Adapting to Rising Tides
SF Bay Area Sea Level Rise

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APA WA OR Conference
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Questions?
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Adapting to Rising Tides

• Climate change vulnerability and risk assessment of transportation assets in a subregion of the San Francisco Bay Area: coastal area of Alameda County

• Client: Metropolitan Transportation Commission (MTC), Bay Conservation and Development Commission (BCDC) and California Department of Transportation (CalTrans)

• Funder: Federal Highways Administration (FWHA)
The Context

- Bay is predicted to rise
  - by 16” by midcentury
  - by 55” by end of century
- 9 county San Francisco Bay Area is home to approx 7 Million people
- Neighborhoods, businesses, industries will be subject to flooding
- 250,000 residents will be directly affected
- Many others will be indirectly affected
Project Objectives

• Test the FHWA model: can it be applied at regional scales?

• Assess the vulnerability of key transportation infrastructure for pedestrian, bicyclists, motorists, transit riders and goods movement.

• Develop approaches that can be applied consistently for similar shoreline typologies.

• Produce a detailed sub-regional vulnerability analysis of SLR impacts on regionally important transportation infrastructure.
Asset Data Inventory

- Developed categories of transportation assets
- Identified information we needed to collect about each asset
- Information collected:
  
  Interstates/Freeways
  Arterial streets*
  Road tunnels/tubes
  Bay bridges
  Alameda bridges
  BART stations
  BART alignments
  Amtrak stations
  Passenger/freight rail alignments
  Ferry terminals
  Transportation Management Centers
  Bus Maintenance Facilities
  BART System Assets
  Passenger and Freight Yards and Depots
Physical Characteristics

- Physical Characteristics, focusing on whether an asset is built at-grade, below grade, or elevated on embankments or structures;
- Functional Characteristics, including lifeline routes, evacuation routes, goods movement routes, transit routes, and bike routes;
- Jurisdiction, referring to the agency, city or other entity with ownership and/or management responsibility for the asset; and
- Social/Economic Functions, such as connecting to jobs, regional importance, and support of transit-dependent populations.
New Mapping

- Existing shoreline protection
- Daily and extreme tide levels
- Storm wave scenarios
- Hydraulic connectivity
- Depth of inundation
Impact of Earthquake – Shaking severity and Liquefaction Susceptibility
Shoreline Categorization

- Engineered Flood Protection Structures
  - Levees
  - Flood Walls
- Engineered Shoreline Protection Structures
  - Bulkheads
  - Revetments
- Non-Engineered Berms
- Wetlands
  - Natural
  - Managed
  - Tidal Flats
- Natural Shorelines (Non-Wetland)
Types of Shoreline Assets

- Revetment, Port of Oakland
- Berm along old salt pond
- Managed wetland
Wetlands

- Natural marsh edge
- Tidal flats
- Managed wetlands
How to Select Transportation Assets

• Politically challenging
• Every asset has important value
• Decided to move forward on representative asset categories:
  • Road
  • Transit
  • Facilities
  • Bike / Pedestrian
Vulnerability to SLR = exposure (how deep?) + sensitivity (physical condition) + adaptive capacity (partial use/reroute)
## What makes an Asset Vulnerable?

### Condition data

<table>
<thead>
<tr>
<th>Asset (Segment)</th>
<th>Level of Use - Average Daily Traffic (ADT) Volume</th>
<th>Operations &amp; Maintenance Cost</th>
<th>Remaining Service Life</th>
<th>Liquefaction Susceptibility</th>
<th>Overall Sensitivity H/M/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Grand Avenue (I-80 to Adeline St.)</td>
<td>22,912 3 pts.</td>
<td>$2.0 M (30 yrs.) 2 pts.</td>
<td>14 yrs. 2 pts.</td>
<td>Very High 3 pts.</td>
<td>Point total: 10 H</td>
</tr>
<tr>
<td>Hegenberger Road (San Leandro St. to Doolittle Dr.)</td>
<td>18,000 2 pts.</td>
<td>$6.3 M (30 yrs.) 3 pts.</td>
<td>21 yrs. 1 pt.</td>
<td>Very High, Medium 2 pts.</td>
<td>Point total: 8 M</td>
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<tr>
<td>I-80 Frontage Road (Ashby Ave. to Powell St.)</td>
<td>15,830 2 pts.</td>
<td>$0.9 M (30-yr. equiv.) 1 pt.</td>
<td>18 yrs. 2 pts.</td>
<td>Very High 3 pts.</td>
<td>Point total: 8 M</td>
</tr>
<tr>
<td>Powell Street (west of I-80)</td>
<td>26,520 3 pts.</td>
<td>$1.2 M (30-yr. equiv.) 2 pts.</td>
<td>25 yrs. 1 pt.</td>
<td>Very High 3 pts.</td>
<td>Point total: 9 H</td>
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<tr>
<td>Mandela Parkway (West Grand Ave. to I-580)</td>
<td>8,030 2 pts.</td>
<td>$1.0 M (30 yrs.) 1 pt.</td>
<td>28 yrs. 1 pt.</td>
<td>Very High, Medium 2 pts.</td>
<td>Point total: 6 L</td>
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<tr>
<td>Third Street (Mandela Pkwy. to Market St.)</td>
<td>12,000 2 pts.</td>
<td>$0.5 M (30 yrs.) 1 pt.</td>
<td>5 yrs. 3 pts.</td>
<td>Very High, Medium 2 pts.</td>
<td>Point total: 8 M</td>
</tr>
<tr>
<td>Cabot Boulevard</td>
<td>524 1 pt.</td>
<td>$2.3 M (30 yrs.) 2 pts.</td>
<td>16 yrs. 2 pts.</td>
<td>Medium 1 pt.</td>
<td>Point total: 6 L</td>
</tr>
</tbody>
</table>
Risk Assessment
Likelihood and Consequence

