COWI North America

# Sea Level Rise and Adaptive Design

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# Outline

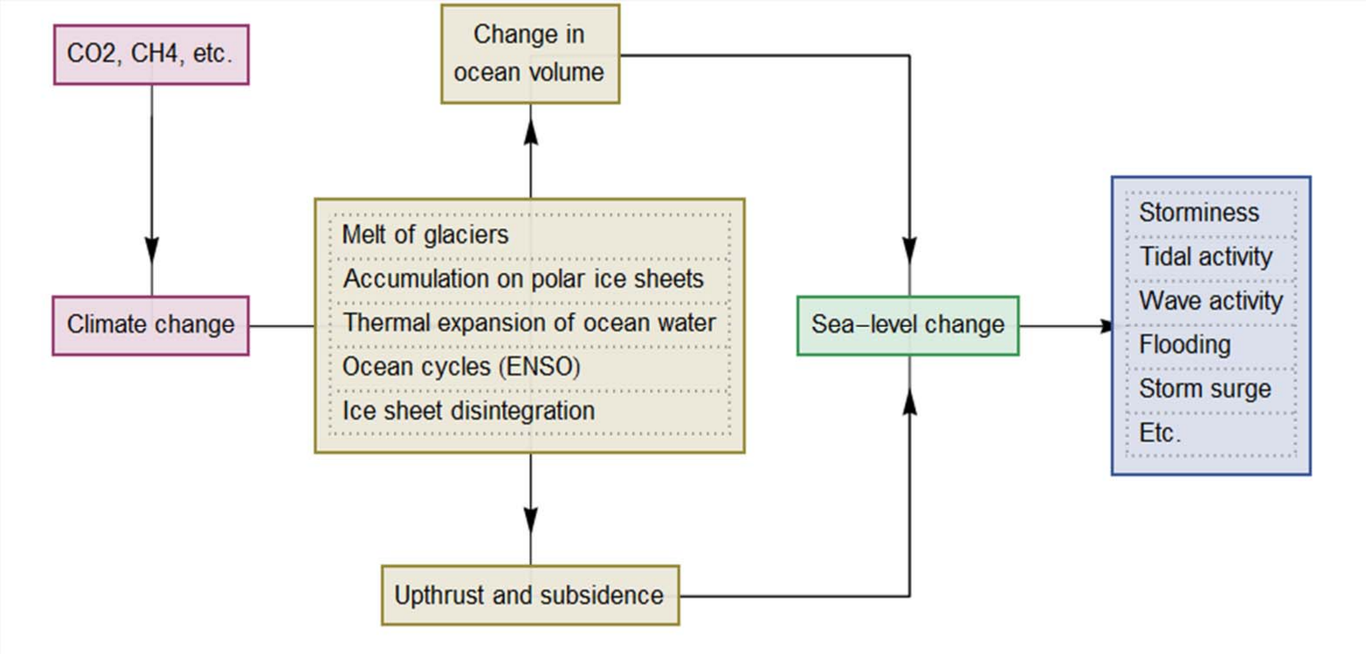
- Sea Level Change Project Approach
  - Assess, Analyze, & Act
- Adaptive Design Project Approach
  - Protect, Accommodate, and/or Manage
- Case Studies
  - Inner Harbor Navigation Channel
  - Elliott Bay Seawall
  - Port of Redwood City
  - Marine Oil Terminal
- Questions & Answers

# California Regulatory Environment

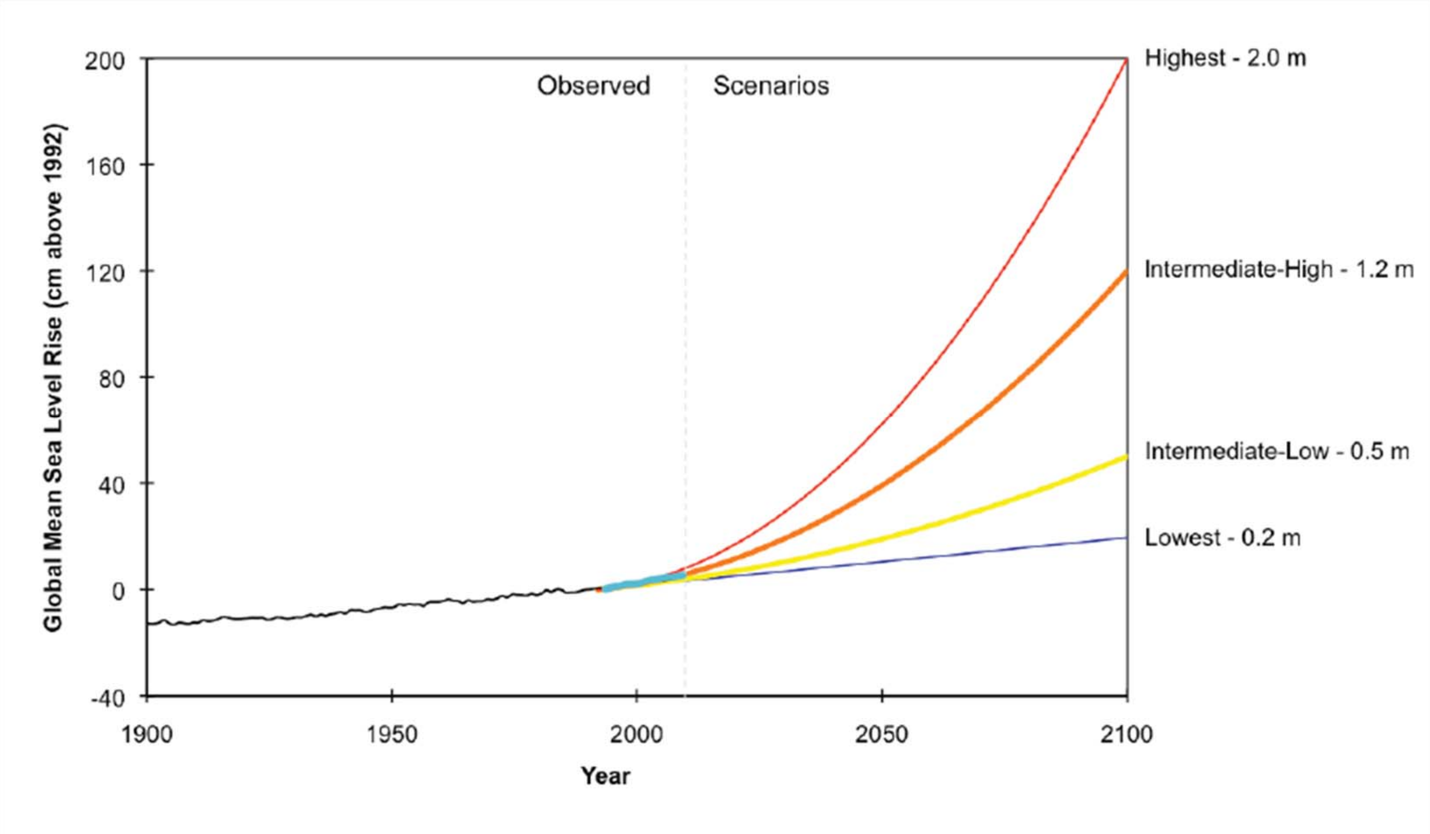
- MOTEMS (2013 CBC)
  - All MOTs shall consider the predicted SLR over the remaining life of the terminal. Consideration shall include variation in fender locations, additional berthing loads, and components near the splash zone.
- Bay Conservation and Development Commission (BCDC)
  - New projects affected by future sea level rise must be set back from shoreline to avoid flooding, be elevated above expected flood levels, be designed to tolerate flooding, or employ other means of addressing flood risks.
- California Coastal Commission
  - Sea-Level Rise Policy Guidance provides recommended steps for addressing SLR in Coastal Commission planning and regulatory actions.

# The Process of Sea Level Change

- › Sea levels have been changing for millions of years.
- › Common concern is that sea level rise is accelerating globally.
- › There are both **global** and **local** contributing factors to the effect of sea level change.



