Summary of Accomplishments for FEMA Region IX CCAMP Open Pacific Coast

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)

<table>
<thead>
<tr>
<th>Phase 1 County</th>
<th>Open Pacific Coast (study miles)</th>
<th>FIS Effective Date for Coastal Study</th>
<th>Pacific Coast Map Panels w/ Coastal Influence</th>
<th>Coastal-Riverine Flood Profile Confluence</th>
<th>Coastal SFHA (Sq. Miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Del Norte</td>
<td>50</td>
<td>09/26/08</td>
<td>15</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Humboldt</td>
<td>160</td>
<td>02/08/99</td>
<td>38</td>
<td>5</td>
<td>81</td>
</tr>
<tr>
<td>Mendocino</td>
<td>110</td>
<td>06/16/92</td>
<td>14</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Sonoma</td>
<td>60</td>
<td>09/06/06</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Marin</td>
<td>100</td>
<td>05/05/97</td>
<td>28</td>
<td>5</td>
<td>27</td>
</tr>
<tr>
<td>San Francisco</td>
<td>15</td>
<td>n/a</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>San Mateo</td>
<td>60</td>
<td>08/05/86</td>
<td>13</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Santa Cruz</td>
<td>40</td>
<td>03/02/06</td>
<td>27</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Monterey</td>
<td>105</td>
<td>09/27/91</td>
<td>25</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>San Luis Obispo</td>
<td>100</td>
<td>02/04/04</td>
<td>32</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>
Study Miles & Panels: Phase 2 So. CA (approx. 535 miles of coast)

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

Discovery Meeting
County Study Kick-off

Outreach Timeline | Open Pacific Coast Study

Data Acquisition
Coastal Analysis
Floodplain Mapping

Map Production Timeline | Typical Coastal Flood Study

Flood Risk Review Meeting
Discuss coastal analysis and review draft work maps

Preliminary FIRM/CCO Meeting

Resilience Workshop
Implement actions to mitigate or reduce coastal flood risks

Provide Study Data
Work Map Comment Tool
Develop Community Outreach Plan

Outreach Timeline | Open Pacific Coast Study

Implement Outreach Plan

Proposed Flood Hazard Determinations | Appeal Period

Issue Letter of Final Determination (LFD)

Effective Maps
Physical Map Revision (PMR)

December 6-7, 2011

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

Tide Frequency Analysis from NOAA Gage Data

CDIP Wave Transformation to MOP for hourly tide/wave data
Coastal Data: LIDAR (CA OPC)

**Elevation (LiDAR)**

<table>
<thead>
<tr>
<th>Specification</th>
<th>State Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Accuracy (95% confidence)</td>
<td>18.2 cm</td>
</tr>
<tr>
<td>Vertical RMSE</td>
<td>9.25 cm</td>
</tr>
<tr>
<td>Horizontal Accuracy (95% Confidence)</td>
<td>50 cm</td>
</tr>
<tr>
<td>Horizontal RMSE</td>
<td>12.26 cm</td>
</tr>
<tr>
<td>Spot Spacing</td>
<td>(\leq 1) m (nominal)</td>
</tr>
<tr>
<td>Tidal Coordination</td>
<td>+/- 1.5hrs MLLW</td>
</tr>
</tbody>
</table>

**Imagery**

<table>
<thead>
<tr>
<th>Specification</th>
<th>State Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Accuracy (95% Confidence)</td>
<td>2 m</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>20 cm RGB, Near IR</td>
</tr>
<tr>
<td>Endlap/Sidelap</td>
<td>60%/30%</td>
</tr>
<tr>
<td>Tidal Coordination</td>
<td>+/- 1.5hrs MLLW</td>
</tr>
</tbody>
</table>

Additional specs in SOW

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Coastal Data: LIDAR (CA OPC)

0–10 m topographic contour, Oregon to Mexico
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)

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Tide Frequency Analysis from NOAA Gage Data

CDIP Wave Transformation to MOP for hourly tide/wave data
Coastal Data:
10,000 Oblique Photos

http://www.californiacostline.org

CA Coastal Records Project

Photography and website Copyright © 2002-2010 Kenneth & Gabrielle Adelman

RiskMAP
Increasing Resilience Together

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1,355 miles of new LIDAR from CA OPC

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Deepwater Waves (OWI)
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)

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Nearshore Waves (Scripps)
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CDIP Wave Transformation to MOP for hourly tide/wave data
Coastal Data: Tides (NOAA CO-Ops)

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

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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)

Tide Frequency Analysis from NOAA Gage Data

CDIP Wave Transformation to MOP for hourly tide/wave data
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.
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.
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
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
New Detailed Analyses Pilot Studies

1,139 Transects Used in 1-D Detailed Analysis

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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

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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