• **Likelihood:** What is the likelihood that the asset will be impacted by SLR?
  • Depends on the certainty of climate projections
  • We have selected one set of projections relating to one impact
  • Likelihood will not play a differentiating role in our risk assessment
Consequence: what is the expected impact or consequence to society if the asset is inundated?

Criteria selected:
- Cost of and time to replace asset
- Economic impact (goods movement, commuter route)
- Socio-economic impact (transit dependent communities)
- Public safety
### Integrated Risk Assessment

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Consequence</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td></td>
<td>2</td>
<td>3</td>
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<td>6</td>
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<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

#### Risk
- **Low**
- **Moderate**
- **High**

**High Risk (Red)**
Unacceptable, major disruption likely; different approach required; priority management attention required

**Moderate Risk (Orange)**
Some disruption; different approach may be required; additional management attention may be needed

**Low Risk (Green)**
Minimum impact; minimum oversight needed to ensure risk remains low
Draft Risk Profile

Includes information on:

- Characteristics
- Vulnerability (condition, exposure, inundation depth)
- Overtopping potential analysis

<table>
<thead>
<tr>
<th>Asset Name</th>
<th>Webster and Posey Tubes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset Location</td>
<td>Oakland - Alameda</td>
</tr>
<tr>
<td>Sensitivity/Background Info</td>
<td>Jurisdiction: Caltrans</td>
</tr>
<tr>
<td>Age</td>
<td>Posey Tube: Built-1927, Retrofit-2004;</td>
</tr>
<tr>
<td></td>
<td>Webster Tube: Built-1963, Retrofit-2005;</td>
</tr>
<tr>
<td>Level of Use</td>
<td>PH=1,850; AADT=22,300;</td>
</tr>
<tr>
<td></td>
<td>AADTT=535</td>
</tr>
<tr>
<td>Average Daily Traffic (ADT)</td>
<td></td>
</tr>
<tr>
<td>Seismic Retrofit</td>
<td>Yes</td>
</tr>
<tr>
<td>Maintenance Costs (O&amp;M)</td>
<td>$83,312</td>
</tr>
<tr>
<td>Liquefaction Susceptibility</td>
<td>Very High</td>
</tr>
</tbody>
</table>

Importance Category: Critical asset
- Commuter Route,
- Goods movement,
- Connects to Jobs

Vulnerability Ranking mid century: High
Vulnerability Ranking end of century: High
Max. Inundation Depths:
- 16 inch SLR: (4 ft)
- 16 inch +100 yr SWEL: 22 ft
- 16 inch +100 yr SWEL + wind & waves: YES
- 55 inch SLR: 23 ft
- 55 inch +100 yr SWEL: 25 ft
- 55 inch +100 yr SWEL + wind & waves: YES

Weak Link Analysis: [shoreline assets responsible for flooding]

Projected Inundation Extent at Asset Location at 55 inch SLR + 100yr SWEL
Next Steps

- Review shoreline assets and confirm overtopping potential
- Use shoreline categories, SLR maps, and weak link analysis to inform vulnerability and risk of community and shoreline assets
- Review consequences with project partners
- Develop adaptation strategies and options
Adapting to Sea Level Rise: Land Use Tool Kit

WA/OR APA Conference
October 21, 2011

Presented by
Nicole Faghin, LEED AP, AECOM
nicole.faghin@aecom.com

Which Way Should We Go?

• Our Choices...
  - Reactive ...
  • Structural Solutions

Walling Up against the Water

Which Way Should We Go?

