Santa Barbara County Association of Governments
Multi-Modal Transportation Network Resiliency Assessment

Phase One:
Multi-Modal Transportation Network Vulnerability Assessment

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Prepared for:
Santa Barbara County Association of Governments
260 North San Antonio Road, Suite B
Santa Barbara, CA 93110
www.sbcag.org

Prepared by:
Energetics, a division of Akimeka, LLC
7075 Samuel Morse Drive, Suite 100
Columbia, MD 21046
www.energetics.com

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Executive Summary

Climate change poses significant threats to the transportation network in Santa Barbara County. Rising temperatures, more intense precipitation events, and rising sea levels are expected to change both the degree and extent of existing natural hazards over the coming century. Changes to temperature and precipitation may increase the severity of wildfire risks, particularly in the western parts of the county. Extreme precipitation days are projected to increase in severity, increasing the frequency of fluvial flooding and landslides in known hazard areas. Rising sea levels threaten more damaging storm surge flooding during coastal storms, permanent nuisance flooding of low-lying areas, and cliff erosion that threatens infrastructure along the north coast.

Climate hazards are already disrupting and damaging the transportation infrastructure in Santa Barbara County. The 2017 Thomas Fire was the largest wildfire in recorded California history at the time (within seven months, this record was surpassed by the Mendocino Complex Fire). The devastation and deaths caused by the Thomas Fire were not limited to the fire itself: before it had even burned out, winter rains saturated the foothills of the Santa Ynez mountains and soils now devoid of moisture-absorbing vegetation gave way to widespread mudslides that killed 21, destroyed over 1,000 structures, and closed the county’s busiest transportation corridor for almost two weeks.

The county’s multi-modal transportation network includes highways, arterial roads, and surface streets; bus transit routes, stops, and stations; the Union Pacific Railroad and the Amtrak routes and stations; the Santa Barbara Municipal Airport; and the county’s network of bicycle paths. In addition to assessing the vulnerabilities these assets, this assessment identifies ten high-priority transportation systems, selected based on their criticality to the county. Each high-priority transportation system is evaluated based on the current usage of the system, the importance of the system for emergency access, and the degree to which it serves low-income communities, as well as its duplicability with already selected systems. The high-priority systems are:

- US 101 Corridor
- Mission Drive (CA 246)
- San Marcos Pass Road (CA 154)
- Broadway/Orcutt Expressway (CA 135)
- Hollister Avenue/State Street
- Union Pacific Railroad
- Santa Barbara Municipal Airport/Goleta Slough
- Santa Barbara Train Station
- Breeze Bus Santa Maria – Lompoc
- UCSB Bicycle Paths

Climate Vulnerabilities

Six distinct hazards are evaluated in the county: coastal storm surge flooding, coastal nuisance flooding, coastal cliff erosion, wildfires, landslides, and fluvial flooding. For coastal hazards, three future time periods are considered (2030, 2060, and 2100); for other hazards, two future time periods are considered: mid-century (2055) and end-of-century (2085).

Storm Surge Flooding

Coastal hazards projections are based on the United States Geological Service (USGS) Coastal Storm Modeling System (CoSMoS) for Southern California and Central California.\(^3\)\(^4\) Coastal hazards associated with storm surge flooding are extensive and severe. Under current conditions, a 100-year flood (i.e., flooding associated with storm surge that has a 1% chance of occurring each year) would inundate large portions of the low-lying transportation infrastructure along the South Coast, including the Santa Barbara Municipal Airport and the Union Pacific Railroad as well as numerous surface roads in Isla Vista, Goleta, and Carpinteria (Figure 1). SLR conditions exacerbate this exposure to the storm surge flooding threat, however the increases are marginal under the 0.25m and 0.75m SLR scenarios (representing a conservative, high-end projection of sea levels in 2030 and 2060, respectively)\(^5\)\(^6\) If SLR reaches 2.0m (SLR in 2100 under a conservative scenario), storm surge flooding could inundate the majority of downtown Carpinteria, the entire Santa Barbara waterfront, and large areas of Goleta/Isla Vista (Figure 2). In this scenario, flooding of critical transportation systems (including the US 101 corridor, the railroad, airport, major urban arterials such as Hollister Ave./State St., and associated bicycle & pedestrian infrastructure) will be only a part of a

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\(^{5}\) SLR of 0.25m in 2030 and 0.75m in 2060 represent the ‘medium-high risk aversion’ scenario in OPC 2018, and are assigned a 0.5% (or 1-in-200) chance of being exceeded.

complex set of infrastructure disruptions that threaten the county’s coastal residences, businesses, institutions, infrastructure, and communities.

Nuisance Flooding

Nuisance flooding exposes similar areas of the South Coast to flooding damage, however unlike storm surge flooding, nuisance flooding represents a permanent, regular inundation (flood stages are associated with spring tide levels, expected to occur eight times per year). Under 0.25m SLR, no significant impacts to county transportation systems are expected. However, with 0.75m of SLR, there is a 1-in-20 chance (also called the ‘maximum uncertainty’ scenario) that the airport tarmac (including runways and service roads) could regularly flood. 0.75m of SLR also exposes the Santa Barbara waterfront (including harbor and parking lots) to regular tidal flooding. In Carpinteria, 0.75m of SLR is projected to flood the Salt Marsh Reserve but includes a 1-in-20 chance that significant areas of the city center may flood on a regular basis (Figure 3).

Under the 2.0m of SLR, nuisance flooding threatens regular-to-persistent inundation of the airport, portions of the US 101 corridor and the railroad, rendering them permanently unusable without adaptation actions. Significant areas of central Santa Barbara, Carpinteria, and the neighborhoods surrounding the Goleta and Devereux Sloughs are also subject to regular flooding (Figure 4, Figure 5).
Coastal Cliff Erosion
Coastal cliff erosion is the primary hazard threatening infrastructure along the north coast, and the Union Pacific Railroad is the primary vulnerability in this area. From Point Conception through Vandenberg Air Force Base (AFB), there are four locations where projected coastal cliff erosion under different SLR scenarios may threaten to undercut the track bed. Some sections of track (such as the tracks near Space Launch Complex 4 in Vandenberg AFB) may occur with as little as 0.25m of SLR. In the long-term these vulnerabilities threaten the sustained use of the railroad’s right of way, as greater sections of the railroad will need to be protected from ongoing erosion.

Wildfire
Wildfires pose a hazard to the county with known impacts and dangerous implications for knock-on impacts such as flooding, debris flows, and landslides. However, the connection between wildfire and climate change in Santa Barbara County is more complex, with significant variation both the direction and magnitude of projected changes to wildfire severity, depending on the timeline, emissions scenario, and area of the county. The Western area of the county – particularly the areas surrounding Lompoc and Vandenberg AFB – are projected to see the greatest increases in fire hazard. In the Santa Ynez Valley and along the South Coast, projections are more mixed. Generally, fire hazards in these areas are projected to stay approximately the same by mid-century (2040 – 2069) in all scenarios; increase slightly by end-of-century (2070 – 2099) in the low-emissions scenario (RCP4.5); and decrease slightly by end-of-century in the high-emissions scenario (RCP8.5).

The most threatened transportation systems are the roads and railroad transiting ‘very high’ fire hazard severity zones (FHSZs) designated by CalFire.7 Along the South Coast, the segments of US 101 and the railroad between Goleta and the Gaviota Pass face some of the greatest hazards (Figure 6). CA 1 north of Lompoc also faces significant hazards, due to the extreme increase in fire hazard projected for that area in all scenarios.

Landslides
Landslide hazards and fluvial flooding (also called river flooding) hazards are projected based on existing landslide and flood hazard maps and projections of increasing intensity of extreme precipitation events.

Atmospheric rivers – extreme precipitation events most associated with inland flooding – are projected to increase in frequency across California.\textsuperscript{8} In Santa Barbara County in particular, projected changes to precipitation indicate that the annual average amount of precipitation may decrease slightly by mid-century, and then increase slightly by the end of the century (relative to the period 1976 – 2005).\textsuperscript{9} However, extreme precipitation events are expected to grow more intense over the same period. Atmospheric river events are projected to become more common across the central coast. Relative to historical climate (1976 – 2005), the wettest day of the year may see 6–12\% more precipitation in a low-emissions scenario by the end of this century (2070 – 2100).\textsuperscript{10} In a high emissions scenario, the central and eastern parts of the county could see an increase of 18–24\% in precipitation, with up to 30\% increases projected for the far southeast corner of the county by the end of this century.\textsuperscript{11}

Landslide hazards are widespread throughout the county, and primarily affect roads and the railroads which transit hilly areas near potentially unstable slopes. Landslide hazard areas are identified using the landslide hazard maps in the Santa Barbara County Comprehensive Plan Seismic Safety and Safety Element.\textsuperscript{12} Hazard areas are those labeled as ‘high problem areas’ in the maps. The most significant extended areas of landslide hazards affect US 101 from Goleta to the Gaviota Pass, the railroad along the entire South Coast west of Goleta, US 1 from Gaviota Pass to Lompoc, and CA 154 along the southern shore of Lake Cachuma (Figure 7). Additional small areas of landslide hazard affect roads and transit routes throughout the county.

**Fluvial Flooding**

Fluvial flooding hazards are identified using FEMA Flood Insurance Risk Maps (FIRMs) which represent the flooding extent given a 100-year streamflow event (i.e., an event with a 1\% chance of occurring each year).\textsuperscript{13} Unlike storm surge events, the FEMA analyses are based on historical climates and do not take into account projected changes to precipitation.

\textsuperscript{8} Langridge 2018
\textsuperscript{9} Langridge 2018
\textsuperscript{10} Langridge 2018
\textsuperscript{11} Langridge 2018
As with coastal flooding, many of the most significant fluvial flooding hazards affect the low-lying areas along the South Coast. Significant precipitation in the Santa Ynez mountains could lead to fluvial flooding of the Goleta Slough/airport area, central Santa Barbara, Montecito, and Carpinteria. In central Santa Barbara, a 100-year flood would inundate much of the waterfront, US 101, the railroad, the Santa Barbara Amtrak station, many key arterial streets, and many transit routes that rely on them (Figure 8). Additional flooding hazards affect nearly every major road or highway in the county at some point, including US 101, CA 1, CA 154, or CA 246. Out of 219 transit routes in the county 209 are exposed to fluvial flooding hazards at some point. Many of these flooding hazards are relatively small exposures. However small areas of exposure can disrupt transit routes for extended periods, especially if roads or culverts are damaged.

RISK-BASED PRIORITIZATION
This study uses a risk-based approach to prioritize the vulnerabilities associated with high-priority transportation systems. Because each climate hazard is assessed using a different methodology (including differences in assumptions, scenarios, and projections), it is difficult to prioritize one vulnerability over another. To prioritize the vulnerabilities in this study, a risk-based approach is used which compares the probability and the costliness of each pair of transportation systems and climate hazards. The subjective risk scoring framework ranks each vulnerability by probability (according to the frequency and geospatial exposure of the asset, and the degree of change of exposure within the future scenario), and consequence (including the cost of damage caused by the hazard, the cost of disruption to the system, the potential duration of disruption, and the extent to which the transportation system serves low-income communities). Figure 9 shows the subjective risk assessment scores of the US 101 corridor for all hazards. Figure 10 and Figure 11 rank all vulnerabilities for all high-priority transportation systems together for mid-century and end-of-century, respectively.
Figure 10. Subjective risk assessment matrix for all hazards – mid-century.

Figure 11. Subjective risk assessment matrix for all hazards – end-of-century
Next Steps
This vulnerability assessment is part of a larger effort to understand the vulnerabilities of the county’s transportation network, identify and plan resilience options, and incorporate a climate smart transportation network into the county’s Regional Transportation Plan (RTP). This report will be followed by a Regional Climate Adaptation Strategy (RCAS) that will identify resilience solutions to mitigate the identified vulnerabilities and recommend strategies that will form the basis of a Climate Smart Transportation Network vision. The RCAS will use the prioritized vulnerabilities identified in this assessment as inputs and provide an approach to improving the understanding of exposure and building resilience.
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Multi-Modal Transportation Network Vulnerability Assessment

**Introduction**

Climate change poses a complex set of challenges to human and natural systems over the coming decades. Rising temperatures, changing precipitation patterns, and rising sea levels are interacting with local climate and weather patterns and hydrological, environmental, and geological systems to create a changing baseline for the human systems that rely on them. Addressing these challenges is an ongoing task which will require both big-picture thinking, as well as detailed studies of individual impacts, systems, and localities.

This study focuses on the multi-modal transportation network in Santa Barbara County. It is part of a multi-step effort to understand the transportation network’s vulnerabilities to climate change, identify resilience options to address those vulnerabilities, and integrate those options into a long-term transportation network planning effort for the county. This report evaluates the transportation infrastructure and systems in the county and assesses their vulnerability to climate change hazards. Additionally, this report highlights the multi-hazard combined vulnerability of specific, high-priority transportation systems. The county’s transportation network includes a diverse set of built infrastructure systems including roads and highways, airports, railroads and stations, transit stops and hubs, and bicycle routes. Climate-related hazards examined in this study include the effects of extreme temperature, sea level rise, wildfires, fluvial (or inland) flooding, and landslides. Precipitation hazards are considered in this study as contributing factors in the fluvial flooding and landslide hazard analysis.

In 2017, the Thomas Fire burned substantial areas in the Santa Ynez Mountains directly north of the South Coast from Carpinteria to Montecito. The fire was at the time the largest fire in recorded California history. Shortly after the fire, the winter rain season caused extreme runoff in the recently-burned foothills north of Montecito, causing the county’s largest natural disaster in a generation. In addition to the loss of 21 lives and dozens of homes, the extensive damage of the Montecito mudflows caused the closure of key transportation systems including the US 101 highway for almost two weeks. Portions of SR 192 remain closed more than a year after the event.

This study is part of a larger effort to understand the vulnerabilities of the county’s transportation network, identify and plan resilience options, and incorporate a climate smart transportation network into the county’s Regional Transportation Plan (RTP). This report will be followed by a Regional Climate Adaptation Strategy that will identify resilience solutions to mitigate the identified vulnerabilities and recommend strategies that will form the basis of a Climate Smart Transportation Network vision. This study is made possible through a grant from the Caltrans Adaptation Planning Program. These grants exist to support planning actions at local and regional levels that advance climate change preparedness for state transportation systems.

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Methodology
This study relies on a large number of sources, infrastructure datasets, climate change projections, and hazard assessments produced by an array of scientists, institutions, and research projects. These resources are brought together to provide a coherent analysis of all the salient climate hazards facing the county’s transportation systems, however considerations must be taken for each resource, including differing baselines, scenarios, assumptions, and other factors that affect the resource’s use in this analysis. This study combines current infrastructure data, known geospatial hazard assessments, climate change projections, and projections of future changes to climate hazards to provide the most complete assessment of the vulnerabilities of the county’s transportation network to climate change hazards possible. A complete description of the methods and sources follows.

Scenarios
Scenarios in this analysis are designed to provide useful analytical perspectives on future risks, while providing sufficient differentiation to provide clarity. Due to inherent differences in the way that oceanic and atmospheric climate parameters (temperature, humidity, precipitation, etc.) are projected to evolve over the coming century, different scenarios are defined for hazards based on climate parameter projections and coastal hazards based on projections of rising sea levels. Climate parameter scenarios are provided for two future time periods: 2055 (i.e., mid-century, or the period 2040 – 2069), and 2085 (end-of-century, or the period 2070 – 2099). These time horizons are further divided into two emissions scenarios: low-emissions (RCP4.5) and high-emissions (RCP8.5). By contrast, coastal hazard scenarios are based on projections of sea level rise (SLR). The SLR-based scenarios address coastal hazards under 0.25, 0.75, and 2.0 meters of SLR, compared to current conditions (1991 – 2009). The scenarios are summarized in Table 1.

<table>
<thead>
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Temperature, Precipitation, Flooding, Wildfire, and Landslides
For all scenarios except those related to SLR, projections of climate parameters are derived from the Coupled Model Intercomparison Project, Phase Five (CMIP5) global climate model simulations. The CMIP5 climate change projections are the gold standard used in both the IPCC Fifth Assessment Report,
and the California Fourth Climate Change Assessment Report (C4CCA).\textsuperscript{17} These climate projections have been further refined for the C4CCA, including the down-selection of constituent models to four which best represent California’s historical climate, and application of California-specific bias correction and downscaling to 3.6 mile grid cells.\textsuperscript{18} Downscaling takes into account local influences on climate projections such as topography and historical weather patterns to create projections which better represent the potential for local weather extremes in temperature and precipitation. Figure 12 provides an illustrative example of the effects of downscaling on local climate projections across California.

\textbf{Figure 12. Effect of downscaling on climate parameter projections in California and Nevada. Left panel represents illustrative example of CMIP5 precipitation projections; right panel represents post-downscaling precipitation projections and exaggerated topography. Source: Pierce et al. 2018.}

\textbf{Temperature}

Temperature projections used in this analysis are limited to extreme temperature. Although increases in average temperature are the primary driver of most climate change hazards relevant to the County’s infrastructure, elevated average temperatures are unlikely to cause any acute damage or disruption to the transportation network. Extreme temperatures are defined by the historical range of temperatures in the county, and C4CCA’s analysis sets the threshold at the 98\textsuperscript{th} percentile day over the historical period (1961 – 1990). Extreme temperature scenarios are defined by the two future emissions pathways, RCP 4.5 (low) and RCP 8.5 (high), and two time horizons, 2055 (2040 – 2069) and 2085 (2070 – 2099). Geospatial projections for temperature change are not used, due to the consistency of the projections across the county as well as the low resolution of the downscaled projections.


Precipitation
Precipitation scenarios are defined by the two future emissions pathways, RCP4.5 (low) and RCP8.5 (high), and two time horizons: mid-century (2040 – 2069) and end-of-century (2070 – 2099). Precipitation projections are not directly used in this analysis but are referred to as contributing factors in the fluvial flooding and landslide hazard analysis.

Wildfire
Wildfire projections are based on the same downscaled CMIP5 modeling, bias-corrected and downscaled for the C4CCA, with additional modeling performed by Dr. Anthony Westerling at University of California-Merced. The wildfire projections reflect mid-century (2040 – 2069) and end-of-century (2070 – 2099) change for both RCP4.5 (low) and RCP8.5 (high) emissions scenarios.

Sea Level Rise, Storm Surge, and Coastal Erosion
Sea level rise (SLR) rates over the coming century are both highly uncertain and relatively insensitive to emissions projections over the coming century. The rate of SLR lags increases in atmospheric carbon concentrations, so projected SLR is expected to occur regardless of emissions mitigation measures taken in the next century. Because of this difference, SLR projections are not presented for given years and emissions scenarios (unlike temperature and precipitation projections). Instead, coastal hazard scenarios are defined by the amount of increase in sea levels, relative to the year 2000 (1991 – 2009), as well as a target year and a degree of risk aversion associated with the target year. These scenarios should be read as a conservative approach to appreciating the SLR risk by the target year, given the degree of risk aversion. In general, low risk-aversion scenarios represent a best-estimate of how high sea levels will rise by a certain date. Because it is usually more costly to protect existing infrastructure than it is to plan future infrastructure with SLR in mind, near-term projections (2030 and 2060) use the higher risk aversion scenarios. For long-term planning (2100), both lower and higher risk-aversion scenarios are provided.

