CALTRANS
Adaptation Priorities
REPORT

DISTRICT 12

September

2020

This page intentionally left blank.

CONTENTS

TABLES

FIGURES

CCAR Adaptation Priorities Report Term and Definitions

- **Adaptation:** The steps to incorporate into community constructs, the design of assets, and/or the operations of a system prior to a disruption those characteristics that will minimize the impacts of disruptions, if not avoid them altogether. This term is used especially in the context of climate change and extreme weather. An example would be increasing the diameter of new culverts in areas likely to experience increased flooding in the future, even though historically such floods have not occurred.
- **Exposure:** The presence of infrastructure in places and settings where it could be adversely affected by hazards and threats, for example, a road in a floodplain**.**[1]
- **Hazards and Stressors:** Stresses on transportation system performance and condition. Whether such impacts occur today (e.g., riverine flooding that closes major highways) or whether they are part of a long- term trend (e.g., sea level rise), mainstreaming resilience efforts into an agency's functions requires an understanding of their nature, scope, and magnitude. The terms are used interchangeably to refer to transportation impacts originating primarily from natural causes (e.g., flooding or wildfire hazards).
- **Resilience:** The characteristic of a system that allows it to absorb, recover from, or more successfully adapt to adverse events.
- **Risk*:*** A combination of the likelihood of exposure and some measure(s) of the consequences of a disruption to the transportation system caused by that exposure.
- **Uncertainty:** The degree to which a future condition or system performance cannot be forecast. Both human-caused and natural disruptions, especially for longer-term climate changes, are by their very nature uncertain events (as no one knows for sure exactly when and where and with what intensity they will occur). Sensitivity tests using multiple plausible scenarios of future conditions can help one understand the range of uncertainty and its implications. This approach is used routinely when working with climate projections to help understand the range of possible conditions given different future greenhouse gas emission scenarios.
- **Vulnerability:** Per the Federal Highway Administration, "the degree to which a system is susceptible to or unable to cope with adverse effects of climate change or extreme weather events."[2]

[1] This definition is adopted from the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report. 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

[2] FHWA. 2014. "FHWA Order 5520. "Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events." Dec. 15. Retrieved June 30, 2020 from https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm

This page intentionally left blank.

1. INTRODUCTION

California's climate is changing. Temperatures are warming, sea levels are rising, wet years are becoming wetter, dry years are becoming drier, and wildfires are becoming more frequent. Most scientists attribute these changes to the unprecedented amounts of greenhouse gases in the atmosphere. Given that global emissions of these gases continue at record rates, further changes in California's climate are, unfortunately, very likely.

The hazards brought on by climate change pose a serious threat to California's transportation infrastructure. Higher than anticipated sea levels can regularly inundate roadways, extreme floods can severely damage bridges and culverts, rapidly moving wildfires present profound challenges to timely evacuations, and higher than anticipated temperatures can cause expensive pavement damage over a broad area. As Caltrans' assets such as bridges and culverts age, they will be forced to weather increasingly severe conditions that they were not designed to handle, adding to agency expenses and putting the safety and economic vitality of California communities at risk.

Recognizing this, Caltrans has initiated a major agency-wide effort to adapt their infrastructure so that it can withstand future conditions. The effort began by determining which assets are most likely to be adversely impacted by climate change in each Caltrans District. That assessment, described in the Caltrans Climate Change Vulnerability Assessment Report for District 12, identified stretches of the State Highway System within the District that are potentially at risk. This Adaptation Priorities Report picks up where the Vulnerability Assessment left off and considers the implications of those impacts on Caltrans and the traveling public, so that facilities with the greatest potential risk receive the highest priority for adaptation. District 12 anticipates that planning for, and adapting to, climate change will continue to evolve subsequent to this report's release as more data and experience is gained.

1.1. Purpose of Report

The purpose of this report is to prioritize the order in which assets found to be exposed to climate hazards will undergo detailed asset-level climate assessments. Since there are many potentially exposed assets in the District, detailed assessments will need to be done sequentially according to their priority level. The prioritization considers, amongst other things, the timing of the climate impacts, their severity and extensiveness, the condition of each asset (a measure of the sensitivity of the asset to damage), the number of system users affected, and the level of network redundancy in the area. Prioritization scores are generated for each potentially exposed asset based on these factors and used to rank them.

1.2. Report Organization

The main feature of this report is the prioritized list of potentially exposed assets within District 12. Per above, this information will inform the timing of the detailed adaptation assessments of each asset, which is the next phase of Caltrans' adaptation work. The final prioritized list of assets for District 12 can be found in Chapter 4 of this document. The interim chapters provide important background information on the prioritization process. For example, those interested in learning more about Caltrans' overall adaptation efforts, and how the prioritization fits into that, should refer to Chapter 2. Likewise, those who are interested in learning more about how the prioritization was determined should refer to Chapter 3.

2. CALTRANS' CLIMATE ADAPTATION FRAMEWORK

Enhancing Caltrans' capability to consider adaptation in all its activities requires an agency-wide perspective and a multi-step process to make Caltrans more resilient to future climate changes. The process for doing so will take place over many years and will, undoubtedly, evolve over time as everyone learns more about climate hazards, better data is collected, and experience shows which techniques are most effective. Researchers have just started examining what steps an overarching adaptation framework for a department of transportation should entail. Figure 1 provides a graphical illustration of one such path called the Framework for Enhancing Agency Resiliency to Natural and Anthropogenic Hazards and Threats (FEAR-NAHT).[3] This framework, developed through the National Cooperative Highway Research program (NCHRP), has been adopted by Caltrans as part of its long-term plan for incorporating adaptation into its activities (hereafter referred to as the Caltrans Climate Adaptation Framework or "Framework").[4] In coastal Districts, like District 12, this work generally aligns with the California Coastal Commission's Sea Level Rise Policy Guidance framework for addressing the impacts of climate change, specifically sea level rise, in the coastal zone (see Figure 1 in the Coastal Commission's guidance document).[5]

Steps 1 through 4 of the Framework represent activities that are currently underway at Caltrans Headquarters to effectively manage its new climate adaptation program and develop policies that will help jumpstart adaptation actions throughout the organization. Step 1, *Assess Current Practice*, and Step 4, *Implement Early Wins*, are both addressed within a document called the Caltrans Climate Adaptation Strategy Report. The Adaptation Strategy Report undertook a comprehensive review of all climate adaptation policies and activities currently in place or underway at Caltrans. The report also includes numerous no-regrets adaptation actions ("early wins") that can be taken in the near-term to enhance agency resiliency. Several of these strategies also touch on elements of Step 2, *Organize for Success*, and Step 3, *Develop an External Communications Strategy and Plan*. In addition to this, a comprehensive adaptation communications strategy and plan for climate change is being developed as part of a Caltrans pilot project with the Federal Highway Administration.

DISTRICT 12 CLIMATE CHANGE VULNERABILITY ASSESSMENT SUMMARY REPORT

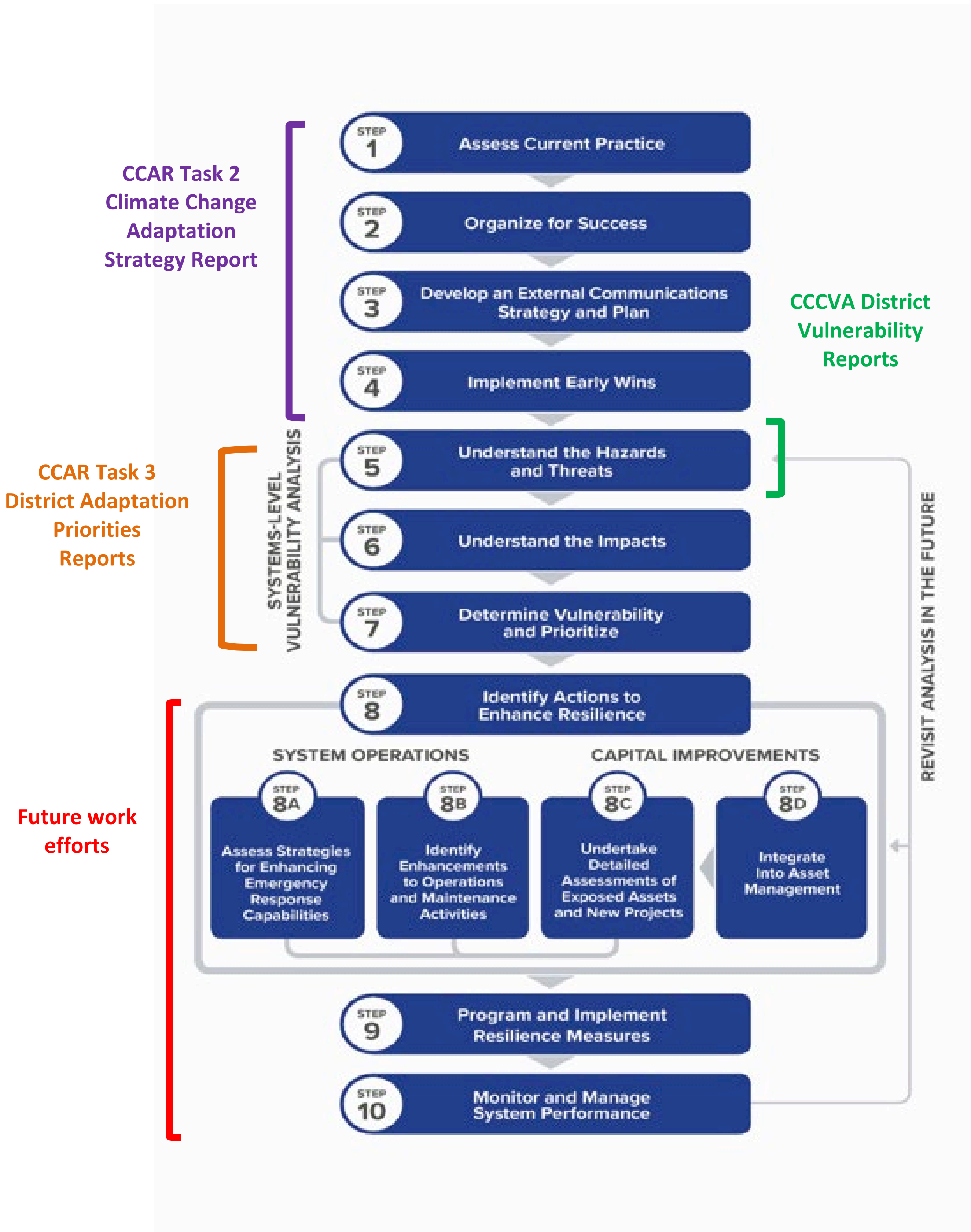
Step 5, *Understand the Hazards and Threats*, is the first step where detailed technical analyses are performed, and in this case, identify assets potentially exposed to various climate stressors. This step has been completed for a subset of the assets and hazards in District and the results are presented in the Caltrans Climate Change Vulnerability Assessment Report for District 12. The exposure information generated in the Vulnerability Assessment

[3] This framework and related guidance for state DOTs is being developed as part of NCHRP 20-117, Deploying Transportation Resilience Practices in State DOTs (expected completion in 2020).

[4] National Cooperative Highway Research Program, "Incorporating Resilience Concepts and Strategies in Transportation Planning" (NCHRP 08-129) Pending.

[5] California Coastal Commission, Sea Level Rise Policy Guidance, Adopted August 2015, Updated November 2018.

FIGURE 1: CALTRANS' CLIMATE ADAPTATION FRAMEWORK



The work undertaken for this study, the District 12 Adaptation Priorities Report, covers both Steps 6 and 7 in the Framework. Step 6, *Understand the Impacts*, is focused on the implications of the exposure identified in Step 5. This includes understanding the sensitivity of the asset to damage from the climate stressor(s) it is potentially exposed to and understanding the criticality of the asset to the functioning of the transportation network and the communities it serves. Developing an understanding of these considerations is part of the prioritization methodology described in the next chapter.

Step 7, *Determine Vulnerability and Prioritize*, focuses on creating and implementing a prioritization approach that considers both the nature of the exposure identified in Step 5 (its severity, extensiveness, and timing) and the consequence information developed in Step 6. The goal of the prioritization is to identify which assets should undergo detailed adaptation assessments first, because resource constraints will prevent all assets from undergoing detailed study simultaneously.

After Step 7, the Framework divides into two parallel tracks, one focused on operational measures to enhance resiliency and the consideration of adaptation (Steps 8A and 8B) and the other on identifying adaptation-enhancing capital improvement projects (Steps 8C and 8D). Collectively, these represent the next steps that should be undertaken using the information from this report. On the operations track, the results of this assessment should be reviewed for opportunities to enhance emergency response (Step 8A) and operations and maintenance (Step 8B). Caltrans' next step on the capital improvement track should be to undertake detailed assessments of the exposed facilities (Step 8C). The prioritization information generated as part of this assessment should also be integrated into the state's asset management system (Step 8D). All projects recommended through the asset management process should also undergo detailed adaptation assessments (hence the arrow from Step 8D to 8C).

Thus, there will be two parallel pathways for existing assets to get to detailed facility level adaptation assessments. The first is through this prioritization analysis, which is driven primarily by the exposure to climate hazards with asset condition as a secondary consideration. The second is through the existing asset management process, which is driven primarily by asset condition and will have vulnerability to climate hazards as a secondary consideration.

