7.0

Adaptation Planning

This page intentionally left blank.

7 Adaptation Planning

7.1 Introduction

Chapter 6 identifies the vulnerability and risk level of the selected representative transportation assets that are exposed to inundation under different sea level rise (SLR) scenarios. The subsequent task is to consider what can be done to mitigate these risks. This chapter explores preliminary ideas and possibilities for adapting to SLR in the pilot project area. Adaptation planning is not part of the Federal Highway Administration conceptual model; however, it is the essential next step in the process.

Section 7.2 reviews a list of potential adaptation measures, some of which were identified through previous planning efforts, including preparation of *San Francisco Bay: Preparing for the Next Level* (BCDC 2009). Section 7.3 provides suggestions on how to use information collected on the risk profiles and additional evaluation criteria to help select adaptation measures. Based on this information, Section 7.4 presents a potential range of near-term and longer term adaptation options for two example assets – the San Francisco–Oakland Bay Bridge (which in this review focuses on the bridge touchdown and toll plaza, R-12) and the Oakland Jack London Square Amtrak Station (T-05). This chapter concludes by recommending next steps for developing an approach to adapting transportation infrastructure to SLR. Consultation with the organizations involved in the Shoreline Asset and Transportation Asset subcommittees would be an essential part of the process.

Note that the adaptation measures presented in this chapter provide a range of possible solutions based only on the information available to the project team. The outcomes of this chapter are not intended to represent specific adaptation measures for the two example assets but rather to identify a range of potential adaptation measures to be further investigated as part of the adaptation planning phase of the ART project.

7.2 Climate Change Adaptation Measures

The risk assessment exercise described in Chapter 6 shows that adapting transportation infrastructure to rising sea levels will be required to maintain the level of service expected within the Alameda County subregion. San Francisco Bay sea levels have already risen by 7 inches (California Natural Resources Agency 2009) in the past century and will continue to rise, and rising tides are already affecting the Bay Area's transportation network. Not adapting to these changing circumstances will likely result in large economic and social impacts to the region. By taking a proactive approach, various agencies around the bay will allow the region to remain safe and competitive.

Key questions to answer at the outset of adaptation planning are: "What is an acceptable impact to the region, and what adaptation measures are needed to achieve this?" In relation to transportation, these questions lead to establishing the minimum level of service that must be provided by the road and rail networks. Under present-day conditions, agencies are likely to require at least the same or a better level of service and the current (or better) level of flood protection. These questions were not addressed for the two example assets reviewed for this project, but it would be a key question in the development of an adaptation strategy.

For this project, adaptation measures have been organized into several categories to structure the discussion on how to select the most appropriate adaptation measures for any given asset – structural and nonstructural measures, and asset-specific and regional (or non asset specific) measures. These categories can be defined as follows:

- Structural Adaptation Measures - are physical measures, such as constructing levees, flood walls, and wetlands or relocating an asset, that mitigate the flooding impacts of SLR.

- Nonstructural Adaptation Measures - are non physical measures that can include changing policies and regulations (e.g., new building codes, zoning requirements like setbacks or buffer zones), updating design guidance, or providing education and community outreach to increase awareness and make communities more resilient. Nonstructural measures could also include rerouting traffic or temporarily closing infrastructure.

- Asset-Specific Adaptation Measures - are measures that are directly related to adapting the transportation asset to SLR impacts.

- Regional Adaptation Measures –are measures that may protect more than one transportation asset and assets in other sectors (e.g., residential, commerce, recreation) in the same area.

Both structural and nonstructural measures are essential for adaptation planning and in many instances, the two complement one another, as the nonstructural measure enables implementation of the structural measure.

In addition, the timing of implementation of adaptation measures can be used as an organizing principle to identify the most appropriate point of intervention in an asset's life cycle for implementation of adaptation measures. Opportunistic adaptation measures are those that can be made during regularly scheduled maintenance or end-of-life-cycle replacement. Proactive adaptation measures are those that are implemented in anticipation of a climate change stressor—in this case, SLR—independent of other activities (e.g., elevating a road before the end of its life cycle to better protect it from rising tides). Consideration of the various categories of adaptation measures and their points of interventions shaped the discussion on conducting an initial screening of appropriate adaptation measures. It should be noted that adaptation measures typically fall into multiple categories, meaning that an asset-specific measure can be, for example, structural in nature as well as opportunistic.

provides an overview of adaptation measures that were found to be potentially applicable for the Alameda County subregion. These measures represent a matrix of structural and nonstructural, and asset-specific and regional adaptation measures. Most of the measures could be implemented as either opportunistic or proactive measures. Note that this table should not be considered an exhaustive list of the potential adaptation options.