# Sea Level Change Projections



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# Define and Agree Upon the Scope for Analysis

- Agree upon the base assumptions
  - Consider the issues specific to the site/structure
  - Determine the design life
- Determine and prioritize the driving concerns
  - Define tolerable risk
  - Identify base and compounding factors
- Plan which scenarios to analyze
  - Define appropriate level of effort



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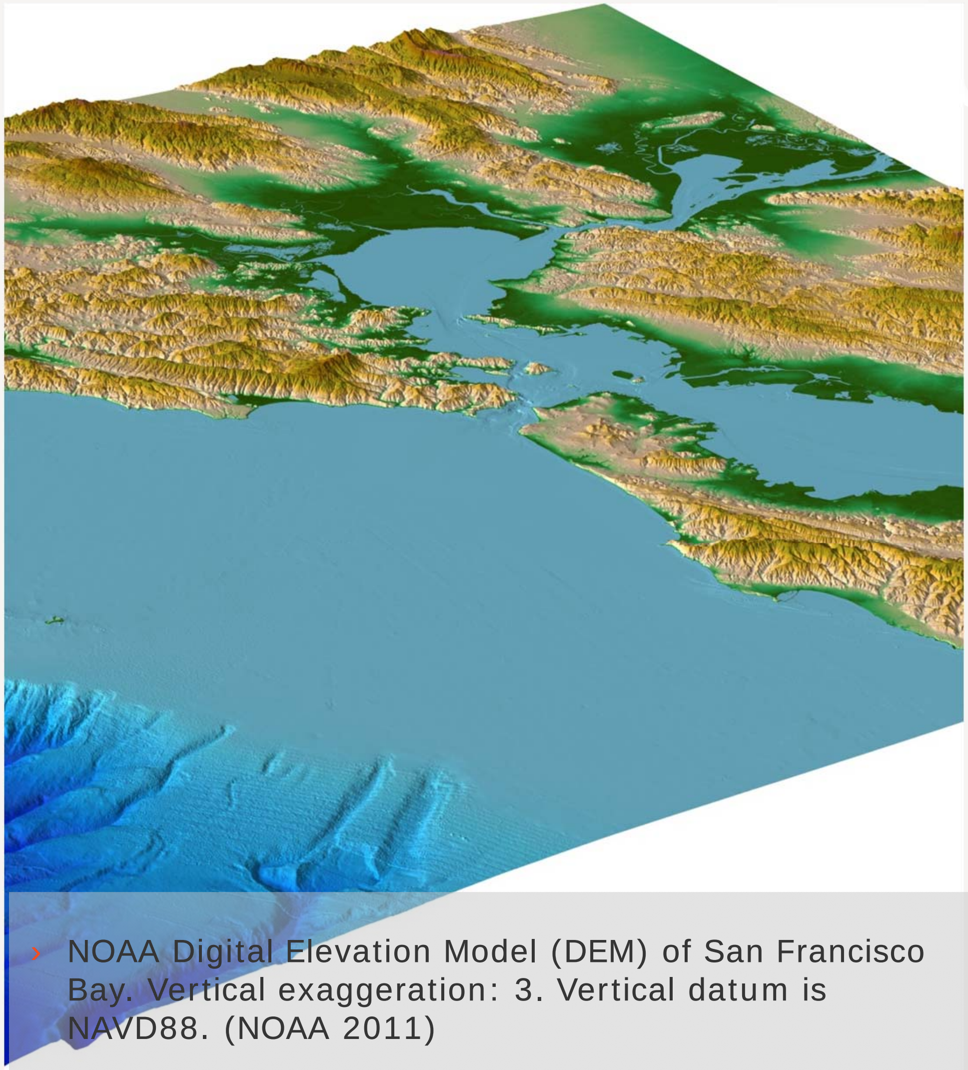
# Data Acquisition

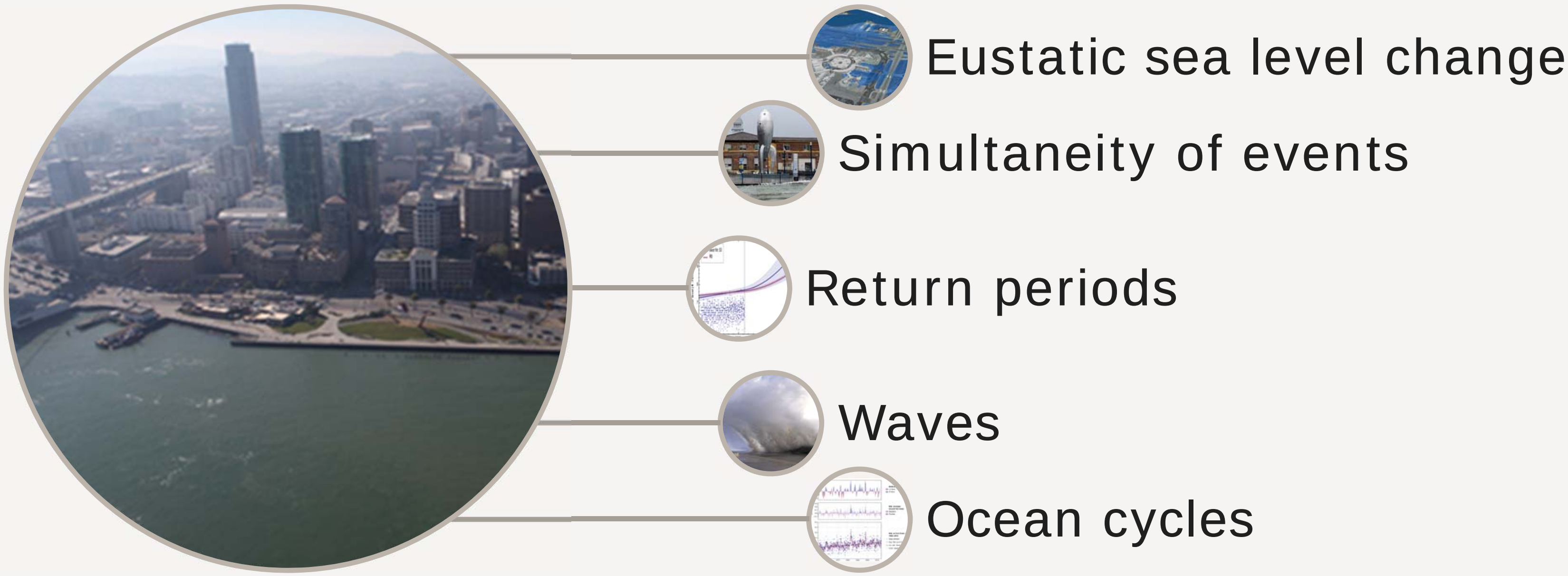
- Components
  - Maps
  - Facilities
  - Topography
  - Bathymetry
  - Tides, Currents, and Runoff
  - Geotechnical and Geological
  - Land uses



- NOAA Digital Elevation Model (DEM) of San Francisco Bay. Vertical exaggeration: 3. Vertical datum is NAVD88. (NOAA 2011)

Sea Level Change Approach

# Compounding Phenomena



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# Path Forward
# Alternatives to Consider

Protect

Accommodate

Manage



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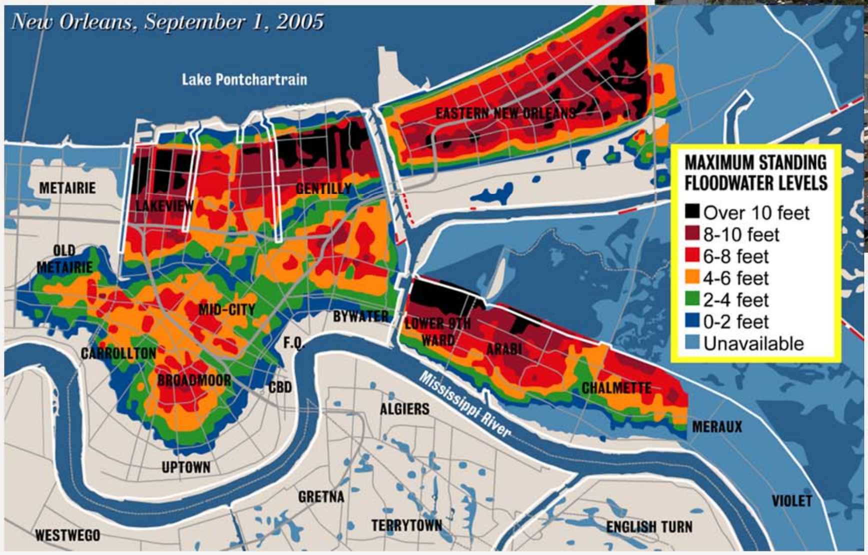
Case Study - Protect