The detailed adaptation assessments in Step 8C will involve engineering-based analyses to verify asset exposure to pertinent climate hazards (some exposed assets featured in this report will not be exposed after closer inspection). Then, if exposure is verified, Step 8C includes the development and evaluation of adaptive measures to mitigate the risk. The highest priority assets from this study will be evaluated first and lower priority assets will be evaluated later. Once specific adaptation measures have been identified, be they operational measures or capital improvements, these projects can then be programmed (Step 9). Step 10 then focuses on continuous monitoring of system performance to track progress towards enhancing resiliency. Note the feedback loops from Step 10 to Steps 5 and 8. The arrow back to Step 5 indicates that the exposure analysis should be revisited in the future as new climate projections are developed. The arrow back to Step 8 indicates how one can learn from the performance indicators and use this data to modify the actions being undertaken to enhance resilience

3. PRIORITIZATION METHODOLOGY

3.1. General Description of the Methodology

The methodology used to prioritize assets exposed to climate hazards draws upon both technical analyses and the on-the-ground knowledge of from all District staff. The technical analysis component was undertaken first to provide an initial indication of adaptation priorities. These initial priorities were then reviewed with District staff at a workshop and, if necessary, adjusted to reflect local knowledge and recommendations. These adjustments are embedded in the final priorities shown in Chapter 4.

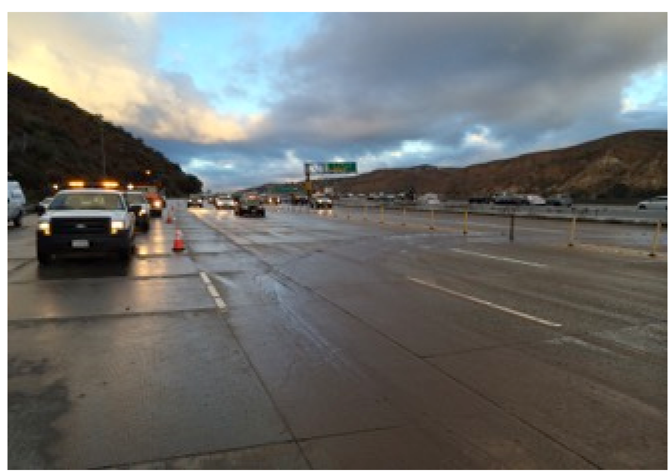
With respect to the technical analysis, there are a few different approaches for prioritizing assets based on their vulnerability to climate hazards. The approach selected for this study is known as the indicators approach. The indicators approach involves collecting data on a variety of variables that are determined to be important factors for prioritization. These are then put on a common scale, weighted, and used to create a score for each asset. The scores collectively account for all the variables of interest and can be ranked to determine priorities.

It is important to note that, since the prioritization process is focused on determining the order in which detailed adaptation assessments are conducted, only assets determined potentially exposed to a climate hazard are included in this analysis. Assets that were determined to have no exposure to the hazards studied are not included in this study.

The remainder of this chapter describes the prioritization methodology in detail. Section 3.2 begins by describing the asset types and hazards studied. Next, Section 3.3 discusses the individual prioritization metrics (factors) that were used in the technical analysis. Following this, Section 3.4 describes how those individual factors were brought together into an initial prioritization score for each asset. Lastly, Section 3.5 describes how the initial prioritization was adjusted with input from District staff.

3.2. Asset Types and Hazards Studied

Caltrans is responsible for maintaining dozens of different asset types (bridges, culverts, roadway pavement, buildings,). Each of these asset types is uniquely vulnerable to a different set of climate stressors. The scope of this study is to investigate a subset of the asset types owned by Caltrans in District 12 and, for those, only a subset of the climate stressors that could impact them. This analysis focused on a selection of critical asset types and impactful climate hazards that could affect each. These selections were made based upon defined vulnerabilities of those asset types to different climate hazards and statewide data availability.



SR-91 ROADWAY REPAIR CAUSING TRAFFIC

District staff noted that there are other asset/stressor combinations that need to be assessed to comprehensively review climate change impacts and responses on the State Highway System. These asset classes include Intelligent Transportation System infrastructure, pumps, signs, guardrails, buildings, among others. These asset classes could not be included due to a lack of consistent, statewide datasets needed to conduct the prioritization analysis and a lack of resources to add more asset types.

Additionally, Caltrans recognizes that there are other hazards that can impact the functionality and resiliency of the State Highway System, including earthquakes and landslides. This District 12 Adaptation Priorities assessment does not evaluate earthquake risks as the connection between climate change and earthquakes is still ill-defined, and there is limited data available to use for this analysis. Landslides, especially those triggered by wildfires and heavy precipitation, are likely to become more frequent in the future as California's climate changes. To date, there is limited statewide data on future-oriented landslide risk in California. Understanding landslide susceptibility is challenging due to range of triggers and geological factors, and there are many types of landslides to evaluate. Caltrans decided to omit landslides from these assessments given limited data availability and resources. Additional exposure and prioritization analyses are needed in the future to gain a fuller understanding of Caltrans' adaptation needs.

The subset of asset types and hazards included in this study generally mirror those that were included in the District 12 Climate Change Vulnerability Assessment Report. That said, exposure to two additional hazards was included as part of this study: (1) riverine flooding impacts to bridges and culverts and (2) temperature impacts to pavement binder grade. Table 1 shows all the asset types included in this study for District 12 and marks with an "X" the hazards that were evaluated for each in the exposure analysis.

TABLE 1: ASSET-HAZARD COMBINATIONS STUDIED

	Sea Level Rise	Storm Surge	Coastal Cliff Retreat	Wildfire	Temperature	Riverine Flooding
Pavement Binder Grade					X	
At-Grade Roadways	X	X	X			
Bridges	X	X	X			X
Large Culverts[6]	X	X	X			X
Small Culverts[7]	X	X	X	X		X

[6] Culverts 20 feet or greater in width.
[7] Culverts less than 20 feet in width.

The various asset-hazard combinations included in the District 12 Adaptation Priorities assessment include:

- **Pavement binder grade exposure to temperature changes:** Binder can be thought of as the glue that holds the various aggregate materials in asphalt together. Binder is sensitive to temperature. If temperatures become too hot, the binder can become pliable and deform under the weight of traffic. On the other hand, if temperatures are too cold, the binder can shrink causing cracking of the pavement. There are various types (grades) of binder, each suited to a different temperature regime. This study considered how climate change will influence high and low temperatures and how this, in turn, could affect pavement binder grade performance.

  Assumptions were made that (1) all roadways are currently (or could be in the future) asphalt and (2) the binder grade currently in place on each segment[8] of roadway matches the specifications in the Caltrans Highway Design Manual. From here, the allowable temperature ranges of each binder grade were compared to projected temperatures in 2040, 2070, and 2100. If the temperature parameters exceeded the design tolerance of the assumed binder grade, that segment of roadway was deemed potentially exposed.

SR-57 PAVEMENT CONDITION

- **Bridge exposure to riverine flooding:** Bridges are sensitive to higher flood levels and river flows. With climate change, precipitation is generally expected to become more intense in District 12 leading to increased flooding on rivers and streams. These higher flows could exceed the design tolerances of bridges. In addition, wildfires are also expected to become more prevalent in District 12 with climate change. After a wildfire burns, the ground can become hard and less capable of absorbing water. As a result, flood flows can increase substantially in the aftermath of a fire, which could further exacerbate the risks to bridges. To better understand the threat posed to bridges in District 12, a flood exposure index was developed and calculated for each bridge that crosses a river or stream. The index considered both the changes in precipitation and wildfire likelihood in the area draining to the bridge in the early, mid, and late century timeframes. The index also considers the capacity of the bridge to handle higher flows using waterway adequacy information from the National Bridge Inventory (NBI). A higher score on the index indicates bridges at relatively greater risk due to a combination of higher projected flows and lower capacity.

- **Large culvert exposure to riverine flooding:** A distinction is made in the analysis between large and small culverts due to different data being available for each. Large culverts are included in the NBI and are generally 20 feet or greater in width. Small culverts are generally shorter than 20 feet in width and covered through a different inventory/inspection program. Large culverts,

[8] Roadway are segmented at intersections with other roads.

like bridges, are sensitive to increased flood flows. Thus, a flood exposure index was calculated for each large culvert in the same manner as was done for bridges.

- **Small culvert exposure to riverine flooding:** Small culverts (those less than 20 feet in width) are, like bridges and large culverts, also sensitive to higher flood flows. Hence, a flood exposure index like the one for bridges and large culverts was calculated for this asset type. The one difference is that the capacity component of the index for small culverts used the actual dimensions of the culvert, information that was not available for bridges and large culverts. Although the actual dimensions of small culverts were available, due to resource and data constraints, no hydraulic analyses were performed to determine overtopping potential. Instead, the size was simply used as a factor in the riverine flood exposure index.

- **Small culvert exposure to wildfire:** In addition to the higher post-fire flood flows captured in the flood exposure analysis, culverts can also be sensitive to the direct impacts of fire on the structure. Certain culvert materials (e.g. wood and plastic) can easily burn or be deformed during a fire. Thus, an assessment was made to determine the likelihood of a wildfire directly impacting each small culvert in the early, mid, and late century timeframes. This analysis was only conducted for small culverts because information on culvert construction materials was not available for large culverts.

- **At-grade roadway exposure to sea level rise:** Sea level rise, caused by the warming of ocean waters and the melting of land-based glaciers, is a prominent hazard brought on by climate change. In low-lying coastal areas, at-grade roads (defined here as those portions of the road network that are not elevated on a bridge) may become subject to regular inundation at high tides as sea levels rise. This can lead to frequent road closures that disrupt travel and accessibility, which can be especially serious in times of emergency where access is needed by first responders and residents need to evacuate. In some locations with regular inundation, premature degradation of the pavement may also occur.

- **Bridge exposure to sea level rise:** There are several ways in which sea level rise may adversely affect bridges. For very low bridges, a rise in sea levels may result in water overtopping the deck and impeding travel. It is important to recognize, however, that serious impacts to bridges can still occur from sea level rise even if water does not overtop the deck. For example, on some bridge designs, if sea levels rise just enough to result in waves contacting the bottom of the deck, the uplifting forces may be enough to separate the deck from the rest of the structure. Even bridges whose decks are well above projected water levels may be impacted by sea level rise. For example, waves may contact piers at a higher elevation than they were designed for leading to more rapid corrosion of bridge components and unexpected strain being put on the bridge structure. The bridge abutments may also be adversely impacted by waves regularly hitting higher than initially designed and eroding the approach embankments. Furthermore, the navigability of shipping channels may become impeded by bridges as sea levels rise and the ship clearances are reduced.

- **Large and small culvert exposure to sea level rise:** Culverts are primarily used to convey streams and stormwater underneath roadways (some are also used in tidally influenced environments). If sea levels rise high enough for seawater to reach the culvert, this can change the hydraulic performance of the culvert leading to more frequent overtopping of the roadway.

For culverts that were not designed for a tidal setting, the frequent unanticipated presence of saltwater can also lead to corrosion and other maintenance issues that may decrease the anticipated lifespan of the asset. And incorrectly sized, blocked, or damaged culverts can threaten the safety of drivers due to improper drainage on highways.

- **At-grade roadway exposure to storm surge:** Storm surge refers to the elevating of coastal waters during major storm events. When strong winds blow onshore during such events, this can cause the water to pile up and reach levels much greater than during the normal tidal cycle. Sea level rise can cause the water to reach even higher during major storm events and increase the frequency of inundation. Inundation of at-grade roadways from storm surge may require the road to be closed, disrupting travel. Also, the surge and associated wave action often associated with storm events can cause erosion of the roadway embankment.

SR-1 FLOOD EVENT (2008)

- **Bridge exposure to storm surge:** Storm surge presents many threats to bridges that may not have been fully anticipated if sea level rise was not considered during the design. Some low bridges may be overtopped by the surge and others may be affected by uplifting forces from wave action hitting the bottom of the deck. Either situation is likely to lead to the closure of the bridge and introduce the potential for serious structural damage. Even if the water is not high enough to reach the bridge deck, the elevated water levels and associated wave action can cause erosion around the bridge approaches. Furthermore, if the surge approaches or recedes at a high enough velocity, scouring of soils can occur around bridge piers and abutments weakening the structure and potentially compromising the bridge's integrity. This is a particularly acute threat for surge-impacted bridges built over other roadways or railroads (as opposed to over water) because scour may not have been considered during their initial designs.

- **Large and small culvert exposure to storm surge:** Storm surge can overtop culverts impeding travel. If the velocity of the surge is great enough, the hydraulic forcing of excessive water through too small an opening can also damage the culvert. Water overtopping the roadway embankment on top of the culvert may also cause erosion resulting in damages to the roadway and the culvert itself.

- **At-grade roadway exposure to coastal cliff retreat:** Cliff retreat refers to the erosion of coastal cliff faces. This process can be accelerated by sea level rise since higher water levels may mean more frequent instances of wave action reaching the base of the cliff and causing erosion. At-grade roadways that are immediately along the coast can be a total loss if erosion encroaches upon them. Indeed, Caltrans has had to relocate several roads already, often at significant expense, to avoid retreating coastal cliff faces.

- **Bridge exposure to coastal cliff retreat:** Any bridges in the vicinity of coastal cliff faces are at risk of a total loss should the cliff retreat towards the bridge abutment. Should the abutment of the bridge be compromised by erosion, the structural stability of the bridge will be lost and the bridge no longer usable.
- **Large and small culvert exposure to coastal cliff retreat:** As with bridges and at-grade roadways, any culverts along a segment of road exposed to coastal cliff retreat are at risk of being damaged or lost. The erosion might compromise their stability causing them, and the roadway above them, to tumble into the sea.

3.3. Prioritization Metrics

Metrics are the individual variables used to calculate a prioritization score for each asset. These can be thought of as the individual factors that, collectively, help determine the asset's priority for adaptation. Each of the asset-hazard combinations described in the previous section has its own unique set of factors that are used in the prioritization. The metrics were selected based on their relevancy to each asset-hazard combination and the data availability. For example, the condition rating of a culvert is a very relevant metric for prioritizing culverts exposed to riverine flooding, however, it is not at all relevant to prioritizing bridges exposed to the same hazard. Table 2 provides an overview of all the metrics included in this study and denotes with an "X" their application to the various asset-hazard combinations studied.