Table 7.1 Potential Adaptation Measures Applicable to Alameda County

	Asset-specific	Regional
Nonstructural	- Requiring temporary closure (road, tunnel, bridge) - Rerouting traffic and transit – provide alternative route to reach same destination - Providing alternative mode of transportation (e.g. ferry instead of bridge) - Abandoning the asset and not replacing it - Developing new building and design codes for transportation assets - Revising transportation planning guidance and policy	- Increasing stakeholder and community awareness and input - Increasing technical knowledge and capacity in relevant agencies - Revising land use planning guidance and policy making, including zoning overlays - Developing new and innovative partnerships – to research, fund, and implement climate change adaptation planning.

	Asset-specific	Regional
Structural	- Providing flood/water proofing to better withstand flooding (tunnel entrances, raising electronics within building) - Improving drainage/foundations to retain or drain floodwater - Designing floating structure (roads, ferry terminals) to accommodate future changes in sea level - Using new materials with increased durability to sustain periods of inundation - Raising the asset (road, railroad tracks, tunnel entrance, bridge on ramp, facility, freeway) - Moving the asset – relocate or rebuild an asset to a location at higher elevation outside the floodplain	**Barriers** - Erecting a closure dam (permanent; shorten the line of defense) (e.g., connect Alameda Island to mainland) - Installing a storm surge/tidal barrier (moveable) to close off parts of the bay during high-water events **Levees** - Raising existing levees - Strengthening existing levees (e.g., overtopping resistant) - Incorporating new technology into levees (smart/Intelligent levees), which include flood early warning systems and sensors in levees - Building a new levee (e.g., ring levees) - Building a "super levee" - one so wide it cannot be breached (e.g., ½ mile wide) - Designing a levee in a dune (levee is essentially hidden by a dune, which can become an amenity) - Designing a levee in a boulevard (levee is hidden by a part of the public realm, such as a boulevard) **Walls** - Raising the height of a permanent sea/flood wall - Building a new permanent sea/flood wall - Installing a demountable floodwall - Incorporating buildings (e.g., houses, office buildings, or parking structures) as flood protection features (urban waterfront) **Land Reclamation** - Developing a port or land extension, which will then provide flood protection for the region - Developing new or existing wetlands to dissipate wave energy at the shoreline - Providing foreshore beach nourishment to dissipate wave energy before or at the shoreline - Building with nature (use of the natural forces of streams and currents to strengthen the shoreline) (e.g., use of sediment for wetland or beach accretion for flood protection)

Source: Preparing for the Next Level, 2009; California Climate Adaptation Strategy, 2009; and Adaptation Toolkit: Sea Level Rise and Coastal Land Use, 2011.

Figure 7.1 through Figure 7.8 illustrate several of the adaption measures listed in Table 7.1.

Figure 7.1 Levee Construction

Figure 7.2 Freeway On Top Of A Levee

Figure 7.3 Rendering Of Levee Placed Out Into The Bay And Wetland Development Inboard of The Levee

Figure 7.4 Demountable Floodwall Along Urban Waterfront

Figure 7.5 Glass Wave Overtopping Wall On A Levee

Figure 7.6 Raising Of Existing Levee

Figure 7.7 Residential Development As Flood Protection Barrier

Figure 7.8 Artist Impression Of Levee Combined With Urban Functions

7.3 Methodology to Analyze and Use Risk Profiles for Adaptation Planning

7.3.1 EVALUATION OF RISK PROFILES

The information presented in the risk profiles (Appendix C) provides valuable information to help understand the most appropriate adaptation measure for a particular transportation asset. Transportation assets with the highest risk ratings should be addressed first, as the impacts of SLR are likely to occur sooner, and the consequences are high relative to other assets. The information in the risk profile can be assessed in six steps:

1. *Exposure* – How would the transportation asset be affected by inundation at midcentury, and what would the impacts be at the end of the century (for this example, we have used the 16-inch and 55-inch 100-year stillwater elevation [SWEL] scenarios)? For example:
    a. If the inundation would be less than 1 foot and would occur only during an extreme weather event, then improved drainage, reinforced foundations, temporary closure, or a demountable flood wall may be appropriate.
    b. If the inundation would be permanent and more than 1 foot, then raising the asset, building a flood protection structure, or abandonment of the asset may be appropriate.
2. *Sensitivity* – What characteristics of the asset can be used to understand its sensitivity to climate change stressors? For example:

a. If the asset is in poor condition, not yet seismically upgraded, or near the end of its service life, opportunistic measures should be taken to raise or reroute the asset, upgrade it with new materials, or waterproof it.
b. If the sensitivity of an asset can be reduced, the likelihood of occurrence of a climate change impact to this asset can also be reduced. Often, reducing sensitivity in this sense can offer a low cost and fast (interim) adaptation solution.