Where possible this assessment seeks to establish parity with the City of Santa Barbara Sea Level Rise Adaptation Plan (CSB Plan). The CSB Plan sets SLR scenarios based on the California Ocean Protection Council’s SLR Guidance 2018 Update. The SLR-based scenarios address coastal hazards under 0.25, 0.75, and 2.0 meters of SLR, compared to current conditions (1991 – 2009). The 0.25m SLR scenario roughly corresponds to possible relative sea levels heights in 2030 using medium-high risk aversion (i.e., a

21 In this context, “risk aversion” is a technical term used by the California Ocean Protection Council referring to the probability of an SLR outcome by a certain timeframe. The OPC provides guidelines for the use of three different categories of risk aversion: low risk aversion (projected SLR values for a specific year with a 17% chance of being exceeded), medium-high risk aversion (values with a 0.5% chance of being exceeded), and extreme risk aversion (no quantifiable probability – based on a single modeled worst-case scenario).
23 OPC 2018
1-in-200 chance sea levels will reach 0.25m by 2030). The 0.75m SLR scenario corresponds to possible sea level heights in 2060 under medium-high risk aversion and corresponds to sea levels in 2100 assuming low risk aversion (i.e., a 66% probability that sea levels will reach 0.75m by 2100). The 2.0m SLR scenario corresponds to possible sea level heights by 2100 under medium-high risk aversion.

Climate Hazard Projections
Climate change is expected to affect human systems in a large number of ways, with some better-understood than others. In order to facilitate this assessment, climate hazards are limited to those which are expected to cause known damage or disruption to built infrastructure and transportation systems. These hazards are outlined in Table 2 and described below.

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24 OPC 2018
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<td>GIS Hazard Analysis (RCP4.5/8.5; Mid/End-Century)</td>
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<td>GIS Hazard Analysis (Low/Mid/High SLR)</td>
<td>GIS Hazard Analysis (RCP4.5/8.5; Mid/End-Century)</td>
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<td>Intercity Routes</td>
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<td>Intercity Stations</td>
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<td>U.S. Highways</td>
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<td>GIS Hazard Analysis (Low/Mid/High SLR)</td>
<td>GIS Hazard Analysis (RCP4.5/8.5; Mid/End-Century)</td>
</tr>
</tbody>
</table>
Temperature

Extreme temperature projections are defined by the historical range of temperatures in the county and are provided as a single data point for each scenario (rather than as geospatially-referenced data). Temperature projections are sourced from the C4CCA regional analysis for the central coast.25

Precipitation

Precipitation projections are not directly used in this analysis but are referred to as contributing factors in the fluvial flooding and landslide hazard analysis. Although regional differences exist in precipitation projections across Santa Barbara County, these are not addressed with geospatial analysis for two reasons: first, projections in extreme precipitation reflect changes in likelihood of extreme events, but the relative difference in change of likelihood is marginal relative to the impact of an extreme event occurring; and second because the geospatial resolution of downscaled projections is too low to have significant meaning beyond a regional summary. Projected changes in extreme precipitation events are sourced from the C4CCA.26 Figure 13 shows the regional differences in extreme precipitation projections across the central coast, including Santa Barbara county.27

Wildfire

The approach used to address wildfire hazards combines two geospatial data sources: projections of changes to fire hazard given different climate scenarios, and existing fire hazard maps produced by the California Department of Forestry and Fire Protection (Cal Fire). This combination of geospatially projected hazards with current hazard zones gives a better estimation of acute impact probability, where projected increases in hazard over a wide area align with known local hazards.

Projected Average Area Burned

Wildfire projections are based on custom modeling developed by Dr. Anthony Westerling at UC Merced for the C4CCA, and hosted on the CalAdapt website.28,29 The wildfire projections are based on the same downscaled CMIP5 modeling as the temperature and precipitation projections in the C4CCA. Wildfire projections present average area burned in each grid cell in each year of the future, given outbreak of a fire. Each grid cell in the downscaled model is approximately 36 km², and the model outputs area burned in hectares.

The data provided by CalAdapt represents annual averages, and include projections based on four different Global Climate Models, or GCMs (HadGEM2-ES, CNRM-CM5, CanESM2, and MIROC5). First, the model results are averaged across these four models to address the uncertainty associated with climate

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25 Langridge 2018
26 Langridge 2018
27 Langridge 2018
28 Westerling 2018
29 https://cal-adapt.org/tools/wildfire/
modeling projections. Second, the annual averages are grouped into three 30-year periods, centered around a representative year, and averaged together: 2000 (1986 – 2015), 2055 (2040 – 2069), and 2085 (2070 – 2099). These 30-year averages are used because the annual projections include the interannual variations for each projected year associated with weather (i.e., some years are hotter and some are cooler), and 30-year averages represent changes in average conditions.

**Fire Hazard Severity Zones**

Fire hazards are highly local, with factors such as presence of combustible fuel sources and geography making all the difference between the presence or lack of a hazard, regardless of climatic conditions. When evaluating threats to specific infrastructure, distances on the scale of meters can be determinative. While C4CCA projections address the change in fire risk for a given area, the resolution of these projections is insufficient to be used for hazard analysis for individual sites and systems. For this reason, local fire hazards are represented using existing fire hazard severity zone (FHSZ) maps generated by Cal Fire. FHSZs account for known vegetation, climate, and geophysical risk factors on the ground, and provide a snapshot of current fire hazard.

**Historical Fires and Fire Return Intervals**

Another important element for evaluating fire hazard is understanding how recently in the past an area has burned, and how much time is likely to be sufficient for fuel to reaccumulate and pose a fire risk. For this analysis, historical fires since 2000 have been layered with the wildfire hazard projections and the FHSZs to provide additional information about near- and long-term risk. Historical fire perimeters are sourced from Cal Fire. From the complete set of fires, only major fires since 2000 are extracted, using the Santa Barbara County Fire Department’s list of major fires. Fire return intervals (FRIs) from the U.S. Forest Service (USFS) also provide an indication of whether an FHSZ is at risk of another fire, given a recent burn. FRIs are based on the types of vegetation (and other factors) dominant in an area, and the historical average frequency of fires given these types of vegetation. Because climate change is likely to affect the underlying factors (water availability, temperature) that affect dominant vegetation within an area, climate change may affect FRIs in unknown ways. Research on the effect of climate change on fire regimes indicates that the subject is too uncertain and complex to say anything definitive.

**Fluvial Flooding**

As with wildfire, the fluvial flooding hazard analysis relies on both a current geospatial hazard zone dataset and long-term climate projections for the primary parameter affecting fluvial flooding hazard frequency and intensity. Geospatial hazards are based on the Federal Emergency Management Agency

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35 Westerling 2018
(FEMA) Flood Insurance Risk Maps (FIRMs), and projections of climate change impacts on extreme precipitation frequency and intensity are based on C4CCA projections.

**FEMA Flood Hazard Maps**
Localized flood hazards associated with floodplains and low-lying areas have been mapped by FEMA, with recent analyses focused on high-risk areas along Santa Barbara’s South Coast. The FIRMs provide detailed flood risk layers associated with a 100-year flood (i.e., a flood with a 1% chance of occurrence each year), based on historical flood stages in each river or stream.

**Extreme Precipitation Projections**
The primary driver of fluvial flooding events in Santa Barbara county is extreme precipitation events. Projected increases in extreme precipitation are sourced from C4CCA.

**Landslides**
Landslide hazards are affected by geological, ecosystem, and hydrological inputs. Slope angle, soil type and depth, and other mechanical factors are the primary drivers of slope stability, while large influxes of absorbed water into soils can trigger landslides in unstable slopes. Climate change can affect slope stability by increasing the frequency and intensity of extreme precipitation events, overloading soils with water and causing landslides. Wildfire can also affect slope stability, as fires destroy the surface vegetation and the associated root systems, reducing the slope’s ability to absorb water and accelerating the rate of debris runoff.

This study relies on existing hazard assessment data to locate potentially unstable slopes and the transportation network infrastructure which may be threatened by them. These hazards are highly localized, thus a geospatial hazard screening approach is used. This assessment also uses regional projections of changes in extreme precipitation and known landslide hazards identified by existing county planning documents.

**Landslide Hazard Maps**
Landslide hazard maps are based on the Santa Barbara County Comprehensive Plan’s Seismic Safety & Safety Element. The Comprehensive Plan’s slope stability study maps include a general survey of the county, excluding the Los Padres National Forest (NF) and Vandenberg Air Force Base (AFB). The Comprehensive Plan’s maps also include several detail maps of the South Coast, Santa Ynez Valley, Lompoc area, and Santa Maria-Orcutt area. The slope study ranks slope stability problem areas on a scale of 1 – 3, with ‘3’ indicating a high problem area. The study also indicates the possible variation from the assigned rating. Figure 14 shows the Comprehensive Plan’s landslide hazard map and legend.

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37 Langridge 2018
39 Langridge 2018
41 County of Santa Barbara 2015
This study uses digitized versions of the Comprehensive Plan’s general and detail maps, indicating slopes with a stability problem rating of 3, including slopes with no variation and possible variation. This is intended to be a ‘conservative screening approach.’

**SLOPE STABILITY, LANDSLIDES**

**SANTA BARBARA COUNTY**

![Map of slope stability and landslides](image)

Figure 14. Adapted from Santa Barbara Comprehensive Plan slope stability hazard map (general plan). Source: County of Santa Barbara 2015.

To ensure that landslide hazards are used to inform transportation network infrastructure hazards as accurately as possible, landslide hazard maps have been combined with flowlines from the USGS National Hydrography Dataset. Flowlines represent the direction that water will flow across a given area. In this analysis, flowlines are used to represent the potential directionality of landslide flow.

**Extreme Precipitation**

Precipitation projections for daily extreme precipitation are drawn from the C4CCA Central Coast chapter. Regional projections are used to distinguish projected changes in the South Coast and eastern portion of the county, from changes in the western portion and north coast.

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Known Hazards
Both the county Comprehensive Plan and the current Santa Barbara Multi-Jurisdictional Hazard Mitigation Plan (SBMHP) include inventories of known landslide hazards.\textsuperscript{44,45} Roads and areas inventoried in these reports have been given additional mention in this assessment.

Coastal Hazards
Three distinct coastal hazards are considered in this analysis: nuisance flooding (also called tidal flooding), storm-surge flooding, and cliff erosion. Due to the geography of the county’s shoreline, flooding hazards are generally projected along the South Coast, and coastal erosion hazards are generally projected along the north coast. All coastal hazard maps are based on projections from the United States Geological Service (USGS) Coastal Storm Modeling System (CoSMoS) for Southern California and Central California.\textsuperscript{46,47} CoSMoS projections include inundated areas during normal high tides, inundated areas during extreme storms, and coastal cliff erosion along the north coast.

CoSMoS model projections are generated using a large number of numerical simulations that represent the range of uncertainty in model inputs. This means that in each scenario, the CoSMoS modeling results present a mean projection, as well as an uncertainty range around that projection. To provide insight into the range of potential outcomes, this analysis includes both the hazards associated with the central (mean) estimate projection, as well as the maximum uncertainty (i.e., most risk-averse) projection. The uncertainty band represents two standard deviations around the mean projection (i.e., 95% confidence interval).\textsuperscript{48}

Nuisance Flooding
Rising sea levels mean that during average conditions, regular tidal action may begin to inundate coastal areas and threaten county infrastructure. This type of flooding that reflects normal conditions is called nuisance or tidal flooding. Nuisance flooding represents changes to the coastal floodplain. Tidal heights are not constant year-round, so to reflect a conservative estimate of tidal flooding, CoSMoS hazard projections for average conditions correspond to projected water levels associated with a spring tide (occurring approximately twice every month).\textsuperscript{49} This represents a near-worst-case scenario, but one that occurs frequently enough to represent approximately average conditions.

\textsuperscript{44} County of Santa Barbara 2015
\textsuperscript{49} Barnard et al. 2018a
Storm Surge Flooding

Extreme storms can push additional water onto land, causing significant flooding. The full coastal flooding impact of sea level rise takes into account the combination of higher relative sea levels, tidal action, storm surge, and wave action to generate a complete model of water run-up given differing storm conditions. CoSMoS projections include inundation areas associated with a 100-year storm (i.e., a storm with a 1% chance of occurring each year over the next century). The 100-year storm is modeled using dynamically downscaled waves, winds, and sea-level pressures from the CMIP5 climate models. In the CoSMoS simulations, 100-year storms are assumed to occur during a high spring tide (i.e., near worst-case scenario).\footnote{Barnard et al. 2018a}

Figure 15 provides a visual example of the different elements affecting storm surge heights.\footnote{National Hurricane Center (NHC). 2009. “Storm Surge Overview.” Miami, FL: National Centers for Environmental Prediction, National Hurricane Center. https://www.nhc.noaa.gov/surge/.} As with nuisance flooding, projections used in this analysis include both the central estimate, as well as the conservative maximum of uncertainties estimate (95% confidence interval).\footnote{Barnard et al. 2018a}

Coastal Cliff Erosion

Coastal cliff erosion is a process modeled using a combination of sea levels, cumulative storm return periods, and other inputs taken from CMIP5 Global Climate Models (GCMs). These inputs are combined with field observations such as historical cliff retreat rate, nearshore slope, coastal cliff height, and mean annual wave power, as part of Coastal Storm Modeling System (CoSMoS). Cliff retreat hazard projections are taken from the CoSMoS v.3.1 model for California’s Central Coast.\footnote{Barnard et al. 2018b}

As with nuisance and storm surge flooding, projections of cliff erosion in this analysis include both the central estimate for each scenario, as well as the conservative maximum of uncertainties estimate (95% confidence interval).\footnote{Barnard et al. 2018b}

North Coast Flooding

In addition to the analysis above, SLR-enhanced storm surge flooding projections are used for segments of the north coast subject to flooding (specifically the mouths of the Santa Ynez River and Honda Creek). These flooding projections are based on the modeling produced for the 2016 County of Santa Barbara Sea Level Rise Coastal Resiliency Project Phase 2 and address a 100-year storm surge.\footnote{Revell Coastal. 2016. 2016 County of Santa Barbara Sea Level Rise Coastal Resiliency Project Phase 2 Final Technical Report. Santa Cruz, CA: Revell Coastal. September 16.} The County of
Santa Barbara projections use different sea level rise scenarios than this analysis, so nearest-neighbor scenarios have been selected (Table 3).

Table 3. Comparison between SLR scenario heights in this analysis vs. County of Santa Barbara hazard projections.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>This Study</th>
<th>County of SB Coastal Resiliency Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near Term, High Risk Aversion</td>
<td>0.25m</td>
<td>0.26m</td>
</tr>
<tr>
<td>Medium Term, High Risk Aversion/Long Term, Low Risk Aversion</td>
<td>0.75m</td>
<td>0.78m</td>
</tr>
<tr>
<td>Long Term, High Risk-Aversion</td>
<td>2.0m</td>
<td>1.53m</td>
</tr>
</tbody>
</table>

Prioritization of Transportation Systems

Santa Barbara county is served by a wide array of transportation systems, however not all roads, facilities, and services are equally as important to the people and businesses of the county. This assessment highlights ten high-priority transportation systems based on their importance according to three key factors: current use (e.g., ridership), emergency access, and access to low-income communities. These high-priority transportation systems are examined in detail to better inform the ways in which climate hazards affect transportation assets.

Economic Impact/Current Use Conditions

An important factor contributing to prioritization of transportation network vulnerabilities is the impact of damage or disruption to the local economy. In most cases, current use is used as the proxy for economic impact, predicated on the presumption that current traffic, ridership, or freight tonnage is an appropriate proxy for the relative importance of a transportation system.

For urban, rural, and inter-city roads, modeled traffic parameters from SBCAG are the determinant of usage. Although these numbers do not account separately for private or commercial cars, trucks, buses or other vehicles, total traffic is considered sufficient for identifying the most heavily used roads in the county. Modeled traffic consists of annual average daily trips along each road segment.

Bus transit is the primary public transit mode in Santa Barbara county. SBCAG modeled data on transit route ridership is used to determine the relative importance of each bus route for the county’s transit users. Because these routes are mapped geospatially, important transit corridors (i.e., road segments that serve multiple bus routes) can also be identified. Passenger data is not available for individual bus transit stops, so expert elicitation is used to determine the most important transit stops in the county (in this case, the full-service MTD Transit Center in the City of Santa Barbara).

Rail transit is only provided along the Union Pacific railroad by Amtrak. Although ridership data may be relevant, the entire railroad corridor is considered high-priority due to its unique nature in the county, so ridership data is unnecessary. The county includes five Amtrak stations: Santa Barbara, Goleta,
Carpinteria, Guadalupe, and Lompoc-Surf. Total annual passengers at each station is identified using Amtrak data.56

The Santa Barbara Municipal Airport (SBA) is identified as the high-priority airport infrastructure in the County. FAA data indicates that SBA has the greatest number of enplanements and largest volume of landed cargo traffic of all six of the county’s civilian airports.57

Bicycle route usage data has been collected from the Santa Barbara Bicycle Coalition’s 2016 Bike Count.58

Emergency Access
Although no official emergency corridors are designated in Santa Barbara county, some corridors are identified for their value for emergency access purposes. In determining the emergency access value of a road, comparisons are made to alternative routes between large communities within the county. For roads that serve as crucial links with alternative routes adding multiples in terms of distance or travel time, emergency access is considered a meaningful justification to qualify the route as high-priority.

Low-Income Communities
Although current usage represents the aggregate needs of a community, evaluating the importance of a transportation system based only on current use may fail to appreciate the importance of the system for disadvantaged or vulnerable populations that may have fewer alternatives given a disruption. For this reason, this analysis categorically evaluates priority transportation systems for low-income communities.

For this study, low-income communities are defined by California Assembly Bill 1550 (AB 1550). AB 1550 defines a low-income community as “census tracts with median household incomes at or below 80 percent of the statewide median income.”59 As part of its Priority Population Investments program, the California Air Resources Board (CARB) created a geospatial dataset for every county indicating which census tracts are low-income communities.60

Transportation network systems that serve low-income communities are considered in the prioritization of hazards. Santa Barbara County’s low-income communities include both urban and rural areas, including downtown Santa Barbara, Isla Vista, Carpinteria, Lompoc, Santa Maria, Guadalupe, and rural communities in the northeast corner of the county (Figure 16 and Figure 17).