TABLE 2: METRICS INCLUDED FOR EACH ASSET-HAZARD COMBINATION STUDIED

Metrics	Sea Level Rise				Storm Surge				Coastal Cliff Retreat				Wildfire	Tempera-ture	Riverine Flooding		
	At-Grade Roadways	Bridges	Large Culverts	Small Culverts	At-Grade Roadways	Bridges	Large Culverts	Small Culverts	At-Grade Roadways	Bridges	Large Culverts	Small Culverts	Small Culverts	Pavement Binder Grade	Bridges	Large Culverts	Small Culverts
Exposure																	
Past natural hazard impacts	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Lowest impactful sea level rise (SLR) increment	X	X	X	X													
Percent of road segment exposed to 6.6 ft. of SLR	X																
Lowest impactful SLR increment with 100-year storm surge					X	X	X	X									
Percent of road segment exposed to a 100-year storm with 6.6 ft. of SLR (4.6 ft. in the Delta)					X												
Lowest SLR increment that results in damage from coastal cliff retreat									X	X	X	X					
Percent of road segment exposed to coastal cliff retreat at 6.6 ft. of SLR									X								
Initial timeframe for elevated level of concern for wildfire													X				
Highest projected wildfire level of concern													X				
Initial timeframe when asphalt binder grade needs to change														X			
Maximum riverine flooding exposure score for the 2010-2039 timeframe															X	X	X
Maximum riverine flooding exposure score															X	X	X
Consequences																	
Bridge substructure condition rating						X									X		
Channel and channel protection condition rating															X	X	
Culvert condition rating							X	X								X	X
Culvert material				X									X				
Scour rating						X									X		
Average annual daily traffic (AADT)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Average annual daily truck traffic (AADTT)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Incremental travel distance to detour around the asset													X		X	X	X
Incremental travel distance to detour around the asset for the lowest impactful SLR increment	X	X	X	X	X	X	X	X	X	X	X	X					
Incremental travel distance to detour around the asset with 6.6 ft. of SLR (4.6 ft. for storm surge in the Delta)	X	X	X	X	X	X	X	X	X	X	X	X					

The metrics included in this study fall into two categories: exposure metrics and consequence metrics. Exposure metrics capture the extensiveness, severity, and timing of a hazard's projected impact on an asset. Assets that have more extensive, more severe, and sooner exposure are given a higher priority. Consequence metrics provide an indication of how sensitive an exposed asset is to damage using information on the asset's condition. Consequence metrics also indicate how sensitive the overall transportation network may be to the loss of that asset should it be taken out of service by a hazard. The poorer the initial conditions of the potentially exposed asset and the more critical it is to the functioning of the transportation network, the higher the priority given. The specific metrics that are included within each of these categories are described in the sections that follow. The sea level rise metrics and projections used generally align with the California Coastal Commission's guidance on sea level rise scenarios for facility level assessments.[9]

3.3.1. Exposure Metrics

The following metrics were used to assess asset exposure in District 12:

FIRE IN DISTRICT 12

- **Past natural hazard impacts:** Assets that have experienced sea level rise, storm surge, cliff retreat, riverine flooding, and wildfire impacts in the past are likely to experience more issues in the future as climate changes and should be prioritized. To obtain information on past impacts, District 12 maintenance staff were surveyed and asked to identify any at-grade roadways, bridges, large culverts, or small culverts that had experienced sea level rise, storm surge, or coastal cliff retreat issues in the past. Staff was also asked to document past riverine flooding impacts for all these asset types except at-grade roadways. Care was taken to ensure that these impacts occurred on assets that had not been replaced with a more resilient design after the event occurred. In addition, staff was also asked if any small culverts were damaged directly by fire and replaced with culverts of the same material. Any asset that was identified as previously impacted by either cliff retreat, flooding, or fire was flagged, and that asset was given a higher priority for adaptation.

- **Lowest impactful sea level rise increment:** Assets that are likely to be impacted by sea level rise sooner should receive higher priority for detailed facility level assessments. To consider this in the asset scoring, a metric was developed that captured the lowest (first) increment of sea level rise[10] to potentially impact each at-grade roadway, bridge[11], large culvert, and small culvert. This

[9] California Coastal Commission, Sea Level Rise Policy Guidance, Adopted August 2015, Updated November 2018.

[10] Sea level rise areas hydrologically connected to the sea and hydrologically disconnected low-lying areas potentially vulnerable to sea level rise inundation were both used for this assessment.

[11] The lowest impactful sea level rise scenario for bridges was determined by whichever increment of sea level rise first causes inundation under the bridge. For bridges already over coastal waters, potential impacts were assumed to occur at the lowest available increment of sea level

metric made use of the sea level rise data used on the District 12 Climate Change Vulnerability Assessment Report. This data was sourced from the United States Geological Survey's (USGS) Coastal Storm Modeling System (CoSMoS) dataset for an annual flooding event and utilized sea level rise increments of 0.0, 0.8, 1.6, 2.5, 3.3, 4.1, 4.9, 5.7, and 6.6 feet. The lower the sea level rise increment that first impacts the asset, the higher priority it will receive.

- **Percent of road segment exposed to 6.6 ft. of sea level rise:** For at-grade roadway segments[12], not only is the timing of sea level rise impacts an important factor in prioritization, but also the extensiveness of the impacts. All else being equal, a segment of road that is impacted over a large proportion of its length should receive higher priority than one impacted over only a small proportion. The 6.6 feet sea level rise increment from the data sources mentioned above was used for this metric in order to provide an indicator of potential impacts at the end of the century under a somewhat pessimistic greenhouse gas emissions scenario.

- **Lowest impactful sea level rise increment with 100-year storm surge:** As with sea level rise, assets that are likely to be impacted by storm surge sooner should receive higher priority for detailed facility level assessments. To factor this into the analysis, this metric captures the lowest (first) sea level rise increment at which the 100-year storm surge[13] could potentially impact each at-grade roadway, bridge[14], large culvert, and small culvert. USGS CoSMoS storm surge data at increments of 0.0, 0.8, 1.6, 2.5, 3.3, 4.1, 4.9, 5.7, and 6.6 feet was used for the analysis. The lower the sea level rise increment that first impacts the asset, the higher priority it will receive.

STORM SURGE AND FLOODING, SR-1

- **Percent of road segment exposed to a 100-year storm surge with 6.6 feet of sea level rise:** This metric measures the proportion of each at-grade roadway segment exposed to a 100-year storm surge. As with the sea level rise length metric, 6.6 feet of sea level rise was used in order to provide an indicator of potential impacts at the end of the century under a somewhat pessimistic greenhouse gas emissions scenario. All else being equal, the greater the proportion of roadway length exposed to storm surge, the higher the priority of that segment.

rise. No analyses were performed to compare the elevations of the bottoms of the bridge decks to the underlying water elevations. The analysis was set up this way in recognition of the aforementioned impacts possible at bridges from sea level rise before water touches the deck (i.e., enhanced corrosion and structural stability, erosion, and navigability concerns).

[12] At-grade roadways are segmented at intersections with other roads thereby matching the segmentation used for the pavement binder grade analysis.

[13] Storm surge areas hydrologically connected to the sea and hydrologically disconnected low-lying areas potentially vulnerable to storm surge inundation were both used for this assessment.

[14] As with sea level rise, the lowest impactful sea level rise scenario for bridges was determined by whichever increment of sea level rise first causes storm surge inundation under the bridge. For bridges already over coastal waters, potential impacts were assumed to occur at the lowest available increment of sea level rise. No analyses were performed to compare the elevations of the bottoms of the bridge decks to the underlying water elevations. The analysis was set up this way in recognition of the aforementioned impacts possible at bridges from storm surge before water touches the deck (i.e., structural stability, erosion, and scour concerns).

- **Lowest sea level rise increment that results in damage from coastal cliff retreat:** At-grade roadways, bridges, large culverts, and small culverts that are exposed to coastal cliff retreat sooner should receive higher priority for facility level adaptation assessments. Thus, this metric was included to capture the timing of impacts. The greatest threat from coastal cliff retreat is along the open Pacific coastline where the erosive effects of waves are highest, so the analysis focused on these areas. As with sea level rise and storm surge, USGS CoSMoS data was utilized. CoSMoS data on coastal cliff retreat was available for sea level rise increments of 0.0, 0.8, 1.6, 2.5, 3.3, 4.1, 4.9, 5.7, and 6.6 feet.

- **Percent of road segment exposed to coastal cliff retreat at 6.6 ft. of sea level rise:** This metric captures the proportion of each at-grade roadway segment that is exposed to coastal cliff retreat. As with sea level rise and storm surge, 6.6 feet of sea level rise was used in order to provide an indicator of potential impacts at the end of the century under a somewhat pessimistic greenhouse gas emissions scenario. All else being equal, the greater the proportion of roadway length exposed to coastal cliff retreat, the higher the priority of that segment.

- **Initial timeframe for elevated level of concern from wildfire:** Assets that are more likely to be impacted by wildfire sooner should be prioritized first. Using the future wildfire projections developed for the District 12 Climate Change Vulnerability Assessment Report, the initial timeframe (2010-2039, 2040-2069, 2070-2099, or Beyond 2099) for heightened wildfire risk was determined for each small culvert. The most recent timeframe across the range of available climate scenarios was chosen. Assets that were impacted sooner were given a higher priority for adaptation.

- **Highest projected wildfire level of concern:** Assets that are exposed to a greater wildfire risk should be prioritized. The wildfire modeling conducted for the District 12 Climate Change Vulnerability Assessment Report classified fire risk into five levels of concern (very low, low, moderate, high, and very high) at various future time periods. Using this data, the highest level of concern was determined for each small culvert between now and 2100 and across all climate scenarios. Assets with higher levels of concern were given a higher priority for adaptation.

SR-91 MUDSLIDE CLEAN UP

- **Initial timeframe when asphalt binder grade needs to change:** Roadway segments that are more likely to need binder grade changes sooner should be prioritized. Using the assumptions and data from the pavement binder grade exposure analysis described above, the initial timeframe (prior to 2010, 2010-2039, 2040-2069, or 2070-2099) for binder grade change was determined. Roadway segments that were found to need binder grade changes sooner were given a higher priority for detailed adaptation assessments.

- **Maximum riverine flooding exposure score for the 2010-2039 timeframe**: Assets that have relatively higher exposure to riverine flooding in the near-term should be prioritized. Using the riverine flood exposure index values calculated using the process described above, the highest score for the near-term (2010-2039) period was determined for each bridge, large culvert, and small culvert considering all climate scenarios and the range of outputs from all climate and wildfire models. Assets with the highest overall riverine flooding scores in this initial period received a higher priority for adaptation.

- **Maximum riverine flooding exposure score:** In addition to understanding the most pressing near-term needs for dealing with riverine flooding, assets that have relatively higher exposure to riverine flooding at any point over their lifespans should also be prioritized. To calculate this metric, the highest riverine flooding exposure score was determined for each asset considering all time periods (from now through 2100), all climate scenarios, and all climate and wildfire models. Assets with the highest overall riverine flooding scores received a higher priority for adaptation.

3.3.2. Consequence Metrics

The following metrics were used to understand the consequences of each asset's exposure, considering both the asset sensitivity to damage and network sensitivity to loss of the asset:

- **Bridge substructure condition rating:** Poor bridge substructure condition can contribute to failure during riverine flooding and storm surge events. The NBI assigns a substructure condition rating to each bridge. Values range from nine to two with lower values indicating poorer condition. Bridges with poor substructure condition ratings were given higher priority for adaptation assessments.

- **Channel and channel protection condition rating:** Poor channel conditions or inadequate channel protection measures can contribute to failure during riverine flooding events. The NBI assigns a channel and channel protection condition rating to each bridge and large culvert. Values range from nine to two with lower values indicating poorer condition. Bridges and large culverts with poor channel or channel protection ratings were given higher priority for adaptation assessments.

- **Culvert condition rating:** Poor culvert condition can contribute to failure during storm surge and riverine flooding events. The NBI assigns a culvert condition rating to each large culvert. Values range from nine to two with lower values indicating poorer condition. Caltrans has developed their own culvert condition rating system for small culverts. Possible ratings in the Caltrans system include good, fair, critical, and poor. Large and small culverts with poorer condition ratings in either system were prioritized.

- **Culvert material:** Culvert material determines the sensitivity of culverts to direct damage from wildfires and material degradation due to sea level rise. Caltrans includes material data in its databases on small culverts (no equivalent information exists for large culverts). Possible culvert materials include HDPE (high density polyethylene [plastic]), PVC (polyvinyl chloride [plastic]), corrugated steel pipe, composite, wood, masonry, and concrete. HDPE, PVC, corrugated steel pipe, composite, and wood culverts are all more sensitive to wildfire and any small culverts made from these materials that are exposed to an elevated risk from wildfire were prioritized for adaptation. Likewise, corrugated steel pipe and concrete are more sensitive to regular saltwater inundation and any small culverts made from these materials that are exposed to sea level rise were assigned a higher priority.

- **Scour rating:** Scour is a condition where water has eroded the soil around bridge piers and abutments. Excessive scour of bridge foundations makes bridges more prone to failure, especially during storm surge and riverine flooding events. The NBI assigns a scour condition rating to each bridge. Values range from eight to two with lower values indicating greater scour concern. Bridges with lower scour values (higher scour concern) were given higher priority for adaptation assessments.

- **Average annual daily traffic (AADT):** AADT is a measure of the average traffic volume on a roadway. The consequences of weather and sea level rise-related failures/disruptions/maintenance are greater for assets that convey a higher volume of traffic. Disruptions on higher volume roads affect a greater proportion of the traveling public and there is a greater chance of congestion ripple effects throughout the network because alternate routes are less likely to be able to absorb the diverted traffic. AADT data was obtained from Caltrans databases and assigned to all the asset types included in this study. Exposed assets with higher AADT values were given greater priority for adaptation.