# IHNC Storm Surge Barrier

- Hurricane Katrina in 2005
- USACE Protection System for New Orleans



Case Study - Protect

# Floodwall New Orleans

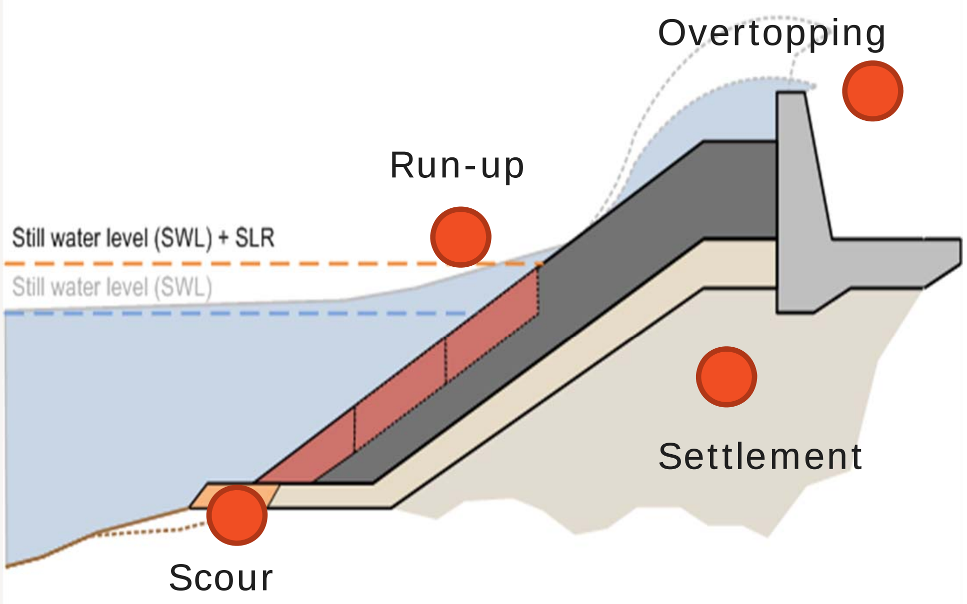
| ASSESS | ANALYZE | ACT |
|---|---|---|
| USACE and USCG | Storm surge sensitivity | Precautionary height |
| State of LA Flood Authority | Overtopping | Opportunistic adaptability |
| SLR guidance: NRC | Polder capacity | Modular concrete cap |
| Risk level critical | Settlement | |
| | Sediment loss | |

Case Study - Protect

# IHNC Storm Surge Barrier

## Vulnerability Revetments

- Drivers
  - Elevated TWL
  - Larger waves
- Response
  - Reduced freeboard
  - More severe overtopping and run-up
  - Foundation and structural instabilities
- Consequences
  - Landward assets at risk



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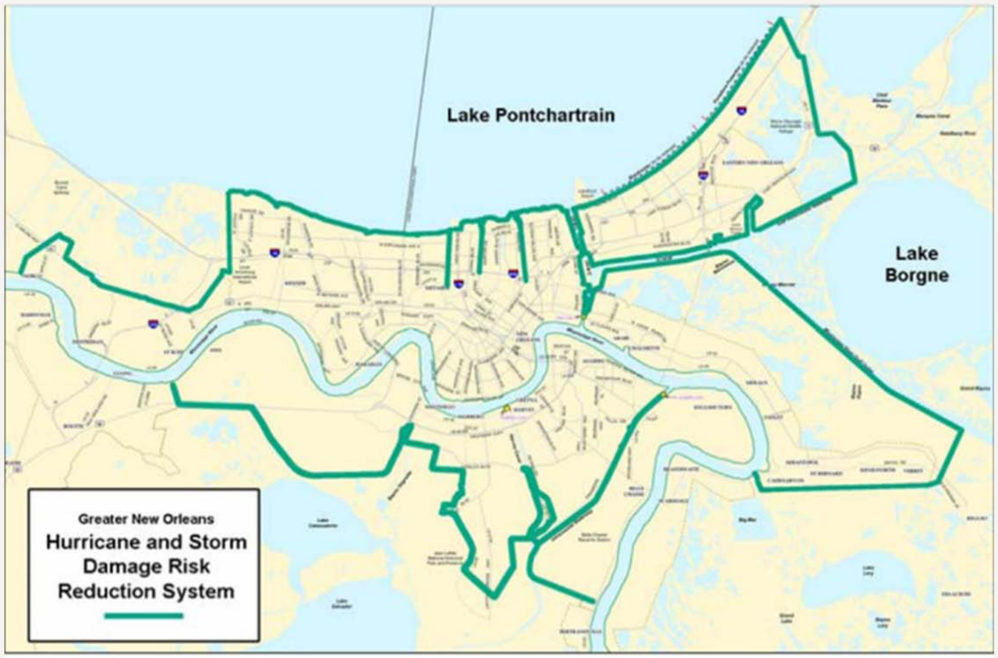
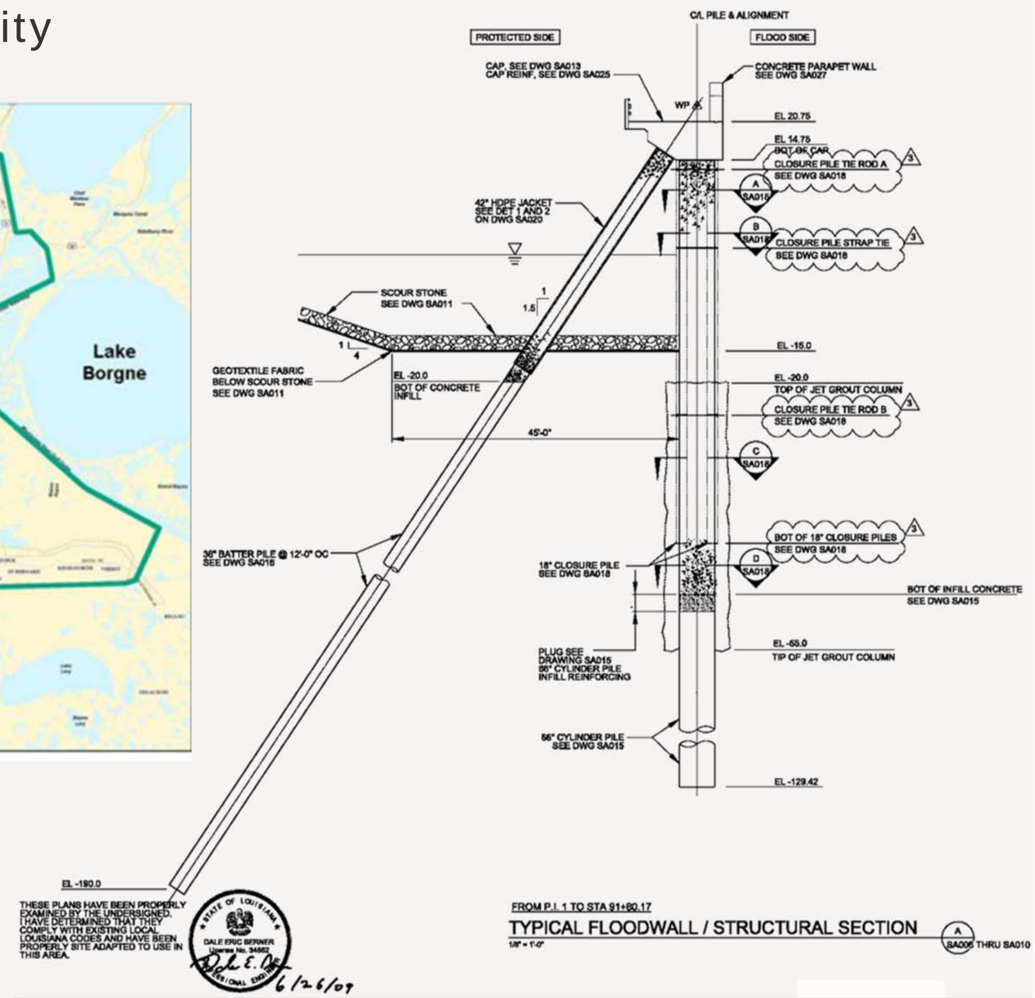
Case Study - Protect

# IHNC Storm Surge Barrier

- Design Surge Barrier in soft soils
- 50-yr Design Life w/ 100-yr durability



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Case Study - Protect

# IHNC Storm Surge Barrier

- 1.7 mile Floodwall with navigable gates
- SLR, subsidence, and local settlement considered
- Tested in August 2012 with Hurricane Isaac



