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U.S. Department of Transportation
Federal Highway Administration

FHWA Climate Change Vulnerability Assessment Pilot Project:

Metropolitan Transportation Commission — MTC

In 2010, the Federal Highway Administration (FHWA) selected **five pilot teams** from across the country to test a climate change vulnerability assessment model. This conceptual model guided transportation agencies through the process of collecting and integrating climate and asset data in order to identify critical vulnerabilities. During this year-long pilot program, the pilot teams formed a community of practice, exchanged ideas, presented draft results, and participated in a series of webinars and peer exchanges. FHWA used the feedback and lessons learned from the pilot projects to revise the draft conceptual model into the Climate Change & Extreme Weather Vulnerability Assessment Framework. The framework is available on the **FHWA website**.

The San Francisco Bay Area is home to approximately 7 million people supported by a dense network of public infrastructure. The region's history of seismic activity and long coastline make it uniquely exposed to earthquakes and sea level rise. The San Francisco Bay Conservation and Development Commission (BCDC), in partnership with the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center, is leading a project called Adapting to Rising Tides (ART). As part of ART, the Metropolitan Transportation Commission (MTC), California Department of Transportation (Caltrans) District 4, and BCDC collaborated on the 2010–2011 FHWA pilot to assess climate vulnerability and risk in Alameda County.

Scope

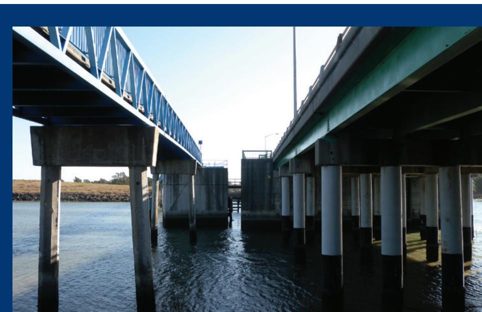
The project team analyzed up to three representative assets in each of four categories of transportation infrastructure in Alameda County: road network; transit network; storage, operations and maintenance, and control facilities; and bicycle and pedestrian networks. The team also evaluated the risk that sea level rise poses to shoreline protection assets, such as natural shorelines and berms.

Objectives

- Enable the Bay Area's transportation planners to craft effective adaptation strategies based on improved vulnerability and risk assessment practices.
- Deploy and test the FHWA conceptual model and provide FHWA with recommendations for evolving the model.

Levee construction. Photo courtesy of MTC.

Port of Oakland. Photo courtesy of MTC.



Bay Farm Island Bridge, Alameda. Photo courtesy of MTC.

Approach

Refine asset inventory and assess sensitivity. The project team worked with its member agencies to inventory available data sources, but quickly realized that many datasets would not contain the information needed to assess vulnerability. For example, key data elements included the age of the asset, its geographic location, and elevation. In order to limit the data collection required, the project team worked with stakeholders to refine the number of assets selected for analysis.

Transportation assets. The project team applied three filters to narrow down the asset inventory to a small set of representative assets. The first filter spatially selected for the assets located within the end-of-century sea level rise inundation area, discarding assets unlikely to be exposed to sea level rise. The second filter analyzed the environmental, economic, and equity characteristics associated with each asset. In most cases, applying these two filters limited the list of representative assets to three or fewer within each of the four asset categories. However, since there were hundreds of discrete arterial, collector, and local streets, the project team hosted a workshop to identify priority assets for evaluation. Participants in the workshop voted for priority transportation assets within Alameda County by affixing stickers to inundation maps.

Shoreline protection assets. The project team used a Geographic Information System (GIS) to categorize highly varied and diverse shoreline protection assets into distinct classes based on their physical characteristics and primary function. Next, the project team drew on existing data from multiple resources to develop maps of the shoreline categories.

Conduct seismic vulnerability assessment. The project team analyzed the impact that rising sea level might have on the seismic vulnerability resilience of transportation and shoreline protection assets. Seismic activity can lead to liquefaction and lateral spreading of unconsolidated soils.

Develop inundation maps. The project team developed inundation maps reflecting six potential inundation scenarios to assess the extent and depth of inundation in the study area. One set of inundation maps represents mid-century estimates for sea level rise (16 inches under daily tidal inundation and 100-year storm event scenarios) and the second set shows end of the century projections (55 inches under daily tidal inundation and 100-year storm event scenarios) (see Figure 1).

The project team used the inundation maps to conduct an assessment of the potential for shoreline overtopping. The transportation asset and shoreline defenses were subdivided into "systems" that act together in influencing inland inundation for a more holistic perspective of potential vulnerability.

