Developing a Robust Design for Consideration of Climate Change Impacts

Hunters Point Naval Shipyard Sediment Case Study

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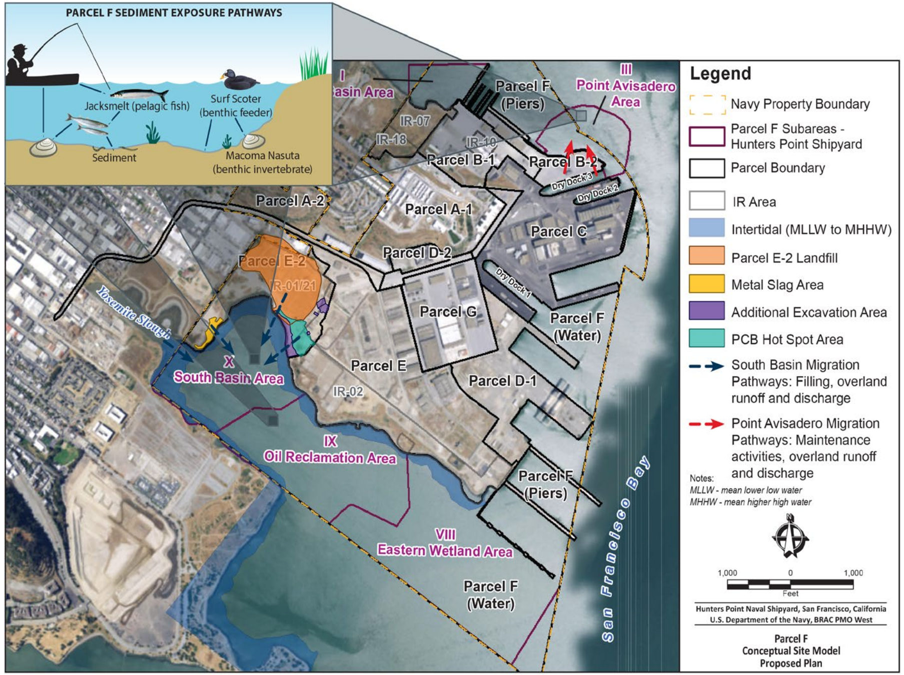
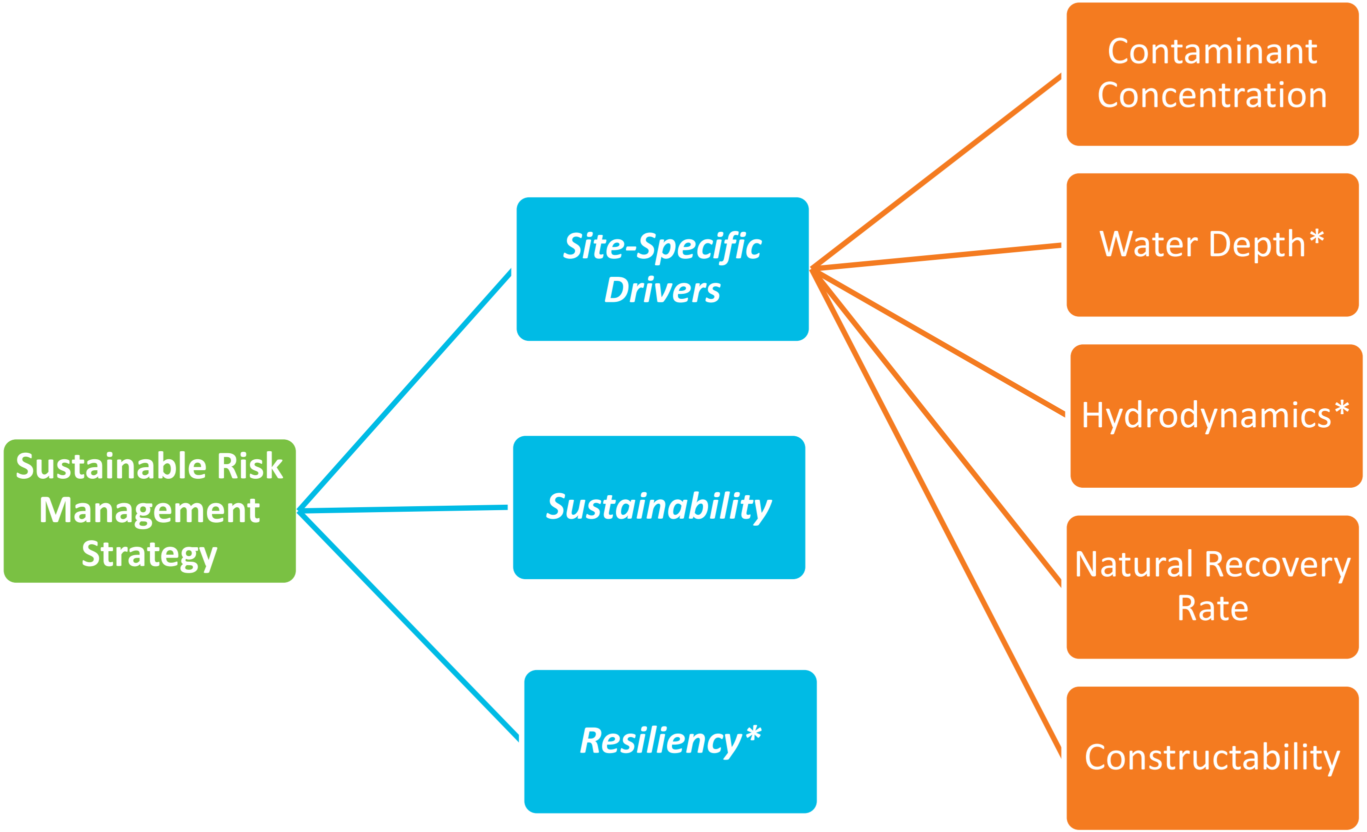
Sediment Remedial Design

