CHAPTER 5

TRANSPORTATION

Transportation, including all the ways people travel within San Francisco, supports economic activity and quality of life.

Residents, commuters, and visitors all use the road network, transit systems, and bicycle and pedestrian infrastructure to get around. People make over four million trips per day on a typical weekday to, from, and within San Francisco by various means – walking, cycling, taking transit, driving, and other travel modes.

San Francisco's local transportation network is overseen primarily by the San Francisco Municipal Transportation Agency (SFMTA), with some overlapping responsibility by San Francisco Public Works (Public Works), the San Francisco County Transportation Authority (SFCTA) and the Port. Regional transportation providers also provide service to, from, and within San Francisco, including AC Transit, BART, CalTrain, Golden Gate Transit, Water Emergency Transportation Authority (WETA), and Sam Trans. The Transbay Joint Powers Authority (TJPA) operates and maintains the Salesforce Transit Center and the Downtown Rail Extension. Each of these agencies has its own capital improvement program. In addition, numerous private mobility services operate on City streets and sidewalks.

The overall transportation network consists of roadways, local and regional transit infrastructure, maintenance and storage facilities, parking, bicycle and pedestrian networks, and an increasing diverse suite of emerging mobility services. The following sections describe the various components of the City's multimodal transportation system and provide information about how key elements of the system may be vulnerable to SLR and coastal flooding.

5.1 ROADWAYS

San Francisco's roadways are a networked system of freeways, and major and minor streets that provide the main pathway for vehicle traffic throughout the City. The transportation network links people with community facilities and services, jobs, family and friends, recreation, and other destinations within the City and throughout the Bay Area region. The City's public ground transportation system (Section 5.3 - 5.5) relies on the roadway network for its safe and reliable operations. The roadways support pedestrian use, bicycling, public transit, vehicle traffic (both commercial and private), and parking. Many roadways within the City are routinely closed to vehicle traffic to support parades, demonstrations, and other recreational uses.

San Francisco's roadway network includes 1,088 miles of roadways and 447 miles of bicycle streets, of which 121 miles are considered the "high-quality bike network."[1]

When roadways are flooded, all transportation modes are affected (e.g., motor vehicles, public transit, bicycles, etc.) and traffic congestion is more likely to occur as traffic is rerouted onto alternate streets, where possible. The roadway surface and subsurface materials can degrade, particularly with repeated inundation by saltwater. As the frequency of flooding increases with SLR, roadways are likely to erode and subside. Electrical components such as traffic signals, lighting, and control systems are particularly sensitive to any inundation. Flooding along roadways can

1 San Francisco Municipal Transportation Agency (SFMTA). https://www.sfmta.com/sites/default/files/reports-and-documents/2019/05/sfmta_2019_bike_program_report.pdf. "High-quality Bike Network" includes bike paths, protected bikeways, neighborways, and buffered bike lanes.

Photo 5.1 San Francisco street. Jeremy Menzies, SFMTA

also provide a conduit for floodwaters to enter utility access holes, vents, underground tunnels, and other low-lying or subsurface infrastructure.

This section describes the roadways that intersect or lie within the SLR Vulnerability Zone, describes their vulnerabilities, and highlights the consequences that could occur if roadway segments are flooded.

5.1.1 Potentially Vulnerable Assets

San Francisco's roadways are classified by their functional use, as described in Table 5.1 and shown in Figure 5.1. The functional use affects the City and roadway users in the event the roadway, or a portion of the roadway, is flooded.

Table 5.1 Functional Transportation Classifications[2]

CLASSIFICATION	DEFINITION
Freeways	Very high-capacity facilities with limited access; primary function is to carry intercity traffic; they may, because of route location, also serve the secondary function of providing for travel between distant sections in the City.
Major Arterials	Cross-town thoroughfares whose primary function is to link districts within the City and to distribute traffic from and to the freeways; these are routes generally of citywide significance; of varying capacity depending on the travel demand for the specific direction and adjacent land uses.
Transit Preferential Streets[3]	Streets with a primary transit function that are not classified as major arterials but experience significant conflicts with automobile traffic.
Secondary Arterials	Primarily intra-district routes of varying capacity serving as collectors for the major thoroughfares; in some cases, supplemental to the major arterial system.
Recreational Streets	A special category of street whose major function is to provide for slow, pleasure drives and cyclist and pedestrian use; more highly valued for recreational use than for traffic movement. The order of priority for these streets should be to accommodate: pedestrians, hiking trails, or wilderness routes, as appropriate; cyclists; equestrians; and automobile scenic driving. Speeds should be slow and consistent with the topography and nature of the area, and there should be adequate parking outside of natural areas.
Collector and Local Streets	**Collector Streets:** Relatively low-capacity streets serving local distribution functions primarily in large, low-density areas, connecting to major and secondary arterials. Also includes streets intended for access to abutting residential and other land uses, rather than for through traffic. **Local Streets:** All other streets intended for access to abutting residential and other land uses, rather than for through traffic; generally, of lowest capacity.
Truck Routes	Designated routes through the City that have, or can accommodate, significant truck traffic for goods movement.

2 These classifications are based on those set by the Federal Highway Administration and adopted by the State of California and the city of San Francisco as documented in the Transportation Element of the General Plan. Source: City of San Francisco Planning Department. San Francisco General Plan, "Table 1: Classification of Elements in Vehicle Circulation Plan." Available at http://generalplan.sfplanning.org/I4_Transportation.htm.

3 Referred to as "Transit Conflict Streets" in the Transportation Element of the San Francisco General Plan

Figure 5.1 Overview of Roadways

Inundation at 108" Sea Level Rise

0 0.5 1.0 2.0
Miles

- Freeways
- Major Arterials
- Transit Preferential Streets
- Secondary Arterials
- Recreational Streets
- Collector and Local Streets
- Truck Routes

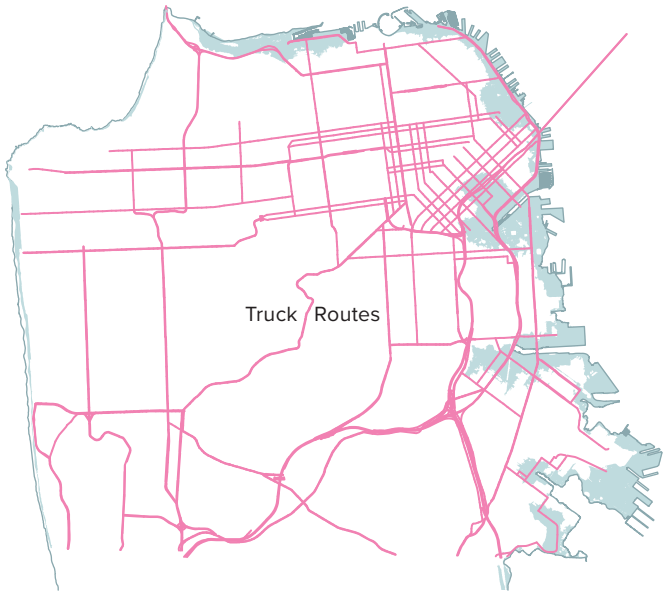

Photo 5.2 **Freeway approach to Bay Bridge.** Thomas Hawk (CC BY-NC 2.0)

Photo 5.3 **Geary Blvd - a major arterial.** Flickcr user eng1ne (CC BY 2.0)

5.1.1.1 Freeways

San Francisco has an urbanized roadway network with a limited number of freeways. Interstate 80 (I-80) enters San Francisco at the western terminus of the San Francisco – Oakland Bay Bridge (Bay Bridge) and continues for four miles until connecting with U.S. Highway 101 (US 101) (see Photo 5.2). I-80 is the only direct roadway link to the East Bay. It connects San Francisco to Oakland and other East Bay cities, and then continues to Sacramento, Reno, and across the country to New Jersey. US 101 operates as a freeway as it enters San Francisco at the San Francisco – San Mateo County line. At the Mission Street / Van Ness Avenue off-ramps, US 101 switches to using arterial streets to connect to the Golden Gate Bridge. US 101 and the Golden Gate Bridge are the only direct roadway link to Marin County and the North Bay. US 101 is also a core connection for commuters between San Francisco and Silicon Valley.

Interstate 280 (I-280) begins south of the Bay Bridge in the South of Market neighborhood, continuing south along the eastern edge of the City, and connecting with US 101 at the Alemany Maze. I-280 extends inland, connecting with California State Route 1 (SR 1) near John Daily Boulevard in Daly City, just south of the San Francisco – Daly City border. I-280 is also a core connection for commuters between San Francisco and Silicon Valley.

I-80 and I-280 are both elevated in areas of potential SLR exposure and, thus, less vulnerable to flooding. However, the footings of the elevated structures may be impacted by temporary flooding by saltwater (e.g., concrete structures may experience enhanced degradation and/or scour). In addition, the on- and off-ramps that connect with surface streets could be impacted through surface flooding. The I-280 on- and off-ramps at 6th and Brannon Street and 5th and King Street are within the SLR Vulnerability Zone. Along I-80, the on-and off-ramps at Fourth, Fifth, Harrison, and Bryant Streets are also within the SLR Vulnerability Zone. Portions of SR 1 are also within the SLR Vulnerability Zone.

Although alternative on- and off-ramps can be used to access the freeways, rerouting traffic increases traffic congestion on City streets. Local and regional public transit also uses the freeways, which would cause additional impacts to the transit system. Regional impacts associated with the freeways are being assessed through the Bay Area Adapting to Rising Tides regional assessment (see Chapter 4, *Supporting Assessments*).

5.1.1.2 Major Arterials

San Francisco is one of the few Bay Area cities with arterial thoroughfares instead of having numerous interstates and highways within the City, due largely to the City's unique geography and the strong public opposition to new freeway construction in the 1960s and 1970s. The arterials are classified as major (i.e., cross-town thoroughfares whose primary function is to link districts within the City and to distribute traffic from and to the freeways), and secondary (i.e., intra-district routes that also serve as collectors for

Photo 5.4 Market Street - a transit preferential street. Sergio Ruiz

Photo 5.5 Jefferson Street, a recreational street in Fisherman's Wharf. Flickr user Ray_LAC (CC BY 2.0)

the major arterials). Other major east-west arterials include Geary Boulevard, Lincoln Way / Fell Street, and Market Street / Portola Drive (see Photo 5.3). The major arterials are concentrated near the financial district and south of Market Street, and fan out to connect to other neighborhoods.

There is some redundancy and alternatives for primary arterials if impacted by flooding. Traffic could be rerouted onto other streets designed to carry lesser traffic loads; however, this also impacts cross-town traffic.

5.1.1.3 Transit Preferential Streets

Transit Preferential Streets are designed to expedite transit services and specifically the movement of transit vehicles. The red lanes and peak-hour transit lane restrictions associated with the City's Transit Preferential Streets serve to reduce congestion and parking movement-related delays within the designated transit lanes.

Transit preferential streets have limited redundancy, particularly for transit streets with tracks, because track-based transit cannot be rerouted. If vehicle traffic is rerouted onto transit preferential streets during a flood event, significant traffic and congestion impacts could occur.

Transit conflict streets in the SLR Vulnerability Zone include Market Street and Mission Street. These streets exhibit many of the same characteristics as major arterials and carry a significant volume of traffic in addition to significant numbers of transit vehicles. Market Street is a key multimodal transit corridor through core financial and commercial districts with multiple transportation stations (Bay Area Rapid Transit [BART] and Municipal Railway [Muni]) along the route, coupled with automobile and bicycle routes (see Photo 5.4). Market Street is also a key connector between the Ferry Terminal and other modes of transportation.

5.1.1.4 Secondary Arterials

Secondary arterials primarily consist of intra-district routes with varying capacity serving as collectors for the major thoroughfares; in some cases, supplemental to the major arterial system.

There is some redundancy and alternatives for secondary arterials if impacted by flooding. Traffic could be rerouted onto other streets designed to carry lesser traffic loads; however, this also impacts cross-town traffic.

5.1.1.5 Recreational Streets

Recreational streets provide multiple amenities, including park-like atmospheres and scenic views, while also accommodating automobile throughput. The streets tend to have lower speed limits, with a preference for cyclists, pedestrians, and, in some instances, equestrian use.

Although traffic on recreational streets can be rerouted if a portion of the street is flooded, the same user experience would not be provided. Recreational

Photo 5.6 A local city street.

streets provide a place-based use with automobile traffic providing the lowest value of use. Recreational streets in San Francisco include Jefferson and Beach Streets in the Fisherman's Wharf area (see Photo 5.5) and portions of Mason and Lincoln Streets in the Presidio area of San Francisco.

5.1.1.6 Collector and Local Streets

Collector and local streets include all other public roadways for vehicle traffic within the City. This includes collector streets that provide access throughput for low-density urban and residential areas and connect traffic flow with major and secondary arterials. This also includes local streets that are intended for residential access rather than for through traffic. Collector and local streets are typically low capacity and provide short-distance mobility (see Photo 5.6).

There is some redundancy for streets that serve a collector function; adjacent streets outside of flooded areas can provide this function with minor disruption and inconvenience, if they are not transit preferential streets. Rerouting motor vehicle traffic onto streets served by public transit (or by transit vehicles in non-revenue service) will likely increase transit delays and reduce service levels in areas beyond the immediate flooded zone. In addition, for businesses and residents located on impacted local streets, alternative routes would not provide direct access.

5.1.1.7 Truck Routes

Truck routes are a secondary roadway classification that is applied to designate the primary pathway through San Francisco for heavy truck traffic for delivering goods to and from San Francisco. The roadways are usually major arterials and key secondary arterials but can also include all roadway types from freeways to City streets, except for transit priority streets, as truck traffic is generally prohibited on these streets (see Sections 5.1.1.3 and 5.1.1.4).

