SAMTRANS ADAPTATION AND RESILIENCE PLAN

February 2021

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NOTE: Any SamTrans ridership information referenced in this report references pre-COVID-19 data.

EXECUTIVE SUMMARY

Sea levels are rising in the San Francisco Bay, with projections reaching up to 10 feet by the end of century. The California Ocean Protection Council (OPC) now advises California to prepare to be resilient to at least 3.5 feet of sea level rise by 2050 (OPC, 2018; OCP, 2019). This large range of uncertainty makes sea level rise (SLR) challenging to address. When combined with major storm events like a 100-year storm[1] or regular tidal events like the king tide,[2] flooding onshore caused by SLR can be exacerbated and pushed even farther inland. Heavy rain events can also cause rivers to swell and overflow; for rivers and creeks that drain into San Francisco Bay, these increased flows can meet SLR and storm surge to cause even more severe flooding. In addition, the San Francisco Bay Area is slowly sinking through a phenomenon known as subsidence[3], which further amplifies SLR and storm surge concerns.

These climate hazards (SLR, storm surge and fluvial flooding) along with subsidence present major issues for SamTrans' transportation infrastructure and, specifically, for SamTrans' low-lying and coastal bus maintenance facilities: North Base and South Base. North Base, SamTrans' primary operations and maintenance (O&M) facility, is in South San Francisco next to the San Francisco Airport (SFO). South Base is in San Carlos, adjacent to the San Carlos Airport. Both facilities are at risk of climate-change related flooding (temporary) and inundation (permanent).

The San Francisco Bay Area is also vulnerable to heat; because the area has historically experienced moderate temperatures with few extreme swings in highs and lows, communities are insufficiently prepared to manage its effects. Climate change is projected to increase overall average temperatures as well as the number and severity of high and extreme heat events. By 2070, most of San Mateo County will experience at least a 4°F increase in average high temperatures[4] and the number of projected extreme heat days will more than double compared to 1995 (San Mateo County, 2018).

Each weekday SamTrans makes over 46,000 trips[5] in San Mateo County through its bus, paratransit and shuttle services. The majority of SamTrans riders are transit-dependent and earn significantly less than the median annual income level in San Mateo County. Affordable public transportation is essential to serving San Mateo County's most vulnerable populations. Loss of bus service or dangerous conditions due to climate change could limit mobility for many of the

[1] A storm that has a 1% chance of occurring in any given year.
[2] A non-scientific term for a very high tide, which occur when the moon is closest to the Earth.
[3] Subsidence is a gradual settling or sudden sinking of the Earth's surface.
[4] Under a high greenhouse gas (GHG) emissions scenario (RCP 8.5).
[5] Based on pre-COVID-19 ridership.

County's most vulnerable residents, including people in resource-limited communities or those with functional and access needs.

The SamTrans Adaptation and Resilience Plan (the Plan) identifies SamTrans' vulnerability to SLR, flood and heat-related climate change impacts and presents potential action alternatives to improve resilience. The Plan was developed through the following process, which is guided by the Naval Facilities Engineering Command (NAVFAC) Climate Change Planning Handbook on Installation Adaptation and Resilience (2017):

- Stage I. Conduct Vulnerability Assessments
- Stage II. Identify and Screen Action Alternatives
- Stage III. Evaluate Benefits and Costs of Action Alternatives
- Stage IV. Assemble a Portfolio of Action Alternatives

The SLR and flooding vulnerability assessment focuses on SamTrans' North and South Base facilities, while the heat vulnerability assessment also evaluates the vulnerability of SamTrans' fleet and passengers. The vulnerability assessment focuses on the potential impacts of SLR and associated hazards on SamTrans' assets and services. It considers three aspects of overall vulnerability for both bases: exposure, sensitivity and adaptive capacity, which represent how much an asset is in harm's way from a hazard, how consequential impacts will be and how successfully the asset is able to withstand the impacts.

SEA LEVEL RISE FLOODING AND INUNDATION SUMMARY

The SLR vulnerability assessment used existing SLR projection data to evaluate present day flood risk and future flood risk in the years 2050 and 2100. Present day flood risk was evaluated using FEMA 1% flood annual flood chance data, also known as the 100-year flood or base flood. Future scenarios were developed to evaluate SLR risk in 2050 and 2100 with or without considering land subsidence.[6]

The results of this assessment found exposure to mid-century SLR, depending upon the scenario, at both bases. North Base will flood under mid and high-end SLR scenarios and a 100-year storm event by 2050, and its access road is vulnerable to flooding under a current 100-year storm. North Base does not benefit from any existing levee protections, and its facilities could flood under near term SLR and storm conditions. In some scenarios, 100-year storms may begin to cause damage to buildings at North Base within the decade, accounting for land subsidence and SLR.

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[6] Due to the nature of storm surge within the San Francisco Bay and along the west coast, the base flood and SLR evaluation depths take into consideration storm surge as part of the regulatory determination and calculations for SLR projections.

South Base is flat and low-lying; it floods under the high-end 2050 SLR scenario and any of the 2100 scenarios considered for this assessment. South Base is protected from mid-level SLR and storm surge in 2050 due to an existing levee; however, the base could flood under this scenario if a 100-year storm were to overtop Phelps Slough. Further study is needed to understand the likelihood of the slough overtopping in a major precipitation event, as this greatly affects South Base's overall flood vulnerability. The entire South Base facility is vulnerable to high-end SLR in 2050.

After evaluating the SLR vulnerabilities of both facilities, SamTrans developed a range of different action alternatives to prepare for and improve resilience to the impacts of SLR over the coming century. These alternatives were screened for their benefits, limitations, feasibility and appropriateness, and ten strategies advanced for further evaluation (retained). Retained action alternatives for each base are listed in Table 1.

Table 1. Retained Action Alternatives for North and South Base

North Base	South Base
Construct a horizontal levee around the perimeter of North Base.	Increase the levee height along Steinberger Slough.
Floodproof planned new construction by elevating all utilities and designing the ground level to accommodate flood water.	Excavate/dredge Phelps Slough.
Elevate new building electrical and HVAC systems, moving relevant equipment to roof, adding elevated platforms to house equipment at ground level and/or raising the elevation of the ground where the equipment rests.	Elevate new building electrical and HVAC systems, moving relevant equipment to roof, adding elevated platforms to house equipment at ground level, or raising the elevation of the ground where the equipment rests.
Consider locating BEB charging stations offsite in the future.	Install and modify pump systems downstream of Phelps Slough.
	Install check dams, ponds and infiltration systems in upper watershed to reduce surface runoff and flow going into Phelps Slough to reduce freshwater flood depths.
	Consider locating BEB charging stations offsite in the future.

A lifecycle benefit-cost analysis (LBCA) was conducted for a horizontal levee action alternative for North Base, which would greatly improve the facility's flood protection from current storm events and near term SLR. This analysis assessed three levee options compared to a "no-action" or baseline scenario. The LBCA demonstrated that there is a clear case for installing suitable flood protection at North Base. Constructing a levee to protect North Base is projected to save SamTrans significant costs under all SLR scenarios evaluated in this study. However, a regional tide gate solution between South San Francisco and North Base could reduce the length of the levee needed around North Base while also providing protection for several other agencies and properties to the west.

South Base is less vulnerable to future SLR because of the protection provided by the existing Redwood City levee. However, the existing levee would be overtopped under the 2050 high-end SLR scenario. In addition, South Base could be flooded from Phelps Slough overtopping during a storm event in the medium-term. Additional study is needed at the County/regional level to understand the potential fluvial flooding from Phelps Slough. Any solutions to address flooding risk at South Base require regional coordination as SamTrans does not have jurisdiction over the infrastructure that would need to be improved to provide flood protection. Eventually, the Redwood City levee will need to be elevated to continue to provide protection against SLR. This effort would need to be led by Redwood City.

Regional coordination will be critical to addressing SLR vulnerabilities as neither site can be protected in isolation. Multiple action alternatives will be outside of SamTrans' control and other alternatives, such as installing a levee, will require extensive stakeholder coordination.

HIGH HEAT SUMMARY

Climate change is projected to increase overall average temperatures as well as the number and severity of high heat events in San Mateo County, as shown in Table 2. Some areas within San Mateo County will experience a greater number of high heat days than others. The greatest number of high heat days are expected in San Mateo, Redwood City and parts of south San Mateo County.

Table 2. Projected Temperature Increase

Year	Countywide Temperature Increase	Max High Heat Days Expected[7]	Average Cooling Degree Days
1995 Baseline	-	13	91.4
2030	1.4 to 2.2°F	21	172.7 (89% increase)
2070	3.8 to 5.0°F	35	709.5 (676% increase)

The high heat vulnerability assessment evaluated heat-related vulnerabilities and adaptation strategies for SamTrans' North and South Base facilities, fleet and passengers based on heat projections for 2030 and 2070. A range of action alternatives was developed to address the impacts

[7] For this analysis, we defined high heat days as the number of days per year over 100°F. See section 3.1 for more information.

of high heat events. These alternatives were screened for their benefits, limitations, feasibility and appropriateness. Twelve strategies were retained for further evaluation.

Existing mechanical and passive cooling installed at North and South bases will likely provide sufficient protection from high heat through 2030. However, as average temperatures and the number of high heat days increase, North and South Base may require additional mechanical cooling after 2030. SamTrans should consider future heat projections when upgrading existing HVAC units, which typically have a lifespan of approximately 15 years, and when constructing new facilities.

Based on this analysis, North Base, South Base and SamTrans' bus fleet have limited heat exposure. Because heat risk to facilities and assets is not significant, greater emphasis was placed on mitigating passenger vulnerabilities to high temperatures while waiting for buses.

Increasing temperatures and high heat events put SamTrans' passengers at risk of heat-related health impacts. Public transit users are vulnerable to heat exposure when traveling to and waiting for transit, which can be exacerbated in urban areas by heat island effects and sparse tree canopy. Passenger sensitivity to heat exposure varies based on a number of factors including age, health (particularly pre-existing respiratory or cardiovascular disease), walking distance to a transit stop and wait time.

High temperatures also disproportionately affect disadvantaged communities[8] that are less likely to have access to a vehicle, more likely to be transit dependent and more likely to reside in areas that experience urban heat island effects. People living in disadvantaged communities may also lack air conditioning at home, or the financial resources to operate air conditioning equipment.

Passenger heat risk was assessed by developing a heat sensitivity score for each census tract within SamTrans' service area to identify high vulnerability zones. Key retained action alternatives to address passenger heat vulnerability include improving shelter and/or shade amenities at SamTrans' bus stops. Approximately 10% of SamTrans' bus stops in San Mateo County have shelters. The majority of the shelters are owned by a third party under a long-term contract for bus shelters featuring advertising (ad shelters), which expires in 2023. The timing of this contract expiration provides an opportunity to incorporate recommendations and/or design specifications into the new contract that provide protections against increasing temperatures. Installing new bus shelters and replacing existing shelters would require coordination and partnership with external stakeholders that own the surrounding property. These action alternatives present an opportunity

[8] Disadvantaged communities are defined as the top 25% scoring areas from CalEnviroScreen along with other areas with high amounts of pollution and low populations.

for cooperative, collaborative projects with partner agencies, stakeholders and nongovernmental organizations to support shared objectives.

Based on public input collected as by SamTrans, late buses feel four times longer to customers when waiting at a stop without a shelter or bench. In addition, respondents who ride SamTrans monthly or more are most likely to want improved bus stop amenities and features such as real-time information screens and shelters with seating among their top priorities. To address customer concerns and high heat risk, SamTrans could update the existing Bus Stop Guidebook (2013) and develop a bus stop improvement plan that incorporates recommendations from this study. A future bus stop improvement plan could also assist SamTrans in championing improvements at the many bus stops outside of its control.

1 INTRODUCTION

Each weekday SamTrans provides over 46,000 trips[9] in San Mateo County through its bus, paratransit and shuttle services. The majority of SamTrans riders are transit-dependent and earn significantly less than the median annual income level in San Mateo County. Affordable public transportation is essential to serving San Mateo County's most vulnerable populations. However, San Mateo County faces significant physical risk from climate change that could affect SamTrans' ability to provide bus services. Loss of bus service or dangerous conditions due to climate change could limit mobility for SamTrans' ridership including people in resource-limited communities, families without access to a vehicle, or individuals with functional and access needs who rely heavily on public transportation.

San Mateo County is extremely vulnerable to climate-change related sea level rise (SLR) and flood inundation. The Bay Area could experience up to 10 feet of SLR by 2100. SLR will result in increased flooding (temporary) and inundation (permanent) in low-lying coastal areas (San Mateo County, 2018). The impacts of SLR will be further exacerbated by other factors including king tides, storm surges, El Niño and land subsidence.

The San Francisco Bay Area is also particularly vulnerable to heat; because the area has historically experienced moderate temperatures with few extreme swings in highs and lows, communities are insufficiently prepared to manage its effects.

The SamTrans Adaptation and Resilience Plan (the Plan) identifies SamTrans' vulnerability to SLR, flood and heat-related climate change impacts and presents potential action alternatives to improve resilience. SamTrans developed the Plan using the following process, guided by the Naval Facilities Engineering Command (NAVFAC) Climate Change Planning Handbook on Installation Adaptation and Resilience (2017):

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The SLR and flooding vulnerability assessment focuses on SamTrans' North and South Base operations and maintenance (O&M) facilities while the heat vulnerability assessment also evaluates the vulnerability of SamTrans' fleet and passengers.

[9] Based on pre-COVID-19 ridership.

Chapter 1 describes the purpose of the Plan and provides background on the SamTrans' assets that were evaluated. Chapter 2 presents the results of the SLR and flooding vulnerability assessment and action alternative analysis. Chapter 3 presents the results of the high heat vulnerability assessment and action alternative analysis. Chapter 4 presents conclusions.

1.1 VULNERABILITY ASSESSMENT OBJECTIVE

The objective of the vulnerability assessment is to evaluate the impacts of SLR on SamTrans' facilities and associated services and of increasing numbers of high heat days on SamTrans' facilities, fleet and passengers. Vulnerability is assessed by evaluating (1) exposure to SLR/high heat days; (2) sensitivity to the effects of SLR/high heat; and (3) adaptive capacity (see Figure 1).

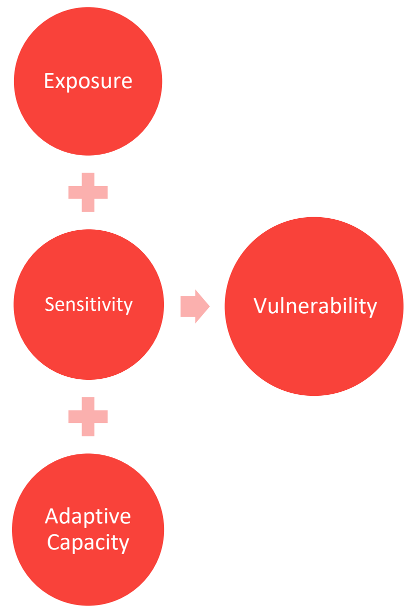


Figure 1. Elements of a Vulnerability Assessment

For the SLR assessment, exposure refers to whether and how much of the asset is located in an area that is or will experience SLR. Sensitivity refers to how the asset or service is impacted by SLR. Adaptive capacity refers to the asset's ability to cope with the impacts of SLR.

For the high heat assessment, exposure refers to whether and how much of the asset/population is in an area that is or will experience an increasing number of high heat days. The exposure analysis evaluates the nature and degree to which SamTrans' facilities, fleet and passengers are subjected to high heat days where they could be adversely affected. Sensitivity refers to how the asset, service or population is impacted by high heat. Adaptive capacity refers to the asset or population's ability to cope with the impacts of high heat.

1.2 SAMTRANS FACILITY AND ASSET DESCRIPTION

1.2.1 Fleet

1.2.1.1 Current Operations

SamTrans operates 304 buses and 67 paratransit vehicles. An additional 10 buses are retained as emergency contingent vehicles. All vehicles are housed at either North Base or South Base. An additional 79 vehicles are operated and maintained under contract offsite. SamTrans also operates 80 non-revenue service support vehicles. The SamTrans Bus Maintenance division includes approximately 101 employees who work in 8-hour shifts. Mechanic support is provided seven days per week, 24 hours per day except for Friday and Saturday, which have no graveyard shift (SamTrans, 2019).

1.2.1.2 Electrification

SamTrans plans to convert its bus fleet from diesel to battery electric buses (BEBs) by 2038. The existing conditions analysis accounted for the facilities as they were in January 2019, when the analysis occurred. SamTrans should update the lifecycle benefit cost analysis once its electrification is complete.

1.2.1.3 Overview

North Base, SamTrans' primary O&M facility, is in South San Francisco next to the San Francisco Airport (SFO) (Figure 2). The facility operates as the SamTrans bus dispatch center and provides fueling, washing, fleet storage and heavy maintenance services. The facility is designed to house 200 buses, the Redi-Wheels paratransit fleet and one disaster relief bus. North Base also contains an operator training facility, paint booth, body shop, service-support shop, chassis and brake dynamometer and two bays for service support vehicles. North Base also contains a trailer used as an emergency operations center. The site has a single point of access from North Access Road. SFO owns North Access Road. A private landowner owns a portion of the eastern shoreline of the island where North Base is located.

Figure 2. North Base Site Location Map

Additional activities occur on the site unrelated to SamTrans operations. An unmaintained section of the San Francisco Bay Trail (approximately one mile long) borders the site. The Bay Trail in its entirety will be a 500-mile continuous walking and cycling trail around the shoreline of San Francisco Bay; as of October 2019, there are 355 completed miles. The San Mateo County Samaritan House is in the southwestern portion of the site. This facility provides housing, food, healthcare and other services for people experiencing homelessness.

Table 3 provides a summary of the facility location, date of original construction, size, number of vehicles housed and replacement costs based on information provided by facility personnel.

Table 3. North Base Asset Summary

Address	301 North Access Road, South San Francisco
Site Size	27 acres
Construction Date	1988
Total SamTrans Building Square Footage	110,400 square feet
Underground Facilities	Storm drains and outfalls, fuel tanks, oil-water separators, electrical infrastructure

Number of Vehicles Housed	200 buses, paratransit fleet, 1 disaster relief bus
Number of Employees	270
Annual O&M Costs of Facility	$375,000
Facilities Valuation	$21 million
Replacement Cost	$21+ million

1.2.1.4 Site Observations

Observations from the site visit are summarized in Table 4 and Table 5.

North Base Bus Yard and Coastline

Table 4. North Base Site Observations

Building No.	Function	Size (square feet)	Observations
100	Maintenance	80,000	Moderate differential subsidence.
200	Operations	13,000	Significant differential subsidence.
300	Tire Shop	7,000	
400	Fuel Island	6,000	
500	Brake Inspection	3,000	

Building No.	Function	Size (square feet)	Observations
600	Bus Washer	1,000	
700	Emergency Generator	400	The building is on-grade and the electrical generator inside is elevated only 18 inches off the ground. A diesel above ground storage tank is next to the building.
Trailer	Maintenance		Contains separate generator.

Table 5. North Base Site HVAC Observations

Building No.	Function	Size (square feet)	Areas HVAC Served
100	Maintenance	80,000	Partially conditioned—ducted space conditioning in office and training rooms. Equipment includes: (1) packaged unit (1) forced air furnace with cooling (1) unit heater in unit repair area (1) furnace in unit repair area (3) gas fired furnaces (heating only) (1) direct fired heater (1) ventilator (20) exhaust fans (2) cooling towers
200	Operations	13,000	Fully conditioned—Equipment includes: (1) packaged unit (2) forced air furnaces with cooling units
300	Tire Shop	7,000	Semi-heated—Equipment includes: (1) unit heater (1) exhaust fan
400	Fuel Island	6,000	Unconditioned
500	Brake Inspection	3,000	Unconditioned
600	Bus Washer	1,000	Unconditioned

Building No.	Function	Size (square feet)	Areas HVAC Served
700	Emergency Generator	400	Unconditioned
Trailer	Maintenance		Unconditioned

Based on document review, site visit observations and interviews with facility personnel, North Base is currently experiencing shoreline erosion and differential settlement, which SLR will exacerbate in the future.

The west side of the site currently experiences wind and tidal erosion. In 2018, HDR conducted a study at North Base to evaluate the extent of shoreline erosion. The study provided recommendations to fortify the shoreline, fix damaged stormwater outfalls and prevent or minimize future erosion. The study showed that the entire west side of the island is experiencing some erosion, with some segments exhibiting severe erosion. Portions of the east side of the island are also eroding but to a lesser extent. The study indicates that erosion has advanced an average of 15 feet landward relative to the North American Vertical Datum of 1988 (NAVD 88[10]), with some areas experiencing up to 20 feet of erosion. Erosion was also observed downstream of many of the island's drainage outfalls. The study concludes, "…if no protection measures are taken, drainage facilities, the San Francisco Bay Trail, and District assets at North Base would be damaged by the continuation of the erosion process along the island shoreline" (HDR, 2018, p. 21). HDR identified three recommendations to address site erosion. One of the three recommendations—construction of a levee around North Base—would also account for future SLR under the 2100 mid-level scenario. SamTrans included this recommendation as a potential action alternative for this study and it will be discussed further.

Based on a survey by Wreco (2019) conducted in October 2018, buildings 100 and 200 both exhibit differential settlement and are tilting southeast. Building 100 has approximately 6 inches of differential settlement and building 200 has approximately 20 inches of differential settlement. However, the amount of differential settlement varies considerably across the foundation slabs with some areas exhibiting higher or lower settlement compared to the average. Based on a comparison of measurements taken in 2010 and 2018, building 200 has experienced up to 1.2 inches of additional differential settlement between 2010 and 2018. Settlement is expected to continue, but the absolute settlement rate cannot be determined without further study. Building 200 appears to have been constructed on top of a channel that existed prior to the site being filled. The portion of building 200 experiencing the greatest amount of settlement was built above this channel. Wreco concluded that building 200 requires highly disruptive remedial measures or complete reconstruction to address the significant tilting of the entire structure and bowing of the

[10] North American Vertical Datum of 1988, which is the vertical control datum used in the United States.

foundation slab. Building 200 will shortly become unusable unless remediation occurs. Building 100 has experienced less dramatic differential settlement and may not require immediate remedial measures or may only require remedial measures for portions of the building. Wreco recommends a structural review of the buildings to determine the amount of slab distortion that requires repair, or whether the buildings need to be replaced. The report outlines three options to address building settlement—localized repair, foundation stabilization or full building replacement, and indicates that SLR should be taken into consideration with any of these options.

In addition to differential settlement of buildings 100 and 200, localized settlement and re-paving operations results in isolated ponding of water during rain events throughout North Base. Although ponding primarily follows rain events at this time, this indicates potential future flooding events due to SLR and higher inundation elevations.

1.2.2 South Base

South Base Buildings 100 and 200

1.2.2.1 Overview

SamTrans' South Base facility is in San Carlos adjacent to the San Carlos Airport (see Figure 3). The facility houses up to 150 buses and contains administration, fueling and service buildings, a tire shop, a bus wash facility and 14 maintenance bays. South Base also contains a trailer used as an emergency operations center. SamTrans owns Pico Boulevard and the employee parking lot at the end of Pico Boulevard past the facility entrance. Pico Boulevard controls access to the site. Table 6 includes information on the facility location, date of original construction, size, number of vehicles housed and replacement costs based on information provided by facility personnel.

Figure 3. South Base Site Location Map

Table 6. South Base Asset Summary

Address	Airport Way, San Carlos
Site Size	13 acres
Construction Date	1984
Total SamTrans Building Square Footage	51,400 square feet
Underground Facilities	Storm drains and outfalls, fuel tanks, oil-water separators, electrical infrastructure.
Maximum Number of Vehicles Housed	150 buses
Number of Employees	170
Annual O&M Costs of Facility	$375,000
Facilities Valuation	$14.8 million
Replacement Cost	$25 – $30 million

The site abuts the Steinberger Slough to the north and the San Carlos Airport to the east, south and west. A levee owned by Redwood City buttresses the shoreline. The levee was raised in 2011 and designed to meet then-current FEMA standards for a 1% flood—it was not designed to account for future SLR. There is a 460-foot-wide gap in the southeastern portion of the levee to allow planes to safely take off and land at San Carlos Airport. The Airport installs a temporary barrier to secure the gap during high water events.

1.2.2.2 Site Observations

South Base Buildings 100 and 200

Observations from the site visit are summarized in Table 7 and Table 8.

Table 7. South Base Site Observations

Building No.	Function	Size (square feet)	Observations
100	Maintenance	26,000	
200	Operations	8,000	
300	Tire Shop	7,000	
400	Fuel Island	6,000	
500	Brake Inspection	3,000	
600	Bus Washer	1,000	
700	Emergency Generator	400	The building and equipment are on-grade and the electrical generator inside is elevated only 3 feet off the ground.
Trailer	Maintenance		Contains separate generator.

Table 8. South Base HVAC Observations

Building No.	Function	Size (square feet)	Areas HVAC Served
100	Maintenance	26,000	Partially conditioned—Equipment includes: (1) temp control unit (1) forced air furnace with cooling (1) gas fired furnace (1) direct fired heater (23) exhaust fans
200	Operations	8,000	Fully conditioned—Equipment includes: (1) packaged unit (1) 5-ton cooling unit
300	Tire Shop	7,000	Semi-heated—Equipment includes: (1) forced air furnace (1) air cleaner
400	Fuel Island	6,000	Unconditioned, ventilation only—Equipment includes: (1) exhaust fan only
500	Brake Inspection	3,000	Unconditioned
600	Bus Washer	1,000	Unconditioned
700	Emergency Generator	400	Unconditioned
Trailer	Maintenance		Fully conditioned—Equipment includes: (1) packaged unit

2 SEA LEVEL RISE

Chapter 2 presents the results of the SLR vulnerability assessment and action alternative analysis for North and South Base.

2.1 VULNERABILITY ASSESSMENT

San Mateo County is leading a multi-year initiative called Sea Change SMC to increase the climate change resilience of the County's economy, environment and communities. As part of this effort, the County published a countywide SLR Vulnerability Assessment in 2018. The assessment evaluated the vulnerability of critical transportation assets and concluded that the SamTrans North Base facility is vulnerable to SLR. Though the study did not evaluate South Base specifically, the San Carlos Airport (adjacent to South Base) was included in the study and found to be vulnerable. This vulnerability assessment builds upon the County assessments by evaluating both facilities at a greater level of detail under additional future scenarios.

2.1.1 METHODOLOGY

This section describes the climate hazards assessed and the data, scenarios and methodology used to assess vulnerability.

2.1.1.1 HAZARD DESCRIPTION

This vulnerability assessment considered four climate-change related hazards: (1) SLR; (2) Storm Surge; (3) Fluvial Flooding; and (4) Land Subsidence (see Table 9). SLR worsens storm surge and fluvial flooding while land subsidence exacerbates the impacts of SLR. Another potential hazard that could increase with SLR is groundwater flooding, but this hazard was not evaluated as part of this vulnerability assessment. SLR impacts on groundwater have not been well studied to date in the Bay Area, but have become an emerging concern that should be considered when investing in alternative actions to protect against SLR.

Table 9. SLR Hazard Definitions

Hazard	Definition
SLR	Increased height of the ocean due to climate change, which causes permanent flooding (inundation) and more frequent temporary flooding during storm events.
Storm Surge	Increased sea-level rise during storm measured as the height of water above the normal predicted tide (NOAA, 2018).
Fluvial Flooding	Riverine flooding during excessive rainfall events.

Hazard	Definition
Land Subsidence	Gradual settling or sudden sinking of land.

2.1.1.2 Inundation Scenarios

This vulnerability assessment uses existing SLR projection data to evaluate present day flood risk and future flood risk in the years 2050 and 2100. Present day flood risk is evaluated using FEMA 1% flood annual flood chance data, also known as the 100-year flood or base flood[11]. Future scenarios were developed to evaluate SLR risk in 2050 and 2100 with and without considering land subsidence. Due to the nature of storm surge within the San Francisco Bay and along the west coast, the base flood and SLR evaluation depths take into consideration storm surge as part of the regulatory determination and calculations for SLR projections.

2100 Scenarios

The 2100 scenarios were selected to align with the San Mateo County SLR Vulnerability Assessment, which developed a mid-level and a high-end SLR scenario. The County scenarios were based on the California Ocean Protection Council's (OPC's) 2013 State of California Sea-Level Rise Guidance document, which used data from a 2012 National Research Council report '*Sea-Level Rise in California, Oregon and Washington*.' This document represented the best available science at the time of the County's assessment. The County mid-level scenario SLR elevation is roughly equivalent to the updated 2018 OPC high emissions 2100 "likely range" scenario, and the County high-end scenario SLR elevation is roughly equivalent to the 2018 OPC high emissions 2100 1-in-200 chance scenario (OPC, 2018).

2050 Scenarios

SamTrans selected 2050 as a second scenario to consider as part of this study in order to evaluate nearer-term impacts SamTrans may need to consider. San Mateo County did not evaluate 2050 SLR scenarios in the Countywide SLR Vulnerability Assessment. The 2050 scenarios used in this assessment were selected based on the updated California OPC State of California Sea-Level Rise Guidance document (2018). The 2018 OPC update uses probabilistic SLR projections instead of scenario-based SLR projections. Unlike scenario-based projections, probabilistic SLR projections associated the likelihood of SLR occurrence (probability) with a range of greenhouse gas (GHG) emissions scenarios.

[11] The 1% flood identifies areas that will be inundated by a flood event having a 1% chance of being equaled or exceeded in any given year.

Land Subsidence Scenarios

In addition to SLR, the Bay Area is also experiencing land subsidence, which will aggravate flooding risk from SLR and storm surge. Land subsidence is not as well studied and so often not included in SLR projections, despite its importance. However, a recent study by Shirzaei and Büurgmann (2018) used historical aerial photography and elevations data to evaluate land subsidence in the Bay Area. The data shows that the majority of the San Francisco Bay coastal area experiences less than 2 mm per year of subsidence, but that some areas underlain by compacting artificial landfill and Holocene mud deposits can experience subsidence of 10 mm per year or more. Two additional 2050 and 2100 scenarios were developed to account for increased SLR due to land subsidence that depict overall flooding depths across both North Base and South Base.

Based on data obtained from Shirzaei and Büurgmann (2018), subsidence rates across North Base ranges from 3.5 millimeters (mm) per year to 11 mm per year, with an average of 7 mm per year. The Wreco (2019) assessment of North Base buildings 100 and 200 determined that the buildings have experienced a settlement rate of up to approximately 4 mm per year between 2010 and 2018. A conservative rate of 7 mm per year was applied to North Base (the average rate from Shirzaei and Büurgmann) for this assessment. No site-specific subsidence evaluations have been conducted at South Base by SamTrans so data from Shirzaei and Büurgmann (2018) was used to apply an average subsidence rate for South Base of 2 mm per year was assumed for this study.

Rates determined by Shirzaei and Büurgmann (2018) are developed with some relative error as it is based on available historical aerial and topographic data. Additionally, subsidence rates are variable over time based on changing settlement and compaction rates, and increasing levels of groundwater. As such, rates were applied conservatively to represent a possible worst-case scenario. Additional study is needed to draw further conclusions as to the extent and potential impact of subsidence on the bases.

Fluvial Flooding

Based on the location of North Base, tidal elevations and SLR dictate flooding at the facility. Fluvial flooding may occur under the SLR scenarios at South Base through the Phelps Slough and across Pico Boulevard. It is anticipated that with higher tide elevations the downstream pumps along the levee will be overtopped unless modified, which may prolong flooding of the downstream basin where Phelps Slough drains. San Mateo County (2019) developed a hydraulic model for the Cordilleras Creek watershed to evaluate climate and sea level changes predicted for thirty-year periods centered at 2030 and 2070.

Nine inundation scenarios were evaluated—a baseline scenario, four 2050 scenarios and four 2100 scenarios (see Table 10). The baseline scenario represents present day flooding, the mid-level scenarios represent likely SLR heights projected in 2050 and 2100, and the high-end scenarios represent an extreme SLR height projection.

Table 10. SLR Scenarios

Scenario	Projection	Source(s)
Baseline		
Baseline	1% annual chance flood (present-day extreme flood also known as 100-year flood)	FEMA flood maps FIRM Panels 06081C0044F, 06081C0169G & 06081C0188F, Effective Date April 04, 2019
2050		
Mid-Level	1% annual chance flood + 1.1 feet of SLR	FEMA flood maps FIRM Panels 06081C0044F, 06081C0169G & 06081C0188F, Effective Date April 04, 2019; 2018 CA OPC Guidance Document
High-End	1% annual chance flood + 1.9 feet of SLR	FEMA flood maps FIRM Panels 06081C0044F, 06081C0169G & 06081C0188F, Effective Date April 04, 2019; 2018 CA OPC Guidance Document
Mid-Level + Subsidence	1% annual chance flood + 1.1 feet of SLR + 7 mm subsidence (North Base) 1% annual chance flood + 1.1 feet of SLR + 2 mm subsidence (South Base)	FEMA flood maps FIRM Panels 06081C0044F, 06081C0169G & 06081C0188F, Effective Date April 04, 2019; 2018 CA OPC Guidance Document; Shirzaei and Büurgmann, 2018
High-End + Subsidence	1% annual chance flood + 1.9 feet of SLR + 7 mm subsidence (North Base) 1% annual chance flood + 1.9 feet of SLR + 2 mm subsidence (South Base)	FEMA flood maps FIRM Panels 06081C0044F, 06081C0169G & 06081C0188F, Effective Date April 04, 2019; 2018 CA OPC Guidance Document; Shirzaei and Büurgmann, 2018
2100[12]		
Mid-Level	1% annual chance flood + 3.3 feet of SLR	FEMA flood maps FIRM Panels 06081C0044F, 06081C0169G & 06081C0188F, Effective Date April 04, 2019; 2013 CA OPC Guidance Document

[12] The 2100 mid and high-level SLR scenarios generally align with the OPC 2018 updated guidance document estimates for SLR under a high GHG emission scenario for the likely range (3.4 feet) and 1-in-200 chance (6.9 feet).

Scenario	Projection	Source(s)
High-End	1% annual chance flood + 6.6 feet of SLR	FEMA flood maps FIRM Panels 06081C0044F, 06081C0169G & 06081C0188F, Effective Date April 04, 2019; 2013 CA OPC Guidance Document
Mid-Level + Subsidence	1% annual chance flood + 3.3 feet of SLR + 7 mm subsidence (North Base) 1% annual chance flood + 3.3 feet of SLR + 2 mm subsidence (South Base)	FEMA flood maps FIRM Panels 06081C0044F, 06081C0169G & 06081C0188F, Effective Date April 04, 2019; 2013 CA OPC Guidance Document; Shirzaei and Büurgmann, 2018
High-End + Subsidence	1% annual chance flood + 6.6 feet of SLR + 7 mm subsidence (North Base) 1% annual chance flood + 6.6 feet of SLR + 2 mm subsidence (South Base)	FEMA flood maps FIRM Panels 06081C0044F, 06081C0169G & 06081C0188F, Effective Date April 04, 2019; 2013 CA OPC Guidance Document; Shirzaei and Büurgmann, 2018

2.1.2 EXPOSURE ANALYSIS

The exposure analysis evaluated the nature and degree to which North and South Base are subjected to SLR, storm surge and fluvial flooding-related hazards where they could be adversely affected. The exposure analysis was conducted by developing a CAD model to evaluate localized topographic data and existing flood elevations and depths. The analysis applied SLR depths based on the scenarios identified in Table 10 to the topographic data to determine the area of flooding under each scenario. Subsidence was incorporated by lowering the topographic terrain model by specific depths of subsidence determined at the North and South Bases following the conservative subsidence rates discussed in Section 2.1.1.2. Flood depths were then evaluated based on the lower terrain model and scenarios.