- *Site Contaminants*
  - Metals
  - PCBs
- *Remedial Technologies Evaluated*
  - Sediment removal
  - *In situ* treatment
  - Capping
  - Monitored natural recovery (MNR)
- *Resiliency Considerations*
  - Natural hydrological processes can disturb sediment and expose contaminants
  - Wave action and strong currents



**Two treatment areas, Area III and Areas IX/X*

Technology Assignment Optimization Framework



Qualitative Resiliency Evaluation

EPA United States Environmental Protection Agency

Office of Superfund Remediation and Technology Innovation
EPA 542-F-15-009
April 2015

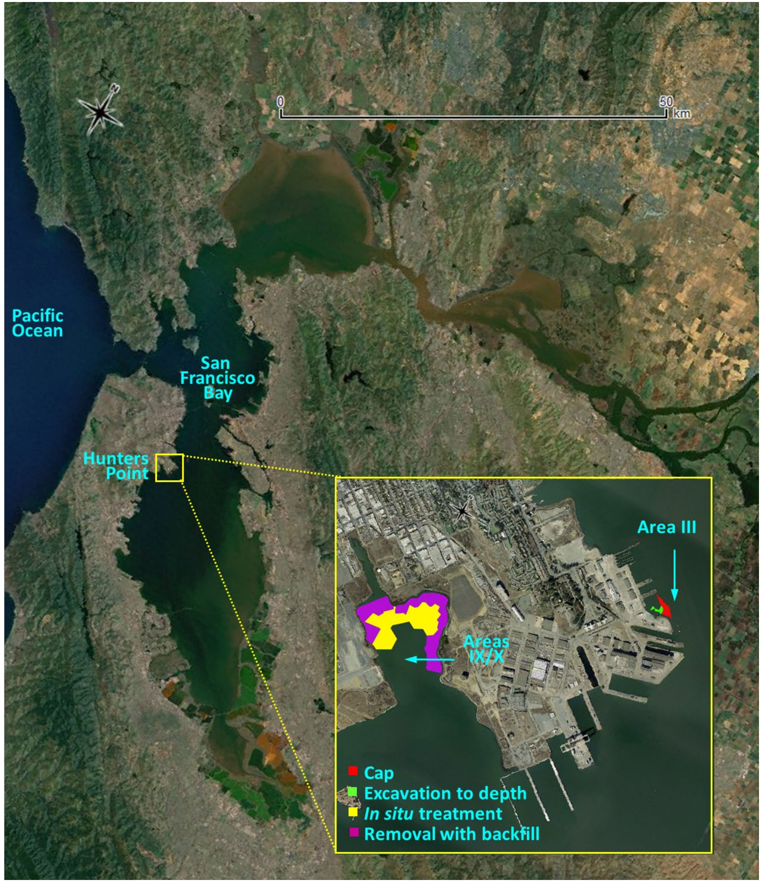
Climate Change Adaptation Technical Fact Sheet: Contaminated Sediment Remedies

