METROLINK

Climate Vulnerability Assessment and Adaptation Plan

A Roadmap to Implementation

FEBRUARY 2022

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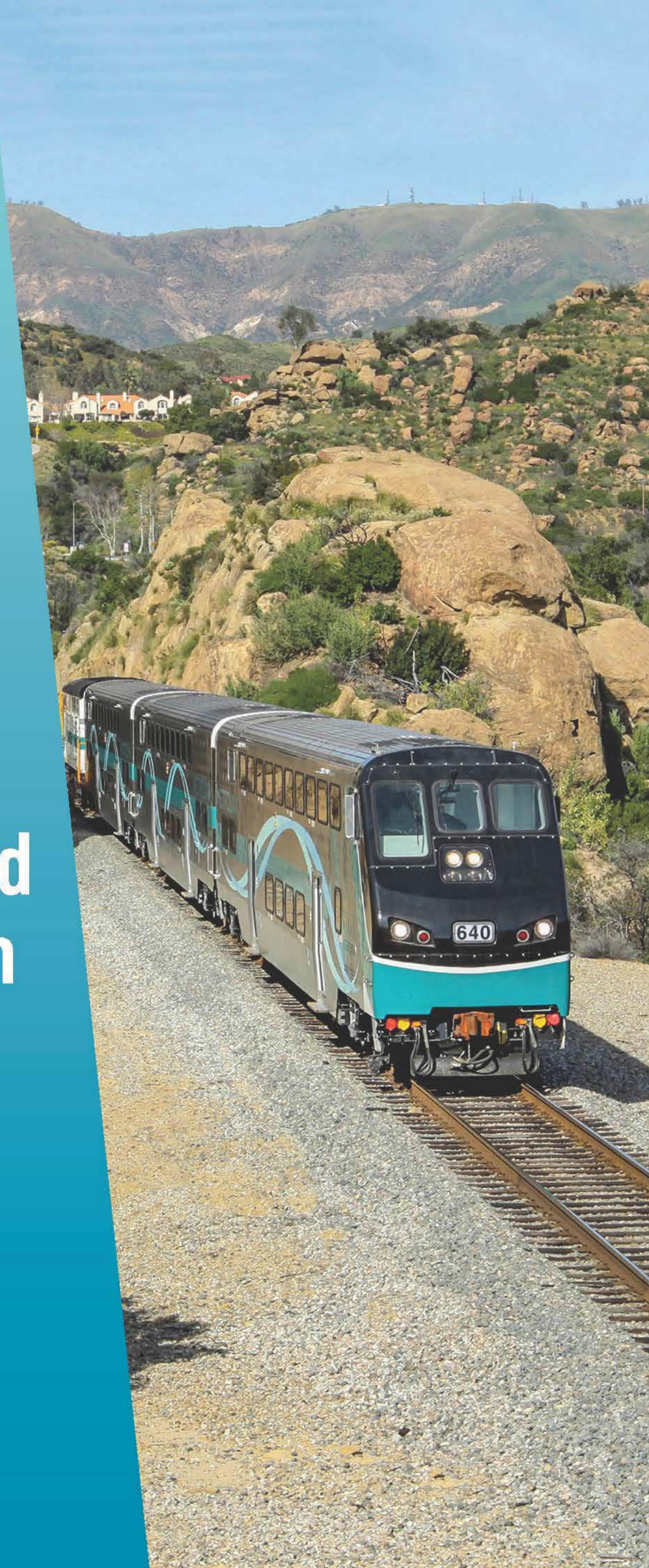
Caltrans SB1 Adaptation Planning Grant



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SCRRA Team:

Joseph McNeely P.E, Principal Engineer – Design and Standards

Lisa Colicchio Director, Special Projects Sustainability Initiatives

David Huang, Planning Manager

Subject Matter Experts that provided guidance and reviews throughout the project

Redman Consulting, LLC (Deborah Hart Redman)

AECOM Team:

Claire Bonham-Carter, Project Manager

Russ Kerwin, Deputy Project Manager

Bettina Kaes, Technical Team Lead

Allan Kapoor, Vulnerability Assessment Lead

Jordan Karp, Emergency Preparedness Planning Lead

Emily Schwimmer, Cost of Inaction/Cost Estimating Lead

Calum Thompson, Subject Matter Specialist, Energy Resilience

Humberto Castro, Subject Matter Specialist, Sustainable Economics

Diana Edwards, Subject Matter Specialist, Climate and Environmental Planning

Alan Boone, AVP, Subject Matter Specialist, Engineering (Rail)

Amir Ehsaei, Subject Matter Specialist, Engineering (Civil)

Todd Dudley, Subject Matter Specialist, Engineering (Bridges & Tunnels)

Christopher Goetz, Subject Matter Specialist, Geology

Phil Mineart, Subject Matter Specialist, Riverine Flooding

Hong Kie Thio, Subject Matter Specialist, Seismic

Justin Vandever, Subject Matter Specialist, Sea Level Rise

As the CEO of Metrolink, I am thrilled that you are taking the time to review our agency's Climate Vulnerability Assessment and Adaptation Plan. When you consider the tremendous natural forces that affect our rail system, this study is critically important.

Throughout our agency's history, we have worked extensively to partner with local, state, and federal jurisdictions to address the realities of the Southern California landscape. As our trains provide outstanding passenger rail service across more than 500 miles of track that span six Southern California counties, our agency faces an ever-changing coastline, canyon mudslides, and flash flooding, along with searing heat that exceeds 120 degrees Fahrenheit.

The goal of this assessment and plan is to better understand the vulnerability of the Metrolink rail system and its other assets while determining how future changes in the climate will affect our core ridership. It is absolutely essential that we understand the issues so that we can prepare for the impending changes on the horizon.

The outputs of this project will be integrated into the Southern California Optimized Rail Expansion (SCORE) Program, a $10 billion capital improvement effort that will enhance track, grade crossings, stations, and signal systems, which will accelerate our progress toward a zero-emissions future. SCORE will also upgrade Metrolink's system in time for the 2028 Olympic and Paralympic Games. In summary, the Climate Vulnerability Assessment and Adaptation Plan will help safeguard investments and take into consideration future climate conditions that will be essential for all project planning, design, and delivery.

We are excited that this assessment and plan falls in line with other Metrolink initiatives including the Transit Asset Management Plan, the Strategic Business Plan, the Fleet Management Plan, and the Climate Action Plan. Each of these efforts will increase our resiliency and safety for all our customers, including our socially vulnerable communities. It is always our goal to provide outstanding customer service while operating the safest railroad in America.

Thank you.

Sincerely,

Darren M. Kettle, CEO, Metrolink

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Acronyms and Abbreviations

°F	degrees Fahrenheit
AB	Assembly Bill
AVL CSI	Antelope Valley Line Capacity and Service Improvement Project
BNSF	BNSF Railway Company
BRIC	Building Resilient Infrastructures and Communities
CAAP	Climate Action and Adaptation Plan
Caltrans	California Department of Transportation
CBO	community-based organization
CCVA	Climate Change Vulnerability Assessment
CDBG-MIT	Community Development Block Grant Mitigation
CH_4	methane
CMF	Central Maintenance Facility
CO_2	carbon dioxide
CoSMoS	Coastal Storm Modeling System
CP	Control Point
CTQI	Combined Track Quality Index
CVA	Climate Vulnerability Assessment
DAC	disadvantaged community
DCM	Design Criteria Manual
DOC	Dispatch and Operations Center
DOT	U.S. Department of Transportation
DWR	California Department of Water Resources
EMF	Eastern Maintenance Facility
EMPG	Emergency Management Performance Grant Program
FEMA	Federal Emergency Management Agency
FTA	Federal Transit Administration’s
GHG	greenhouse gas
GIS	geographic information system
HMCEA	Hazard Mitigation Cost-Effectiveness Analysis
HMGP	Hazard Mitigation Grant Program
HOA	homeowner association
HQ	Metrolink headquarters
HVAC	heating, ventilation, and air conditioning

I-5	Interstate 5
ID	Identification
IPCC	International Panel on Climate Change
ISRF	Infrastructure State Revolving Fund
JPA	Joint Powers Authority
K	thousand
LA	Los Angeles
LA Metro	Los Angeles County Metropolitan Transportation Authority
LARC	Los Angeles Regional Collaborative for Climate Action and Sustainability
LIC	Low-Income Community
M	million
Metrolink	Southern California Regional Rail Authority
MOC	Metrolink Operations Center
MP	Mile Post
MRP	Metrolink Rehabilitation Plan
N_2O	nitrous oxide
O&M	operation and maintenance
OC	Orange County
OCTA	Orange County Transportation Authority
ppm	parts per million
project	Metrolink's study to develop a Climate Vulnerability Assessment and Adaptation Plan
PSPS	public safety power shutoffs
PTC	Positive Train Control
PV	photovoltaics
RAMS	Rail Asset Management System
RASC	Railway Association of Southern California
RCP	representative concentration pathway
RCTC	Riverside County Transportation Commission
ROW	right-of-way
RRIF	Railroad Rehabilitation and Improvement Financing Loan
SB	Senate Bill
SBCTA	San Bernardino County Transportation Authority
SCAG	Southern California Association of Governments
SCE	Southern California Edison
SCORE	Southern California Optimized Rail Expansion
SCRRA	Southern California Regional Rail Authority
SLR	sea level rise

SOC	Security and Operations Center
SSP	socio-economic pathway
STORM	Safeguarding Tomorrow through Ongoing Risk Mitigation
TCS	Trackbed Conditions Summary
TDC	transit-dependent community
TIFIA	Transportation Infrastructure and Innovation Act
UASI	Urban Areas Security Initiative
UCLA	Univeristy of California, Los Angeles
UPRR	Union Pacific Railroad
UPS	uninterruptible power supply
USGS	U.S. Geological Survey

Glossary of Terms

The following definitions have been adapted from those provided in the California Adaptation Planning Guide (Governor's Office of Emergency Services 2020).

Adaptation (climate change): Making changes in response to current or future conditions (such as the increased frequency and intensity of climate-related hazards), usually to reduce harm and to take advantage of new opportunities. Climate change adaptation describes actions that address the projected impacts on all aspects of community function that may result from climate change. This can include impacts related to hazard events (flood, wildfire, drought, or severe storms), as well as slow changes; ecosystem structure and function; and public health.

Climate Change refers to a change in the climate that can be identified by changes in the mean and/or variability of its properties and that persists for an extended period, typically decades or longer.

Climate Hazard (or climate threat): An event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, damage to the environment, interruption of business, or other types of harm or loss.

Disadvantaged Communities (DAC)–Senate Bill (SB) 535: Areas disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, exposure, or environmental degradation, or with concentrations of people that are of low income, high unemployment, low levels of homeownership, high rent burden, sensitive populations, or low levels of educational attainment. DACs are defined in accordance with SB 535, based on CalEnviroScreen 3.0 statewide percentile scores.

Energy Resilience: Ensuring a reliable supply of energy and continued operations in the event of a power failure (during an extreme event) or during a public safety power shutoff (PSPS); for example using microgrids, distributed energy resources, or hardened distribution feeders.

Environmental Justice: The fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies.

Exposure is the presence of people and physical assets in areas that are subject to harm.

Extreme (Climate) Event: An event occurs when a weather or climate variable exceeds the upper or lower thresholds of its observed range.

Low-Income Communities: Assembly Bill (AB) 1550 defines low-income communities as census tracts with median household incomes at or below 80 percent of the statewide median income (per California Air Resources Board).

Nature-Based Solutions: Adaptation strategies that harness natural systems to function, often providing ecological, aesthetic, or social benefits beyond their primary purpose.

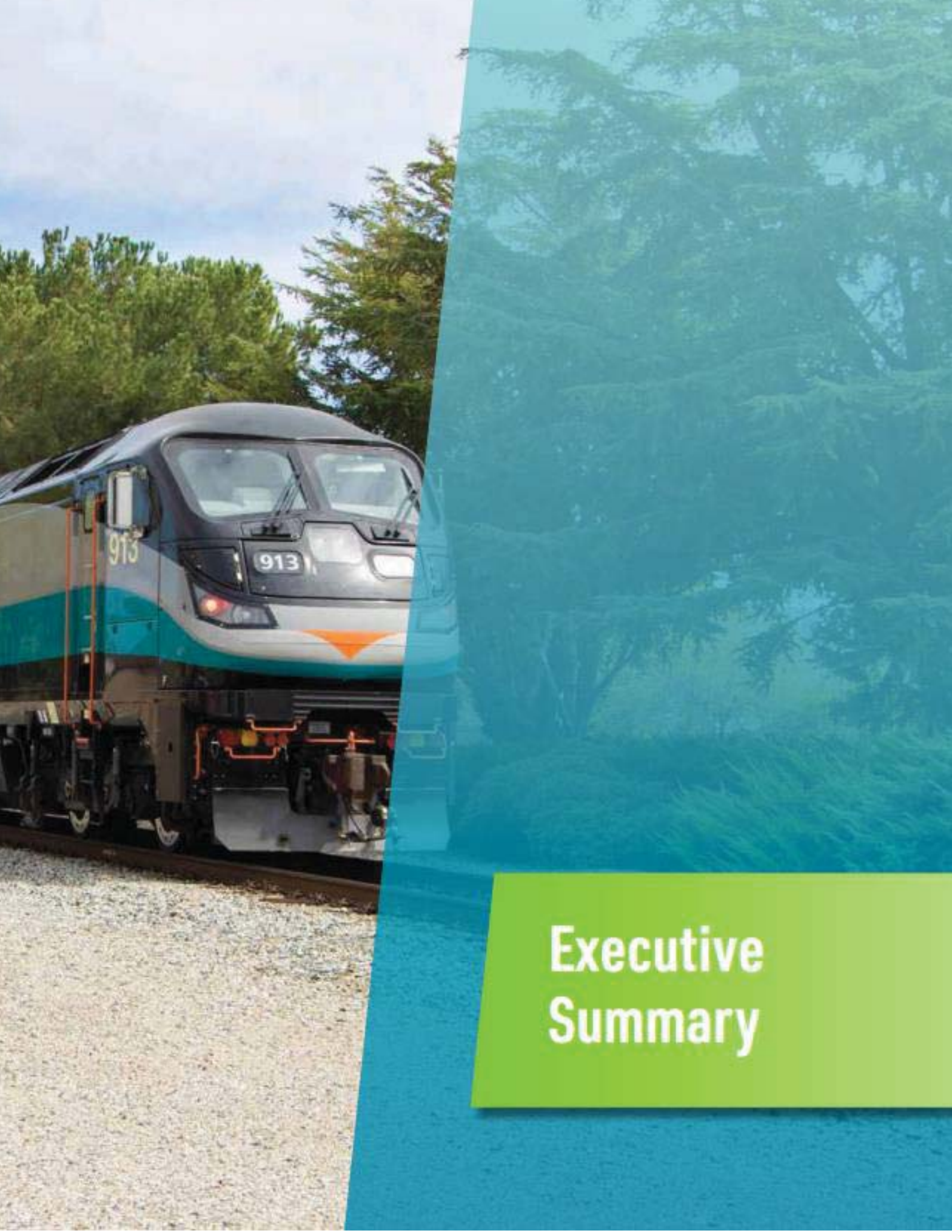
Risk: Risk is the potential for damage or loss created by the interaction of hazards with assets such as buildings, infrastructure, or natural and cultural resources. For natural hazards, risk tends to be calculated based on evaluation of the probability (likelihood) of a hazard event occurring, vulnerability, and the event's potential consequences.

Resilience (climate): The capacity of any entity—an individual, a community, an organization, or a natural system—to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from a disruptive experience. Adaptation actions contribute to increasing resilience.

Sensitivity is the degree to which people and physical assets would be affected by changing climate conditions.

Social Vulnerability: Social vulnerability is the susceptibility of a given population to harm from exposure to a hazard, directly affecting its ability to prepare for, respond to, and recover.

Vulnerability is the exposure of human life and property to damage from natural and human-made hazards. Climate vulnerability describes the degree to which natural, built, and human systems are at risk of exposure to climate change impacts. Vulnerability can increase because of physical (built and environmental), social, political, and/or economic factor(s). For this project vulnerability comprises a combination of exposure and sensitivity.



Executive Summary

Executive Summary

Metrolink is the nation's third-largest passenger rail system based on its 538 total route miles serving six Southern California counties with a cumulative population of 21.5 million people—more than half of California's total population. Approximately 15 million people live within 5 miles of Metrolink's 62 stations throughout Southern California.

Recent events, such as the wildfires that raged through California in the summer and fall of 2020 and 2021 are clear evidence of the climate-related threats faced by jurisdictions, businesses, and residents. Metrolink has long been prepared to handle periodic flooding, wildfires, and go-slow heat orders. However, the increasing size, scale, and frequency of these extreme weather events requires a new level of attention.

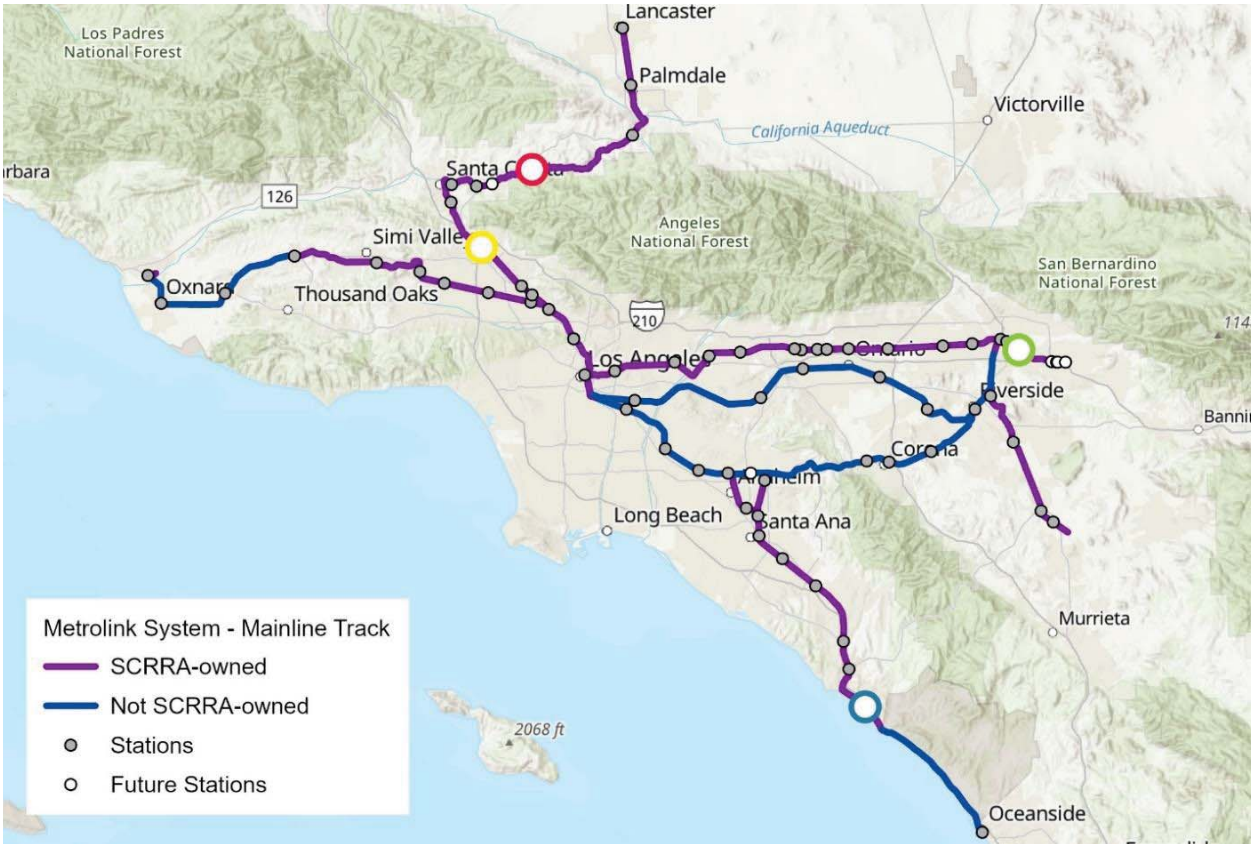
The Southern California Regional Rail Authority (SCRRA), the owner/operator of the Metrolink system, commissioned this Climate Vulnerability Assessment and Adaptation Plan (CVA, the project), to better understand the vulnerability of the Metrolink rail system, its other assets, and its core ridership to existing and future changes in the climate.

The timing for this study is critical because SCRRA has initiated delivery for the first set of multiple projects, which are part of a 10-year major investment in a comprehensive, regional multi-agency program to restructure and revolutionize regional rail in the Southern California service area, known as the Southern California Optimized Rail Expansion (SCORE) Program. To safeguard these investments over their useful life, which ranges from 20 to 100+ years, consideration of future climate conditions will be essential for project planning, design, and delivery. This investment program also is a significant opportunity to increase the overall resilience of the Metrolink rail system and the people it serves. Furthermore, this study aligns with the following SCRRA initiatives: the Transit Asset Management Plan, the Strategic Business Plan, the Fleet Management Plan, the Climate Action Plan, and the Rehabilitation Plan.

Climate change already is affecting SCRRA's assets and operations. Figure ES-1 highlights some examples of current climate-related challenges that are projected to become even more common and widespread in the future.

To address these challenges, this Plan:

- identifies the parts of the network that are most vulnerable to extreme weather events, including extreme heat, riverine flooding, sea level rise, drought, wildfire, and landslides;
- includes prioritized climate-adaptation strategies and a roadmap for implementation to enhance the resiliency of the passenger rail system in Southern California while ensuring the health and safety of passengers;
- identifies opportunities for collaboration with new and existing partners, to address emergency management and climate resilience;



EXTREME HEAT EXAMPLE

Rail "Sun Kink" (Sept 2020 and June 2021)
Extreme temperatures have caused pressure in the rail (when metal expands due to heat) along the Metrolink Antelope Valley Line on two occasions, creating a weak point in the track. In both instances engineers spotted the sun kink and the trains were stopped in time and customers were safely off-loaded.

EXTREME PRECIPITATION EXAMPLE

Redlands Subdivision Flooding (Annual): The Mission Zanja Channel is the primary source of flooding in the City of Redlands, which experiences flooding on an almost yearly basis. Morey Arroyo is an additional source of flooding to the area. Modeling has suggested that during a 100-year event, the track will be overtopped and inundated at various locations between the Santa Ana River and Bridge 9.4 (just before the easterly I-10 overpass).

WILDFIRE EXAMPLE

Saddleridge Fire (Oct 2019)
A wildfire encroached along the Antelope Line in Sylmar, Porter Ranch, which caused service to stop in Santa Clarita. Through our established emergency management Quality Service Pledge, Metrolink was able to provide rideshare or alternative transit reimbursement for passengers to reach their final destination.

SEA LEVEL RISE EXAMPLE

San Clemente Erosion (July 2018 and Nov 2021)
In 2014 track workers first reported incidents of waves striking the revetment in San Clemente and sending spray over the top and onto tracks. Damage to the rail-line could stop all service (passenger and freight) between Los Angeles and San Diego. To prevent wave erosion and in light of recent events, Metrolink has been working closely with OCTA and the U.S. Army Corps of Engineers to repair riprap, improving protection now and into the future.

Figure ES-1: Map of Metrolink Network and Examples of Climate-Related Challenges

- identifies opportunities for integration of SCRRA's ongoing seismic preparations with climate adaptation efforts;
- focuses on the protection of the mobility of Southern Californians, keeping equity in mind and focusing on the most vulnerable, disadvantaged, and transit-dependent populations; and
- includes communication strategies regarding climate hazards and resilience efforts for staff and the general public.

Assessing and prioritizing climate-related risks is essential to understand Metrolink's overall vulnerability to a changing climate. The guiding principles for the project were developed to align with the SCRRA Board of Directors adopted Strategic Business Plan, with focuses on safety; collaboration and partnerships; modernizing business practices; and advancing key regional goals. The project has included a robust stakeholder engagement process, involving representation from 20+ groups, in such sectors as public health, environmental justice, emergency management, SCRRA member agencies, and local and State government.

The Introduction chapter describes the project purpose, guiding principles, and stakeholder engagement efforts, conducted during development of the plan.

VULNERABILITY TO CLIMATE CHANGE

The Climate Vulnerability chapter summarizes the climate vulnerability assessment undertaken for a range of assets and asset types, including track, stations, communications, signals, facilities, culverts, and bridges. Exposure and sensitivity was assessed for SLR, precipitation/riverine flooding, extreme heat, wildfire, drought, landslides/mudslides, seismic/earthquakes, and electrical outages caused by climate hazards. The chapter includes a summary of current climate science and projections for each hazard, the assessment methodology, key findings, maps showing mid-century vulnerability by hazard (see Figure ES-2 for an example), and vulnerability profiles for each asset type. The vulnerability profiles each contain a description of the assets included, a chart showing the vulnerability rating by hazard, a table to identify assets vulnerable to multiple hazards, and a list of all assets considered to have high vulnerability. The focus of the assessment primarily is on assets with high vulnerability by mid-century.

Key findings of the climate vulnerability assessment include the following:

- Coastal track on the Orange subdivision has a minimum elevation of 17 feet and therefore are not projected to be exposed to permanent inundation from SLR. However, sections already are exposed to overtopping from waves during storm events, which could cause damage to track and other assets. This vulnerability will increase as SLR occurs.
- Track, stations, and facilities assets in Simi Valley, Burbank, Santa Clarita, Redlands, and Perris Valley already are within the 100-year floodplain and watersheds that are projected to experience an increase in 100-year storm event precipitation depth.

- Most inland parts of the rail system are projected to experience temperatures above 110 degrees Fahrenheit (°F) annually by mid-century, including most of the San Gabriel, Shortway, Redlands, and Perris Valley rail subdivisions. Portions of the Redlands and Perris Valley subdivisions will experience temperatures above 115°F.
- Because extreme temperatures are projected to increase across all inland parts of the rail system, impacts potentially could occur anywhere that rail is in poor condition, not just in those areas projected to have the highest temperatures.
- Wildfire vulnerability is restricted to the parts of the rail system that are within or adjacent to wildland areas, namely to specific stretches of the Ventura and Valley rail subdivisions.
- Direct effects from drought have been determined to be low system-wide; however, drought may indirectly increase exposure to other hazards.
- Landslide and mudslide hazards are local and can affect Metrolink assets only where they are near steep, unstable slopes. Thus, vulnerability is mostly confined to portions of the rail system running through mountainous terrain along the Ventura, Valley, and Orange subdivisions.

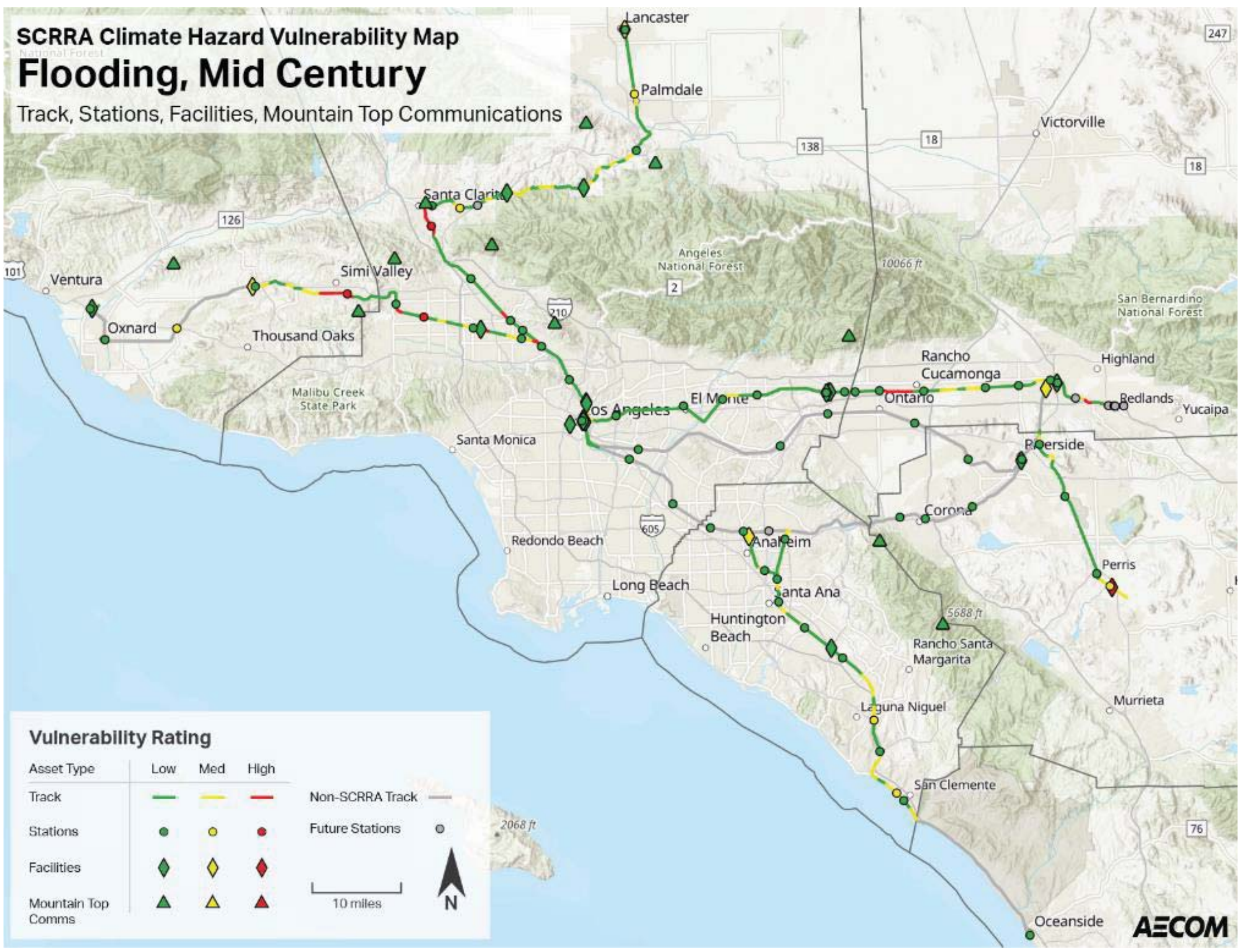


Figure ES-2: Example Map illustrating Flood Vulnerability of Metrolink Assets

- Most track (as well as signals and track-level communications) across the rail system were determined to have medium vulnerability to earthquakes, with segments rated as having high vulnerability in three places on the Valley Subdivision. Bridges in high exposure areas with physical attributes contributing to high sensitivity were rated as having high vulnerability and are mainly along the Ventura, Valley, and San Gabriel rail subdivisions.
- The whole network potentially is vulnerable to electrical outages that can be unintended interruptions caused by direct climate impacts (i.e., spike in power consumption during an extreme heat day), or public safety power shutoffs that are planned outages to avoid starting wildfires during dry/windy weather conditions.

To understand the potential economic impact of specific climate or extreme weather events as described in the vulnerability profiles, three "cost of inaction" case studies were developed for the following areas: Rancho Cucamonga, Santa Clarita, and San Bernardino. The case studies are intended to demonstrate the potential magnitude of costs related to flooding and extreme heat within different parts of the rail system, to guide future planning for adaptation.

SOCIAL VULNERABILITY

Socially vulnerable communities that may be particularly sensitive to climate-related hazards were identified within Metrolink catchment areas to inform prioritization of adaptation strategies. Socially vulnerable communities included those defined by the State as: Senate Bill 535 Disadvantaged Communities (DACs) and Assembly Bill 1550 Low-Income Communities (LICs), and LICs within 0.5 mile of a DAC. In Metrolink's home catchment areas (the areas around Metrolink stations that include 90 percent of trip origins), 31.4 percent of people (5.4 million) live in census tracts designated as DACs and 46 percent of people (8.3 million) live in those designated in LICs. In addition, transit-dependent communities (TDCs) were considered—an index created specifically for this project. TDCs are based on tract-level census data, including vehicle access, race/ethnicity, income, seniors, and persons with disabilities. The direct exposure of vulnerable communities to climate hazards was not assessed because SCRRA is not directly responsible for reducing direct impacts on vulnerable communities (e.g., flood damage to homes). However, SCRRA does provide a service that is heavily used by vulnerable communities—the transit dependency analysis is a way to identify communities for which loss of access to transit because of climate change impacts on the Metrolink system would be particularly harmful.

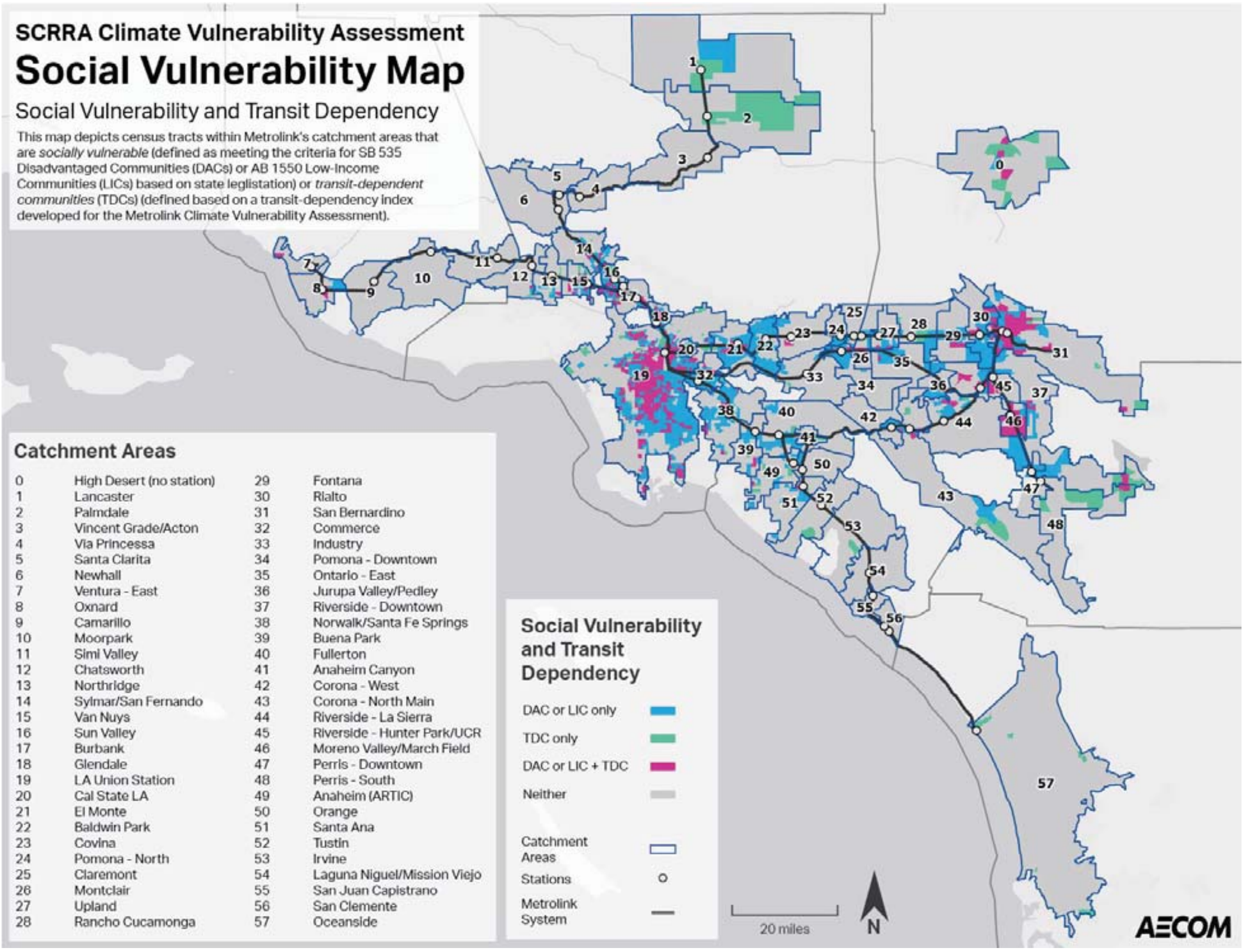


Figure ES-3: Social Vulnerability and Transit Dependency

EMERGENCY PREPAREDNESS

A comprehensive review of SCRRA's emergency management plans, procedures, and coordination processes was conducted to better understand the agency's current emergency preparedness program and the opportunities and challenges it may face because of increasing climate change-related events. A robust emergency management program enables SCRRA both to address disruptions to the Metrolink system rapidly and efficiently, and contributes to multi-agency/regional response efforts more effectively. A suite of emergency preparedness documents and a targeted list of internal and external emergency management stakeholders were interviewed. Based on these efforts, key findings and adaptation strategies were developed to further expand SCRRA's internal response capabilities; to support its ongoing efforts to further define its role as a regional mobility provider during an emergency and to fortify institutional relationships and procedures with its partner agencies at the local, regional, and state levels.

CLIMATE ADAPTATION AND IMPLEMENTATION

The Climate Adaptation and Implementation chapter summarizes the strategies identified to address the climate vulnerabilities and describes the methodology used to develop them, including the integral role of stakeholders. Federal grants and other grants available at the time of writing this document also are presented. Strategies have been organized into four types: governance, informational, emergency management, and structural.

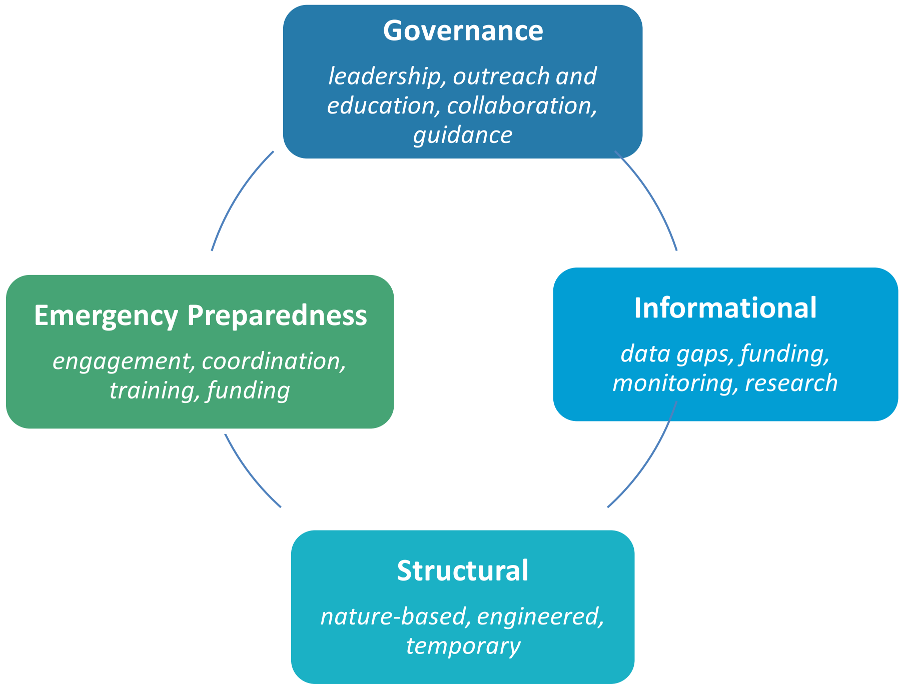


Figure ES-4: Types of Climate Adaptation Strategies

Governance, informational, and emergency preparedness strategies are ordered by implementation time frame, and structural strategies are categorized by the climate hazard that they address and potential locations identified. A key department has been identified to lead the implementation of each strategy, while recognizing that some will require partnerships with other agencies and regional collaboration.

Governance strategy types focus on improving organizational climate resilience through mainstreaming a consideration of climate resilience into key planning, design and operational policy, as well as programs and procedures. Key short-term strategies (within the next 2 years) include:

- G.1 Align SCORE and Capital Projects with recommended climate adaptation strategies
- G.2 Add climate adaptation strategies to the SCRRA Design Criteria Manual
- G.3 Create an internal SCRRA Climate Resilience Advisory Committee

Informational strategy types focus on learning more about climate change to be able to make more informed decisions to improve resilience. Key short-term strategies (within the next 2 years) include:

- I.1 Create a web-based climate vulnerability dashboard (completed)
- I.2 Research funding opportunities to support implementation of climate adaptation strategies (in progress)
- I.3 Add new data about rail track condition, to further refine the climate vulnerability assessment

Emergency Preparedness strategy types focus on improving internal and external engagement, coordination and supporting additional training. Key short-term strategies (within the next 2 years) include:

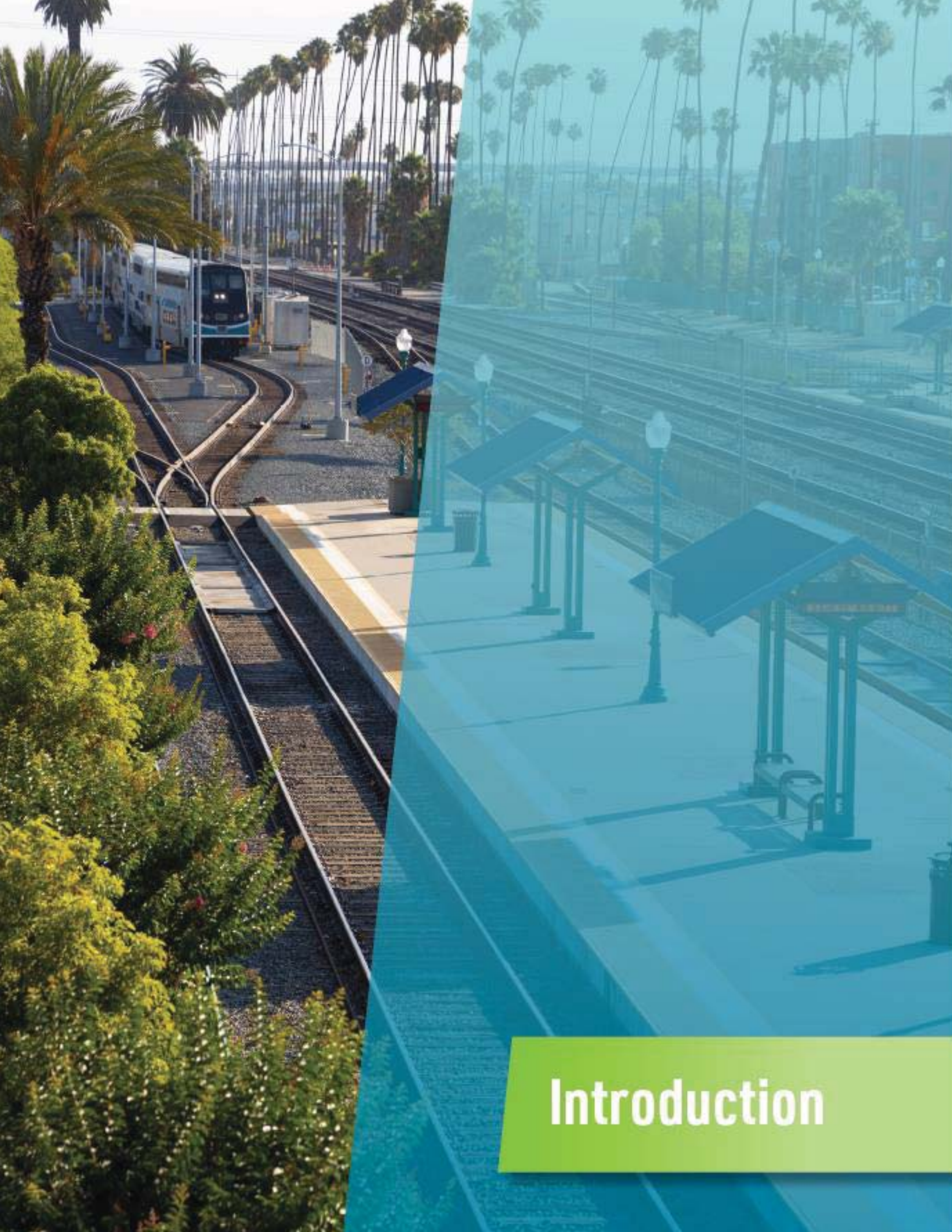
- EM.2 Foster relationships with partner transit agencies, local agencies, and member agencies
- EM.5 Review and revise SCRRA's Incident Response Plan and the EOC Manual
- EM.8 Conduct a briefing and/or training with SCRRA emergency personnel

Structural strategy types focus on temporary and permanent infrastructure that include both nature-based and engineered solutions, which are organized as a toolkit for designers to apply based on a project scope, rather than a prioritized list of actions.

Although a number of the governance, informational, and emergency preparedness strategies may be implemented without significant extra funding, additional resources such as federal and state grants and loans may be required for integrating climate resilience strategies into structural projects. Key funding and financing sources (available at the time of writing) were identified to fund climate adaptation investments in California, with a focus on sources that are suited for the structural, nature-based, or engineered adaptation strategies.

APPLICATION OF ADAPTATION STRATEGIES

In addition to developing these high-level adaptation strategies, four strategies were developed in more detail to provide guidance and support for future implementation of the full suite of strategies. The purpose was to show how a strategy may be implemented at a specific location, and/or to help ensure that the findings would be operational across SCRRA departments, after this study is completed. They include an interactive browser-based dashboard that visually displays the vulnerability assessment results and includes the climate hazard maps and asset-level vulnerability ratings; a review of five SCORE projects using the CVA results to identify opportunities for adaptation; a detailed review of track conditions and extreme heat on a subset of the Antelope Valley Subdivision prone to sun kinks; and a detailed review of track conditions and flooding (originating from the Cucamonga Channel) on a subset of the San Gabriel Subdivision. The Application of Adaptation Strategies chapter summarizes the efforts each of these strategies and includes background, methodology, and summary/recommendations.



Introduction

Project Purpose

Recent events, such as the wildfires that raged through California in the summer and fall of 2020 and 2021 are clear evidence of the climate-related threats faced by jurisdictions, businesses, and residents. The Southern California Regional Rail Authority (SCRRA/Metrolink[1]) has long been prepared to handle periodic flooding, wildfires, and go-slow heat orders. However, the increasing size, scale, and frequency of these extreme weather events requires a new level of attention.

SCRRA commissioned a study to develop this Climate Vulnerability Assessment and Adaptation Plan (CVA; the project), to better understand the vulnerability of the rail system, its other assets, and its core ridership to existing and future changes in the climate. SCRRA's passenger rail service is a critical component of the region's transportation system, forming an accessible connection between affordable housing and key economic centers.

The timing for this study is critical because SCRRA has initiated design for the first set of multiple projects, which are part of a 10-year major investment in a comprehensive, regional multi-agency program to restructure and revolutionize regional rail in the Southern California service area, known as the SCORE Program. To safeguard these investments over their useful life, which ranges from 20 to 100+ years, consideration of future climate conditions will be essential to project planning, design, and delivery. This investment program also is a significant opportunity to increase the overall resilience of the Metrolink system and the people it serves. Furthermore, this study aligns with the following SCRRA initiatives: the Transit Asset Management Plan, the Strategic Business Plan, the Fleet Management Plan, and the Climate Action Plan.

Guiding Principles

Assessing and prioritizing climate risks is essential to understand Metrolink's overall vulnerability to a changing climate. The following guiding principles for the project were developed to align with the SCRRA Board of Directors-adopted Strategic Business Plan:

Safety is Foundational: Improve the resiliency of infrastructure and mitigate the impacts of climate change to ensure a safe, reliable regional rail system.

Connect and Leverage Partnerships: Collaborate with partners on climate action and align with regional climate-related projects and plans to improve efficiency in climate resilience for the region.

Modernize Business Practices: Prioritize strategies that mainstream climate adaptation measures throughout SCRRA's planning, operations, and program delivery groups. Maximize

[1] This document uses "SCRRA" when referring to ownership/the organization and "Metrolink" when referring to service/the passenger system.

efficiency of resilience investments by identifying synergies between climate adaptation and seismic response, and evaluate projects based on economic, environmental, and social values.

Advance Key Regional Goals: Create an adaptive plan that can be updated as new information becomes available, and prioritize nature-based adaptation strategies that can be more cost-effective than traditional infrastructure and provide additional co-benefits. Prioritize disadvantaged communities that have fewer resources to cope with the impacts of climate change, and for which improved transit accessibility can help improve social equity.

Stakeholder Engagement

Stakeholder involvement and feedback was instrumental in developing the project, based on the number of other climate adaptation efforts being carried out within the Metrolink service area, and because climate impacts do not stop at ownership boundaries. The main goals of the engagement process were to ensure member agencies, regular SCRRA partners, and other organizations working on climate in the region were aware of the project, to give them the opportunity to provide input and feedback on the process and key outputs, and to identify opportunities for future collaboration on strategies. The stakeholder group included representation from 20+ groups, in such sectors as public health, environmental justice, emergency management, SCRRA member agencies, and local and State government. Although community-based organizations were invited to participate, they were unable to do so. SCRRA acknowledges the importance of community participation and will focus on getting appropriate input after structural strategies are programmed.

Stakeholder collaboration on the project was particularly important to facilitate building on recent climate-related projects, such as the San Bernardino County Climate Vulnerability Assessment and Resilience Strategy, the LA Metro Climate Action and Adaptation Plan, the OCTA Defense Against Climate Change Plan, and the SCAG resources on Adaptation and Resilience Planning for Providers of Public Transportation. Other regional climate adaptation efforts were ongoing at the same time—such as the SCAG Regional Climate Adaptation Framework and the LA County Climate Vulnerability Assessment. The stakeholders all agreed in principle to engage in ongoing dialogue around implementation of SCRRA's plan, which will be realized in part through SCRRA joining LARC, a network of local and regional decision-makers working to ensure that Los Angeles County is prepared for the impacts of climate change. This is one of seven regional collaboratives in California that are supporting climate change science, policy, and planning efforts across multiple sectors.

The stakeholder group met three times during the course of the project. The first meeting was focused on reviewing the project goals and principles, identifying current climate vulnerabilities, and recognizing potential cascading (or indirect) impacts. The second meeting focused on discussing the key findings from the vulnerability assessment and brainstorming initial climate adaptation strategies to address the vulnerabilities. The third meeting was held to highlight the risk assessment case studies, the full suite of adaptation strategies, and consider implementation efforts around collaboration, funding, and lessons learned.

A separate emergency management stakeholder focus group was convened to discuss a multi-agency response.

The feedback from stakeholders informed the process and the content throughout, and the final plan greatly benefited from having these diverse viewpoints represented. The project team is grateful for the support of the stakeholders—the plan is better because of them.