2.1.2.1 North Base

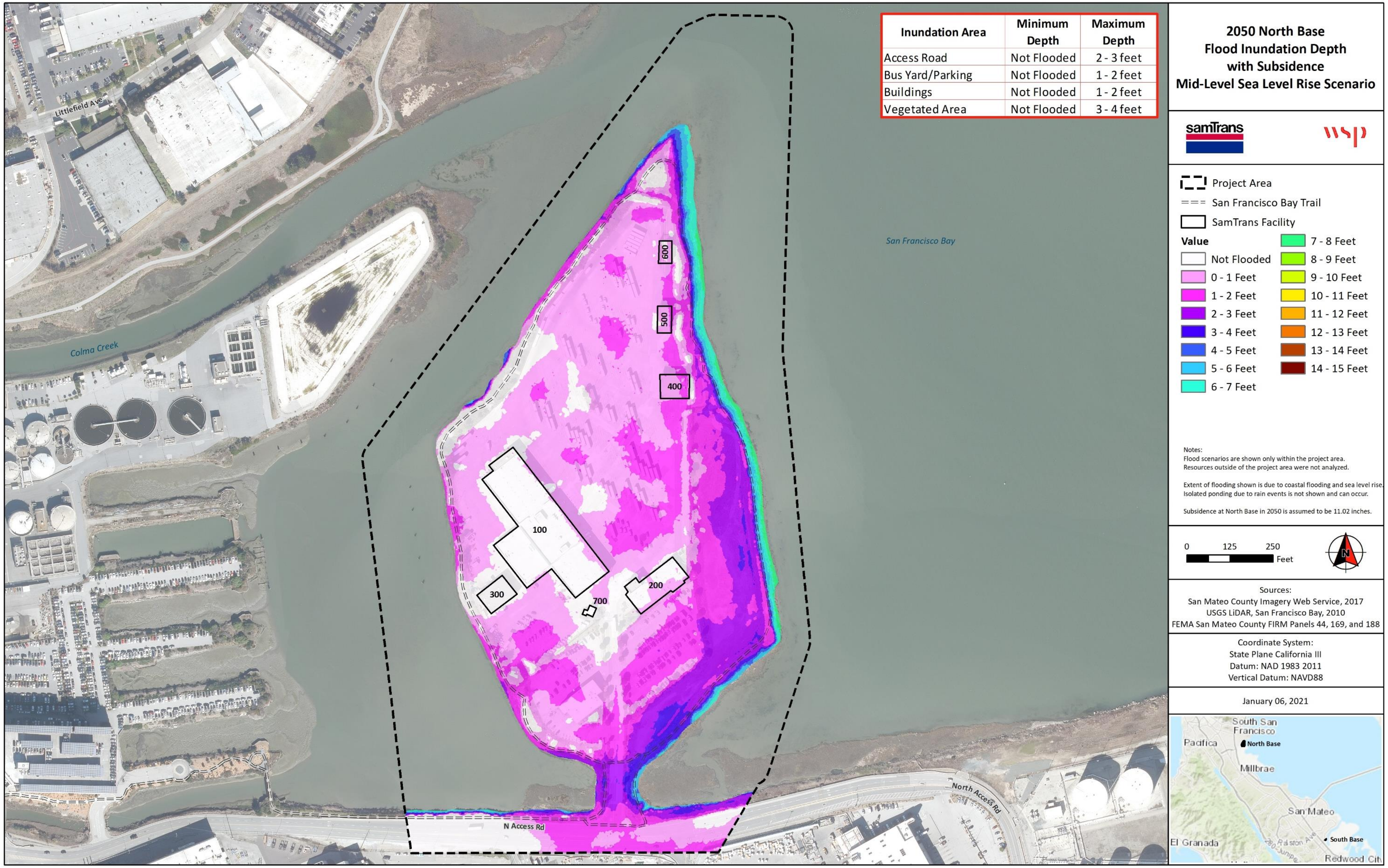
Figure 4 through Figure 9 (below) depict SLR-related flood inundation at North Base. Colma Creek is west of the island and drains into the San Francisco Bay. Because the creek is tidally influenced in this area, no additional fluvial flooding is expected to occur at the facility under the 2050 or 2100 scenarios. However, fluvial flooding has the potential to exacerbate coastal erosion on the west side of the island.

2050

Figure 4 depicts flood inundation at North Base in 2050 without considering subsidence for the baseline, mid-level and high-end scenarios. Figure 5 depicts flood inundation depth at North Base in 2050 under the mid-level scenario with subsidence, and Figure 6 depicts flood inundation depth under the high-end scenario with subsidence. By 2050, subsidence is projected to total 11.02 inches. Table 11 summarizes the projected extent of flooding at North Base in 2050.

Figure 4. 2050 North Base Flood Inundation Map

Figure 5. 2050 North Base Flood Inundation Depth with Subsidence Mid-Level SLR Scenario



Inundation Area	Minimum Depth	Maximum Depth
Access Road	Not Flooded	2 - 3 feet
Bus Yard/Parking	Not Flooded	1 - 2 feet
Buildings	Not Flooded	1 - 2 feet
Vegetated Area	Not Flooded	3 - 4 feet

Figure 6. 2050 North Base Flood Inundation Depth with Subsidence High-End SLR Scenario

Inundation Area	Minimum Depth	Maximum Depth
Access Road	Not Flooded	3 - 4 feet
Bus Yard/Parking	Not Flooded	2 - 3 feet
Buildings	Not Flooded	2 - 3 feet
Vegetated Area	Not Flooded	4 - 5 feet

Table 11. North Base Extent of Flooding in 2050

Scenario	Figure No.	Extent of Flooding During 100-Year-Storm Event
Baseline	Figure 4	During a 100-year storm (when water surface elevations reach 12 to 24 inches above the current mean higher high water (MHHW)[13] level), water from the San Francisco Bay could overtop the berm east of the North Access Road. This would cause North Access Road to temporarily or periodically flood up to 3 feet in depth as well as portions of the eastern shoreline. No buildings would be expected to flood, and no significant flooding of the bus yard or parking lot is expected.
Mid-Level	Figure 4	Under the mid-level scenario, a larger portion of the eastern shoreline would periodically flood along with a small portion of the western shoreline and isolated low spots in the interior of the island. This would result in partial temporary flooding of buildings 400 and 500, the employee parking lot and portions of the bus yard.
High-End	Figure 4	Under the high-end scenario, the majority of the site would be inundated. Buildings 400, 500 and 600 would be flooded and buildings 100 and 200 would be partially flooded, at the minimum have small ponded areas abutting the façade of the structure. Buildings 300 and 700 are the only buildings that would not be expected to experience some flooding.
Mid-Level + Subsidence	Figure 5	Accounting for subsidence, the mid-level scenario flooding worsens, primarily along the eastern portion of the site. Buildings 400, 500 and 600 would be flooded with up to a foot of water. Buildings 100 and 200 would experience partial flooding up to 1 foot. Buildings 300 and 700 are the only structures that would not be expected to experience flooding. North Access Road would be flooded up to 3 feet and portions of the bus yard and employee parking would be flooded up to 1 foot.
High-End + Subsidence	Figure 6	With subsidence factored in, the high-end scenario flooding would worsen, causing complete flooding in buildings 100 through 600 and partial flooding in building 700. Portions of the eastern shoreline and North Access Road would flood up to 4 feet. Buildings 400, 500 and 600 would experience flooding up to 3 feet and buildings 100,200 and 300 would experience flooding up to 2 feet. The majority of the bus yard and the employee parking lot would be flooded under 1 to 2 feet of water.

[13] Mean higher high water level is the daily high tide height.

2100

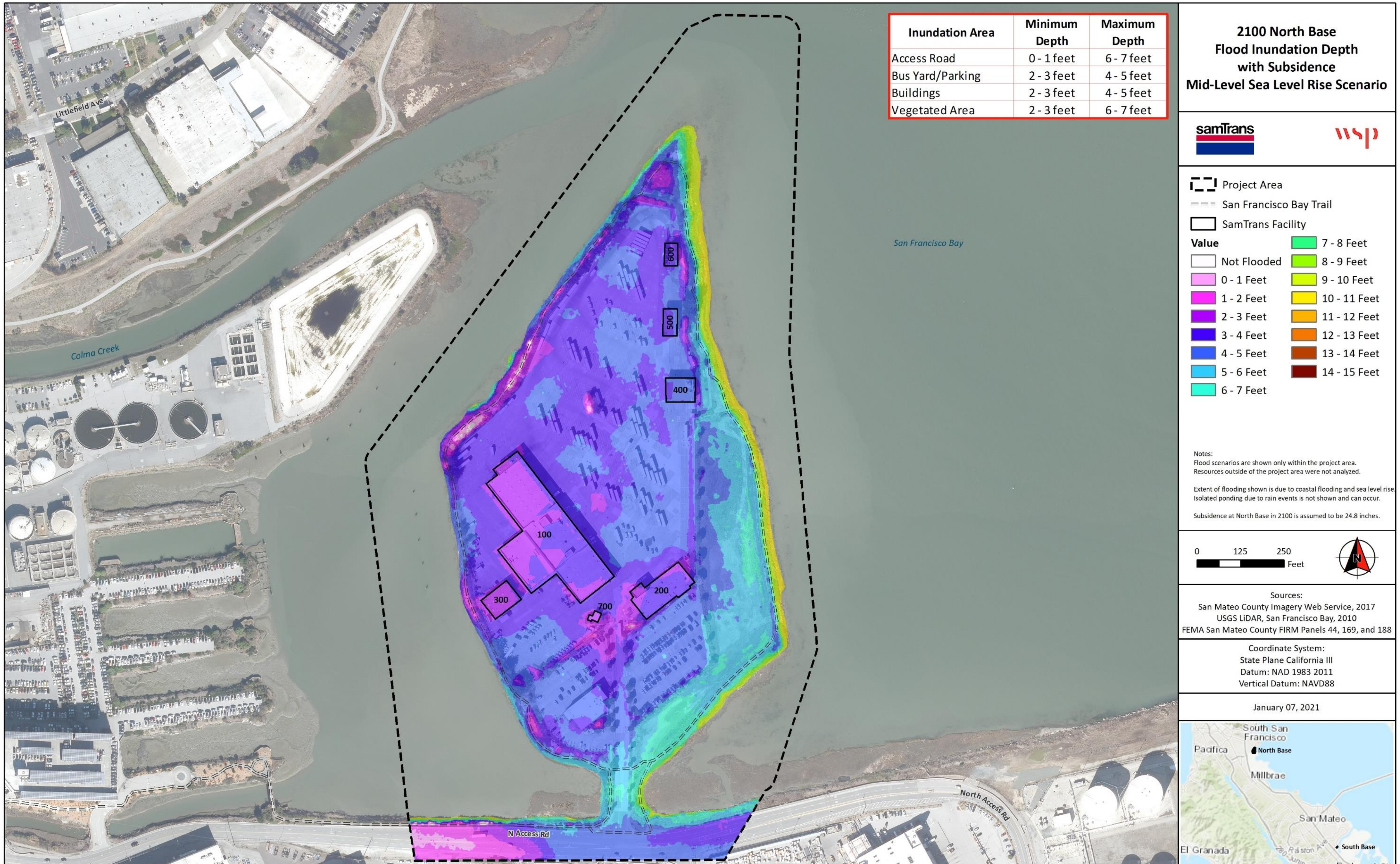
Figure 7 depicts flood inundation at North Base in 2100 without considering subsidence. Figure 8 depicts flood inundation depth at North Base in 2100 under the mid-level scenario with subsidence and Figure 9 depicts flood inundation depth under the high-end scenario with subsidence. Subsidence by 2100 is estimated to total 24.8 inches. Table 12 summarizes the projected extent of flooding at North Base in 2100.

Table 12. North Base Extent of Flooding in 2100

Scenario	Figure No.	Extent of Flooding During 100-Year-Storm Event
Mid-Level	Figure 7	Under the mid-level scenario, the entire site would be inundated with a few small gaps in high spots. All site assets would be flooded along with North Access Road.
High-End	Figure 7	Under the high-end scenario, 100% of the site would be inundated.
Mid-Level + Subsidence	Figure 8	With subsidence factored in, the eastern and southern portions of the site would be inundated with 4 to 5 feet of water and the rest of the site would generally be inundated with 3 to 4 feet of water under the mid-level scenario. North Access Road would be inundated with up to 7 feet of water.
High-End + Subsidence	Figure 9	With subsidence factored in, the entire site would be inundated with at least 6 feet of water. The eastern and southern portions of the site would be under 7 to 8 feet of water while the western portion of the site would be under 6 to 7 feet of water. North Access Road and a large portion of the eastern part of the site would be inundated with 8 to 10 feet of water. Some areas would be inundated up to 12 feet.

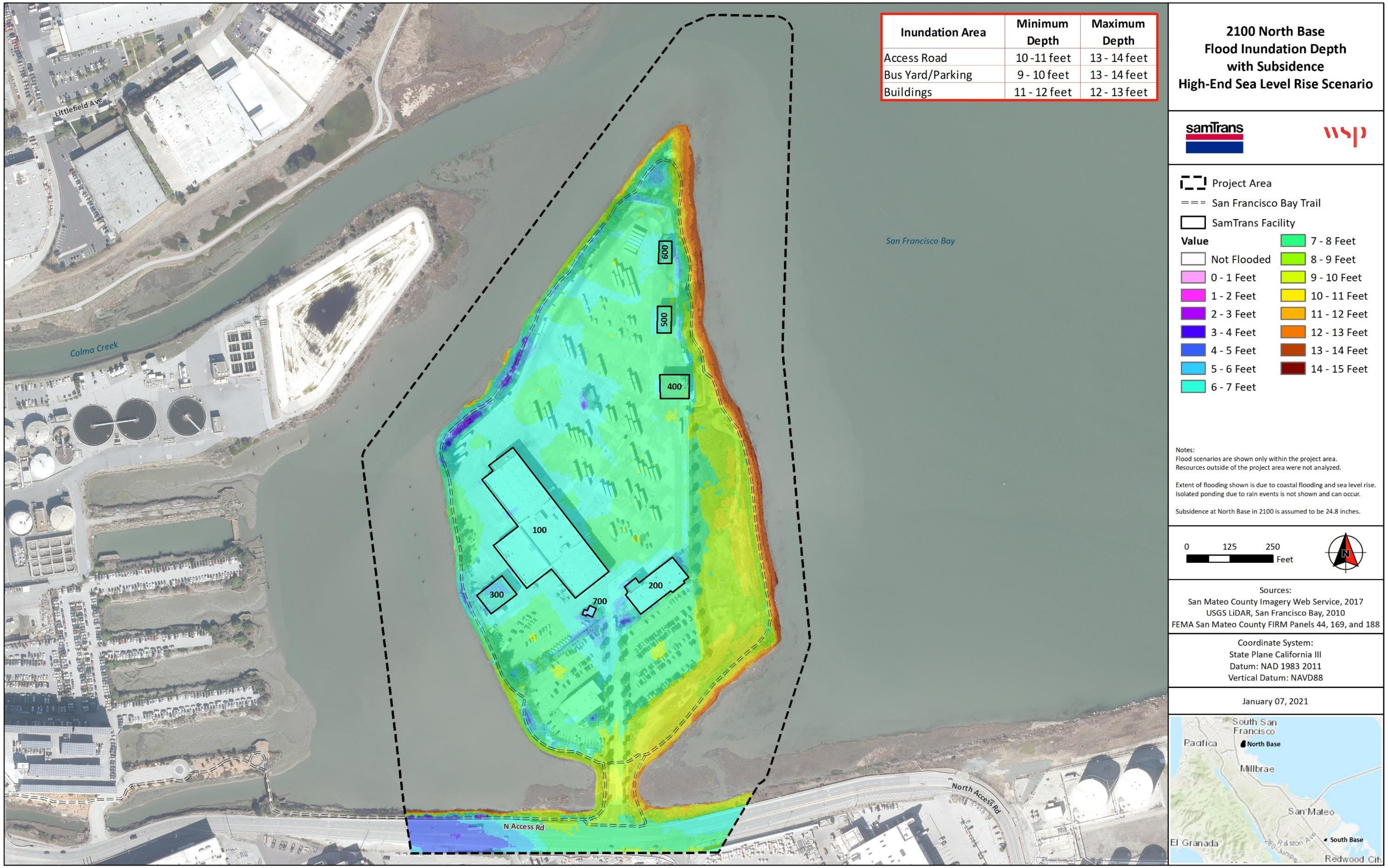
Figure 7. 2100 North Base SLR Flood Inundation Map

Figure 8. 2100 North Base Flood Inundation Depth with Subsidence Mid-Level SLR Scenario



Inundation Area	Minimum Depth	Maximum Depth
Access Road	0 - 1 feet	6 - 7 feet
Bus Yard/Parking	2 - 3 feet	4 - 5 feet
Buildings	2 - 3 feet	4 - 5 feet
Vegetated Area	2 - 3 feet	6 - 7 feet

Figure 9. 2100 North Base Flood Inundation Depth with Subsidence High-End SLR Scenario



2.1.2.2 South Base

Figure 10 through Figure 12 depict SLR-related flood inundation at South Base. Phelps Slough may experience backwater flooding resulting from higher tide levels caused by SLR. There are four stormwater pumps at the San Carlos Airport, which can reduce the extent of flooding from precipitation onsite in a 100-year storm. However, the pumps are only designed to pump freshwater. They are would be ineffective at pumping saltwater that inundated the area (San Mateo County, 2018) because they are designed for freshwater pumping. A hydraulic model was completed for the Corilleras Creek watershed to evaluate future SLR and precipitation effects on fluvial flooding (San Mateo County, 2019).

2050

Figure 10 depicts flood inundation at South Base in 2050 without considering subsidence for both the mid-level and high-end scenarios. Figure 11 depicts flood inundation depth at South Base in 2050 under the mid-level scenario with subsidence, and Figure 12 depicts flood inundation depth under the high-end scenario with subsidence. Subsidence by 2050 is estimated to be 3.15 inches at South Base. Table 13 summarizes the projected extent of flooding at South Base in 2050.

Table 13. South Base Extent of Flooding in 2050

Scenario	Figure No.	Extent of Flooding During 100-Year-Storm Event
Baseline	Figure 10	No flooding is anticipated under the baseline scenario.
Mid-Level	Figure 10	No flooding is anticipated under the mid-level scenario due to inundation. Wave overtopping of the levee could occur under this scenario, which may lead to flooding adjacent to the levee that may reach into the site. Additionally, fluvial flooding may occur from Phelps Slough during an extreme storm if modifications are not made to downstream pumps along the levee.[14]
High-End	Figure 10	The entire facility would be inundated under the high-end scenario.
Mid-Level + Subsidence	Figure 11	No flooding is anticipated under the mid-level scenario with limited subsidence.
High-End + Subsidence	Figure 12	The entire facility would be inundated with up to 12 feet of water under the high-end scenario with limited subsidence. All buildings would be flooded with up to 7 feet of water.

[14] This would need to be verified using hydraulic modeling. Current FEMA maps indicate no flooding in this area due to the levee and control structures. Backwater conditions create potential to modify and affect the extent of flooding under the base flood event with SLR.

Figure 10. 2050 South Base SLR Flood Inundation Map

Figure 11. 2050 South Base Flood Inundation Depth with Subsidence Mid-Level SLR Scenario

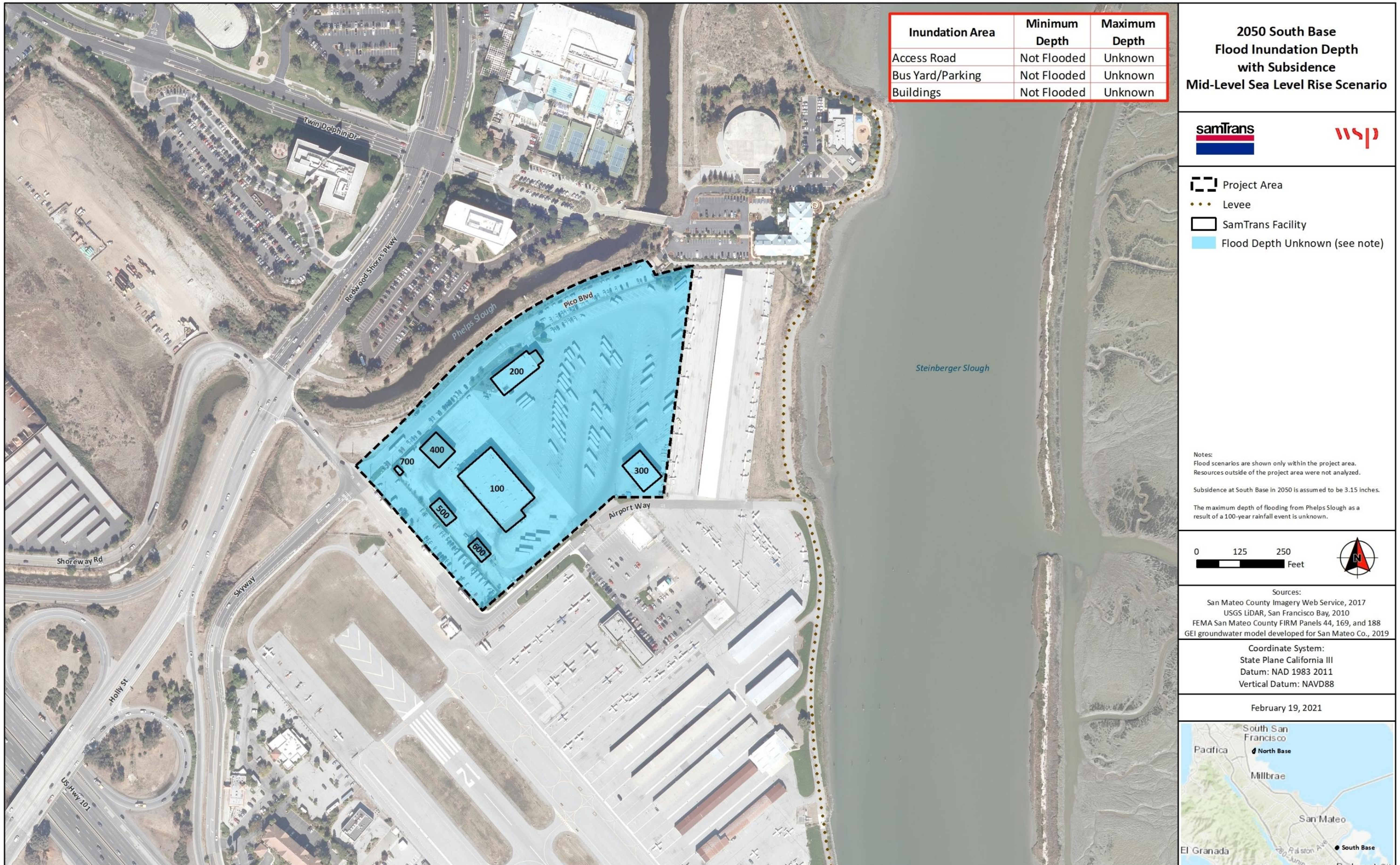
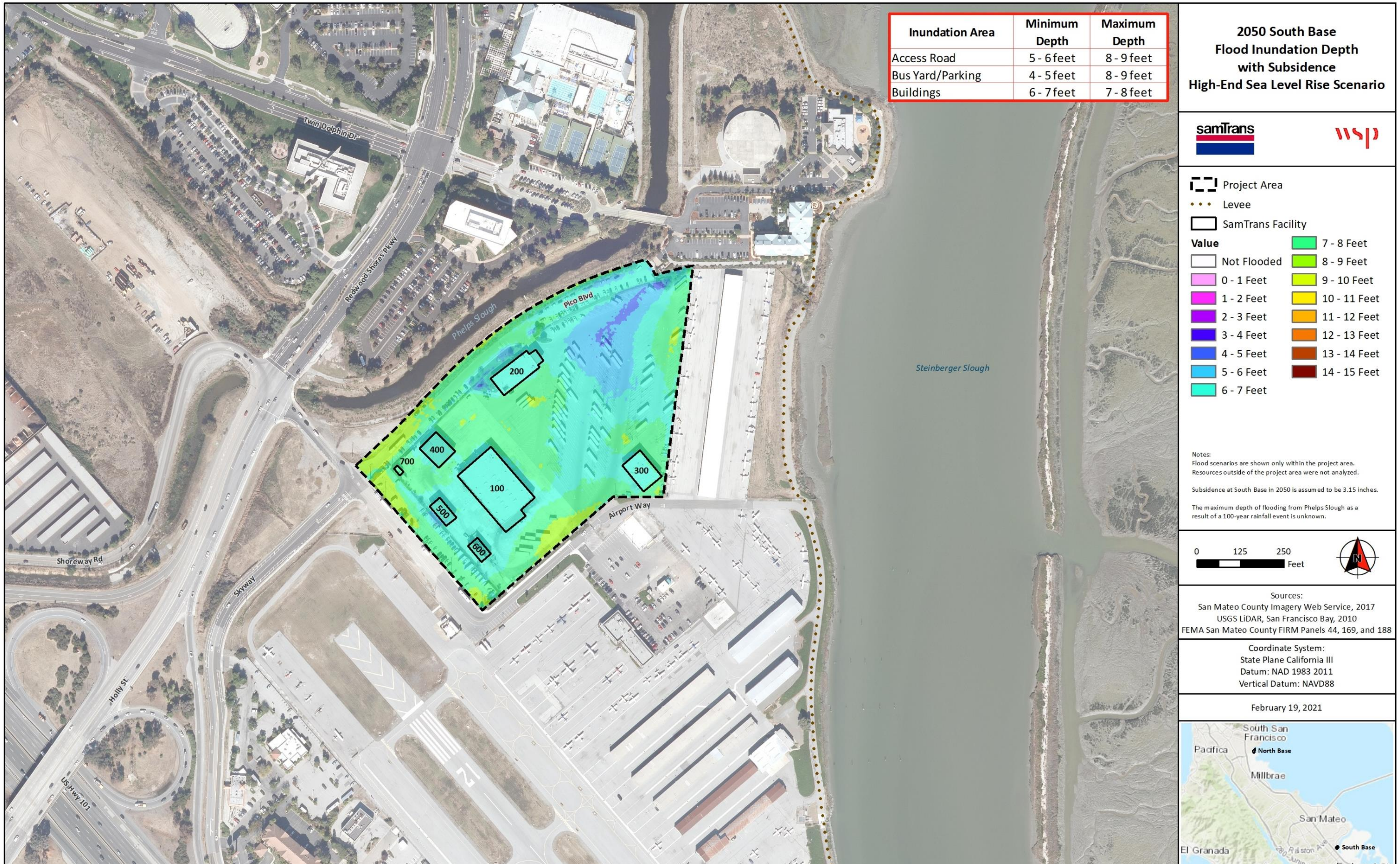


Figure 12. 2050 South Base Flood Inundation Depth with Subsidence High-End SLR Scenario



Inundation Area	Minimum Depth	Maximum Depth
Access Road	5 - 6 feet	8 - 9 feet
Bus Yard/Parking	4 - 5 feet	8 - 9 feet
Buildings	6 - 7 feet	7 - 8 feet

2100

Figure 13 depicts flood inundation at South Base in 2100 without considering subsidence. Figure 14 depicts flood inundation depth at South Base in 2100 under the mid-level scenario with subsidence, and Figure 15 depicts flood inundation depth under the high-end scenario with subsidence. In 2100, subsidence is assumed to be 7.09 inches. Table 14 summarizes the projected extent of flooding at South Base in 2100.

Table 14. South Base Extent of Flooding in 2100

Scenario	Figure No.	Extent of Flooding During 100-Year-Storm Event
Mid-Level	Figure 13	The entire facility would be inundated under the mid-level scenario.
High-End	Figure 13	The entire facility would be inundated under the high-end scenario.
Mid-Level + Subsidence	Figure 14	The entire facility would be inundated with up to 15 feet of water under the mid-level scenario with subsidence.
High-End + Subsidence	Figure 15	The entire facility would be inundated with up to 16 feet of water under the mid-level scenario with subsidence.

Figure 13. 2100 South Base SLR Flood Inundation Map

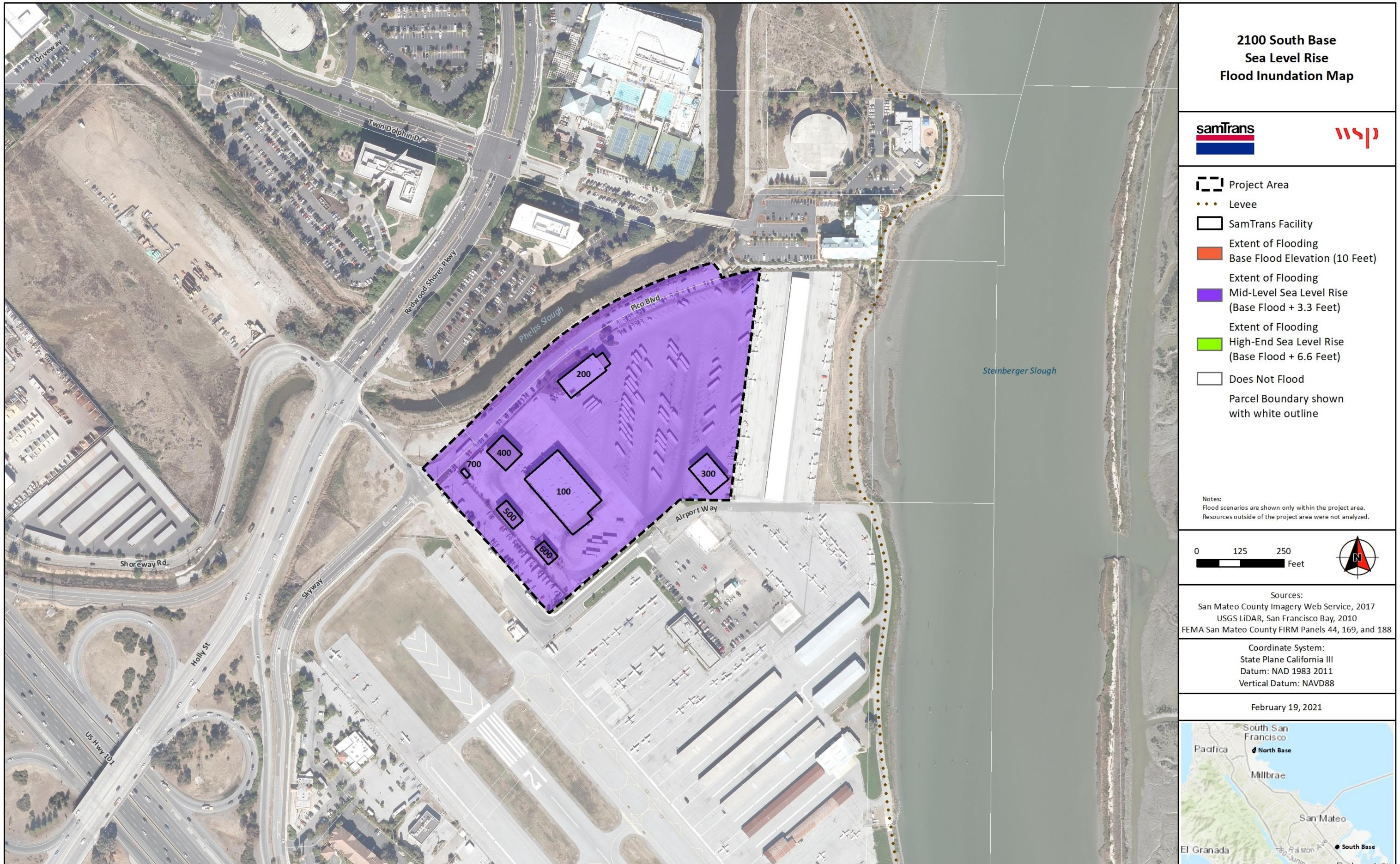


Figure 14. 2100 South Base Flood Inundation Depth with Subsidence Mid-Level SLR Scenario

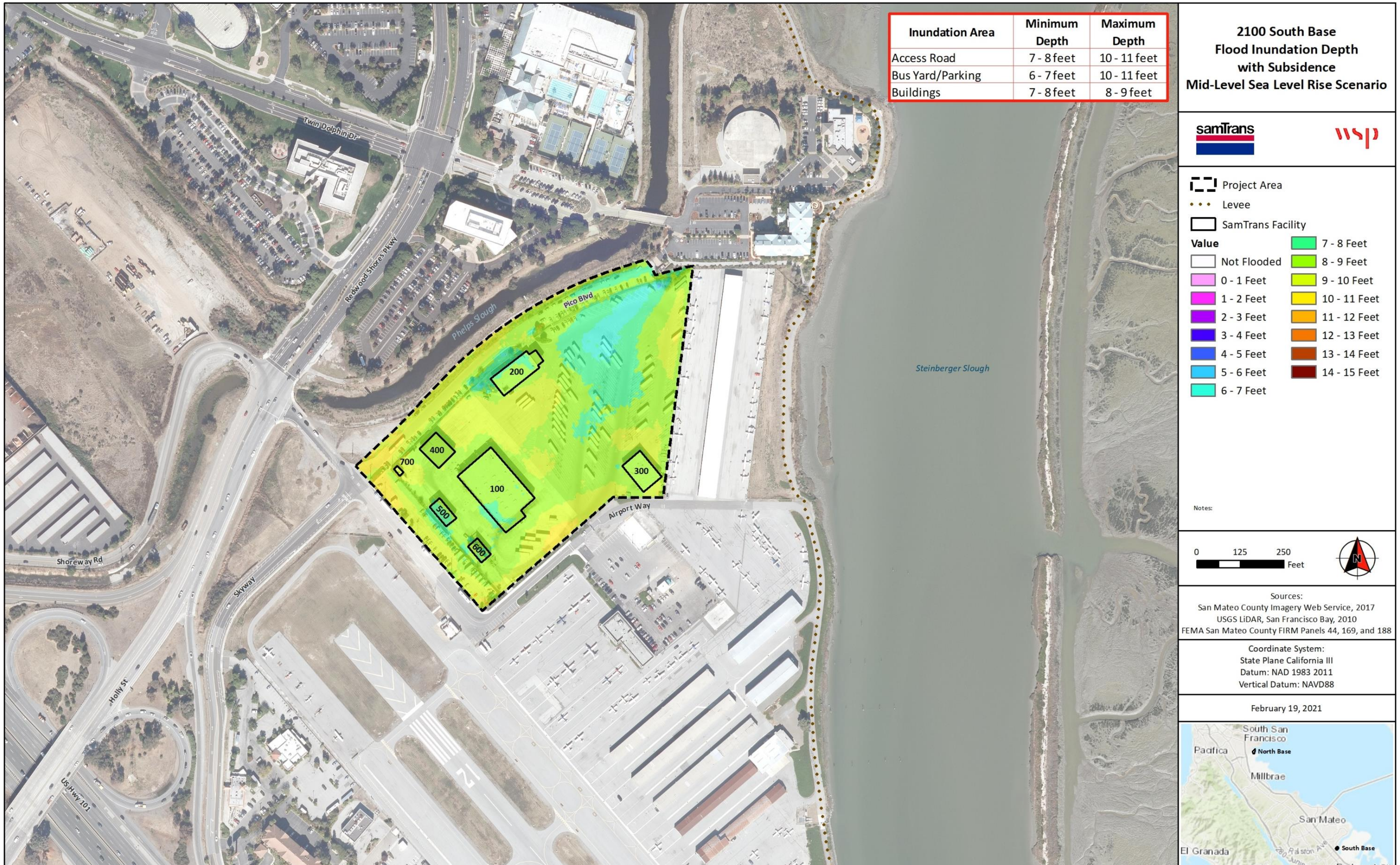


Figure 15. 2100 South Base Flood Inundation Depth with Subsidence High-End SLR Scenario

2.1.3 Asset Sensitivity

Asset sensitivity describes the degree to which North and South Bases are affected by SLR, storm surge and fluvial flooding impacts. The asset sensitivity analysis is based on 2019 existing site conditions. This information can be used to inform the location and design of proposed BEB infrastructure. This section builds upon the information contained in the San Mateo County North Base asset vulnerability profile (San Mateo County, 2018, Appendix D).

2.1.3.1 North Base

The facility is highly sensitive to flooding. The facility is only accessible from North Access Road. If this road floods, which could occur under current conditions during a 100-year flood event, the facility would be completely cut-off. This road is owned by the San Francisco Airport, which is planning to protect this road with tide gates that could also potentially cut off access to the road. If the bus yard were to flood, the buses, the paratransit fleet, the disaster relief bus and other vehicles would no longer be able to access the site for repairs or fuel. This could disrupt service to the community, as operations would likely have to divert to South Base for repairs and fuel, which would exceed South Base's capacity (assuming South Base is not simultaneously flooded). Further, fleet vehicles could become flooded and damaged or destroyed if not moved ahead of the storm event. If underground assets were inundated, there are no systems in-place to remove water or maintain their functionality. The underground fuel tanks, which are dual-walled and anchored with secondary containment and monitoring systems, are not considered vulnerable to inundation or saltwater intrusion. Electrical infrastructure would not function if flooded and could become corroded by saltwater.

One of the two oil-water separators is a new, spill-resistant model while the other is older and more vulnerable. Flooding of the older oil-water separator could cause it to overflow onsite and enter the San Francisco Bay.

In the case of temporary flooding, the facility could be inoperable for seven days or more, potentially leading to a higher rate of bus breakdowns and further disruption to transportation services in the County.

Permanent flooding was evaluated for North Base depending on the affected areas, see Table 15 for flooding in 2050 and Table 16 for estimates in 2100. The buildings at North Base are not predicted to be affected by permanent flooding in the 2050 scenarios.

Table 15. North Base Depth of Permanent Flooding in Tidal Range in 2050

	Access Road		Bus Yard/Parking		Vegetated Areas	
Scenario	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Mid-Level		0 ft		0 ft		0 ft
High-End		0 ft		0 ft	0 ft	0 – 1 ft
Mid-Level + Subsidence	0 ft	0 – 1 ft		0 ft	0 ft	0 – 1 ft
High-End + Subsidence	0 ft	0 – 1 ft	0 ft	0 – 1 ft	0 ft	1 – 2 ft

Table 16. North Base Depth of Permanent Flooding in Tidal Range in 2100

	Access Road		Bus Yard/Parking		Buildings		Vegetated Areas	
Scenario	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Mid-Level	0 ft	1 – 2 ft	0 ft	0 – 1 ft		0 ft	0 ft	1 – 2 ft
High-End	0 ft	4 – 5 ft	0 – 1 ft	3 – 4 ft	1 – 2 ft	3 – 4 ft	0 ft	0 – 1 ft
Mid-Level + Subsidence	0 ft	3 – 4 ft	0 ft	2 – 3 ft	0 ft	1 – 2 ft	0 ft	0 – 1 ft
High-End + Subsidence	1 – 2 ft	6 – 7 ft	2 – 3 ft	5 – 6 ft	3 – 4 ft	5 – 6 ft	0 ft	1 – 2 ft

2.1.3.2 South Base

The facility is highly sensitive to flooding. The site is flat, so even low levels of flood water could cover much of the bus yard. If the bus yard were to flood, the buses, the disaster relief bus and other vehicles would no longer be able to access the site for repairs or fuel. This could disrupt service to the community, as operations would likely have to divert to North Base for repairs and fuel (assuming North Base is not simultaneously flooded). Even though North Base is a larger facility, it is not designed to accommodate the entire SamTrans fleet, which would exceed North Base's capacity. As above, fleet vehicles could become flooded and damaged or destroyed if not moved in advance of flooding. If underground assets were inundated, there are no systems in-place to remove water or maintain their functionality. However, the underground fuel tanks, which are dual-walled and anchored with secondary containment and monitoring systems, are not considered vulnerable to inundation or saltwater intrusion. Electrical infrastructure would not function if flooded and could become corroded by saltwater as in North Base. Similarly, if the site is flooded, the oil-water separators could overflow and discharge onsite.