5.1.1.8 Sidewalks and Pedestrian Facilities

San Francisco sidewalks allow pedestrian travel across the City and provide access to buildings, open spaces, roadways, and public transit. San Francisco sidewalks are typically six to 12 feet wide and have distinct zones that divide the sidewalk space into the pedestrian throughway, street curb, building frontage, and if space allows, street furnishings, planting strips, and lighting. Sidewalks also typically have subsurface utilities with access points for maintenance. Most sidewalks are elevated six to eight inches above the roadway surface and have curb ramps that provide disability access in compliance with the Americans with Disabilities Act (ADA).There are approximately 2,000 miles of sidewalk curb in San Francisco.[4]

In general, new roadways are designed to carry the 100-year flood event within the curb line (i.e., the roadway is intended to carry the floodwaters without flooding the adjacent sidewalk and structures). However, many roadways in San Francisco were constructed before this design criteria became standard practice. Many roadways and sidewalks have subsided and impacted their drainage potential, and in some areas roadways repairs and re-grading efforts have reduced flood capacity of the street.

Sidewalks are generally not sensitive to flooding and can resume their function once floodwaters recede; however, during flood events, accessibility and safety are issues. Traffic and pedestrian signals have conduits below grade and control boxes at grade that may be sensitive to flooding. Sidewalks have minimal adaptive capacity for flooding because they cannot be easily raised and need to consider ADA accessibility and maximum slope restrictions when meeting the roadway.

4 Based on a GIS analysis performed for the Citywide Infrastructure Level of Service Study, by Hatch Economics, 2019. Counting both sides of the street (but not accounting for breaks in the sidewalk where intersections may be), equals 2,267 linear miles of sidewalk curb, discounted by 10% to account for intersections.

5.1.1.9 Bicycle Facilities

San Francisco has 447 miles of streets on the bike network[5], of which 121 miles are counted as part of the "High-Quality Bike Network."[6] San Francisco bikeways are classified using the Caltrans classification system, as shown in Table 5.2. Bikeway designations are not a hierarchy. Each class of roadway has its appropriate application.

Bicycle lanes and bikeways can experience flooding without significant damage; however, there are impacts to accessibility and safety until floodwaters recede. During flood events, alternative bikeways and shared roadways can be used for bike mobility if needed; however, disruptions will occur. Similar to roadways, bicycle lanes have minimal adaptive capacity to adapt to flood events (Photo 5.7).

Photo 5.7 A protected bicycle lane on the Embarcadero. Sergio Ruiz

5 https://www.sfmta.com/sites/default/files/reports-and-documents/2019/05/sfmta_2019_bike_program_report.pdf; Mileage counts for bike network are directional: a 1-way street is counted as one mile, a two-way street is counted as two miles

6 "High-quality Bike Network" includes bike paths, protected bikeways, neighborways, and buffered bike lanes.

Table 5.2 California Department of Transportation Bikeway Classifications

CLASSIFICATION	DEFINITION
Shared Roadway (No Bikeway Designation)	Bicycle travel in the State occurring on streets and highways without bikeway designations. Street systems considered adequate for safe and efficient bicycle travel.
Bike Path (Class I Bikeway)	Bike paths providing mobility corridor that is not served by streets and highways or where a wide right-of-way exists to allow a bike path to be constructed away from the influence of parallel streets. Bike paths also offer recreational opportunities or serve as direct high-speed commute routes if cross-flow by motor vehicles and pedestrian conflicts is minimized. Commonly located along waterways, abandoned railroad rights-of-way, or within and between parks.
Bike Lane (Class II Bikeway)	Bike lanes are established along streets in corridors where there is significant bicycle demand. Bike lanes delineate the right-of-way assigned to bicyclists and motorists to provide for more predictable movements by each.
Bike Route (Class III Bikeway)	Bike routes are shared facilities which serve either to provide continuity to other bicycle facilities (usually Class II bikeways); or designate preferred routes through high-demand corridors. Bike routes are shared with motor vehicles; the routes are maintained consistent with the needs of bicyclists.
Separated Bikeways (Class IV Bikeway)	Separated bikeways are intended for the exclusive use of bicycles and require a separation between the bikeway and the through vehicle traffic. The separation may include, but is not limited to, grade separation, flexible posts, inflexible posts, inflexible barriers, or on-street parking.

Source: Caltrans. 2015. California Highway Design Manual. Available at http://www.dot.ca.gov/design/ manuals/hdm/chp1000.pdf.

Since 2006, bicycling has increased 184 percent with approximately 82,000 bicycle trips occurring around San Francisco daily.[7] In 2015, biking comprised 4.3 percent of all commute trips.[8] To accommodate the rapid growth in bicycling across San Francisco, SFMTA has focused on improvements to bicycle infrastructure through protected bikeways (bicycle lanes), neighborways, and streetscape projects. Protected bicycle lanes are physically separated from vehicle traffic using flexible posts, concrete barriers, or parking lanes. Neighborways are residential streets redesigned to promote increased foot and bicycle traffic. Streetscape projects are large-scale street plans that make streets safer through upgraded utilities, transit amenities, and lighting.

7 San Francisco Municipal Transportation Agency (SFMTA). 2016. 2015 Transportation Fact Sheet. Available at https://www.sfmta.com/reports/2015-transportation-fact-sheet.

8 San Francisco County Transportation Authority (SFCTA). 2017. San Francisco Transportation Plan 2040. Available at https://www.sfcta.org/san-francisco-transportation-plan-2040-plan-details.

As of 2017, San Francisco has 5,200 bicycle racks and 70 bicycle corrals dispersed throughout the City. By 2021, an additional 2,500 bicycle racks and 50 corrals are planned. Bicycle parking infrastructure that allows bikes to be secured is primarily made of durable metal structures with no mechanical or electrical equipment required for operation. Therefore, bicycle parking infrastructure has low sensitivity to flooding. Bicycle-share stations are discussed in Section 5.6.

5.1.2 Exposure Assessment

The exposure of each roadway and roadway right-of-way type was evaluated relative to the 10 SLR scenarios (see Chapter 2). The mileage of roadway type that could be inundated under each scenario was calculated and is presented in Table 5.3. The mileage of inundated roadway right-of-way access is presented in Table 5.4.

Table 5.3 Roadway Exposure Summary (Miles Inundated)

	Miles of Roadway within Each Sea Level Rise Scenario									
Roadway Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Freeways[9]	-	-	-	0.1	0.4	1.6	2.4	2.8	3.9	5.0
Major Arterials	-	-	0.1	0.8	1.1	6.4	7.6	8.2	9.6	10.9
Transit Preferential Streets	-	-	-	0.1	0.2	0.6	0.7	0.8	0.9	1.0
Secondary Arterials	-	-	-	-	0.1	0.7	1.0	1.4	2.2	3.3
Recreational Streets	-	-	0.2	0.3	0.7	1.8	2.4	2.5	2.5	2.6
Collector and Local Streets	-	0.2	4.7	8.7	14.1	32.2	41.0	46.1	53.1	60.1
Truck Routes	-	-	0.1	0.9	1.9	6.7	8.5	9.3	11.3	13.5

Table 5.4 Bicycle Facility Asset Exposure Summary (Miles Inundated)

	Miles of Bicycle Facility within Each Sea Level Rise Scenario									
Bicycle Facility	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Bike Path (Class I)	0.1	0.1	0.4	1.8	3.2	11.5	16.6	17.4	17.9	18.3
Bike Lane (Class II)	-	-	0.1	1.2	3.6	9.9	13.6	14.9	16.9	18.8
Bike Route (Class III)	-	-	0.9	1.4	2.2	7.3	8.6	9.7	12.0	13.7
Separated Bikeway (Class IV)	-	-	-	-	-	0.2	0.4	0.6	0.9	1.2

9 As noted in text, freeways are generally elevated, but freeway supports and ramps may be affected by SLR. This number represents all freeway miles within the SLR Vulnerability Zone.

5.1.3 Consequence Summary

This report evaluates key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Flooded roadways affect all transportation modes (i.e., motor vehicles, public transit, bicycles, etc.) and can cause traffic congestion on alternate streets. Critical access in neighborhoods and through traffic in large areas of the City would be impeded, affecting the ability to respond to emergencies, and everyday life. Degradation of the roadway surface and subsurface materials from repeated inundation by saltwater further stress an already stressed system and can cause additional road closures due to repairs. As the frequency of flooding increases with SLR, roadways are likely to erode and subside. Electrical components such as traffic signals, lighting, and control systems are particularly sensitive to any inundation. Flooding along roadways can also provide a conduit for floodwaters to enter utility access holes, vents, underground tunnels, and other low-lying or subsurface infrastructure. Permanent inundation would make roadways and the neighborhoods and destinations to which they provide access inaccessible.

Society and Equity: The number of vehicles using a roadway provides a good proxy for magnitude of impact. Freeway disruption impacts commuter traffic (person vehicles, car shares, public transportation, etc.), resulting in more dangerous road conditions, longer commute times, missed work days, and regional economic impacts on the labor force. I-80 and I-280 are also designated lifeline routes[10] and access is critical both before and after an emergency event.

Disruption along major and secondary arterials will impact commuters, cross-town traffic, local businesses, and residents. It could also result in longer transit times for emergency access vehicles, resulting in delays in lifesaving healthcare, fire suppression, and police support. Flooded roadways could also impair the City's ability to clear roadways after an earthquake. Clearing roadways is generally the first step to bring back other essential functions, such as power and water supply.[11]

Along transit preferential streets, such as Market Street, and other streets with fixed transit lines inaccessible portions of the roadway could cause major delays of critical public transportation routes and affect connections with regional transit links.

Disruption along City streets can impact residential access to home, school, work, local services, and parks, and can impact emergency vehicle access to residents. Inaccessible City streets in disadvantaged neighborhoods will be particularly impactful on community mobility, including access to public transportation, paratransit, schools, healthcare, and access to services and jobs. Flooding will likely require rerouting local buses and transit, impacting residents and causing delays in commute times.

Disruption to roadways could prevent or inhibit access to healthcare services (at a facility or in-home care); this may disproportionately impact disadvantaged communities, the elderly, young children, and those with pre-existing medical conditions. Disruption to roadways will also increase congestion on alternative routes, impacting traffic, travel times, and increasing the likelihood for accidents as well as exposing neighborhoods adjacent to alternate routes to more air pollution and associated health problems. Restrictions to sidewalk access during flood events can adversely impact pedestrian safety.

10 The criteria for state lifeline route designation include providing emergency relief access through or across a potentially impacted region, connecting major population centers within the region; for areas with more than one route providing interregional access, the route provides the most effective emergency relief access; providing direct or nearby access to and from major emergency response and recovery supply centers and staging areas; and providing access to an airport (military or civilian), seaport, major rail facility, or a major distribution center that would be involved in immediate relief activities. Source: Caltrans. Purpose and Need for Project, "Lifeline Structure." Available at http://www.dot.ca.gov/dist4/sfobb/PurposeandNeed.html.

11 The Lifelines Council of the City and County of San Francisco. 2014. Lifelines Interdependency Study. Report. April. Available at https://sfgov.org/orr/sites/default/files/documents/Lifelines%20Council%20Interdependency%20Study.pdf.

Limited alternate bike routes are available, and some routes may shift to shared roadways with vehicles. Alternate routes would have increased congestion and limited bike facilities, leading to potentially unsafe conditions for bicyclists. Bicycle commuters may shift to other transportation means, such as public transportation or personal vehicles.

Moped and e-bicycle charging stations would be inaccessible in flooded areas. Although moped and e-bicycles can be returned to charging stations in non-impacted areas, charging spaces could be limited. Mopeds and e-bicycles in the flooded areas would be inaccessible (and may be permanently damaged by floodwaters) for check out by local commuters and tourists. Safety issues could arise if commuters and tourists attempt to access charging stations in flooded areas.

Economy: If short- or long-term flooding occurs and causes freeway disruption, this can impact the movement of goods. This can also impact public transportation revenue (due to less workers flowing in/out) or shift revenue between agencies (e.g., from bus to BART). Disruption along transit preferential streets can cause delays and a reduction in transit agency revenue (i.e., decreased fares or ridership).

Disruption to truck routes can result in the delay or prevention of goods distribution and deliveries of commercial facilities, grocery stores, medical facilities, etc. Trucks are not as easily rerouted as other vehicles due to weight restrictions on potential alternate routes.

Disruptions along major and secondary arterials can impact patronage and access to local businesses adjacent to impacted routes. The flow of people in and out of the City will be impacted. Damage to the multimodal system will also require additional capital and operating funds to both protect and repair damage from flood events.

Environment: Flooded roadways may be contaminated by oil, gas, and other spilled substances. These contaminants will be mobilized and may drain to the sewer system, open space, wetland habitats, or directly to the ocean and Bay. Neighborhoods adjacent to alternate routes could be exposed to more air pollution from additional vehicles and associated congestion.

Governance: Managing and identifying alternate routes for vehicle traffic, public transportation, and truck routes may be a challenge during an extreme event. Identifying funds for the planning and repairs to damaged infrastructure will also require working with local, regional, state and federal partners.

5.2 BRIDGES

San Francisco's bridges provide vehicular, railroad, public transit, and bicycle/pedestrian access across waterways and/or above other City streets or parkways to connect adjacent areas. San Francisco bridges include four drawbridges, the Bay Bridge, and the Golden Gate Bridge (Photo 5.8). Although bridges are generally elevated structures, and vehicle traffic flow on the bridges may be above the floodwaters, the bridge supports (e.g., pilings, steel trusses), abutments, and bridge on- and off-ramps may be impacted by flooding at ground level or by an elevated water surface within the waterway itself.

The four drawbridges are vulnerable to SLR and coastal flooding, and the elevated approach to the Bay Bridge is also vulnerable. The Golden Gate Bridge abutment in San Francisco is elevated on a hill and located outside of the SLR Vulnerability Zone. The vulnerability of the Golden Gate Bridge's supporting structures to SLR was not evaluated as part of this Assessment.

This section describes the bridges that intersect or lie within the SLR Vulnerability Zone, describes their vulnerabilities, and highlights the consequences that could occur if these assets or their companion roadway segments (Section 5.1) are temporary flooded or permanently inundated.

5.2.1 Potentially Vulnerable Assets

The City of San Francisco has four drawbridges, including three historic drawbridges that were constructed in the early- to mid-19th century. Two drawbridges (Lefty O'Doul Third Street Bridge and Peter R. Maloney Fourth Street Bridge) cross the Mission Creek Chanel, and two drawbridges (Illinois Creek Bridge and the Third Street Bridge) cross the Islais Creek channel. Historically, these waterways extended farther inland and supported ship traffic, earning them a designation of a "navigable waterway." Over time, the upstream portions of both waterways were filled in and culverted (i.e., constrained in pipes below ground) and only the downstream tidal portions of both channels remain.