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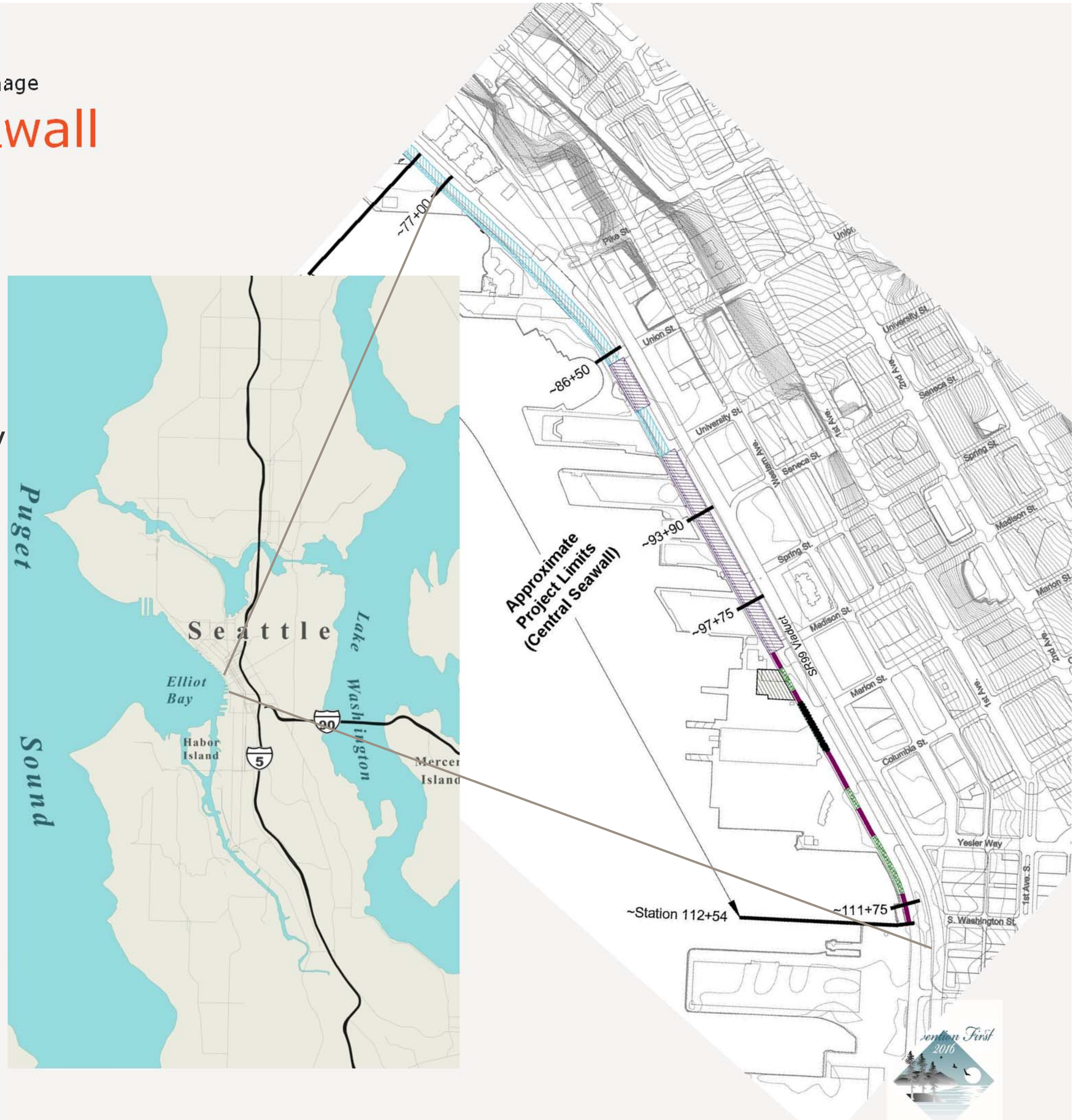
Case Study – Accommodate / Manage

# Elliott Bay Seawall

- 3,500 ft long seawall replacement
- Project driven by seismic vulnerability of existing wall
- Construction started with completion scheduled for 2017



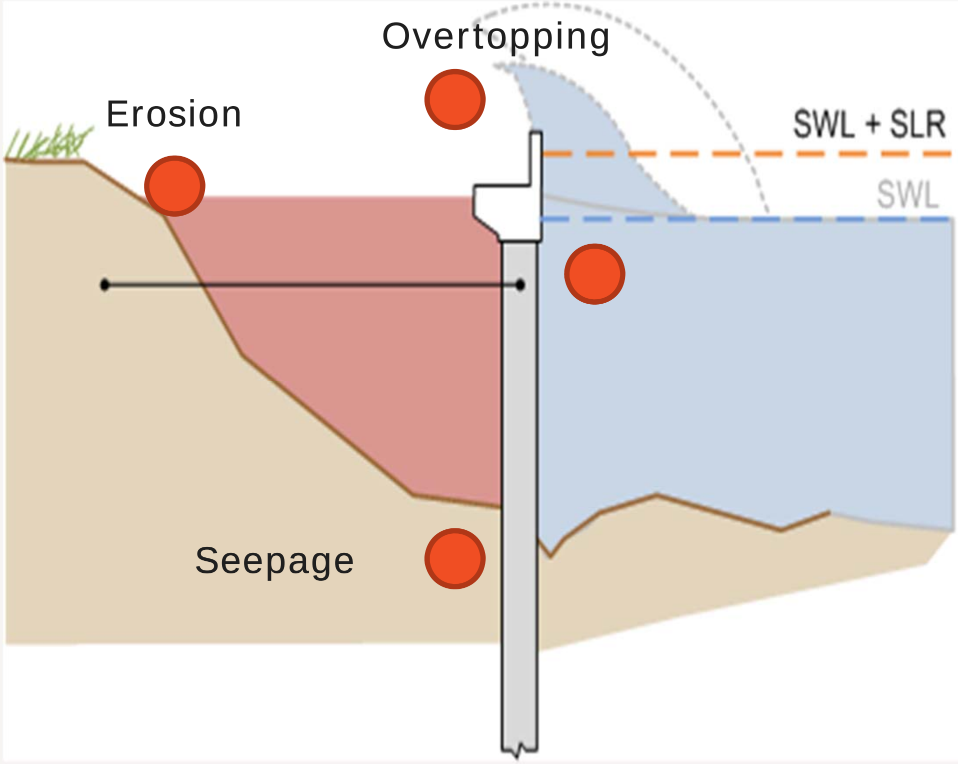
Case Study – Accommodate / Manage

# Elliott Bay Seawall

| ASSESS | ANALYZE | ACT |
|---|---|---|
| City, Public, and Property Owners | Wave processes | Limited upgrade |
| Ecosystem improvement | Wave uplift vs. deck elevations | Precautionary elevations |
| City Policy | Overtopping and Groundwater Intrusion | Opportunistic measures |
| | Overturning Stability | |

# Elliott Bay Seawall

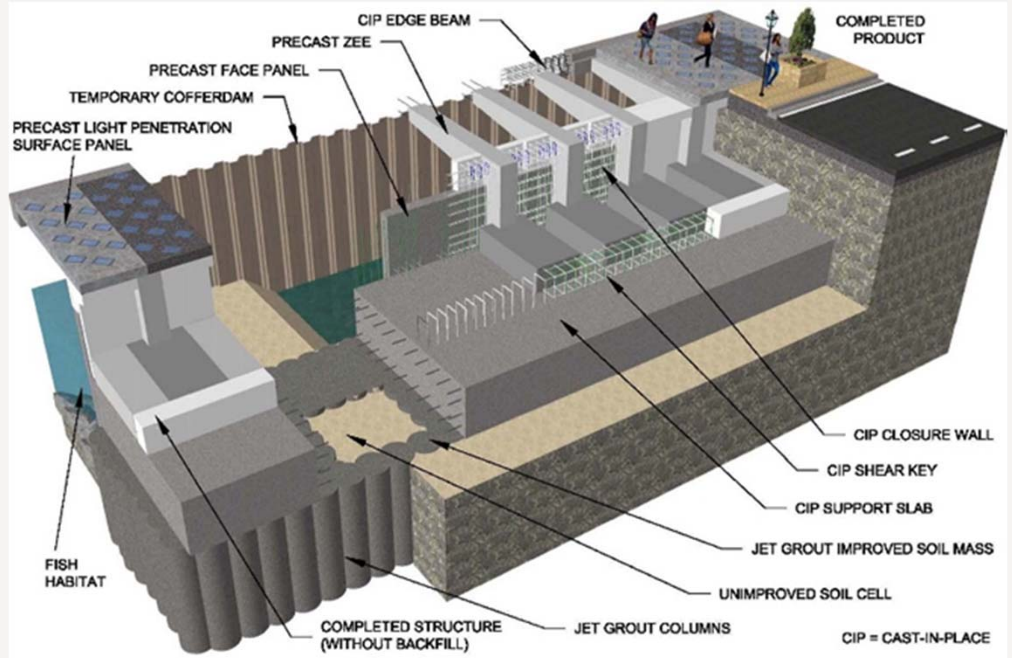
- Drivers
  - Elevated TWL (Total Water Level)
  - Larger waves
- Response
  - Reduced freeboard
  - More severe overtopping
  - Reduced breakwater efficiency
  - Seepage
- Consequences
  - Assets at risk
  - Tranquility (breakwaters)