In the case of temporary flooding, the facility could be inoperable for seven days or more, potentially leading to a higher rate of bus breakdowns and further disruption to transportation services in the County. Under the high-end 2050 scenario and any 2100 scenario, South Base would flood. South Base would only be expected to flood under the baseline or mid-level scenarios should the Redwood City levee fail or experience wave overtopping, or if Phelphs Slough is overtopped.

Permanent flooding is not estimated to effect South Base in 2050 under the mid-level or high-end scenarios because the area is protected by the Redwood City levee. See Table 17 for the estimated permanent flooding in 2100.

Table 17. South Base Depth of Permanent Flooding in Tidal Range in 2100

	Access Road		Bus Yard/Parking		Buildings	
Scenario	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Mid-Level	Protected by levee – 0 ft					
High-End	7 – 8 ft	10 – 11 ft	6 – 7 ft	10 – 11 ft	7 – 8 ft	8 – 9 ft
Mid-Level + Subsidence	Protected by levee – 0 ft					
High-End + Subsidence	8 – 9 ft	10 – 11 ft	7 – 8 ft	10 – 11 ft	8 – 9 ft	9 – 10 ft

The SamTrans Bus Transit System Safety Program Plan (2019) details how SamTrans would respond in an emergency, such as a flooding event at one or both bases. According to this plan:

> *Both North and South bases have been prepared to continue services even after the main buildings sustain heavy damage. Trailers were purchased and equipped to serve as alternate Dispatch and Maintenance centers. The Bus Transportation trailer has alternate radio and cell phone communications capabilities. The Bus Maintenance trailer can sustain fueling and lubricating operations. Each base is equipped with a sea-container, containing food, drinking water, and hygiene related articles. These sea-containers also contain minimal equipment suitable for light search and rescue and first aid supplies. Each trailer is equipped with a generator capable of providing alternative power in the event of electrical failure. Each base is equipped with a motorcycle should off-road transportation capability be needed (p. 38).*

SamTrans also has specific Earthquake Orders for dispatches and bus operators as well as a standard operating practice for Emergency Preparedness. These plans can be enacted during flood events, but do not address protecting assets in advance of flooding, nor long-term flooding such as SLR inundation. In addition, if both sites were inaccessible and/or completely flooded, SamTrans would need a plan for hosting temporary functions at an alternate location.

2.1.4 Adaptive Capacity and Vulnerability Summary

Adaptive capacity is the ability of North and South Bases to adjust to or minimize potential damages caused by SLR, storm surge and fluvial flooding-rated hazards to avoid disruptions to transit service. This section builds upon the information contained in the San Mateo County North Base asset vulnerability profile (San Mateo County, 2018, Appendix D).

2.1.4.1 North Base

North Base has moderate adaptive capacity. All of the facility's functions could be moved to South Base in the event of a 100-year storm event and under the 2050 mid-level scenario, which are not projected to affect South Base (assuming Phelps Slough does not overtop). However, under a high-end 2050 scenario and either 2100 scenarios, South Base would also be flooded without further intervention. SamTrans has a plan in place for an earthquake, which could be enacted for severe flooding. If vehicles are capable of leaving the facility, the plan assumes that the dispatch, fueling and repair operations would be transferred to South Base. If North Access Road were inundated, the revenue and non-revenue vehicles would be stranded, which could severely impair the adaptive capacity of the SamTrans network. As noted previously, North Access Road is not in SamTrans' control, so SamTrans will need to coordinate with the property owner (SFO) to fortify or protect the access road from flooding.

The facility has backup generators at grade and subject to inundation by 2100, but an event that flooded the generators would also flood the facility yard and interrupt service with or without backup power. The auto shop brake pits are equipped with sump pumps to mitigate groundwater flooding but are likely to be overloaded with salt-water inundation. The site is experiencing differential settlement and subsidence at an alarming rate that will be difficult to adapt existing site features without major modifications of the land. Additionally, areas around the facility will be flooded concurrently with North Base that, should modifications to the site be made to adapt to SLR impacts, may strand the facility during storm events that prevent vehicles from getting to the base until after the storm and flood waters recede.

2.1.4.2 South Base

South Base has moderate adaptive capacity. Unlike North Base, if South Base is flooded it does not have the capacity to relocate functions to North Base, since North Base would likely be flooded also. The existing Redwood City levee protects South Base from flooding under a 100-year storm event and under the 2050 low-end scenario. However, the levee is only constructed to the current 100-year storm. Therefore, the levee would be overtopped under the 2050 high-end scenario and either 2100 scenario without further intervention. In addition, the levee has a 460-foot gap south of the San Carlos Airport that allows planes to safely take off and land. This gap is protected by a temporary barrier that San Carlos Airport deploys during storm events. If the barrier is not installed in time or fails, South Base could flood under a 100-year storm event. The levee could be raised before 2050 outside of the airport landing and takeoff zones to provide protection against future SLR. This also will likely require modifications to the downstream pumping system of Phelps Slough to account for SLR. SamTrans does not have control of the levee and does not own land directly adjacent to the Bay, so will need to coordinate with Redwood City and San Carlos Airport to develop coastal resilience strategies.

2.1.5 Limitations

This assessment relied on existing published SLR and subsidence data. Topographic information is based on 2-meter resolution Digital Elevation Models (DEMs) from 2010. Any changes after 2010 may not be captured. It is not possible to determine a site-specific subsidence rate based on current information. The subsidence rate used in this assessment is an estimate based on the most recent study available at the time of the analysis, which evaluated historical subsidence in the Bay Area. The value incorporated into this assessment is conservative. Actual site subsidence could occur at a slower or faster rate. In addition, based on an evaluation of North Base buildings 100 and 200, subsidence is not occurring evenly throughout the site.

2.2 ACTION ALTERNATIVES

Following the SLR vulnerability assessment, SamTrans evaluated possible adaptation responses to address and mitigate SLR impacts to North and South bases, referred to as "action alternatives." To develop these action alternatives, SamTrans referenced the NAVFAC Climate Change Installation Adaptation and Resilience Planning Handbook (2017). Stage II of the handbook includes a five-step process for identifying and screening action alternatives:

1. Identify potentially suitable adaptation options
2. Identify benefits and limitations
3. Evaluate feasibility
4. Evaluate appropriateness
5. Characterize approach to decisions under uncertainty

Action alternatives that are not feasible or appropriate are eliminated from further consideration. The remaining action alternatives were carried forward for evaluation in Stage III of the NAVFAC process, which involves evaluating costs and benefits of each retained action alternative to identify the most cost-effective solutions. Figure 16 summarizes the Stage II action alternative assessment/screening process and how it feeds into Stage III.

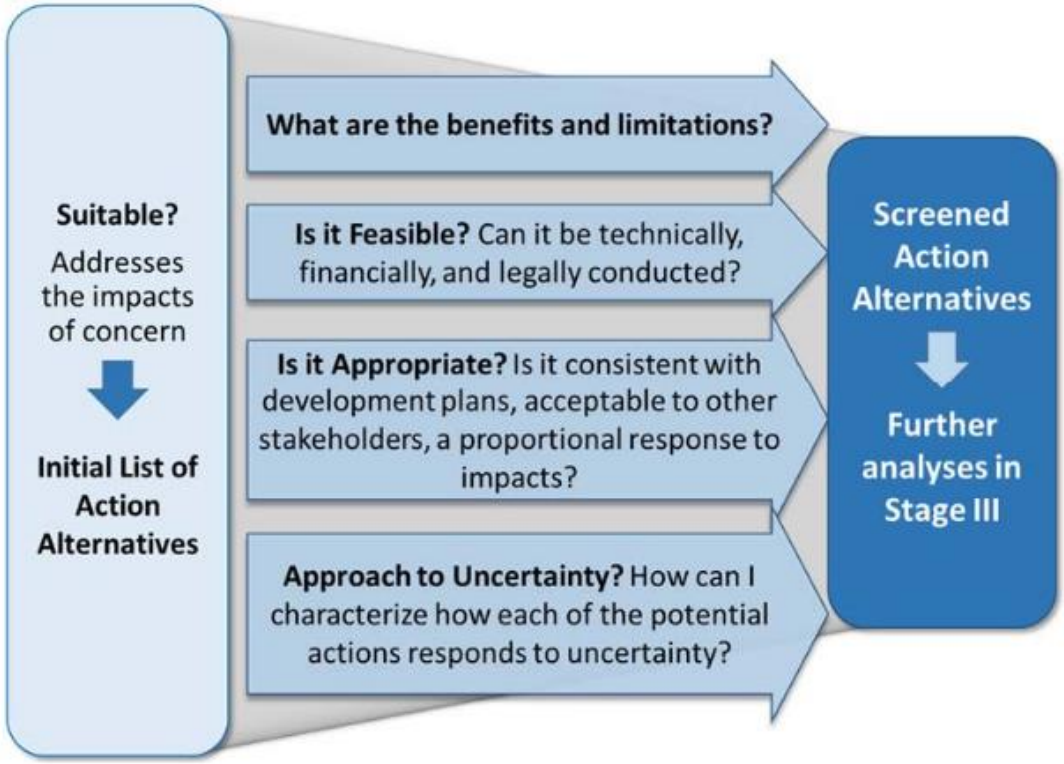


Figure 16. Depiction of Stage II Screening Process

By referencing the NAVFAC process, SamTrans developed an initial list of potentially suitable action alternatives that would build resilience against SLR and subsidence at North and South bases. Action alternatives were categorized into one of four types of adaptation approaches, which align with the U.S. Army Corps of Engineers (USACE) risk management strategy classification: (1) structural; (2) natural and nature-based; (3) facilities; and (4) non-facilities (Table 18).

Table 18. Adaptation Approaches for SLR

Approach	Definition
Structural	Use a built structure to alter the flow of floodwater to protect large areas from flooding.
Natural/Nature-based	Constructing or modifying natural features such as dunes, tidal marshes and living shorelines to reduce the impact of storm surge.
Facilities	Construction solutions such as building to a new standard that accounts for changing flood risk, constructing smaller scale built structures designed to protect an asset, making physical alterations to an existing asset to reduce flood damage and relocating a facility.
Non-facilities	A range of techniques that rely on changes in siting, management or maintenance of infrastructure to reduce flood damage.

Source: Adapted from NAVFAC, 2017, p. II-3

The complete list of action alternatives SamTrans considered is summarized in Appendix A.1. SamTrans identified the benefits and limitations of each action alternative. A broad set of action alternatives was reviewed during a workshop that included SamTrans staff from the following departments: planning, operations planning, fleet, communications, facilities and finance. Staff discussed the limitations, feasibility and appropriateness of the action alternatives. Through these discussions, SamTrans was able to eliminate or defer action alternatives that were not suitable. Table A.1 in Appendix A summarizes benefits and limitations associated with the North Base action alternatives, and Table A.2 summarizes the South Base action alternatives.

2.2.1 North Base Action Alternatives

As shown in Table A.1 in Appendix A, 11 action alternatives were initially identified for North Base. Six of the North Base action alternatives were considered infeasible and/or inappropriate and eliminated from further consideration. Retained action alternatives are listed in Table 19. Details on both retained and eliminated action alternatives are provided in Table A.1 in Appendix A.

Table 19. Retained North Base Action Alternatives

No.	Action Alternative
Structural Approaches	
1	Levee/breakwater perimeter protection system.
Facilities Approaches	
3	Reconstruct facility and provide foundation support to address settlement.
4	Floodproof planned new construction by elevating all utilities and designing the ground level to accommodate flood water. The new buildings shall have no basement, slab-on-grade only; commercial occupancy on 2nd floor and up.
5	Elevate new building electrical and HVAC systems, moving relevant equipment to roof, adding elevated platforms to house equipment at ground level, or raising the elevation of the ground where the equipment rests.
Non-Facilities Approaches	
8	Consider locating BEB charging stations offsite in the future.

Action alternative 1, constructing a levee protection system, was retained for further analysis. Unrelated to the Plan, SamTrans had retained HDR to complete a conceptual design of a horizontal levee system for North Base, which is a “hybrid” strategy, meaning it incorporates both structural and nature-based solutions to flood mitigation. A horizontal levee includes space for tidal planted ecotone, which absorbs the force of oncoming storm surge. The levee would both address a current erosion issue as well as provide protection against future SLR and incorporate natural infrastructure. The natural infrastructure and living shoreline elements would need to be studied to determine if it would result in avian conflicts with SFO. A map of the conceptual levee system is shown in Figure 17.

Figure 17. North Base Conceptual Levee System

As currently envisioned above (HDR, 2019), the levee system consists of a horizontal levee around the perimeter of the North Base peninsula with an ecotone transition zone along the east side of the base and a levee with a rock slope protection revetment along the west side of North Base. The ecotone transition zone proposed for the east side includes a very gradual slope that extends from the rim of the island approximately 200 to 300 feet out the tidal zones for wave dampening. The ecotone fill in the transition zone will serve as a sacrificial buffer for flood protection. The slope of the ecotone would be vegetated to provided habitat for added local biodiversity. The transition zone would be backed by a more traditional earthen levee that would wrap around the entire perimeter of the island. The two distinct sections are needed due to spatial constraints on the west side of the island, where a transition zone would effectively block the strait through which Colma Creek and the San Bruno Channel drain. The crown of the levee to extend around the perimeter of the island would be approximately at an elevation of 13.3 feet NAVD 88 to protect against a 100-year flood event and SLR. The crown would have a minimum width of 20 feet. The San Francisco Bay Trail would be restored and placed on the crown of the levee to allow for space and for added aesthetics. Importantly, the levee system will need to tie into SFO's proposed sea wall to be effective. See section 2.2.3 for a discussion of SFO's proposed sea wall. A lifecycle benefit-cost analysis (LBCA) was performed for the construction of the levee protection system to evaluate the cost effectiveness of different levee designs (see Section 2.3 and Appendix B).

Four additional action alternatives were retained, as indicated in Table 19 and Table A.1 in Appendix A. Action alternatives for future consideration include 3 – reconstructing North Base buildings and providing support to address settlement, 4 – floodproofing new construction, 5 – elevating new building electrical and HVAC systems and 8 – potentially locate BEB chargers offsite. However, action alternative 3 may be addressed by the reconstruction of building 200 and will not be evaluated further in this study. Appendix C summarizes high-level next steps, costs and considerations for each retained action alternative.

2.2.2 South Base Action Alternatives

As shown in Table A.2 in Appendix A, 11 action alternatives were identified for South Base. Five action alternatives were not considered feasible and/or appropriate for South Base and were eliminated from further consideration. Retained action alternatives are listed in Table 20. Details on both retained and eliminated action alternatives are provided in Table A.2 in Appendix A.

Table 20. Retained South Base Action Alternatives

No.	Action Alternative
Structural Approaches	
1	Increase the levee height along Steinberger Slough

No.	Action Alternative
Natural and Nature-based Approaches	
3	Excavate/dredge Phelps Slough.
Facilities Approaches	
4	Elevate new building electrical and HVAC systems, moving relevant equipment to the roof, adding elevated platforms to house equipment at ground level, or raising the elevation of the ground where the equipment rests.
5	Install and modify pump systems downstream of Phelps Slough.
6	Install check dams, ponds and infiltration systems in upper watershed to reduce surface runoff and flow going into Phelps Slough to reduce freshwater flood depths.
Non-Facilities Approaches	
9	Consider locating some BEB charging stations offsite in the future.

Action alternatives 1, 3, 4, 5 and 6 were retained, all of which focus on regional solutions to address immediate concerns about flooding at Phelps Slough and long-term overtopping of the Redwood City levee. Action alternative 9 was also retained, which focuses on placing some BEB chargers offsite. SamTrans determined that a detailed cost-benefit analysis was not appropriate for South Base at this time, as the key action alternatives would require regional coordination and SamTrans' role and potential cost share, if any, is currently unknown. Appendix C summarizes high-level next steps, costs and considerations for each retained action alternative.

2.2.3 Regional Adaptation Projects

Communities and agencies in the Bay Area are responding to future SLR in various ways. Foster City will be raising their levee height. The San Francisco International Airport plans to install a perimeter wall and horizontal levee. The Port of San Francisco has proposed a sea wall, redesigning the Ferry Building and raising future project elevations. Regional collaboration with adjacent landowners will provide greater protection against future conditions. San Mateo County has created the Flood and Sea Level Rise Resiliency District to coordinate cross-jurisdictional response efforts.

2.2.3.1 San Francisco Airport

SFO is planning to construct a 10-mile-long sea wall around the airport perimeter, including along North Access Road. The sea wall will have a top of elevation of 15.3 feet, which corresponds to the stillwater elevation plus two feet of freeboard and three feet of SLR. The new sea wall should protect SFO through 2085. The design has not yet been finalized, but due to the presence of existing gas lines, it may not be feasible re-grade North Access Road to a higher elevation. Therefore, the current design would require the installation of a flood gate at the entrance to North

Base along North Access Road and a deployable flood gate further west along the lowest point of North Access Road that will be used during storm events in the future once needed. This design would result in North Base being inaccessible during a future storm event that would require use of floodgates. As proposed in SFO's November 2020 Notice of Preparation (NOP) of an Environmental Impact Report, the SFO sea wall and floodgates across North Access Road are expected to be in place by 2032.

A regional alternative that would involve constructing an operable tide gate stretching from the northern end of the North Base property across the San Bruno canal to South San Francisco was studied as part of the San Bruno Creek/Colma Creek Resiliency Study (SFO, 2015) and would protect a number of properties to the west, would reduce the length of sea wall needed to protect SFO, and the length of a horizontal levee needed around North Base.

2.3 LIFECYCLE BENEFIT COST ANALYSIS

A LBCA was conducted to assess future SLR and flood risks to North Base and the potential costs/cost savings from constructing a horizontal levee around its perimeter (action alternative 1). The LBCA examined expected costs due to SLR and associated flooding for a "no-action" alternative, which assumes current conditions, and three different levee alternatives. In this LCBA, the benefits are represented as the avoided hazard-related costs that would have occurred under a no-action alternative. A LBCA was not conducted for South Base because regional solutions outside of SamTrans' jurisdiction is required for adequate flood protection.

Each levee alternative was assumed to tie into a broader regional levee system to form a closed system of flood protection. The three levee alternatives included (1) a standard option, based on a conceptual design included in the North Base Erosion Control Alternatives study (HDR, 2019); (2) a risk-averse option with a higher crest designed to withstand higher magnitude flood levels; and (3) a flexible option with an initial crest that could later be added onto as conditions change.

Simulations of future annual maximum water levels were developed for three different OPC SLR scenarios (2018):

1) High Emissions Median (50% chance sea level rise meets or exceeds)
2) High End of Likely Range (17% chance sea level rise meets or exceeds)
3) 1-in-200 (0.5% chance sea level rise meets or exceeds)

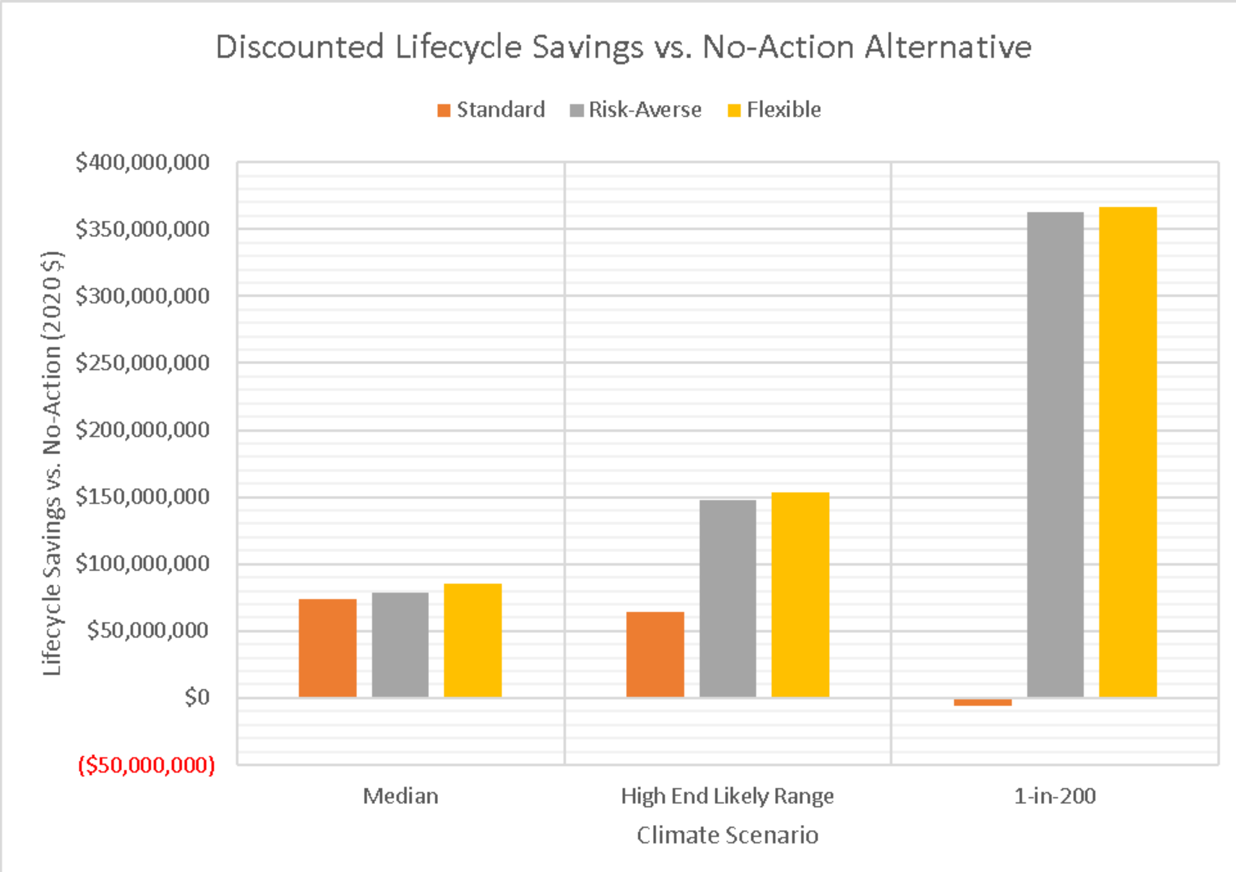
The analysis included hazard-related costs such as flood damage and service disruption costs, capital costs of investment and O&M costs. See Appendix B for more details on the LBCA methodology and detailed results.

Table 21 and Figure 18 show lifecycle savings for each alternative compared to the baseline no-action option. All three of the levee options represent a substantial cost savings compared to the no-action alternative under the median and high-end likely SLR scenarios. The flexible and risk-adverse alternatives produce even more cost savings under the 1-in-200 SLR scenario. The no action alternative is very costly under all three SLR scenarios.

Table 21. Present Discounted Cost Savings (Loss) Compared to Baseline (No Action) Alternative

Scenario	Levee Option Name	80% C.I. Low	Expected Value	80% C.I. High
Median	No-Action	$0	$0	$0
Median	Standard	$79,883,000	$73,702,000	$71,158,000
Median	Risk-Averse	$70,132,000	$78,412,000	$91,774,000
Median	Flexible	$76,598,000	$84,878,000	$98,240,000
High End Likely Range	No-Action	$0	$0	$0
High End Likely Range	Standard	$70,479,000	$64,175,000	$55,155,000
High End Likely Range	Risk-Averse	$136,635,000	$147,364,000	$159,683,000
High End Likely Range	Flexible	$143,101,000	$153,830,000	$155,625,000
1-in-200	No-Action	$0	$0	$0
1-in-200	Standard	$2,898,000	($5,453,000)	($14,358,000)
1-in-200	Risk-Averse	$352,600,000	$362,576,000	$377,002,000
1-in-200	Flexible	$356,562,000	$366,538,000	$365,907,000

Figure 18: Lifecycle Savings versus No-Action Alternative



2.3.1 Socioeconomic and Environmental Impacts

This North Base LBCA assesses the upfront capital costs and long-term O&M costs to SamTrans from SLR and associated flooding. However, SamTrans riders and the broader regional transportation system, economy, environment and communities would be affected by flood hazards to North Base as well in ways not accounted for in this analysis.

In cases where flooding to North Base disrupts or delays bus service, riders would incur extra costs. For delays, these could include value-of-time costs to the riders. Based on data prior to COVID-19, approximately 61% of SamTrans riders have no access to a car, and 44% of riders use SamTrans to commute to work (SamTrans, n.d.) suggesting that service disruption could cause lost wages and potentially greater transportation costs if riders must switch from bus service to a more expensive travel mode. Such service disruption would have a disproportionate impact on the SamTrans' ridership, over half of whom make less than half of San Mateo County's median of household income $113,776 (US Census, 2018).[15] Indeed, 18% of SamTrans' riders have an annual household of less than $10,000, 19% make between $10,000 to $24,999 and 17% between $25,000 to $49,999 (SamTrans, n.d.). SamTrans' ridership relies on SamTrans' service and may find it challenging to afford more costly modes of travel.

Further, disruption-related shifts from bus service to modes such as auto use could increase safety risks, pollutant emissions, GHG emissions and congestion on the regional transportation system. There could also be local environmental impacts in the event of North Base flooding. Chemicals or other waste from North Base could pollute the water and soil during a flood event. Cleanup costs for this type of event could be very significant. In general, protecting North Base from projected future flooding would help prevent these broader impacts to the region and reduce long-term costs for SamTrans.

[15] In 2018 dollars.

2.4 PORTFOLIO OF ACTION ALTERNATIVES

As discussed, and based on the vulnerability assessment and action alternative analysis, five action alternatives were retained for North Base and six action alternatives were retained for South Base. Table 22 presents the portfolio of action alternatives for each base and summarizes the key benefits and anticipated implementation duration should SamTrans decide to implement the action alternative. SamTrans should study whether to advance alternatives in the near-term, delay others until a later time, and ultimately not pursue some of the action alternatives due to staff time, financial, or other limitations.

Table 22. Portfolio of SLR Action Alternatives

Action Alternative	Key Benefits	Implementation Time
North Base		
Install a levee/breakwater perimeter protection system.	Protects North Base from the impacts of SLR flooding and inundation.	Begin study in next 1 to 3 years, will require a lengthy permitting process.
Reconstruct facility and provide foundation support to address settlement.	Reduces risk of permanent flooding under SLR projections.	Building 200 to be reconstructed; evaluate for other buildings that require major renovations as needed.
Floodproof planned new construction by elevating all utilities and designing the ground level to accommodate flood water.	Prevent damage to utilities if a flooding event were to occur.	Consider when reconstructing building 200 and for any major facility upgrades.
South Base		
Increase the levee height along Steinberger Slough.	Protects South Base from the impacts of SLR flooding and inundation.	Coordinate with other regional stakeholders in next 1 to 3 years and determine appropriate next steps for SamTrans.
Excavate/dredge Phelps Slough.	Protects South Base from fluvial flooding.	
Install check dams, ponds and infiltration systems in upper watershed to reduce surface runoff and flow going into Phelps Slough to reduce floodwater flood depths.	Protects South Base from fluvial flooding.	
Install and modify pump systems downstream of Phelps Slough.	Protects South Base from fluvial flooding.	

Action Alternative	Key Benefits	Implementation Time
Both Bases		
Elevate new building electrical and HVAC systems.	Ensure reliable operation of facilities and BEB fleet.	Consider when constructing/ reconstructing new buildings and when installing new HVAC equipment.
Locate some BEB chargers offsite.	Ensure reliable operation of BEB fleet if the bases are inaccessible during a flooding event.	Consider once fleet is electrified (estimated 2038).

Appendix C summarizes high-level next steps, costs and considerations for each retained action alternative.

3 HEAT

Chapter 3 presents the results of the SamTrans high heat vulnerability assessment and action alternative analysis.

3.1 VULNERABILITY ASSESSMENT

SamTrans assessed the vulnerability of its facilities, vehicles and passengers to high temperatures. The San Francisco Bay Area is particularly vulnerable to heat because it has historically experienced moderate temperatures with few extreme swings in highs and lows. Consequently, communities are ill prepared to manage the effects of extreme temperature.

High heat is a public health threat that disproportionately harms disadvantaged and vulnerable communities. The vulnerability assessment adopted CalEnviroscreen's standard for disadvantaged communities, which uses a number of indicators to highlight communities that are severely burdened by pollution and environmental health harm. Vulnerable communities are defined as disproportionately affected by high heat due to physical (built and environmental), social, political and/or environmental factor(s).

3.1.1 Methodology

This section describes the climate hazards assessed and the data, scenarios and methodology used to assess vulnerability to high heat.

3.1.1.1 Hazard Description

Cal-Adapt defines an extreme heat day as a day in April through October where the maximum temperature exceeds the 98th historical percentile of maximum temperatures, which is based on daily temperature data from 1961 to 1990 (2019). The 98th percentile varies by locality. Cal-Adapt defines an extreme heat event as a period of five or more consecutive extreme heat days. Along the coast, a heat wave is defined as five days over 72°F to 77°F. The threshold is in the mid- to upper 90s in other areas (California Department of Public Health, 2017).

For this analysis, high heat days represent the number of days per year over 100°F. This definition is consistent with San Mateo County's Climate Ready initiative, which evaluated countywide high heat impacts and adaptation strategies. Increases in temperature result in increased cooling degree days, defined as every degree that the mean temperature is above 65°F during a day when air conditioning is likely to be needed.[16]

[16] For example, if the high temperature for the day is 100 and the low temperature is 50, the average temperature of the day is 75. That equates to 10 cooling degree days (75—65) for that day. Cooling degree days are not a unit of time; it is a combination of time and temperature.

3.1.1.2 High Heat Scenarios

As part of San Mateo County's Climate Ready initiative, the County downscaled temperature data retrieved from Cal-Adapt using elevation data from the five meter LiDAR-derived DEM of San Mateo County. SamTrans used this data to develop maps of projected temperature changes for 2030 and 2070 under the representative concentration pathway (RCP) 8.5 scenario[17] compared to a baseline year (1995). These years were selected to align with San Mateo County's high heat analysis. Table 23 summarizes the results of the temperature analysis. Figures 19 through 21 illustrate the baseline number of high heat days (1995) and the projected number of high heat days in 2030 and 2070.

Climate change is projected to increase overall average temperatures as well as the number and severity of high heat events. By 2070, most of San Mateo County will experience a least a 4°F increase in average high temperatures under RCP 8.5 and the number of projected extreme heat days will more than double compared to 1995 (San Mateo County, 2018). As shown in Figure 19, Figure 20 and Figure 21, some areas within San Mateo County will experience a greater number of high heat days than others. Please note that Figures 19, 20 and 21 overlay the January 2019 bus route network on maps heat data for other years, for the purpose of example and scale. The bus network represented on the following figures is not the 1995 bus network, nor is it likely to be the formation of the SamTrans bus route network in 2030 or 2070.

Table 23. Projected Temperature Increase

Year	Countywide Temperature Increase	Max High Heat Days Expected	Average Cooling Degree Days
1995 Baseline	-	13	91.4
2030	1.4 to 2.2°F	21	172.7 (89% increase)
2070	3.8 to 5.0°F	35	709.5 (676% increase)

[17] An RCP is a greenhouse gas (GHG) concentration trajectory adopted by the International Panel on Climate Change (IPCC). RCP 8.5 represents the high emissions scenario where emissions continue to rise throughout the 21st century.