Subjective Risk Assessment of High-Priority Transportation Systems

For high-priority transportation systems, this study provides a risk scoring system to allow comparison of climate hazard risks faced by each system for each hazard. This approach combines the quantitative projections and geospatial analyses used in this assessment with the subjective input of expert analysts to provide a subjective probability score and consequence score. Together, these scores are used to create a subjective risk assessment profile for each high-priority system. The probability score takes into account the geospatial exposure and frequency/projected change in frequency of exposure differently for coastal and climate hazards (Table 4). The probability score also calculates two scores for mid-century and end-of-century impacts. The consequence score considers the cost of damage, the cost and
duration of disruptions, and the effect on low-income communities to calculate an aggregate consequence score (Table 5).

Table 4. Scoring matrix for subjective probability score.

<table>
<thead>
<tr>
<th>Probability Score</th>
<th>Geospatial exposure</th>
<th>Frequency of exposure</th>
<th>Change in frequency/ intensity of exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>- : Hazard is not relevant to this system</td>
<td>0: No exposure</td>
<td>0: Never</td>
<td>0: Decreasing frequency/intensity</td>
</tr>
<tr>
<td>1: Small areas of exposure or uncertain exposure</td>
<td>1: 1-in-100 event (e.g., 100-year storm surge)</td>
<td>1: Slight increase or uncertain projection with increases and decreases</td>
<td></td>
</tr>
<tr>
<td>2: Multiple, small, discontinuous areas of exposure, or one moderate area of exposure</td>
<td>2: More frequent than 1-in-100 (e.g., 100-year fluvial flooding under increasing precip. Projections)</td>
<td>2: Moderate increase in frequency</td>
<td></td>
</tr>
<tr>
<td>3: Extensive area(s) of exposure central to system</td>
<td>3: Much more frequent than 1-in-100 (e.g., wildfire in ‘very high’ zones)</td>
<td>3: High increase in frequency</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Scoring matrix for subjective consequence score.

<table>
<thead>
<tr>
<th>Consequence Score</th>
<th>Cost of Damage</th>
<th>Cost of disruption</th>
<th>Duration of disruption</th>
<th>Low-income communities</th>
</tr>
</thead>
<tbody>
<tr>
<td>- : Hazard is not relevant to this system</td>
<td>0: No or marginal damage</td>
<td>0: No or marginal disruption cost</td>
<td>0: No disruption</td>
<td>0: No LICs affected</td>
</tr>
<tr>
<td>1: Light damage (&lt;10% replacement cost)</td>
<td>1: Small disruption or cost of disruption is small</td>
<td>1: Brief disruption on the order of a day</td>
<td>1: No proximity to LICs, but connection via other transportation systems</td>
<td>1: No proximity to LICs, but connection via other transportation systems</td>
</tr>
<tr>
<td>2: Heavy damage, less than total replacement cost</td>
<td>2: Heavy disruption, or moderate disruption with heavy cost</td>
<td>2: Moderate disruption on the order of days to a week</td>
<td>2: One or two LICs</td>
<td>2: One or two LICs</td>
</tr>
<tr>
<td>3: Total damage, system requires near complete reconstruction</td>
<td>3: Total disruption of a major system</td>
<td>3: Disruption greater than a week</td>
<td>3: Multiple LICs or central system to one LIC</td>
<td>3: Multiple LICs or central system to one LIC</td>
</tr>
</tbody>
</table>

Aggregate near-term/ mid-century Coastal hazards: average of frequency and geospatial conditions (current and 0.25m SLR) Climate hazards: average of geospatial exposure and mid-century change in frequency (RCP4.5+RCP8.5)

Aggregate long-term/ end-of-century Coastal hazards: average of frequency and geospatial conditions (0.75m and 2.0m SLR) Climate hazards: average of geospatial exposure and end-of-century change in frequency (RCP4.5+RCP8.5)

Aggregate consq. Average of all consequence parameters
Climate Change Projections and Hazards

For Santa Barbara County, the warming global climate means higher temperatures, rising sea levels, and changes to precipitation patterns. These changing climatic conditions affect the frequency and intensity of existing natural hazards, including wildfire, landslides/mudslides, inland and coastal flooding, and coastal cliff erosion.

Temperature Projections

Average Temperatures

By the end of this century, average temperatures in the county are projected to increase by 4.8 – 7.4°F. Table 6 indicates the range of projected outcomes as reported in the California Fourth Climate Change Assessment. Although increasing temperatures are the cause of many hazards that threaten county infrastructure, changes in average temperatures are not considered a direct threat to the transportation network.

Table 6. Projected changes to average temperature in Santa Barbara County in degrees Fahrenheit. Source: Langridge 2018.

<table>
<thead>
<tr>
<th>Year</th>
<th>Medium-Low (RCP 4.5)</th>
<th>High (RCP 8.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical (1961 - 1990)</td>
<td>68.6</td>
<td>68.6</td>
</tr>
<tr>
<td>2055 (2040 - 2069)</td>
<td>72.3</td>
<td>73.4</td>
</tr>
<tr>
<td>2085 (2070 - 2099)</td>
<td>73.4</td>
<td>76</td>
</tr>
</tbody>
</table>

Extreme Temperatures

Extreme temperatures are defined by the historical range of temperatures in the county, and C4CCA’s analysis sets the threshold at the 98th percentile day over the historical period (1961 – 1990). In Santa Barbara County, this temperature is 87.5°F, which is a relatively moderate high temperature, compared to other counties in the central coast region. Historically, 4.3 days per year could be expected to exceed 87.5°F. By mid-century, this could be 12 – 17 days, and by the end of the century, this could be 17 – 33 days, depending on the emissions scenario.

In general, extreme temperatures are a relevant threat to transportation infrastructure. For example, extreme high temperatures can lead to railroad tracks buckling (also known as sun-kinking), or to asphalt failure. However these hazards typically occur at temperatures more extreme than those projected in Santa Barbara County. Due to the county’s mild climate moderated by its proximity to the Pacific Ocean, temperature extremes are not expected to be a significant threat to transportation networks in the county.

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61 Langridge 2018
62 Langridge 2018
However, extreme temperatures may impact bicycle mode share. Studies of factors affecting bicycle ridership in urban settings find strong correlation with temperature and precipitation, as well as weaker effects associated with other factors like humidity and daylight hours. In general, higher temperatures increase ridership up to a peak, after which higher temperatures reduce ridership. These effects may reflect a particular local threshold as well. Efforts to quantify the effects of elevated temperatures on ridership in Montreal showed that a large increase over long-term averages (+9°F) caused a 14% increase in ridership in cold winter months and an 11% decrease in warm summer months. This finding is similar in other cities, where in Seattle, the peak ridership was modeled to occur on days with an average temperature of 75°F, but in San Diego, California, peak ridership occurred at 69°F. Because of Santa Barbara’s temperate climate, projected increases in extreme temperature may not consistently push temperatures above modeled thresholds where ridership decreases. Moreover, any reduction associated with extreme temperatures may be offset by increases in ridership during the rest of the year due to the projected increase of annual average daily minimum temperatures.


66 Miranda-Moreno and Nosal 2011

67 Ermagun et al. 2017
Coastal Hazards
Coastal hazards are projected over the coming century in three different scenarios set for three different timeframes and levels of risk aversion. Near-term projections address SLR of 0.25m, which is expected by 2030 given a medium-high level of risk aversion (i.e., 0.25m represents the very high end of the probability distribution of SLR levels by 2030). A mid-term projection of 0.75m of SLR is projected to occur by 2060 given a medium-high level of risk aversion, and by 2100 for a low level of risk aversion (i.e., 0.75m by 2100 is more likely than not). In the long-term, 2.0m of SLR is projected for 2100, given a medium-high level of risk aversion.68

Nuisance Flooding
Nuisance flooding indicates that at high tides low-lying areas are subject to regular inundation from typical wave action. Despite the name, areas subject to nuisance flooding are candidates for retreat-based adaptation, as regular tidal flooding will become the norm. The location and extent of nuisance flooding correlates with the vulnerability to storm-surge flooding, as powerful storms will increase water levels even higher. Nuisance flooding poses an existential threat to transportation infrastructure, as regular flooding will result in accelerated corrosion of rails, signposts, or electrical equipment and erosion or settling of roadbeds. Nuisance flooding of transportation assets will typically indicate that they will either need to be systematically protected or relocated.

The greatest areas of concern for nuisance flooding by mid-century are the Goleta Slough/Santa Barbara Municipal Airport, the Santa Barbara harbor, and the Carpinteria Salt Water Marsh Reserve. In the 0.75m SLR scenario, nuisance flooding becomes a significant threat to the Santa Barbara and Carpinteria waterfronts and threatens segments of the Union Pacific and US 101 corridors. In the 2.0m scenario, substantial portions of central Santa Barbara and Carpinteria are subject to regular tidal flooding, the Santa Barbara Municipal Airport is entirely flooded, and multiple lengthy segments of critical roadways are subject to tidal flooding.

68 OPC 2018
Near Term, High Risk Aversion – 0.25m
Under 0.25m of SLR, regular tidal flooding of beaches and tidal infiltration into the Goleta Slough and the Carpinteria Salt Marsh will extend beyond current levels, although no direct impacts to existing high-priority transportation infrastructure are expected. The only segments of county transportation infrastructure projected to be affected by 0.25m of SLR in spring tide conditions are small parts of the Refugio State Beach bike path near the intersection of Venadito Canyon Road with Calle Real.

Central Estimate vs. Maximum Uncertainty
For each coastal hazard projection, hundreds of simulations are run in the CoSMoS model. Each simulation incorporates slight variations of assumed parameters (e.g., wind speed and direction). Modelers then combine these simulation outputs and take the average flooding scenario; this becomes the projection’s central estimate. To provide an additional risk-averse perspective on potential flooding outcomes, this assessment also includes the maximum uncertainty scenario, which includes the maximum flooding from all simulations, up to two standard deviations from the central estimate.

Medium Term, High Risk Aversion/Long Term, Low Risk Aversion – 0.75m
Under 0.75m of SLR, substantially more infrastructure is affected by nuisance flooding. In the central estimate projection, the Goleta Slough is largely inundated, as are the westernmost service roads for the Santa Barbara Municipal airport (Figure 19). Nuisance flooding also affects the Obern Trail bikeway at the Slough’s inlet. This trail is a high-priority bicycle route.

In Santa Barbara, nuisance flooding may inundate parking lots for the Santa Barbara Harbor, as well as overtopping the Harbor’s protective jetty. In Carpinteria, nuisance flooding may overtop sections of Avenue del Mar and Sand Point Rd.

Figure 19. Nuisance flooding of the Goleta Slough area under 0.75m of SLR.
If the maximum range of uncertainty is considered, significant areas surrounding the Goleta Slough are at risk of inundation. These include the airport tarmac, runways, service roads, parking, and parts of the terminal. Hollister Avenue may be overtopped (btw. Los Carneros and Aero Camino), and South Los Carneros Rd. may be inundated between Hollister and El Colegio. Several neighborhoods and their surface streets may also be flooded, as well as sandspit road and the Goleta Pier parking areas (Figure 19).

In Santa Barbara, under the maximum range of uncertainty, the Harbor parking areas and service roads are all subject to inundation, as well as the eastern portions of Ledbetter Park parking (Figure 20). Shoreline Drive may be overtopped near Harbor Way, and substantial sections of Cabrillo Boulevard and its intersecting surface streets may flood along the waterfront (from west of Castillo St. to Chase Palm Park), at Cabrillo Park (between Calle Puerto Vallarta and South Milpas St.) and at the Zoological Gardens. The Bike path parallel to Cabrillo is likewise subject to flooding. Surface streets between East Yanonali St. and East Cabrillo Boulevard and between State St. and Garden St. may flood, as may a section of the Union Pacific Railroad between Anacapa St. and Garden St., and a second section between Garden St. and South Calle Cesar Chavez.

In Carpinteria, substantial flooding of surface roads, the Union Pacific Railroad, and Carpinteria Avenue in and around the Saltwater Marsh Reserve may occur (Figure 21). Padaro Lane may experience flooding near the junction with US 101. Future bicycle infrastructure planned for this area may also be affected, and planning should take into account future exposure. Carpinteria Avenue may experience nuisance flooding from Holly Ave to the junction with US 101, as may the railroad. Neighborhood streets between the City Beach and the Marsh may flood as well.
Minor flooding at Refugio state beach, including inundation of the eastern parking/camping area is possible under the maximum range of uncertainty. Similarly, at the Gaviota State Park campground, the parking area and camping areas may flood under the maximum range of uncertainty.

**Long Term, High Risk-Aversion – 2.0m**

Under 2.0m of SLR, nuisance flooding may extend over the entire grounds of the Santa Barbara Municipal Airport, overtop Hollister Avenue, South Los Carneros Rd., and other surrounding roads and neighborhood roads. Sections of Ward Memorial Boulevard (CA 217) near San Jose Creek may be subject to flooding, as may transit routes serving the affected roads, and a potential future extension of the San Jose Creek Bikeway (Figure 22). The Obern bikeway/pedestrian trail and parking/access to Goleta Pier are subject to flooding.

The UCSB Lagoon may regularly flood with high tides, and access to Campus Point trails and Isla Vista Beach may be overtopped.

In Santa Barbara, widespread nuisance flooding of waterfront roads, rail, and pedestrian/bike paths are projected in the 2.0m scenario. Shoreline Drive/Cabrillo Boulevard is overtopped from Santa Barbara City College to the junction with US 101, excepting the stretch between South Milpas Street and Niños Drive. Surface streets from Between Cabrillo and Yanonali Street, and from South Quarantina St. to Castillo St. may experience widespread nuisance flooding. The Union Pacific railroad may flood from Santa Barbara Station to South Milpas St. and overtopped near South Salinas St. In central Santa Barbara, access ramps to US 101 are also projected to experience flooding (Figure 23).

The Andree Clark Bird Refuge is projected to experience flooding, including the adjacent segment of US 101 and other surrounding roads. Beachfront surface streets may also experience flooding, including Posilipo Lane.

In Carpinteria, the Union Pacific railroad and adjacent Padaro lane and Santa Claus Lane may flood along a substantial length of the shoreline and in central Carpinteria (Figure 24). US 101 is projected to flood north of the Salt Water Marsh Reserve, as is Carpinteria Avenue and adjacent surface streets. Substantial areas of central Carpinteria may flood, including all blocks between Palm Avenue and Ash Avenue between the railroad and the shore, and blocks west of Holly Avenue between Carpinteria...
Avenue and the railroad. Access roads to US 101, including Reynolds Avenue and Santa Claus Lane may flood as well. Substantial areas of Carpinteria City Beach, including parking and access roads are expected to flood.

![Figure 24. Nuisance flooding in Carpinteria under 2.0m SLR.](image)

In the maximum uncertainty flooding scenario, nuisance flooding extends beyond Hollister Ave to the north, and further into neighborhoods east and west of the Airport. Ward Memorial Boulevard (CA 217) is subject to greater flooding from Hollister Avenue to San Jose Creek.

![Figure 25. Nuisance flooding of the Devereux Slough area under 2.0m SLR.](image)

In the maximum uncertainty case, the entirety of the Devereux Slough could flood, including Slough Rd serving the UCSB West Campus, Venoco Road, and residential roads and parking areas abutting the Slough (Figure 25). At the Arroyo Burro Beach County Park, segments of Cliff Drive may flood.

In Santa Barbara, extensive neighborhood flooding north of US 101 is possible, from Garden Street to Nopal Street as far north as East Ortega St. The Santa Barbara Amtrak Station and train platforms may flood, as may the parking area and adjoining access Streets. State Street may flood as far north as West Gutierrez St. Pershing Park and its parking areas are projected to flood, as are the parking areas serving the La Playa Field at Santa Barbara City College.
Near the Andree Clark Bird Refuge, flooding of the US 101/Union Pacific railroad may extend from South Canada Street to Los Patos way, including access ramps, the Old Coast Highway, some surface streets north of US 101, and the zoo train in the Santa Barbara Zoological Gardens (Figure 26). In Montecito, Channel Drive may be overtopped near the Four Seasons.

In Carpinteria, surface street flooding extends in all directions, threatening greater stretches of US 101, surface streets north of US 101 around the Salt Marsh Reserve, the Villa Real access road to US 101, and the Carpinteria Amtrak station.

West of Goleta, some segments of the Union Pacific railroad may flood, including near Venadito Canyon Road, Tajiguas Creek, Cañada del Gato, and Cañada del Cojo.

*Figure 26. Nuisance flooding in the Andree Clark Bird Refuge under 2.0m SLR.*
**Storm Surge Flooding**

Under current conditions, storm surge flooding associated with a 100-year storm already threatens substantial transportation assets. Because of the low annual probability of a 100-year storm, adaptation responses to flooding risk are different than those associated with nuisance flooding. For example, while a road or railroad may be disrupted or damaged by storm surge flooding, the right of way need not necessarily be abandoned.

However, much of the inundation associated with a 100-year storm in current conditions is substantially similar to storm surge flooding in SLR scenarios in the central estimate. Differences between current conditions and SLR-scenario storm surge flooding are smallest farther inland, and greatest along the coast. For this reason, storm surge flooding in neighborhoods north of Devereux Slough in Goleta appears largely similar across scenarios, while flooding along the Santa Barbara waterfront is much greater in SLR scenarios than under current conditions.

**Current Conditions**

Under current conditions, the Santa Barbara waterfront is only at risk of flooding in the maximum uncertainty case. In the central estimate, no infrastructure is currently threatened. However, in Goleta, the entire Slough and Airport grounds are potentially subject to flooding, including the runways, taxiways, service roads, parking, and terminal buildings (Figure 27). Flooding may overtop Hollister Avenue, South Los Carneros Rd., and other adjacent surface roads, including residential roads east and west of Ward Memorial Boulevard (CA 217). Flooding in the Devereux Slough may extend deep into residential neighborhoods north of the Slough and flood Phelps road and adjacent streets. In Carpinteria, large areas of the waterfront, including the Salt Water Marsh Reserve, the Union Pacific railroad, Carpinteria Avenue, and substantial areas of Carpintera northeast of Linden Avenue may flood (Figure 28).

In the maximum uncertainty scenario, flooding in Goleta extends well outside the Goleta Slough, and connects with flooding from the Devereux Slough. Substantial segments of Hollister Avenue and Ward Memorial Boulevard (CA 217) are flooded (Figure 27). In a worst case scenario, Isla Vista’s low-income communities may be left with Storke Road as the only access route in or out of town, posing serious
emergency access challenges. In Santa Barbara, the harbor and harbor access roads and parking may flood. East Cabrillo Boulevard may flood from Chase palm Park to State Street, and the surface streets between East Cabrillo and the railroad may flood as well. The railroad may flood north of Chase Palmer park. In Carpinteria, flooding is extended to include US 101 and the Carpinteria Amtrak station (Figure 28).

