Trinity Associates

On behalf of:

Caltrans

HUMBOLDT COUNTY ASSOCIATION OF GOVERNMENTS

DISTRICT 1 CLIMATE CHANGE VULNERABILITY ASSESSMENT AND PILOT STUDIES

FHWA CLIMATE RESILIENCE PILOT

APPENDICES

DECEMBER 2014

District 1 Climate Change Vulnerability Assessment and Pilot Studies

FHWA Climate Resilience Pilot Final Reports

December 2014

Table of Contents

Figures

Tables

Appendices

Appendix 1

Caltrans TCR Segment Criticality

Memorandum

15 October 2014

To	Rex Jackman, Chief, Transportation Planning Caltrans District 1		
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From	Rebecca Crow	Tel	707 443 8326
Subject	Caltrans TCR Segment Criticality	Job no.	84/10842/20

1 Background

This memorandum constitutes part of the vulnerability assessment phase of the Caltrans District 1 Climate Change Pilot Study (D1CCPS). Herein is presented a methodology for evaluating the criticality of transportation assets along with the testing of this methodology through the evaluation of District 1 assets. The findings of this evaluation are then combined with other studies to identify the assets most vulnerable to climate change.

It should be noted that this overall Climate Change Pilot Study is intended to develop and evaluate methodologies and to consider District 1 assets as test cases. Since many of the actual adaptation measures may need to be undertaken years into the future, the findings of this study will need to be updated and reevaluated based on the conditions and policies relevant at the time of the adaptation decision. The overall pilot study helps to identify critical assets, vulnerabilities, adaptations, and recommended future actions. This memorandum focuses on considering the criticality of assets.

For this study, the concept of criticality is used to gauge the relative importance of each transportation asset within the District. Criticality is evaluated through consideration of a combination of quantitative and qualitative measures, including the input of the project's Technical Advisory Group and stakeholders. Criticality evaluations are based on existing conditions and are independent of climate change factors. The concept of vulnerability includes the consideration of an asset's exposure and potential for impact as related to climate change and is considered in a separate Technical Memo.

2 Introduction

District 1 is comprised of Del Norte, Humboldt, Mendocino and Lake Counties (Attachment A, Figure A1). Stakeholders from throughout the District collaborated to consider the factors and their relative importance in evaluating criticality. These factors included the following:

- Socioeconomic functions (e.g. access to major employment centers or business districts),
- Use and operational characteristics (e.g. average daily traffic or functional classification),
- Health and safety functions (e.g. access to medical facilities or evacuation routes),

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- Replacement costs (e.g. number of large bridges or length/width of highway segment), and
- Degree of redundancy (i.e. parallel assets that can provide equivalent functions).

Although there tended to be general agreement among the group on some characteristics, there was a diversity of opinions regarding what was most important. This is to be expected given the diverse back-grounds and responsibilities of the group and points to the importance of focusing on this Pilot Study as a flexible tool rather than a rigid process to derive the “right” answer. Among the group there was discussion regarding how priorities should be set and that there should be caution exercised to avoid preference being given to more highly populated areas at the expense of life-and-safety needs in more isolated or rural areas. In fact, there can be many such tradeoffs which should be considered as part of policy setting and project specific implementation.

The work that is described in this memorandum was conducted by Robert Holmlund, AICP, Brett Vivyan, EIT, Luke Halonen, EIT, and Elizabeth Gutierrez, EIT with review by Steve McHaney, PE, Rebecca Crow, PE, Colin Chung, PhD, and Louis White, PE.

3 Methodology

The methodology used in this assessment was based on the Federal Highway Administration (FHWA) documents “Climate Change & Extreme Weather Vulnerability Assessment Framework” (December 2012) and “Assessing Criticality in Transportation Adaptation Planning” (June 2011).” In particular, the methodology adopts the “Hybrid Approach,” which consists of analyzing both qualitative inputs (from local stakeholders) and quantitative inputs (from GIS and other data). The method also considered the approaches of the following previously completed Federal Highway Administration (FHWA) pilot projects:

- Climate Impacts Vulnerability Assessment, November 2011, Washington State Department of Transportation
- Assessing Infrastructure for Criticality in Mobile, AL: Draft Final Technical Memo, Task 1, March, 2011, US DOT Center for Climate Change and Environmental Forecasting
- Addressing Climate Change Adaptation in Regional Transportation Plans: A Guide for California MPOs and RTPAs: Final Report, February 2013, California Department of Transportation

3.1 Summary of Overall Approach

The overall approach to determining the criticality of transportation assets was developed as summarized below in Image 1: Criticality Methodology Overview. The overall process began with an initial inventory of assets and related characteristics throughout the District, grouping the assets into logical transportation segments, and then evaluating the segments to assess criticality.

Criticality of segments was evaluated based on 40 criticality factors by evaluating raw data and then calculating a relative scaled score or Rating. The Rating is then multiplied by an importance weighting resulting in a criticality score. This score was then scaled to a range of 1 to 10. This final score presented the criticality of all segments on the same basis that can then be used for comparison and prioritization. A technical advisory group (TAG) and local stakeholders were engaged throughout the process.

The overall approach is summarized in the following sections starting with a list of attachments highlighting the process and findings.

3.1.1 List of Attachments

Graphics and tables illustrate and clarify steps in the criticality analysis process. Some are embedded in the memo and others are provided as separate attachments. Images and Tables are embedded in this memo; Attachments provide supplemental material following this memo. Attachments are described below:

Attachment A: Map Figure Set A.

- Figure A1: Vicinity Map
- Figure A2: TCR Segments
- Figure A3: Asset Data, Comprehensive Assets
- Figure A4: Asset Data, Stormwater Facility Cluster Density
- Figure A5: Asset Data, Bridge Cluster Density
- Figure A6: Criticality Factor Score, Redundancy
- Figure A7: Criticality Factor Score, Composite ADT
- Figure A8: Criticality Factor Score, Population
- Figure A9.1: Cluster Density by Cost of Events
- Figure A9.2: Cluster Density by Cost of Events
- Figure A10: Criticality Factor Score, Overall Criticality Score per TCR Segment

Attachment B: TCR segment descriptions and post miles

Attachment C: List of criticality groups and factors

Attachment D: Land use categories and descriptions

Attachment E: Criticality raw scores

Attachment F: Criticality scaled scores

Attachment G: TAG criticality feedback

Attachment H: Pairwise analysis

Attachment I: Criticality weights obtained from pairwise analysis

Attachment J: Comparison graph criticality scores

Attachment K: Comparison table of the scaled TCR segments

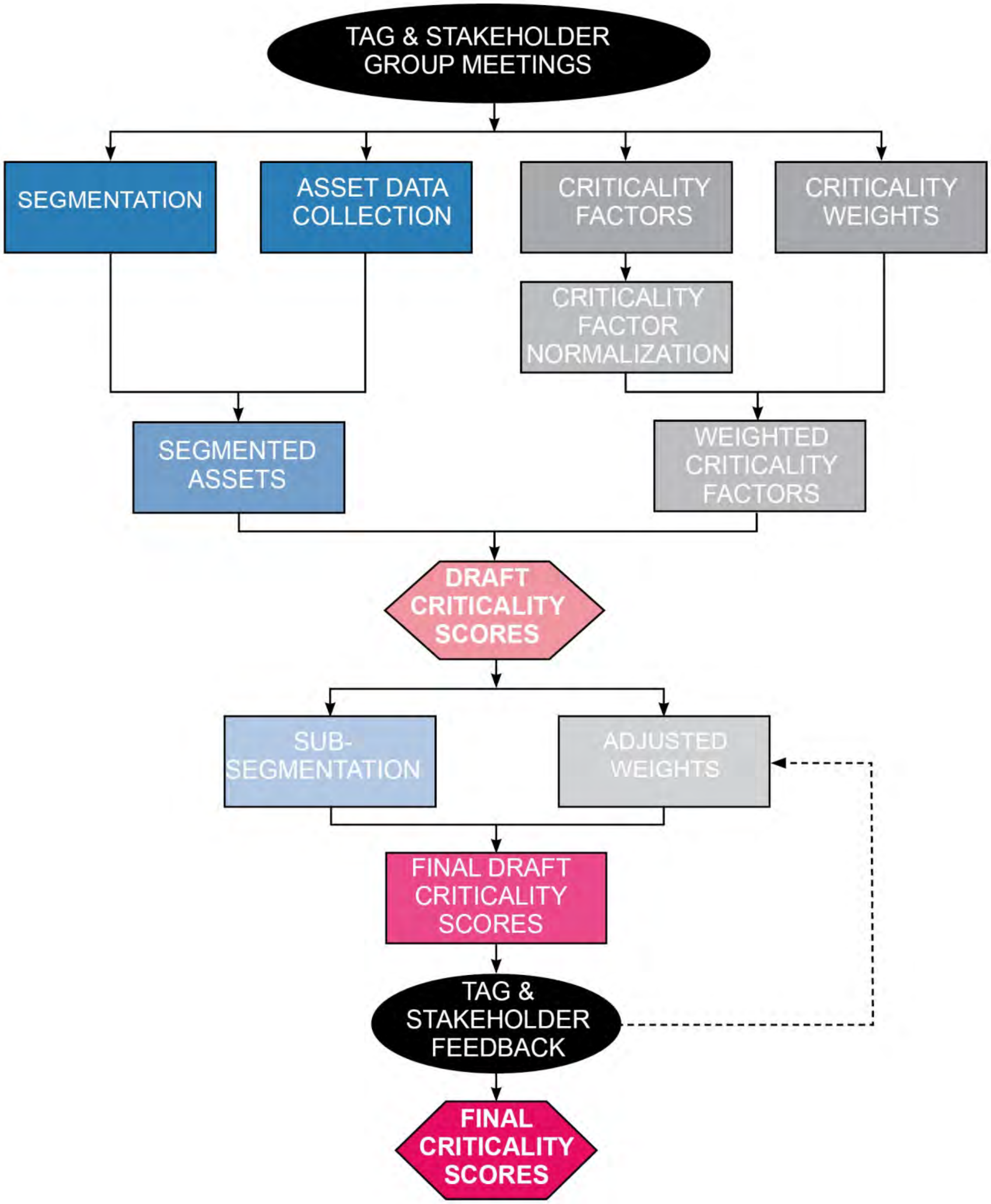

Image 1: Criticality Methodology Overview

3.2 Inventory of Transportation Assets, Assets Services, and Indicators of Need for Services

Caltrans District 1 provided several GIS layers representing all significant "transportation assets" that were to be analyzed for this study. Transportation assets are defined as "existing physical entities that required capital investment upon their installation, that have current capital value, that would require capital investment to replace, and that are functionally necessary for the day-to-day operations of the transportation system that is owned, operated, and maintained by Caltrans District 1.” The assets that fall within this category include:

- Bridges,
- Stormwater Facilities
- Rest Areas,
- Park & Ride Facilities,
- Weigh Stations,
- Traffic Signals,
- Road Weather Information Systems,
- Call Boxes, and
- Other Similar Significant Assets.

Over 16,000 such assets were inventoried and analyzed based on existing data sources as part of this study. Attachment A, Figure A3, highlights examples of the types of assets evaluated.

Data sufficient for analysis in this study were not available for all assets that fall within the definition above. For instance, data for regulatory signage (e.g. speed limit signs), barriers (e.g. guardrails and concrete barriers), and retaining walls is not currently available.

Caltrans District 1 owns and operates several types of assets that do not fall l within the definition presented above. These include land holdings that serve as restoration/mitigation sites, vehicles, and roadside landscaping installed by the District. This study does not consider these types of assets that are not directly necessary for the day-to-day operations of the transportation system per the definition above.

Also incorporated into this study are analyses of the “services” provided by the above assets. Such services include: Average Daily Traffic (ADT), which indicates the average volume of vehicles that travel within a given segment of roadway’, designated Bus Routes, designated Bike Routes, and other similar services. Caltrans District 1 provided GIS data for the “services” provided by the assets.

In addition, “indicators of potential needs for services” were evaluated such as the population within a given distance of a roadway’s commercially-zoned parcels as well as other indicators. GIS data for these indicators of potential needs for services were provided by the four Regional Transportation Planning Agencies (RPTAs) within District 1 and the four Counties within District 1. The relevant information obtained from all sources was compiled resulting in hundreds of thousands of individual data points that were evaluated in association with the services and indicators of need for service.

3.3 Segmentation of Assets within District 1

The scope and scale of this project did not allow for an individual analysis of each of the more than 16,000 physical assets and the hundreds of thousands of data points associated with the services/indicators. Such an analysis is not conducted at this level of study due to both the very significant effort and the resulting large bank of data. Instead, a more focused strategy is needed to consider the large amount of existing data and to effectively lead to manageable and logical conclusions and so a segmentation strategy was used.

There are 23 Caltrans roadways within District 1. Caltrans currently utilizes several approaches of dividing these roadways into segments depending on how the information is to be used. For example, long-range planning may have a different need for segmenting roadways than day-to-day maintenance and operations. Also, roads are segmented to facilitate the collection of certain types of data. For instance, different segmentation strategies are used for evaluating Average Daily Traffic (ADT) segments, Traffic Accident

Surveillance and Analysis System (TASAS), Highway Logs, maintenance districts, and Transportation Concept Report (TCR) segments. Of all the segmentation strategies in use, the TCR strategy appeared to be the best match for evaluating criticality of assets within the District, because this type of segmentation is commonly associated with broader transportation needs. Attachment A, Figure A2 displays these segments.

Each Caltrans roadway in District 1 has a Transportation Concept Report, which is a long-range planning document that describes the current characteristics of the transportation corridor and establishes a twenty-year planning strategy. The TCRs define goals for the development of the transportation corridor in terms of level of service (LOS) and type of facilities, and broadly identifies the improvements needed to reach those goals.

There are 87 TCR segments within District 1 (herein referred to as segments): 12 in Del Norte County, 30 in Humboldt County, 28 in Mendocino County, and 17 in Lake County. TCR segments vary in length from 0.3 to 69.2 miles. Those segments greater than 25 miles in length were evaluated for sub-segmentation so that each sub-segment would better represent the location of community and highway connections. Segments on Highway 101, 1 and 162 were sub-segmented resulting in a total of 93 TCR segments and subsegments. A list of TCR segments and descriptions is provided in Attachment B.

3.4 Criticality Factors

Criticality factors are defined as quantifiable measures that contribute to a roadway segment's relative importance in relation to other roadway segments. All criticality factors were quantitatively derived from existing GIS data

A total of 41 Criticality Factors arranged in 6 Criticality Groups were considered in the analysis and are summarized in Attachment C. Data were gathered from a number of sources as summarized in Table 1.

Table 1: Data Types and Their Sources

Data Type	Source
Annual Average Daily Traffic (2012)	Caltrans
Peak Hour Volume	Caltrans
Census Block Group and Tract Population (2010)	U.S. Census Bureau TIGER Products
Land Use and Parcels	Counties of Del Norte, Humboldt, Mendocino, and Lake
Road Base (2013)	U.S. Census Bureau TIGER Products
Segment Post Miles and Number of Lanes	Caltrans Transportation Concept Reports
Roadway Designations	Caltrans
Functional Classifications (2011)	California Road System
Bridges	Caltrans
Stormwater Facilities	Caltrans
Scenic Routes, Eligible and Officially Designated (2013)	Caltrans Scenic Highway Program
Bike Routes	Caltrans
Traffic Operating Systems	Caltrans
Call Boxes	Regional Transportation Planning Agencies

The assets in each segment were quantified through spatial GIS analyses. Where spatial GIS data were not available, GIS data were created from tabular data by matching post mile information.

A raw criticality score for each segment was calculated based on the physical assets and associated service/indicators present in each segment. Raw criticality scores were then scaled as described under Section 2.5 and could be compared in the subsequent analysis.

Factors were grouped according to their related characteristics. The following sections identify the criticality groupings and describe the methods for quantifying each criticality factor.

3.4.1 Criticality Group 1: System Connectivity, Average Daily Traffic, and Population

Connectivity, average daily traffic, and population metrics were used to evaluate current access, use, and community services. Criticality Factors in this group are:

Criticality Factor 1A: Level of Access

Criticality Factor 1B: Ability to Re-Route

Criticality Factor 1C: Composite Average Daily Traffic (SDT)

Criticality Factor 1D: Composite Peak Hour Volume

Criticality Factor 1E, 1F, 1G, 1H: Population

Criticality Factor 1I, 1J, 1K, 1L: Land Uses

Criticality Factor 1M: Critical Nodes

Criticality Factor 1A: Level of Access (System Redundancy Measure 1)

System redundancy is the degree to which a segment can be bypassed via parallel roadways that are generally capable of providing equivalent functions to the given segment. For instance, US 101 through the City of Eureka is paralleled by dozens of city streets that could provide alternate routes (i.e. are redundant to US 101) in the event that the segment of US 101 through Eureka was temporarily impassable. It is acknowledged that the “redundant” routes are not necessarily equivalent in all respects and in particular may not have the capacity to carry the volume of traffic of US 101 at the same level of service.

Assessing the multitude of characteristics associated with redundancy posed challenges because there are at least four Transportation Demand Models (TDM) in use based on various data-driven approaches. This pilot study does not require a numerical analysis of the many characteristics of redundancy, but rather only a relative gauge of redundancy is necessary. Therefore, an alternate approach was developed using two measures of redundancy.

Measure 1 is defined as a qualitative consideration of the approximate percentage of a segment that can be bypassed by existing alternative roadways. Measure 1 is Criticality Factor 1A that is further discussed in this section. Measure 2 is Criticality Factor 1B discussed in the following section.

The roadways that were considered in the redundancy analyses included highways and their connectors, major roads, and local roads. Private and off-highway vehicle roads were not included in this analysis.

Measure 1 is Level of Access. The percent of a roadway that is accessible by an alternate route was scored as shown inTable 2.

Table 2: System Redundancy Measure 1 Ranges and Scoring Table

Percent Redundancy	Score
80-100	1
60-80	2
40-60	3
20-40	4
0-20	5

This analysis was based on two criteria:

- The alternate route did not require backtracking into the previous segment;
- The alternate route was less than approximately twice the original distance.

For example, a roadway with numerous connecting roads throughout the segment that may be used to bypass or access any section of the road was given a score of 1 (Image 2). A road segment that has very limited access to alternate routes was scored a 5 (Image 3). Attachment A, Figure A6 displays the results of System Redundancy Measure 1.

Criticality Factor 1B: Ability to Reroute (System Redundancy Measure 2)

The second criticality factor associated with redundancy that was evaluated is the Ability to Reroute (System Redundancy Measure 2), which is a quantitative measure of the total length of all roads that occur within one mile from each segment. This metric assumes that if there are a large number of road miles adjacent to the segment, existing routes may be used to temporarily or permanently reroute a segment of highway.

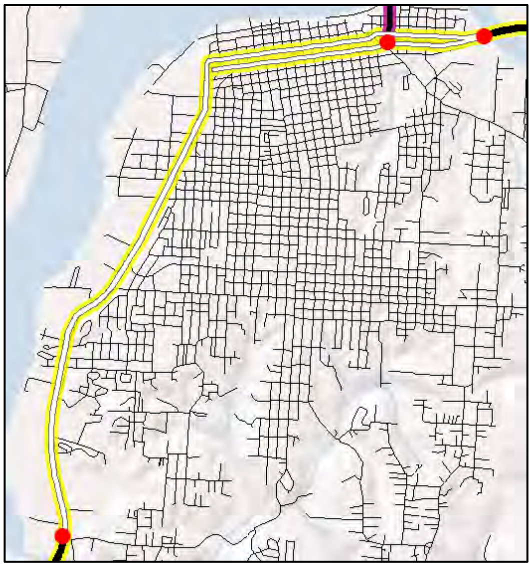

Image 2: High redundancy example (score = 1): Highway 101, Segment 12

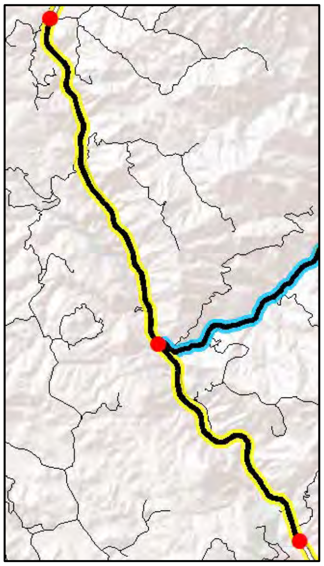

Image 3: Low redundancy example (score = 5): Highway 101, Segment 5

It is important to note that this redundancy analysis is for screening purposes and if an adaptation strategy is to be based on using alternate routes, then more detailed site specific investigations should be undertaken during the decision process.

Criticality Factory 1C: Composite Average Daily Traffic (ADT)

Average daily traffic (ADT) considers both the ahead and back traffic counts at a given post mile, and was evaluated as a composite ADT for each TCR segment. The composite ADT was determined by summing the ahead and back ADTs of each measured reach within the segment, then weighting each combined ADT value by the reach length. The composite ADT was found using the following equation:

$$\mathrm{ADT_{segment}} = \frac{\sum \mathrm{ADT_i} * (\mathrm{Reach\ Length})_\mathrm{i}}{\sum (\mathrm{Reach\ Length})_\mathrm{i}}$$

There were a number of segments where traffic counts were not available. For the purposes of this analysis, a null or zero data point would misrepresent the ADT for that segment and skew the segment's criticality with respect to ADT. To mitigate this issue, the ADT for segments without data was synthesized by averaging the ADT for adjacent segments ahead and back. Attachment A, Figure A7 displays the results of Composite ADT.