Climate Change Impacts	Remedy Vulnerability	Site-Specific Drivers
• Increased intensity of wave action and currents • Increased frequency of severe weather events • Sea level rise and storm surge	• Scour backfill or underlying sediment/ amendments • Backfill/amendment/ sediment resuspension	• Water depth, intertidal sediment subject to wind- and vessel-generated waves • Hydrodynamics, impacts of wave action, tidal currents, storm surge, and sea level rise

Technology Assignment

- Area III
  - Subject to strong wave currents
    - tides, storm surges, etc.
  - *In situ* treatment not feasible
  - Nearshore sediments = removal/backfill
  - Offshore sediments = cap

- Areas IX and X
  - Subject to wave action
    - generated locally by winds
  - Intertidal sediments = removal/backfill
  - Subtidal sediments = *in situ* treatment and MNR



Integrate Stakeholder Values: Proposed Plan Comments/Recommendations

- Performed Hydrodynamic & Chemical Isolation Modeling
  - Area III
    - cap resists erosion from tidal currents and wave actions as well as re-contamination potential from the deeper Area III sediments
  - Areas IX and X
    - net deposition rate consider 100-year winter events and king tide events
  - Area III & Areas IX and X
    - erosion and deposition rate calculations, assumptions and data should consider using local weather data and include other factors such as rainfall, storm surge, climate change, and sea level rise

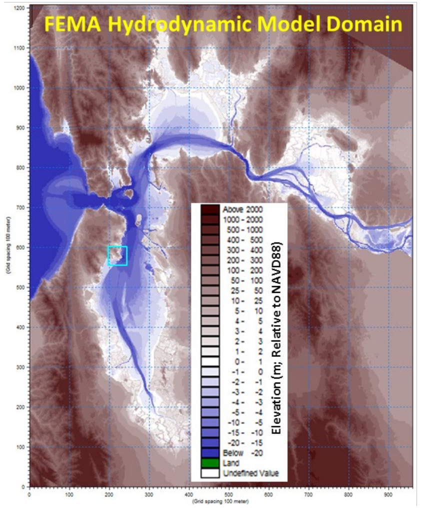
Quantitative Resiliency Evaluation Numerical Model Framework

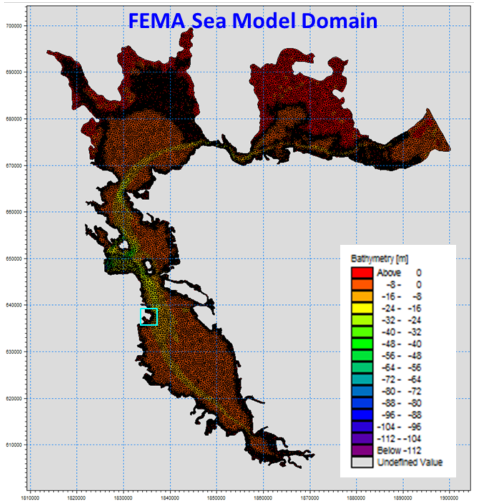
- HPNS site location precludes application of a local model covering only the project area
  - Currents dependent on overall area of Bay subject to tidal inundation
  - Waves dependent on wind direction and fetch length
  - Model domain needs to include, at a minimum, southern San Francisco Bay
    - Significant development effort
- Adapt existing models of San Francisco Bay
  - Developed by FEMA for coastal defense studies
  - Refine and extend for application to HPNS remedy design

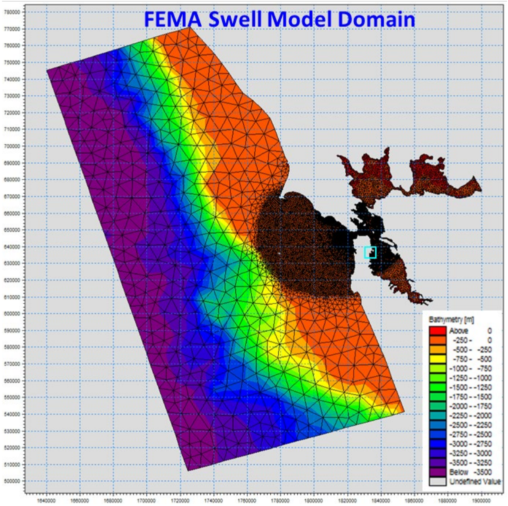
FEMA Models Overview

- Hydrodynamic model
  - Simulate extreme water levels due to storm surge propagating from offshore
- Wave model – Seas
  - Simulate waves generated by winds locally within SF Bay
- Wave model – Swell
  - Simulate wave propagation from offshore (ocean waves) into SF Bay
  - Negligible at HPNS and therefore not considered for HPNS remedy design