1,139 Transects Used in 1-D Detailed Analysis

Analysis of Key Coastal Processes

12 Harbor Breakwater Overtopping Assessments

Pilot Study of Wave Runup Depth-Velocity Grid

Pilot Study Probabilistic Tsunami Hazards

Pilot Study of Sea Level Rise at San Francisco

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Special Projects: Wave Runup Depth & Velocity Grid

### Physical Components

<table>
<thead>
<tr>
<th>Water Level</th>
<th>SWL</th>
<th>StWL</th>
<th>DWL</th>
<th>TWL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronomical Tides, Storm Surge, El Niño Processes</td>
<td>SWL + ζ</td>
<td>StWL + ζ</td>
<td>SWL + ζ + ξ</td>
<td>DWL + R</td>
</tr>
<tr>
<td>(SWL + ζ + ξ)</td>
<td>(SWL + ζ + ξ + R)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 ($dV^2$).
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

<table>
<thead>
<tr>
<th>Flood Severity Category</th>
<th>Depth Range (ft)</th>
<th>Depth x Velocity Range (ft²/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt; 0.5</td>
<td>&lt; 2.2</td>
</tr>
<tr>
<td>Medium</td>
<td>0.5 – 1.0</td>
<td>2.2 – 5.4</td>
</tr>
<tr>
<td>High</td>
<td>1.0 – 2.0</td>
<td>5.4 – 16.1</td>
</tr>
<tr>
<td>Very High</td>
<td>2.0 – 2.8</td>
<td>16.1 – 26.9</td>
</tr>
<tr>
<td>Extreme</td>
<td>&gt; 2.8</td>
<td>&gt; 26.9</td>
</tr>
</tbody>
</table>
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.
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)
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
Special Projects: PTHA w/ UW in Crescent City (Del Norte Co)
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
Pilot Study: San Francisco & SLR

Linear Superposition

Offshore Zone
- Offshore Waves
  - Wave Transformations
    - Nearshore Waves
      - Wave Setup
        - Wave Runup
          - Overtopping
  - Water Levels

Shoaling Zone
- Wave Transformations
  - Nearshore Waves
    - Wave Setup
      - Wave Runup
        - Overtopping

Surf Zone and Backshore
- Erosion
- Coastal Structures

Assume negligible SLR effect

Direct Analysis

Offshore Zone
- Offshore Waves
  - Wave Transformations
    - Nearshore Waves
      - Wave Setup
        - Wave Runup
          - Overtopping
      - Water Levels

Overland Wave Propagation (if necessary)

SLR

Erosion
- Coastal Structures

Wave Runup
- Overtopping

TWL
- Flood Hazard Mapping

TWL

Assume negligible SLR effect

TWL_{SLR} = TWL + SLR

TWL_{SLR} > TWL + SLR

Flood Hazard Mapping

Shoreline Change & Profile Adjustment

RiskMAP

Increasing Resilience Together
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

Crest at 30-31 ft NAVD
- TWL response to SLR (ex. cond./24”/66”)
- **Existing conditions:** peak TWL is \~5 ft below crest
- **24” SLR:** peak TWL is \~1-2 ft below crest
- **66” SLR:** many TWL events exceed crest
- TWL results exhibit non-linear response to SLR
- 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

<table>
<thead>
<tr>
<th>SLR (ft)</th>
<th>ΔBFE (ft)</th>
<th>BFE (ft)</th>
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<tbody>
<tr>
<td>0</td>
<td>-</td>
<td>25.6</td>
</tr>
<tr>
<td>1.0</td>
<td>2.2</td>
<td>27.8</td>
</tr>
<tr>
<td>2.0</td>
<td>4.3</td>
<td>29.9</td>
</tr>
<tr>
<td>3.0</td>
<td>6.3</td>
<td>31.9</td>
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<td>4.0</td>
<td>9.6</td>
<td>35.2</td>
</tr>
<tr>
<td>5.5</td>
<td>12.9</td>
<td>38.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1% TWL</th>
<th>Current</th>
<th>+24 in</th>
<th>+66 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>25.6 ft</td>
<td>27.6 ft</td>
<td>31.1 ft</td>
</tr>
<tr>
<td>Direct</td>
<td>25.6 ft</td>
<td>29.9 ft</td>
<td>38.5 ft</td>
</tr>
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</table>
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
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

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

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New Detailed Mapping
Wave Overtopping

- 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 SFHA
- Challenges
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
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.
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.
Communities and Map Revisions

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 Map Revisions

Challenges
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 the hazard levels.

The field work will begin on February 15, 2011 and may be necessary to access public lands, private properties, and campgrounds. Access to the study sites will be necessary and may be limited. Therefore, it will be necessary to move equipment and personnel around the Coast. It is anticipated that campgrounds, private properties, and public lands will be closely monitored during the fieldwork.

Sincerely,

[Signature]

[Name]

[Title]
Questions?