Photo 5.8 **Bay Bridge approach.** Todd Lappin (CC BY-NC-ND 2.0)

Because the designation of a navigable waterway remains, the U.S. Coast Guard regulates drawbridge operations and requires the drawbridges to remain in operational condition.

5.2.1.1 Lefty O' Doul Bridge

Lefty O'Doul Bridge on Third Street is a moveable bridge (i.e., drawbridge) that crosses Mission Creek Channel and connects the Mission Bay and China Basin neighborhoods (see Photo 5.9). It was completed in 1933 and is a registered San Francisco landmark (#194). The drawbridge allowed for cargo ship traffic to access the north bank of Mission Creek where bananas were offloaded and processed through the 1950s. In the 1960s, a community of about 35 boats and 20 houseboats was relocated from Islais Creek to Mission Creek; since the 1960s, the primary ship traffic through Mission Creek is recreational boaters. Currently, the drawbridge is undergoing mechanical and structural rehabilitation and is closed to navigation.

The bridge has five lanes that provide vehicular and shared bicycle mobility in addition to separated pedestrian walkways. There are three northbound lanes and two southbound lanes with no left turn onto Terry Francois Street. Future plans include a two-way cycle track on the easternmost lane. Lefty O'Doul Bridge has a single-level deck with structural components (support piles, steel trusses), mechanical components (counterweights, motors), and electrical components that allow the bridge to open for ship navigation in Mission Creek. Inundation of the mechanical or electrical components could impact bridge operations, although they are located at a higher elevation than the bridge deck.

The area surrounding Mission Creek is built on fill, and subsidence of the bridge approach slabs could increase with repeated flooding and increased high tides. Total and differential settlement due to subsidence of fill could adversely impact operation of the bridge. The lower portion of the bridge span already experiences submergence during present-day high tides; during very high tides, bearing plates and anchor bolts at the bridge pier become submerged and can reach the bottom flange of the main bridge stringers. Some high tides also overtop the concrete pier.

There is limited redundancy for bridges. Inland roadways can provide alternative routes for street traffic. However, Third Street is one of the primary north-south corridors on the southeast side of the City. Closures along Third Street would increase traffic and congestion. If drawbridge operations are impacted and the bridge cannot open for navigation, the primary impact would be to the houseboat community. Bridge operations may resume after floodwaters recede and inspections are completed.

Lefty O'Doul bridge will be inundated on the south side at Scenario 2 (24 inches of SLR or 12 inches of SLR and an annual extreme high tide with a 1-year recurrence interval) and on both sides at Scenario 4 (48 inches of SLR or six inches of SLR and a 100-year extreme tide).

5.2.1.2 Peter R. Maloney Fourth Street Bridge

Peter R. Maloney Bridge on Fourth Street is a drawbridge that crosses the Mission Creek Channel to connect the Mission Bay and China Basin neighborhoods. The bridge was completed in 1917 and is a registered historical landmark. Bridge rehabilitation work was completed in 2007; the rehabilitation included earthquake retrofitting, replacing mechanical and electrical operating equipment, and the addition of trackwork and an overheard catenary and traction electrification system to support the San Francisco Municipal Railway (Muni) T-Line public transportation route. Fourth Street Bridge is located inland (i.e., upstream or west) of Third Street Bridge (see Section 5.2.1.4).

This bridge has multiple vehicular lanes, supports the Muni T-Line, and has separated pedestrian and bicycle access. Fourth Street Bridge has a single-level deck and structural components (support piles, steel trusses), mechanical components (counterweights, motors), and electrical components that allow the bridge to open for ship navigation through the Mission Creek channel. Inundation of the mechanical or electrical components could impact bridge operations.

Similar to Lefty O'Doul Bridge, the drawbridge no longer supports cargo ship traffic within the channel. The primary ship traffic within the Mission Creek

Photo 5.9 **Lefty O'Doul Bridge.** Don Barrett (CC BY-NC-ND 2.0)

Photo 5.10 **Fourth Street Bridge.** Jim Maurer (CC BY-NC-ND 2.0)

channel is related to the sail boats docked near the houseboat community. In addition, houseboats may be moved out of the channel under the drawbridges for repair and/or maintenance (i.e., houseboats can be hauled out of the water at a shipyard for significant rehabilitation or repair).

The area surrounding Mission Creek is built on fill, and subsidence of the bridge approach slabs could increase with repeated flooding and increased high tides. There is limited redundancy for bridges. Inland roadways can provide alternative routes for street traffic.

Fourth Street is one of the primary north-south corridors on the southeast side of the City (Photo 5.10). Closures along Fourth Street would increase traffic and congestion. The Muni T-Line is track-based and could not be rerouted. If drawbridge operations are impacted and the bridge cannot open for navigation, the primary impact would be to the houseboat community.

Fourth Street bridge will be inundated on the south side at Scenario 2 (24 inches of SLR or 12 inches of SLR and an annual extreme high tide with a 1-year recurrence interval) and on both sides at Scenario 3 (36 inches of SLR or 12 inches of SLR and an annual extreme high tide with a 5-year recurrence interval).

5.2.1.3 Illinois Street Bridge

Illinois Street Bridge is a drawbridge that crosses the Islais Creek channel and connects the Hunter's Point/Bayview and Central Waterfront/Dogpatch neighborhoods. Illinois Street Bridge is the City's newest drawbridge. It was completed in 2006 and primarily serves to provide railroad and heavy truck access to Piers 90-96 (see Chapter 11, *Port of San Francisco*), while also relieving congestion on Third Street. The bridge includes two vehicle traffic lanes, a shared centerline railroad track, and separate bicycle/pedestrian lanes.

Unlike the historic truss design drawbridges, Illinois Street Bridge has a modern and low-profile design. It is operated by hydraulic cylinders that raise the bascule (i.e., bridge "leaf") 84 degrees to provide a navigable channel for boat traffic. This bridge is rarely opened and requires 72 hours advance notice for it to open. Historically, Islais Creek served as a docking area for World War II ocean-going vessels, and hosted cargo ships for transporting coconuts to a nearby coconut processing plant and sardines to support the local sardine canning industry. Today, Islais Creek channel does not support any commercial shipping industries inland of the drawbridges.

The lower portion of the bridge could experience submergence during present-day high tides. There is limited redundancy for bridges. Although inland roadways can provide alternative routes for light vehicle traffic, there are limited routes for heavy truck traffic, and no alternate routes for the railroad corridors or routes that could provide redundancy for street traffic, including Islais Creek Bridge. Closures along Illinois Street would increase traffic and congestion for the remaining transit network.

Photo 5.11 Islais Creek/Third Street Bridge. Craig Philpott

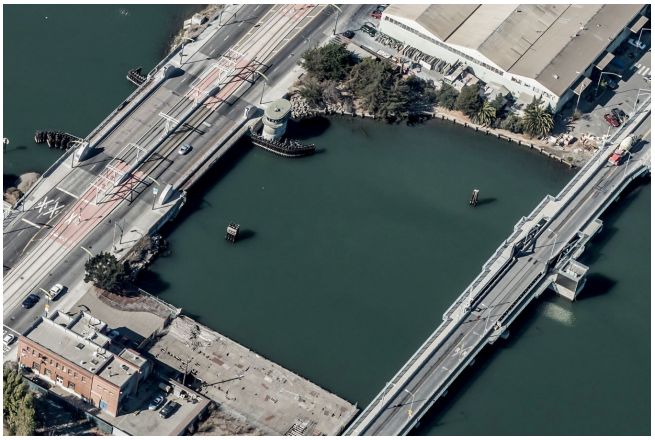

Photo 5.12 Aerial view of the Islais Creek/Third Street Bridge (left) and the Illinois Street Bridge (right). Bing Maps

This bridge access will be partially inundated at Scenario 4 (48 inches of SLR or six inches of SLR and a 100-year extreme tide) and completely inundated at Scenario 5 (52 inches of SLR or 12 inches of SLR and a 100-year extreme tide).

5.2.1.4 Islais Creek Third Street Bridge

Islais Creek Bridge on Third Street (a.k.a., the Levon Hagop Nishkian Bridge, and more commonly known as Third Street Bridge) is a drawbridge crossing the Islais Creek channel directly west of Illinois Street Bridge (Photos 5.11 and 5.12). This bridge also connects the Hunter's Point/Bayview and Central Waterfront/Dogpatch neighborhoods. This draw-bridge was completed in 1945 to replace a previous drawbridge at the same location. Unlike the other three bridges that have a single bascule, Third Street Bridge is a double-bascule bridge (i.e., it has two bridge leafs that open, one on each side). Similar to Illinois Street Bridge, there is rarely a need to open Third Street Bridge to support boat traffic.

The bridge supports four lanes of vehicle traffic (two lanes in each direction) with the track-based Muni T-Line in the center. The bridge has separated lanes for bicycle/pedestrian access. Islais Creek Bridge has a single-level deck with structural components (support piles, steel trusses), mechanical components (counterweights, motors), and electrical components that allow the bridge to open for ship traffic. Flooding of underground tunnels and equipment rooms can occur if access openings are not floodproofed.

There is limited redundancy for bridges. Inland roadways could provide alternative routes for street traffic. However, Third Street is one of the primary north-south corridors on the southeast side of the City. Closures along Third street would increase traffic and congestion. This bridge also carries the Muni T-Line, which is track-based public transit and cannot be rerouted.

This bridge is partially inundated with flooding on the road leading to it at Scenario 5 (52 inches of SLR or 12 inches of SLR and a 100-year extreme tide) and completely inundated at Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide).

5.2.1.5 Bay Bridge Approach

The Bay Bridge is the primary connector between San Francisco and the East Bay. Within the City, the approach to the Bay Bridge includes elevated structures that are within the SLR Vulnerability Zone. Like the smaller City drawbridges, the support pilings and other structural members could be impacted by flooding at ground level.

The Bay Bridge approach is a 1-mile stretch of I-80 that leads to the Bay Bridge, carrying approximately 270,000 vehicles daily[12] between San Francisco and the East Bay, and supporting commuter and goods movement for the region. The approach begins as two single-level concrete decks in parallel starting at Fifth Street and transitions into a double-deck design,

12 Caltrans. 2019. The San Francisco/Oakland Bay Bridge. Available at http://www.dot.ca.gov/hq/esc/tollbridge/SFOBB/Sfobbfacts.html. Accessed July 2018.

Table 5.5 Bridge Exposure Summary

Bridge	Approach Inundated (Y/N) within Each Sea Level Rise Scenario									
	1	2	3	4	5	6	7	8	9	10
Lefty O'Doul	-	●	●	●	●	●	●	●	●	●
Peter R. Maloney Fourth Street Bridge	-	●	●	●	●	●	●	●	●	●
Illinois Street Bridge	-	-	-	●	●	●	●	●	●	●
Islais Creek/Third Street Bridge	-	-	-	-	●	●	●	●	●	●
Bay Bridge Approach	-	-	-	-	-	●	●	●	●	●

each with their own independent column and foundation support systems. Although most of the approach infrastructure is not sensitive to flooding, the concrete foundations and supports could be impacted by prolonged exposure to saltwater.[13]

The approach to the Bay Bridge from Fremont Street is not exposed in any scenario. The approach on Fifth Street between Bryant and Harrison is inundated under Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide).

There are no good alternative routes for the Bay Bridge approach if street-level sections are flooded. If motorists want to avoid the congestion that would stem from only having one functioning access ramp available (at Fremont Street), they would have to drive around the Bay via San Jose or access San Francisco via other major bridges, such as San Mateo Bridge to the south, or Richmond-San Rafael Bridge and Golden Gate Bridge to the north, further increasing existing traffic on those roadways. Drivers could also convert to using public transit that is not dependent on the Bay Bridge, such as BART or ferry services, if those services remain functional.

5.2.2 Exposure Assessment

The exposure of the bridges was evaluated qualitatively relative to the 10 SLR scenarios (see Chapter 2). The assessment evaluated if the bridge approach (i.e., the roadway leading up to each bridge) was inundated, under the assumption that if the bridge approach is inundated, the bridge would be out of service until floodwater recedes. Table 5.5 presents the bridge exposure summary. A more detailed assessment of bridge exposure would consider the elevation of the lowest structural member over open water, as well as the elevation of mechanical or electrical controls. This information was not available at the time of the assessment.

5.2.3 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE 1: Reduced access to the Bay Bridge approach would cause cascading consequences that could extend far beyond the localized approach and cause congestion and reduced mobility in other cities as vehicles would likely be rerouted across the Golden Gate and San Mateo bridges. Regional transit would be severely impacted if access to the Bay Bridge is reduced and it could cause overcrowding on alternative roadways or on public transit such as BART, Caltrain, and the ferry system.

KEY ISSUE 2: Flooding would cause increased congestion and impaired people and goods movement, particularly around the Oracle Park, King Street Station, and the Mission Bay area, affecting the drawbridges. San Francisco public transit options that run across the drawbridges are on

13 The portions of concrete foundations discussed here are made from uncoated concrete. They are not currently adapted to saltwater submergence.

fixed rail and unable to be rerouted; buses would be needed to replace light rail cars. These buses would need to be rerouted to alternative streets, meaning that some stops would no longer be served.

KEY ISSUE 3: The drawbridges are built on fill, and subsidence of the bridge approach slabs could increase with repeating flooding and increased high tides. Total and differential settlement due to subsidence of fill could adversely impact operation of the bridges. Flooding could also impact the electrical controls of the bridges, which would be of most consequence for any boaters relying on the drawbridges to remain functional.

Society and Equity: Disruption or blocked access to the Bay Bridge approach would impact commuter traffic (e.g., personal vehicles, car shares, and public transportation, etc.), resulting in longer commute times, missed work days, and would have regional economic impacts on the labor force.

Bridge closures of the drawbridges on the major arterials, Third and Fourth Streets, due to flooding or subsidence repair work, would impair person and goods movement and increase traffic and congestion on alternative routes. Congestion impacts would also increase if both Mission Bay bridges and/or if both Islais Creek bridges are closed. Fourth Street carries the Muni T-Line (track-based rail) which cannot be rerouted. It serves several already vulnerable communities that would have to contend with reduced and rerouted public transit, which may result in missed work time and other mobility limitations for the local residents.