FLOODING ON SR-22 WESTBOUND
AT HASTER OFFRAMP (2017)

- **Average annual daily truck traffic (AADTT):** AADTT is a measure of the average truck volumes on a roadway. Efficient goods movement is important for maintaining economic resiliency and for providing relief supplies after a disaster. The consequences of weather and sea level rise-related failures/disruptions/maintenance are greater for assets that are a critical link in supply chains. AADTT data was obtained from Caltrans databases and assigned to all the asset types included in this study. Potentially exposed assets with higher AADTT values were given greater priority for adaptation.

- **Incremental travel distance to detour around the asset:** This metric measures the degree of network redundancy around each asset. A detour routing tool was developed for this project that can find the shortest path detour around a segment of road, bridge, large culvert, or small culvert and calculate the additional travel distance that would be required to take that detour. A simplified version of the tool that did not consider whether the detour routes would be passible during a flood event was run for each of the bridge and culvert assets studied that were exposed to riverine flooding.[15] Assets that had very long detour routes were given greater priority for adaptation. These assets were given a higher priority because they are more critical to the roadway network. This metric is especially important when considering emergency access and evacuation impacts. Highways with low redundancy are often in more rural areas with higher wildfire and/or flood risk, and residents living in those areas may depend upon the highway to evacuate. This detour routing tool was developed, in part, to incorporate an understanding of these concerns and needs on the State Highway System.

STORM EVENT SR-22 WESTBOUND AT HASTER OFFRAMP (JANUARY 2017)

- **Incremental travel distance to detour around the asset for the lowest impactful SLR increment:** A more complex version of the detour routing tool was used to determine the shortest path detour for the lowest impactful sea level rise increment that would result in sea level rise, storm surge, and coastal cliff retreat affecting each asset. This provides an indication of the initial network redundancy issues that may be created by climate change in coastal areas. For these hazards, the detour tool considered the inundation/erosion throughout the roadway network for the increment of sea level rise to be evaluated. This ensured that detours were not routed onto roads that would also be inundated or eroded under the same amount of sea level rise. When being run for assets exposed to sea level rise or coastal cliff retreat, the detour routing algorithm ensured that no road affected by either sea level rise or coastal cliff retreat at the same increment of sea level rise that was being evaluated could be considered as a detour

[15] The exposure of detour routes to flooding was not able to be determined within the resources of this project since no future riverine flooding floodplains with climate change were available at the time of publication.

route. When being run for assets exposed to storm surge, the detour routing algorithm ensured that no road affected by either sea level rise, coastal cliff retreat, or storm surge at the same increment of sea level rise could be considered as a detour route. As with the riverine flooding detours, assets that had very long detour routes were given greater priority for adaptation.

- **Incremental travel distance to detour around the asset with 6.6 feet of SLR:** This metric captures the level of network redundancy around exposed at-grade roadways, bridges, large culverts, and small culverts at 6.6 feet of sea level rise. As with the coastal hazard exposure metrics, 6.6 feet was chosen sea level rise increment representative of end of the century conditions under a somewhat pessimistic greenhouse gas emissions scenario. The detour values for this metric were calculated the same way as was done for the lowest impactful sea level rise increment detour metrics described above. Likewise, assets that had very long detour routes under this sea level rise increment were given greater priority for adaptation.

3.4. Calculation of Initial Prioritization Scores

Once all the metrics had been gathered/developed, the next step was to combine them and calculate an initial prioritization score for each asset. Calculating prioritization scores is a multi-step process that was conducted using Microsoft Excel. The primary steps are as follows:

1. **Scale the raw metrics:** Several of the metrics described in the previous section have different units of measurement. For example, the AADT metric is measured in vehicles per day whereas the incremental travel time to detour around the asset is measured in minutes. There is a need to put each metric on a common scale to be able to integrate them into one scoring system.

   For this study, it was decided to use a scale ranging from zero to 100 with zero indicating a value for a metric that would result in the lowest possible priority level and 100 indicating a value for a metric that would result in the highest possible priority level. The District-wide minimum and maximum values for each metric were used to set that metric's zero and 100 values.

   The past weather/fire impacts metric (which had binary values) was assigned a zero if the condition was false (i.e., there were no previous weather/fire impacts reported) and 100 if the condition was true. Categorized or incremental values, like the various condition rating metrics or the sea level rise increments, were generally parsed out evenly between zero and 100 (e.g., if there were seven condition rating values, the minimum and maximum values were coded as zero and 100, respectively, with the five remaining categories assigned values at intervals of 20). The remaining metrics with continuous values were allowed to fall at their proportional location within the re-scaled zero to 100 range.

2. **Apply weights:** Some metrics have been determined by Caltrans to be more important than others for determining priorities. Therefore, the relative importance of each metric was adjusted by multiplying the scaled score by a weighting factor. Metrics deemed more important to prioritization were multiplied by a larger weight. For consistency, Caltrans Headquarters staff harmonized the weights to be used in all Districts based on national best practices and input from the Districts. Table 3 shows the weighting schema applied to the asset-hazard combinations in District 12. The weights are percentage based and add to 100% for all the metrics within a given asset-hazard combination (column).

In general, higher weights were assigned to the future exposure metrics (including those considering both the hazard timing and severity) as they are the primary drivers of adaptation need. This helps ensure adaptations are considered proactively before the hazards affect the assets. It also focuses the first detailed assessments on those assets that are projected most severely affected by climate change.

Amongst the consequence metrics, more weight is given to the AADT and detour route variables relative to the condition rating related variables (bridge substructure condition rating, channel and channel protection condition rating, culvert condition rating, and scour rating). The logic for this is as follows:

a. First, except for the scour rating, the connection between asset condition and asset failure during a hazard event is not always straightforward. Where there is less confidence in a metric, it is weighted less.[16]

b. Second, other prioritization systems used by Caltrans, namely the asset management system, focus on condition to prioritize assets. Thus, poor condition assets will already be prioritized through that program and, per Caltrans' Climate Adaptation Framework shown in Figure 1, will also undergo detailed adaptation assessments before upgrades are made. There is little value in duplicating that prioritization system for this report; instead this effort puts more priority on assets based on their exposure to climate change-related hazards.

c. Lastly, the traffic volume and detour length variables are the primary measures by which impacts to users of the system are captured and, given the importance of mobility to the functioning of the state, were weighted higher.[17]

An exception to some of the logic noted above can be found with small culvert exposure to wildfire and sea level rise. For these assets, nearly as much weight is given to the culvert material variable as to the AADT and detour route variables collectively. This is because the very nature of the threat to small culverts from wildfire and sea level rise is highly related to the material of the culvert. For example, if the culvert is plastic or wood, it is much more susceptible to fire damage than, say, a concrete culvert. Since they are less likely to be adversely affected by fire in the first place, one would not want to give high priority to concrete culverts for wildfire just because they convey a high AADT or have long detour routes. That is why more weight is placed on the material metric for this particular asset-hazard combination.

[16] Note that the scour rating metric is weighted somewhat higher than the other condition related assets because of its more direct connection to asset failure.

[17] Within the traffic volume related metrics, note that slightly more weight is given to AADT as opposed to truck AADT given that the majority of traffic on a roadway is non-truck. Thus, it was reasoned that the total volume should factor in somewhat more heavily than the truck volume. One exception to this was for temperature impacts to pavement. This asset-hazard combination is unique in that the traffic volume information is not just an indicator of how many users may be affected by necessary pavement repairs but also an indicator of how much damage may occur to the pavement should temperatures exceed binder grade design thresholds. Given that, for this asset-hazard combination, more weight is given to truck volumes since trucks do disproportionately more damage to temperature-weakened pavement.

TABLE 3: WEIGHTS BY METRIC FOR EACH ASSET-HAZARD COMBINATION STUDIED

	Percentage Weights by Asset Class																
	Sea Level Rise				Storm Surge				Cliff Retreat				Wildfire	Tempera-ture	Riverine Flooding		
Metric	At-Grade Roadways	Bridges	Large Culverts	Small Culverts	At-Grade Roadways	Bridges	Large Culverts	Small Culverts	At-Grade Roadways	Bridges	Large Culverts	Small Culverts	Small Culverts	Pavement Binder Grade	Bridges	Large Culverts	Small Culverts
Exposure																	
Past natural hazard impacts	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	-	20%	20%	20%
Lowest impactful sea level rise (SLR) increment	22.5%	45%	45%	40%	-	-	-	-	-	-	-	-	-	-	-	-	-
Percent of road segment exposed to 6.6 ft. of SLR	22.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowest impactful SLR increment with 100-year storm surge	-	-	-	-	22.5%	45%	45%	45%	-	-	-	-	-	-	-	-	-
Percent of road segment exposed to a 100-year storm with 6.6 ft. of SLR (4.6 ft. in the Delta)	-	-	-	-	22.5%	-	-	-	-	-	-	-	-	-	-	-	-
Lowest SLR increment that results in damage from coastal cliff retreat	-	-	-	-	-	-	-	-	22.5%	45%	45%	45%	-	-	-	-	-
Percent of road segment exposed to coastal cliff retreat at 6.6 ft. of SLR	-	-	-	-	-	-	-	-	22.5%	-	-	-	-	-	-	-	-
Initial timeframe for elevated level of concern for wildfire	-	-	-	-	-	-	-	-	-	-	-	-	17.5%	-	-	-	-
Highest projected wildfire level of concern	-	-	-	-	-	-	-	-	-	-	-	-	17.5%	-	-	-	-
Initial timeframe when asphalt binder grade needs to change	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	-	-	-
Maximum riverine flooding exposure score for the 2010-2039 timeframe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.5%	22.5%	22.5%
Maximum riverine flooding exposure score	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.5%	22.5%	22.5%
Consequences																	
Bridge substructure condition rating	-	-	-	-	-	1.5%	-	-	-	-	-	-	-	-	1%	-	-
Channel and channel protection condition rating	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.5%	2.5%	-
Culvert condition rating	-	-	-	-	-	-	5%	5%	-	-	-	-	-	-	-	2.5%	5%
Culvert material	-	-	-	15%	-	-	-	-	-	-	-	-	20%	-	-	-	-
Scour rating	-	-	-	-	-	8.5%	-	-	-	-	-	-	-	-	6.5%	-	-
Average annual daily traffic (AADT)	10%	10%	10%	7%	10%	7%	7%	7%	10%	10%	10%	10%	7%	13%	7%	10%	10%
Average annual daily truck traffic	5%	5%	5%	3%	5%	3%	3%	3%	5%	5%	5%	5%	3%	27%	3%	5%	5%
Incremental travel distance to detour around the asset	-	-	-	-	-	-	-	-	-	-	-	-	15%	-	15%	15%	15%
Incremental travel distance to detour around the asset for the lowest impactful SLR increment	10%	10%	10%	7.5%	10%	7.5%	10%	10%	10%	10%	10%	10%	-	-	-	-	-
Incremental travel distance to detour around the asset with 6.6 ft. of SLR (4.6 ft. for storm surge in the Delta)	10%	10%	10%	7.5%	10%	7.5%	10%	10%	10%	10%	10%	10%	-	-	-	-	-
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

3. **Calculate prioritization scores for each hazard**: After the weights were applied, the next step was to calculate prioritization scores for each individual hazard. This was done by first summing the products of the weights and scaled values for all the metrics relevant to the particular asset-hazard combination being studied (i.e., summing up the products for each column in Table 3). Since there are different numbers of metrics used to calculate the score for each asset-hazard combination, these values were then re-scaled to range from zero to 100 with zero representing the lowest priority asset and 100 the highest priority asset. These interim scores provide useful information for understanding asset vulnerability to each specific hazard.

4. **Calculate cross-hazard prioritization scores:** While the prioritization scores for each hazard provide useful information, they do not provide the full picture on the threats posed to each asset. It was decided that the final scores used as the basis for prioritization need to look holistically across all the hazards analyzed. This cross-hazard perspective provides a better view of the collective threats faced by each asset and a better basis for prioritization. To calculate the cross-hazard scores, the scores for each hazard analyzed for the asset were summed. These were then re-scaled yet again to a zero to 100 scale since different asset types have different numbers of hazards. As before, the higher the score, the higher the adaptation priority of that asset. These cross-hazard scores represent the final scores calculated for each asset during the technical assessment portion of the methodology.

SR-1 EL MORO LANDSLIDE (2013)

5. **Assign priority levels**: The final step in the technical assessment was to group together assets into different priority levels based on their cross-hazard scores. This was done to make the outputs more oriented to future actions, decrease the tendency to read too much into minor differences in the cross-hazard scores, and better facilitate dialogue at the workshop with District 12 staff. Five priority levels were developed (Priority 1, 2, 3, 4, and 5) and assets were assigned to those groups on a District-wide basis. An equal number of assets were assigned to each priority level to help facilitate administration of the facility-level adaptation assessments that will follow this study.

3.5. Adjustments to Prioritization

A workshop was held with the District to explain the scoring methodology and go over the preliminary results. District staff invited to participate in the workshop included representatives from asset management, maintenance, traffic operations, planning, and environmental. District 12 staff was given the opportunity to make recommendations on adjusting asset priorities. After reviewing the prioritization results, District 12 did not adjust the asset rankings.

4. DISTRICT ADAPTATION PRIORITIES

This chapter presents Caltrans' priorities for undertaking detailed adaptation assessments of assets exposed to climate change in District 12. The material presented in this chapter reflects the results of the technical analysis and the coordination with District 12 staff described in the previous chapter. The information is broken out by asset type with priorities for bridges discussed in the first section, followed by those for large culverts, small culverts, and roadways.

4.1. Bridges

A total of 47 bridges were assessed for vulnerability to sea level rise, storm surge, coastal cliff retreat, and enhanced riverine flooding associated with climate change. All these bridges should eventually undergo detailed adaptation assessments. However, due to resource limitations, this will not be possible to do all at once. Instead, the bridges will be analyzed over time according to the priorities presented here.

