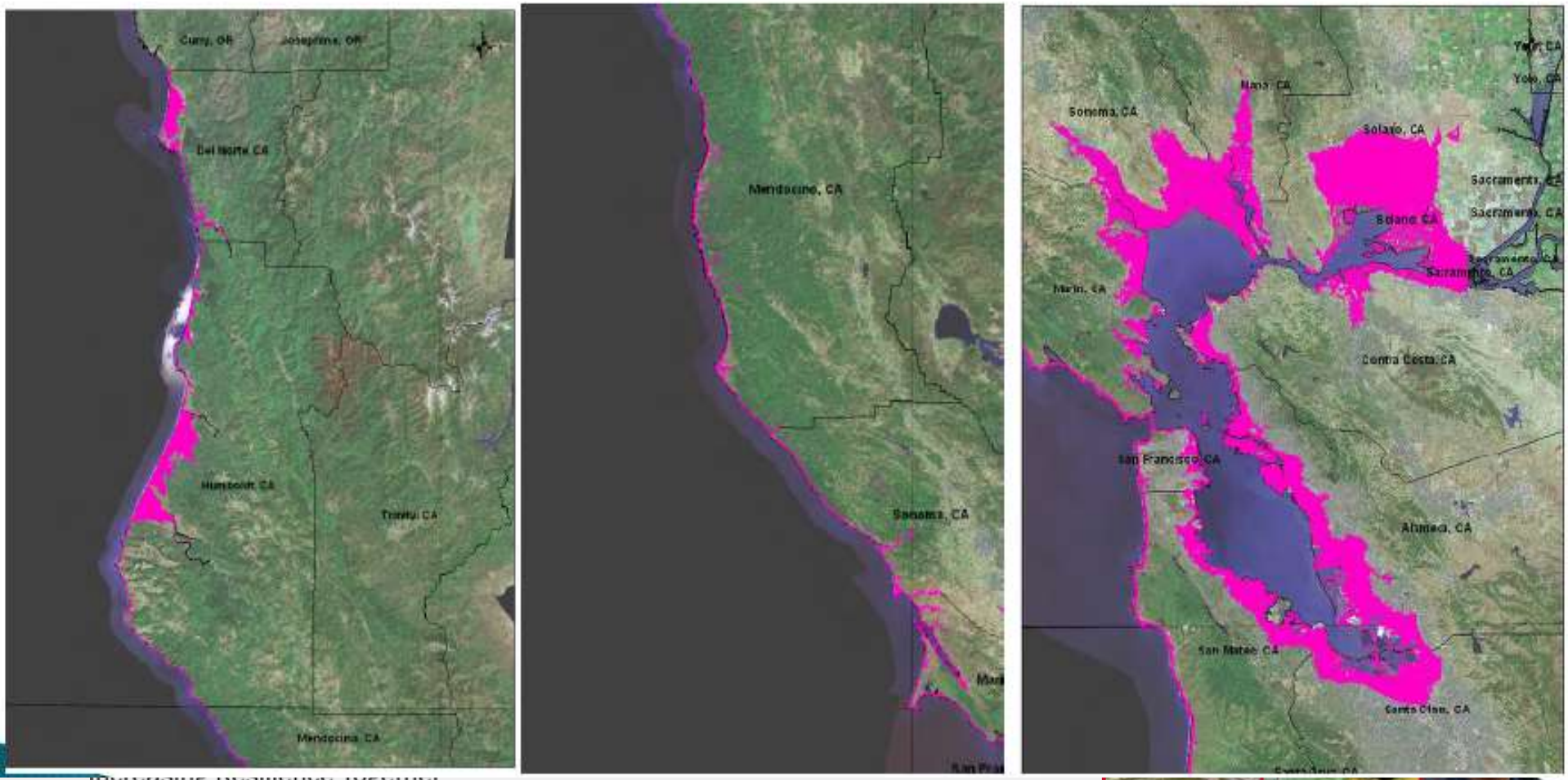
Elevation (LiDAR)	
Specification	**State Standard**
Vertical Accuracy (95% confidence)	18.2 cm
Vertical RMSE	9.25 cm
Horizontal Accuracy (95% Confidence)	50 cm
Horizontal RMSE	12.26 cm
Spot Spacing	</=1 m (nominal)
Tidal Coordination	+/- 1.5hrs MLLW

Imagery	
Specification	**State Standard**
Horizontal Accuracy (95% Confidence)	2 m
Spatial resolution	20 cm RGB, Near IR
Endlap/Sidelap	60%/30%
Tidal Coordination	+/- 1.5hrs MLLW

Additional specs in SOW

Coastal Data: LIDAR (CA OPC)

0–10 m topographic contour, Oregon to Mexico



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Coastal Data: 10,000 Oblique Photos

http://www.californiacoastline.org/

CA Coastal Records Project

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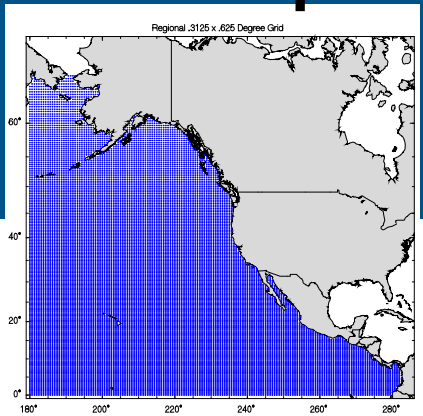
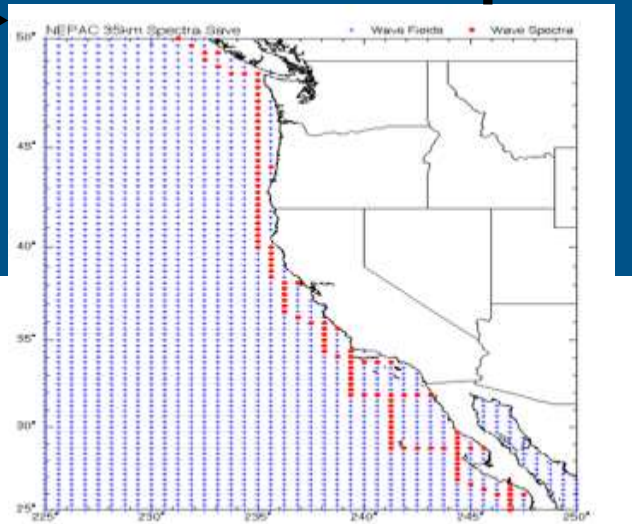
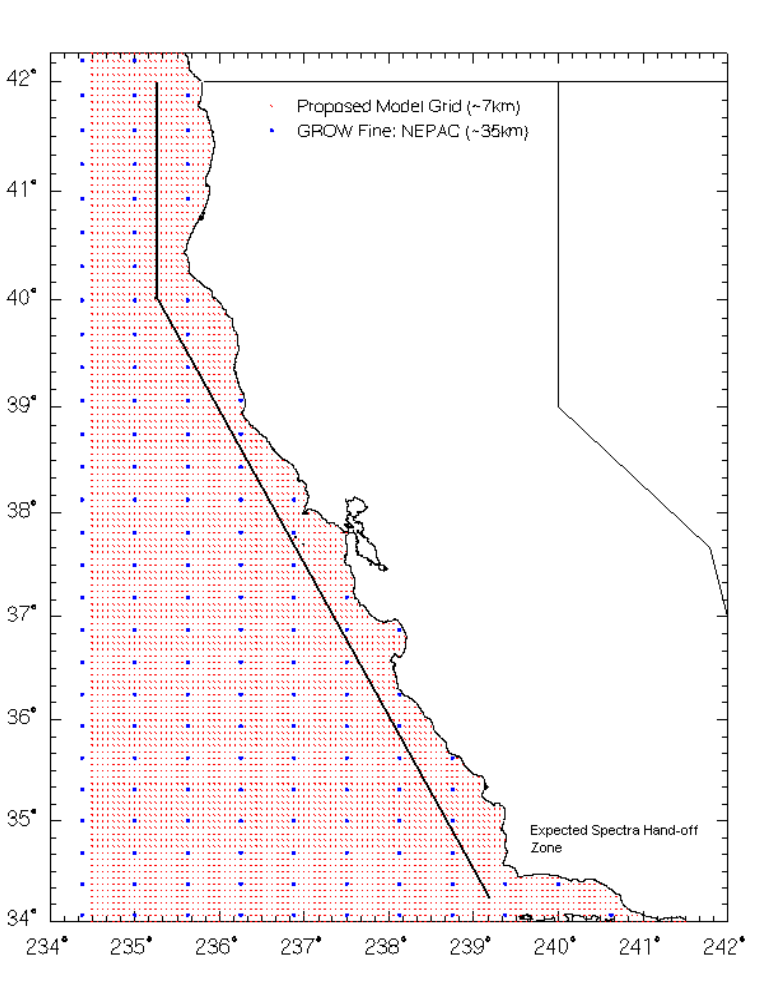
Deepwater Waves (OWI)







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Nearshore Waves(Scripps)