Adapted for HPNS remedy design (applies to Hydrodynamic model and Wave model – Seas)







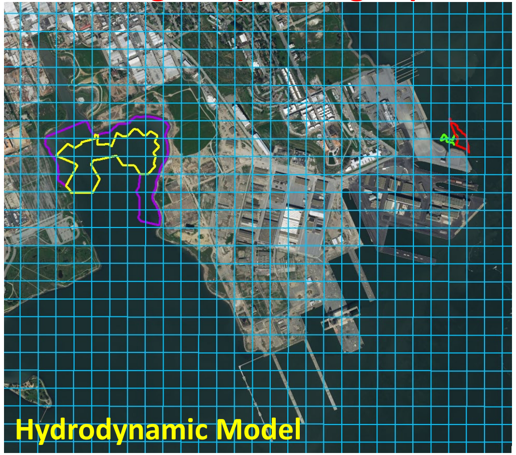
FEMA Models Overview (Contd.)

- Software platform – DHI's MIKE 21
- Hydrodynamic model setup
  - Domain covering SF Bay, upland areas, extending about 10 miles into Pacific
  - Topography, bathymetry, levee elevations
  - Boundary conditions – measured water levels at the ocean boundary, river inflows, measured winds
  - Calibration – to water level data at several locations
  - Application – quantify 100- and 500-year return water levels
- Wave (seas) model setup
  - Domain covering only SF Bay
  - Bathymetry
  - Boundary conditions – measured winds, water levels
  - Model performance assessment
    - Parameterization based on previous studies
    - Validated using wave measurements at several locations
  - Application – quantify 100- and 500-year wave heights

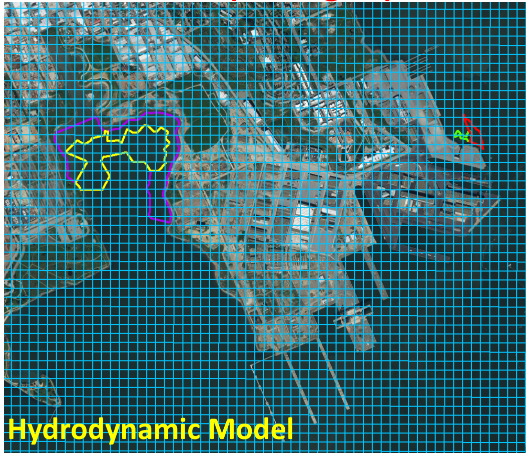
FEMA Models – Application to HPNS

- Refinements to hydrodynamic and wave models
  - Increased model grid resolution at project area
    - 2-4X higher resolution in both models
  - Bathymetry and topography updated using project data
  - Maintain calibration developed by FEMA for water levels, and waves

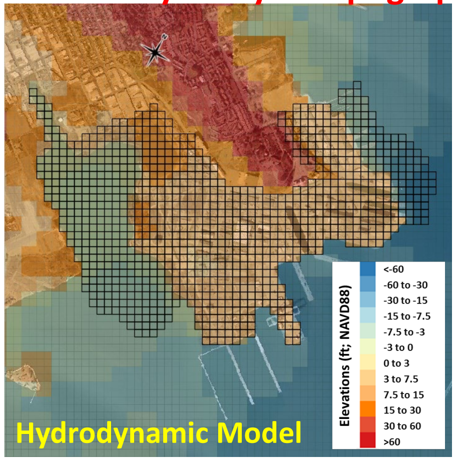
Original (100 m grid)



Refined (50 m grid)