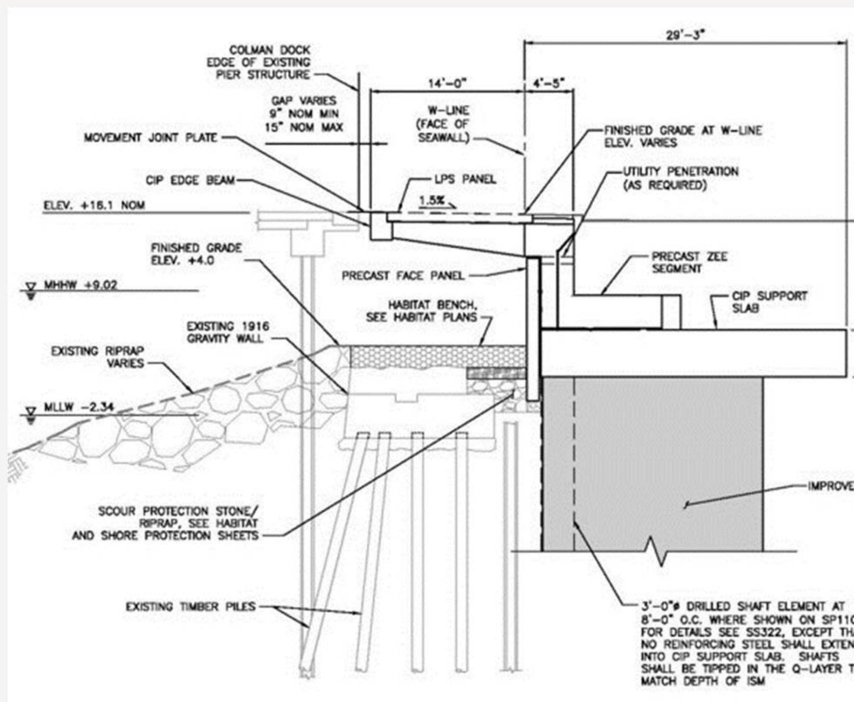


Case Study – Accommodate / Manage

# Elliott Bay Seawall

- Maximum 75-yr design life
- Varying levels of SLR scenarios considered for different elements
- Seawall Structure
  - Year 2100
  - High estimate = 4.2'
- Storm water drains
  - Year > 2050
  - Medium estimate = 2.1'

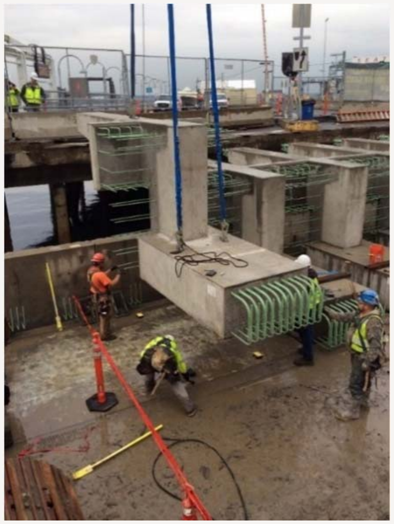


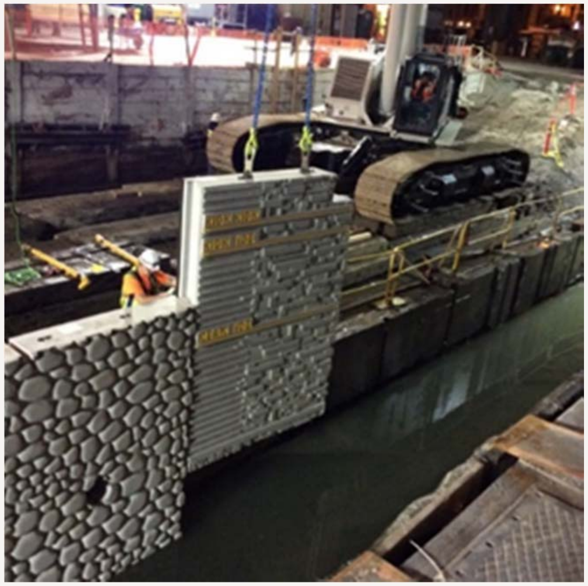



Case Study – Accommodate / Manage

# Elliott Bay Seawall

- New Waterfront Seawall
  - Mitigate overtopping and flooding of surface streets
  - Adaptive measures include
    - Moderate SLR to 2100, then comprehensive plans
    - seawall overhang considered wave slam
    - Jet grout mitigated seepage and erosion





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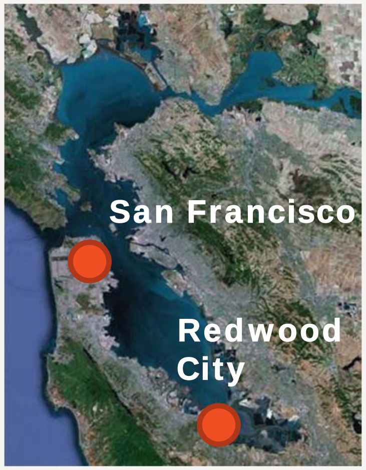
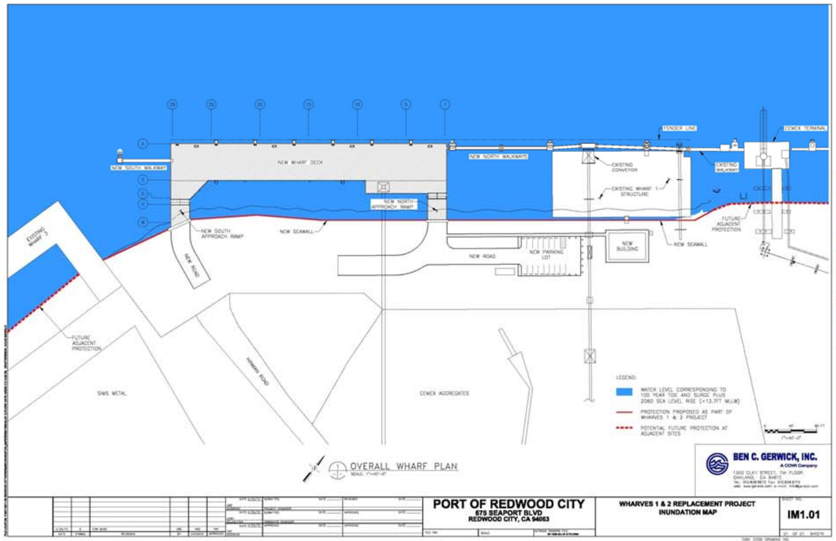
Case Study - Accommodate

# Port of Redwood City

- Project Features
  - Replace (E) Timber Berths
  - New Multi-purpose Berth
    - Barge & Panamax Traffic
  - New Seawall
    - Flooding and seepage
  - New Longshoreman Building
  - 50-yr design life



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Wharves 1 and 2 Replacement Project