...or Proactive
  • Planning
  • Regulations

Key Agency Players

• EPA (Clean Water Act)
• NOAA
• FEMA
• Coastal Zone Management (CZM) and State Programs
  - Shoreline Management Act (SMA) in Washington
  - Land Conservation and Development Commission (LCDC) in Oregon
• Association Of State Floodplain Managers:
  - NO ADVERSE IMPACT (NAI)
Planning Tools

- Comprehensive Plans
- Coastal Zone Management
- Shoreline Master Programs (WA)
- Floodplain Plans
- Stormwater Plans

River Planning Context

Coastal Planning Context

Taking the Long View

Coastal Management Plans

Using Example of Washington State
1. Shoreline Jurisdiction
2. Inventory
3. Goals and Policies
4. Regulations
   - Shoreline Protects - Soft shore
   - Buffers
   - Setbacks
   - Non-conforming uses


Regulatory Tools

- Zoning and Overlay
- Floodplain Regulations
- Building Codes
- Setbacks and Buffers
- Conditions, mitigation, dedications
- Subdivisions and cluster development
- Permit Conditions
  - Hard armoring vs. soft coastal protection
  - Rolling coastal easements
SLR Toolkit Evaluation

<table>
<thead>
<tr>
<th>Domain</th>
<th>Evaluation Criteria</th>
<th>Conformance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td></td>
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</tbody>
</table>

Resources

- Georgetown Climate Center Adaptation Tool Kit
- Climate Adaptation Knowledge Exchange (CAKE)
- NOAA Climate Adaptation

Adapting to Sea Level Rise: Regulatory Tools

WA/OR APA Conference
October 21, 2011

Presented by
Nicole Faghin, LEED AP, AECOM
nicole.faghin@aecom.com

http://www.youtube.com/watch?v=k3i3UM7Z3ps
Adapting to Climate Change

1. Contextual Overview
2. Understanding the Choices
3. Site Understanding
4. Master Plan Process
5. Designing the “first win”

Case Study: Richmond Waterfront
Richmond, British Columbia

1

Contextual Overview

Forecasted Change in the Environment
- The River – Increased Spring Melt & Runoff
- The Sea – Tidal Change & Sea Level Rise
- The Land – Currently at or below Sea Level

A City in a Delta
Mountains, Rivers, and the Sea

Richmond Waterfront

Increased Spring Melt
2 Understanding the Choices

Protect & Armor Shoreline

Strategies for Climate Change
Case Study: Richmond Waterfront
Richmond, British Columbia

Acceptance of a New Shoreline

Strategies for Climate Change
Case Study: Richmond Waterfront
Richmond, British Columbia

Adapting to Change

Strategies for Climate Change
Case Study: Richmond Waterfront
Richmond, British Columbia

3 Site Understanding
Adapting to Change
Quick Facts

- 1.3 Kilometers in length
- On top of an existing dike
- Between Canada Line station & Olympic Speed Skating Oval
- 3 Plazas; UBC Boat House & racing; Navy League; private
  Marina; themed playground
- Raise dike to 4M & plan for 5M
- Completion of Phase 1 by 12/09
- $5.0 million Construction Budget – Phase 1

Case Study: Richmond Waterfront
Richmond, British Columbia

The Big Ideas / Big Picture Goals

- Braided Delta System
- Flood Control / Sculptured engineering
- Sustainability & Ecology
- Engage Road in Phase one
- City / River Monuments
- Olympic Legacy
- Identify a “first win” to claim the bigger goals ahead

Case Study: Richmond Waterfront
Richmond, British Columbia
Adapting to Change
Engineering & Shoreline Protection

Adapting to Climate Factors

Case Study: Richmond Waterfront
Richmond, British Columbia

5
“First win” design

Adapting to Change
Environments that evolve

Capture Views

Case Study: Richmond Waterfront
Richmond, British Columbia

Adapting to Change
Making every inch (or mm) count

Capture Views

Case Study: Richmond Waterfront
Richmond, British Columbia
Adapting to Change

Making every inch (or mm) count

Case Study: Richmond Waterfront
Richmond, British Columbia

Function and Form

Communication to future generations

Case Study: Richmond Waterfront
Richmond, British Columbia
Adapting to Change

Blurring the edge and living with nature again

Case Study: Richmond Waterfront
Richmond, British Columbia

Adapting to Change

Communicating to future generations

Case Study: Richmond Waterfront
Richmond, British Columbia

Thank you
Preparing Washington State: An update on Climate Change Response Efforts

Paula Hammond, P.E.
Secretary of Transportation
Carol Lee Rosikvam
Environmental Policy Manager
Steve Reinmuth
Chief of Staff
Joint Oregon and Washington APA
October 21, 2011
Portland, OR