Figure 19:High Heat Days -- 1995

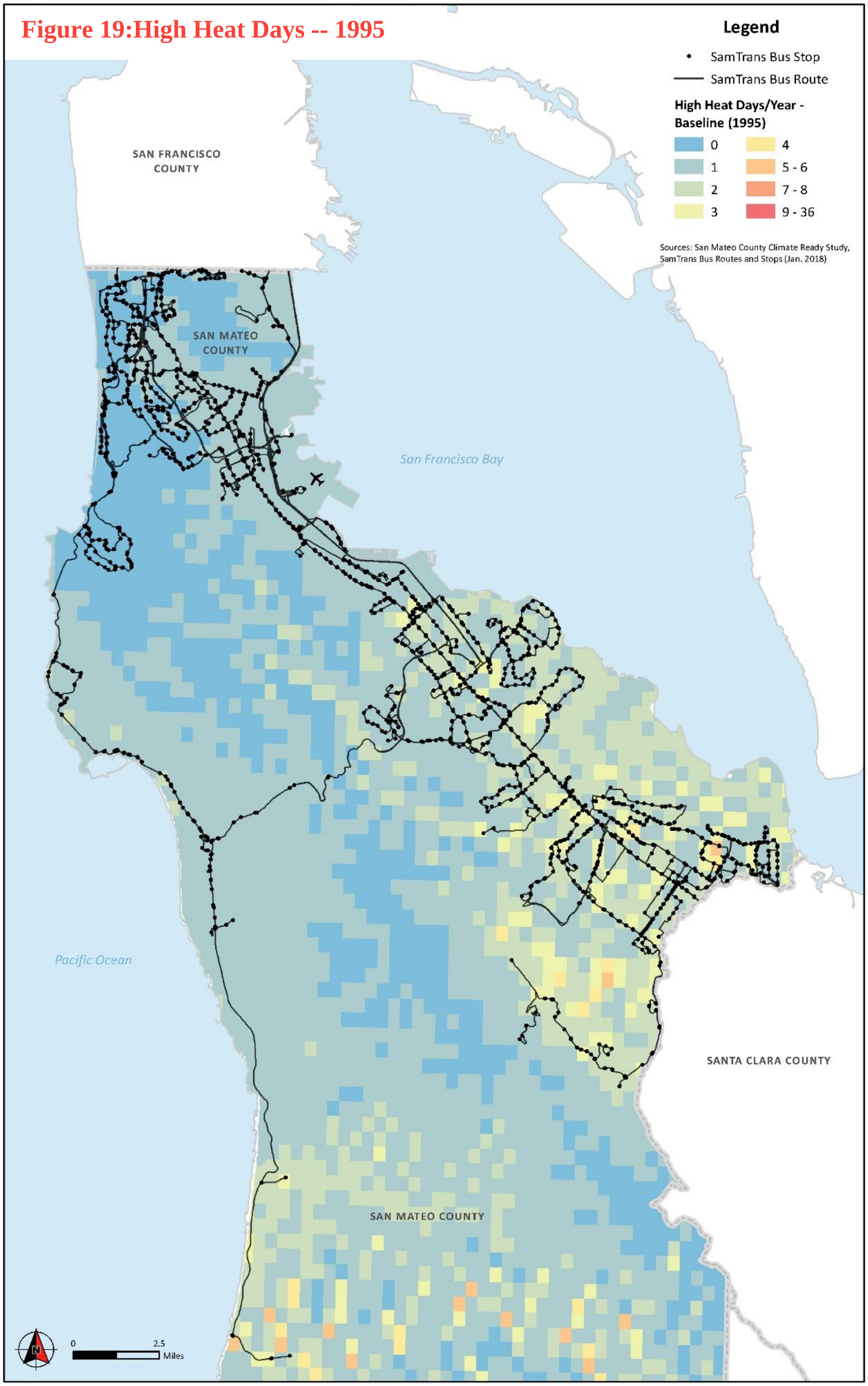


Figure 20:High Heat Days -- 2030

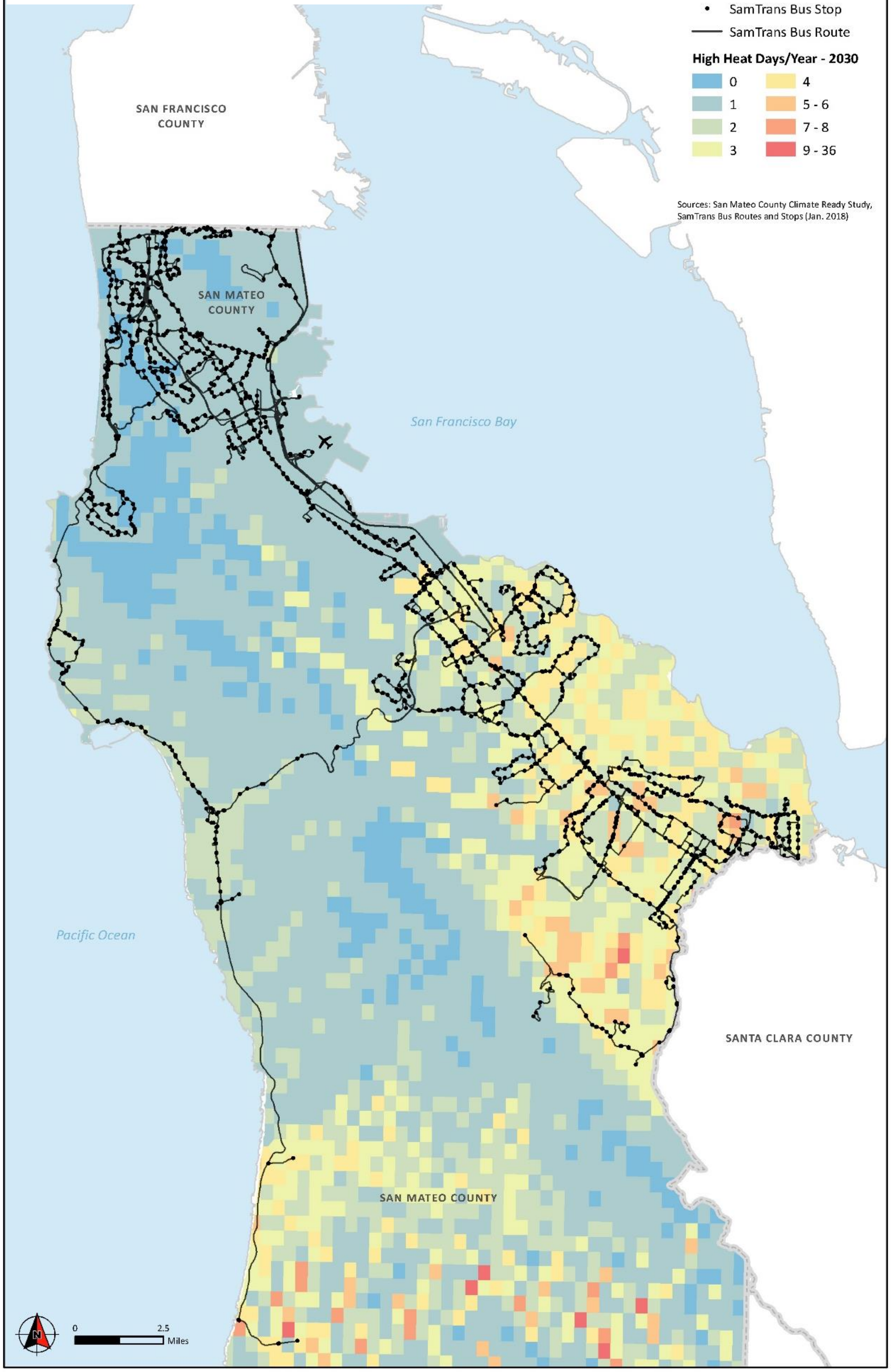
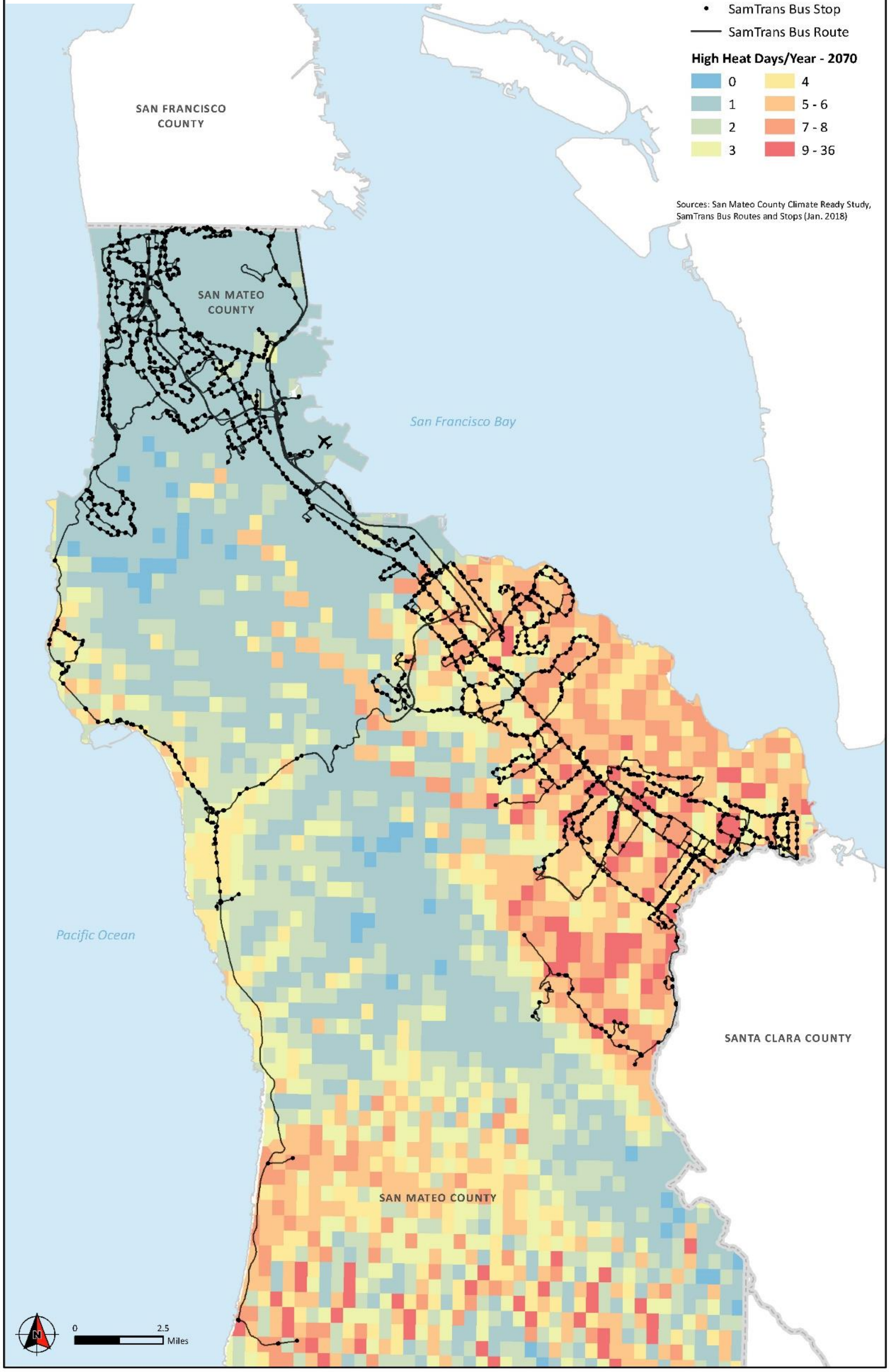


Figure 21:High Heat Days -- 2070



3.1.2 Facility Vulnerability

3.1.2.1 Exposure Analysis

Given the type of facilities and HVAC systems outlined in Section 1.2, the primary risk at both North and South Base is inadequate cooling capacity by 2070, whether that be mechanical cooling or reduced passive cooling potential caused by increased ambient temperatures. Currently, most facilities are semi-heated or unconditioned and may be subject to cooling loads that exceed the current cooling strategy. For the areas with mechanical cooling, the existing cooling equipment may not have adequate capacity depending on the severity of the heat hazard. The risk of exposure to excessive temperatures under high heat conditions has been evaluated using the cooling degree data presented in Section 3.1.1 for the current conditions, the 2030 moderate hazard conditions and the 2070 severe hazard conditions.

The optimal ambient temperature range for natural, ventilation based passive cooling is 55°F to 75°F under which the existing conditions and the 2030 moderate hazard conditions will allow for adequate indoor temperatures via passive cooling. By 2070, SamTrans could face severe hazard conditions in which the average cooling season ambient temperature (85°F) is significantly greater than the passive cooling upper limit (75°F), and will not allow for adequate passive cooling.

3.1.2.2 Sensitivity

There are no existing heat related issues at North Base or South Base for any of the fully conditioned, semi-conditioned or unconditioned spaces. The areas served by heating and cooling units (i.e. the training rooms and second floor maintenance rooms) are unlikely to experience heat related issues under the moderate 2030 hazard conditions given the spare cooling capacity typically built into system selections. However, under the more severe 2070 hazard conditions where the severity and duration of high heat events increases significantly, the cooling loads are likely to exceed the capacities of the cooling units and additional capacity will be required. The increased capacity requirements may affect building 200, the trailer and portions of building 100 at both sites.

For semi-heated and ventilated only spaces (i.e., some offices, the body shop and the maintenance bays), the 2030 moderate hazards may require minor adaptions by personnel to increase ventilation (mechanical and/or natural) and passive cooling during the hottest hours. However, under the more severe 2070 hazard conditions mechanical cooling will likely be required as the outdoor temperatures will be too warm for ventilation and passive cooling to meet the increased cooling loads and ensure adequate protection for personnel and equipment. The affected areas may include portions of building 100 as well as buildings 300, 400 and 500 at both sites. The bus washer and emergency generator would not be affected given their design and use. Personnel, particularly those working outdoors, will be more exposed to heat stress. Approximately 440 employees spend some amount of time working outdoors.

Excessive heat also strains the electricity grid, which can lead to blackouts that limit the ability to cool facilities. During the 2017, 2019 and 2020 Bay Area heat waves, the electricity grid experienced intermittent downtime (Rocha, 2017; Smith, 2019). The Bay Area experienced three heat waves in 2020 and set records for temperature highs in the months of August, September and October 2020 (Moench, 2020).

In response to widespread wildfires in recent years, the California Public Utility Commission (CPUC) and regulated utilities have implemented planned Public Safety Power Shutoffs (PSPS) in 2019 in which power to users is purposely turned off in high heat and high wind conditions. As of 2020, PSPS events have not affected North or South bases but both bases could be subject to a planned outage in the future. South Base is situated on an electric circuit that services "essential" loads, and is less likely to be affected by a PSPS event or a rolling blackout. However, North Base is not part of a circuit that serves an essential load (and SamTrans is not currently designated as an essential load), so the facility is subjected to planned outages. SamTrans should continue to seek its certification as an essential provider to decrease the likelihood substations it relies on for operations are depowered to address wildfire.

3.1.2.3 Adaptive Capacity

Under the 2030 moderate risk conditions, the existing HVAC systems and passive cooling potential are expected to be adequate to mitigate any potential high heat related hazard risks for buildings at both North and South bases with only minor behavioral and operational adaptations during peak cooling load hours. Under the 2070 severe risk conditions, it is expected that the existing systems will not be adequate to mitigate the high heat related hazard risks and increased cooling capacity. Additional mechanical cooling may be required at both facilities to ensure adequate protection for personnel and equipment.

3.1.3 Fleet Vulnerability

3.1.3.1 Exposure Analysis

External temperatures have implications on the performance of the battery in BEBs. This study researched the impacts of heat and cold external temperatures on existing BEB battery technology capacity and range, acknowledging that battery technology and range capacity is likely to improve over time. Temperature impacts to BEBs are not well documented to date, but there are concerns that both colder and higher temperatures could affect state of charge (SOC) and overall battery reliability. Electric heat is the primary factor that could affect battery range, with electric cooling as a secondary factor, and the individual driver performance (how the operator starts/stops/brakes) as the tertiary factor. These three factors are not directly impacted by ambient air temperature, but managing the heating and cooling of the ambient air through heaters and air conditioners contributes to the decrease in battery range.

Research from the National Renewable Energy Laboratory (NREL) indicates that the desired operating temperature to maximize efficiency for a BEB ranges between 59 and 95°F (NREL, 2011). The same research indicates that lithium ion batteries, which are the only battery type currently used by BEBs, experience higher rates of power loss over a 15 year lifecycle of the asset in high temperature environments, when compared to moderate and lower temperature environments. Operating at temperatures that exceed the desired range result in discharge degradation. The power loss through the HVAC system used to keep the bus operator and passengers cool influences the overall SOC, resulting in a reduced range for the bus (Carter, 2019).

Figure 22 shows modeled changes to SOC on an average, hot or cold day. The model data are from a study conducted for a transit agency in the Northeast and were generated using WSP's Battery Optimization Lifecycle Tool (BOLT). The model results identify an approximately 14.5% decrease in range in cold environments and a 10% decrease in range in hot environments. It should be noted that temperatures in San Mateo County are considerably more moderate compared to the Northeast. In addition, battery performance and range are expected to improve over time as the technology matures.

High temperatures can also lead to non-uniform aging of batteries due to the experienced thermal gradients, which has implications for the full lifecycle cost of the asset or fleet. For example, BEB pilot trials in Phoenix and Minnesota saw increased operating costs due to the demands for running cooling and heating systems (Levy, 2019). If cooling systems must be run more frequently and consistently, it may wear the battery and ultimately shorten its effective design life.

Another possible risk to vehicles from high heat comes from an increase in humidity/condensation following high heat. High humidity and wet conditions can lead to dangers from electrical arcs through the air. To prevent accidents associated with electrical arcs, there should be well-delineated arc flash zones and arc flash/discharge personal protection equipment (PPE) should be worn near BEB charging equipment.

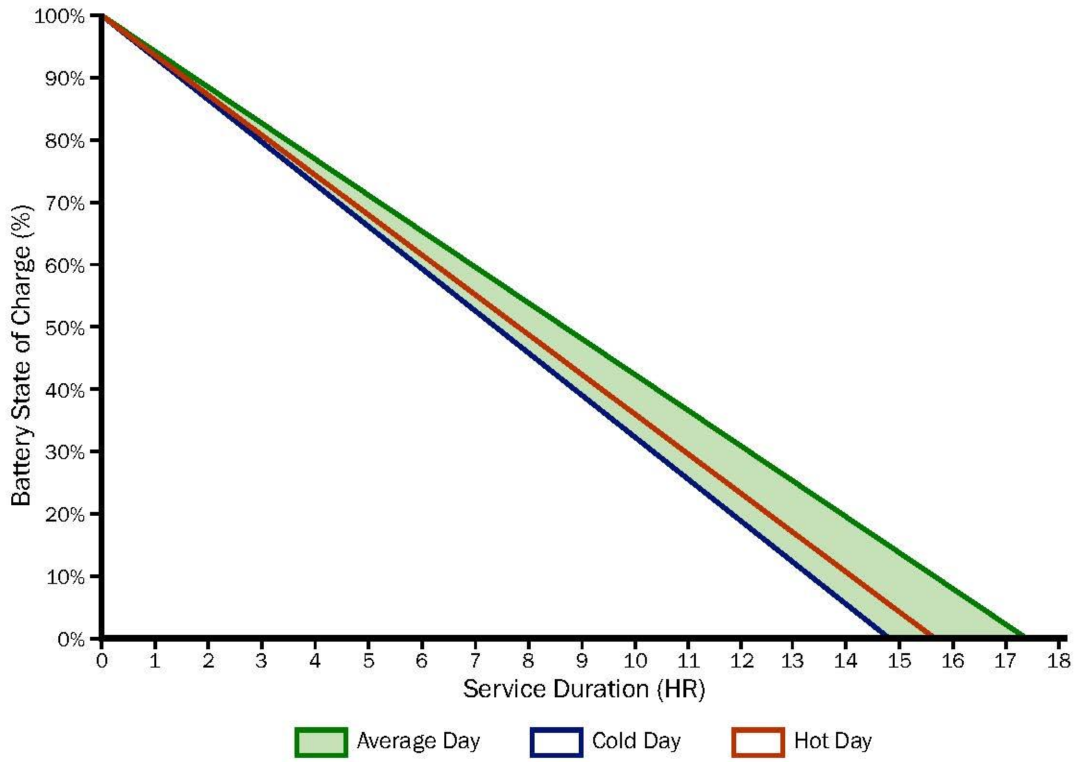


Figure 22: BEB Change in SOC Under Different Temperature Conditions

3.1.3.2 Sensitivity

SamTrans' diesel bus fleet is equipped with air conditioning and its future BEB fleet will include air conditioning. In general, higher temperatures will result in an increased use of vehicle air conditioning and corresponding potential impacts to BEB range. Heat waves may also cause interruptions to the electric grid, which could disrupt vehicle charging if backup power is not available.

3.1.3.3 Adaptive Capacity

The action alternative analysis provides recommendations on how SamTrans can prepare for and adapt to the impacts of high heat days as the agency transitions to electric vehicles, as well as additional areas of study as fleet electrification plans progress and battery technology matures.

3.1.4 Passenger Vulnerability

3.1.4.1 Exposure Analysis

High heat events are associated with an increased risk of heat-related morbidity and mortality. In the US, heat results in more deaths than any other extreme weather or natural event (Four Twenty

Seven, 2018). The 2006 California heat wave resulted in over 600 deaths, 1,200 hospitalizations and 16,000 emergency department visits (Four Twenty Seven, 2018). More recently, six elderly people died from heat-related causes during the 2017 Bay Area heat wave (Rocha, 2017).

Increasing temperatures and high heat events put SamTrans' passengers at greater risk to heat related health impacts. Public transit users are vulnerable to heat exposure when they walk, bicycle or otherwise utilize outdoor active transportation to access transit stops (Arishi et al, 2017). This risk is greater in urban areas with little tree canopy and heat island effects.

As of December 2019, SamTrans' routes stop at approximately 1,855 bus stops in San Mateo County. Of these, approximately 192 (10 percent) include bus shelters.

3.1.4.2 Sensitivity

Coastal populations, including the Bay Area, are more sensitive to heat events because they are unaccustomed to high heat and humidity and may lack air conditioning (Four Twenty Seven, 2018). People living in the Bay Area are not used to extreme temperatures and as a result may have a harder time thermoregulating. It takes the human body about two weeks to acclimate to temperature extremes (SFDPH, 2013, p. 3). This can exacerbate the degree of heat-related morbidity or mortality (SFDPH, 2013).

Passenger sensitivity to heat exposure varies based on a number of factors including age, health—particularly pre-existing respiratory or cardiovascular disease—socioeconomic status, walking distance to a transit stop and wait time.

While it is unclear how ridership will change in a post-Covid-19 recovery, most SamTrans riders continue to be transit-dependent and earn significantly less than the median annual income level in San Mateo County. According to a 2018 ridership survey, 58% of SamTrans riders have no access to a car and 71% of riders earn less than $50,000 per year (SamTrans, 2018). Based on the San Mateo County Transportation Plan for Low-Income Populations (C/CAG, 2012), 12 of SamTrans' routes are considered "lifeline" routes, which are defined as routes that are considered critical to meeting the needs of low-income communities. Three of SamTrans' lifeline routes serve the county's highest concentration of low-income populations in East Palo Alto.

Approximately 19% of San Mateo County residents have annual incomes of less than 200% of the federal poverty level, which the Metropolitan Transportation Commission (MTC) uses to determine low incomes in the Bay Area where living expenses are extraordinarily high. Public transportation is essential to serving San Mateo County's most underserved populations. Loss of bus service or dangerous conditions due to climate change impacts could limit mobility for many in the County including people in resource-limited communities or those with functional and access needs who rely on public transportation.

Data from the California Heat Assessment Tool (CHAT) was used to evaluate passenger sensitivity to high heat. CHAT is a decision-support tool developed as part of the State of California's Fourth Climate Change Assessment. CHAT provides information on current and future high heat risk and identifies a series of 24 social, health and environmental indicators at the census tract level that contribute to heat-health vulnerability.

The State of California Environmental Protection Agency (CalEPA) identifies disadvantaged communities as required by Senate Bill 535 (SB 535). The Office of Environmental Health Hazard Assessment (OEHHA) CalEnviroScreen tool was used to identify disadvantaged communities designated by CalEPA for the purposes of SB 535. These areas represent the highest scoring census tracts in the tool and areas with high pollution and low populations. There are six SB 535 disadvantaged census tract communities in SamTrans' service territory in San Mateo County.

Six CHAT indicators were selected that most directly relate to both likelihood of transit-dependency and heat related health risk in addition to the SB 535 list to develop a composite heat sensitivity index for San Mateo County (see Table 24).

Table 24. Indicators Associated with Heat Sensitivity

Indicator	Definition	Source	Why Included
Percent elderly	Percent of population aged 65 years or older.	American Community Survey (ACS), US Census Bureau	Pre-existing health conditions, poor thermoregulation, the side effect of some medications and social isolation can increase susceptibility to climate change-related heat impacts.
Rate of asthma[18]	Asthma emergency department visits per 10,000 people.	California Office of Statewide Health Planning and Development	High heat degrades air quality, which can worsen asthma symptoms.
Percent no vehicle access	Percent of occupied households with no vehicle ownership.	ACS, US Census Bureau	Persons with no vehicle access are more likely to be transit-dependent. People without vehicle access may experience increased exposure to

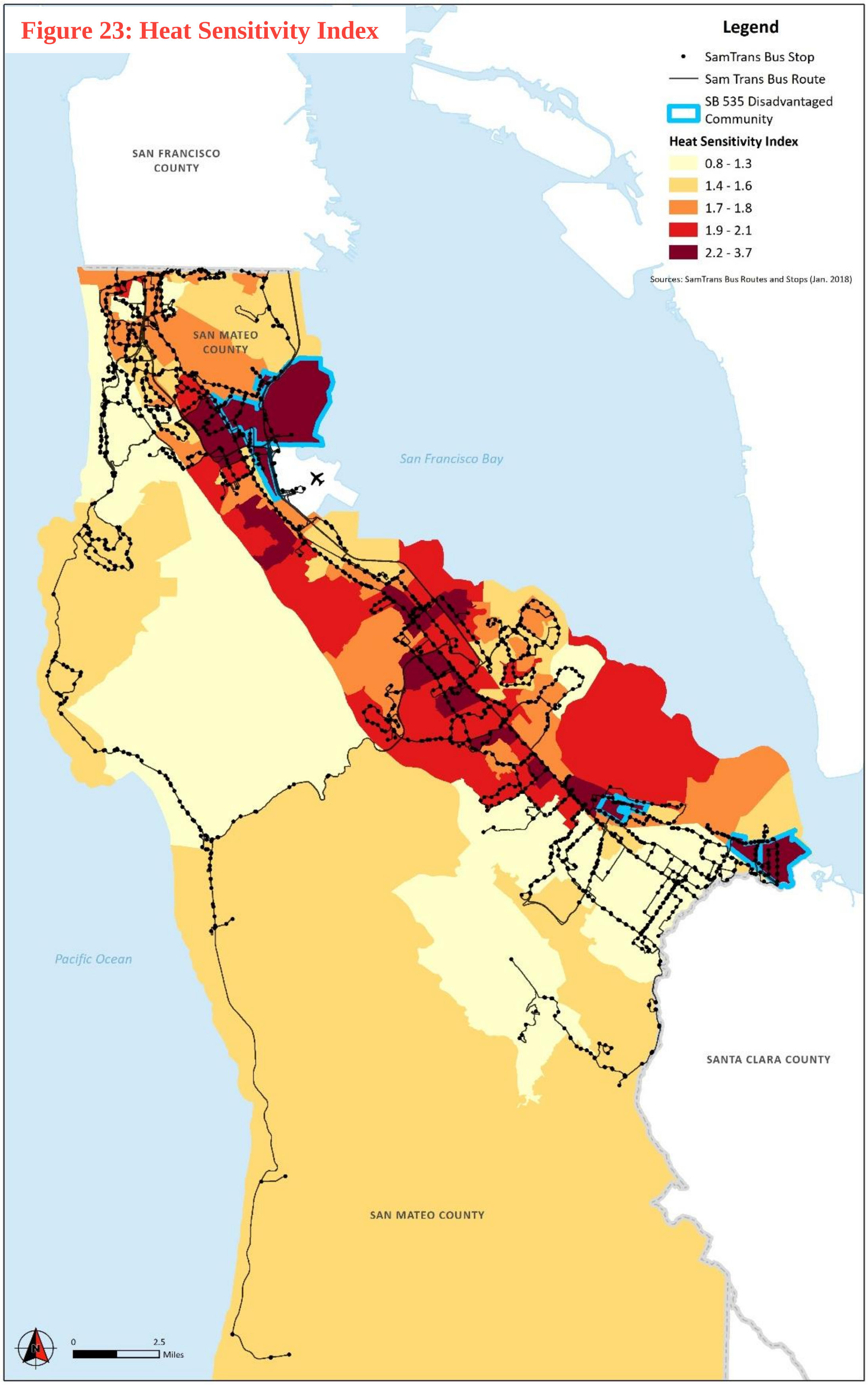
[18] Rate of heart attacks per 1,000 people (cardiovascular risk) was not included because the incidents of cardiovascular risk are strongly correlated with the rate of asthma.

Indicator	Definition	Source	Why Included
			elements during "last mile" trips going to and from transit."
Percent poverty	Percent of population whose income in the past year was below poverty level.	ACS, US Census Bureau	Poverty is associated with increased transit-dependency. In addition, low-income earners are more likely to suffer from chronic diseases which may be exacerbated by high heat.
Percent ambulatory disability	Percent of population having serious difficulty walking or climbing stairs.	ACS, US Census Bureau	Persons with physical disabilities are more likely to be dependent on public transit.
Urban Heat Island	When built up areas are hotter than nearby rural or undeveloped areas.	CalEPA	Buildings and pavement absorb more heat during the day and radiate heat at night, which intensifies daily temperatures.
SB 535 Disadvantaged Communities	Disadvantaged communities are defined as the top 25% scoring areas from CalEnviroScreen along with other areas with high amounts of pollution and low populations.	CalEPA	SB 535 communities represent a subset of low-income communities and are disproportionately affected by pollution that contributes to heat-related health impacts.

Reference: Four Twenty Seven, 2018

Each indicator was scaled from 1 to 100 and summed to create a composite heat sensitivity score for each census tract in San Mateo County within a quarter mile of a SamTrans bus stop. Figure 23 illustrates the overall heat sensitivity score per census tract. Figures 33 through 38 in Appendix D illustrate the individual vulnerability by census tract for each indicator evaluated.

Figure 23: Heat Sensitivity Index



3.1.4.3 Adaptive Capacity

The adaptive capacity of bus passengers will vary based on the presence of shade, bus stop amenities, and personal factors such as age, socioeconomic status, health, mobility impairments and access to a personal vehicle. Adaptive capacity is anticipated to be lower in communities with higher sensitivity scores (see Figure 23). Passengers who are not transit-dependent may opt to drive instead of taking the bus during periods of high heat. For example, a study of Lane Transit District in Oregon found that on hot weekdays (defined as temperatures exceeding 85°F), ridership declined 2.2% and on weekends, ridership fell by 1.1% (Barlow, 2019).

Where bus stops are near publicly accessible buildings, passengers can potentially seek shelter inside. SamTrans provides amenities at some bus stations, which may provide some relief from high heat. The majority of SamTrans' shelters (66%) are owned and maintained by a third party under an existing long-term advertising shelter contract that expires in 2023. Should SamTrans reissue this contract, it provides a key opportunity to incorporate recommendations from this study. Approximately 192 (10%) of bus stops along SamTrans' routes include shelters. SamTrans owns 26% standard shelters and the remaining 8% are non-standard shelters owned by other entities.

Bus stop amenities vary. Approximately 211 bus stops include benches, some of which are co-located with a bus shelter. Some locations have "simmee-seats". See Appendix D.4 for photos of typical amenities. SamTrans has considered climate when placing shelters in the past (SamTrans, 2015), however bus shelter placement and amenity choice is impacted by a range of factors. SamTrans Bus Stop Guidebook (2013) indicates the types of amenities typically installed at its bus stops. As indicated in the guidebook, placement of amenities are subject to site conditions, capital and operating budgets.

3.1.5 Representative Bus Stops

Based on the heat sensitivity index (Figure 23), eight representative bus stops within the SamTrans service territory were identified as examples to evaluate action alternatives for addressing passenger vulnerability to high heat. The following process was used to identify study areas and representative bus stops throughout SamTrans' service area based on high heat exposure, heat sensitivity, ridership and tree canopy:

- **Step 1:** Identified all census tracts within a quarter mile of a bus stop.[19] From these selected tracts, four general study areas were defined:
    - South San Francisco
    - Redwood City

[19] A couple tracts were added in Millbrae that were just outside of the quarter mile buffer.

- San Mateo
- Half Moon Bay

These study areas are outlined in blue in Figure 24.

- **Step 2:** Within each study area, the two census tracts with the highest heat vulnerability scored were identified. These tracts are shown in red in Figure 24 and identified in Table 25.

Table 25. Vulnerable Census Tracts per Study Area

Study Area	Vulnerable Census Tract IDs
South San Francisco	06081602100 (SB 535) 06081602300 (SB 535)
Redwood City	06081610202 06081610203
San Mateo	06081607200 06081604400
Half Moon Bay	06081603400 06081613700

- **Step 3:** All bus stops within a quarter mile of the selected census tracts were identified. This resulted in a total of 283 bus stops. The analysis focused on stand-alone bus stops for control purposes.
- **Step 4:** The bus stop with the highest summer ridership within a quarter mile of each regional census tract was identified. This involves calculating the total summer ridership for each bus stop by averaging the total monthly boardings for June through September.
- **Step 5:** Ensured that selected bus stops did not have more than 50% tree canopy (see Figure 38).
- **Step 6:** Ensure selected bus stops demonstrate a 50% or more increase in high heat days between 2070 and 2030 (see Figure 19, Figure 20 and Figure 21).

Eight representative bus stops were selected by following the steps above. Riders waiting at these stops may be particularly sensitive to heat-health impacts, because the bus stops are located in areas with high composite heat sensitivity scores indicating:

- Elderly populations
- Asthma
- No vehicle access

- Percent poverty
- Percent ambulatory disability
- Urban heat island effects

These stops are also identified as having high ridership during summer months,[20] having limited shade from tree canopies, and being in areas with significant projected increases in high heat days over the coming century. Four out of the eight stops identified have no shade structures, and two of the stops have no benches. Riders at these stops may face additional heat stress from lack of shade and a place to rest in high heat. Although some of the stops have shelters, it is unknown if the shelters provide shade during the hottest part of the day and whether or not they protect passengers from heat or amplify the effect of heat. Appendix D.4 presents the full list of these selected bus stops, their locations and amenities and shelter ownership, if applicable.

SamTrans could use this or a similar methodology to help prioritize future bus stop improvements in communities with the greatest risk of high heat impacts.

[20] Identified as start of June to end of September for the purposes of this study.

Figure 24: Study Regions and Selected Tracts

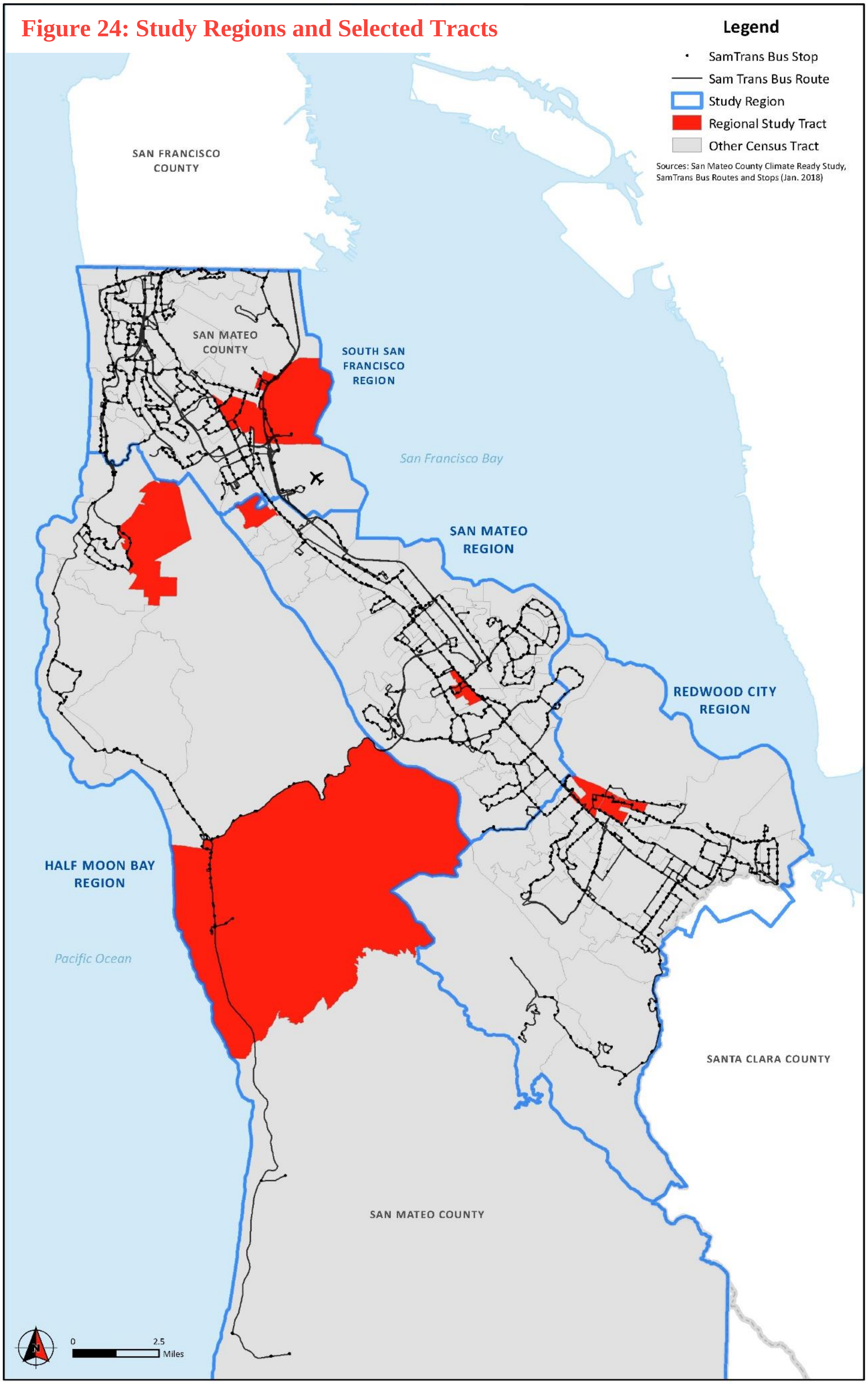
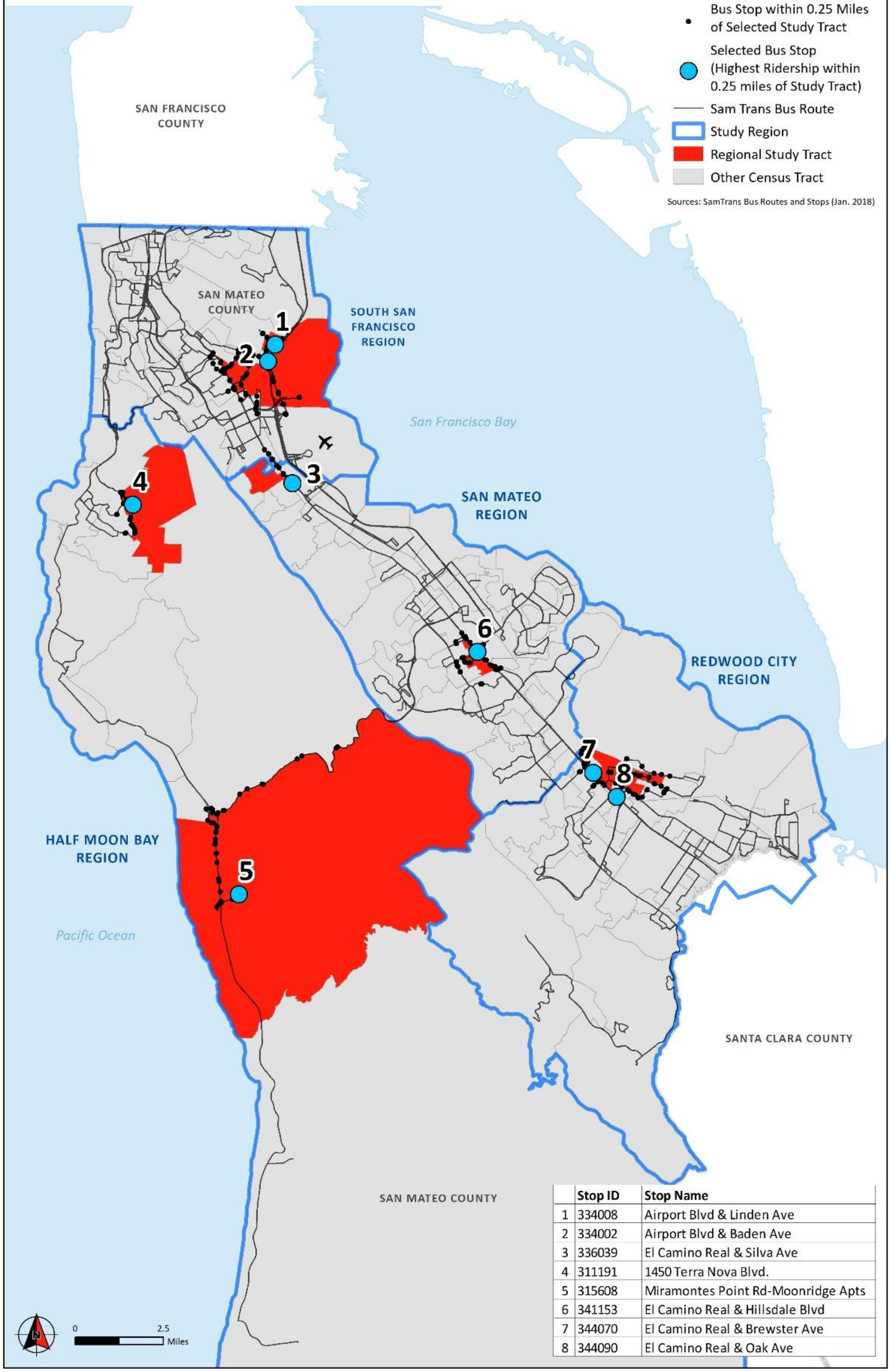


Figure 25: Selected Bus Stops Across Study Region



	Stop ID	Stop Name
1	334008	Airport Blvd & Linden Ave
2	334002	Airport Blvd & Baden Ave
3	336039	El Camino Real & Silva Ave
4	311191	1450 Terra Nova Blvd.
5	315608	Miramontes Point Rd-Moonridge Apts
6	341153	El Camino Real & Hillsdale Blvd
7	344070	El Camino Real & Brewster Ave
8	344090	El Camino Real & Oak Ave

3.2 ACTION ALTERNATIVES

Following the high heat vulnerability assessment, SamTrans evaluated possible adaptation responses to address and mitigate potential impacts to SamTrans' assets and passengers referred to as "action alternatives." To develop these action alternatives, SamTrans referenced the NAVFAC Climate Change Installation Adaptation and Resilience Planning Handbook (2017). Stage II of the handbook includes a five-step process for identifying and screening action alternatives (see Figure 16 in section 2.2):

1. Identify potentially suitable adaptation options
2. Identify benefits and limitations
3. Evaluate feasibility
4. Evaluate appropriateness
5. Characterize approach to decisions under uncertainty

Action alternatives that are not feasible or appropriate were eliminated from further consideration. The remaining action alternatives were carried forward for evaluation in Stage III of the NAVFAC process, which involves evaluating costs and benefits of each retained action alternative to identify the most cost-effective solutions.