Treasure Island residents dependent on Muni's 25 Treasure Island Service would be directly impacted by inundated streets and reduced Bay Bridge Access.

The local houseboat community in Mission Bay would also be impacted if the drawbridges were no longer in operation. The sail boats would not be able to leave the channel, and the houseboats themselves could not be moved out of the channel for service or repairs.

Economy: Reduced Bay Bridge access would impact the ability of commuters to reach their jobs and impair regional labor economies.

Goods movement would be impacted for truck traffic and rail traffic if the local bridges are closed to through traffic. As Fourth Street serves as a truck route with significant truck traffic, bridge closures would impair goods movement and increase traffic and congestion on alternative routes. Truck traffic may be more difficult to reroute because there are weight limitations on some of the potential alternate routes.

Illinois Street is a City street, and a truck route for providing heavy truck access to Piers 90-96. The bridge also has rail tracks for cargo traffic from Piers 90-96, and the rail line connects with the regional Union Pacific Railroad to the South Bay. Bridge closure would increase traffic and congestion on alternative routes (although not as much as a Third Street Bridge closure). The rail line cannot be rerouted, creating economic impacts to dependent industries. Congestion impacts would increase if both Islais Creek bridges are closed, causing time delays and higher transportation costs. Damage to the bridges will also require additional capital and operating funds to both protect and repair damage from flood events.

Environment: Increased traffic due to rerouted bridge access, congestion, or conversion to private or shared vehicles from public transit would lead to higher greenhouse gas emissions.

Governance: The bridges and associated infrastructure are overseen by different agencies, including the Port, Public Works, SFMTA, and CalTrans. There is also jurisdictional oversight of the drawbridges and navigable waterways by the United States Coast Guard. Interagency coordination will be imperative for drawbridge closures or financing of repairs.

5.3 LOCAL PUBLIC TRANSPORTATION

San Francisco's network of Muni buses, light rail trains, historic streetcars, and cable cars covers all corners of the City. SFMTA has one of the most diverse transit fleets in the world and is also the most environmentally sustainable multimodal fleet in California. The network consists of 54 bus lines, 17 electric trolley bus lines, six light rail lines that operate above and below ground, three cable car lines, and two historic streetcar lines. SFMTA's daily transit ridership is approximately 700,000 passengers.

The network also relies on increasingly data-driven communication infrastructure, which allows users to stay informed in real time about next-bus arrivals, transit delays, and traffic interruptions, for example through the website 511.org. This system relies on technology, power, and the telecommunication system to work, which may be a vulnerability. The transit system relies heavily on the energy grid which can be impacted by flood events. Disruptions to the power system would lead to disruptions to transit service as well.

If they stay operational, these communications systems can be very useful in warning of traffic disruptions and providing alternate routes for motorists and public transit users. San Francisco's network connects with regional transportation services, such as BART, Caltrain, SamTrans, Golden Gate Transit, Alameda-Contra Costa Transit (AC Transit), Amtrak, Greyhound, and the ferry systems operating at Pier 41, the Ferry Building, and Oracle Park by Golden Gate Ferry and the San Francisco Bay Ferry (see Section 5.5, *Regional Transit*).

5.3.1 Potentially Vulnerable Assets

5.3.1.1 Buses

SFMTA is replacing aging vehicles with low-floor biodiesel-electric hybrid buses. The new hybrids run on B20, a blend of diesel and biodiesel, which is made from recycled oil and fat. The 30-foot, 40-foot,

Photo 5.13 **Passengers boarding a Muni bus on Market Street.** Jeremy Menzies, SFMTA

Photo 5.14 **Electric trolley buses.** Jeremy Menzies, SFMTA

and 60-foot biodiesel and biodiesel-hybrid buses help connect surrounding communities with central San Francisco. This bus fleet includes 477 vehicles from various manufacturers and is the backbone of SFMTA's Muni service (see Photo 5.13), carrying over 40 percent of the public transportation system's riders.

Although some bus lines also operate on US 101 and I-280, the bus lines generally operate on local streets, which can be impacted by localized flooding (see Section 5.1, *Roadways*). Buses can be moved out of the inundation zone to safety during temporary flood events and bus routes can be rerouted to avoid areas of flooding. This would impact specific bus routes and all bus stops within flooded areas.

Buses can also be used to provide adaptive capacity for other types of public transit during a flood event. For example, if BART or the light rail is taken out of service during a flood event, additional buses can be brought into service to provide temporary alternative transportation for passengers. Because San Francisco has a limited diesel bus reserve fleet with spare buses (per federal rules associated with capital funding), any buses used to replace Muni or BART rail service will likely be pulled from other bus routes, reducing service on those lines. Finding enough drivers to operate additional buses is also critical and may be challenging during a flood event.

5.3.1.2 Electric Trolley Buses

Electric trolley buses operate citywide on a fixed overhead line network that provides the electricity to power the trolley buses (see Photo 5.14). These zero-emission vehicles carry about 30 percent of the public transportation system's riders and operate on local streets that can be impacted by localized flooding (see Section 5.1, *Roadways*).

Electric trolley bus routes have been disrupted during temporary precipitation-driven flood events, and additional routes along the waterfront are projected to be inundated as sea levels rise. Although the trolley buses themselves can be moved to safety during a flood event, unlike standard buses, electric trolley buses are not as easy to reroute along adjacent streets as a connection to the overhead line is required to maintain service.[14] If a portion of the route is impacted by flooding, the service along a much larger portion of the route may be impacted.

14 Trolley buses can use battery power to operate off the overhead lines. However, this range is limited. When off the wires, trolley coach operation depletes both electricity and air reserves. Braking, doors, and wheelchair ramps use air. In congested traffic and down hills, trolleys will be forced to brake often, quickly depleting air reserves. Driving up hills will require more electricity usage than driving on flat ground. The manufacture claims the new trolleys can go up to six miles on battery power, but that is based on flat terrain without braking much, if at all, reducing the off-grid radius in San Francisco.

Photo 5.15 Cable car. Matthew Black (CC BY-SA 2.0)

Photo 5.16 Historic streetcar on the Embarcadero. Dennis Jarvis (CC BY-SA 2.0)

To provide traction power to the OCS (Overhead Contact System) as well as electricity to traffic signals, SFMTA operates and maintains major duct banks which consist of a series of concrete-encased electrical ducts. A duct bank is an assembly of conduits or ducts installed between structures or buildings to protect electrical wiring. The duct bank is used for traction power and communications infrastructure. In general, duct banks can withstand rain driven flood events. However further study is warranted to better understand their sensitivity and performance under projected sea level rise scenarios.

Service may also be disrupted during power outages as they rely on the energy grid. Buses can provide service along alternate routes during disruptions if sufficient buses are readily available; however, this likely requires pulling buses from other routes, reducing service on those lines. Finding enough drivers to operate additional buses is also critical and may be challenging during a flood event.

5.3.1.3 Cable Cars

Cable cars operate on fixed routes on select lines along Market, Powell, Hyde, California, and other Streets. Cable cars were invented in San Francisco nearly 150 years ago and were named a historic landmark in 1964 (see Photo 5.15). The cars are hauled by a continuously moving cable running at a constant speed located just below street level. Individual cars stop and start by releasing and gripping the cable. The cable car lines are all powered from the Washington-Mason Powerhouse at 1201 Mason Street. Each cable has its own drive machinery at the powerhouse.

Two cable car lines are within the SLR Vulnerability Zone: the California Street line terminus near California and Drumm Streets and the Powell/Mason Street line terminus at Bay and Taylor Streets. Exposure to saltwater would likely increase the corrosion rate of the cables, resulting in an increased need for inspection and maintenance. The cable car terminals include underground pits which are designed for minimal water intrusion. The pits contain sump pumps that become overburdened easily and are not designed to pump saltwater, only freshwater or rain runoff. Cable cars can continue to operate during minimal flooding[15]; however, operation would likely cease until floodwaters recede for safety reasons. Cable cars are currently not used during severe weather.

Buses can provide alternative service during disruptions if enough buses are available and conditions allow; however, buses would not provide the same user experience. If the California and Drumm Street terminus is impacted, it may not have systemwide disruptions on the cable car system because cars can reverse direction prior to the impacted area. Although there is a switchback on California between Montgomery and Kearny, it is rarely used. During parades or other events that make the California Street/Drumm terminal unusable, cable cars are usually temporarily replaced with buses.

5.3.1.4 Historic Streetcars

Historic streetcars operate on Market Street (F Line) and the Embarcadero (E Line) (see Photo 5.16). The

15 The standard used in San Francisco is whether the operator can see the top of the rails.

Photo 5.17 **Muni light rail.** Jeremy Menzies, SFMTA

Photo 5.18 **Embarcadero Station.** BrokenSphere (CC BY-SA 3.0)

streetcars operate on tracks along the roadway, with some track sections separated from the regular auto traffic on dedicated streetcar right-of-way.

Service on the historic streetcar lines has been disrupted due to precipitation-based flooding in the past. Historic streetcar routes are projected to be inundated by SLR along the Embarcadero waterfront, Don Chee Way, Steuart Street, and Market Street. If a portion of the route is flooded, the entire streetcar line would not operate until after the floodwaters recede. There is limited redundancy or alternatives for the historic streetcar lines. Buses could provide alternative service during disruptions; however, if the historic streetcar routes are inundated by floodwaters, bus operations would be impacted similarly, and service would be reduced on other lines as buses are redeployed. Like other rail vehicles, service can continue to operate during minimal flooding. More severe flooding would trigger a disruption in service.

5.3.1.5 Muni Metro Light Rail / Subway / BART

The Muni Metro light rail system includes 71.5 miles of standard-gauge track, seven light rail lines (six regular lines and one peak-hour shuttle), three tunnels, nine subway stations, 24 surface stations, and 87 surface stops (see Photo 5.17). The fleet will include 219 light rail vehicles (LRV) by the end of 2019[16], with an average weekly ridership of 173,500 passengers. Muni Metro operates below ground in the subway along Market Street, sharing four of the nine subway stations with BART. BART is generally operated at the lowest level underground, with Muni Metro located between BART and the surface streets. LRV service also operates along the Embarcadero and King Street at surface grades, with long portions of track and stations located in the SLR Vulnerability Zone.

Muni Metro LRVs enter the Market Street tunnel along the Embarcadero between Howard and Folsom Streets (Photo 5.18). The Embarcadero Muni portal is vulnerable to SLR at 48 inches (Scenario 4). If the Embarcadero Muni portal were flooded, water could enter the Embarcadero Station and the BART/Muni tunnel, causing significant service disruptions for the City and region.

As of this publication, BART is conducting a SLR Assessment to understand the impact of SLR on the BART system. This study will provide more detailed information on flood pathways into Embarcadero Station and the BART/Muni tunnel system.

Muni Metro is currently under expansion through the Central Subway Project, which will expand subway service through the South of Market Neighborhood, Union Square, and Chinatown, increasing public transportation to and from some of the City's busiest, most densely populated areas and connecting to the CalTrain and BART systems. Central Subway portal is on Fourth Street between Harrison and Bryant Streetsin the SLR Vulnerability Zone. The lowest point within the Central Subway is under Market Street, below the existing Market Street subway. The Central Subway Project is planned to be completed in 2020.

16 https://www.sfmta.com/projects/expansion-and-upgrade-muni-light-rail-vehicle-fleet

The Embarcadero Station

The Embarcadero BART/Muni Station,located at the intersection of Market Street and the Embarcadero, is the most vulnerable subway station to SLR and to coastal flooding in San Francisco (Photo 5.19).

As part of the U.S. Army Corps of Engineers San Francisco Waterfront Continuing Authorities Program, potential impacts to Muni and BART service related to coastal flooding are currently being evaluated to support the need for flood protection for the entire San Francisco Waterfront. BART is conducting a SLR Assessment to understand the impact of SLR on the BART system. This study will provide more detailed information on flood pathways into Embarcadero Station and the BART/Muni tunnel system.

Photo 5.19 **Embarcadero Station.** Franco Folini (CC BY-SA 2.0)

Floodwaters could enter the underground station through multiple pathways, such as manholes, vents, access hatches, and the Embarcadero Muni portal. Muni Metro LRVs enter the Market Street tunnel along the Embarcadero between Howard and Folsom Streets. The Embarcadero Muni portal is vulnerable to SLR at 48 inches (Scenario 4). The first pedestrian entrances to the underground Embarcadero Muni/ BART Station would be impacted in Scenario 5 (52" of SLR or 12" of SLR and a 100-year extreme tide). The BART vent located on Ferry Plaza would be affected by SLR at 60 inches, or Scenario 6.The BART rail tracks (whether above or below ground) are fixed electric third-rail routes that are sensitive to inundation. Exposure to saltwater would accelerate corrosion risks and damage sensitive electrical equipment. There are other less visible components that are vital to maintaining operations including tunnels, ventilation tubes, street vents, and control equipment.

If floodwaters enter the station, flooding can impact communication equipment, electrical systems, fuel supplies, station operations, and BART service connecting San Francisco with the East Bay, and southbound service including service to SFO. Depending on the scope and the duration of the flood event, the Muni light rail system might be able to continue to operate west of Van Ness Station.

Any impacts here would ripple throughout the entire system. The length of repairs and the amount of disruption would depend on the duration and extent of the flooding and the corresponding damage.

Impacts to the Embarcadero Station would cause significant citywide and regional impacts to transportation. The Embarcadero station is the last San Francisco BART stop before connecting to Oakland via the Transbay Tube. Impacts to the Embarcadero BART station would cause significant delays and impact the ability for commuters to reach San Francisco from the East Bay. BART service is a key remaining link to the East Bay for hundreds of thousands of riders when there are traffic closures or heavy traffic affecting the Bay Bridge.

Muni service going to the Southern Waterfront or to other parts of San Francisco would also be impacted. Disruption of the Embarcadero Station would lead to congestion of other modes of transportation such as buses, personal vehicles, and ferries, and would impact people's ability to get to work, school, or to or from the East Bay. Alternate modes of mobility can be used by certain passengers if the impact is short term; however, there is minimal redundancy within the transit network to alleviate long-term impacts to BART rail or stations.