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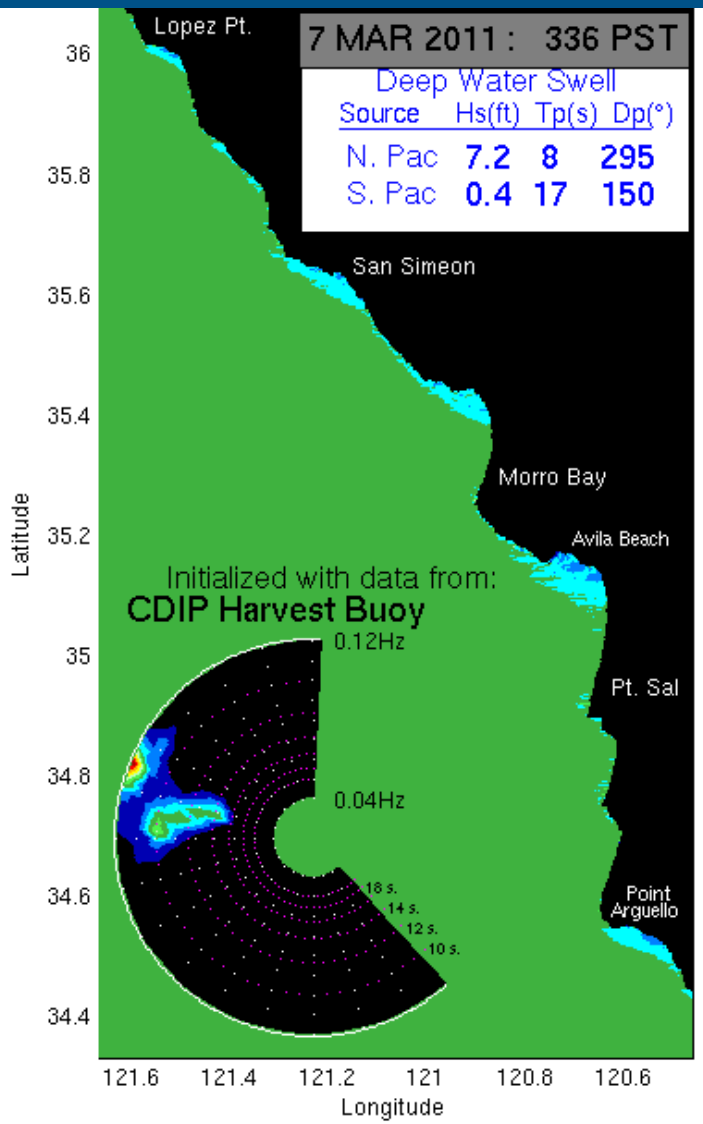
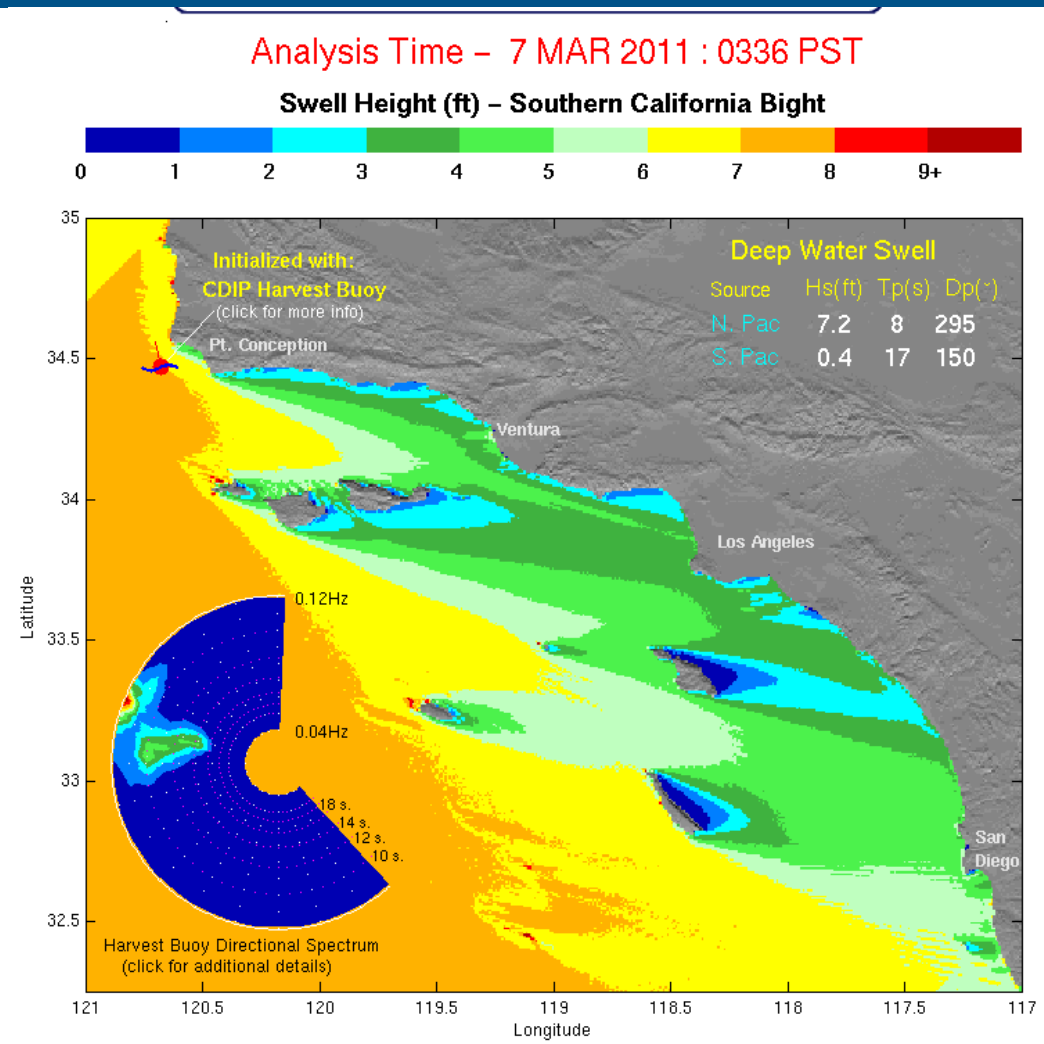
Nearshore Waves(Scripps)





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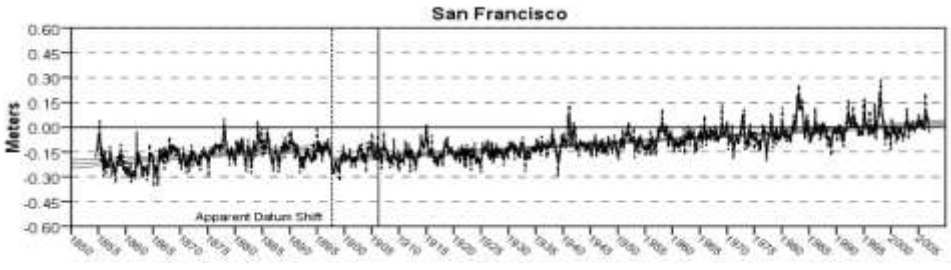
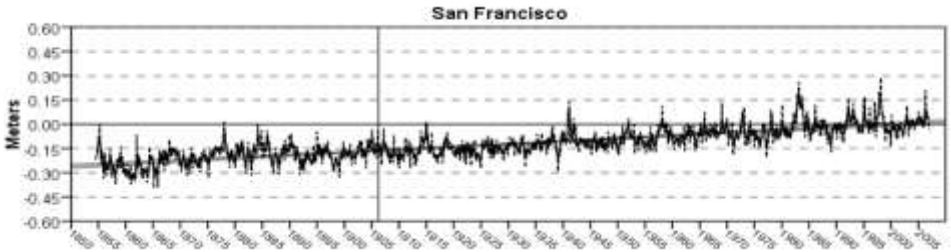
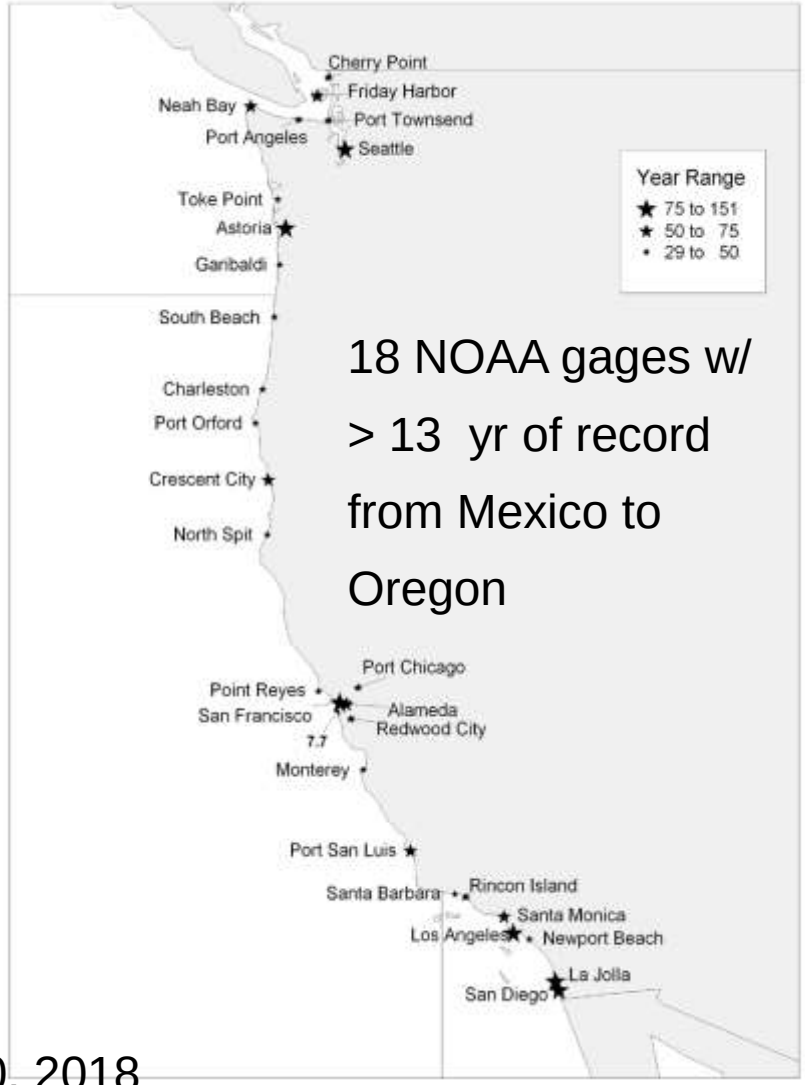
Coastal Data: Tides (NOAA CO-Ops)







18 NOAA gages w/ > 13 yr of record from Mexico to Oregon

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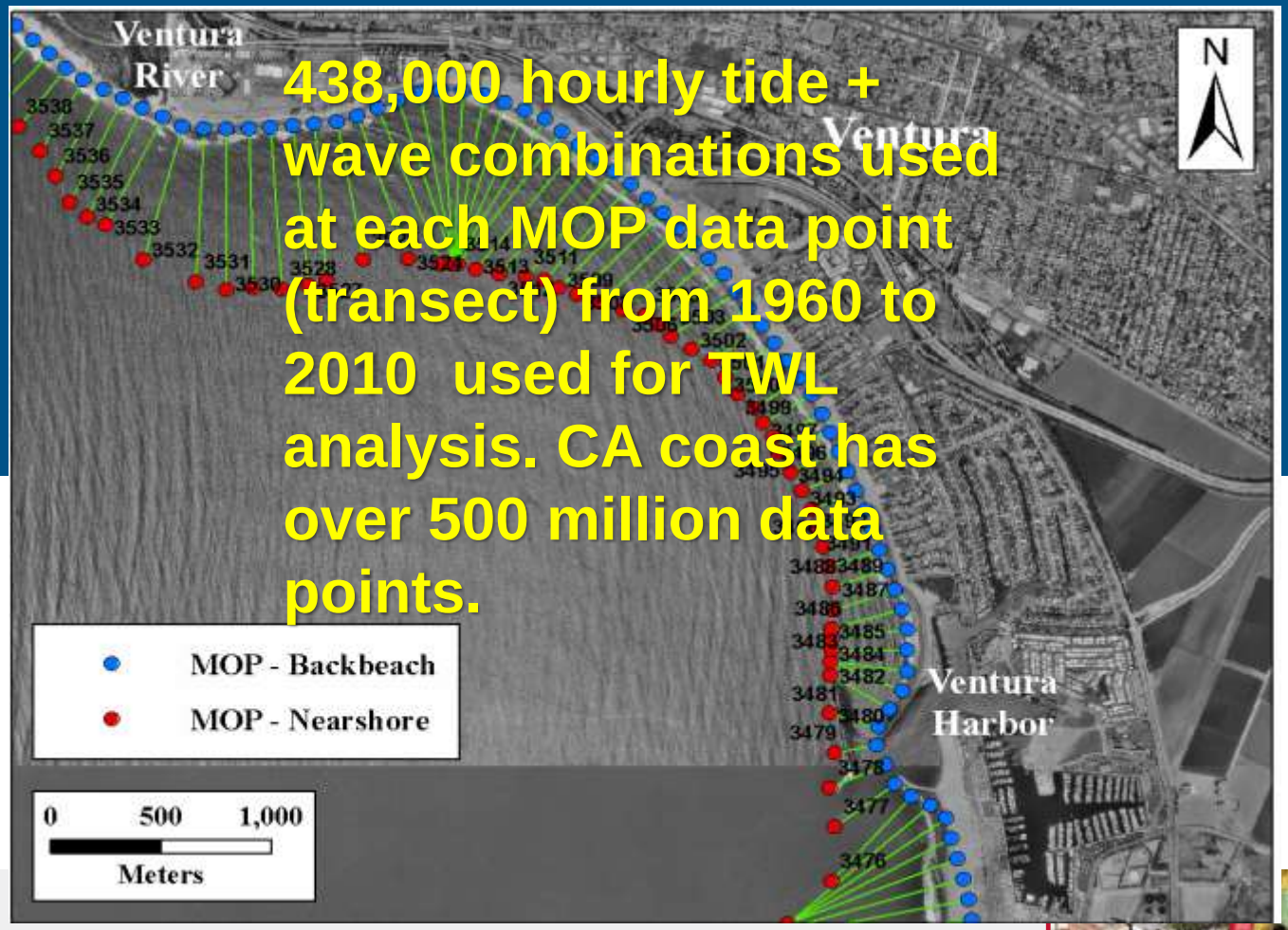
MOP Nearshore Wave Prediction Sites (Scripps)



438,000 hourly tide + wave combinations used at each MOP data point (transect) from 1960 to 2010 used for TWL analysis. CA coast has over 500 million data points.