Figure 2 provides a map of all the bridges assessed for riverine flooding in the District. The color of the points corresponds to the priority assigned to each bridge; darker red colors indicate higher priority assets. The map shows that high priority bridges are scattered throughout the District. There are nine Priority 1 bridges in District 12. Several high priority bridges are located along State Route 1 between Newport Beach and Seal Beach as well as along Interstate 405. These bridges are given high priority scores because of exposure to near-term sea level rise and storm surge, amongst other factors. The State Route 1 bridge over Anaheim Bay received the highest cross-hazard score due to exposure to sea level rise and storm surge and having experienced past flood damages.

Table 4 presents a summary of all the Priority 1 bridges in District 12 sorted by their cross-hazard prioritization scores. A complete listing of all bridges ranked by their prioritization scores appears in Table 8 in the appendix.

TABLE 4: PRIORITY 1 BRIDGES

Priority	Bridge Number	County [18]	Route	Feature Crossed	Postmile	Cross-Hazard Prioritization Score
1	55 0010	ORA	STATE ROUTE 1	ANAHEIM BAY	31.75	100.00
1	55 0258	ORA	ROUTE 405	SANTA ANA RIVER	12.41	75.56
1	55 0035	ORA	STATE ROUTE 55	NEWPORT BEACH CHANNEL	0.18	73.00
1	55 0614	ORA	STATE ROUTE 1	NORTH ARM NEWPORT BAY	R18.22	57.90
1	55 0001	ORA	STATE ROUTE 1	SANTA ANA RIVER	21.55	56.59
1	55 0070	ORA	SR 39 (BEACH BLVD)	BREA CREEK CHANNEL	15.83	50.00
1	55 0285	ORA	INTERSTATE 405	SAN DIEGO CREEK CHANNEL	6.41	49.97
1	55 0658	ORA	STATE ROUTE 1	TALBERT CHANNEL	21.82	47.51
1	55 0731R	ORA	SR 73 NB	SAN DIEGO CREEK	24.36	43.47

[18] ORA = Orange

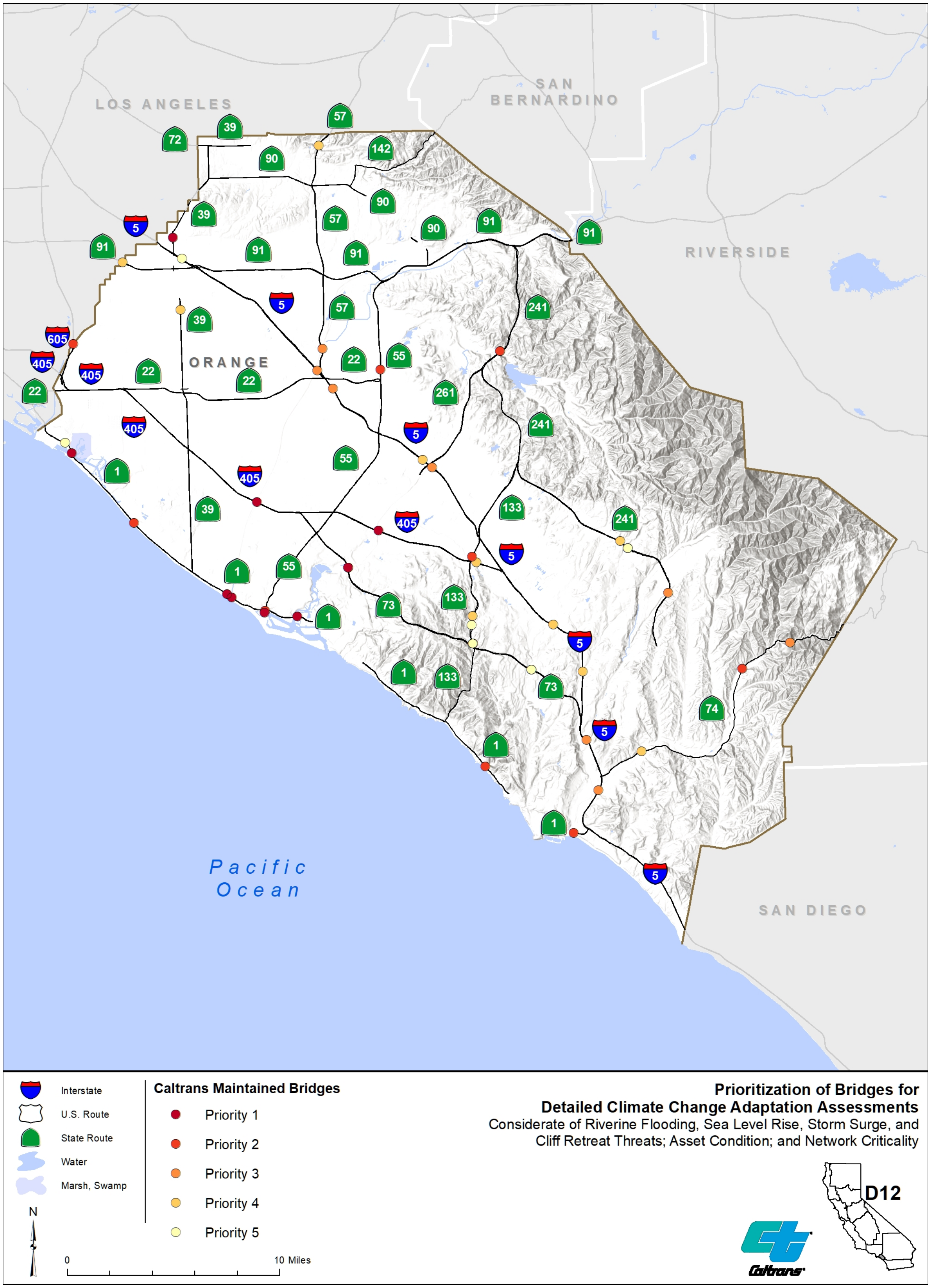


FIGURE 2: PRIORITIZATION OF BRIDGES FOR DETAILED ADAPTATION ASSESSMENTS

4.2. Large Culverts

A total of 15 large culverts were assessed for vulnerability to sea level rise, storm surge, coastal cliff retreat, and more severe riverine flooding associated with climate change. Figure 3 provides a map of all the large culverts potentially exposed to enhanced riverine flooding in the District and colored by their priority level. Given the limited number of large culverts in District 12, it is hard to draw spatial patterns to the vulnerabilities. That said, it is worth nothing that several of the vulnerable large culverts identified are along Interstate 5 and Interstate 405, the primary north-south arteries in the District. The high traffic volumes on these roads (including high truck traffic volumes) contribute to them receiving a high priority.

Table 5 presents a summary of all the Priority 1 large culverts in District 12 sorted by their cross-hazard prioritization scores. A complete listing of all large culverts ranked by their prioritization scores appears in Table 9 in the appendix.

TABLE 5: PRIORITY 1 LARGE CULVERTS

Priority	Bridge Number	County[19]	Route	Feature Crossed	Postmile	Cross-Hazard Prioritization Score
1	55 0119	ORA	STATE ROUTE 1	MORO CREEK	11.9	100.00
1	55 0910	ORA	INTERSTATE 5	CARBON CREEK	40.2	39.18
1	55 0522	ORA	INTERSTATE 405	SAN JOAQUIN CHANNEL	6.13	25.85

[19] ORA = Orange

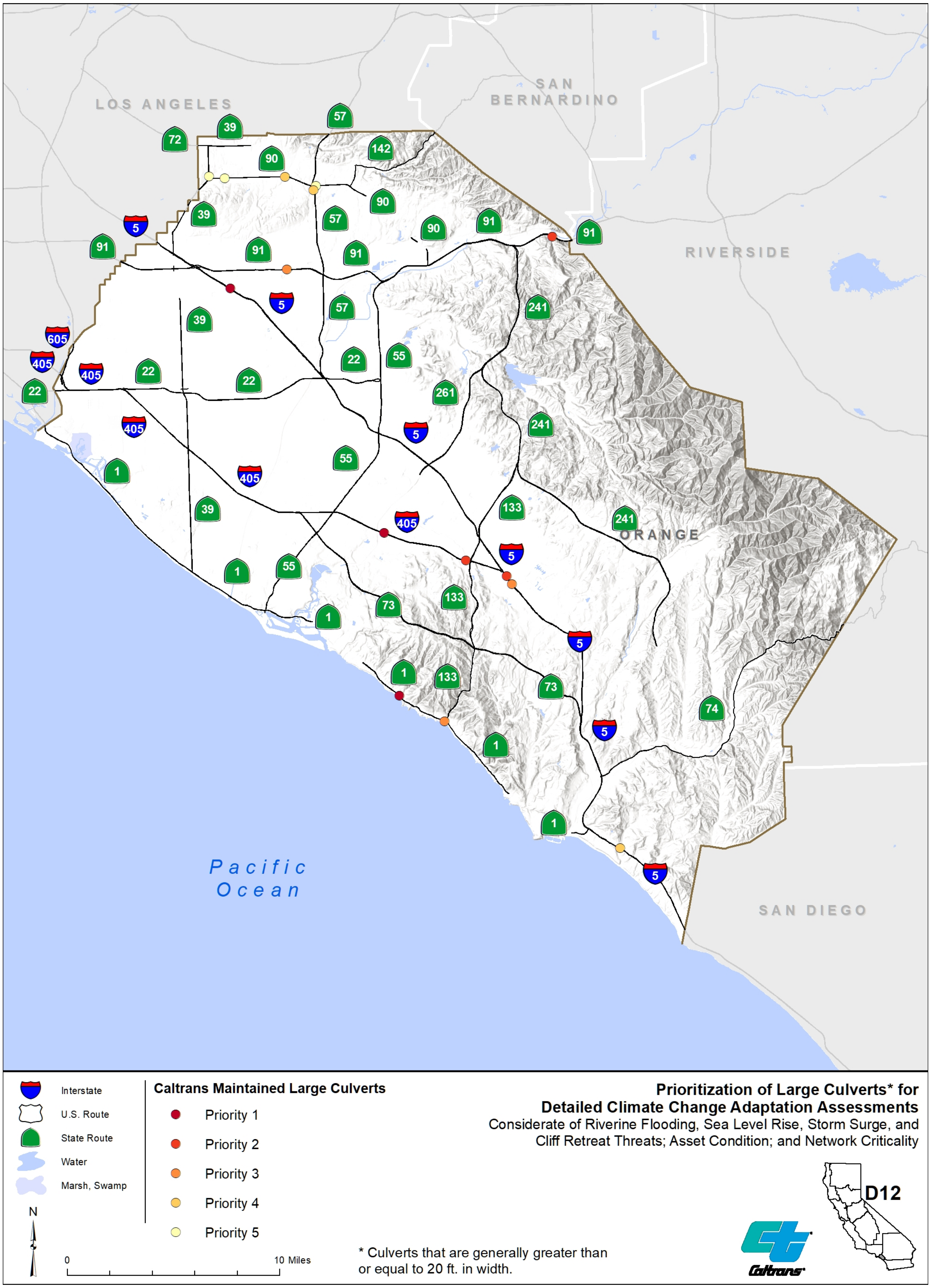


FIGURE 3: PRIORITIZATION OF LARGE CULVERTS FOR DETAILED ADAPTATION ASSESSMENTS

4.3. Small Culverts

A total of 43 small culverts were assessed for vulnerability to sea level rise, storm surge, coastal cliff retreat, and more severe riverine flooding and wildfire associated with climate change.

SINKHOLE EXPOSES UNDERGROUND CULVERT ON SR-39

Figure 4 provides a map of all the small culverts potentially exposed to more severe riverine flooding and wildfire in the District. The small culverts are colored according to their priority level. There are eight Priority 1 small culverts in District 12.

Given the limited number of small culverts in District 12, it is hard to draw spatial patterns to the vulnerabilities. That said, two clusters of high priority small culverts occur in the eastern portion of Orange County, where there is mountainous terrain and vegetation contributing to higher wildfire risk. Specifically, numerous high priority small culverts are located along State Route 74 and State Route 142. All the Priority 1 small culverts in these clusters have high, projected riverine flood and fire exposure, and many have experienced wildfire and flood impacts in the past. These routes also have limited detour routes if they were to be temporarily closed, contributing to higher prioritization scores.

Table 6 presents a summary of all the Priority 1 small culverts in District 12 sorted by their cross-hazard prioritization scores. A complete listing of all small culverts ranked by their prioritization scores appears in Table 10 in the appendix.