**Near Term, High Risk Aversion — 0.25m**

In Goleta, storm surge flooding may inundate the entire Slough and Airport grounds, including the runways, taxiways, service roads, and parking, but excluding the main terminal building (Figure 29). Flooding may overtop Hollister Avenue, South Los Carneros Rd., and other adjacent surface roads, including residential roads east and west of Ward Memorial Boulevard (CA 217). Flooding in the Devereux Slough may extend deep into residential neighborhoods north of the Slough and flood Phelps road and adjacent streets.

In Santa Barbara, waterfront flooding may affect the Harbor parking and waterfront bike path, but no other infrastructure.

In Carpinteria, storm surge flooding may inundate large areas of central Carpinteria, similar to the area affected by nuisance flooding in the 2.0m scenario. This area includes city blocks west of Linden Avenue and south of US 101. The Union Pacific railroad and Carpinteria Avenue may flood in central Carpinteria. The Reynolds Avenue access ramps to US 101 may also flood.

In the maximum uncertainty case, Goleta flooding extends from the Airport in every direction, overtopping Hollister Avenue in three places, and overtopping South Los Carneros Rd. to flood UCSB housing north of El Colegio Rd. Flooding north of Devereux Slough is also more extensive, flooding most streets south of Phelps Rd, as well as many to the north. To the east of the Airport, blocks between Fairview Avenue and Ward Memorial Boulevard (CA 217) are at risk of flooding, as are the arterials.
In Santa Barbara, storm surge flooding may overtop Shoreline Drive/Cabrillo Boulevard near Santa Barbara City College and from Castillo St. to Chase Palm Park. The waterfront and Harbor may experience widespread flooding. Flooding may extend inland along surface streets as much as one block between Castillo Street and Garden Street. The Union Pacific Railroad may also flood between Garden Street and South Calle Cesar Chavez. Cabrillo Park and surrounding streets may also flood, as well as Cabrillo Boulevard near the Zoological Gardens.

In Montecito, flooding may affect coastal streets like Posilipo Lane and Miramar Beach.

In Carpenteria, flooding from the Salt Marsh reserve may extend north, overtopping US 101 and affecting surface streets in residential blocks to the north (Figure 30). Flooding in central Carpinteria may extend eastward, affecting blocks to Elm Avenue and Sawyer Avenue, and affecting the Amtrak station. Padaro Lane may also experience flooding northwest of the junction with US 101.

Medium Term, High Risk Aversion/Long Term, Low Risk Aversion – 0.75m
In Goleta, storm surge impacts are substantially similar to 0.25m and current conditions scenarios in the central estimate. The most significant difference in inundated areas is that the UCSB campus lagoon may flood under 0.75m SLR scenario.

In Santa Barbara, waterfront flooding may inundate much of the Harbor, including parking, access roads, and bike/pedestrian paths. Flooding may also overtop Cabrillo Boulevard adjacent to the Harbor between State and Castillo Streets (Figure 31).
In Carpinteria, storm-surge related flooding may affect larger segments of Avenue del Mar and Sand Point Road than in the 0.25m SLR scenario (Figure 32). However, flooding in central Carpinteria may be substantially similar to the 0.25m scenario.

In the maximum uncertainty case, flooding in Santa Barbara may extend much farther inland than in the 0.25m scenario, inundating Garden Street and US 101 access ramps, the railroad, and waterfront surface streets from the City College to Cabrillo Park. Flooding along East Cabrillo Boulevard may also extend further. In Montecito, storm surge flooding in the maximum uncertainty case may reach deeper inland than the 0.25m SLR scenario, affecting greater lengths of beachfront roads like Posilipo Lane, Edgecliff Lane, and Maceta Lane. In Goleta, flooding may be similar to the 0.25m case, however higher flooding may overtop South Patterson Avenue.

Long Term, High Risk-Aversion – 2.0m
In Goleta, storm surge flooding may extend well-beyond the 0.75m scenario, with coastal flooding along Del Playa Drive in Isla Vista, portions of the UCSB campus adjacent to the lagoon, and areas in west campus such as Slough Road exposed to flooding (Figure 33). Flooding of areas adjacent to the Goleta Slough may extend well beyond prior scenarios. To the west of the Slough, flooding may extend deep into residential neighborhoods north of El Colegio Road, inundating large segments of South Los Carneros and Mesa Roads. Large segments of Hollister Avenue may be overtopped, as well as blocks to the north. Ward Memorial Boulevard (CA 217) may be flooded along San Jose Creek, and flooding of surface streets may extend to South Patterson Avenue. Along the coast, Goleta Beach State park, as well as parking and access to Goleta Pier may be completely inundated.

Figure 32. Storm surge flooding in Carpinteria under 0.75m SLR.
Figure 33. Storm surge flooding in the Goleta area under 2.0m SLR.

To the west of Goleta, flooding along Haskell’s Beach may overtop Hollister Avenue in some places. Roads in Naples may experience flooding. The Union Pacific railroad may experience flooding in multiple locations along the South Coast, including at El Capitan State Beach, near Refugio State Beach, near Gaviota, and multiple other locations (Figure 34).

Figure 34. Storm surge flooding at El Capitan State Park under 2.0m SLR.
In Santa Barbara, storm surge flooding may extend deep into the city center, inundating blocks between Garden Street and North Milpas Street up to East de la Guerra Street (Figure 35). Most flooding may occur between Garden Street and North Calle Cesar Chavez. Extensive flooding may occur between the beach and US 101. The Santa Barbara Amtrak station platforms may flood, as well as significant sections of the railroad from Los Patos Way to the Amtrak station. US 101 may flood between Sycamore Creek and the junction with East Cabrillo Boulevard. The entire waterfront may flood, inundating Cabrillo Boulevard/Shoreline Drive from the junction with US 101 to La Marina, and again near the intersection with Salida del Sol. Large parking areas for the Santa Barbara City College may also flood. Additional flooding may overtop Cliff Drive near the Arroyo Burro Beach County Park.

In Montecito, storm surge flooding may inundate coastal blocks, including overtopping the railroad and US 101 near Posilipo Lane (Figure 36). Channel Drive, Bonnymede Drive, and Edgecliff Lane may also experience flooding.
In Carpinteria, storm surge flooding may extend north from the Salt Marsh Reserve, overtopping both the railroad and US101, as well as its access roads, and the surface streets in neighborhoods north of the highway (Figure 37). This flooding extends beyond the 0.75m scenario. In central Carpinteria, flooding may extend east to Linden Avenue, inundating the Amtrak platform, as well as northeast from the City Beach to include blocks up to 6th Street. Northwest of Carpinteria, flooding may inundate Padaro Lane and Santa Claus Lane, as well as overtop US 101. In Summerland, flooding may overtop the railroad and short segments of Wallace Avenue. The railroad may also flood in eastern Carpinteria, along the city border.

In the maximum uncertainty scenario, flooding in Goleta may extend in every direction, affecting greater segments of roads affected in the central scenario. Austin Road along More Mesa Beach may also be affected by flooding.

In Santa Barbara, the maximum uncertainty scenario likewise extends the potential flooding of the 2.0m storm surge scenario, including potential flooding of the waterfront blocks west of Mission Creek up to West Montecito Street, the entire area of the Santa Barbara Amtrak station, and additional blocks in central Santa Barbara. US 101 may also be overtopped near Garden Street, and North Milpas Street may be overtopped north of East Cota Street. Flooding of blocks east of Milpas Street and north of US 101 is also more extensive.

In Montecito and Summerland, the maximum uncertainty scenario includes flooding of greater areas of the waterfront in all locations.

In Carpenteria, the maximum uncertainty scenario includes even greater residential blocks north of US 101, extending up to Racquet Club Drive, Venice Lane, and El Carro Lane east of Linden Avenue. In central Carpinteria east of Linden Avenue, flooding may extend beyond 6th and 7th streets.
Cliff Erosion and Flooding – North Coast

Along the north coast, the most significant threats to infrastructure are to the Union Pacific railroad. Eroding coastal cliffs along the railroad’s right of way threaten the long-term use of the railroad at multiple points along its right of way. North of Long Horn Canyon, 0.25m of SLR could erode the rail bed. Farther north at Cañada del Jolloru, 2.0m of SLR could threaten the rail infrastructure. Just south of Point Arguello, another hazard occurs where 0.75m of SLR could threaten the rail tracks (Figure 38). Finally, multiple hazards occur near Space Launch Complex 4, where only 0.25m of SLR could threaten the rail tracks (Figure 39).

In addition to the railroad, several shoreline roads face hazards from cliff erosion. Point Sal Road in Vandenberg Air Force Base faces threats from coastal cliff erosion in two locations: near the intersection with Combar Road, erosion under even 0.25m of SLR threatens the current location (Figure 40); farther south near Lions Head, the current road location is within the range of maximum uncertainty of erosion under 2.0m of SLR (Figure 41). Cliff erosion under a 2.0m SLR scenario may also erode away Jalama Beach Road south of Jalama Beach State Park.

Coastal flooding along the north coast is projected to be most severe along the mouth of the Santa Ynez River. Under 0.26m69 of SLR during a 100-year storm surge, Ocean Beach State Park may flood, as well as Ocean Park Road and the Lompoc lead of the Union Pacific railroad. Under 0.78m and 1.53m of SLR, this flooding may extend farther inland, affecting the same infrastructure.

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69 Due to differences in SLR scenarios used in this analysis and the County of Santa Barbara Coastal Hazard Assessment, north coast flooding scenarios correspond to 0.26m, 0.78m, and 1.53m of SLR, for near term, medium term, and long term scenarios, respectively. Storm surge flooding along the north coast is the only coastal hazard for which this difference is noted.
Figure 40. Coastal cliff erosion under SLR scenarios near Point Sal Road in Vandenberg Air Force Base

Figure 41. Coastal cliff erosion scenarios near intersection of Point Sal Road and Combar Road in Vandenberg Air Force Base
Wildfire Hazards

Wildfire is the most pressing climate change hazard threatening the county’s transportation systems in the near future. California communities and government agencies have extensive experience managing wildfires and fire risk, and Santa Barbara County has experienced two of the state’s largest wildfires in history, including the Thomas Fire in 2017 and the Zaca Fire in 2007.  

Fires affect transportation systems through both damage and disruption. Wildfire damage to road infrastructure is typically limited to damage to road furniture and signage, but rapid changes to vegetation on slopes surrounding roads can affect slope stability and runoff rates. Wildfires can also damage vehicles trapped on roads affected by wildfire, rapidly destroying large numbers of vehicles. By contrast, disruptions to roads (and the transit routes that use them) and railroads caused by wildfires can be very costly, depending on the size of the fire and the length of the closure. During the 2017 Thomas Fire, CA 154 was closed intermittently through San Marcos Pass from Santa Barbara to CA 246. This closure diverted road traffic from Santa Barbara to the Santa Ynez Valley to US 101 through the Gaviota Pass, nearly doubling the length of the trip.

Railroad tracks, signaling, and other infrastructure are likewise subject to damage and disruption. Wooden ties can be burned in fires, as can wooden bridge or culvert structures. Extremely hot fires may kink tracks, as well. Electrical signaling equipment can be damaged by fire or fouled by soot. As with roadways, disruption to railroad operations can be costly as well.

Wildfires have even greater potential to damage the county’s transportation systems by increasing the risk of landslides and flooding. Fires that occur on unstable slopes or on slopes directly above infrastructure systems acutely increase the threat of landslides and runoff to those systems. Wildfires destroy the vegetation and root systems on slopes that serve the dual purpose of absorbing moisture and holding soil in place. As the combined hazards of increased fire severity and increased extreme precipitation intensity grow over the coming century, managing these threats will pose an even greater challenge.

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70 Cal Fire 2018
72 Langridge 2018
Current Wildfire Hazard

Current wildfire threat in Santa Barbara County is highest in the Santa Ynez and San Rafael Mountains and their foothills. Figure 43 shows the fire threat (including a characterization of both fire frequency, as well as the fire hazard, or severity of a fire if one is ignited) as well as the perimeters of major fires since 2000.\(^73\)\(^74\) Past fires are included in Figure 43 because recent fire activity reduces the threat of a reoccurrence in the following years and decades, as fuel supply is limited. How long a recent fire will reduce the threat of reoccurrence depends on several factors such as the dominant type of vegetation. The United States Forest Service tracks vegetation types and has identified the Fire Return Interval (FRI) for the Santa Ynez Mountains. Most forests adjacent to the South Coast have current FRIs between 22 and 35 years (Figure 44).\(^76\)

\(^73\) Santa Barbara County Fire Department 2018
\(^74\) Cal Fire 2018
\(^76\) USFS 2011
Current wildfire hazard is also a reflection of recent climate changes. The recent fires in Santa Barbara County may have been made more intense due to climate change. A comparison of historical climate conditions (1961-1990) to the last 30-year period (1986-2015) reveals that projected change in climate hazard has increased in the San Rafael Mountains, while decreasing elsewhere in the county (Figure 45).
Climate Change Projections

In general, it is well understood that warmer and drier conditions increase wildfire hazard. However in the central coast region, the complex interaction of temperatures and precipitation with vegetative growth and fuel accumulation indicate that warmer temperatures do not necessarily increase fire season length and water availability to the same extent that they do in other areas, such as the snow-dominated Sierra Nevada mountains. Because warmer temperatures may increase climatic water deficit (i.e., dry soils) and reduce vegetation growth, increases in projected temperatures may reduce future fire hazard.

Projected fire hazard based on Westerling 2018 shows the complex story over the coming century. In both the high- and low-emissions scenarios, and in both mid- and end-of-century time horizons, some areas of the county see large increases in fire hazard, and other areas see large decreases (Figure 46, Figure 47, Figure 48, and Figure 49).

Figure 46. Projected change in wildfire hazard severity by 2055 (2040-2069) in the low-emissions scenario (RCP4.5).

77 Langridge 2018
78 Langridge 2018
79 Westerling 2018
Figure 47. Projected change in wildfire hazard severity by 2055 (2040-2069) in the high-emissions scenario (RCP8.5).

Figure 48. Projected change in wildfire hazard severity by 2085 (2070-2099) in the low-emissions scenario (RCP4.5).
Due to the distribution of dangerous vegetation and other fuel sources, wildfire hazards are highly localized, while climate change affects the change of these hazards over a much longer timeline. To address these disparities in scale, this analysis compares existing FHSZs to projected changes in fire intensity in each downscaled grid cell. The resulting analysis highlights areas where fire risk is projected to grow the most, while using high-resolution FHSZs to identify transportation systems potentially at risk.
Geospatial Wildfire Hazards

South Coast
Along the South Coast, significant populated areas remain threatened by ‘very high’ FHSZs which were not burned in the Thomas Fire. These areas include most of Montecito north of US 101 and the foothills east and north of central Santa Barbara (Figure 50). These hazards threaten large neighborhoods and arterials that serve them, including CA 192 (Foothill Road, Mountain Drive, Mission Ridge Road, Starwood Drive, Sycamore Canyon Road, and East Valley Road), CA 144 (Sycamore Canyon Road), Mission Canyon Road (serving the MTD 22 bus route), East Los Olivos Street, Alameda Padre Serra, Hot Springs Road (serving the MTD 14 bus route), Olive Mill Road, San Ysidro Road, Sheffield Drive, Ortega Ridge Road, and Toro Canyon Road.

Figure 50. FHSZs along the South Coast, from Carpinteria to Santa Barbara, including outline of 2017 Thomas Fire. Fire hazard projections show low-emissions scenario (RCP4.5) by 2085.
To the west of Santa Barbara and north of Goleta, ‘very high’ FHSZs are largely constrained to the more sparsely populated foothills north of Cathedral Oaks Road (serving MTD route 10). However, CA 154 transits an extensive area of ‘very high’ hazard (although some of this area was burned recently in the 2009 Jesusita fire). Additionally, North San Marcos Road, North Fairview Ave, North La Patera Lane, Glen Annie Road, Winchester Canyon Road, and Vereda Leyenda all transit ‘very high’ FHSZs (Figure 51).

Figure 51. FHSZs along the South Coast, from Santa Barbara to Goleta. Fire hazard projections show low-emissions scenario (RCP4.5) by 2085.
To the west, from Goleta to Gaviota, most of the US 101/Union Pacific railroad corridor abuts or transits ‘very high’ FHSZs, although much of this area has burned recently in the 2016 Sherpa fire and the 2004 Gaviota fire (Figure 52).

The South Coast is projected to see either small increases or decreases in fire hazard by 2055 (2040 – 2069), regardless of scenario. In general, this indicates that fire hazard is not likely to change appreciably from the ‘new normal’ of the last 30 years. In the long-term (2070-2099), projections diverge considerably. Under a low-emissions scenario (RCP4.5), the South Coast is projected to experience a consistent, moderate increase in fire severity. Conversely, under a high-emissions scenario (RCP 8.5), the South Coast is projected to experience a slight to moderate decrease in fire hazard severity. This unexpected outcome may be associated with the vegetation response effect described in the C4CCA whereby higher temperatures reduce water availability. This reduction in turn reduces fuel growth, and associated fire hazard.

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80 Langridge 2018
Santa Ynez Valley
In the Santa Ynez Valley, most of the primary roads transit at least one very high FHSZ, with much of the span of the valley’s primary highways (US 101, CA 154, CA 246) in high FHSZs (Figure 53). South of the Santa Ynez River, US 101 crosses a very high FHSZ in the Santa Ynez Mountains north of Goleta Pass. North of the river, US 101 spans high FHSZs nearly its entire length to Santa Maria. CA 246 is likewise in a ‘high’ FHSZ in the entirety of the Santa Rita Hills. CA 154 transits a ‘very high’ FHSZ along the South Coast of Lake Cachuma (some of this area burned in the 2017 Whittier fire), and is in ‘high’ FHSZs for much of the rest of its span.

Figure 53. FHSZs in the Santa Ynez Valley, including projected changes to fire hazard in a low-emissions scenario by 2085.

The Santa Ynez Valley sits in an area that is projected to either see slight increases or decreases in existing fire hazard by 2055, depending on the emissions scenario. This uncertainty is exacerbated by the end-of-century, with a low-emission scenario showing significant increases in fire hazard, and a high-emissions scenario showing significant decreases. As in the South Coast, this counter-intuitive response to climate change may be the result of the effect described in Langridge 2018, whereby elevated temperatures reduce vegetation growth. However, other factors may be at play in the Westerling model.

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81 Langridge 2018
82 Westerling 2018
Lompoc Area

In the Lompoc Area, ‘very high’ hazard zones are present in the hills to the north and to the south, with many other areas classified as ‘high’ hazard. All of the major highways connecting Lompoc are overlapped by these zones at some point. To the south, CA 1 (San Julian Road, serving the Clean Air Express commuter routes from Lompoc to Goleta and Santa Barbara) transits a large ‘very high’ FHSZ to the northwest of Gaviota Pass, and runs adjacent to two zones in the hills southeast of Lompoc. Part of the latter zones has burned as recently as 2007 in the Cemetery fire. The rest of this stretch is also dominated by ‘high’ fire hazard areas. Notably, much of this area has not been affected by recent burns.