3. *Adaptive capacity* – How does adaptive capacity affect the vulnerability of the asset, and can this be used as part of an adaptation strategy? For example:
    a. If use of the asset can be wholly or partially rerouted, then structural measures could potentially be avoided; temporary closure could be acceptable in the short term.
4. *Consequence rating* – What are the consequences if this asset is temporarily or permanently out of use? What is its importance to the subregion or Bay Area or beyond? Assets with high consequence ratings should be prioritized for adaptation planning.
    a. If the asset has a high consequence rating, then temporary or partial closure is unlikely to be acceptable; an asset with a low consequence rating, however, could likely be temporarily or partially closed.
5. *Overtopping potential* – Which stretches of shoreline would be overtopped and therefore, would be responsible for inundation of the asset? (An explanation of overtopping is presented in Chapter 4.) For example:
    a. If a short length of shoreline is overtopped, this segment alone could be raised.
    b. If a long length of shoreline is overtopped, a major rebuild, raise, or strengthening of the entire shoreline may be required.
6. *Shoreline systems* – Are there other assets protected by the same shoreline system, and what type of shoreline category does the system consist of? (Descriptions and location of the different shoreline assets are presented in Chapter 2.) For example:
    a. If more than one system or asset is involved, more jurisdictions may need to be involved, and more complex solutions and planning may be required.

Table D1 in Appendix D provides additional examples of how to interpret the information in the risk profiles to inform decisions about potential adaptation measures.

7.3.2 USE OF EVALUATION CRITERIA

After going through these six steps, decision makers can evaluate the adaptation measures (presented in Table 7.1) that may be suitable to reduce the risk of inundation from SLR and the level of service that the adaptation measures will facilitate.

In addition to the categories of adaptation measures, **Error! Reference source not found.**a range of criteria and considerations should be used to evaluate the different adaptation measures, presented in **Error! Reference source not found.**. These criteria have been grouped according to the lenses of economy, ecology, equity, and governance, defined in the larger Adapting to Rising Tides project:

- Equity – Addresses the effects on communities and the services on which they rely, with specific attention to disproportionate impacts due to existing inequalities.
- Economy – Addresses the economic values that may be affected, such as costs of physical/infrastructure damages or lost revenues during periods of recovery.
- Ecology – Describes the environmental values that may be affected, including ecosystem function and services and species biodiversity.
- Governance – Addresses factors such as ownership, management responsibilities, jurisdiction, mandates, and organizational structure that influence vulnerability and resilience.

Table 7.2 Criteria for Helping Selection of Adaptation Measures

Economy	Ecology
- *Protection of functionality* – Although the continued use of the asset may be limited, the function of the system as a whole can be protected if other facilities (e.g., Bay Area Rapid Transit [BART] or ferries, alternative routes) can provide the same or similar functionality. - *Protection of asset* – When the asset is protected, the asset could still be used. - *Economic benefit* – Does the improved flood protection/climate resiliency spur new investment or growth? - *Cost and time to build* – What are the time and costs associated with implementing the adaptation measures? - *Operation and maintenance cost* – What are the operation and maintenance costs? - *Spatial requirements* – How much land is required to implement the adaptation measure? - *Adaptability* – Can an adaptation measure be designed to adapt to future climatic changes as likelihood increases or new technologies become available? - *Applicability in time* – Which measures are appropriate for the midterm and which for the longer term, given different SLR scenarios?	- *Ecological value* – Does the adaptation measure provide benefits to the natural environment through species or habitat protection? - *Ecological function* – Does the adaptation measure improve ecological function (e.g., wetland vs. flood wall)? - *Sustainability (longevity)* – Do the different adaptation measures provide long-term sustainable solutions (e.g., next 50, 100, or 200 years)? - *Sustainability (materials)* – Are the materials used for the adaptation measure environmentally sustainable? - *Environmental impacts* – What are the environmental impacts of implementing the adaptation measure, can they be mitigated, and do they reduce green house gas emissions?
Equity	**Governance**
- *Safety*- does the adaptation measure enhance public safety and security? - *Environmental justice* – does the adaptation measure benefit underserved populations? - *Regional benefit* – Is there a regional benefit to the local community selecting a specific adaptation measure (e.g., systems approach to protect the region vs. asset-specific protection)? - *Awareness* – Does the measure enhance public awareness and technical knowledge about SLR? - *Public access and aesthetic importance* – Can the adaptation measure be integrated into the natural or urban landscape so that it becomes an amenity and (for example) provides public access to the shoreline? - *Unintentional consequences* – Are there beneficial or negative consequences to the surrounding community or other assets by implementing this measure?	- *Institutional (organizational) arrangements*, *including jurisdiction* – Are governmental bodies and current policies and regulations equipped to ensure or facilitate long-term planning and timely implementation of the adaptation measure? - *Funding* – Which organization is providing the funding for the adaptation measure, and are there funds available? - *Public or private land* – Which entity or individual owns the land, and how does this affect implementation of the adaptation measure? - *Policies* – Does the adaptation measure build on existing policies, and do new policies allow for modifications as new climate change data/insights become available? - *Development* – does the adaptation measure facilitate (undesired) development in low lying areas (through improving the flood protection level)?