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New Detailed Analyses Pilot Studies

1,139 Transects Used in 1-D Detailed Analysis

↓

Analysis of Key Coastal Processes

↓

12 Harbor Breakwater Overtopping Assessments

↓

Pilot Study: Wave Runup Depth-Velocity Grids

↓

Pilot Study Probabilistic Tsunami Hazards

↓

Pilot Study of Sea Level Rise at San Francisco

1-D Coastal Analysis for 1,139 transects

- Wave Setup
- Wave Runup
- Wave Overtopping
- Overland Waves
- Dune & Bluff Erosion

For 15 Phase 1 & 2 counties, there are 1,139 transects used for wave analyses and erosion assessments.

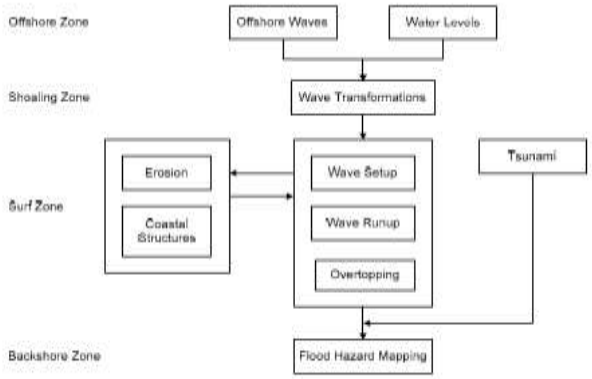

Figure D.4.2-4. Coastal Zones and Processes

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New Detailed Analyses & Pilot Studies

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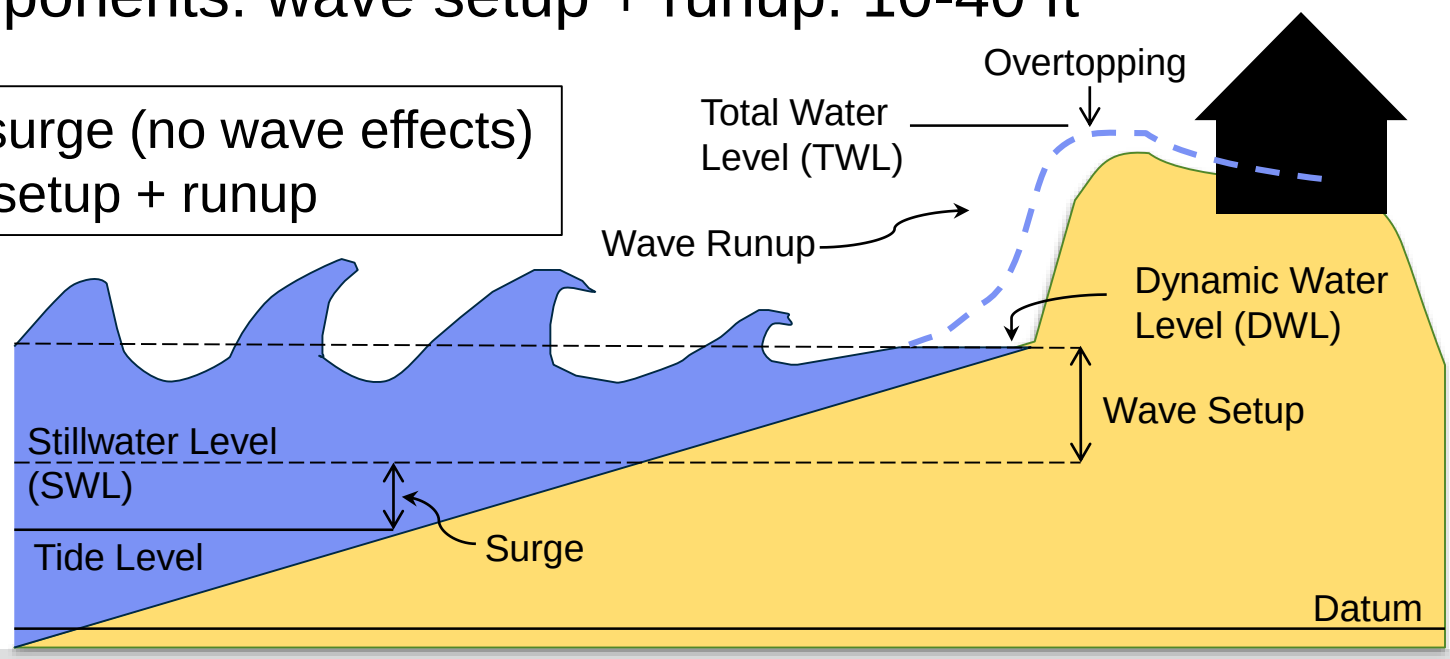
Detailed Analysis: Total Water Levels

Components of the total water level (TWL)

- Astronomical tide (predicted tide): 5-7 ft
- Surge components: atmospheric pressure, wind setup, El Niño sea level effects: 1-4 ft
- Wave components: wave setup + runup: 10-40 ft

SWL = Tide + surge (no wave effects)
TWL = SWL + setup + runup



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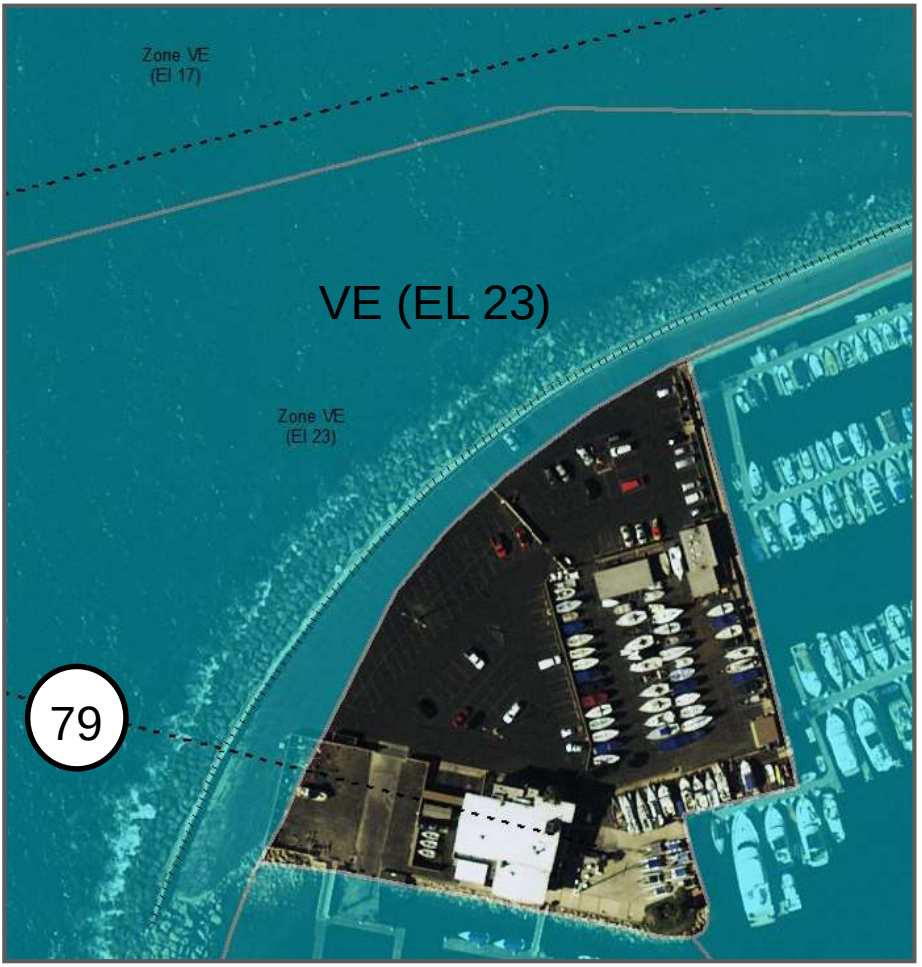
Detailed Analysis: Harbor Breakwaters



Coastal Analysis Results

- 1% SWEL = 8.0 ft NAVD
- 0.2% SWEL = 8.4 ft NAVD
- 1% Runup (TWL) = 23.4 (intact only) ft NAVD
- 0.2% Runup (TWL) = 26.4 (intact only) ft NAVD
- Overtopping distance from crest = 44.7 ft (intact only)

New Detailed Analyses Pilot Studies

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Pilot Study of Wave Runup Depth-Velocity Grid