10/27/2011

Governor and Legislative Direction

State Law plus Executive Orders 07-02 (2007) and 09-05 (2009)
- Reduce emissions – referred to as “mitigation”
  - Improve vehicle technology and fuels
  - Reduce VMT
  - Create a more efficient transportation system
  - Conserve Energy and Resources
- Support our economy – create more sustainable economy
  - West Coast Green Highway
- “Adaptation” prepare for climate change impacts (esp. sea-level rise / coastal impacts)

Washington Climate Change Impacts Assessment

- Funded by the Washington State Legislature
- Comprehensive assessment of climate change impacts on Washington
- Downscaled from global climate models
- Products include comprehensive data sets

Regional Climate Impacts

UW Climate Impacts Group report covers more than Washington State
www.cses.washington.edu/cig/

Seattle Sea Level Rise

Climate Impact Areas of Concern

Western WA
- Sea level rise
- Salt water intrusion
- Landslides
- Habitat loss
- Erosion, scour
- Flooding
- Extreme heat
- Drought

Eastern WA
- Heat and Drought
- Toxic temps for fish
- Habitat migration
- Rain dominant rivers
- Water timing
- Scour
- Flooding
- Invasive Species
**State Agency Climate Leadership Act, 2009**

- Requires development of an "*integrated climate change response strategy...*" which must address "regional capacity to take action, existing ecosystem and resource management concerns, and health and economic risks."
- Requires state agencies “…to incorporate adaptation plans of action as priority activities when planning or designing policies and programs. ..and funding infrastructure projects...”
- Executive Order 09-05: requires focus on sea-level rise and water resources

**Seven State Agencies**

- Ecology
- Natural Resources
- Transportation
- Commerce
- Health
- Agriculture
- Fish & Wildlife

**Broad Goals**

- Mainstream adaptation into state agency planning, policies and investment decisions
- Improve understanding & access to climate science
- Foster collaboration and coordination between agencies, tribes, NGOs and all levels of government
- Support efforts of local communities to prepare for changing climate
- Build awareness among decision-makers and public through communication and engagement

**Key Strategies - DRAFT**

- Incorporate impacts and adaptation into long-range planning
- Consider climate projections when making public investments (all sectors)
- Strengthen state’s emergency preparedness
- Protect human health by addressing impacts into existing public health activities
- Enhance monitoring (track emerging risks)

**Major elements of strategy**

- Human Health and Security
- Ecosystems, Habitats and Species
- Coastal and Ocean Resources
- Water Management
- Agriculture
- Forestry
- Infrastructure
- Monitoring and Research
- Communication and Public Engagement
- Implementation Framework

**Topic Advisory Groups:**

- TAG1: Built Environment/Infrastructure and Communities
- TAG2: Human Health and Security
- TAG3: Ecosystems, Species, Habitats
- TAG4: Natural Resources (working lands and waters)
Key Strategies (cont.)

- Maximize mutual benefits: economic, social and environmental
- Protect ecosystem processes and services
- Encourage protection of conservation areas and avoid conversion of agriculture and forest lands
- Implement policies to achieve sustainable water resources management
- Improve availability & access to climate data

Moving Washington –

Our framework for investing, maintaining, preserving and getting the most out of the transportation system

Sustainable:
Meet today's needs without compromising the ability of future generations to meet their own needs.

Preserving Assets in a Changing Environment

- Understand the climate forecast for PNW
- Be ready for severe weather events and long-term changes in site conditions
  - tides, streams, glacial melt and debris flows...
- Inform long-term decisions
- Build resilience where possible

FHWA / WSDOT climate change vulnerability & risk assessment

- WSDOT Goals:
  - Informed decision-making
  - Assess our risks
  - Assist in prioritizing needs – feeds into planning and project development
  - Resilient and sustainable transportation system regardless of the future we face
  - Test FHWA methodology

- Boundaries:
  - State-owned infrastructure
  - Report due to FHWA November 30, 2011

FHWA Risk Assessment Model

- Local maintenance, bridge preservation, hydraulics, geotechnical, materials, project development, planners, environmental staff
- Workshop format (similar to cost/risk assessments)
- Share climate change information and why this was important – stressed what is happening now (observed)
- Question: “How resilient is our existing system?”
We use our experience to gauge future impacts

Responsible Asset Management
Reliable Transportation System

- Vulnerability - Risk Assessment (near complete!)
- Sea-level rise mapping
- Scour & hazard monitoring
- Strategic plan element
- Planning guidance
- Project-level analysis

See WSDOT’s project-level guidance on WSDOT’s Energy webpage:
http://www.wsdot.wa.gov/Environment/Air/Energy.htm

Climate and weather-related impacts

Being prepared means:
- Understand the forecast
- Assess our risks
- Integrate into planning and design
- Partner with others
- Build to last