By generally following the NAVFAC process, SamTrans developed an initial list of potentially suitable action alternatives that would build resilience against high heat. Action alternatives were categorized into one of four types of adaptation approaches, which align with the USACE risk management strategy classification: (1) structural; (2) natural and nature-based; (3) facilities; and (4) non-facilities (see Table 26.

Table 26. Adaptation Approaches for High Heat

Approach	Definition
Structural	Use a built structure such as a bus shelter to protect from heat.
Natural/Nature-based	Constructing or modifying natural features such as tree shading to reduce the impact of heat.
Facilities	Construction solutions such as building to a new standard that accounts for changing heat risk, constructing smaller scale built structures designed to protect an asset, making physical alterations to an existing asset to reduce flood damage and relocating a facility.
Non-facilities	A range of techniques that rely on changes in siting, management or maintenance of infrastructure to reduce the impacts of heat.

Source: Adapted from NAVFAC, 2017, p. II-3.

The complete list of action alternatives considered is summarized in Appendix A.2. SamTrans identified the benefits and limitations of each action alternative. The action alternatives were then reviewed during a workshop, which included staff from various departments including planning, operations planning, fleet, communications, facilities and finance to discuss other limitations, feasibility and appropriateness. Through these discussions, SamTrans was able to eliminate or defer action alternatives that were not suitable to move forward. Table 32 through 34 in Appendix A.2 summarize the benefits and limitations associated with both the retained and eliminated high heat action alternatives.

3.2.1 Facility Action Alternatives

As shown in Table 32 in Appendix A.2, six action alternatives were developed to support adapting North and South bases to future temperatures and improve operations during high heat events. As discussed in section 3.1.2, North and South bases are unlikely to experience heat related issues under the moderate 2030 hazard conditions given the space cooling capacity typically built into system selections. Therefore, when evaluating action alternatives, SamTrans should plan to deploy these or similar responses by 2070. Similarly, SamTrans should consider the expected design lifespan of the asset being installed and where that falls on the heat impacts timeframe; the closer to 2070, or the longer the life of the asset, the more important it is heat risks be addressed. For example, a typical HVAC system will last for 12 years while a new building may be designed to last for 50 years. SamTrans will likely utilize more than one HVAC system for its useful life before heat impacts are apparent, whereas a building with a 50 year expected asset life should be built to withstand the extreme temperature conditions to which it may be subjected. The initial list of action alternatives was narrowed down to two primary strategies that were retained for consideration and further evaluation (see Table 27). Table 32 summarizes the benefits, limitations, feasibility and appropriateness of retained and eliminated action alternatives that were considered.

Table 27. Retained Facility Action Alternatives

No.	Action Alternative
1	Changes in operation of operable doors and windows by staff on both North Base and South Base to ensure adequate natural ventilation and passive cooling during moderate and high heat events.
2	Modify SamTrans Facility Design Standards to include design considerations related to high heat. This could be a checkbox or more involved revisions to specifications for to heat reduction.

Action alternatives 1 and 2 were found to be the most suitable and implementable strategies for SamTrans' North and South bases. Changing the use and operations of facility windows/doors during high heat events (action alternative 1) is a straightforward strategy and would require only staff awareness, training and possibly SOPs. Staff already open windows on warm days so this alternative is a simple modification of current practices by requiring certain windows/doors to be opened to maximize airflow throughout the bases. In addition, SamTrans determined that it might be appropriate to update facility design standards to ensure that heat vulnerability is accounted for (action alternative 2). This will require internal collaboration to identify which standards should be added or changed and in what ways.

Action alternatives 3, 4, 5 and 6 (see Table 32 in Appendix A) were removed because they are neither appropriate nor feasible at this time. The first declined action, action alternative 3, would involve modifying the types of PPE that SamTrans North and South Base employees wear during the hottest months of the year. In the near term, SamTrans will likely need to increase its PPE requirements to address the risk of working on battery electric buses. In the long term, SamTrans will need to reconcile the need for more insulative PPE to protect personnel dealing with battery electric buses with increasing outdoor temperatures. Future technology advances may provide solutions to this issue.

Action alternatives 4 and 5, which were to upgrade/install additional HVAC systems at the North and South Bases, may be possible in the future, but are not appropriate at this time. The existing HVAC is not on a replacement cycle and some parts of the facilities cannot have HVAC for design reasons. In addition, the lifespan for typical HVAC units is around 15 years, so this strategy may be warranted in the future but not presently. SamTrans had also previously considered installing green roofs on the North and South Bases (action alternative 6), but this is infeasible because green roofing requires replacing existing roofs and installing additional structural support for the greater weight of a green roof. This option is not cost effective outside a total renovation, and even then warrants further analysis for cost effectiveness compared to alternatives.

3.2.2 Fleet Action Alternatives

As shown in Table 33 in Appendix A.2, nine action alternatives were developed to support adapting SamTrans' fleet to future temperatures and high heat events. SamTrans' existing fleet is predominately diesel vehicles. All existing vehicles are equipped with air conditioning that is regularly maintained. Diesel and combustion engines are well-established technology proven to perform in a range of extreme circumstances and temperatures. For this reason, diesel and internal combustion engines were not analyzed further.

According to the 2020 Innovative Clean Transit Plan, SamTrans plans to transition away from diesel by 2038, well ahead of when San Mateo County can expect to experience hazardous high heat events. Fleet action alternatives considered the potential implications of high heat on the performance of the battery in BEBs. However, because BEBs are new technology, temperature impacts to BEBs are not well documented to date, but there are concerns that both colder and higher temperatures can affect SOC and overall battery reliability. The actions identified in Table

33 were evaluated as strategies to adapt BEBs to future temperatures/improve BEB operations during high heat events.

The first four strategies are already being evaluated by SamTrans for implementation and will not be further analyzed as part of this study. The five remaining strategies were considered and declined, mainly because these action alternatives were found to be infeasible from a design or operations perspective. For example, expanding the AC capacity of purchased BEBs (action alternative 8) may not be possible or necessary. Additionally, changing bus routes in advance of a high heat event (action alternatives 9 and 10) would take significant coordination that is not feasible or justified at this time. Therefore, no fleet action alternatives were retained for further evaluation as part of this study. Table 33 in Appendix A summarizes the benefits, limitations, feasibility and appropriateness of retained and eliminated action alternatives that were considered. SamTrans should revisit whether heat negatively impacts fleet performance in the future once the technology has stabilized and high heat becomes a challenge.

3.2.3 Passenger Action Alternatives

As shown in Table 34 in Appendix A.2, 17 action alternatives were developed to address passenger vulnerabilities during high heat events. High heat is the single most dangerous weather and climate-related impact to people. Temperature rise and more frequent, severe heat waves present a significant public health risk. For those who are dependent upon transit, the risk can be even greater because they can be exposed to weather conditions while travelling to access transportation. Ten passenger action alternatives were retained for further consideration as part of this study, as shown in Table 28. Table 33 summarizes the benefits, limitations, feasibility and appropriateness of retained and eliminated action alternatives.

Table 28. Retained Passenger Action Alternatives

No.	Action Alternative
1	Install bus shelters (SamTrans-owned, Ad, or other) or shade structures at transit stops without shelters. Consider prioritizing bus shelter locations based on high ridership and in disadvantaged/underserved communities.
2	Provide benches at SamTrans bus stops where shelters are not feasible.
3	Design a custom shelter to meet multiple conditions at sites where SamTrans owns the shelter infrastructure. A custom design could also be incorporated into future ad shelter contract specifications.
4	Use ad revenue for bus shelter improvements.
5	Provide free/discount fare rides to cooling centers on high heat days. Coordinate with Department of Health (DOH) for County and City for advance notice of Cooling Center locations; notify dispatch, drivers, advise passengers on how to get there.

No.	Action Alternative
6	Provide informational materials on dangers of heat stress and where/how to access local resources such as cooling centers. This information could be displayed on SamTrans buses through brochures, possibly through interior bus signs and posters and online through social media/SamTrans website.
7	As temperatures rise and large wildfires become more frequent and severe, there will be negative impacts to air quality. Provide informational materials on dangers of poor air quality and where/how to access local resources like N95 face masks, public locations to seek shelter, and additional information through the Bay Area Air Quality Management District. This information could be displayed on SamTrans buses through advertisements and online through social media/SamTrans website. Can provide in multiple languages.
8	Train SamTrans bus operators to recognize symptoms of heat-related illness and appropriate actions (e.g., when to call 911).
9	Investigate policy initiative to waive "no beverage" policy during high heat events.
10	Distribute SamTrans branded fans and/or cooling packs during high heat events.

One of the key actions SamTrans can take to improve passenger heat safety is addressing rider exposure to high heat while at bus stops waiting for service. Therefore, several strategies focus on improving bus stop amenities such as installing new or improved bus shelters. As previously discussed, the majority of SamTrans' bus shelters are owned and maintained by a third party under an existing ad shelter contract that expires in 2023, and SamTrans should incorporate this study's recommendations into future ad shelter contracts. Further, SamTrans could initiate a bus stop improvement program to review the system's bus stop infrastructure.

3.3 PORTFOLIO OF ACTION ALTERNATIVES

Based on the vulnerability assessment and action alternative analysis, twelve high heat action alternatives were retained for further consideration as part of this study. Table 29 presents the portfolio of action alternatives and summarizes the key benefits, high-level costs and estimated implementation time for each. Due to the relatively modest heat risk posed to its capital assets, the majority of the retained action alternatives focus on reducing high heat impacts to SamTrans' passengers.

Many of the retained action alternatives could be implemented at low cost. For this reason, SamTrans determined that a detailed cost-benefit analysis was not appropriate. However, this section includes high-level estimated costs for each of the retained action alternatives. Table 43 in Appendix C.3 outlines high-level next steps for each action alternative. Additional discussion is provided below regarding issuing new bus shelter design/advertising contracts and designing a custom shelter to meet SamTrans' needs, which are more involved and potentially costly action alternatives. Either initiative would require coordination with multiple stakeholders and in some cases may not be within SamTrans' control.

Investing in passenger amenities such as bus shelters improves the overall transit experience by making facilities more comfortable, safe and functional for users. The SamTrans Bus Stop Guidebook (2013) serves as reference when designing new or modifying existing transit facilities for the SamTrans fixed-route bus service. The bus stop guidelines are designed to encourage use of public transit by providing (p. 1):

- Safe, attractive and convenient transit facilities
- Design criteria that meets both passenger and operational needs
- Consistency in design and placement of bus stops
- Relatively cost-effective construction and maintenance
- Compliance with the Americans with Disabilities (ADA) regulations and other state and federal mandates

Table 29. Portfolio of High Heat Action Alternatives

Action Alternative	Key Benefits	High-Level Cost Estimate	Implementation Time
Facilities			
Increase natural ventilation and passive cooling by changes in operation of operable doors/windows.	Reduce high heat risk projected for after 2030.	• None	As needed
Update SamTrans facility design standards to recommend consideration of heat vulnerability in design.	Reduce indoor temperatures through design.	• Staff time	1 to 3 years
Passengers			
Install additional bus shelters (SamTrans-owned, Ad or other).	Provide shade and protection for passengers during high heat events.	• Up to $45,000 each to purchase and install. • $1,000 each for annual maintenance.	2 to 5 years
Install additional benches.	Provides a place for passengers to rest, reduces impact of high heat exposure.	• $210 – $800 purchase cost per bench and $500 to install.	2 to 5 years
Design and install custom shelter.	Provides shade for passengers; greater ability to customize.	• Up to $45,000 estimate per custom shelter depending on design and number of units purchased.	2 to 5 years
Use ad revenue for shelter improvements	A revenue stream could support upgrades and potentially the creation of more ad revenue.	• No cost, but would need to evaluate how ad funds are currently allocated.	2 to 5 years

Action Alternative	Key Benefits	High-Level Cost Estimate	Implementation Time
Provide free/discount fare rides to cooling centers on high heat days.	Supports public health and safety by helping the public access locations where they are better protected from high heat.	• Depends on the extent of route changes needed, whether it impacts staffing costs.	1 to 3 years
Provide informational materials on the dangers of heat stress and where/how to access local resources.	Supports public health and safety by educating public on heat risk.	• Limited to costs for printing flyers (or procuring pre-printed flyers) and a staff time for distribution.	1 to 3 years
Provide informational materials on dangers of poor air quality and where/how to access local resources.	Supports public health and safety by educating public on heat risk.	• Limited to costs for printing flyers and a few hours of staff time.	1 to 3 years
Train SamTrans bus operators to recognize symptoms of heat-related illness at their discretion, take actions such as calling 911.	Supports public health and safety by helping to address on-site heat related emergencies.	• Operator training	1 to 5 years
Waive "no beverage" policy on high heat days.	Help passengers alleviate heat risk by staying hydrated during high heat events.	• Limited to costs for printing flyers and staff time to publicize.	1 to 3 years
Distribute SamTrans branded fans and cooling packs on high heat days.	Provides a method for passengers to reduce heat stress during high heat events.	• $2 to $5 per unit	1 to 3 years

The ability to provide protection from the environment (rain, cold, heat and wind) is a key function of bus shelters. As climate change increases temperatures increase in the Bay Area, passengers are more susceptible to heat-related discomfort and health impacts. Current shelter design emphasize protection from rain or cold rather than heat, which has historically not been a significant issue in the Bay Area. Some shelter designs can provide shade, but those with an enclosed area or walls can also trap heat.

SamTrans could work with a bus shelter manufacturer to design a shelter and/or shade structure that better protects against heat. This could also be an opportunity to incorporate additional features desired by SamTrans' riders. Custom shelters will be more expensive than standard shelters depending on materials, design and quantity ordered. Custom shelters are further challenging in that not all of SamTrans' jurisdiction shares the same bus stop needs. In particular, SamTrans' coastal riders are less likely to face high heat risk and may benefit from shelters that offer protection from coastal elements such as fog and wind.

Several of the retained passenger action alternatives identified in Table 29 could be pursued jointly. SamTrans could update the 2013 Bus Stop Guidebook and develop a Bus Stop Improvement Plan that incorporates recommendations from this study. An updated guidebook and Bus Stop Improvement Plan could address changes to recommended shelter design and be used to inform future ad shelter contracts. Appendix C.3 summarizes high-level next steps, costs and considerations for each retained action alternative.

4 CONCLUSION

4.1 SLR FLOODING AND INUNDATION

Both SamTrans' North and South Base facilities are vulnerable to flooding and inundation from future SLR, storm surge and/or fluvial flooding. Regional coordination will be critical to addressing these vulnerabilities as neither site can be protected in isolation. At North Base, SamTrans could build a horizontal perimeter levee that connects with SFO's proposed levee system. There is a clear financial case for installing suitable flood protection at North Base. Constructing a levee to protect North Base is projected to save SamTrans significant long-term costs under all SLR scenarios evaluated in this study. A regional tide gate solution positioned in the waterway between South San Francisco and North Base was discussed in the San Bruno Creek/Colma Creek Resiliency Study (SFO, 2015) and could reduce the length of levee needed for North Base, while protecting several properties to the west, and could be funded regionally. The actual costs would depend on the cost of the tide gate, engineering areas, dredging requirements, the challenges and costs of working with regional partners to implement, the percentage of the cost that SamTrans would bear and the incremental cost savings of not having to build the levee on the west side of North Base.

South Base is less vulnerable to future SLR because of the protection provided by the existing Redwood City levee. However, the existing levee would be overtopped under the 2050 high-end SLR scenario. In addition, South Base could be flooded from Phelps Slough overtopping during a storm event in the medium-term. Additional studies at the County/regional level are needed to understand the potential fluvial flooding from Phelps Slough. Any solutions to address flooding risk to South Base require regional coordination as SamTrans does not own of have jurisdiction over the infrastructure that would need to be improved to provide ongoing flood protection. Eventually, Redwood City will need to raise the Redwood City to continue to provide protection against SLR.

4.2 HIGH HEAT

As the number of high heat events in the Bay Area continue to rise, SamTrans' passengers will be at increased risk to heat-related health impacts when they travel to or wait for transit. Individual passenger vulnerability depends on socioeconomic, built environment and health-related factors.

SamTrans, in collaboration with others, can implement strategies to help reduce this risk. Key strategies include updating SamTrans' bus shelter design to address high heat risk and installing additional shelters or other amenities at bus stops. SamTrans can use the heat sensitivity index developed as part of this study to help prioritize bus stops targeted for improvements.

Though SamTrans' facilities and vehicles are less vulnerable to high heat at this time, SamTrans should consider future temperature projections when updating equipment such as HVAC systems, procuring new vehicles, and making significant infrastructure investments based on the expected lifespan of the asset. In particular, SamTrans will face increasing heat impacts as the century progresses and, given the short timeframe needed for deployment on many heat strategies, should consider deployment in coming decades when heat impacts become more problematic.

4.3 PROGRAMMATIC APPROACH TO CLIMATE RESILIENCE

In addition to taking action to prepare for specific climate impacts discussed in this study, SamTrans would benefit from developing a programmatic approach to climate resilience. For example:

- Form a working group to convene internal stakeholders on the topic;
- Form a process for integrating the recommendations identified in the Plan into SamTrans capital planning and bus operation;
- Continue to engage with external stakeholders and participate in regional coordination initiatives;
- Monitor climate conditions and stay abreast of latest climate projection from State and other sources;
- Develop a process for assessing climate risk at new properties or at new project locations; and
- Update this report once SamTrans' BEB electrification is complete.

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APPENDICES

APPENDIX A ACTION ALTERNATIVES

A.1 SLR ACTION ALTERNATIVES

Table 30 summarizes North Base action alternatives and Table 31 summarizes South Base action alternatives. SamTrans evaluated the benefits, limitations, feasibility and appropriate of each action alternative. Based on this analysis, including input from SamTrans stakeholders during a workshop, five action alternatives were retained for North Base and six action alternatives were retained for South Base.

Table 30. North Base Action Alternatives

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
RETAINED FOR FURTHER EVALUATION					
Structural Approaches					
1	Levee/breakwater protection system around perimeter of North Base.	• Prevent flooding and flood damage. • Provide long term SLR protection.	• Would need to tie in to SFO project at North Access Road, could be complex. • Costly, though LBCA shows costs are justified.	• Yes, but SamTrans will need to collaborate with many stakeholders, particularly SSF and SFO.	• Yes – though collaboration on a regional tide gate solution may be more appropriate and could potentially provide savings through cost sharing amongst agencies. It would be a more complex project however; lead agency unclear.
Facilities Approaches					
3	Reconstruct facility and provide foundation support to address settlement.	• Reduce risk of permanent flooding under SLR projections.	• Requires additional studies. • Will not prevent projected flooding without adding significant elevation; would still need perimeter levee otherwise.	• Possible – SamTrans is already planning to install 60-foot-deep pylons to address settlement for building 200. •	• Yes – existing settlement onsite poses a safety hazard if not addressed. However likely to be addressed as part of facilities renovation for BEB installation and building replacement.
4	Floodproof new construction by elevating all utilities and designing the ground level to accommodate flood waters.	• Provide resilience to flooding. • Operations could be less affected by SLR if building designed to accommodate it. • Designed-to-flood building could provide a location for operations in other buildings without a floodable-ground floor.	• Construction heights may be limited by airport requirements. • Potentially increases project cost by adding a story.	• Yes – elevating equipment should be considered as part of new construction and significant renovations.	• Possibly – depends on technology available at the time, impact on operations and additional cost needs to be considered.
5	Elevate new building electrical and HVAC systems, moving relevant equipment to roof, adding elevated platforms to house equipment at ground level, or raising the elevation of the ground where the equipment rests.	• Ensure reliable operation of facilities and BEB fleet.	• Site and structural limitations may limit options for implementation.	• Yes – elevating equipment should be considered as part of new construction and significant renovations.	• Possibly – depends on technology available, impact on operations and additional cost needs to be considered.

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
Non-facilities Approaches					
8	Explore locating some BEB charging offsite.	• Increase the reliability of BEB fleet operations.	• Cost of site and/or installation modifications. • Could be challenging to modify bus routes/ schedule to accommodate en-route charging.	• Yes – though it is not possible to conduct all charging en-route at this time. • A few en route chargers could be considered to provide emergency charging capacity.	• Possible in the future; may not be appropriate until a large portion of the fleet has been transitioned to BEBs. • Not currently included in ICT; will need to align with SamTrans' Innovative Clean Transit (ICT) plan/ BEB deployment status at time of consideration.
REMOVED FROM FURTHER CONSIDERATION AT THIS TIME					
Natural and Nature-based Approaches					
2	Living shoreline and wetland system.	• Provides buffer to tidal waters.	• Not likely to prevent all flooding projections without other alternatives in place. • Conflicts with airport's need to avoid bird collision; may be limited by FAA rules.	• No, this option significantly conflicts with airport operations and safety.	• No, this option significantly conflicts with airport operations and safety.
Facilities Approaches					
6	Increase elevation of BEB charging station installation location.	• Ensure reliable operation of BEB fleet.	• Cost of site and/or installation modifications.	• No – would be difficult to operate at higher elevation	• No – doesn't comport with SamTrans' ICT plan
7	Flood proof buildings and install pump systems.	• Prevents long-term flood damage to critical infrastructure. • Pump systems will mitigate for underground flooding.	• Pump systems will not be effective until temporary flooding waters have receded. • Pump systems need reliable power supply that could also be disrupted by flooding, preventing pump use. • Dry flood proofing may provide damage protection to interior facilities but not to equipment stored outside.	• Limited – dry flood proofing is limited to barriers up to 3 feet in height, which is likely not sufficient in the long term.	• No – the amount of protection provided would not warrant the expense. • Creates operational challenges.

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
Non-facilities Approaches					
9	Relocate facility to outside of the potential flooding area.	• Reduce/ change risk of flood damage and interruption of services during emergencies. • Preempts need for a perimeter levee, which would be a significant capital project and expense.	• Requires purchasing new property and reconstruction. • No apparent appropriate facilities currently available; would require eminent domain. • Eminent domain politically difficult.	• No – based on an initial real estate assessment, there is no readily available real estate that is suitable for operations and structural sufficient to handle the weight of bus infrastructure. • Would require eminent domain displacing other tenants at considerable cost.	• No – it would not be appropriate to relocate the base and displace other tenants, at present less expensive to protect North Base
10	Evaluate and redefine building construction standards for the base to raise site floor elevations above projected flooding conditions.	• Will raise facilities above future temporary flooding conditions through long-term reconstruction operations.	• Does not prevent flooding of the base, would still leave bus assets at risk and disrupt operations in floods.	• No – would be very costly and not provide long-term protection.	• No – very capital intensive without providing a total solution.
11	Plan for future distributed bus operations and maintenance.	• Provides redundancy. • Requires smaller acreage of land per site. • Could co-locate with other services	• Cost of site(s). • Would require a total overhaul operations.	• No – distributed operations have been tried in the past and were challenging to manage.	• No – would also need to consider flood protection at any site considered for distributed operations.

Table 31. South Base Action Alternatives

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
RETAINED FOR FURTHER EVALUATION					
Structural Approaches					
1	Increase the levee height along Steinberger Slough.	• Address future tidal flood conditions.	• Not under SamTrans' jurisdiction, requires collaboration with County and others.	• Yes – though SamTrans does not have control over this solution. • The current levee protects through 2050, so this solution is not needed in short-term.	• Yes – the levee will need to be raised in the future. Regional collaboration is recommended.
Natural and Nature-based Approaches					
3	Excavate/dredge Phelps Slough.	• Increase capacity of Phelps Slough.	• Not under SamTrans' jurisdiction, requires collaboration with County and other stakeholders.	• Yes – though SamTrans does not have control over this solution.	• Possibly – further study would be needed to evaluate the effectiveness of this solution in preventing fluvial flooding.
Facilities Approaches					
4	Elevate new building electrical and HVAC systems, moving relevant equipment to the roof, adding elevated platforms to house equipment at ground level, or raising the elevation of the ground where the equipment rests.	• Ensure reliable operation of facilities and BEB fleet by ensuring availability of building systems required for facility operation.	• Cost of site and/or installation modifications. Site and structural limitations may limit options for implementation.	• Yes – elevating equipment should be considered as part of new construction and significant renovations.	• Possibly – depends on technology available, impact on operations and additional cost.
5	Install and modify pump systems downstream of Phelps Slough.	• Increase storage capacity of Phelps Slough for future temporary flooding conditions.	• Requires partnership with Redwood City. Projected SLR will require larger pump system.	• Yes – though SamTrans does not have control over the solution.	• Possibly – further study would be needed to evaluate the effectiveness of this solution in preventing fluvial flooding.
6	Install check dams, ponds and infiltration systems in upper watershed to reduce surface runoff and flow going into Phelps Slough to reduce freshwater flood depths.	• Reduction of runoff from upstream or reduce fluvial flood elevations downstream.	• Requires partnership with surrounding communities.	• Yes – though SamTrans does not have control over the solution.	• Possibly – further study would be needed to evaluate the effectiveness of this solution in preventing fluvial flooding.
Non-facilities Approaches					
9	Locate some BEB charging stations offsite.	• Ensure reliable operation of facilities and BEB fleet.	• Cost of site and/or installation modifications.	• Yes – though it is not possible to conduct all charging en-route • A few en-route chargers could be considered to provide emergency charging capacity.	Yes – though this may not be appropriate until a large portion of the fleet has been transitioned to BEBs; will need to align with SamTrans' Innovative Clean Transit (ICT) plan.

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
			REMOVED FROM FURTHER CONSIDERATION AT THIS TIME		
Structural Approaches					
2	Deployable flood wall system.	• Prevent flooding from offsite.	• Limited to design protection levels (2050 or 2100 projections), interrupts use of facility during a major storm.	• Yes – system that can be deployed as needed and then removed.	• No – would direct water to nearby properties if the wall only protected SamTrans. • At this level of flooding the base would also not be accessible during this time.
Facilities Approaches					
7	Increase elevation of BEB charging station installation location.	• Ensure reliable operation of BEB fleet.	• Cost of site and/or installation modifications.	• No – would be difficult to operate at higher elevation.	• No – this conflicts with SamTrans' ICT plan.
8	Flood proof buildings and install pump systems.	• Prevents long-term flood damage to critical infrastructure. • Pump systems will mitigate for underground flooding.	• Pump systems will not be effective until temporary flooding waters have receded. • Dry flood proofing will provide damage protection to interior facilities but not to equipment stored outside.	• Limited – dry floodproofing is limited to barriers up to 3 feet in height, which may not be sufficient. • Further study of fluvial impacts is needed to understand the potential flooding from overtopping of Phelps Slough. • Wet floodproofing would not be feasible for many types of equipment.	• No – if it is determined that flooding from Phelps Slough would be below 3 feet and a regional solution could not be implemented in time to mitigate, dry floodproofing could protect the buildings but not the outdoor equipment.
Non-facilities Approaches					
10	Relocate facility to outside of the potential flooding area.	• Remove risk of flood damage and interruption of services during emergencies.	• Requires purchasing new property and reconstruction.	• No – based on a real estate study, there is no available real estate that is suitable for operations without displacing other tenants at considerable cost.	• No – it would not be appropriate to relocate the base and displace other tenants.
11	Plan for future distributed bus operations and maintenance.	• Provides redundancy. • Requires smaller acreage of land per site. • Could co-locate with other services.	• Cost of site(s), operational changes.	• No – distributed operations have been tried in the past and were challenging to manage.	• No – would also need to consider flood protection at any site considered for distributed operations.

A.2 HIGH HEAT ACTION ALTERNATIVES

Table 32 summarizes facility action alternatives, Table 33 summarizes vehicle action alternatives and Table 34 summarizes passenger action alternatives. SamTrans evaluated the benefits, limitations, feasibility and appropriate of each action alternative. Based on this analysis, including input from SamTrans stakeholders during a workshop, three facility action alternatives were retained, four vehicle action alternatives were retained and 14 passenger action alternatives were retained.

Table 32. Initial List of Facility Action Alternatives

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
RETAINED FOR FURTHER EVALUATION					
1	Changes in operation of operable doors and windows by staff on both North Base and South Base to ensure adequate natural ventilation and passive cooling during moderate and high heat events.	• Reduce high heat risk projected for after 2030.Protect equipment from damage due to overheating. • No capital cost for implementation.	• Potential impacts on operation. • Potential training costs and time.	• Yes – Staff already open doors and windows on hot days. This action alternative may require that specific windows/doors be opened to maximize air flow through the bases. Some doors/ windows cannot be opened. Staff training may be necessary.	• Yes – revisit when heat impacts intensify after 2030/ mid-century. • Protect equipment from damage due to overheating.
2	Modify SamTrans Facility Design Standards to include design considerations related to high heat. This could be a checkbox or more involved specifications related to heat reduction.	• Cooler temperatures inside facilities. • Reduced electricity bills. • Improve worker comfort in the future when temperatures are more extreme.	• Initial cost of writing the standards. • Potential for increased cost during installation of measures, depending upon standards. • Potential for increased maintenance, depending upon standards.	• Yes – but would require more internal discussion and consideration to identify which standards to add/modify.	• Yes – the standard can be written in a way that allows for flexibility. • Can be considered when North Base building 200 is reconstructed.
REMOVED FROM FURTHER CONSIDERATION AT THIS TIME					
3	Adapt PPE requirements for summer months or high heat days; explore if lighter color or lighter weight PPE clothing/equipment is an appropriate option.	• Improve worker comfort on high heat events expected after 2050. • Could reduce chances of heat-related illness. • Relatively inexpensive and easy to implement.	• Cost of new PPE equipment for workers. • SamTrans will need to update PPE requirements for working on BEBs.	• Potentially feasible –identify if lighter/more comfortable PPE that still meets safety requirements.	• Not necessary in the near-term, and can be revisited in the future. Relatively easy to implement.
4	Increase cooling capacity of existing HVAC systems for buildings.	• Improve staff comfort in relevant facilities, reduced risk of heat related health risk. • Protect equipment from heat damage.	• Cost of replacement & potential impacts on operations; HVAC is not on a replacement schedule at this point. Some areas in the shops cannot have HVAC. • Not needed to address near term risk; consider after 2030.	• Potentially feasible for the future, but facilities are not expected to require additional cooling capacity under the 2030 scenario; HVAC units typically last approximately 15 years.	• Won't benefit facilities that are not mechanically cooled; may be appropriate to consider for HVAC units replacement as part of Building 200 renovation.

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
5	Add mechanical cooling to semi-heated and ventilated only spaces on both North Base and South Base that may be at risk during high heat events.	• Improve staff comfort in relevant facilities, reduced risk of heat related health risk. • Protect equipment from high heat damage.	• HVAC ineffective in open-air facility areas. • Cost of replacement & impacts on operations. • Not needed to address near term risk; consider after 2030.	• Not feasible – for areas with open air maintenance bays where HVAC would be ineffective	• Not appropriate at this time –key areas do not currently accommodate HVAC; would require significant modifications to facilities and is not justified until after 2030
6	Decreasing building temperature through measures such as green roofs.	• Reduced indoor and outdoor air temperatures. • Aesthetics, water filtration, habitat benefits. • Reduced utility bills and GHG emissions from electricity consumption.	• Existing roofing structures would not support green roofs. • Order of magnitude more expensive to install compared to a traditional roof. • Maintenance requirements.	• Not feasible, – structures cannot support green roofs at this time; would require new roofs and possibly foundations • May be cost prohibitive	• Not appropriate at this time; facilities are not very vulnerable to near term high heat to warrant green roof solely for the purpose of providing additional cooling

Table 33. Initial List of Vehicle Action Alternatives

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
RETAINED FOR FURTHER EVALUATION					
1	Where possible, purchase BEBs that are proven to operate well under high heat events.	• Avoided operational impacts. • Cost savings. • Ensures adequate performance and operability.	• The technology is still new and there are limited case studies to provide data regarding high heat.	• Feasible – SamTrans has looked at other systems in hotter environments including other areas of California and Arizona	• Appropriate – Already being considered as part of SamTrans BEB transition, no further action as part of this study.
2	Provide power redundancy for BEB charging given potential uncertainties in grid availability (e.g. shut offs due to wildfire, blackouts from high temperatures). On-site power generation and/or power storage will increase available power sources for BEB charging.	• Reliable power in situations where the grid is affected. • On-site power generation/storage can provide cost savings.	• Power storage costs are high. • On-site generation may be limiting in terms of how much energy can be produced. • Back-up power may not be enough to power the entire fleet due to space and technology limitations.	• Feasible – SamTrans is currently evaluating emergency backup power technologies as part of the BEB transition plan and energy procurement study.	• Appropriate – Already being considered as part of SamTrans BEB transition, no further action as part of this study.
3	Procure BEBs with solar reflective windows if not included in current specs.	• Reflects light reducing interior temperature.	• Additional cost. • Difficult to replace if damaged. • Commercial films do not hold up to bus environment.	• Feasible – but windows with UV protection are costly. SamTrans currently purchases for driver window.	• Inappropriate- SamTrans has researched, considered and declined this option.
4	Purchase and install en-route chargers for the purpose of operational assistance, including high heat events.	• Ability to drive longer distances without stopping to charge.	• Cost and space to install chargers.	• Potentially feasible – En-route chargers are not currently part of SamTrans' BEB transition plan. However, they may become necessary to service longer routes until the technology matures. Depending on the location of potential en-route charges, it may or may not be feasible to leverage for certain routes during high heat events.	• Potentially appropriate – SamTrans would need to identify locations for en-route chargers and incorporate en-route charging into the bus service plan.

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
REMOVED FROM FURTHER CONSIDERATION AT THIS TIME					
5	Develop an emergency BEB contingency plan for high heat events. The plan could include the following strategies: • Procure additional BEBs to deploy in case of emergency or high heat events. • Deploy alternative bus types during high heat events (hybrid or diesel). • Alter bus charging schedule during high heat events	• Increased SamTrans reliability during high heat events.	• Insufficient room to store additional buses at bases. • Potential for increased operational costs and problems during these events. • SamTrans is required to convert to a zero emission fleet by 2040.	• Not feasible – there is insufficient room to store additional BEBs. • It would be cost prohibitive to purchase additional buses exclusively for high heat events. • SamTrans evaluated the feasibility of hydrogen fuel cell buses and determined that the technology is not currently feasible.	• Not appropriate – benefits do not justify the costs.
6	More frequent AC maintenance.	• Improved operation, efficiency.	• Cost of increased maintenance.	• Feasible – but frequent AC maintenance is already in place.	• Not appropriate – existing AC maintenance is sufficient.
7	Purchase BEBs with an additional AC condenser on the roof.	• Heat accumulated from the interior is expelled outside and keeps the AC running on the hottest days.	• There is not enough room on the bus roof to accommodate a second AC condenser.	• Not feasible – There is not enough room to support.	• Not appropriate – benefits do not justify the costs even if future BEBs could accommodate a second AC unit.
8	Decreased bus frequency for some routes during high heat events. Re-direct buses to routes with higher ridership and/or higher vulnerable population ridership.	• Could adjust bus routes during high heat events to support high demand areas or highly vulnerable populations	• Would require extensive planning and precise execution during a high heat event.	• Not feasible – This would be time-consuming and complicated to plan for and execute.	• Not appropriate – There more appropriate strategies to address passenger vulnerability.
9	Adjust block lengths of BEBs during high heat, to ensure there is sufficient charge to complete the route during periods of higher AC usage.	• Ability to avoid route disruptions due to battery SOC.	• Riders would need to know where the bus will stop. • Riders may potentially need to walk further.	• Not feasible – This would be very challenging to implement and communicate to drivers and passengers.	• Not appropriate – It would be more appropriate to plan for en-route charging as needed during high heat events.