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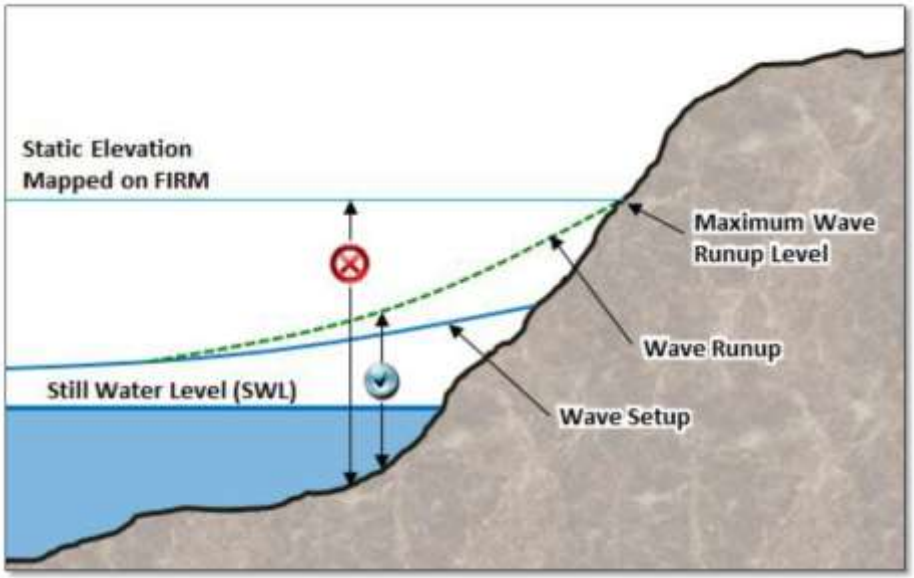
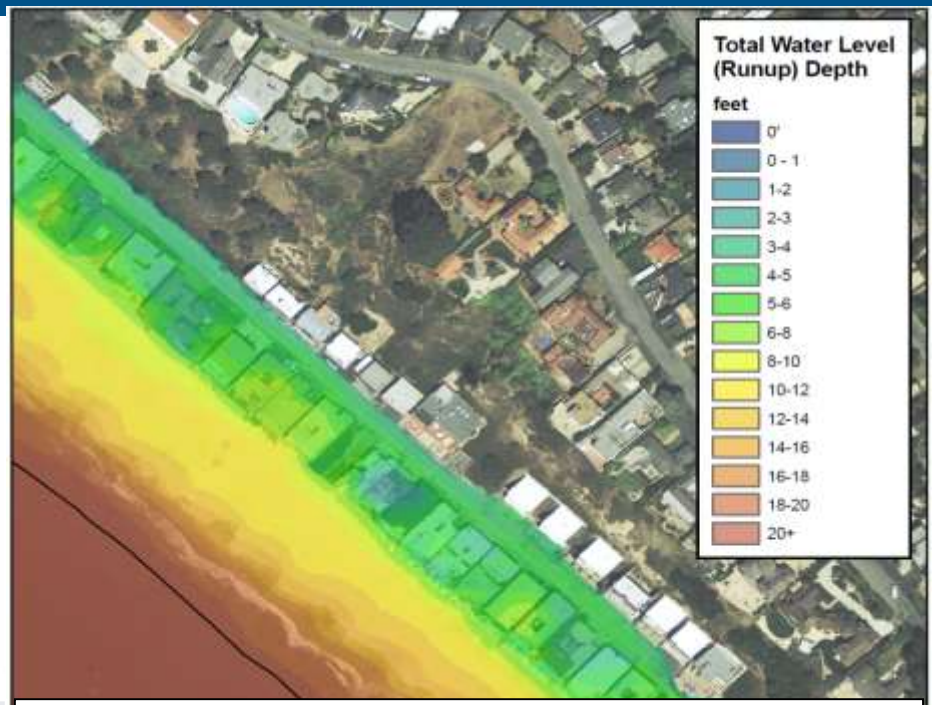
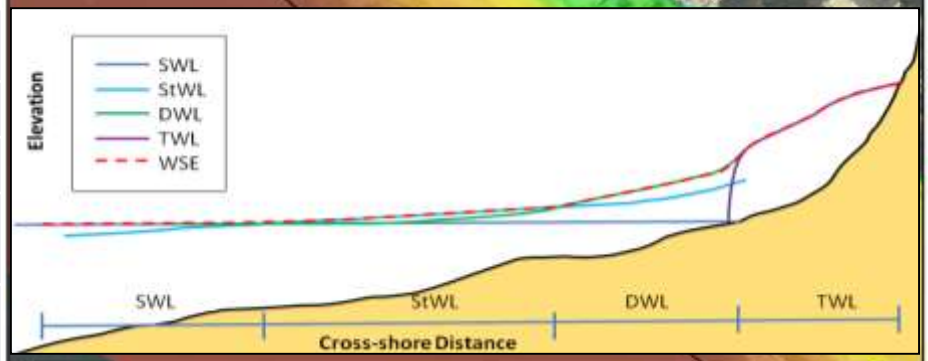
Special Projects: Wave Runup Depth & Velocity Grid

Figure 9: Coastal Flood Depth Calculation Methods in Wave Runup-Dominated Areas



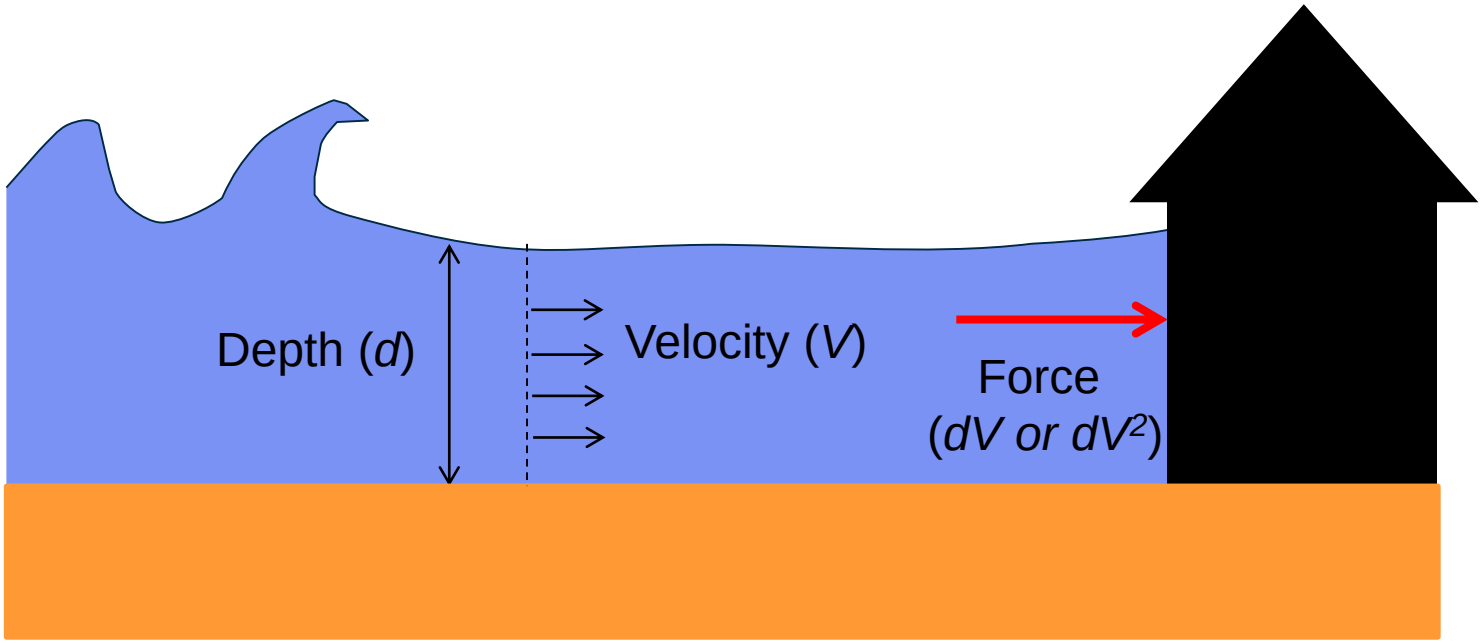
Water Level	Physical Components
SWL	Astronomical Tides, Storm Surge, El Niño Processes
StWL	SWL + ζ
DWL	StWL + ξ (SWL + ζ + ξ)
TWL	DWL +R (SWL + ζ + ξ + R)





Santa Cruz County Open Pacific Coast Draft Runup Depth Grid

Special Projects: Wave Runup Depth & Velocity Grid



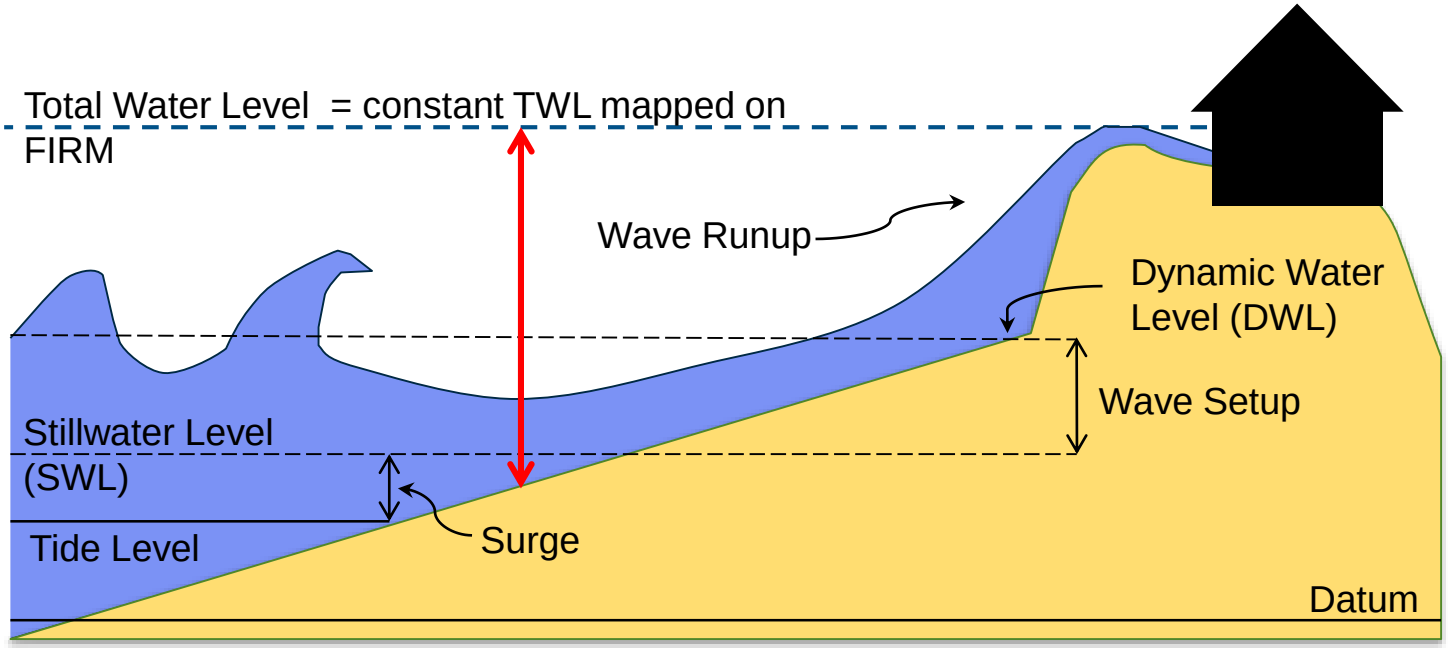
- Hydrodynamic forces can overturn walls, damage structural components, and scour foundations
- The forces are a function of both Depth (*d*) and Velocity (*V*)
- The forces can be approximated by Depth x Velocity (*dV*) and Depth x Velocity Squared (dV^2)

Special Projects: Wave Runup Depth & Velocity Grid

Flood Severity Category	Depth Range (ft)	Depth x Velocity Range (ft^2/sec)
Low	< 0.5	< 2.2
Medium	0.5 – 1.0	2.2 – 5.4
High	1.0 – 2.0	5.4 – 16.1
Very High	2.0 – 2.8	16.1 – 26.9
Extreme	> 2.8	> 26.9