TABLE 6: PRIORITY 1 SMALL CULVERTS

Priority	Culvert System Number	County[20]	Route	Postmile	Cross-Hazard Prioritization Score
1	550740000597	ORA	74	5.97	100
1	550740000528	ORA	74	5.28	95.88991132
1	550740000525	ORA	74	5.25	95.86017987
1	551424000621	ORA	142	6.21	91.65558478
1	550740000753	ORA	74	7.53	89.00640685
1	550740000637	ORA	74	6.37	88.30428024
1	551424000398	ORA	142	3.98	88.30388472
1	551424000463	ORA	142	4.63	83.58165538

[20] ORA = Orange

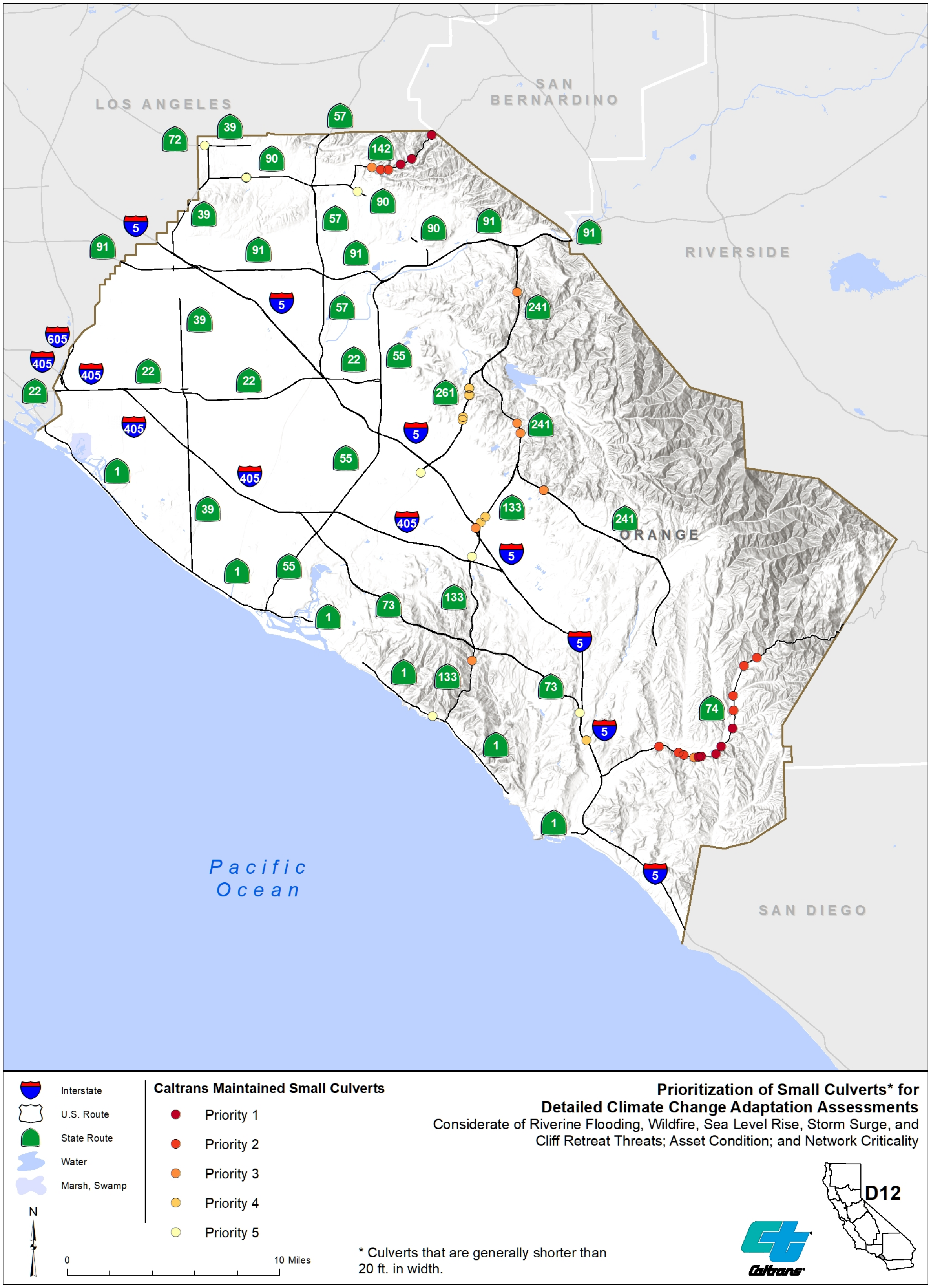


FIGURE 4: PRIORITIZATION OF SMALL CULVERTS FOR DETAILED ADAPTATION ASSESSMENTS

4.4. Roadways

A total of 2,072 roadway segments were assessed for vulnerability to sea level rise, storm surge, coastal cliff retreat, and temperature changes that affect pavement performance. To make the analysis as detailed as possible, the original segments were short with beginning and end points at intersections with other streets (including smaller local streets) in the roadway network. Once the processing of vulnerability scores was complete, smaller segments sharing the same priority score as their neighbors on the same route were consolidated into longer segments to simplify the presentation of the results. This reduced the number of segments to those presented here. Only roadways under the jurisdiction of District 12 were included in this analysis. Roadways that were relinquished by District 12 and owned and maintained by other city, county, or private entities are were not included in this analysis.

Figure 5 provides a map of the consolidated roadway segments potentially exposed to pavement degrading temperature changes or coastal hazards in the District. Each segment of roadway is colored by priority level. There are 32 Priority 1 roadways in District 12. The map shows that many roadway segments along State Route 1 should be a high priority given their exposure to sea level rise, storm surge, cliff retreat and due to past coastal flood impacts. State Route 1, or the Pacific Coast Highway, in Orange County is an important route for commuter, recreation, and tourism use. If the highway were impacted by sea level rise it would be a challenging to repair. Understanding potential future impacts enables the District to take steps to adapt the Pacific Coast Highway to current and future hazards. Additionally, Interstate 5, State Route 57, State Route 91, and State Route 55 receive high prioritization scores due to temperature impacts on binder grade coupled with high traffic volumes, including truck traffic.

Table 7 presents a summary of all the Priority 1 roadways in District 12 sorted by their cross-hazard prioritization scores. A complete listing of all roadways ranked by their prioritization scores appears in Table 11 in the appendix.

TABLE 7: PRIORITY 1 ROADWAYS

Priority	Route	Carriageway[21]	From County & Postmile / To County & Postmile[22]	Average Cross-Hazard Prioritization Score[23]
1	1	S	ORA 1 11.359 / ORA 1 12.206	77.68
1	1	S	ORA 1 25.898 / ORA 1 27.045	77.68
1	1	S	ORA 1 27.055 / ORA 1 31.576	77.68
1	1	S	ORA 1 32.718 / ORA 1 33.715	77.68
1	1	S	ORA 1 R18.071 / ORA 1 R18.158	77.68
1	1	S	ORA 1 R18.508 / ORA 1 24.273	77.68
1	1	P	ORA 1 11.881 / ORA 1 12.156	72.30
1	1	P	ORA 1 27.054 / ORA 1 32.196	72.30
1	1	P	ORA 1 32.715 / ORA 1 33.626	72.30
1	1	P	ORA 1 R18.073 / ORA 1 24.271	72.30

21 Caltrans' alignment codes designate the carriageway on divided roadways: "P" always represents northbound or eastbound carriageways whereas "S" always represents southbound or westbound carriageways. Undivided roadways are always indicated with a "P".

22 ORA = Orange

23 These values represent the average of the cross-hazard prioritization scores amongst all the abutting small segments on the same route sharing a common priority level that were aggregated to form the longer segments listed in this table.

Priority	Route	Carriageway[21]	From County & Postmile / To County & Postmile[22]	Average Cross-Hazard Prioritization Score[23]
1	39	P	ORA 39 0 / ORA 39 0.379	59.91
1	22	P	ORA 22 T0.182 / ORA 22 R0.65	57.55
1	39	S	ORA 39 0.007 / ORA 39 0.63	55.47
1	91	P	ORA 91 1.97 / ORA 91 3.255	42.58
1	91	P	ORA 91 R3.854R / ORA 91 R3.868R	42.58
1	91	P	ORA 91 R9.171 / ORA 91 R11.539	42.58
1	91	S	ORA 91 1.943 / ORA 91 3.255	41.99
1	91	S	ORA 91 R9.07 / ORA 91 R11.538	41.99
1	5	P	ORA 5 34.008 / ORA 5 34.998	39.86
1	5	P	ORA 5 37.643 / ORA 5 39.183	39.86
1	5	P	ORA 5 42.93 / ORA 5 43.437	39.86
1	5	P	ORA 5 R27.253 / ORA 5 33.849	39.86
1	5	S	ORA 5 27.46 / ORA 5 33.869	39.85
1	5	S	ORA 5 34.036 / ORA 5 35.028	39.85
1	5	S	ORA 5 37.671 / ORA 5 39.045	39.85
1	5	S	ORA 5 42.8 / ORA 5 43.424	39.85
1	55	S	ORA 55 R7.591 / ORA 55 R9.959	39.41
1	55	P	ORA 55 R7.618 / ORA 55 R9.96	39.39
1	57	S	ORA 57 15.58 / ORA 57 17.312	39.33
1	57	S	ORA 57 19.583 / ORA 57 R22.533	39.33
1	57	P	ORA 57 15.581 / ORA 57 17.309	39.33
1	57	P	ORA 57 19.59 / LA 57 R0.002	39.33

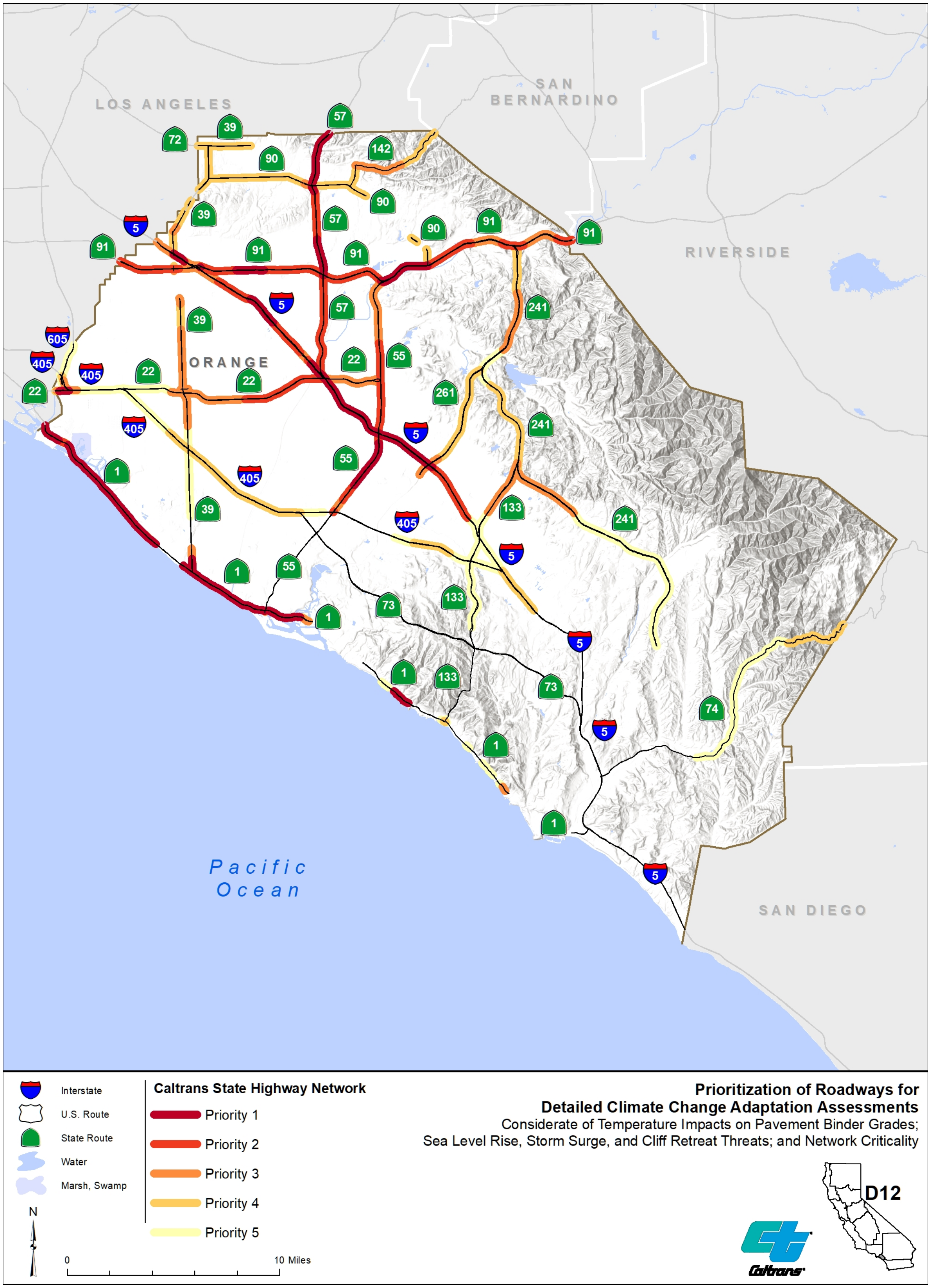


FIGURE 5: PRIORITIZATION OF ROADWAYS FOR DETAILED ADAPTATION ASSESSMENTS

5. NEXT STEPS

This report has identified the bridge, large culvert, small culvert, and roadway assets exposed to a variety of climate hazards in District 12 and assigned them priority levels for detailed assessments based on their vulnerability rating. Caltrans' next step will be to begin undertaking these detailed adaptation assessments for the identified assets starting with the highest priority (Priority 1) assets first and then proceeding to lower priority assets thereafter. These detailed adaptation assessments will take a closer look at the exposure to each asset using more localized climate projections and more detailed engineering analyses. The benefit of performing these detailed adaptation assessments is determining the bounds of the studies, including whether and how to amalgamate the individual exposed assets prioritized in this study into a facility level assessment that considers multiple exposed assets. If impacts are verified, Caltrans will develop and evaluate adaptation options for the asset to ensure that it is able to withstand future climate changes. Importantly, the detailed adaptation assessment will include coordination with key stakeholder groups whose actions affect or are affected by the asset and its adaptation.

SR-91 ROADWAY REPAIR AFTER DAMAGE

Another next step will be to integrate the prioritization measures into the asset management system used in the District. This will ensure that climate change is a consideration in the identification of future projects alongside traditional asset condition metrics. As noted previously, assets identified for capital investments, especially those flagged as being a high priority for climate change, should then undergo detailed climate change assessments prior to project programming.

In addition, District staff can use the results of this study as a useful starting point to begin discussions with various important stakeholders in the District about addressing climate change and its impacts. This includes state and federal environmental agencies, local transportation agencies, nonprofits, and others. Multi-agency stakeholder coordination and involvement of the private sector are essential because the impacts from climate change, and ability to effectively address those impacts, cross both jurisdictional and ownership boundaries. For example, Caltrans could increase the size of a culvert to accommodate higher stormwater and debris flows while the more cost-effective solution may be better land management in the adjacent drainage area. The approach to climate change cannot just be Caltrans-centric. A common framework across all state agencies must be established for truly effective long-term solutions to be achieved.