Light rail tracks (above and below ground) are sensitive to inundation. LRVs can continue to operate during minimal flooding. However, rail service would be suspended if inundation exceeds a minimum safe depth. Exposure to saltwater would accelerate corrosion risks and damage sensitive electrical equipment of tracks along the shoreline. LRVs can be moved out of potentially inundated areas prior to a storm event with enough notice, but finding adequate and safe storage for the fleet is a challenge. The rail system would require inspection by regulators before placing the system back in service.

Underground subway stations are sensitive to projected flooding and inundation, as numerous flood pathways are available for floodwater to enter the stations (portals, utility access holes, conduits, vents, grates, stairs, etc.). Portions of the light rail system may continue to operate if inundation impacts are localized. However, impacts to the subway portions and the electrical systems could cause systemwide disruptions and impacts to stations that are outside of inundated areas.[17] Buses can provide limited alternative service during disruptions and maintenance. Buses are placed into service to provide alternate transportation during construction and/or long-term repairs to portions of the system. However, short-term replacements would require pulling buses from other routes, impacting residents on those revenue lines.

5.3.2 Exposure Assessment

The exposure of the local public transportation network (Muni only, see Regional Transit for other transit providers) was evaluated relative to the 10 SLR scenarios (see Chapter 2). Table 5.6 shows the mileage of each type of transit that would be inundated under each scenario. Table 5.7 describes the number of riders impacted by transit type. Table 5.8 shows the number of stops impacted.

17 If the Muni Metro Turn-back Facility (MMT) or Embarcadero Muni/BART Station are flooded, there will likely be no Muni Metro service to downtown. Inbound trains will likely be switched back at Van Ness Station. N-Judah service would not be able to access its terminus point at the Caltrain Station. LRVs would not be able to pull out from, or pull into, the Muni Metro East Yard. Green and Cameron Beach Yards are already at capacity in terms of storage. Other than parking trains overnight on the mainlines in the subway or on public streets (which is difficult to do for operational and security reasons), there is nowhere to store LRVs that are currently stored at MMT. The Mint Yard at Church and Duboce Streets can only store four to six cars.

5.3.3 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Disruptions to any sector of public transit will have cascading consequences throughout the City and the region. If public transit routes are impacted by flooding and cannot operate as usual, transit that does not operate on fixed rail can be rerouted; however, this would impact residents and businesses on alternate routes through increased traffic congestion and environmental pollution from increased auto trips. Transit that operates on fixed rail often relies on bus service during periods of disruption. The Federal Transit Authority only allows SFMTA to have a 20% reserve bus fleet, which is not large enough to substitute rail or trolley service without pulling buses from other revenue lines, diminishing service on those lines. Driver availability in flood events may also be a limiting factor.

Vulnerable communities, such as the transit-dependent, elderly, or impaired, would be left with reduced mobility if there were no alternative transit options that were easy to access. The impacts could also reach a regional level if BART or Caltrain are affected. If commuters are unable to get to their workplace, there is a potential for missed work days and increased reliance on the already limited parking resources from a transition to personal vehicles, adding to congestion issues.

Society and Equity: Impacts and downtime at the Embarcadero Muni/BART Station would significantly impact travelers between San Francisco and the East Bay. If impacts to the electrical system occur, systemwide outages or disruptions are possible. Disruption and delays in public transit could result in more individuals driving personal vehicles or using ride-hailing services, leading to more congestion and time delays. This option may be cost-prohibitive for some transit-dependent persons in vulnerable communities.

Table 5.6 Public Transit Route Exposure Summary (Miles Inundated)

	Miles of Public Transit within Each Scenario									
Transit Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Bus	-	-	0.7	1.3	3.6	14.2	20.3	24.0	31.0	37.2
Electric Trolley Bus	-	-	-	0.7	2.6	10.1	13.4	15.4	18.4	21.1
Cable Car	-	-	-	-	-	0.2	0.3	0.4	0.4	0.5
Historic Streetcar	-	-	-	0.4	1.5	7.1	10.5	10.8	11.1	11.5
Muni Metro	-	-	-	1.1	3.0	11.1	13.5	15.0	16.3	18.0
Total	**-**	**-**	**0.7**	**3.5**	**10.7**	**42.7**	**58.0**	**65.6**	**77.2**	**88.3**

Table 5.7 Total Weekday Passenger Trips Potentially Impacted by Each Scenario

	Trips[1] Impacted within Each Scenario									
Transit Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Bus	-	-	-	17,000	68,000	182,000	190,000	207,000	221,000	221,000
Electric Trolley Bus	-	-	-	74,000	112,000	172,000	172,000	172,000	172,000	172,000
Cable Car	-	-	-	-	-	5,000	5,000	5,000	5,000	11,107
Historic Streetcar	-	-	-	23,000	23,000	23,000	23,000	23,000	23,000	23,000
Muni Metro	-	-	-	83,000	83,000	158,000	158,000	158,000	158,000	158,000
Total Ridership Impacted	**-**	**-**	**-**	**197,000**	**287,000**	**540,000**	**548,000**	**565,000**	**579,000**	**586,000**

Table 5.8 Public Transit Stops Exposure Summary

	Number of Transit Stops Impacted within Each Scenario									
Transit Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Bus	-	-	8	15	22	82	98	119	165	208
Electric Trolley Bus	-	-	-	2	15	47	62	70	86	104
Cable Car	-	-	-	-	1	4	6	7	8	9
Historic Streetcar	-	-	-	-	1	39	49	49	53	53
Muni Metro	-	-	-	-	-	32	33	36	44	44
Total	**-**	**-**	**8**	**17**	**39**	**204**	**248**	**281**	**356**	**418**

1 Impacted riders were estimated based on total ridership values in 2015. If a bus route is impacted under a specific SLR scenario, the total ridership along that route was included in the totals presented in Table 5.7.

Flooding of mostly fixed transit systems, such as electric trolley buses (which require a connection to the overhead powerline), and fixed transit systems, such as light rail, historic streetcars, and cable cars, can lead to widespread outages and delays because even if only a portion of a route is impassable, a larger service area may be disrupted. Buses may provide replacement service; however, sufficient buses and/or operators may not be available to meet demands, which means that some areas will remain without service.

Although buses can be rerouted around flooded areas, individuals living or working in flooded areas would need to be able to walk farther and potentially through a flooded area to reach a serviced bus stop. People in affected vulnerable neighborhoods, in particular transit-dependent, elderly, and infirm persons would be the most impacted and could be left without access to mobility services, rendering them unable to go about their daily lives, get to work on time, or access health services.

Economy: Disruptions to public transit can have major impacts on the economy, affecting the ability of millions of commuters to access their workplaces, shopping, etc. Transit disruptions would impact local travelers by increasing commute times, reducing work hours, and requiring potentially more costly mobility solutions. Transit disruptions would also negatively impact tourism industry revenue. Cable cars and the historic streetcars are popular tourist attractions in and of themselves, in addition to providing transportation to tourist attractions and local San Francisco businesses. Transit disruptions would also impact local businesses and the transit agencies due to lost revenue and worker productivity. Damage to the multimodal system will also require additional capital and operating funds to both protect and repair damage from flood events.

Environment: Reduced access to public transit could shift riders to using standard buses or private vehicles that have higher greenhouse gas emissions. Additional vehicle traffic would increase vehicle miles traveled and greenhouse gas emissions.

Governance: If fixed transit lines are affected, there may not be enough alternate means of public transportation options available to meet demand. Muni, BART, and the ferries all note buses as a possible alternative mode during construction or during short- or long-term downtime; however, there are only a limited number of buses, and bus yards. Maintenance facilities may also be affected (see Section 5.5). Relationships and mutual aid agreements with private transportation firms or other municipalities may be required. Identifying funds for the planning and repairs to damage infrastructure will also require working with local, regional, state and federal partners.

Mitigating these effects and adapting the public transit system will require concerted and coordinated efforts across agencies because ownership and rights-of-way for each component of the public transportation infrastructure (e.g., rail, roads, stations, and maintenance facilities) vary.

5.4 TRANSIT OPERATIONS AND MAINTENANCE FACILITIES

The City's public ground transportation system relies on a variety of operations and maintenance facilities where vehicles and equipment are stored, serviced, assembled, repaired, tested, painted, and fueled (see Figure 5.2). These facilities are required for continued safe and reliable operation of the public transit system. Many of these facilities are in low-lying areas within the SLR Vulnerability Zone and vulnerable to both temporary and permanent flooding as sea levels rise. The facilities within the SLR Vulnerability Zone were evaluated individually.

5.4.1 Potentially Vulnerable Assets

5.4.1.1 Muni Metro East

Muni Metro East is a 13-acre storage and operations and maintenance facility located east of Illinois Street, between 25th Street and Cesar Chavez Street (Photo 5.20). This is currently the main facility where LRVs are repaired and maintained. The facility includes an 180,000-square-foot maintenance building, an electric substation, a diesel back-up generator, and paved outdoor track and storage space. Large portions of the parcel are low-lying and have experienced precipitation-driven flooding.

SFMTA plans to expand the facility eastward. The Muni Metro East Expansion Project would develop an empty 4-acre lot east of the existing 17-acre Facility. Improvements will include paving the site, installation of light rail storage track for up to 36 light rail vehicles, and construction of a maintenance building for light rail vehicles. Increasing the capacity of the site will provide vehicle storage capacity for future expansion of both the bus and light rail fleets. This site is also subject to future flooding as sea levels rise.

There is limited redundancy for Muni Metro East and systemwide impacts to the Muni transit lines would occur if this facility is out of service for an extended period. Vehicles could be moved offsite prior to a storm event with enough notice; however, options are limited.

Photo 5.20 **Muni Metro East facility.** Flickr user mliu92 (CC BY-SA 2.0)

Figure 5.2 Transit Maintenance Facilities

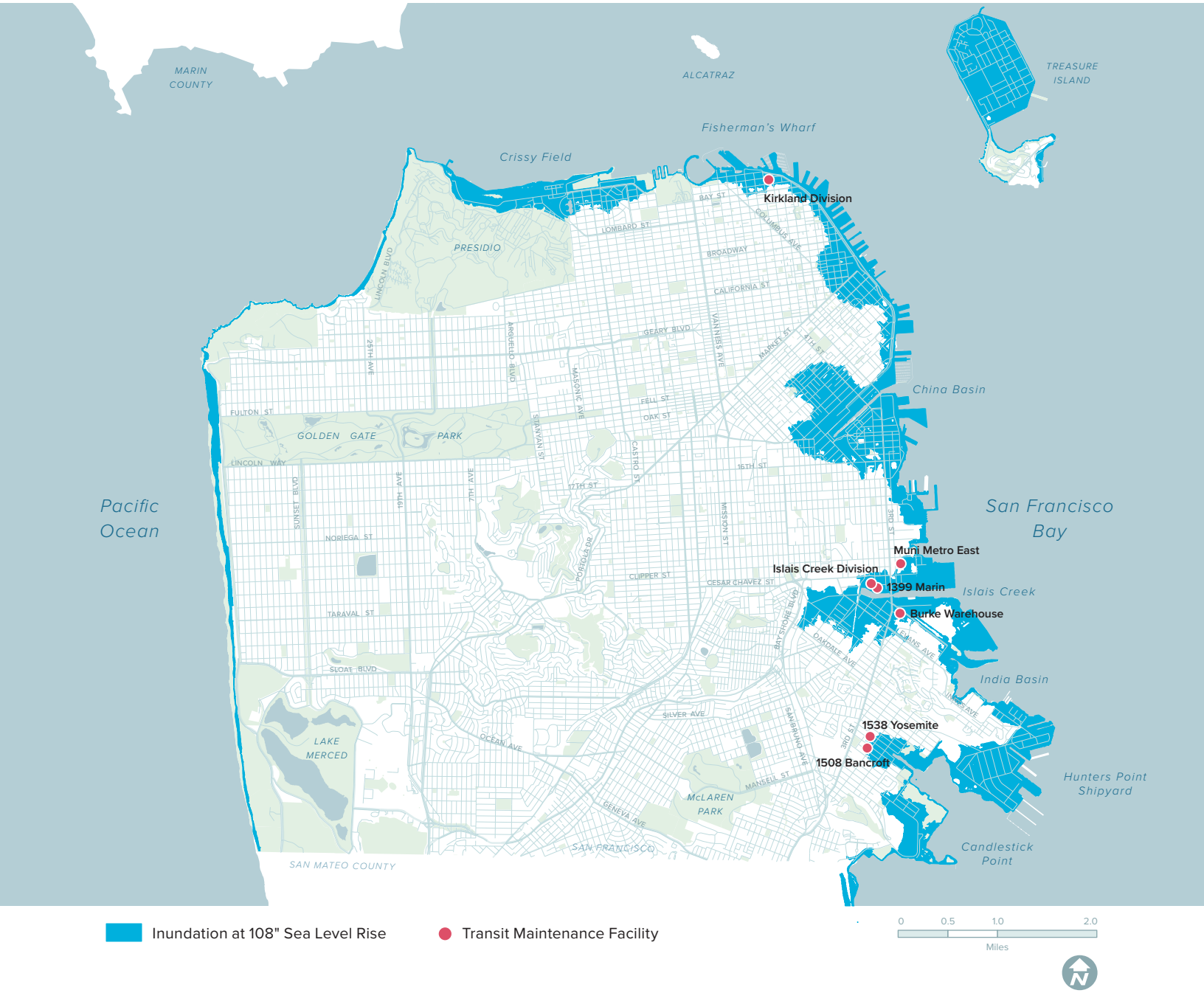

Photo 5.21 **Muni Metro East facility.** Jim Maurer (CC BY-NC-ND 2.0)

Photo 5.22 **Maintenance facility at 1399 Marin.** Todd Lappin (CC BY-NC 2.0)

SFMTA operates one other yard, Green Yard, that services and maintains LRVs, which has capacity to service 12 LRVs. However, no other facility can accept the same volume of vehicles and equipment. Additionally, vehicles would not be able to access Muni Metro East if Mission Creek or Islais Creek bridges were flooded (Photo 5.21). This current facility is not anticipated to be subjected to future flooding until Scenario 10 (108 incher of SLR, or 66 inches of SLR and a 100-year extreme tide).