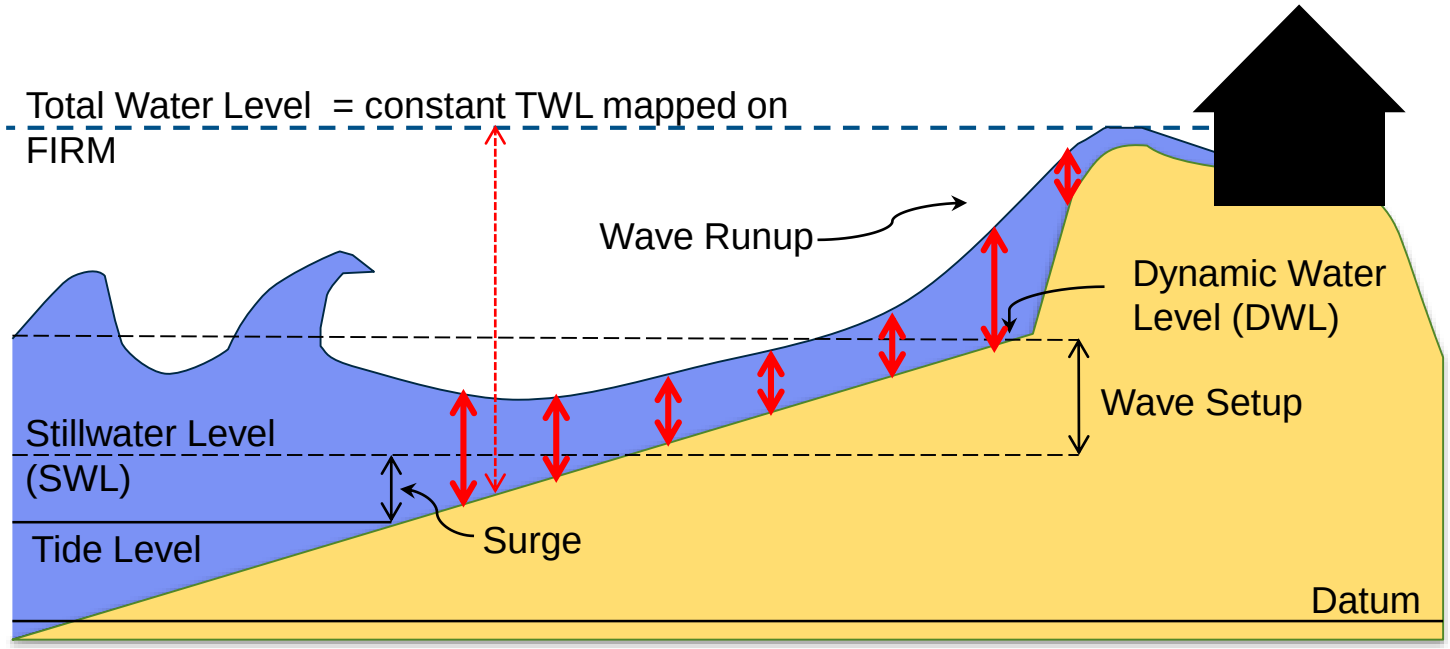
- FEMA developed Flood Severity Categories for flood depth and velocity data
- Allow communities to readily identify areas that are most at risk

Special Projects: Wave Runup Depth & Velocity Grid



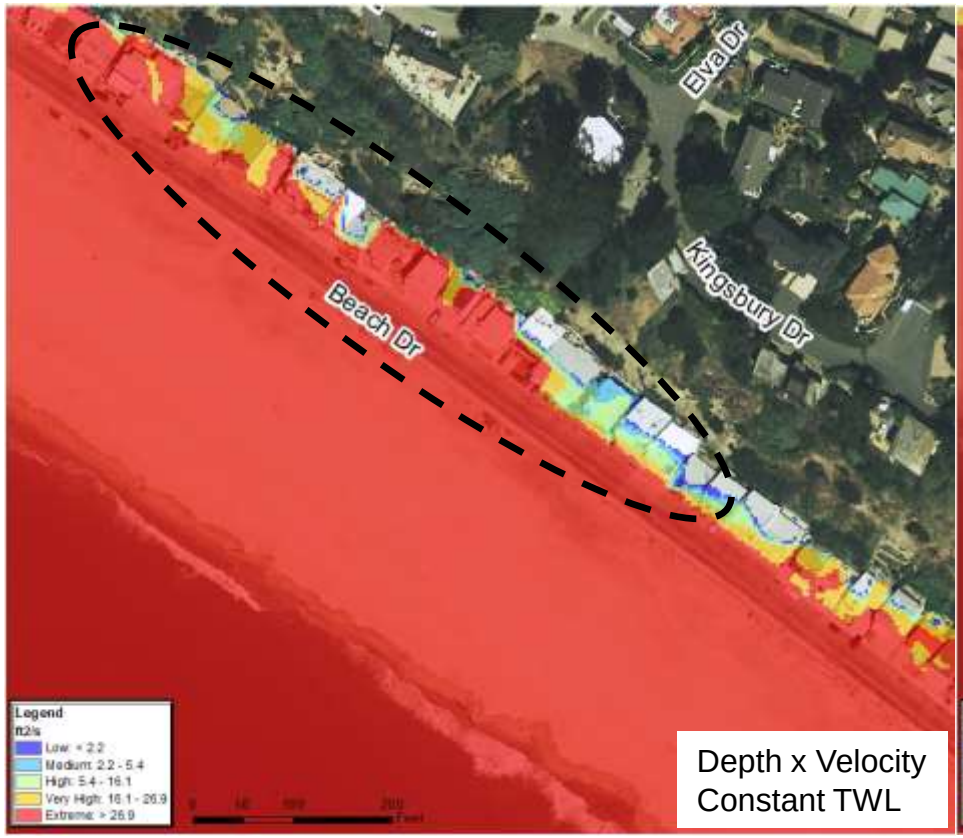
- One potential method is to calculate depths and velocities using this constant TWL elevation
- Although TWL is constant, depths and velocities vary across the beach

Special Projects: Wave Runup Depth & Velocity Grid

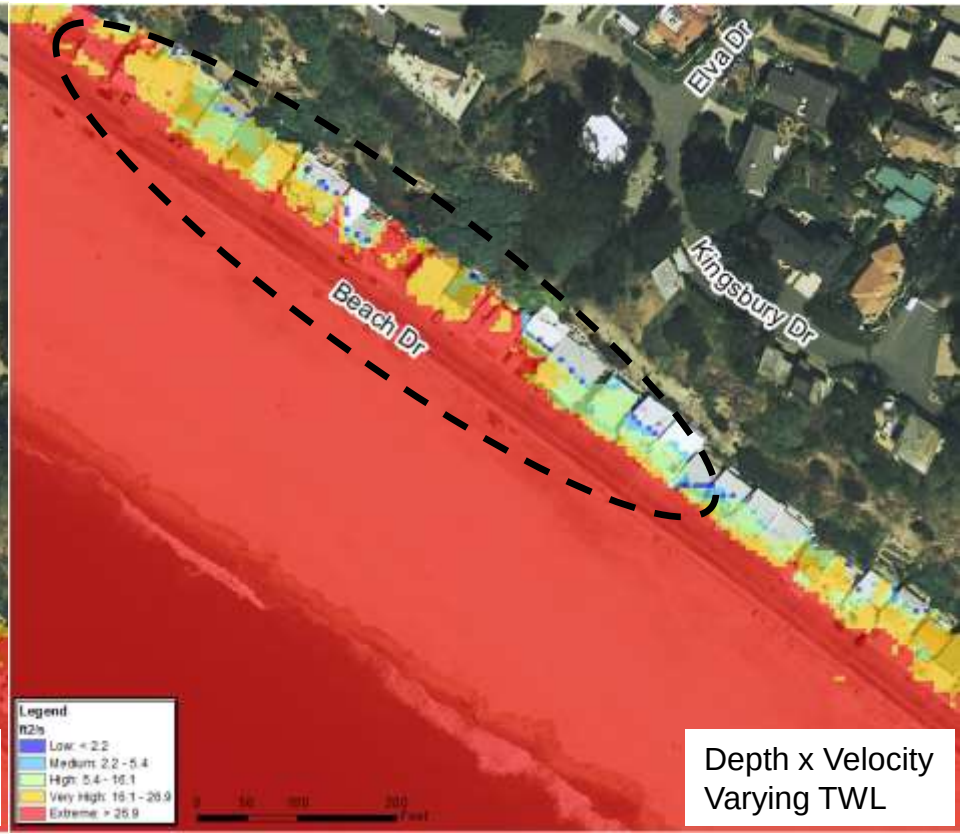


- In reality, TWL varies across the beach and backshore
- Another method is to use FEMA Guidelines equations to calculate the TWL up the beach and then calculate depths and velocities
- The method accurately captures TWL variation across beach
- Does not overestimate depths and velocities across beach
- BakerAECOM developed new analysis approach

Special Projects: Wave Runup Depth & Velocity Grid



Depth x Velocity
Constant TWL



Depth x Velocity
Varying TWL

New Detailed Analyses Pilot Studies

1,139 Transects Used in 1-D Detailed Analysis

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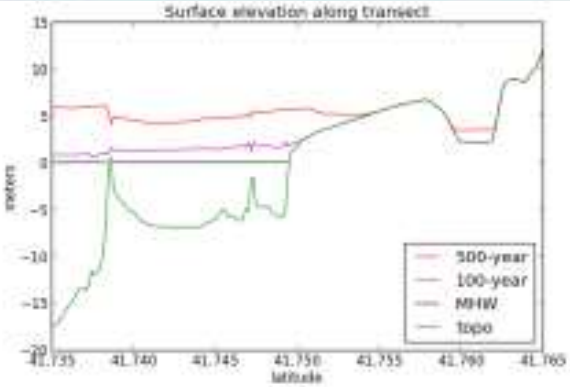
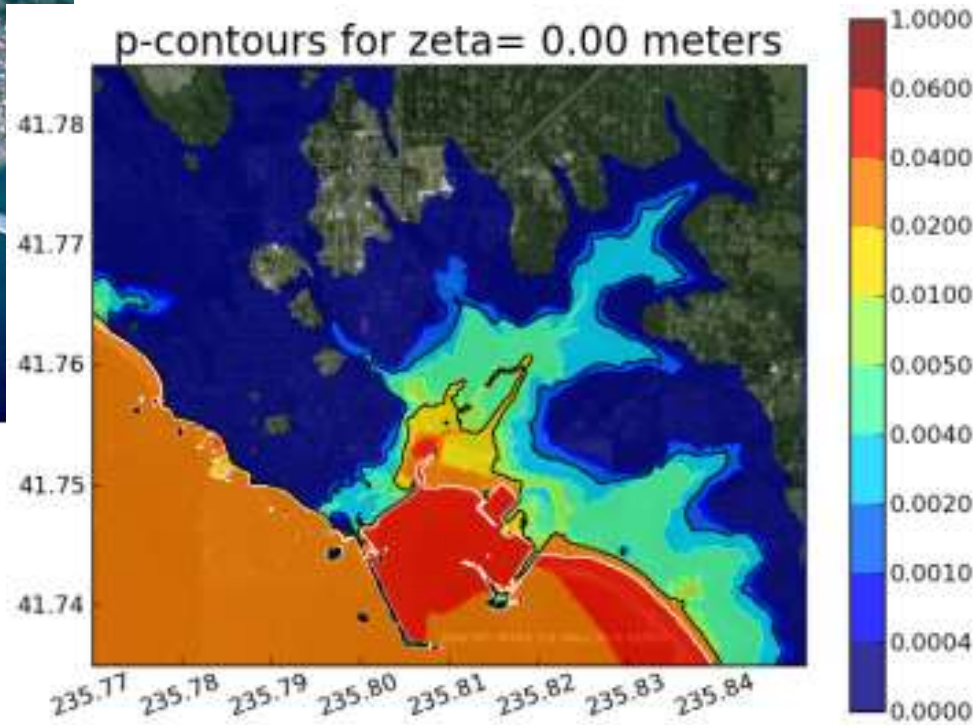
Special Projects: PTHA w/ UW in Crescent City (Del Norte Co)