6. APPENDIX

TABLE 8: PRIORITIZATION OF BRIDGES FOR DETAILED CLIMATE CHANGE ADAPTATION ASSESSMENTS

Priority	Bridge Number	County[24]	Route	Feature Crossed	Postmile	Cross-Hazard Prioritization Score
1	55 0010	ORA	STATE ROUTE 1	ANAHEIM BAY	31.75	100.00
1	55 0258	ORA	ROUTE 405	SANTA ANA RIVER	12.41	75.56
1	55 0035	ORA	STATE ROUTE 55	NEWPORT BEACH CHANNEL	0.18	73.00
1	55 0614	ORA	STATE ROUTE 1	NORTH ARM NEWPORT BAY	R18.22	57.90
1	55 0001	ORA	STATE ROUTE 1	SANTA ANA RIVER	21.55	56.59
1	55 0070	ORA	SR 39 (BEACH BLVD)	BREA CREEK CHANNEL	15.83	50.00
1	55 0285	ORA	INTERSTATE 405	SAN DIEGO CREEK CHANNEL	6.41	49.97
1	55 0658	ORA	STATE ROUTE 1	TALBERT CHANNEL	21.82	47.51
1	55 0731R	ORA	SR 73 NB	SAN DIEGO CREEK	24.36	43.47
2	55 0731L	ORA	SR 73 SB	SAN DIEGO CREEK	24.36	40.21
2	55 0547	ORA	STATE ROUTE 1	SAN JUAN CREEK	R.97	38.38
2	55 0406	ORA	INTERSTATE 605	COYOTE CREEK	R1.6	37.97
2	55 0966	ORA	SR 55	SR55/SR1 SEPARATION	0.27	35.59
2	55 0062	ORA	STATE ROUTE 74	SAN JUAN CREEK	10.44	25.52
2	55 1068	ORA	STATE ROUTE 1	TIDAL INLET CHANNEL	27.31	25.48
2	55 0033	ORA	STATE ROUTE 55	SANTIAGO CREEK	13.42	24.54
2	55 0290R	ORA	ROUTE 133 NB	SAN DIEGO CREEK	8.59	22.61
2	55 0003	ORA	STATE ROUTE 1	ALISO CREEK	6.49	22.38
2	55 0823L	ORA	SR 241 SB	SANTIAGO CREEK	33.7	21.92
3	55 0823R	ORA	SR 241 NB	SANTIAGO CREEK	33.7	21.92
3	55 0228	ORA	INTERSTATE 5	SAN JUAN CREEK	8.87	21.86
3	55 0811	ORA	I 5	SANTA ANA RIVER	34.47	21.34
3	55 1046L	ORA	I 5 SB	SANTIAGO CREEK	33.39	21.29
3	55 0715R	ORA	SR 241	TIJERAS CREEK	17.4	21.09
3	55 0064	ORA	STATE ROUTE 74	SAN JUAN CANYON	13.29	19.31
3	55 0289	ORA	INTERSTATE 5	TRABUCO CREEK	11.45	19.27
3	55 0663	ORA	INTERSTATE 5	PETERS CANYON	R27.25	19.17
3	55 0400	ORA	STATE ROUTE 57	SANTA ANA RIVER	11.96	18.94
4	55 0014	ORA	INTERSTATE 5	ALISO CREEK	17.75	16.76
4	55 0233	ORA	INTERSTATE 5	OSO CREEK	14.79	14.65
4	55 0850R	ORA	STATE ROUTE 74	SAN JUAN CREEK	R2.28	14.54
4	55 0504	ORA	ROUTE 57	TONNER CANYON ROAD UC	21.78	14.23
4	55 0655	ORA	INTERSTATE 5	EL MODENA IRVN CHANNEL	27.82	12.78

[24] ORA = Orange

Priority	Bridge Number	County[24]	Route	Feature Crossed	Postmile	Cross-Hazard Prioritization Score
4	55 0451	ORA	INTERSTATE 405	SAN DIEGO CREEK CHANNEL	1.5	11.89
4	55 0704R	ORA	ROUTE 241	ALISO CREEK	21	11.65
4	55 0306	ORA	STATE ROUTE 91	COYOTE CREEK	R.1	9.95
4	55 0395	ORA	SR 39 (BEACH BLVD)	CARBON CREEK CHANNEL	12.37	8.69
4	55 0999L	ORA	STATE ROUTE 133 SB	LAGUNA LAKES TRAIL	R5.62	8.29
5	55 1059L	ORA	STATE ROUTE 133 SB	LAGUNA CANYON CREEK	M4.29	8.12
5	55 1059R	ORA	STATE ROUTE 133 NB	LAGUNA CANYON CREEK	M4.31	8.12
5	55 0754L	ORA	SR 73 SB	ALISO CREEK	13.82	7.87
5	55 0754R	ORA	SR 73 NB	ALISO CREEK	13.82	7.46
5	55 0998L	ORA	STATE ROUTE 133 SB	LITTLE SYCAMORE CANYON	M5.2	7.34
5	55 1073L	ORA	INTERSTATE 5 SB	FULLERTON CREEK	42.98	5.16
5	55 0065	ORA	STATE ROUTE 1	NAVAL AMMUNITION DEPO OH	32.36	0.00
5	55 0703L	ORA	STATE ROUTE 241	UPPER OSO RESERVOIR	20.4	0.00
5	55 0703R	ORA	STATE ROUTE 241	UPPER OSO RESERVOIR	20.4	0.00

TABLE 9: PRIORITIZATION OF LARGE CULVERTS FOR DETAILED CLIMATE CHANGE ADAPTATION ASSESSMENTS

Priority	Bridge Number	County[25]	Route	Feature Crossed	Postmile	Cross-Hazard Prioritization Score
1	55 0119	ORA	STATE ROUTE 1	MORO CREEK	11.9	100.00
1	55 0910	ORA	INTERSTATE 5	CARBON CREEK	40.2	39.18
1	55 0522	ORA	INTERSTATE 405	SAN JOAQUIN CHANNEL	6.13	25.85
2	55 0608	ORA	STATE ROUTE 91	COAL CANYON CREEK	R17.92R	22.78
2	55 0288	ORA	INTERSTATE 5	SERRANO CREEK	20.97	21.90
2	55 0520	ORA	INTERSTATE 405	LAGUNA CHANNEL	2.03	20.99
3	55 0072	ORA	INTERSTATE 5	SAN DIEGO CREEK	20.49	20.58
3	55 0196	ORA	ROUTE 91	CARBON DITCH	4.28	20.18
3	55 1106	ORA	STATE ROUTE 1	LAGUNA CANYON CHANNEL	9.39	17.64
4	55 0277	ORA	INTERSTATE 5	PRIMA DESCHECA CANADA	5.03	17.25
4	55 0528	ORA	STATE ROUTE 57	LOFTUS DIVERSION CHANNEL	19.66	14.71
4	55 0083	ORA	SR 90 (IMPERIAL)	BREA CANYON CREEK	4.07	2.30
5	55 0222	ORA	SR 90 (IMPERIAL)	LOFTUS DIVERSION CHANNEL	5.63	2.18
5	55 0129	ORA	SR 39 (BEACH BLVD)	COYOTE CREEK CHANNEL	19.23	0.69
5	55 0080	ORA	SR 90 (IMPERIAL)	IMPERIAL CHANNEL	1.23	0.00

[25] ORA = Orange

TABLE 10: PRIORITIZATION OF SMALL CULVERTS FOR DETAILED CLIMATE CHANGE ADAPTATION ASSESSMENTS

Priority	Culvert System Number	County[26]	Route	Postmile	Cross-Hazard Prioritization Score
1	550740000597	ORA	74	5.97	100
1	550740000528	ORA	74	5.28	95.88991132
1	550740000525	ORA	74	5.25	95.86017987
1	551424000621	ORA	142	6.21	91.65558478
1	550740000753	ORA	74	7.53	89.00640685
1	550740000637	ORA	74	6.37	88.30428024
1	551424000398	ORA	142	3.98	88.30388472
1	551424000463	ORA	142	4.63	83.58165538
2	550740000802	ORA	74	8.02	81.18894042
2	550740000443	ORA	74	4.43	76.86302434
2	551424000297	ORA	142	2.97	76.54763297
2	550744001062	ORA	74	10.62	75.62590904
2	550744001139	ORA	74	11.39	75.5435208
2	550740000316	ORA	74	3.16	73.3388075
2	550740000915	ORA	74	9.15	70.1473513
2	550740000446	ORA	74	4.46	67.58372315
2	551424000334	ORA	142	3.34	67.47527414
3	551424000250	ORA	142	2.5	67.18137763
3	551334000345	ORA	133	3.45	64.34823861
3	552410002546	ORA	241	25.46	60.27690141
3	550740000497	ORA	74	4.97	57.13898951
3	552410002546	ORA	241	25.46	53.04162775
3	552410002890	ORA	241	28.9	52.63528255
3	552414003645	ORA	241	36.45	51.73076255
3	552410002929	ORA	241	29.29	41.94634427
3	550054002375	ORA	5	23.75	40.37473
4	551330001002	ORA	133	10.02	26.54561088
4	552614000329	ORA	261	3.29	25.28484123
4	550050001142	ORA	5	11.42	21.61367737
4	551330001002	ORA	133	10.02	21.07488522
4	552610000348	ORA	261	3.48	20.16686269
4	552610000457	ORA	261	4.57	19.09237203
4	552610000457	ORA	261	4.57	18.78034514
4	552610000490	ORA	261	4.9	17.91051944
4	552610000490	ORA	261	4.9	17.91051944
5	551330000859	ORA	133	8.59	15.01878847

[26] ORA = Orange

Priority	Culvert System Number	County[26]	Route	Postmile	Cross-Hazard Prioritization Score
5	552614000000	ORA	261	0	13.48824063
5	550904000228	ORA	90	2.28	11.38263754
5	550904000228	ORA	90	2.28	11.38263754
5	550730001065	ORA	73	10.65	6.779875902
5	550724001159	ORA	72	11.59	6.340993344
5	550902000770	ORA	90	7.7	5.777223183
5	550010000998	ORA	1	9.98	0

TABLE 11: PRIORITIZATION OF ROADWAYS FOR DETAILED CLIMATE CHANGE ADAPTATION ASSESSMENTS

Priority	Route	Carriageway [27]	From County & Postmile / To County & Postmile [28]	Average Cross-Hazard Prioritization Score [29]
1	1	S	ORA 1 11.359 / ORA 1 12.206	77.68
1	1	S	ORA 1 25.898 / ORA 1 27.045	77.68
1	1	S	ORA 1 27.055 / ORA 1 31.576	77.68
1	1	S	ORA 1 32.718 / ORA 1 33.715	77.68
1	1	S	ORA 1 R18.071 / ORA 1 R18.158	77.68
1	1	S	ORA 1 R18.508 / ORA 1 24.273	77.68
1	1	P	ORA 1 11.881 / ORA 1 12.156	72.30
1	1	P	ORA 1 27.054 / ORA 1 32.196	72.30
1	1	P	ORA 1 32.715 / ORA 1 33.626	72.30
1	1	P	ORA 1 R18.073 / ORA 1 24.271	72.30
1	39	P	ORA 39 0 / ORA 39 0.379	59.91
1	22	P	ORA 22 T0.182 / ORA 22 R0.65	57.55
1	39	S	ORA 39 0.007 / ORA 39 0.63	55.47
1	91	P	ORA 91 1.97 / ORA 91 3.255	42.58
1	91	P	ORA 91 R3.854R / ORA 91 R3.868R	42.58
1	91	P	ORA 91 R9.171 / ORA 91 R11.539	42.58
1	91	S	ORA 91 1.943 / ORA 91 3.255	41.99
1	91	S	ORA 91 R9.07 / ORA 91 R11.538	41.99
1	5	P	ORA 5 34.008 / ORA 5 34.998	39.86
1	5	P	ORA 5 37.643 / ORA 5 39.183	39.86
1	5	P	ORA 5 42.93 / ORA 5 43.437	39.86
1	5	P	ORA 5 R27.253 / ORA 5 33.849	39.86
1	5	S	ORA 5 27.46 / ORA 5 33.869	39.85
1	5	S	ORA 5 34.036 / ORA 5 35.028	39.85
1	5	S	ORA 5 37.671 / ORA 5 39.045	39.85
1	5	S	ORA 5 42.8 / ORA 5 43.424	39.85
1	55	S	ORA 55 R7.591 / ORA 55 R9.959	39.41
1	55	P	ORA 55 R7.618 / ORA 55 R9.96	39.39
1	57	S	ORA 57 15.58 / ORA 57 17.312	39.33
1	57	S	ORA 57 19.583 / ORA 57 R22.533	39.33
1	57	P	ORA 57 15.581 / ORA 57 17.309	39.33
1	57	P	ORA 57 19.59 / LA 57 R0.002	39.33
2	1	S	ORA 1 32.371 / ORA 1 32.718	38.53
2	5	S	ORA 5 35.028 / ORA 5 35.217	38.18

[27] Caltrans' alignment codes designate the carriageway on divided roadways: "P" always represents northbound or eastbound carriageways whereas "S" always represents southbound or westbound carriageways. Undivided roadways are always indicated with a "P".
[28] ORA = Orange
[29] The average of the cross-hazard prioritization scores amongst all the abutting small segments on the same route sharing a common priority level that were aggregated to form the longer segments listed in this table.