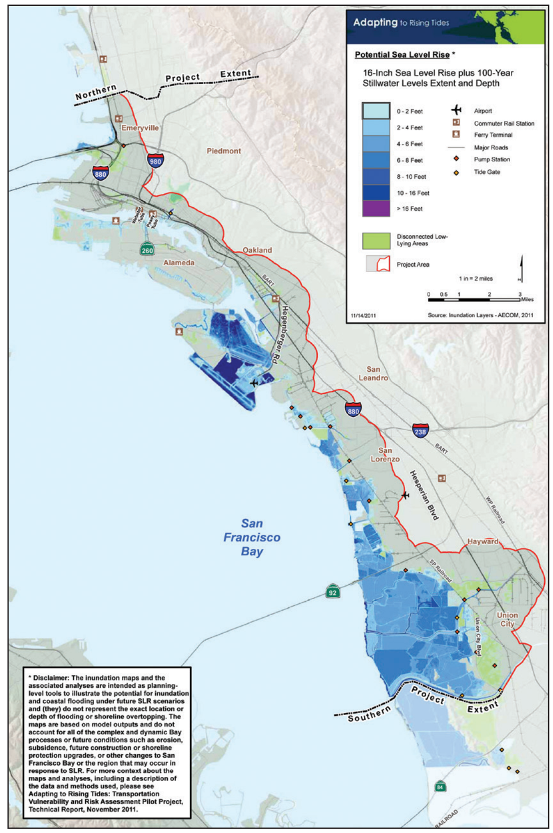


Figure 1: Alameda County inundation map of a scenario featuring 16-inch sea level rise plus 100-year stillwater levels with potential wind waves.

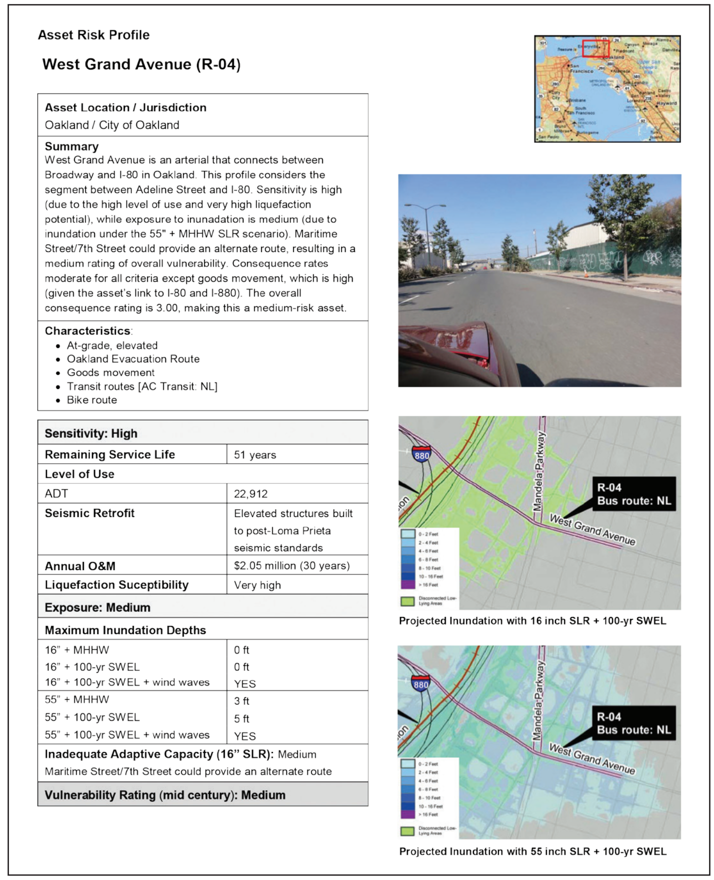
Assess vulnerability. The vulnerability assessment rated each transportation asset "high," "medium," or "low" for each factor of vulnerability: exposure, sensitivity, and adaptive capacity. The analysis defined exposure based on the location of assets within the sea level rise inundation areas. Sensitivity was calculated based on the stressor criteria (e.g., facility age) described previously. The assessment rated the adaptive capacity of an asset based on the availability of alternative assets and other factors.

Assess risk. To assess risk, the project team rated the likelihood and consequence of climate impacts on a 1 to 5 scale for the most vulnerable assets within each asset category. Since this study considered only two climate change scenarios and the project area was relatively small, the likelihood rating was determined to be "3" for each transportation asset. The project team rated consequence based on criteria such as economic impact, public safety, and socioeconomic impact. For each asset, the project team categorized the sum of the likelihood and consequence scores to develop an overall score that is categorized as high, moderate, or low risk.

Develop risk profiles. In order to communicate and capture the findings from this study, the project team developed risk profiles for select assets. Each risk profile summarizes the asset's exposure, sensitivity, adaptive capacity, consequence rating, and overtopping potential of shoreline protection systems. These profiles are tools for the future development and prioritization of adaptation strategies (see Figure 2).