To the north, CA 1 (Cabrillo highway, serving the Colt bus route 4 and Breeze bus Santa Maria to Lompoc routes), transits a large ‘high’ FHSZ, and abuts one ‘very high’ zone on the route to Vandenberg AFB. This section of CA 1 is the most heavily used road in or out of Lompoc. Additional arterials serving Vandenberg Village and the Mesa Oaks/Mission Hills area also cross this ‘very high’ zone, including Harris Grade Road, Burton Mesa Boulevard, and Purisma Road. To the east, CA 246 (serving the Colt bus Santa Barbara Shuttle route) transits several large ‘high’ FHSZs which have not burned in recent years.

To the south, San Miguelito Road also transits a large ‘very high’ FHSZ.

The Lompoc area is projected to see increased fire hazard severity in all scenarios and time horizons, ranging from slight to severe. By the middle of the century, areas to the north and west of Lompoc (particularly Vandenberg Village) are projected to see the highest increases in fire hazard in the entire county, regardless of the emissions scenario. In the low-emissions scenario, Lompoc and its surrounding foothills to the east, south, and west are projected to also see moderate increases in fire hazard severity. In the high-emissions scenario, projected increases in the south and east may be slight-to-moderate. By the end of the century (2070-2099), projected increases in fire hazard severity are uniformly moderate-to-high in the low emissions scenario. This indicates that the severe hazard increase in Vandenberg Village in the mid-century may moderate by the end of the century, even as other surrounding areas continue to see increasing wildfire hazard. In the high-emissions scenario, mid-century increases are also projected to moderate, with the potential for a slight decrease in fire hazard in the foothills directly south of Lompoc.
Santa Maria Area
In the Santa Maria area, FHSZs are largely constrained to the foothills south of Guadalupe and Orcutt (Figure 54). These areas are largely classified as ‘high’ hazard areas, with some small ‘very high’ areas. Both CA 1 and US 101 transit these ‘high’ zones, with the only recent burning north of Vandenberg AFB in the 2000 Harris fire. The Union Pacific railroad and Black Road/West Lompoc Casmalia Road also transit these ‘high’ hazard zones from Casmalia. South of Guadalupe, Brown Road transits one of the areas ‘very high’ hazard zones near its junction with CA 1.

![Map of Santa Maria area with FHSZs and projected changes to fire hazard in a low-emissions scenario by 2085.](image)

Figure 54. FHSZs in the Santa Maria area, including projected changes to fire hazard in a low-emissions scenario by 2085.

In the Santa Maria area, areas to the west and south of Santa Maria and Orcutt are projected to see moderate increases in fire hazard by the middle of the century (2040 – 2069) in all scenarios. Central Santa Maria and Orcutt may see a slight increase or decrease in fire severity, depending on the scenario. By the end of the century (2070 – 2099), fire hazard severity is projected to increase slightly from the mid-century projections in the low-emissions scenario, with hazards in the populated area increasing slightly to moderately from the current baseline. In the high-emissions scenario, fire hazards may increase to the east of the cities.
Landslide Hazards
Landslides pose significant threats in Santa Barbara county with multiple modes of potential landslides across the county’s slopes. Generally, landslides threaten roads and railroads in the county’s mountainous regions, particularly where roads transit along the base of large slopes. Earth movements underlying transportation infrastructure can cause buckling or washout of roads, large mud or debris flows can overtop roads, and cause substantial damage and lengthy disruption.

Landslides can include several different modes of impact. Shallow landslides can cause debris to flow onto roads at the base of a slope (Figure 55). In these cases, the disruption may be brief and the damage to road foundations limited. In the worst-case scenario, deep-seated landslides like the Mud Creek landslide in San Luis Obispo County can destroy entire segments of road as the underlying soil flows as a bulk unit down slope (Figure 56). The Mud Creek landslide followed an extensive period of above-average precipitation along the central coast.

Climate Change Impacts
Changes to precipitation that saturate and overload the water-bearing capacity of soils are the main climatic factor increasing the likelihood of landslides in the county (especially when combined with vegetation loss due to wildfire). Extreme precipitation hazards are projected to increase in severity across the county, as the overall variability of

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85 Langridge 2018
precipitation increases. Atmospheric rivers – extreme precipitation events most associated with inland flooding – are projected to increase in frequency across California. Atmospheric rivers are weather events, so although there are differences in the projected average increase in precipitation across the county, the threat of atmospheric rivers is still relevant to all locations.

Geospatial projections of changes to extreme precipitation indicate larger increases in the southeastern portion of the county in a high-emissions scenario. Relative to historical climate (1976–2005), the wettest day of the year may see 6–12% more precipitation in a low-emissions scenario by the end of this century (2070–2100). In a high emissions scenario, the central and eastern parts of the county could see an increase of 18–24% in precipitation, with up to 30% increases projected for the far southeast corner of the county by the end of this century; west of Buellton, precipitation on the wettest day may increase 12–18% (Figure 57). Combined with existing landslide hazards, projected increases in precipitation indicate a growing landslide hazard, particularly along the southeast coast.

Landslide hazards are also intensified by vegetation loss caused by recent wildfire. Vegetation prevents slope erosion, so sudden vegetation loss followed by intense rainfall in the following years can produce rapid rain-driven erosion and sediment runoff. The Montecito Debris Flows in 2018 following the 2017 Thomas fire are recent examples of the hazards posed by these modes of sediment transport. Notably, the areas affected by the Montecito debris flow were not indicated as ‘high’ problem areas in the county’s existing landslide hazard maps.

Projected changes in wildfire across the county are relevant to the threat of landslides at any given point in the future, however geospatial analysis is far more effective in the period immediately following a fire. Due to the heightened risk of sudden debris flows on recently-burned slopes, County planners should consider these urgent and developing threats as they occur in the future.

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86 Langridge 2018
87 Langridge 2018
88 Langridge 2018
89 Langridge 2018
Geospatial Hazards

South Coast
The Comprehensive Plan’s Seismic Safety and Safety Element has identified several areas with known land sliding hazards in the South Coast.90 These areas are represented geospatially in this analysis and include:

- Foothills in the Summerland area
- Foothills of the South Coast – from Santa Barbara west to Gaviota Pass
- Hope Ranch area – west of Lavigia Hill to Goleta
- Sea cliffs along the coast from Santa Barbara to Gaviota, particularly those with out-of-slope dips

Additionally, the SBMHP has identified areas and roads subject to rain-induced landslides.91 including:

- Palomino Road in Mission Canyon
- Gibraltar Road in Cielito
- Glen Annie Road in Goleta
- Refugio Road west of Goleta
- Ortega Hill Road in Summerland
- Stagecoach Road near Lake Cachuma
- Painted Cave Road
- Old San Marcos Road
- Gobernador Canyon Road east of Carpinteria
- East Mountain Drive in Santa Barbara

This analysis includes these known vulnerabilities and identifies additional potentially vulnerable areas. In the Summerland area, landslide hazards affecting Ortega Hill Rd may also impact US 101 and the railroad, due to the proximity of the corridor to high risk slopes (Figure 58). Surface roads in at-risk neighborhoods may also be affected, as well as bus routes along US 101 and the stops along Ortega Hill Road (MTD route 20).

Figure 58. Summerland area landslide hazards

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90 County of Santa Barbara 2015
91 County of Santa Barbara 2017
In Santa Barbara, landslide hazards in Eucalyptus Hill pose threats to surrounding arterials, with a specific threat to South Salinas Street, which serves the MTD Route 2 bus (Figure 59).

![Figure 59. Eucalyptus Hills landslide hazard areas](image)

In the foothills, streets in Mission Canyon, Northridge Estates, and Foothill sections are all in the hazard zone. San Marcos Pass Road (CA 154) abuts small areas of hazardous slopes near San Antonio Creek (Figure 60). North San Marcos Road and North Patterson Avenue also transit landslide hazard zones.

![Figure 60. Landslide hazard areas in Santa Barbara foothills.](image)
North of Goleta, landslide hazard zones encroach on Cathedral Oaks Road, Glen Annie Road, and Storke Road, as well as surface streets on Cathedral Oaks Road west of Glen Annie Road. These roads include those that serve the MTD route 23 bus, and the Dos Pueblos HS AM Booster route. Neighborhood streets off Winchester Canyon road also lie in a landslide hazard zone (Figure 61).

Figure 61. Landslide hazard areas in western foothills.

From Goleta to Gaviota, landslide hazard zones threaten the US 101 corridor, including the Union Pacific railroad in a nearly contiguous stretch (Figure 62).

Figure 62. Landslide hazards along US 101 corridor from Goleta to Gaviota.
West of Gaviota, landslide hazards overlap the railroad through much of Hollister Ranch and the Jack and Laura Dangermond Preserve (Figure 63).

**Figure 63. South coast landslide hazard areas west of Gaviota.**

**Santa Ynez Valley**

In the Santa Ynez Valley, there are two major known hazard areas identified in the Consolidated Plan:  

- Solvang area south of the Santa Ynez River in the vicinity of, and east of Alisal Ranch
- Areas east and northeast of Los Olivos near the Los Padres National Forest boundary

The SBHMP identifies the following roads as threatened by known landslide hazards:  

- Figueroa Mountain Road at the Los Padres NF boundary
- Santa Rosa Road (CA 246) west of Buellton
- Mail Road and Drum Canyon Road west of Buellton
- Point Sal Road

This analysis identifies San Marcos Pass Road (CA 154) as the most significant landslide hazard in the county. CA 154 transits the southern shore of Lake Cachuma in an extended landslide hazard zone, with an additional smaller exposure near the Crawford Airport south of the Santa Ynez River (Figure 64). In addition to significant vehicle traffic, this segment serves the Amtrak express bus route.

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92 County of Santa Barbara 2015
93 County of Santa Barbara 2017
To the West of Buellton, the foothills on the north and south banks of the Santa Ynez River expose both CA 246 and Santa Rosa Road to landslide hazards (Figure 65). CA 246 abuts unstable slopes at Cañada de los Palos Blancos, about three miles west of Buellton. CA 246 serves the Colt Santa Barbara Shuttle bus route connecting Santa Barbara and Lompoc. Additional roads transiting or adjacent to landslide hazard zones include Sweeney Road and Mail Road.
North of Buellton, US 101 transits two landslide hazard zones to the south and north of Jonata Park (Figure 66). US 101 is a major express route, with this segment carrying Central Coast Shuttle’s Santa Maria to LAX bus route, Clean Air Express’ Santa Maria to Santa Barbara and Santa Maria to Goleta bus routes, Greyhound’s San Luis Obispo to Los Angeles bus route, and Amtrak’s Thruway 768 SB route. The landslide hazard zones may also threaten Jonata Park Road.

Figure 66. Landslide hazard zones north of Buellton.

In Solvang, a small landslide hazard zone overlaps High Meadow Drive, and may affect CA 246 in central Solvang (Figure 67). Adjacent to this section of CA 246 is Alamo Pintado Road, where the Santa Ynez Valley Transit bus routes A and B have stops. To the southeast of Solvang, South Refugio Road also transits a large hazard zone.

Figure 67. Landslide hazard zone in Solvang.
Finally, to the north and northeast of Los Olivos, large landslide hazard zones abut the Los Padres NF. Both Foxen Canyon Road and Figueroa Mountain Road transit large sections of the hazard areas.

Lompoc Area
The Comprehensive Plan identifies a known hazard area near Lompoc south of the Santa Ynez River. Additionally, vulnerable roads identified in the SBMHP include:

- Jalama Road through the Jack and Laura Dangermond Preserve
- Sweeney Road north of the Santa Ynez River
- San Miguelito Road past the Imerys mine

The foothills south of Lompoc pose a landslide hazard to significant lengths of CA 1 between Gaviota and Lompoc. Likewise, landslide hazards threaten San Miguelito Road south of Lompoc and Santa Rosa Road along the south bank of the Santa Ynez river (Figure 68). CA 1 is served by the Clean Air Express Santa Barbara to Lompoc and Goleta to Lompoc routes, important commuter bus routes.

Figure 68. Landslide hazards south and east of Lompoc.

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94 County of Santa Barbara 2015
Southwest of Lompoc, the Union Pacific railway is threatened by additional landslide hazard zones (Figure 69). North of Lompoc, Harris Grade Road transits a landslide hazard zone as well.

Figure 69: Landslide hazard zones southwest of Lompoc.
Santa Maria Area

The known hazard areas in the Santa Maria area are the mountains south of Guadalupe and east of Point Sal. The SBHMP identifies Point Sal Road from US 1 to Vandenberg AFB as a vulnerable asset. Using the landslide hazard map, this analysis confirms and extends these findings, identifying Point Sal Road, West Lompoc Casmalia Road, and Black Road as potentially vulnerable segments between CA 1 and Casmalia (Figure 70). The railroad transits this pass as well and is likewise exposed to these landslide hazard areas. Brown Road south of Guadalupe is also in this zone.

![Image of landslide hazards southwest of Santa Maria](image)

**Figure 70. Landslide hazards southwest of Santa Maria.**

East of Santa Maria, Tepusquet Road and Colson Canyon Road transit a large landslide hazard zone along the boundary of the Los Padres NF, nearly the entire distance to CA 166 at the boundary with San Luis Obispo County.

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95 County of Santa Barbara 2015
Fluvial Flooding Hazards

Many of the hazards facing the county’s transportation infrastructure are related to existing fluvial flood risks (also called river/stream flooding or inland flooding). Many of these hazards are already well-understood due to modeling and hazard mapping conducted by the U.S. Federal Emergency Management Agency. FEMA has produced fluvial flood hazard zones associated with 100-year floods across the county (i.e., a flood with a 1% chance of occurring in any given year). However, FEMA’s flood maps are based on a statistical analysis of historical experience in the county and do not address the changing flood risks associated with climate change. As the intensity of extreme precipitation in Santa Barbara county is projected to increase through 2100, the hazard areas identified in the 100-year flood maps may become more likely as the century marches on.

Depending on the type of flood and transportation system, the location, and the flood intensity, flooding can cause nuisance disruption as roads become impassible, or it can cause significant damage as fast-moving flood water erodes roadbeds and culverts, destroys built structures, and damages electronic equipment. Flooding in Santa Barbara county can also bring significant sediment flow (also called debris flows, and in extreme cases mudslides). The difference between flooding with significant debris and sediment flows and landslides can be technical, however both outcomes can cause significant damage and disruption to transportation systems.

The connection between wildfire and flooding is similar to the effect of fire on landslides. Fires destroy vegetation and root systems that can hold moisture and stabilize soils. Slopes that have recently burned have less capacity to retain water during precipitation events and are more likely to erode. In the extreme case, mudslides like the 2018 Montecito debris flow are possible. However even in less extreme cases, fire can contribute to flooding. For example, recent flooding in February 2019 caused by heavy rains in the Santa Ynez mountains led to the closure of CA 154 between Santa Barbara and Santa Ynez.\(^\text{96}\) The flooding was caused not by a 100-year discharge event, but by a blocked culvert which allowed water to flow under the highway and into Lake Cachuma. Rains flushed debris (including rocks and dead branches) down the slopes which had been recently burned in the 2017 Whittier fire. The resulting clog caused the road surface to flood and parts to wash out, causing an extended closure of the critical route between Santa Barbara and communities to the north.

Extreme Precipitation Hazards

Projected changes to precipitation across Santa Barbara county indicate that the annual average amount of precipitation may decrease slightly by mid-century, and then increase slightly by the end of the century (relative to the period 1976 – 2005).\(^\text{97}\) However, extreme precipitation events are expected to grow more intense over the same period. As the variability of weather increases, atmospheric river events are projected to become more common across the central coast. Relative to historical climate (1976–2005), the wettest day of the year may see 6–12% more precipitation in a low-emissions scenario by the end of this century (2070–2100).\(^\text{98}\)

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\(^\text{97}\) Langridge 2018

\(^\text{98}\) Langridge 2018
Geospatial Hazards
Known flood hazards exist in FEMA’s Flood Insurance Risk Maps (FIRMs) which address fluvial flooding associated with a 100-year event. Unlike storm surge projections, these flood zones are based on historical data, and do not reflect projected future changes to precipitation.

South Coast
In Goleta, significant areas are exposed to fluvial flooding hazards. The infrastructure most affected by fluvial flooding is the area around the Santa Barbara Municipal Airport. As the highest-priority airport infrastructure in the county, this poses a high vulnerability. The fluvial flood hazards inundate the entire airport grounds, similar to the long-term high-risk aversion scenario for 2.0m SLR, according to CosMoS model. Affected areas include the airport tarmac, runways, service roads, parking, and the terminal. In addition, parts of US Route 101 are at risk for flooding, including Los Carneros County Park (Figure 71). Substantial lengths of the railroad are at risk of flooding, as is a portion of the Goleta Amtrak Station.

Figure 71. Fluvial flooding hazard zones associated with Santa Barbara Municipal Airport and Goleta Slough
To the east of the airport, the town of Goleta is at risk along Hollister Avenue, continuing up San Jose Creek. Atascadero creek exposes the new road that runs parallel to it, as well as South Patterson avenue and neighboring housing communities as far north east as El Sueno (Figure 72). Similar to current conditions and storm surge flooding in SLR scenarios in the central estimate, neighborhoods north of Devereux Slough in Goleta are at risk for flooding.

Figure 72. Fluvial flooding hazard zones associated with Goleta and along Atascadero Creek
In Santa Barbara, Mission Creek exposes large areas of central Santa Barbara to fluvial flooding hazards (Figure 73). These flood hazards affect many city blocks and threaten US 101, the Amtrak station, railroad, and important downtown arterials, as well as the transit routes they serve. Additional flooding in Santa Barbara is associated with Mission Creek along West Alamar Avenue from State Street to US 101, Sycamore Creek along the US 101 Corridor, and Burro, Arroyo to the west.

US 101 is exposed to fluvial flooding in multiple locations: from State Street to Castillo Street, between South Voluntario Street and the junction with East Cabrillo Street and near South Hope Avenue to the west. In central Santa Barbara, access ramps at Bath Street, Garden Street, Laguna Street, Salinas Street, and Los Patos way are in flood hazard zones, as are key feeders Haley Street, Gutierrez Street, North Milpas Street, and Garden Street. The railroad is in a flood zone from Castillo Street to Milpas Street, and Cabrillo Boulevard/Shoreline Drive is exposed to flooding hazard from the Santa Barbara City College Campus to Calle Cesar Chavez.

West of center, US 101 access streets West Pueblo Street, West Junipero Street and Oak Park Lane may flood, and West Alamar Avenue may flood from State Street to US 101. The railroad may also be overtopped near Pilgrim Terrace Drive. At South Hope Avenue, US 101, the railroad, and Access ramps may flood due to flooding associated with Burro, Arroyo. Associated flooding may affect Modoc Road and surface streets to the south (Figure 74).
To the east of central Santa Barbara, Sycamore Creek-related flooding may flood the section of US 101 and the railroad from South Voluntario Street to the junction with East Cabrillo Street (Figure 75). Sycamore Creek-related flooding may also affect Old Coat Highway, East Cabrillo Street, and nearby surface streets.