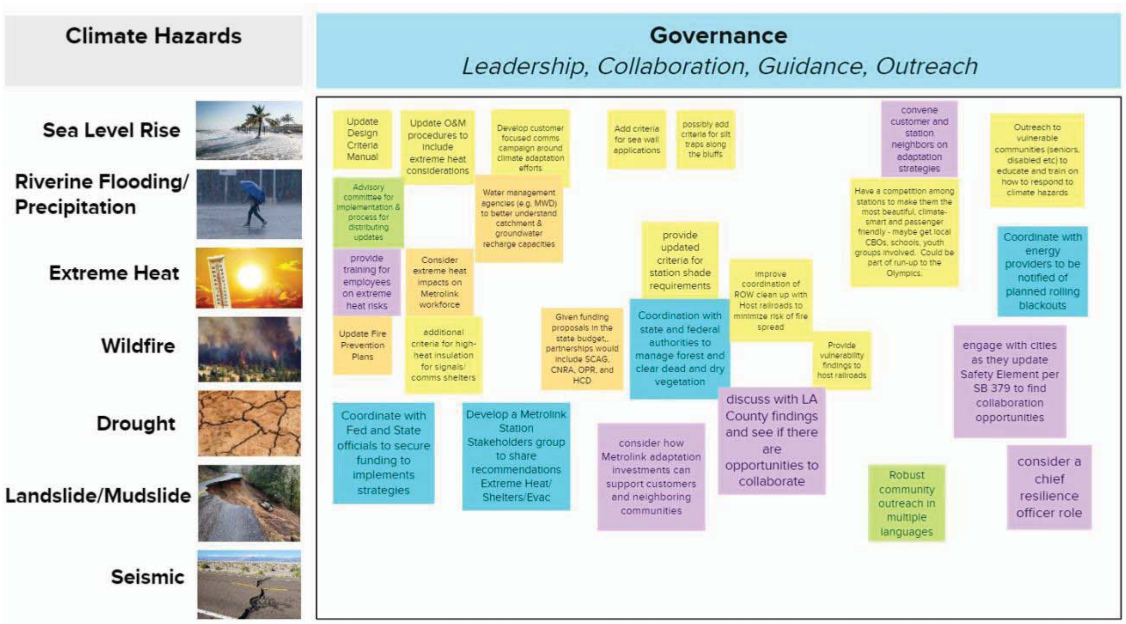
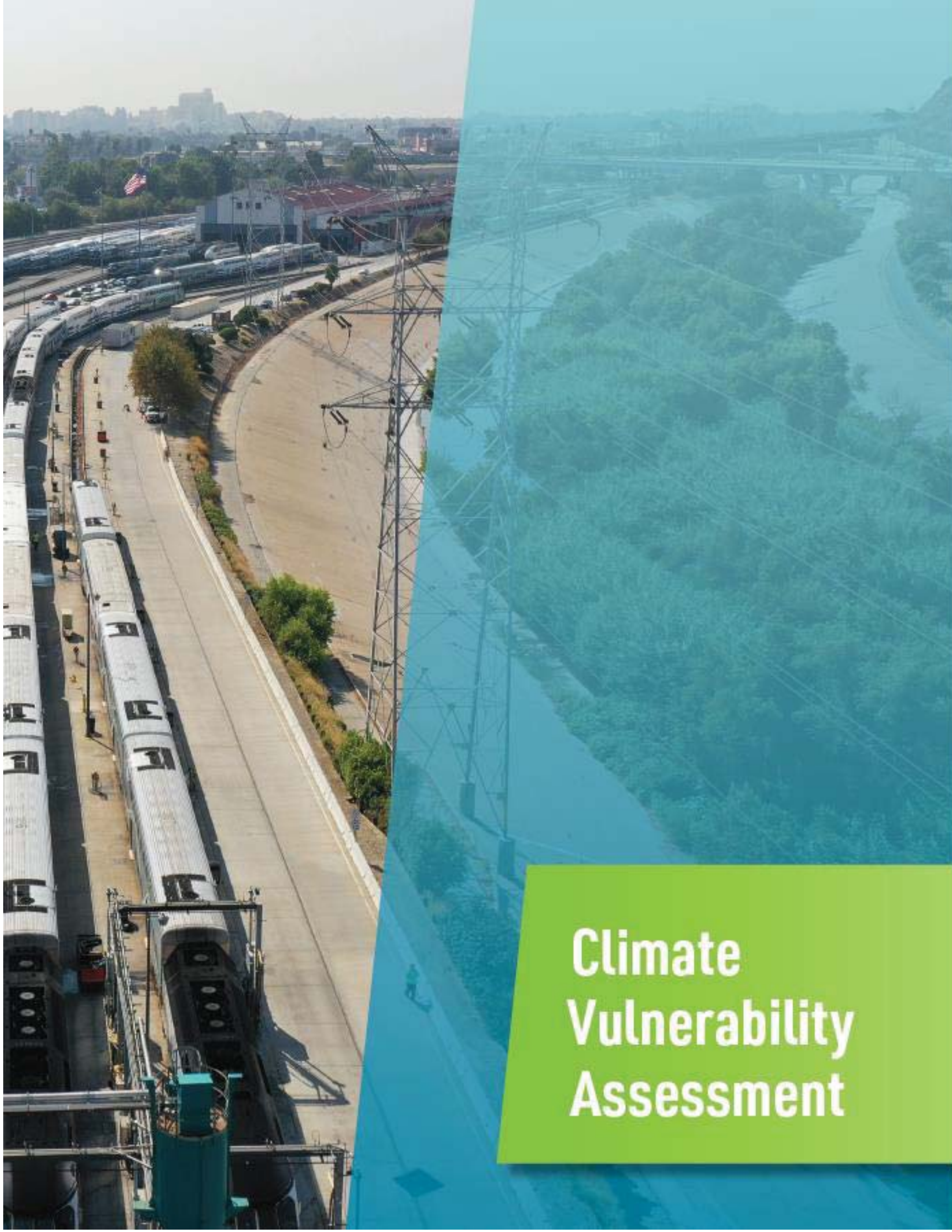


Figure 1: Snapshot of Mural Board Created During Stakeholder Meeting

Table 1: Stakeholder Group

Stakeholder Group	Emergency Preparedness Focus Group
BNSF Railway Company (BNSF)	City of Covina Emergency Management
California Department of Transportation (Caltrans)	City of Lancaster Emergency Management
City of Los Angeles	LACMTA
Climate Resolve	Los Angeles County Office of Emergency Management
Los Angeles County	NCTD
Los Angeles County Metropolitan Transportation Authority (LACMTA)	Orange County Sheriff's Department
Los Angeles Department of Transportation (LADOT)	OCTA
Los Angeles Regional Collaborative for Climate Action and Sustainability (LARC)	RCTC
Los Angeles – San Diego – San Luis Obispo Corridor Agency (LOSSAN)	San Bernardino County Office of Emergency Services
North County Transit District (NCTD)	SBCTA
Orange County Transportation Authority (OCTA)	VCTC
Public Health Alliance of Southern California	
Riverside County Transportation Commission (RCTC)	
San Bernardino County Transportation Authority (SBCTA)	
Southern California Area Government (SCAG)	
Union Pacific Railroad (UPRR)	
Ventura County Transportation Commission (VCTC)	



Climate Vulnerability Assessment

Overview

This chapter identifies the Metrolink assets that are highly vulnerable to climate hazards, including sea level rise (SLR), precipitation/riverine flooding, extreme heat, wildfire, landslides/ mudslides, earthquakes, drought, and electrical outages caused by climate hazards. It includes a summary of current climate science and projections for each hazard, the assessment methodology, key findings, maps showing mid-century vulnerability by hazard, and vulnerability profiles for each asset type.

The assessment describes climate projections for mid-century (2040–2069) and late-century (2070–2099) time horizons and rates asset vulnerability (low, medium, or high) for each hazard. The focus primarily was on assets with high vulnerability by mid-century, as near- to mid-term vulnerability had a stronger influence on both prioritization and adaptation strategy development. Apart from extreme heat and sea level rise, no substantial changes in hazard vulnerability are anticipated between mid-century and late-century.

This report focuses on the vulnerability of SCRRA-owned assets and subdivisions (where SCRRA has more direct control of adaptation action implementation).

Climate Science

The Earth's habitable climate is maintained by the greenhouse effect—a blanket of gases that trap heat in the atmosphere and keep surface temperatures relatively stable. Greenhouse gases (GHGs) trap warmth generated from solar radiation, similar to how a car heats in the sun.

If not for these gases, the Earth's surface would be frigid and we would have no air to breathe. However, since the Industrial Revolution in the mid-1800s, because of human activities such as the burning of fossil fuels and the conversion of natural lands into agriculture and settlements, additional greenhouse gases are being released into the atmosphere at an unprecedented rate, causing increased warming.

Among the many GHGs, the most common are:

- carbon dioxide (CO_2)–generated from the burning of fossil fuels or organic matter;
- nitrous oxide (N_2O)–a byproduct of burning fossil fuels and fertilizing crops; and
- methane (CH_4)–created from the decomposition of waste and off-gassing from livestock and fugitive emissions from fossil fuel production and distribution.

MODELING CLIMATE CHANGE

To project future climate conditions, scientists rely on numerical models, known as general circulation models. These models incorporate the inter-related processes of the atmosphere, ocean, and land surface to simulate the response of climate systems to changing GHG emissions.

These models have been demonstrated to accurately reproduce observed changes of recent and past climates. However, some uncertainty exists in climate projections because the amount of GHGs that will be emitted in the future is not known for certain. Will annual emissions continue to increase rapidly, or will strong global action lead to lower annual emissions? To account for this uncertainty, climate scientists present projections as ranges, based on representative concentration pathways (RCPs), which are future emissions scenarios created by the International Panel on Climate Change (IPCC) to show atmospheric GHG concentrations based on various policy decisions. Figure 2 shows the two most commonly used scenarios:

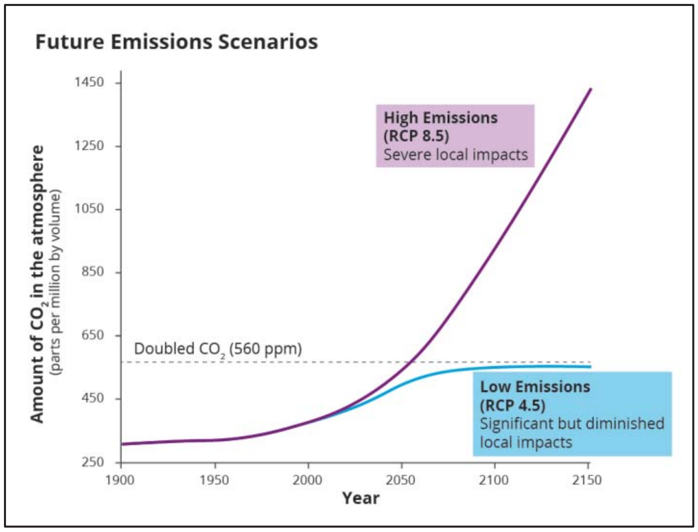


Figure 2: Future Emissions Scenarios Comparison

- RCP 8.5 represents a high emissions scenario in a future with continued rapid economic growth and little action to curb emissions, continuing to increase through 2100 and beyond. The continued rise in atmospheric CO_2 concentrations (parts per million [ppm] by volume) could result in a rise of global temperatures by approximately 5 to 6 degrees Celsius by 2100.
- RCP 4.5 represents a low emissions scenario in a future where emissions rise until mid-century and then stabilize. This scenario could result in a rise of global temperatures by approximately 2 to 3 degrees Celsius by 2100.

The data used for this analysis was obtained from the IPCC Fifth Assessment report.

INFORMATION SOURCES AND BEST PRACTICES

This assessment followed the best practices that are detailed in the California Adaptation Planning Guide (Cal OES 2020) and includes climate projections that draw on Cal-Adapt, a web-based climate data and information portal produced by California's scientific and research community. It provides the best downscaled models of California and is the adaptation planning standard for the state. The site contains historic data (1950–2013) and projections (2010–2100) from a variety of sources that have downscaled global climate models for more fine-scale resolution (Cal-Adapt 2020). Additional data sources are listed in Table 2 and include data used in the Caltrans Climate Change Vulnerability Assessments (CCVAs), and by the Federal Emergency Management Agency (FEMA), California Geological Survey, and U.S. Geological Survey (USGS).

EMISSIONS SCENARIOS, PLANNING HORIZONS AND TIME FRAMES

Climate projections based on the high future emissions scenario (RCP 8.5) were recommended for the planning horizons and time frames that are summarized in Table 2.

Table 2: Emission Scenario Planning Horizons

Horizon	Time Frame
Mid-century	2040–2069
Late-century	2070–2099

These recommendations are based on the best practices that are recommended by the California Adaptation Planning Guide (Cal OES 2020) and the following considerations:

- **Consistency with other regional efforts:** These recommendations match those used for the Caltrans CCVAs. The LA Metro Climate Action and Adaptation Plan (CAAP) used a mid-century time frame (2041–2060) but did not look at late-century projections (Metro 2019). The Caltrans, San Bernardino County, Western Riverside, and LA Metro vulnerability assessments all used climate projections based on the high emissions scenario (RCP 8.5).
- **The lifespan and criticality of Metrolink's assets:** The California Adaptation Planning Guide (Cal OES 2020) recommends that for assessments which include assets that are critical, expensive, and/or have long useful lives, planners should take a conservative approach that uses projections based on a high emissions scenario and should assess vulnerability over a longer time frame.
- **Availability of existing data sources:** Using the same planning horizons and time frames as the Caltrans CCVA enabled the project team to leverage datasets that were produced for those studies for hazard mapping. In addition, Cal-Adapt climate projections data are not available for the years beyond 2099.

CLIMATE STRESSORS AND HAZARDS

Climate stressors are conditions that are affected by climate variability and atmospheric and ocean temperature changes, which include SLR, precipitation, and temperature changes. Additional stressors, which are conditions affected by complex interactions between other stressors, include changes in precipitation combined with temperature changes that may result in drought. *Hazards* are conditions or events which may cause damage or harm, and they are listed in Table 3. For this project, climate stressors and hazards are referred hereafter as hazards.

Interaction can occur between hazards that increase the risk of one or more hazards. For example, landslides can occur in the years immediately after wildfires, in response to high intensity precipitation events. For this assessment, each hazard was mapped individually, and thus these interactions were not captured qualitatively. However, qualitative analyses were included to identify areas that are particularly vulnerable because of exposure to multiple hazards. For example, identifying locations that have high wildfire concern *and* high landslide risk. Figure 3 summarizes climate hazards and potential impacts and primary consequences that were considered in this assessment. The Technical Appendix includes a full cascading consequences diagram, which includes secondary consequences affecting the environment, local and regional economy, social and public health, and SCRRA fiscal health.

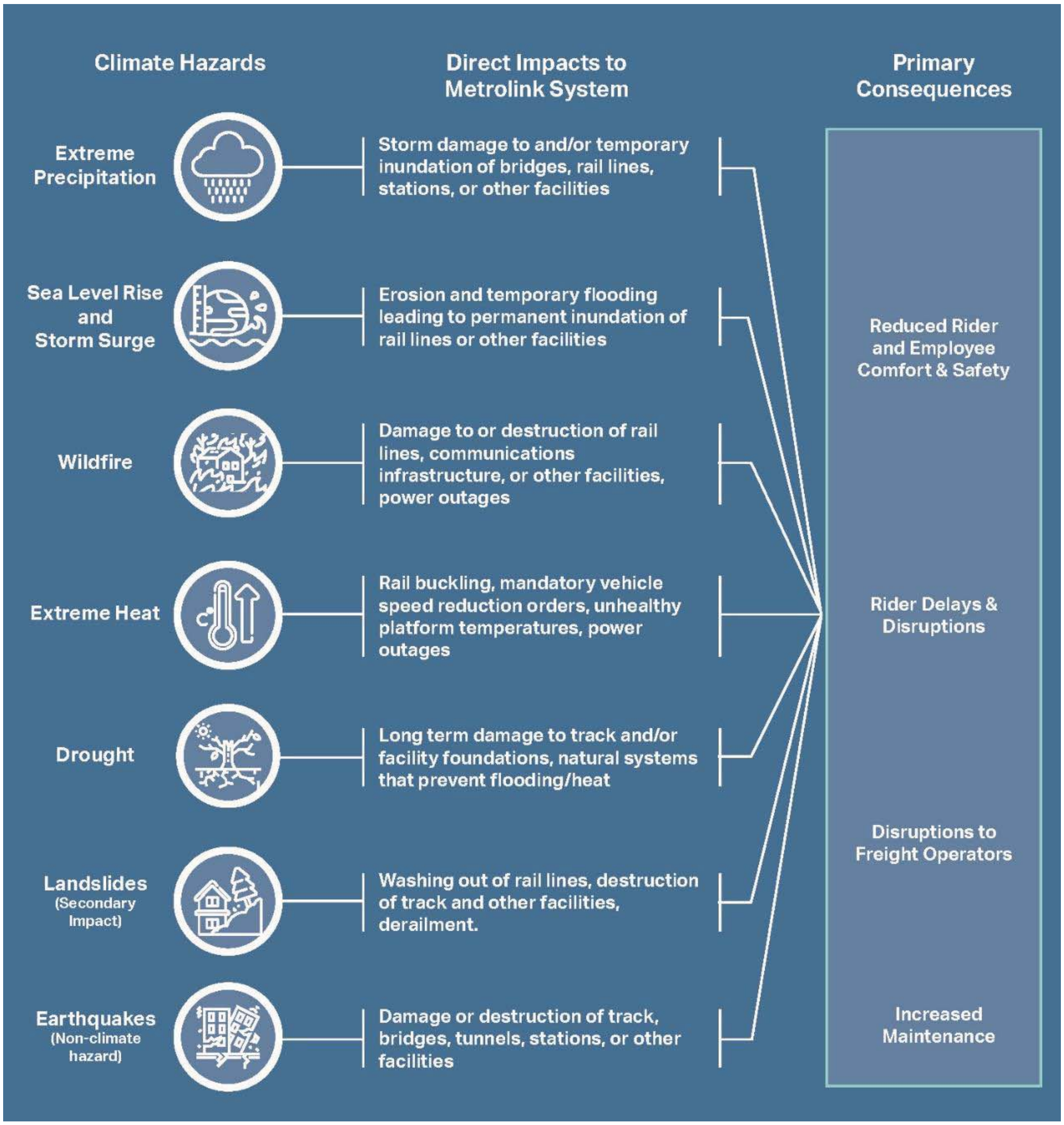


Figure 3: Climate Hazards and Impacts Considered in the CVA

Methodology

The vulnerability assessment is based on the framework summarized in Figure 4. Geographic information system (GIS) data were developed for mid- and late-century time horizons for each hazard. GIS and tabular attribute data on Metrolink assets were gathered into an asset inventory. The exposure of each asset then was determined by overlaying asset location data on the climate hazard maps. The sensitivity of exposed assets was determined based on physical attributes and in consultation with SCRRA engineers. Each of these steps are summarized in greater detail next. Maps were produced for the mid-century scenario only. For an in-depth explanation of the vulnerability assessment methodology, see the Technical Appendix.

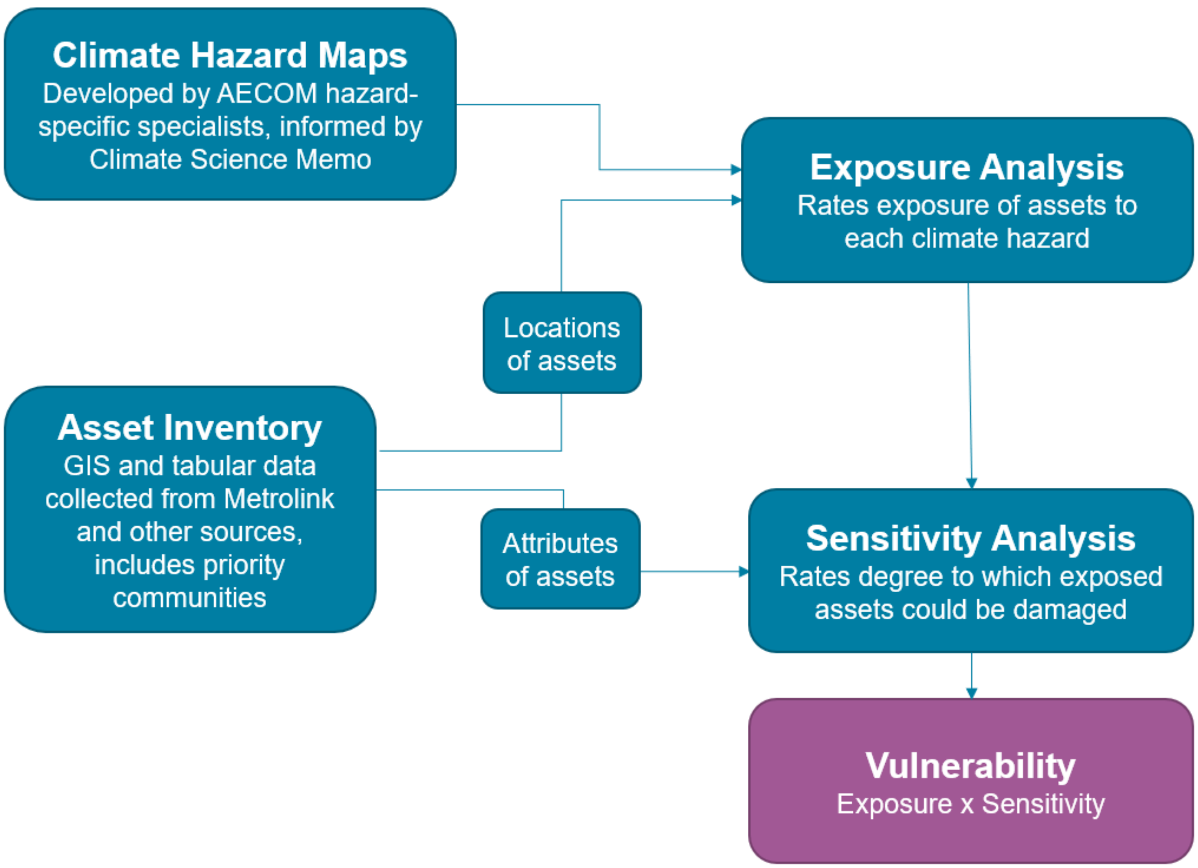


Figure 4: Climate Vulnerability Assessment Framework

ASSET INVENTORY

This project assessed the vulnerability of the following types of assets: track (including ties and ballast), bridges, tunnels, stations, facilities, signals, culverts, and communications infrastructure (including track-level equipment and mountain top towers). Although primarily focused on assets owned by SCRRA, in some instances, assets owned by other jurisdictions, such as stations, also were included in the assessment because SCRRA has an influence in their planning, design, and operations, and the resilience of these assets is essential for delivery of service to Metrolink passengers. Other associated assets, which SCRRA has less control over (e.g., track on non-SCRRA subdivisions) are included in the map book and tabular outputs but are not addressed in this report.

CLIMATE HAZARD MAPS

Vulnerability to SLR, precipitation/riverine flooding, extreme heat, wildfires, drought, landslides/mudslides, earthquakes (seismic), and electrical outages were assessed. Although earthquakes are not a climate hazard, they were included in this assessment to identify assets and regions that are vulnerable to both climate change and seismic impacts (to facilitate alignment of seismic and climate-related retrofits in the future). Table 3 shows information on each of the hazards, including a summary of the projected trends based on the latest climate science, data sources used, and brief notes on the hazard mapping methodology. Often projections used by other regional climate studies were selected for consistency.

Table 3: Summary of Hazard Projections and Mapping Approaches

Hazard	Future Trends	Dataset(s) and Source(s)	Hazard Mapping/Exposure Summary
Sea Level Rise (SLR)	Hazard increasing though late-century, coastal areas only.	State of California Sea-Level Rise Guidance (OPC 2018) Inundation data: CoSMoS (Coastal Storm Modeling System) (Barnard et al. 2018)	For Orange County (OC), findings of the Orange County Transportation Authority (OCTA) OC Rail Infrastructure Defense Against Climate Change Plan were converted into hazard scores. For San Diego County, CoSMoS data was leveraged in an approach similar to the OCTA study.
Precipitation/ Riverine Flooding	Precipitation depth during major storms projected to increase system-wide, especially for watersheds on San Gabriel, Valley, and Ventura subdivisions. More extreme swings between wet and dry years, but no substantial change in annual averages.	Floodplain: County Flood Insurance Rate Maps (FEMA 2020) Precipitation: Percent change in 100-year storm precipitation depth (Caltrans 2019; Pierce et al. 2018)	Level of exposure rated on existing FEMA 100-year and 500-year floodplain and then adjusted based on projections of future change in 100-year storm precipitation depth by watershed.
Extreme Heat	Substantial increase in annual maximum temperatures through late-century. Highest temperatures (exceeding 115°F) will be inland (Riverside and San Bernardino counties, Palmdale/Lancaster).	LOCA Downscaled CMIP5 Climate Projections (Pierce et al. 2018))	Average annual maximum temperatures were calculated for mid-century and late-century time frames based on daily temperature projections from four priority climate models. Localized heat projections were produced for each grid cell in Metrolink's service area.
Wildfire	Substantial increase of wildfire hazards in mountainous wildland areas across the region, especially around Simi Valley and between Santa Clarita and Palmdale.	Statewide wildfire projections (Caltrans, pers. comm, 2020)	Rated based on existing wildfire projections data from the Caltrans CCVAs. The Caltrans data incorporated the results from three different wildfire projections models.

Hazard	Future Trends	Dataset(s) and Source(s)	Hazard Mapping/Exposure Summary
Landslides/ Mudslides	Increased wildfire frequency and changing precipitation patterns could exacerbate landslide hazards where they already exist.	MS58 Deep-Seated Landslide Susceptibility (Wills et al. 2011) Soil-Slip Susceptibility Maps, Southwestern California (Morton et al. 2003)	Rated based on proximity to zones identified as having high potential for landslides or mudslides to start. Impact of climate change on landslides was not assessed spatially. Mapping was based on current hazard.
Earthquakes (Seismic)	Hazard currently is high across Southern California. Climate change is not anticipated to have a substantial influence on seismic impacts.	Earthquake ground-shaking potential (U.S. Seismic Hazard Model) (Peterson et al. 2019) Liquefaction hazard zones (CGS 2017) Quaternary Fault and Fold Database of the United States (USGS 2019)	Rated based on three elements: ground-shaking potential, fault rupture/displacement, and liquefaction zones. Impact of climate change on seismic hazard was not assessed; this is not well understood and unlikely to be significant compared to already high regional seismic hazard. Mapping was based on current hazard.
Drought*	Increase in frequency and severity system-wide through late-century.	Diffenbaugh et al. 2015	No substantial spatial differentiation in hazard across the Metrolink service area anticipated, and sensitivity of Metrolink assets to drought is generally low, so a qualitative approach was taken. Focus was on potential effects of drought on other direct hazards, such as wildfires and landslides.
Electrical Outages*	Short-term peak in frequency of both intended and unintended outages followed potentially by reduction as service providers upgrade utility infrastructure.	California Public Utilities Commission 2021	Spatial information on relative exposure to electrical outages was not available. Sensitivity of assets to electrical outages is addressed in Table 4. Electrical outages include unintended interruptions caused by direct climate impacts (i.e., spike in power consumption during an extreme heat day) or public safety power shutoffs (PSPS) that are planned outages to avoid starting wildfires during dry/windy weather conditions.

Note:
* Climate hazard mapping and exposure analyses were not performed for these hazards. Electrical outages are not an environmentally determined hazard and spatial information on relative exposure to outages was not available. However, sensitivity of assets to electrical outages is addressed in Table 4. Similarly, because substantial spatial differentiation in drought exposure across the Metrolink system is not anticipated (droughts will occur across all of Southern California at the same time, not in just one part) and because Metrolink assets were determined to have low direct sensitivity to drought, drought was not included in the exposure analysis. For a qualitative discussion of how drought may affect the frequency of other climate hazards (e.g., wildfires, landslides), see the Technical Appendix.

EXPOSURE ANALYSIS

Exposure is the degree to which an asset is likely to experience a given hazard. Each asset was assigned an exposure score of 0 (none) to 5 (high) for each hazard by overlaying asset location data on the climate hazard maps.

SENSITIVITY ANALYSIS

Sensitivity is the degree to which an asset could be physically damaged and/or result in service interruption if exposed to a given hazard. For example, an asset is considered sensitive to flood waters if its function or construction integrity can be impaired or damaged from being wet. Each asset was given a sensitivity score of 0 (none) to 3 (high), based on a qualitive logic determined in consultations with SCRRA engineers (see the Technical Appendix for details). Table 4 summarizes sensitivity ratings for each hazard/asset combination. A range indicates that sensitivity was rated differently for assets within that asset type, based on physical attributes.

Table 4: Summary of Sensitivity Ratings

Asset Type	Hazard							
	SLR + Storm Surge	Riverine Flooding	Extreme Heat	Wildfire	Landslides Mudslides	Drought	Seismic	Electrical Outages
Track	Medium	Medium	Medium	Low	High	Low	Medium	None
Bridges	Low to High	Low to High	Low	Medium to High	High	Low	Low to High	None
Tunnels	n/a	Medium	None	Low	Medium	Low	High	Medium
Culverts	Low to Medium	Low to Medium	None	Low	High	Low	Medium	None
Signals	Medium	Medium	Low	High	Medium	Low	Medium	Medium
Communica-tions	Low	Medium	Low	Medium to High	High	Low	Medium	Medium
Stations	Medium	Medium	Low to High	Medium	High	Low	Low to Medium	Low
Facilities	n/a	High	Low to High	Low to Medium	High	Low	Low to High	Low to High

VULNERABILITY

Exposure and sensitivity scores were multiplied together to arrive at a vulnerability score. This score can be interpreted as an asset's combined vulnerability to a given hazard, based on the degree to which it may experience the hazard, and the degree to which it may be damaged or result in service delays if exposed. The maximum vulnerability score that an asset could receive was 15. Any asset that received an exposure or sensitivity score of 0 for a given hazard automatically also would receive a vulnerability score of 0 (low) for that hazard as well. To facilitate interpretation of the results and use prioritize adaptation strategies on the most vulnerable, assets were rated as having low, medium, or high vulnerability based on the thresholds summarized in Table 5. The threshold for high vulnerability was intentionally set to a high value so that only especially vulnerable assets would make it into this category, to help facilitate prioritization of assets/strategies for adaptation.

Table 5: Vulnerability Scores and Rating Logic

Exposure	Sensitivity		
	1	2	3
1	1	2	3
2	2	4	6
3	3	6	9
4	4	8	12
5	5	10	15
Vulnerability Ratings: Low = 1 to 5, Medium = 6 to 9, High = 10 to 15			

Social Vulnerability Analysis

Socially vulnerable communities that may be particularly sensitive to climate-related hazards were identified within Metrolink catchment areas to inform prioritization of adaptation strategies. Socially vulnerable communities included those defined by the State as: Senate Bill (SB) 535 Disadvantaged Communities (DACs), Assembly Bill (AB) 1550 Low-Income Communities (LICs), and LICs within 0.5 mile from a DAC, as well as transit-dependent communities (TDCs), which was an index created specifically for this project. TDCs are based on tract-level census data, including vehicle access, race/ethnicity, income, seniors, and persons with disabilities. The direct exposure of vulnerable communities to climate hazards was not assessed because SCRRA is not directly responsible for reducing direct impacts on vulnerable communities (e.g., flood damage to homes). However, Metrolink does provide a service that is heavily used by vulnerable communities—the transit dependency analysis is a way to identify communities for which loss of access to transit because of climate change impacts on the Metrolink system would be particularly harmful (see Technical Appendix for details).

Two social vulnerability maps were created—one showing vulnerable communities as defined by State Legislation (DACs, LICs, and LICs within 0.5 mile from DAC), and the other that overlays vulnerable communities and transit-dependent communities (see Figure 6 through Figure 18). Table 6 summarizes social vulnerability by catchment area. The results generated from this approach then can be used to demonstrate the degree to which specific projects benefit DACs/LICs, potentially helping unlock sources of funding. Furthermore, because such a large proportion of census tracts within Metrolink's catchment areas are DACs/LICs, incorporating transit dependency will enable SCRRA to further refine the prioritization of adaptation measures for its assets, to maintain service for those communities.

Table 6: Top Catchment Areas by Percent of Households in Socially Vulnerable Communities and Transit Dependent Communities

Rank	Socially Vulnerable (DAC or LICs)		Transit Dependent		Both Socially Vulnerable and Transit Dependent	
	Catchment Area	% of HHs	Catchment Area	% of HHs	Catchment Area	% of HHs
1	Sun Valley	91%	Glendale	34%	Lancaster	44%
2	Baldwin Park	87%	Burbank North South DT	29%	Glendale	38%
3	Van Nuys	86%	Sun Valley	28%	Van Nuys	36%
4	Commerce Montebello Commerce	86%	San Bernardino Depot DT	26%	Hunter Park UCR	35%
5	Lancaster	86%	Van Nuys	26%	Burbank North South DT	34%
6	Rialto	83%	La Union Station	25%	San Bernardino Depot DT	32%
7	Glendale	83%	Hunter Park UCR	21%	La Union Station	30%
8	Cal State La	82%	Rialto	21%	Sun Valley	28%
9	Anaheim	82%	Moreno Valley	18%	High Desert	24%
10	El Monte	82%	Commerce Montebello Commerce	17%	Perris South	22%

Key Vulnerability Findings

The following discussion is a summary of the key findings from the climate vulnerability assessment. The findings are organized by climate hazard to match the vulnerability maps in the following section. For a more detailed summary of vulnerability by asset type, see the Asset Vulnerability Profiles. The key findings also include a summary and map of hotspots, which are areas or assets that are projected to be vulnerable to multiple hazards, as well as a summary and map of social vulnerability considerations.

SEA LEVEL RISE

- SLR vulnerability is confined to the coastal stretches of track in Orange and San Diego counties. The SLR vulnerability of the Orange subdivision was studied in-depth as part of the OC Rail Infrastructure Defense against Climate Change Plan, led by the OCTA. The results from that study were leveraged for this project.
- Coastal track on the Orange subdivision have a minimum elevation of 17 feet and therefore are not projected to be exposed to permanent inundation from SLR. However, sections already are exposed to overtopping from waves during storm events, which could cause damage to track and other assets. This vulnerability will increase as SLR occurs.
- At the San Clemente Pier station, structures seaward of the track currently are exposed to wave runup during a 100-year storm event. However, the track and the parking lot landward of the track likely would not be exposed until late-century.

- Although this report focuses on mid-century vulnerability, by late-century, almost the entire coastal stretch of the Orange subdivision (from Mile Post [MP] 200.3 to 207.3) could be exposed to overtopping from storm surges, as could both stations (San Clemente and San Clemente Pier) and all bridges, culverts, signals, and communications equipment. About one-third of this track has a "likely" (66 percent) chance of being exposed by 2070, according to National Oceanic and Atmospheric Administration SLR projections.
- As the San Diego subdivision is not owned or maintained by SCRRA, it is not addressed in the vulnerability profiles discussed next. Most of the San Diego subdivision is not vulnerable to SLR because the track is further inland and/or elevated on bluffs. However, one segment of track just south of the Orange County border and north of the outlet of San Mateo Creek/Trestles bridge currently is exposed to waves from the 100-year storm. In addition, shoreline erosion could undercut track by mid-century, where it is closest to the shoreline just east of San Onofre Creek. By late-century, some stretches of track fronted by Trails State Beach south of the San Onofre Nuclear Power Plant could become exposed to undercutting as well.

RIVERINE FLOODING/PRECIPITATION

- Major areas of flood vulnerability are in Simi Valley, Burbank, Santa Clarita, Redlands, and Perris Valley. Track, stations, and facilities assets in these areas are within the 100-year floodplain. These areas also are projected to experience an increase in 100-year precipitation mid-century, meaning that the 100-year floodplain could be flooded more frequently.
- At some points, long continuous stretches of track are vulnerable, while in other locations where track crosses a flood channel, short sections may be vulnerable where the 100-year floodplain extends slightly outside the channel. Different types of adaptation strategies likely will need to be considered for these two types of flood vulnerabilities.
- The approaches for several bridges across the system are within the 100-year floodplain, suggesting that these bridges could be vulnerable to overtopping/substructure damage during flood events. However, as this study did not assess depth of flooding versus bridge height, these preliminary findings should be verified. Bridges that were not determined to be potentially exposed to overtopping still may be vulnerable to damage from scour from high velocity flows within a channel or river, even if flooding does not occur.
- Four tunnels (25, 26, 27, and 28) are known to be exposed frequently to flooding during precipitation events currently and have pumps in place to maintain service, although keeping these pumps operational is an annual maintenance challenge.
- Tunnels 26, 27, and 28 are within watersheds projected to have a 6 to 7 percent increase in 100-year precipitation mid-century, compared to historic rates, although this is projected to lower to a 5.5 percent increase over historic rates by late-century. Tunnel 25 is projected to experience increases in 100-year precipitation through late-

century (4 percent increase mid-century, 6 percent increase late-century versus historic rates). The current pump capacity may not be sufficient to handle increased flows during storm events.

- Overall, assets have medium to high sensitivity to flooding because of the potential for high velocity flows to damage structures or for standing water to cause service delays or damage electrical components.

EXTREME HEAT

- Most inland portions of the system are projected to experience temperatures above 110°F annually by mid-century, with portions including most of the San Gabriel, Shortway, Redlands, and Perris Valley subdivisions experiencing temperatures above 115°F. Although this report focuses on mid-century impacts, track with high vulnerability to heat is projected to increase substantially by late-century (Lancaster to Palmdale, Redlands to Ontario, longer stretch of Perris Valley line).
- Track is vulnerable to thermal misalignment under extreme conditions, as evidenced by recent events on the Valley subdivision in September 2020 and June 2021. Because extreme temperatures are projected to increase across all inland parts of the system, impacts potentially could occur anywhere, not just in those areas projected to have the highest temperatures—almost the entire system is rated to have medium vulnerability by mid-century. Large portions of the system are likely to experience frequent conditions requiring Level 2 speed restrictions by mid-century, and almost all the non-coastal areas will be exposed to these extreme temperatures by late-century.
- Stations in inland areas are projected to experience temperatures as high as 115°F, severely affecting both passenger safety and comfort. The most vulnerable stations are those in Los Angeles, Riverside, and San Bernardino counties that do not have adequate amenities (such as platform shading, seating, and/or drinking fountains/hydration stations) to help passengers cope with heat while waiting for trains. High vulnerability stations have been identified on the Ventura, Valley, San Gabriel, Perris Valley, and Redlands subdivisions. Although the four future stations on the Redlands subdivision were not formally included in this vulnerability assessment, they are in an area with projected high exposure to extreme heat.
- Unmanned infrastructure, such as signals, mountain top communications facilities, bridges, culverts, and tunnels, are not projected to have high vulnerability, although extreme heat may contribute to general wear and tear. Track-level communications equipment, such as communication shelters, were determined by SCRRA engineers not to have high vulnerability because of existing air-conditioning equipment with backup power.

WILDFIRE

- Wildfire vulnerability is restricted to portions of the system that are within or adjacent to wildland areas. As most routes are within urban/suburban zones, wildfire vulnerability is confined to specific areas, mostly stretches of the Ventura and Valley subdivisions.
- Assets with the highest wildfire vulnerability are mountain top communications towers. They are sensitive to fire and are in high wildfire exposure areas at the tops of mountains where fire is likely to travel uphill via dry vegetation.
- Most stations and facilities do not have high vulnerability because they either are not in exposed areas or they are surrounded by buffers (parking lots, cleared right-of-way [ROW]), and thus they are unlikely to be directly affected.
- Track vulnerability was determined to be low overall, as track in wildland areas runs through a ROW cleared of vegetation. However, wildfires occurring near a section of track may cause slow orders or delays.

DROUGHT

- Direct impacts from drought were determined to be low system-wide. Although drought frequency and severity are projected to increase across the region, sensitivity of Metrolink assets to damage from drought is low.
- Drought may indirectly increase exposure to other hazards. For example, prolonged drought could increase wildfire hazards, and areas cleared of vegetation by wildfire are more prone to landslides. Oscillations between wet and dry years also may lead to more intense flooding when precipitation occurs. These interactions are discussed qualitatively in the Technical Appendix.

LANDSLIDE/MUDSLIDE

- Landslide and mudslide hazards are local and usually are determined based on site-specific geotechnical studies. The results of this assessment should be interpreted as revealing regional patterns only (not at the asset level).
- This hazard can affect only Metrolink assets, where they are near steep, unstable slopes. Thus, vulnerability is mainly confined to portions of the system running through mountainous terrain along the Ventura, Valley, and Orange County subdivisions. The rest of the system runs on relatively flat land.
- No stations or facilities were determined to be vulnerable to landslide hazards. These asset types are on flat land that is not near landslide/mudslide hazard zones.
- Some bridges and tunnel portals in mountainous areas are vulnerable, especially when bridge foundations or supports are within high exposure areas.
- A review of mountain top communications facilities revealed that none have high vulnerability to landslides or mudslides.

SEISMIC/EARTHQUAKE

- Most track (as well as signals and track-level communications) across the system was determined to have medium vulnerability, with three segments rated as high vulnerability on the Valley subdivision.
- Bridges in high exposure areas with physical attributes contributing to high sensitivity were rated as having high vulnerability. These bridges mainly are on the Ventura, Valley, and San Gabriel subdivisions.
- Tunnel 25 was determined to have high seismic vulnerability.
- A concentration of facilities at the center of the system in Downtown Los Angeles have high seismic vulnerability. Maintenance facilities, such as the Central Maintenance Facility (CMF), contain hazardous materials that could spill because of seismic events and potentially affect adjacent communities.
- Vulnerability of stations is low to medium. Many stations do not have major structural components or buildings, and therefore would be unlikely to suffer major damage. A survey of station managers revealed that no stations are known to have seismic deficiencies, including those with buildings and indoor areas.
- Seismic exposure is lower in mountainous areas than in valleys, where fault lines and liquefaction zones are concentrated. Therefore, mountain top communications facilities have the lowest seismic vulnerability of any asset type.
- These vulnerability statements are based on current seismic hazard. The interaction between climate change and seismic hazard is not well understood, but its influence is unlikely to be significant compared to total seismic hazard.

HOTSPOTS (AREAS OR ASSETS WITH HIGH VULNERABILITY TO MULTIPLE HAZARDS)

- Facilities, track, and the station at the southern end of the Perris Valley subdivision have high vulnerability to both extreme heat and flooding. Similarly, a segment of track in Redlands has high vulnerability to both heat and flooding.
- The Northridge and Simi Valley stations on the Ventura line have high vulnerability to both extreme heat and flooding.
- Portions of coastal track along the bluffs in Orange County have high vulnerability to both SLR and landslides. This combined vulnerability is addressed in greater detail in OCTA's OC Rail Infrastructure Defense against Climate Change Plan.
- Several tunnels have high vulnerability to multiple hazards, including Tunnel 25 (flooding, seismic) and Tunnels 26 and 27 (flooding, landslides).
- Stretches of track on the Valley subdivision running through Santa Clarita have high vulnerability to flooding, earthquakes, and/or landslides, as well as medium vulnerability to extreme heat.
- Bridge 41.260-MT on the Valley subdivision and Bridge 428.630-MT on the Ventura subdivision have high vulnerability to flooding and earthquakes.

SOCIAL VULNERABILITY

- LA Union Station, San Bernardino- Downtown, Downtown Burbank, Van Nuys, Glendale, Lancaster, High Desert, and Perris South catchment areas stand out as having both high proportions and high absolute numbers of households in communities that are both socially vulnerable and transit-dependent.
- SB 535 DACs tend to be more concentrated in denser urban areas while AB 1550 LICs are spread throughout the Metrolink service area. Catchment areas with the highest proportions of households in DACs include Sun Valley (91 percent), Rialto (72 percent) and Commerce (72 percent). Catchment areas with the highest proportions of households in LICs include Sun Valley (87 percent), Lancaster (86 percent), and Cal State LA (82 percent).
- TDCs are present throughout the Metrolink service area. Catchment areas with the highest proportions of households in TDCs include Lancaster (44 percent), Glendale (38 percent), and Van Nuys (36 percent). Catchment areas with the greatest absolute numbers of households in TDCs include LA Union Station, San Bernardino Downtown, and Van Nuys.

Vulnerability Maps

The following pages present maps showing regional vulnerability by hazard. The maps show vulnerability by mid-century, except the maps for landslides/mudslides and seismic hazards, which show current vulnerability. As mentioned previously, vulnerability is a function of both exposure and sensitivity. This is important to consider when viewing the maps because an asset that is exposed to a hazard may not be rated as having high vulnerability if its sensitivity to that hazard is low.

To maximize legibility, two maps are included for each hazard, one showing the vulnerability of track, stations, facilities, and mountain top communication towers, and another showing the vulnerability of bridges and tunnels. The vulnerability of culverts, signals, and track-level communications are not shown on these regional maps because these assets are too numerous to show effectively on regional-scale maps. Information on the vulnerability of these asset types is included in the Vulnerability Profiles. To improve legibility at the regional scale, vulnerable track is shown by milepost—if, for example, a section of track between two MPs is rated as having high vulnerability to flooding, the entire MP segment is colored red on the maps. Unlike the regional maps for other hazards, the single vulnerability map for SLR shows a portion of the system because only the coastal areas are exposed to SLR hazards, and several asset types (such as facilities and tunnels) are not exposed at all to this hazard.

After the vulnerability maps by hazard, a multi-hazard vulnerability map for all asset types is presented, which shows hotspots where assets have high vulnerability to multiple hazards.

Furthermore, a social vulnerability map shows census tracts within Metrolink's catchment areas that are socially vulnerable (defined as meeting the criteria for DACs or LICs is based on State Legislation) and/or TDCs (defined based on a transit-dependency index developed specifically for the CVA).

Figure 5: Sea Level Rise Vulnerability Map for Track, Stations, and Bridges

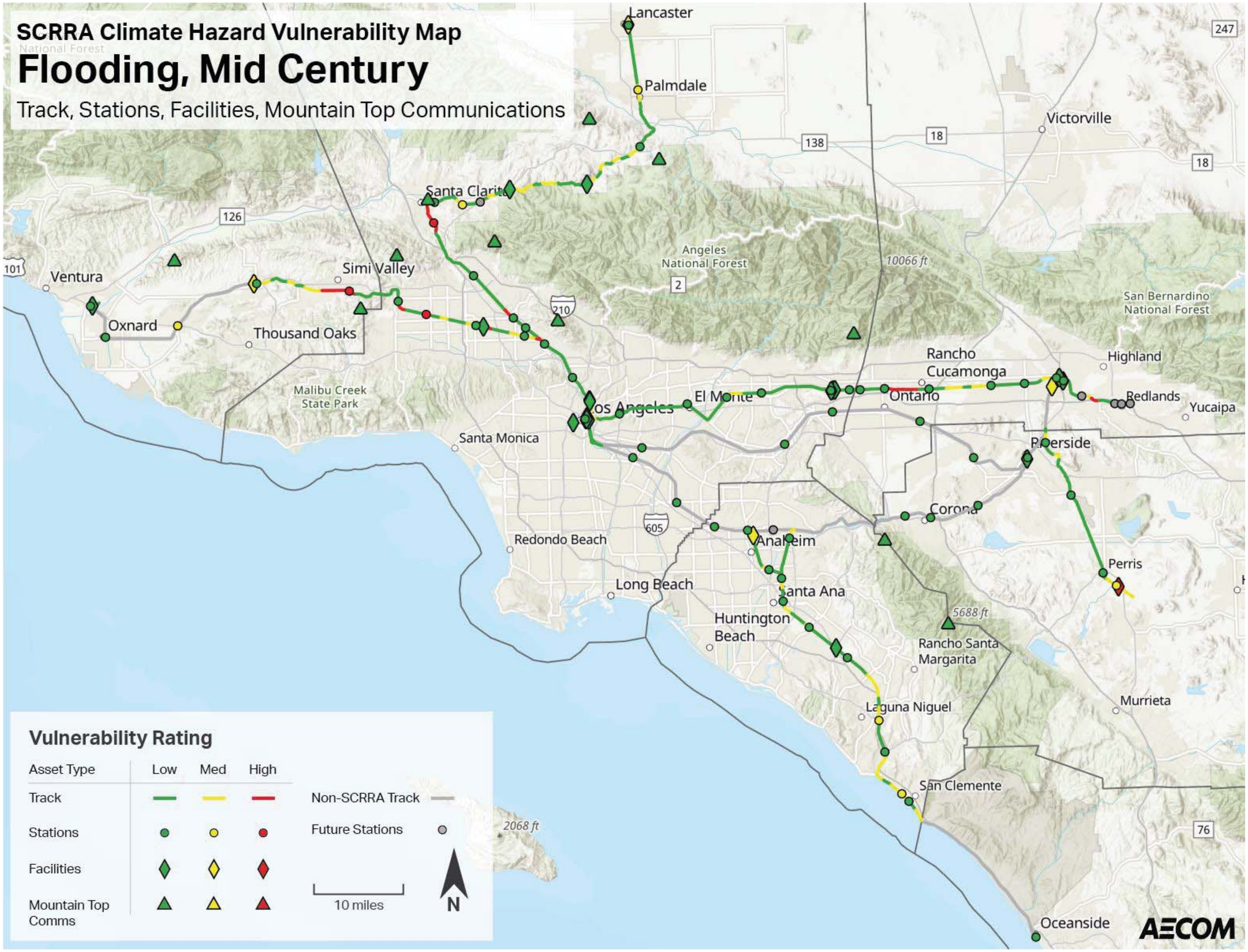


Figure 6: Flooding Vulnerability Map for Track, Stations, Facilities, and Mountain Top Communications

Figure 7: Flooding Vulnerability Map for Bridges and Tunnels

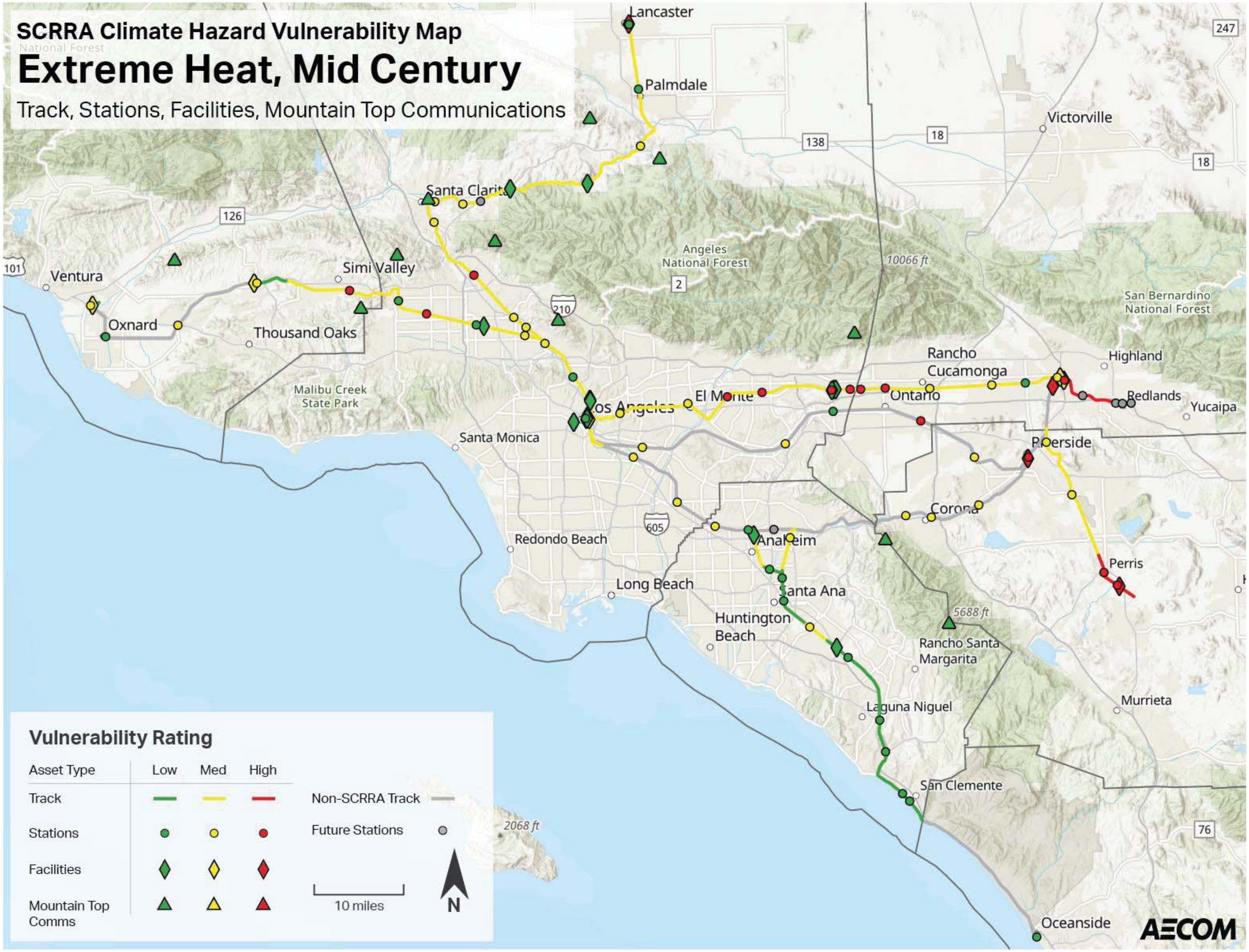


Figure 8: Extreme Heat Vulnerability Map for Track, Stations, Facilities, and Mountain Top Communications