Table 34. Initial List of Passenger Action Alternatives

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
RETAINED FOR FURTHER EVALUATION					
1	Install bus shelters (SamTrans-owned, Ad, or other) or shade structures at transit stops without shelters. SamTrans could prioritize bus shelters in high ridership locations. Alternatively, SamTrans could prioritize shelters in disadvantaged/ underserved communities first.	• Shade for SamTrans passengers. Urban shade can have broader benefits for the UHI effect and general public comfort/health and safety. • Opportunity for additional ad revenue if installing more ad shelters. • Improvements to bus stops may have indirect impacts to transit use and overall greenhouse gas reductions (if improved amenities results in new riders start taking the system).	• Cost of shelters and installation. • Monitoring/ management oversight. Maintenance requirements. • Locations must be deemed suitable for a shelter. If not suitable there may be additional costs associated with retrofitting the location for a bus shelter (e.g. site must be large enough for a shelter). • There may be permitting requirements to install new shelters. • Shelters are sometimes occupied by people experiencing homelessness and not available to customers. • Shelters sometimes attract criminal activity, although lighting could deter criminal activity.	• Potentially feasible – but requires sufficient financial resources and/or updates to the ad shelter contract and support from city and county partners. • Many factors must be considered when evaluating new or upgraded bus shelter amenities.	• Appropriate –SamTrans could evaluate opportunities to enhance bus stop amenities and shade to provide protection from heat. comprehensively throughout the system.
2	Provide benches at SamTrans bus stops where shelters are not feasible.	• Provides a place to rest for SamTrans passengers and ill reduce exertion during high heat events. • Based on public input collected by SamTrans, late buses feel 4 times longer to customers when waiting at a stop without a shelter or bench. • Improvements to bus stops may have indirect impacts to transit use and overall greenhouse gas reductions (if new riders start taking the system).	• Cost of benches and installation. • Locations must be deemed suitable for a bench – if not suitable there may be additional costs associated with retrofitting the location. • There may be permitting requirements to install new benches. • Some maintenance requirements.	• Feasible – but requires sufficient financial resources and SamTrans would need to work with communities and ensure compliance with relevant regulations.	• Appropriate – a lower-cost option to provide relief to passengers than building an entire shelter. • Could be part of a comprehensive bus shelter review.
3	Design a custom shelter to meet multiple conditions. The design could be used in place of SamTrans' current standard shelter and/or be incorporated into the specifications for a future ad shelter contract.	• Reduce temperature inside shelter through one or more of the following: • Use of composite materials. • Louvers to allow breezes, provide shade and help reduce radiant temperatures of surrounding pavement.	• This would not be possible for existing ad shelters under the current contract. However, it could be incorporated into a new ad shelter contracts. • A custom shelter design would be more expensive. • Some features could require additional cost and/or maintenance.	• Potentially feasible – but requires sufficient financial resources and/or updates to the ad shelter contract. Investing in a custom design could provide long term benefits to SamTrans. However, any community customization would take	• Potentially appropriate – SamTrans has had some challenges with existing shelters in the past. • Designing a custom shelter would allow SamTrans to address these other issues (e.g. maintenance, vandalism).

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
		• "Blue Bus" "flagpole" type shade structures. • Roof partition or shade canopy that blocks the sun. • Increased cross ventilation. •	• SamTrans would be responsible for maintenance of any SamTrans-owned shelters. • One shelter design may not meet needs for various climates within SamTrans jurisdiction.	a lot of engagement and partnership building. • SamTrans could possibly sponsor a local university design contest. • SamTrans could collaborate with communities to align with their desired shelter design preferences.	
4	Use ad revenue for bus shelter improvements (as suggested above and more general improvements and maintenance).	• A revenue stream could support upgrades and potentially the creation of more ad revenue.	• This would require an internal policy change and could negatively affect other programs/efforts funded by ad revenue. • Ad revenue is extremely minimal.	• Potentially feasible – could be evaluated by SamTrans as part of any future ad shelter contracts however with such a minimal income stream it is likely insignificant.	• Inappropriate – potentially appropriate but not substantial enough to be worthwhile to pursue.
5	Provide free/discount fare rides to cooling centers on high heat days. Coordinate with Department of Health (DOH) for County and City for advance notice of Cooling Center locations; notify dispatch, drivers, advise passengers on how to get there.	• Benefits current SamTrans passengers. • Benefits public comfort/health and safety by providing a public service.	• Associated operational communications costs and logistics – no additional service or route deviations anticipated. Can request list of cooling centers along routes so no route changes will be necessary. • Lost revenue could be a challenge, and SamTrans would potentially need grant funding to support (e.g. PG&E funds cooling centers). Fresno Area Express (FAX) offers free rides to cooling centers. SamTrans could coordinate with FAX on how they have implemented their program.	• Feasible with DOH, county/city support and identified funds to make up for lost revenue. Will require developing a list of community shelters and relevant bus routes, developing messaging and protocols in advance, in addition to ensuring communications protocols with DOH.	• Appropriate – Could have far reaching public health benefits and could be easy to do in operations (with enough support).
6	Provide informational materials on dangers of heat stress and where/how to access local resources such as cooling centers. This information could be displayed on SamTrans buses through brochures, possibly through interior bus signs and posters and online through social media/SamTrans website.	• Benefits current SamTrans passengers. • Benefits public comfort/health & safety by providing a public service. • Could provide in multiple languages.	• This action alternative assumes that informational content/materials would be developed, translated and printed by others (DOH, public health organizations). • Assumes SamTrans can absorb cost of distributing printed materials to be displayed in the "Take One" spot on buses.	• Feasible – but as in #6 above, this involves improved coordination with DOH and others who develop materials. Materials can be displayed in the "Take One" spot on the buses. Social media alerts can also be shared.	• Appropriate – collaborative response to the problem of heat with minimal cost to SamTrans.

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
7	Provide informational materials on dangers of poor air quality and where/how to access local resources like N95 face masks, public locations to seek shelter, and additional information through the Bay Area Air Quality Management District.	• Benefits current SamTrans passengers. • Benefits public comfort/health and safety by providing a public service.	• Assumes informational content/ materials will be developed, translated and printed by others. • Assumes SamTrans can absorb cost of distributing printed materials to be displayed in the "Take One" spot on buses.	• Feasible – but as in #5 and #6 above, this involves improved coordination with DOH and others who develop materials. Materials can be displayed in the "Take One" spot on the buses. Social media alerts can also be shared.	• Appropriate – collaborative response to the problem of heat with minimal cost to SamTrans. • This information could be displayed on SamTrans buses through advertisements and online through social media/SamTrans website. Can provide in multiple languages.
8	Train SamTrans bus operators to recognize symptoms of heat-related illness and appropriate actions (e.g., when to call 911).	• Benefit to SamTrans passenger health and safety. • Bus operator professional development/ opportunity.	• Cost of training for current and future operators.	• Potentially feasible – However, this strategy should avoid putting additional duties, expectations or liabilities on drivers.	• Potentially appropriate – Operators are not expected or trained to perform first aid but are trained to recognize emergencies and when to call for help. Training drivers to recognize symptoms and call 911 does not drastically change SamTrans' current practice.
9	Help to facilitate last mile solutions that reduce heat risk to passengers.	• May reduce waiting time for passengers, reduce exposure to high heat in accessing SamTrans services.	• Cost of new service. • Potential solutions unclear. • Some solutions, such as microtransit, were withdrawn after pilot.	• Potentially feasible, but scope would need to be narrowed. • Challenging to solve and already a significant concern of SamTrans and most transit agencies	• Appropriate – would need to determine how to approach and narrow the issue and take next steps.
10	Investigate policy initiative to waive "no beverage" policy on high heat days.	• Allowing customers to drink water on high heat days would alleviate heat stress.	• Would be difficult to restrict to just water; could lead to abuse of policy on other days. • Spillage can create slipping hazards and potential liability. SamTrans must avoid putting drivers at risk of liability. • Riders may leave water bottle type trash on bus.	• Potentially feasible – low cost and limited effort would be required to implement.	• Potentially appropriate – This is a simple solution that could provide an immediate benefit to passengers on high heat days.
11	Provide real-time information at bus stops.	• Provides the public with more information. • Can reduces wait time in heat when riders stay inside/in the shade until just prior to the arrival of the bus, then move to the bus stop.	• Producing/implementing the technology. Policy decisions required.	• Feasible – many agencies do this. Requires additional technology and infrastructure at bus stops, however.	• Appropriate – Future bus stop improvement studies could identify high ridership stops where real time signs would be beneficial.

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
12	Distribute SamTrans branded fans and cooling packs during high heat events.	• Would provide the public with tools to cool down. • Potential education opportunity if items are printed with information about heat risk. • Branding and good public relations for SamTrans.	• Cost of creating these products. • Creates waste stream that may end up on buses.	• Feasible – SamTrans has already developed. similar, branded goods to hand out.	• Appropriate – This is a simple solution that is easy to implement.
REMOVED FROM FURTHER CONSIDERATION AT THIS TIME					
13	Transit riders in off peak hours may experience longer wait hours during the hottest times of the day. Reduce risks to vulnerable transit riders by altering bus frequencies during off peak hours in the hottest part of the afternoon (approximately between 1 – 3 PM).	• Benefits to comfort/health and safety of SamTrans passengers, focusing on those that are in locations with higher heat vulnerability. • Minimizes passenger exposure to heat on high risk days. • Can serve equity goals by redirecting resources to support routes in disadvantaged and underserved communities during high heat events.	• Potential for increased operational costs. • This can be done by redirecting resources away from less heat vulnerable to more heat vulnerable bus routes. Decreased bus frequency for less heat vulnerable routes when this strategy is implemented. • This may only be necessary during high heat days and certain times of the day (hottest hours).	• Not feasible at time of study but may be worth considering in the future as heat conditions intensify.	• Not appropriate – Resource intensive to plan and execute. Requires significant forward-looking route and scenario planning. Recommend revisiting as heat intensifies in the future.
14	Provide additional bus stop amenities to increase passenger comfort such as commercial misters for use in high heat events, ventilation/fans and water fountains. Solar panels could also be used on bus shelters.	• Misters reduce the UHI effect, benefit public comfort/health and safety and will improve the cooling effect of bus shelters. • Water fountains provide benefits to public comfort/health and safety. • Solar panels generate additional revenue and energy. • Misters and solar panels each provide a public education opportunity. • Improvements to bus stops may have indirect impacts to transit use and overall greenhouse gas reductions (if new riders start taking the system).	• Misters and water fountains may be costly, including long-term maintenance and utility costs. • Solar panels have upfront costs but will pay for themselves in time. • Each action has capital and maintenance needs associated with it. • Increased amenities could make the bus stop more hospitable for people experiencing homelessness. • Increased amenities could make the bus stop more hospitable for criminal activity. • Requires bus stops to have access to electricity and water utilities which is not always the case.	• Likely not feasible – Solar panels are already on many shelters and not working due to vandalism, age and/or maintenance. • Misters are likely not feasible due to need for reliable power and water sources. • Cost intensive.	• Potentially appropriate – in the future, post 2030, as heat intensifies, greater investment and complexity of amenities may be justified.
15	Install green roofs on bus shelters to provide cooling.	• Green roofs reduce the Urban Heat Island effect, benefit public comfort/health and safety and will	• Green roofs very costly due to ongoing maintenance and water utility costs.	• Likely not feasible due to cost.	• Likely not appropriate due to cost and maintenance requirements.

NO.	ALTERNATIVE	BENEFITS	LIMITATIONS	FEASIBILITY	APPROPRIATENESS
		improve the cooling effect of bus shelters. • Provide urban wildlife habitat and beautify neighborhoods. • Provide a public education opportunity. • Improvements to bus stops may have indirect impacts to transit use and overall greenhouse gas reductions (e.g., if new riders start taking the system).	• Would require fundamentally new shelter design to support weight of roof. • Restrictions of existing shelter contract.	• Can be considered / valuated as part of the proposed SamTrans shelter design initiative- see item 3.	
16	Plant shade trees and vegetation near bus stops. Plantings could prioritize in high ridership locations in areas with more significant heat island effects.	• Shade for SamTrans passengers. Urban tree canopy reduces the UHI effect. Benefits public comfort/health & safety. • Provides urban wildlife habitat. • Improves air quality and mitigates greenhouse gases. • Can have broader economic impacts (e.g., neighborhoods with urban tree canopy are more desirable). • Improvements to bus stops may have indirect impacts to transit use and overall greenhouse gas reductions (e.g., if new riders start taking the system).	• In many cases relies on collaboration with other government agencies and is outside the scope of SamTrans control. • Significant maintenance and watering costs if SamTrans or contractor assumes these roles, depending on location. • Cost of landscaping and installation, if SamTrans or contractor assumes these roles, depending on location. • Locations must be deemed suitable for landscaping. If not suitable there may be additional costs associated with retrofitting the location (e.g., removing sidewalk concrete for tree basins, access to utilities).	• Potentially feasible but would require coordination and approval from external stakeholders.	• Likely not appropriate. Bus-tree conflict is a common issue in bus operations. • SamTrans commonly does not own the property where bus stops are, so decisions regarding street tree installation and maintenance are commonly outside SamTrans' control and require coordination with property owners, likely the local municipality or Caltrans, to execute. • Would need to avoid any potential conflicts with bus operations and consider maintenance requirements. • Would require collaboration and support from agency where bus stops are.
17	Collect operational data to understand correlation/causation of transit stop use and heat exposure. Study could be used to identify if ridership declines during high heat days at certain stops. These bus stops could be prioritized for actions/responses listed above.	• Gain a better understanding of the direct impact to ridership from high heat days. • SamTrans already collects ridership data that can be used for this analysis.	• Requires SamTrans staff time or consultant support.	• Feasible – Coordination between Bus Planning and Bus Operations would be required.	• Potentially appropriate – if SamTrans has sufficient resources to support. The study could be used to inform the amount of resources SamTrans should dedicate to bus stop amenities.

APPENDIX B NORTH BASE LIFECYCLE BENEFIT COST ANALYSIS

Appendix B provides more detail on the lifecycle benefit cost analysis (LBCA) that was conducted to assess future climate risk at SamTrans North Base facility. The LBCA examined expected costs due to SLR and associated flooding for a "no-action" alternative, which assumes current conditions, and three different levee alternatives. In LBCA, benefits are typically represented as the avoided hazard-related costs that would have occurred under a no-action alternative.

Each levee alternative was assumed to tie into a broader regional levee system to form a closed system of flood protection. The three levee alternatives included (1) a standard option, based on a conceptual design included in a recent erosion study at the site; (2) a risk-averse option with a higher crest designed to withstand higher magnitude flood levels; and (3) a flexible option with an initial crest that could later be added onto as conditions change.

Simulations of future annual maximum water levels were developed for three different SLR scenarios. The analysis included hazard-related costs (flood damage and service disruption costs), capital costs and operating and maintenance (O&M) costs.

B.1 APPROACH

The LCBA examined expected costs due to sea level rise and associated flooding for a no-action alternative and three different levee alternatives. In addition to hazard-related costs, the analysis included capital and O&M costs. The following alternatives were evaluated:

- **No-Action.** This serves as a base case that can be used to help justify investment in flood protection infrastructure.
- **Standard levee** designed for "mid-level" SLR of 3.3 feet in 2100 plus a 100-year storm event.[21] This alternative is based on the "Alternative 3" levee concept and accompanying cost estimates described in the erosion study report. As described in the report, the levee crest elevation is 13.3 feet North American Vertical Datum of 1988 (NAVD88).
- **Risk-averse levee** designed for "high-level" sea level rise of 6.6 feet in 2100 plus a 100-year storm event.[22] The design is based on the Alternative 3 concept and cross sections, but the crest elevation of 19.0 feet NAVD88 accounts for greater sea level rise, projected future subsidence and a slight increase in current extreme water levels.[23]
- **Flexible levee** design with two stages of installation. The first stage would provide

[21] "Mid-level" and "High-level" SLR estimates for 2100 are defined by San Mateo County and were used in SamTrans' North and South Base SLR Assessment (San Mateo County, 2018).
[22] Ibid.
[23] Based on the San Francisco Bay Tidal Datums and Extreme Tides Study (AECOM, 2016).

protection against 3.3 feet of SLR plus a 100-year storm event. The second stage would build the levee crest upward to provide protection against 6.6 feet of SLR plus a 100-year storm event. The solution is also based off the Alternative 3 concept and cross sections. Both stages account for projected future subsidence and a slight increase in current extreme water levels in addition to SLR. The initial and final levee crest elevations would be 15.7 and 19.0 feet NAVD88.

For the LBCA, it was assumed the three levee options would form a closed coastal protection system with other levees or similar measures along North Access Road and the southern neck of the peninsula where North Base is located. It was assumed other SLR protection systems would provide at least the same level of protection as the North Base levee system and that they would not be installed or funded by SamTrans.

The LCBA damage estimates were based on overtopping heights and did not assess hydrostatic or hydrodynamic loads (forces generated by water at rest or in movement, respectively, against the structure). Given available information, it was assumed that impacts from high velocity water including waves would be minimal at North Base. The full design should include further analysis of these impacts and determine how the design should account for them.

Order-of-magnitude capital costs were estimated using material quantities and unit costs from the previous erosion study. Soft cost and contingencies were applied to materials and labor. In the accompanying spreadsheet, the Cost_Est_Ref tab shows the line item capital cost estimates. The capital cost estimates are also summarized in Table 35. Some costs, such as environmental damage, were not included in this analysis. This analysis also excludes future electric bus infrastructure and vehicles. However, the accompanying spreadsheet allows SamTrans to input those costs in the future to update the LBCA results as desired.

Table 35. Levee Alternative Installation Costs

Levee Option	Installation Cost	Crest Elevation (feet NAVD88)
Standard Levee	$8.1 million	13.3
Flexible Levee (once stage 1 and stage 2 are constructed)	$13.2 million	19.0
Flexible Levee Stage 1	*$9.2 million*	*15.9*
Flexible Levee Stage 2	*$4.0 million*	*19.0*
Risk-Averse Levee	$11.5 million	19.0

The analysis period spans from 2030 through 2100. For the purposes of this analysis, 2030 was assumed to be the earliest year that a levee alternative would feasibly be installed. Therefore, the risk analysis starts in 2030. All costs are in 2020 dollars. As described later in this section, all costs are discounted based on the year in which they occur, except for initial capital costs of the levee. An annual O&M cost of 4.25% of replacement value was applied for each alternative.[24] This 4.25% consists of:

- Regular annual O&M costs of 2-5% replacement value. The midpoint of this range, 3.5%, was used.
- A major rehabilitation cost of approximately 30% replacement value needed every 30-50 years. This is assumed to lengthen the levee's useful life out beyond the end of the analysis period. The midpoint of the range, 40 years, was used. For simplification purposes, these rehabilitation costs were spread evenly across all years for 0.75% per year (30% spread over 40 years) for the entire analysis period.

For the hazard-related costs, three time series of sea level rise projections out to 2100 were used from the State's guidance (OPC, 2018). These time series are the high emissions Median (50% chance of exceedance), High End of Likely Range (17% chance of exceedance) and 1-in-200 (0.5% chance of exceedance) scenarios. The High End of Likely Range projection for 2100 (3.4 feet) roughly coincides with San Mateo County's Mid-Level projection for 2100 (3.3 feet). Similarly, the 1-in-200 chance projection for 2100 (6.9 feet) roughly coincides with San Mateo's High-Level projection for 2100 (6.6 feet). Figure 26 shows the projections.

[24] The levee replacement costs were assumed to be equivalent to initial capital costs. For the flexible levee after the second phase of construction, the replacement cost was assumed to be equivalent to initial capital costs of the risk-averse levee alternative.

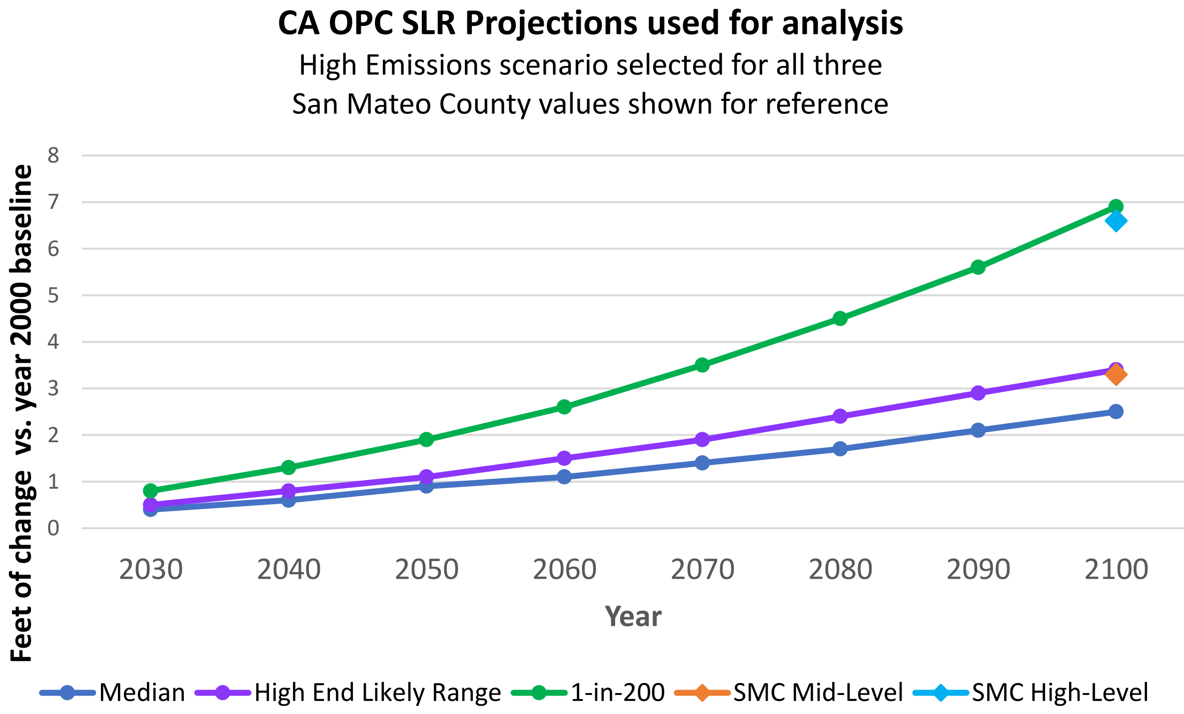

Figure 26. CA OPC SLR Projections used for LBCA

For baseline extreme water levels, the San Francisco Bay Tidal Datums and Extreme Tides Study was used. This study provides stillwater elevations for several return periods for hundreds of locations in the Bay. For each climate scenario, return period and future projection year, SLR increments were added to these baseline water levels to estimate future water levels. Interpolation was used to develop projections for each analysis year.

For the flexible levee option, the timing of the second stage of construction was allowed to vary between the climate scenarios. It was assumed that the second stage would need to be installed before the future 100-year flood level exceeded the levee crest height, and that costs for this upgrade would be incurred five years before installation.

Rather than assessing how alternatives performed in a particular return period event in a particular year, the entire distribution of annual maximum water level events was assessed for each climate scenario and year. This provides an estimate of the full costs of flooding to the facility over the entire analysis period, rather than just the cost of a single event. Knowing this full cost is critical to analyzing which alternative(s) are most cost-effective. Annual maximum water levels were generated for each climate scenario and analysis year using a Monte Carlo simulation with 500 iterations. The simulated water levels were the basis for calculating expected hazard-related costs.

There were several types of hazard-related costs included in the LCBA. Generally, these costs were applied in a top-down manner given available information and the scope of the analysis.

- **Levee repair/replacement costs.** For the levee alternatives, it was assumed that overtopping would result in levee failure, and that repair costs would be 80% of the capital cost of the levee.
- **Facility repair costs.** Facility repair costs were estimated using depth damage functions. It was assumed that buildings would need to be restored after flooding and would not need to be entirely replaced. Replacement costs were assigned to each SamTrans building at North Base by allocating a total facility replacement cost of $40 million among the different buildings according to their square footages. Elevation information was obtained from the digital elevation model (DEM) used for the study (Dewberry, 2011). Several depth damage functions were reviewed and one was chosen for the LCBA. The function was developed by the U.S. Army Corps of Engineers (USACE) for Commercial Engineered buildings as part of the North Atlantic Coast Comprehensive Study (2015). This is shown in the Depth_Damage_Inputs tab of the spreadsheet. The function was applied to each building based on its average elevation. For the levee alternatives, facility repair costs were assumed to incur only when the levees were overtopped. It was assumed that the relationship between inundation depth and damage percentage was the same for building structures and contents. It was assumed damage costs would only be incurred at the building and not to the bus fleet or any other assets at North Base. Figure 7 shows facility damage costs for all buildings by flood depth.

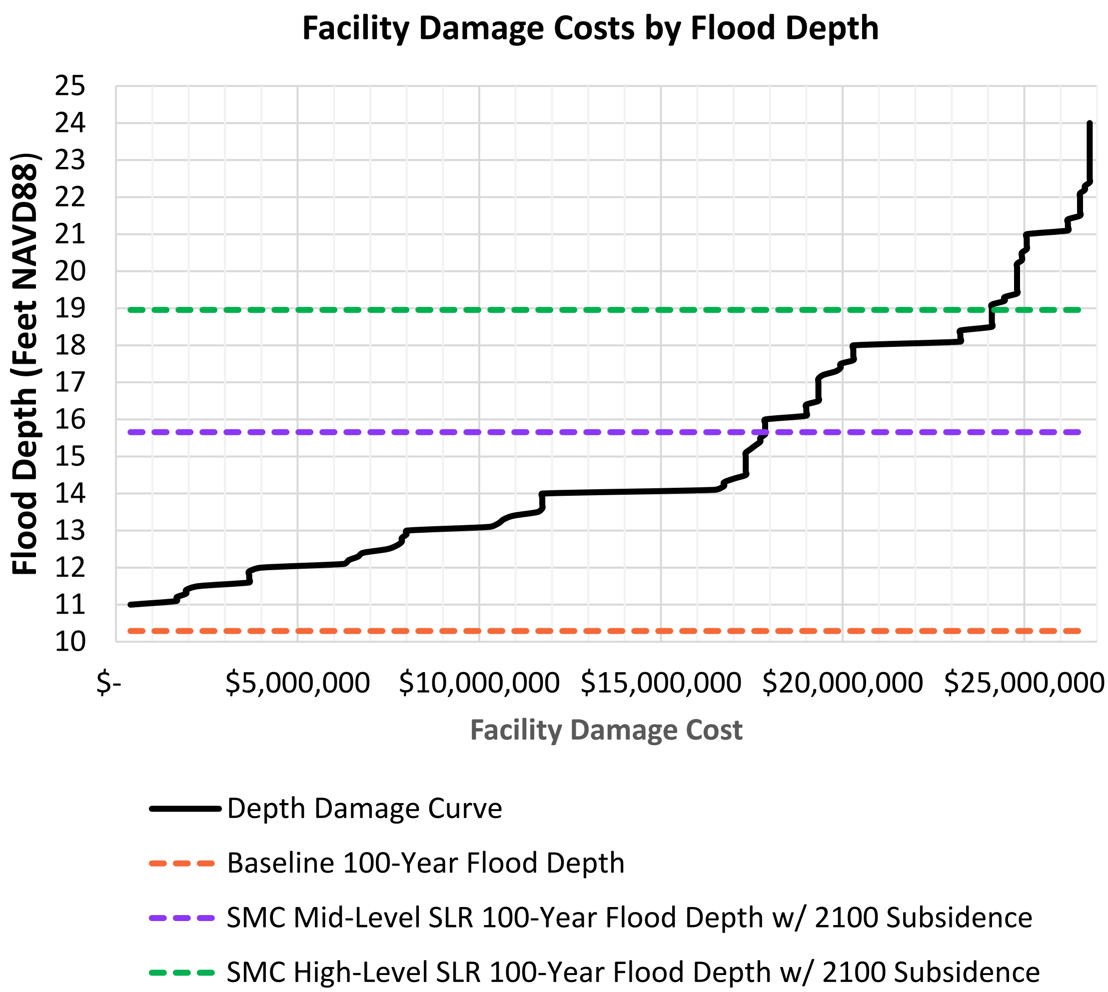

Figure 27. Facility Damage Costs by Flood Depth

- **Lost fare revenue due to bus service impacts.** It was assumed that flood events causing facility damage would disrupt SamTrans bus service and therefore lower bus fare revenue. A set of placeholder assumptions was used to estimate these costs based on pre-COVID-19 ridership. A maximum lost fare revenue cost was calculated using estimates of days to repair North Base after a major flood event, SamTrans annual bus fare revenue, and the percentage of bus fare revenue that would be lost while North Base was being repaired. After this maximum disruption cost was estimated, it was applied in proportion to the amount of facility damage incurred during each event (i.e., it was assumed the following two percentages were equal: (1) the facility damage value of event X as a percentage of the maximum facility damage; and (2) the lost fare revenue value of event X as a percentage of the maximum disruption cost). For example, if an event caused $250,000 of flood damage out of a total possible $500,000 of flood damage, then it caused 50% of total possible damage. This same percentage is applied to the disruption cost.

- **Temporary fleet relocation costs.** It was assumed that a fixed cost for bus fleet relocation would be incurred in the event of levee overtopping. For the no-action alternative, this cost was incurred when the access road was flooded. There was also a maximum fleet relocation cost for the maximum duration disruption event. The relocation cost was scaled between the minimum and maximum values based on the proportion of facility damage incurred during a given event. The relocation is assumed to have been preemptive, therefore avoiding potential fleet damage costs.

For simplification purposes, costs were only assumed to occur during annual maximum water levels. It was also assumed that each levee alternative would be replaced in-kind rather than upgraded after an overtopping event.

Hazard-related costs, capital costs and O&M costs were summed for each alternative, simulation, climate scenario and year. Costs were discounted based on year. The choice of discount rate can heavily influence estimates of present discounted costs, particularly when assessing future climate risk. A real discount rate of 1.5% was used, though the "Results" tab of the workbook used for the LCBA includes a sensitivity analysis of how different real discount rates affect the analysis. The "General_Inputs" tab describes the selection of the real discount rate in more detail.

After discounting, costs were aggregated by alternative, climate scenario and simulation. Results were given for different percentiles to help account for uncertainty in the future conditions. The "Results" tab shows 10th, 50th and 90th percentile simulations. The 10th percentile represents the lower bound of the 80% confidence interval, the 50th percentile represents an expected value and the 90th percentile represents the upper bound of the 80% confidence interval. Results include present discounted lifecycle costs, cost savings (or loss) compared to the no-action alternative, benefit-cost ratios (BCRs) and "regret." In this case, BCRs refer to the lifecycle hazard-related cost savings for a levee alternative compared to the baseline alternative, divided by the lifecycle capital and O&M costs for that levee alternative. Regret is calculated as the difference between an alternative's discounted lifecycle costs and the minimum discounted lifecycle cost across each alternative for a given climate scenario-simulation combination. Maximum regret is an alternative's highest regret across all climate scenario-simulation combinations.

B.2 RESULTS

Key results include the following:

- In terms of cost effectiveness, the flexible and risk-averse levee alternatives are the most robust options – they perform the best across the set of future scenarios analyzed.
- The no action alternative is very costly under all three SLR scenarios. There is a clear case for installing suitable flood protection at North Base.

- The levee alternative performs the best under all three SLR scenarios.
- Of the nine combinations of SLR scenarios and percentile simulations shown in the results, the flexible levee option performs the best in six of them. The risk-averse option performs the best in two of the higher impacts combinations (90th percentile for both the High End Likely Range and 1-in-200 SLR). The standard option performs the best in the lowest impact combination (10th percentile for median SLR).
- The risk-averse levee alternative had the lowest maximum regret among the alternatives, followed by the flexible option.
- Using a lower discount rate, such as 0.1% or 1%, weights future hazard-related costs more heavily than a higher discount rate. A higher discount weights initial capital costs more heavily. Therefore, the no-action and standard levee alternatives, which have lower capital costs but higher hazard-related costs than the other two alternatives, perform worse under lower discount rate scenarios. Under a higher discount rate of 3%, these two options perform somewhat better, but the flexible and risk-averse levee alternatives are still more cost-effective.
- The results demonstrate the importance of implementing flexible solutions that can be further adapted as climate conditions continue to change over time.
- Performance hinges on the assumptions, inputs and framing of the analysis discussed in the document and the spreadsheet.[25] While LCBA can be a helpful decision support tool, users need to be aware of its limitations.
- The tool is focused primarily on cost-effectiveness rather than regional coordination, social, environmental and safety issues associated with different alternatives. Some of these issues are discussed qualitatively in the Socioeconomic Impacts section below.

Table 36 and Figure 28 show discounted lifecycle costs for the four alternatives and three SLR scenarios. The expected value (50th percentile) results is shown along with the lower bound (10th percentile, or lower end of 80% confidence interval) and upper bound (90th percentile, or upper end of 80% confidence interval). These costs include installation costs, O&M costs and hazard-related costs over the entire analysis time period of 2030 to 2100. Cost are discounted by the year in which they occur. A 1.5 discount rate was used.

Under all three SLR scenarios, the flexible levee alternative is the lowest cost option for the Expected Value.

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[25] For instance, if the assumption that North Base would form a closed system with a broader regional levee system does not hold, the economics would shift substantially. SamTrans would likely need a hydraulic gate at the neck of the North Base peninsula and buses would not be able to enter and exit the base if the surrounding area were flooded, significantly disrupting the bus service.

As visualized in Table 36 and Figure 28, the flexible and risk-averse levees are the more robust options. In other words, these two options protect North Base under a range of SLR scenarios. Given the high cost of the facility flooding, it is more cost effective to install one of these two levee options.

Table 36. Discounted Lifecycle Costs by Alternative, Climate Scenario and Simulation Percentile (1.5% Discount Rate)

Scenario	Levee Option Name	80% C.I. Low	Expected Value	80% C.I. High
Median	No_Action	$102,514,000	110,794,000	124,156,000
Median	Standard	$22,631,000	$37,092,000	$52,998,000
Median	Risk-Averse	$32,382,000	$32,382,000	$32,382,000
Median	Flexible	$25,916,000	$25,916,000	$25,916,000
High End Likely Range	No_Action	$169,017,000	179,746,000	192,065,000
High End Likely Range	Standard	$98,538,000	115,571,000	136,910,000
High End Likely Range	Risk-Averse	$32,382,000	$32,382,000	$32,382,000
High End Likely Range	Flexible	$25,916,000	$25,916,000	$36,440,000
1-in-200	No_Action	$384,982,000	394,958,000	409,384,000
1-in-200	Standard	$382,084,000	400,411,000	423,742,000
1-in-200	Risk-Averse	$32,382,000	$32,382,000	$32,382,000
1-in-200	Flexible	$28,420,000	$28,420,000	$43,477,000

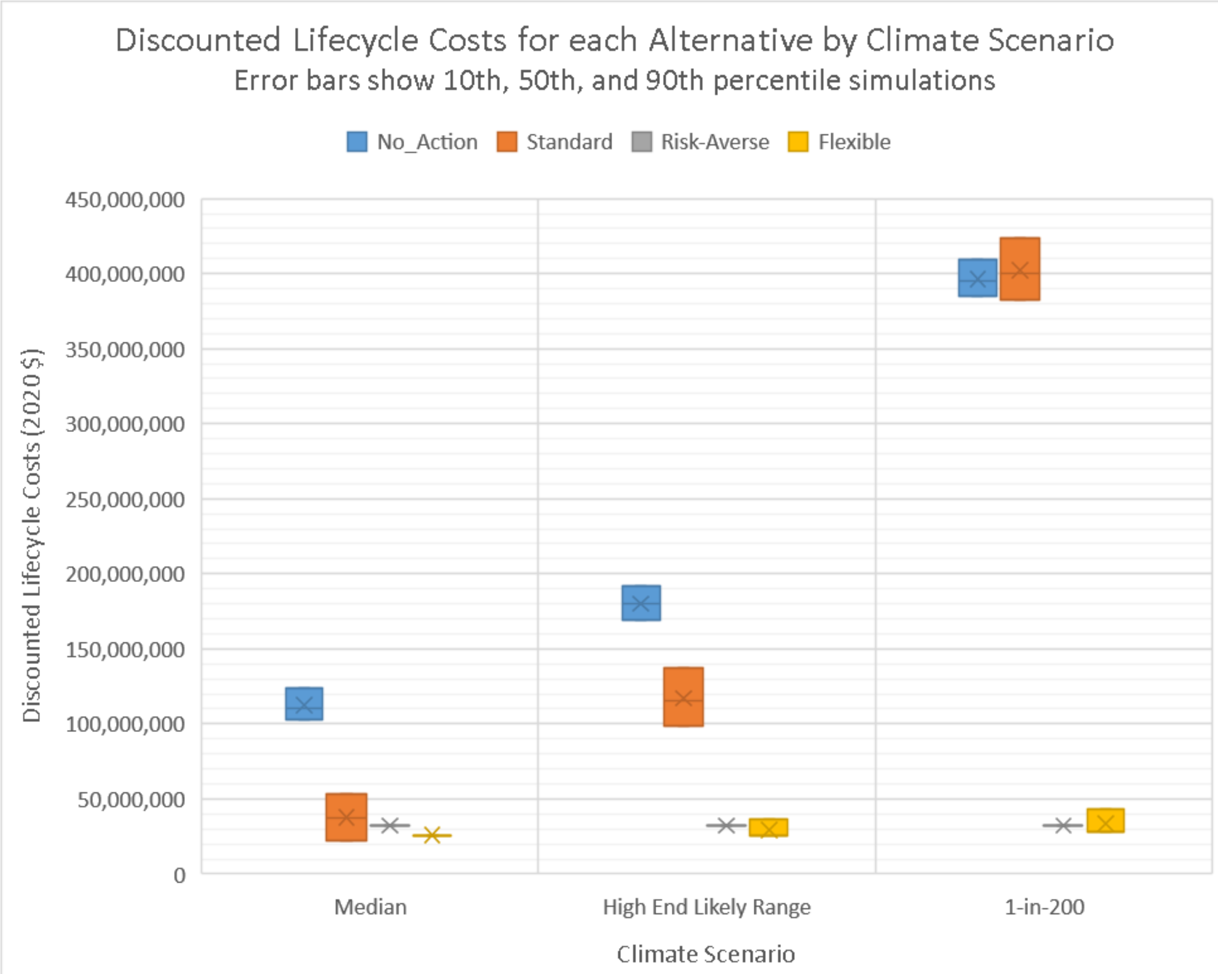


Figure 28. Discounted Lifecycle Costs for each Alternative by Climate Scenario (X's shows expected values)

Table 37 and Figure 29 show lifecycle savings for each alternative compared to the baseline option. All three of the levee options represent a substantial cost savings compared to the no-action alternative under the median and high-end likely range SLR scenarios. The flexible and risk-averse alternatives produce even more cost savings under the 1-in-200 SLR scenario.