5.4.1.2 Burke Warehouse

The Burke Warehouse is located between Burke Avenue and Cargo Way, just east of Third Street. This facility is SFMTA's central warehouse and the new home of Muni's Overhead Lines Maintenance Division (2017 capital project). The facility includes approximately 100,000 square feet of warehouse space that stores Muni parts and equipment and is the primary location for overhead line repairs. The existing warehouse has at-grade entrances and flooding currently occurs during high tides coupled with heavy rains.

Sand bags are the primary measure used to mitigate flood damage and disruption. Warehouse operations are disrupted until flooding subsides. There are no pumps located onsite and storm drains are the primary mechanism for removing floodwaters. Although there is some redundancy in the system with respect to warehouse storage, this is the only facility where overhead lines are repaired. Vehicles could be moved offsite prior to a storm event with sufficient notice.

This facility is first exposed to inundation from SLR with Scenario 5 (54 inches of SLR or 12 inches of SLR and a 100-year extreme tide).

5.4.1.3 1399 Marin

This facility is located between Tennessee and Indiana Streets, west of Third Street, just north of Islais Creek Channel (Photo 5.22). 1399 Marin is under the jurisdiction of the Port of San Francisco, and the SFMTA has a Memorandum of Understanding (MOU) with the Port to use the property. The primary structure is a metal-clad 27,000-square-foot warehouse located on a 3.2-acre site with an asphalt and concrete paved yard. This facility is used to accept, store, maintain, repair, and refuel Muni buses. The existing warehouse has at-grade entrances and flooding currently occurs during high tides coupled with heavy rains.

Sand bags are the primary measure used to mitigate flood damage and disruption. There are no pumps located onsite and storm drains are the primary mechanism for removing floodwaters. The electrical lifts are at or below grade and cannot be used when flooded, and the disruption lasts until flooding subsides and equipment is inspected and ready for operation.

The primary uses of this facility are storage and bus acceptance. Storage could be relocated, though current storage inventory is low. Bus acceptance could be completed at a lower efficiency at an alternate bus division; however, it is possible that an alternative facility outside of the SLR Vulnerability Zone could handle bus acceptance needs, such as

Photo 5.23 Islais Creek Division transit facility. Jeremy Menzies, SFMTA

Photo 5.24 Kirkland Division facility. Wayne Hsieh (CC BY-NC 2.0)

Woods, Flynn, Potrero, or Presidio. However, some locations have limitations on the size of vehicle they can accept (e.g., Woods could accept 40-foot coaches, but not 60-foot buses). Additionally, bus acceptance needs will likely decrease by 2020-2025 based on anticipated procurement trends. However, the SFMTA plans to use this facility to service and maintain the fleet as other facilities are rehabilitated such as the Potrero facility. Therefore, its important role in providing daily transit service will increase.

This facility is first exposed to SLR inundation with Scenario 5 (54 inches of SLR or 12 inches of SLR and a 100-year extreme tide). This facility already experiences flooding during rain events and high tide conditions.

5.4.1.4 1508 Bancroft

This facility is located on a 1-acre site located between Bancroft, Armstrong, Jennings, and Keith Streets just east of Third Street. The primary structure is a metal clad, two-story, 90,000-square-foot warehouse for street signage, temporary signage, and parking meter shops. The structure has at-grade entrances and below-grade loading docks within the building footprint, and no stormwater infrastructure or flood protection measures located onsite. There is no redundancy for the sign and meter shop within SFMTA's system. Fleet parking is also located at this location; however, fleet parking could be temporarily relocated if required.

This facility is not anticipated to be subjected to future flooding until Scenario 10 (108 inches of SLR or 66 inches of SLR and a 100-year extreme tide).

5.4.1.5 1538 Yosemite

This facility is located between Yosemite, Wallace, Jennings, and Keith Streets just east of Third Street. This site includes 40,000 square feet of leased warehouse space used primarily as a paint shop that operates in association with the field operations at 1508 Bancroft. SFMTA's Non-Revenue Vehicles (NRVs) are parking inside the leased areas. Paint shop operations include installation and maintenance of lane lines, crosswalks, bicycle lanes, and bus-only lanes, as well as all pavement messages and color curb zones. The shop holds paint materials, operational supplies, equipment, and vehicles. There is no redundancy for the paint shop within SFMTA's system. Fleet parking could be temporarily relocated if required.

This facility is not anticipated to be subjected to future flooding until Scenario 10 (108 inches of SLR or 66 inches of SLR and a 100-year extreme tide).

5.4.1.6 Islais Creek Division

The Islais Creek Division is a major transit facility located between Indiana Street and I-280, just north of Islais Creek Channel. 1301 Cesar Chavez at Islais Creek is a 395,356 square foot, (9.08 acre site) that is under the jurisdiction of the SFMTA and/or leased from Caltrans. This facility functions primarily as a bus operations and maintenance facility with the capacity to serve and house 164 buses. This facility includes one fuel and vehicle wash building (approximately 18,000 square feet), one operations and maintenance building (approximately 65,000 square feet), bus parking, public open space, and a bicycle path on Islais Creek.

Table 5.9 Transit Facility Exposure Summary

Facility	Transit Facility Exposure within Each Scenario (Y/-)									
	1	2	3	4	5	6	7	8	9	10
Muni Metro East (current boundary)	-	-	-	-	-	-	-	-	-	Y
Burke	-	-	-	-	Y	Y	Y	Y	Y	Y
1399 Marin	-	-	-	-	Y	Y	Y	Y	Y	Y
1508 Bancroft	-	-	-	-	-	-	-	-	-	Y
1538 Yosemite	-	-	-	-	-	-	-	-	-	Y
Islais Creek Division	-	-	-	-	Y	Y	Y	Y	Y	Y
Kirkland Division	-	-	-	-	-	Y	Y	Y	Y	Y

Although some redundancy for this facility may be provided at other locations (e.g., 1399 Marin and Kirkland Division - if those facilities remain functional), the Islais Creek Division is the largest bus operations and maintenance facility. SFMTA's bus system would be severely impacted if this facility is not operational. It should be assessed whether fouling of the underground fuel storage tank could occur from flooding events or rising groundwater.

This facility is first exposed to SLR inundation with Scenario 5 (52 inches of SLR or 12 inches of SLR and a 100-year extreme tide). This facility already experiences flooding during rain events and high tide conditions.

5.4.1.7 Kirkland Division

This facility is located on a 2.6-acre site between North Point, Beach, Stockton, and Powell Streets (Photo 5.24). This facility provides bus storage, operations, and limited maintenance for 135 40-foot hybrid buses. The site includes mostly flat, paved surfaces with small operations and maintenance structures and underground storage tanks. An underground fuel storage tank and fueling station is also located onsite, and this facility provides back up fuel for the City's emergency response in the event of an emergency. If this facility is flooded, water can enter the underground storage tank through openings such as fill pipes, vent pipes, gaskets, loose fittings, covers, and sumps. Water will settle on the bottom of the tank, allowing the fuel to float on top until it exits the tank and is released into the environment. The underground storage tank and fueling system will require inspection and servicing before it can be safely used. Rising groundwater levels can also cause additional problems for underground storage tanks.

Although this location has not experienced flooding issues yet, it has experienced power outages during extreme weather conditions. Disruption lasts until power is restored. No stormwater infrastructure or flood protection measures are located onsite.

This facility is first exposed to SLR inundation with Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide).

5.4.2 Exposure Assessment

The exposure of the transit facilities was evaluated relative to the 10 SLR scenarios (see Chapter 2) and is presented in Table 5.9.

5.4.3 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Day to day transit service is reliant on the functioning of the facilities. If facilities are inundated and unable to function or operate at a reduced capacity, it would reduce the ability to provide transit service. It would also reduce

the ability of the City to respond to a flooding event. For example, without sign making shops to inform the public of rerouted bus and transit route alternatives the public access and use of transit will be diminished. The maintenance and fueling facilities are imperative to keeping the largest number of buses running as buses are the first line of defense to respond to impacts on fixed transit lines.

Society and Equity: The majority of these facilities (Muni Metro East, Islais Creek, Burke Warehouse, 1508 Bancroft, 1538 Yosemite, and the Kirkland Division) all play a critical role in maintaining the transit system, vehicle maintenance, and storage. If these facilities are inaccessible and/or not operational due to flooding, this would have systemwide consequences, limiting the number of substitute buses available and the ability to store, repair, and maintain vehicles.

Closure of these sites could also directly impact the workers, causing missed work time and potentially lost income. As discussed above, public transit outages would particularly impact transit-dependent persons and vulnerable communities throughout the City.

- Repair and service of LRV and historic streetcars would be delayed until Muni Metro East facility is re-opened. Systemwide impacts could occur if this facility is out of service for an extended period.
- This Islais Creek Facility is the primary facility for maintaining buses. Although some redundancy is available at other facilities, overall operation and maintenance of the City's bus fleet would be impacted if this facility is not operational.
- Repair of overhead lines for electric trolley buses could not occur while the Burke Warehouse is impacted. Substantial disruption in electric trolley bus service could occur if this facility is out of service for an extended period.
- If 1508 Bancroft is impacted, delays and disruptions to field operations and access to appropriate signage could result in safety issues and concerns in flooded areas throughout the City. This facility operates in coordination with 1538 Yosemite. Both facilities are likely to be impacted by the same flood event or SLR scenario.
- The Kirkland Division facility provides back-up fuel for the City's emergency response services in the event of an emergency. The back-up fuel would not be accessible if this facility is impacted. This is a smaller, back-up facility for maintaining buses. The redundancy this facility can provide in the event larger facilities are impacted would be lost if this facility is also impacted.

Economy: As facilities are impacted, the repair, fueling, and maintenance of vehicles might have to be outsourced to alternative locations, causing increased fees and reducing labor needs, potentially affecting the existing workforce. In addition, if the loss of a facility results in a reduced capacity of the system (less buses or ability to reroute), there could be lost revenue and tremendous indirect economic costs in lost work time and limited service to some San Francisco neighborhoods.

Environment: Hazardous materials and/or waste stored at the Kirkland Division, Islais Creek Division, 1538 Yosemite, 1399 Marin, Burke Warehouse, and Muni Metro East facilities could be mobilized by floodwaters (particularly the Kirkland Division, which includes underground fuel storage tanks and a fueling station) and transported into the groundwater and/or Bay.

Governance: Managing flood response for mobility requires coordination across SFMTA, Public Works, and multiple regional transit agencies. Impacts to transit facilities will require an emergency operations and contingency plan for accommodating potential downtime at any one facility. Relationships and emergency response plans in coordination with neighboring jurisdictions could help SFMTA and other transportation agencies backfill some services while facilities are brought back online. SFMTA may be able to backfill some services for other jurisdictions if SFMTA's facilities remain online while neighboring jurisdictions are impacted.

Impacts to transit facilities will require an emergency operations and contingency plan for accommodating potential downtime at any one facility. Relationships and emergency response plans in coordination with neighboring jurisdictions could help SFMTA and other transportation agencies backfill some services while facilities are brought back online.

5.5 REGIONAL PUBLIC TRANSPORTATION

The City coordinates closely with the Metropolitan Transportation Commission (MTC) to ensure that critical regional and local priorities are incorporated into the Regional Transportation Plan and Plan Bay Area. Key projects include the Downtown Rail Extension, Caltrain Electrification, second Transbay rail crossing, and Muni and BART core capacity projects.

Like many counties in California, San Francisco is a "self-help" county where local revenues make up the majority of transportation funding. As a major regional employment hub, San Francisco depends on various regional public transportation systems to transport riders to and from the City daily. These include regionally operating trains, buses, and ferries (see Figure 5.3). Regional transportation lines that operate in San Francisco are discussed below (only assets within San Francisco are included in this assessment).

5.5.1 Potentially Vulnerable Assets

5.5.1.1 Bay Area Rapid Transit (BART)

BART provides regional transit service across five lines connecting Alameda, Contra Costa, San Mateo, and San Francisco counties, including direct service to SFO (Photo 5.25). BART is operated by the San Francisco Bay Area Rapid Transit District, with headquarters in Oakland. BART is the fifth-busiest heavy rail rapid transit system in the United States and carries more than 440,000 daily passengers to access many of the region's prime destinations for work, school, and recreation. The total transit network provides service across 121 route miles: 28 miles in subways and tunnels, 32 miles on elevated structures, and 61 miles at ground level.[18] The service network includes the 3.6-mile Transbay Tube, which connects the East Bay with San Francisco and serves half of BART's daily ridership.

18 https://www.bart.gov/about/history/facts

Photo 5.25 **BART train.** Christian Ramiro González Verón (CC BY-NC-ND 2.0)

Figure 5.3 Regional Transit Map

Photo 5.26 **Caltrain terminal at Mission Bay/China Basin area.** Jim Maurer (CC BY-NC-ND 2.0)

Of the 44 regional BART stations, eight BART stations are in San Francisco. Of these eight, only one station, the Embarcadero Station, is located within the SLR Vulnerability Zone. Because all trains connecting the San Francisco Peninsula and the East Bay pass through the Embarcadero Station, its functionality is critical for the system. When there are traffic closures or heavy traffic affecting the Bay Bridge, BART service is a key remaining link to the East Bay for hundreds of thousands of riders.

The Embarcadero Station is one of the two most heavily used BART stations in the system and shares facilities with San Francisco's Muni Metro Light Rail system (see Section 5.3.1.5).

5.5.1.2 Caltrain

Caltrain is a commuter rail line that provides regional transit services along a single line connecting San Francisco, San Mateo, and Santa Clara counties (Photo 5.26). Caltrain is owned and operated by the Peninsula Corridor Joint Powers Board, which is composed of the City and County of San Francisco, the San Mateo County Transit District (SamTrans), and the Santa Clara Valley Transportation Authority.

Caltrain carries over 60,000 daily passengers, along San Francisco, the Peninsula, and Santa Clara Valley, for work, school, and recreation. Caltrain provides service across 51 route miles from 31 stations, two of which are within San Francisco. Caltrain has a fleet of 215 rail cars that provide daily service. Currently, Caltrain uses electricity for lighting, equipment, and amenities at its stations, Centralized Equipment Maintenance and Operations Facility, and for signals along the right-of-way.