Fluvial flooding hazard zones affect the large majority of metro and commuter bus routes along some part of their route. Virtually every transit route in the county (208 out of 219 routes) is exposed to fluvial flooding hazards at some point on its route. Many of these flooding hazards occur on major inter-city roads such as US 101, CA 1, CA 154, or CA 246, or at minor creek or river crossings (Figure 76, Figure 77).
In Montecito, flooding hazard zones associated with Montecito Creek, Oak Creek, San Ysidro Creek, and Romero Creek dominate the fluvial hazard zones. These creeks are the primary channels for both flooding and debris flow during the 2018 mudflow disaster, as well as the recent flooding in 2019 that shut down sections of US 101.

Along the waterfront, large sections of US 101 are within the combined flood zones of all four channels; from Olive Mill Road to Humphrey Road, and from Hixon Road to Arroqui Road (Figure 78). Between US 101 and the waterfront, the railroad is also within extensive areas of flood zone, as are adjacent surface streets, including North and South Jameson Lane.
Along Montecito Creek, large sections of Olive Mill Road north and south of Hot Springs Road are within the flood zone (Figure 79). This stretch serves the MTD route 14 bus, as well as a primary access road to US 101. Montecito Creek flooding may also overtop East Valley Road to the north (CA 192). Flooding from Oak Creek may overtop CA 192 near San Ysidro Road, affecting the MTD route 14 bus. To the east, flooding from the east fork of Romero Creek threatens another section of CA 192. Finally, Romero Creek may also affect flooding on Sheffield Drive at San Leandro Lane, again affecting the MTD route 14 bus.

In Toro Canyon, flooding near Toro Canyon Road may overtop US 101 (Figure 80). Flooding of Toro Canyon Road to the north is also possible.
In Carpenteria, Paredon Arroyo Creek, Franklin Creek, Carpinteria Creek, and Rincon Creek are the primary fluvial flooding hazards, as well as potential flooding of the Salt Marsh Reserve (Figure 81).

As shown in Figure 81, flooding of Paredon Arroyo Creek may affect US 101 and Via Real along the waterfront, as well as Foothill Road (CA 192) farther inland. Flooding north of the Salt Marsh Reserve may overtop US 101 and the railroad near Cravens Lane, as well as flood the Carpinteria Avenue access ramp. In central Carpenteria, flooding from Franklin and Carpinteria Creeks may flood US 101 from Santa Ynez Avenue to Carpinteria Creek, as well as Carpinteria Avenue and the Reynolds Avenue, Linden Avenue and Casitas Pass Road access ramps and nearby surface streets. Near the waterfront, Carpinteria Creek may flood the railroad along 4th street.

Farther inland, fluvial flooding may flood large sections of Casitas Pass Road (CA 192 and CA 150) along Rincon Creek and near Shepard Mesa Drive.

![Figure 81. Fluvial flooding hazard zones in Carpenteria.](Image)
Santa Ynez Valley
The Santa Ynez River presents fluvial flood risk to its north and south banks along the communities of Buellton and Solvang (Figure 82). Portions of US 101 are at risk for fluvial flooding in Buellton, and Highway 246. There are various roads within neighborhoods between the two towns that are affected by flooding. Bus stops in Buellton on the corner of Avenue of Flags and Shadow Mountain Drive are in a flood hazard zone as well. There is one bus stop along Mission Drive in Solvang in a flood hazard zone.

The Santa Ynez River continues to the west from Lake Cachuma and poses risks to Highway 154 at the intersection of Armour Ranch Road. The town of Santa Ynez is exposed to fluvial flooding from Zanja de Cota Creek, which affects a small number of bus stops on the corner of Sagunto and Meadowvale Road (Figure 83). Flooding in Santa Ynez may also affect properties owned by the Santa Ynez band of Chumash Indians, particularly the triangular property bounded by Meadowvale Road, CA 154, and CA 246. Flood risk is also exposed through the Santa Agueda Creek branching to the north off the Santa Ynez River.
Lompoc Area
In the Lompoc area, there is significant fluvial flooding risk. To the west of the town of Lompoc, a neighborhood is vulnerable to flooding on the south bank of the Santa Ynez River. The Lompoc airport is slightly affected by flooding risk on the tarmac. The Lompoc Spur of the Union Pacific railroad is affected by fluvial flooding parallel to West Ocean Avenue and where it intersects Floradale Avenue (Figure 84). To the east of downtown Lompoc, the entirety of River Bend Community Park is in a flood hazard zone, including all parking lots for the public. The Santa Ynez River continues to the south west and poses a flood risk to the intersection of East CA-246 and River Park Road into Sweeney Road to the south.

Figure 84. Fluvial flooding hazard in Lompoc
Santa Maria Area

In the town of Santa Maria, most of the fluvial flooding risk is north of the Santa Barbara County Line. The Santa Maria River exposes areas of land to fluvial flooding hazards between Santa Maria and the coast to the west. These flood hazards affect an intersection of the Union Pacific railroad and an intersection of Cabrillo Highway in Guadalupe. One bus stop in downtown Santa Maria is affected by flood hazard zone on Preisker Lane parallel to US 101. Orcutt Creek exposes areas of land near Orcutt to fluvial floods, and a portion of US 101 to the east. (Figure 85).

To the east of Santa Maria, the Sisquoc River flows into the Santa Maria River in the Valley. Large areas of land are exposed to flooding hazards due to the river on both the north and south banks. Palmer Road stems south from the small town of Sisquoc, which is exposed to a flood hazard zone all the way to the intersection of Cat Canyon Road and on. Tupesquet Road is at risk for fluvial flooding as it crosses the Sisquoc River and intersects Santa Maria Mesa Road (Figure 86).
Southeast along US 101, Los Alamos is exposed to fluvial flooding hazard from San Antonio Creek. Streets in the northwest and central part of town are affected by flood zones. To the east of US 101, surface streets are affected by flooding hazards off of Price Ranch Road. The bus stop is likewise in a flood hazard zone on the corner of Bell Street and Centennial Street (Figure 87).

In New Cuyama, the entire town is at risk for fluvial flooding during a 100-year discharge event. Salisbury Canyon Wash exposes the town to the flood zones, which includes a large portion of CA 56. Perkins Road, which branches off CA 56 to the south is largely exposed to flood zones due to a branch of Salisbury Canyon Wash (Figure 88).
High-Priority Infrastructure Risk Assessment
Each transportation system faces all climate hazards simultaneously, and the impact of any individual hazard should be addressed in the context of other interconnected hazards (e.g., the connection between wildfire, fluvial flooding and landslides). Likewise, the scope of time over which hazards are projected to occur must be taken into account: if an asset faces no mid-century hazards, but is likely to face serious hazards by the end of the century, planning adaptation efforts earlier may reduce the impact to the overall transportation network. To provide insight into how these considerations affect the response to the county’s transportation network vulnerabilities, this assessment highlights ten individual high-priority transportation systems, describes the complete set of hazards, and provides a subjective risk assessment for the array of hazards facing the system.

High-priority transportation systems are selected based on their relative importance according to three key factors: current use (e.g., traffic or ridership), emergency access, and access to low-income communities. Where assets facing hazards are duplicative (e.g., bus routes that follow high-priority roads), alternative transportation systems with unique hazards are considered.

- US 101 Corridor
- Mission Drive (CA 246)
- San Marcos Pass Road (CA 154)
- Broadway/Orcutt Expressway (CA 135)
- Hollister Avenue/State Street
- Union Pacific Railroad
- Santa Barbara Municipal Airport/Goleta Slough
- Santa Barbara Train Station
- Breeze Bus Santa Maria – Lompoc
- UCSB Bicycle Paths

US 101 Corridor

Priority
US 101 is the most heavily used transportation system in Santa Barbara County. The road is most heavily used between Carpinteria and Goleta, and north of Santa Maria (in San Luis Obispo County). US 101 also serves as a crucial linkage between the South Coast and the north county, through Gaviota Pass. In addition to passenger and freight traffic, US 101 serves as the corridor for many inter-city transit routes, including the Clean Air Express commuter buses, the Central Coast Shuttle, Greyhound, Airport Shuttle, Los Alamos Shuttle, etc. Along the South Coast, US 101 also serves multiple intracity routes, including the MTD express routes. As the county’s primary transportation route, US 101 connects multiple low-income communities in Carpinteria, Santa Barbara, Goleta, and Santa Maria.

Hazards
Despite the highway’s importance to the county’s residents, businesses, tourists, and emergency services, the corridor is exposed to some of the most severe hazards in the county. From Carpinteria to Gaviota, US 101 is threatened by multiple flooding and landslide hazards. Low-lying sections in central Carpinteria and near the Andree Clark Bird Refuge in Santa Barbara are especially vulnerable to sea level rise and storm surge. However, in the worst case scenario (2m SLR and maximum of the uncertainty range), large sections in central Santa Barbara may also be vulnerable to inundation.
Fluvial flooding is also a hazard for US 101 and in the near-term, much of the road through Santa Barbara and Montecito lies in the existing 100-year flood plains, with additional stretches in Carpinteria and Goleta (Figure 89). In recent years, flooding and mudslides have shut down US 101 through Montecito at least twice. Devastating mudslides closed the road for nearly two weeks in January, 2018 (Figure 90).

One year later in February 2019, flooding once again closed US 101 in some of the same locations (along Olive Mill Road), albeit for less than one day. Similar patterns of flooding were experienced in the 1995 floods across the South Coast.

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**Figure 89. Portions of the US 101 corridor in Santa Barbara and Montecito that lie in current 100-year floodplain**

**Figure 90. US 101 at Olive Mill Road following 2018 mudslides. Source: Caltrans 2018.**

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Fluvial flooding is a threat in other areas of the county as well. In Santa Maria, US 101 may flood at the junction with North Broadway. In Buellton, US 101 may flood from Santa Rosa Road to the Damassa Road bridge (Figure 91). In Los Alamos, the Foxen Lane access ramps to US 101 may be affected by a 100-year flood (Figure 92).

The greatest landslide hazards facing US 101 likely exist in five sections: the coastal slopes between Goleta and Gaviota (Figure 93), a mountainous segment north of Buellton and south of the junction with CA 154 (Figure 94), a slope-abutting segment directly north of Las Cruces, and a segment in
Summerland, directly abutting the foothills. In terms of damage and disruption costs, the greatest traffic exists in the Summerland section, followed by the sections immediately west of Goleta.

Figure 93. Landslide hazard areas along US 101 from Gaviota to Goleta.

Figure 94. Landslide hazard areas on US 101 north of Buellton.
Wildfire hazards threaten US 101 primarily in areas in Montecito which were not burned in the Thomas Fire and areas along the South Coast between Goleta and Gaviota which were not burned by recent fires. In 2016, the Sherpa fire forced closure of this section of the highway for two days as winds pushed flames toward the corridor. An additional ‘very high’ hazard area exists directly south of Buellton.

**Subjective Risk Assessment**

Table 8, Table 9, and Figure 95 show the subjective risk scoring for hazards faced by the US 101 corridor currently and through 2100.

*Table 8. Subjective probability scoring indicating exposure of the US 101 corridor and frequency of impacts.*

<table>
<thead>
<tr>
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<th>Frequency of exposure</th>
<th>Geospatial exposure</th>
<th>Aggregate Probability</th>
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<td>Coastal Cliff Erosion</td>
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<table>
<thead>
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<th>Change in frequency/intensity of exposure</th>
<th>Aggregate Probability</th>
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<td>Landslides</td>
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</tr>
<tr>
<td>Fluvial Flooding</td>
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<td>1</td>
</tr>
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</table>

Table 9. Subjective consequence scoring, indicating consequences of an impact for the US 101 corridor were it to occur.

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<thead>
<tr>
<th>Event</th>
<th>Cost of Damage</th>
<th>Cost of Disruption</th>
<th>Duration of Disruption</th>
<th>Low-inc. comm.</th>
<th>Aggregate Consq.</th>
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</thead>
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<tr>
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<td>3</td>
<td>3</td>
<td>3</td>
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<td>Storm Surge Flooding</td>
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<td>2</td>
<td>3</td>
<td>2.25</td>
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<td>Coastal Cliff Erosion</td>
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<tr>
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<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Landslides</td>
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<td>3</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Fluvial Flooding</td>
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<td>3</td>
<td>2</td>
<td>3</td>
<td>2.25</td>
</tr>
</tbody>
</table>

Figure 95. Risk matrix for US 101 corridor indicating the relative degree of risk caused by potential hazards and how they are affected by climate change.
Mission Drive (CA 246)

Priority
CA 246 is a high-priority rural traffic route connecting the Santa Ynez Valley from Lompoc through Buellton, Solvang, and Santa Ynez. After US 101, CA 246 has the highest-traffic segments of other inter-city highways in the county. In addition to serving critical inter-city traffic, CA 246 serves Santa Ynez Valley Transit (SYVT), Express, Colt, Amtrak, and Chumash Casino bus routes.

Hazards
Compared to US 101, CA 246 faces less exposure to climate hazards, despite similar long-term trends. Fluvial flooding hazards threaten CA 246 at several places along the Santa Ynez River and its tributaries. Such risks exist at Faraday Street and Cuesta Streets in Santa Ynez, at Alamo Pintado Road in Solvang, in Buellton east of Ballard Canyon Road, and at the junction with US 101, at the culvert near the junction of Drum Canyon Road, and segments adjacent to the Robinson Bridge on the Santa Ynez River in Lompoc. In the major floods of 1969, the Robinson Bridge was closed by river water overtopping the bridge. Current climate projections from the C4CCA include increasing extreme precipitation hazard across the entire Santa Ynez River watershed, indicating an increased risk of severe fluvial flooding.

CA 246 does not serve any coastal areas, however west of Lompoc, the highway turns into West Ocean Ave, which faces storm surge hazards in the Santa Ynez River delta. CA 246 transits large ‘high’ FHSZs, however no ‘very high’ zones. This is largely due to the highway’s course through non-forested areas and the lack of substantial fuel adjacent to the highway. Although the highway does not transit ‘very high’ FHSZs, its course through the Santa Rita Hills is an area projected to see some of the largest increases in wildfire hazard under the low-emissions scenario.

Landslide hazards threaten CA 246 in two key areas: one west of Buellton, and one in eastern Solvang near High Meadow Road. In both cases, these hazard areas are coincident with ‘high’ FHSZs, indicating the potential for an acute risk of wildfire-induced landslides.

Figure 96. CA 246 junction with CA 154 east of Santa Ynez. Source: Caltrans 2016.

105 Langridge 2018
**Subjective Risk Assessment**

Table 10, Table 11, and Figure 97 show the subjective risk scoring for hazards faced by CA 246 currently and in the coming century.

*Table 10. Subjective probability scoring indicating exposure of CA 246 and frequency of impacts.*

<table>
<thead>
<tr>
<th>Frequency of exposure</th>
<th>Geospatial exposure</th>
<th>Aggregate Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current 0.25m 0.75m 2.0m</td>
<td>Near-term</td>
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<td>Nuisance Flooding</td>
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<td>Storm Surge Flooding</td>
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<td>Coastal Cliff Erosion</td>
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<td>- -</td>
</tr>
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<table>
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<tr>
<th>Geospatial exposure</th>
<th>Change in frequency/intensity of exposure</th>
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<td>Mid-century RCP4.5</td>
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<td>Mid-century</td>
</tr>
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<td>Wildfire</td>
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<td>1 2 1 2 0</td>
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<td>Landslides</td>
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<td>1 1 2 2 3</td>
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<tr>
<td>Fluvial Flooding</td>
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<td>2 1 2 2 3</td>
</tr>
</tbody>
</table>

*Table 11. Subjective consequence scoring, indicating consequences of an impact for CA 246 were it to occur.*

<table>
<thead>
<tr>
<th>Cost of Damage</th>
<th>Cost of Disruption</th>
<th>Duration of disruption</th>
<th>Low-inc. comm.</th>
<th>Aggregate Consq.</th>
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<td>Storm Surge Flooding</td>
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<tr>
<td>Coastal Cliff Erosion</td>
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<tr>
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<td>2</td>
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San Marcos Pass Road (CA 154)

Priority
From Santa Barbara through the San Marcos Pass, past Lake Cachuma, across the Santa Ynez Valley, and to the junction with US 101, CA 154 serves as a critical road for county traffic. Although its traffic use is very high, CA 154 is identified as priority infrastructure primarily due to its criticality as an important emergency access road connecting the South Coast to the Santa Ynez Valley. Given the exposure of US 101 along the coast from Goleta to Gaviota, CA 154 is the only alternative route to access the Santa Ynez Valley from the south. Additionally, CA 154 serves two bus transit routes: the Amtrak express route, and the Chumash Casino route.

CA 154 bounds the east end of the Oak Glen/El Sueno low-income community (between US 101 and Cathedral Oaks road and bounded on the west by North San Marcos Road). CA 154 also skirts the southern boundary of the census tract which includes most of Los Padres NF in the county; this tract is identified as an AB 1550 low-income community, although due to the size and extent of the tract, it is not clear the extent to which low-income communities within the tract are served by CA 154.

Hazards
San Marcos Pass Road (CA 154) faces extensive exposure to landslide hazards along the southern shore of Lake Cachuma and near the Santa Ynez River (Figure 98). Although this hazard is well-known, a section of the road was flooded and washed away in February 2019 during flooding in areas previously
burned by the 2017 Whittier Fire.\textsuperscript{106} Heavy rainfalls in the Whittier Fire zone washed debris downslope, clogging a culvert, and causing floodwaters and debris to flow above the road surface.\textsuperscript{107} As a result, the highway was closed from Santa Barbara to the junction with CA 246. In addition to the hazards along Lake Cachuma, the road also abuts small areas of hazardous slopes near San Antonio Creek. Due to the lack of alternative routes along this segment, a closure here would be particularly disruptive.

\begin{figure}
\includegraphics[width=\textwidth]{figure98}
\caption{Landslide hazards along the southern shore of Lake Cachuma.}
\end{figure}

CA 154 transits several ‘very high’ FHSZs, exposing the road to significant wildfire hazards. Most of the road’s span from Santa Barbara to the western corner of Lake Cachuma is within ‘very high’ FHSZs. However, many of these areas have burned in recent years. Directly north of Santa Barbara, the 2009 Jesusita fire burned much of the area east of CA 154, and the 2008 Gap fire burned areas to the west. Past San Marcos Pass, the 2017 Whittier fire burned areas south of Lake Cachuma (Figure 99). However between these areas and to the west of the Whittier burn area, areas of ‘very high’ FHSZs have not burned in decades and pose a risk to the road and the hillsides.