Criticality Factory 1D: Composite Peak Hour Volume

Similar to the analysis completed for Composite ADT, Composite Peak Hour Volumes were calculated based on available traffic counts at a given post mile and composited for each TCR segment. Similar data synthesis techniques of averaging data from adjacent areas were also used when peak hour data was not available for a given post mile.

Criticality Factors 1E, 1F, 1G, and 1H Related to Population

Population factors were used to evaluate the size and proximity of the local population served by each segment. Population was evaluated by evaluating census data in several ways resulting in the development of four separate criticality factors. The segment was considered to serve a given population in a census region if the segment passed through (intersected) the boundary of the delineated region. In some instances, the boundary intersected the segment in more than one location. Duplicate counts were removed in post-processing. If segments terminated within a boundary, the population within that boundary was assumed to be served by those segments and that population was added to all segments that intersected the boundary. Population density was calculated by dividing the sum of the populations by the sum of the land areas intersected by the segment. Attachment A, Figure A8, displays the results of population. Criticality Factors 1I, 1J, 1K, and 1L Related to Land Use

Land use was used to quantify the types of parcels and potential services associated within each segment. Parcels were categorized by Commercial, Residential, Industrial, and Non Park Municipal uses resulting in evaluation of four criticality factors. The types of land uses that qualified for each category can be found in Attachment D. Land use classifications were ranked in highest significance to lowest significance as Municipal, Commercial, Residential, and Industrial. Significance was based on potential services and uses associated with the land use. Municipal (non-park) parcels were assumed to provide essential services such as wastewater, drinking water and emergency services. Humboldt County parcel data was obtained as a shapefile with land use designations embedded as an attribute field. Parcel data for Del Norte, Mendocino, and Lake Counties was intersected with available land use data for each county. The intersection of land use with parcels resulted in some parcels with multiple land use designations. These parcels were assigned as single land use in post-processing, based on the highest ranking land use.

The total number of parcels and associated land use that occurred within one mile of each segment were summed and recorded for each segment.

Criticality Factor 1M: Number of Critical Nodes

Critical Nodes were considered to be intersections/interchanges between state highways. These nodes were assumed to support the bulk of inter-regional and intra-regional traffic flow within District 1. The Critical Nodes were summed for each segment.

3.4.2 Criticality Group 2: Highway Length and Classifications

Total centerline length of segments and highway classifications within segments were used to evaluate Criticality Group 2. Criticality Factors in this group are:

Criticality Factor 2A: Total Miles of Segment

Criticality Factor 2B: Functional Classification

Criticality Factor 2C: Miles of Access Control Highway per Mile of Segment

Criticality Factor 2D: Average Number of Lanes/Mile

Criticality Factor 2E: Miles of Designated Bike Routes per Mile of Segment

Criticality Factor 2F: Miles of Bus Routes per Mile of Segment

Criticality Factor 2G, 2H: Scenic Highways

Criticality Factor 2I: Miles of Designated Network Truck Route per Mile of Segment

Criticality Factor 2A: Total Miles of Segment

Highway length was used to quantify several physical assets within each segment, including pavement type (i.e, asphalt or concrete), roadway signage, barriers (e.g. guardrails), retaining walls, and other physical assets directly associated with roadways. Classifications were used to quantify the physical and available service level and capacity of each segment. Segment lengths were determined based on the post miles listed in the TCRs. Highway classifications were evaluated on a mile of classification per total length of road segment to reduce the influence and variability associated with differing segment lengths.

Criticality Factor 2B: Functional Classification

Functional classifications information for each segment was obtained from the California Road System maps published in August 5, 2011. Each roadway is given one of seven classifications (see

Table 3). These classifications were then assigned weights to represent their relative significance.

Most segments fell under a single classification. However, eight segments had multiple classifications. For these cases, the segment was assigned the classification that made up the majority of the segment. For example, Highway 101, Segment 13 is approximately 6.0 miles long and is primarily assigned a classification of 2 (Other Freeways or Expressways). This segment also has a 1 mile section with a classification of 3 (Other Principal Arterial). In this example, the 5 of the 6-mile segment is classification 2. Therefore, for this analysis that segment was assumed to have a classification of 2. Attachment A, Figure A1 displays the functional classifications of roadways in District 1.

Table 3: Roadway Functional Classification Descriptions and Weights

Functional Classification	Classification Code	Weight
Interstate	1	N/A
Freeways or Expressways	2	10
Principal Arterial	3	7
Minor Arterial	4	5
Major Collector	5	2
Minor Collector	6	N/A
Local	7	1

Criticality Factor 2C: Miles of Access Control Highway Per Mile of Segment

Access Control Highway was evaluated based on the portion of a segment that was classified as limited access. This factor evaluates the amount of a segment that has controlled-access, separation of opposing traffic flow, grade separated interchanges to some extent, and few or no intersecting cross-streets.

Criticality Factor 2D: Average Number of Lanes/Mile

The number of lanes in a segment was used to evaluate the physical asset associated with total road-base and pavement surface area in each segment. The number of lanes for each segment was obtained from the Caltrans TCRs. The number of lanes varied between 1-lane conventional to 4-lane expressway. In some instances, the segments were listed as both 2- and 4-lane roadways, or as 2-lane with some passing lanes.

The number of lanes in these segments was averaged and was treated as 3 lanes and 2.5 lanes, respectively.

Criticality Factor 2E: Miles of Designated Bike Routes per Mile of Segment

Bicycle route lengths were evaluated based on their representative fraction of the total segment length. Bicycle touring routes were obtained from Caltrans' Bicycle Touring Guide for the California Northcoast. Seventy-five percent of Caltrans roadways in District 1 are identified as bicycle routes.

Criticality Factor 2F: Miles of Designated Bus Routes per Mile of Segment

Bus route lengths, independent of organizing authority, were calculated as a portion of the segment length. Bus routes reaches and authorities on segments varied between counties. The bus routes that were considered for this analysis included both municipal and regional in their jurisdiction. Municipal routes included Redwood Transit Authority in Humboldt County, Mendocino Transit Authority, Lake Transit, Del Norte County Public Transit, and Greyhound.

Criticality Factor 2G and 2H Related to Scenic Highways

Scenic highways were included to quantify the service asset associated with potential tourism implications of scenic highways. District 1 currently lists only one Officially Designated scenic highway, which is a 12.1 mile reach of Highway 101 between Prairie Creek Redwoods and Del Norte Redwoods State Parks. However, as of December 2013 Caltrans lists 8 other highways that are eligible for the Scenic Highway designation. Both the Officially Designated and Eligible Scenic Highways were included in this analysis as separate criticality factors.

Criticality Factor 2I: Miles of Designated Network Truck Route per Mile of Segment

Caltrans District 1 roadways support the following four major types of truck routes:

- Terminal Access (STAA),
- California Legal Network,
- California Legal Advisory route, and
- Special Restrictions routes.

Total length of STAA route present along a segment, as a proportion of the total segment length, was calculated to represent the ability for goods movement along the segment.

3.4.3 Criticality Group 3: Bridges

The bridges that were considered in this study included bridges that span roadways, railroads, and waterways. These bridges were separated into two categories: bridges over road and rail, and bridges over waterways. The former were further classified as overpasses and underpasses.

To assess the criticality of the bridges in a given segment, the bridges were assessed using the following metrics:

- Criticality Factor 3A: Number of bridges over waterways, over 100 feet in length
- Criticality Factor 3B: Number of bridges over waterways, less than 100 feet in length
- Criticality Factor 3C: Number of overpasses and underpasses per road segment

Bridges were assessed based characteristics including length and type of span, and potential structural, logistical and physical considerations associated with risks to bridge assets. For example, bridges spanning greater than 100 feet require significantly more structural support and pose substantial challenges to reestablishment following damage. Also, bridges over waterways were considered more critical infrastructure than bridges spanning roadways and railroads under the assumption that there is often no immediate alternative route to bypass a failed bridge over a waterway. Bridges spanning roadways and railroads, on the other hand, are assumed to present alternate options to redirect traffic, including a temporary road at grade. Bridges were ranked high in criticality by the Technical Advisory Group (TAG) due to the inherent challenges in recovering from damage to bridge assets. Attachment A, Figure A5 displays the cluster density of bridges on highways in District 1.

3.4.4 Criticality Group 4: Stormwater Management Facilities

Assessment of the criticality of stormwater facilities was based on Criticality Factor 4A: Number of Stormwater Inlets, Outfalls, and Ditches, and Criticality Factor 4B: Number of Stormwater Culverts. Stormwater infrastructure was evaluated within segments and at locations where stormwater flow either enters or exits Caltrans property. Where a facility lies at the junction of two segments, the facility was assigned to the closest segment spatiallyAttachment A Figure A4 displays the cluster density of stormwater facilities on highways in District 1.

3.4.5 Criticality Group 5: Amenities and Buildings

Amenities and buildings were evaluated within each segment based on the following criticality factors:

- Criticality Factor 5A: Number of Rest Areas (6 Total in District 1)
- Criticality Factor 5B: Number of Park & Ride Sites (7 Total in District 1)
- Criticality Factor 5C: Number of Vista Points (16 Total in District 1)
- Criticality Factor 5D: Number of Weigh and Agricultural Inspection Stations (2 Total in District 1)
- Criticality Factor 5E: Number of Caltrans Office Buildings (2 Total in District 1)
- Criticality Factor 5F: Number of Caltrans Maintenance Facilities (20 Total in District 1)

Criticality Factors 5A through 5C encompass amenities to the traveling public and commerce that enhance the transportation experience, but are not as significant as other types of assets. Criticality Factor 5D, Number of Weigh and Agricultural Inspect Stations, address facilities important to managing truck traffic and protection of California's agricultural industry Criticality Factor 5E was established to address Caltrans offices and headquarters used to manage District 1's transportation assets, and Criticality Factor 5F to address the network of maintenance facilities necessary to keep the assets operational on a daily basis.

3.4.6 Criticality Group 6: Traffic Control Systems and Call Boxes

Five types of traffic control systems are included in the data provided by Caltrans and call box information was provided by the Regional Transportation Planning Agencies (RTPA) for each county. These data were analyzed as criticality factors as follows:

- Criticality Factor 6A: Number of Traffic Signals (congestion management systems)
- Criticality Factor 6B: Number of Closed Circuit Television Systems
- Criticality Factor 6C: Number of Extinguishable Message Signs
- Criticality Factor 6D: Number of Highway Advisory Radio Systems
- Criticality Factor 6E: Number of Road Weather Information systems
- Criticality Factor 6F: Number of Call Boxes Road Weather Information systems

For each segment, the presence of these systems was summed to determine a raw criticality score. The raw criticality scores for all criticality factors evaluated were then scaled as discussed in the following section.

3.5 Criticality Factor Scaling

With wide ranging raw values for the criticality factors, such as census tract populations of 1,373 and 34,025, or call boxes ranging from 0 to 17, it is difficult to directly compare or aggregate data. A common basis for comparison needed to be created. Mathematical scaling of the data, from 1 to 10, provides a comparable rating for the criticality factor.

To achieve this scaled rating, the raw criticality factor values within each segment were divided by the maximum segment value for each associated criticality factor:

$$V_{scaled,i} = V_i / V_{max} * (10 - 1) + 1$$

Where i is the segment, $V_{scaled,i}$ is the scaled value within each factor, V_i is the raw value, and V_{max} is the maximum segment value recorded within each factor.

Unity-based normalization, also known as feature scaling, was considered as an alternate method of scaling but was ultimately discarded due to the potential to amplify minor differences in grouped data. For example, this would occur when considering the number of lanes in a roadway, which only vary from 1 to 4. Therefore, a mathematical scaling from 1 to 10 was used.

There are two versions of the Matrix used in this analysis. Attachment E contains the Criticality Matrix with all the raw values that were obtained for each criticality factor and segment. Attachment F contains a scaled version of the raw values. Additionally, the scaled version contains the weights that were determined for each criticality factor.

3.6 Criticality Factor Weighting

Once ratings were calculated by normalizing each criticality factor's raw score within each segment, the next step was to determine the relative weights of each criticality factor so they could be multiplied by the ratings to determine the overall score.

Feedback from a technical advisory group (TAG) and local stakeholders was a significant part of the process of defining and analyzing criticality. Based on TAG and stakeholder feedback and priorities, criticality factors were assigned importance and weighting. Some factors were relatively straightforward to prioritize with broad consensus from the group. For example, the number of rest areas in a given segment was defined to be less important in determining the overall "criticality" of a segment than the ADT within that segment. Likewise, an "eligible scenic highway" was a less important designation than a "truck route." However, in relative comparison to each other, many criticality factors do not have an obvious or inherent relative importance to one another and there were varied opinions from the TAG and stakeholders. For instance, the relative importance of the number of highway advisory radio systems or the number of call boxes may be less clear.

To facilitate obtaining input for importance weighting, the TAG and stakeholders were asked to assign a value between 1 and 10 for each factor. Attachment G summarizes the factors and the averaged scale of importance.

To further hone in on the relative importance of criticality factors, TAG and stakeholders were asked to perform a pairwise analysis (paired comparison) of each criticality factor (see Attachment H). The pairwise method compares the relative importance of each factor against every other factor on a one-to-one basis without considering how any other factors compare to those two. The evaluator chooses one factor as more important (with a score of one) than another (with a score of zero). The pairwise analysis is repeated for all factors until each factor has been evaluated against every other factor. The gray shaded cells are automatically populated as the opposite values of the unshaded cells the opposite pairwise comparison. Summing values in the columns for each row and dividing that sum by the total count produces a weight for each factor. The resulting weight determines the relative importance of all criticality factors evaluated. These were then averaged for all participants.

Once the relative weights were calculated, they were scaled to a range of 1 to 10 using the same method described in Section 3.5. Attachment I presents the results of the weighting process. The top 15 most heavily weighted criticality factors are as follows (in order of weight):

1. 1A: Level of Access (System Redundancy Measure 1)
2. 1C: Composite ADT
3. 1D: Composite peak hour volume
4. 3A: Number of bridges over water longer than 100 feet
5. 2B: Functional classification
6. 1M: Number of critical nodes
7. 2C: Miles of access control highway per mile of segment
8. 2I: Miles of designated network truck route per mile of segment
9. 1L: Number of non-park municipal land use parcels with 1-mile buffer
10. 4A: Number of stormwater inlets, outfalls, and ditches
11. 4B: Number of stormwater culverts
12. 1B: Ability to Reroute (System Redundancy Measure 2)
13. 1G: Total population in census tracts
14. 2F: Miles of designated bus route per mile of segment
15. 3C: Number of overpasses and underpasses

The weighting was combined with the previously determined criticality factor ratings to determine the criticality score discussed in the following section.

3.7 Criticality Score

The scaled criticality factor ratings (1-10) for each segment were multiplied by the corresponding scaled criticality factor weighting to calculate a total weighed criticality score. The total weighted criticality scores were then scaled 1-10 by the same methods described previously. The result was a criticality score from 1 to 10 with all scores relative to the top score. The score describes criticality in terms of least (1) to most (10) critical. Image 4 displays the general meaning of each score along the 1 to 10 criticality rating scale. Image 4 is based on FHWA's "Climate Change & Extreme Weather Vulnerability Assessment Framework" (December 2012) and Washington State Department of Transportation's "Climate Impacts Vulnerability Assessment (November 2011).

In general, scores above "7" are most critical, scores between "4" and "7" demonstrate moderate criticality, and scores below "4" are least critical. It is important to note that criticality is defined as the relative importance (as established by local stakeholders) of a transportation facility or asset in comparison to equivalent facilities or assets within District 1. In other words, each segment's criticality score indicates the segment's relative importance to other segments in the District as defined by the measures of the criticality factors established by project stakeholders.

LEVELS OF RELATIVE CRITICALITY OF SEGMENTS IN DISTRICT		
LEAST	MODERATE	MOST
1 2 3	4 5 6	7 8 9 10
THE RELATIVE CRITICALITY OF SEGMENTS THAT FALL WITHIN THESE GROUPS ARE GENERALLY CHARACTERIZED BY:		
SYSTEM CONNECTIVITY, TRAFFIC VOLUME, & POPULATION		
• Higher redundancy and ability to reroute • Less than 10,000 composite ADT • Less then 1,000 composite peak hour volume (PHV) • Less than 5,000 people in intersected census tracts • Less than 200 non-park municipal parcels within one mile	• Variable redundancy and ability to reroute • Between 10,000 and 30,000 ADT • Between 1,000 and 2,500 composite PHV • Between 5,000 and 15,000 people in intersected tracts • Variable number of municipal/residential parcels within one mile	• Lower redundancy and ability to reroute • Greater than 40,000 composite ADT • Greater then 4,000 composite PHV • Greater than 20,000 people in intersected census tracts • Greater than 4,000 non-park municipal parcels and greater than 1,000 residential parcels within one mile
HIGHWAY LENGTH & CLASSIFICATION		
• Mostly collectors (minor and major) and minor arterial • No access control	• Mostly principal or minor arterial • Variable amount of access controlled	• Mostly freeway, expressway or principal arterial • Greater 70% access controlled
BRIDGES & STORMWATER FACILITIES		
• Fewest number of stormwater management facilities • Few bridges spanning water, overpasses and underpasses	• Variable number of stormwater management facilities • Variable number of bridges (all types)	• Greatest number of stormwater management facilities • More than 5 bridges spanning water, over 100 feet long • More then 15 overpasses/ underpasses
AMENITIES, BUILDINGS, & TRAFFIC OPERATING SYSTEMS		
• No amenities or maintenance buildings • No Traffic Operating Systems (TOS)	• Variable amenities and maintenance buildings • Variable number of TOS and call boxes	• More amenities and maintenance buildings • More TOS and call boxes

Image 4: General Segment Attributes for Criticality Evaluation of District 1

4 Results

The 93 TCR segments and subsegments were ranked according to their criticality score. Image 5 shows the sorting of criticality scores, showing the score of each segment, with segments color-coded by county. Attachment J includes labels for the different segments, as well as criticality scoring by county. Tabular results for all of District 1 are presented in Attachment K. Attachment A, Figure A10 displays these results on a District-wide map.

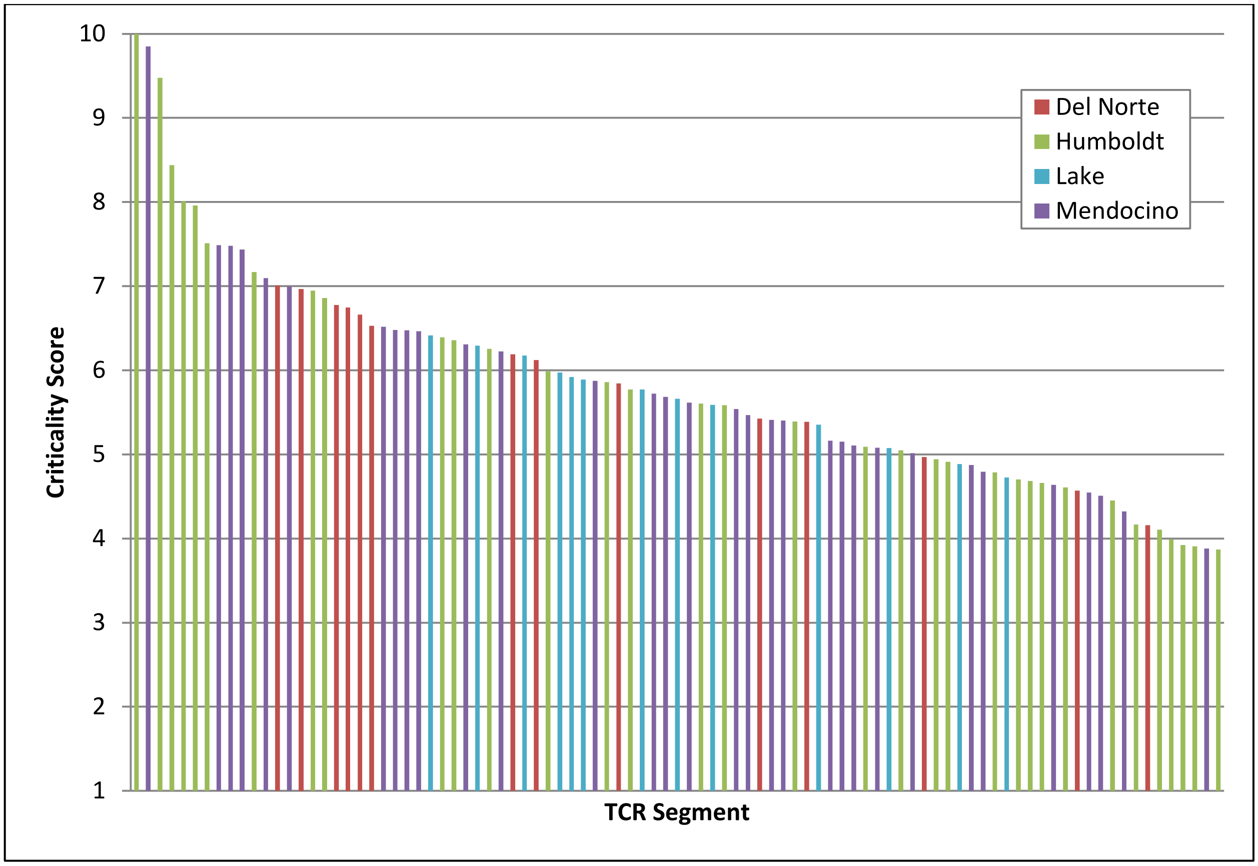

Image 5: Criticality Scores of Segments by County. The weighted results of all segments in District 1 show criticality scores range from 10 to approximately 3.9.