Caltrain tracks are within the SLR Vulnerability Zone along the San Francisco shoreline in the low-lying area around Islais Creek and approaching the terminal at Fourth and King Streets. Of its stations, only the current terminal is located in the SLR Vulnerability Zone. The station is in the Mission Bay/China Basin area, bordered by Townsend Street to the north, Third Street to the east, Fourth Street to the west, and King Street to the south. The station is primarily located at street level, including pedestrian access, rail infrastructure, and equipment; there is no public parking available. It has building structures, fare vending equipment, waiting areas, and bicycle facilities, as well as bus and shuttle loading areas. It experiences the highest average weekday boarding volume of all Caltrain stations.

Downtown Rail Extension (DTX)

The City, in coordination with CalTrain, the Transbay Joint Powers Authority, and California High Speed Rail, is currently studying how to bring Caltrain and High Speed Rail to the Salesforce Transit Center while connecting San Francisco's fastest-growing neighborhoods on the east side of the City. The Rail Alternatives and Benefits Study (RAB) studied various underground rail alignments to connect rail to the Salesforce Transit Center from the County line to the Salesforce Transit Center. The Pennsylvania Avenue Extension, which includes a modified DTX and would extend underground rail south under Pennsylvania Avenue to the 22nd Street CalTrain Station area, is the City's preferred alignment. Both the DTX and the Pennsylvania Avenue extension would pass through the SLR Vulnerability Zone and include an underground station at 4th and Townsend Streets.

The Transit Center has two belowground levels with a Lower Concourse and Train Platform. The Lower Concourse houses retail space, fare equipment, and passenger waiting areas. The Transit Center will also accommodate future High-Speed Rail service that will connect to the greater regions of California (see discussion of Salesforce Transit Center).[20]

20 Transbay Program. Downtown Rail Extension. Available at http://tjpa.org/project/downtown-rail-extension.

Photo 5.27 Rendering of the RAB.

Photo 5.28 Cross section rendering of the Salesforce Transit Center. Steelblue

Caltrain rail tracks (whether above or below ground) are not currently electrified. However, CalTrain is currently in the process of electrifying the CalTrain system, which would involve electrified tracks, foundations, poles, and overhead wires. Phase I of CalTrain electrification is expected to be complete by 2022.[19] For current non-electrified tracks, exposure to saltwater would accelerate corrosion risks. Caltrain stations also have sensitive electrical equipment at ground level. Within Caltrain stations and structures, there are other less-visible components that maintain operations, including tunnels, ventilation tubes, street vents, and control equipment.

If floodwaters enter a station, flooding could impact communication equipment, electrical systems, fuel supplies, and station operations. If the impacts are localized to a single station, the remaining stations could continue to operate; however, there would be severe disruption to the trip schedules. The length of repairs needed for a station and the amount of disruption would depend on the duration and extent of the flooding and the corresponding damage.

19 CalTrain is. See: https://calmod.org/

Figure 5.4 Ferry Connections

Photo 5.29 **A Golden Gate ferry docked at the Ferry Building terminal.** Melinda Young (CC BY-NC-ND 2.0)

5.5.1.3 Ferries

Ferries provide commute and leisure transportation for passengers to connect to communities along the San Francisco Bay shoreline (see Figure 5.4). There are three main operators that service the network of ferry routes that provide access to and from three designated San Francisco terminals.

San Francisco Bay Ferry (operated by the San Francisco Bay Area Water Emergency Transportation Authority [WETA]) provides ferry service to communities throughout the Bay Area from ferry terminals in San Francisco, Alameda, Oakland, South San Francisco, and Vallejo (see Photo 5.29). Annual ridership exceeds 2.8 million across 14 high-speed ferries.[21] San Francisco Bay Ferry is also responsible for coordinating and managing emergency ferry service after a catastrophic incident that severely disrupts normal regional transportation systems, such as during temporary Bay Bridge closures. San Francisco Bay Ferry also operates service from SF to Richmond as of Jan 2019 and serves an average of 10,000-11,000 passengers per weekday.

The Golden Gate Ferry is owned by the Golden Gate Bridge, Highway, and Transportation District. Ferry service is provided between San Francisco (San Francisco Ferry Building) and the communities of Larkspur, Sausalito, and Tiburon in Marin County. Limited service is also provided between Oracle Park and Larkspur for San Francisco Giants baseball games. The Golden Gate Ferry has seven vessels and an annual ridership of 2.5 million, with an average daily ridership of 8,000 on weekdays across all routes.

San Francisco Bay Ferry facilities (float, piles, and gangways) are designed to be resilient to SLR as it pertains to rising tides. Facilities may be impacted by debris from increased storm frequency and intensity. Surrounding supportive shoreside facilities (i.e. vehicle, pedestrian, bicycle access) may also be impacted (see Chapter 11, *Port of San Francisco*).

The Blue and Gold Fleet provides bay cruise and excursion services in San Francisco Bay as well as ferry services to Angel Island, Tiburon, Sausalito, and Pier 41 with a total of 19 vessels.[22]

In addition, Tideline Ferry, an official small-scale ferry and on-demand service owned by the Port of San Francisco, serves Transbay commuters primarily

21 Water Emergency Transportation Authority (WETA). Available at https://weta.sanfranciscobayferry.com/. Accessed September 2018.

22 Port of San Francisco. Ferries. Available at https://sfport.com/ferries. Accessed September 2018.

between Berkeley and Pier 1½ in San Francisco during weekday hours. The Tideline Ferry operates two small vessels, each with a 40-passenger capacity.

All of the San Francisco ferry terminals are located within the SLR Vulnerability Zone, including the San Francisco Ferry Building, Pier 41/Fisherman's Wharf, and Oracle Park. The Port of San Francisco is leading a project to build a new ferry terminal at Mission Bay, which will be designed to accommodate expected SLR.

Ferry vessels are designed to operate in saltwater and are not directly impacted by rising tides. However, they may be damaged from debris impacts during storm events. During severe storm events and high wind conditions, ferries may suspend operations until hazardous wave conditions in the Bay subside. During route closures, passengers are directed to use alternative public transportation methods, leading to added delays and disruptions of the operating transit network. Increasing storm intensities in the Bay may create increased disruption in service, particularly during the winter months.

Mooring locations (standard steel floating facilities) at the terminals may be impacted by debris and wave impacts during storms, reducing the operational capacity of the ferry network. Additionally, piers and ferry terminals will require adaptation to operate during permanently higher tide levels, resulting in loss of service while terminals are retrofitted.

Ferries can be used to provide adaptive capacity for other types of public transit during a flood event. For example, if regional buses or BART service is impacted, ferries can be used to provide temporary alternative transportation for commuters and recreational passengers if the ferry terminals remain accessible.

5.5.1.4 Regional Buses and Transbay Terminal

Regional buses shuttle passengers to and from San Francisco to the greater San Francisco Bay Area and beyond. A significant number of regional bus lines terminate at the Salesforce Transit Center, including Golden Gate Transit, Amtrak, and Greyhound.

5.5.1.5 SamTrans

The San Mateo County Transit District (SamTrans) is a bus service that provides regional transit throughout San Mateo County and San Francisco. SamTrans also provides shuttle service to BART stations, other community shuttles, and service to SFO.

SamTrans has approximately 312 fixed-route vehicles and 67 paratransit vehicles in service. SamTrans provides several bus lines with direct service to San Francisco, terminating at the Salesforce Transit Center. Travelers living on the San Francisco Peninsula can reach destinations in San Francisco by taking SamTrans to a BART or Caltrain station or connect to SFMTA bus network.

SamTrans stops typically have minimal infrastructure, including stop signage and lighting. Some route sections may be inaccessible during flood events resulting in some disruption in service. Buses may use alternate routes to maintain a reduce level of service. A stop may still function as intended with minimal impact after floodwaters recede. During a flood event, buses could use an alternate drop off and pick up location, but this will be accompanied by a disruption in service. Travelers may be able to find alternate public transit modes to reach their destinations (e.g. BART or CalTrain).

5.5.1.6 AC Transit

AC Transit is a bus service that provides regional transit through portions of Alameda and Contra Costa counties (Photo 5.30). AC Transit also provides

Photo 5.30 AC Transit bus at Salesforce Transit Center. Sergio Ruiz

Salesforce Transit Center

The Salesforce Transit Center is a new facility that replaced the seismically-unstable Transbay Bus Terminal. The Transit Center opened in 2018 and currently houses operations for Transbay bus lines and Muni, with the ability to handle future CalTrain and California High Speed Rail trains in a lower train platform. The Transit Center is located within the SLR Vulnerability Zone and is exposed at 77 inches (Scenario 7).

Photo 5.31 **Salesforce Transit Center.** Sergio Ruiz

services to San Francisco and select areas of San Mateo and Santa Clara counties. There are 24 different bus routes for passengers to reach the Salesforce Transit Center from the East Bay. Transbay commutes to the Transit Center comprise approximately 60 percent of the total ridership across the network.

Most AC Transit buses travel directly from the Bay Bridge to elevated ramps into the Transit Center. They do not use surface roads in San Francisco. Line 800 which provides all-night service from the East Bay to San Francisco travels along surface streets, but does not intersect with the SLR Vulnerability Zone. Other impacts to AC Transit would be concentrated to impacts to the Bay Bridge (see Section 5.2.1.5) and the Salesforce Transit Center (see sidebar above). AC Transit may also provide redundant service if other transit modes (i.e. BART) are impacted by flooding.

5.5.1.7 Golden Gate Transit

Golden Gate Transit is a bus service that primarily provides regional transit for Marin and Sonoma counties but also extends service to San Francisco and Contra Costa counties. Golden Gate Transit is owned by the Golden Gate Bridge, Highway, and Transportation District. Average daily weekday ridership is approximately 10,800, of which 7,500 is transit across the Golden Gate Bridge.

Golden Gate Transit operates 150 buses (with an additional 27 owned by Marin Transit) in the active fleet across the four counties. Golden Gate Transit provides mobility to key City services, including the Kaiser Permanente Medical Center, financial areas, and other transit connections (e.g., Salesforce Transit Center and Ferry Building).

There is typically minimal infrastructure required for bus stops; however, some locations have covered structures with seating and minimal digital signage. In the event of flooding on some of the routes along the Embarcadero and northern waterfront, there are several alternate routes that provide mobility through San Francisco, primarily through the SOMA neighborhood, the Van Ness corridor, and areas north of Golden Gate Park. However, all are governed by traffic conditions and prone to lengthy delays from any traffic disruptions.

There is a bus layover lot located under I-80 between Third Street and Fourth Street. No maintenance is performed at this location. During a flood event, buses could use an alternate drop-off and pick-up location, but this will be accompanied by a disruption in service. Ferries may provide some redundancy to reach San Francisco from Marin County if there is major disruption in Golden Gate Transit service.

5.5.2 Exposure Assessment

The exposure of the regional transportation network was evaluated relative to the 10 SLR scenarios (see Chapter 2). The mileage of each transit route (within the San Francisco City limits) that could be inundated under each scenario was calculated and is presented in Table 5.10. The number of transit stops in each scenario was also evaluated, as shown in Table 5.11.

Many of these transit routes could also be exposed to floodwaters outside of San Francisco, and this would result in additional impacts to regional commuters. However, assessing the overall impacts to these transit routes outside of the City limits was beyond the scope of this assessment.

Table 5.10 Regional Transit Routes Exposure Summary [23]

	Miles of Transit Route Impacted within Each Scenario [24]									
Agency	1	2	3	4	5	6	7	8	9	10
BART	-	-	-	-	Y	Y	Y	Y	Y	Y
Caltrain Rail	-	-	-	-	4.1	5.6	6.2	6.3	6.7	7.1
Transit Center	-	-	-	-	-	-	Y	Y	Y	Y
SamTrans	-	-	-	-	-	1.0	1.6	2.1	3.1	4.3
AC Transit [25]	-	-	-	-	-	-	-	-	-	-
Golden Gate Transit [26]	-	-	-	-	0.6	23.8	36.6	44.5	56.6	66.1

Table 5.11 Regional Transit Stop Exposure Summary

	Regional Transit Stop Exposure Summary									
Agency	1	2	3	4	5	6	7	8	9	10
BART	-	-	-	-	1	1	1	1	1	1
Caltrain	-	-	-	-	-	1	1	1	1	1
Salesforce Transit Center	-	-	-	-	-	-	1	1	1	1
Ferry Terminals	-	-	-	-	-	3	4	4	4	4
SamTrans	-	-	-	-	-	-	-	-	-	2
AC Transit	-	-	-	-	-	-	-	-	-	-
Golden Gate Transit	-	-	-	-	-	4	5	7	11	24
Total	-	-	-	-	-	8	15	22	27	46

23 Table 5.10 shows grade level exposure; however, grade level exposure doesn't account for how much track would be flooded due to grade changes along the route. BART is shown as "Y" because once floodwaters enter the station, the water will run downhill and impact the entire line.

24 For all providers, miles of route were calculated by adding all segments of all routes together (that is, if two lines share the same street for one mile, it was counted as two miles of transit routes).

25 AC Transit operates primarily on elevated roadways including the Bay Bridge, and ramps connecting to and from the Salesforce Transit Center. Only surface portions of AC Transit routes are included in this calculation, none of which intersect with the SLR vulnerability zone.

26 Golden Gate Transit operates 21 separate bus routes (including express bus routes) that cross the Golden Gate Bridge into San Francisco. Many of these bus routes occupy the same (or similar) routes along the shoreline within the SLR Vulnerability Zone, thereby creating a high mileage total of transit routes inundated under each SLR scenario.

5.5.3 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: The regional transit network connects commuters from across the Bay Area with jobs in San Francisco. If these commuters are unable to get to local and regional jobs, there could be both economic and labor impacts in missed work days and reduced services.

Society and Equity: Impacts and downtime at the Embarcadero Muni/BART Station would significantly impact commuters between San Francisco and the East Bay, and southbound service including SFO. This could also lead to increased traffic congestion due to a mode-shift and more personal vehicles on the roadways, and mode shift to ferries.

Disruption and access issues to Caltrain tracks or stations in San Francisco would impact commuting between San Francisco, the Peninsula, and the South Bay; ridership may shift to SamTrans, BART, or personal vehicles.