\textsuperscript{106} Santa Ynez Valley News 2019
Fluvial flooding hazards are primarily associated with bridges and culverts over major creeks or waterways. Depending on flooding height, inundation may be possible at the junction with US 101 west of Los Olivos, at the crossing of the Santa Ynez River/junction with Armour Ranch Road, at several points along Lake Cachuma, and at the intersection with Cathedral Oaks Road (CA 192) in Santa Barbara.

The two major factors affecting these climate hazards are extreme precipitation and wildfire. Projections of precipitation indicate increasing extreme precipitation hazards over the century in both low- and high-emissions scenarios. Wildfire projections diverge with projections of slight increases or decreases in fire hazard severity along the highway by mid-century. By the end of the century, fire hazard severity is projected to increase moderately in a low-emissions scenario and decrease moderately in a high-emissions scenario.

**Subjective Risk Assessment**

Table 12, Table 13, and Figure 100 show the subjective risk scoring for hazards faced by CA 154 currently and in the coming century.
Table 12. Subjective probability scoring indicating exposure of CA 154 and frequency of impacts.

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Table 13. Subjective consequence scoring, indicating consequences of an impact for CA 154 were it to occur.

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<tr>
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<th>Cost of Damage</th>
<th>Cost of Disruption</th>
<th>Duration of disruption</th>
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Broadway/Orcutt Expressway (CA 135)

**Priority**

Broadway/Orcutt Expressway (CA 135) within the urban areas of Santa Maria and Orcutt is the most heavily-traveled urban roadway in the county, other than highways and road segments immediately connected to highway access ramps. CA 135 serves the SMAT route 1 bus, the Los Alamos Shuttle, the Cuyama Transit bus route, the Breeze Santa Maria to Lompoc bus routes. CA 135 also serves the low-income communities in Santa Maria.

**Hazards**

Fluvial flooding hazards in Santa Maria occur in small, distributed areas, disconnected from larger floodplains. One such area is at the intersection with Miller Street. Another is at the intersection with East Clark Avenue. At the far north end of CA 135, the access ramps connecting North Broadway to US 101 may also flood. As an urban roadway, CA 135 is not exposed to any wildfire, landslide, or coastal hazard zones.

**Subjective Risk Assessment**

Table 14, Table 15, and Figure 101 show the subjective risk scoring for hazards faced by Broadway/Orcutt Expressway currently and in the coming century.
Table 14. Subjective probability scoring indicating exposure of Broadway/Orcutt Expressway and frequency of impacts.

<table>
<thead>
<tr>
<th>Frequency of exposure</th>
<th>Geospatial exposure</th>
<th>Aggregate Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current</td>
<td>0.25m</td>
</tr>
<tr>
<td>Nuisance Flooding</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Storm Surge Flooding</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Change in frequency/intensity of exposure

<table>
<thead>
<tr>
<th>Geospatial exposure</th>
<th>Change in frequency/intensity of exposure</th>
<th>Aggregate Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mid-century</td>
<td>End-of-Century</td>
</tr>
<tr>
<td>Wildfire</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Landslides</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fluvial Flooding</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

1.00 1.00

Table 15. Subjective consequence scoring, indicating consequences of an impact for Broadway/Orcutt Expressway were it to occur.

<table>
<thead>
<tr>
<th>Cost of Damage</th>
<th>Cost of Disruption</th>
<th>Duration of disruption</th>
<th>Low-inc. comm.</th>
<th>Aggregate Consq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuisance Flooding</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Storm Surge Flooding</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wildfire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Landslides</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fluvial Flooding</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Hollister Avenue/State Street

**Priority**

Hollister Avenue and State Street together run just over 14 miles through central Goleta and Santa Barbara. Together, the roads constitute one of the most heavily used urban roads outside of major highways and their access ramps. In Santa Barbara, State Street connects the waterfront with the central business district, US 101, and neighborhoods to the northwest. In Goleta, Hollister Avenue runs parallel to US 101, connecting multiple north-south routes, the airport, and Ward Memorial Blvd. The Road also serves multiple bus routes, including many MTD routes in downtown Santa Barbara, and routes connecting Santa Barbara and Goleta to outlying neighborhoods.

State Street in Santa Barbara serves as a central arterial in the city’s downtown low-income communities from the waterfront to Arrellaga Street and borders the south side of the Oak Glen/El Sueno low-income community.

**Hazard**

Wildfire hazard areas in the foothills north of CA 192 do not directly threaten Hollister Ave/State Street, however there are some ‘very high’ FHSZs west of Ellwood Ridge Road and within city boundaries that did not burn in the 2008 Gap fire. These areas are correlated with unstable landslide hazard zones which could pose debris flow hazards down the Tecolotito Creek, Bell Canyon, or Tecolote Canyon channels to
the west of Goleta, and Atascadero, Cieneguitas, Burro Arroyo, San Roque, and Mission Creeks in Santa Barbara.

Fluvial flooding hazards along Hollister Avenue primarily occur along the north side of the Goleta Slough, where 100-year floodplains threaten the entire length of the road from Ward Memorial Boulevard to Los Carneros Road. Flooding in this section of Hollister Avenue could potentially affect US 101 and Ward Memorial Boulevard as well, leaving few alternative road routes between Goleta and Santa Barbara (Figure 102). Flooding associated with the Slough is described in greater detail in the section, “Santa Barbara Municipal Airport/Goleta Slough.” A second significant area of fluvial flooding hazard affects State Street near the waterfront. From Cabrillo Boulevard, through the US 101 underpass to Gutierrez Street, flooding from Mission Creek could inundate State Street.

![Inland Flooding Hazards](image)

*Figure 102. Fluvial flooding from the Goleta Slough could inundate Hollister Avenue from Ward Memorial Boulevard to Los Carneros Road.*

Coastal hazards threaten State Street under mid- and end-of-century scenarios. In the central mean scenarios (which are used in the subjective risk assessment), nuisance flooding only affects state street in the 2.0m SLR scenario, flooding waterfront blocks up to Yanonali Street (Figure 103). If the maximum uncertainty range is considered, State Street may flood south of the railroad under the 0.75m SLR scenario, and up to Gutierrez Street under the 2.0m SLR scenario.

Given a 100-year storm surge event, State Street may flood to Gutierrez Street under 2.0m of SLR in the central mean estimate. In the maximum uncertainty scenarios, storm surge may flood State Street south of the railroad under current conditions, 0.25m of SLR, or 0.75m of SLR. In a 2.0m SLR scenario, the max uncertainty storm surge flooding hazard zone is similar to the central mean estimate.
**Subjective Risk Assessment**

Table 16, Table 17, and Figure 104 show the subjective risk scoring for hazards faced by Hollister Avenue/State Street currently and in the coming century.

*Table 16. Subjective probability scoring indicating exposure of Hollister Avenue/State Street and frequency of impacts.*

<table>
<thead>
<tr>
<th>Hazard Type</th>
<th>Frequency of Exposure</th>
<th>Geospatial Exposure</th>
<th>Geospatial Change</th>
<th>Aggregate Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuisance Flooding</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Storm Surge Flooding</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Frequency of Exposure</th>
<th>Geospatial Exposure</th>
<th>Geospatial Change</th>
<th>Aggregate Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wildfire</td>
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<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Landslides</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fluvial Flooding</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 17. Subjective consequence scoring, indicating consequences of an impact for Hollister Avenue/State Street were it to occur.

<table>
<thead>
<tr>
<th></th>
<th>Cost of Damage</th>
<th>Cost of Disruption</th>
<th>Duration of disruption</th>
<th>Low-inc. comm.</th>
<th>Aggregate Consq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuisance Flooding</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Storm Surge Flooding</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2.25</td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wildfire</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.25</td>
</tr>
<tr>
<td>Landslides</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2.25</td>
</tr>
<tr>
<td>Fluvial Flooding</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 104. Risk matrix for Hollister Avenue/State Street indicating the relative degree of risk caused by potential hazards and how they are affected by climate change.
Union Pacific Railroad

Priority
The Union Pacific railroad serves both freight traffic and Amtrak mass transit lines, connecting Santa Barbara’s major populated areas with San Luis Obispo county to the north and Ventura and Los Angeles counties to the southeast, as well as to the rest of California. Freight service in the county connects to the Lompoc spur and the Imerys mine south of Lompoc, as well as the Santa Maria Valley Railroad short line, which connects to agricultural producers and manufacturers.

The Amtrak line serves five stations in the county: Carpinteria, Santa Barbara, Goleta, Lompoc-Surf, and Guadalupe. Except Goleta, all of these stations are located in low-income communities. Additionally, many of the county’s freight rail access points serve businesses in low-income communities.

Hazard
The Union Pacific railroad faces a broad array of climate hazards, including coastal flooding, cliff erosion, landslides, wildfire and fluvial flooding. Hazards include both near-term and long-term risks and threaten both temporary disruption and the long-term viability of the current right of way.

Both nuisance and storm-surge flooding threaten the railroad along the South Coast, and cliff and shoreline erosion threaten the railroad along the north coast. Nuisance flooding is most severe in Carpinteria, where just 0.75m of SLR could regularly flood sections of the railroad near the Salt Marsh Reserve (in the central mean scenario, the only scenarios used in the subjective risk assessment). In the maximum uncertainty scenario, tidal flooding hazards may extend to central Carpinteria as well as the segments northwest near Paredon Arroyo Creek. Under 0.75m of SLR, large segments in downtown Santa Barbara could flood, too (between State Street to Calle Cesar Chavez, in the maximum uncertainty scenario). Under 2.0m of SLR flooding of the railroad in Carpinteria and Santa Barbara is even more extensive (in the central mean estimate).

Landslides are a persistent threat along the South Coast, and nearly the entire stretch of railroad from Goleta to the Jack and Laura Dangermond Preserve passes through landslide hazard zones. Additionally, landslides within populated areas threaten the railroad, particularly in Summerland where steep slopes abut the railroad to the north. Along the north coast, the railroad passes through landslide hazard zones near Oak Mountain and Round Hill, south of Wild Horse Peak, and at the crossing of Honda Creek (Figure 105). An additional area of landslide hazards threatens the railroad in the foothills southwest of Orcutt.
Wildfire hazards are most severe along the South Coast, where the railroad transits multiple ‘very high’ FHSZs. Although a large section of the South Coast burned in the 2004 Gaviota fire, some sections between Goleta and Gaviota have not burned since 1955 and others have no fire history on record. West of Gaviota, most of the railroad is in ‘high’ FHSZs, but very little of these areas have ever burned. Moreover, large parts of the Hollister Ranch ‘very high’ FHSZ have never burned (Figure 106). Along the north coast, the railroad transits areas of unknown fire hazard in Vandenberg AFB. In the foothills south of Guadalupe the railroad transits a ‘high’ FHSZ.
Along the South Coast from Gaviota to Jack and Laura Dangermond Preserve, wildfire hazard is projected to change little or increase slightly by mid-century (2040 – 2069) in both the low- and high-emissions scenarios. By the end of the century, wildfire hazard is projected to increase moderately in the low-emissions scenario, and decrease slightly to moderately in the high-emissions scenario. In all scenarios, fire hazard is projected to increase in along the north coast and in the Casmalia Hills.

Fluvial flooding threatens temporary inundation at many points along the railroad. In Carpinteria, flooding in central Carpinteria and adjacent to the Salt Marsh Reserve is most significant, with additional flooding hazard at Paredon Arroyo Creek. In Montecito, the combined flood hazards of Oak, San Ysidro, and Romero Creeks threaten the railroad along much of the Montecito waterfront. Flooding of Montecito Creek may also flood the railroad at Olive Mill Road. In Santa Barbara, flooding of Sycamore Creek and Mission Creek could flood nearly the entire span of the railroad in central Santa Barbara (Figure 107). Flooding may also affect the Santa Barbara Amtrak Station, as well as its parking and access roads.

In Goleta, fluvial flooding hazards occur at each of the major tributaries to the Goleta Slough, including the San Jose, Las Vegas, San Pedro, Carneros, and Tecolotito Creeks. Flooding may also affect the Goleta Amtrak station platform and parking area. In all, flooding associated with a 100-year discharge event would flood much of the railroad in Goleta (Figure 108).

To the west of Goleta, fluvial flooding may affect the railroad at creek mouths including Capital, Refugio, Cañada San Onofre, Cañada de Santa Anita, Cañada del Agua, Arroyo Bulito, Cañada de las Agujas,
Cañada del Pescado, Cañada del Cojo, and Wood Canyon. Along the north coast, fluvial flood hazards are not mapped within Vandenberg AFB. North of the military base, no known fluvial flooding hazards threaten the railroad.

**Subjective Risk Assessment**

Table 18, Table 19, and Figure 109 show the subjective risk scoring for hazards faced by the Union Pacific Railroad currently and in the coming century.

Table 18. Subjective probability scoring indicating exposure of the Union Pacific Railroad and frequency of impacts.

<table>
<thead>
<tr>
<th>Frequency of exposure</th>
<th>Geospatial exposure</th>
<th>Aggregate Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current 0.25m 0.75m</td>
<td>Near-term Long-term</td>
</tr>
<tr>
<td>Nuisance Flooding</td>
<td>3 0 0 1 3</td>
<td>1.00 2.33</td>
</tr>
<tr>
<td>Storm Surge Floodling</td>
<td>1 2 2 2 3</td>
<td>2.00 2.00</td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td>3 1 2 3 3</td>
<td>2.00 3.00</td>
</tr>
</tbody>
</table>

| Wildfire              | Change in frequency/intensity of exposure | Aggregate Probability |
|                       | Current RCP4.5 RCP8.5 | Mid-century End-of-Century |
|                       | 3 2 2 3 2            | 2.33 2.67               |
| Landslides            | 3 1 2 3 3            | 2.00 2.67               |
| Fluvial Flooding      | 3 1 2 3 3            | 2.00 2.67               |

Table 19. Subjective consequence scoring, indicating consequences of an impact for the Union Pacific Railroad were it to occur.

<table>
<thead>
<tr>
<th>Cost of Damage</th>
<th>Cost of Disruption</th>
<th>Duration of disruption</th>
<th>Low-inc. comm.</th>
<th>Aggregate Consq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuisance Flooding</td>
<td>3 3 3 2</td>
<td>2.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storm Surge Floodling</td>
<td>2 3 2 2</td>
<td>2.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td>2 3 3 2</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wildfire</td>
<td>1 3 1 2</td>
<td>1.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landslides</td>
<td>3 3 3 2</td>
<td>2.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluvial Flooding</td>
<td>3 3 3 2</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Santa Barbara Municipal Airport/Goleta Slough

Priority

The Santa Barbara Municipal Airport is the most heavily used airport in the county and serves more passengers than any airport in the region outside of Los Angeles County. For this reason, the airport is considered high-priority transportation infrastructure. Additionally, the airport serves the South Coast’s low-income communities, although it is not located in one.

The airport is entirely situated within the Goleta Slough, which is a low-lying area containing considerable areas of wetland habitat. The Goleta Slough Management Committee (GSMC) created the 2015 Goleta Slough Management Plan to address the complex set of interests in governing the Goleta Slough, including the environmental, land-use, and safety regulatory constraints. The plan explores the flooding risks (both coastal and fluvial) of the Slough and the airport in detail, as well as the Slough’s use and management history. The plan also establishes management policies to accomplish GSMC’s goals to protect existing resources, functions, and values; restore and enhance historic resources, functions, and values; and to enable education and research of the Slough’s ecosystem and functions. This assessment uses updated SLR-associated coastal hazards maps to assess the airport’s associated flooding risk in line with consistent scenarios and the latest modeling, however the 2015 plan includes

Figure 109. Risk matrix for the Union Pacific Railroad indicating the relative degree of risk caused by potential hazards and how they are affected by climate change.

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greater detail associated with both management-based risks such as flooding risks associated with closing the Slough’s inlet.

**Hazards**

Flooding hazards are the most significant challenge for the airport and the slough. Both coastal and fluvial flooding threaten the airport (including its buildings, runways, tarmac, service roads, parking lots and outlying infrastructure).

Coastal flooding is projected to be severe under 100-year storm surge conditions, even without sea level rise (Figure 110). In the central mean scenario (which is used for subjective risk scoring), the airport terminal is not subject to flooding, but most of the rest of the airport is, including the runways, tarmac, general aviation hangars and services, commercial hangars and services (including FedEx hangars), areas surrounding the fuel storage tanks, parking areas, and access roads to the terminal (including the MTD bus stops). In the maximum uncertainty scenario; flooding is more extensive and affects the terminal building, as well as overtopping Hollister Avenue in multiple locations.

![Figure 110. 100-year storm surge flooding under current conditions.](image)

Under 0.25m and 0.75m of SLR, the extent of flooding is not affected during a 100-year storm surge event, compared to current conditions in the central mean. However, under the 2.0m SLR scenario storm surge is projected to be much more extensive, flooding the terminal building and more extensive areas along the north and eastern ends of the airport. The maximum uncertainty 2.0m SLR scenario extends this flooding even farther (Figure 111).
Nuisance flooding poses a long-term existential threat to the airport and slough. Under 0.25m of SLR, flooding of the slough channels is projected, however none of the airport surfaces or facilities are expected to flood in the central estimate. Under 0.75m of SLR, regular tidal flooding may encroach on the runway perimeters in the central estimate (Figure 112).
Without adaptation measures, 2.0m of SLR will inundate the entire slough and airport grounds with regular tidal flooding. Tidal flooding would extend beyond the airport’s perimeters, affecting surrounding blocks, and inundating almost all airport structures and service areas (Figure 113).

Fluvial flooding poses similar risks to the airport. The FEMA FIRMs for the airport indicate the entire airport lies within the 100-year floodplain (Figure 114). The slough is fed by the San Jose, Las Vegas, San Pedro, Carneros, and Tecolotito Creeks, all of which are subject to greater flooding risk over the next century as extreme precipitation events increase in severity. Unlike some other areas in the county, fluvial flooding risks in the slough are affected by human actions as well as natural events, and the GSMC must determine when it is appropriate to open and close the slough inlet.
Figure 114. FEMA 100-year floodplain for the Goleta Sough and Santa Barbara Municipal Airport.

Subjective Risk Assessment

Table 20, Table 21, and Figure 115 show the subjective risk scoring for hazards faced by the Santa Barbara Municipal Airport currently and in the coming century.

Table 20. Subjective probability scoring indicating exposure of the Santa Barbara Municipal Airport and frequency of impacts.

<table>
<thead>
<tr>
<th>Frequency of exposure</th>
<th>Geospatial exposure</th>
<th>Aggregate Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current 0.25m 0.75m 2.0m</td>
<td>Near-term Long-term</td>
</tr>
<tr>
<td>Nuisance Flooding</td>
<td>3 0 0 1 3</td>
<td>1.00 2.33</td>
</tr>
<tr>
<td>Storm Surge</td>
<td>2 3 3 3 3</td>
<td>2.67 2.67</td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td>- - - - -</td>
<td>- -</td>
</tr>
</tbody>
</table>

| Wildfire               | - - - - - | - - |
| Landslides             | - - - - - | - - |
| Fluvial Flooding       | 3 2 2 3 3 | 2.33 3.00 |
Table 21. Subjective consequence scoring, indicating consequences of an impact for the Santa Barbara Municipal Airport were it to occur.