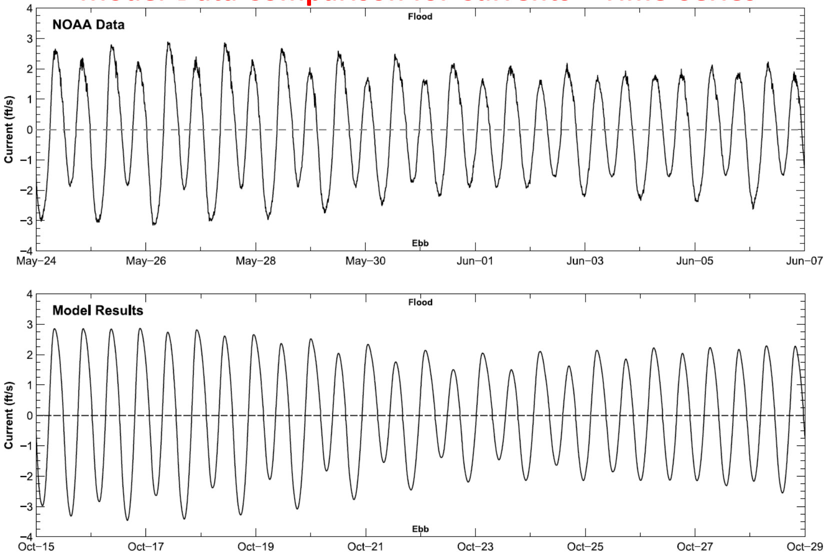
Refined Bathymetry & Topography



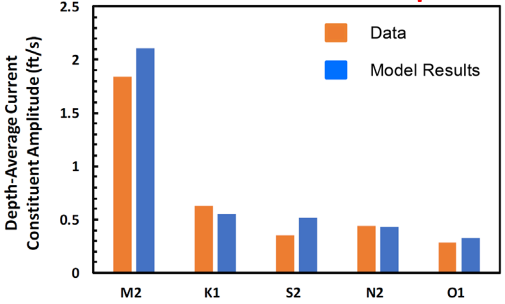
FEMA Models – Application to HPNS (Contd.)

- Extension of FEMA's hydrodynamic model application
  - Validation of model performance for currents
    - FEMA application only examined water levels – relevant for flooding
  - Currents relevant for armor design

Model-Data Comparison for Currents – Time-Series



Model-Data Comparison for Currents – Constituent Amplitude



Climate Change Resiliency
Sea Level Rise Parameters

- Approach for sea level rise
  - Based on State of California Guidance and Proposed Plan recommendations
    - 6.9 feet of sea level rise by year 2100
    - Relatively extreme scenario with only 0.5% chance of occurrence
      - Median estimate is 2.5 feet
  - Included in hydrodynamic and wave models by a constant 6.9 feet increase in water level at the ocean boundary
    - Used to characterize armor design parameters for future climate

Armor Layer Design

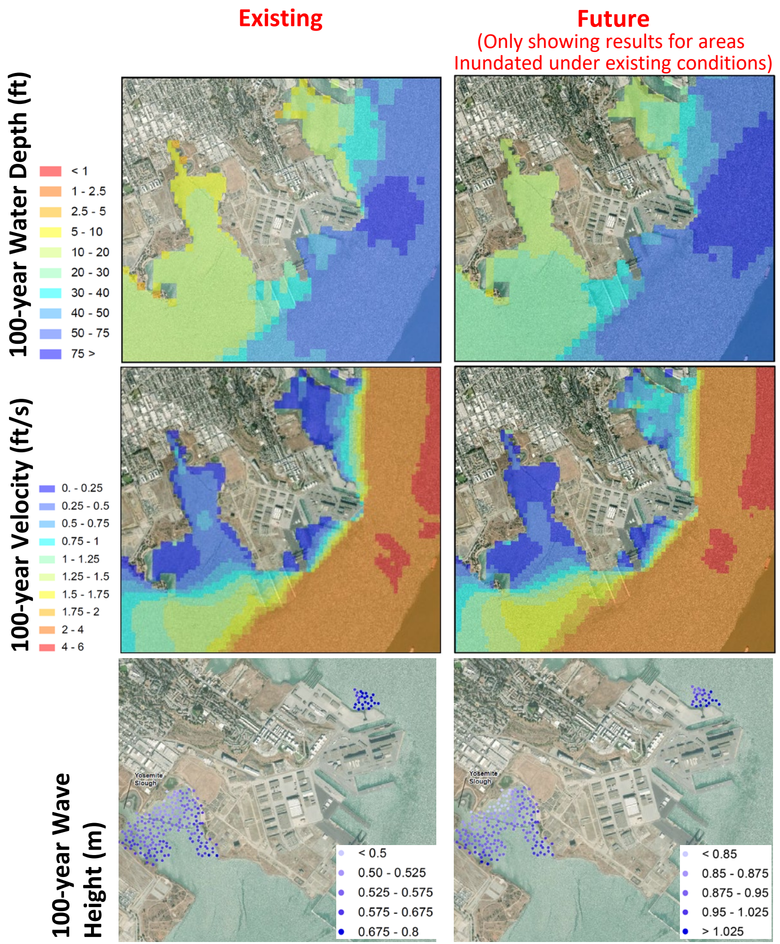
- Armor layer design includes calculation of
  - Particle (sand) diameter (D50)
  - Layer thickness = function of D50
- Armor design criteria
  - Design parameters
    - Hydrodynamics – water depths and flow velocities
    - Waves – near-bed orbital velocities (calculated from wave height, period, and water depth)
  - Climate change resiliency
    - Incorporated by considering future sea level rise
  - Design conditions
    - Design parameters characterized at the 100-year return interval
      - Existing conditions and future with sea level rise
- Armor design based on more conservative of
  - Designs for protection against hydrodynamics and waves
  - Designs for protection against existing and future 100-year event