Disruption at the Ferry Terminal, or limitations in access due to flooding, would impact local commuter access between San Francisco and Marin County/North Bay, South San Francisco, and East Bay, shifting ridership to BART, AC Transit, Golden Gate Transit, and personal vehicles.

Disruption to SamTrans service would impact commuters between San Francisco and San Mateo County; ridership may shift to Caltrain and BART (if available), or personal vehicles. However, bus service may offer the best alternative transportation because buses can use alternative routes outside of flooded areas.

Economy: Any and all disruption to regional transit links can impact access to jobs and have cascading effects on the local and regional economy. Significant disruption to major transit lines such as BART or CalTrain could have significant impacts on the local and regional economy and the ability of workers to access jobs. Disruptions to regional transit providers would cause major commute delays, decreased productivity, and impacts on other systems such as roadways and ferries. Increased ferry service (if unaffected) could partially offset loss of BART or Bay Bridge access.

Impacts to regional transit links and transit stops will decrease revenue for regional transit providers, or shift this revenue to other providers such as ferries or bridge tolls.

Disruption of the railway will impact the flow of goods from Piers 90-96 (see Chapter 11, *Port of San Francisco*).

Environment: Increased traffic due to conversion to private vehicle from public transit would lead to more congestion and higher greenhouse gas emissions.

Governance: The regional transit system involves the coordination of multiple agencies over many jurisdictions. Making the transportation system resilient to SLR and coastal flooding requires significant local and regional cooperation regarding capital investments, service operations, reimbursements, financing, and emergency funding. For example, dedicated money for regional transit operators to subsidize emergency service enhancements does not exist. Operators are eligible for reimbursement from FEMA or CalOES in some instances.

5.6 OTHER TRANSPORTATION SERVICES

San Francisco is committed to creating an accessible City, and that includes providing taxi and paratransit options for seniors and people with disabilities, as well as incorporating emerging mobility services and technologies that can provide safe, reliable, sustainable, and equitable transportation choices. SFMTA operates SF Paratransit, a van and taxi program for people unable to independently use or access public transit because of a disability or disabling health condition.

Innovations in transportation are rapidly changing how people navigate San Francisco's streets. These "Emerging Mobility Services and Technologies" include ride-hailing services like Lyft and Uber, ride-pooling services, bike share, autonomous vehicle technologies, and more (Photo 5.32). City agencies are working with community partners to better understand how these services and technologies are influencing San Francisco's transportation network.[27] The City's studies focus on identifying and defining emerging mobility technologies,[28] setting guidelines,[29] and evaluating their services. SFMTA has adopted policies to encourage and facilitate emerging mobility facilities that comply with its 10 principles , as many deliver social, environmental, and transportation benefits to the City. For example, in February 2017, SMFTA expanded commuting options by approving the Commuter Shuttle Program, a partnership with privately operated commuter shuttles that transport workers from their neighborhoods to places of work or transportation hubs.

27 San Francisco County Transportation Authority (SFCTA). Emerging Mobility Studies. Available at https://www.sfcta.org/emerging-mobility/studies.

28 According to SFCTA and SFMTA, an "Emerging Mobility Service or Technology" is one that automates three or more of the following services: Driving, Routing, Reservations/Orders, Vehicle Tracking, Billing, Customer Feedback, Matching/Sharing, Crowd-Sourced Routing, (Un)locking. Source: San Francisco County Transportation Authority (SFCTA). Emerging Mobility Inventory of Service and Technology Types. Available at https://www.sfcta.org/emerging-mobility/inventory.

29 If a service provider or technology does not meet the 10 Guiding Principles, SFCTA and SFMTA will work with the service provider to meet the principles or may choose to limit their access to City resources.

Photo 5.32 **Bay Area Bikeshare station on the Embarcadero.** Mario Roberto Duran Ortiz (CC BY-SA 4.0)

5.6.1 Potentially Vulnerable Assets

5.6.1.1 Paratransit and Taxis

SF Paratransit provides complementary paratransit services for SFMTA in accordance with the ADA. SF Paratransit performs about 800,000 passenger trips per year, with two-thirds provided by pre-reserved van and the remaining one-third provided by same-day taxis. All vans used to provide SF Paratransit services are wheelchair accessible. In addition, SFMTA issues permits and provides incentives for wheelchair accessible taxis, known as ramp taxis. Like all San Francisco taxicabs, ramp taxis are also part of the SF Paratransit Taxi program.[30]

SFMTA works to promote a vibrant taxi industry through intelligent regulation, enforcement, and partnership with the industry. The City's fleet of licensed cabs exceed clean-air vehicle standards.[31] As of August 2019, the taxi fleet included 1,602 approved taxis in 23 color schemes (fleets). There are no taxi color scheme facilities in the SLR Vulnerability Zone.

SFMTA contracts with a paratransit broker, Transdev, to manage SF Paratransit. The paratransit broker administration offices are currently located in San Francisco, California. Dispatch and reservations are in San Francisco at Executive Park. All operations and maintenance services for SF Paratransit are in Brisbane, in San Mateo County. SF Paratransit also offers Shop-a-Round, a grocery shopping shuttle, and Van Gogh, a recreational shuttle, to older adults and people with disabilities.

The paratransit and taxi systems rely on the roadway network; hence, their vulnerability is tied to the vulnerability of the roadway system (see Section 5.1). The SF Paratransit system has been disrupted during heavy precipitation and flood events. As these shuttles and taxis provide door-to-door service that is not tied to fixed routes, access to SF Paratransit is governed by the impacts to roadways, overall traffic conditions, and how many customers are located in the SLR Vulnerability Zone.

Photo 5.33 San Francisco Paratransit bus. Heather Moran, SFMTA

Although vans can be rerouted to non-impacted roadways, paratransit customers rely more on customized services and prescribed locations than non-disabled customers using the standard public transit system.

5.6.1.2 Emerging Transportation Services

Emerging transportation services including car share, ride-hailing services / transportation network companies (TNCs), electric moped, kick scooter, and bicycle share (Photos 5.34 and 5.35).

SFTMA has adopted policies to encourage and facilitate vehicle sharing that is compliant with its guiding principles, including providing on-street parking spaces within the public right-of-way and off-street parking spaces within SFMTA parking lots and parking garages for shared vehicle storage. Car sharing programs are operated by private companies, and the partnership with SFMTA enhances the overall benefits of car sharing to the City.

More recently, the City has launched a shared electric moped parking permit program. The shared mopeds do not require designated parking spaces; however, when they are not in use, they must be parked at designated charging stations located in parking lots and garages.

30 San Francisco Paratransit. Taxi and Ramp Taxi Services. Available at https://www.sfparatransit.com/taxi-ramp-taxi-services.htm.

31 San Francisco Municipal Transportation Agency (SFMTA). Taxi. Available at https://www.sfmta.com/taxi.

Photo 5.34 **Zipcar vehicle share in downtown San Francisco.** Yusuke Kawasaki (CC BY 2.0)

Photo 5.35 **Ford GoBike bicycle share station.** Paul Sableman (CC BY 2.0)

Bicycle share programs are also expanding in San Francisco. Currently, the BayWheels system has over 170 stations with over 4,000 docks located throughout the City. Stationless bicycle share programs are also emerging; these networks do not require fixed stations for charging and, therefore, are very resilient to potential flooding.

Some of the emerging transportation service providers are using or progressing to electric power and, thus, there is more fixed infrastructure associated with their operations, which also require electricity. These shared vehicles (e.g., cars, mopeds, electric bikes) are sensitive to flooding because they have electrical and mechanical components that may not function if exposed to water. Also, the related vehicle sharing infrastructure (e.g., charging stations) located at street level has more substantial electrical equipment sensitive to inundation and would likely require repair after floodwaters recede. Shared vehicles could be moved offsite prior to a storm event with sufficient notice.

If inundation impacts are localized, there is some redundancy across the shared network to maintain operations with a reduced fleet across roadways that are outside of inundated areas.

5.6.1.3 Commuter Shuttle

Privately operated commuter shuttles, which transport workers from their neighborhoods to places of work or transportation hubs, are common on the streets of San Francisco. Shuttles support local San Francisco and regional goals by decreasing single-occupancy vehicle trips, vehicle miles traveled, and private vehicle ownership, while encouraging walking and transit use.

Through a partnership with SFMTA, commuter shuttles can use a network of up to 125 shuttle-stop locations, including shared Muni zones and shuttle-only loading zones. Commuter shuttle operators are required to develop a Service Disruption Prevention Plan with their permit application.

5.6.2 Exposure Assessment

Consistent citywide GIS information was not available for the emerging mobility services. The location of car share spaces, bike and moped docking stations, and other facilities are subject to change substantially as these services grow, limiting the value of a detailed exposure assessment of these assets. Paratransit drop-off and pick-up locations are also user dependent and not at fixed locations. However, paratransit operations and maintenance services are potentially susceptible to flooding in Brisbane.

5.6.3 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE 1: All services depend on the accessibility and integrity of roadways, sidewalks, bike lanes, and parking areas. If public transit and other shared commuter systems are impacted, there could be a shift in the mode of transport to private or shared vehicles (taxi, ride-hail services), which could increase congestion and associated greenhouse gas emissions and time delays.

KEY ISSUE 2: Flooding could limit paratransit service to affected neighborhoods and vulnerable communities, which would impair the ability of elderly or disabled persons to access these services for healthcare, employment, and basic services such as access to groceries.

Society and Equity: Paratransit door-to-door service for eligible individuals would not be available in flooded areas, leaving members of the community with few mobility services. Lack of available services could make their ability to live independently in their own home impossible over the longer term and force them to relocate.

Economy: If there is reduced paratransit access, those that depend on its service may have to rely on delivery services and in-home care, which some individuals may not be able to afford or have access to through their available support systems.

Emerging mobility systems that require electrical components to function may be impacted by saltwater flooding and damaged causing economic losses. With sufficient notice, they could be relocated out of the SLR Vulnerability Zone, potentially leading to economic losses if the new location is less prominent or convenient for users.

Environment: Reduced use of transit and the shift to private or shared vehicles could increase greenhouse gas emissions.

Governance: Currently, the City outsources paratransit services. The operations and maintenance services are in neighboring Brisbane, so there would be impacts to the ability of the system to respond to localized change in routing or conditions.

Currently private commuter shuttles use the same bus stops and roadways as SFMTA and regional transit. If use of these stops by public transit agencies increase because of rerouted buses, there would be a need for more coordination between public and private use. Public use would generally take precedence, requiring rerouting private commuter vehicles.

5.7 PARKING

San Francisco's parking supply consists of on-street (metered, signed, colored curb and unregulated) and off-street (garages and lots) spaces. Although there are many privately owned parking garages and lots, this assessment focuses only on the City-owned parking supply. SFMTA currently manages approximately 280,000 on-street spaces including 27,000 metered on-street spaces, 12,000 signed or colored on-street curb spaces, and 94,000 on-street spaces in neighborhoods through the City as part of the Residential Permit Program. In addition, SFMTA manages 19 parking garages and 21 metered parking lots.

On-street parking is impacted similar to roadways (see Section 5.1) (see Photo 5.36). Some parking spots would be inaccessible during flood events but would regain full functionality once floodwaters recede. In areas that experience more substantial and regular flooding, parking areas may be lost entirely. Parking along Ocean Beach and the Great Highway was lost permanently due to coastal erosion and flooding during severe winter storms.

Many City garages have mechanical equipment for ventilation, elevator pits, and mechanical/electrical rooms located in lower levels or below-grade. In some garages, this equipment is located on the rooftop and would be less vulnerable to flooding. Garage entry points are usually at grade and could become inaccessible. Parking floors that are at or below grade may also flood. Access can be restored once floodwaters recede. Below-grade parking areas may require pumps to remove standing water.

Other parking garages could provide redundancy (if they are not full and owners agree) if a few garages are impacted during a flood event.

Photo 5.36 **On-street parking along the Embarcadero.** Heather Moran, SFMTA

Table 5.12 Parking Spaces Exposure Summary

	Parking Spots (#) within Each Scenario									
	1	2	3	4	5	6	7	8	9	10
On-Street Parking	-	4	110	740	2,025	6,650	8,115	9,315	11,275	13,415
Off-Street Parking	-	-	60	1,000	1,775	14,875	26,600	29,800	37,125	40,050
Total Spaces Exposed	-	4	170	1,740	3,800	21,525	34,715	39,115	48,400	53,465

5.7.1 Exposure Assessment

The exposure of the parking spaces was evaluated relative to the 10 SLR scenarios (see Chapter 2) and is presented in Table 5.12. The number of off-street parking spaces (i.e., parking in a parking garage or parking lot) may overestimate the number of impacted spaces. If a parking garage is partially within the SLR Vulnerability Zone, the entire parking garage was considered out of service while inundated.

5.7.2 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: If an impaired public transit system causes a mode shift to private vehicle usage, this could correlate with an increased demand for parking. The loss of one or more garages could impact the capacity of remaining garages. This could lead to fewer travelers accessing their destinations and increased congestion/travel time.

Society and Equity: Access to parking garages in the SLR Vulnerability Zone could be impacted. Although vehicles parked above grade can be accessed once floodwaters recede, they would not be available for use until that occurs. This could result in mobility impacts, as drivers may need to find alternative transportation. On-street parking spots may remain accessible in flooded areas, and cars left parked in these spots may be damaged by floodwaters. This can impact residents, commuters, and tourists.

Economy: Revenue at parking meters and parking garages would be reduced while parking spots are inaccessible. Some parking meters and garage payment facilities may require repair after floodwaters recede. Vehicles parked at or below grade in impacted garages or at street level in the SLR Vulnerability Zone could be damaged by floodwaters, causing economic losses.

Environment: If drivers must commute further to find parking, the increased driving would increase greenhouse gas emissions. Parking garages and areas often accumulate oil drippings and other hazardous materials, which could be washed into parks, open spaces, wetlands, and to the Bay by floodwaters.

Governance: Fleet parking areas that need to be evacuated prior to a potential storm event could access the upper floors of City-owned parking garages for safe storage of vehicles. This will require coordination and advance planning.

Hetch Hetchy Reservoir
Photo by Sara Lowgren (CC BY 2.0)