Priority	Route	Carriageway [27]	From County & Postmile / To County & Postmile [28]	Average Cross-Hazard Prioritization Score [29]
2	5	S	ORA 5 35.76 / ORA 5 37.671	38.18
2	5	S	ORA 5 39.045 / ORA 5 40.95	38.18
2	5	S	ORA 5 R24.33 / ORA 5 27.46	38.18
2	5	P	ORA 5 34.998 / ORA 5 35.217	38.08
2	5	P	ORA 5 35.951 / ORA 5 37.643	38.08
2	5	P	ORA 5 39.183 / ORA 5 40.833	38.08
2	5	P	ORA 5 R24.716 / ORA 5 R27.253	38.08
2	55	P	ORA 55 R6.003 / ORA 55 R6.059	37.96
2	55	P	ORA 55 R6.736 / ORA 55 R7.618	37.96
2	55	P	ORA 55 R9.96 / ORA 55 14.711	37.96
2	55	S	ORA 55 R5.992 / ORA 55 R6.049	37.87
2	55	S	ORA 55 R6.804 / ORA 55 R7.591	37.87
2	55	S	ORA 55 R9.959 / ORA 55 14.713	37.87
2	91	P	LA 91 R20.741 / ORA 91 R2.856	37.86
2	91	P	ORA 91 3.255 / ORA 91 R9.171	37.86
2	91	P	ORA 91 R11.539 / ORA 91 R13.861R	37.86
2	91	P	ORA 91 R15.366 / ORA 91 R16.415	37.86
2	91	P	ORA 91 R18.17R / RIV 91 R0.001	37.86
2	91	P	ORA 91 R3.868R / ORA 91 1.97	37.86
2	91	S	LA 91 R20.736 / ORA 91 R2.861	37.77
2	91	S	ORA 91 3.255 / ORA 91 R9.07	37.77
2	91	S	ORA 91 R11.538 / ORA 91 R13.852L	37.77
2	91	S	ORA 91 R15.427 / ORA 91 R16.412	37.77
2	91	S	ORA 91 R18.14L / ORA 91 R18.899	37.77
2	91	S	ORA 91 R3.867L / ORA 91 1.943	37.77
2	57	S	ORA 57 11.072 / ORA 57 15.58	37.66
2	57	S	ORA 57 17.312 / ORA 57 19.583	37.66
2	57	P	ORA 57 11.084 / ORA 57 15.581	37.65
2	57	P	ORA 57 17.309 / ORA 57 19.59	37.65
2	1	P	ORA 1 32.37 / ORA 1 32.715	37.55
2	1	P	ORA 1 33.626 / ORA 1 33.719	37.55
2	22	S	ORA 22 R6.576 / ORA 22 R10.382	36.43
2	22	P	ORA 22 R6.576 / ORA 22 R10.386	36.43
3	55	S	ORA 55 14.713 / ORA 55 R17.876	36.08
3	55	S	ORA 55 R6.049 / ORA 55 R6.804	36.08
3	55	P	ORA 55 0.199 / ORA 55 0.239	35.78
3	55	P	ORA 55 14.711 / ORA 55 R17.876	35.78
3	55	P	ORA 55 R6.059 / ORA 55 R6.736	35.78
3	5	P	ORA 5 33.849 / ORA 5 34.008	32.63
3	5	P	ORA 5 35.217 / ORA 5 35.951	32.63

Priorit y	Route	Carriageway [27]	From County & Postmile / To County & Postmile [28]	Average Cross-Hazard Prioritization Score [29]
3	5	P	ORA 5 40.833 / ORA 5 42.93	32.63
3	5	P	ORA 5 43.437 / LA 5 0	32.63
3	5	S	ORA 5 33.869 / ORA 5 34.036	32.62
3	5	S	ORA 5 35.217 / ORA 5 35.76	32.62
3	5	S	ORA 5 40.95 / ORA 5 42.8	32.62
3	5	S	ORA 5 43.424 / ORA 5 44.376	32.62
3	57	S	ORA 57 10.734L / ORA 57 11.072	32.48
3	57	P	ORA 57 10.734R / ORA 57 11.084	31.62
3	91	P	ORA 91 R13.861R / ORA 91 R15.366	31.50
3	91	P	ORA 91 R16.415 / ORA 91 R18.17R	31.50
3	91	P	ORA 91 R2.856 / ORA 91 R3.854R	31.50
3	91	S	ORA 91 R13.852L / ORA 91 R15.427	31.24
3	91	S	ORA 91 R16.412 / ORA 91 R18.14L	31.24
3	91	S	ORA 91 R2.861 / ORA 91 R3.867L	31.24
3	22	S	ORA 22 0.088 / ORA 22 R0.383	31.03
3	22	S	ORA 22 R10.382 / ORA 22 R13.144	31.03
3	22	S	ORA 22 R3.02 / ORA 22 R6.576	31.03
3	22	P	ORA 22 R10.386 / ORA 22 R13.158	30.88
3	22	P	ORA 22 R2.981 / ORA 22 R6.576	30.88
3	1	S	ORA 1 17.631 / ORA 1 R18.071	30.02
3	1	S	ORA 1 31.576 / ORA 1 32.371	30.02
3	1	S	ORA 1 5.067 / ORA 1 5.282	30.02
3	405	P	ORA 405 22.895 / ORA 405 23.837	28.08
3	022U	P	ORA 22U 3.34 / ORA 22U 3.7	27.46
3	1	P	ORA 1 25.897 / ORA 1 27.044	26.33
3	39	P	ORA 39 0.379 / ORA 39 1.053	26.02
3	39	P	ORA 39 12.686 / ORA 39 12.959	26.02
3	39	P	ORA 39 14.269 / ORA 39 14.384	26.02
3	39	P	ORA 39 16.132 / ORA 39 16.375	26.02
3	39	P	ORA 39 6.872 / ORA 39 11.486	26.02
3	39	S	ORA 39 0.63 / ORA 39 1.134	25.73
3	39	S	ORA 39 12.685 / ORA 39 12.959	25.73
3	39	S	ORA 39 14.269 / ORA 39 14.383	25.73
3	39	S	ORA 39 16.13 / ORA 39 16.376	25.73
3	39	S	ORA 39 6.871 / ORA 39 11.486	25.73
3	133	P	ORA 133 10.894 / ORA 133 13.554	24.98
3	133	S	ORA 133 10.893 / ORA 133 13.605	24.98
3	241	S	ORA 241 23.657 / ORA 241 27.06	24.91
3	241	S	ORA 241 33.919 / ORA 241 36.764	24.91
3	241	P	ORA 241 24.557 / ORA 241 27.033	24.90

Priority	Route	Carriageway [27]	From County & Postmile / To County & Postmile [28]	Average Cross-Hazard Prioritization Score [29]
3	241	P	ORA 241 33.925 / ORA 241 36.763	24.90
3	261	S	ORA 261 0 / ORA 261 1.142	24.80
3	261	P	ORA 261 0.001 / ORA 261 1.154	24.80
3	90	S	ORA 90 5.077 / ORA 90 R5.447	24.79
3	90	P	ORA 90 5.079 / ORA 90 R5.446	24.79
3	142	P	ORA 142 R1.768 / ORA 142 3.996	24.77
4	22	P	LA 22 1.459 / ORA 22 T0.182	24.64
4	90	P	ORA 90 0.501 / ORA 90 5.079	23.88
4	90	P	ORA 90 11.147 / ORA 90 11.497	23.88
4	90	P	ORA 90 12.074 / ORA 90 12.828	23.88
4	90	P	ORA 90 R5.446 / ORA 90 8.147	23.88
4	90	S	ORA 90 0.504 / ORA 90 5.077	23.85
4	90	S	ORA 90 11.148 / ORA 90 11.497	23.85
4	90	S	ORA 90 12.075 / ORA 90 12.827	23.85
4	90	S	ORA 90 R5.447 / ORA 90 8.146	23.85
4	1	P	ORA 1 11.356 / ORA 1 11.881	23.75
4	1	P	ORA 1 17.63 / ORA 1 R18.073	23.75
4	1	P	ORA 1 9.353 / ORA 1 9.459	23.75
4	39	S	LA 39 18.457 / ORA 39 22.66	23.67
4	39	S	ORA 39 11.486 / ORA 39 12.685	23.67
4	39	S	ORA 39 14.383 / ORA 39 14.531	23.67
4	39	S	ORA 39 15.001 / ORA 39 16.13	23.67
4	39	S	ORA 39 16.376 / ORA 39 17.264	23.67
4	39	S	ORA 39 17.571 / ORA 39 17.834	23.67
4	39	P	LA 39 D17.553 / LA 39 D17.845	23.50
4	39	P	LA 39 D18.445 / LA 39 22.66	23.50
4	39	P	ORA 39 1.053 / ORA 39 1.134	23.50
4	39	P	ORA 39 11.486 / ORA 39 12.686	23.50
4	39	P	ORA 39 14.384 / ORA 39 14.531	23.50
4	39	P	ORA 39 15.001 / ORA 39 16.132	23.50
4	39	P	ORA 39 16.375 / LA 39 D17.274	23.50
4	133	P	ORA 133 13.554 / ORA 133 13.599	23.29
4	72	P	LA 72 0.001 / ORA 72 11.421	23.25
4	72	S	LA 72 0.001 / ORA 72 11.421	23.25
4	261	S	ORA 261 1.142 / ORA 261 6.037	22.86
4	261	P	ORA 261 1.154 / ORA 261 6.041	22.78
4	241	S	ORA 241 27.06 / ORA 241 31.68	22.13
4	241	S	ORA 241 36.764 / ORA 241 39.079	22.13
4	241	P	ORA 241 27.033 / ORA 241 31.677	21.92
4	241	P	ORA 241 36.763 / ORA 241 39.079	21.92

Priority	Route	Carriageway [27]	From County & Postmile / To County & Postmile[28]	Average Cross-Hazard Prioritization Score[29]
4	142	P	ORA 142 3.996 / SBD 142 0.001	21.77
4	142	P	ORA 142 R0.753 / ORA 142 R1.768	21.77
4	142	S	ORA 142 R0.753 / ORA 142 1.447	21.46
4	74	P	ORA 74 13.178 / ORA 74 16.161	20.10
4	74	P	ORA 74 16.224 / RIV 74 0	20.10
4	5	P	ORA 5 18.92 / ORA 5 21.304	19.82
4	5	S	ORA 5 19.02 / ORA 5 21.332	19.78
4	405	P	ORA 405 10.278 / ORA 405 14.805	18.97
4	405	P	ORA 405 14.82 / ORA 405 17.673	18.97
4	405	P	ORA 405 2.871 / ORA 405 4.667	18.97
4	405	P	ORA 405 24.012 / ORA 405 24.049	18.97
4	405	S	ORA 405 10.292 / ORA 405 17.755	18.92
4	405	S	ORA 405 2.876 / ORA 405 4.679	18.92
4	405	S	ORA 405 23.99 / ORA 405 24.042	18.92
5	5	P	ORA 5 21.304 / ORA 5 R24.716	15.75
5	5	S	ORA 5 21.332 / ORA 5 R24.33	15.61
5	73	P	ORA 73 R27.952R / ORA 73 R27.797R	15.13
5	405	P	ORA 405 0.23 / ORA 405 2.871	14.20
5	405	P	ORA 405 14.805 / ORA 405 14.82	14.20
5	405	P	ORA 405 17.673 / ORA 405 22.895	14.20
5	405	P	ORA 405 23.837 / ORA 405 24.012	14.20
5	405	P	ORA 405 24.049 / LA 405 0	14.20
5	405	P	ORA 405 4.667 / ORA 405 5.389	14.20
5	405	P	ORA 405 9.186 / ORA 405 10.278	14.20
5	405	S	ORA 405 0.235 / ORA 405 2.876	13.41
5	405	S	ORA 405 10.263 / ORA 405 10.292	13.41
5	405	S	ORA 405 17.755 / ORA 405 23.99	13.41
5	405	S	ORA 405 24.042 / ORA 405 24.178	13.41
5	405	S	ORA 405 4.679 / ORA 405 5.627	13.41
5	22	S	LA 22 1.452 / ORA 22 0.088	11.14
5	22	S	ORA 22 R0.383 / ORA 22 R0.65	11.14
5	22	S	ORA 22 R0.666 / ORA 22 R3.02	11.14
5	22	P	ORA 22 R0.66 / ORA 22 R2.981	10.85
5	605	S	ORA 605 3.105 / ORA 605 R0.876	10.60
5	605	S	ORA 605 R1.011 / ORA 605 R1.599	10.60
5	605	P	ORA 605 3.091 / LA 605 R0.005	10.02
5	39	S	ORA 39 2.652 / ORA 39 6.871	6.77
5	39	P	ORA 39 2.652 / ORA 39 6.872	6.41
5	1	P	ORA 1 32.196 / ORA 1 32.37	5.89
5	1	P	ORA 1 9.293 / ORA 1 9.353	5.89

Priority	Route	Carriageway[27]	From County & Postmile / To County & Postmile[28]	Average Cross-Hazard Prioritization Score[29]
5	133	S	ORA 133 M5.116 / ORA 133 10.893	5.24
5	133	P	ORA 133 0 / ORA 133 0.142	5.02
5	133	P	ORA 133 R6.091 / ORA 133 10.894	5.02
5	1	S	ORA 1 12.479 / ORA 1 12.876	3.77
5	1	S	ORA 1 5.382 / ORA 1 5.503	3.77
5	1	S	ORA 1 6.003 / ORA 1 6.309	3.77
5	1	S	ORA 1 6.475 / ORA 1 6.752	3.77
5	1	S	ORA 1 7.671 / ORA 1 7.873	3.77
5	1	S	ORA 1 9.418 / ORA 1 9.606	3.77
5	241	P	ORA 241 14.604 / ORA 241 24.557	3.29
5	241	P	ORA 241 31.677 / ORA 241 33.925	3.29
5	241	S	ORA 241 14.614 / ORA 241 23.657	3.25
5	241	S	ORA 241 31.68 / ORA 241 33.919	3.25
5	261	S	ORA 261 6.037 / ORA 261 6.178	2.83
5	261	P	ORA 261 6.041 / ORA 261 6.185	2.83
5	74	P	ORA 74 5.086 / ORA 74 13.178	0.26

This page intentionally left blank.