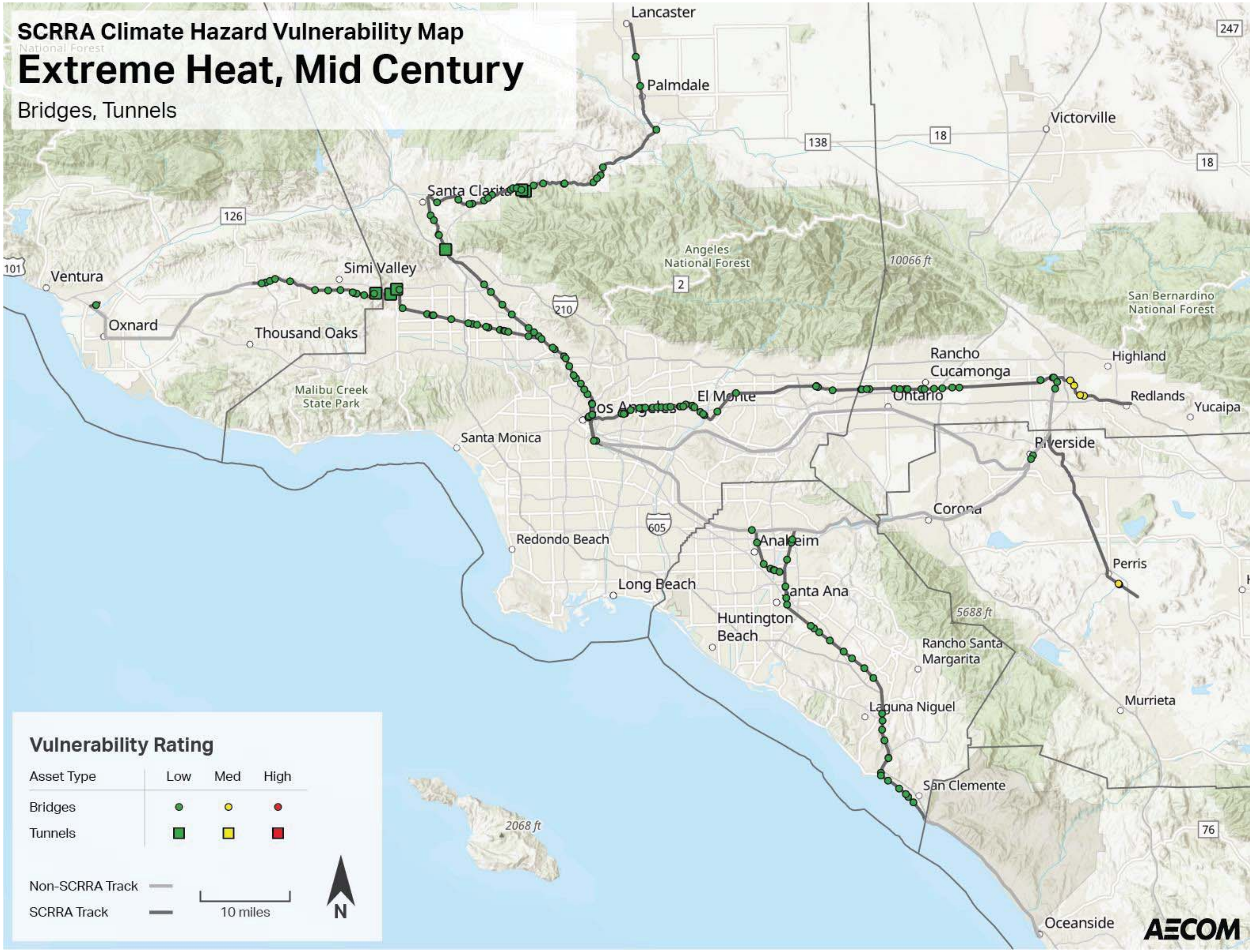


Figure 9: Extreme Heat Vulnerability Map for Bridges and Tunnels

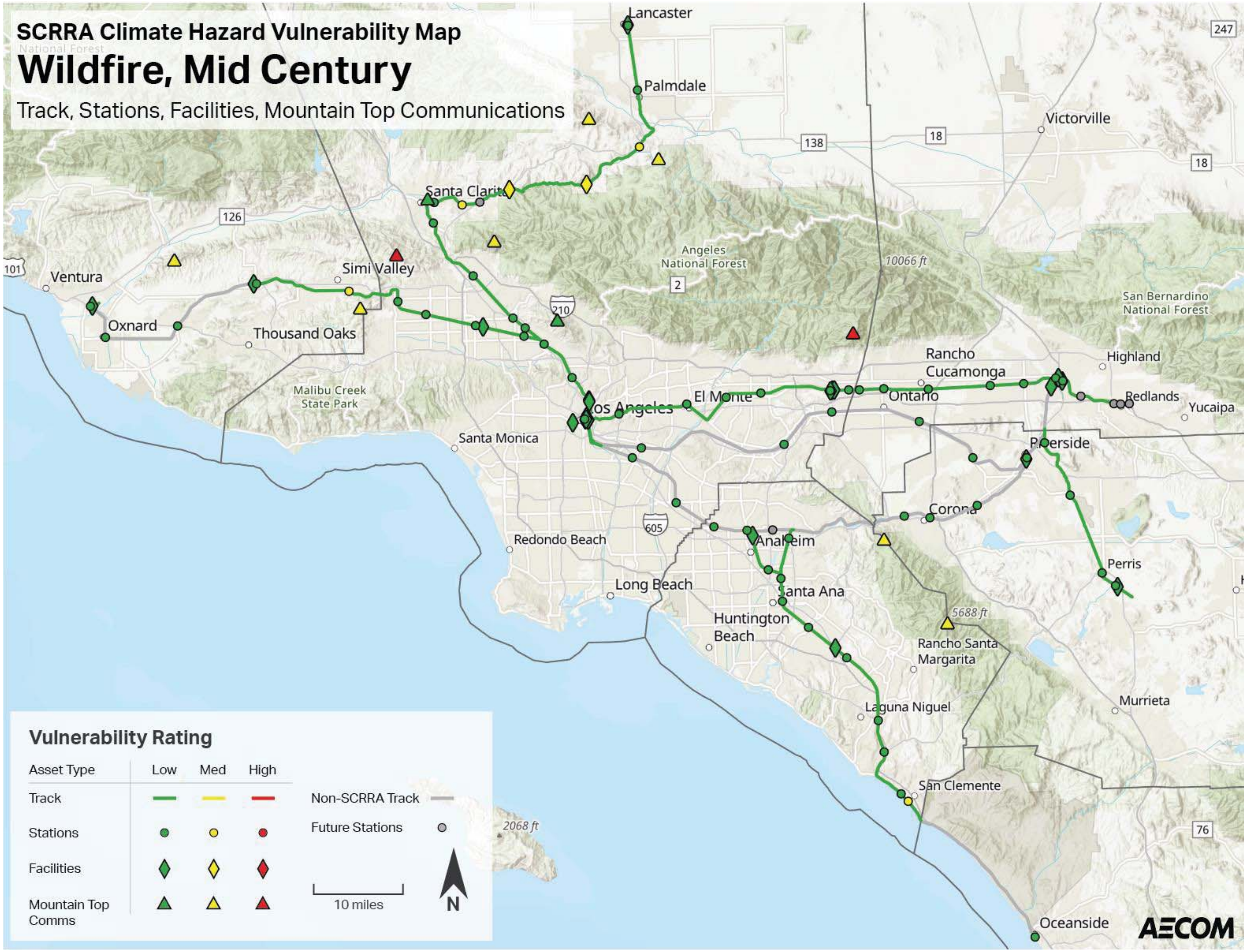


Figure 10: Wildfire Vulnerability Map for Track, Stations, Facilities, and Mountain Top Communications

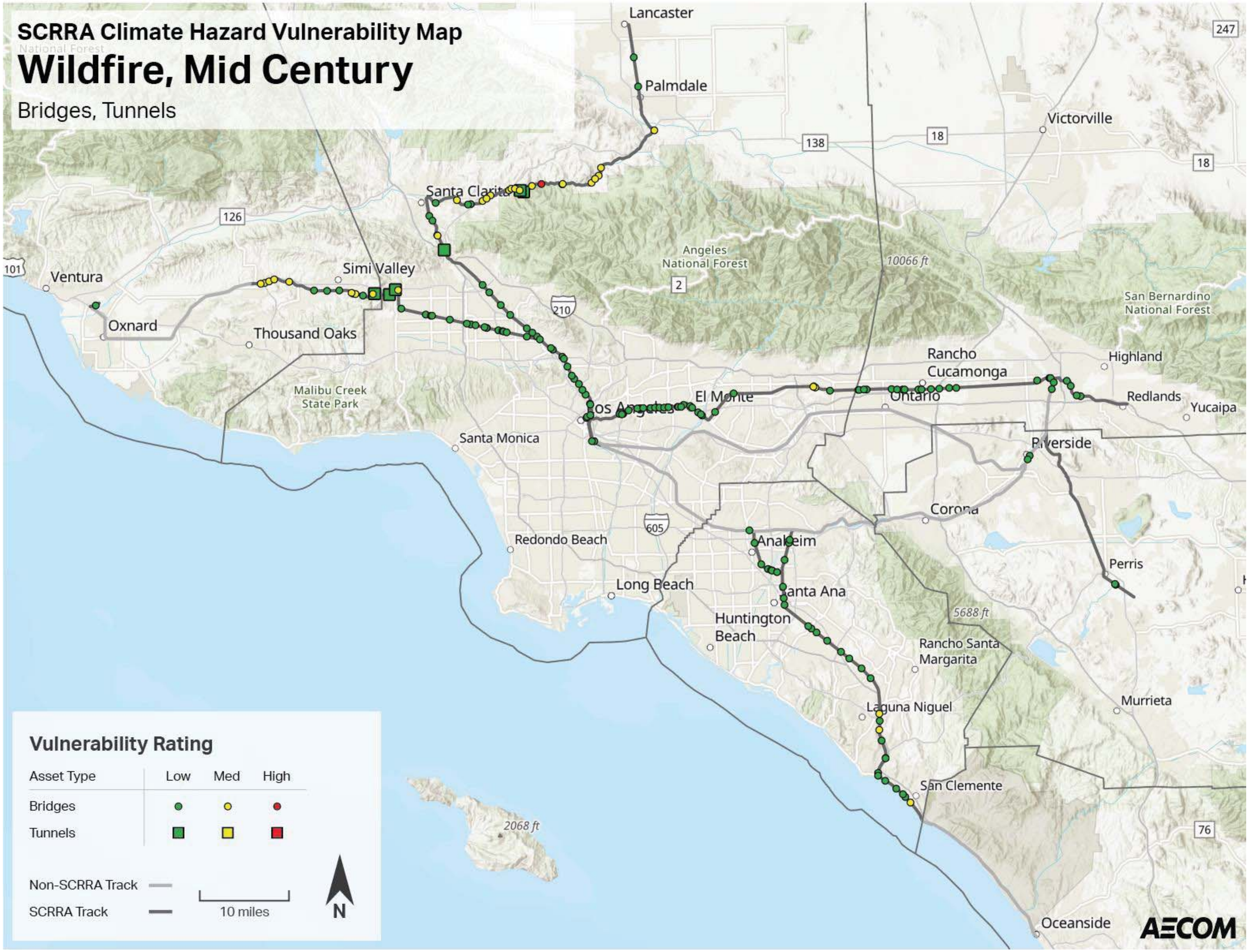


Figure 11: Wildfire Vulnerability Map for Bridges and Tunnels

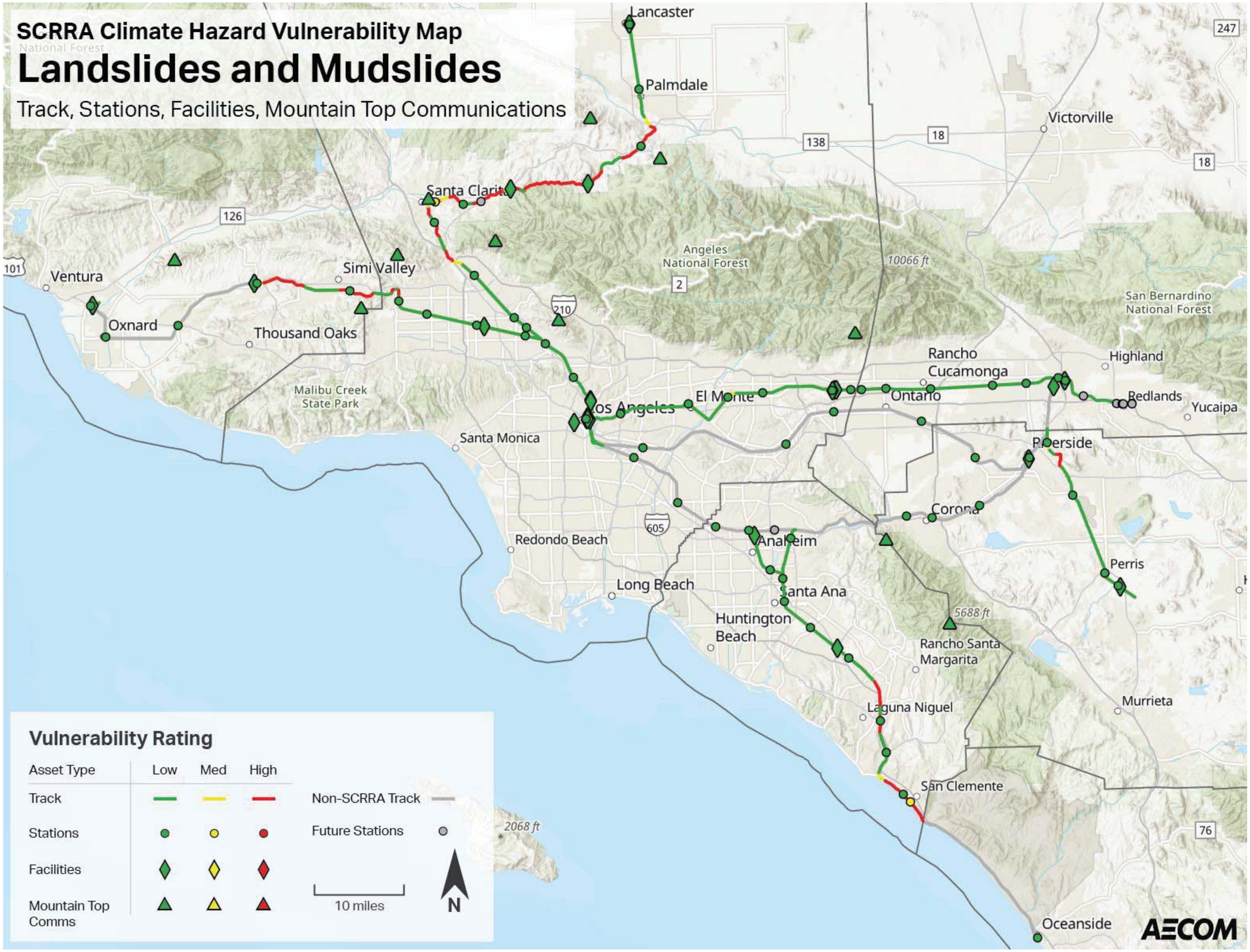


Figure 12: Landslides/Mudslides Vulnerability Map for Track, Stations, Facilities, and Mountain Top Communications

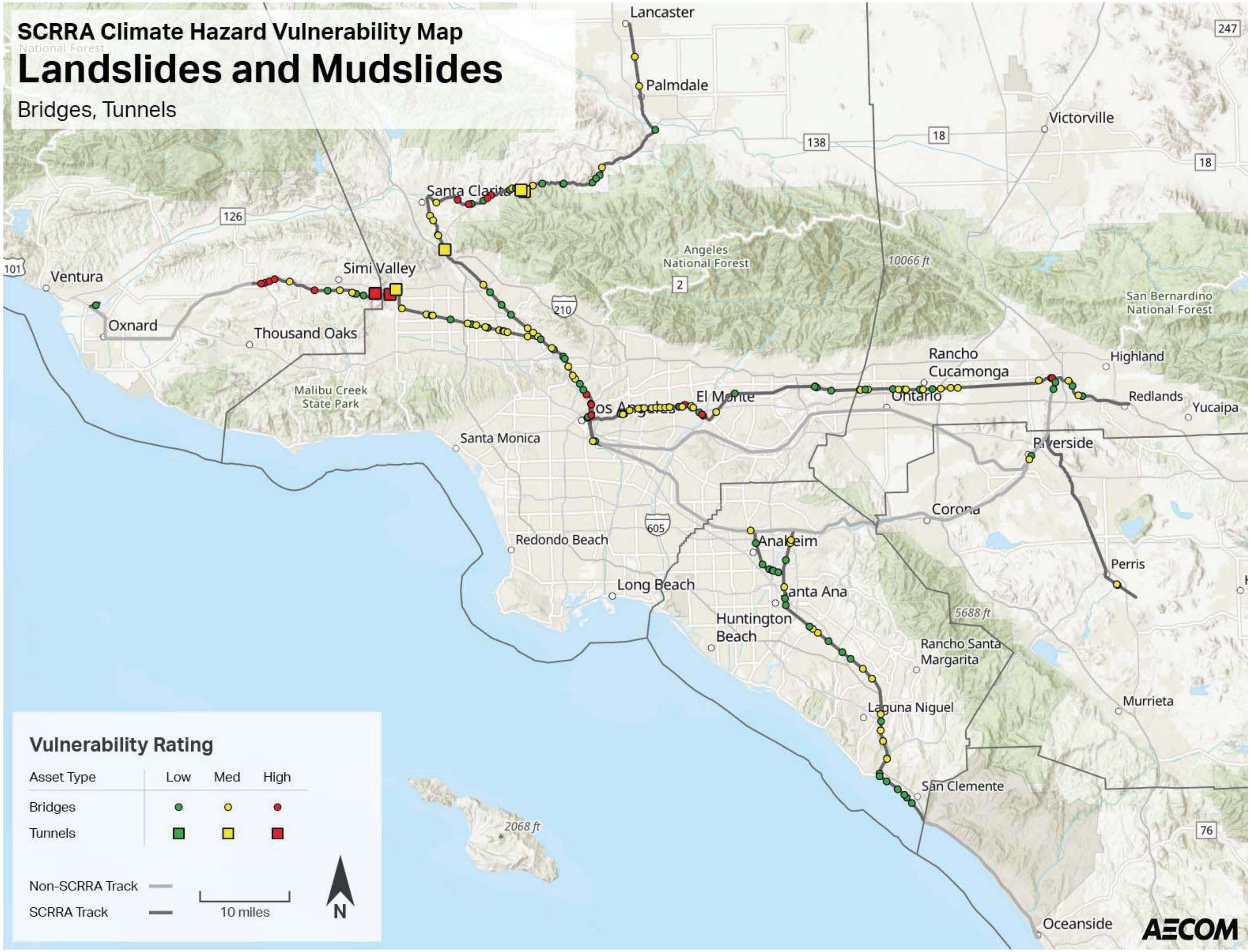


Figure 13: Landslides/Mudslides Vulnerability Map for Bridges and Tunnels

Figure 14: Seismic Vulnerability Map for Track, Stations, Facilities, and Mountain Top Communications

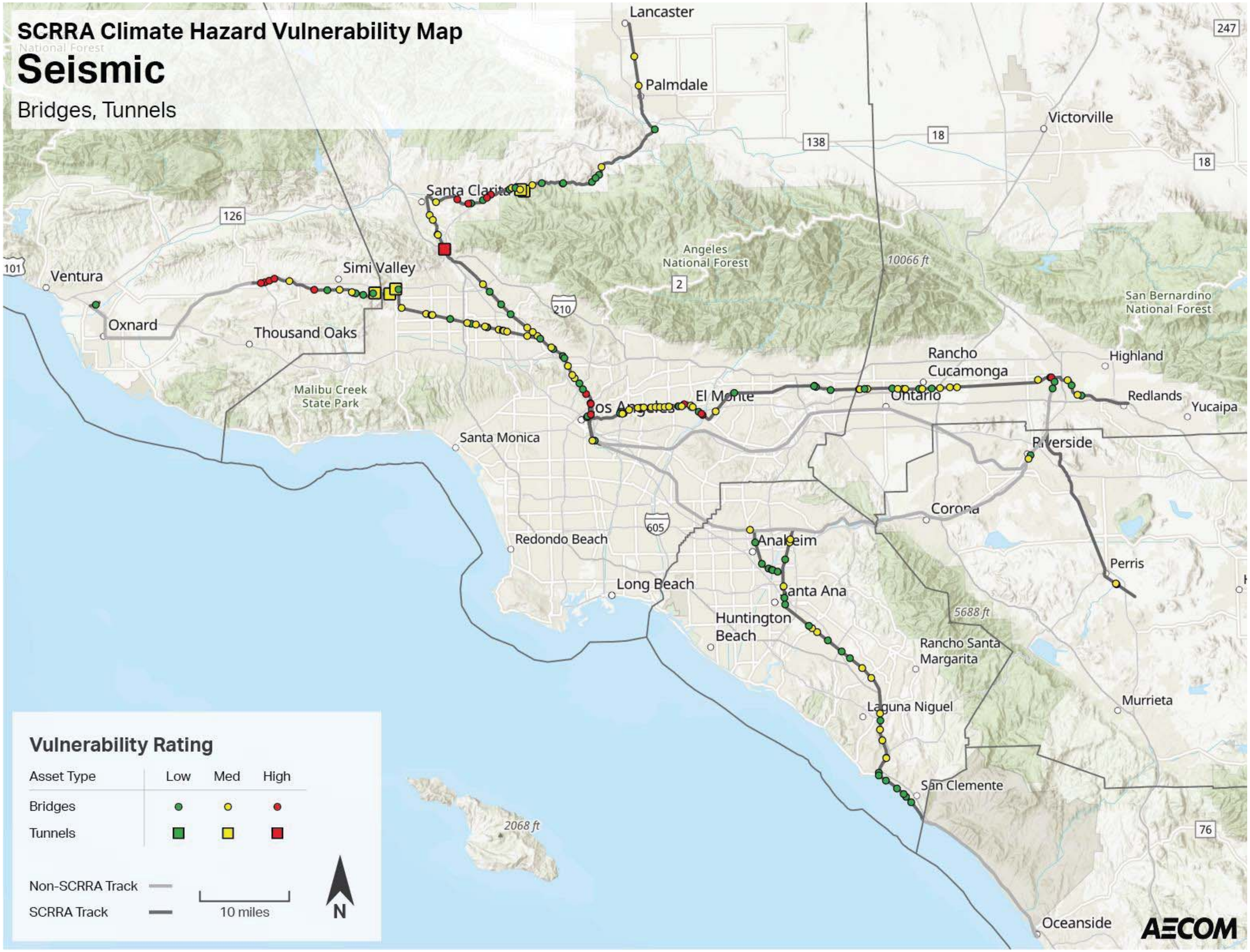


Figure 15: Seismic Vulnerability Map for Bridges and Tunnels

Figure 16: Multi-Hazard Vulnerability Map for All Asset Types

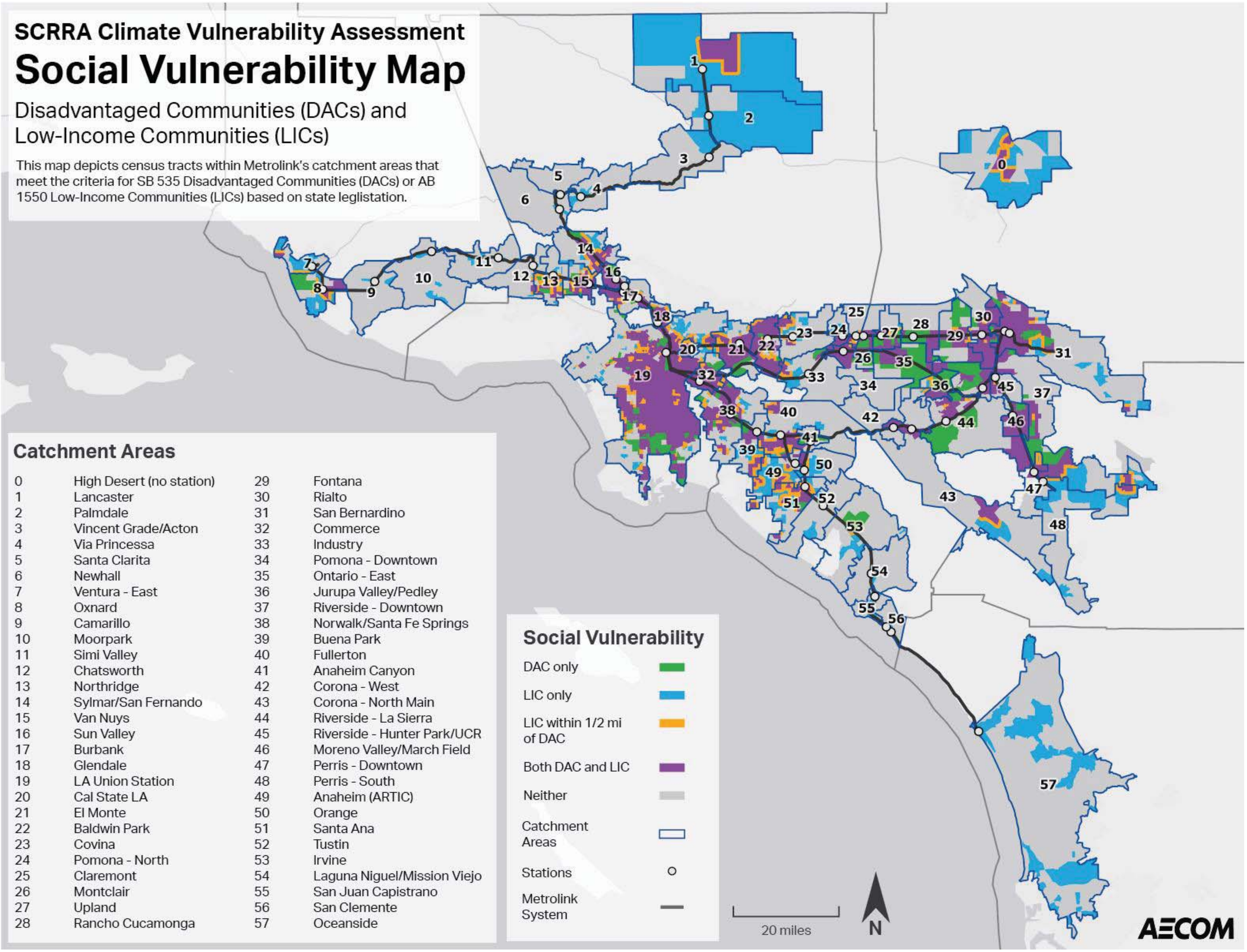


Figure 17: Social Vulnerability Map—DACs and LICs

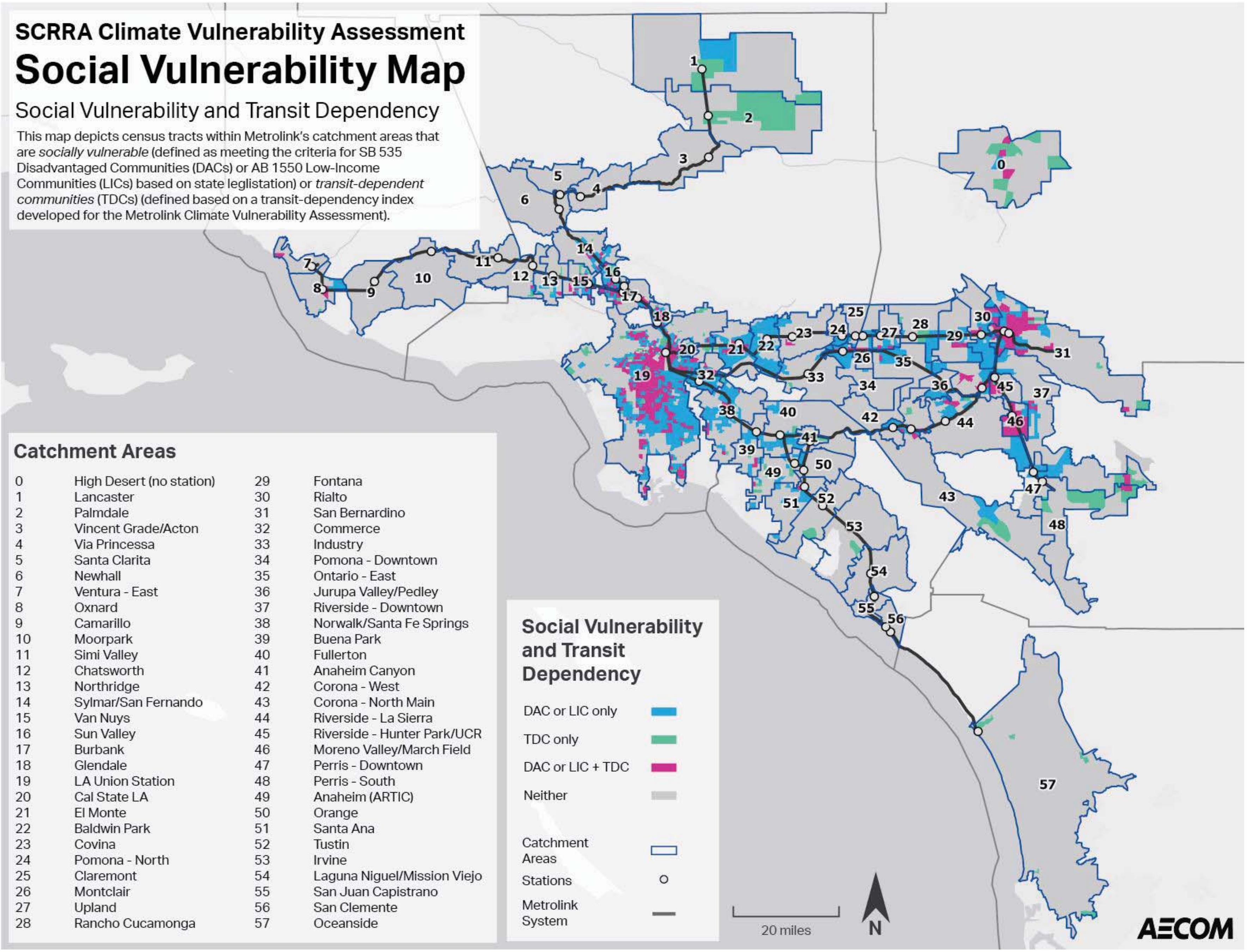


Figure 18: Social Vulnerability and Transit Dependency Map

Asset Vulnerability Profiles

The following sections summarize vulnerability by asset type. Vulnerability profiles are included for the following types of assets: track (including ties and ballast), bridges, tunnels, stations, facilities, signals, culverts, and communications infrastructure (including track-level equipment and mountain top communications towers).

Each profile includes the following:

- **Overview:** a description of what assets are included in the profile.
- **Vulnerability by hazard:** a chart to show the number of assets that have low, medium, and high vulnerability by hazard, as well as a brief discussion of regional patterns.
- **Multi-hazard vulnerability:** a table to identify the assets that are highly vulnerable to two or more hazards.
- **Most vulnerable assets**: lists of every asset that is considered to have a high vulnerability by hazard. For asset types with numerous assets, this information is aggregated into tallies by subdivision.

Vulnerability calculations for each asset were performed using Microsoft Excel, based on outputs from the GIS-based exposure analysis. The tabular outputs are intended to enable SCRRA staff to explore and query specific assets and gain a deeper understanding of the results than just referring to the summaries that are presented in the profiles. Both the GIS and tabular outputs are available to SCRRA staff in an interactive browser-based dashboard, along with GIS data. Some intentional repetition occurs between profiles, for readers who are interested in only one asset type.

Vulnerability Profile: Track

OVERVIEW

This section summarizes the vulnerability of the following mainline SCRRA-owned subdivisions: Valley, Ventura, Montalvo, River, Perris Valley, Orange, Olive, Redlands, San Gabriel, and Shortway. Rialto and Pasadena subdivisions do not carry Metrolink passenger trains, and therefore are not included in this assessment. Track includes railroad track, ties, and ballast. Signals and communications equipment that run along the track are addressed in separate profiles.

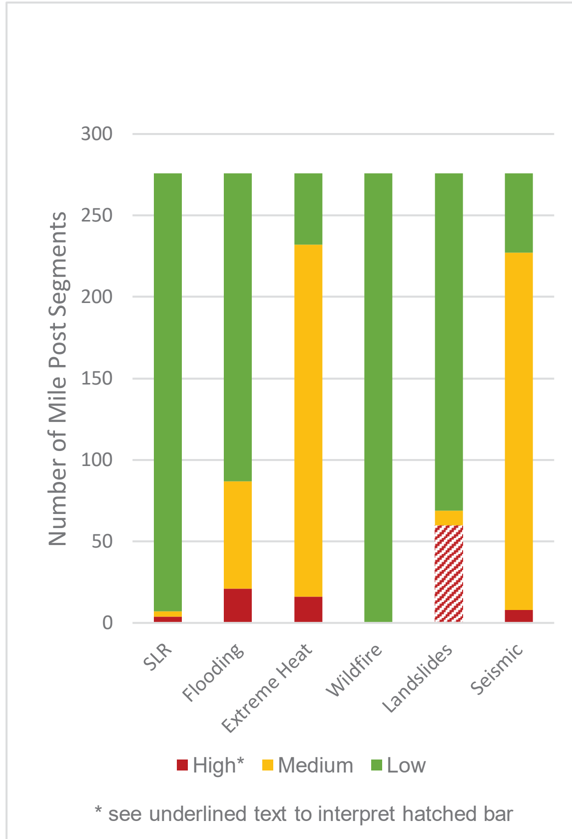


Figure 19: Vulnerability of Track by Hazard (Mid-Century)

VULNERABILITY BY HAZARD

Figure 19 highlights the number of track segments that received high, medium, and low vulnerability scores by hazard. Vulnerability is a composite of exposure (the degree to which an asset is in the hazard area) and sensitivity (the potential for exposure to cause damage/service disruption). For system-wide reporting, SCRRA track was split into segments by mile post (MP). Each MP segment was assigned a score, based on the highest vulnerability score for track between the corresponding two MPs.

At first glance, landslide vulnerability appears to be a big concern (60 track segments have high vulnerability to landslides). However, the bar for high vulnerability to landslides has been modified with hatching to communicate that caution should be taken when interpreting this as indicating that the landslide hazard is higher than flooding or heat. This is because zones marked as having high landslide hazards in input hazard data from USGS are likely to experience landslides less often than, for example, flooding will occur in the 100-year floodplain. Also, although these results are summarized by MP segment, in many cases, only a portion of track between two MP segments actually is exposed to landslides.

A greater portion of track segments received high or medium vulnerability scores to extreme heat, flooding, and seismic hazards, suggesting that these hazards are greater system-wide. No track segments have high vulnerability to wildfires—track was determined to have low sensitivity to wildfires because it runs through a ROW that is kept clear of vegetation (for more information, see the Technical Appendix). Track was found to have low sensitivity to electrical outages because track does not require electricity to function.

MULTI-HAZARD VULNERABILITY

Some segments of track are especially vulnerable because they have high vulnerability to multiple hazards (see Table 7).

Table 7: Track Segments with High Vulnerability to Multiple Hazards

MP Beg	MP End	Sub	County	SLR	Flooding	Heat	Wildfire	Landslides	Seismic
25	26	Valley	Los Angeles	Low	Low	Medium	Low	High	High
33	34	Valley	Los Angeles	Low	Low	Medium	Low	High	High
34	35	Valley	Los Angeles	Low	Low	Medium	Low	High	High
32	33	Valley	Los Angeles	Low	High	Medium	Low	Medium	High
31	32	Valley	Los Angeles	Low	High	Medium	Low	High	Medium
438	439	Ventura	Ventura	Low	High	Medium	Low	High	Medium
437	438	Ventura	Ventura	Low	High	Medium	Low	High	Medium
29	30	Valley	Los Angeles	Low	High	Medium	Low	High	Medium
202	203	Orange	Orange	High	Medium	Low	Low	High	Medium
203	204	Orange	Orange	High	Medium	Low	Low	High	Medium
204	205	Orange	Orange	High	Medium	Low	Low	High	Medium
207	Sub end	Orange	Orange	High	Medium	Low	Low	High	Low

MOST VULNERABLE TRACK SEGMENTS BY HAZARD

Table 8 summarizes which track segments were rated as having high vulnerability for each hazard. The maximum vulnerability score that an asset could receive was 15, and an asset that received a score of 10 or higher was considered to have high vulnerability.

Table 8: Most Vulnerable Track Segments by Hazard

Mile Post Begins	Mile Post Ends	Subdivision	County	Score
Sea Level Rise (Mid-Century)				
202	205	Orange	Orange	10
207	Sub end	Orange	Orange	10
Flooding/Precipitation				
11	12	Valley	Los Angeles	10
15	17	Valley	Los Angeles	10
29	33	Valley	Los Angeles	10
37	41	San Gabriel	San Bernardino	10
435	439	Ventura	Ventura	10
446	447	Ventura	Los Angeles	10
449	450	Ventura	Los Angeles	10
456	457	Ventura	Los Angeles	10
462	End	Ventura	Los Angeles	10
Start	404	Montalvo	Ventura	10
Extreme Heat (Mid-Century)				
Start	1	Shortway	San Bernardino	10
56	65	Redlands	San Bernardino	10
81	82	Perris Valley	Riverside	10
82	83	Perris Valley	Riverside	10

Mile Post Begins	Mile Post Ends	Subdivision	County	Score
83	84	Perris Valley	Riverside	10
84	85	Perris Valley	Riverside	10
85	Sub end	Perris Valley	Riverside	10
Wildfire (Mid-Century)				
No track has high vulnerability to wildfires				
Landslides				
1	3	River	Los Angeles	15
25	30	Valley	Los Angeles	15
31	32	Valley	Los Angeles	15
33	35	Valley	Los Angeles	15
36	38	Valley	Los Angeles	15
39	43	Valley	Los Angeles	15
44	56	Valley	Los Angeles	15
59	61	Valley	Los Angeles	15
68	69	Perris Valley	Riverside	15
189	190	Orange	Orange	15
191	192	Orange	Orange	15
194	195	Orange	Orange	15
204	End	Orange	Orange	15
429	433	Ventura	Ventura	15
439	440	Ventura	Ventura	15
441	444	Ventura	Ventura	15
62	65	Valley	Los Angeles	12
69	70	Perris Valley	Riverside	12
190	191	Orange	Orange	12
193	194	Orange	Orange	12
201	204	Orange	Orange	12
428	429	Ventura	Ventura	12
437	439	Ventura	Ventura	12
440	441	Ventura	Ventura	12
444	445	Ventura	Los Angeles	12
Seismic				
21	23	Valley	Los Angeles	10
25	26	Valley	Los Angeles	10
32	35	Valley	Los Angeles	10
65	67	Valley	Los Angeles	10

Vulnerability Profile: Bridges

OVERVIEW

This section summarizes the vulnerability of bridges on SCRRA-owned subdivisions. Bridges on non-SCRRA-owned subdivisions (San Bernardino, Los Angeles, San Diego) as well as non-passenger rail subdivisions (Pasadena) are not included. In total, 246 SCRRA bridges were assessed.

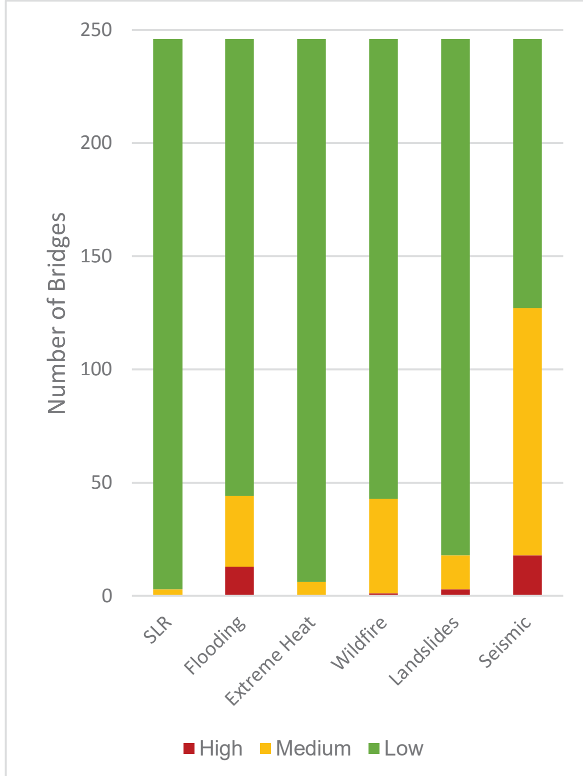


Figure 20: Vulnerability of Bridges by Hazard (Mid-Century)

VULNERABILITY BY HAZARD

Figure 20 highlights the number of bridges that received high, medium, and low vulnerability scores by hazard. Vulnerability is a composite of exposure (the degree to which an asset is in the hazard area) and sensitivity (the potential for exposure to cause damage/service disruption). Sensitivity was rated on physical attributes, such as bridge type and condition ratings.

Seismic vulnerability appears to be the biggest concern system-wide (36 bridges have high vulnerability and 149 have medium vulnerability to earthquakes). A small number of bridges also have high vulnerability to flooding, wildfire, and landslides. No bridges have high vulnerability to heat. All bridges were determined to have low sensitivity to electrical outages because they do not require electricity to function.

MULTI-HAZARD VULNERABILITY

Some bridges are especially vulnerable because they have high vulnerability to multiple hazards. Table 9 highlights the bridges with high vulnerability to multiple hazards.

Table 9: Bridges with High Vulnerability to Multiple Hazards

Bridge No.	Subdivision	County	SLR	Flooding	Heat	Wildfire	Landslides	Seismic
428.630-MT	Ventura	Ventura	Low	High	Low	Medium	Medium	High
0.800-LT2, ST	River	Los Angeles	Low	High	Low	Low	Low	High
41.260-MT	Valley	Los Angeles	Low	High	Low	Medium	Low	High

MOST VULNERABLE BRIDGES BY HAZARD

Table 10 summarizes which bridges were rated as having high vulnerability for each hazard. The maximum vulnerability score that an asset could receive was 15, and an asset that received a score of 10 or higher was considered to have high vulnerability.

Table 10: Most Vulnerable Bridges by Hazard

Bridge	Subdivision	County	Score
Sea Level Rise (Mid-Century)			
No bridges have high vulnerability to sea level rise			
Flooding (Mid-Century)			
30.940-MT	Valley	Los Angeles	15
436.960-MT	Ventura	Ventura	15
38.900-MT	San Gabriel	San Bernardino	15
39.200-MT	San Gabriel	San Bernardino	15
428.630-MT	Ventura	Ventura	12
41.260-MT	Valley	Los Angeles	12
0.800-LT2, ST	River	Los Angeles	12
192.800-ST	Orange	Orange	12
858-MT	Perris Valley	Riverside	12
84.980-MT	Perris Valley	Riverside	12
173.600-MT2	Orange	Orange	12
188.500-MT2	Orange	Orange	12
446.400-MT	Ventura	Los Angeles	10
Extreme Heat (Mid-Century)			
No bridges were rated as having high vulnerability to heat			
Wildfire (Mid-Century)			
47.830-MT	Valley	Los Angeles	12
Landslides/Mudslides			
195.800-MT	Orange	Orange	15
44.940-MT	Valley	Los Angeles	12
205.900-MT	Orange	Orange	12
20500-MT	Orange	Orange	12
Seismic			
428.630-MT	Ventura	Ventura	12
427.700-MT	Ventura	Ventura	12
40.660-MT	Valley	Los Angeles	12
428.150-MT	Ventura	Ventura	12
429.260-MT	Ventura	Ventura	12
36.980-MT	Valley	Los Angeles	12
41.260-MT	Valley	Los Angeles	12
3.350-MT1	River	Los Angeles	12
3.350-MT2	River	Los Angeles	12
0.800-LT2, ST	River	Los Angeles	12
480.820-MT1, MT2	River	Los Angeles	12
11.774-MT	San Gabriel	Los Angeles	12
14.160-MT(UPRR)	San Gabriel	Los Angeles	12
55.710-MT	San Gabriel	San Bernardino	12
14.160-MT	San Gabriel	Los Angeles	12
38.430-MT	Valley	Los Angeles	12

Bridge	Subdivision	County	Score
434.120-MT	Ventura	Ventura	12
55.630-MT	San Gabriel	San Bernardino	12
192.800-ST	Orange	Orange	12

Vulnerability Profile: Tunnels

OVERVIEW

This section summarizes the vulnerability of SCRRA-owned tunnels. In total six tunnels were assessed: tunnels 18, 19 and 25 on the Valley subdivision and tunnels 26, 27, and 28 on the Ventura sub.

VULNERABILITY BY HAZARD

Figure 21 highlights the number of tunnels that received high, medium, and low vulnerability scores by hazard. Vulnerability is a composite of exposure (the degree to which an asset is in the hazard area) and sensitivity (the potential for exposure to cause damage/service disruption). Sensitivity was rated on a review of physical attributes of each tunnel as reflected in the Rail Asset Management System (RAMS) database.

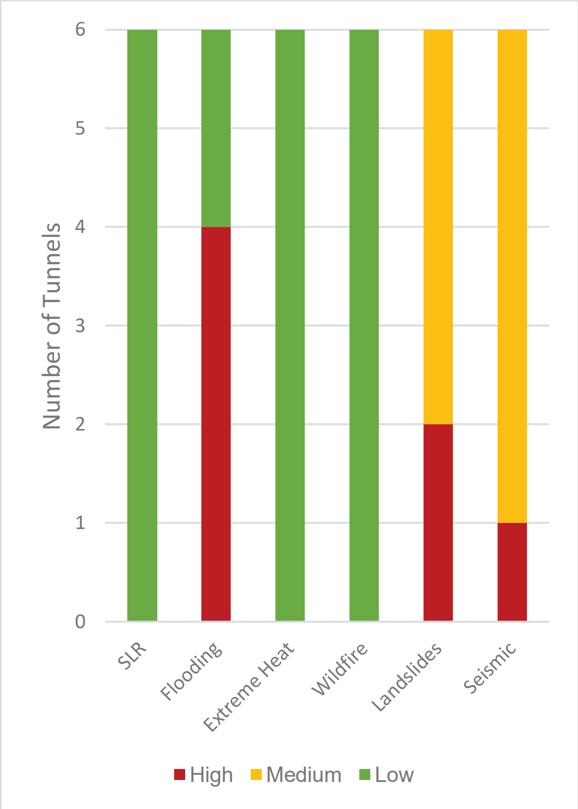


Figure 21: Vulnerability of Tunnels (Mid-Century)

Flood vulnerability appears to be the biggest concern for tunnels. Tunnels 25, 26, 27, and 28 are known to be highly exposed to flooding currently, and tunnels were rated as having medium sensitivity to flooding, so their combined vulnerability score for riverine flooding was high. Landslide and seismic vulnerability also are a concern because all six tunnels had either high or medium vulnerability to these hazards. No tunnels had medium or high vulnerability to heat or wildfire, because of tunnels receiving low sensitivity scores for both hazards. None of the tunnels would be exposed to SLR.

MULTI-HAZARD VULNERABILITY

Some tunnels would be especially vulnerable because they would have high vulnerability to multiple hazards. Table 11 highlights tunnels with high vulnerability for multiple hazards.

Table 11: Tunnels with High Vulnerability to Multiple Hazards

Tunnel No.	Subdivision	County	SLR	Flooding	Heat	Wildfire	Landslides	Seismic
25	Valley	Los Angeles	Low	High	Low	Low	Medium	High
26	Ventura	Los Angeles	Low	High	Low	Low	High	Medium
27	Ventura	Los Angeles	Low	High	Low	Low	High	Medium

MOST VULNERABLE TUNNELS BY HAZARD

Table 12 summarizes which tunnels were rated as having high vulnerability for each hazard. The maximum vulnerability score that an asset could receive was 15, and an asset that received a score of 10 or higher was considered to have high vulnerability.

Table 12: Most Vulnerable Tunnels By Hazard

Tunnel No	Subdivision	County	Score
Sea Level Rise (Mid-Century)			
No tunnels were rated as having high vulnerability to SLR.			
Flooding (Mid-Century)			
25	Metrolink	Valley	10
26	Metrolink	Ventura	10
27	Metrolink	Ventura	10
28	Metrolink	Ventura	10
Extreme Heat (Mid-Century)			
No tunnels were rated as having high vulnerability to heat.			
Wildfire (Mid-Century)			
No tunnels were rated as having high vulnerability to wildfire.			
Landslides/Mudslides			
26	Ventura	Los Angeles	10
27	Ventura	Los Angeles	10
Seismic			
25	Metrolink	Valley	12

Vulnerability Profile: Stations

OVERVIEW

This section summarizes the vulnerability of stations serving Metrolink riders. Although the stations are not owned directly by Metrolink, they are an integral part of the passenger rail system, and SCRRA has some influence on their design and operational standards. In total, 62 stations were assessed, including those on subdivisions where the track is not owned by SCRRA.

VULNERABILITY BY HAZARD

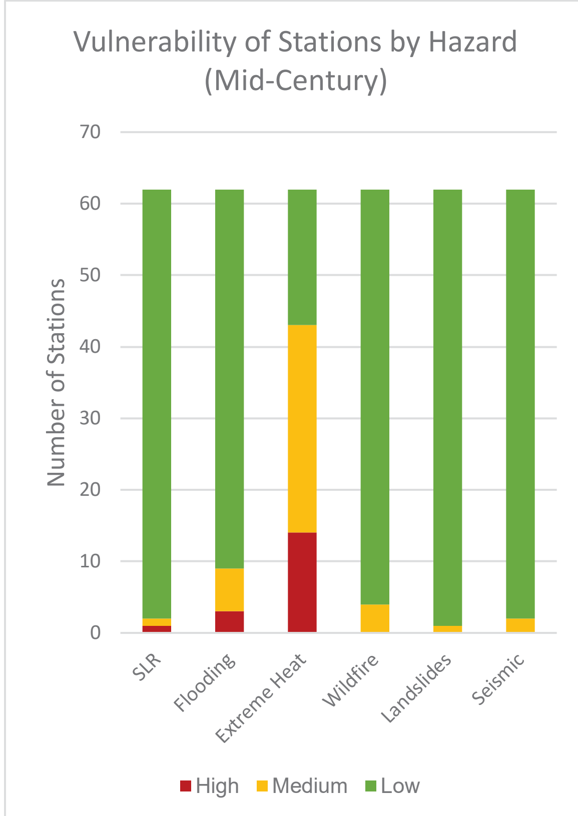


Figure 22: Vulnerability of Stations by Hazard (Mid-Century)

Figure 22 highlights the number of stations that received high, medium, and low vulnerability scores by hazard. Vulnerability is a composite of exposure (the degree to which an asset is in the hazard area) and sensitivity (the potential for exposure to cause damage/service disruption). Sensitivity to some hazards was rated uniformly for all stations, but for some other hazards, it was rated on information on physical attributes of the stations, collected from the station survey. For sensitivity to heat, the ratings were focused more on potential impacts on passenger safety/comfort than on the potential for physical damage to the stations themselves.

Vulnerability to extreme heat was the greatest concern system-wide, with 14 stations rated as having high vulnerability and 29 stations rated as having medium vulnerability. These scores were driven both by high exposure to extreme heat and the lack of amenities that help riders cope with heat at some stations, contributing to medium and high sensitivity scores. Although the four future stations on the Redlands subdivision were not formally included in this vulnerability assessment, they are in an area with projected high exposure to extreme heat.

Three stations would have high vulnerability to flooding. No stations would have high vulnerability to wildfire or landslides because they are not exposed to these hazards. No stations would have high vulnerability to seismic hazards because no stations with high or medium sensitivity are in areas of high exposure. Based on the results of the station survey, no stations have known seismic deficiencies, and many do not have larger structures or indoor areas. All stations were determined to have a low sensitivity to electrical outages because trains still can operate through the station during a station-specific outage.

MULTI-HAZARD VULNERABILITY

Some stations would be especially vulnerable because they have high vulnerability to multiple hazards. Table 13 highlights the two stations with high vulnerability for multiple hazards.

Table 13: Stations with High Vulnerability to Multiple Hazards

Station	Subdivision	County	SLR	Flooding	Heat	Wildfire	Landslides	Seismic
Simi Valley	Ventura	Ventura	Low	High	High	Medium	Low	Low
Northridge	Ventura	Los Angeles	Low	High	High	Low	Low	Low

MOST VULNERABLE STATIONS BY HAZARD

Table 14 summarizes which stations were rated as having high vulnerability for each hazard. The maximum vulnerability score that an asset could receive was 15, and an asset that received a score of 10 or higher was considered to have high vulnerability.

Table 14: Most Vulnerable Stations by Hazard

Station	Subdivision	County	Score
Sea Level Rise (Mid-Century)			
San Clemente Pier	San Diego	San Diego	10
Flooding (Mid-Century)			
Simi Valley	Ventura	Ventura	10
Santa Clarita/Newhall	Valley	Los Angeles	10
Northridge	Ventura	Los Angeles	10
Extreme Heat (Mid-Century)			
Sylmar/San Fernando	Valley	Los Angeles	12
Simi Valley	Ventura	Ventura	12
Northridge	Ventura	Los Angeles	12
Claremont	San Gabriel	Los Angeles	12
Pomona (North)	San Gabriel	Los Angeles	12
East Ontario	Los Angeles	San Bernardino	12
San Bernardino Downtown	San Bernardino	Riverside	12
Baldwin Park	San Gabriel	Los Angeles	12
Covina	San Gabriel	Los Angeles	12
Montclair	San Gabriel	San Bernardino	12
Upland	San Gabriel	San Bernardino	12
Riverside Downtown	Redlands	San Bernardino	10
Perris–South	Perris Valley	Riverside	10
Perris Downtown	Perris Valley	Riverside	10
Wildfire Landslides/Mudslides, Seismic (Mid-Century),			
No stations have high vulnerability to wildfires, landslides or earthquakes.			

Vulnerability Profile: Facilities

OVERVIEW

This section summarizes the vulnerability of SCRRA facilities. In total, 24 facilities were assessed. The facilities included storage yards and maintenance shops, as well as five “priority” facilities that were assessed in greater detail because of their significance: the Eastern Maintenance Facility (EMF), CMF, Dispatch and Operations Center (DOC), Metrolink Operations Center (MOC), and Metrolink Headquarters (HQ).