# Port of Redwood City

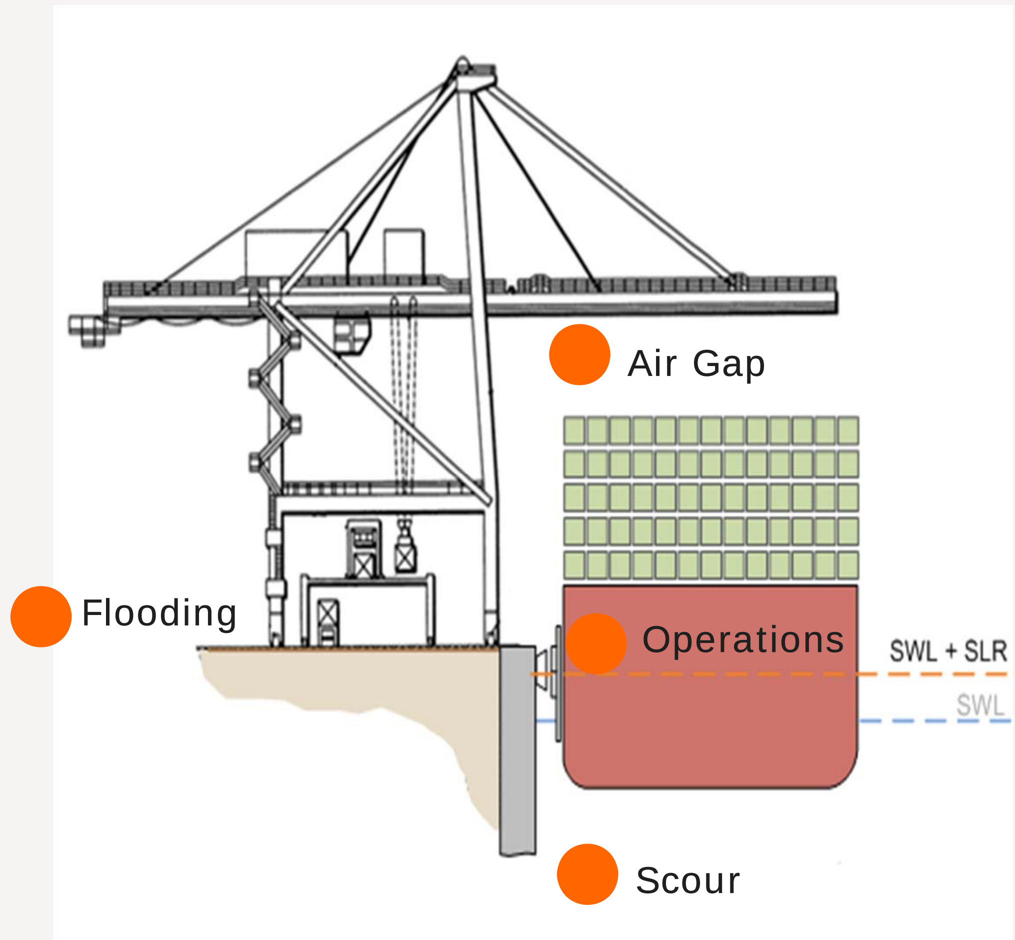
| ASSESS | ANALYZE | ACT |
| --- | --- | --- |
| State guidelines | Wave processes | Precautionary deck level |
| | Water levels vs. deck elevations | |
| BCDC requirements | Run-up and overtopping | Opportunistic seawall |
| | Simultaneity of events | |

Case Study - Accommodate

# Port of Redwood City

- Scour
  - Low current – limited impact
- Wave slam
  - Limited fetch – limited impact
- Operations and Air Gap
  - Need to meet current and future water levels
  - Berthing or mooring compatibility issues
  - Loading and unloading equipment compatibility issues
  - Potential utility maintenance issues
- Flooding
  - Potential for flooding the upland areas

San Francisco



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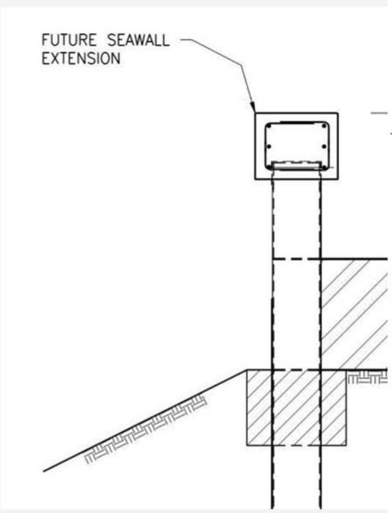
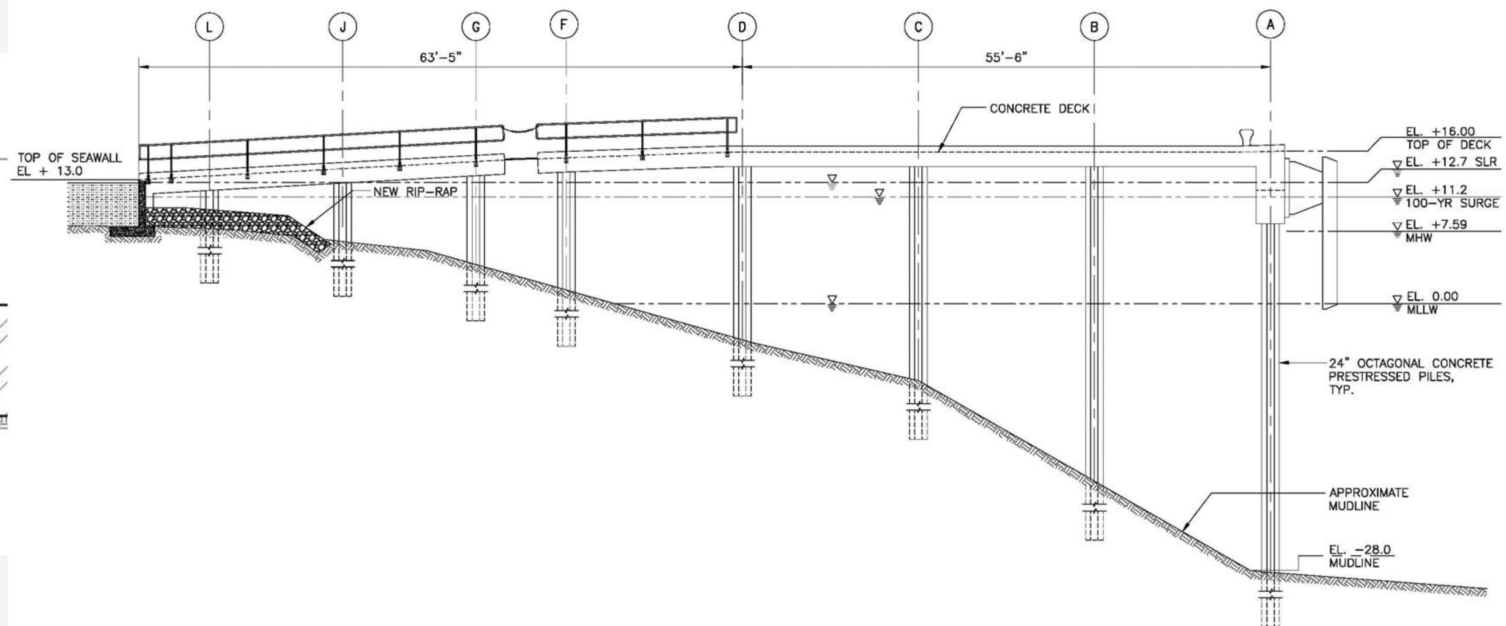
Case Study - Accommodate

# Port of Redwood City

- Operations
  - Utilities
  - Mooring and Berthing Hardware and Geometry
  - Deck Elevation for Loading Operations
- Flooding
  - Seawall
  - Adaptive design



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Case Study - Accommodate

# Port of Redwood City

- Multipurpose Wharf
  - Accommodate barges and Panamax vessels today and in 50-years
  - Adaptive measures include
    - 2-ft SLR allowance for fenders and utilities
    - Seawall designed for future 2-ft extension.