The median, mean, and range of segment criticality scores for each county are illustrated in the box-and-whisker plot shown in Image 6. The median value is represented by the black horizontal line within the boxplot, while the mean is shown as the circle. The minimum and maximum values for each county are graphically indicated by the whiskers above and below each box. The whiskers also represent the bottom and top 25% of the data, or first and fourth quartile, respectively. The box represents the middle 50% of the data, or second and third quartile. These plots help to indicate the degree of dispersion (spread) and skewness in the data.

The results indicate that the segments in District 1 scored between 3.9 and 10, with the top 25% of the segments scoring between approximately 6.5 and 10. Del Norte and Lake Counties scored within narrow ranges and their maximum scores were significantly lower than the maximum scores for Humboldt and Mendocino Counties. The range of scores for Humboldt and Mendocino spanned the entire range for District 1, indicating that they contain some of the lowest and highest scoring segments.

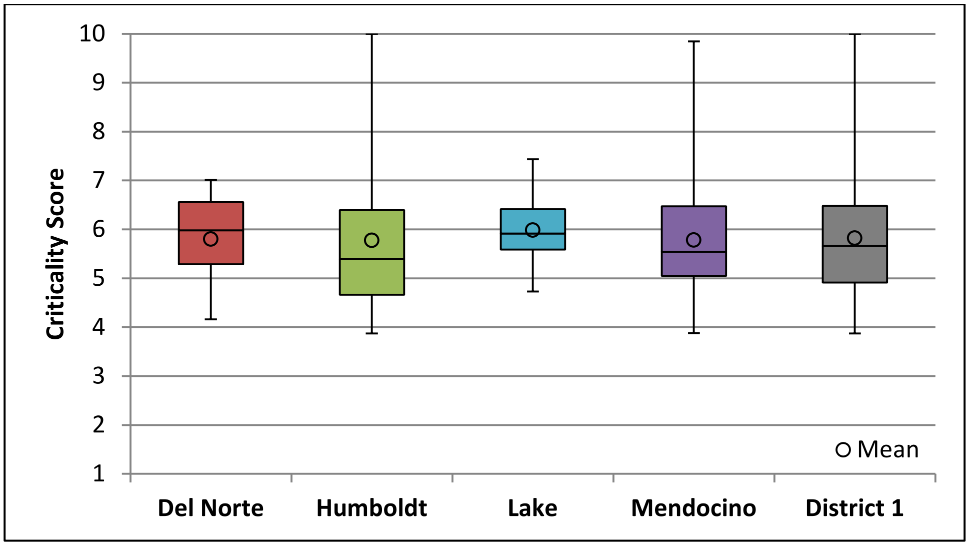

Image 6: Box-and-Whisker Plot Showing the Dispersion of the Criticality Scores by County and District 1.

Further analysis indicates that Humboldt and Mendocino have several outlying segments with scores significantly higher than the bulk of the scores in their respective counties. The high outliers included scores between 9.5 and 10 and represent the top 3 highest scoring segments. The next top 3 scoring segments ranged between 8.0 and 8.4. The distribution of the segment criticality scores in District 1 shown on the right side of Image 6 is further detailed in Image 7. As shown in Image 7, the distribution of scores has a central tendency around the 5.0 to 5.9 range, which corresponds to the mean score of 5.8 and median score of 5.7.

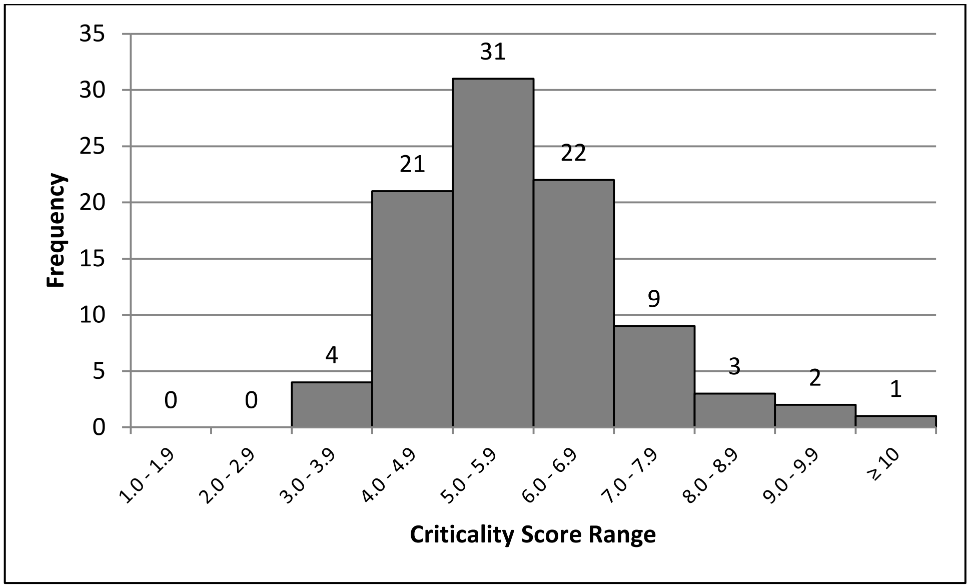

Image 7: Distribution of the Segment Criticality Scores in District 1.

Approximately 5.4% of the segments scored above a criticality of 8, 89.2% of the segments scored between 4 and 8, and 5.4% scored below 4. Criticality scores greater than 8 indicate the most critical segments and the following six segments received scores above 8:

1. US 101 Segment 14.1
2. US 101 Segment 3.1
3. US 101 Segment 11.3
4. US 101 Segment 12
5. US 101 Segment 11.1
6. US 101 Segment 13

Five of these segments are in Humboldt County and one is in Mendocino County. Each of the top six segments is described below, including an analysis of why each segment received a high criticality score.

4.1 US 101 Segment 14.1

The segment that received the highest criticality score of 10.0 is US 101 Segment 14.1 in Humboldt County and includes the stretch of US 101 from the south end of Arcata to the north end of McKinleyville. The segment is 8.2 miles long and extends from the junction of US 101 with SR 255 (post mile 85.8) to Airport Road (post mile 94.0). The segment scored above the 95th percentile for the following criticality factors: ADT, population, number of residential parcels, number of non-park municipal parcels, number of critical nodes, functional classification, majority of highway classifications, bridges over roadways and railroads, stormwater inlets, outlets and ditches, many amenities and buildings and traffic operating systems.

4.2 US 101 Segment 3.1

The segment that received the second highest criticality score of 10.0 is US 101 Segment 3.1 in Mendocino County and generally described as the stretch from south of Ukiah to the intersection of Route 20. The segment is approximately 13.5 miles long from post mile 17.6 to 31.1. The segment scored above the 95th percentile for the following criticality factors: ADT, population, number of commercial parcels, number of industrial parcels, number of critical nodes, functional classification, majority of highway classifications, all bridge categories, stormwater inlets, outlets and ditches, and many amenities and buildings.

4.3 US 101 Segment 11.3

The segment that received the third highest criticality score of 9.3 is US 101 Segment 11.3 in Humboldt County and generally described as the stretch from Rio Dell to the south Eureka urban boundary. The segment is approximately 22.1 miles long from post mile 52.7 to 74.8. The segment scored above the 95th percentile for the following criticality factors: ADT, population, number of non-park municipal parcels, functional classification, majority of highway classifications, all bridge categories, and all amenities and buildings.

4.4 US 101 Segment 12

The segment that received the fourth highest criticality score of 7.8 is US 101 Segment 12 in Humboldt County and generally described as the stretch from the south Eureka urban boundary to near north Eureka city limits. The segment is approximately 5 miles long from post mile 74.8 to 79.8. The segment scored above the 95th percentile for the following criticality factors: ADT, peak hour volume, population, population density, number of non-park municipal parcels, functional classification, majority of highway classifications, both stormwater facility categories, and many amenities, buildings and traffic operating systems.

4.5 US 101 Segment 11.1

The segment that received the fifth highest criticality score of 7.5 is US 101 Segment 11.1 in Humboldt County and generally described as the stretch north of Richardson Grove to Weott. The segment is approximately 27.6 miles long from post mile 5.6 to 33.2. The segment scored above the 95^{th} percentile for the following criticality factors: Number of critical nodes, total length of segment, functional classification, majority of highway classifications, number of culverts, and many amenities and buildings and call boxes.

4.6 US 101 Segment 13

The segment that received the sixth highest criticality score of 7.4 is US 101 Segment 13 in Humboldt County and generally described as the stretch from the north Eureka city limits to the junction with Route 255 (South Arcata). This segment is generally coincident with the safety corridor of US 101 between Eureka and Arcata. The segment is approximately 6 miles long from post mile 79.8 to 85.8. The segment scored above the 95^{th} percentile for the following criticality factors: ADT, peak hour volume, population, number of non-park municipal parcels, functional classification, majority of highway classifications, and many amenities, buildings and traffic operating systems.

5 Discussion

The criticality scores for each segment were derived from the relative analysis of the criticality rating and the criticality weighting. Initial review of preliminary results indicated that longer segments could generally score higher than shorter segments in part due to the number of assets along their length, number of factors that were a function of length (i.e. miles of bus routes, limited access freeway, and truck routes) and initial weighting of those factors. To avoid skewing of the results, criticality factors were removed and/or combined, reducing duplication of physical and service assets and increasing the overall weight of specific factors based on feedback provided by the TAG and stakeholders. Other methods were employed for reducing the influence of length on the overall score including considering factors such as a percentage or fraction of the total segment length (factor per mile of segment) and breaking longer segments into smaller sub-segments.

The process resulted in findings that road segments near more populated areas scored more highly critical than more rural or low population areas, despite knowledge that some of these roads are more likely to fail. TAG and stakeholder feedback regarding this included:

- Criticality weighting reflects to some degree the priorities of the participants engaging in the weighting process.
    - How does an agency ensure balanced representation of interests between populated urban areas and less populated rural ones?
    - How are the needs of a minority (in this case, rural populations) protected or met?
- Consider using tax information of a region/segment to inform economic rankings;
- Calculate population density by political (inhabited area) boundaries rather than census tracts.
- State and national parks drive local economies and should be included land uses.

- These parks may include geologically unstable or active areas and may be an indicator of potential hazards to nearby road segments.

Regardless the outcome of the criticality rankings, rural or lower-ADT roads with known instabilities and maintenance issues are likely to rank higher in terms of the Sensitivity and Exposure analyses, and possibly Potential for Impact. These multiple points of analysis provide balance. These analytical tools highlight where adaptation issues may occur; selecting and moving forward with projects is ultimately a political process.

The application of the methods described above was an iterative process involving analysis of the results and assets contained in the high and low scoring segments. The goal of the process was to quantitatively describe the criticality of segments relative to one another according to the qualitative feedback provided by the TAG and stakeholders. The application of the relative scale, where the highest score determines a score of 10 and all other scores represent a fraction of that score, can create a large range of scores within the top 10 scoring segments. This issue was mitigated by applying the methods described above. Figures showing segment scores for the higher-weighted criticality factors are shown in Attachment A, figure A10.

6 Conclusions

Segments with high criticality scores typically had large ADTs, a relatively large number of long bridges, high populations, a relatively large number of critical nodes, higher functional classifications, a relatively high number of overpasses/underpasses, and a relatively high number of stormwater facilities. This is an unsurprising result given that this tends to represent transportation assets of both high use and high costs.

7 References

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Attachment A

Map Figure Set A

Functional Classifications

- Freeway or Expressway
- Principal Arterial
- Minor Arterial
- Major Collector
- Local Road
- City
- National or State Park
- District 1 Boundary
- County Boundary
- Outside of District 1

Paper Size 8.5" x 11" (ANSI A)

0 10 20 30 40 50

Miles

Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

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Date 24 Jun 2014

Vicinity Map

Figure A1

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Highway

- 1
- 101
- 101U
- 128
- 162
- 169
- 175
- 197
- 199
- 20
- 200
- 211
- 222
- 253
- 254
- 255
- 271
- 281
- 283
- 29
- 299
- 36
- 53
- 96

Route by Segment

- Route Segment (Even Number)
- Route Segment (Odd Number)
- Segment Break

- National or State Park
- County Boundary
- District 1 Boundary
- Outside of District 1

Paper Size 8.5" x 11" (ANSI A)
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Miles
Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

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TCR Segments

Figure A2

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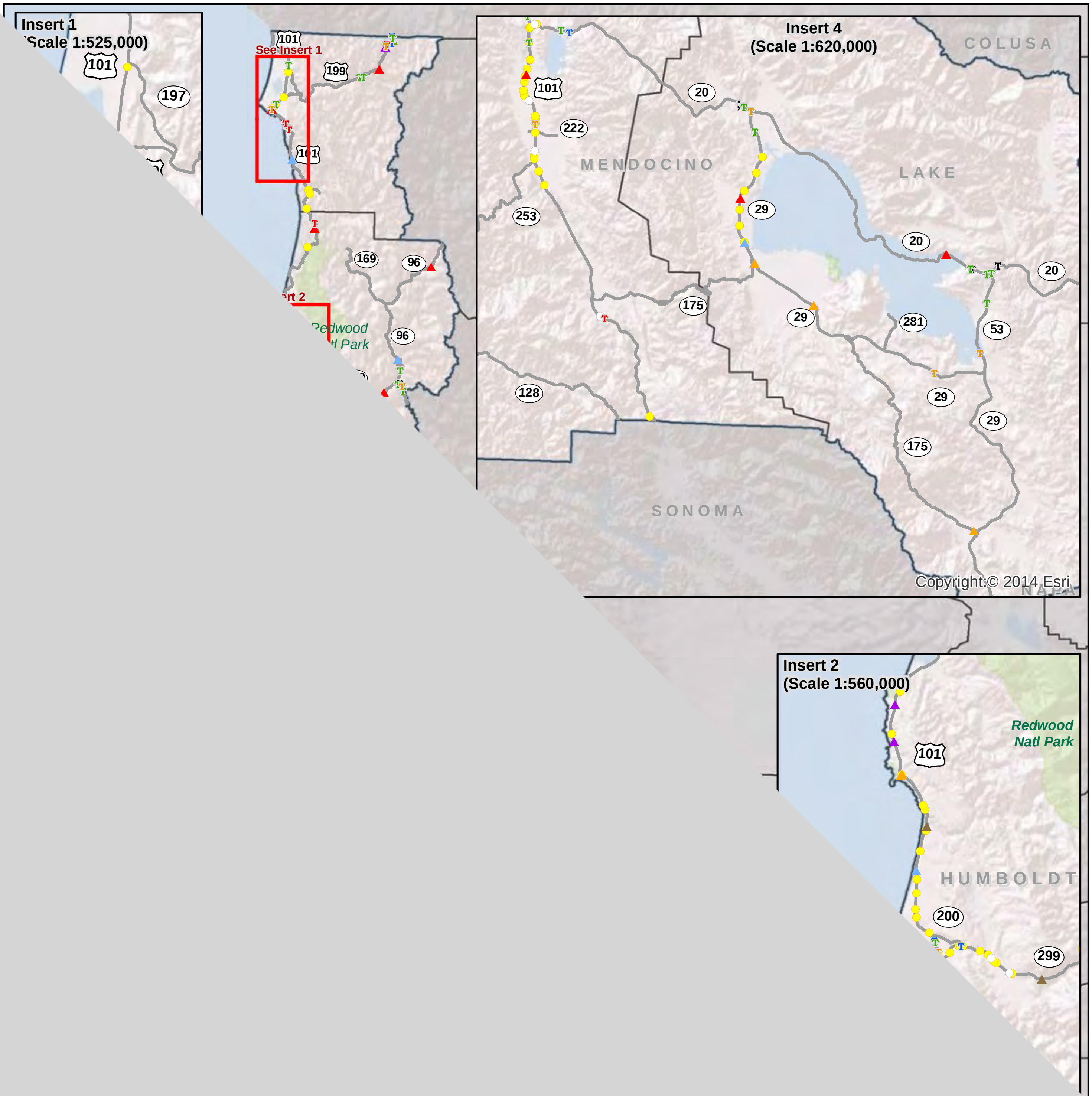
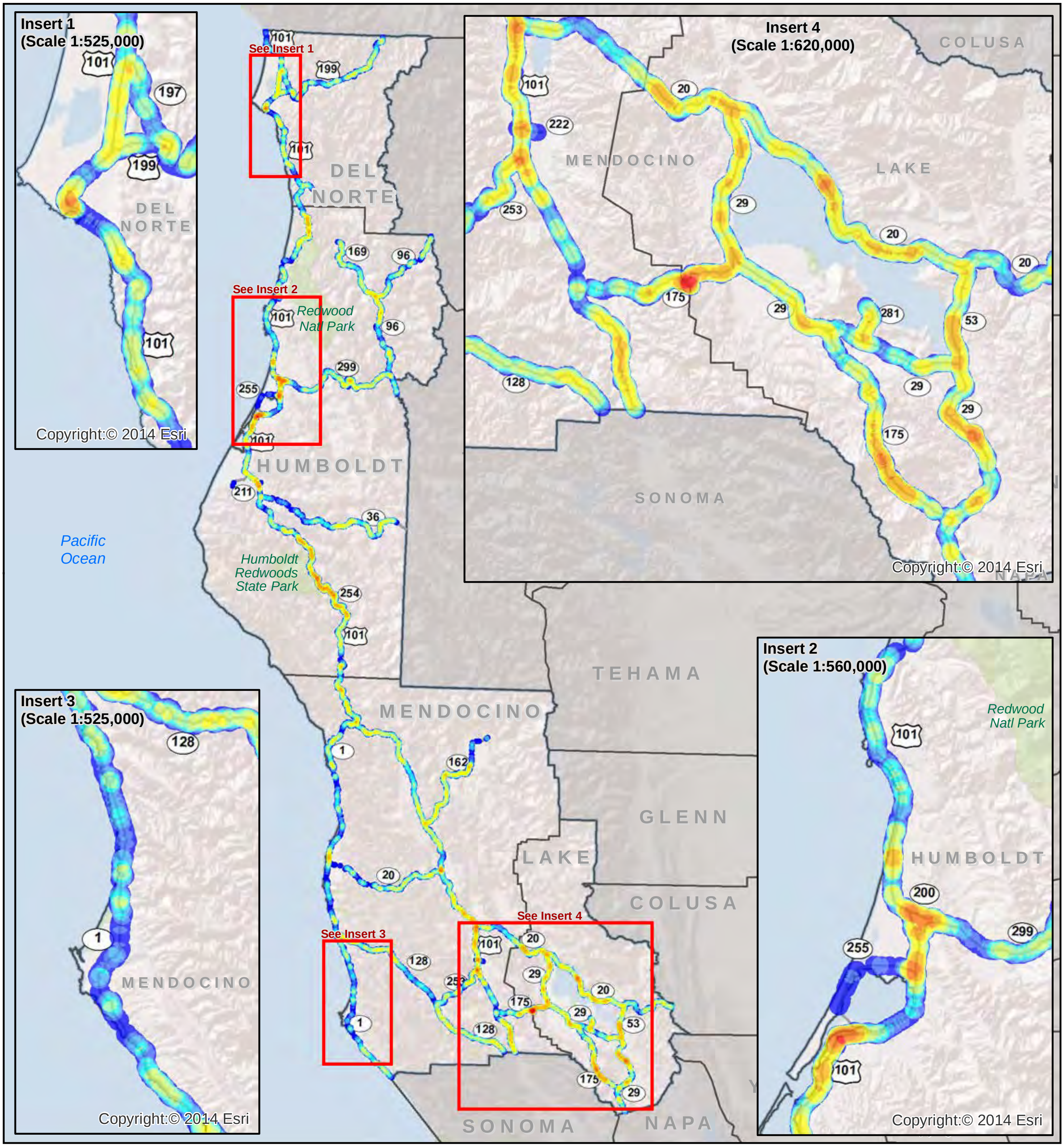


Insert 1
(Scale 1:525,000)
101
197
See Insert 1
199
169
96
Redwood
Natl Park
Insert 4
(Scale 1:620,000)
COLUSA
MENDOCINO
LAKE
SONOMA
101
222
253
20
29
175
281
53
128
Copyright:© 2014 Esri
Insert 2
(Scale 1:560,000)
Redwood
Natl Park
HUMBOLDT
200
299



Stormwater Facility Cluster Density

- 0.824 - 6.32
- 6.33 - 9.65
- 9.66 - 11.7
- 11.8 - 15
- 15.1 - 20.5
- 20.6 - 29.6
- 29.7 - 44.5
- 44.6 - 69.1
- 69.2 - 110
- 111 - 176

- National or State Park
- County Boundary
- District 1 Boundary
- Outside of District 1

Paper Size 8.5" x 11" (ANSI A)
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Miles
Map Projection: Albers
Horizontal Datum: North American 1983
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Asset Data
Stormwater Facility Cluster Density Figure A4