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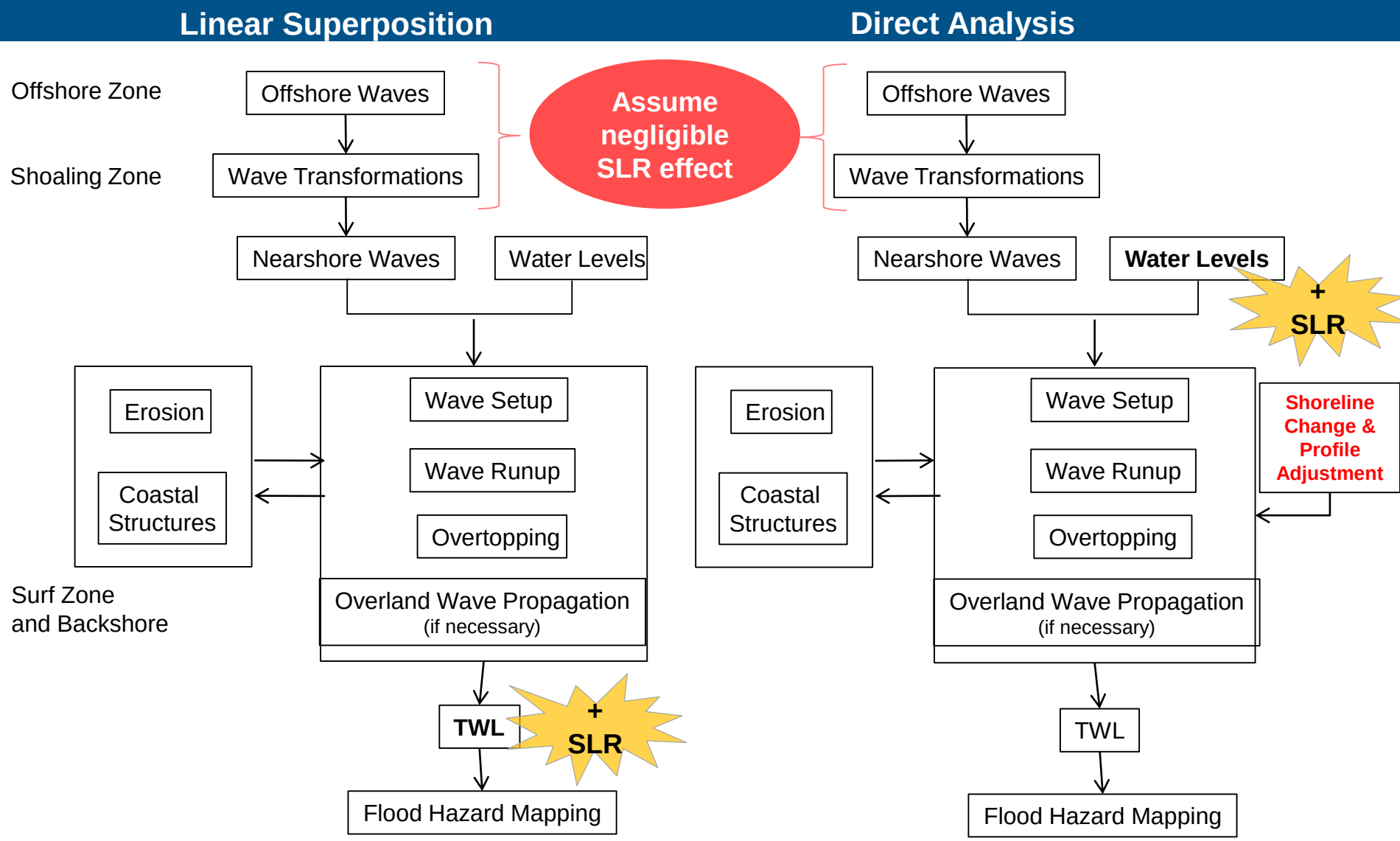
Pilot Study: San Francisco & SLR



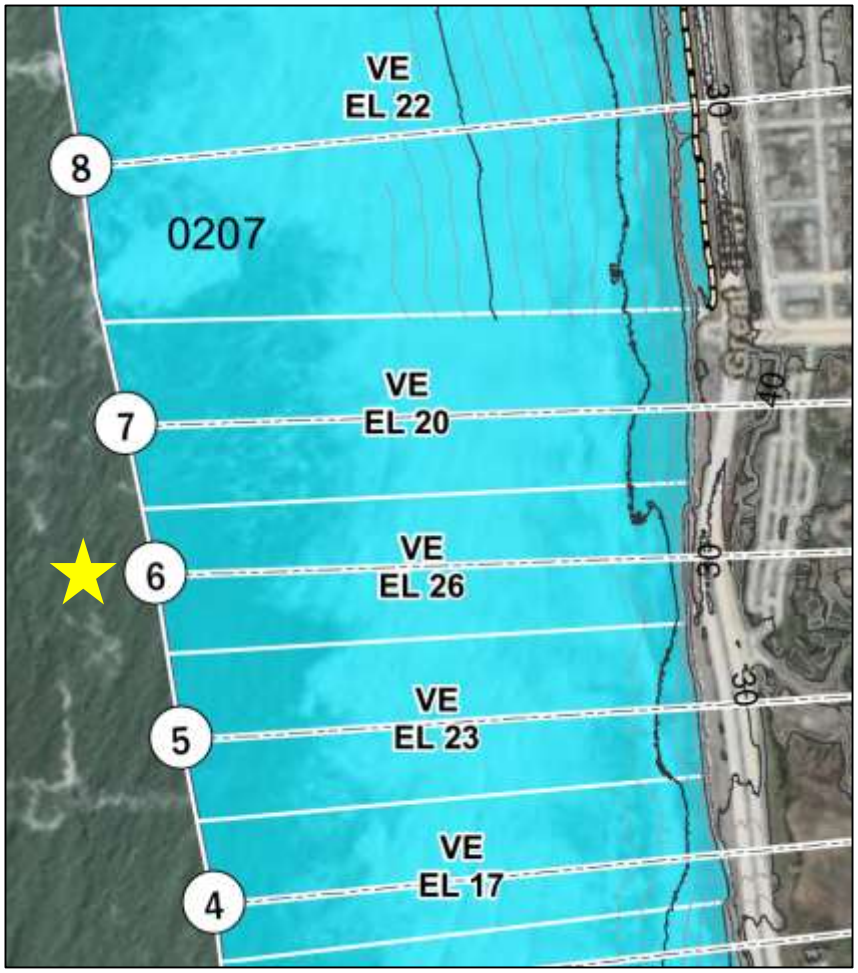
$TWL_{SLR} = TWL + SLR$

$TWL_{SLR} > TWL + SLR$

Pilot Study: San Francisco & SLR

Trial Run Methods and Results

Sloat Blvd – Armored Low Bluff



Coastal Analysis Results

(Existing Conditions)

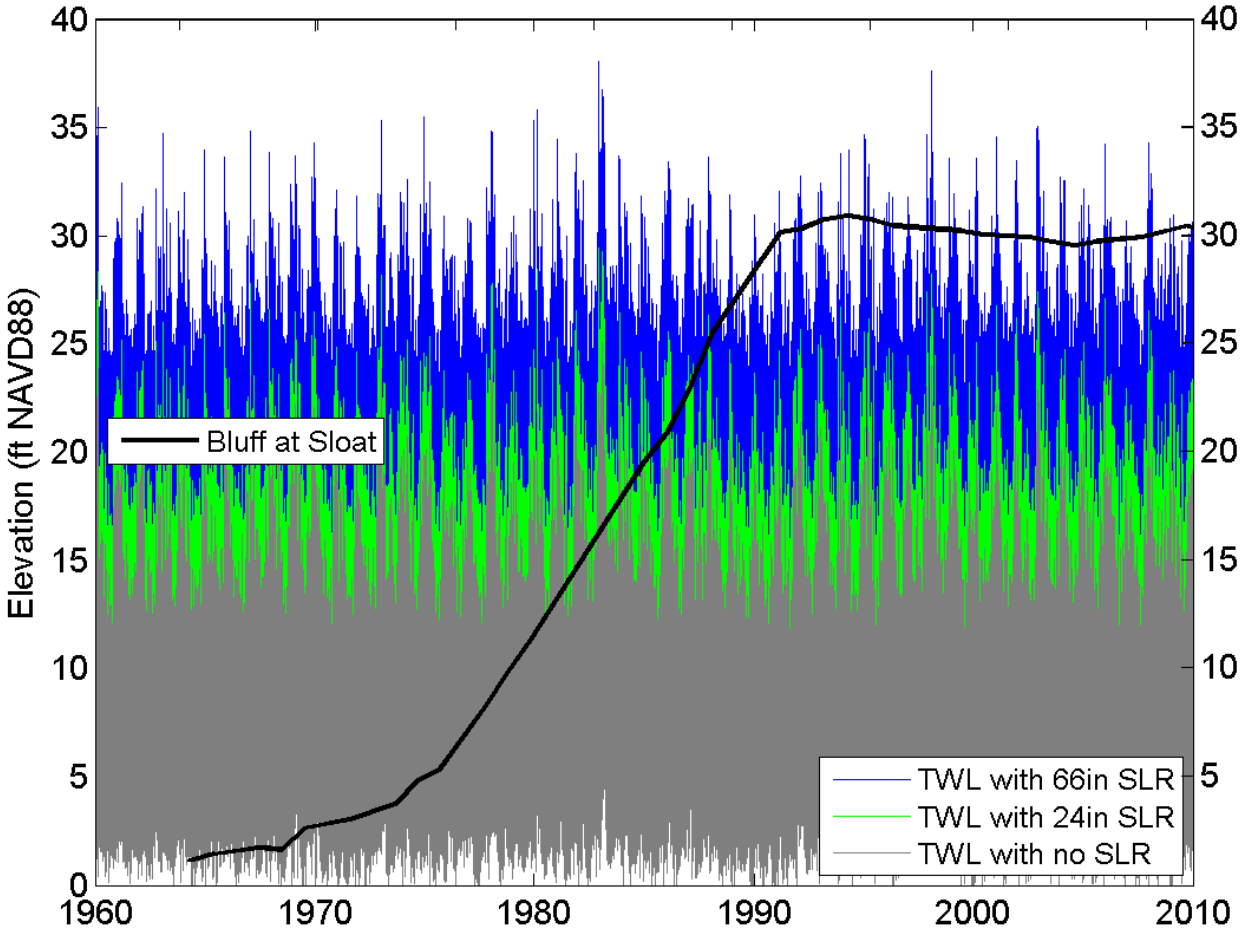
- **1% SWEL = 9.0 ft NAVD**
- **0.2% SWEL = 9.7 ft NAVD**
- **1% Runup (TWL) = 26 ft NAVD**
- **0.2% Runup (TWL) = 27 ft NAVD**
- **No overtopping under existing conditions**

Pilot Study: San Francisco & SLR

Trial Run Methods and Results

Sloat Blvd – Armored Low Bluff

- **TWL response to SLR (ex. cond./24”/66”)**
- **<u>Existing conditions</u>: peak TWL is ~5 ft below crest**
- **<u>24” SLR</u>: peak TWL is ~1-2 ft below crest**
- **<u>66” SLR</u>: many TWL events exceed crest**
- **TWL results exhibit non-linear response to SLR**