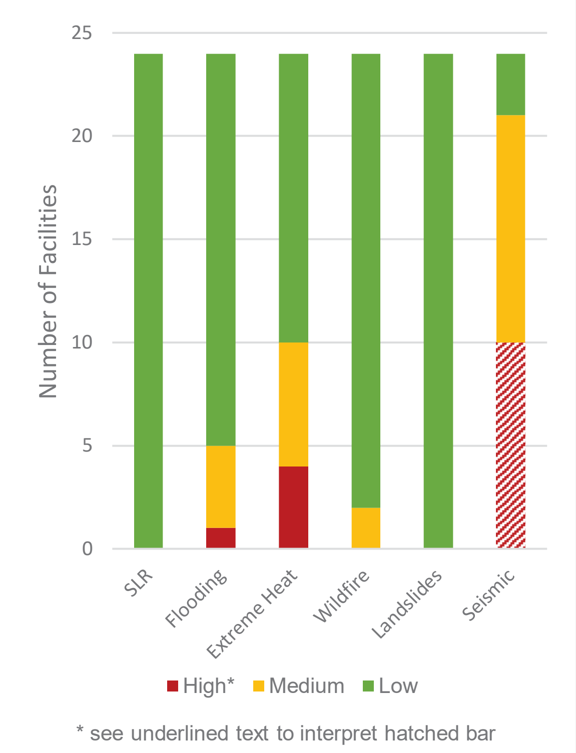


Figure 23: Vulnerability of Facilities (Mid-Century)

VULNERABILITY BY HAZARD

Figure 23 highlights the number of facilities that received high, medium, and low vulnerability by hazard. Vulnerability is a composite of exposure (the degree to which an asset is in the hazard area) and sensitivity (the potential for exposure to cause damage/service disruption). For the critical facilities, sensitivity was rated individually, while the less critical assets were split into categories, and each category was rated on common physical attributes.

Overall, the seismic vulnerability of facilities was relatively high, with almost half rated as having high vulnerability and only two rated as having low vulnerability. However, the high vulnerability section of the seismic bar has been updated with hatching to reflect the assumption that SCRRA facilities are up to code and do not have any major known seismic deficiencies. Of the priority facilities, the Metrolink HQ and CMF were rated as having high seismic vulnerability, and the EMF was rated as having high vulnerability to extreme heat. Most facilities were determined to have medium sensitivity to electrical outages; however, a more in-depth assessment of priority facilities is summarized next.

SENSITIVITY OF PRIORITY FACILITIES TO ELECTRICAL OUTAGES

During the vulnerability assessment, the project team determined that the sensitivity of priority facilities to electrical outages would have the greatest influence on how the overall system would react to electrical outages. Therefore, a detailed review of each facility’s power needs and backup power systems was completed (see the Technical Appendix). Rating relative exposure to electrical outages across the system was not possible, and therefore these ratings are for sensitivity only.

Table 15: Sensitivity of Priority Facilities to Electrical Outages

Facility Name	Power Needs	Backup Power	Sensitivity Rating	Explanation
Central Maintenance Facility (CMF)	The CMF performs maintenance—including servicing and fueling, light and medium repairs, and heavy repairs—for the Metrolink fleet and relies on power for critical operations to perform daily or scheduled maintenance.	Two backup power generators are on site that are assumed to cover all necessary operational loads.	Low to medium	If the facility requires uninterruptible power, the facility is at risk of losing power while the generators ramp up when an outage occurs.
Eastern Maintenance Facility (EMF)	The EMF performs some servicing, fueling, and light repairs for the Metrolink fleet, but all heavy repairs and preventative maintenance are completed at the CMF. Operations rely on power to support maintenance demand for the CMF.	A backup generator is in place, assumed to cover all necessary operational loads.	Low	If the generator unprecedentedly fails, it is assumed that critical operations could relocate to the CMF and continue functioning.
Dispatch and Operations Center (DOC)	Administrative facility that is comprised of office space, the primary dispatch center, primary data center (and server room) for all Metrolink applications and devices, Metrolink lab, and Security and Operations Center (SOC). The center includes critical equipment that supports Metrolink communications requires continuous power.	Two backup power generators are connected to the facility.	High	With an abrupt loss of power, communications equipment could become damaged, requiring replacement without an uninterruptible power supply (UPS) system in place, but partial communications presumably could be rerouted through the MOC, and thus not all communications within Metrolink would be severed.
Metrolink Operations Center (MOC)	The MOC houses the SCRRA Engineering Office and the secondary dispatch office and data center. It includes critical equipment that supports Metrolink communications and requires continuous power.	A generator and UPS system are in place for the data center.	High	Backup systems for the data center need replacement, posing a risk to indefinite loss of power, equipment damage, and immediate loss of operations. The primary dispatch center at the DOC and the alternative center at this facility are electrically supplied from the same Southern California Edison (SCE) circuit; therefore, the DOC and MOC would experience the same electrical outages.
Metrolink Headquarters (HQ)	HQ uses power to complete administration, planning, and command tasks for Metrolink.	No backup power is available.	High	The facility and communications equipment require power to operate, and no backup power generation is allocated to this facility.

MULTI-HAZARD VULNERABILITY

Some assets are especially vulnerable because they have high vulnerability to multiple hazards. Table 16 shows that the South Perris facility has high vulnerability for multiple hazards.

Table 16: Facilities with High Vulnerability to Multiple Hazards

Facility	Sub	County	SLR	Flooding	Heat	Wildfire	Landslides	Seismic
South Perris	Perris	Riverside	Low	High	High	Low	Low	Medium

MOST VULNERABLE FACILITIES BY HAZARD

Table 17 summarizes which facilities were rated as having high vulnerability for each hazard. The maximum vulnerability score that an asset could receive was 15, and an asset that received a score of 10 or higher was considered to have high vulnerability. Priority facilities are highlighted in bold.

Table 17: Most Vulnerable Facilities to Hazard

Facility	Subdivision	County	Score
Sea Level Rise (Mid-Century)			
No facilities are vulnerable to sea level rise.			
Flooding (Mid-Century)			
South Perris	Perris Valley	Riverside	12
Extreme Heat (Mid-Century)			
South Perris	Perris Valley	Riverside	15
Lancaster	Valley	Los Angeles	12
Eastern Maintenance Facility	Shortway	San Bernardino	12
Riverside	San Bernardino	Riverside	12
Wildfire (Mid-Century)			
No facilities have high vulnerability to wildfires.			
Landslides/Mudslides			
No facilities have high vulnerability to landslides.			
Seismic			
Central Maintenance Facility	River	Los Angeles	12
Metrolink Headquarters	River	Los Angeles	12
Los Angeles Union Station	River	Los Angeles	12
Keller Yard	River	Los Angeles	12
Moorpark	Ventura	Ventura	12
East Ventura/Montalvo	Montalvo	Ventura	12
Lang Yard	Valley	Los Angeles	12
Dayton Yard	River	Los Angeles	12
Los Angeles Union Passenger Terminal	River	Los Angeles	12
Los Angeles Union Station Positive Train Control Simulator Building	River	Los Angeles	12
Bootlegger	Valley	Los Angeles	12

Vulnerability Profile: Signals

OVERVIEW

This section summarizes the vulnerability of crossing and railroad signals on the following SCRRA-owned subdivisions: Valley, Ventura, Montalvo, River, Perris Valley, Orange, Olive, Redlands, San Gabriel, Shortway, and a portion of San Bernardino. Rialto and Pasadena subdivisions do not carry Metrolink passenger trains, and therefore are not included in this assessment.

VULNERABILITY BY HAZARD

Figure 24 highlights the number of track segments for which signals received high, medium, and low vulnerability scores by hazard. Vulnerability is a composite of exposure (the degree to which an asset is in the hazard area) and sensitivity (the potential for exposure to cause damage/service disruption). Because of the large number of individual signals and their relatively even distribution across the system, the exposure of signals was assessed using GIS data for track linework, but with different sensitivity ratings specific to signals.

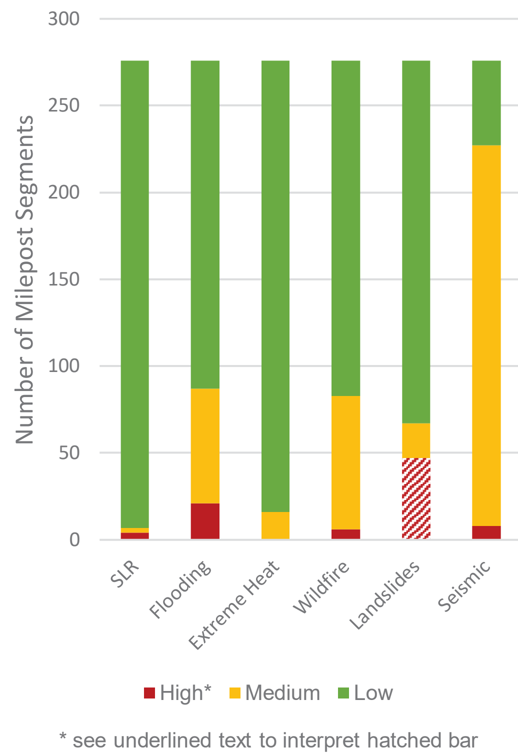


Figure 24: Vulnerability of Signals (Mid-Century)

At first glance, landslide vulnerability appears to be a big concern (47 track segments have high vulnerability to landslides). However, the bar for high vulnerability to landslides has been modified with hatching to communicate that caution should be taken when interpreting this as indicating that landslide vulnerability is especially high. This is because zones designated as having high landslide hazard in the input hazard data from USGS are likely to experience landslides less often than, for example, flooding occurring in the 100-year floodplain. Also, although these results are summarized by MP segment, in some cases the exposed portion of track may not include signals. However, as signals are necessary for the track to function, they should not be assessed completely separately from the track that they serve.

A greater portion of track segments received high or medium vulnerability scores to seismic hazards, suggesting this hazard is greater system-wide. For 21 track segments, signal vulnerability was rated as high for flooding. Signals were determined to have medium sensitivity to electrical outages because they require electricity to function but are supplied with backup power.

MULTI-HAZARD VULNERABILITY

Signals on some track segments are especially vulnerable because they have high vulnerability to multiple hazards. Table 18 highlights track segments where signals may have high vulnerability for multiple hazards.

Table 18: Signals with High Vulnerability to Multiple Hazards

MP Beg	MP End	Sub	County	SLR	Flooding	Heat	Wildfire	Landslides	Seismic
25	26	Valley	Los Angeles	Low	Low	Low	Medium	High	High
33	34	Valley	Los Angeles	Low	Low	Low	Low	High	High
34	35	Valley	Los Angeles	Low	Low	Low	Low	High	High
31	32	Valley	Los Angeles	Low	High	Low	Low	High	Medium
32	33	Valley	Los Angeles	Low	High	Low	Low	Medium	High
46	47	Valley	Los Angeles	Low	Medium	Low	High	High	Medium
48	49	Valley	Los Angeles	Low	Medium	Low	High	High	Medium
49	50	Valley	Los Angeles	Low	Medium	Low	High	High	Medium
47	48	Valley	Los Angeles	Low	Low	Low	High	High	Medium
50	51	Valley	Los Angeles	Low	Low	Low	High	High	Medium
51	52	Valley	Los Angeles	Low	Low	Low	High	High	Medium
204	205	Orange	Orange	High	Medium	Low	Medium	High	Medium
207	Sub end	Orange	Orange	High	Medium	Low	Medium	High	Low

MOST VULNERABLE SIGNALS BY HAZARD

Table 19 summarizes which signals were rated as having high vulnerability for each hazard. The maximum vulnerability score that an asset can receive is 15 and an asset that receives a score of 10 or higher is considered to have high vulnerability.

Table 19: Most Vulnerable Signals by Hazard

Beginning Mile Post	Ending Mile Post	Substation	County	Score
Sea Level Rise (Mid-Century)				
202	205	Orange	Orange	10
207	Sub end	Orange	Orange	10
Flooding (Mid-Century)				
11	12	Valley	Los Angeles	10
15	17	Valley	Los Angeles	10
29	33	Valley	Los Angeles	10
37	41	San Gabriel	San Bernardino	10
435	439	Ventura	Ventura	10
446	447	Ventura	Los Angeles	10
449	450	Ventura	Los Angeles	10
456	457	Ventura	Los Angeles	10
462	End	Ventura	Los Angeles	10
Start	404	Montalvo	Ventura	10
Extreme Heat (Mid-Century)				
No signals have high vulnerability to heat				
Wildfire (Mid-Century)				
46	52	Valley	Los Angeles	12
Landslides				
1	3	River	Los Angeles	10
25	29	Valley	Los Angeles	10
31	32	Valley	Los Angeles	10
33	35	Valley	Los Angeles	10
36	38	Valley	Los Angeles	10
39	43	Valley	Los Angeles	10
44	56	Valley	Los Angeles	10
59	61	Valley	Los Angeles	10
63	65	Valley	Los Angeles	10
68	69	Perris Valley	Riverside	10
189	190	Orange	Orange	10
191	192	Orange	Orange	10
194	195	Orange	Orange	10
204	207	Orange	Orange	10
207	End	Orange	Orange	10
429	433	Ventura	Ventura	10
439	440	Ventura	Ventura	10
441	444	Ventura	Ventura	10
Seismic				
21	23	Valley	Los Angeles	10
25	26	Valley	Los Angeles	10
32	35	Valley	Los Angeles	10
65	67	Valley	Los Angeles	10

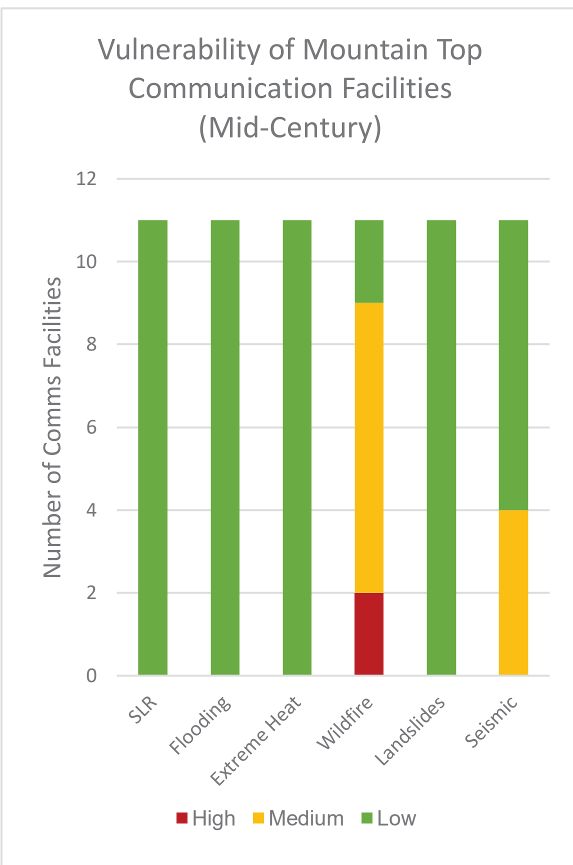
Vulnerability Profile: Communications Infrastructure

OVERVIEW

This section summarizes the vulnerability of communications infrastructure on the following SCRRA-owned subdivisions: Valley, Ventura, Montalvo, River, Perris Valley, Orange, Olive, Redlands, San Gabriel, Shortway, and a portion of San Bernardino. Rialto and Pasadena subdivisions do not carry Metrolink passenger trains, and therefore are not included in this assessment. Communications infrastructure includes sensor equipment running along the track (e.g., control points, intermediates, hot box detectors, communication shelters, Positive Train Control [PTC] wayside) as well as 11 mountain top communications towers.

VULNERABILITY BY HAZARD

Figure 25 highlights the vulnerability of mountain top communication towers and track-level equipment. Vulnerability is a composite of exposure (the degree to which an asset is in the hazard area) and sensitivity (the potential for exposure to cause damage/service disruption).



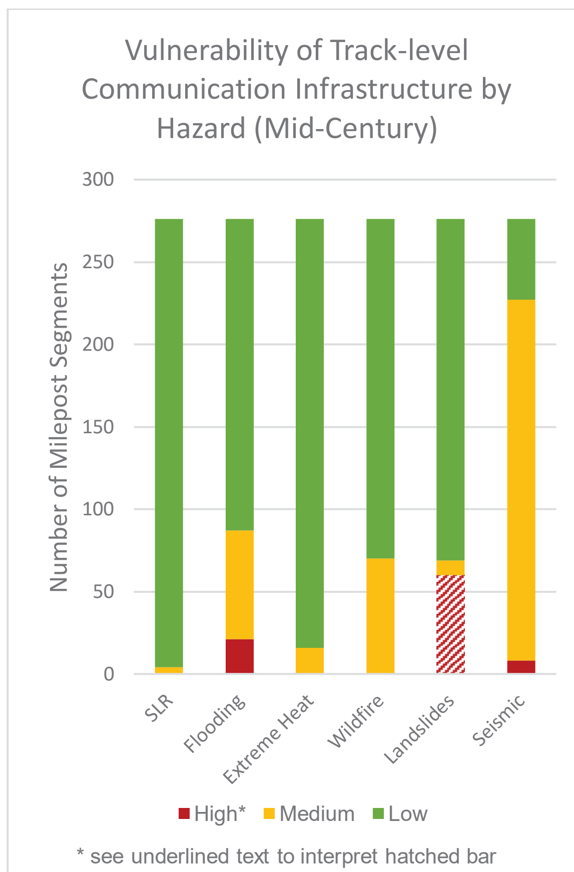


Figure 25: Vulnerability of Mountain Top Communications Facilities and Track Level Communications Infrastructure

Because of the large number of individual pieces of communications equipment and their relatively even distribution across the system, the exposure of track-level communications infrastructure was assessed using GIS data for track linework, but with different sensitivity ratings specific to communications equipment. For mountain top communications towers, the exposure of the facilities themselves was assessed based on location data from RAMS.

Mountain top communications towers have the greatest vulnerability to wildfire, and therefore two facilities received a high vulnerability score, and seven facilities received a medium vulnerability score. No mountain top facilities would be vulnerable to SLR, flooding, extreme heat, or landslides, and four facilities received a medium vulnerability score for earthquakes.

At first glance, landslide vulnerability appears to be a big concern (60 track segments have high vulnerability to landslides). However, the bar for high vulnerability to landslides has been modified with hatching to communicate that caution should be taken when interpreting this as indicating that landslide vulnerability is especially high. This is because zones marked as having high landslide hazards in input hazard data from USGS are likely to experience landslides less often than, for example, flooding occurring in the 100-year floodplain. Also, although these results are summarized by MP segment, in many cases, only a small portion of track between two MP segments actually is exposed to landslides.

Communications infrastructure was determined to have medium sensitivity to electrical outages because they require electricity to function but are supplied with backup power.

MULTI-HAZARD VULNERABILITY

Some assets are especially vulnerable because they have high vulnerability to multiple hazards. Table 20 highlights track segments where communications equipment has high vulnerability for multiple hazards. No mountain top communications towers received high vulnerability ratings for multiple hazards.

Table 20: Track Segments with High Vulnerability of Communications Equipment to Multiple Hazards

MP Beg	MP End	Sub	County	SLR	Flooding	Heat	Wildfire	Landslides	Seismic
25	26	Valley	Los Angeles	Low	Low	Low	Medium	High	High
33	34	Valley	Los Angeles	Low	Low	Low	Low	High	High
34	35	Valley	Los Angeles	Low	Low	Low	Low	High	High
31	32	Valley	Los Angeles	Low	High	Low	Low	High	Medium
438	439	Ventura	Ventura	Low	High	Low	Medium	High	Medium
437	438	Ventura	Ventura	Low	High	Low	Low	High	Medium
29	30	Valley	Los Angeles	Low	High	Low	Medium	High	Medium
32	33	Valley	Los Angeles	Low	High	Low	Low	Medium	High

MOST VULNERABLE COMMUNICATIONS INFRASTRUCTURE BY HAZARD

Table 21 and Table 22 summarize which communication facilities or track segments for track-level communications equipment were rated as having high vulnerability for each hazard. The maximum vulnerability score that an asset could receive was 15, and an asset that received a score of 10 or higher is considered to have high vulnerability.

Table 21: Most Vulnerable Mountain Top Communications Infrastructure

Facility	Substation	County	Score
Wildfire (Mid-Century)			
Sunset Ridge	San Gabriel	Los Angeles	12
Oat Mountain	Ventura	Los Angeles	12

Note:
Only mountain-top communications facilities have high vulnerability to wildfires.

Table 22: Most Vulnerable Track-level Communications Infrastructure by Hazard

Beginning Mile Post	Ending Mile Post	Substation	County	Score
Sea Level Rise (Mid-Century)				
No track-level comms have high vulnerability to sea level rise.				
Flooding (Mid-Century)				
11	12	Valley	Los Angeles	10
15	17	Valley	Los Angeles	10
29	33	Valley	Los Angeles	10
37	41	San Gabriel	San Bernardino	10
435	439	Ventura	Ventura	10
446	447	Ventura	Los Angeles	10
449	450	Ventura	Los Angeles	10
456	457	Ventura	Los Angeles	10
462	End	Ventura	Los Angeles	10
Start	404	Montalvo	Ventura	10
Extreme Heat (Mid-Century)				
No track-level comms have high vulnerability to heat.				
Wildfire (Mid-Century)				
No track-level comms have high vulnerability to wildfires.				
Landslides				
1	3	River	Los Angeles	15
25	29	Valley	Los Angeles	15
31	38	Valley	Los Angeles	15
39	40	Valley	Los Angeles	15
41	43	Valley	Los Angeles	15
44	56	Valley	Los Angeles	15
59	61	Valley	Los Angeles	15
63	65	Valley	Los Angeles	15

Beginning Mile Post	Ending Mile Post	Substation	County	Score
68	69	Perris Valley	Riverside	15
189	190	Orange	Orange	15
191	192	Orange	Orange	15
194	195	Orange	Orange	15
204	207	Orange	Orange	15
207	End	Orange	Orange	15
429	433	Ventura	Ventura	15
439	440	Ventura	Ventura	15
441	444	Ventura	Ventura	15
29	30	Valley	Los Angeles	12
62	63	Valley	Los Angeles	12
69	70	Perris Valley	Riverside	12
190	191	Orange	Orange	12
193	194	Orange	Orange	12
201	204	Orange	Orange	12
428	429	Ventura	Ventura	12
437	439	Ventura	Ventura	12
440	441	Ventura	Ventura	12
444	445	Ventura	Los Angeles	12
Seismic				
21	23	Valley	Los Angeles	10
25	26	Valley	Los Angeles	10
32	35	Valley	Los Angeles	10
65	67	Valley	Los Angeles	10

Vulnerability Profile: Culverts

OVERVIEW

This section summarizes the vulnerability of culverts on SCRRA-owned track. In total, 550 culverts were assessed.

VULNERABILITY BY HAZARD

Figure 26 highlights the number of culverts that received high, medium, and low vulnerability scores by hazard. Vulnerability is a composite of exposure (the degree to which an asset is in the hazard area) and sensitivity (the potential for exposure to cause damage/service disruption). Sensitivity to some hazards was rated on embankment/scour protection for flooding and SLR, and uniformly for other hazards.

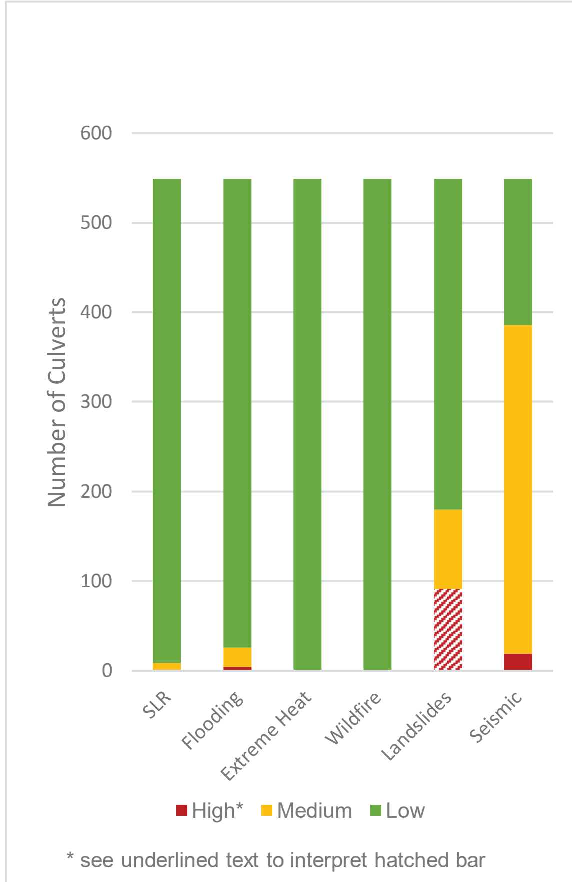


Figure 26: Vulnerability of Culverts by Hazard (Mid-Century)

In general, culverts have higher vulnerability to landslides and earthquakes than to climate-induced hazards. This study did not include a detailed conditions assessment of culverts because this already was completed separately by Metrolink. The bar for high vulnerability to landslides has been modified with hatching to communicate that caution should be taken when interpreting this as indicating that landslide hazard is higher than flooding or heat. This is because zones marked as having high landslide hazards in input hazard data from USGS are likely to experience landslides less often than, for example, flooding occurring in the 100-year floodplain.

MULTI-HAZARD VULNERABILITY

Some assets are especially vulnerable because they have high vulnerability to multiple hazards. Table 23 highlights the two culverts with high vulnerability for multiple hazards.

Table 23: Culverts with High Vulnerability to Multiple Hazards

Culvert No.	Sub	County	SLR	Flooding	Heat	Wildfire	Landslides	Seismic
33.77-MT	Valley	Los Angeles	Low	Low	Low	Low	High	High
31.18-MT	Valley	Los Angeles	Low	High	Low	Low	High	Medium
204.35-MT	Orange	Orange	High	Low	Low	Low	High	Low

MOST VULNERABLE CULVERTS BY HAZARD

Table 24 summarizes which culverts were rated as having high vulnerability for each hazard. The maximum vulnerability score that an asset could receive was 15, and an asset that received a score of 10 or higher is considered to have high vulnerability. For brevity, the results for landslides have been presented as tallies rather than individual culverts.

Table 24: Most Vulnerable Culverts by Hazard

Culvert No.	Substation	County	Score
Sea Level Rise (Mid-Century)			
204.35-MT	Orange	Orange	10
Flooding (Mid-Century)			
31.18-MT	Valley	Los Angeles	10
30.88-MT	Valley	Los Angeles	10
37.9-MT	San Gabriel	San Bernardino	10
38.6-MT	San Gabriel	San Bernardino	10
Extreme Heat (Mid-Century)			
No culverts have high vulnerability to heat.			
Wildfire (Mid-Century)			
No culverts have high vulnerability to wildfires.			
Landslides (presented as a tally because of large number)			
35	Valley	Los Angeles	15
1	Ventura	Ventura	15
2	Ventura	Los Angeles	15
6	Orange	Orange	15
23	Valley	Los Angeles	12
4	Ventura	Ventura	12
3	Ventura	Los Angeles	12
17	Orange	Orange	12
Seismic			
33.77-MT	Valley	Los Angeles	10
25.71-MT	Valley	Los Angeles	10
32.8-ST	Valley	Los Angeles	10
34.28-MT	Valley	Los Angeles	10
34.33-MT	Valley	Los Angeles	10
34.39-MT	Valley	Los Angeles	10
34.58-MT	Valley	Los Angeles	10
34.74-MT	Valley	Los Angeles	10
25.34-MT	Valley	Los Angeles	10
32.77-MT, ST	Valley	Los Angeles	10
33.4-MT, ST	Valley	Los Angeles	10
34.18-MT	Valley	Los Angeles	10
32.92-MT, ST	Valley	Los Angeles	10
34.78-MT	Valley	Los Angeles	10
25.23-MT, ST	Valley	Los Angeles	10
25.25-MT, ST	Valley	Los Angeles	10
66.35-MT	Valley	Los Angeles	10
32.94-MT, ST	Valley	Los Angeles	10
22-MT	Valley	Los Angeles	10

Risk Assessment Case Studies

To understand the potential economic impact of specific climate or extreme weather events as described in the vulnerability profiles, three case study areas in the Metrolink service area were selected for analysis. The case studies are intended to help SCRRA understand the potential magnitude of costs related to flooding and extreme heat in different parts of the rail system, to guide future planning for adaptation. In addition, the "cost of inaction" was estimated as a first step in establishing a business case for investments that are needed to minimize the impacts of hazards and economic consequences for SCRRA, its riders, and Southern California's general economy.

APPROACH

Criticality Evaluation

First, a criticality evaluation was completed to inform selection of three focus areas for the case studies (see Technical Appendix). In the context of this assessment, *criticality* is defined as "a measure of the importance of an asset to Metrolink providing high quality service to riders, including those from disadvantaged communities."

The selection of criticality indicators was primarily informed by LA Metro's Climate Action and Adaptation Plan (LA Metro 2019) for consistency. A few of the indicators were not included because of data availability limitations for the full Metrolink service area, and others were adjusted slightly to fit the context, based on input from the project team. The selected indicators are listed in Table 25, along with definitions and sources.

Table 25: Criticality Analysis Indicators and Data Sources

Indicator	Definition/Units	Data Source
Ridership	Average monthly boardings by station (2019)	SCRRA (Henning Eichler)
Jobs	Jobs within 0.5 mile of each station (2018)	U.S. Census (Longitudinal Employer-Household Dynamics)
Transit Connections	Number of other transit services serving each station	SCRRA (Deborah Redman)
Economic Development*	Opportunity zone within 0.5 mile (binary)	State of California, U.S. Department of Housing and Urban Development
Social Vulnerability**	Total and percentage of households in disadvantaged communities by catchment area	CalEnviroScreen (California Environmental Protection Agency's Office of Environmental Health Hazard Assessment)
	Total and percentage of households in transit dependent communities by catchment area	U.S. Census (AECOM)

Notes:

* Opportunity zones were nominated by state governors. Nominated tracts had to meet one of the criteria under the definition of “low-income community” in IRS Code Section 45D(e): (1) a poverty rate of at least 20 percent; (2) a median family income below 80 percent of the greater of the statewide or metropolitan area median family income; or (3) a median family income below 80 percent of the median statewide family income if the community is located outside a metropolitan area. For more info: https://opzones.ca.gov/. Opportunity zones were selected as a proxy for economic development centers in the absence of other readily available datasets with spatial coverage across the Metrolink system. In the future, a more appropriate dataset may become available and could be used for this analysis.

** Low-income communities not included because of significant overlap with Opportunity Zones.

Based on the criticality analysis, the highest criticality portions are toward the center of the network. This is to be expected because these areas are more densely populated, and most indicators (especially ridership and jobs) are related to population. Lines that connect major population centers, such in Los Angeles, San Bernardino, inland Orange County, and Burbank, received high criticality ratings, while portions of lines further out with lower ridership received lower criticality ratings.

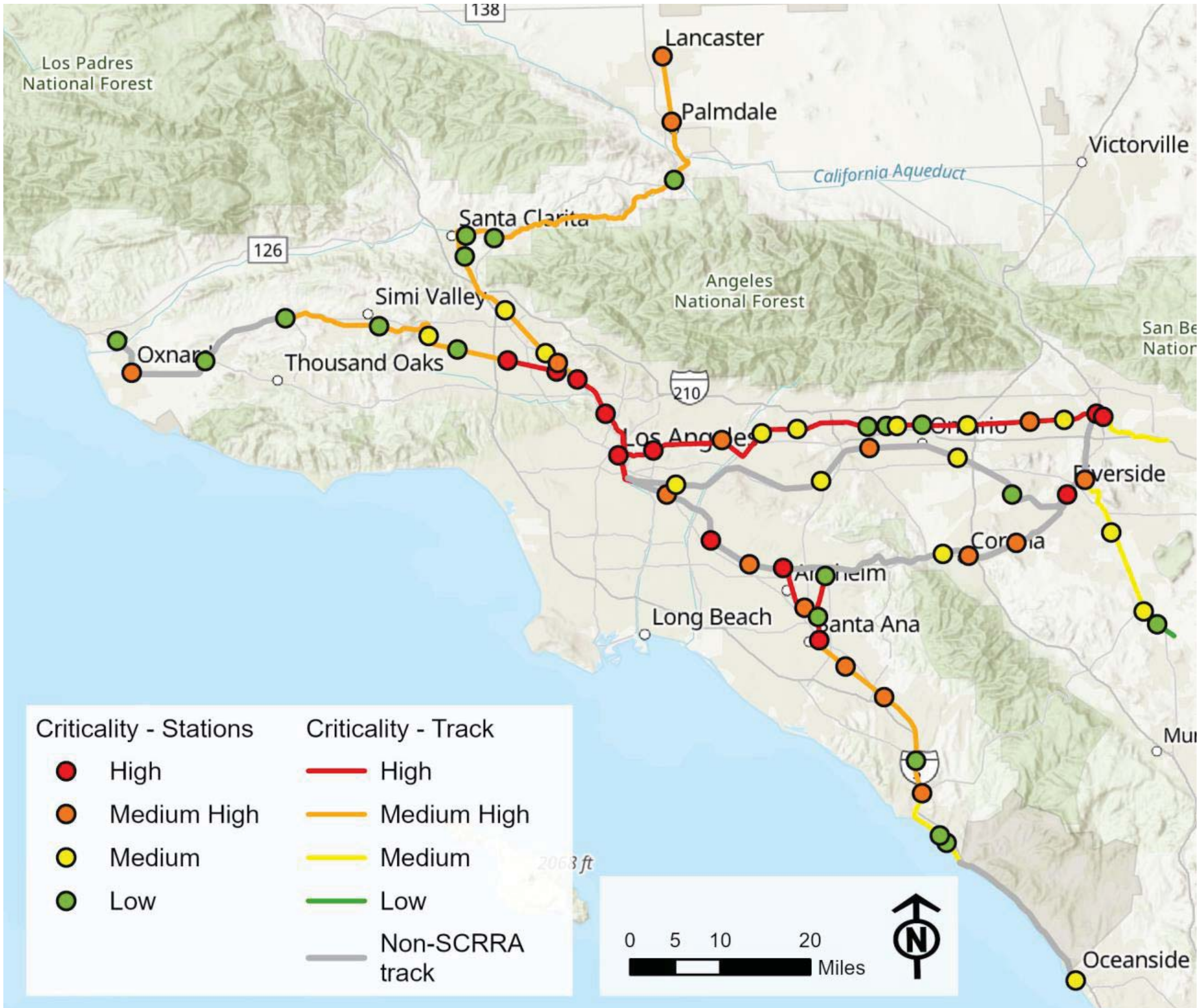


Figure 27: System-Wide Criticality Ratings Map

In summary, the project team selected three case study areas that are highly vulnerable to flood and extreme heat, and are representative of the types of climate impacts facing the Metrolink system. These included Rancho Cucamonga, Santa Clarita, and San Bernardino, as follows:

1. **Rancho Cucamonga.** Located on the San Bernardino Line, the Rancho Cucamonga study area has a high vulnerability rating because a portion of it is in the 100-year floodplain, and it is within a watershed that is projected to experience increased flooding. The line is highly critical to Metrolink because it connects San Bernardino to Downtown Los Angeles.
2. **Santa Clarita.** Located in the northern portion of the Antelope Valley Line, the Santa Clarita study area has a high vulnerability rating with several stretches of track and Newhall station in the 100-year floodplain. The study area is highly critical to the region because it connects Palmdale and Lancaster to Burbank and Downtown Los Angeles.
3. **San Bernardino.** The San Bernardino study area includes both the San Bernardino Depot and San Bernardino Downtown stations, at the eastern terminus of the San Bernardino line and the northern terminus of the Inland Empire line. The vulnerability assessment found this

study area to be highly vulnerable to extreme heat events because it experiences the hottest temperatures system-wide. The study area connects the San Bernardino and Inland Empire lines. It also houses the EMF, a maintenance facility that is critical to the system. Furthermore, San Bernardino - Downtown is the transfer point for Metrolink riders connecting to the Redlands Passenger Rail Project, a new rail system known as the Arrow, which will connect San Bernardino to Loma Linda and Redlands. Arrow is scheduled to start operations in 2022.

Cost of Inaction

To assess the potential cost of inaction, a model was developed that estimates both direct costs to SCRRA—including infrastructure damage, emergency response, and recovery costs—and the broader economic consequences from the loss of service (i.e., the cost of rider delays). The general framework for the model was based on the Federal Transit Administration's (FTA) Hazard Mitigation Cost-Effectiveness Analysis (HMCEA) tool. Infrastructure damages were calculated using a variety of resources, including FEMA's HAZUS (desktop software program) flood model, academic literature, and historical reports from the National Train Safety Board. Ridership disruptions were calculated using Metrolink's origin-destination data for 2019. Infrastructure replacement, maintenance, and repair costs came from Metrolink's 2020 Rehabilitation Plan, service invoices provided by SCRRA, and infrastructure assessment data published by FEMA.

To estimate the economic impact of different disaster scenarios, an economic model was adapted from FTA's HMCEA framework. The chief purpose of HMCEA is to present and analyze the costs and benefits of resiliency projects in monetary terms. HMCEA costs include capital, operating, and maintenance costs of a specific resiliency project or strategy. The benefits are expressed as the avoided damages and losses associated with a proposed project (i.e., the disaster impacts that a specific project would prevent).

For this analysis, the HMCEA framework was adopted with two major differences. First, the model focuses specifically on quantifying the costs of specific climate events. Also, unlike HCMEA, it does not analyze the capital or operational costs of mitigation projects or strategies. In other words, the costs evaluated in this model represent the potential costs associated with a specific climate event. In a full benefit-cost analysis for a resiliency project, these costs would represent avoided damages (or benefits). Estimating the likely costs of inaction is the first step in calculating the cost-effectiveness (or present value) of a resiliency strategy.

The second major difference between the model presented here and HMCEA is that this model analyzes and quantifies impacts as if they occurred in 2021. Neither the probability of each event nor potential future changes in costs are quantified or incorporated into the final figures. In a full benefit-cost analysis, the costs would reflect the likelihood and/or the recurrence interval of a specific disaster event.

The HMCEA framework outlines three types of costs associated with natural disasters:

- **Infrastructure damage**: The cost of damage to capital assets owned and operated by an agency (in this case, SCRRA), including damage to fixed structures (e.g., stations, track, bridges, maintenance facilities) and rolling stock.
- **Response and recovery costs**: Emergency repairs, cleanup, and other costs associated with an agency's response during and immediately after the event.
- **Economic impacts because of service disruption:** These impacts include the monetized value of increased travel time because of rider delays, the cost of shuttling stranded riders, and increases in vehicle miles traveled.

Although service interruptions may result in loss of ridership and decreased fare revenue, FTA typically does not include loss of fare revenue in cost-effectiveness calculations, and fare revenue impacts are not included in the economic cost estimates. In addition, the health and productivity impacts on riders or maintenance workers because of heat are not included in the overall costs.

The economic costs of a climate event also can be categorized as "direct" and "indirect" costs. Direct costs are costs incurred directly by a transit agency (SCRRA), while indirect costs are broader societal costs that are relevant to understanding the overall economic consequences of a climate event. Table 26 summarizes the different categories of costs that are discussed above.

Table 26: Disaster Event Costs

	Infrastructure Damage	Response and Recovery Costs	Economic Impacts from Loss of Transit Service
Direct Costs	**Repair/replacement of:** **Fixed Structures:** <u>Stations</u> <u>Track/track infrastructure</u> <u>Maintenance facilities</u> <u>Bridges</u> Rolling Stock: <u>Rail cars</u> Buses Ferries	**Response Costs:** <u>Emergency repairs</u> Temporary facilities <u>Equipment rental</u> Recovery Costs: <u>Debris removal and disposal</u> <u>Environmental cleanup costs</u>	<u>Cost to the agency of providing alternative travel modes (bus or shuttle bridges)</u> Reduction in fares*
Indirect Costs	N/A	N/A	<u>Rider delay (increased travel time)</u> Reduced transit ridership and loss of confidence* Additional mileage in personal vehicles

Notes:
<u>Underlined items</u> are included in the economic cost of a disaster estimate.
* Not included in the FTA's cost-effectiveness model or the cost estimates provided in this model.

CASE STUDY KEY FINDINGS

Table 27 shows the aggregated economic consequences associated with different disruption levels in each of the three study areas. The disaster costs summarized in this chart represent rough order of magnitude costs directly experienced by SCRRA as well as approximated societal costs experienced by Metrolink passengers. The Rancho Cucamonga and Santa Clarita study areas discussion focuses on flooding, whereas the San Bernardino study area discussion assesses the impact of a sun kink during an extreme heat event.

All monetary figures are in 2021 dollars. The estimates are high-level ones, based on a number of assumptions, and are intended to represent a range of possible costs rather than to predict the costs associated with any specific event. This work effort did not analyze or account the probability of the events described. For each study area, two scenarios were assessed:

- **Minor damage scenarios** outline the economic consequences associated with events with limited damage, such as minor flooding or a thermal misalignment (sun kink) that is located and fixed without any injuries or cleanup. Minor damage scenarios are assumed to need 2 days of event management and 8 hours of service disruption. For the flood scenarios, a 100-year flood event is assumed.
- **Major damage scenarios** outline the economic impact associated with events that cause severe damage to the Metrolink system, such as a 500-year flood or a derailment caused by an undetected sun kink. Besides a train car derailment, this scenario represents damage from a disaster event that disrupts service for 3 full weekdays and requires 5 days of disaster management. Medical response assumes 1 to 4 fatalities, 10 to 30 serious injuries, and 100 minor injuries.

Table 27: Total Costs of Disruption by Study Area

	Damage Scenario	Infrastructure Damage	Response and Recovery Costs	Economic Impacts from Loss of Transit Service	Modeled Scenario Totals
Study Area 1: Rancho Cucamonga (riverine flooding)	Minor	$3,055,000	$133,000	$48,000	$3,236,000
	Major	$11,523,000	$433,000	$279,000	$12,235,000
Study Area 2: Santa Clarita (riverine flooding)	Minor	$1,939,000	$133,000	$37,000	$2,108,000
	Major	$10,177,000	$433,000	$191,000	$10,802,000
Study Area 3: San Bernardino (extreme heat)	Minor	$94,000	$83,000	$10,000	$187,000
	Major	$13,921,000	$865,000	$51,000	$14,837,000

The remainder of this section looks at each case study in greater detail and describes the context as well as the economic consequences (by infrastructure damage, response and recovery, and loss of transit service).

STUDY AREA 1—RANCHO CUCAMONGA

Context

The Rancho Cucamonga study area has a high vulnerability rating. An approximately 0.4-mile segment is in the 100-year floodplain and an approximately 1.7-mile segment is in the 500-year floodplain. Also, the study area is in a watershed that is projected to experience increased flooding by mid-century. The Metrolink line is considered highly critical as it connects San Bernardino to Downtown Los Angeles.

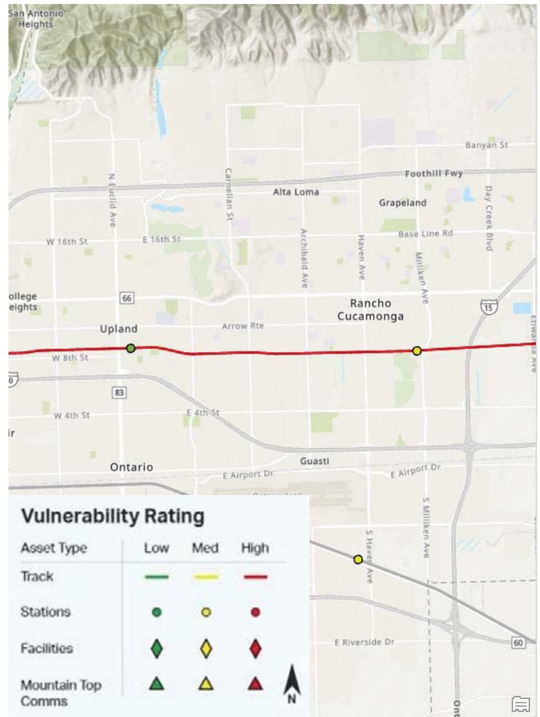


Figure 28: Vulnerability Map of Study Area 1, Rancho Cucamonga

Economic Consequences

Table 28 shows the costs associated with a minor damage scenario (100-year flood with minor damage to rolling stock and bridges and no medical injuries) and a major damage scenario (a 500-year flood with moderate damage to rolling stock bridges, stations and 1 to 4 fatalities, 10 to 30 serious injuries, and 100 minor injuries).

Table 28: Total Disaster Costs for Study Area 1–Rancho Cucamonga

Cost Category	Cost Subcategory	Minor Scenario	Major Scenario
Infrastructure Damage	Track Damage Costs (includes signals, switches, and auxiliary infrastructure)	$136,000	$1,143,000
	Bridge Damage Costs	$2,210,000	$4,200,000
	Station Damage Costs	$233,000	$1,400,000
	Rolling Stock Costs	$475,000	$4,781,000
Response and Recovery Costs	Management Oversight Communications	$42,000	$160,000
	Emergency Management/Repairs	$30,000	$105,000
	Equipment to Support Cleanup/Repairs	$8,000	$30,000
	Management & Crews for Train Ops	$4,000	$12,000
	Management & Crews for Mechanical	$4,000	$20,000
	Specialized Cleanup	$45,000	$56,000
	Specialized Service to Upright Train	$0	$50,000
Economic Impacts from Loss of Transit Service	Rider Delay Costs	$13,000	$120,000
	Emergency Shuttling Costs	$35,000	$157,000
	Additional Carbon Emissions	$0	$3,000
Total Disaster Costs		**$3,237,000**	**$12,237,000**

STUDY AREA 2—SANTA CLARITA

Context

The Santa Clarita study area has a high vulnerability rating with approximately 1.4 miles of track, Newhall station is in the 100-year floodplain, and approximately 1.8 miles is in the 500-year floodplain. The track has a medium-high criticality rating because it connects Palmdale and Lancaster to Burbank and Downtown Los Angeles. This area contains one bridge (30.940-MT) that has a high vulnerability rating (with a score of 15/15).

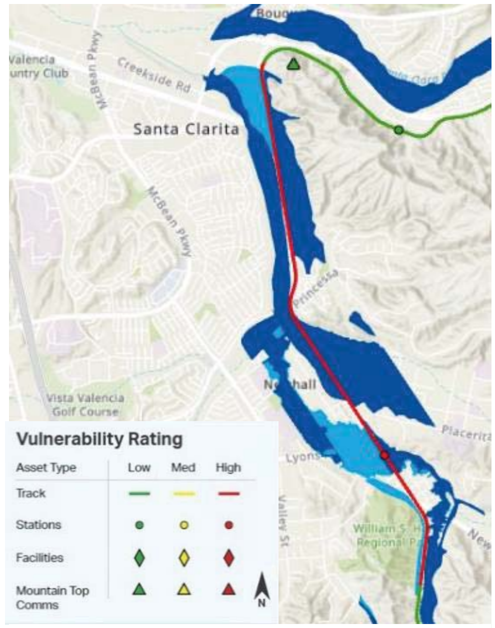


Figure 29: Vulnerability Map of Study Area 2, Santa Clarita

Economic Consequences

Table 29 shows the costs associated with a minor damage scenario (100-year flood with minor damage to rolling stock and bridges and no medical injuries) and a major damage scenario (a 500-year flood with moderate damage to rolling stock, bridges, stations, and 1 to 4 fatalities, 10 to 30 serious injuries, and 100 minor injuries).

Table 29: Total Disaster Costs for Study Area 2–Santa Clarita

Cost Category	Cost Subcategory	Minor Scenario	Major Scenario
Infrastructure Damage	Track Damage Costs (includes signals, switches, and auxiliary infrastructure)	$493,000	$1,197,000
	Bridge Damage Costs	$737,000	$2,800,000
	Station Damage Costs	$233,000	$1,400,000
	Rolling Stock Costs	$475,000	$4,781,000
Response and Recovery Costs	Management Oversight Communications	$42,000	$160,000
	Emergency Management/Repairs	$30,000	$105,000
	Equipment to Support Cleanup/Repairs	$8,000	$30,000
	Management & Crews for Train Ops	$4,000	$12,000
	Management & Crews for Mechanical	$4,000	$20,000
	Specialized Cleanup	$45,000	$56,000
	Specialized Service to Upright Train	$0	$50,000
Economic Impacts from Loss of Transit Service	Rider Delay Costs	$5,000	$48,000
	Emergency Shuttling Costs	$31,000	$141,000
	Additional Carbon Emissions	$0	$2,000
Total Disaster Costs		**$2,107,000**	**$10,802,000**

STUDY AREA 3—SAN BERNARDINO

Context

The study area includes both the San Bernardino Depot and San Bernardino Downtown stations, and connects the eastern terminus of the San Bernardino line and the northern terminus of the Inland Empire line. The study area is highly vulnerable to extreme heat events, experiencing the hottest temperatures system-wide. It also houses the EMF. In addition, San Bernardino - Downtown is the transfer point for Metrolink riders connecting to the Redlands Passenger Rail Project, a new rail system known as the Arrow, which will connect San Bernardino to Loma Linda and Redlands.

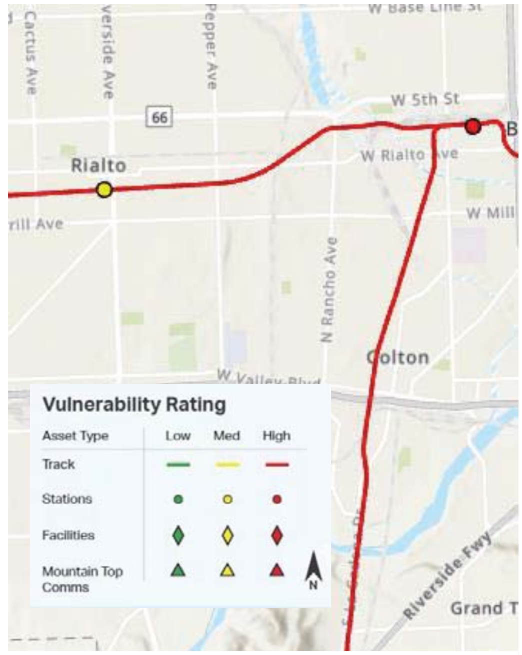


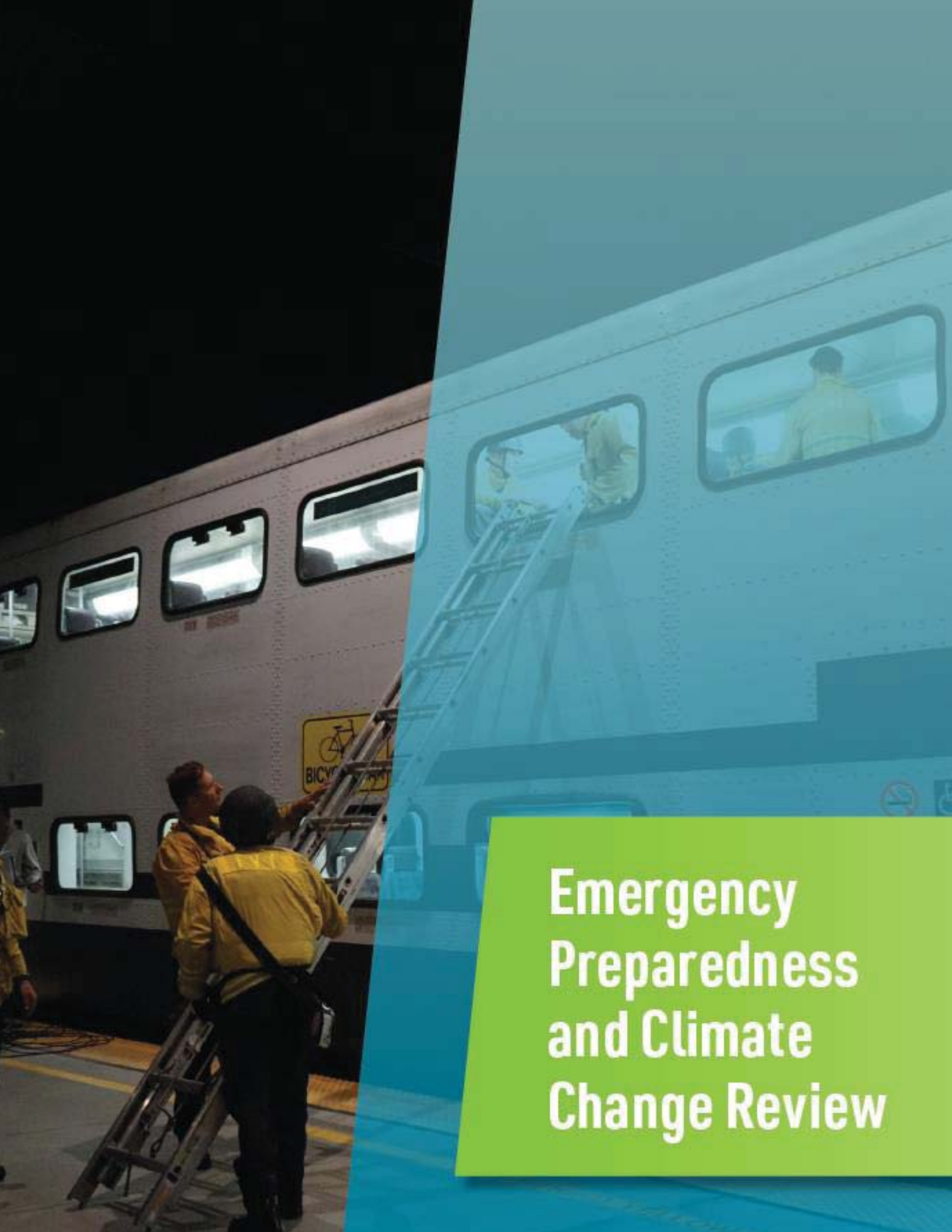
Figure 30: Vulnerability Map of Study Area 3, San Bernardino

Economic Consequences

Table 30 shows the costs associated with a minor damage scenario (sun kink detected without a derailment) and a major damage scenario (an undetected sun kink that causes a derailment).