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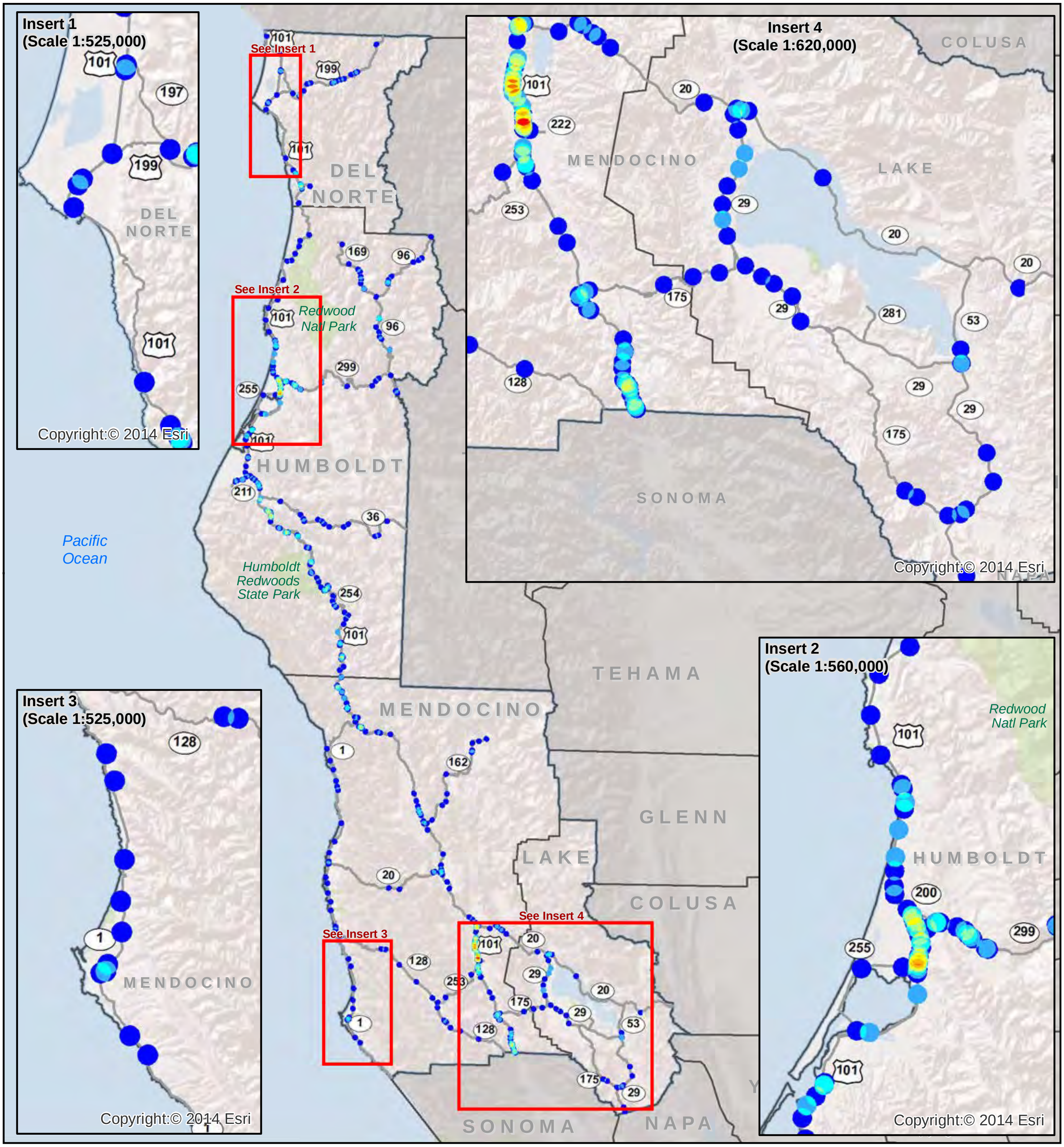

Number of Bridge / Square Mile

- 0.82
- 0.83 - 1.6
- 1.7 - 2.5
- 2.6 - 3.3
- 3.4 - 4.1
- 4.2 - 4.9
- 5 - 5.8
- 5.9 - 6.6
- 6.7 - 7.4
- 7.5 - 8.2

- State Route
- National or State Park
- County Boundary
- District 1 Boundary
- Outside of District 1

Paper Size 8.5" x 11" (ANSI A)
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Miles
Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

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Asset Data
Bridge Cluster Density

Figure A5

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Redundancy Score (1 - 10)

1 = High, 10 = Low

- 2
- 4
- 6
- 8
- 10

City

National or State Park

District 1 Boundary

County Boundary

Outside of District 1

Paper Size 8.5" x 11" (ANSI A)

0 10 20 30 40 50

Miles

Map Projection: Albers
Horizontal Datum: North American 1983
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Criticality Factor Score
Redundancy

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Revision	A
Date	24 Jun 2014

Figure A6

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ADT Score

(1 = Lowest, 10 = Highest)

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- 5.1 - 6.0
- 6.1 - 7.0
- 7.1 - 8.0
- 8.1 - 9.0
- 9.1 - 10.0
- City
- National or State Park
- District 1 Boundary
- County Boundary
- Outside of District 1

Paper Size 8.5" x 11" (ANSI A)

0 10 20 30 40 50

Miles

Map Projection: Albers
Horizontal Datum: North American 1983
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Criticality Factor Score
Composite ADT

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Date	24 Jun 2014

Figure A7

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Population Score

1 = Lowest, 10 = Highest

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- 5.1 - 6.0
- 6.1 - 7.0
- 7.1 - 8.0
- 8.1 - 9.0
- 9.1 - 10.0

City

National Park or Forest

District 1 Boundary

County Boundary

Outside of District 1

Paper Size 8.5" x 11" (ANSI A)

0 10 20 30 40 50

Miles

Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

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Criticality Factor Score Population

Figure A8

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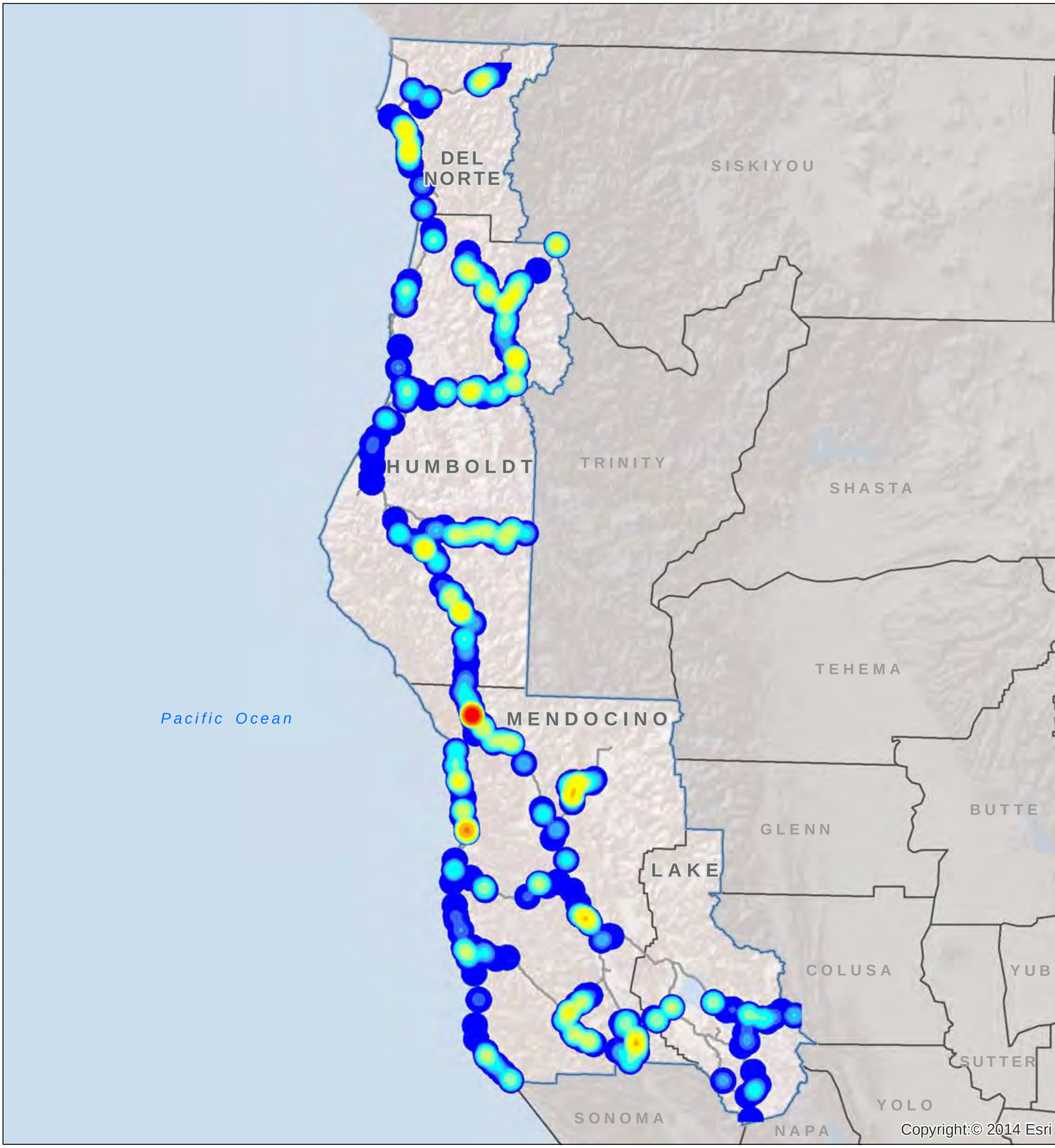

Historic Cost of Events

- 1- 25,000
- 25,001- 50,000
- 50,001 - 100,000
- 100,001 - 250,000
- 250,001 - 500,000
- 500,001 - 1,000,000
- 1,000,001 - 2,500,000
- 2,500,001 - 5,000,000
- 5,000,001 - 10,000,000
- 10,000,001 - 20,000,000

- State Route
- District 1 Boundary
- County Boundary
- Outside of District 1

Paper Size 8.5" x 11" (ANSI A)

0 10 20 30 40 50

Miles

Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

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Cluster Density by Cost of Events **Figure A9.1**

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Historic Event

- No Date
- 1986-1999
- 2000-2009
- 2010
- 2011
- 2012
- 2013
- 2014
- Chronic

- State Route
- District 1 Boundary
- County Boundary
- Outside of District 1

Paper Size 8.5" x 11" (ANSI A)

0 10 20 30 40 50

Miles

Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

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Revision	A
Date	25 Jun 2014

Cluster Density by Cost of Events Figure A9.2

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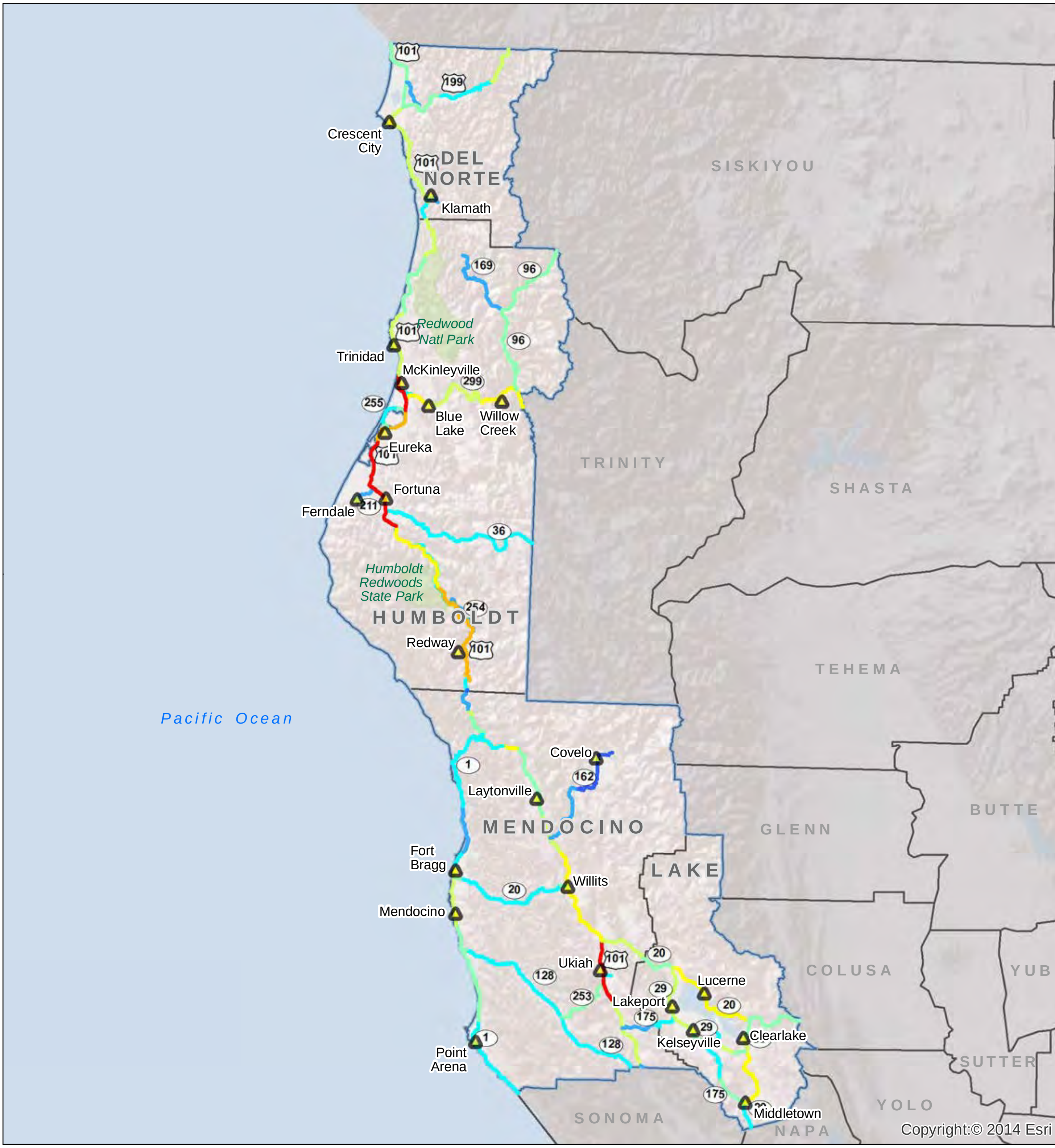

Overall Criticality Score

1 = Low, 10 = High

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- 5.1 - 6.0
- 6.1 - 7.0
- 7.1 - 8.0
- 8.1 - 9.0
- 9.1 - 10.0
- City
- National or State Park
- District 1 Boundary
- County Boundary
- Outside of District 1

Paper Size 8.5" x 11" (ANSI A)

0 10 20 30 40 50

Miles

Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

N

Caltrans District 1 and HCAOG
District 1 Climate Change Pilot Study

Job Number 84-11905
Revision A
Date 24 Jun 2014

Criticality Factor Score
Overall Criticality Score Per TCR Segment

Figure A10

718 Third Street Eureka CA 95501 USA T 707 443 8326 F 707 444 8330 E eureka@ghd.com W www.ghd.com

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Attachment B

TCR Segment Descriptions and Post Miles

Attachment B: TCR segment descriptions and post miles

Highway	TCR Segment	Segment Description	Begin Post Mile	End Post Mile
1	1.1	Sonoma/Mendocino County line to Point Arena (north)	0.0	20.4
	1.2	Point Arena (north) to Route 128	20.4	40.3
	2	Junction Route 128 to Little River	40.3	48.0
	3	Little River to south Fort Bragg City limit	48.0	59.7
	4	So. Fort Bragg City limits to No. Fort Bragg City limit	59.7	62.4
	5	No. Fort Bragg City limits to Little Valley Road	62.4	66.8
	6	Little Valley Road to North Westport	66.8	77.7
	7	North Westport to Junction Rte. 101 at Leggett	77.7	105.6
20	1	From Route 1 at Fort to Summer Lane	0.0	2.1
	2	Summer Lane to Broaddus Creek	2.1	31.6
	3	Broaddus Creek to Route 101 at Willits	31.6	R33.2
	4	Route 101 to MEN/LAK Co. Line	33.2	44.1
	5	MEN/LAK Co. Line to Route 29	0.0	8.3
	6	Route 29 to Route 53	8.3	31.6
	7	Route 53 to LAK/COL Co. Line	31.6	46.5
29	1	Napa/Lake Co. line to Junction Route 175	0.00	5.80
	2	Junction Route 175 to Junction Route 53	5.80	20.30
	3	Junction Route 53 to North of Diener Drive	20.30	23.80
	4	North of Diener Dr to North of Junction Rte. 175	23.80	31.60
	5	No. of Junction Rte. 175 to Kelseyville	31.60	R34.58
	6	Kelseyville to 0.5 mile South of Lakeport (w/ Rte 175)	R34.58	R40.90
	7	0.5 mile South of Lakeport City limit to 0.7 mile North of Lucerne Cutoff	R40.90	48.58
	8	0.7 mile North of Lucerne Cutoff to Junction Route 20	48.58	52.53
36	1	Rte 101 to Hely Creek Bridge	0.0	11.5
	2	Hely Creek Bridge	11.5	24.8
	3	Bridgeville to Trinity Co. Line	24.8	45.7
53	1	Junction SR 29 to 40th Ave. City of Clearlake	0.0	2.96
	2	40th Ave to Junction SR 20	2.96	7.445
96	1	Rte. 299 to 1.3 km (0.8 mi) south of Rock Chute Viaduct.	0.0	16.0
	2	1.3 km (0.8 mi) south Rock Chute Viaduct to HUM Co. line.	16.0	R45.0

Attachment B: TCR segment descriptions and post miles

Highway	TCR Segment	Segment Description	Begin Post Mile	End Post Mile
101	0	101U: SON/MEN Co. line to Jct. Rte. 101	0	0.655
	1	SON/MEN Co. line to Pieta Creek	R0.1	5.8
	2	Pieta Creek to South of Ukiah	5.8	17.6
	3.1	South of Ukiah to Rte 20	17.6	31.06
	3.2	Rte 20 to South of Willits	31.06	43.5
	4	South of Willits to Arnold	T43.5	55.4
	5	Arnold to South of Laytonville	55.4	64.7
	6	South of Laytonville to Bell Springs Rd.	64.7	81.4
	7	Bell Springs Rd. to Jct. Rte. 1 at Leggett	81.4	T91.2
	8	Jct. Rte. 1 at Leggett to Red Mountain Creek	T91.2	100.3
	9	Red Mountain Creek to MEN/HUM County line	100.3	T106.8
	10	MEN/HUM County line to North of Richardson Grove	T0.0	R5.6
	11.1	North of Richardson Grove to Weott	R5.6	33.24
	11.2	Weott to north of Rio Dell	33.24	52.68
	11.3	North of Rio Dell to South Eureka Urban boundary	52.68	74.8
	12	South Eureka Urban boundary to near North Eureka city limits	74.8	79.8
	13	Near North Eureka city limits to Jct. Rte 255	79.8	85.8
	14.1	Jct 255 to Airport	85.8	93.968
	14.2	Airport to Big Lagoon	93.968	109.4
	15	Big Lagoon to Redwood National Park Bypass	109.4	R125.8
	16	Redwood National Park Bypass	R125.8	R137.1
	17	HUM/DN Co. line to Kamp Klamath	M0.0	R3.6
	18	Del Norte Redwoods State Park Area	R3.6	12.5
	19	Wilson Creek to South of Crescent City.	12.5	25.7
	20	South of Crescent City to North of Crescent City	25.7	27.2
	21	North of Crescent City to Jct. Rte. 199	27.2	31.3
	22	Jct. Rte. 199 to Oregon border	31.3	46.5
128	1	Route 1 to Indian Creek Bridge	0.0	23.3
	2	Indian Creek Bridge to Route 253	23.3	29.6
	3	Route 253 to the Sonoma County Line	29.6	50.9

Attachment B: TCR segment descriptions and post miles

Highway	TCR Segment	Segment Description	Begin Post Mile	End Post Mile
162	1.1	Route 101 to PM 16.76	0.0	16.76
	1.2	PM 16.76 to Short Creek Bridge	16.76	34.0
169	1	Route 101 to Klamath Glen	R0.0	3.5
	4	Wautec to Ke'pel Road	13.2	23.7
	5	Ke'pel Road to Martins Ferry	23.7	30.0
	6	Martins Ferry to Weitchpec	30.0	33.8
175	1	Route 101 to MEN/LAK County Line	0.0	9.9
	2	MEN/LAK County Line to Route 29 South of the City of Lakeport	0.0	R8.2
	3	Route 29 South of the community of Kelseyville to the community of Cobb	8.3	19.6
	4	From the community of Cobb to Route 29 in the community of Middletown	19.6	28.0
197	1	Route 199 to Route 101	0.0	7.1
199	1	Route 101 to near Gasquet	T0.5	13.0
	2	Near Gasquet to west of Patrick Creek	13.0	19.8
	3	West of Patrick Creek to near Idlewild	19.8	27.1
	4	Near Idlewild to the Calif./Oregon Border	27.1	36.4
200	1	Jct. Rte. 101 to Jct. Rte. 299	R0.0	R2.7
211	3	Ocean Ave. in Ferndale to Route 101	73.2	79.2
222	1	Rte. 101 to East Site Road in Talmage	R0.0	2.2
253	1	Rte 128 at Boonville to Junction Rte 101 near Ukiah	0.0	17.2
254	1	Route 101 to Myers Flat	0.0	12.3
	2	Myers Flat to Route 101 at Jordan Road	12.3	46.5
255	1	Route 101 to Eureka Urban Limits	0.0	1.7
	2	Eureka Urban Limits to 0.2 mi. North Mad River Slough Br. #4-257	1.7	5.4
	3	0.2 Mi. North Mad River Slough Br. #257 to Arcata Urban Limits	5.4	7.2
	4	Arcata Urban Limits to Junction Rte. 101	7.2	8.8
271	1	Route 101 to Route 1	0.0	7.3
	2	1.5 miles so. of Reynolds Overcrossing to the MEN/HUM County line	17.1	22.7
	3	MEN/HUM Co. line to Route 101	0.0	T0.3
281	2	Near Konoctl Bay to Route 29	14.0	17.0

Attachment B: TCR segment descriptions and post miles

Highway	TCR Segment	Segment Description	Begin Post Mile	End Post Mile
283	1	Rte 101 to end of Eel River Bridge #4-15	0.0	0.4
299	1	Route 101 To The City Of Blue Lake	0.0	R5.9
	2	City Of Blue Lake To Community Of Willow Creek	R5.9	29.1
	3	Community Of Willow Creek To Humboldt/Trinity Line	29.1	43.0