Different weightings or rankings of importance can be applied to the criteria presented in Table 7.2. For example, more emphasis could be placed on the level of service an asset provides and its implementation cost (in the face of SLR). Whether to assign weightings to the criteria (or rankings of importance) is a determination to be made by transportation agencies. (Note that weightings were not assigned to the criteria for the example assets discussed in this chapter, but should be considered a potential approach by agencies when reviewing adaptation options for specific assets in the subregion.)

(Also note that the likelihood of climate change impacts occurring needs to be reviewed regularly, along with updates to regional climate modeling data, in case predictions regarding the depth and timing of SLR change (from the 16 inches predicted for midcentury and the 55 inches predicted for the end of century).

7.4 Example Assets

The two example assets selected to test the methodology presented in this chapter are the San Francisco-Oakland Bay Bridge, focusing on the bridge touchdown and toll plaza (R-12), and the Oakland Jack London Square Amtrak Station (T-05). These two assets were selected because they represent two different categories of transportation assets and are close to the shoreline. Assets close to the shoreline were selected to avoid overlapping with other sectors (e.g., communities, land) being addressed in the larger Adapting to Rising Tides project.

A range of adaptation measures can be considered from the options presented in Section 7.2 and the information provided by the risk profiles, as discussed in Section 7.3. The Project Management Team and the Consultant Team held a joint work session to select potentially applicable measures looking at midterm (16 inches + 100-year SWEL) and end-of-century (55 inches + 100-year SWEL) SLR scenarios for the two example assets. This was an initial, qualitative assessment that will need further investigation to determine the real cost-effectiveness, applicability, and viability of proposed adaptation measures. The structural measures discussed in this session are further described in Sections 7.4.1. and 7.4.2. Due to time constraints, nonstructural adaptation measures were not discussed during the meeting, but a narrative with some suggested measures is provided in Section 7.4.3. Note that the adaptation measures described cannot be seen in isolation of one another— ultimately, a system consisting of a combination of different types of adaptation measures, both structural and nonstructural, will have to be developed to protect against inundation from SLR.

7.4.1 SAN FRANCISCO–OAKLAND BAY BRIDGE

The San Francisco–Oakland Bay Bridge connects Alameda County with the City and County of San Francisco. For this assessment, the bridge touchdown on the Oakland side and toll plaza are considered. Also note that the Bay Bridge does not function in isolation and should be considered in relation to the freeways it connects with.

A review of the risk profile identifies that:

1. The *exposure* is rated medium because the bridge would be inundated only under the 16 inches + 100-year SWEL and 55 inches + 100-year SWEL SLR scenarios. However, under both scenarios, significant inundation could occur (2 and 5 feet) that could be exacerbated by wind wave effects.
2. The *sensitivity* of the asset is high because of the high level of use and very high liquefaction potential (although the new span under construction is being built to current seismic standards). Given its high operations and maintenance (O&M) costs, opportunistic measures could be considered as part of scheduled maintenance and upgrades to the facility.
3. Some *adaptive capacity* is provided by the alternative routes of BART and ferries, but this is likely inadequate for the volume of commuters and for goods movement. Given its limited adaptive capacity, structural adaptation of either the asset or the region will be critical.
4. The *consequence rating* for this asset is high due to its high level of use and importance to the region, limiting options for temporary or partial closure during inundation under the midcentury scenario.
5. The bridge touchdown and toll plaza are protected by Shoreline System 2, which is a combination of engineered shoreline protection and natural shoreline (wetlands). The overtopping potential at midcentury and at the end of the century is quite high: 10,510 feet of shoreline would be overtopped by midcentury at an average depth of 1.7 feet, and at the end of the century, more than 16,900 feet would be overtopped at an average depth of 3.9 feet for the 16 inches + 100-year SWEL and 55 inches + 100-year SWEL SLR scenarios, respectively. Asset-specific adaptation could, therefore, still have significant impacts on the region surrounding the asset. Other transportation assets that are affected by overtopping of Shoreline System 2 include other parts of Interstate 80 (I-80), West Grand Avenue, Mandela Parkway, Burma Road, 7th Street Highway and Railroad Pumps (55 inches), and Union Pacific Martinez subdivision.

Table 7.3 provides an overview of potential adaptation measures for the San Francisco-Oakland Bay Bridge. These measures are described in more detail in the paragraphs below.