Table 37. Cost Savings (Loss) Compared to Baseline (No Action) Alternative

Scenario	Levee Option Name	80% C.I. Low	Expected Value	80% C.I. High
Median	No_Action	$0	$0	$0
Median	Standard	$79,883,000	$73,702,000	$71,158,000
Median	Risk-Averse	$70,132,000	$78,412,000	$91,774,000
Median	Flexible	$76,598,000	$84,878,000	$98,240,000

Scenario	Levee Option Name	80% C.I. Low	Expected Value	80% C.I. High
High End Likely Range	No_Action	$0	$0	$0
High End Likely Range	Standard	$70,479,000	$64,175,000	$55,155,000
High End Likely Range	Risk-Averse	$136,635,000	$147,364,000	$159,683,000
High End Likely Range	Flexible	$143,101,000	$153,830,000	$155,625,000
1-in-200	No_Action	$0	$0	$0
1-in-200	Standard	$2,898,000	($5,453,000)	($14,358,000)
1-in-200	Risk-Averse	$352,600,000	$362,576,000	$377,002,000
1-in-200	Flexible	$356,562,000	$366,538,000	$365,907,000

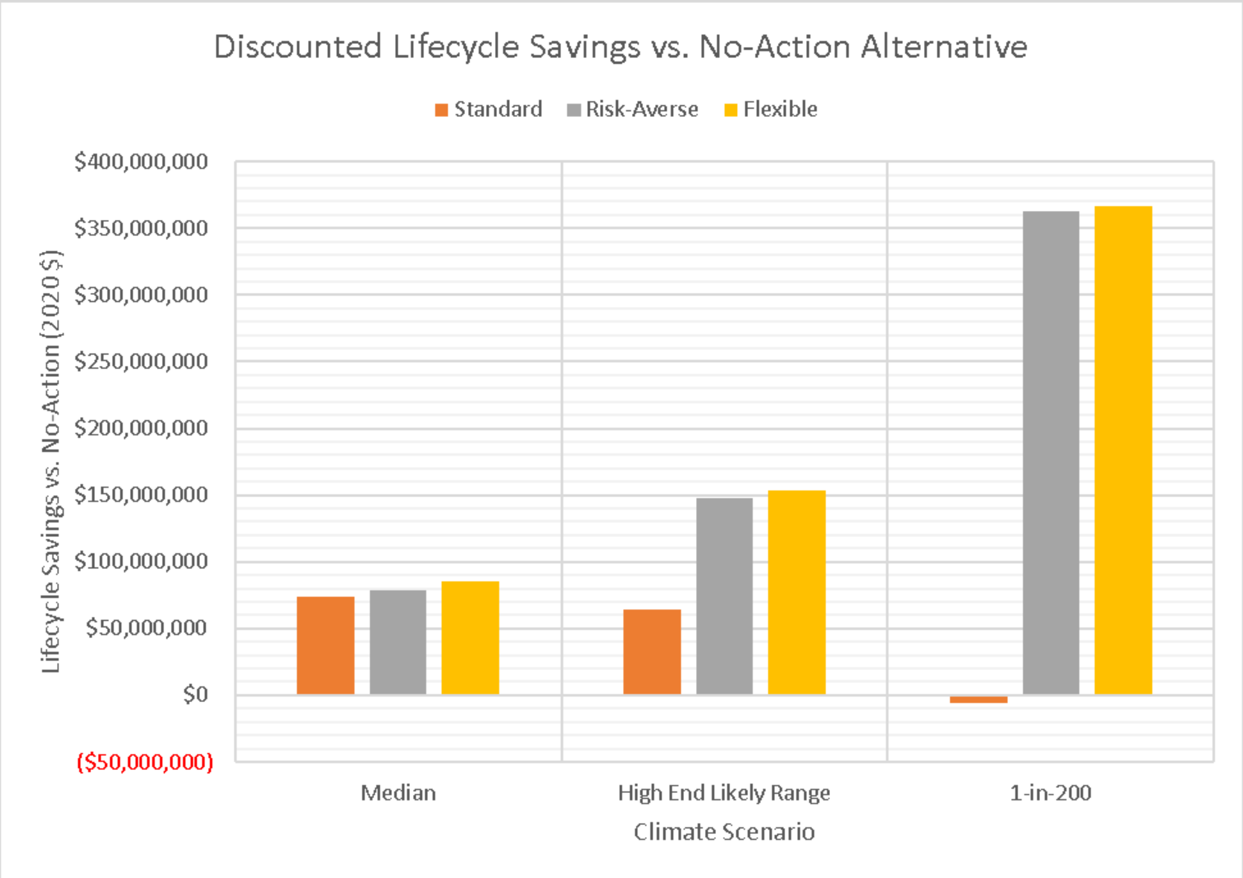


Figure 29. Discounted Lifecycle Savings vs. No-Action Alternative (50th Percentile)

Table 38 shows the benefit cost ratios (BCRs) for the three levee alternatives. For this analysis, an alternative's benefits (numerator) are the hazard-related cost savings (i.e., avoided damage and disruption costs) compared to the no-action alternative. The costs (denominator) are the capital and O&M cost of the alternative. The flexible and standard options have the highest BCR for the median SLR scenario. The flexible option has the highest BCR for the two higher SLR options. The BCRs of the flexible and risk-averse options well exceed one under all three scenarios. The greater the SLR increase, the more cost effective these two options become.

Table 38. Benefit/Cost Ratios. Benefits are the hazard-related cost savings versus the baseline/no-action alternative. Costs are the capital and O&M costs for the alternative.

Scenario	Levee Option Name	80% C.I. Low	Expected Value	80% C.I. High
Median	No_Action	--	--	--
Median	Standard	4.5	4.3	4.1
Median	Risk-Averse	3.2	3.4	3.8
Median	Flexible	4	4.3	4.8

Scenario	Levee Option Name	80% C.I. Low	Expected Value	80% C.I. High
High End Likely Range	No_Action	--	--	--
High End Likely Range	Standard	4.1	3.8	3.4
High End Likely Range	Risk-Averse	5.2	5.6	5.9
High End Likely Range	Flexible	6.5	6.9	7
1-in-200	No_Action	--	--	--
1-in-200	Standard	1.1	0.8	0.4
1-in-200	Risk-Averse	11.9	12.2	12.6
1-in-200	Flexible	13.5	13.9	13.9

Table 39 shows the regret for each of the nine combinations of SLR scenario and percentile. Each of these has a dark outline around it. An alternative's regret is the difference between its cost under a particular scenario-percentile and the lowest cost alternative for that same scenario-percentile combination. The flexible levee alternative has no regret for six of the nine combinations, and the risk-averse levee has no regret for two of the nine combinations. The standard levee has no regret for one of the nine combinations.

Table 39. Regret: Cost difference between each option and the lowest cost option for that scenario-percentile combination

Scenario	Levee Option Name	80% C.I. Low	Expected Value	80% C.I. High
Median	No_Action	$79,883,000	$84,878,000	$98,240,000
Median	Standard	$-	$11,176,000	$27,082,000
Median	Risk-Averse	$9,751,000	$6,466,000	$6,466,000
Median	Flexible	$3,285,000	$-	$-
High End Likely Range	No_Action	$143,101,000	$153,830,000	$159,683,000
High End Likely Range	Standard	$72,622,000	$89,655,000	$104,528,000
High End Likely Range	Risk-Averse	$6,466,000	$6,466,000	$-

Scenario	Levee Option Name	80% C.I. Low	Expected Value	80% C.I. High
High End Likely Range	Flexible	$-	$-	$4,058,000
1-in-200	No_Action	$356,562,000	$366,538,000	$377,002,000
1-in-200	Standard	$353,664,000	$371,991,000	$391,360,000
1-in-200	Risk-Averse	$3,962,000	$3,962,000	$-
1-in-200	Flexible	$-	$-	$11,095,000

Table 40 shows the maximum regret for each alternative across all nine of the scenario-percentile combinations shown in Table 24. A common strategy is to select an alternative that minimizes the maximum regret. The risk-averse alternative has the lowest maximum regret, followed by the flexible option.

Table 40. Maximum Regret by Alternative

Levee Option Name	Maximum Regret
No-Action	$377,002,000
Standard	$391,360,000
Risk-Averse	$9,751,000
Flexible	$11,095,000

Figure 30 shows the results of the discount rate sensitivity analysis across alternatives and SLR scenarios. With a relatively low discount rate, there is little difference between spending $1 today and spending $1 later in the analysis period. Thus, hazard-related costs receive relatively high weight in the analysis, since hazard costs are worse later in the period. With a relatively high discount rate, there is greater difference between spending $1 today and spending $1 later in the analysis period. Thus, hazard-related costs are weighted lower in the analysis compared to initial capital costs.

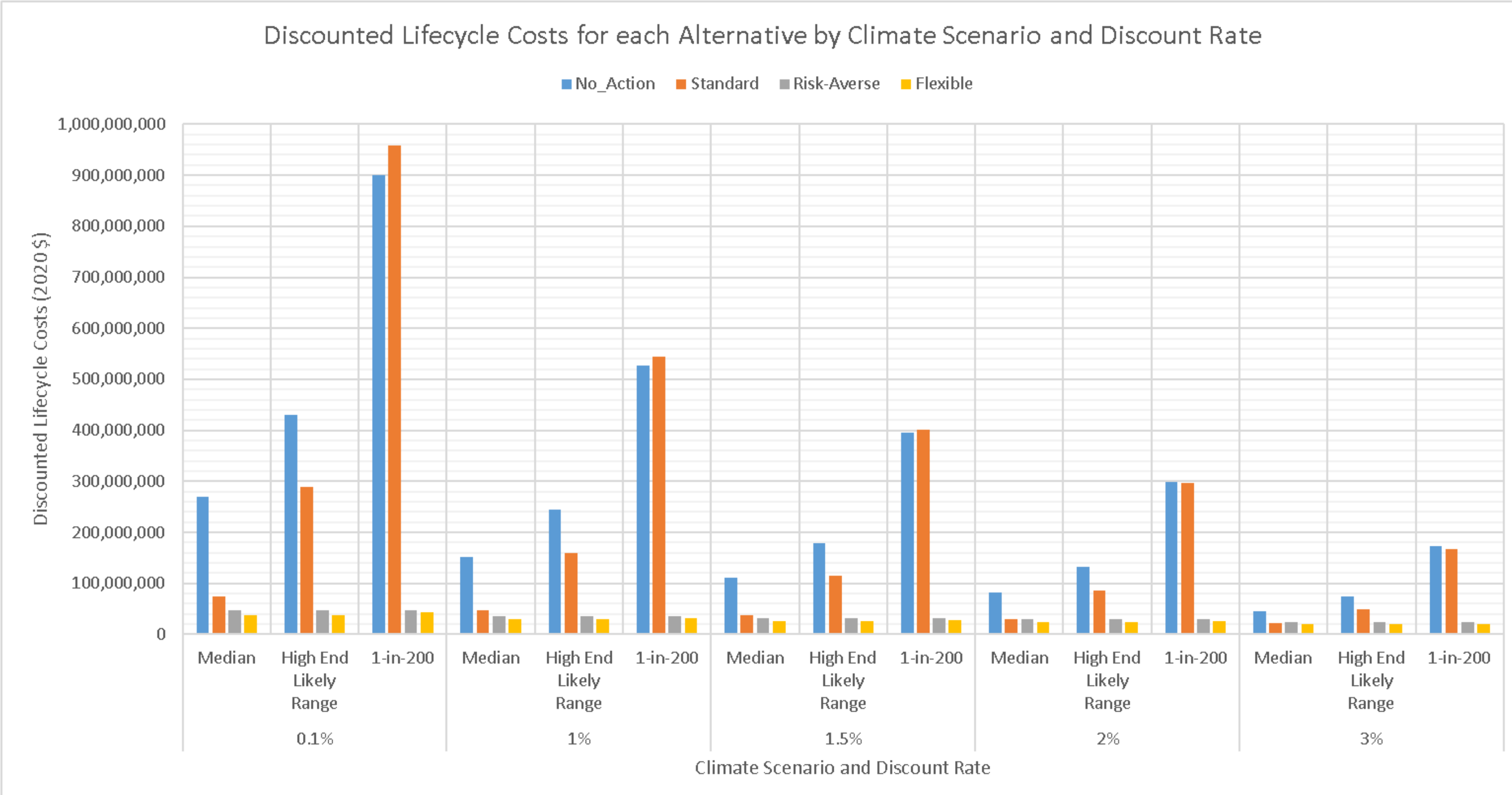


Figure 30. Discounted Lifecycle Costs for each Alternative by Climate Scenario and Discount Rate (50th Percentile)

APPENDIX C SUMMARY OF NEXT STEPS FOR RETAINED ACTION ALTERNATIVES

As noted in Section 2.2, five action alternatives were retained for North Base for further consideration as part of this study (#1, 3, 4, 5 and 8). Alternative 3 involves reconstructing/rehabilitating North Base buildings 100 and 200, which are experiencing differential settlement. Both buildings are scheduled to be reconstructed/rehabilitated and are not discussed in this section. Six action alternatives were retained for South Base (#1, 3, 4, 5, 6 and 9). This section summarizes the steps that SamTrans would need to take, at a high-level, to advance each alternative and which actions could be taken in the near versus long term. Additional details and cost information are provided where available.

C.1 NORTH BASE SLR ACTION ALTERNATIVES

Each of the North Base action alternatives represent long-term strategies to protect the base and its facilities from flood damages and disruptions. These are all alternatives that SamTrans has control over and can lead on its own, though stakeholder engagement is necessary in some cases. The North Base levee action alternative (#1) has been reviewed thoroughly as part of the LBCA conducted for this assessment, and two different levee types present reasonable investments for SamTrans that could save on costs over time. Action alternatives #4, 5 and 8 were evaluated at a high level. Each action alternative includes a description and discussion of known permits/approvals, implementation steps and costs. The list of permits/approvals is not comprehensive, and the implementation of each action alternative depends on specific site conditions, designs and products used. Recommended next steps for implementation are only provided at a high level.

Action Alternative 1. Construct a horizontal levee around the perimeter of North Base.

Description

The proposed levee system would consist of a horizontal levee with an ecotone transition zone along the east side of the base and a levee with a rock slope protection revetment along the west side of North Base. The ecotone transition zone to be used on the east side includes a very gradual slope that extends from the rim of the island approximately 200 to 300 feet out the tidal zones for wave dampening. The ecotone fill in the transition zone will serve as a sacrificial buffer for flood protection and would be vegetated and provide a buffer from oncoming storm surge. The transition zone would be backed by a more traditional earth levee which would wrap around the entire perimeter of the island. The two distinct sections are needed due to spatial constraints on the west side of the island, where a transition zone would effectively block the strait through which Colma Creek and the San Bruno Channel drain. The crown of the levee to extend around the perimeter of the island would be approximately at an elevation of 13.3 feet NAVD 88 to protect against a 100-year flood event and SLR. The crown would have a minimum width of 20 feet. The San Francisco Bay Trail would be restored and placed on the crown of the levee to allow for space and for added aesthetics. The levee system will need to tie into the San Francisco International Airport's proposed levee to be effective.

The specific levee options evaluated for North Base in the LBCA represent a loss compared to the no-action alternative under the median SLR scenario. However, the flexible and risk-averse alternatives produce cost savings under the higher magnitude SLR scenarios.

Costs

The upfront installation costs for these levee options are provided in Table 41 below. These costs could be shared by other regional stakeholders who may benefit from the levee.

Table 41: North Base Levee Installation Costs

Levee Option	Installation Cost	Crest Elevation (feet NAVD88)
Standard Levee	$8.1 million	13.3
Flexible Levee once stage 1 and stage 2 constructed	$13.2 million	19.0
Flexible Levee Stage 1	*$9.2 million*	*15.9*
Flexible Levee Stage 2	*$4.0 million*	*19.0*
Risk-Averse Levee	$11.5 million	19.0

Known Permits/Approvals

Levee design and construction would be a major effort for SamTrans and will require extensive internal and external coordination. The levee would require compliance with both the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) regulations. SamTrans will need to secure permits with the US Army Corps of Engineers, the California Coastal Commission and San Francisco Bay Conservation and Development Commission (BCDC). As part of the NEPA process, consultation would be required with the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) under Section 7 of the federal Endangered Species Act (ESA) and the Magnuson-Stevens Fishery Conservation and Management Act. As discussed in the HDR report (2019) a full Environmental Impact Report (EIR)/Environmental Impact Statement (EIS) would likely be required due to the quantities of materials that would be required for revetment, habitat upgrades and replacement of outfalls. Additional detail on the anticipated permitting requirements are included in the separate HDR report (2019).

Before initiating the stakeholder engagement process and high-level next steps listed above, SamTrans will need to convene an internal working group to drive the North Base horizontal levee process.

Implementation

Next steps for SamTrans to install a horizontal levee around North Base are, generally:

- Coordinate with regional stakeholders and evaluate preferable regional approach
- Identify funding sources
- Initiate planning study and CEQA/NEPA evaluation
- Preliminary engineering design and permitting
    - Landowner coordination and easement acquisition
    - Collection and analysis of additional detailed data
    - O&M plan development
- Final design
- Construction

Action Alternatives 4 and 5. Floodproof planned new construction by elevating all utilities and designing the ground level to accommodate floodwater. Elevate new building electrical and HVAC systems, moving relevant equipment to roof, adding elevated platforms to house equipment at ground level, or raising the elevation of the ground where the equipment rests.

Description

Floodproofing new buildings and structures, also known as dry floodproofing, is the practice of elevating critical infrastructure above flood elevation levels and designing the exterior envelope of the building or structure to be watertight below the base flood elevation. This strategy is focused on keeping critical infrastructure like utilities out of harm's way and ensuring that any structures that may be touched by floodwaters are watertight and impermeable. Types of dry floodproofing strategies include:

- Sealants, coatings and membranes
- Installation of watertight closures for doors and windows
- Installation of flood barriers or shields around the structure

- Reinforcement of walls to withstand floodwater and floating debris
- Anchoring of the building to resist flotation, collapse and lateral movement
- Installation of pumps to control interior water levels
- Installation of check valves to prevent the entrance of floodwater or sewage flows through utilities
- Location of electrical, mechanical, utility and other valuable damageable equipment and contents above the expected flood level

Costs

Costs depend on the type of measure and flood depth. Architects and engineers working on building or structure design will evaluate the specific conditions and estimate costs. According to the FEMA's Selecting Appropriate Mitigation Measures for Floodprone Structures, Chapter 7, "costs for dry floodproofing a structure will depend on the following factors: the size of the structure, the height of the Flood Protection Elevation (FPE), types of sealant and shield materials used, number of plumbing lines …, and number of openings…" Table 27 provides general estimates of unit costs for dry floodproofing projects as compiled in the US Army Corps of Engineers' publication *Flood Proofing – How to Evaluate Your Options* (2002) referenced in FEMA's Selecting Appropriate Mitigation Measures for Floodprone Structures document (2013). While this publication is dated, it provides a rough estimation of costs.

Table 42. Example Dry Floodproofing Costs

Dry Floodproofing Strategy	Unit Cost Estimate
Waterproofing a concrete block or brick-faced wall by applying a polyethylene sheet or other impervious material and covering with a facing material (e.g. brick)	$3.50/square foot
Acrylic latex wall coating	$3.00/square foot
Caulking/sealant (high performance electrometric "urethane" sealant is recommended)	$2.50/linear foot
Bentonite grout (below grade waterproofing, 6 feet deep)	$20/linear foot

Other costs to account for include fees associated with building codes, annual maintenance expenses, cost of professional and specialized dry floodproofing designs, contractor profit and contingency.

Known Permits/Approvals

Applying dry floodproofing in a new design and build requires a FEMA certification: the Floodproofing Certificate for Non-Residential Structures (FEMA Form 81-65).

Implementation

Dry floodproofing strategies would need to comport with SamTrans' operational requirements. Dry floodproofing should be implemented during a building's design and construction to seal and strengthen the structure, though some dry floodproofing strategies (e.g. pumps) can be installed in existing structures. See FEMA document 551, Chapter 7 and FEMA document: Floodproofing Non-Residential Buildings FEMA P-936 / July 2013 for more information on dry floodproofing.[26]

Action Alternative 8. Locate some BEB charging stations offsite.

Description

Given known flood vulnerability on the site, SamTrans could locate one or more BEB charging stations offsite in a safer location.

Costs

Approximately $500,000 to purchase and install an en route charger. This assumes that SamTrans or Caltrain own the land needed. Costs can potentially be reduced if SamTrans works cooperatively with other agencies to share strategically placed en route charger facilities.

Known Permits/Approvals

The California Governor's Office of Business and Economic Development Electric Vehicle Charging Station Permitting Guidebook (2019) provides more information on how to plan charging station locations, permitting considerations and interconnection with the grid.

Implementation

- Identify study area where installation of an en route charger could be beneficial
- Identify SamTrans or Caltrain property within the study area that could be feasible for locating an en route charger
- Identify additional locations not owned by SamTrans or Caltrain that may be potentially feasible for an en route charger
- Evaluate the feasibility and cost of potential en route charging locations
- Install charger(s) if determined feasible

[26] Action alternative information provided by WSP subject matter experts (structural, maritime engineer).

C.2 SOUTH BASE SLR ACTION ALTERNATIVES

The action alternatives identified for South Base are primarily long-term strategies to protect the base and its facilities from flood impacts. Most of these strategies are under SamTrans control, but #1 and #3 are reliant on outside stakeholders.

While South Base is relatively less vulnerable to flooding than North Base, San Mateo County's data on the Phelps Slough indicate that South Base facility could flood if it overtopped. The risk posed by fluvial flooding needs further analysis to understand South Base's flood vulnerability and determine if the vulnerability will be addressed at a regional level or if SamTrans should consider any nearer term flood mitigation strategies may need to be compiled and explored for South Base.

Each action alternative includes a description and discussion of known permits/approvals, implementation steps and costs. The list of permits/approvals is not comprehensive and the implementation of each action alternative is dependent upon specific site conditions, designs and products used and recommended next steps for implementation are only provided at a high level.

Action Alternative 1. Increase the height along Steinberger Slough #3. Excavate/dredge Phelps Slough. #6. Install check dams, ponds and infiltration systems in upper watershed to reduce surface runoff and flow going into Phelps Slough to reduce freshwater flood depths.

Further study is needed to understand fluvial flood risks to South Base and the region. These action alternatives are outside SamTrans' jurisdiction and will likely need to be led by the County or another regional lead agency. SamTrans should discuss these alternatives with the County. Redwood City owns the levee and would likely lead action alternative 1.

Action Alternative 4. Elevate new building electrical and HVAC systems, moving relevant equipment to roof, adding elevated platforms to house equipment at ground level, or raising the elevation of the ground where the equipment rests.

See discussion under North Base action alternative #4 and #5.

Action Alternative 5. Install and modify pump systems downstream of Phelps Slough.

Description

Pumps can be used in emergencies to quickly remove water and mitigate nearby flood impacts. Pump systems can be temporary or installed permanently depending upon the need. Factors that affect pump system performance and flow rate include the amount and size of debris (e.g., silt, sand, mud, organic matter, etc.) in the water, the distance (and height) that water is pumped, the type and length of pipe or hose used for suction and discharge lines.

Costs

Costs vary depending on type and size. Small pumps can range from $1,000 to $2,000 (portable dewatering pumps with capacities up to several hundred gallons per minute). Large mobile pumps can be in the range of $10,000 to $50,000 (larger skid or trailer mounted mobile systems with capacities of 500 to several thousand gallons per minute).

Known Permits/Approvals

Permanent installation may require permits with the California Coastal Commission and San Francisco BCDC. Potential air quality impacts from onsite generators may trigger related permit requirements.

Implementation

Implementation and setup time vary depending on site conditions, ease of access to flooded areas and placement location for pump, pump size and type and length/size/configuration of discharge lines. For areas with easy access and smaller pump sizes, implementation could take less than an hour. Temporary pump systems such as portable dewatering pumps are less than 250 pounds and can be carried and set up by two people. Mobile pumps are larger (500 to several thousand gallons per minute) and need to be transported via trailer or skid. Submersible pumps are lowered into the flooded area to draw water down and require an external power source. Placement and location of portable generators outside of flood prone areas should be considered for temporary pump systems.[27]

Action Alternative 9. Locate some BEB charging stations offsite

See discussion under North Base action alternative #8

[27] Action alternative information provided by WSP subject matter expert (water resources engineer).

C.3 HIGH HEAT

Twelve high heat action alternatives were retained for further consideration as part of this study. Table 43 summarizes the steps that SamTrans would need to take to further study or advance each alternative along with estimated costs where known. It is expected that SamTrans may elect to advance some of these alternatives in the near-term, delay others until a later time and ultimately not pursue some of the action alternatives due to staff time, financial or other limitations. Due to the relatively modest heat risk posed to its capital assets, the majority of the retained action alternatives focus on reducing impacts to SamTrans' passengers.

Table 43. Heat Action Alternatives Next Steps and Cost Summary

ACTION ALTERNATIVE NEXT STEPS	ESTIMATED COSTS
Facilities	
Increase natural ventilation and passive cooling by changes in operation of operable doors/windows • Determine which doors/windows should be opened to provide passive cooling during high temperatures • Assign responsibility to implement as needed	None
Update SamTrans facility design standards to recommend consideration of heat vulnerability in design • Update design standards to prompt user to consider if increasing temperatures should be factored into design • For example, the Boston Planning and Development Agency (2017) developed a climate resiliency checklist that requires applicants to specify: ○ High heat design conditions ○ Efforts to reduce heat-island effect at the site and adaptation strategies for the building and its systems to manage future higher average temperatures, higher extreme temperatures, additional heatwaves and longer heatwaves ○ A description of all mechanical and non-mechanical strategies that will support building functionality and use during extended interruptions of utility services and infrastructure including proposed and future adaptations	None aside from minimal staff time to develop the checklist
Passengers	
Install additional bus shelters (SamTrans-owned, Ad or other) • Define criteria for new shelter placement • Determine if SamTrans will re-issue the Ad shelter contract and under what terms	Up to $45,000 each to purchase and install (if not covered by ad contract) $1,000 each for annual maintenance (maintenance is not included in the current ad contract)
Install additional benches • Determine criteria for new bench placement and style of benches to be used	$210 – $800 purchase cost per bench and $500 to install
Design and install custom shelter • Assemble design team • Define criteria and amenities • Seek quotes • Establish schedule and budget	Up to $40,000 estimate per custom shelter depending on design and number of units purchased

ACTION ALTERNATIVE NEXT STEPS	ESTIMATED COSTS
Use ad revenue for bus shelter improvements • Can be evaluated in conjunction with the bus shelter design contract action alternative • Would need to evaluate how ad revenues are currently used and implications of redirecting funds • A new policy may need to be developed to guide the use of ad shelter revenues if this action alternative is pursued	None, but will need to evaluate the potential impact of redirecting ad revenue
Provide free/discount fare rides to cooling centers on high heat days • Map location of existing and potential cooling centers along existing routes • Determine which cooling centers could be served by existing SamTrans routes • Determine if SamTrans would make any changes to routes to serve cooling centers • Advertise	Potential revenue impact, but limited if no routing changes are made. Could potentially seek grant funding to offset costs.
Provide informational materials on the dangers of heat stress and where/how to access local resources • Identify existing sources of information (e.g., CDC, Health Department) • Secure printed flyers and determine how to procure and distribute to buses • Post information on SamTrans website and social media accounts as needed	Limited to costs for printing flyers (or procuring pre-printed flyers) and a few hours of staff time for distribution
Provide informational materials on dangers of poor air quality and where/how to access local resources • Identify existing sources of information (e.g., CDC, Health Department) • Secure printed flyers and determine how to procure and distribute to buses • Post information on SamTrans website and social media accounts as needed	Limited to costs for printing flyers and a few hours of staff time
Train SamTrans bus operators to recognize symptoms of heat-related illness and appropriate actions such as calling 911. • Identify existing sources of information (e.g., CalOSHA [California DIR, 2020]) • Provide training video/brochure to supervisors, operators and other outdoor workers consistent with requirements on worker safety, including recognizing symptoms such as: https://www.dir.ca.gov/dosh/heatillnessinfo.html; https://www2.cstcsafety.com/__media/pdfs/CorVol45No30.pdf • Note: Operators are not expected or required to intervene, but are to be trained to call for help if needed. This is somewhat analogous to some drivers being trained in CPR on a voluntary basis. Safely operating the bus is their primary duty; protecting the safety of passengers is part of that duty, but does not extend to rendering first aid.	Cost of training
Waive "no beverage" policy on high heat days • Define criteria for when water is allowed • Determine enforcement policy/procedures • Advertise policy	Limited to costs for printing flyers and a minimal amount of staff time
Distribute SamTrans branded fans and cooling packs during high heat events.	$2 to $5 each

Many of the retained action alternatives could be implemented at little to no cost. Additional detail is provided below about the more involved action alternatives—issuing new bus shelter design/advertising contracts and designing a custom shelter to meet SamTrans' needs. Each initiative would require coordination with multiple stakeholders and in some cases may not be entirely within the control of SamTrans.

C.3.1 Future Shelter Design/Advertising Contract Considerations

The following guidance and considerations for future shelter design and advertising contracts are based on the SamTrans' heat workshop as well as reviews of the practices in other localities, including the 2019 Alameda County AC Transit Request for Proposal for Transit Shelter Advertising (Alameda-Contra Costa Transit District, 2019).

C.3.1.1 Bus Shelter Vision and Objectives

SamTrans should develop a vision and objectives for the new bus shelter design and placement such as:

- **Vision:** Increase bus ridership by providing visible, comfortable and safe waiting areas for riders. Note that the advertising revenue objective is not addressed in these recommendations, as that is a function of policy, markets and contractual obligations, and is not the focus of this analysis.
- **Objective**: Provide bus shelters throughout the SamTrans service area to provide shade, information and a safe place to wait for the bus on high heat days, while also providing shelter from rain and cold.

SamTrans can implement its vision and objectives by developing a bus stop improvement plan. A bus stop improvement plan can define a process for regular bus shelter amenity improvements based on relevant factors, such as ridership, community vulnerability and escalating climate impacts. It could also be used to update bus stop design standards and existing bus stop guidance to reflect the findings of this study.

C.3.1.2 Design

SamTrans should consider adopting shelter design elements to promote both cooling and warmth as well as long-term maintainability. It may be helpful to develop shelter design guidelines or update SamTrans Bus Stop Guidebook. The design elements/guidelines should be incorporated into any future ad shelter contracts. Examples of existing or proposed heat-related design considerations from other transit agencies include:

- LA Metro is considering requiring louvers on new shelters, but it is not clear what would be the maintenance as well as cooling implications of such a change. LA Metro also designed an umbrella that can be retrofitted onto bus benches (see Figure 31) (Flores, 2019).
- Designs in Las Vegas and Phoenix focus on shade and heat, rather than accommodating both high heat and cold weather.
- A demonstration project in Marana, Arizona designed as part of a design build project with students at The University of Arizona included a horizontal louver system

calibrated to eliminate early morning and late afternoon solar exposure (Portland State University School of Architecture, 2017).

Figure 31. LA Metro Bench Umbrella (left); Marana, Arizona Shelter (right)

Additional design considerations:

- Current bus shelters (as well as benches and bus stops) in the SamTrans service area include shelters provided by different sponsors and bus providers, but vary significantly in appearance and by community. It may be helpful to work towards a common design (which could be "off-the-shelf" or custom) among different stakeholders, with common signage and information features, to improve SamTrans brand recognition, and protect passengers in a comprehensive manner throughout the system. Having a common design would also facilitate more efficient shelter maintenance.
- Some communities have resisted placing bus shelters because the design does not fit with the aesthetic of their community, comport with design guidelines or because shelters become a site for activity requiring law enforcement resources. Such communities may be encouraged to develop their designs that both meet their needs, protect riders and fit the SamTrans bus shelter program in a cohesive manner.

C.3.1.3 Shelter Distribution and Placement

SamTrans could develop shelter distribution and placement guidelines and into a future ad shelter contract. Considerations include:

- Coordinate placement of new bus shelters and possible refurbishment and/or relocation of existing shelters with the cities and residents throughout the service area.
- Develop comprehensive bus stop design guidelines that include minimum requirements, considerations and preferences.
- Where possible orient shelters to provide ideal shading while still providing for safety

and clear driver visibility. For example, east-and west-facing shelters benefit from seating on both sides of a shade element (RPTA/Valley Metro, 2017).

- Consider pilot testing new design(s) in several neighborhoods to vet acceptance, functionality and maintenance prior to issuing contracts and specifications for the full system.
- Incentivize placement of new and moved shelters in areas with limited or no shade, high heat indexes, high ridership, high poverty, low vehicle ownership and/or high percentages of residents with mobility or health issues.

C.3.1.4 Additional Shelter Contract Administration and Shelter Provision Considerations

- The upcoming bus shelter contract represents a key opportunity to update contract terms for shelter design, shelter placement and overall administration. Contract renewal in 2023 provides sufficient time to design and pilot new shelter materials, designs and placement policies, if desired. The last contract was initiated approximately 15 years ago. Key opportunities related to heat:
    - Create requirements (e.g., on shelter placement) regarding heat vulnerability
    - Potentially change shelter design requirements in the contract based on heat and shading
- Some municipalities separate the design, construction and maintenance of shelters from the advertising and revenue elements of shelter contracts, to provide better accountability (along with a somewhat greater administrative burden) (Salt Lake City, 2013).

C.3.2 Custom Shelter Design Considerations

SamTrans could work with a bus shelter manufacturer to design a shelter and/or shade structure that meets their specific criteria, including protection against heat. This could also be an opportunity to incorporate additional features desired by SamTrans' riders. Custom shelters will be more expensive that the standard shelters that SamTrans uses today. The cost difference will vary based on materials, design and quantity ordered. If SamTrans renews the shelter ad contract, some of the cost could be negotiated under the contract.