Attachment C

List of Criticality Groups and Factors

Attachment C: List of criticality groups and factors

Criticality Group	Criticality Factor
Criticality Group 1: System Connectivity, Average Daily Traffic, and Population	1A: Level of Access (System Redundancy Measure 1)
	1B: Ability to Reroute (System Redundancy Measure 2)
	1C: Composite ADT
	1D: Composite peak hour volume
	1E: Total population in census block groups
	1F: Total population density in census block groups (ppl/sm)
	1G: Total population in census tracts
	1H: Total population density in census tracts (ppl/sm)
	1I: Number of commercial land use parcels with 1-mile buffer
	1J: Number of residential land use parcels with 1-mile buffer
	1K: Number of industrial land use parcels with 1-mile buffer
	1L: Number of non-park municipal land use parcels with 1-mile buffer
	1M: Number of critical nodes
Criticality Group 2: Highway Length and Classifications	2A: Total miles of segment
	2B: Functional classification
	2C: Miles of access control highway per mile of segment
	2D: Average number of lanes/mile
	2E: Miles of designated bike routes per mile of segment
	2F: Miles of designated bus route per mile of segment
	2G: Miles of officially designated scenic highway per mile of segment
	2H: Miles of eligible scenic highway per mile of segment
	2I: Miles of designated network truck route per mile of segment
Criticality Group 3: Bridges	3A: Number of bridges over water longer than 100 feet
	3B: Number of bridges over water shorter than 100 feet
	3C: Number of overpasses and underpasses
Criticality Group 4: Stormwater Management Facilities	4A: Number of stormwater inlets, outfalls, and ditches
	4B: Number of stormwater culverts
Criticality Group 5: Amenities and Buildings	5A: Number of rest areas
	5B: Number of park & ride sites
	5C: Number of vista points
	5D: Number of weigh station and agricultural inspection stations
	5E: Number of maintenance facilities
	5F: Number of Caltrans office buildings
Criticality Group 6: Traffic Control Systems and Call Boxes	6A: Number of traffic signals (congestion management systems)
	6B: Number of closed circuit television systems
	6C: Number of extinguishable message signs
	6D: Number of highway advisory radio systems
	6E: Number of road weather information systems
	6F: Number of call boxes

Attachment D

Land Use Categories and Descriptions

Attachment D: Land use categories and descriptions

Residential	
Coastal Fishing Village	Medium Density Residential
Coastal Rural Remote Residential	Medium Density Residential Planned Development
Coastal Rural Remote Residential Development Limitation	Mendocino Multiple Family Residential
Coastal Rural Remote Residential Planned Unit Development	Mendocino Rural Residential
Coastal Rural Residential	Mendocino Rural Residential Planned Unit Development
Coastal Rural Residential Contract Rezone	Mendocino Suburban Residential
Coastal Rural Residential Development Limitation	Mendocino Town Residential
Coastal Rural Residential Development Limitation PD	Multi family residential – vacant
Coastal Rural Residential Planned Unit Development	Multi-Family Residential
Coastal Rural Village	Multi-Family Residential District
Gualala Planned Development	Multiple Residence
Gualala Village Mixed Use	Planned Development Residential District
High Density Residential	Residential Agriculture - 2 Acre
High Density Residential Planned Development	Residential Estates
Inland Residential Multiple Family	Residential Medium Density
Inland Residential Multiple Family Contract Rezone	Rural residential
Inland Residential Single Family	Rural residential – vacant
Inland Residential Single Family Contract Rezone	Rural Residential District
Inland Residential Two Family	Single Family Residence
Inland Rural Community	Single Family Residence Special Lot Size
Inland Rural Community Contract Rezone	Single family residential
Inland Rural Residential	Single family residential – vacant
Inland Rural Residential Contract Rezone	Single Family Residential Planned Development
Inland Rural Residential Planned Unit Development	Single-Family Residential District
Inland Suburban Residential	Suburban Reserve District
Inland Suburban Residential Isolated Service	Suburban Residential
Inland Suburban Residential Planned Unit Development	Suburban Residential - 1 Acre
Inland Upland Residential	Suburban Residential - 1/2 Acre
Inland Upland Residential Contract Rezone	Two-Family Residential District
Inland Upland Residential Planned Unit Development	Urban Residential
Low Density Residential	Very High Density Residential

Attachment D: Land use categories and descriptions

Commercial	
Central business District	Highway Visitor Commercial
Coastal Commercial	Inland General Commercial
Coastal Commercial Planned Unit Development	Inland General Commercial Contract Rezone
Commercial	Inland General Commercial Isolated Service
Commercial – vacant	Inland Limited Commercial
Commercial Core	Inland Limited Commercial Contract Rezone
Community Commercial	Local Commercial District
Community Commercial District	Mendocino Commercial
General Commercial	Mendocino Mixed Use
Gualala Highway Mixed Use	Neighborhood Commercial
Harbor Commercial	Office Commercial
Harbor Dependent Commercial	Planned Development Commercial District
Heavy Commercial	Resort Commercial District
Highway Commercial	Service Commercial District
Highway Commercial District	Visitor-Serving Commercial

Industrial	
Agricultural Industrial	Industrial Park
Coastal Industrial	Inland General Industrial
Commercial/Manufacturing District	Inland Limited Industrial
General Industrial	Inland Limited Industrial Contract Rezone
Gualala Industrial	Inland Pinoleville Industrial District
Heavy industrial	Light industrial
Heavy Industrial	Light Industrial
Heavy industrial – vacant	Light industrial – vacant
Heavy Industrial District	Limited Industrial
Industrial	Timber Resources Industrial

Municipal	
Administrative Office	Inland Airport District
Airport Business Park Planned Development	Inland Public Facilities
City	Mendocino Public Facilities
Coastal Public & Semi Public Facilities	Public
Harbor Dependent	Public Facilities
Harbor Dependent Recreational	Public Facilities and Services
Harbor District	Public Facility
Harbor Related	School

Attachment D: Land use categories and descriptions

Other	
Agricultural District	Inland Agriculture Contract Rezone
Agricultural Preserve District	Inland Forest Land
Agricultural Primel	Inland Open Space
Agriculture	Inland Rangeland
Agriculture Exclusive	Inland Rangeland Contract Rezone
Agriculture General (20ac)	Inland Timber Production
Agriculture General (5 ac)	Mendocino Forest Land
Agriculture General 20	Mendocino Open Space
Agriculture General 5	MR
Blank	Natural Hazard
Camp	No description
Cemetery	Open Space
Church	Open Space District
Coastal Agriculture	Open space/parks
Coastal Forest Land	Park
Coastal Open Space	Parks and Recreation
Coastal Open Space Contract Rezone	Resource Conservation Area
Coastal Rangeland	Rural Lands District
Coastal Rangeland Planned Unit Development	State and Federal Lands
Coastal Timber Production	Timber production
Golf	Timberland
Golf course	Timberland Preserve District
Gravel mining	Tribal lands
Grazing/timber	Tribal Lands
Greenery	Vacant
Inland Agriculture	

Attachment E

Criticality Raw Scores

Attachment E: Criticality Raw Scores

					System Connectivity, Average Daily Traffic, and Population													Highway Length and Classifications									Bridges			Stormwater Management Facilities		Amenities and Buildings						Traffic Control Systems and Call Boxes					
				Weight																																						
Highway	**TCR Segment**	**Segment Description**	**Begin Post Mile**	**End Post Mile**	Level of Access (System Redundancy Measure 1)	Ability to Reroute (System Redundancy Measure 2)	Composite ADT	Composite peak hour volume	Total population in census block groups	Total population density in census block groups (ppl/sm)	Total population in census tracts	Total population density in census tracts (ppl/sm)	Number of commercial land use parcels with 1-mile buffer	Number of residential land use parcels with 1-mile buffer	Number of industrial land use parcels with 1-mile buffer	Number of non-park municipal land use parcels with 1-mile buffer	Number of critical nodes	Total miles of segment	Functional classification	Miles of access control highway per mile of segment	Average number of lanes/mile	Miles of designated bike routes per mile of segment	Miles of designated bus route per mile of segment	Miles of officially designated scenic highway per mile of segment	Miles of eligible scenic highway per mile of segment	Miles of designated network truck route per mile of segment	Number of bridges over water longer than 100 feet	Number of bridges over water shorter than 100 feet	Number of overpasses and underpasses	Number of stormwater inlets, outfalls, and ditches	Number of stormwater culverts	Number of rest areas	Number of park & ride sites	Number of vista points	Number of weigh station and agrigultural inspection stations	Number of maintenance facilities	Number of Caltrans office buildings	Number of traffic signals (congestion management systems)	Number of closed circuit television systems	Number of extinguishable message signs	Number of highway advisory radio systems	Number of road weather information systems	Number of call boxes
1	1.1	Sonoma/Mendocino County line to Point Arena (north)	0.0	20.4	4	115	3,667	487	3,915	12.2	3,915	12.2	176	1,867	1	74	0	20.4	5	0.0	2	1.0	1.0	0.0	0.0	0.0	3	3	0	0	148	0	0	0	0	1	0	0	0	0	0	0	3
	1.2	Point Arena (north) to Route 128	20.4	40.3	4	100	4,609	644	2,535	7.3	5,867	14.7	0	957	0	17	1	19.9	5	0.0	2	1.0	1.0	0.0	0.0	0.0	4	1	0	0	132	0	0	1	0	0	0	0	0	0	1	0	4
	2	Junction Route 128 to Little River	40.3	48.0	5	48	12,300	1,440	1,952	25.1	1,952	25.1	13	845	0	12	1	7.7	5	0.0	2	1.0	1.0	0.0	0.0	0.0	2	0	0	0	71	0	0	0	0	0	0	0	0	0	1	0	1
	3	Little River to south Fort Bragg City limit	48.0	59.7	4	109	21,704	2,707	7,440	28.1	9,636	34.0	353	2,684	3	106	0	11.7	5	0.0	3	1.0	1.0	0.0	0.0	0.8	5	1	0	0	53	0	0	3	0	0	0	1	0	1	0	0	3
	4	So. Fort Bragg City limits to No. Fort Bragg City limit	59.7	62.4	2	70	33,577	3,471	6,272	37.2	12,178	64.6	724	2,632	48	136	1	2.7	5	0.0	3	1.0	1.0	0.0	0.0	1.0	2	0	0	91	101	0	0	0	0	1	0	0	0	1	1	0	0
	5	No. Fort Bragg City limits to Little Valley Road	62.4	66.8	5	53	3,448	608	2,412	163.3	7,739	41.4	305	1,424	42	40	0	4.4	5	0.0	2	1.0	0.0	0.0	0.0	0.6	0	1	0	15	39	0	0	0	0	0	0	0	0	0	0	0	2
	6	Little Valley Road to North Westport	66.8	77.7	5	61	1,640	240	3,198	9.5	8,427	9.1	10	717	0	17	0	10.9	5	0.0	2	1.0	0.0	0.0	0.0	0.0	1	0	0	0	70	0	0	1	0	0	0	0	0	0	0	0	4
	7	North Westport to Junction Rte. 101 at Leggett	77.7	105.6	5	132	1,359	220	1,205	3.3	4,155	5.6	0	307	7	126	2	27.9	5	0.0	2	1.0	0.0	0.0	0.0	0.0	3	4	0	0	196	0	0	1	0	0	0	0	0	0	0	0	2
20	1	From Route 1 at Fort to Summer Lane	0.0	2.1	3	46	6,157	646	2,890	17.4	8,711	46.9	239	1,191	4	38	1	2.1	5	0.0	2	1.0	1.0	0.0	1.0	1.0	0	0	0	4	9	0	0	0	0	0	0	1	1	1	0	0	0
	2	Summer Lane to Broaddus Creek	2.1	31.6	5	180	4,800	510	7,840	15.1	22,756	39.3	0	673	14	25	0	29.5	5	0.0	2	1.0	0.0	0.0	1.0	0.2	1	3	0	0	225	0	0	0	0	0	0	0	0	0	0	0	6
	3	Broaddus Creek to Route 101 at Willits	31.6	R33.2	4	36	16,350	1,886	3,784	38.0	13,120	44.3	429	1,278	139	115	1	1.6	5	0.0	2	1.0	0.0	0.0	1.0	1.0	1	0	0	0	14	0	0	0	0	0	0	1	1	0	0	0	0
	4	Route 101 to MEN/LAK Co. Line	33.2	44.1	5	97	21,511	2,283	5,788	33.1	16,213	41.4	77	668	27	153	1	10.9	7	0.0	3	0.0	1.0	0.0	0.0	1.0	5	2	3	21	111	0	0	0	0	0	0	1	1	1	0	0	4
	5	MEN/LAK Co. Line to Route 29	0.0	8.3	4	40	16,795	1,734	1,551	3.4	3,121	6.8	132	611	0	14	1	8.3	5	0.0	2	0.0	1.0	0.0	1.0	1.0	0	1	0	163	242	0	0	0	0	0	0	1	1	0	0	0	6
	6	Route 29 to Route 53	8.3	31.6	5	198	15,926	1,658	14,786	25.1	17,346	23.6	1,045	16,300	1	0	2	23.3	5	0.0	2	0.0	1.0	0.0	1.0	0.0	1	2	1	386	596	0	0	0	0	1	0	1	1	0	0	0	12
	7	Route 53 to LAK/COL Co. Line	31.6	46.5	4	41	11,600	1,620	3,244	21.5	12,329	71.5	0	89	0	0	1	14.9	7	0.0	2	0.0	0.0	0.0	0.0	1.0	1	0	0	8	151	0	0	0	0	0	0	2	1	0	0	0	17
29	1	Napa/Lake Co. line to Junction Route 175	0.00	5.80	5	43	17,750	1,645	2,612	23.0	7,575	62.2	183	670	0	0	1	5.8	5	0.0	2	1.0	1.0	0.0	0.0	0.0	2	0	0	41	80	0	0	0	0	0	0	0	0	0	0	0	1
	2	Junction Route 175 to Junction Route 53	5.80	20.30	5	110	21,092	2,098	9,800	45.2	10,773	40.6	409	4,130	18	0	2	14.5	5	0.0	2	1.0	1.0	0.0	0.0	1.0	2	2	0	311	429	0	0	0	0	0	0	0	0	0	0	0	5
	3	Junction Route 53 to North of Diener Drive	20.30	23.80	5	31	18,899	1,859	3,280	75.1	9,257	51.2	163	620	1	0	1	3.5	7	0.0	1	1.0	1.0	0.0	0.0	1.0	0	1	0	64	82	0	0	0	0	0	0	0	0	0	0	0	0
	4	North of Diener Dr to North of Junction Rte. 175	23.80	31.60	4	21	18,445	1,897	6,982	79.5	9,924	91.6	20	94	0	0	2	7.8	7	0.0	2	1.0	1.0	0.0	0.0	1.0	0	0	0	59	96	0	0	0	0	0	0	0	0	0	1	0	6
	5	No. of Junction Rte. 175 to Kelseyville	31.60	R34.58	2	40	21,700	2,270	6,124	83.5	15,969	96.9	169	933	3	0	1	3.0	7	0.0	2	1.0	1.0	0.0	0.0	1.0	0	1	0	74	99	0	0	0	0	0	0	0	0	0	0	0	1
	6	Kelseyville to 0.5 mile South of Lakeport (w/ Rte 175)	R34.58	R40.90	1	84	24,292	2,361	7,028	100.3	15,465	158.0	315	1,175	24	0	2	6.3	7	0.0	2	1.0	1.0	0.0	0.0	1.0	1	3	0	100	138	0	2	1	0	0	0	0	0	0	0	0	2
	7	0.5 mile South of Lakeport City limit to 0.7 mile North of Lucerne Cutoff	R40.90	48.58	1	112	18,854	2,040	12,541	25.0	12,541	25.0	158	2,025	0	0	0	7.7	7	0.9	4	1.0	1.0	0.0	0.0	1.0	0	0	9	197	253	0	0	1	0	1	0	0	0	0	0	0	0
	8	0.7 mile North of Lucerne Cutoff to Junction Route 20	48.58	52.53	3	22	18,854	2,040	3,121	6.8	3,121	6.8	91	441	0	0	1	4.0	7	0.0	2	1.0	1.0	0.0	0.0	1.0	1	1	0	51	72	0	0	0	0	0	0	1	1	0	1	0	3
36	1	Rte 101 to Hely Creek Bridge	0.0	11.5	4	81	4,500	726	5,113	13.0	13,314	29.8	23	1,126	17	106	1	11.5	5	0.0	2	1.0	0.0	0.0	0.0	0.1	1	1	0	0	51	0	0	0	0	0	0	0	0	0	0	0	0
	2	Hely Creek Bridge	11.5	24.8	5	68	2,153	422	1,556	4.2	4,143	10.2	2	339	0	19	0	13.3	5	0.0	2	1.0	0.0	0.0	0.0	0.0	7	0	0	0	112	0	0	0	0	0	0	0	0	0	0	0	0
	3	Bridgeville to Trinity Co. Line	24.8	45.7	4	107	2,100	280	678	2.4	4,143	10.2	4	424	1	8	0	20.9	5	0.0	2	1.0	0.0	0.0	0.0	0.2	3	0	1	0	180	0	0	0	0	1	0	0	0	0	0	0	0
53	1	Junction SR 29 to 40th Ave. City of Clearlake	0.0	2.96	2	117	35,003	5,199	9,148	280.7	14,355	74.5	166	747	1	0	1	3.0	10	0.0	4	1.0	1.0	0.0	1.0	1.0	1	1	0	114	145	0	0	0	0	0	0	0	0	0	1	0	0
	2	40th Ave to Junction SR 20	2.96	7.445	3	78	17,000	1,970	5,796	108.1	12,606	213.7	6	113	0	0	1	4.5	7	0.0	2	1.0	1.0	0.0	1.0	1.0	0	0	0	78	108	0	0	0	0	0	0	1	1	0	0	0	2
96	1	Rte. 299 to 1.3 km (0.8 mi) south of Rock Chute Viaduct.	0.0	16.0	3	117	3,926	401	4,856	8.9	5,925	6.4	49	1,341	0	25	1	16.0	5	0.0	2	1.0	1.0	0.0	0.0	0.2	4	1	2	0	119	0	0	1	0	1	0	1	1	0	0	0	0
	2	1.3 km (0.8 mi) south Rock Chute Viaduct to HUM Co. line.	16.0	R45.0	5	131	1,215	162	2,469	5.4	5,925	6.4	2	419	0	9	1	29.0	5	0.0	2	1.0	0.3	0.0	0.0	0.8	9	0	3	0	288	0	0	0	0	1	0	0	0	0	0	0	0