Table 7.3 Suggested Potential Adaptation Strategies for the San Francisco-Oakland Bay Bridge

	Midcentury	End-of-Century
Asset-specific adaptation	- Improve drainage - Retrofit – make waterproof - Raise touchdown and toll plaza area - Partial closure	- Raise road surface - Build causeway
Regional adaptation (along Shoreline System 2)	- Create berm - Wetland restoration/ creation - Construct floodwall	- Build levee - Build floodwall - Wetland restoration/ creation
Nonstructural adaptation	- Develop new building and design codes - Revise transportation planning guidance and policy - Form multi-jurisdictional partnerships	- Continue implementation and revision of nonstructural adaptation measures as needed

ASSET-SPECIFIC ADAPTATION

Near-term and midterm asset-specific adaptation for the Bay Bridge touchdown and toll plaza seems to be a viable option, as limited inundation will occur under the midcentury scenario. Minor modifications to the asset can be made in an opportunistic manner during scheduled maintenance to mitigate for future inundation to improve resilience to flooding. The following adaptation measures are considered for this location:

- Improve drainage – The drainage system around the freeway and the toll plaza could be improved so that when inundation occurs, there might be only partial closure of the roadway and, after a storm/high tide event, water would drain off the road surface quickly enough to minimize disruption. This measure can be considered "low regret" adaptation.
- Retrofit – To minimize the consequences of temporary inundation for the physical infrastructure of the asset, retrofitting can be considered. For the toll plaza, this would require that water-sensitive elements (such as wiring and electronics) be placed above a certain flood elevation. Entrances to buildings, buildings themselves, and toll booths can be made flood resilient through water proofing so that they can withstand temporary inundation. This measure would assume periodic partial or temporary closure of the freeway. (The level of service required would determine whether this adaptation response is considered adequate.)
- Raise road surface – As part of regularly scheduled maintenance for the midcentury planning horizon, raising the road in areas identified as vulnerable to inundation could be considered.
- Conduct partial or temporary closure – A nonstructural/management option during extreme events could be to close part or all parts of the freeway. (The level of service required would determine whether this adaptation response is considered adequate.) It is unlikely that recurring closure would be acceptable.

For the end-of-century scenario, minor modifications to the bridge touchdown and toll plaza would not likely be adequate to address the projected inundation. Given the potential consequences of this impact, the following more drastic adaptation measures can be considered:

- Raise road surface – Rather than raising the road during regularly scheduled maintenance, a more proactive approach could address greater inundation levels. The entire freeway could be elevated above the end-of-century 100-year storm level. Although this is described as an asset-specific measure, it might also provide benefits to the region because the raised road could serve as a levee protecting West Oakland.
- Build causeway – The freeway leading up to the Bay Bridge could be transformed into a causeway bridging the low-lying areas, similar to the Hayward–San Mateo Bridge that spans part of the bay. It would be very expensive, however, to accommodate a toll plaza on a causeway.

REGIONAL ADAPTATION

For the midcentury scenario, with only minor modifications to the landscape, most of the bridge touchdown, the toll plaza, and I-80 leading up to the bridge could be protected from inundation, which would also protect a wider area. Note that these adaptation measures would become part of a flood control system that might extend beyond the immediate area to create a closed flood protection system:

- Create berm – Along the perimeter of the freeway and the off- and on-ramps, a berm could be constructed to keep rising tides back. With this measure, the drainage system of the freeway and toll plaza would need to be altered, and pumps might be needed to pump out stormwater. This berm could be constructed such that it allows for modifications in the future to withstand greater SLR.
- Support wetland growth – Wetlands are able to absorb wave action and can reduce flood elevations at the asset. Wetlands are located along the north side of the toll plaza and I-80. If wetlands are able to grow organically with SLR (through sediment deposition, for example) they provide a natural and attractive form of flood protection. Note that fringing wetlands can reduce the flooding only associated with waves. High tide and storm stillwater levels would still inundate the shoreline unimpeded. A

recent study by PRBO Conservation Science (PLoS 2011), however, indicates that it is unlikely that Bay Area marshes will be able to keep pace with anticipated SLR at the end of the century.

- Construct floodwall – A small floodwall could be constructed along the perimeter of the freeway to prevent flooding and wave overtopping at the asset. A floodwall would impair the existing drainage system, which would therefore have to be modified as well (e.g., installation of pumps).

Regional adaptation at the end of the century would require greater interventions to deal with the potential inundation scenarios. Without major interventions, it is unlikely that wetlands would be able to address a 55-inch SLR scenario and would reduce the impacts of flooding associated only with waves.

- Construct levees – A berm built at midcentury could be reconstructed as a levee. As discussed under asset-specific adaptation, an elevated freeway could also be built on top of a new levee, which would also serve a regional flood protection function.
- Construct floodwall – A flood wall built at midcentury could be strengthened and raised.
- Support wetland growth/build wetlands – As stated earlier wetlands are able to absorb wave action and can reduce flood elevations at the asset. It is unlikely that wetlands will accrete to the end of century level of SLR. Therefore, wetland growth could be supported by beneficial use of dredged material. However, to provide proper flood protection, this measure likely should be integrated with the construction of a levee or floodwall further inland.