Table 30: Total Disaster Costs for Study Area 3–San Bernardino

Cost Category	Cost Subcategory	Minor Scenario	Major Scenario
Infrastructure Damage	Track Damage Costs (includes signals, switches, and auxiliary infrastructure)	$37,000	$13,920,000
	Bridge Damage Costs	$14,000	
	Station Damage Costs	$39,000	
	Rolling Stock Costs	$4,000	
Response and Recovery Costs	Management Oversight Communications	$30,000	$250,000
	Emergency Management/Repairs	$30,000	$240,000
	Equipment to Support Cleanup/Repairs	$15,000	$160,000
	Management & Crews for Train Ops	$4,000	$20,000
	Management & Crews for Mechanical	$4,000	$40,000
	Specialized Cleanup	$0	$80,000
	Specialized Service to Upright Train	$0	$75,000
Economic Impacts from Loss of Transit Service	Rider Delay Costs	$1,000	$13,000
	Emergency Shuttling Costs	$8,000	$38,000
	Additional Carbon Emissions	$0	$0
Total Disaster Costs		**$186,000**	**$14,836,000**



Emergency Preparedness and Climate Change Review

Overview

A robust emergency preparedness program will enable SCRRA both to address disruptions to the Metrolink system rapidly and efficiently, and to contribute to multi-agency/regional response efforts more effectively. A comprehensive review of SCRRA's emergency management plans, procedures, and coordination processes was undertaken, to better understand the current emergency preparedness program and the opportunities and challenges it may face as a result of increasing climate change-related events. Further, a targeted list of internal and external emergency management stakeholders were interviewed.

Internal stakeholders included the SCRRA staff who directly oversee the emergency preparedness program, and staff members who have significant roles in managing emergency response efforts. External agency stakeholders included the emergency management organizations in the five counties and major cities that Metrolink serves, as well as the regional and local transportation agencies with whom SCRRA is likely to partner during a large-scale emergency response. Efforts were focused on SCRRA's internal emergency response framework and operations, as well as its external coordination processes and the expectations of its agency partners.

The key findings, discussed next, are intended to support SCRRA's ongoing efforts to further define its role as a regional mobility provider during an emergency, and to fortify institutional relationships and procedures with its partner agencies at the local, regional, and state levels.

The following plans were reviewed:

- Metrolink Passenger Train Emergency Preparedness Plan
- Metrolink Signal Maintenance Manual, Section 3.0: Emergency Instructions and Test
- SCRRA Standard Operating Procedure 1000.16: Earthquake Response
- SCRRA/Metrolink Continuity of Operations (COOP) Plan
- SCRRA/Metrolink Design Criteria Manual
- SCRRA/Metrolink Emergency Operations Center (EOC) Manual
- SCRRA/Metrolink Incident Response Plan
- SCRRA/Metrolink Operational Supplemental Instructions
- SCRRA/Metrolink Passenger Train Emergency Preparedness Plan
- SCRRA/Metrolink Recovery Plan, In Response to COVID-19 Pandemic (Draft)
- SCRRA/Metrolink System Safety Program Plan
- SCRRA/Metrolink Threat and Vulnerability Assessment
- Ventura County Multi-Hazard Mitigation Plan

Representatives from the following agencies were interviewed or provided input from October–November 2020:

- City of Covina Emergency Management
- City of Lancaster Emergency Management
- Los Angeles County Metropolitan Transportation Authority (LACMTA)
- Los Angeles County Office of Emergency Management
- North County Transit District (NCTD)
- Orange County Sheriff's Department
- Orange County Transportation Authority (OCTA)
- Riverside County Transportation Commission (RCTC)
- San Bernardino County Office of Emergency Services
- San Bernardino County Transportation Authority (SBCTA)
- SCRRA/Metrolink
- Ventura County Transportation Commission (VCTC)

Key Findings

The following key findings focus on the emergency management program structure, internal resources, expected roles and responsibilities, and joint coordination with partner agencies and jurisdictions, as they pertain to emergency preparedness.

EMERGENCY MANAGEMENT PROGRAM STRUCTURE

Program Leadership. SCRRA has developed a robust emergency management program, with multiple staff members dedicated to development and maintenance of agency-wide emergency plans, policies, and procedures, and training and outreach with partner agencies. This group is led by the Chief Safety, Security & Compliance Officer, whose inclusion in the SCRRA Executive Team is evidence that emergency preparedness and response are core values for the agency.

Emergency Management Framework. The emergency management program is designed to take an all-hazards approach, and therefore is well suited to address climate change-related incidents, both minor and major. It addresses, in various capacities, the following elements:

- Mitigation: activities that reduce the potential for an incident, or reduce the impacts of a disaster or the organization’s vulnerability to a given disaster or emergency.
- Prevention: actions to prevent a disaster or emergency, and to safeguard employees, passengers, vehicles, and facilities (i.e., Preventive Maintenance, SOPs).
- Preparedness: training, resourcing, and other activities before an emergency or disaster, with the goal to protect lives, minimize damages, and otherwise reduce the impacts from an incident.
- Response: actions taken after a disaster, to provide emergency assistance.
- Recovery: short and long-term activities that help return all operations to normal and/or improved standards.

Internal Response Frameworks. SCRRA has a well-defined incident command structure, as identified in its Incident Response Plan. The organizational structure adheres to the principles and guidance of the Incident Command Structure (ICS) and the National Incident Management System (NIMS), and describes the hierarchy and communication flow of the various response positions within the Railroad ICS.

Detailed frameworks for operation of SCRRA’s Emergency Operations Center (EOC) are described in the EOC Manual. This document includes specific organizational and communication flow charts for varying levels of activation, according to the severity of the incident. These organizational frameworks also follow the structures set forth in the ICS and NIMS.

Although the incident command-level and EOC-level organizational structures are both critical to the overall command and coordination of the emergency response program, neither the Incident

Response Plan nor the EOC Manual make it clear how the two structures interact with one another. The DOC is the primary facility for coordinating both command-level and EOC-level incident response, but neither plan references nor compares how the two organizations operate. A specific explanation about the relationship between the two organizations would be helpful, including information about when they simultaneously could be activated and how their roles and responsibilities may compliment/coordinate with one another.

INTERNAL RESOURCES

Plans, Policies, and Procedures. SCRRA has numerous plans, policies, and procedures that address the full spectrum of emergency management: prevention, mitigation, response, and recovery. Within the past 12 months, a majority of the plans submitted for review have been developed, updated, or are in some stage of this process. Among them are a Threat and Vulnerability Assessment, an Incident Response Plan, an EOC Manual, a Continuity of Operations Plan, and a Recovery Plan. Staff also noted that recent updates have been made to the Everbridge Alert System and the Standard Operating Procedures (SOPs) for communication with stakeholder groups.

The existence of this broad spectrum of plans and the recent attention to them indicates that the agency is committed to maintaining a current and relevant emergency management program. We recommend that these plans be revised to reference one another and clearly identify how each plan contributes to SCRRA's overarching emergency management program. This can be incorporated during the plans' normal update cycle.

Response Resources. SCRRA has made efforts to enhance its communications' capabilities during an emergency by partnering with a vendor who provides resources such as satellite phones, two-way radios, and antennas that enable SCRRA staff and field crews to maintain communication channels needed to address emergencies. The agency also recently updated its Everbridge Alert System for staff-wide notifications.

EXPECTED ROLES AND RESPONSIBILITIES

Internal Roles and Responsibilities. As identified in the agency's emergency plans and referenced during interviews, SCRRA primary internal roles and responsibilities during an emergency are to:

- Protect the safety and security of personnel, riders, visitors, and others at risk from all hazards (including those related to climate change) while on the public transit system.
- Protect SCRRA facilities, physical assets, and electronic information.
- Coordinate movement of trains and associated staff.
- Conduct repairs to locomotives, cars, rail, and other equipment in a timely and safe manner.
- Coordinate response activities with SCRRA contractors.

- Protect SCRRA’s reputation, brand, and image.
- Provide transportation services to the public as feasible.
- Prevent environmental contamination.
- Maintain customer service by minimizing interruptions or disruptions of transit operations.
- Provide travel continuity, restoration, and resumption of normal transit operations in the most timely and effective manner possible.

External Roles and Responsibilities. Based on information obtained through a review of SCRRA’s emergency plans as well as input received during stakeholder interviews, SCRRA’s primary external roles and responsibilities during an emergency are to:

- Conduct movement of people, goods, supplies, and equipment in support of the response.
- Coordinate emergency response activities with local public safety agencies/first responders.
- Coordinate transportation emergency response activities with member agencies, local agencies, and partner transit agencies by providing or requesting, as appropriate, alerts/notifications, situation status information, resources, and/or other information pertinent to the response activities.
- Provide logistical support to other government agencies, as required, in performance of their essential functions.
- Participate in interagency emergency response activations, trainings, exercises, and workgroups, as applicable.

Regional Response Capabilities. During a large-scale emergency, SCRRA staff anticipate their agency may be called on to assist with evacuations and/or movement of emergency response resources, because of SCRRA’s ability to travel quickly throughout a large part of the region. However, this role generally is speculative and is not specifically detailed in either SCRRA’s internal plans or in external partner agencies’ plans. Because SCRRA would be likely to receive such a request in an emergency situation, conducting or participating in regional planning efforts with relevant partner agencies would be advisable, to define the expectations for SCRRA’s response activities more clearly.

JOINT COORDINATION WITH PARTNER AGENCIES/JURISDICTIONS

Interagency Coordination. SCRRA participates in several regional organizations that focus on interagency collaboration. SCRRA also has strong relationships with many partner agencies and jurisdictions within its service area. Recent best practices include:

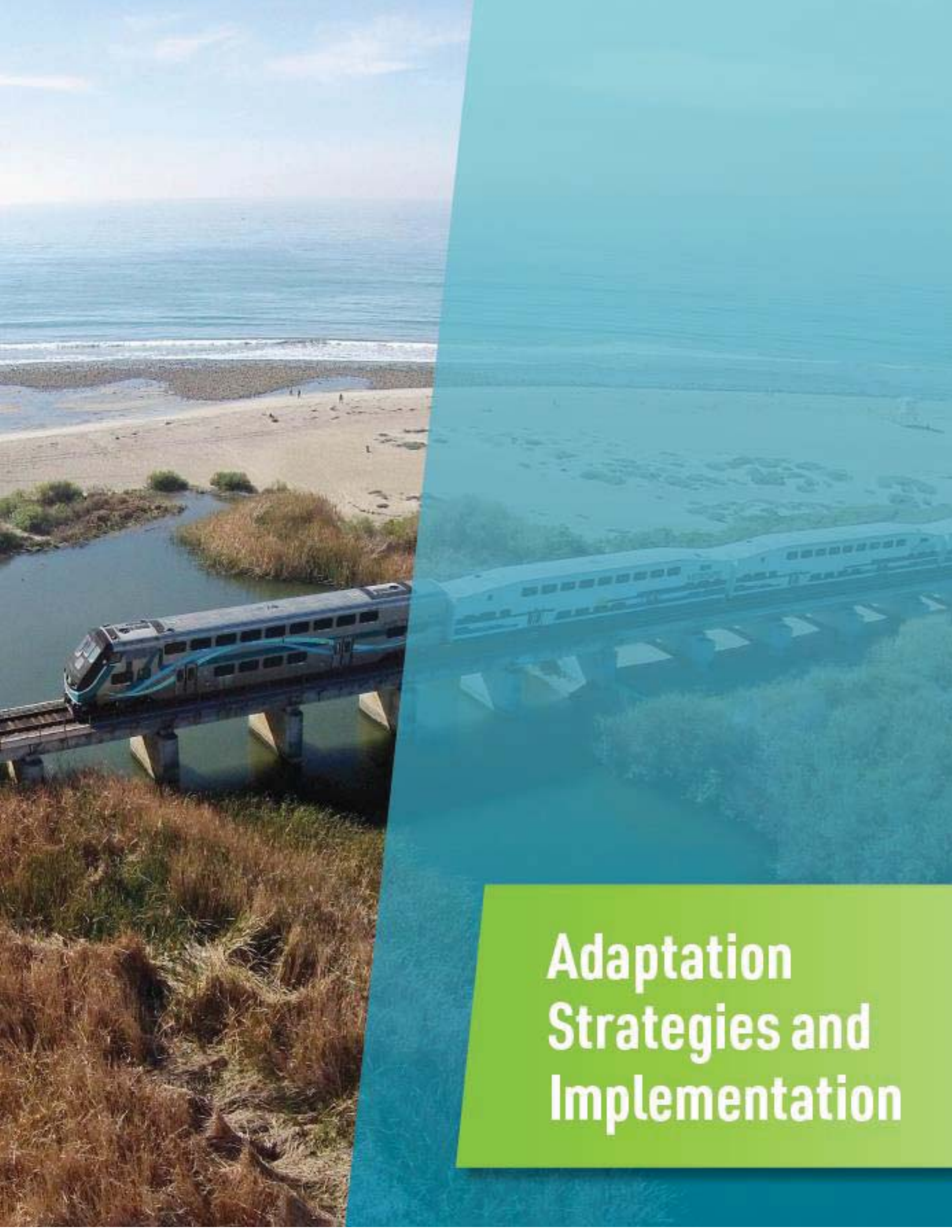
- ongoing interagency communications during the COVID-19 response, to share information about ridership, safe operating practices, and personal protective equipment for staff;

- having a formal reciprocal mutual-aid agreement with the County transportation organization;
- having a contract with the County Sheriff's Department, to address safety/security on trains and at stations within its jurisdiction;
- collaborating development of a partner transit agency's emergency plans;
- having a designated seat at a partner agency's EOC;
- participating in interagency emergency activations and exercises; and
- providing numerous trainings to partner agencies, to improve their knowledge of SCRRA's equipment and emergency response processes/procedures.

Such relationships can be critical to emergency response operations, and SCRRA is encouraged to continue expanding these relationships with other agencies throughout its service area. Some agencies may be unaware of how SCRRA can be used as an emergency management resource, or the best way to communicate information (e.g., situation status updates or resource requests) to SCRRA. SCRRA would benefit from seeking out and fostering better relations with partner agencies, to develop procedures defining how coordination should take place. In particular, including the following information in emergency plans would be helpful:

- communication/coordination protocols with local agencies/jurisdictions, member agencies, and partner transit agencies, including:
  - interagency notification procedures (triggers for notification, who is notified, and how), including contact-information lists for partner agencies,
  - situation status reporting procedures (what kind of information SCRRA shares and when, such as operational status or ability to provide support),
  - methods of communication (e.g., emergency management software, alert system, e-mail, phone calls),
  - resource request/fulfillment processes, and
- references to standing mutual aid agreements between SCRRA and local agencies, member agencies, and partner transit agencies.

Regional Coordination. SCRRA is not involved actively in any regional groups that facilitate transportation-specific emergency management planning or discussions. All coordination with partner agencies in the region has occurred at an individual agency level. During the plan review, it was also noted that there is no mention of state or regional organizational structures, such as Operational Areas (OAs), the Cal OES' Regional Emergency Operations Center (REOC), or the Standardized Emergency Management System (SEMS). Therefore, how SCRRA may receive or contribute to a regional situational status report, how it may receive or submit regional resource requests, and where SCRRA's place is within the regional emergency response framework is unclear. This is a gap needing to be addressed so that SCRRA is best able to support regional response efforts.



Adaptation Strategies and Implementation

Overview

This chapter provides a summary of the methodology used to develop the strategies to address the climate vulnerabilities that are identified and detailed in the Climate Vulnerability Assessment chapter in this document. This chapter also describes each of the prioritized strategies and planned implementation.

The strategies have been organized into four types: governance, informational, emergency preparedness, and structural. The first three types focus on improving organizational climate resilience through mainstreaming a consideration of climate resilience into key planning, design and operational policy, programs, and procedures. Each of these non-structural strategies includes recommendations on implementation time frame and lead department to spearhead the effort. Structural strategies are focused on methods to adapt specific asset types to each climate hazard identified in the CVA. The structural strategies are intended to be used as a toolkit from which applicable strategies can be selected to reduce future vulnerability and potential locations where the strategy could be implemented are identified.

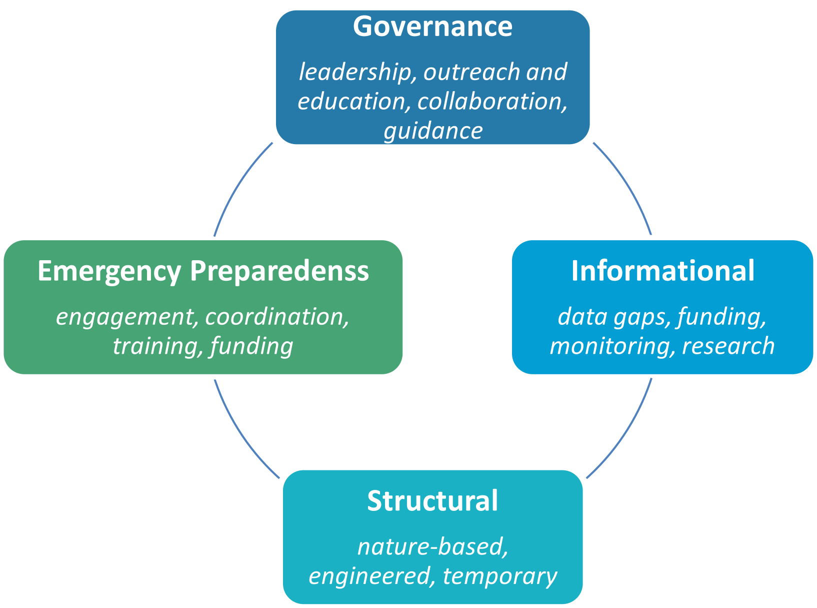


Figure 31: Types of Climate Adaptation Strategies

Further definition of the four strategy types is as follows:

- **Governance strategies** cover how SCRRA will proactively integrate climate adaptation in day-to-day activities through updating policies, plans, operations and maintenance (O&M) procedures and design guidelines; collaborate with regional partners to identify opportunities to work together; create training for employees on how to assess climate vulnerability and develop adaptation strategies; and provide outreach and educational opportunities to inform employees and riders about climate resilience.

- **Informational strategies** cover how SCRRA will continue to learn about climate adaptation through addressing data gaps in understanding the vulnerability of assets, such as by completing feasibility studies and data collection to make more informed decisions; tracking updates to climate projections over time to understand when strategies need to be adjusted; and identifying funding opportunities to support climate resilience projects.
- **Emergency Management strategies** cover how SCRRA will be prepared to: respond to potential increases in major incidents because of climate change, deepen external partnerships to address SCRRA's role in conducting emergency transportation efforts, provide additional emergency response and management trainings, and identify funding to support emergency management efforts.
- **Structural strategies** cover how SCRRA will build in climate resilience in all future projects (where appropriate), with a focus on design and implementation of nature-based solutions where possible. Short-term solutions that will provide temporary protection measures also are included.

Strategy Development

The strategies were developed by drawing on internal and external stakeholder input, best management practices, and consultation with subject matter experts. These efforts are summarized next.

STAKEHOLDER INPUT

The initial "running-list" of the adaptation strategies was developed during stakeholder workshops, where participants were invited to provide ideas through an interactive web-based platform for each of the four strategy types. Figure 32 provides screenshots of the virtual whiteboards that were created during the stakeholder workshops. Governance, information, and structural strategies were discussed in one workshop, and emergency management was addressed in a separate workshop.

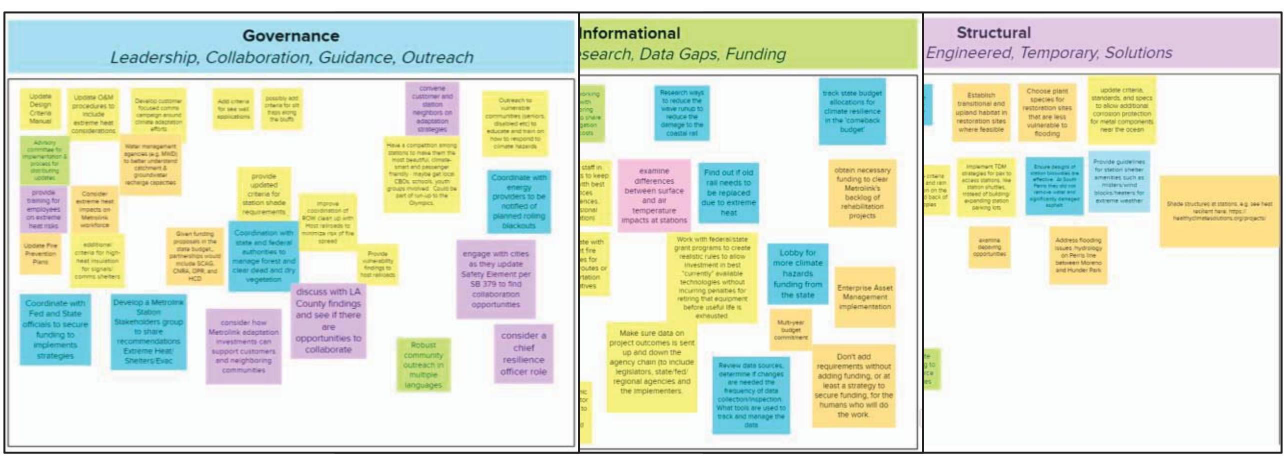


Figure 32: Virtual Whiteboards used in Stakeholder Workshops

BEST MANAGEMENT PRACTICES

A literature review was conducted to identify new and emerging best management practices and guidelines from other transportation agencies, including LA Metro, the Massachusetts Bay Transportation Authority, the Port Authority of New York and New Jersey, the Federal Highway Administration, and California Department of Transportation.

SUBJECT MATTER EXPERT INTERVIEWS

The project team conducted interviews with several subject matter experts, both consultant engineers working specifically on Metrolink assets and SCRRA staff, to review proposed strategies for applicability and identify additional strategies to address gaps.

STRATEGY REFINEMENT

Based on this input, strategies were refined to create a final suite of approximately 100 adaptation strategies. Some of the strategies will need to be implemented in collaboration with other stakeholders.

Each of the strategies then were prioritized, using evaluation criteria covering the feasibility of the strategy and any co-benefits (additional benefits) that the strategy may provide. Feasibility criteria included: SCRRA control, stakeholder acceptability, staff burden, O&M cost, and ease of funding. Co-benefits criteria included: community, environmental, regional, mainstreaming, and adaptability of intervention. Table 31 summarizes the evaluation criteria and ratings. Strategies that were considered to be more feasible and provide more co-benefits got a higher score. The evaluation process was used both to remove some lower scoring strategies from the list as well as inform the timing of implementation.

Table 31: Strategy Evaluation Criteria

Criteria Type	#	Criteria	Rating Description
Feasibility	1	Control	3 = SCRRA has direct control over implementation 2 = SCRRA has indirect control through member agency 1= SCRRA does not have direct control and could only advocate for implementation
	2	Stakeholder acceptability	3 = Member agencies support 2 = Member agencies neutral (or some support, others don't) 1 = Member agencies oppose
	3	Staff burden	3 = Staff can integrate strategy into existing workload and practices 2 = Moderate need for additional staffing and/or training 1 = Significant need for additional staffing (e.g., new position, organization/department-wide training, expensive equipment) *Note: Structural rated on ongoing burden after being implemented*
	4	O&M Cost	3 = Will reduce O&M costs 2 = structural: <$1m annually | informational/governance: <$250k annually 1 = structural: >$1m annually | informational/governance: >$250k annually
	5	Ease of Funding	3 = Fundable within existing capital/operations budget 2 = Would require modifying existing budget or external funding, source identified or likely to secure 1 = Would require external funding, source unknown or unlikely

Criteria Type	#	Criteria	Rating Description
Co-benefits	6	Community (social vulnerability)	3 = Provides direct benefits to socially disadvantaged populations 2 = Provides indirect benefits to socially disadvantaged populations 1 = Does not provide benefits to socially disadvantaged populations *Note: Apply score assuming intervention in a DAC/LIC area Community benefits does not include improvements to reliability of service.*
	7	Environmental	3 = Provides substantial water, air, habitat, and/or emissions reduction benefits 2 = Could provide some water, air, habitat, and/or emissions reduction benefits, depending on implementation 1 = Project would not provide water, air, habitat, and/or emissions reduction benefits
	8	Regional, state, federal benefit	3 = Directly supports regional/state/federal efforts/defined objectives 2 = Indirectly or generally supports regional/state/federal efforts 1 = Does not contribute to regional/state/federal efforts
	9	Mainstreaming	3 = Directly contributes to mainstreaming of climate adaptation system-wide 2 = Encourages climate adaptation in a specific location or department 1 = Does not contribute to mainstreaming of climate adaptation *Note: For info/governance actions only*
	10	Adaptability of intervention	3 = Flexibility after implementation without wasting capital investment 2 = Flexibility after implementation but may result in wasting some capital investment 1 = No flexibility after implementation and/or would result in substantial waste of capital investment *Note: For structural actions only*

Implementation of Adaptation Strategies

NON-STRUCTURAL STRATEGIES

To support implementation, non-structural strategies have been organized into short-, mid- and long-term implementation time frames with an identified lead department. These timelines have been identified to ensure certain mainstreaming and collaboration strategies start as soon as possible (so that opportunities are not missed), as well as to provide a realistic workload for SCRRA staff. Timeline definitions are as follows:

- Short-term (0 to 2 years)
- Mid-term (2 to 5 years)
- Long-term (5+ years)

The identified lead department will be responsible for spearheading implementation of the strategy, although many of the strategies are assumed to need the support of multiple departments.

In the next section of this chapter, strategies are presented by type and timeline.

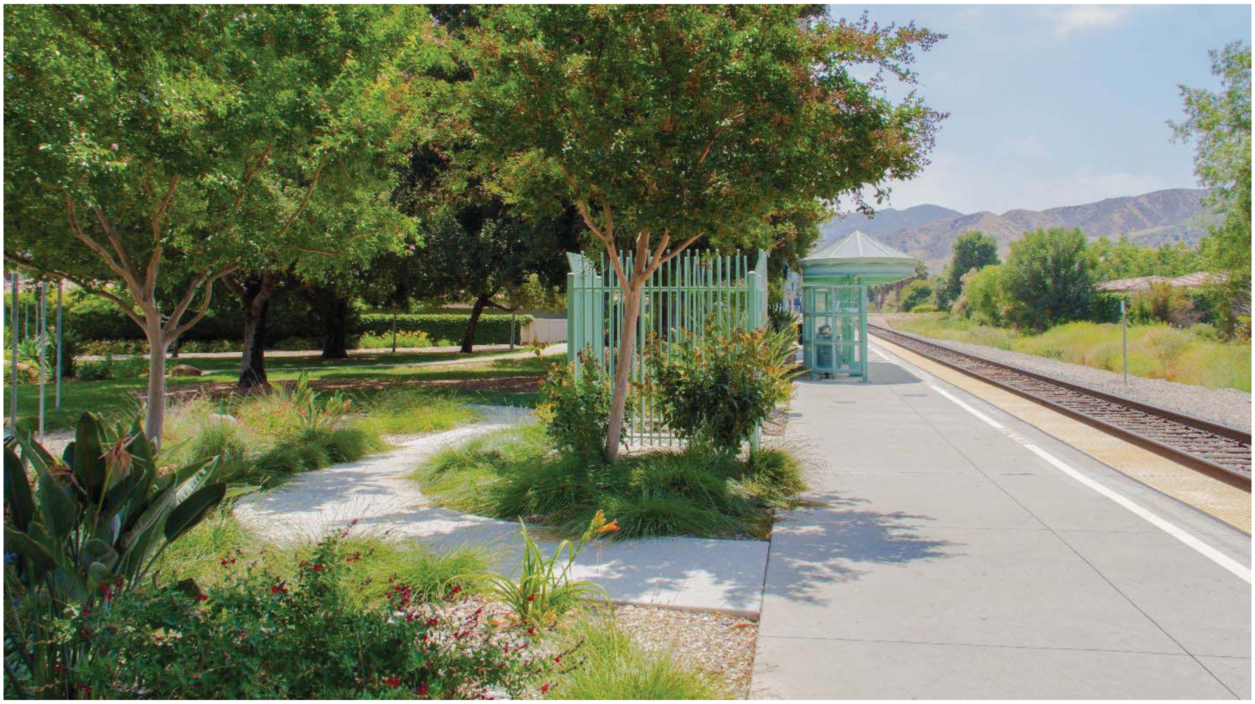
STRUCTURAL STRATEGIES TOOLKIT

The structural strategies are organized as a "toolkit," and depending on the climate hazard and asset type, a number of strategies may be appropriate to adapt a particular asset. Therefore, the structural strategies are organized by hazard, identifying the applicability for each asset type and highlighting nature-based solutions. The list of strategies is available to SCRRA staff as an Excel spreadsheet that can be sorted by hazard type and asset. No time frames are associated with structural strategies because they are based on project scope and applicability.

FUNDING

Although a number of the governance and information strategies may be implemented without significant extra funding, additional resources may be required for integrating climate resilience strategies to capital projects.

Federal and state grants are the primary funding sources available to SCRRA as a joint powers authority (JPA), and they are highly competitive and require thoughtful preparation, especially if local matching funds are required. Positioning projects for grants, especially federal grants, requires sufficient time, resources, and support from a widespread coalition of member agencies, county and city governments, and stakeholders. SCRRA will need to focus the first phase of its grant pursuit efforts in sourcing funds for design and engineering, while simultaneously laying the groundwork to pursue construction funding. The Technical Appendix summarizes grants intended to specifically fund climate adaptation and post-disaster recovery investments. However, traditional transportation grants also may fund adaptation investments, particularly when paired with other system improvement or expansion projects, and a list of SCRRA-relevant transportation grants also is included in the Technical Appendix. When pursuing grant funding, SCRRA and its member agencies may strategize to prioritize and match projects with grants, to reduce local competition and improve success rates in winning grants. Regional multi-agency support for projects can play an important role in securing grant funding. Decisions to prioritize and position certain projects for grant funding may be driven by the competitive landscape, annual funding priorities, and SCRRA's ability to secure local matching funds, which most of the identified grants require at varying levels.



Governance Strategies

SHORT-TERM (0 TO 2 YEARS)

G.1 Align SCORE and Capital Projects with recommended climate adaptation strategies

Review existing Southern California Optimized Rail Expansion (SCORE), rehabilitation, and third-party projects to identify applicable climate adaptation strategies from the structural strategies toolkit that still can be integrated into projects, to ensure that investments made now increase system resilience. This effort will become a core part of all forthcoming SCORE project development. Staff will leverage the Climate Vulnerability Assessment Dashboard (created as part of this project, also see Strategy I.1) to understand the vulnerability of assets within a project scope.
Note: Implementation of this strategy already is in progress (see chapter titled *Application of Selected Strategies* for examples of this assessment).

Lead Department: Program Delivery (Engineering and Construction)

G.2 Add climate adaptation strategies to the SCRRA Design Criteria Manual

Update SCRRA Design Criteria Manual (DCM) to include climate change considerations based on CVA findings and vulnerabilities, to ensure that investments made now increase system resilience. (Both a stand-alone sustainability chapter and embedded language should be included in the technical sections.) Stakeholders should provide feedback so that strategies are feasible, have buy-in, and will be implemented by staff and member agencies.
Note: Implementation of this strategy is in progress as it has been funded, and the update to the

DCM is expected to be completed in 2022/2023. Example design criteria recommendations (which will all be location-specific, referencing the results of the CVA) will include to:

- add criteria for silt traps along the bluffs to protect against erosion;
- add criteria for station shade requirements;
- add criteria for high-heat insulation for signals/communications shelters;
- add criteria for sea wall applications;
- allow additional corrosion protection for metal components near the ocean;
- modify landscaping to low-maintenance, climate-smart plants (to reduce water usage), and add criteria requiring drought tolerant plants and landscaping at stations and along rail trails (to exceed regulatory requirements);
- provide sufficient station shelter amenities, such as shade canopies/misters/wind blocks/heaters, for increasing extreme weather events;
- update criteria to allow more forms of slope erosion protection in vulnerable areas;
- provide criteria for wind and rain protection on the sides and back of canopies;
- add criteria to stabilize hillsides, to reduce mudslides/landslides; and
- modify thermal stress temperature for rail lines.

SCRRA notes that some agencies (e.g., RCTC) already have updated their own design guidelines to include shade and wind requirements for stations.

Lead Department: Program Delivery (Engineering and Construction)

G.3 Create an internal SCRRA Climate Resilience Advisory Committee

Establish an advisory committee to oversee all climate resilience efforts and support internal and external collaboration, outreach, and implementation of strategies. The advisory committee should include one representative from each department and will be responsible for championing implementation of climate adaptation projects through dedicated budget allocation and applications for grants). The committee also will ensure monitoring the performance of projects and sharing the data throughout the agency and beyond (which may include legislators, State/federal/regional agencies and implementing departments and partners, as appropriate). Efforts will focus on strategies that can maximize potential economic, environmental, and social co-benefits for SCRRA, stakeholders, local communities, and riders. This will include prioritizing benefits for low-income, transit-dependent communities. More specifically, committee responsibilities will include to:

- designate a chairperson,
- hold quarterly meetings (attended by entire committee),
- progress implementation of strategies,

- support development of grant applications,
- develop climate adaptation tracking metrics and targets,
- complete an annual monitoring summary to report on climate resilience efforts, and
- communicate efforts to other departments.

Lead Department: Strategy (Sustainability)

G.4 Share CVA findings with municipalities and consider collaboration efforts

Provide CVA findings to municipalities in the Metrolink service area that currently are updating their Local Hazard Mitigation Plan or General Plan Safety Element, or are developing a stand-alone Climate Adaptation Plan per SB 379, and consider collaboration on resulting climate adaptation projects that will benefit both entities, if applicable.

Lead Department: Strategy (Planning and Development)

G.5 Engage with community-based organizations on climate adaptation projects

Engage with community-based organizations (CBOs) to review and provide feedback on location-specific climate adaptation projects that are a result of this CVA. SCRRA values CBO participation and will conduct additional outreach efforts, to ensure that the community has an opportunity to participate (e.g., SCRRA Community Relations will conduct additional outreach, explore stipends to select number of CBOs, and discuss collaboration opportunities with Climate Resolve and other local partners).

Lead Department: Strategy (Government and Community Relations)

G.6 Share CVA findings with host railroads and consider collaboration efforts

Share detailed vulnerability findings with host railroads—UPRR, BNSF, Amtrak—and identify potential collaboration efforts to build climate resilience (such as improving coordination of ROW cleanup to minimize risk of fire spread or vegetation management).
Note: Host railroads were included in the stakeholder group during CVA development.

Lead Department: Strategy (Planning and Development)

G.7 Join Los Angeles Regional Collaborative for Climate Action and Sustainability (LARC)

Become a LARC member and participate in regional member meetings and public forums, and benefit from grant matchmaking, newsletters, and legislative tracking. By joining LARC, SCRRA will continue to collaborate with external stakeholders who are engaged with regional climate resilience efforts (e.g., SCAG, Climate Resolve, LA County, LA Metro).

Lead Department: Strategy (Sustainability)

MEDIUM-TERM (2 TO 5 YEARS)

G.8 Mainstream climate considerations into guiding policy documents

Update policy documents to include climate change considerations so that climate resilience is mainstreamed across SCRRA's decision-making and capital planning processes, ensuring that investments made now will increase system resilience. Priority documents should include:

- Strategic Plan (2021): e.g., Sections: "Strategic Actions" and/or "Insights for Future Direction."
- Climate Action Plan (2021): e.g., Section "Resiliency."
- Design Procedures Manual (2014): e.g., "Design Scope Matrix" or create a new stand-alone climate resilience checklist.

Lead Department: Strategy (Planning and Development) and Program Delivery for DPM modifications.

G.9 Support Member Agencies to implement adaptation strategies

Support member agencies in implementation of new requirements (e.g., through the Design Guidelines Update) and other adaptation strategies based on CVA findings. Some examples may include:

- OCTA: Coordinate with adjacent landowners to address landslide issues along the coastal stretch of track in Orange County (current project).

- OCTA: Coordinate with regional beach nourishment efforts. Beach nourishment would be performed by other agencies outside the SCRRA ROW. OCTA/SCRRA may be able to assist with access and permit needs for these efforts. (Addressed in Board meeting held in October 2021, for OCTA to complete study and identified $700k in funding to assess long-term solutions to ensuring resiliency of coastal rail corridor).
- All: Coordinate with freight rail operators to ensure that the PTC system on non-SCRRA-owned track has sufficient redundancies (both for their dispatch center and track-level equipment), to allow trains to continue to run during an extended electrical outage.
- All: Coordinate to ensure that the maintenance/servicing of station amenities is adequately budgeted (e.g., regular servicing of misters to prevent dripping that creates slip hazards on the station platform).

Lead Department: Strategy (Government and Community Relations), Operations (coordinate PTC resilience with other railroads and for coordination with cities for maintenance/servicing of station amenities), and Program Delivery (Standards and Design)

G.10 Develop community outreach plans for climate adaptation projects

Develop specific community outreach plans for climate adaptation projects that would have an impact on adjacent communities to include participation of at least one CBO, riders, and other affected station neighbors. Ensure that community outreach is in multiple languages and attention is given to format and location of engagement, to maximize participation, particularly by vulnerable populations.

Lead Department: Strategy (Government and Community Relations)

G.11 Add climate adaptation strategies to the SCRRA O&M Plans

Update O&M plans to include climate change considerations, to ensure that investments made now will increase system resilience. Considerations should include:

- identifying future workforce needs (examining whether additional staff need to be hired to perform additional O&M because of extreme weather event wear and tear);
- budgeting for maintenance (identifying additional funding needs);
- increasing maintenance (making additional inspections because of increased asset deterioration or for vegetation control);
- shifting O&M procedures to take place at night rather than during the day, to avoid extreme heat temperatures (already being done at some locations);
- adding staff capacity to enable more efficient infrastructure inspections;
- incorporating new and future technologies and system requirements (as new materials and products are researched and piloted);
- adding training opportunities for employees (e.g., enhancing their ability to recognize extreme heat climate risks to equipment and for employee safety);
- updating the track maintenance manual for sun kink prevention, to adjust allowable track maintenance activities during or prior to extreme heat days, to prevent thermal misalignment; and
- developing operational guidelines for addressing short-term landslide hazards, caused by wildfire events (may include site visit by geotechnical engineers, or short-term solutions such as nets or retaining walls, and longer-term solutions, such as revegetating hillsides).

Lead Department: Operations (Facilities)

LONG-TERM (5+ YEARS)

G.12 Create a resilience checklist for stations

Develop a resilience checklist for stations that can be used to celebrate stations that are most resilient, based on the number of features they include (e.g., hydration stations, bioswales, shade structures). Consider acknowledging stations on Metrolink's website and other publications. Build on the station survey that was completed as part of the CVA, to better understand gaps in facility amenities, help riders and staff cope with extreme heat, and determine which amenities (e.g., water fountains, shade structures, seating, misters) are feasible while balancing maintenance and vandalism concerns.

Lead Department: Strategy (Sustainability) and Operations (Facilities)

G.13 Strengthen relationships with utility providers to improve climate resilience

Many of Metrolink's services are reliant on other providers, such as electric utilities and water management agencies, and SCRRA needs to understand the preparation that those organizations have made in relation to climate change. The aim of this strategy is to strengthen relationships with utility providers, to improve collective climate understanding and resilience. The following examples include relationships with:

- Electricity suppliers (e.g., Southern California Edison, San Diego Gas and Electric), to better understand which portions of the network will be affected by public safety power shutoffs (PSPS), to develop potential partnerships for increasing access to renewable energy/diversified power sources, to evaluate utility capacity during surge periods and identify actions to minimize outages and establish back-up power supplies. Ongoing communication with electricity suppliers may be necessary to remain aware of PSPS predictions, because of natural hazards (e.g., wildfires, capacity limitations). Currently, suppliers have rudimentary methods of documenting and predicting PSPS and limited data on previous events. More accurate and timely PSPS predictions can increase resilience for SCRRA, by ensuring adequate time to position back-up power supplies and implement other mitigating measures.
- Water management agencies, to better understand catchment and groundwater recharge capacities so that ponding does not occur.
- County Flood Control Districts, to identify efficient ways to address localized flooding to Metrolink track when it originates from overtopped flood control channels.
- County/State/Federal/City Public Works. for vegetation management and drainage.
- Telecommunications, to understand potential issues during wildfires or other events.

Lead Department: Operations and Maintenance, Program Delivery and Safety

G.14 Add climate vulnerabilities to the Asset Management Database

Add asset climate vulnerability ratings to the Asset Management Database, to capture this valuable indicator of future condition (or deterioration) with the attributes of an asset condition (e.g., state of good repair, age). This will provide a more comprehensive understanding of the current and likely future condition of each asset.

Lead Department: Program Delivery (Business Operations)

G.15 Develop a climate resilience communications campaign

Develop a customer-focused communications campaign around climate adaptation efforts, with a focus on language and media/methods that will reach vulnerable communities (e.g., seniors, people with disabilities, transit-dependent communities), to inform the public about climate resilience at Metrolink, and more specifically:

- develop signage (in multiple languages) at stations, to inform riders about climate resilience initiatives;
- educate community neighbors on how to respond to climate hazards (e.g., around vegetation control [fire hazards] and system-wide for riders on hydration [extreme heat]); and
- leverage a Metrolink rider app and/or Twitter account to inform the public on weather hazards and alternative routes, and to provide real-time reports from the public to help SCRRA respond to an event.

Lead Department: Marketing (Customer Relations)

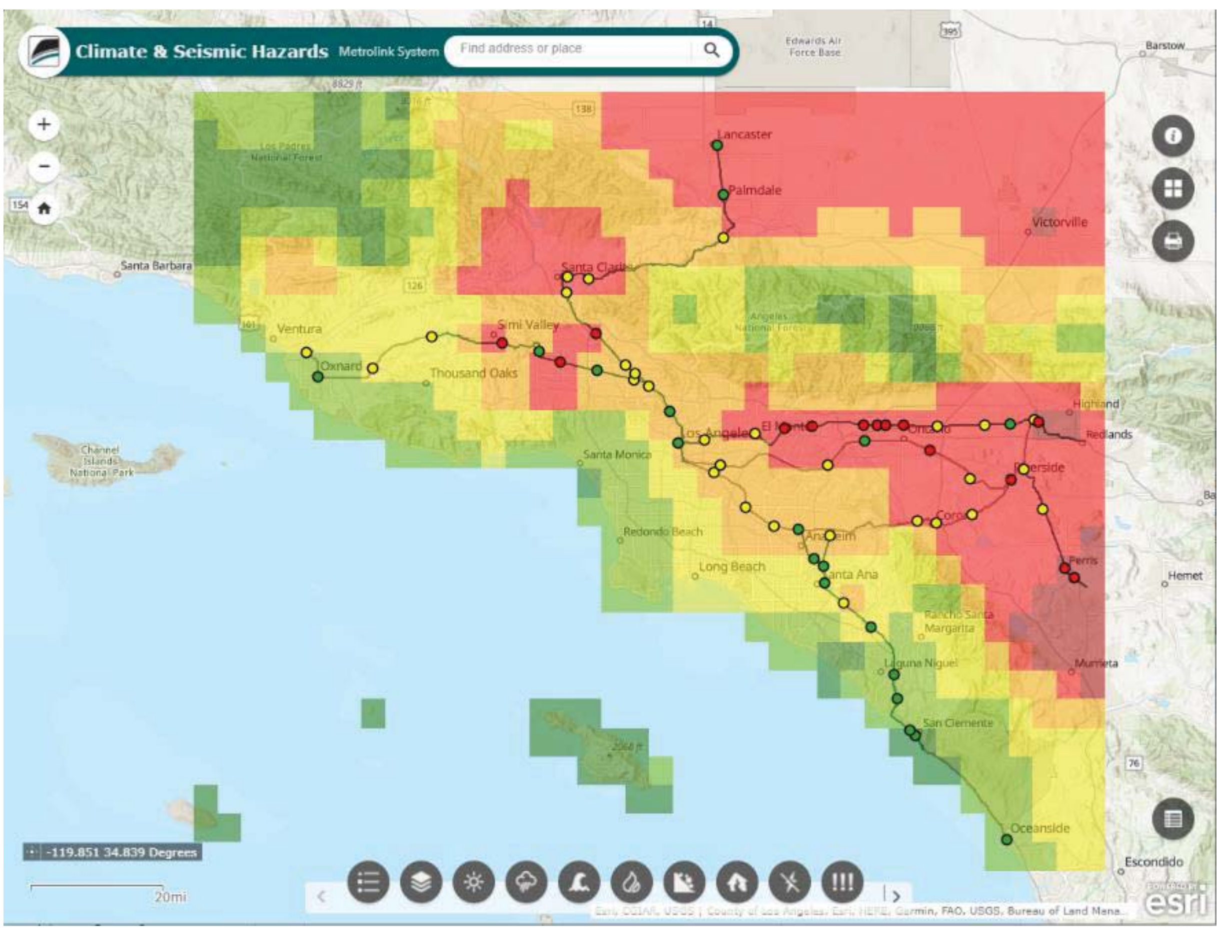
Informational Strategies

SHORT-TERM (0 TO 2 YEARS)

I.1 Create a web-based Climate Vulnerability Assessment Dashboard

Develop an interactive, web-based climate vulnerability dashboard to enable SCRRA staff to view tabular and GIS outputs of the Climate Vulnerability Assessment by asset type and hazard. The dashboard will provide departments with an easy way to explore the climate vulnerability of specific assets and/or locations and will help ensure that vulnerability assessment results are leveraged across the organization. The dashboard will be accompanied by a short reference manual to guide users and highlight the importance of the tool. The intent of this effort is to support SCRRA planning/design staff in identifying potential climate vulnerabilities of assets when working on or reviewing projects. If vulnerabilities are identified, staff will be directed to use the structural strategies toolkit for potential solutions to reduce those vulnerabilities. The dashboard will include data on socially vulnerable populations and will highlight the importance of prioritizing strategies that will benefit those vulnerable communities.
Note: Implementation of this strategy is in progress and is anticipated to be completed in 2022.

Lead Department: Program Delivery (Standards and Design), Strategy (Sustainability/Planning)



I.2 Research funding opportunities to support implementation of climate adaptation strategies

Identify potential funding streams (including existing budgets, federal and State grants, bonds, loans, other incentives) to support climate resilience projects. Increasingly, federal and State grant programs have climate and equity eligibility criteria. Furthermore, because of funding proposals in the State budget, partnerships could include the Southern California Association of Governments, California Natural Resources Agency, California Governor's Office of Planning and Research, and California Department of Housing and Community.
Note: Implementation of this strategy is in progress.

Lead Department: Finance (Grants)

I.3 Add new data about rail track condition to further refine climate vulnerability assessment

Incorporate results of railroad tie scans and rail condition assessments from the Metrolink Rehabilitation Plan (MRP) into the CVA, to better understand local variations in track vulnerability to extreme heat (degraded ties are more susceptible to thermal misalignment). This data should be used to update the track vulnerability profiles in the CVA.
Note: Initial steps for implementation of this strategy are in progress. SCRRA has established a program through its Maintenance of Way Contractor for performing tie scans and assessments of track condition across the territory on a recurring basis each year and analyzing the results. In late 2021, work began on an update of the MRP, to provide a comprehensive analysis of Metrolink's asset condition, including its track and ties. In the future, the findings of this analysis can be included in the CVA tool to reflect the latest condition and vulnerability information.

Lead Department: Program Delivery (Engineering and Design), and Operations (Maintenance)

I.4 Research nature-based strategies and funding opportunities to reduce coastal erosion

Explore the feasibility of nature-based strategies (such as dune restoration), to reduce wave runup and address coastal erosion to minimize damage to the coastal rail. Identify case studies and assess the applicability to SCRRA, as well as permitting considerations. Nature-based strategies are preferred by State agencies for sea level rise adaptation. Furthermore, in the future, more grants/funding to support nature-based solutions may be anticipated.

Lead Department: Finance (Grants)

I.5 Include social and environmental considerations to cost-benefit analysis for climate adaptation projects

Require that a cost-benefit analysis be completed for climate-related projects enhancements, so that the additional social and environmental benefits provided by adaptation strategies can be quantified to help make a case for any additional upfront cost. This also is in accordance with U.S. Department of Transportation (DOT) guidelines. This analysis will require careful consideration of how SCRRA adaptation investments can benefit riders and neighboring communities, and therefore the organization as a whole.

Lead Department: Strategy (Sustainability)

I.6 Track climate change impacts on assets

Monitor asset climate impacts and resulting costs over time to justify the need for climate adaptation strategy implementation. Determine data sources and streamlined tracking methods for the different assets and related departments (e.g., data collection tools, work orders, labor tracking systems, inspection routines), to contribute to annual reporting by monitoring:

- rail temperatures and track alignment to identify patterns between extreme heat and sun kinks;
- extreme wind events and related power shutdowns, to understand service impacts (e.g., fallen trees/power issues at signals and crossings); and/or
- all costs (e.g., capital, revenue lost) associated with weather related impacts.

Lead Department: Program Delivery (Business Operations), and Operations (Maintenance)

I.7 Track climate change impacts on operations

Monitor operational climate impacts on riders and employees, as well as resulting economic impacts over time, to justify the need for climate adaptation strategy implementation. Determine data sources and streamlined tracking methods as appropriate for different operations and departments (e.g., data collection tools, work orders, labor tracking systems, inspection routines), to contribute to annual reporting by monitoring:

- ridership complaints related to extreme weather events (e.g., heat, wildfire smoke, flooding, wind, power outages) and associated costs related to go-slow orders, bus bridges, or other operational intervention; and/or
- extreme heat impacts/wildfire smoke days and SCRRA workforce/track workers through missed work days or compensation claims on high heat or poor air quality days.

Lead Department: Marketing (Customer Relations), Operations (Maintenance) and Human Resources

I.8 Research climate resilient plant species at stations

Identify non-invasive plant species that improve climate resilience to precipitation/landslide (erosion of restoration sites), extreme heat (drought tolerant), and wildfire (less prone to burn and/or quick to regenerate). This effort will reduce vulnerability to wildfire and drought conditions and will support the Design Criteria Manual update.

Lead Department: Program Delivery (Standards and Design)

MEDIUM-TERM (2 TO 5 YEARS)

I.9 Stay up-to-date with current climate projection releases and update accordingly

Monitor climate projection updates and make CVA adjustments as necessary, at a minimum every 5 years. Regular updates occur for the California State Climate Assessment (every 3 to 4 years; last updated in 2018), the National Climate Assessment (every 4 years; last updated in 2018), and the International Panel on Climate Change global assessments (every 4 to 5 years; last updated in 2021), which may indicate a slowing down or speeding up of the rate of change. Significant updates to the CVA may be needed, depending on assessment findings.

Lead Department: Strategy (Planning and Development)

I.10 Create climate resilience budget line items under applicable department budgets

Commit to a multi-year budget to support climate resilience efforts. This funding can be used to support integration of adaptation strategies identified in this document into the Southern California Optimized Rail Expansion and other capital projects (e.g., raising a seawall or installing pervious pavement instead of asphalt). This funding also could support SCRRA staff in their efforts to keep current with best practices, by conducting internal webinars, training, participating in conferences, and/or attending professional education opportunities.