Attachment E: Criticality Raw Scores

					System Connectivity, Average Daily Traffic, and Population													Highway Length and Classifications									Bridges			Stormwater Management Facilities		Amenities and Buildings						Traffic Control Systems and Call Boxes					
Highway	TCR Segment	Segment Description	Begin Post Mile	End Post Mile	Level of Access (System Redundancy Measure 1)	Ability to Reroute (System Redundancy Measure 2)	Composite ADT	Composite peak hour volume	Total population in census block groups	Total population density in census block groups (ppl/sm)	Total population in census tracts	Total population density in census tracts (ppl/sm)	Number of commercial land use parcels with 1-mile buffer	Number of residential land use parcels with 1-mile buffer	Number of industrial land use parcels with 1-mile buffer	Number of non-park municipal land use parcels with 1-mile buffer	Number of critical nodes	Total miles of segment	Functional classification	Miles of access control highway per mile of segment	Average number of lanes/mile	Miles of designated bike routes per mile of segment	Miles of designated bus route per mile of segment	Miles of officially designated scenic highway per mile of segment	Miles of eligible scenic highway per mile of segment	Miles of designated network truck route per mile of segment	Number of bridges over water longer than 100 feet	Number of bridges over water shorter than 100 feet	Number of overpasses and underpasses	Number of stormwater inlets, outfalls, and ditches	Number of stormwater culverts	Number of rest areas	Number of park & ride sites	Number of vista points	Number of weigh station and agrigultural inspection stations	Number of maintenance facilities	Number of Caltrans office buildings	Number of traffic signals (congestion management systems)	Number of closed circuit television systems	Number of extinguishable message signs	Number of highway advisory radio systems	Number of road weather information systems	Number of call boxes
			Weight																																								
101	0	101U: SON/MEN Co. line to Jct. Rte. 101	0	0.655	5	6	0	0	1,180	4.9	2,082	8.2	0	0	0	1	1	0.7	1	0.0	4	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	SON/MEN Co. line to Pieta Creek	R0.1	5.8	3	26	29,400	2,500	1,180	4.9	2,082	8.2	0	0	0	3	2	5.7	7	0.0	4	1.0	1.0	0.0	0.0	1.0	2	0	12	0	118	0	0	0	0	0	0	0	0	0	0	0	4
	2	Pieta Creek to South of Ukiah	5.8	17.6	4	80	29,568	2,500	2,975	10.2	8,054	22.7	96	318	10	18	2	11.8	7	0.0	2	1.0	1.0	0.0	0.0	1.0	3	3	1	0	109	0	0	0	0	0	0	0	0	0	0	1	2
	3.1	South of Ukiah to Rte 20	17.6	31.06	2	212	46,097	4,759	14,025	238.6	32,941	87.3	1,297	5,312	255	306	2	13.5	7	0.8	4	1.0	1.0	0.0	0.0	1.0	9	8	25	368	112	0	0	0	0	1	0	1	1	0	1	0	0
	3.2	Rte 20 to South of Willits	31.06	43.5	4	103	28,900	3,150	6,193	38.2	17,164	35.0	133	1,175	28	80	1	12.4	7	0.0	4	1.0	1.0	0.0	0.9	1.0	1	1	2	82	188	0	0	0	0	0	0	1	1	1	0	1	3
	4	South of Willits to Arnold	T43.5	55.4	4	81	17,152	1,972	10,212	35.7	13,120	44.3	476	2,105	162	167	1	11.9	7	0.0	3	1.0	1.0	0.0	0.2	1.0	1	4	1	0	131	0	0	0	0	1	0	1	1	1	1	0	3
	5	Arnold to South of Laytonville	55.4	64.7	5	53	13,200	1,640	2,165	6.3	11,072	10.8	0	137	0	7	1	9.3	7	0.0	4	1.0	1.0	0.0	0.0	1.0	4	4	0	0	115	2	0	0	0	0	0	0	0	0	0	0	0
	6	South of Laytonville to Bell Springs Rd.	64.7	81.4	5	99	12,058	1,525	3,708	6.4	4,155	5.6	139	668	0	60	0	16.7	7	0.0	2	1.0	1.0	0.0	0.0	1.0	0	1	0	0	167	0	0	0	0	0	0	0	0	0	0	0	0
	7	Bell Springs Rd. to Jct. Rte. 1 at Leggett	81.4	T91.2	5	75	11,874	1,527	1,646	4.3	4,155	5.6	0	158	0	234	2	9.8	7	0.5	4	1.0	1.0	0.0	0.0	1.0	0	3	2	0	68	1	0	0	0	1	0	1	1	0	1	1	0
	8	Jct. Rte. 1 at Leggett to Red Mountain Creek	T91.2	100.3	5	41	11,800	1,520	758	3.7	4,155	5.6	0	90	0	175	0	9.1	7	0.0	2	1.0	1.0	0.0	0.8	1.0	4	1	1	0	84	0	0	0	0	0	0	0	0	0	0	0	2
	9	Red Mountain Creek to MEN/HUM County line	100.3	T106.8	5	58	9,976	1,435	758	3.7	4,155	5.6	1	187	0	13	2	6.5	7	0.5	4	1.0	1.0	0.0	1.0	1.0	3	0	2	0	30	0	0	0	0	0	0	0	0	0	0	0	2
	10	MEN/HUM County line to North of Richardson Grove	T0.0	R5.6	5	26	9,163	1,498	2,812	18.1	8,542	11.6	4	90	0	4	1	5.6	7	0.1	2	1.0	1.0	0.0	0.6	0.1	0	0	1	0	39	0	0	0	0	0	0	0	0	0	0	0	3
	11.1	North of Richardson Grove to Weott	R5.6	33.24	3	184	10,773	1,569	7,469	16.8	8,542	11.6	146	1,437	30	83	2	27.6	7	1.0	4	1.0	1.0	0.0	1.0	1.0	11	0	15	0	460	0	0	0	0	1	0	0	0	0	0	0	14
	11.2	Weott to north of Rio Dell	33.24	52.68	4	134	12,226	1,615	5,540	30.1	9,109	17.9	15	470	10	1,197	2	19.4	7	0.7	4	1.0	1.0	0.0	1.0	1.0	12	0	10	0	290	0	0	1	0	0	0	0	0	0	0	0	10
	11.3	North of Rio Dell to South Eureka Urban boundary	52.68	74.8	4	215	39,398	4,172	11,860	70.8	20,574	102.0	224	3,241	43	5,285	1	22.1	7	0.7	4	1.0	1.0	0.0	1.0	1.0	8	4	16	142	226	0	1	1	0	1	0	3	2	0	1	0	10
	12	South Eureka Urban boundary to near North Eureka city limits	74.8	79.8	1	126	59,825	6,210	9,632	2,450.4	24,792	3,294.4	34	1,952	43	7,649	1	5.0	7	0.1	4	1.0	1.0	0.0	1.0	1.0	0	0	0	248	292	0	1	0	0	0	2	1	6	0	1	0	0
	13	Near North Eureka city limits to Jct. Rte 255	79.8	85.8	2	95	72,428	7,778	11,607	248.7	21,390	430.2	33	1,231	2	4,286	1	6.0	10	0.0	4	1.0	1.0	0.0	1.0	1.0	2	2	0	71	94	0	0	0	0	1	0	1	3	0	0	0	0
	14.1	Jct 255 to Airport	85.8	93.968	2	151	48,739	5,193	25,047	87.0	34,025	112.5	151	4,252	50	4,494	3	8.2	10	1.0	4	1.0	1.0	0.0	1.0	1.0	5	0	19	250	61	2	2	1	0	0	0	2	2	2	1	0	0
	14.2	Airport to Big Lagoon	93.968	109.4	3	138	12,675	1,576	6,671	26.2	6,671	26.2	50	2,323	32	365	0	15.4	7	0.8	4	1.0	1.0	0.0	1.0	1.0	2	0	9	32	108	0	0	0	0	0	0	0	0	0	0	0	8
	15	Big Lagoon to Redwood National Park Bypass	109.4	R125.8	4	79	7,586	1,097	1,259	5.4	2,983	12.4	48	228	6	16	0	16.4	7	0.0	2	1.0	1.0	0.0	1.0	1.0	3	2	1	0	139	0	0	0	0	0	0	0	0	0	0	0	4
	16	Redwood National Park Bypass	R125.8	R137.1	3	63	5,800	860	2,406	4.4	5,867	5.7	0	1	1	0	0	11.3	7	0.0	4	1.0	1.0	0.0	1.0	1.0	2	0	0	0	184	0	0	0	0	1	0	0	0	0	0	1	6
	17	HUM/DN Co. line to Kamp Klamath	M0.0	R3.6	3	45	6,056	883	1,373	9.6	1,373	9.6	49	0	6	8	0	3.6	7	0.0	4	1.0	1.0	0.0	1.0	1.0	0	0	2	0	34	0	0	0	0	0	0	0	0	0	0	0	2
	18	Del Norte Redwoods State Park Area	R3.6	12.5	5	51	8,849	1,332	1,373	9.6	1,373	9.6	247	145	10	15	1	8.9	7	0.0	2	1.0	1.0	0.2	1.0	1.0	4	4	0	0	50	0	0	0	0	0	0	0	0	0	0	0	2
	19	Wilson Creek to South of Crescent City.	12.5	25.7	3	74	14,979	2,121	4,359	8.1	8,797	9.2	90	1,073	123	469	0	13.2	7	0.0	3	1.0	1.0	0.9	1.0	1.0	1	0	0	0	124	0	0	2	0	0	0	2	2	0	0	2	4
	20	South of Crescent City to North of Crescent City	25.7	27.2	2	64	33,341	3,958	7,639	736.3	9,589	900.3	366	1,877	132	1,532	0	1.5	7	0.0	4	1.0	1.0	0.0	1.0	1.0	0	1	0	62	89	0	0	0	0	1	0	0	0	0	1	0	0
	21	North of Crescent City to Jct. Rte. 199	27.2	31.3	2	97	16,080	1,871	6,408	510.7	19,643	335.5	423	3,268	29	813	1	4.1	7	0.7	4	1.0	1.0	0.0	0.3	1.0	0	0	3	55	72	0	0	0	0	0	0	1	1	0	0	0	2
	22	Jct. Rte. 199 to Oregon border	31.3	46.5	1	113	13,393	1,585	9,003	84.7	10,681	12.7	259	2,197	25	70	1	15.2	7	0.0	2	1.0	1.0	0.0	0.7	1.0	3	0	1	93	197	0	0	0	1	0	0	1	1	0	0	0	2
128	1	Route 1 to Indian Creek Bridge	0.0	23.3	4	146	5,278	701	4,314	13.6	5,245	15.9	61	549	4	41	1	23.3	5	0.0	2	1.0	1.0	0.0	0.0	0.0	2	1	0	0	245	0	0	0	0	0	0	0	0	0	0	0	0
	2	Indian Creek Bridge to Route 253	23.3	29.6	3	61	4,751	641	1,996	22.7	3,293	13.1	104	378	4	95	1	6.3	5	0.0	2	1.0	1.0	0.0	0.0	0.0	2	0	0	0	37	0	0	0	0	1	0	0	0	0	0	0	0
	3	Route 253 to the Sonoma County Line	29.6	50.9	5	75	3,300	380	2,245	7.0	5,375	10.7	68	151	0	29	1	21.3	5	0.0	2	1.0	0.0	0.0	0.0	0.0	1	5	0	0	257	0	0	0	0	0	0	0	0	0	0	0	0
162	1.1	Route 101 to PM 16.76	0.0	16.76	4	69	1,629	160	2,724	2.4	13,659	7.6	0	112	0	50	1	16.8	2	0.0	2	0.0	0.0	0.0	0.0	0.0	5	2	0	0	233	0	0	0	0	0	0	0	0	0	0	0	1
	1.2	PM 16.76 to Short Creek Bridge	16.76	34.0	2	91	2,246	252	2,587	3.3	2,587	3.3	110	439	7	348	0	17.2	2	0.0	2	0.0	0.0	0.0	0.0	0.0	3	2	0	0	132	0	0	0	0	0	0	0	0	0	0	0	2

Attachment E: Criticality Raw Scores

Highway	TCR Segment	Segment Description	Begin Post Mile	End Post Mile	Level of Access (System Redundancy Measure 1)	Ability to Reroute (System Redundancy Measure 2)	Composite ADT	Composite peak hour volume	Total population in census block groups	Total population density in census block groups (ppl/sm)	Total population in census tracts	Total population density in census tracts (ppl/sm)	Number of commercial land use parcels with 1-mile buffer	Number of residential land use parcels with 1-mile buffer	Number of industrial land use parcels with 1-mile buffer	Number of non-park municipal land use parcels with 1-mile buffer	Number of critical nodes
					System Connectivity, Average Daily Traffic, and Population												
			Weight														
169	1	Route 101 to Klamath Glen	R0.0	3.5	5	33	1,997	264	1,373	9.6	1,373	9.6	359	193	14	43	1
	4	Wautec to Ke'pel Road	13.2	23.7	5	45	520	100	457	7.6	2,884	3.7	0	162	0	0	0
	5	Ke'pel Road to Martins Ferry	23.7	30.0	5	43	690	130	457	7.6	2,884	3.7	0	146	0	0	0
	6	Martins Ferry to Weitchpec	30.0	33.8	4	28	690	130	457	7.6	2,884	3.7	0	104	0	1	1
175	1	Route 101 to MEN/LAK County Line	0.0	9.9	4	57	4,785	502	2,082	8.2	2,082	8.2	95	173	4	84	1
	2	MEN/LAK County Line to Route 29 South of the City of Lakeport	0.0	R8.2	3	59	4,337	510	2,295	38.7	9,891	104.5	81	171	8	11	1
	3	Route 29 South of the community of Kelseyville to the community of Cobb	8.3	19.6	4	81	5,310	630	3,865	54.4	3,865	54.4	140	2,622	0	0	2
	4	From the community of Cobb to Route 29 in the community of Middletown	19.6	28.0	5	66	6,282	749	4,216	58.2	11,440	59.3	244	2,174	5	0	2
197	1	Route 199 to Route 101	0.0	7.1	5	52	3,900	520	2,003	4.3	3,655	4.5	46	613	0	27	2
199	1	Route 101 to near Gasquet	T0.5	13.0	5	70	7,379	993	7,538	9.8	10,681	12.7	129	953	0	57	2
	2	Near Gasquet to west of Patrick Creek	13.0	19.8	5	33	6,000	820	814	2.4	3,655	4.5	62	301	0	50	0
	3	West of Patrick Creek to near Idlewild	19.8	27.1	5	36	6,000	6,000	814	2.4	3,655	4.5	0	6	0	13	0
	4	Near Idlewild to the Calif./Oregon Border	27.1	36.4	5	40	6,000	6,000	814	2.4	3,655	4.5	1	7	0	10	0
200	1	Jct. Rte. 101 to Jct. Rte. 299	R0.0	R2.7	3	51	4,324	464	6,010	475.2	11,916	798.5	52	1,134	16	268	1
211	3	Ocean Ave. in Ferndale to Route 101	73.2	79.2	2	50	10,948	1,111	5,789	13.8	8,005	18.9	22	141	1	801	1
222	1	Rte. 101 to East Site Road in Talmage	R0.0	2.2	3	60	14,237	1,480	6,244	659.2	16,722	233.4	614	2,289	8	105	1
253	1	Rte 128 at Boonville to iunction Rte 101 near Ukiah	0.0	17.2	5	72	4,800	460	8,096	18.6	15,528	23.0	144	636	24	94	2
254	1	Route 101 to Myers Flat	0.0	12.3	5	85	2,230	588	1,655	24.3	4,133	10.5	38	533	0	34	1
	2	Myers Flat to Route 101 at Jordan Road	12.3	46.5	5	110	849	234	6,906	10.0	13,518	15.9	30	557	0	23	1
255	1	Route 101 to Eureka Urban Limits	0.0	1.7	5	51	17,500	1,930	5,065	291.6	10,643	584.2	10	77	4	3,287	1
	2	Eureka Urban Limits to 0.2 mi. North Mad River Slough Br. #4-257	1.7	5.4	3	19	14,646	1,615	1,479	93.6	1,479	93.6	24	406	16	60	1
	3	0.2 Mi. North Mad River Slough Br. #257 to Arcata Urban Limits	5.4	7.2	3	17	19,483	2,109	1,479	93.6	1,479	93.6	6	77	11	622	0
	4	Arcata Urban Limits to Junction Rte. 101	7.2	8.8	4	49	24,320	2,604	4,648	269.8	13,735	635.6	0	41	11	2,761	1
271	1	Route 101 to Route 1	0.0	7.3	5	85	360	53	758	3.7	4,155	5.6	0	207	0	195	3
	2	1.5 miles so. of Reynolds Overcrossing to the MEN/HUM County line	17.1	22.7	5	47	300	50	758	3.7	4,155	5.6	1	175	0	3	2
	3	MEN/HUM Co. line to Route 101	0.0	T0.3	5	119	300	50	2,165	6.6	8,564	7.9	1	325	0	197	1
281	2	Near Konoctl Bay to Route 29	14.0	17.0	3	32	10,563	1,035	5,176	145.8	6,059	162.5	244	2,455	0	0	1
283	1	Rte 101 to end of Eel River Bridge #4-15	0.0	0.4	5	28	4,300	500	3,885	33.6	4,976	42.8	0	29	7	1,058	1
299	1	Route 101 To The City Of Blue Lake	0.0	R5.9	4	88	21,189	2,338	6,749	13.6	13,574	26.4	12	1,128	44	1,922	1
	2	City Of Blue Lake To Community Of Willow Creek	R5.9	29.1	4	141	6,563	817	2,536	4.7	6,491	6.3	2	338	4	580	0
	3	Community Of Willow Creek To Humboldt/Trinity Line	29.1	43.0	5	81	7,863	1,035	1,147	3.7	2,884	3.7	40	760	0	25	1

Highway	TCR Segment	Total miles of segment	Functional classification	Miles of access control highway per mile of segment	Average number of lanes/mile	Miles of designated bike routes per mile of segment	Miles of designated bus route per mile of segment	Miles of officially designated scenic highway per mile of segment	Miles of eligible scenic highway per mile of segment	Miles of designated network truck route per mile of segment	Number of bridges over water longer than 100 feet	Number of bridges over water shorter than 100 feet	Number of overpasses and underpasses	Number of stormwater inlets, outfalls, and ditches	Number of stormwater culverts	Number of rest areas	Number of park & ride sites	Number of vista points	Number of weigh station and agrigultural inspection stations	Number of maintenance facilities	Number of Caltrans office buildings	Number of traffic signals (congestion management systems)	Number of closed circuit television systems	Number of extinguishable message signs	Number of highway advisory radio systems	Number of road weather information systems	Number of call boxes
		Highway Length and Classifications									Bridges			Stormwater Management Facilities		Amenities and Buildings						Traffic Control Systems and Call Boxes					
169	1	3.5	2	0.0	2	0.0	0.0	0.0	0.0	0.0	1	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0
	4	10.5	2	0.0	1	0.0	0.0	0.0	0.0	0.0	2	0	0	0	103	0	0	0	0	0	0	0	0	0	0	0	0
	5	6.3	2	0.0	1	0.0	0.0	0.0	0.0	0.0	3	2	0	0	52	0	0	0	0	0	0	0	0	0	0	0	0
	6	3.8	2	0.0	1	0.0	0.0	0.0	0.0	0.0	0	2	0	0	59	0	0	0	0	0	0	0	0	0	0	0	0
175	1	9.9	5	0.0	2	0.0	0.0	0.0	0.0	0.5	2	0	1	0	87	0	0	0	0	0	0	0	0	0	0	0	8
	2	8.2	5	0.0	2	0.0	0.0	0.0	0.0	0.0	0	2	0	214	314	0	0	0	0	0	0	0	0	0	0	0	7
	3	11.3	2	0.0	2	0.0	0.7	0.0	0.0	0.0	0	0	0	143	221	0	0	0	0	0	0	0	0	0	0	0	6
	4	8.4	5	0.0	2	0.0	1.0	0.0	0.0	0.0	2	1	0	180	274	0	1	0	0	0	0	0	0	0	0	0	2
197	1	7.1	5	0.0	2	0.0	0.0	0.0	0.9	0.0	0	0	0	0	60	0	0	0	0	0	0	0	0	0	0	0	0
199	1	12.5	7	0.0	2	1.0	1.0	0.0	1.0	0.0	4	0	3	3	100	0	0	0	0	0	0	0	0	0	0	0	4
	2	6.8	7	0.0	4	1.0	0.0	0.0	1.0	0.0	2	0	2	0	52	0	0	0	0	0	0	0	0	0	0	0	2
	3	7.3	7	0.0	2	1.0	0.0	0.0	1.0	0.0	4	0	0	0	66	0	0	0	0	0	0	2	0	0	0	0	2
	4	9.3	7	0.0	2	1.0	0.0	0.0	0.9	0.0	0	0	1	0	89	1	0	0	1	1	0	1	2	2	1	1	2
200	1	2.7	2	0.0	2	0.0	0.0	0.0	0.0	1.0	0	0	2	70	113	0	0	0	0	0	0	0	0	0	0	0	0
211	3	6.0	2	0.0	2	0.0	0.0	0.0	0.0	1.0	5	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
222	1	2.2	5	0.0	2	0.0	0.0	0.0	0.0	1.0	1	0	0	27	30	0	0	0	0	0	0	0	0	0	0	0	0
253	1	17.2	5	0.0	2	0.0	1.0	0.0	0.0	0.0	2	1	1	44	192	0	0	0	0	0	0	0	0	0	0	0	0
254	1	12.3	2	0.0	2	0.0	0.0	0.0	1.0	0.0	3	0	1	0	166	0	0	0	0	0	0	0	0	0	0	0	0
	2	34.2	2	0.0	2	0.0	0.0	0.0	1.0	0.0	4	0	3	0	192	0	0	0	0	0	0	0	0	0	0	0	0
255	1	1.7	5	0.0	2	0.0	1.0	0.0	0.0	1.0	0	0	1	6	7	0	0	0	0	0	0	0	0	0	0	0	0
	2	3.7	5	0.0	2	0.0	1.0	0.0	0.0	1.0	1	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
	3	1.8	5	0.0	2	0.0	1.0	0.0	0.0	1.0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
	4	1.6	5	0.0	4	0.0	1.0	0.0	0.0	1.0	0	1	1	33	40	0	0	0	0	0	0	0	0	0	0	0	0
271	1	7.3	2	0.0	2	0.0	0.0	0.0	0.0	0.0	2	0	1	0	67	0	0	0	0	1	0	0	0	0	0	0	0
	2	5.6	2	0.0	2	0.0	0.0	0.0	0.0	0.0	2	0	3	0	52	0	0	0	0	0	0	0	0	0	0	0	0
	3	0.3	2	0.0	2	0.0	0.0	0.0	0.0	0.0	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0
281	2	3.0	2	0.0	2	0.0	1.0	0.0	0.0	1.0	0	0	0	69	87	0	0	0	0	0	0	0	0	0	0	0	0
283	1	0.4	2	0.0	2	0.0	0.0	0.0	0.0	0.0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
299	1	5.9	7	1.0	4	1.0	1.0	0.0	1.0	1.0	3	0	8	38	72	0	0	0	0	0	0	0	0	1	0	0	2
	2	23.2	7	0.0	2	1.0	1.0	0.0	1.0	1.0	3	0	0	0	218	0	0	2	0	1	0	0	0	0	0	1	6
	3	13.9	7	0.0	2	1.0	1.0	0.0	1.0	1.0	4	0	1	0	141	0	0	0	0	1	0	2	2	0	1	0	4