NONSTRUCTURAL ADAPTATION

As stated earlier, given the importance of this asset, temporary closure, rerouting traffic, using an alternative mode of transportation or even abandoning the asset are not considered viable options for non-structural adaptation measures. Measures specific to this asset include:

- Changes to building codes and design guidance – As new designs and plans are made for construction, retrofitting, or maintenance, they should include guidance on how to adapt to SLR. This guidance can help enable the implementation of structural measures, such as improving drainage, raising the road surface, or making structures around the touchdown and toll plaza more resilient to flooding.
- Modification of policies and planning guidelines – For proactive planning and to facilitate adaptation to rising sea levels, existing policies for SLR and flood management for this asset should be reviewed and revised.
- Multi-Jurisdictional Partnerships – Since areas inland of the San Francisco-Oakland Bay Bridge peninsula are vulnerable to flooding that originates at the shoreline of this facility, exploring partnerships with the Port of Oakland, City of Oakland and City of Emeryville may facilitate cost-sharing or implementation of structural solutions needed to address vulnerabilities and risks identified in the risk profile. The Bay Bridge Peninsula is currently the subject of a collaborative planning effort being conducted by Caltrans, the Bay Area Toll Authority, the Port of Oakland, City of Oakland, BCDC, the East Bay Regional Park District and East Bay Municipal Utility District to facilitate redevelopment of the peninsula for a mix of uses. This partnership could expand its focus to address adaptation solutions in conjunction with other planning.

7.4.2 OAKLAND JACK LONDON SQUARE AMTRAK STATION

The Oakland Jack London Square Amtrak Station is an at-grade, multi-modal facility on the Capitol Corridor. Although the risk profile assesses only the station and the passengers that pass through the station, the Union Pacific Niles subdivision railroad track serving the station is also an important goods movement corridor for the Port of Oakland, and the tracks would be affected by inundation near the station and at other locations in the subregion. Although the impacts to the station itself can be limited, the major concern is the inundation of railroad tracks both close to the station and at other locations in the subregion.

A review of the risk profile identifies that:

1. The *exposure* is rated medium for this asset because inundation under the 55 inches + 100-year SWEL SLR scenario would be about 1 foot. There would be no impact on the station at 16 inches + 100-year SWEL, except for potential wind wave impacts by midcentury. The railroad tracks would be affected under the 16 inches + 100-year SWEL scenario. Given the minor impacts at midcentury, these could likely be mitigated with little intervention, if any.
2. During the study, limited information was available on *sensitivity* for this asset. More information should be obtained to investigate if implementation of any adaptation measure could go along with scheduled maintenance or construction.
3. The *adaptive capacity* is inadequate, with the nearest station along the line (Emeryville) located 4 miles away. This means that adaptation of the asset or the shoreline protecting it is necessary.
4. *Consequence* is rated moderate for time to rebuild and commuter use and low for all other considerations. The overall consequence rating makes the station a low-risk asset. This could imply that temporary closure might be an option.
5. Shoreline System 3 protects the Amtrak station. Although the shoreline would be overtopped at 16 inches + 100-year SWEL, this overtopping would result in minimal inundation on land in the vicinity of the asset and no inundation at the asset. At 55 inches + 100-year SWEL, the overtopping of the shoreline would be significant, with an average overtopping depth of 2.6 feet and more than 20,000 feet of the shoreline overtopped.

Many other assets are protected by Shoreline System 3, including 7th Street Highway and Railroad Pumps (55 inches), Capitol Corridor Norcal O&M Yard, Burlington Northern Santa Fe International Gateway Intermodal Yard, Jack London Square Ferry Terminal, elevated BART line (Transbay Tube and Oakland Wye). However, not all these assets would be inundated from shoreline overtopping close to this train station.

Table 7.4 provides an overview of potential suggested adaptation measures for the Oakland Jack London Square Amtrak Station. These measures are described in more detail in the paragraphs below.