Lead Department: Finance

I.11 Evaluate on-site energy opportunities

Conduct a feasibility study to assess the potential for on-site renewable energy generation, energy storage, and/or microgrids at Metrolink facilities or stations, to provide more reliable, decentralized, grid-independent renewable energy (similar to the 2-megawatt solar photovoltaic (PV) carport installation at Industry Station, made possible in part by a 20-year power purchase agreement with Southern California Edison).

On-site energy technologies can include rooftop solar PV, optionally paired with electrical energy storage systems to improve power reliability. Potential applications for PV initially can be for priority facilities with adequate roofs or parking areas, such as the DOC, MOC, CMF, EMF, and HQ. Additional resilience benefits can be achieved by applying on-site energy technologies to other facilities. A feasibility study will be needed to analyze the structural integrity of existing rooftops for rooftop solar PV. Other facilities with large shading structures or hard surface areas, such as the materials storage yards, may be feasible for solar carport applications to support critical functions in the project vicinity. Ground-mounted solar PV or other on-site energy generation applications can support transportation stations owned by SCRRA, if the surrounding land area allows the required space. Some facilities have existing back-up power systems (e.g., emergency generators) that potentially can connect to other on-site renewable energy generation systems and energy storage systems, to develop a microgrid that supports the entirety of a transportation station. Applying on-site energy opportunities should be considered for facilities and stations owned by SCRRA, for additional ease of implementation and prioritizing locations based on critical operations, power requirements, and risks of electrical outages. Feasibility should include consideration of emerging technologies and the value of resilience as a community service, in addition to cost metrics. This strategy will be in line with the energy -related goals and actions in SCRRA's 2021 Climate Action Plan.

Lead Department: Operations (Facilities)

I.12 Evaluate nature-based strategy opportunities

Research de-paving opportunities and identify nature-based best management practices to reduce flooding suitable for SCRRA property, with a focus primarily on opportunities in facility and station parking lots. Consideration should include a suite of nature-based strategies (e.g., restoring to natural landscape, pervious/porous pavements, bioswales), proper drainage design based on future precipitation projections, and long-term O&M costs. The best management practices should be vetted with SCRRA staff who will be responsible for implementation and long-term maintenance of the solutions.

Lead Department: Operations (Facilities)

LONG-TERM (5+ YEARS)

I.13 Improve understanding of critical power needs at facilities

An essential step in improving energy resilience is clearly defining the need for facility energy use. Understanding what loads are considered to be critical for operations, and how the existing systems are supporting them will serve as the basis for developing solutions to improve supply availability and quality. This definition task will require additional asset-level energy analysis and testing, which may include the following steps:

- Re-evaluate which facilities need continuous or uninterruptible power supply for critical loads that will be imperative for steady operations. Continuous power supply requirements may dictate the need for back-up power systems.
- For facilities with existing back-up power, such as the DOC, MOC, CMF, and EMF, identify loads that are connected to back-up power and assess whether all critical loads will be supported adequately. Continue to evaluate the condition of back-up power systems, because aged or problematic equipment is prone to failure when in use. Document the duration that back-up power systems can provide sufficient power during extended outages without replenishing energy sources (e.g., diesel fuel for generators).
- Determine the necessity of redundant back-up power systems at those facilities that need back-up power, including considerations such as likelihood of losing commercial power supply, likelihood of failing primary back-up power system, historical power outages, and criticality of electrical loads that may result in interrupted Metrolink operations if lost. An example of redundant back-up power systems is a facility with two back-up generators that could use one generator to supply all critical loads but has a secondary generator that is capable of supporting all critical loads in the event that the primary generator becomes inoperable.
- Perform full-load (operating backup power systems at full capacity) and hard-drop testing (abruptly interrupting the primary power supply) on all backup power systems, to ensure the longevity of equipment and smooth operations during outages.
- For facilities without back-up power that may require continuous power, such as Metrolink HQ, identify critical loads that need uninterrupted power and implement back-up power for those prioritized loads.
- For facilities without back-up power that may not need a continuous supply of power but need power to operate, such as trailers, consider implementing back-up power for prioritized loads versus all electrical loads, for additional benefit to SCRRA’s resilience posture.
- Review back-up power systems for electrical equipment along the track (with a focus on cooling communications boxes), to determine the condition and duration that they can provide sufficient power during extended outages.

Lead Department: Operations (Facilities)

I.14 Evaluate irrigation opportunities using graywater

Explore opportunities for connecting station and facility irrigation systems to recycled water lines to reduce vulnerabilities to drought and support water conservation. This effort will involve mapping existing reclaimed water systems that will be available to tap into, collaborating with water agencies, and overlaying with SCRRA assets to determine feasible locations.
Note: Los Angeles County owns and operates one of the largest wastewater recycling systems in the world, and the City of Los Angeles has committed to recycling 100 percent of its wastewater by 2035.

Lead Department: Operations (Facilities)

I.15 Evaluate temporary flood protection strategies

Identify the most appropriate temporary flood protection barriers for different types of assets (e.g., sandbags, tiger dam, aqua fence), to be better prepared during an event (based on cost, labor, and storage). This effort will improve asset protection and response time to temporary flood events. The type of temporary flood protection strategy will depend on the type of flooding to which a particular asset is vulnerable. Sandbags are likely to be more appropriate for assets vulnerable to ponding during a heavy rainstorm, while an aqua fence can be deployed to protect high criticality assets during more extreme storms.

Lead Department: Operations (Maintenance)

I.16 Consider piloting a community resilience hub that can be deployed during an emergency

Identify potential stations that can become temporary community resilience hubs in the event of a power failure (provide electricity), extreme heat (provide cooling), or wildfire smoke (clean air), and work with member agencies to determine feasibility. This will involve identifying stations that will be good candidates (locations with high exposure and low vulnerability to extreme heat and high social vulnerability). These hubs will be operational only during emergency situations.
Note: At the time of writing, University of California, Los Angeles (UCLA) researchers are looking for a location for a prototype cooling center facility, and Los Angeles (LA) Metro has indicated that it will consider Sun Valley as a potential location for the pilot.

Lead Department: Operations (Facilities)

I.17 Further assess bridge vulnerability to flooding

Complete additional evaluation of bridge elevation versus flood water surface elevation, to verify whether bridges are prone to damage from increased flooding because of a changing climate (e.g., scour, substructure damage, over topping). The CVA identified bridges whose approaches are within the floodplain, suggesting that the track on the span likely is vulnerable to overtopping. Because of data limitations, the CVA was not able to identify bridges that are vulnerable to substructure damage but not overtopping. This data will be used to update the flooding vulnerability map and bridge vulnerability profiles.

Lead Department: Program Delivery (Standards and Design)

I.18 Further assess relationship between landslide vulnerability and climate change

Complete additional geotechnical studies of landslide-prone areas, to identify specific areas that are most at risk. This data will be used to update the CVA, which relied on regionally available landslide hazard data from USGS. The CVA identified high hazard regions in this dataset that indicate areas where the hazard is high enough to suggest the need for more granular local review, but did not necessarily indicate immediate threats from active landslides.

Lead Department: Program Delivery (Standards and Design)

I.19 Assess the indirect impacts from electrical outages

Complete a study to understand the full system impacts from acute electrical outages or power quality fluctuation elsewhere in the system. For example, if Station A lost power and Station B did not, Station B still may experience delays in its operational schedule because of the outage at Station A. Signals and other network systems also should be included to have a comprehensive map of dependencies that will serve to highlight areas requiring the greatest levels of energy resilience to maintain their missions.

Lead Department: Operations (Facilities)

Emergency Preparedness Strategies

SHORT-TERM (0 TO 2 YEARS)

EM.1 Identify funding for managing climate change-related incidents

Identify potential funding sources for further improving capabilities to manage climate change-related incidents. These include opportunities through the Los Angeles Urban Area Security Initiative (UASI), as well as from state and federal transportation and homeland security grant programs.

Lead Department: Safety, Security & Compliance

EM.2 Foster relationships with partner transit agencies, local agencies, and member agencies

This may include involvement in ongoing partner agency emergency management meetings and/or disaster councils, and/or participation in partner agency emergency preparedness trainings and exercises. Recommended outreach should include:

- Lancaster Disaster Council
- Antelope Valley PIO group (for Metrolink PIO)
- Los Angeles County Office of Emergency Services
- Los Angeles Emergency Management Council meetings
- Transit Mutual Assistance Compact (TransMAC)
- Southern California Association of Governments (SCAG)
- Orange County Transportation Authority (OCTA)
- San Bernardino Operational Area (OA) Coordination Council quarterly emergency management meetings
- City of Covina

Lead Department: Safety, Security & Compliance

EM.3 Engage with the California Governor's Office of Emergency Services (Cal OES)

Engage with regional Cal OES representatives to better understand how SCRRA is expected to receive or contribute to regional situational status reports and resource requests. Participate in Cal OES planning and coordination sessions for the transportation sector and for regional response coordination.

Lead Department: Safety, Security & Compliance

EM.4 Share completed emergency management plans

Share emergency management plans for socialization with the jurisdictions served by Metrolink service. Conduct outreach to clarify response elements of the plans and to highlight SCRRA's capabilities to support response efforts within its service area. Coordinate mutual reviews of plans, to determine how response strategies and operations align among partners agencies and jurisdictions.

Lead Department: Safety, Security & Compliance

EM.5 Review and revise SCRRA's Incident Response Plan and the EOC Manual
Review and revise the Incident Response Plan and the EOC Manual to clarify how the incident command-level and EOC-level organizational structures interact with one another, such as when they simultaneously may be activated and how their roles and responsibilities may complement/coordinate with one another. Verify that no inherent conflicts between the frameworks, to avoid confusion during potential response activations.

Lead Department: Safety, Security & Compliance

EM.6 Review After Action Reports from past evacuation efforts
Review After Action Reports from past evacuation efforts, to identify targeted resiliency opportunities for communities in Metrolink's service area. Identify and assess remediation strategies for any identified gaps or issues, and assign corrective actions to improve future evacuation efforts.

Lead Department: Safety, Security & Compliance

EM.7 Review CVA Social Vulnerability Assessment results

Review CVA Social Vulnerability Assessment results with a focus on vulnerable populations/communities, such as populations with access & functional needs (AFN). Assess how these populations/communities are addressed and served by the elements of the current response plans. Refine recommendations as appropriate and if needed identify corrective actions to undertake.

Lead Department: Safety, Security & Compliance

EM.8 Conduct a briefing and/or training with SCRRA emergency personnel

Conduct a briefing and/or training with SCRRA emergency personnel about climate change hazards and increased frequency of incidents. Focus on prevention and mitigation strategies to minimize the impacts of these hazards.

Lead Department: Safety, Security & Compliance

MEDIUM-TERM (2 TO 5 YEARS)

EM.9 Establish contingency contracts

Identify likely needs and potential shortfalls of capabilities and materials needed for an emergency response. Establish contingency contracts with relevant suppliers who provide prioritized access to resources, to enable more reliable and rapid access to services and supplies needed during an emergency response effort.

Lead Department: Safety, Security & Compliance

EM.10 Establish emergency maintenance/repair teams

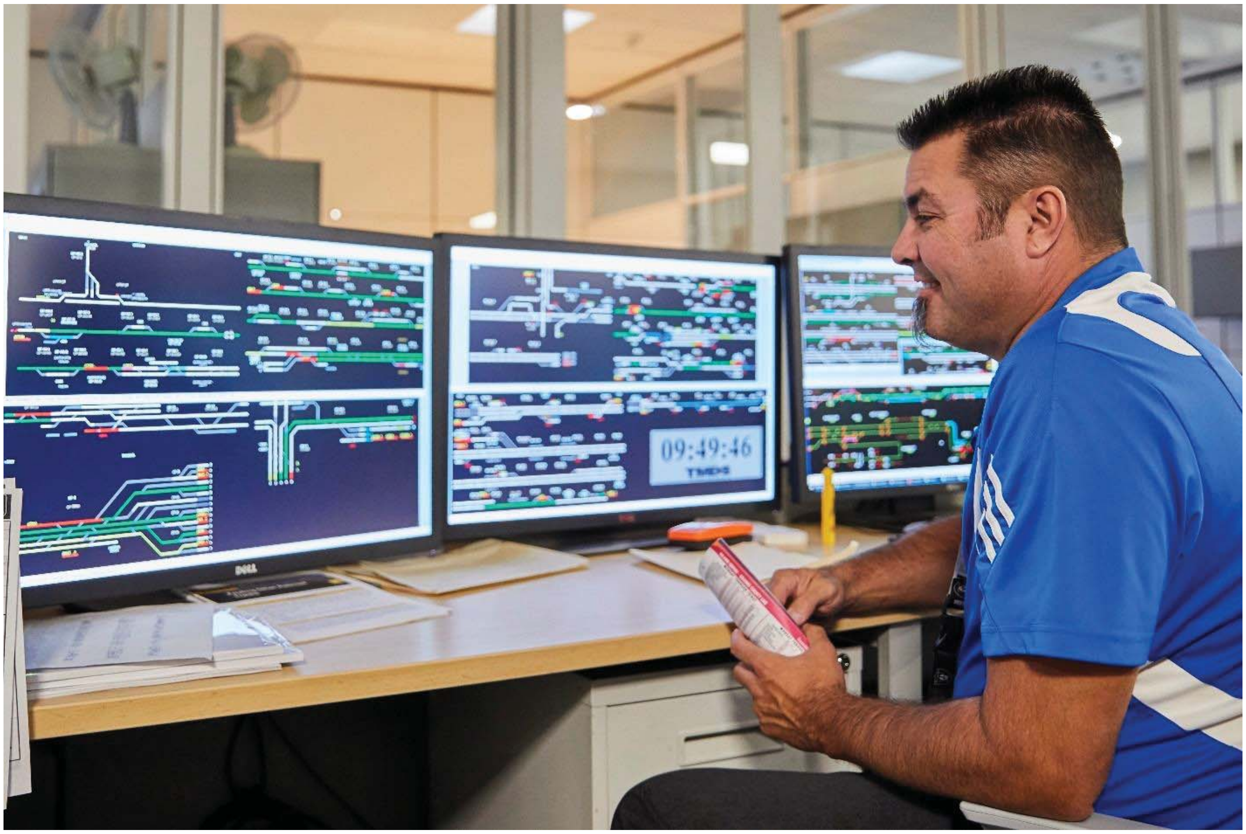
Establish emergency maintenance/repair teams who can deploy rapidly following an incident. These should include in-house staff and/or contracted support (via ongoing or contingency contracts). Identify key capabilities, such as structural damage assessment or electrical system repair, and identify primary and secondary staff resources to meet those needs.

Lead Department: Safety, Security & Compliance

EM.11 Develop procedures to include in the EOC Manual and Incident Response Plan

Develop procedures to include in the EOC Manual and Incident Response Plan that define how coordination will take place between SCRRA and partner transit agencies, local agencies, and member agencies. Where possible identify specific communication/coordination protocols (e.g. situation status reporting, resource request/fulfillment process) and mutual aid agreements. Involve partner stakeholders in preparation of these procedures so that accurate and feasible procedures are developed.

Lead Department: Safety, Security & Compliance



EM.12 Develop climate scenario-specific response plans

Develop climate scenario-specific response plans to guide SCRRA’s efforts to protect life safety and high-value equipment following a major incident. Examples include:

1. Supporting the current effort to install earthquake detection and warning systems to automate the halting of trains
2. Sandbagging and/or relocating equipment in response to flood warnings

Lead Department: Safety, Security & Compliance

EM.13 Update emergency plans to include information about climate change hazards and potential impacts

Update emergency plans to include information about climate change hazards and potential impacts (e.g. hazard types, vulnerable areas and systems). Include references to other relevant plans and clearly identify how such plans contribute to SCRRA’s overarching emergency management program:

1. SCRRA/Metrolink Continuity of Operations (COOP) Plan,
2. SCRRA/Metrolink EOC Manual,
3. SCRRA/Metrolink Incident Response Plan, and
4. SCRRA/Metrolink Threat and Vulnerability Assessment

Lead Department: Safety, Security & Compliance

EM.14 Conduct emergency-response exercises with both internal and external partners

Conduct exercises with both internal and external partners by inviting partner agencies to join emergency-management drills and exercises being conducted by SCRRA, and have SCRRA staff participate in drills and exercises being hosted by partner agencies and jurisdictions. These should include exercise scenarios that focus on SCRRA-specific facilities and disruptions, and scenarios that address multi-agency responses to large-scale incidents.

Lead Department: Safety, Security & Compliance

Structural Strategies–Toolkit

The structural strategies are organized as a toolkit by hazard type, with applicability of the strategy for each asset type and nature-based solutions highlighted. For SCRRA staff, this toolkit also is available as an Excel spreadsheet that can be sorted by hazard type and asset. No time frames are associated with structural strategies because their implementation will depend partly on forthcoming project scope and applicability. Potential locations where the strategy may be suitable to reduce vulnerability to a specific hazard are included (based on the vulnerability assessment). The dashboard (Informational strategy 1) can be used to identify further locations.

SEA LEVEL RISE

Impacts from SLR include erosion, temporary flooding, and potential damage to track structure and stations from wave runup. SLR vulnerability is confined to the coastal stretches of track in Orange and San Diego counties. For example, sections of coastal track on the Orange subdivision, at the San Clemente Pier station, and one segment of track just south of the Orange County border and north of the outlet of San Mateo Creek/Trestles bridge already are exposed to overtopping from waves during storm events, which could cause damage to track and other assets. This vulnerability will increase as sea levels rise. Furthermore, by late-century, almost the entire coastal stretch of the Orange subdivision (from MP 200.3 to 207.3) could be exposed to overtopping from storm surges, as may be both stations (San Clemente and San Clemente Pier) and all other rail assets along the line. In addition, shoreline erosion could undercut track where it is closest to the shoreline, just east of San Onofre Creek, by mid-century. By late-century, some stretches of track fronted by Trails State Beach south of the San Onofre Nuclear Power Plant could become exposed to undercutting as well.

Applicability ***= *nature-based*	Track	Bridge	Tunnel	Station	Facilities	Signals	Comms	Culverts
SLR.1***	X					X	X	X
SLR.2				X				
SLR.3	X					X	X	

SLR.1: ***Support beach nourishment and restoration to slow beach erosion and reduce wave runup. Nourishment can be sand placement, but gravel and/or cobble also can be considered where appropriate. Beach nourishment will be performed by other agencies outside the rail ROW (see Governance Strategies).

Potential locations for implementation: San Clemente City Beach, San Clemente State Beach, Trestles Beach, San Onofre State Beach

SLR.2: Add a low floodwall at San Clemente Pier Station, to prevent wave runup from reaching station structures and the below-grade pedestrian rail crossing seaward of the track.

Potential locations for implementation: San Clemente Pier Station: station structures seaward of the track, vulnerable to flooding from 100-year storm event wave runup.

SLR.3 Construct improved revetments (larger rock armor size, more gradual slope, higher crest) where rail is exposed (or is projected to be exposed) to excessive runup and overtopping from waves during a 100-year storm event. Revetments that are designed with an additional seawall at the top will not need to have as wide a footprint as those without, which will maximize beach space.

Potential locations for implementation: Out of the entire coastal stretch of track in Orange County, MP 207.3 to 207.4 currently is the most exposed to wave action under existing conditions. Other stretches currently exposed are MP 202.0 to 202.5 and MP 203.8 to 204.5. Additional stretches will become vulnerable over time.

FLOODING

Flooding from extreme precipitation can cause damage or service delays because of the exposure of bridges, rail lines, stations, or other facilities to temporary inundation and/or high velocity flows. Track, stations, and facilities assets in Simi Valley, Burbank, Santa Clarita, Redlands, and Perris Valley already are within the 100-year floodplain and are projected to experience an increase in chance of a 100-year precipitation event in mid-century, meaning that the 100-year floodplain extent could expand in the future. Four tunnels (25, 26, 27, and 28) already flood during precipitation events and are fitted with pumps to handle the issue. The tunnels are in areas projected to experience an increase in 100-year precipitation in the future, and the current pump capacity likely will not be sufficient to handle increased flows during these storm events.

Applicability ***= nature-based	Track	Bridge	Tunnel	Station	Facilities	Signals	Comms	Culverts
F.1***	X			X	X	X	X	
F.2	X			X	X	X	X	
F.3	X					X	X	X
F.4		X						
F.5		X						
F.6								X
F.7		X						
F.8		X						
F.9		X						
F.10		X						
F.11	X					X	X	
F.12	X					X	X	
F.13			X					
F.14					X			
F.15***				X	X			
F.16						X	X	
F.17	X					X	X	

F.1: ***Prioritize nature-based solutions (e.g., bioretention, bioswales) as strategies for reducing stormwater flooding in locations where the geotechnical conditions are appropriate and/or with adequate foundation/substrate. Design bioswales or other bioretention/nature-based features to reduce stormwater runoff where feasible, choosing low maintenance, non-invasive plant species. Types of locations that should be considered include parking lots and landscaping around structures as well as along track in the Metrolink ROW.

Potential location for implementation: South Perris Station.

F.2: Consider drilling injection wells where clay soils or impermeable surfaces limit the ability for stormwater to infiltrate and where transferring water away from the site is not feasible. Injection wells are simple bores that extend through impermeable/clay soils to allow water to infiltrate into the groundwater table below. Although they do not require extensive maintenance or mechanical equipment, they require a U.S. Environmental Protection Agency permit, which requires stormwater to be filtered through dirt or sediment before injection. Therefore, injection wells can be added at the bottom of swales, basins, or other retention features to aid infiltration. This strategy can be considered in combination with Strategy F.1.

Potential locations for implementation: Flood prone locations where soil immediately below the surface (0 to 10 feet) is clay or other low-permeability soil type.

F.3: Address flooding at the point of overtopping, where a short stretch of track is exposed to flooding from a discrete flood path, using berms, raising channel walls, or widening flood channels.

Potential location for implementation: Flooding originates from overtopping of the flood channel at San Gabriel MP 39.2 in Rialto.

F.4: Base the storm scenario design for new bridges or bridge retrofits on future precipitation/ flood projections. If projections are uncertain, consider adding additional freeboard and/or scour protection beyond the design storm, based on current conditions.

Potential locations for implementation: Bridges that are crossing flood channels south of Lytle Creek Basin, which drains a watershed that is projected to have 12 percent greater precipitation during the 100-year storm event by mid-century. (Shortway 0.880-MT, San Gabriel 55.630-MT)

F.5: For new bridges only, consider through-girder or truss designs rather than deck/box girder designs at locations where deck elevation is constrained. The load-bearing elements of these types of bridges are above the deck, and therefore can withstand higher flood depths without changing the bridge deck elevation.

Potential locations for implementation: Bridges 173.600-MT2 and 188.500-MT2 on the Orange subdivision are prestressed concrete, single-box girder bridges and have high vulnerability to flooding. Bridge 41.260-MT on the Valley subdivision is a prestressed concrete, single-box girder bridge and has high vulnerability to flooding. When these bridges are designated for replacement/refurbishment, this strategy should be considered.

F.6: Remove sediment from culverts prioritized in the 2020 Metrolink Rehabilitation Plan to maximize capacity to convey floodwaters.

*Potential locations for impleme*ntation: Culverts with a site condition rating of 1 (very poor) or 2 (poor) in the Rail Asset Management System database.

F.7: Stockpile riprap near bridges known to be exposed to scour or high velocity flows, so that replacement materials quickly can be moved in place if damage occurs.

Potential locations for implementation: Bridges vulnerable to overtopping that cross natural channels, such as 173.600-MT2 and 188.500-MT2 on the Orange subdivision.

F.8: Add riprap revetments, concrete erosion protection, or other armoring to bridge abutments/approaches that are within the floodplain, to protect against scour.

Potential locations for implementation: Any bridge identified as having high vulnerability to flooding in the CVA potentially can have abutments exposed to the 100-year flood event. Of those, bridges in natural areas are especially vulnerable to scour around the abutments. Some examples include Valley 30.940-MT and 41.260-MT, Ventura 428.630-MT, and Orange 173.600-MT2.

F.9: Consider pier modifications to reduce flood water surface elevation immediately under bridge crossing for bridges vulnerable to overtopping.

Potential locations for implementation: Bridges identified as having high vulnerability to flooding in the CVA that have pier supports (versus no supports or columns/piles), such as San Gabriel 39.200-MT and Orange 192.800-ST.

F.10: Consider replacing shallow pile/column foundations of vulnerable bridges with deep foundations that extend into non-scourable bedrock.

Potential locations for implementation: The Rail Asset Management System database does not include information on foundation depth. Ventura 428.630-MT is an older bridge (built in 1953) that has high vulnerability to flooding, crosses a natural channel, and has several supports that may not extend to bedrock.

F.11: Install linear swales along flood-prone track, to direct water away from the track bed. This strategy can be coupled with sub-ballast armoring and elevation of sensitive mechanical/electrical equipment, to create multiple lines of defense for the most vulnerable areas.

Potential locations for implementation: Long stretches of track are exposed to flooding during storm events (e.g., Ventura Sub MP 434.0-436.2, MP 436.7-438.1, and Valley Sub MP 31.5-32.2).

F.12: Armor subgrade and sub-ballast with riprap or other materials, to protect sensitive components of track structure from weakening because of saturation or washout.

Potential locations for implementation: Stretches in floodplains where track is above-grade (meaning that subgrade/sub-ballast is exposed) and high velocity flows may occur (e.g., track around the South Perris Station, track adjacent to Cucamonga Channel on the San Gabriel subdivision [MP 39.0-39.5], and on the Ventura subdivision along Arroyo Simi).

F.13: Prepare/harden pumps within tunnels for increased strain because of projected increases in precipitation during major storms. These pumps will be needed 24/7 to pump out water that is seeping to the tunnels from above. The rate of seepage will increase after rainstorms and loss of function to the pumps will result in flooding and track closure.

Potential locations for implementation: Tunnels 25, 26, 27, and 28.

F.14: Add local floodproofing measures to high value, below-grade mechanical equipment, such as the wheel chewing machine and drop table in below-grade pits at the Central Maintenance Facility.

Potential location for implementation: Central Maintenance Facility.

F.15: ***Use permeable pavers instead of concrete to reduce runoff volumes in station parking areas that are exposed to stormwater flooding.

Potential locations for implementation: Stations within the current 100-year floodplain, including Simi Valley, Northridge, Newhall, Palmdale, Via Princessa, and Mission Viejo.

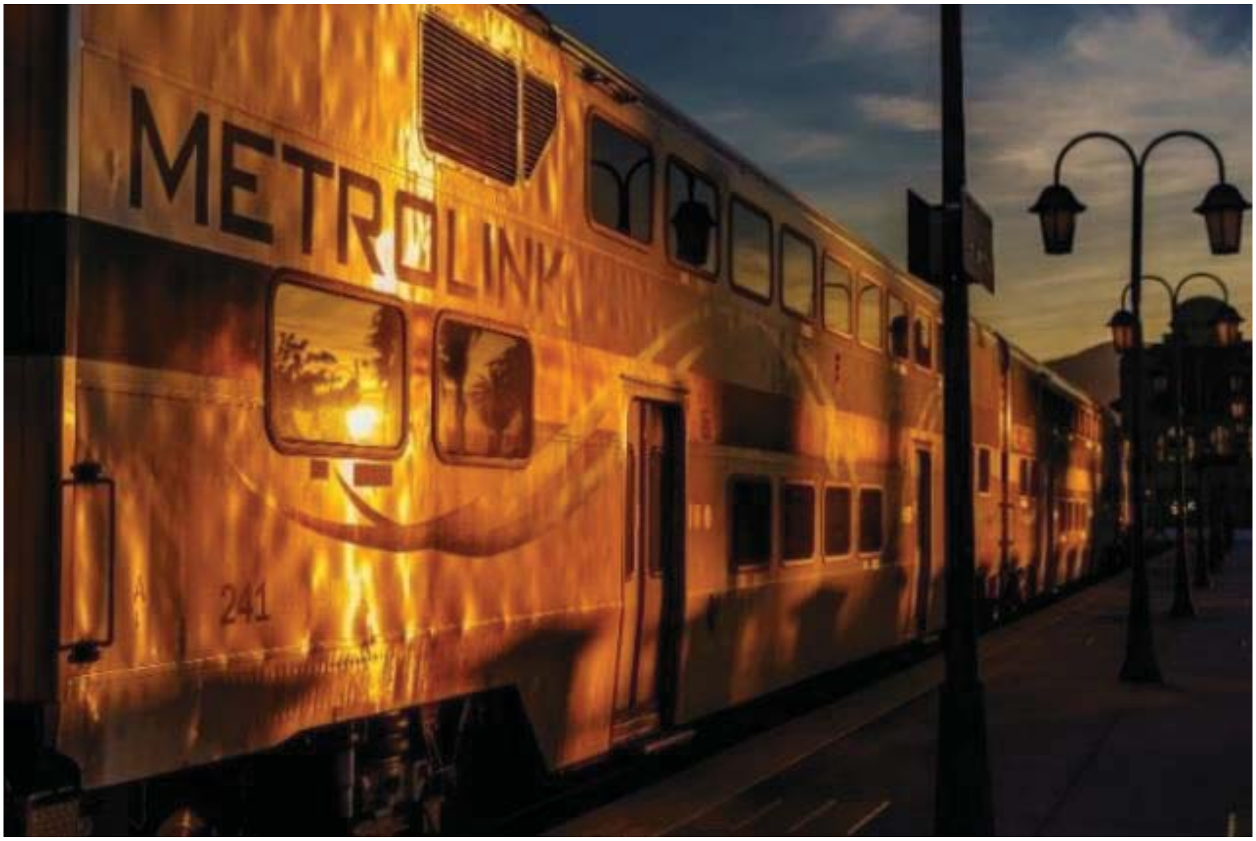
F.16: Elevate electrical components of signal/communications systems along track that are sensitive to water damage, either by elevating the concrete pads or attaching the equipment on poles above the design flood elevation. If elevating is not feasible (i.e., the equipment must be at track level), waterproof the equipment itself.

Potential locations for implementation: Long stretches of track exposed to flooding during storm events, such as Ventura Sub MP 434.0-436.2, MP 436.7-438.1, and Valley Sub MP 31.5-32.2.

F.17: Raise ballast or raise track subgrade. Although this is likely to be a more expensive option, it should be considered for frequently flooded areas where other solutions are not feasible.

Potential locations for implementation: Perris subdivision MP 84-86, Ventura subdivision MP 437-438.

EXTREME HEAT



Impacts of extreme heat include rail buckling, mandatory slowdown orders, unhealthy platform temperatures for riders, and power outages. Most inland portions of the system are projected to experience temperatures above 110°F annually by mid-century, with portions (including most of the San Gabriel, Shortway, Redlands, and Perris subdivisions) experiencing temperatures above 115°F. Track is vulnerable to thermal misalignment under extreme conditions, as shown in the recent events on the Valley subdivision in September 2020 and June 2021. Because extreme temperatures are projected to increase across all inland parts of the system, impacts potentially can occur anywhere, not just in those areas projected to have the highest temperatures. Stations in inland areas are projected to experience temperatures as high as 115°F, severely affecting both passenger safety and comfort. The most vulnerable stations will be those in Los Angeles, Riverside, and San Bernardino counties that do not have adequate amenities (such as platform shading, seating, and/or drinking fountains/hydration stations) to help riders cope with the heat while waiting for trains, including stations on the Ventura, Valley, San Gabriel, Perris Valley, and Redlands subdivisions.

Applicability ***= nature-based	Track	Bridge	Tunnel	Station	Facilities	Signals	Comms	Culverts
EH.1					X			
EH.2***				X	X			
EH.3				X	X			
EH.4	X							
EH.5	X							
EH.6	X							
EH.7					X			
EH.8				X	X			
EH.9	X							
EH.10	X							
EH.11				X	X			
EH.12	X							

EH.1: Provide an adequate drinking water supply for maintenance/service workers while reducing waste and cost. Also consider offering electrolyte rehydration powder along with water to combat dehydration on very hot days.

Potential locations for implementation: Central Maintenance Facility, where service/maintenance work is carried out during the day.

EH.2: ***Where feasible, plant shade trees at stations and/or facilities, such as in parking lots and/or entry areas. Plant heat and drought-tolerant, low-maintenance native plant species. Trees are not recommended for installation on platforms or planting close to the track.

Potential locations for implementation: Stations with high heat exposure and few shade trees (e.g., San Bernardino - Downtown , Upland, Baldwin Park, Perris).

EH.3: Install cool roof treatments for stations and facilities, to reduce cooling needs and the urban heat island effect. Cool roof treatments include materials with high solar reflectance, such as reflective paints and reflective shingles/tiles.

Potential locations for implementation: Stations in high heat exposure areas that have indoor waiting areas with suitable roofs, such as Lancaster and Rialto.

EH.4: Stress newly installed and existing rail with a rail zero-stress temperature that is calculated based on projected temperatures for the lifetime of the rail, rather than on current or historic conditions. Prioritize locations with a history of sun kinking and those with the highest projected heat exposure, as well as all rails being replaced or restressed.

Potential locations for implementation: Areas with a history of sun kinking (e.g., Valley subdivision between Santa Clarita and Palmdale) and areas with the highest projected heat exposure (e.g., eastern San Gabriel subdivision, Perris Valley subdivision).

EH.5: Re-tamp ballast to increase ballast density, increasing lateral resistance and reducing chances of thermal misalignment. This strategy should be coordinated with Strategy EH.10 for efficiency, as appropriate.

Potential locations for implementation: Stretches of track identified as needing tamping, per the ballast scans carried out by Balfour Beatty Rail and Zetica Rail, as summarized in the 2020 Metrolink Rehabilitation Plan.

EH.6: Replace wood ties with concrete ties, which are heavier and more resistant to movement, reducing chances of thermal misalignment. This strategy should be coordinated with Strategy EH.12 for efficiency, as appropriate.

Potential location for implementation: The Valley subdivision is mostly wood ties and is known to be a hotspot for thermal misalignments.

EH.7: Outfit major facilities with industrial/commercial-grade evaporative coolers (swamp coolers), which can reduce temperatures in covered outdoor areas, such as locomotive shops.

Potential location for implementation: Central Maintenance Facility, where service/maintenance work is carried out during the day.

EH.8: Add station amenities to help riders cope with extreme heat where gaps exist. Although some stations are well equipped to deal with heat, opportunities exist to improve conditions in others (e.g., shading parking lots/bike racks, adding platform shading, adding seating under shade structures, and adding misters and air conditioning or fans in indoor waiting areas). The budget for routine maintenance/servicing of some amenities (such as misters) should be considered before their installation, to avoid disrepair/maintenance issues.

Potential locations for implementation: The Simi Valley station currently does not have shade or an indoor waiting area and has high heat exposure, and the Sun Valley station does not have platform seating.

EH.9: Install sensors to indicate potential kinking and rail defects. Options include rail thermometers that can be remotely monitored, which can reduce operational costs associated with rail inspection requirements during hot weather, or motion sensors that can identify a thermal misalignment when it occurs and automatically halt trains.

Potential locations for implementation: Inland regions where temperatures are projected to be the highest, and therefore are most likely to experience speed restrictions/inspection triggers the most frequently (e.g., eastern San Gabriel subdivision, Perris Valley subdivision).

EH.10: Increase the width of the ballast shoulder, which will increase lateral resistance and reduce the chances of thermal misalignment. This strategy should be considered only in situations where Strategies EH.4, EH.5, and/or EH.6 are not sufficient.

Potential locations for implementation: Stretches of track with high heat exposure, with raised track bed (e.g., Valley, eastern San Gabriel, Perris Valley).

EH.11: Install hydration stations (water fountain plus spout for filling water bottles) on station platforms and in maintenance areas to ensure that riders/staff have access to water when needed. This strategy will need to be assessed bearing in mind concerns about vandalism and misuse of hydration facilities.

Potential locations for implementation: Several stations with high vulnerability to heat do not have drinking fountains/hydration stations, including Baldwin Park, Claremont, Covina, Northridge, and Simi Valley.

EH.12: Reduce tie spacing, which provides additional weight to the track structure and increased lateral resistance because of increased exposure to shoulder ballast, reducing chances of thermal misalignment. This strategy should be considered only in situations where Strategies EH.4 and/or EH.6 are not sufficient.

Potential locations for implementation: Any significant stretches where wood or concrete ties are prioritized for replacement, per the 2020 Metrolink Rehabilitation Plan, and that are on subdivisions at high risk for thermal misalignment (e.g., Valley, eastern San Gabriel, Perris Valley).

WILDFIRE

Impacts of wildfire include damage or destruction of rail line, communications infrastructure or other facilities, and power outages. Wildfire vulnerability is restricted to portions of the system that are within or adjacent to wildland areas, and specific stretches of the Ventura and Valley subdivisions. Communication towers have the highest wildfire vulnerability because they are sensitive to fire and are in high wildfire exposure areas at the tops of mountains, where fire is likely to travel uphill via dry vegetation. The vulnerability of track has been determined to be low overall, as track in wildland areas runs through a right-of-way cleared of vegetation. However, wildfires occurring near track may cause slow orders or delays. Wildfire smoke may cause degraded air quality, which may affect passenger safety and comfort at outdoor stations and crews working in outdoor locations.

Applicability ***= nature-based	Track	Bridge	Tunnel	Station	Facilities	Signals	Comms	Culverts
WF.1***	X					X	X	
WF.2				X	X			

WF.1: ***Manage vegetation in the right-of-way in high wildfire exposure areas. Depending on the location and vegetation, this can mean either complete clearing of vegetation or appropriate management for wildfire resilience.

Potential locations for implementation: Valley and Ventura subdivisions.

WF.2: Add high performance air filtration systems to indoor stations/facilities to manage poor air quality because of wildfires.

Potential locations for implementation: Stations in areas that experience concentrated poor air quality during wildfire season and have indoor areas (e.g., Lancaster and Palmdale on the Valley line).

DROUGHT

Impacts from long-term drought include damage on track and/or facility foundations, or on natural systems that prevent flooding/heat. Direct impacts from drought were determined to be low system-wide; however, drought may indirectly increase exposure to other hazards. For example, prolonged drought can increase wildfire hazards, and areas cleared of vegetation by wildfire are more prone to landslides. Oscillations between wet and dry years also may lead to more intense flooding when precipitation occurs.

Applicability ***= nature-based	Track	Bridge	Tunnel	Station	Facilities	Signals	Comms	Culverts
D.1***				X	X			
D.2				X				
D.3					X			
D.4				X	X			

D.1: ***Reduce outdoor water use by transitioning landscapes to climate-smart planting. Planting in any landscaped areas should be low-maintenance, non-invasive, and heat and drought tolerant to reduce water use and maintenance costs.

Potential locations for implementation: Any stations with planned, upcoming outdoor and/or landscaping improvements.

D.2: When/where feasible, replace traditional sprinkler systems with drip irrigation systems, which are more water efficient.

Potential locations for implementation: Any stations with planned, upcoming outdoor and/or landscaping improvements.

D.3: When/where feasible, retrofit water fixtures in yards used for washing trains or other service/maintenance activities, so that water sprays are at higher pressure but lower volume to reduce water consumption.

Potential locations for implementation: Central Maintenance Facility, Eastern Maintenance Facility.

D.4: When/where feasible, replace water fixtures, toilets, and urinals in station and facility restrooms with low-flow options.

Potential locations for implementation: Any stations with planned, upcoming upgrades to bathrooms or bathroom installations.

LANDSLIDES/MUDSLIDES

Impacts from landslides include washed out rail lines, destruction of track and other facilities, and derailment. Landslide and mudslide hazards are local and can affect only Metrolink assets where they are near steep, unstable slopes. Thus, vulnerability mainly is confined to portions of the system running through mountainous terrain along the Ventura, Valley, and Orange County subdivisions. Some bridges and tunnel portals in mountainous areas are vulnerable, especially when bridge foundations or supports are in high exposure areas.

Applicability ***= *nature-based*	Track	Bridge	Tunnel	Station	Facilities	Signals	Comms	Culverts
LS.1***	X							
LS.2	X					X	X	
LS.3	X							
LS.4***	X					X	X	
LS.5***		X						
LS.6								
LS.7	X	X				X	X	

LS.1: ***Plant drought-tolerant vegetation that stabilize slopes and contributes to erosion prevention in appropriate locations that can support vegetation without irrigation. Note that in some places slopes are too sleep for vegetation to take root. Where the slope is steeper than the maximum for vegetation to attach, erosion is likely to occur and require rip rap or other slope protection

Potential locations for implementation: Locations where track passes close to an active landslide, steep slope, or where a hill has been cut to make way for track (e.g., Valley Sub MP 49.0-50.0).

LS.2: Improve protection on the coastal side of rail to prevent the undercutting of landslide toes, which exacerbates land side bluff erosion/slope failure.

Potential location for implementation: Track at the base of the active landslide that was identified by the Cyprus Shores Homeowners Association at Orange MO 206.5 to 207.0.

LS.3: Perform "surgical" landslide debris removal after material has stopped moving, to ensure that removing debris does not inadvertently exacerbate slope failure. Complimentary site work (e.g., soil retention systems, internal/surface drainage, and erosion control BMPs) may be required.

Potential locations for implementation: Mariposa Promontory (roughly MP 203.9 to 204.5) and other portions of southern Orange County (roughly MP 206.8 to 207.2).

LS.4: ***Proactively deploy slope stabilization strategies to areas near track that have been recently burned by wildfire. Short-term engineered strategies (retaining walls) can be paired with mid-term, nature-based strategies (planting vegetation).

Potential locations for implementation: Now: Valley Sub MP 25-27 recently was burned by the Saddleridge Fire and is a high landslide hazard area; Mid-term: portions of the system where landslide and wildfire exposure are both high (Valley sub MP 47-52, MP 60-61).

LS.5: ***Implement slope stabilization (vegetation or engineered) where bridge foundations or supports are within high landslide exposure areas.

Potential location for implementation: Bridge 44.940-MT on the Valley subdivision.

LS.6: Address active landslides near track at the source with retaining walls and shotcrete.

Potential locations for implementation: Locations where track passes close to an active landslide, steep slope, or where a hill has been cut to make way for track (e.g., Valley Sub MP 49.0-50.0).

LS.7: Implement pre-emptive lower bluff improvements for ground stabilization or failure mitigation, such as a soil nail wall with shotcrete facing.

Potential locations for implementation: Mariposa Promontory (roughly MP 203.9 to 204.5) and other portions of southern Orange County (roughly MP 206.8 to 207.2), and bluffs near Bridge 205.900-MT on the Orange subdivision.

SEISMIC/EARTHQUAKES

Impacts of earthquakes include damage or destruction of track, bridges, tunnels, stations, and other facilities and assets. Most track (as well as signals and track-level communications) across the system has been determined to have medium vulnerability, with segments rated as high vulnerability in three places on the Valley line. Bridges in high exposure areas with physical attributes contributing to high sensitivity were rated as having high vulnerability and mainly are on the Ventura, Valley, and San Gabriel subdivisions. Tunnel 25 was determined to have high seismic vulnerability. A concentration of facilities at the center of the system in Downtown Los Angeles also have high seismic vulnerability. Maintenance facilities, such as the CMF, contain hazardous materials that present an increased risk if spills or leaks occur during seismic events and potentially affect adjacent communities. The DOC, pictured above, has been designed to be able to withstand a significant earthquake.

Applicability ***= nature-based	Track	Bridge	Tunnel	Station	Facilities	Signals	Comms	Culverts
S.1		X	X	X	X			X

S.1: Update the design process for all seismic retrofits so that it includes a climate change vulnerability review. This will allow identification of opportunities to simultaneously address climate hazard vulnerability based on projected future conditions within the anticipated lifetime of the asset. Conversely, if undertaking climate adaptation measures/retrofits, combine with seismic retrofits where needed to ensure that assets are resilient to both earthquakes and a changing climate, and so that disruptions in service are minimized.

Potential locations for implementation: Assets that were identified as having high seismic vulnerability and high vulnerability to at least one climate hazard (e.g., bridges identified as having high seismic vulnerability and high vulnerability to flooding, including River 0.800-LT2,ST, Valley 41.260-MT, and Ventura 428.630-MT).

ELECTRICAL OUTAGES

Electrical outages include unintended interruptions caused by direct climate impacts (i.e., a spike in power consumption causing a brown out during an extreme heat day) or PSPS that are planned outages (usually to avoid starting wildfires during dry/windy weather conditions). The MOC and HQ have high sensitivity to electrical outages. The MOC has a back-up generator and associated uninterruptible power supply (UPS) system, but they are in critical need of replacement, which poses a risk to loss of power, equipment damage, and immediate loss of operations. HQ lacks back-up power, and the building and communications equipment require power to operate. The DOC has a medium sensitivity to an outage because two generators are in place, with an UPS system to provide power while the generator is ramping up; however, the facility does not have a redundant UPS system. Therefore, if an electrical outage occurs and the generator is operating but the primary UPS system is inoperable, critical communications equipment will experience temporary, abrupt power loss until the generator is fully operating. The brief power interruption may damage critical communications equipment and inhibit the capabilities to communicate, even if power is restored. Primary dispatch in the DOC and the alternate dispatch in the MOC are powered through the same SCE circuit, therefore loss of power to that circuit may disable the primary and secondary dispatch centers if adequate back-up power systems are not in place.

Applicability ******= nature-based***	**Track**	**Bridge**	**Tunnel**	**Station**	**Facilities**	**Signals**	**Comms**	**Culverts**
EO.1				X	X			
EO.2					X	X	X	
EO.3					X	X	X	
EO.4				X				

EO.1: Ensure that all backup power systems are hardened and protected from the effects of climate events.

Examples include installing block heaters on generators in climates with freezing conditions, adding wall structures to protect against wildfires and high winds, and elevating systems out of flooding-prone areas.

Potential locations for implementation: Facilities with back-up generators or UPS systems

EO.2: Implement adequate Uninterruptible Power Supply (UPS) systems in communications and signal boxes and operations centers to ensure that the Positive Train Control (PTC) system and other systems can continue to operate during extended power outages associated with heat, wind, or wildfire events.

The DOC requires a redundant UPS system so that critical communications equipment receives continuous power, and the MOC needs the UPS system serving the server room to be replaced. New UPS systems for these facilities need to be adequately sized to provide enough power while the back-up generators are ramping up, or to support connected loads for longer periods before switching to generator power. Communications and signal boxes also can benefit from larger UPS systems. Although the boxes do not have back-up generators, UPS systems should be sized to support critical loads for between 30 minutes and 4 hours (based on load assessment), until primary power can be restored. New or expanded UPS systems will require additional electrical storage units, which also may require sizing or resizing areas for equipment housing.

A long-term strategy may also include alternate commercial feeds for important points, providing auxiliary ports to connect portable generators to signal houses to charge batteries during a power outage, and providing stand-by portable generators to power HVAC systems that provide air conditioning for critical communications assets (as an example).

Potential locations for implementation: Strategies to address the resilience of the PTC system to electrical outages will require a network approach because loss of function to a node in the network will automate trains stopping across the system.

EO.3: Implement a centralized monitoring system to remotely monitor the status of the backup power systems, including elements such as operations mode, battery or fuel levels, communication box HVAC status, faults, or errors.

The centralized feedback display quickly can prompt personnel to attend to an issue, provide additional generator fuel, or perform a staged shutdown of critical equipment on backup batteries, to prevent equipment damage from an outage.

Potential locations for implementation: The centralized workstation that the monitoring system reports to can be located at the MOC because the SCRRA Engineering Office can monitor the system. Remote alerts from the monitoring system can have the capabilities of transferring to the DOC to address emergencies promptly, especially for emergencies occurring in non-business hours. Monitoring system hardware can be applied to back-up power systems (e.g., generators) and HVAC systems at highly critical facilities and assets.

EO.4: Develop a 'resilient hub' by identifying an effective area (strategically located based on climate hazard exposure and social vulnerability), to be independently powered by a small-scale microgrid capable of managing islanded solar photovoltaics (PV) and a battery energy storage system.

When a facility or group of facilities has been identified to have significant community support value during events such as extreme heat or local power outages, they can be identified as a resilience hub This hub, with its ability to maintain operations during an outage with on-site generation and storage, will provide accessible power during outages to other nearby locations. Such a hub can be used for emergency communications and charging phones. This strategy is related to I.16, with Sun Valley being considered as a potential location.

Potential location: Pilot at single location, expand over time

Climate Adaptation Funding Opportunities

OVERVIEW

To support implementation of the adaptation strategies listed in the previous sections key funding and financing sources were identified that are available at time of writing to fund climate adaptation investments in California, with a focus on sources that are suited for the structural, nature-based, or engineered adaptation strategies.

For many of the structural strategies, implementation will require planning and coordination, design and engineering, and construction, which typically occurs over several years rather than within a single budget cycle. The high price tag of the more capital-intensive engineered and nature-based adaptation strategies will require that funding and financing strategies be given early consideration, to ensure that each phase is resourced adequately.

SCRRA is a JPA comprised of five Southern California county transportation commissions. This status allows SCRRA to operate the Metrolink service independent of its member agencies, but simultaneously it creates administrative barriers for accessing financial tools. Based on direction provided by SCRRA, the project team has focused specifically on funding and financing opportunities that are of interest to SCRRA (grant and loan opportunities)[2].

GRANT FUNDING

Substantial competition exists for grant funding because public agencies, especially transit agencies, across the country generally are underfunded. This is a challenge that has been exacerbated by the COVID-19 pandemic, which drastically reduced ridership and farebox revenues. Although State and federal support has become available for transit agencies in the wake of the COVID-19 pandemic, the final form of that support still is unknown. Furthermore, increasing competition for public grant monies is viewed within the context of a changing climate, which has resulted in more frequent and intense weather events that pose risks to vulnerable assets and communities. In SCRRA's case, these climate stressors have heightened demand further for adaptation grants.

The grants that are summarized herein are those that are intended to specifically fund climate adaptation and post-disaster recovery investments.[3] However, traditional transportation grants also may fund adaptation investments, particularly when paired with other system improvement or expansion projects. A full list of SCRRA-relevant transportation grants is provided in the Technical Appendix.

When pursuing grant funding, SCRRA and its member agencies may strategize to prioritize and match projects with grants, to reduce local competition and improve success rates. Regional

[2] This direction is based on two meetings with SCRRA: held September 27 October 11, 2021.

[3] This analysis considered grants from both public agencies and philanthropies; however, limited opportunities exist for philanthropic grants that will be suited to SCRRA's recommended adaptation strategies.

multi-agency support for projects can play an important role in securing grant funding. Decisions to prioritize and position certain projects for grant funding may be driven by competitive landscape, annual funding priorities, and SCRRA's ability to secure local match monies, which most of the grants that are discussed next require at varying levels.

Federal Sources

Federal grants tend to offer larger dollar amounts per grantee than state grants, but tend to have more requirements and lengthier application processes, which can be resource-intensive for the receiving entity. Because of this, federal grants generally are better suited for higher price tag projects, for which the grant can cover a significant portion. A list of the federal grants that are most relevant to the adaptation strategies are summarized in Table 32. A full list of federal grants for adaptation, resilience, and post-disaster investments is provided in the Technical Appendix (including more details about each grant). The landscape of federal grants is poised to expand with implementation of the $1 trillion bipartisan infrastructure bill (Infrastructure Investment and Jobs Act), and therefore close attention should be paid to agencies that are earmarked to receive grant monies.

Table 32: Most Applicable Federal Grants

Administering Organization	Program/ Grant Name	Eligible Projects	Match Requirement	Funding Uses	Funding Range per Grantee
FEMA	Building Resilient Infrastructures and Communities (BRIC) grant program (previously Pre-Disaster Mitigation Program)	Public infrastructure projects, nature-based solutions, and enforcement of modern building codes	Yes (25 percent)	Planning and implementation	Up to $1.2M ($600K on mitigation planning activities)
FEMA	Emergency Management Performance Grant Program (EMPG)	Disaster financial management, resilient communications, debris removal, and protections against the effects of climate change	Yes (at least 50 percent)	Data collection, planning, and implementation	$60K to $800K
FEMA	Hazard Mitigation Grant Program (HMGP)	All projects related to hazard reduction	Yes (25 percent)	Data collection, planning, implementation, and disaster response	Up to $3M
FEMA	Urban Areas Security Initiative (UASI) Program	Infrastructure systems, operational communications, and risk and disaster resilience assessments	No	Data collection, planning, and implementation	$150K
National Oceanic and Atmospheric Administration	Coastal Resilience Grants Program	Coastal property and infrastructure protection	Yes (at least 50 percent)	Data collection and planning	$100K to $2M
U.S. Department of Housing and Urban Development	Community Development Block Grant Mitigation Program	Increased resilience to disasters and reduced or eliminated long-term risk	May be used as matching funds for other federal programs	Planning and implementation	Up to $500K

Administering Organization	Program/ Grant Name	Eligible Projects	Match Requirement	Funding Uses	Funding Range per Grantee
U.S. Department of Transportation and Federal Transit Administration	Emergency Relief Program	Capital costs incurred by a transit agency to protect from and/or respond to a disaster	Yes (20 percent)	Response	$8K to $5.5M

State Sources

California offers an array of adaptation and resilience-related grants for which SCRRA's adaptation strategies may be well-suited. In September 2021, Governor Newsom announced an additional $15 billion in state funding over the next three years, to address climate impacts across the state, including extreme heat, SLR, flooding, and wildfires—all climate stressors that pose risks to the Metrolink system (California Department of Finance, 2021). State grant programs that are earmarked to receive increased funding allocations because of this increased budget allocation are shown in Table 33, along with other state grants that are especially relevant to the Metrolink adaptation strategies. A full list of State grants for adaptation, resilience, and post-disaster investments is provided in the Technical Appendix (including more details about each grant).