Pilot Study: San Francisco & SLR

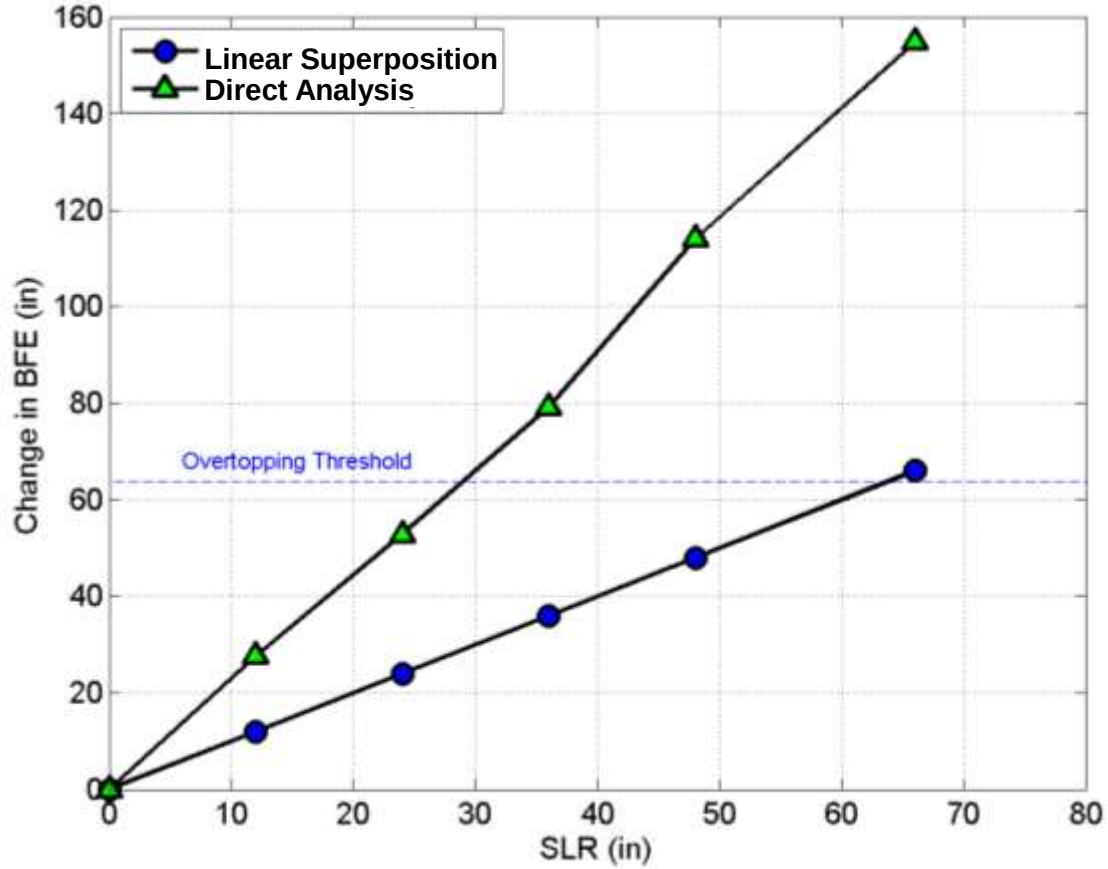
Linear Superposition vs. Direct Analysis

Sloat Blvd – Armored Low Bluff

- **BFE increase greatly exceeds the linear superposition rate (by a factor of ~2)**
- **Wave runup feedback important at this transect**
- **Overtopping occurs at much lower SLR under direct analysis vs. linear superposition method**

1% TWL	Current	+24 in	+66 in
Linear	25.6 ft	27.6 ft	31.1 ft
Direct	25.6 ft	29.9 ft	38.5 ft

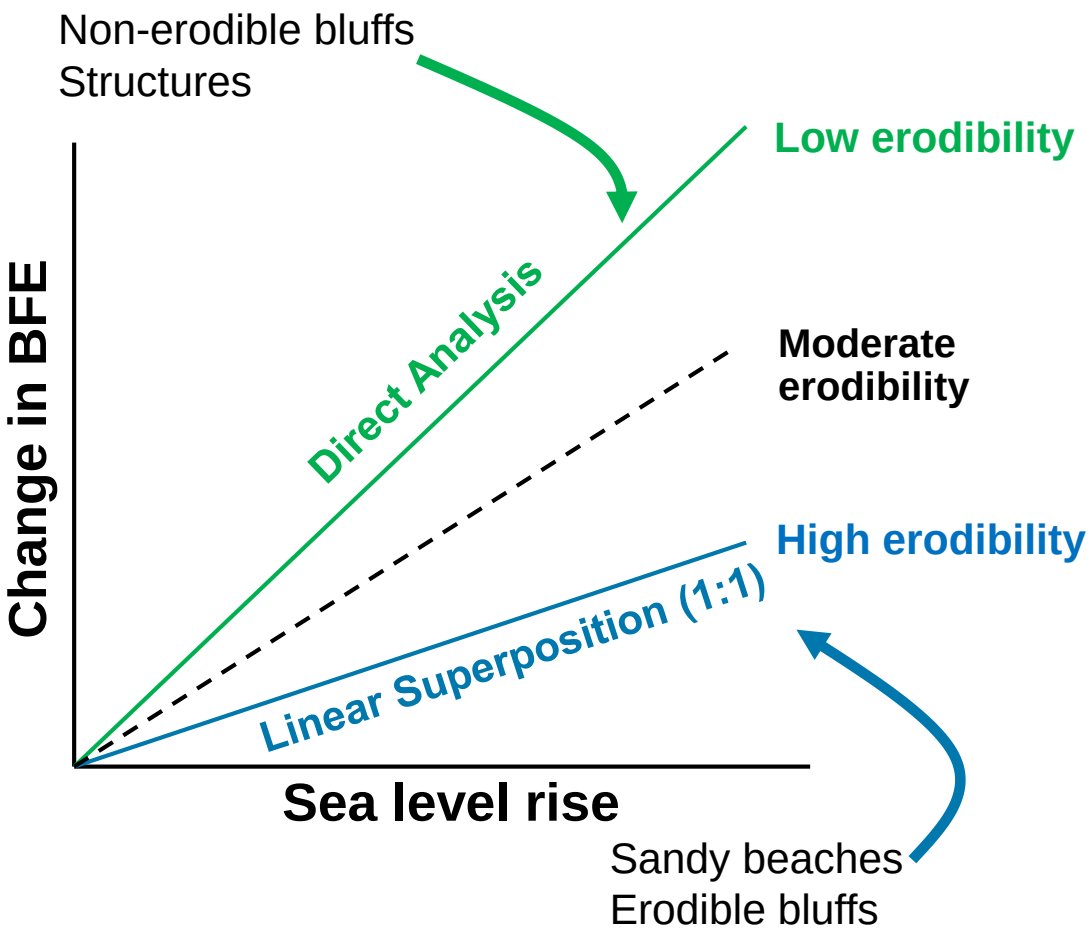
SLR (ft)	ΔBFE (ft)	BFE (ft)
0	-	25.6
1.0	2.2	27.8
2.0	4.3	29.9
3.0	6.3	31.9
4.0	9.6	35.2
5.5	12.9	38.5



Pilot Study: San Francisco & SLR

Key Concepts – Direct Analysis Response

- **Static profile (no shoreline retreat) exhibits direct analysis behavior**
- **Shoreline retreat mitigates impact of SLR as shoreline adjusts to new equilibrium position**
- **Profile erodibility/armoring dictates TWL behavior: direct analysis vs. linear superposition**
- **Bluffs, sandy beaches, and structures will exhibit different responses**



New Detailed Analyses

San Diego Bay 2-D Surge/Wave Modeling for 50-yr Hindcast

↓

Wave Overtopping AO Zones

↓

Primary Frontal Dune VE Zone Mapping

↓

Number of Communities Impacted by SFHA

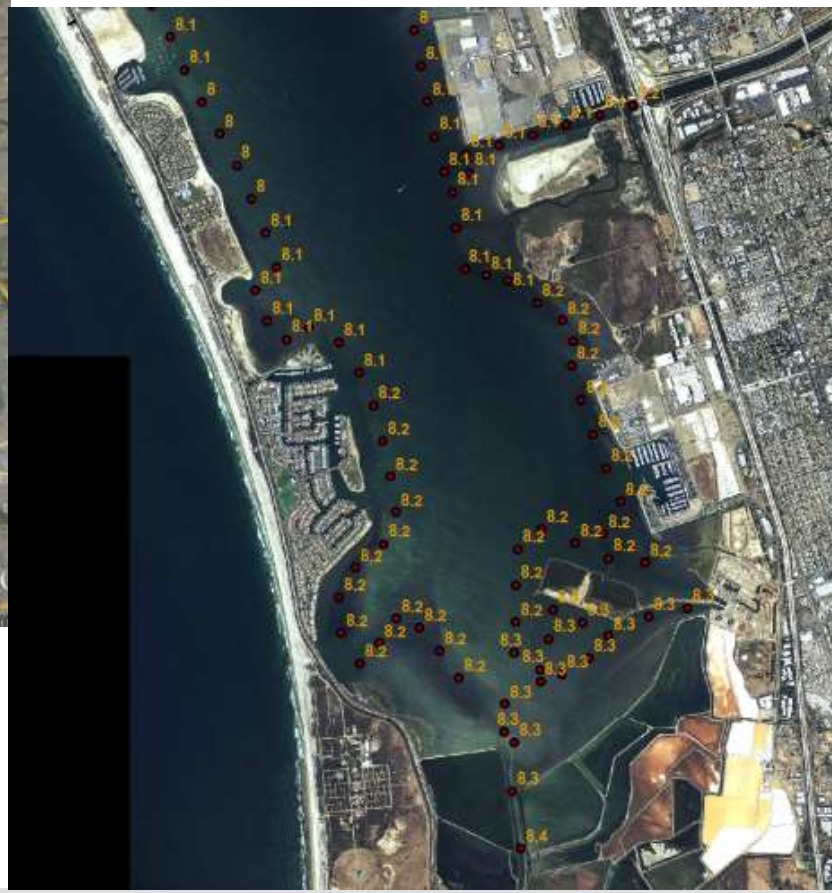
↓

Challenges

CCAMP

RiskMAP
Increasing Resilience Together

Special Projects: 2-D Modeling of San Diego Bay w/ DHI



New Detailed Mapping Primary Frontal Dunes

San Diego Bay 2-D Surge/Wave Modeling for 50-yr Hindcast

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Primary Frontal Dune VE Zone Mapping