Figure 32. Example Custom Bus Shelters

APPENDIX D HIGH HEAT FIGURES AND REPRESENTATIVE BUS STOPS

D.1 HEAT VULNERABILITY BY INDICATOR

Figure 33. Percent Elderly Population

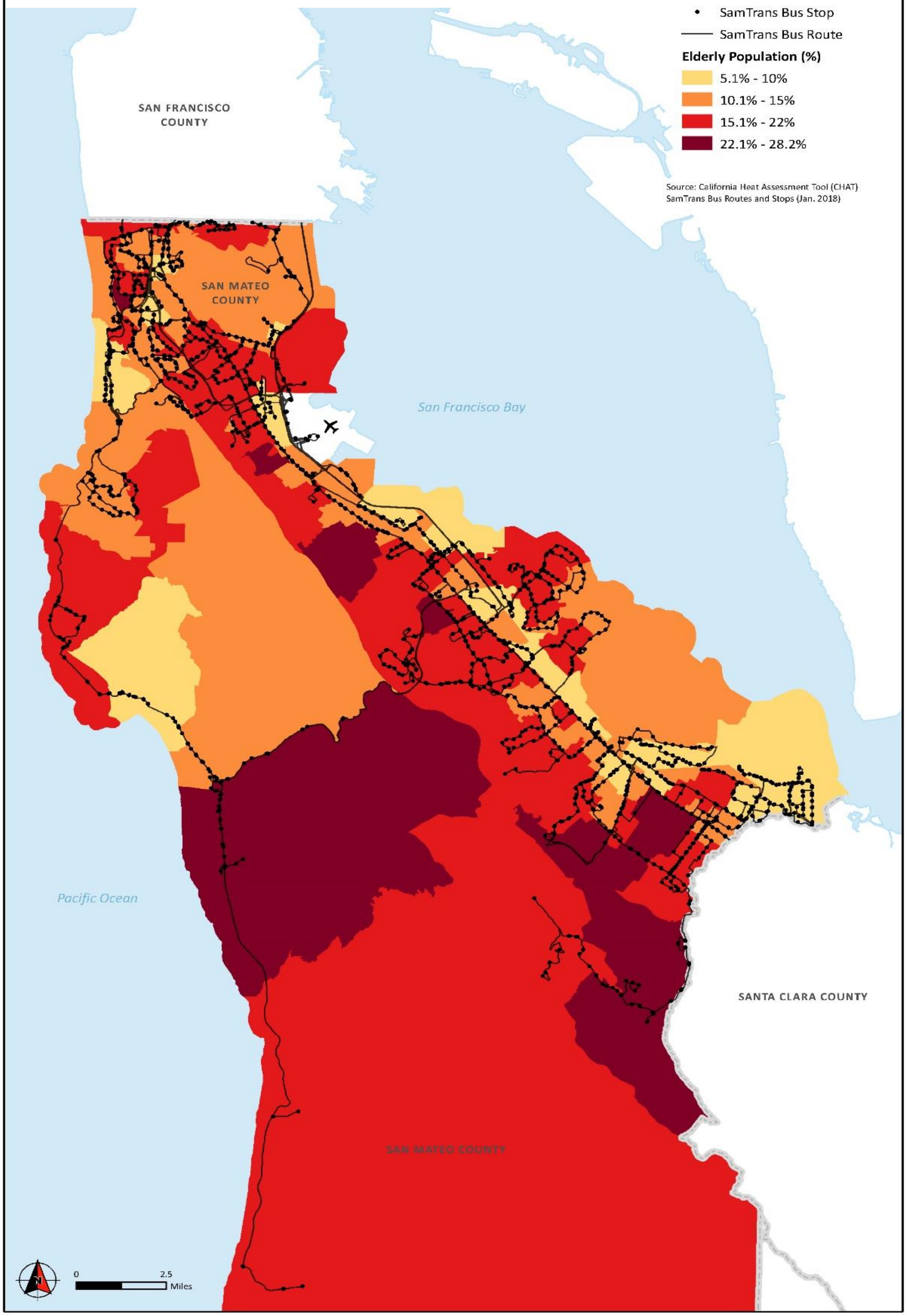


Figure 34. Percent Population with Income Below the Poverty Level

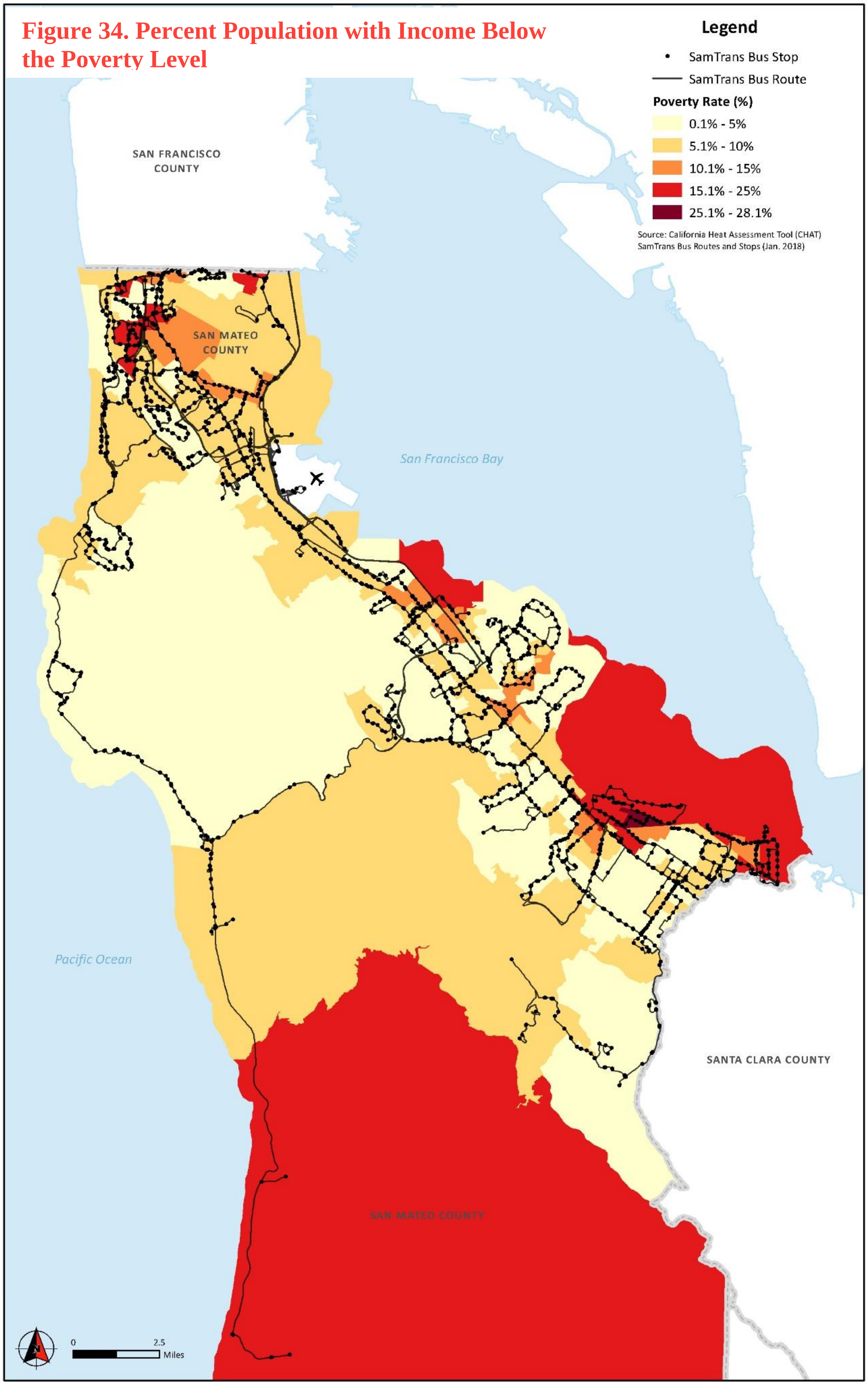


Figure 35. Percent Population with Ambulatory Disability

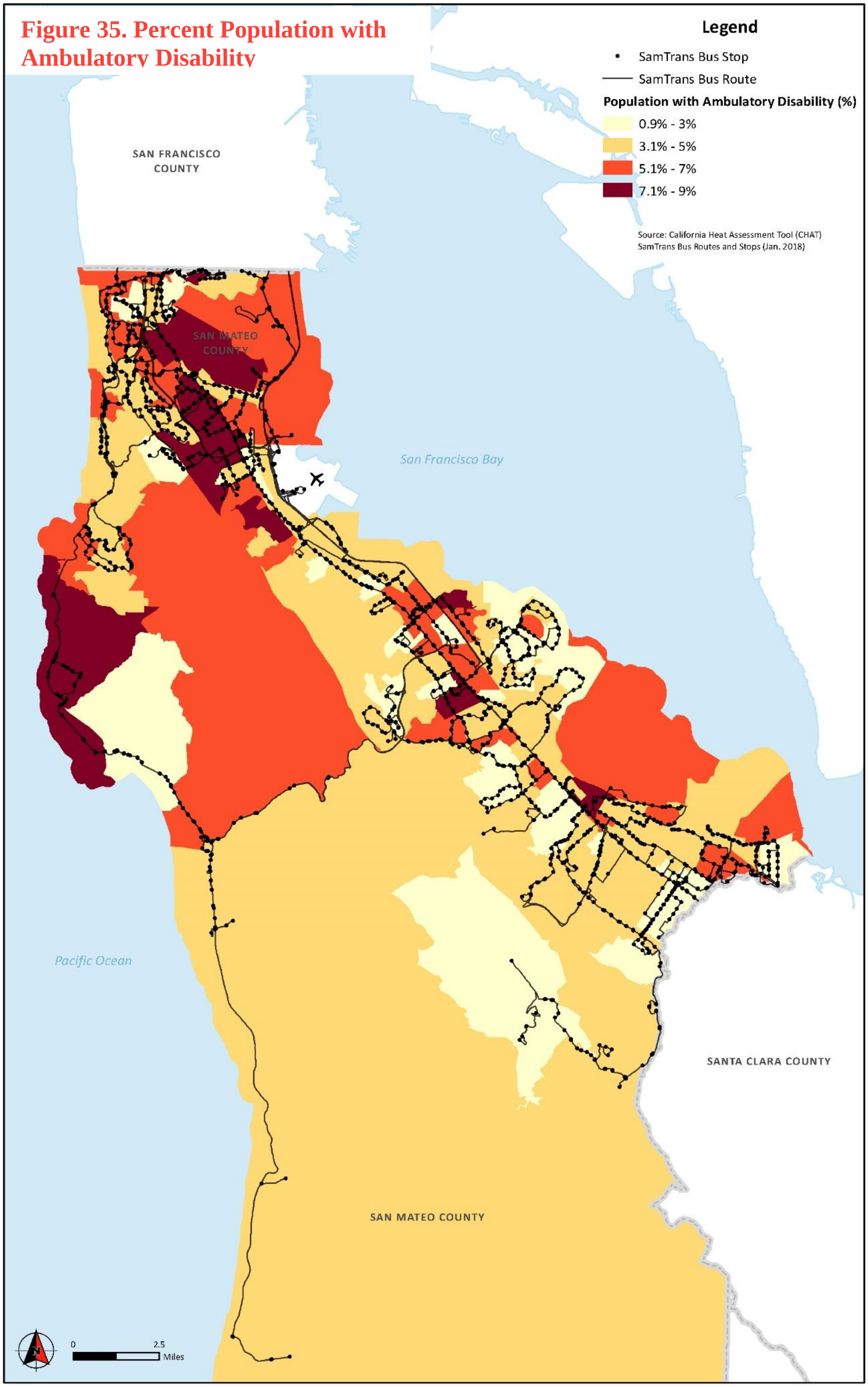


Figure 36. Percent Population with No Vehicle Access

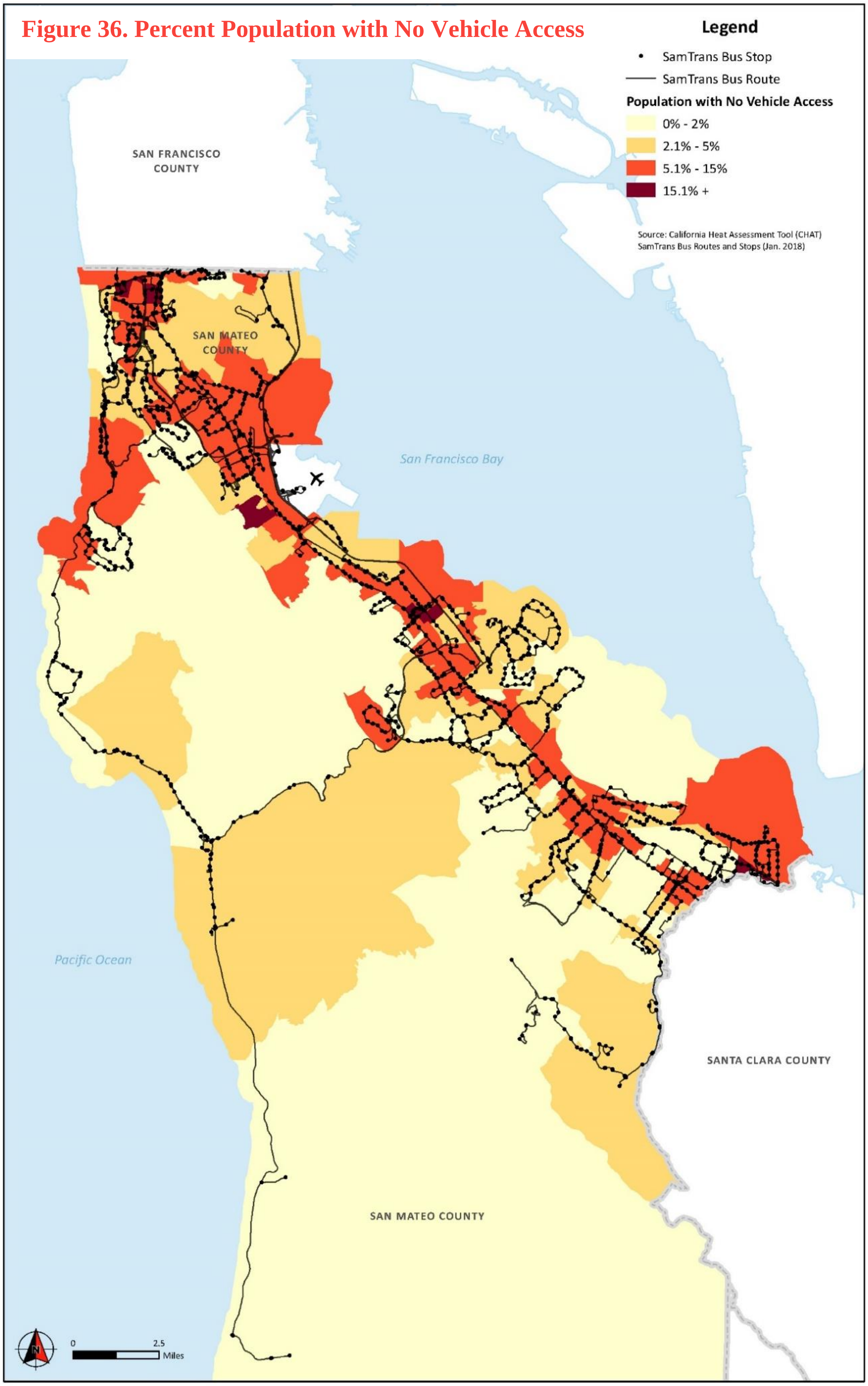


Figure 37. Asthma Emergency Department Visits per 10,000 People

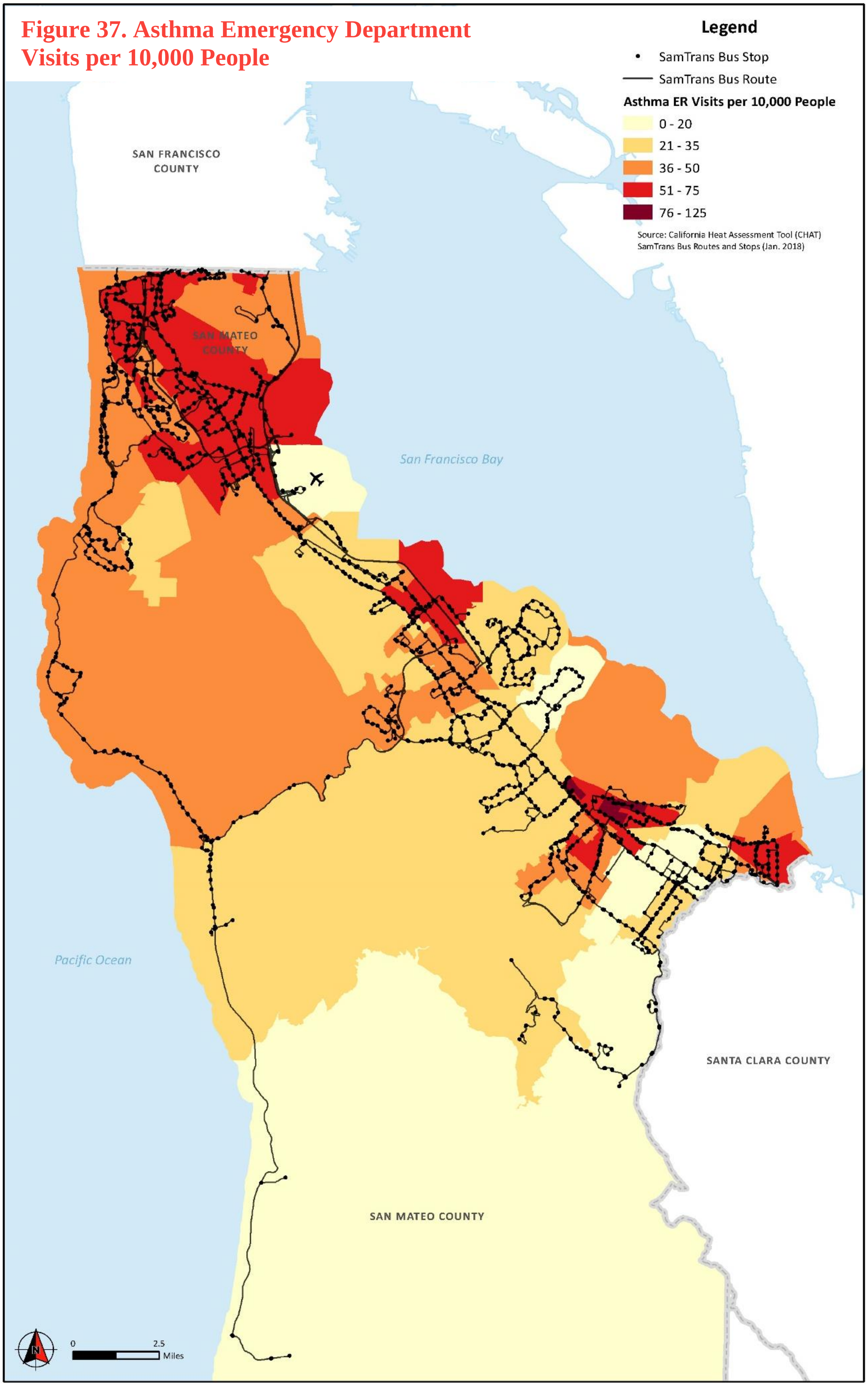
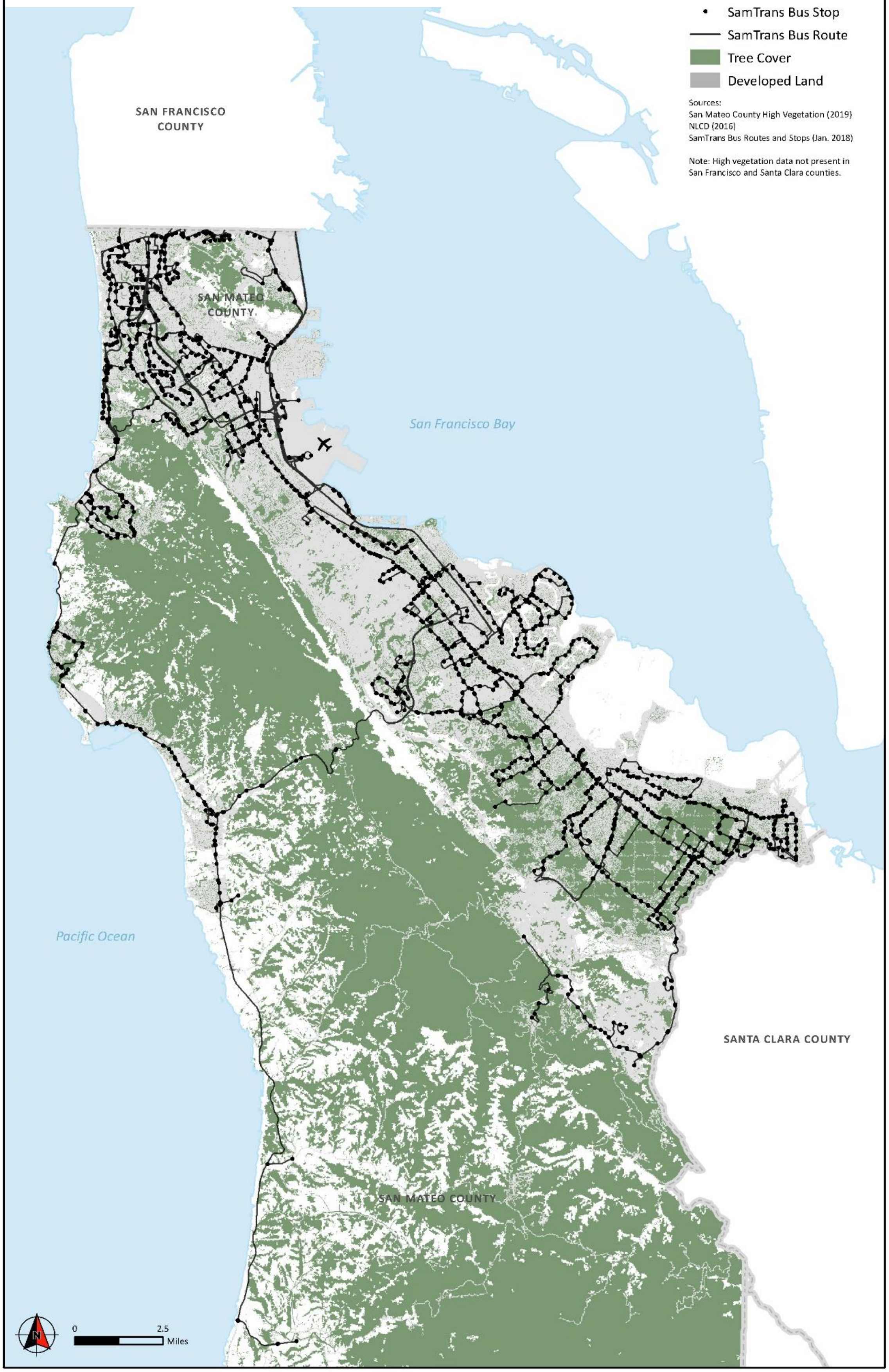


Figure 38. Tree Canopy



D.2 REPRESENTATIVE BUS STOP LOCATIONS

Based on the heat sensitivity index (Figure 23), eight representative bus stops within the SamTrans service territory were identified as examples to evaluate action alternatives for addressing passenger vulnerability to high heat. Attributes of each bus stop are described below.

Bus Stop #	Bus Stop ID and Name	Average Summer Boardings	Composite Vulnerability Score	SB 535	Percent Elderly	Percent No Vehicle Access	Percent Poverty	Percent Ambulatory Disability	Asthma ER Visits Per 10,000	Urban Heat Island Delta	Amenities
1	334008: Airport Blvd & Linden Ave	5,198	2.68	Yes	8.4%	8.5%	10.5%	6.9%	64.6	0.73	Ad shelter and bench
2	334002: Airport Blvd & Baden Ave	4,421	2.85	Yes	16.6%	5.3%	8.3%	5.7%	63.4	1.05	Ad shelter and bench
3	336039: El Camino Real & Silva Ave	2,034	2.51	No	13.2%	7.6%	6.6%	3.4%	39.52	2.59	Bench
4	311191: 1450 Terra Nova Blvd.	573	1.52	No	19.7%	1.9%	4.6%	5.5%	31.80	0.91	No shelters or benches
5	315608: Miramontes Point Rd-Moonridge Apts	1,360	1.45	No	22.1%	3.1%	8.1%	4.4%	33.11	<0.00	No shelters, bench
6	341153: El Camino Real & Hillsdale Blvd	6,757	2.54	No	18.4%	10.6%	8.2%	8.9%	42.65	3.62	Ad shelter and bench
7	344070: El Camino Real & Brewster Ave	1,602	3.12	No	12.1%	14.9%	24.9%	8.1%	71.93	4.61	Ad shelter
8	344090: El Camino Real & Oak Ave	2,979	3.73	No	5.3%	11.7%	22.2%	5.6%	67.49	<0.00	Bench

D.3 TYPICAL BUS SHELTERS

Standard Shelter (54 total), owned by SamTrans

Ad Shelter (137 total), owned by Outfront Media

Other Shelters (18 total, various ownership. Example on right is owned by MTA.)

Three Styles of Benches (229 total, including some co-located with shelters) and Simmee Seats (7 total)

D.4 SELECTED BUS STOP LOCATION DETAILS

This section includes photographs and additional details on ownership and amenities associated with the eight representative bus stops.

Stop #1

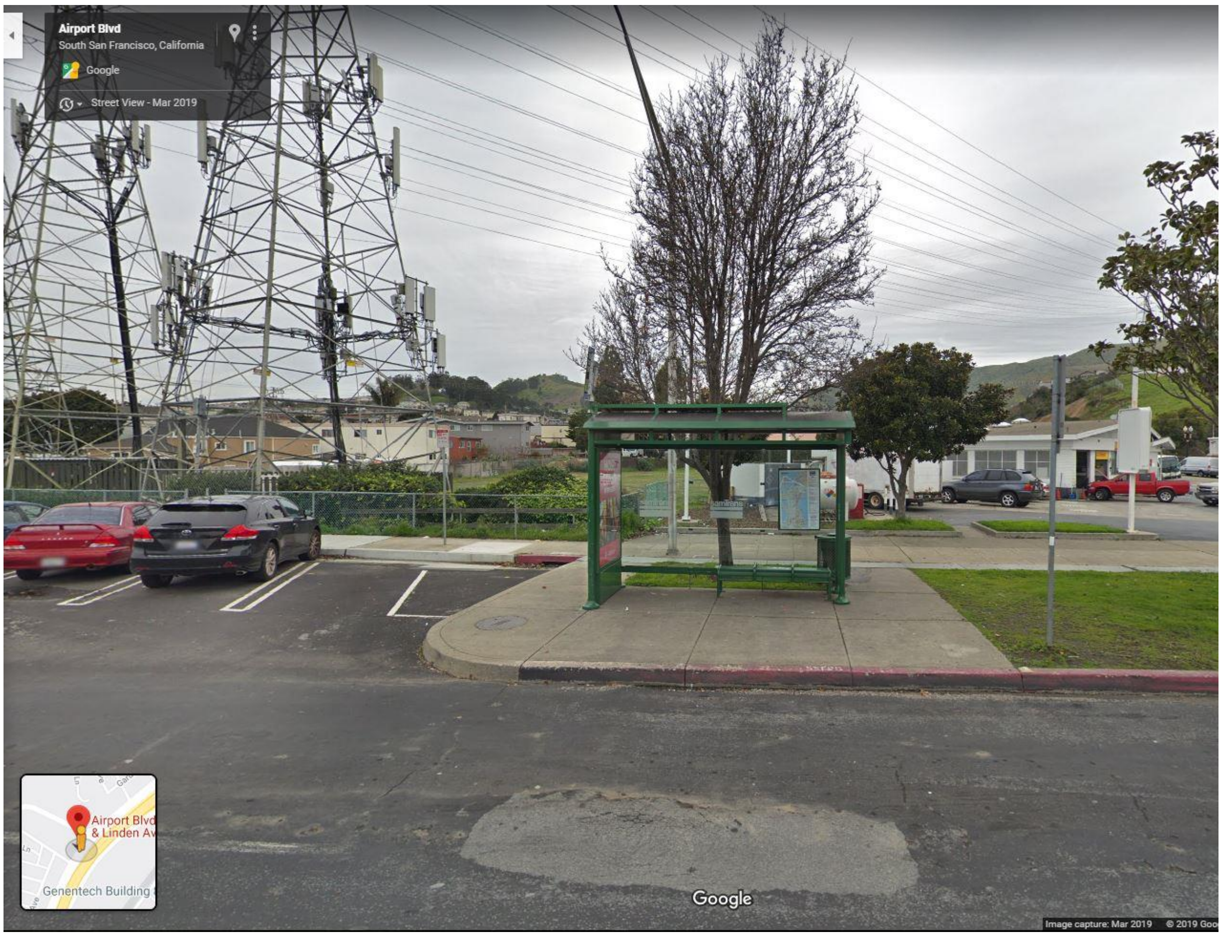
Stop name: Airport Blvd & Linden Ave

Stop ID: 334008

City: South San Francisco

Shelter Owner: Outfront Media

Notes: Highest ridership in SSF, but low geographic diversity. Shade structure and place to sit.



Stop #2

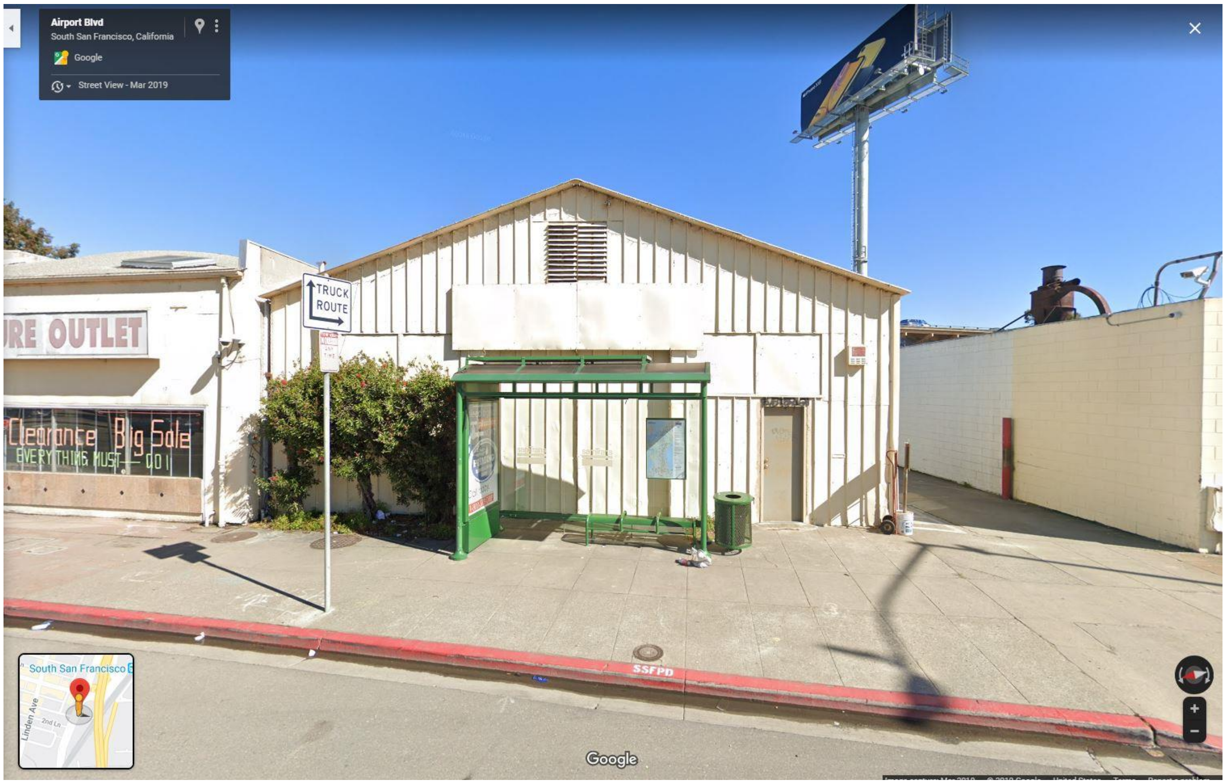
Stop name: Airport Blvd & Baden Ave

Stop ID: 334002

City: South San Francisco

Shelter Owner: Outfront Media

Notes: Highest ridership in SSF, but low geographic diversity. Shade structure and place to sit.



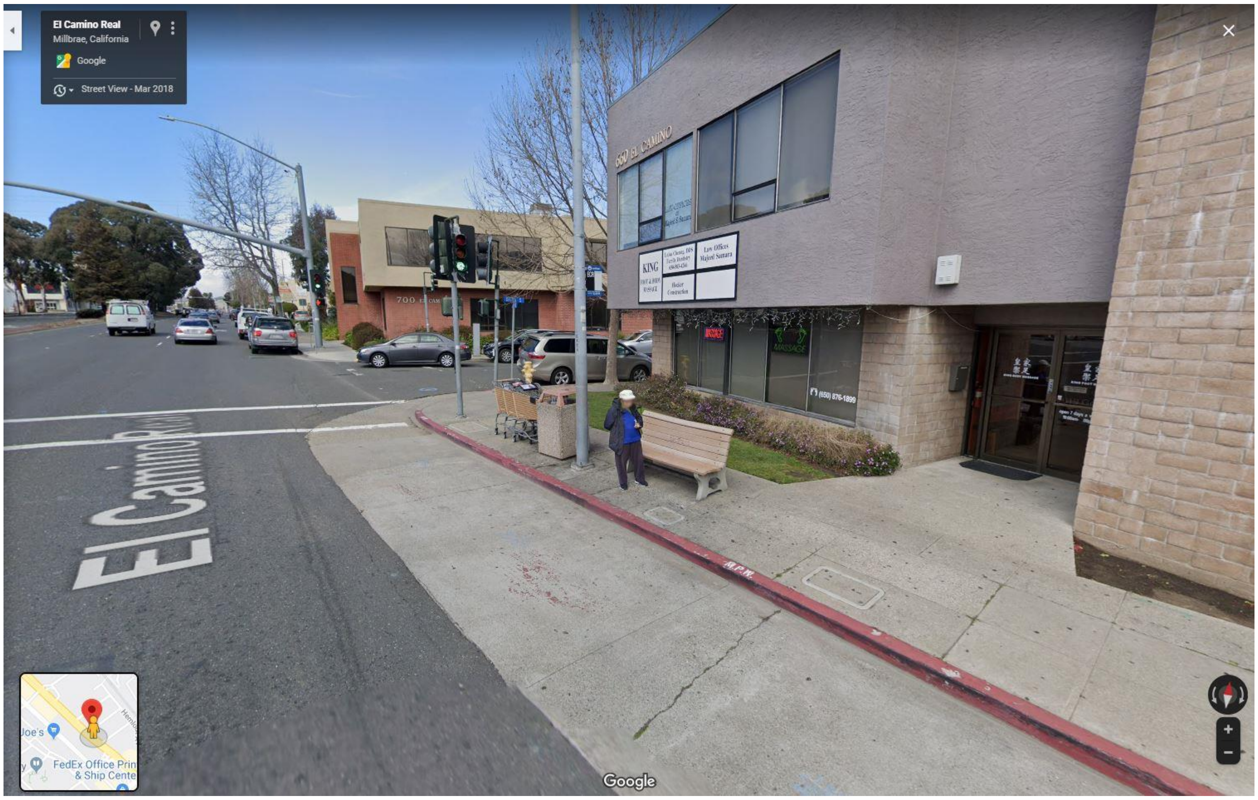
Stop #3

Stop name: El Camino Real & Silva Ave

Stop ID: 336039

City: Millbrae

Notes: Highest ridership for north SM, although not particularly close to tract. No shade structure. Place to sit.



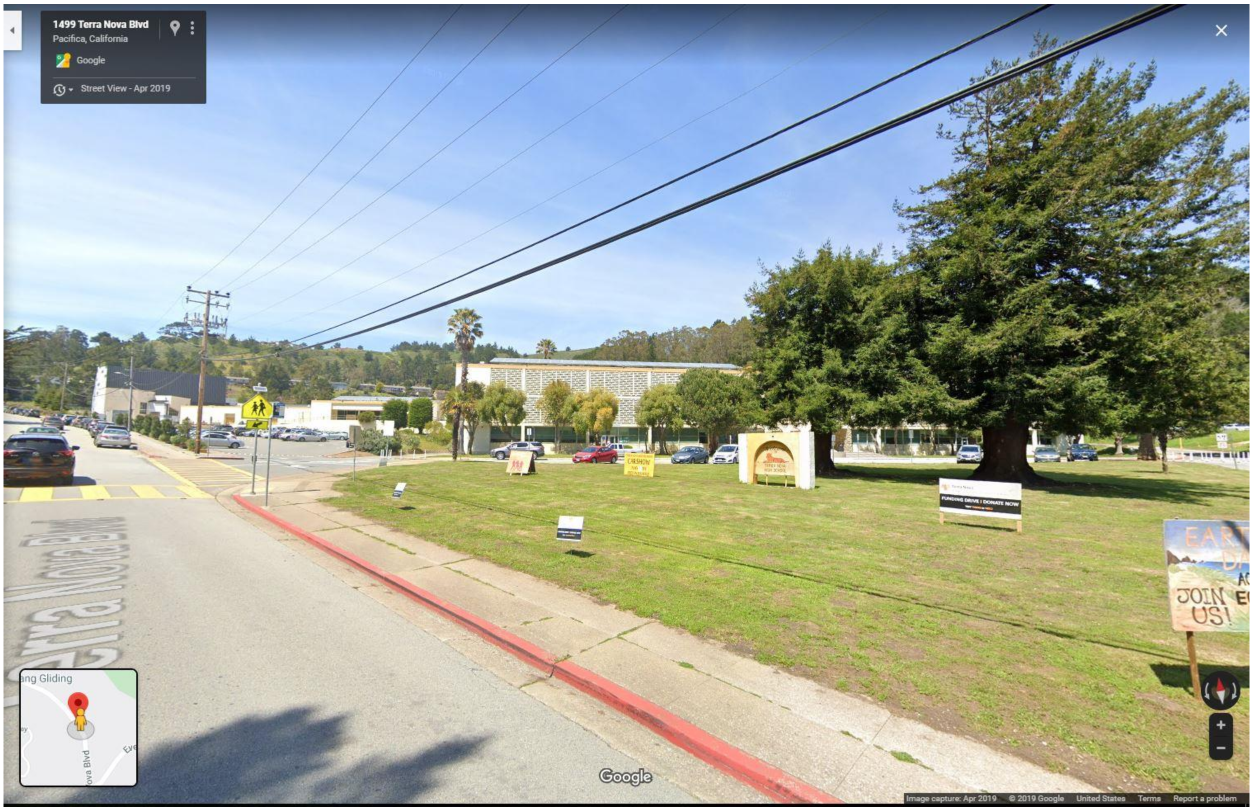
Stop #4

Stop name: 1450 Terra Nova Blvd.

Stop ID: 311191

City: Pacifica

Notes: Stop near school. If riders are high school students, they may be less vulnerable than the general population. No shade structure or place to sit.



Stop #5

Stop name: Miramontes Point Rd-Moonridge Apts

Stop ID: 315608

City: Half Moon Bay

Notes: No shade structure or place to sit. Is in a rural area.

Stop #6

Stop name: El Camino Real & Hillsdale Blvd

Stop ID: 341153

City: San Mateo

Shelter Owner: Outfront Media

Notes: Highest ridership for south SM. Shade structure and place to sit. Right next to mall.

Stop #7

Stop name: El Camino Real & Brewster Ave

Stop ID: 344070

City: Redwood City

Shelter Owner: Outfront Media

Notes: Top ridership for Redwood City, but further away from study areas. Shade structure and place to sit.

Stop #8

Stop name: El Camino Real & Oak Ave

Stop ID: 344090

City: Redwood City

Notes: Top ridership for Redwood City, but further away from study areas. No shade structure. Place to sit.