Review adaptation options. The project reviewed a list of potential adaptation measures organized in the following categories: structural and nonstructural measures, and asset-specific and regional measures. The project team developed criteria that can be weighed and ranked in evaluating adaptation measures for each of the following groups:

- Equity
- Economy
- Ecology
- Governance



Asset Risk Profile

West Grand Avenue (R-04)

Asset Location / Jurisdiction
Oakland / City of Oakland

Summary
West Grand Avenue is an arterial that connects between Broadway and I-80 in Oakland. This profile considers the segment between Adeline Street and I-80. Sensitivity is high (due to the high level of use and very high liquefaction potential), while exposure to inunadation is medium (due to inundation under the 55" + MHHW SLR scenario). Maritime Street/7th Street could provide an alternate route, resulting in a medium rating of overall vulnerability. Consequence rates moderate for all criteria except goods movement, which is high (given the asset's link to I-80 and I-880). The overall consequence rating is 3.00, making this a medium-risk asset.

Characteristics:
- At-grade, elevated
- Oakland Evacuation Route
- Goods movement
- Transit routes [AC Transit: NL]
- Bike route

Sensitivity: High	
Remaining Service Life	51 years
Level of Use	
ADT	22,912
Seismic Retrofit	Elevated structures built to post-Loma Prieta seismic standards
Annual O&M	$2.05 million (30 years)
Liquefaction Suceptibility	Very high
Exposure: Medium	
Maximum Inundation Depths	
16" + MHHW 16" + 100-yr SWEL 16" + 100-yr SWEL + wind waves	0 ft 0 ft YES
55" + MHHW 55" + 100-yr SWEL 55" + 100-yr SWEL + wind waves	3 ft 5 ft YES
Inadequate Adaptive Capacity (16" SLR): Medium Maritime Street/7th Street could provide an alternate route	
Vulnerability Rating (mid century): Medium	

Figure 2: Example risk profile for West Grand Avenue in Oakland, CA

Key Results & Findings

Vulnerable assets. The inundation maps reveal that the shoreline protection assets would protect the transportation assets to a certain extent under the mid-century and end-of-century sea level rise scenarios. However, nearly all the shoreline assets would be inundated in the 55 inches of sea level rise scenario with the most severe flood and wave conditions. The transportation assets that are most vulnerable to increased seismic impact in the face of climate change are located in the Emeryville, Oakland, and Alameda waterfront and Oakland International Airport fill areas because of high liquefaction susceptibility and projected sea level rise inundation.

Potential adaptation options. The initial adaptation assessment identified near-, mid-, and long-term actions for the Bay Bridge touchdown and toll plaza. Limited inundation of the asset is expected to occur under the midcentury scenario and minor modifications to the asset can be made in an opportunistic manner during scheduled maintenance. However, potential consequences of sea level rise in the end-of-century scenario require more drastic adaptation measures such as raising the road surface and building a causeway. Regional and nonstructural adaptation measures include constructing a floodwall, wetland restoration, and developing new design codes.

Lessons Learned

Leverage existing information. The project team was able to develop seismic impact and inundation maps using existing data. The team gathered GIS information from the California Department of Conservation, USGS, and ABAG for the seismic vulnerability assessment. The inundation mapping leveraged data and modeling approaches from coastal studies previously conducted by USGS and the Federal Emergency Management Agency. Additionally, some of the potential adaptation measures that were reviewed in this pilot were identified through previous planning efforts.

Factor societal value of assets into vulnerability assessment. The project team decided not to determine the criticality of assets relative to each other (since the assessment would have been largely based on professional judgment and limited data). The importance of the asset to the region was factored into the analysis, however. For example, the San Francisco Bay Trail is an important regional recreational/commuting asset for pedestrians and bicyclists. The Bay Trail is highly vulnerable due to its location at the shoreline; from the regional transportation perspective, however, the impact of its inundation is low when compared to other transportation assets in the County. Given the Bay Trail's importance to the region, the project team decided that it was not appropriate to characterize flooding impacts to the trail as being of low consequence.

"We want to house our growing population and we want to do it in a way that is safe from sea level rise and seismic risk, while achieving our greenhouse gas emission goals."

-Joe LaClair, BCDC

Next Steps

Assess adaptation options. In the second round of FHWA's Climate Resilience Pilot Program, a collaborative team is building off work conducted in the first round and BART's Federal Transit Administration climate vulnerability pilot project. The upcoming pilot will develop a regional and multi-modal adaptation plan in three focus areas in Alameda County. The team will determine core transportation assets and vulnerabilities by collecting data (e.g., on past performance during extreme weather) and updating sea level rise maps. Then, the team will explore a wide range of adaptation strategies and compare adaptation options using the criteria defined in the first round.

For More Information

Resources:

Adapting to Rising Tides: Transportation Vulnerability and Risk Assessment Pilot Project Briefing Book

Adapting to Rising Tides Webpage

MTC Project Webpage

Contacts:

Joe LaClair
Chief Planning Officer
Bay Conservation and Development Commission
joel@bcdc.ca.gov, 415-352-3656

Becky Lupes
Sustainable Transport and Climate Change Team
Federal Highway Administration
Rebecca.Lupes@dot.gov, 202-366-7808