Attachment F

Criticality Scaled Scores

Attachment F: Criticality scaled scores

					System Connectivity, Average Daily Traffic, and Population													Highway Length and Classifications									Bridges			Stormwater Management Facilities		Amenities and Buildings						Traffic Control Systems and Call Boxes						TOTALS			
				Weight	10.0	7.2	9.8	9.1	2.2	1.2	6.5	1.5	5.8	5.2	4.5	7.9	8.8	5.2	8.8	8.4	6.1	4.2	6.5	3.5	2.4	8.2	9.1	5.8	6.3	7.9	7.7	2.8	2.8	2.2	2.6	6.1	3.8	4.9	2.8	5.8	5.6	6.1	3.1				
Highway	**TCR Segment**	**Segment Description**	**Begin Post Mile**	**End Post Mile**	Level of Access (System Redundancy Measure 1)	Ability to Reroute (System Redundancy Measure 2)	Composite ADT	Composite peak hour volume	Total population in census block groups	Total population density in census block groups (ppl/sm)	Total population in census tracts	Total population density in census tracts (ppl/sm)	Number of commercial land use parcels with 1-mile buffer	Number of residential land use parcels with 1-mile buffer	Number of industrial land use parcels with 1-mile buffer	Number of non-park municipal and use parcels with 1-mile buffer	Number of critical nodes	Total miles of segment	Functional classification	Miles of access control highway per mile of segment	Average number of lanes/mile	Miles of designated bike routes per mile of segment	Miles of designated bus route per mile of segment	Miles of officially designated scenic highway per mile of segment	Miles of eligible scenic highway per mile of segment	Miles of designated network truck route per mile of segment	Number of bridges over water longer than 100 feet	Number of bridges over water shorter than 100 feet	Number of overpasses and underpasses	Number of stormwater inlets, outfalls, and ditches	Number of stormwater culverts	Number of rest areas	Number of park & ride sites	Number of vista points	Number of weigh station and agricultural inspection stations	Number of maintenance facilities	Number of Caltrans office buildings	Number of traffic signals (congestion management systems)	Number of closed circuit television systems	Number of extinguishable message signs	Number of highway advisory radio systems	Number of road weather information systems	Number of call boxes	Total Score	Weighted Score	Scaled Score	Rank
1	1.1	Sonoma/Mendocino County line to Point Arena (north)	0.0	20.4	8.2	5.5	1.5	1.6	2.4	1.0	2.0	1.0	2.2	2.0	1.0	1.1	1.0	6.4	5.5	1.0	5.5	10.0	10.0	1.0	1.0	1.0	3.3	4.4	1.0	1.0	3.2	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	1.0	1.0	1.0	2.6	107.4	664.5	5.4	56
	1.2	Point Arena (north) to Route 128	20.4	40.3	8.2	6.1	1.6	1.7	1.9	1.0	2.6	1.0	1.0	1.5	1.0	1.0	4.0	6.2	5.5	1.0	5.5	10.0	10.0	1.0	1.0	1.0	4.0	2.1	1.0	1.0	3.0	1.0	1.0	4.0	1.0	1.0	1.0	1.0	1.0	1.0	10.0	1.0	3.1	111.2	685.3	5.5	52
	2	Junction Route 128 to Little River	40.3	48.0	10.0	8.3	2.5	2.7	1.7	1.1	1.5	1.1	1.1	1.5	1.0	1.0	4.0	3.0	5.5	1.0	5.5	10.0	10.0	1.0	1.0	1.0	2.5	1.0	1.0	1.0	2.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	10.0	1.0	1.5	104.5	674.4	5.5	53
	3	Little River to south Fort Bragg City limit	48.0	59.7	8.2	5.7	3.7	4.1	3.7	1.1	3.5	1.1	3.4	2.5	1.1	1.1	1.0	4.1	5.5	1.0	7.8	10.0	10.0	1.0	1.0	8.0	4.8	2.1	1.0	1.0	1.8	1.0	1.0	10.0	1.0	1.0	1.0	4.0	1.0	5.5	1.0	1.0	2.6	129.4	788.3	6.2	32
	4	So. Fort Bragg City limits to No. Fort Bragg City limit	59.7	62.4	4.6	7.4	5.2	5.0	3.3	1.1	4.2	1.2	6.0	2.5	2.7	1.2	4.0	1.7	5.5	1.0	7.8	10.0	10.0	1.0	1.0	10.0	2.5	1.0	1.0	3.1	2.5	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	5.5	10.0	1.0	1.0	140.9	905.0	7.0	14
	5	No. Fort Bragg City limits to Little Valley Road	62.4	66.8	10.0	8.1	1.4	1.7	1.9	1.6	3.0	1.1	3.1	1.8	2.5	1.0	1.0	2.2	5.5	1.0	5.5	10.0	1.0	1.0	1.0	6.7	1.0	2.1	1.0	1.3	1.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	92.3	584.9	4.9	72
	6	Little Valley Road to North Westport	66.8	77.7	10.0	7.8	1.2	1.3	2.1	1.0	3.2	1.0	1.1	1.4	1.0	1.0	1.0	3.9	5.5	1.0	5.5	10.0	1.0	1.0	1.0	1.0	1.8	1.0	1.0	1.0	2.1	1.0	1.0	4.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.1	86.9	529.5	4.5	83
	7	North Westport to Junction Rte. 101 at Leggett	77.7	105.6	10.0	4.8	1.2	1.3	1.4	1.0	2.1	1.0	1.0	1.2	1.2	1.1	7.0	8.3	5.5	1.0	5.5	10.0	1.0	1.0	1.0	1.0	3.3	5.5	1.0	1.0	4.0	1.0	1.0	4.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	99.4	626.4	5.1	61
20	1	From Route 1 at Fort to Summer Lane	0.0	2.1	6.4	8.4	1.8	1.7	2.0	1.1	3.3	1.1	2.7	1.7	1.1	1.0	4.0	1.6	5.5	1.0	5.5	10.0	10.0	1.0	10.0	10.0	1.0	1.0	1.0	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	4.0	2.5	5.5	1.0	1.0	1.0	117.1	707.2	5.7	46
	2	Summer Lane to Broaddus Creek	2.1	31.6	10.0	2.7	1.6	1.6	3.8	1.1	7.0	1.1	1.0	1.4	1.5	1.0	1.0	8.8	5.5	1.0	5.5	10.0	1.0	1.0	10.0	3.1	1.8	4.4	1.0	1.0	4.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4.2	108.4	628.4	5.2	60
	3	Broaddus Creek to Route 101 at Willits	31.6	R33.2	8.2	8.8	3.0	3.2	2.4	1.1	4.5	1.1	4.0	1.7	5.9	1.1	4.0	1.4	5.5	1.0	5.5	10.0	1.0	1.0	10.0	10.0	1.8	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.0	4.0	2.5	1.0	1.0	1.0	1.0	116.9	712.9	5.7	45
	4	Route 101 to MEN/LAK Co. Line	33.2	44.1	10.0	6.2	3.7	3.6	3.1	1.1	5.3	1.1	1.5	1.4	2.0	1.2	4.0	3.9	7.3	1.0	7.8	1.0	10.0	1.0	1.0	10.0	4.8	3.3	2.1	1.5	2.7	1.0	1.0	1.0	1.0	1.0	1.0	4.0	2.5	5.5	1.0	1.0	3.1	124.5	833.1	6.5	22
	5	MEN/LAK Co. Line to Route 29	0.0	8.3	8.2	8.6	3.1	3.0	1.6	1.0	1.8	1.0	1.9	1.3	1.0	1.0	4.0	3.2	5.5	1.0	5.5	1.0	10.0	1.0	10.0	10.0	1.0	2.1	1.0	4.8	4.7	1.0	1.0	1.0	1.0	1.0	1.0	4.0	2.5	1.0	1.0	1.0	4.2	118.0	750.4	6.0	37
	6	Route 29 to Route 53	8.3	31.6	10.0	2.0	3.0	2.9	6.3	1.1	5.6	1.1	8.3	10.0	1.0	1.0	7.0	7.1	5.5	1.0	5.5	1.0	10.0	1.0	10.0	1.0	1.8	3.3	1.4	10.0	10.0	1.0	1.0	1.0	1.0	10.0	1.0	4.0	2.5	1.0	1.0	1.0	7.4	159.6	971.4	7.4	10
	7	Route 53 to LAK/COL Co. Line	31.6	46.5	8.2	8.6	2.4	2.9	2.2	1.1	4.3	1.2	1.0	1.0	1.0	1.0	4.0	4.9	7.3	1.0	5.5	1.0	1.0	1.0	1.4	10.0	1.8	1.0	1.0	1.2	3.3	1.0	1.0	1.0	1.0	1.0	1.0	7.0	2.5	1.0	1.0	1.0	10.0	108.7	692.5	5.6	50
29	1	Napa/Lake Co. line to Junction Route 175	0.00	5.80	10.0	8.5	3.2	2.9	1.9	1.1	3.0	1.2	2.3	1.4	1.0	1.0	4.0	2.5	5.5	1.0	5.5	10.0	10.0	1.0	1.0	1.0	2.5	1.0	1.0	2.0	2.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	100.2	657.0	5.4	59
	2	Junction Route 175 to Junction Route 53	5.80	20.30	10.0	5.7	3.6	3.4	4.5	1.2	3.8	1.1	3.8	3.3	1.6	1.0	7.0	4.8	5.5	1.0	5.5	10.0	10.0	1.0	1.0	10.0	2.5	3.3	1.0	8.3	7.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.6	136.1	900.3	7.0	15
	3	Junction Route 53 to North of Diener Drive	20.30	23.80	10.0	9.0	3.3	3.2	2.2	1.3	3.4	1.1	2.1	1.3	1.0	1.0	4.0	1.9	7.3	1.0	3.7	10.0	10.0	1.0	1.0	10.0	1.0	2.1	1.0	2.5	2.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	109.8	738.1	5.9	39
	4	North of Diener Dr to North of Junction Rte. 175	23.80	31.60	8.2	9.4	3.3	3.2	3.5	1.3	3.6	1.3	1.1	1.1	1.0	1.0	7.0	3.1	7.3	1.0	5.5	10.0	10.0	1.0	1.0	10.0	1.0	1.0	1.0	2.4	2.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	10.0	1.0	4.2	125.8	817.5	6.4	26
	5	No. of Junction Rte. 175 to Kelseyville	31.60	R34.58	4.6	8.6	3.7	3.6	3.2	1.3	5.2	1.3	2.2	1.5	1.1	1.0	4.0	1.8	7.3	1.0	5.5	10.0	10.0	1.0	1.0	10.0	1.0	2.1	1.0	2.7	2.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	110.8	720.2	5.8	44
	6	Kelseyville to 0.5 mile South of Lakeport (w/ Rte 175)	R34.58	R40.90	2.8	6.8	4.0	3.7	3.5	1.4	5.1	1.4	3.2	1.6	1.8	1.0	7.0	2.7	7.3	1.2	5.5	10.0	10.0	1.0	1.0	10.0	1.8	4.4	1.0	3.3	3.1	1.0	10.0	4.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	130.7	798.9	6.3	30
	7	0.5 mile South of Lakeport City limit to 0.7 mile North of Lucerne Cutoff	R40.90	48.58	2.8	5.6	3.3	3.4	5.5	1.1	4.3	1.1	2.1	2.1	1.0	1.0	1.0	3.0	7.3	9.4	10.0	10.0	10.0	1.0	1.0	10.0	1.0	1.0	4.2	5.6	4.8	1.0	1.0	4.0	1.0	10.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	136.7	867.3	6.7	19
	8	0.7 mile North of Lucerne Cutoff to Junction Route 20	48.58	52.53	6.4	9.4	3.3	3.4	2.1	1.0	1.8	1.0	1.6	1.2	1.0	1.0	4.0	2.0	7.3	1.0	5.5	10.0	10.0	1.0	1.0	10.0	1.8	2.1	1.0	2.2	2.1	1.0	1.0	1.0	1.0	1.0	1.0	4.0	2.5	1.0	10.0	1.0	2.6	121.4	781.2	6.2	34
36	1	Rte 101 to Hely Creek Bridge	0.0	11.5	8.2	6.9	1.6	1.8	2.8	1.0	4.5	1.1	1.2	1.6	1.6	1.1	4.0	4.0	5.5	1.0	5.5	10.0	1.0	1.0	1.0	2.3	1.8	2.1	1.0	1.0	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	88.5	558.9	4.7	76
	2	Hely Creek Bridge	11.5	24.8	10.0	7.5	1.3	1.5	1.6	1.0	2.1	1.0	1.0	1.2	1.0	1.0	1.0	4.5	5.5	1.0	5.5	10.0	1.0	1.0	1.0	1.0	6.3	1.0	1.0	1.0	2.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	85.6	555.9	4.7	77
	3	Bridgeville to Trinity Co. Line	24.8	45.7	8.2	5.8	1.3	1.3	1.2	1.0	2.1	1.0	1.0	1.2	1.0	1.0	1.0	6.5	5.5	1.0	5.5	10.0	1.0	1.0	1.0	3.2	3.3	1.0	1.4	1.0	3.7	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	93.4	590.4	4.9	70
53	1	Junction SR 29 to 40th Ave. City of Clearlake	0.0	2.96	4.6	5.4	5.3	7.0	4.3	2.0	4.8	1.2	2.2	1.4	1.0	1.0	4.0	1.8	10.0	1.0	10.0	10.0	10.0	1.0	10.0	10.0	1.8	2.1	1.0	3.7	3.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	10.0	1.0	1.0	140.8	884.3	6.9	17
	2	40th Ave to Junction SR 20	2.96	7.445	6.4	7.0	3.1	3.3	3.1	1.4	4.3	1.6	1.0	1.1	1.0	1.0	4.0	2.2	7.3	1.0	5.5	10.0	10.0	1.0	10.0	10.0	1.0	1.0	1.0	2.8	2.6	1.0	1.0	1.0	1.0	1.0	1.0	4.0	2.5	1.0	1.0	1.0	2.1	121.3	742.4	5.9	38
96	1	Rte. 299 to 1.3 km (0.8 mi) south of Rock Chute Viaduct.	0.0	16.0	6.4	5.4	1.5	1.5	2.7	1.0	2.6	1.0	1.3	1.7	1.0	1.0	4.0	5.2	5.5	1.0	5.5	10.0	10.0	1.0	1.0	3.0	4.0	2.1	1.7	1.0	2.8	1.0	1.0	4.0	1.0	10.0	1.0	4.0	2.5	1.0	1.0	1.0	1.0	113.6	694.7	5.6	49
	2	1.3 km (0.8 mi) south Rock Chute Viaduct to HUM Co. line.	16.0	R45.0	10.0	4.8	1.2	1.2	1.9	1.0	2.6	1.0	1.0	1.2	1.0	1.0	4.0	8.6	5.5	1.0	5.5	10.0	3.5	1.0	1.0	7.9	7.8	1.0	2.1	1.0	5.3	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	114.1	752.7	6.0	36