↓

Wave Overtopping AO Zones

↓

Number of Communities Impacted by SFHA

↓

Challenges

Primary Frontal Dune VE Zones

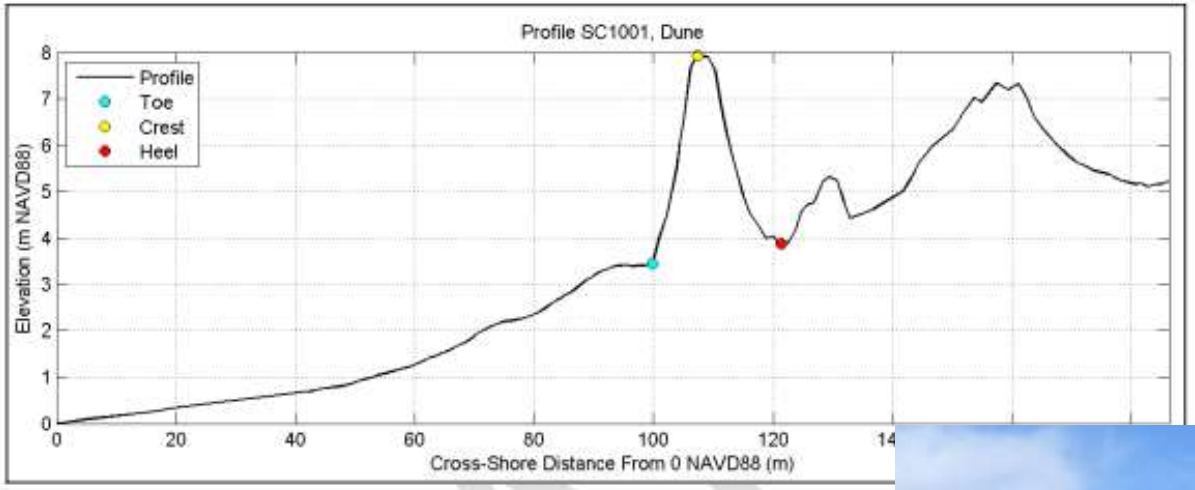
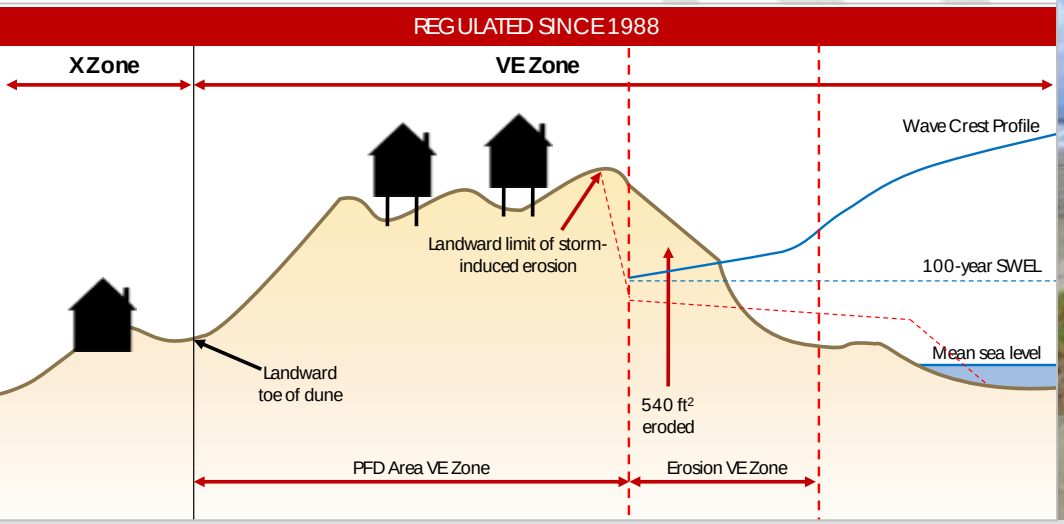


Figure IX.1.2. Cross-shore profile of Transect 1001.

Pajaro Dunes, Santa Cruz Co



New Detailed Mapping Wave Overtopping

San Diego Bay 2-D Surge/Wave Modeling for 50-yr Hindcast

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Primary Frontal Dune VE Zone Mapping

↓

Wave Overtopping AO Zones

↓

Number of Communities Impacted by SFHA

↓

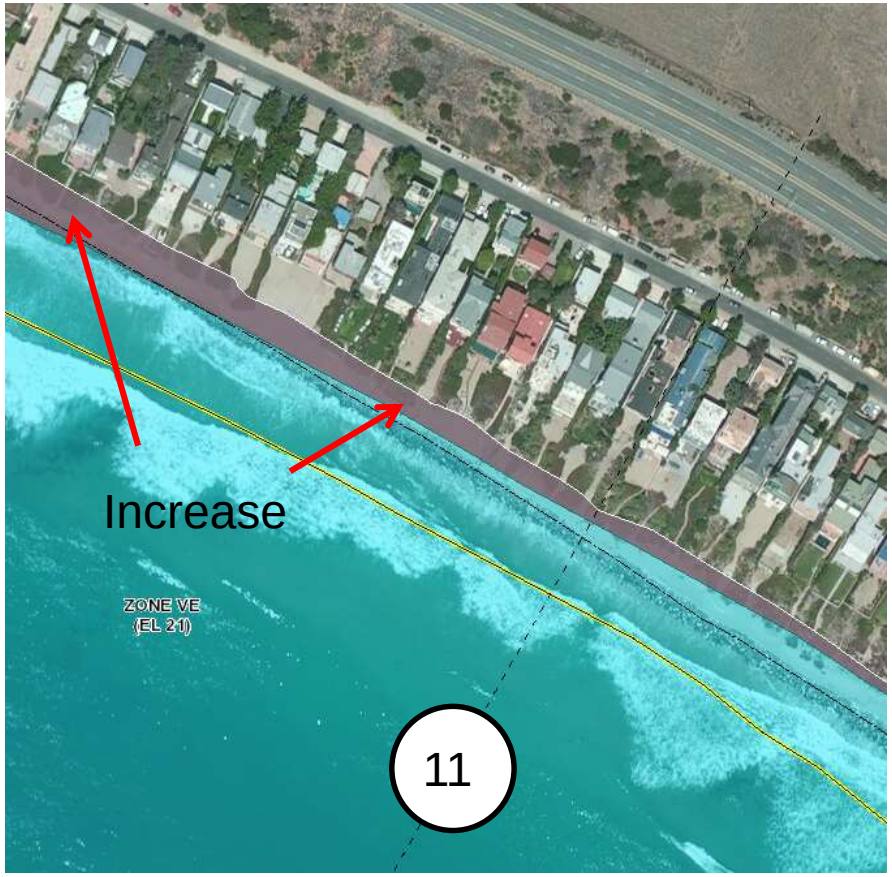
Challenges

CCAMP

RiskMAP
Increasing Resilience Together

New Detailed Mapping Wave Overtopping

Malibu, Los Angeles Co



Coastal Analysis Results

- 1% SWEL = 8.0 ft NAVD
- 0.2% SWEL = 8.4 ft NAVD
- 1% Runup (TWL) = 31 ft (failed) or 21 (intact) ft NAVD
- 0.2% Runup (TWL) = 37 ft (failed) or 25 (intact) ft NAVD
- Overtopping distance from crest = 34 ft (intact) or 26 ft (failed)

Communities and Map Revisions

San Diego Bay 2-D Surge/Wave Modeling for 50-yr Hindcast

↓

Primary Frontal Dune VE Zone Mapping

↓

Wave Overtopping AO Zones

↓

Number of Communities Impacted by Map Revisions

↓

Challenges

Communities and Map Revisions

Geographic Coverage and Impacts

The coastal study and hazard mapping included 15 coastal counties

Phase 1:

- **for the 10 counties (in Northern and Central CA) CCAMP OPC covered 958 miles of detailed analyses,**
- **impacting 220 FIRM panel revisions**
- **in 31 communities.**

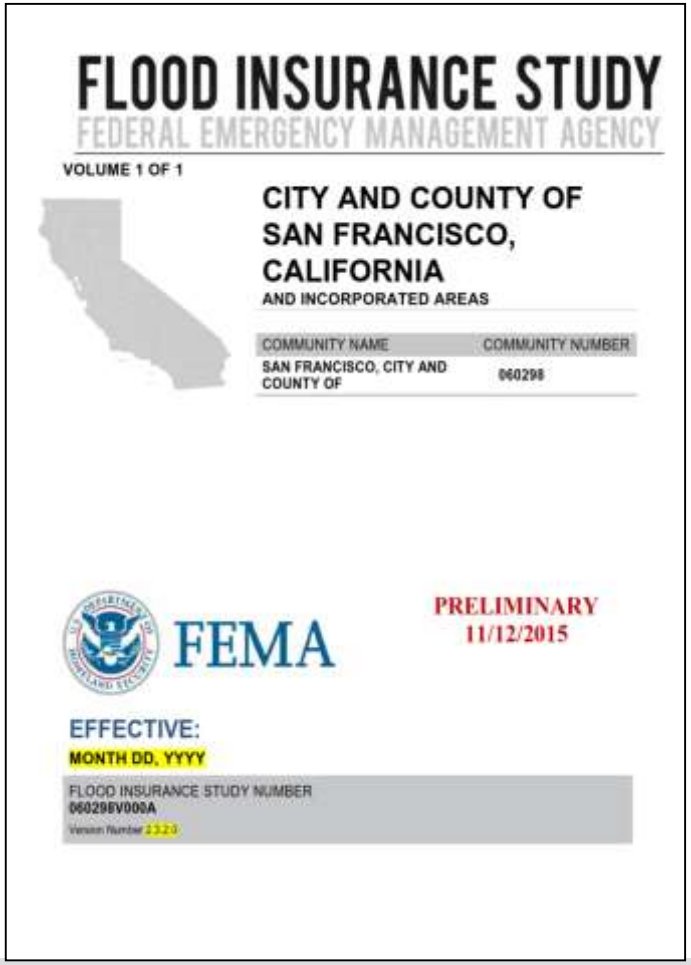
Phase 2:

- **for the 5 counties (in Southern CA) CCAMP OPC covered 529 miles of detailed analyses,**
- **impacting 180 FIRM panel revisions**
- **in 47 communities.**

Communities and Map Revisions

Achievements in Map Production

- **The CCAMP OPC and CCAMP BAC (in San Francisco Bay Area) studies are being used to create the first ever San Francisco City/County FIRM and FIS;**
- **Study is still preliminary but soon to be adopted and effective.**


FLOOD INSURANCE STUDY

FEDERAL EMERGENCY MANAGEMENT AGENCY

VOLUME 1 OF 1

CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA

AND INCORPORATED AREAS

COMMUNITY NAME	COMMUNITY NUMBER
SAN FRANCISCO, CITY AND COUNTY OF	060298

FEMA

PRELIMINARY 11/12/2015

EFFECTIVE:

MONTH DD, YYYY

FLOOD INSURANCE STUDY NUMBER

060298V000A

Version Number 2.3.2.0

Communities and Map Revisions

San Diego Bay 2-D Surge/Wave Modeling for 50-yr Hindcast

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Wave Overtopping AO Zones

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Primary Frontal Dune VE Zone Mapping

↓

Number of Communities Impacted by Map Revisions

↓

Challenges

Challenges/Lessons Learned

U.S. Department of Homeland Security
1111 Broadway, Suite 1200
Oakland, CA 94607-4052
FEMA

February 15, 2011

RE: FEMA California Coastal Analysis and Mapping Project/Open Pacific Coast Study

Dear Sir or Madam:

The U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) is in the process of performing a detailed coastal engineering study of the Pacific coast of California. Results from the California Coastal Analysis and Mapping Project (CCAMP)/Open Pacific Coast (OPC) Study will be used to remap the coastal flood risk and wave hazards for California. BakerAECOM, LLC is performing a field investigation to collect data to support the project. This field research will help FEMA better define th

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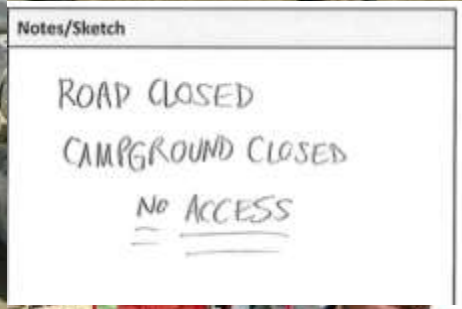

BakerAECOM
An Integrated Production Team

FEMA

Questions?

CCAMP

RiskMAP

Increasing Resilience Together