Table 33: Most Applicable State Grants

Administering Organization	Program/Grant Name	Eligible Projects	Match Requirement	Funding Use	Funding Range per Grantee
California Coastal Conservancy	California Air Resources Board (Cap and Trade Funds)–Climate Ready Program	Adaptation planning and green infrastructure	No (recommended)	Data collection, planning, and implementation	$60K to $400K ($26M in total available funding in 2021)
California Department of Water Resources	Floodplain Management, Protection, and Risk Awareness Grant Program	Structural flood management projects	Yes (at least 25 percent)	Data collection, planning, and implementation	Up to $5M
California Strategic Growth Council	Transformative Climate Communities Program*	Transit stations and facilities, bicycle and car share programs, urban greening projects, bicycle and pedestrian access, low-carbon transit vehicles and clean vehicle rebates, and health and well-being projects	Yes (at least 50 percent)	Planning and implementation	Up to $28M (implementation); $200K (planning)
California Strategic Growth Council	Wildfire Resiliency and Recovery Planning Grants (Proposition 84)	Local and regional land use planning activities that advance climate adaptation and resilience efforts to reduce the risk of wildfires	No	Data collection, planning, and implementation	$150K to $250K

Note:* These grants have been allocated additional funding in Governor Newsom's 2021 Budget Act.

FINANCING STRATEGIES

Loans

The primary financing strategies considered are infrastructure loans, all of which JPAs are eligible to receive (California State Legislature 2007).[4] A full list of financing strategies evaluated, including those that are available to SCRRA as a JPA and those that would require member agency support, is provided in the Technical Appendix. Table 34 summarizes current loan opportunities that are most suitable for SCRRA. Notably, the California Infrastructure and Economic Development Bank's Infrastructure State Revolving Fund (ISRF) can be used as a source of matching funds for grants or other financing needs. DOT's Railroad Rehabilitation and Improvement Financing Loan (RRIF) may provide another funding stream to support planning, design, and construction of railroad capital projects, including those that are intended to improve or rehabilitate rail equipment or facilities (DOT 2021a). An RRIF loan also can be used to pay down other project-related outstanding debt, such as an ISRF loan (California IBank 2021a). Furthermore, DOT's Transportation Infrastructure and Innovation Act (TIFIA) loan can be used to finance construction activities (DOT 2021b). Both the RRIF and TIFIA loans offer 35-year payback periods, with the option to delay initial payment until 5 years after substantial completion of the project.

Table 34: Infrastructure Loans Most Relevant to SCRRA's Adaptation Strategies

Loan	Issuing Entity	Considerations
Infrastructure State Revolving Fund (ISRF)	California Infrastructure and Economic Development Bank	Can be used as matching funds for other financing needs. Applications are continuously accepted.
Climate Catalyst Fund Program	California Infrastructure and Economic Development Bank	Intended to be a general-purpose financing vehicle for California's critical climate and sustainability infrastructure. Staff currently are developing criteria, priorities, and guidelines for the selection of projects and the Bank currently is not issuing funds. Fund priorities are likely to change on an annual or semi-annual basis.
Railroad Rehabilitation & Improvement Financing (RRIF) Loan	U.S. Department of Transportation	Funds are available only for railroad projects and can be used to fund up to 100 percent of a project. Funds can be used to reimburse planning and design expenses, and to refinance other outstanding debt related to a project. Applications are accepted continuously.
Transportation Infrastructure and Innovation Act (TIFIA) Loan	U.S. Department of Transportation	Funds are available only for shovel-ready projects. Loans are available for all transportation projects, not just railroad projects. Applications are accepted continuously.
Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM) Act Revolving Loan Funds (*not yet approved)*	Federal Emergency Management Agency (FEMA)	If approved, this FEMA program will provide capitalization grants to states to establish revolving loan funds for projects designed to reduced risks from disasters, natural hazards, and other related environmental harm. If California pursues this opportunity, then it may create a new potential loan source for SCRRA adaptation projects.

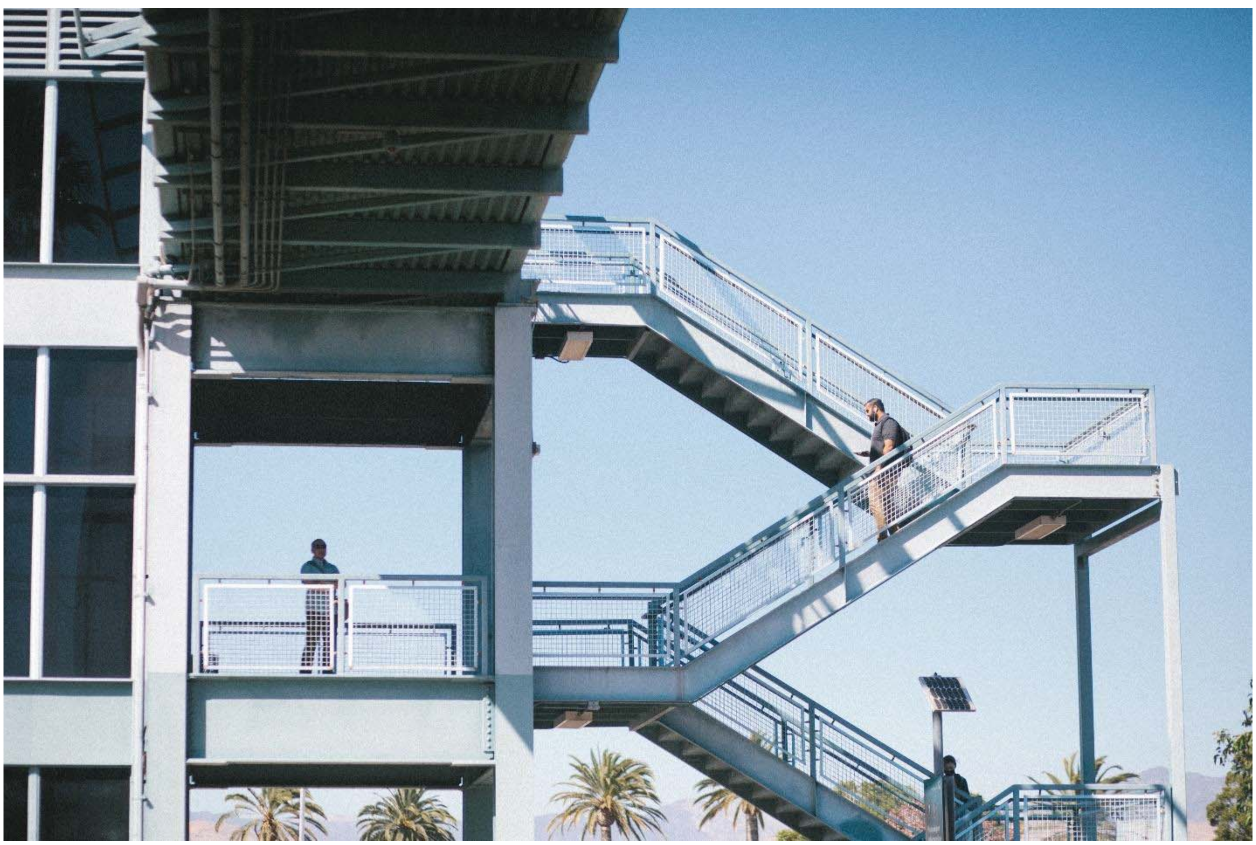
Note:
Information provided by the issuing agencies does not specifically state whether loans can be issued as joint loans. Only the RRIF loan explicitly states that joint ventures are allowed.

[4] JPAs, as public entities, can secure grants, issue bonds, and take out loans. They also are able to develop revenue streams to pay down bonds or loans but can do so only with approval (through passing of an ordinance) from member agencies. The member agencies of the JPA can implement non-farebox revenue generation mechanisms that can facilitate increased financial support for JPA activities.

To fund the design and implementation of the structural adaptation strategies, SCRRA can pursue a series of loans for each phase of project design and implementation (Wilson 2021). The debt service on the loan(s) then will become an ongoing line item in SCRRA's budget (California IBank 2021b).

Budget Strategies

Another key component to building Metrolink's resilience to climate change impacts will be creating a budget that can support adaptation investments as well as preparation and post-disaster response activities. SCRRA may want to consider adopting a budget policy that allocates a portion of its annual operating budget to specifically fund climate change actions. This budget item can include two components: one that funds smaller scale capital investments, such as landscape upgrades or pervious surface installation, and one that funds capacity building activities, such as staff training or data collection.[5] The San Francisco Municipal Transportation Agency instituted a similar policy in 2007, the Contingency Reserve Policy, to fund continuation of regular service and reduce immediate downsizing in the wake of an emergency event or economic recession, similar in function to a rainy-day fund (SFMTA 2019).

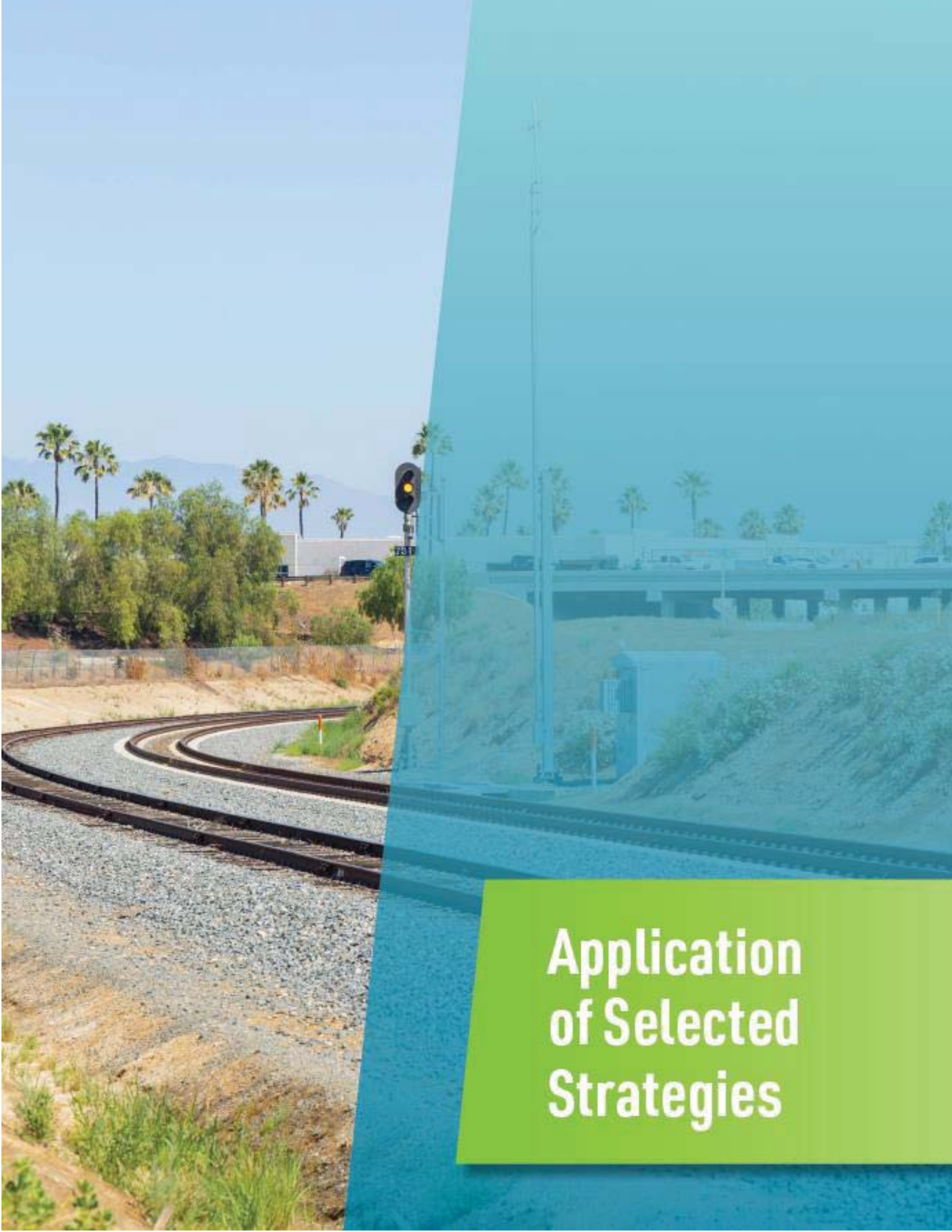


[5] This budget approach is in line with Strategy I.10 from the CVA chapter: commit to a multi-year budget to support climate resilience efforts.

FURTHER CONSIDERATIONS

Near-term next steps for initiating implementation of the structural adaptation strategies and securing funding may include the following:

- **Identifying partnership opportunities** to plan, fund, and implement adaptation strategies (including those that are non-structural). Other local and regional public agencies, such as Los Angeles County or SCRRA member agencies, that face similar climate stressors are ideal candidates for partnerships (as discussed during the third stakeholder meeting held for the project). Partnerships between public agencies also can increase the competitive edge of grant applications. Other civic institutions, notably local universities, also may offer partnership opportunities, particularly in support of Metrolink's informational strategies.
- **Identifying alignment opportunities** with other planned capital projects. One way of identifying adaptation strategies to easily implement, thus offering potential for quick wins, is by determining whether any planned capital improvement projects exist that can be augmented to include adaptation improvements. This approach is suitable for all structural strategies, including less capital-intensive strategies such as landscape design enhancements.
- **Determining which strategies will require environmental review, technical analysis, and/or complex partnerships and permitting**. Many of the CVA's adaptation strategies will have longer implementation timelines because of required multi-jurisdictional oversight, environmental review, and financing coordination. Beginning the first phase of work on these longer-term projects can build on the momentum created by this planning effort and capitalize on the State's current grant offerings.
- **Paying close attention to the distribution of funds,** such as when President Biden's $1 trillion bipartisan infrastructure bill (Infrastructure Investment and Jobs Act) is implemented. This infrastructure plan is expected to provide a once-in-a-generation level of investment in infrastructure across all categories, ranging from broadband to highways to climate adaptation. As SCRRA positions its projects for grant funding, it should pay attention simultaneously to distribution of the infrastructure plan funds and identification of new federal grant opportunities as they arise.
- **Preparing application materials for the state grants** that have been allocated additional funding in the Governor's 2021 budget. Funding for these grants is expected to become available as early as January 2022, and application periods are expected to be less than 2 months. An early start on application materials will give SCRRA more time to match strategies to grant opportunities, define strong proposal narratives, and identify potential partnership. Dedicating staff time to develop project concepts, cost estimates, statements of work and working with partners to memorialize needed agreements (especially commitment of matching funds and transit service), as well as to track and prepare grant proposals will help to ensure that SCRRA capitalizes on key upcoming funding opportunities.



Application of Selected Strategies

Overview

In addition to developing all of the high-level adaptation strategies included in the previous chapter, the project team selected four strategies to expand on further. These four strategies were selected from a range of strategy types—governance, informational, and structural—to provide guidance and support for future implementation of adaptation strategies. The purpose of the in-depth analysis was to:

- show how a strategy or strategies may be implemented for a specific location, and/or
- help ensure that the results of this study can be set into operation across SCRRA departments, and that climate adaptation planning will be integrated into decisions going forward after this study is completed.

The following discussion is a brief description of the four strategies that were selected. The remainder of this chapter summarizes the work efforts that have been completed for each of these strategies and includes background, methodology, and summary/recommendations.

1. **Create a web-based Climate Vulnerability Assessment Dashboard:** An interactive web-based dashboard was developed that visually displays the vulnerability assessment results and includes the climate hazard maps and asset-level vulnerability ratings. The purpose of this dashboard is to facilitate the ongoing /mainstreaming of climate adaptation across SCRRA operations and ensure that outputs easily can be explored/accessed by SCRRA staff. Climate hazard and vulnerability data necessary to carry out studies similar to 2-4 below can be accessed by non-GIS staff via the dashboard.
2. **Align SCORE and Capital Projects with recommended climate adaptation strategies:** Five SCORE projects were reviewed to identify applicable climate vulnerabilities based on the CVA and recommended climate adaptation strategies from the structural strategy toolkit. The purpose of this effort was to identify opportunities to improve resilience of SCORE projects currently in early design and demonstrate how the CVA outputs—assessment and toolkit—can be applied at a project level.
3. **Improve track resilience to extreme heat**: A detailed review of track conditions and extreme heat has been completed on a subset of the Antelope Valley Line prone to sun kinks. The purpose of this effort was to address an existing climate hazard at a higher granularity than the regional analysis, demonstrate how existing Metrolink data/resources can be leveraged to rate local risk, identify track typologies that can improve resilience, and provide recommendations to improve resilience.
4. **Improve track resilience to precipitation flooding**: A detailed review of track conditions and flooding (originating from the Cucamonga Channel) was completed on a subset of the San Gabriel line. The benefit of this effort was to demonstrate how existing SCRRA data/resources can be leveraged at the site level, to address flooding hazards and provide a framework for identifying opportunities for nature-based solutions in Metrolink ROW.

Climate Vulnerability Assessment Dashboard

BACKGROUND

In an effort to operationalize/mainstream climate adaptation across Metrolink, a web app was developed that enables SCRRA staff to view results from the CVA including climate hazard maps, asset-level exposure, sensitivity, and vulnerability, as well as social vulnerability and criticality. SCRRA staff can use this tool to understand the future climate vulnerability of existing assets or locations where future assets are being planned or designed.

Some ways that SCRRA staff can use this dashboard include:

- Identifying climate vulnerability for a particular asset or project location
- Understanding which parts of the system are most vulnerable to each climate hazard, or to multiple hazards
- Investigating the relationship between climate vulnerability, system-wide criticality of assets, and the locations of disadvantaged communities
- Producing PDF or printed maps of climate vulnerability
- Filtering assets based on locations or attributes and exporting the data to Excel

METHODOLOGY

To maximize usability, the dashboard was developed iteratively with the group of SCRRA staff who are the intended users. After an initial discussion about desired features and functionalities, a beta version was developed and tested with the target user group. Feedback from the beta test was then incorporated into the final version.

The dashboard was developed using ESRI Web App Builder, a platform for developing interactive web-based geospatial applications, and is hosted through SCRRA's ArcGIS Online license. All GIS data deliverables produced for the project including climate hazard layers, asset vulnerability layers, and the transit-dependent communities index were uploaded into the platform and then organized and symbolized in the app. Context layers such as county boundaries and Metrolink catchment areas were also included.

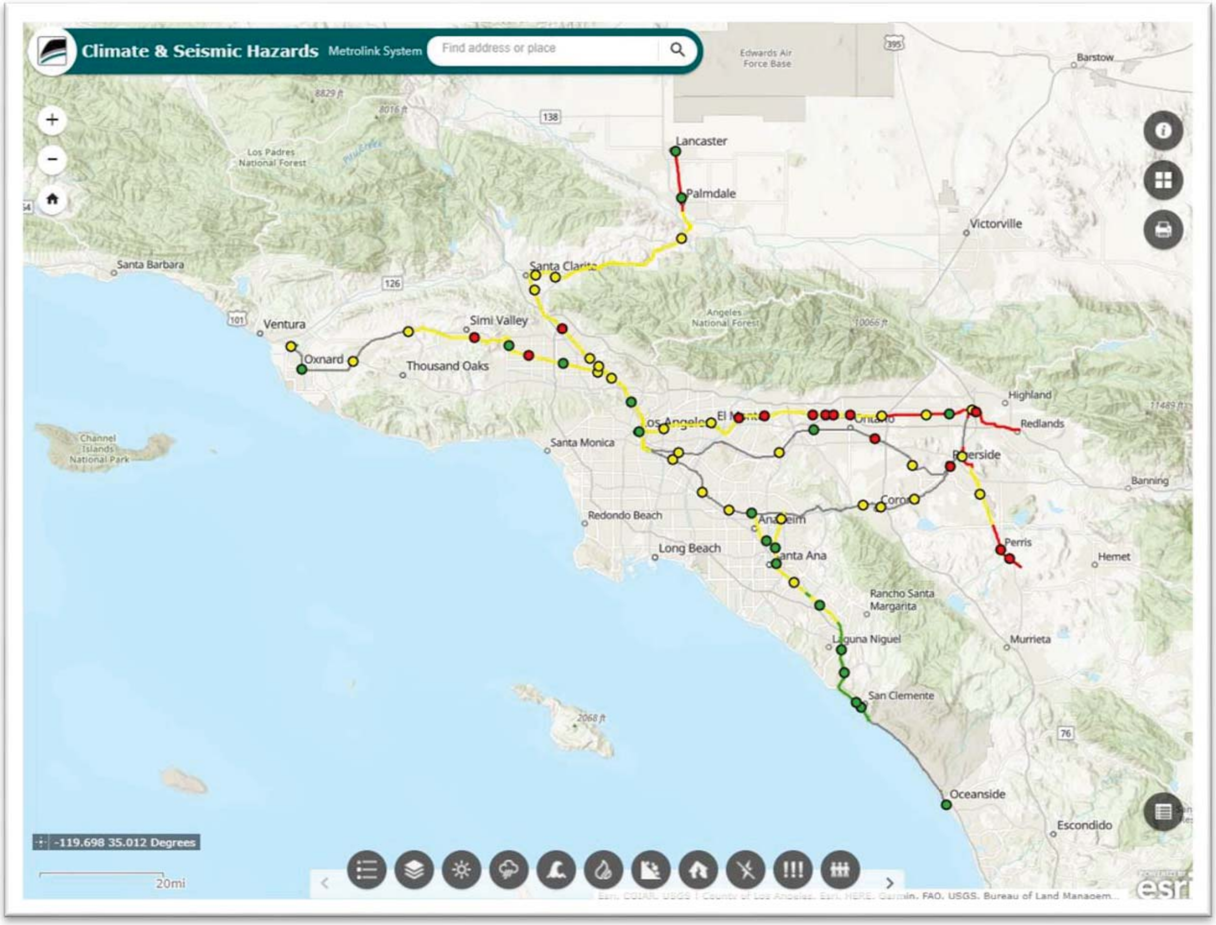


Figure 33: Example Screen from Dashboard

SUMMARY

The app itself features a large interactive web map supported by several widgets and modules. There is a module for each climate hazard as well as modules for multihazard vulnerability (indicating assets that have high vulnerability to multiple hazards) and social vulnerability/criticality. Hazard and vulnerability layers in each module can be selected for viewing in the map. Visible layers are symbolized according to vulnerability and popups reveal additional information on exposure and sensitivity. Widgets provide additional functionality, allowing users to select and filter features as well as print and export the map view.

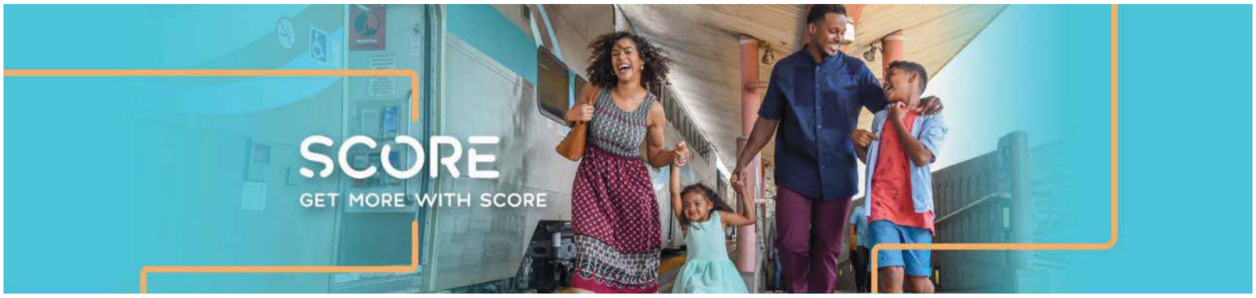
Align SCORE and Capital Projects with Recommended Climate Adaptation Strategies

BACKGROUND

The purpose of this strategy development was to review selected SCORE[6] funded projects to identify climate adaptation strategies that still can be integrated into each project scope, to reduce future vulnerability/likely service disruptions because of climate impacts.

More specifically, the five SCORE projects (listed below and shown map **Error! Reference s ource not found.**) were evaluated to identify the climate vulnerabilities of each project (focusing on the assets) and select appropriate adaptation strategies from the CVA structural strategies toolkit that can reduce those future vulnerabilities. This toolkit includes generic strategies that address specific climate hazards by asset type and is intended to be a guide and starting point to identify strategies that should be considered to increase project resilience.

- **Antelope Valley Line–Canyon**
  Antelope Valley Line Capacity and Service Improvement Project (AVL CSI), Santa Clarita Double Track from Control Point (CP) Lang to CP Canyon
- **Antelope Valley Line–Balboa**
  Antelope Valley Line Capacity and Service Improvement Project (AVL CSI), Balboa Siding Extension and Speed Improvements
- **Lone Hill to White**
  Lone Hill Avenue to CP White Double Track
- **Lilac to Rancho**
  SBCTA Lilac to Rancho Double Track
- **Irvine Station Improvements**
  Reconfigure Irvine Station and Add a Fourth Track



[6]SCORE (Southern California Optimized Rail Expansion) is Metrolink's $10 billion capital improvement program to upgrade the system, including grade crossing, station, and signal improvements as well as track additions.

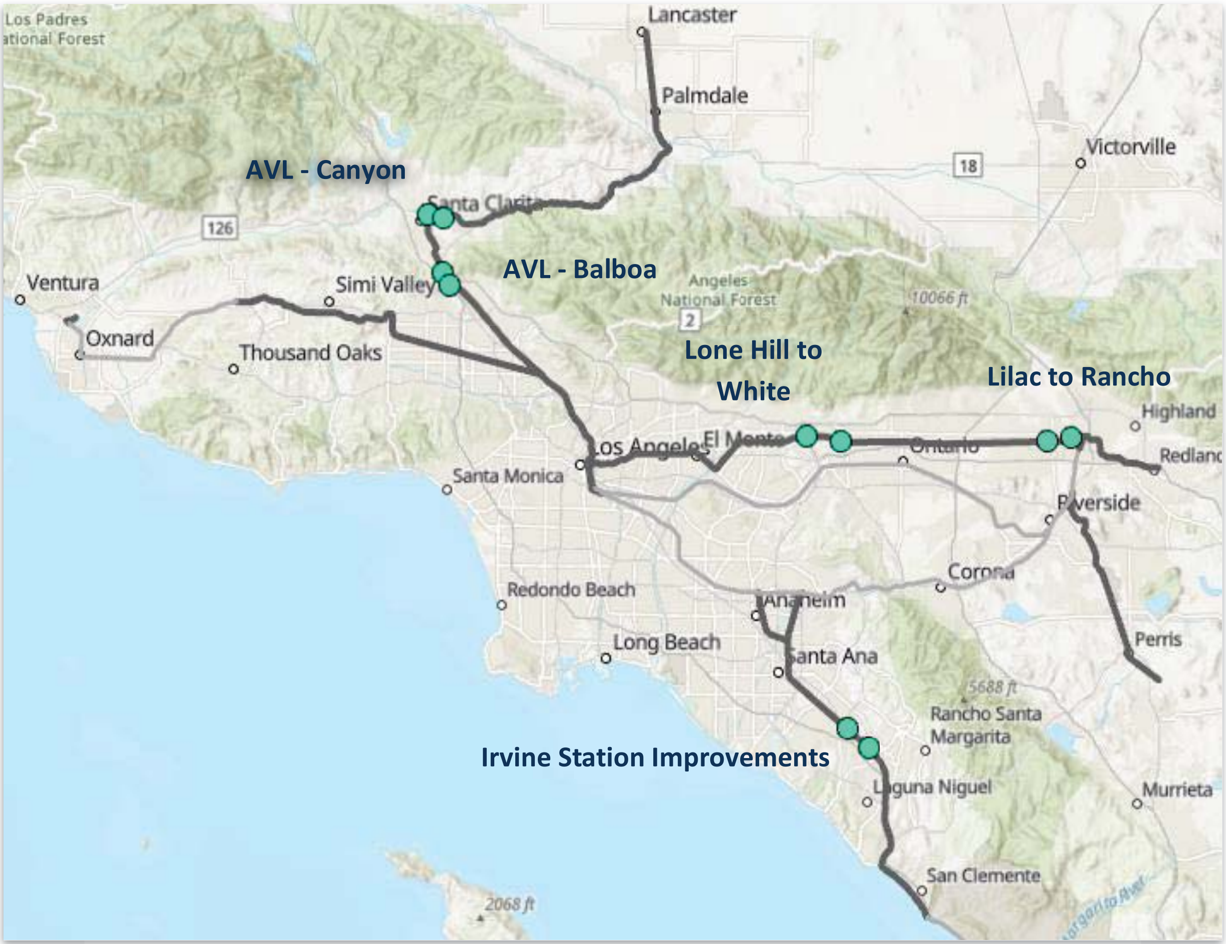


Figure 34: SCORE Projects Reviewed

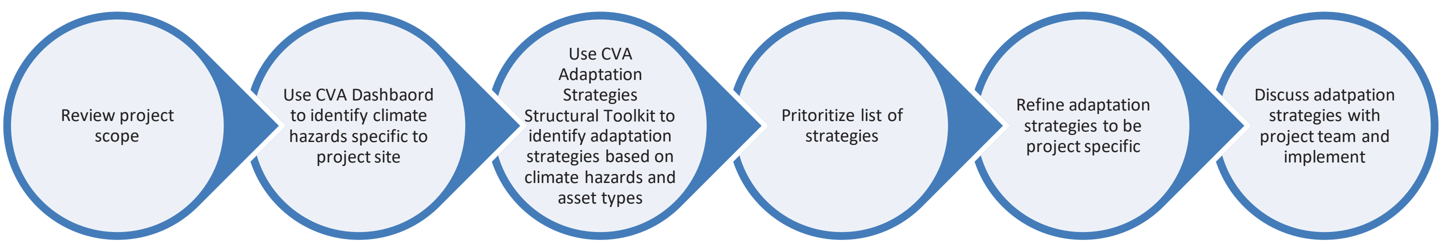
METHODOLOGY

The following steps were used to understand specific climate vulnerabilities and identify applicable climate adaptation strategies that still can be integrated into each project to increase resilience.

1. **Review project scope:** The planning/design documents were reviewed, and key project elements/parts of the network identified, such track, station/facilities, bridges, tunnels, culverts, communication, or signals that were part of the SCORE project.
2. **Use the CVA Dashboard to identify which climate hazards will make the project site vulnerable:** Vulnerability (high, medium, or low) and related impacts of project assets (e.g., track, stations, signals, communications, bridges) to climate hazards were determined, including SLR, riverine flooding, extreme heat, wildfires, drought, landslides/mudslides, earthquakes, and electrical outages, using the CVA findings.

3. **Use CVA Adaptation Strategies Structural Toolkit to identify adaptation strategies based on vulnerability:** Climate adaptation strategies were identified that still can be integrated into the project, to reduce the impact of each climate hazard.
4. **Prioritize the list of strategies:** Recommended strategies were identified that address the high and medium-rated asset vulnerabilities for each project. High priority strategies were included for asset vulnerabilities rated as high, and lower priority strategies to consider were included for asset vulnerabilities rated as medium.
5. **Refine adaptation strategies to be project specific:** Generic adaptation strategies were tailored from the CVA structural strategies toolkit to each project, based on the project scope/asset, geographic context, and vulnerability rating of assets.

Figure 35: Process to Evaluate Project Climate Hazards and Identify Resilience Strategies



SUMMARY

The following sections include a summary of each SCORE project scope, an exposure map showing climate hazards, and a summary of the vulnerability ranking for each climate hazard by asset type, along with a description of potential impacts. Adaptation strategies are listed for each project based on high and medium-rated asset vulnerability. For example, the Antelope Valley Line Capacity and Service Improvement Project has high vulnerability to landslides for track, signals, and communications, and thus strategies are included as a priority to consider, to address these vulnerabilities. Additional strategies that can be considered are included that address medium vulnerability.

Many assets are vulnerable to seismic hazards; however, current standard design specifications are assumed to be sufficient to address this known risk, and therefore seismic hazards and resulting strategies are not included in this assessment.

PROJECT: ANTELOPE VALLEY LINE CAPACITY AND SERVICE IMPROVEMENT PROJECT (AVL CSI), SANTA CLARITA DOUBLE TRACK FROM CP LANG TO CP CANYON

Project Scope[7]

- Add approximately 8,400 feet of new track between Bouquet Canyon Road and Golden Oak Road.
- Install crossover track south of Santa Clarita Station.
- Construct a new bridge over Bermite Road.
- Add new road traffic signals, new striping throughout the intersection, curb adjustments, new crossing gates, and high visibility crosswalk markings for the at-grade crossing at Golden Oak Road.
- Add a second side-platform at Santa Clarita Station, to provide similar amenities as on the existing station platform (e.g., canopies, seating).
- Add an at-grade pedestrian crossing, connecting the new side platform to the existing platform and station plaza.
- Extend the existing station platform approximately 180 feet.
- Consider the current two design options—Option #1: Pedestrian undercrossing connecting the new side platform to the existing platform and the existing station plaza; and Option #2: Island platform having two platform faces and a pedestrian undercrossing connecting the existing lower level station plaza and ticketing area to the new platform).

Primary Climate Vulnerabilities

Based on the project scope, the following assets were assessed for climate vulnerability: track, bridge, signals, tunnel, communications, and a station. Landslide exposure is shown in Figure 36 because it varies the most across the project area, compared to other hazards, which are summarized in Table 35.

[7] Documents reviewed:
Antelope Valley Line Environmental and Technical Studies Basis of Design, June 2021
Antelope Valley Line Capacity and Service Improvements Program Draft Environmental Impact Report, July 2021

Table 35: Potential Vulnerabilities, AVL–Canyon

Hazard	Vulnerability	Potential Impacts
Extreme Heat	Medium (track, station) Low (signals, communications, bridge)	• Passenger discomfort while waiting for trains • More frequent slowdown orders • Thermal misalignment of track
Wildfires	Low (all asset categories)	• Disruption to service because of wildfire smoke, loss of vegetation on hillsides could increase landslide hazard
Drought	Low (station, track)	• Increased cost of irrigation for station landscaping, loss of vegetation on hillsides could increase landslide hazard
Landslides/ Mudslides	High (track, signals, communications) Medium (station, bridge, tunnel)	• Damage to track structure, communications, and signal equipment • Potential damage to station platform
Electrical Outages	Low (signals, communications, station, tunnel)	• Loss of power to communications, signal infrastructure if outage time exceeds capacity of backup systems

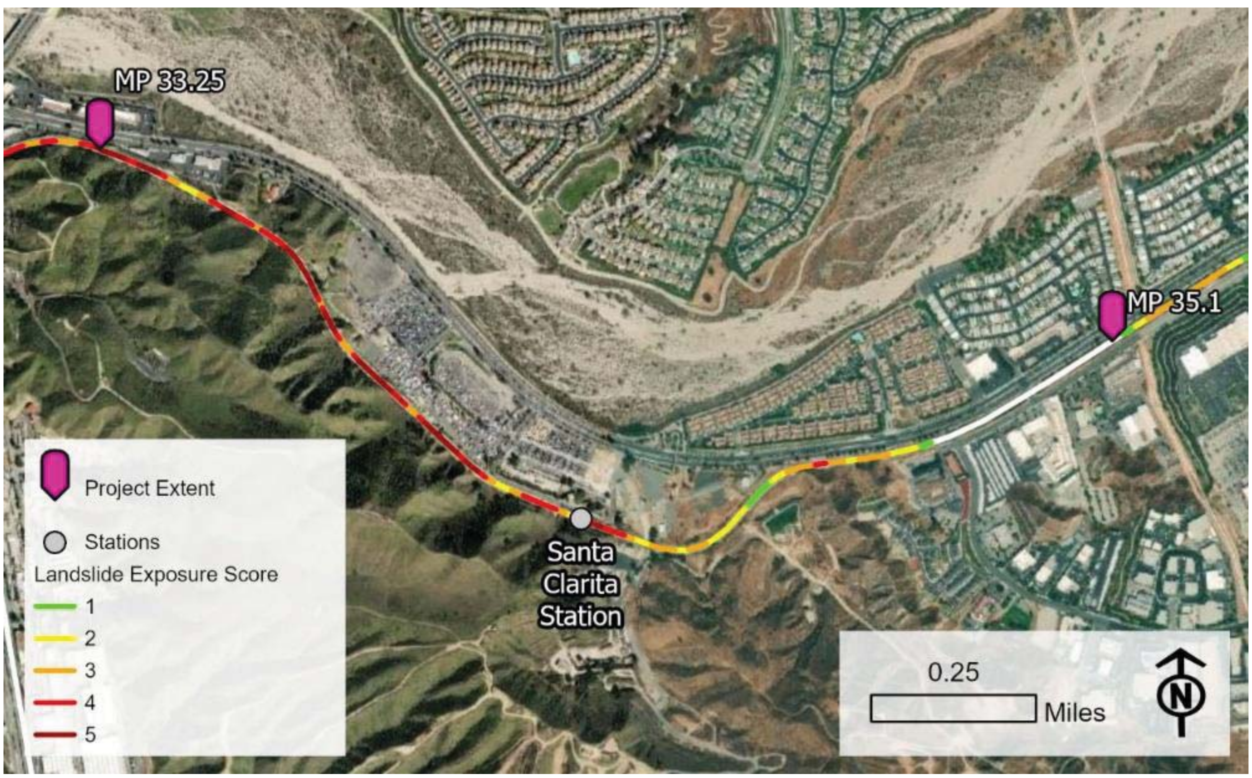


Figure 36: Project Area Map and Landslide Exposure, AVL–Canyon

Potential Adaptation Strategies to Improve Climate Resilience

The strategies listed next are derived from the structural strategies toolkit that were developed as part of the CVA.

High Priority Strategies

Because of the vulnerabilities identified above, high priority strategies have been identified to address the high vulnerability of track, signals, and communications assets to landslides. The area of track adjacent to Santa Clarita Station currently is protected by a barrier on the hill slope side. The slopes adjacent to the new track should be assessed for current vegetation cover and slope, to determine whether landslide risk can be an issue post-wildfire and heavy rain.

General

- LS.1: Plant drought-tolerant vegetation that stabilizes slopes and contributes to erosion prevention in appropriate locations that can support vegetation without irrigation.
- LS.4: Proactively deploy slope stabilization strategies to areas near track that have been recently burned by wildfire. Short-term engineered strategies (retaining walls) can be paired with mid-term, nature-based strategies (planting vegetation).

Lower Priority Strategies to Be Considered

Strategies are also included to address medium vulnerability of the station, bridge, and tunnel assets to landslides, and the medium vulnerability of track and station assets to extreme heat. Some of the strategies already have been included in the project scope (such as canopies to provide shade).

Bridges

- LS.5: Implement slope stabilization (vegetation or engineered) where bridge foundations or supports are within high landslide exposure areas.

Track Improvements

- EH.4: Stress newly installed and existing rail with a rail zero-stress temperature that is calculated based on projected temperatures for the lifetime of the rail, rather than on current or historic conditions.
- EH.6: Replace wood ties with concrete ties, which are heavier and more resistant to movement, reducing chances of thermal misalignment. This strategy should be coordinated with Strategy EH.12 for efficiency, as appropriate.
- EH.12: Reduce tie spacing, which provides additional weight to the track structure and increased lateral resistance because of increased exposure to shoulder ballast, reducing chances of thermal misalignment. This strategy should be considered only in situations where Strategies EH.4 and/or EH.6 are not sufficient.

Station/Facilities Improvements

- EH.2: Where feasible, plant shade trees at stations and/or facilities, such as in parking lots and/or entry areas. Plant heat and drought-tolerant, low-maintenance native plant species. Trees are not recommended for installation on platforms or planting close to the track.
- EH.3: Install cool roof treatments for stations and facilities, to reduce cooling needs and the urban heat island effect. Cool roof treatments include materials with high solar reflectance, such as reflective paints and reflective shingles/tiles.
- EH.8: Add station amenities to help riders cope with extreme heat where gaps exist. Although some stations are well equipped to deal with heat, opportunities exist to improve conditions in others (e.g., shading parking lots/bike racks, adding platform shading, adding seating under shade structures, and adding misters and air conditioning or fans in indoor waiting areas). The budget for routine maintenance/servicing of some amenities (such as misters) should be considered before their installation, to avoid disrepair/maintenance issues.
- EH.11: Install hydration stations (water fountain plus spout for filling water bottles) on station platforms and in maintenance areas to ensure that riders/staff have access to water when needed. This strategy will need to be assessed bearing in mind concerns about vandalism and misuse of hydration facilities.

PROJECT: ANTELOPE VALLEY LINE CAPACITY AND SERVICE IMPROVEMENT PROJECT (AVL CSI), BALBOA SIDING EXTENSION AND SPEED IMPROVEMENTS

Project Scope[8]

- Extend the existing Sylmar siding approximately 6,300 feet north from Balboa Boulevard to Sierra Highway.
- Re-align the existing main track through portions of the site, to accommodate the second track and the required clearance to existing structures.
- Install pier protection under Interstate 5 (I-5), along the west side of the corridor where required clearance cannot be provided.
- Construct a 475-foot-long retaining wall along the west side of the corridor, to support the realigned main track and proposed Sylmar siding extension just south of the Sierra Highway bridge.
- Re-align the existing spur track and access road south of the new double track
- Construct retaining walls along the embankment of the I-5 truck route to minimize ROW encroachment.

Primary Climate Vulnerabilities

Based on the project scope, the following assets were assessed for climate vulnerability: track, signals, and communications. Landslide exposure is shown in Figure 37 because it varies the most across the project area, compared to other hazards.

Table 36 summarizes the projected climate hazards, asset vulnerability ratings, and highlights the potential impacts on the project area.

Table 36: Potential Vulnerabilities, AVL–Balboa

Hazard	Vulnerability	Potential Impacts
Extreme Heat	Medium (track) Low (signals, communications)	• More frequent slowdown orders • Thermal misalignment of track
Wildfires	Medium (all asset categories)	• Disruption to service because of wildfire smoke
Landslides/Mudslides	High (all asset categories)	• Damage to track structure, communications, and signal equipment
Electrical Outages	Low (signals, communications)	• Loss of power to communications, signal infrastructure if outage time exceeds capacity of backup systems

[8] Documents reviewed:
Antelope Valley Line Environmental & Technical Studies Basis of Design, June 2021
Antelope Valley Line Capacity and Service Improvements Program Draft Environmental Impact Report, July 2021

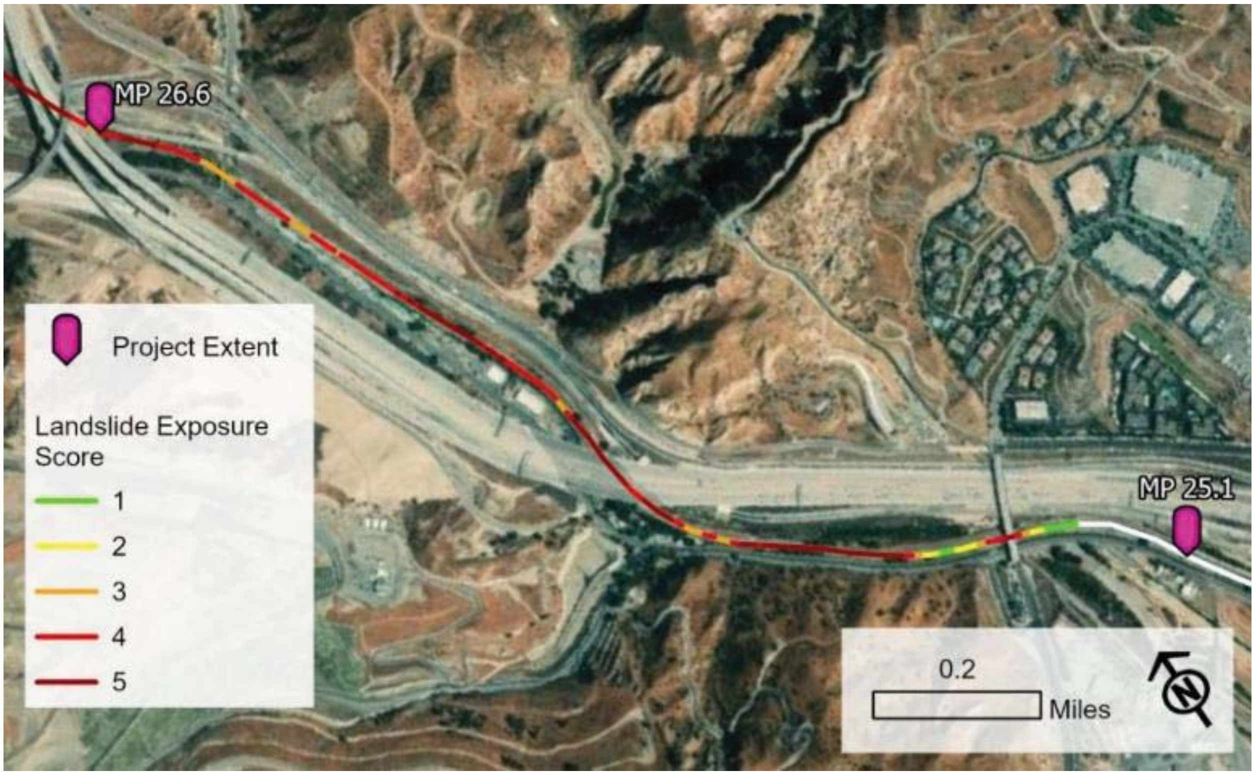


Figure 37: Project Area Map and Landslide Exposure, AVL–Balboa

Potential Adaptation Strategies to Improve Climate Resilience

The strategies listed next were derived from the structural strategies toolkit that was developed as part of the CVA.

High Priority Strategies

Because of the vulnerabilities identified above, high priority strategies have been identified to address the high vulnerability of track, signals, and communications assets to landslides. Although the track is in a high exposure zone for landslides in general, it is somewhat protected by adjacent roads that will be affected first.

General

- LS.1: Plant drought-tolerant vegetation that stabilizes slopes and contributes to erosion prevention in appropriate locations that can support vegetation without irrigation.
- LS.4: Retaining walls could be paired with nature-based strategies (planting vegetation) for soil stabilization.
- LS.7 Implement pre-emptive lower bluff improvements for ground stabilization or failure mitigation, such as a soil nail wall with shotcrete facing.

Pier Foundations

- LS.5 Implement slope stabilization (vegetation or engineered) where bridge foundations or supports are within high landslide exposure areas.

Lower Priority Strategies

Strategies also are included to address medium vulnerability of the track to extreme heat and the medium vulnerability of all assets to wildfire. EH.10 and EH.5 are included because wood ties currently exist in the project area.

Track

- EH.4: Stress newly installed and existing rail with a rail zero-stress temperature that is calculated based on projected temperatures for the lifetime of the rail, rather than on current or historic conditions.
- EH.5: Re-tamp ballast to increase ballast density, increasing lateral resistance and reducing chances of thermal misalignment. This strategy should be coordinated with Strategy EH.10 for efficiency, as appropriate.
- EH.6: Replace wood ties with concrete ties, which are heavier and more resistant to movement, reducing chances of thermal misalignment. This strategy should be coordinated with Strategy EH.12 for efficiency, as appropriate.
- EH.10: Increase the width of the ballast shoulder, which will increase lateral resistance and reduce the chances of thermal misalignment. This strategy should be considered only in situations where Strategies EH.4, EH.5, and/or EH.6 are not sufficient.
- EH.12: Reduce tie spacing, which provides additional weight to the track structure and increased lateral resistance because of increased exposure to shoulder ballast, reducing chances of thermal misalignment. This strategy should be considered only in situations where Strategies EH.4 and/or EH.6 are not sufficient.

All Assets

- WF.1: Manage vegetation in the right-of-way in high wildfire exposure areas. Depending on the location and vegetation, this can mean either complete clearing of vegetation or appropriate management for wildfire resilience.

PROJECT: LONE HILL AVENUE TO CP WHITE DOUBLE TRACK

Project Scope[9]

- Add a 3.9-mile second mainline from Lone Hill Avenue in San Dimas to White Avenue in La Verne.
- Upgrade the existing track.
- Improve the drainage and landscaping.
- Lengthen the existing platform at Pomona Fairplex Station.
- Upgrade 12 roadway at-grade crossings, including sidewalk and driveway modifications at grade crossings, to enhance safety.
- Improve connections to the industry spur track.

Primary Climate Vulnerabilities

Based on the project scope, the following assets were assessed for climate vulnerability: track, bridges, signals, station, and communications equipment. Figure 38 shows the project area. Exposure/vulnerability to climate hazards does not vary substantially across the project area.

Table 37 summarizes the projected climate hazards, asset vulnerability ratings, and highlights the potential impacts on the project area.

Table 37: Potential Vulnerabilities, Lone Hill Avenue to CP White Double Track Project

Hazard	Vulnerability	Potential Impacts
Extreme Heat	High (station) Medium (track, signals, communications) Low (bridges)	• More frequent slowdown orders
Wildfires	Low (all asset categories)	• Disruption to service because of wildfire smoke
Electrical Outages	Low (signals, communications, station)	• Loss of power to communications, signal infrastructure if outage time exceeds capacity of backup systems

[9] Document reviewed:
Lone Hill to White Double Track Study Fact Sheet, May 2017

Figure 38: Project Area Map, Lone Hill Avenue to CP White Double Track Project

Potential Adaptation Strategies to Improve Climate Resilience

The strategies listed next were derived from the structural strategies toolkit that was developed as part of the CVA.

High Priority Strategies

Because of the vulnerabilities identified above, high priority strategies have been identified to address the high vulnerability of station assets to extreme heat. Their suitability may depend on the seasonal nature of the station.

Station

- EH.8: Add station amenities to help riders cope with extreme heat where gaps exist. Although some stations are well equipped to deal with heat, opportunities exist to improve conditions in others (e.g., shading parking lots/bike racks, adding platform shading, adding seating under shade structures, and adding misters and air conditioning or fans in indoor waiting areas). The budget for routine maintenance/servicing of some amenities (such as misters) should be considered before their installation, to avoid disrepair/maintenance issues.
- EH.11: Install hydration stations (water fountain plus spout for filling water bottles) on station platforms and in maintenance areas to ensure that riders/staff have access to

water when needed. This strategy will need to be assessed bearing in mind concerns about vandalism and misuse of hydration facilities.

Lower Priority Strategies to Be Considered

Strategies also are included to address medium vulnerability of the track to extreme heat.

Track

- EH.4: Stress newly installed and existing rail with a rail zero-stress temperature that is calculated based on projected temperatures for the lifetime of the rail, rather than on current or historic conditions.
- EH.5: Re-tamp ballast to increase ballast density, increasing lateral resistance and reducing chances of thermal misalignment. This strategy should be coordinated with Strategy EH.10 for efficiency, as appropriate.
- EH.6: Replace wood ties with concrete ties, which are heavier and more resistant to movement, reducing chances of thermal misalignment. This strategy should be coordinated with Strategy EH.12 for efficiency, as appropriate.
- EH.10: Increase the width of the ballast shoulder, which will increase lateral resistance and reduce the chances of thermal misalignment. This strategy should be considered only in situations where Strategies EH.4, EH.5, and/or EH.6 are not sufficient.
- EH.12: Reduce tie spacing, which provides additional weight to the track structure and increased lateral resistance because of increased exposure to shoulder ballast, reducing chances of thermal misalignment. This strategy should be considered only in situations where Strategies EH.4 and/or EH.6 are not sufficient.

Landscaping

- D.1: Reduce outdoor water use by transitioning landscapes to climate-smart planting. Planting in any landscaped areas should be low-maintenance, non-invasive, and heat and drought tolerant to reduce water use and maintenance costs.
- D.2: When/where feasible, replace traditional sprinkler systems with drip irrigation systems, which are more water efficient.

PROJECT: SBCTA LILAC TO RANCHO DOUBLE TRACK

Project Scope[10]

- Add approximately 3 miles of additional double track in Rialto and San Bernardino.
- Add a second passenger platform at Rialto Station, as well as a pedestrian underpass for access.
- Improve 8 at-grade crossings within and near the double track footprint, with quiet zone safety enhancements.
- Add new railroad signals as well as PTC considerations and required improvements.
- Add civil improvements, including grading, drainage, and utilities.