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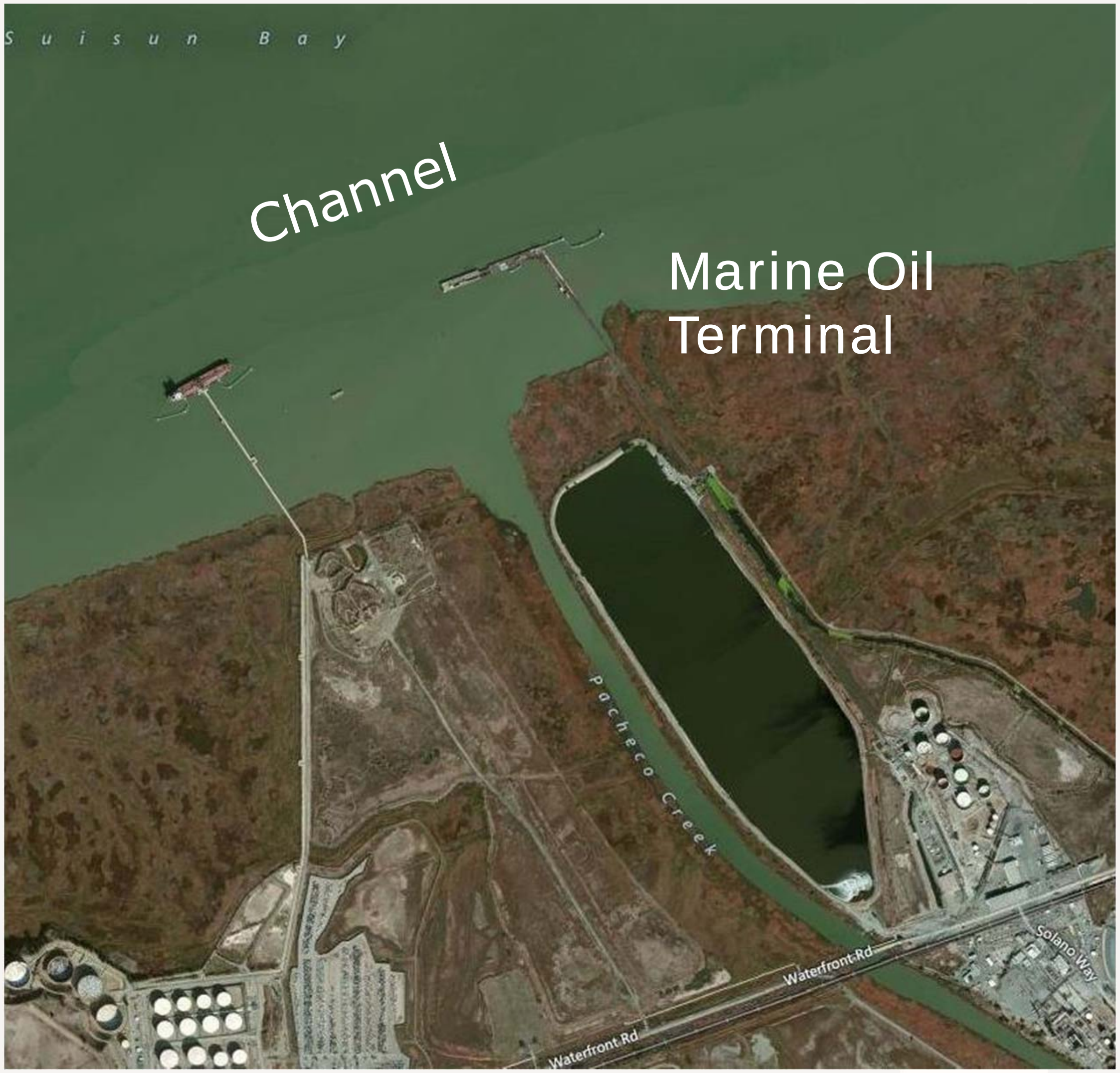
Case Study – Accommodate / Manage

# Marine Oil Terminal

- Project Features
  - (E) Timber Berth and mile long Timber Trestle with collapse potential.
  - New Berth
    - Barge & Aframax Traffic
  - New Trestle
    - 50-yr design life
  - Improved Trestle
    - 25-yr design life



Case Study – Accommodate / Manage

# Marine Oil Terminal

San Francisco

## ASSESS

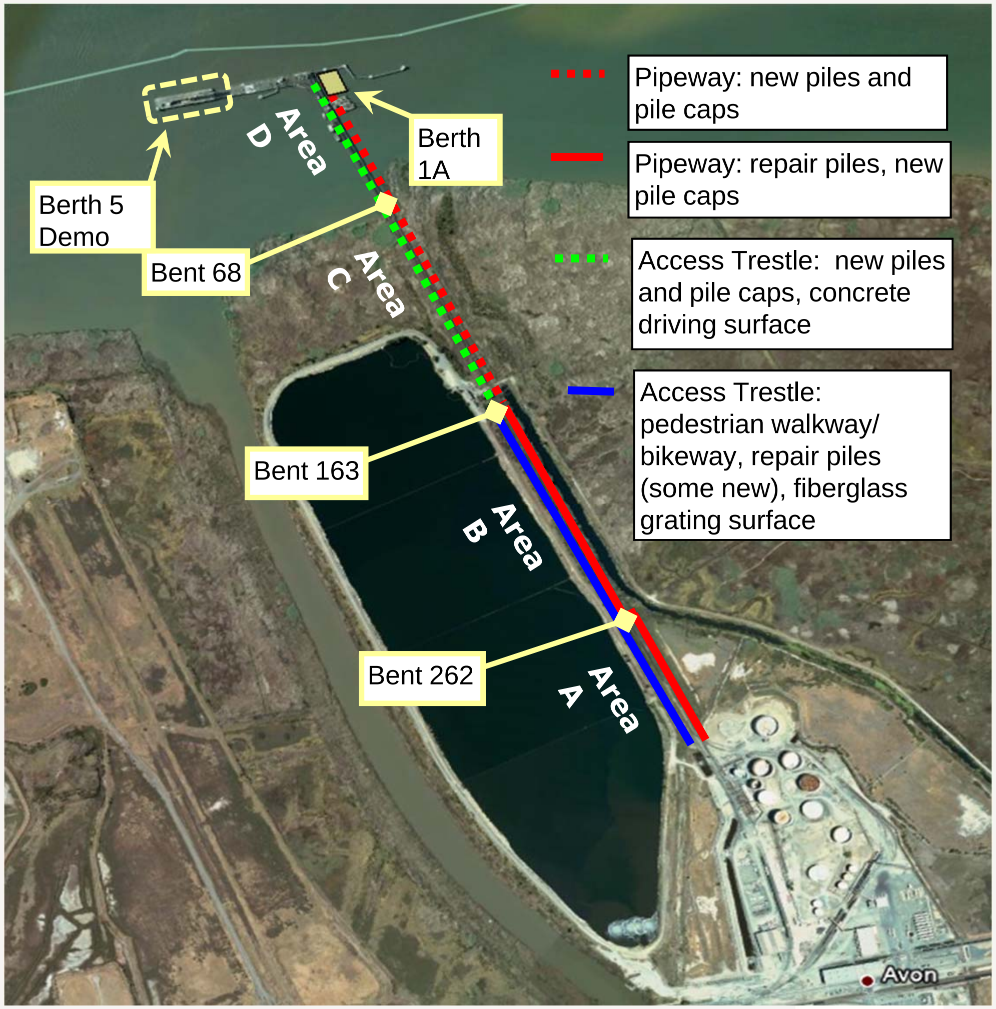
- State guidelines
- BCDC requirements

## ANALYZE

- Wave processes
- Water levels vs. piping elevations
- Simultaneity of events
- Wave slam