Model Application for Armor Design Criteria

- Model applied to calculate 100-year return statistics for design parameters
  - Using annual maxima from simulations over 1973-2003
    - For currents, water depths, and wave heights/periods
  - Statistics calculated by fitting Generalized Extreme Value and Weibull distributions
- 100-year return statistics calculated for
  - Existing climate using measured water levels over 1973-2003
  - Future climate (year 2100) with sea level rise
    - Simulating same events over 1973-2003

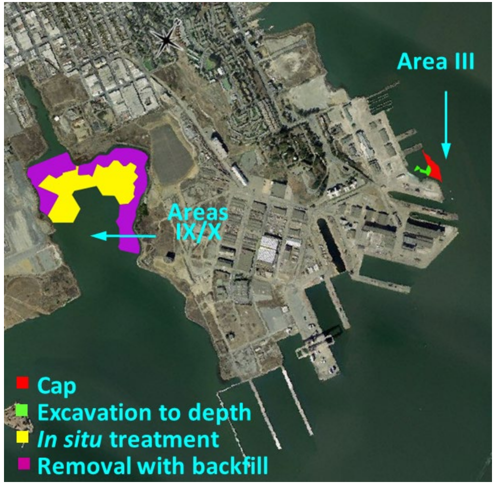
Armor Design Criteria

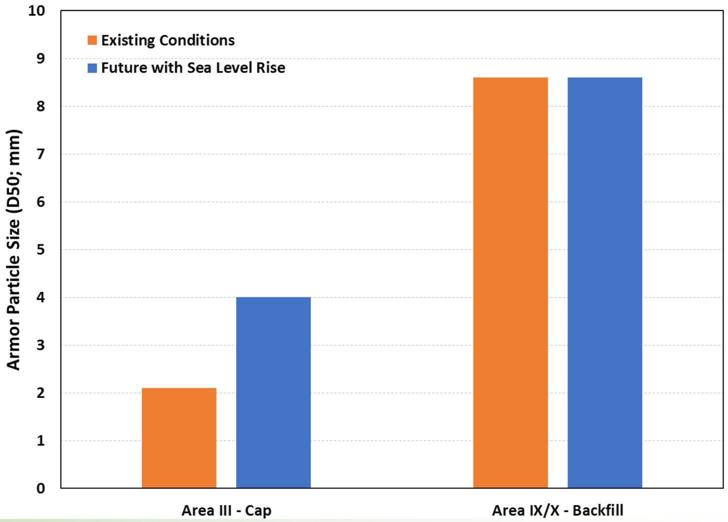
- 100-year return statistics
  - Non-linear response of tidal currents to sea level rise over project area
    - Increase in Area III
    - Decrease in Area IX/X
  - Increase in wave heights
    - However, water depths greater
    - Net result is a decrease in near-bed orbital velocity in future with sea level rise



Armor Design

- Armor particle sizing based on USEPA guidance
- Non-linear impact of sea level rise apparent in armor sizing
  - No impact in Area IX/X
  - Requires larger-sized sands in Area III





Summary

- A numerical hydrodynamic and wave model applied to support remedy design at HPNS
  - Significant savings in labor and schedule (>10X) by adapting an existing model
- Use of a numerical model to characterize design criteria for the armor layer also allowed to mechanistically incorporate climate change resiliency into remedy design
- Generic finding that incorporating climate change resiliency in remedy design need not always incur significant changes to a design developed on basis of existing climate

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