Primary Climate Vulnerabilities

Based on the project scope, the following assets were assessed for climate vulnerability: track, signals, communications, station, and tunnel. Flood exposure is shown in Figure 39 because it varies the most across the project area, compared to the other hazards, which are summarized in Table 38.

Table 38: Potential Vulnerabilities - Lilac to Rialto Station Double Track Project

Hazard	Vulnerability	Potential Impacts
Extreme Heat	Medium (track) Low (signals, communications, station)	• Passenger discomfort while waiting for trains • More frequent slowdown orders
Riverine Flooding	Low (all asset categories)	• Track runs adjacent to 100-year and 500-year floodplain; damage to track structure could occur in extreme flooding event
Electrical Outages	Low (signals, communications)	• Loss of power to communications, signal infrastructure if outage time exceeds capacity of backup systems

[10] Documents Reviewed:
Lilac to Ranch Double Track Project Public Meeting Boards. July 2017.

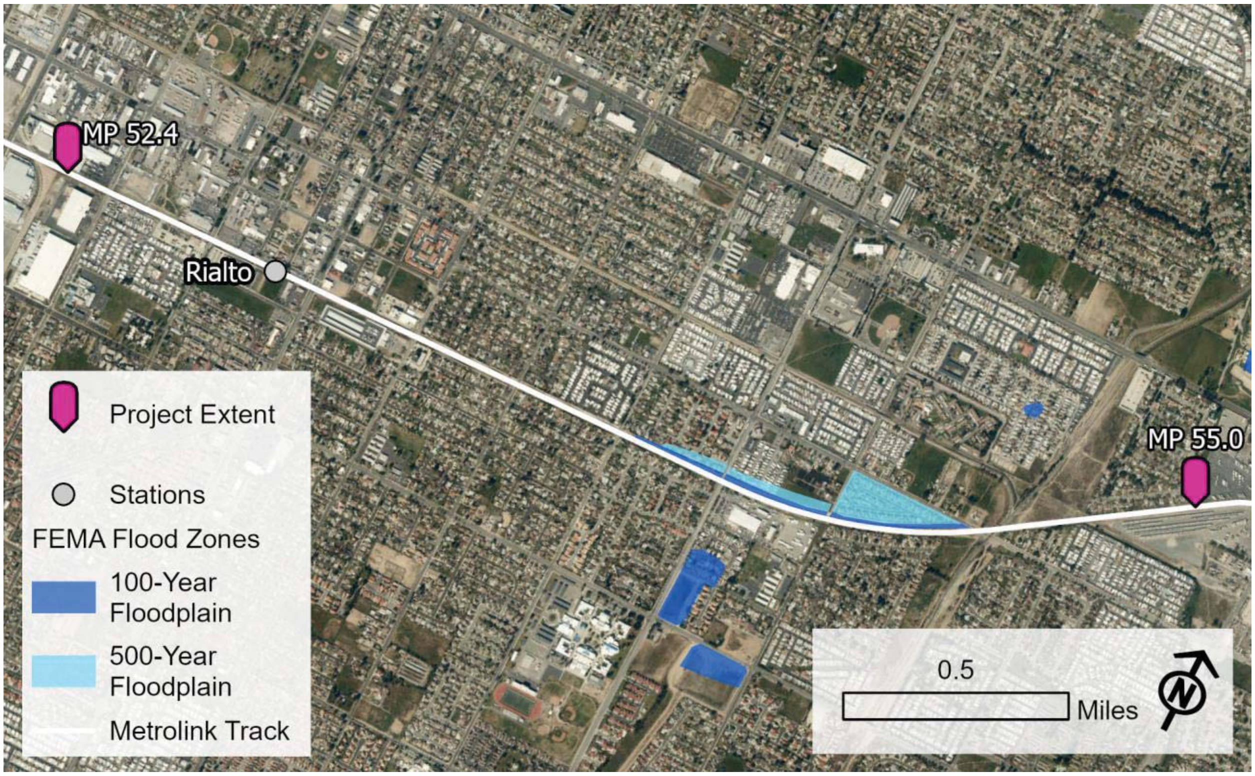


Figure 39: Project Area Map and Flood Exposure, Lilac to Rancho Double Track Project

Potential Adaptation Strategies to Improve Climate Resilience

The strategies listed next were derived from the structural strategies toolkit that was developed as part of the CVA.

High Priority Strategies

No assets are highly vulnerable to any hazard.

Lower Priority Strategies to Be Considered

Strategies have been identified to address the medium vulnerability of the track to extreme heat.

Track Improvements

- EH.4: Stress newly installed and existing rail with a rail zero-stress temperature that is calculated based on projected temperatures for the lifetime of the rail, rather than on current or historic conditions.
- EH.6: Replace wood ties with concrete ties, which are heavier and more resistant to movement, reducing chances of thermal misalignment. This strategy should be coordinated with Strategy EH.12 for efficiency, as appropriate.

PROJECT: IRVINE STATION IMPROVEMENTS

Project Scope[11]

- Upgrade and extend existing siding by 0.8 mile to the east.
- Three alternatives are currently under consideration
    - Alternative 1A: Add a fourth track from CP Tinkham to CP Bake. Reconfigure Irvine Station to include two center platforms. Construct a pedestrian underpass. Modify the existing park and ride.
    - Alternative 1B (this is a phased implementation of Alternative 1A): Maintain the three main tracks from CP Tinkham to CP Bake. Reconfigure Irvine Station to include two center platforms, a center platform and a side-board platform. Modify the existing pedestrian overpass to accommodate the new center platform.
    - Alternative 2: Add a fourth track from CP Tinkham to CP Bake. Reconfigure Irvine Station to include two center platforms. Construct a pedestrian underpass.

Primary Climate Vulnerabilities

Based on the project scope, the following assets were assessed for climate vulnerability: track, signals, bridges, communications, and a station. Figure 40 shows the project area. Exposure/vulnerability to climate hazards does not vary substantially across the project area.

Table 39 summarizes the projected climate hazards, asset vulnerability ratings, and highlights the potential impacts on the project area.

Table 39: Potential Vulnerabilities - Reconfigure Irvine Station and add 4th track Project

Hazard	Vulnerability	Potential **Impacts**
Extreme Heat	Low (all asset categories)	• Increased energy costs from air conditioning at Irvine Station • Occasional slowdown orders
Drought	Low (all asset categories)	• Increased cost of irrigation for station landscaping
Electrical Outages	Low (station, signals, communications)	• Loss of power to communications, signal infrastructure if outage time exceeds capacity of backup systems

[11] Document reviewed:
Project Definition Report–Orange Corridor Southern California Regional Rail Authority, June 2019

Figure 40: Project Area Map, Reconfigure Irvine Station and Add a Fourth Track

Potential Adaptation Strategies to Improve Climate Resilience

No adaptation strategies are proposed because each asset has low vulnerability.

High Priority Strategies

None have been identified.

Lower Priority Strategies to Be Considered

EH.8: Add station amenities to help riders cope with extreme heat where gaps exist. Although some stations are well equipped to deal with heat, opportunities exist to improve conditions in others (e.g., shading parking lots/bike racks, adding platform shading, adding seating under shade structures, and adding misters and air conditioning or fans in indoor waiting areas). The budget for routine maintenance/servicing of some amenities (such as misters) should be considered before their installation, to avoid disrepair/maintenance issues.

Improve Track Resilience to Extreme Heat

BACKGROUND

The purpose of this concept design is to provide recommendations to reduce the risk of track displacements because of extreme heat (also referred to as thermal misalignments or "sun kinks"). The study area is a 23.6-mile segment of the Valley Subdivision, from Via Princessa Station (MP 37.9) to Vincent Grade/Acton Station (MP 61.5). Even though this stretch of track is not projected to experience the most extreme absolute temperatures across the system, two thermal misalignment events have occurred in this area over the last few years, including one on the main track close to MP 45 in September 2020, and another on the siding at Humphreys Siding (MP 39.9) in June 2021. During these events, other portions of the system experienced higher absolute temperatures but no thermal misalignments. This suggests that the track structure in the study area is particularly sensitive to thermal misalignment, and that targeted physical interventions can reduce this impact. Figure 41 shows the study area and average annual maximum temperatures for mid-century.

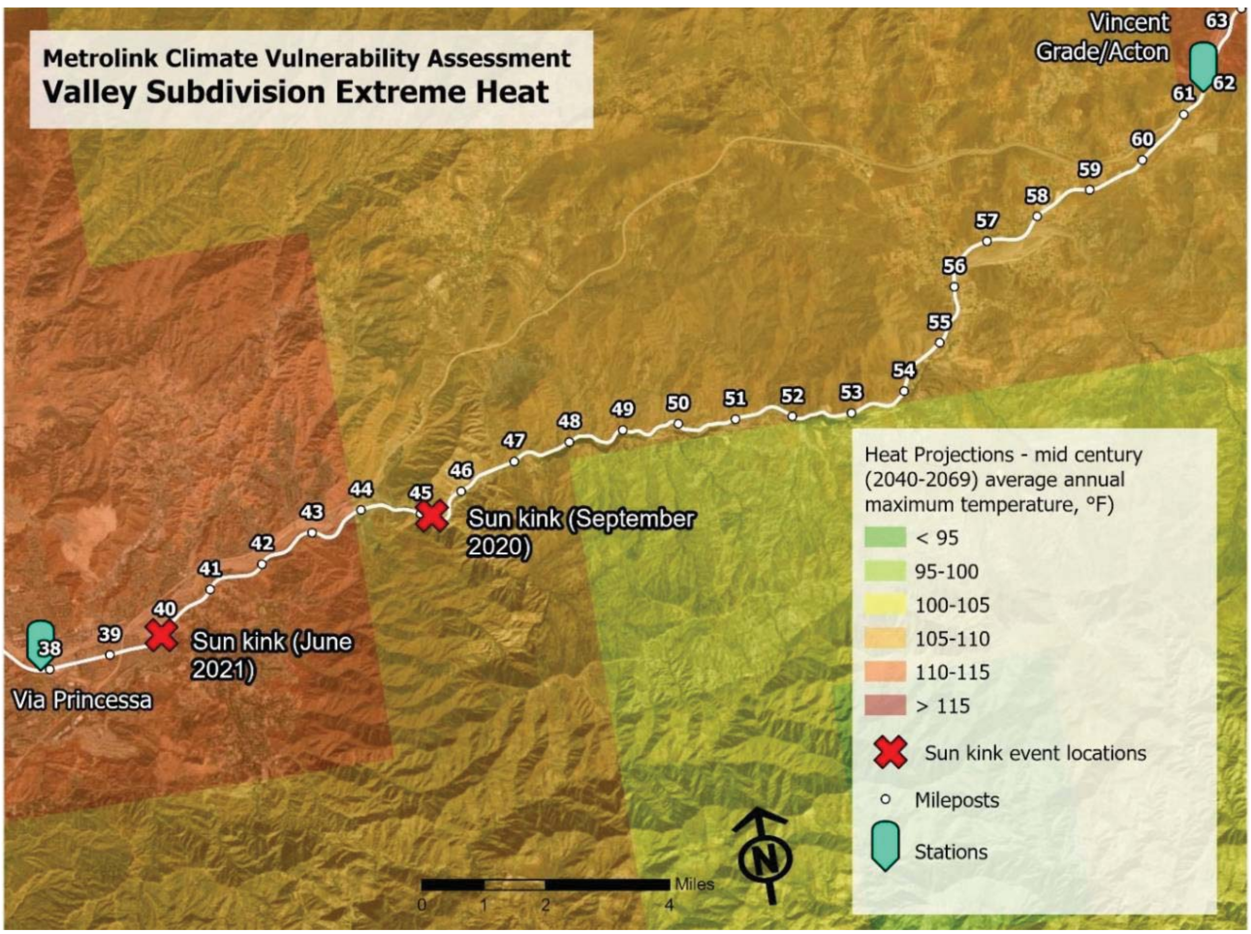


Figure 41: Average Annual Maximum Temperatures in the Valley Subdivision MP 37.9 to 61.5 Study Area

METHODOLOGY

A literature review was conducted to understand rail design and why thermal misalignments occur. This was followed by a review of existing conditions in the study area, with the goal of identifying stretches of track that are particularly sensitive, based on physical factors such as design, construction materials, and condition. The following discussion describes the advantages and disadvantages of various physical strategies that can be used to prevent thermal misalignments. The discussion concludes with specific recommendations for the study area, including a matrix connecting a typology of existing conditions to strategies particularly applicable for each type of track.

SUMMARY

Track Design and Thermal Misalignments

The current practice of constructing railroad track involves welding the individual rail sections into long "strings." Two rails in the railroad track are fastened to the crossties, and thus behave like an infinitely long beam. The rails are restrained from longitudinal movement by the crosstie fasteners, otherwise they would expand and contract because of changes in the ambient temperature. Because the rails are restrained from movement, internal stresses are generated within the rails as the temperature changes.

When track is constructed, the rails are fastened to the crossties at a specific temperature (rail temperature, not ambient). This temperature is called the "zero neutral stress temperature." When the rail exceeds this temperature, it will be in compression because the rail is restrained from expanding. When the rail falls below this temperature, it will be in tension because the rail is restrained from contracting. The zero neutral stress temperature for the Metrolink system is 110°F in outdoor areas and 70°F in tunnels. When the rail exceeds either of these temperatures, it has a natural tendency to expand. However, this expansion is restrained by the crossties, both longitudinally and laterally.

As mentioned previously, the term commonly used to describe displacement of track during periods of excessive heat is a thermal misalignment or "sun kink." Sun kinks are caused when the internal temperature of the rails increases to the point where the stress within the rails overcomes the ability of the track structure to maintain the alignment, either horizontally, vertically, or both.

Resistance to movement of the track (i.e., resistance to thermal misalignment) is affected by the following physical/design factors:

- The ballast placed at the ends of the ties (called the shoulder ballast) affects resistance to lateral movement.
- The weight of the track (rails, ties, tie plates, and rail anchors) affects resistance to vertical and lateral movement.
- Spacing of the crossties affects resistance to lateral movement (closer tie spacing increases the tie surface area contacting the shoulder ballast).

- The ballast placed between the ties, called the crib ballast, prevents longitudinal movement of the ties.

If any vertical movement of the track (lifting) occurs, the resistance to lateral movement decreases because of the reduction in tie surface area contacting the shoulder ballast. Other factors can contribute to the potential for sun kinks, such as deformations in the rail, which can weaken the lateral strength, and train movements through curves that exert lateral pressure on the track.

Federal Research on Thermal Misalignment Prevention

A significant amount of research has been conducted over the years to identify the causes of sun kinks and methods to reduce potential occurrences. The DOT Volpe Center and the Federal Railway Administration’s Office of Research and Development have sponsored many of these studies. The common theme that has been identified for prevention of sun kinks is the amount of shoulder ballast resisting the lateral movement of the crossties. Several other factors have been identified that can contribute to the problem to a lesser degree, including deviations to the track alignment and missing ballast under or between the ties. Track that has been tamped but not consolidated also is susceptible to sun kinks.

Existing Conditions in the Study Area

A review of existing conditions was carried out for each one-tenth MP using the following resources:

- Track charts and curve data from the PTC Project (SCRRA 2019c)
- Trackbed condition summary from the Railway Association of Southern California (RASC) Survey (SCRRA 2019b)
- Volume 1 of the Metrolink Rehabilitation Plan (SCRRA 2020)
- Aurora Metrolink Valley Subdivision Wood Tie Grade Summary Report (SCRRA 2019b)
- Spatial KMZ files of the Valley Subdivision (SCRRA 2018)

The 23.6 mile-long corridor includes wood ties with tie plates that are secured with spikes and rail anchors (10.5 miles), concrete ties (9.3 miles) and wood ties with Pandrol elastic fasteners (3.8 miles). Approximately half of the track within the corridor is in a curved alignment. A significant number of tighter curves have a centerline radius of less than 1,000 feet. Curves are more sensitive to thermal misalignment than tangent track because the rails already are bent in one direction, reducing resistance to additional bending, and rail operations exert significant lateral force on curved track. The trackbed surveys included 13 miles of the corridor, and the results indicated approximately 15 separate areas (less than 500 feet) where the trackbed was in poor condition[12]. A weak trackbed structure could affect lateral resistance to movement, depending on the nature of the weakness.

The Technical Appendix includes a schematic representation of the 23.6-mile-long corridor, summarizing physical factors that increase sensitivity to thermal misalignment, such as the crosstie type, fastener type for wood ties, locations of substandard track, and locations of curves. Based on these factors, sections of track with elevated sensitivity to thermal misalignments are identified on the schematic.

Two sun kinks have recently occurred in the study area (the locations of both are shown in Figure 41). One occurred in September 2020 at MP 45.2 on the mainline track. This section of track is within a curve with a centerline radius of 882 feet and track supported by wood ties and spikes. The section of track with wood ties is approximately 1,200 feet long, with concrete tie track on either side. This location has been rated as having high sensitivity to sun kinks. Another sun kink occurred in June 2021 at MP 39.9, on siding at CP Humphreys. The siding track has wood ties with a mix of cut-spike and Pandrol plate e-clip tie fasters[13]. This track was flagged by RailPros (a construction management consultant) as requiring rehabilitation (38 percent of the ties were rated as “failed”). This location has not been rated as having high sensitivity to sun kinks because the ratings are for mainline track only (for more information on sensitivity ratings, see Adaptation Strategies Based on Track Typology, below).

Rail engineers also reviewed SCRRA’s design criteria, to understand current specifications for design factors related to thermal misalignment sensitivity. Current specifications for crosstie size and spacing for both tangent and curved track are summarized as follows:

- Wood ties: 7 inches by 9 feet by 9 feet at 19.5-inch spacing
- Concrete ties: 8 feet 3 inches long at 24-inch spacing
- Ballast shoulder width: wood ties, 9 inches; concrete ties, 12 inches
- Rail laying temperature: 110°F outside; 70°F in tunnels

Data from the Aurora Metrolink Valley Subdivision Wood Tie Grade Summary Report (2019) indicates that in the study area, 19 percent of the wood ties have failed and 31 percent of them are marginal. Failed and marginal ties will reduce the effectiveness of the rail fasteners to prevent displacement of the rail (loose tie plates reduce the effectiveness of rail anchors).

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[12] This was determined based on Trackbed Conditions Summary (TCS) scores, as indicated in the Trackbed Conditions Summary reports from the 2019 RASC Survey. TCS scores summarize Combined Track Quality Index (CTQI) scores from the left shoulder, right shoulder, and center. CTQI scores are based on several factors, including variations in ballast thickness and ballast fouling (see page 2-62 of the 2020 Metrolink Rehabilitation Plan for more information).

[13] *Vista Canyon Station Project, Summary of Rehabilitation Work Undertaken to Humphreys Siding*, Metrolink memo, June 23, 2021.

ADAPTATION STRATEGIES FOR CONSIDERATION

This section summarizes a series of potential strategies to reduce sensitivity of track to thermal misalignments. Prevention of sun kinks includes a combination of good monitoring and maintenance practices along with upgrades to the track structure in high risk areas. Specific recommendations for the study area include the following:

- **Allocate adequate funding** to address infrastructure State of Good Repair and backlog as outlined in the Metrolink Rehabilitation Plan.
- **Replace failed and marginal ties**: As mentioned above, 50 percent of the wood ties in the study area are in marginal or failed condition. Replacing these ties is imperative because track constructed with wood ties is more susceptible to sun kinks. Replacement should include new tie plates, and elastic-type rail fastenings are recommended.
- **Replace wood ties with concrete ties**: Concrete ties are heavier and have a larger end-of-tie surface area in contact with the shoulder ballast. Concrete tie track weighs approximately 441 pounds per foot of track, with an end-of-tie surface area of 48 square inches per foot of track. Wood tie track is 245 pounds per foot, with 38 square inches of end surface. Mass replacement of wood ties with concrete would be a major effort, requiring reconstruction of the track including the sub-ballast and subgrade because a thicker ballast section is required for concrete ties (12 inches versus 9 inches). Replacing wood ties with concrete would be more feasible in selected areas, where a large number of failed or marginal wood ties occur.
- **Increase ballast shoulder width**: Increasing the ballast shoulders will increase the resistance to lateral movement of the track during extreme heat. Adding shoulder ballast is relatively simple; however, in some areas, it will require placement of additional sub-ballast along the edge of track. UPRR and BNSF track standards, along with most major railroads and passenger rail agencies, include 12 inches of shoulder ballast. The current Metrolink standard requires 9 inches of shoulder ballast for wood tie track.
- **Reduce tie spacing and increase shoulder widths on curves**: Operation of trains exerts lateral forces on the track in curves, adding to the thermal forces contributing to the potential for sun kinks. Additional shoulder ballast and reduced tie spacing increases the resistance to lateral shifting of the track in curves.
- **Increase zero neutral stress temperature**: Increasing the rail laying temperature decreases the compressive forces in the rails during extreme temperatures, and thus increasing the resistance to track buckling. Implementing this change in rail laying temperature will be a major effort, requiring removal and re-installation of rail anchors and rail spikes on all wood ties and rail clips on concrete ties. The rails will have to be cut at intervals, to allow stretching the rail to mimic the elevated temperature, and then they will have to be re-welded after the rail has been secured to the ties. However, this strategy can be applied incrementally, when rail is lifted for tie replacement or other maintenance. This strategy is less applicable in areas that experience very low temperatures in addition to hot temperatures. During cold temperatures, rails set at higher temperatures will contract more, potentially resulting in the track shifting inward

toward the curve center. Because the study area does experience low winter temperatures, this strategy may be less applicable here than it would be in other parts of the system.

- **Expand monitoring capabilities through installation of sensors**: Under current practices per Federal Railroad Administration track safety standards, track must be inspected visually twice a week. A track inspector will drive on the track in a high rail vehicle at a low speed and visually determine any misalignments in the track that may be a sign of a potential sun kink. However, sun kinks can occur suddenly, and the risk of derailments can be reduced further by installation of sensors in high hazard areas. Sensors can monitor either rail temperature or detect track movement (i.e., a sun kink event).

Temperature monitoring involves installing measuring devices on the rails at selected intervals that are connected to a central monitoring system. Over the years, various systems have been developed for this purpose, but very few of them have been implemented. However, detection of elevated rail temperatures does not guarantee an impending sun kink because so many other contributing factors can exist.

Track movement monitoring involves placing strain gauges along the track, to detect lateral and vertical movement. These gauges also need to be connected to a central monitoring system. This type of system is more accurate because actual movement is detected. Two companies offer these systems—Voestalpine AG and Durham Geo-Enterprises, Inc. Although the costs of these systems have not been determined, recent advances in and the proliferation of IoT (internet of things) technology have greatly reduced the costs of sensor equipment, compared to previous decades.

Adaptation Strategies Based on Track Typology

As discussed previously, although thermal misalignment events ultimately are triggered by extreme heat, physical attributes of the track structure leading to increased sensitivity have been found to be a stronger influence on overall vulnerability than exposure to high temperatures. Table 40 shows track conditions, sun kink sensitivity, and applicable adaptation strategies. This table can be used, along with the track conditions schematic in the Technical Appendix to prioritize strategies for implementation. Adaptation strategies should be implemented first for the stretches of track shown in rated as having high sensitivity. For these stretches, strategies should be considered in order of priority, as shown in Table 40. The sensitivity of specific stretches of track should be evaluated by taking into consideration all local factors and evaluation of track conditions (see Technical Appendix).

Table 40: Sun Kink Sensitivity and Adaptation Strategies Based on Track Conditions Typology

Crosstie Type	Alignment	Sun kink Sensitivity	Adaptation Strategies (in order of priority)
Wood ties with spikes and anchors	Curved (gentle and tight)	High	Replace failed and marginal ties with elastic fasteners Increase ballast shoulder width Reduce tie spacing Replace with concrete ties
	Tangent	Medium-High	Replace failed and marginal ties with elastic fasteners Increase ballast shoulder width Replace with concrete ties
Wood ties with Pandrol plates	Curved (gentle and tight)	Medium-High	Replace failed and marginal ties with elastic fasteners Increase ballast shoulder width Reduce tie spacing
	Tangent	Medium	Replace failed and marginal ties with elastic fasteners Increase ballast shoulder width
Concrete	Curved (gentle and tight)	Low	Not necessary
	Tangent	Low	Not necessary

RECOMMENDATIONS

The primary recommended solution for minimizing the potential for thermal misalignments in the study area is to replace all wood ties with concrete ties. It is recognized, however, that implementation of this strategy will be difficult to achieve because of budgetary constraints, thus a phased combination of the strategies likely will be more feasible. Recommendations include the following:

- Allocate adequate funding to address infrastructure State of Good Repair and backlog as outlined in the Metrolink Rehabilitation Plan
- Replace all failed/marginal wood ties, focusing first on the sections identified as having high sensitivity to sun kinks, and then the sections identified as having medium-high sensitivity. Specific locations of failed ties are too granular to include in the schematic; for locations of failed ties, see the Aurora tie scan data that was developed for the Metrolink Rehabilitation Plan.
- Increase ballast shoulder width for high sensitivity stretches, from 9 inches (as currently required for wood ties) to 12 inches (as currently required for concrete ties). First focus on stretches of track where substandard trackbed has been identified based on ballast scans. These sections also may need to be re-tamped.
- Selectively upgrade to concrete ties. Although replacing all wood ties in the study area with concrete ties may not be feasible, a subset of stretches should be prioritized, focusing on high-sensitivity stretches that are between or adjacent to existing stretches of concrete ties, such as MP 45.1 to 45.2, MP 45.5 to 45.8, and MP 52.3.
- Consider reducing tie spacing for stretches with wood ties on tight curves, such as MP 52.0 to 52.4.

The approach can be carried out for other portions of the system. The data sources used here are available for the entire system, and the track conditions typology, shown in Table 40, can be applied elsewhere. This study area was selected because it currently is the portion of the system experiencing thermal misalignment events, but as temperature patterns and track conditions change over time, sun kinks may occur in other parts of the system, where wood ties and extreme heat are present. To carry out a similar study for other areas, SCRRA engineers should perform the following:

- Gather available track conditions data for the area of interest (see the list of sources under Existing Conditions of Study Area above).
- Consolidate data on track conditions into a single schematic.

Based on the track conditions schematic and using Table 40 as a guide along with best professional judgment, rate the sensitivity of each 1/10th MP stretch of track.

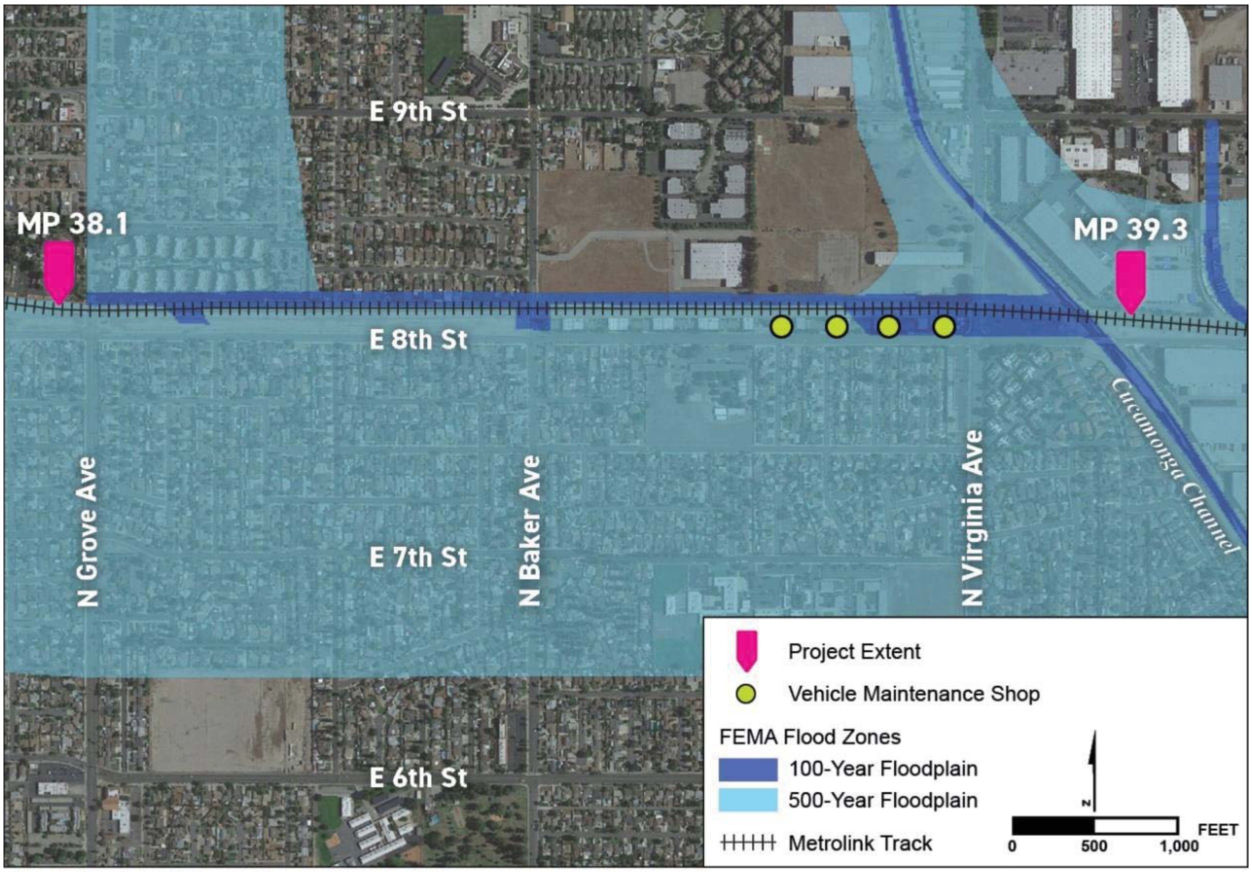
- Prioritize stretches for adaptation strategy implementation based on the sensitivity ratings as well as other consideration, such as maintenance/rehabilitation schedules and the location of prioritized stretches relative to other prioritized stretches in the study area.
- For prioritized stretches, strategies should be considered in order of priority, based on the Adaptation Strategies column in Table 40.

Following the process will result in high-level ratings and recommendations (similar to this section) that will need to be followed with a more in-depth engineering study before strategies actually can be implemented.

Improve Track Resilience to Precipitation Flooding

BACKGROUND

The purpose of this concept design is to explore options to minimize riverine flooding on a discrete stretch of track on the San Gabriel Subdivision (MP 38.1 to 39.3), with a focus on nature-based solutions.



Source: Google Earth Pro, 2021.

Figure 42: Flooding Concept Design Study Area

METHODOLOGY

This evaluation begins with an overview of the potential flood exposure in the study area, followed by a discussion of design considerations, constraints, and opportunity areas. The recommendations section presents a framework for the selection of suitable locations for nature-based solutions, widely applicable across the Metrolink system, and then identifies specific locations for linear swales in the project area. Recommendations for gray infrastructure and non-physical strategies also are included. The Technical Appendix provides a summary of relevant nature-based/green infrastructure solutions, including design criteria.

SUMMARY

Overview of Flood Hazard

This section provides a summary of flood hazards in the study area, including flood paths, key vulnerabilities, and potential impacts. The water from the Cucamonga Channel drains south and combines with other local channels before draining into the Prado Basin. The channel carries surface waters that are collected from urban areas adjacent to it. During 100-year storm events, the channel overflows to adjacent areas, resulting in local flooding around the track (see Figure 42 for the extent of flooding). Because of the human-made barriers along the track, an overflow of the channel will result in local flooding along the tracks. Prolonged presence of water along the track may jeopardize the structural integrity of the track and damage mechanical and electrical track equipment. In addition to damaged track and equipment, flooding appears to affect some of the properties on the north side of the track, although the affected areas appear to be limited to backyards, parking areas, and side streets.

Stretches of track between MP 38.1 and MP 39.3 are within the 100-year floodplain. Flooding originates from overtopping of the Cucamonga Channel, which crosses the San Gabriel subdivision at MP 39.2 in Rialto. The approximate elevation of the track at MP 38.1 is 1,170 feet above sea level, and the Cucamonga Channel crosses under the track at an elevation of 1,110 feet. Because of the human-made barriers along the track, an overflow of the channel will result in local flooding, particularly on the north side of the track, with isolated flooded areas south of the track.

A flood in the study area is likely to begin with overtopping of the Cucamonga Channel. Water then will move westward, flooding the low-lying areas near the track. Depending on the intensity of a rainstorm, flooding can happen slowly or fast, as the volume of water entering the Cucamonga Channel exceeds its conveyance capacity. After the water overtops the channel, it is likely to stay in the track areas until infiltrated, evaporated, or otherwise removed.

Constraints and Opportunity Areas

This section summarizes design requirements, considerations, and constraints in the study area, and then suggests opportunity areas for physical interventions.

Protection of Existing and Future Assets and Infrastructure

The buildings on the south side of the track, between Vineyard Avenue and Baker Avenue (MP 38.6 to 39.1) are mainly vehicle maintenance shops (e.g., autobody shops, auto electric shops, tire shops). Flooding in this area may result in hazardous materials moving with water. Any solution must significantly reduce the likelihood of local flooding at these properties, by either diverting the water away from them or providing upstream solutions to capture runoff before it gets to these properties. Some of these locations are marked on Figure 42.

Between Baker Avenue and Grove Avenue (MP 38.1 to 38.6), flooding also appears to affect the properties north of the track. Backyards, structures, and parking spaces at Rancho Verde Village Apartments are all in flooded areas. Another constraint in this area is a structure at 1235 East 8th Street (MP 38.13), owned by Zayo Group LLC, a fiber optic service provider. The structure appears to be a major access point for fiber conduit running under the strip of City-owned land parallel to the SCRRA ROW. SCRRA confirmed that no fiber is within the ROW in this area. Although this structure is not within the areas that are likely to experience local flooding, attention has to be paid to ensure that downstream solutions will not increase the risk of flooding elsewhere, including at this site.

Existing utilities in the project area should be considered a constraint, as they may require additional protective measures and can substantially increase the project cost. Based on a preliminary assessment, it appears that no major third-party utilities are within the ROW, with the exception of some private electrical lines crossing the track at some locations. A more detailed analysis (as part of any design effort) will need to be done, to ensure that the recommendations in this study will be feasible to construct. The presence of the existing utilities will not be a fatal flaw, but they are likely to increase the cost associated with the proposed strategies that are designed to alleviate the risk of flooding along the track.

SCRRA Design Requirements

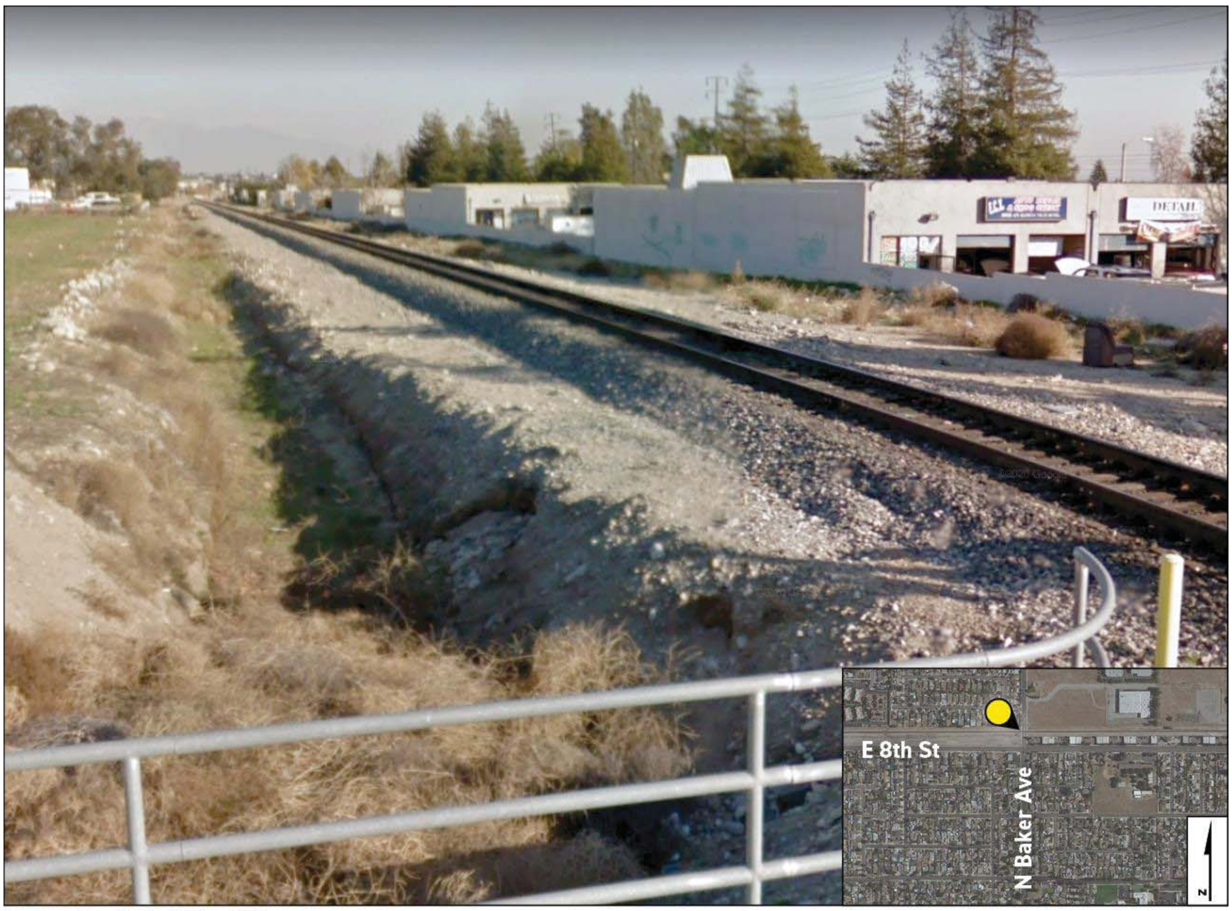
The SCRRA Design Criteria Manual (SCRRA 2021) lists requirements and considerations necessary for facilities and grading within a SCRRA ROW and for other drainage facilities outside a SCRRA ROW that are affected by SCRRA construction activities. These guidelines are intended to protect Metrolink facilities from stormwater, and any solution that is a deviation from the design criteria needs the approval of SCRRA via a Request for Special Design Considerations (Form DPM-13).

The following list summarizes some of the design guidelines related to any stormwater management solutions within a SCRRA ROW:

- Plants cannot be planted within 3 feet or block visibility of an existing sign.
- No plantings are allowed closer than 25 feet from the nearest track.
- Ground covers, shrubs, and hedges are permitted only within 10 feet of the edges of the ROW and landscaped areas.
- A zero-growth herbicide-treated buffer zone, 10 feet in width, shall be provided between the ROW and any landscaped areas.
- A perforated high-density polyethylene underdrain must be located in areas where groundwater is anticipated to interfere with the stability of track, roadbeds, and side slopes, and at a minimum the underdrain must be 6 inches in diameter, or 8 inches if it is within 20 feet of the track, and it must be wrapped in geotextile fabric and bedded in aggregate filter material.
- SCRRA-preferred stormwater BMPs are for infiltration systems, capture and use, biofiltration/bioretention systems, and structural best management practices. These strategies reflect SCRRA's preference for the use of such BMPs in their ROWs and projects.

Identification of Opportunity Areas

The SCRRA ROW appears to extend 47.5 feet from the outside of the track, 25 feet of which is off-limits, for planting. The width of the track is 4 feet 8.5 inches, assumed as 5 feet for this analysis, and the raised track bed occupies approximately 25 feet of the center of the ROW. A width of 5 feet closest to the edges of the SCRRA ROW should be left as a buffer, to allow any utilities, future fence, or wall structures. This leaves a 20-foot-wide zone for any stormwater mitigation measures, starting from 5 feet from the edge of the ROW at either side of the track. In some areas, this zone already is occupied by a low-lying ditch, which can be formalized to capture excess runoff (see Figure 43). However, in other areas, this zone may include electrical or mechanical infrastructure, or billboards/street/track signage, which must be protected from stormwater (see Figure 44). Such areas and a 10-foot buffer around them should be kept clear of any stormwater management solutions, to minimize the impacts of construction.



Source: Google Earth Pro, 2021.

Note: viewing east from Baker Avenue

Figure 43: Existing Low-Lying Areas Can Be Formalized to Capture Excess Runoff

Source: Google Earth Pro, 2021.

Note: viewing west from Baker Avenue

Figure 44: Track Equipment is a Constraint for Stormwater Solutions

ADAPTATION STRATEGY RECOMMENDATIONS

The following section summarizes recommended adaptation strategies for alleviating flood hazards in the study area. Nature-based solutions are physical infrastructure that leverage natural materials, plants, and natural processes to reduce flooding. Gray infrastructure requires the use of traditional stormwater management systems, such as large detention basins, to temporarily store peak flow, large underground pipes, or additional channel capacity. Non-physical strategies are more general recommendations for permitting/planning that do not involve a specific structure.

Nature-Based Solutions

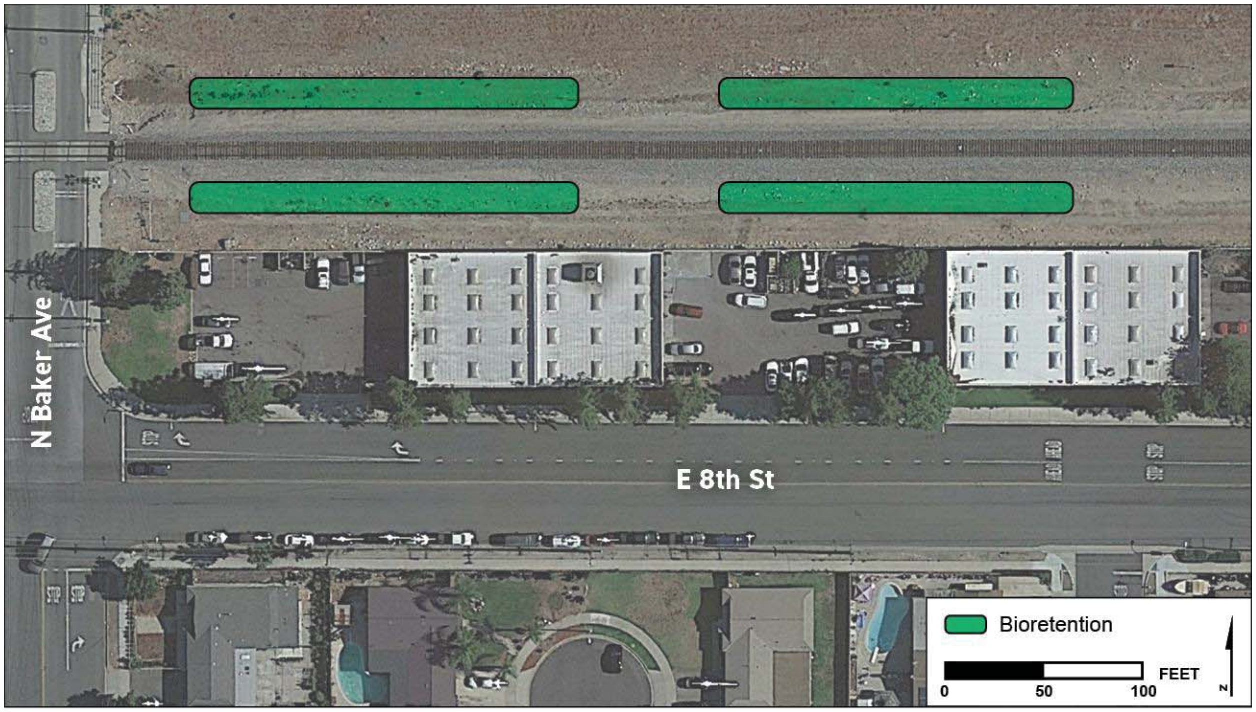
Nature-based solutions suitable for applications along SCRRA track include linear bioretention features, linear vegetated swales, and underground detention and infiltration systems. These systems mimic natural drainage by slowing down the movement of surface runoff and providing an opportunity for infiltration into existing soils, while protecting the railroad and nearby roadway base layers and structural components from over-saturation.

The following steps are recommended as a “process of elimination” approach to finding the best locations for nature-based solutions in a study area:

1. **Identify constraints**: These include areas off-limits, as described in SCRRA's Design Criteria Manual, or other permitting requirements as well as physical constraints, such as buried utility lines, SCRRA mechanical/electric equipment, and associated buffers (see Identification of Opportunity Areas above for an example of this process).
2. **Identify opportunity areas**: From the remaining areas, identify those that can accommodate a fairly large stormwater feature. Because of the cost of mobilization, utility locating, and other fixed construction costs, larger basins will prove more economical for every captured gallon of runoff. A feature that is at least 50 feet long, 5 feet wide, and 8 feet deep, and filled with aggregate and engineered soils can provide somewhere between 500 and 700 cubic feet (more than 5,000 gallons) of storage for excess runoff.
3. **Survey the study area topography**: These features are best placed in low-lying areas, where topography can support drainage of any excess stormwater runoff toward them.
4. **Complete a geotechnical study for percolation rates**: Nature-based solutions rely on the existing soils' capacity to infiltrate stormwater runoff, and thus before finalizing any design, geotechnical analysis may be needed to confirm the soils' capacity to accommodate these features.
5. **Screen for contaminated soils**: Infiltration of over-contaminated soils can spread contaminants and should be avoided. If any areas are suspected to be contaminated, they should be avoided.

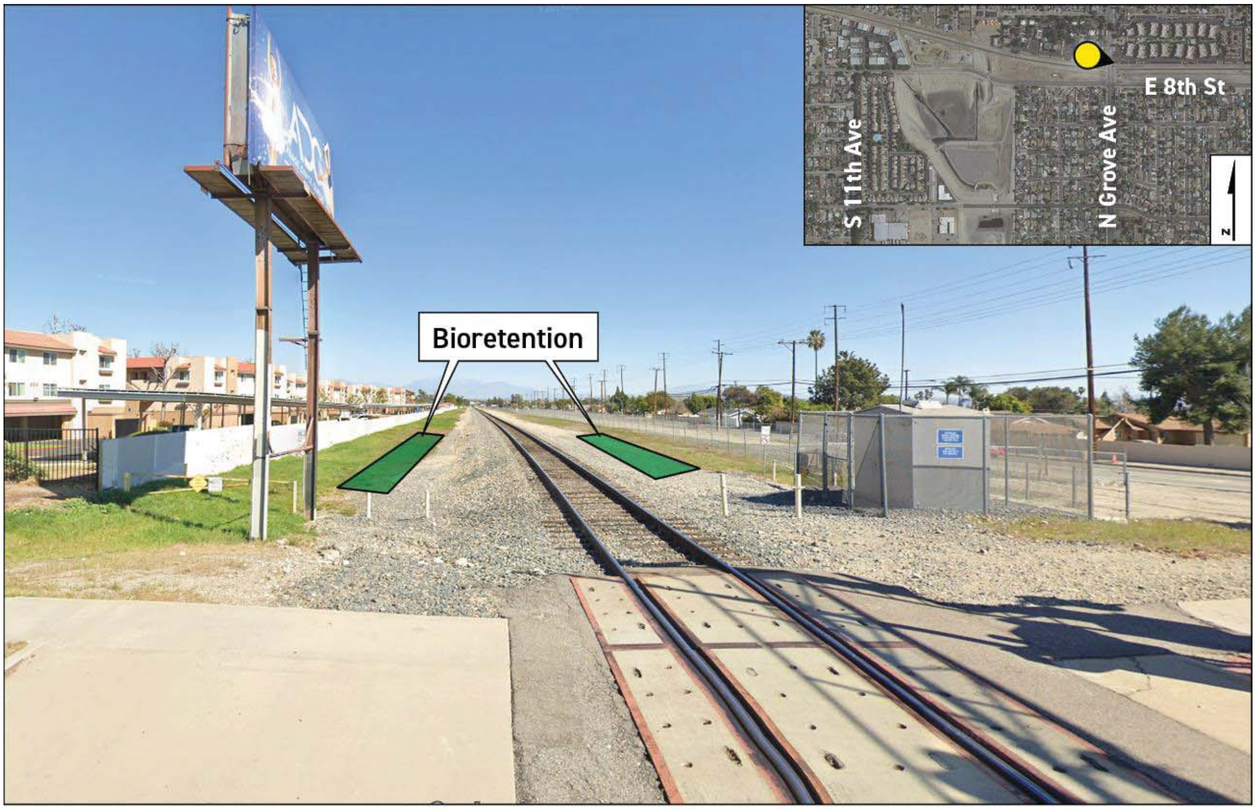
After suitable locations are determined, nature-based solutions can be selected from those listed in the Technical Appendix, which provides detailed technical information on various nature-based solutions for alleviating stormwater. This resource has been developed based on best practices and lessons learned over the course of many green infrastructure design projects. It has been modified for the context of this study, to include solutions that are suitable for linear applications (i.e., along track), but many of these solutions are applicable in other contexts as well (such as parking areas).

To demonstrate the approach described above, the two locations in the study area were selected as being suitable for linear green infrastructure solutions (see Figure 45 and Figure 44). These locations were selected based on factors that are described under Constraints and Opportunity Areas, above**.** From the nature-based solutions detailed in the Technical Appendix, linear swales or bioretention features parallel to the track are recommended for this study area. These solutions will require re-grading of the low-lying areas, to direct stormwater to these green infrastructure features. These features should be at least 5 feet wide, 50 feet long, and 8 feet deep, to provide sufficient storage for runoff. A permeability test may be required to assess the existing soils' capacity for infiltration of runoff.



Source: Google Earth Pro, 2021.

Figure 45: Example Location for a Linear Swale at Baker Avenue and 8th Street



Source: Google Earth Pro, 2021.

Figure 46: Example Location for Linear Swale at Grove Avenue and 8th Street

Gray Infrastructure

Gray infrastructure is the use of traditional stormwater management systems, such as large detention basins, to temporarily store peak flow, large underground pipes, or additional channel capacity. Gray infrastructure solutions will reduce the risk of structural damage by providing temporary storage for any peak flow within a 100-year floodplain (through open-top or sub-surface solutions) and will redirect any captured stormwater to downstream areas after the flood has subsided. The benefit of such systems is that they can provide an immediate solution to areas prone to flooding. However, they are costly to construct, and sizing them requires a thorough understanding of any change in weather patterns, to ensure their effectiveness in the long run. Furthermore, releasing any captured stormwater runoff requires a good understanding of downstream conditions.

Using existing gray infrastructure in the study area will be a good alternative to construction of new detention basins, because it will provide cost savings and immediate benefits. Figure 47 shows an existing stormwater basin that is near the track west of the study area, near MP 37.9. Flooding adjacent to the track can be channelized or piped to the existing stormwater basin. The elevation difference will need to be considered for this solution, and it likely will require a lift station.

Source: Google Earth Pro, 2021.

Figure 47: Existing Gray Infrastructure near the Track

Coordinating with the municipality and using these existing assets to redirect excess stormwater runoff from the SCRRA ROW can alleviate flooding. Gray infrastructure solutions like this one will require coordination with the municipality and work outside the SCRRA ROW, and may take longer (because of involving more stakeholders).

Although increasing the elevation of the Cucamonga Channel walls potentially can reduce the likelihood of overtopping and flooding of the study area, this strategy was not considered for this study for the following reasons. Modifying hardened channels to avoid overtopping in one location can have unintended consequences elsewhere (i.e., an increased flood hazard downstream). A floodplain study will need to be conducted to determine the best approach on how to increase the capacity of the system of channels that drain to Prado Basin. Furthermore, modifying a channel managed by the County Flood Control District will require coordination with other stakeholders, and SCRRA may not have much control of the timeline or other project details. Therefore, and considering the objective of recommending solutions that will provide more immediate alleviation of flooding in the study area, this strategy is not recommended.

Non-Physical Strategies

If any future developments are planned for this corridor, the potential impact of additional impervious surfaces and how that may affect the drainage patterns within the SCRRA ROW need to be considered. SCRRA should review the impact of such future projects and require all improvements not only to result in "no increase of water levels on developed properties and no increase in erosion, sedimentation or other adverse impacts on downstream developments"[14], but also, as required, to ensure that the post-development parcels are not contributing any runoff toward the SCRRA ROW.

Any increase in impervious surfaces upstream from the flooding area may exacerbate the issue along the track, and thus future development scenarios need to be considered in designing the stormwater management solution, assuming that any empty upstream lots are paved. The blocks between Baker Avenue and Vineyard Avenue are good examples of the undeveloped parcels that may be developed in the future, with their additional runoff increasing the flow in the Cucamonga Channel.

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[14] Section 9.5.1, page 9-5 of the SCRRA Design Criteria Manual.

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