## ACT

- Precautionary deck and pipeway level
- Opportunistic Trestle Pipeway

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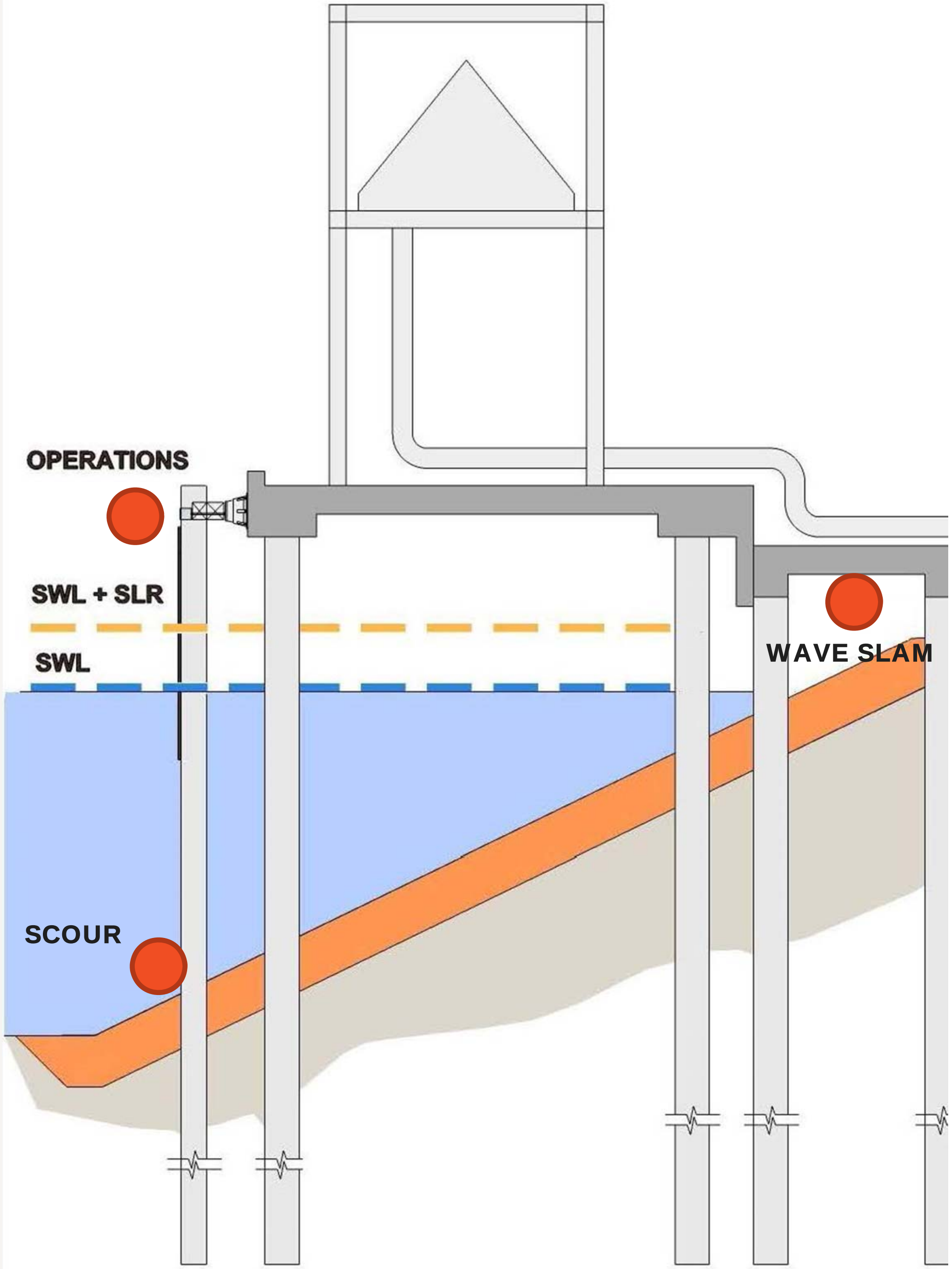
Case Study – Accommodate / Manage

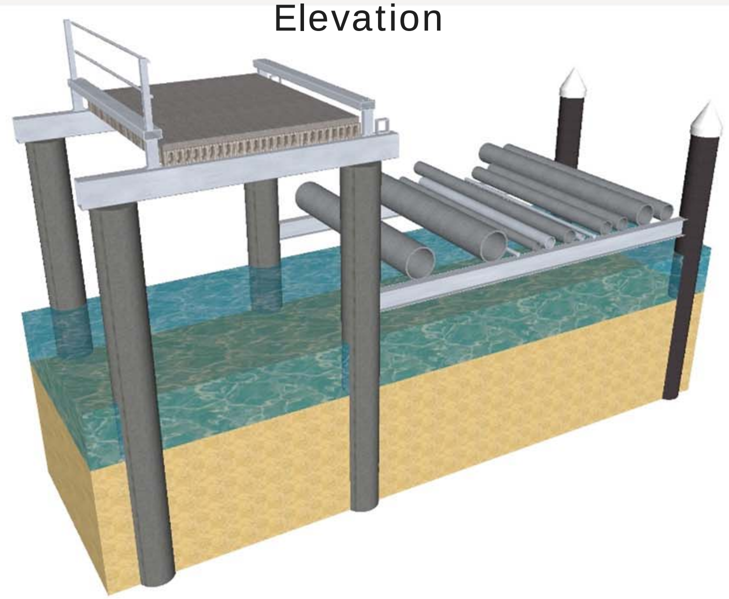
# Marine Oil Terminal

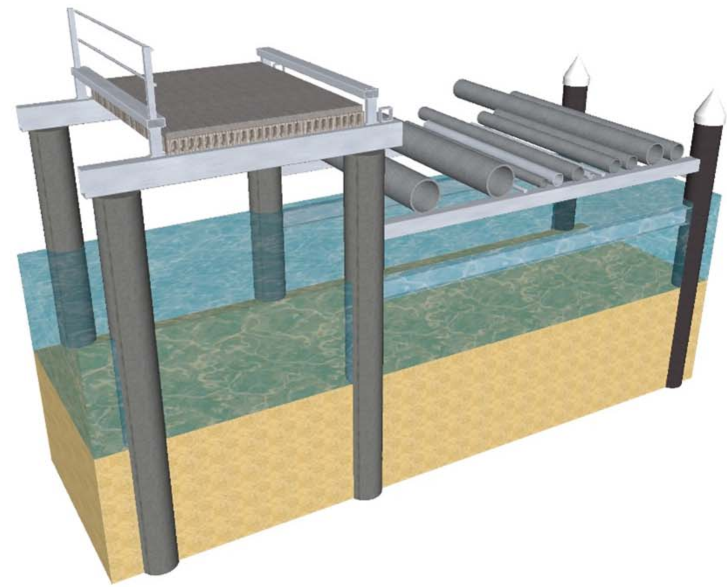
- Drivers
  - Frequent storms
  - Increased wave activity
  - Water Levels
- Response
  - Soil and structural instability
  - Pipeway wave loading
- Consequences
  - Reduced vessel operations
  - Pipeway exposure
  - Reduced berm performance
  - Vulnerable landside assets



# Marine Oil Terminal

- SLR Considerations
  - Higher pipeway beam included as part of design, however will not be installed until required
  - As sea level rises and begins to present a vulnerable situation, then MOT to address impact.
  - New beam and piping installed and then existing piping cleaned and removed.

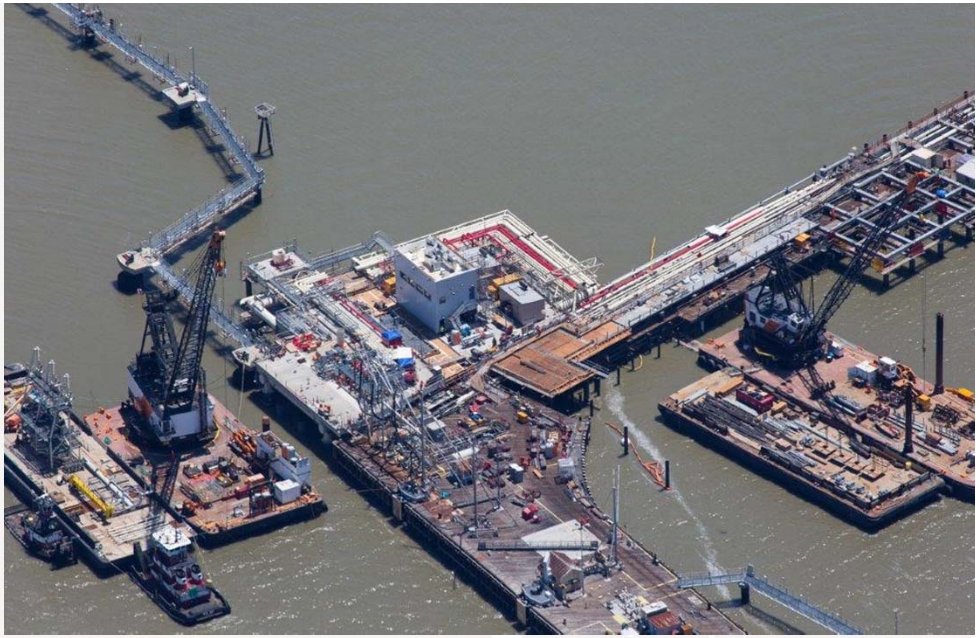


Case Study – Accommodate / Manage

# Marine Oil Terminal

- › New Berth and Dolphins
  - › Accommodate barges and Aframax vessel today and in 50-years
- › Trestle Adaptive Measures
  - › Use (E) Piping in good condition
  - › Elevate Pipeway in future to accommodate 2- 4-ft sea level rise
  - › Raise berm or relocate piping for future sea level rise
  - › Reduce risk to vulnerable assets



# Conclusions

- Agencies have implemented sea level change into regulation
- Projections of sea level change vary
  - Locally, globally, and within the scientific community
- Establish a rational approach for incorporating SLR into design
- Establish practical and pragmatic measures to reduce risk from SLR