<table>
<thead>
<tr>
<th></th>
<th>Cost of Damage</th>
<th>Cost of Disruption</th>
<th>Duration of disruption</th>
<th>Low-inc. comm.</th>
<th>Aggregate Consq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuisance Flooding</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
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<td>2.25</td>
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<tr>
<td>Coastal Cliff Erosion</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wildfire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Landslides</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fluvial Flooding</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2.25</td>
</tr>
</tbody>
</table>

Figure 115. Risk matrix for the Santa Barbara Municipal Airport indicating the relative degree of risk caused by potential hazards and how they are affected by climate change.
Santa Barbara Train Station

Priority

The Santa Barbara Train Station is the most heavily used train station in the county, and the only train station with indoor customer facilities and staff. The station is located in central Santa Barbara between US 101 and the railroad, and directly adjacent to Mission Creek. The station serves the low-income communities in central Santa Barbara.

Hazard

Both coastal and fluvial flooding pose the greatest hazards to the Santa Barbara station. In a 100-year discharge event where Mission Creek overflows its channel in central Santa Barbara, wide areas of flooding are expected (Figure 116), including the train station building, parking lot, access roads, nearby Greyhound Bus Station and connecting railroad. Projections of precipitation over the next century are expected to increase the intensity of extreme precipitation events and the associated risk of flooding in Mission Creek.

Coastal flooding threatens the Amtrak station only in worst-case scenarios. In a 100-year storm surge event, the station may flood as the building, parking lot and access roads lie in between the central mean estimate and the maximum uncertainty flood stages (Figure 117).
Under 2.0m of SLR, regular tidal flooding is expected to approach but not reach the station (Figure 118). However, in such a scenario, flooding of the railroad tracks will either necessitate significant adaptive actions or relocation of the station and tracks inland.
Subjective Risk Assessment

Table 22, Table 23, and Figure 119 show the subjective risk scoring for hazards faced by the Santa Barbara Train Station currently and in the coming century.

Table 22. Subjective probability scoring indicating exposure of the Santa Barbara Amtrak station and frequency of impacts.

<table>
<thead>
<tr>
<th>Frequency of exposure</th>
<th>Geospatial exposure 0.25m</th>
<th>Geospatial exposure 0.75m</th>
<th>Geospatial exposure 2.0m</th>
<th>Aggregate Probability Near-term</th>
<th>Aggregate Probability Long-term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuisance Flooding</td>
<td></td>
<td></td>
<td>1</td>
<td>1.00</td>
<td>1.33</td>
</tr>
<tr>
<td>Storm Surge Flooding</td>
<td></td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0.67</td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 23. Subjective consequence scoring, indicating consequences of an impact for the Santa Barbara Amtrak station were it to occur.

<table>
<thead>
<tr>
<th>Cost of Damage</th>
<th>Cost of Disruption</th>
<th>Duration of disruption</th>
<th>Low-inc. comm.</th>
<th>Aggregate Consq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuisance Flooding</td>
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<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Storm Surge Flooding</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wildfire</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Landslides</td>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fluvial Flooding</td>
<td>2</td>
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<td>2</td>
<td>3</td>
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</tbody>
</table>
Figure 119. Risk matrix for the Santa Barbara Amtrak station indicating the relative degree of risk caused by potential hazards and how they are affected by climate change.

Breeze Bus Santa Maria to Lompoc

Priority

Bus transit is the primary mass transit option in Santa Barbara county, and multiple transit agencies and companies serve the county’s various cities. The Breeze bus serving between Santa Maria and Lompoc has neither the highest peak passenger count (MTD routes 1 and 2), nor the highest passenger-miles count (SMAT routes 1, 2, and 4). However the Breeze bus serves a route that faces distinct climate hazards, while other routes face similar hazards to roads already addressed by high-priority infrastructure risk assessments. Additionally, the communities of Santa Maria and Lompoc are low-income communities, as is the Vandenberg AFB community also served by this bus route.

The Santa Maria – Lompoc route runs from the Santa Maria Transit Center down Miller Street, Broadway, McCoy Lane, and Skyway Drive in Santa Maria (connecting to the Santa Maria Airport) before running back to the Orcutt Expressway (CA 135) through Orcutt (Figure 120). South of Orcutt, the route follows CA 1 to Vandenberg AFB (stopping at California Boulevard) and Vandenberg Village (stopping at Burton Mesa Boulevard and Constellation Road). Finally, the route ends at the Albertson’s grocery store on North H Street in Lompoc.
Hazard

Wildfire is a significant hazard along the bus route. In the Casmalia Hills southwest of Orcutt, the route transits a large ‘high’ severity FHSZ without any recent fire history. The route also abuts an area of ‘very high’ fire hazard without any recent fire history outside of Vandenberg Village (Figure 121). Within Vandenberg AFB, FHSZs are not mapped, but existing fire threat in the area is ‘very high.’109 Multiple large past fires have burned along the bus route in Vandenberg AFB, with the 2000 Harris fire being the most recent.

109 Cal Fire 2005
Wildfire is perhaps the most near-term hazard, as fire hazards are projected to increase along the route in all scenarios by mid- and end-of-century. The area around Vandenberg Village is projected to see the greatest increases in fire hazard in the county by mid-century.

Fluvial flooding hazards may affect the bus route in three small locations: at the Santa Ynez river crossing, at the junction of CA 1 and CA 135, and at the junction of East Clark Avenue and the Orcutt Expressway (CA 135). Although the trend toward more intense precipitation events is positive over the current century, each of these hazard areas is relatively small, and the effect of fluvial flooding would likely be temporary.\(^{110}\)

Landslide hazards are not a direct threat to the bus route or CA 1, however potentially unstable slopes exist to the west of CA 1 through Graciosa Canyon south of Orcutt. It is unknown if a landslide or debris flow here could affect CA 1 and the bus route (Figure 122).

\(^{110}\) Langridge 2018
Subjective Risk Assessment

Table 24, Table 25, and Figure 123 show the subjective risk scoring for hazards faced by the bus route currently and through 2100.

Table 24. Subjective probability scoring indicating exposure of the Breeze Santa Maria – Lompoc bus route and frequency of impacts.

<table>
<thead>
<tr>
<th>Frequency of exposure</th>
<th>Current</th>
<th>Geospatial exposure</th>
<th>Aggregate Probability</th>
<th>Geospatial exposure</th>
<th>Change in frequency/intensity of exposure</th>
<th>Aggregate Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.25m</td>
<td>0.75m</td>
<td>2.0m</td>
<td>Near-term</td>
<td>Long-term</td>
</tr>
<tr>
<td>Nuisance Flooding</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Storm Surge Flooding</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wildfire</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2.67</td>
<td>-</td>
</tr>
<tr>
<td>Landslides</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0.67</td>
<td>-</td>
</tr>
<tr>
<td>Fluvial Flooding</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1.00</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 122. Landslide hazard zones to the west of CA 1 in the Casmalia Hills.
Table 25. Subjective consequence scoring, indicating consequences of an impact for the Breeze Santa Maria – Lompoc bus route were it to occur.

<table>
<thead>
<tr>
<th></th>
<th>Cost of Damage</th>
<th>Cost of Disruption</th>
<th>Duration of disruption</th>
<th>Low-inc. comm.</th>
<th>Aggregate Consq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuisance Flooding</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Storm Surge</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Flooding</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coastal Cliff</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Erosion</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wildfire</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1.75</td>
</tr>
<tr>
<td>Landslides</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Fluvial Flooding</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Figure 123. Risk matrix for the Breeze Santa Maria – Lompoc bus route indicating the relative degree of risk caused by potential hazards and how they are affected by climate change.
UCSB Bicycle Paths

Priority
The class I bicycle paths in Isla Vista in and around the UCSB Campus are the most heavily used bicycle paths in the county, according to the latest ridership count taken by the Santa Barbara Bicycle Coalition. Counts at just the Pardall Road bike tunnel (under Ocean Road) accounted for 40% of users in the entire South Coast survey. High counts were also found at the El Colegio Road bikeway (at Camino del Sur), and at the Obern bike path. For the purposes of this study, the bike route segments addressed as high-priority transportation network infrastructure include the Class I bikeway on El Colegio Road, the north-south bikeway parallel to Ocean Road, the Pardall Bike Tunnel, the Class I bikeway through the UCSB campus, and the Class I Obern Trail to the east.

In addition to their utility for bicycle mode share, the El Colegio Road Class I path connects to multiple MTD bus routes, potentially serving as an intermodal connector. The UCSB bikeways serve the low-income community of Isla Vista.

Hazards
The primary hazards faced by the UCSB-area bike paths are related to sea level rise and storm-surge related flooding. East of campus, the Obern bike path is particularly susceptible to storm surge flooding, especially where it follows and traverses Ward Memorial Boulevard (CA 217). The low-lying segments are susceptible to flooding from a 100-year storm even under current conditions. With SLR enhancements, the hazard area grows slightly on the Obern bike path. Under 2m of SLR, a 100-year storm surge event may flood the entirety of the bikeway from Goleta Beach State park, across the Slough inlet, almost to South Patterson Avenue. Flooding may not be limited to the waterfront; flooding of Goleta Slough may also overtop the Class I bikeway on South Los Carneros Road.

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111 Sanford and Fishbein 2016
Without storm surge, the low-lying parts of the Obern bike path are vulnerable to flooding, even under 0.25m of SLR (in the maximum uncertainty case). Under 0.75m, the Obern path floods in the central mean case, and under 2.0m, the trail floods past Ward Drive to the east. Although the paths on El Colegio Road and Pardall Road are unaffected by high SLR scenarios, nuisance flooding may overtop the Class I bikeway on South Los Carneros Road in a 2m SLR scenario.

Fluvial flooding also threatens the Goleta Slough, and low-lying sections of the Obern bike path also lie within the 100-year floodplain for the Slough and Atascadero Creek. In a 100-year flood, the Obern bike trail may flood all the way from the Slough to its terminus at Arroyo Road. Additional fluvial floodplains may affect the Class I bikeway on South Los Carneros Road.

Wildfire hazards are not considered a threat to the UCSB bikeways as they are not within a FHSZ. Likewise, landslide hazard zones in Isla Vista are limited.

Projected climate change indicates an increasing risk of extreme precipitation affecting the Goleta Slough and Atascadero Creek.

Subjective Risk Assessment
Table 26, Table 27, and Figure 125 show the subjective risk scoring for hazards faced by the UCSB bike paths currently and in the coming century.

Table 26. Subjective probability scoring indicating exposure of UCSB bicycle paths and frequency of impacts.
Table 27. Subjective consequence scoring, indicating consequences of an impact for UCSB bike paths were it to occur.

<table>
<thead>
<tr>
<th></th>
<th>Cost of Damage</th>
<th>Cost of Disruption</th>
<th>Duration of disruption</th>
<th>Low-inc. comm.</th>
<th>Aggregate Conseq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuisance Flooding</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2.25</td>
</tr>
<tr>
<td>Storm Surge Flooding</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1.25</td>
</tr>
<tr>
<td>Coastal Cliff Erosion</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wildfire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Landslides</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fluvial Flooding</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Figure 125. Risk matrix for UCSB bicycle paths indicating the priority of potential hazards and how they are affected by climate change.
Discussion and Conclusions
Santa Barbara County’s transportation network faces a variety of vulnerabilities from familiar but changing hazards like wildfire and landslides as well as from hazards like coastal nuisance flooding which have yet to manifest themselves. Climate change will affect each of these hazards differently. Increasing temperatures, changing and more variable precipitation patterns, and rising sea levels will interact in complex ways that affect the frequency, severity, and geospatial extent of these hazards, and the county’s transportation network faces a wide variety of vulnerabilities over the coming decades.

Methodological and data gaps constrain the types of impact projections available for different types of climate hazards. As a result of these constraints, each climate hazard is evaluated using a distinct methodology making direct comparisons of vulnerabilities untenable. The subjective risk scoring approach used to compare the probability and the costliness of hazards for high-priority systems produces a set of directly comparable vulnerabilities. Figure 126 and Figure 127 show the subjective risk assessment scores of all climate hazards for all high-priority transportation systems in this study for mid-century and end-of-century time periods, respectively. The highest-risk vulnerabilities are located in the top-right corner of the risk matrix. Here, vulnerabilities with a high combined risk score (i.e., likelihood and consequence) are identified, while lower-risk vulnerabilities are not (all vulnerabilities are listed in the High-Priority Infrastructure Risk Assessment section).

Figure 126. All-hazard subjective risk assessment - mid-century
Priority Vulnerabilities

One general trend evident in the subjective risk assessment is that hazards move from lower-risk to higher-risk over the course of this century. In the mid-century projection, 12 vulnerabilities are within the ‘high-risk’ category; by the end-of-century this increases to 18 vulnerabilities. For almost all hazards, the direction of change is positive from mid-century to end-of-century timeframes. This effect is due to the increasing frequency of hazards and exposure to hazards, as the subjective consequence metrics generally do not change from mid-century to end-of-century.

Santa Barbara Municipal Airport/Goleta Slough

Perhaps the most urgent and challenging mid-century vulnerabilities in the county are associated with the Goleta Slough and the Santa Barbara Municipal Airport. The slough faces challenges associated with coastal and fluvial flooding hazards. Hazards are compounded by management decisions which must take into consideration multiple stakeholders with interests which may sometimes conflict. One large uncertainty associated with airport flooding hazards is the cost associated with such flooding. Widespread flooding of the airport runways, tarmac, and service roads will cause costly disruptions to airport service, but it is unknown the extent to which the repair costs are comparable with the disruption costs. By contrast, flooding of airport facilities (including the terminal building, hangars,
warehouses, parking lots, fuel storage tanks, etc.) would likely cause much more costly damage if these facilities are not hardened to flooding. As part of any future management planning, an engineering analysis of airport facilities and systems should be undertaken to determine which facilities may be exposed to flooding, and at what depth, given specific coastal and fluvial flooding scenarios and heights.

**US 101 Corridor and Union Pacific Railroad**

The US 101 Corridor also faces significant risks in the County, due to both the frequency and extent of exposure to hazards, and the significant cost of closures of the corridor. By mid-century, fluvial flooding and landslide hazards threaten the both US 101 and the railroad through the densely populated cities along the South Coast. The corridor’s vulnerabilities along the South Coast are correlated with vulnerabilities of the county’s non-transportation sectors, including businesses, residences, recreational and institutional assets, and other critical infrastructure. This connection increases the risk that hazards impacting US 101 will occur simultaneous to hazards affecting other elements of the county’s infrastructure, compounding the impact and potentially delaying the recovery. Efforts to protect the US 101 corridor from both coastal and fluvial flooding hazards will need to account for the broader implications of these widespread flooding impacts for South Coast communities.

Outside the populated areas of the South Coast, US 101 and the railroad share significant exposure to landslide hazard between Goleta and Gaviota. Due to the extent of this hazard area, a detailed slope stability study that considers the risks of high-precipitation future scenarios, post-fire impacts, and other non-climate events such as seismic events would significantly improve understanding of the hazards in this corridor.

The Union Pacific Railroad faces additional high-risk vulnerabilities by mid-century to the west of Gaviota Pass, with simultaneous threats from fluvial and storm surge flooding, landslides along the South Coast, and coastal cliff erosion along the north coast. Although the railroad faces the same correlated hazards risk as US 101, the railroad’s role in emergency response may be less impactful on interconnected systems. Unlike the US 101 corridor, the railroad faces significant coastal hazards along the north coast associated with cliff erosion. These hazards imply a long-term need for hardening or relocation.

**Sea Level Rise by End-of-Century**

By the end of the century, sea level rise is the primary factor affecting long-term vulnerabilities. Nuisance flooding associated with end-of-century scenarios threatens significant areas along the South Coast and pushes six new vulnerabilities into the ‘high risk’ category in Figure 127. Nuisance flooding of the airport, railroad, and US 101 corridors compound the many threats that already face these systems by mid-century. In the case of the airport, nuisance flooding may render the current layout permanently inoperable without substantial hardening. These considerations must also take into account other interests in slough management including habitat protection.

End-of-century nuisance flooding also threatens additional high-priority systems including the Hollister Avenue/State Street corridor, the Santa Barbara Amtrak station, and the UCSB bike paths. Together, these vulnerabilities indicate that end-of-century nuisance flooding threatens to regularly inundate and render inhabitable substantial areas of the South Coast. In these scenarios, transportation vulnerabilities are only a part of a much larger set of threats facing South Coast communities.
Wildfire Projections and Local Impacts

Projected change in wildfire over the coming century is distinct from other climate hazards, with an uncertain direction and magnitude of projected change in different scenarios and regions of the county. However despite the uncertainty, wildfire projections consistently indicate increasing fire hazards in and around Lompoc over the coming decades. Based on current projections, the most severe increases in wildfire severity will occur by mid-century to the north and west of Lompoc. Vandenberg Village and CA 1 experience the greatest increases in fire hazard. Lompoc and its surrounding communities also face a unique hazard associated with increasing fire severity affecting transportation corridors connecting the city to the rest of the county’s transportation network.

Next Steps

This vulnerabilities assessment will be followed by a Regional Climate Adaptation Strategy (RCAS) that will identify resilience solutions that address the vulnerabilities identified in this assessment report. The RCAS will provide a portfolio of potential resilience measures, and relevant qualitative and quantitative attributes for each option, including descriptions, costs, effectiveness, barriers to implementation, and potential co-benefits. The RCAS will also recommend strategies for incorporating resilience solution into the county’s Regional Transportation Plan (RTP) that take into account the prioritization of vulnerabilities, as well as resilience building opportunities. These strategies will form the foundation of the county’s Climate Smart Transportation Network. Once complete, this assessment and the RCAS will be combined in a final report: Santa Barbara County Multi-Modal Transportation Network Vulnerability Assessment and Regional Climate Adaptation Strategy.

Outside the scope of this effort, several additional opportunities exist to gain a better understanding of the ways in which climate hazards are likely to affect the county’s transportation network. Detailed engineering studies may aid in understanding of vulnerabilities identified here. Along the South Coast, a hydrologic analysis of future maximum annual daily streamflow under climate change scenarios could be used to provide detailed projections of peak streamflow under future precipitation conditions. With these values, new flood maps could be constructed that identify fluvial flooding exposure given future climate parameters. Because these types of assessments are time consuming, effort should first focus on the densely-packed vulnerabilities along the South Coast from Goleta to Carpinteria. Another opportunity for further study is an assessment of landslide and hazards. Current hazard areas are identified from studies conducted more than thirty years ago, and new landslide hazard mapping efforts could take advantage of updated landslide inventories and fire burn area maps. Of particular importance are the US 101 corridor and railroad along the South Coast west of Goleta: these crucial transportation systems share a common hazard exposure in this area, and an improved landslide hazard assessment that includes projected changes to extreme precipitation should be considered.
References