Table 7.4 Potential Suggested Adaptation Strategies for the Oakland Jack London Square Amtrak Station

	Midcentury	End-of-Century
Adaptation of asset	- Limited impacts – consider revising asset management plans to incorporate considerations of end of the century impacts	- Improve drainage - Retrofit – make waterproof - Temporary closure - Raise station and/or track - Relocation
Regional adaptation (along Shoreline System 3)	- Limited impacts – consider revising shoreline protection plans to incorporate considerations of end of the century impacts	- Construct floodwall - Build levee - Integrate flood protection in urban fabric
Nonstructural adaptation	- Temporary closure - Providing alternative mode of transportation - Abandoning the asset and not replacing it - New building and design codes - Revision of planning guidance and policy	- Continue implementation and revision of nonstructural adaptation measures as needed

ASSET-SPECIFIC ADAPTATION

There would be very little impact on the Oakland Jack London Square Amtrak Station under the midcentury SLR scenario, apart from possible wind wave effects. Therefore, the range of potential adaptation measures focuses on the end-of-century SLR scenario. Minor modifications to the asset can be made in an opportunistic manner during scheduled maintenance to mitigate for future inundation to improve resilience to flooding.

- Improve drainage – The drainage system around the station could be improved so that when inundation occurs, the station itself might not be affected, or at least would be only temporarily closed. Improved drainage would enhance the resiliency of the station and would drain off floodwater more quickly.
- Retrofit – Modifications to entrances of the station would minimize the volume of floodwater that might inundate the station, and placing water-sensitive elements (such as wiring and electronics) above a certain flood elevation would minimize damage in the event of flooding. Temporary closure of the station might still be required under this measure.
- Raise railroad track and/or station – The station and the railroad tracks could be raised above the level of inundation. However, raising the railroad track adequately might be difficult or very expensive because many other transportation assets (e.g., bridges) cross the tracks, and adequate clearances must be maintained.
- Conduct partial or temporary closure – A nonstructural/management option during extreme events could be to close part or all of the station. (The level of service required would determine whether this adaptation response is considered adequate.) It is unlikely that recurring closure would be acceptable. In the case of such closures, passengers using the station could be served at adjacent stations (e.g., Emeryville or Oakland Coliseum), or “bus bridges” could connect passengers traveling to/from the Jack London Square area with trains at other locations. An alternative route for goods traffic is less readily available.

REGIONAL ADAPTATION

Regional adaptation for the Oakland Jack London Square Amtrak Station and tracks would mean protecting the area around Jack London Square and the Lake Merritt Channel:

- Construct permanent or temporary floodwall/barrier – With the heavily developed and engineered waterfront at Jack London Square, there is limited space available to construct flood protection. Temporary or permanent floodwalls or barriers that have a small footprint could be considered. Temporary barriers could be used as an early adaptation measure and installed, with proper forecasting, before a storm event. Permanent floodwalls could be considered as a measure for the longer term and could be integrated into the design of the waterfront.
- Build levee – The waterfront of Jack London Square is not suitable for the construction of a levee. Levees could be considered along the Lake Merritt Channel but could significantly affect the recreational values along the Lake Merritt Connector Trail. With this measure, raising of the railroad tracks at the channel might still be needed.
- Integrate flood protection into the urban fabric – As the waterfront of Jack London Square is renewed and redeveloped over the next decades, building codes could be modified so that new development along the waterfront (e.g., residential or commercial) also serves as flood protection barrier and becomes an integrated part of a flood protection system.

NONSTRUCTURAL ADAPTATION

Due to its low level of use, more nonstructural measures are possible for this asset than for the Bay Bridge (R-12). Measures that can be taken at this asset include:

- Temporary closure – If the area surrounding the station is temporarily inundated and the tracks are still operable, then temporary closure of the station can be an option.
- Providing an alternative mode of transportation – Along with the measure above passengers can be offered a different mode of transportation (to get to the Emeryville station for example). Providing an alternative for goods movement that passes through the station is considered less viable.
- Abandoning the asset – If the inundation impacts are too great and the capital expense to modify the asset is not justified, abandoning the station could be considered.
- Revision of building codes and design guidance – To enable the implementation of structural measures, such as improving drainage, raising the railroad tracks or making the station itself more resilient to flooding or providing design guidance or alternative building codes can be considered to ensure future use of the station.
- Policies and jurisdiction – With the location of the station in a heavily urbanized area and with many government agencies involved that are responsible for transportation, land use planning and flood protection, all with overlapping responsibilities, it will be difficult to make specific policy changes related to flood management/SLR geared to this asset alone . Regional coordination will be needed to accommodate this.

7.4.3 NONSTRUCTURAL REGIONAL ADAPTATION MEASURES

An integrated regional adaptation strategy also should involve nonstructural regional measures. Some of the regional nonstructural measures relevant for both the example assets that could be considered by transportation and planning agencies in developing SLR adaptation plans include:

- Stakeholder and community awareness and input – To gain critical public understanding of, and support for, implementation of climate change adaptation plans, public education and outreach could be conducted. Stakeholder input is also essential to help identify and shape the most appropriate adaptation measures for a given asset and location, particularly if the measure may have regional impacts. Outreach also provides an opportunity to explain how local planning decisions should be informed by detailed risk and vulnerability assessments to ensure the prioritization of actions. These efforts help to create greater awareness and a more resilient community.
- Increased technical knowledge and capacity – To allow agencies to better understand the impacts of climate change and the different options for adaptation, further research and education is needed. Building up the level of knowledge and technical capacity through research and education would allow for development of new climate change adaptation plans and smoother implementation.
- Planning and policy making – This option was also discussed as part of the asset-specific measures. However, many planning and policy-making decisions are made at the regional level and then applied at the local level or in this case, to specific assets. Many existing government policies do not yet take SLR into account and need to do so. This applies to planning policy and guidance documents, building codes, design standards, and zoning requirements, for example. California and the Bay Area, in particular, however, are quite progressive when it comes to addressing climate change issues and are leaders in the United States. This is demonstrated, for example, by the Ocean Protection Council Guidance on SLR, California Department of Transportation guidance on SLR, and the recent Bay Plan Amendment of the San Francisco Bay Conservation and Development Commission. The Bay Plan Amendment requires new development along the bay potentially affected by 16 inches of SLR to conduct a vulnerability assessment and, if vulnerable, clearly describe the economic and/or ecological benefits of the project. For transportation planning, local and regional entities will be looking for guidance from other regional and state organizations on how to incorporate climate change into planning.
- Funding – Funding is needed to conduct further vulnerability assessments and adaptation planning analyses and implement climate change adaptation plans for both example assets. Adapting to rising tides will inevitably bring additional costs to their capital improvement projects. Funding can be sought through traditional mechanisms, but also new funding methods could be considered, such as through public private partnerships and new or other user fees. Planning proactively for SLR now should avoid major unexpected costs in the future. In addition, being prepared for the risk of climate change should attract new investments and make the Bay Area more competitive compared to other regions around the world.
- New and innovative partnerships – To research, fund, and implement climate change adaptation planning, new partnerships should be fostered to explore and establish cooperation among research institutions, governments, nonprofit organizations, and business entities to prepare for climate change. This can involve public private partnerships, in which a new commercial or residential development funds (part of) the climate change adaptation measures protecting a larger area. The business community can potentially take the lead in driving the climate adaptation debate and spur government and related agencies to take proactive measures to keep the region competitive. This could involve new partnerships to share knowledge and expertise on climate adaptation because many other regions will be affected by SLR.

7.5 Next Steps in Adaptation Planning

This chapter provides preliminary suggestions for potential climate change adaptation measures for the Alameda County subregion, but this is only the first step in developing an adaptation plan. The wealth of information that has been generated in this pilot project can be more thoroughly analyzed for all the selected representative assets to inform further decision making on adaptation measures. Stakeholder consultation will be a vital part of this process. The Adapting to Rising Tides program will take the outputs from this study to inform the 2012 and 2013 adaptation planning efforts for all sectors within the subregion. As it specifically relates to transportation planning, the following potential projects are recommended:

- Prepare further vulnerability and risk assessments of some of the transportation assets that could not be included in this study because of time and budget constraints, using the methodology developed as part of the pilot project and drawing on the new inundation mapping. In addition, a more in-depth analysis of the inundation mapping and shoreline overtopping information for specific transportation assets could be carried out to better understand the potential impacts under different storm scenarios and to inform the selection of adaptation measures.
- Conduct a more detailed alternatives analysis and feasibility study of different climate change adaptation measures at selected locations, reviewing all the criteria (relative to economy, ecology, equity, and governance) outlined in Table 7.1 This study could be accompanied by visualizations of adaptation measures under different SLR scenarios. These results can then be discussed with stakeholders to identify the most appropriate and cost-effective solutions.
- Conduct traffic flow and economic impact analyses to understand the primary and secondary effects of reduced mobility in the Bay Area attributable to SLR inundation of transportation assets.
- Ensure that all assets due for upgrade, repair, or retrofit in the near future are reviewed for adaptation opportunities, particularly in terms of new materials, drainage, and waterproofing improvements.
- Develop a SLR or climate change preparedness plan for the Metropolitan Transportation Commission that serves as a guidance document for local and other regional transportation agencies on how they can incorporate SLR into their own transportation planning.

7.6 References

California Natural Resources Agency. 2009. *2009 California Climate Adaptation Strategy, a Report to the Governor of the State of California in Response to Executive Order S-13-2008.* Available: http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF.

San Francisco Bay: Preparing for the Next Level (BCDC 2009)

Stralberg D, Brennan M, Callaway JC, Wood JK, Schile LM, et al. (2011) Evaluating Tidal Marsh Sustainability in the Face of Sea-Level Rise: A Hybrid Modeling Approach Applied to San Francisco Bay. PLoS ONE 6(11)

Adaptation Tool Kit: Sea-Level rise & Coastal Land Use How Governments Can Use Land Use Practices to Adapt to Sea Level Rise. (Georgetown Climate Centre 2011)