Highway	TCR Segment	Segment Description	Begin Post Mile	End Post Mile	System Connectivity, Average Daily Traffic, and Population													Highway Length and Classifications									Bridges			Stormwater Management Facilities		Amenities and Buildings						Traffic Control Systems and Call Boxes						TOTALS			
				Weight	10.0	7.2	9.8	9.1	2.2	1.2	6.5	1.5	5.8	5.2	4.5	7.9	8.8	5.2	8.8	8.4	6.1	4.2	6.5	3.5	2.4	8.2	9.1	5.8	6.3	7.9	7.7	2.8	2.8	2.2	2.6	6.1	3.8	4.9	2.8	5.8	5.6	6.1	3.1				
Highway	**TCR Segment**	**Segment Description**	**Begin Post Mile**	**End Post Mile**	Level of Access (System Redundancy Measure 1)	Ability to Reroute (System Redundancy Measure 2)	Composite ADT	Composite peak hour volume	Total population in census block groups	Total population density in census block groups (ppl/sm)	Total population in census tracts	Total population density in census tracts (ppl/sm)	Number of commercial land use parcels with 1-mile buffer	Number of residential land use parcels with 1-mile buffer	Number of industrial land use parcels with 1-mile buffer	Number of non-park municipal land use parcels with 1-mile buffer	Number of critical nodes	Total miles of segment	Functional classification	Miles of access control highway per mile of segment	Average number of lanes/mile	Miles of designated bike routes per mile of segment	Miles of designated bus route per mile of segment	Miles of officially designated scenic highway per mile of segment	Miles of eligible scenic highway per mile of segment	Miles of designated network truck route per mile of segment	Number of bridges over water longer than 100 feet	Number of bridges over water shorter than 100 feet	Number of overpasses and underpasses	Number of stormwater inlets, outfalls, and ditches	Number of stormwater culverts	Number of rest areas	Number of park & ride sites	Number of vista points	Number of weigh station and agrigultural inspection stations	Number of maintenance facilities	Number of Caltrans office buildings	Number of traffic signals (congestion management systems)	Number of closed circuit television systems	Number of extinguishable message signs	Number of highway advisory radio systems	Number of road weather information systems	Number of call boxes	Total Score	Weighted Score	Scaled Score	Rank
101	0	101U: SON/MEN Co. line to Jct. Rte. 101	0	0.655	10.0	10.0	1.0	1.0	1.4	1.0	1.6	1.0	1.0	1.0	1.0	1.0	4.0	1.2	1.9	1.0	10.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	71.1	468.6	4.1	88
	1	SON/MEN Co. line to Pieta Creek	R0.1	5.8	6.4	9.2	4.7	3.9	1.4	1.0	1.6	1.0	1.0	1.0	1.0	1.0	7.0	2.5	7.3	1.0	10.0	10.0	10.0	1.0	1.0	10.0	2.5	1.0	5.3	1.0	2.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.1	119.7	801.1	6.3	29
	2	Pieta Creek to South of Ukiah	5.8	17.6	8.2	7.0	4.7	3.9	2.1	1.0	3.1	1.1	1.7	1.2	1.4	1.0	7.0	4.1	7.3	1.0	5.5	10.0	10.0	1.0	1.0	10.0	3.3	4.4	1.4	1.0	2.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	5.5	2.1	123.3	826.8	6.5	23
	3.1	South of Ukiah to Rte 20	17.6	31.06	4.6	1.4	6.7	6.5	6.0	1.9	9.7	1.2	10.0	3.9	10.0	1.4	7.0	4.5	7.3	8.6	10.0	10.0	10.0	1.0	1.2	10.0	7.8	10.0	10.0	9.6	2.7	1.0	1.0	1.0	1.0	10.0	1.0	4.0	2.5	1.0	10.0	1.0	1.0	207.6	1,335.6	9.8	2
	3.2	Rte 20 to South of Willits	31.06	43.5	8.2	6.0	4.6	4.6	3.2	1.1	5.5	1.1	1.9	1.6	2.0	1.1	4.0	4.3	7.3	1.0	10.0	10.0	10.0	1.0	9.2	10.0	1.8	2.1	1.7	2.9	3.8	1.0	1.0	1.0	1.0	1.0	1.0	4.0	2.5	5.5	1.0	5.5	2.6	147.3	919.8	7.1	12
	4	South of Willits to Arnold	T43.5	55.4	8.2	6.9	3.1	3.3	4.7	1.1	4.5	1.1	4.3	2.2	6.7	1.2	4.0	4.1	7.3	1.0	7.8	10.0	10.0	1.0	3.2	10.0	1.8	5.5	1.4	1.0	3.0	1.0	1.0	1.0	1.0	10.0	1.0	4.0	2.5	5.5	10.0	1.0	2.6	158.9	979.2	7.5	8
	5	Arnold to South of Laytonville	55.4	64.7	10.0	8.1	2.6	2.9	1.8	1.0	3.9	1.0	1.0	1.1	1.0	1.0	4.0	3.4	7.3	1.0	10.0	10.0	10.0	1.0	1.0	10.0	4.0	5.5	1.0	1.0	2.7	10.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	128.4	826.6	6.5	24
	6	South of Laytonville to Bell Springs Rd.	64.7	81.4	10.0	6.2	2.5	2.8	2.3	1.0	2.1	1.0	2.0	1.4	1.0	1.1	1.0	5.4	7.3	1.0	5.5	10.0	10.0	1.0	1.0	10.0	1.0	2.1	1.0	1.0	3.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	106.1	696.8	5.6	48
	7	Bell Springs Rd. to Jct. Rte. 1 at Leggett	81.4	T91.2	10.0	7.2	2.5	2.8	1.6	1.0	2.1	1.0	1.0	1.1	1.0	1.3	7.0	3.6	7.3	5.7	10.0	10.0	10.0	1.0	1.0	10.0	1.0	4.4	1.7	1.0	2.0	5.5	1.0	1.0	1.0	10.0	1.0	4.0	2.5	1.0	10.0	5.5	1.0	151.7	978.1	7.5	9
	8	Jct. Rte. 1 at Leggett to Red Mountain Creek	T91.2	100.3	10.0	8.6	2.5	2.8	1.3	1.0	2.1	1.0	1.0	1.0	1.0	1.2	1.0	3.4	7.3	1.0	5.5	10.0	10.0	1.0	8.3	10.0	4.0	2.1	1.4	1.0	2.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	114.8	735.5	5.9	40
	9	Red Mountain Creek to MEN/HUM County line	100.3	T106.8	10.0	7.9	2.2	2.7	1.3	1.0	2.1	1.0	1.0	1.1	1.0	1.0	7.0	2.7	7.3	5.2	10.0	10.0	10.0	1.0	10.0	10.0	3.3	1.0	1.7	1.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	126.9	824.5	6.5	25
	10	MEN/HUM County line to North of Richardson Grove	T0.0	R5.6	10.0	9.2	2.1	2.7	2.0	1.1	3.3	1.0	1.0	1.0	1.0	1.0	4.0	2.5	7.3	1.6	5.5	10.0	10.0	1.0	6.4	1.8	1.0	1.0	1.4	1.0	1.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.6	105.2	663.0	5.4	57
	11.1	North of Richardson Grove to Weott	R5.6	33.24	6.4	2.6	2.3	2.8	3.7	1.1	3.3	1.0	2.0	1.8	2.1	1.1	7.0	8.3	7.3	10.0	10.0	10.0	10.0	1.0	10.0	10.0	9.3	1.0	6.4	1.0	7.9	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	1.0	1.0	1.0	8.4	167.7	1,057.8	8.0	5
	11.2	Weott to north of Rio Dell	33.24	52.68	8.2	4.7	2.5	2.9	3.0	1.1	3.4	1.0	1.1	1.3	1.4	2.4	7.0	6.1	7.3	7.7	10.0	10.0	10.0	1.0	10.0	10.0	10.0	1.0	4.6	1.0	5.4	1.0	1.0	4.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	6.3	154.4	982.6	7.5	7
	11.3	North of Rio Dell to South Eureka Urban boundary	52.68	74.8	8.2	1.3	5.9	5.8	5.3	1.3	6.4	1.3	2.6	2.8	2.5	7.2	4.0	6.8	7.3	7.3	10.0	10.0	10.0	1.0	10.0	10.0	7.0	5.5	6.8	4.3	4.4	1.0	5.5	4.0	1.0	10.0	1.0	10.0	4.0	1.0	10.0	1.0	6.3	209.8	1,279.4	9.5	3
	12	South Eureka Urban boundary to near North Eureka city limits	74.8	79.8	2.8	5.0	8.4	8.2	4.5	10.0	7.6	10.0	1.2	2.1	2.5	10.0	4.0	2.3	7.3	1.8	10.0	10.0	10.0	1.0	10.0	10.0	1.0	1.0	1.0	6.8	5.4	1.0	5.5	1.0	1.0	1.0	10.0	4.0	10.0	1.0	10.0	1.0	1.0	200.4	1,122.9	8.4	4
	13	Near North Eureka city limits to Jct. Rte 255	79.8	85.8	4.6	6.3	10.0	10.0	5.2	1.9	6.7	2.2	1.2	1.7	1.1	6.0	4.0	2.6	10.0	1.0	10.0	10.0	10.0	1.0	10.0	10.0	2.5	3.3	1.0	2.7	2.4	1.0	1.0	1.0	1.0	10.0	1.0	4.0	5.5	1.0	1.0	1.0	1.0	165.7	1,050.3	8.0	6
	14.1	Jct 255 to Airport	85.8	93.968	4.6	4.0	7.1	7.0	10.0	1.3	10.0	1.3	2.0	3.3	2.8	6.3	10.0	3.1	10.0	10.0	10.0	10.0	10.0	1.0	10.0	10.0	4.8	1.0	7.8	6.8	1.9	10.0	10.0	4.0	1.0	1.0	1.0	7.0	4.0	10.0	10.0	1.0	1.0	226.2	1,358.5	10.0	1
	14.2	Airport to Big Lagoon	93.968	109.4	6.4	4.5	2.6	2.8	3.4	1.1	2.8	1.1	1.3	2.3	2.1	1.4	1.0	5.1	7.3	8.3	10.0	10.0	10.0	1.0	10.0	10.0	2.5	1.0	4.2	1.7	2.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	5.2	132.8	813.7	6.4	27
	15	Big Lagoon to Redwood National Park Bypass	109.4	R125.8	8.2	7.0	1.9	2.3	1.5	1.0	1.8	1.0	1.3	1.1	1.2	1.0	1.0	5.3	7.3	1.0	5.5	10.0	10.0	1.0	10.0	10.0	3.3	3.3	1.4	1.0	3.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.1	116.6	720.2	5.8	43
	16	Redwood National Park Bypass	R125.8	R137.1	6.4	7.6	1.7	2.0	1.9	1.0	2.6	1.0	1.0	1.0	1.0	1.0	1.0	4.0	7.3	1.0	10.0	10.0	10.0	1.0	10.0	10.0	2.5	1.0	1.0	1.0	3.8	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	1.0	1.0	5.5	4.2	130.5	793.2	6.3	31
	17	HUM/DN Co. line to Kamp Klamath	M0.0	R3.6	6.4	8.4	1.8	2.0	1.5	1.0	1.4	1.0	1.3	1.0	1.2	1.0	1.0	1.9	7.3	1.0	10.0	10.0	10.0	1.0	10.0	10.0	1.0	1.0	1.7	1.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	109.6	668.0	5.4	54
	18	Del Norte Redwoods State Park Area	R3.6	12.5	10.0	8.2	2.1	2.5	1.5	1.0	1.4	1.0	2.7	1.1	1.4	1.0	4.0	3.3	7.3	1.0	5.5	10.0	10.0	2.8	10.0	10.0	4.0	5.5	1.0	1.0	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	124.1	783.2	6.2	33
	19	Wilson Creek to South of Crescent City.	12.5	25.7	6.4	7.2	2.9	3.5	2.6	1.0	3.3	1.0	1.6	1.6	5.3	1.6	1.0	4.5	7.3	1.0	6.6	10.0	10.0	10.0	10.0	10.0	1.8	1.0	1.0	1.0	2.9	1.0	1.0	7.0	1.0	1.0	1.0	7.0	4.0	1.0	1.0	10.0	3.1	154.1	871.7	6.8	18
	20	South of Crescent City to North of Crescent City	25.7	27.2	4.6	7.6	5.1	5.6	3.7	3.7	3.5	3.5	3.5	2.0	5.7	2.8	1.0	1.4	7.3	1.0	10.0	10.0	10.0	1.0	10.0	10.0	1.0	2.1	1.0	2.4	2.3	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	1.0	10.0	1.0	1.0	152.0	906.9	7.0	13
	21	North of Crescent City to Jct. Rte. 199	27.2	31.3	4.6	6.2	3.0	3.2	3.3	2.9	6.2	1.9	3.9	2.8	2.0	2.0	4.0	2.1	7.3	7.5	10.0	10.0	10.0	1.0	3.6	10.0	1.0	1.0	2.1	2.3	2.1	1.0	1.0	1.0	1.0	1.0	1.0	4.0	2.5	1.0	1.0	1.0	2.1	133.5	834.3	6.5	21
	22	Jct. Rte. 199 to Oregon border	31.3	46.5	2.8	5.6	2.7	2.8	4.2	1.3	3.8	1.0	2.8	2.2	1.9	1.1	4.0	5.0	7.3	1.0	5.5	10.0	10.0	1.0	7.0	10.0	3.3	1.0	1.4	3.2	4.0	1.0	1.0	1.0	10.0	1.0	1.0	4.0	2.5	1.0	1.0	1.0	2.1	132.4	773.2	6.1	35
128	1	Route 1 to Indian Creek Bridge	0.0	23.3	8.2	4.2	1.7	1.8	2.6	1.0	2.4	1.0	1.4	1.3	1.1	1.0	4.0	7.1	5.5	1.0	5.5	10.0	10.0	1.0	1.0	1.0	2.5	2.1	1.0	1.0	4.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	97.3	615.9	5.1	64
	2	Indian Creek Bridge to Route 253	23.3	29.6	6.4	7.7	1.6	1.7	1.7	1.1	1.9	1.0	1.7	1.2	1.1	1.1	4.0	2.7	5.5	1.0	5.5	10.0	10.0	1.0	1.0	1.0	2.5	1.0	1.0	1.0	1.6	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	98.1	619.8	5.1	62
	3	Route 253 to the Sonoma County Line	29.6	50.9	10.0	7.2	1.4	1.4	1.8	1.0	2.4	1.0	1.5	1.1	1.0	1.0	4.0	6.6	5.5	1.0	5.5	10.0	1.0	1.0	1.0	1.0	1.8	6.6	1.0	1.0	4.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	94.8	605.9	5.0	67
162	1.1	Route 101 to PM 16.76	0.0	16.76	8.2	7.4	1.2	1.2	2.0	1.0	4.6	1.0	1.0	1.1	1.0	1.1	4.0	5.4	2.8	1.0	5.5	1.0	1.0	1.0	1.0	1.0	4.8	3.3	1.0	1.0	4.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	81.5	535.5	4.5	82
	1.2	PM 16.76 to Short Creek Bridge	16.76	34.0	4.6	6.5	1.3	1.3	1.9	1.0	1.7	1.0	1.8	1.2	1.2	1.4	1.0	5.5	2.8	1.0	5.5	1.0	1.0	1.0	1.0	1.0	3.3	3.3	1.0	1.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	70.3	434.8	3.9	92

Attachment F: Criticality scaled scores

					System Connectivity, Average Daily Traffic, and Population													Highway Length and Classifications									Bridges			Stormwater Management Facilities		Amenities and Buildings						Traffic Control Systems and Call Boxes						TOTALS			
				Weight	10.0	7.2	9.8	9.1	2.2	1.2	6.5	1.5	5.8	5.2	4.5	7.9	8.8	5.2	8.8	8.4	6.1	4.2	6.5	3.5	2.4	8.2	9.1	5.8	6.3	7.9	7.7	2.8	2.8	2.2	2.6	6.1	3.8	4.9	2.8	5.8	5.6	6.1	3.1				
Highway	TCR Segment	Segment Description	Begin Post Mile	End Post Mile	Level of Access (System Redundancy Measure 1)	Ability to Reroute (System Redundancy Measure 2)	Composite ADT	Composite peak hour volume	Total population in census block groups	Total population density in census block groups (ppl/sm)	Total population in census tracts	Total population density in census tracts (ppl/sm)	Number of commercial land use parcels with 1-mile buffer	Number of residential land use parcels with 1-mile buffer	Number of industrial land use parcels with 1-mile buffer	Number of non-park municipal land use parcels with 1-mile buffer	Number of critical nodes	Total miles of segment	Functional classification	Miles of access control highway per mile of segment	Average number of lanes/mile	Miles of designated bike routes per mile of segment	Miles of designated bus route per mile of segment	Miles of officially designated scenic highway per mile of segment	Miles of eligible scenic highway per mile of segment	Miles of designated network truck route per mile of segment	Number of bridges over water longer than 100 feet	Number of bridges over water shorter than 100 feet	Number of overpasses and underpasses	Number of stormwater inlets, outfalls, and ditches	Number of stormwater culverts	Number of rest areas	Number of park & ride sites	Number of vista points	Number of weigh station and agrigultural inspection stations	Number of maintenance facilities	Number of Caltrans office buildings	Number of traffic signals (congestion management systems)	Number of closed circuit television systems	Number of extinguishable message signs	Number of highway advisory radio systems	Number of road weather information systems	Number of call boxes	Total Score	Weighted Score	Scaled Score	Rank
169	1	Route 101 to Klamath Glen	R0.0	3.5	10.0	8.9	1.2	1.3	1.5	1.0	1.4	1.0	3.5	1.1	1.5	1.1	4.0	1.9	2.8	1.0	5.5	1.0	1.0	1.0	1.0	1.0	1.8	1.0	1.0	1.0	1.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	71.9	476.7	4.2	87
	4	Wautec to Ke'pel Road	13.2	23.7	10.0	8.4	1.1	1.1	1.2	1.0	1.8	1.0	1.0	1.1	1.0	1.0	1.0	3.8	2.8	1.0	3.3	1.0	1.0	1.0	1.0	1.0	2.5	1.0	1.0	1.0	2.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	66.5	439.0	3.9	91
	5	Ke'pel Road to Martins Ferry	23.7	30.0	10.0	8.5	1.1	1.2	1.2	1.0	1.8	1.0	1.0	1.1	1.0	1.0	1.0	2.7	2.8	1.0	3.7	1.0	1.0	1.0	1.0	1.0	3.3	3.3	1.0	1.0	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	68.2	451.3	4.0	89
	6	Martins Ferry to Weitchpec	30.0	33.8	8.2	9.1	1.1	1.2	1.2	1.0	1.8	1.0	1.0	1.1	1.0	1.0	4.0	2.0	2.8	1.0	3.7	1.0	1.0	1.0	1.0	1.0	1.0	3.3	1.0	1.0	1.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	67.2	441.2	3.9	90
175	1	Route 101 to MEN/LAK County Line	0.0	9.9	8.2	7.9	1.6	1.6	1.7	1.0	1.6	1.0	1.7	1.1	1.1	1.1	4.0	3.6	5.5	1.0	5.5	1.0	1.0	1.0	1.0	5.9	2.5	1.0	1.4	1.0	2.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	5.2	83.6	549.0	4.6	79
	2	MEN/LAK County Line to Route 29 South of the City of Lakeport	0.0	R8.2	6.4	7.8	1.5	1.6	1.8	1.1	3.6	1.3	1.6	1.1	1.3	1.0	4.0	3.2	5.5	1.0	5.5	1.0	1.0	1.0	1.0	1.0	1.0	3.3	1.0	6.0	5.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4.7	87.0	562.6	4.7	75
	3	Route 29 South of the community of Kelseyville to the community of Cobb	8.3	19.6	8.2	6.9	1.7	1.7	2.4	1.2	2.0	1.1	2.0	2.4	1.0	1.0	7.0	4.0	2.8	1.0	5.5	1.0	7.6	1.0	1.0	1.0	1.0	1.0	1.0	4.3	4.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4.2	90.4	586.4	4.9	71
	4	From the community of Cobb to Route 29 in the community of Middletown	19.6	28.0	10.0	7.5	1.8	1.9	2.5	1.2	4.0	1.2	2.7	2.2	1.2	1.0	7.0	3.2	5.5	1.0	5.5	1.0	10.0	1.0	1.0	1.0	2.5	2.1	1.0	5.2	5.1	1.0	5.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	106.9	703.6	5.7	47
197	1	Route 199 to Route 101	0.0	7.1	10.0	8.1	1.5	1.6	1.7	1.0	2.0	1.0	1.3	1.3	1.0	1.0	7.0	2.9	5.5	1.0	5.5	1.0	1.0	1.0	9.5	1.0	1.0	1.0	1.0	1.0	1.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	84.9	539.1	4.6	81
199	1	Route 101 to near Gasquet	T0.5	13.0	10.0	7.4	1.9	2.1	3.7	1.0	3.8	1.0	1.9	1.5	1.0	1.1	7.0	4.3	7.3	1.0	5.5	10.0	10.0	1.0	10.0	1.0	4.0	1.0	2.1	1.1	2.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.1	118.4	731.2	5.8	42
	2	Near Gasquet to west of Patrick Creek	13.0	19.8	10.0	8.9	1.7	1.9	1.3	1.0	2.0	1.0	1.4	1.2	1.0	1.1	1.0	2.8	7.3	1.0	10.0	10.0	1.0	1.0	10.0	1.0	2.5	1.0	1.7	1.0	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	98.7	599.1	5.0	68
	3	West of Patrick Creek to near Idlewild	19.8	27.1	10.0	8.8	1.7	7.9	1.3	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	2.9	7.3	1.0	5.5	10.0	1.0	1.0	10.0	1.0	4.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	7.0	1.0	1.0	1.0	1.0	2.1	106.5	662.4	5.4	58
	4	Near Idlewild to the Calif./Oregon Border	27.1	36.4	10.0	8.6	1.7	7.9	1.3	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	3.4	7.3	1.0	5.5	10.0	1.0	1.0	8.9	1.0	1.0	1.0	1.4	1.0	2.3	5.5	1.0	1.0	10.0	10.0	1.0	4.0	4.0	10.0	10.0	5.5	2.1	148.5	854.5	6.7	20
200	1	Jct. Rte. 101 to Jct. Rte. 299	R0.0	R2.7	6.4	8.2	1.5	1.5	3.2	2.7	4.2	3.2	1.4	1.6	1.6	1.3	4.0	1.7	2.8	1.0	5.5	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.7	2.6	2.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	86.8	552.8	4.7	78
211	3	Ocean Ave. in Ferndale to Route 101	73.2	79.2	4.6	8.2	2.4	2.3	3.1	1.1	3.1	1.1	1.2	1.1	1.0	1.9	4.0	2.6	2.8	1.0	5.5	1.0	1.0	1.0	1.0	10.0	4.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	81.6	544.5	4.6	80
222	1	Rte. 101 to East Site Road in Talmage	R0.0	2.2	6.4	7.8	2.8	2.7	3.2	3.4	5.4	1.6	5.3	2.3	1.3	1.1	4.0	1.6	5.5	1.0	5.5	1.0	1.0	1.0	1.0	10.0	1.8	1.0	1.0	1.6	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	93.8	611.2	5.0	66
253	1	Rte 128 at Boonville to iunction Rte 101 near Ukiah	0.0	17.2	10.0	7.3	1.6	1.5	3.9	1.1	5.1	1.1	2.0	1.4	1.8	1.1	7.0	5.5	5.5	1.0	5.5	1.0	10.0	1.0	1.0	1.0	2.5	2.1	1.4	2.0	3.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	100.3	665.5	5.4	55
254	1	Route 101 to Myers Flat	0.0	12.3	10.0	6.7	1.3	1.7	1.6	1.1	2.1	1.0	1.3	1.3	1.0	1.0	4.0	4.2	2.8	1.0	5.5	1.0	1.0	1.0	10.0	1.0	3.3	1.0	1.4	1.0	3.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	83.8	520.8	4.5	84
	2	Myers Flat to Route 101 at Jordan Road	12.3	46.5	10.0	5.7	1.1	1.3	3.5	1.0	4.6	1.0	1.2	1.3	1.0	1.0	4.0	10.0	2.8	1.0	5.5	1.0	1.0	1.0	10.0	1.0	4.0	1.0	2.1	1.0	3.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	94.0	571.7	4.8	74
255	1	Route 101 to Eureka Urban Limits	0.0	1.7	10.0	8.2	3.2	3.2	2.8	2.1	3.8	2.6	1.1	1.0	1.1	4.9	4.0	1.4	5.5	1.0	5.5	1.0	10.0	1.0	1.0	10.0	1.0	1.0	1.4	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	102.1	692.2	5.6	51
	2	Eureka Urban Limits to 0.2 mi. North Mad River Slough Br. #4-257	1.7	5.4	6.4	9.5	2.8	2.9	1.5	1.3	1.4	1.3	1.2	1.2	1.6	1.1	4.0	2.0	5.5	1.0	5.5	1.0	10.0	1.0	1.0	10.0	1.8	1.0	1.0	1.0	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	91.0	617.3	5.1	63
	3	0.2 Mi. North Mad River Slough Br. #257 to Arcata Urban Limits	5.4	7.2	6.4	9.6	3.4	3.4	1.5	1.3	1.4	1.3	1.0	1.0	1.4	1.7	1.0	1.5	5.5	1.0	5.5	1.0	10.0	1.0	1.0	10.0	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	88.1	595.2	4.9	69
	4	Arcata Urban Limits to Junction Rte. 101	7.2	8.8	8.2	8.3	4.0	4.0	2.7	2.0	4.6	2.7	1.0	1.0	1.4	4.2	4.0	1.4	5.5	1.0	10.0	1.0	10.0	1.0	1.0	10.0	1.0	2.1	1.4	1.8	1.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	109.0	733.6	5.9	41
271	1	Route 101 to Route 1	0.0	7.3	10.0	6.8	1.0	1.1	1.3	1.0	2.1	1.0	1.0	1.1	1.0	1.2	10.0	2.9	2.8	1.0	5.5	1.0	1.0	1.0	1.0	1.0	2.5	1.0	1.4	1.0	2.0	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	84.7	572.5	4.8	73
	2	1.5 miles so. of Reynolds Overcrossing to the MEN/HUM County line	17.1	22.7	10.0	8.3	1.0	1.1	1.3	1.0	2.1	1.0	1.0	1.1	1.0	1.0	7.0	2.5	2.8	1.0	5.5	1.0	1.0	1.0	1.0	1.0	2.5	1.0	2.1	1.0	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	74.1	501.2	4.3	85
	3	MEN/HUM Co. line to Route 101	0.0	T0.3	10.0	5.3	1.0	1.1	1.8	1.0	3.3	1.0	1.0	1.2	1.0	1.2	4.0	1.1	2.8	1.0	5.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.0	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	65.7	432.9	3.9	93
281	2	Near Konoctl Bay to Route 29	14.0	17.0	6.4	8.9	2.3	2.2	2.9	1.5	2.6	1.4	2.7	2.4	1.0	1.0	4.0	1.8	2.8	1.0	5.5	1.0	10.0	1.0	1.0	10.0	1.0	1.0	1.0	2.6	2.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	93.4	615.3	5.1	65
283	1	Rte 101 to end of Eel River Bridge #4-15	0.0	0.4	10.0	9.1	1.5	1.6	2.4	1.1	2.3	1.1	1.0	1.0	1.2	2.2	4.0	1.1	2.8	1.0	5.5	1.0	1.0	1.0	1.0	1.0	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	71.9	478.0	4.2	86
299	1	Route 101 To The City Of Blue Lake	0.0	R5.9	8.2	6.6	3.6	3.7	3.4	1.1	4.6	1.1	1.1	1.6	2.6	3.3	4.0	2.6	7.3	9.6	10.0	10.0	10.0	1.0	10.0	10.0	3.3	1.0	3.9	1.9	2.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	5.5	1.0	1.0	2.1	144.9	931.1	7.2	11
	2	City Of Blue Lake To Community Of Willow Creek	R5.9	29.1	8.2	4.4	1.8	1.9	1.9	1.0	2.7	1.0	1.0	1.2	1.1	1.7	1.0	7.1	7.3	1.0	5.5	10.0	10.0	1.0	10.0	10.0	3.3	1.0	1.0	1.0	4.3	1.0	1.0	7.0	1.0	10.0	1.0	1.0	1.0	1.0	1.0	5.5	4.2	136.2	808.9	6.4	28
	3	Community Of Willow Creek To Humboldt/Trinity Line	29.1	43.0	10.0	6.9	2.0	2.2	1.4	1.0	1.8	1.0	1.3	1.4	1.0	1.0	4.0	4.7	7.3	1.0	5.5	10.0	10.0	1.0	10.0	10.0	4.0	1.0	1.4	1.0	3.1	1.0	1.0	1.0	1.0	10.0	1.0	7.0	4.0	1.0	10.0	1.0	3.1	146.1	897.5	6.9	16

Attachment G

TAG criticality feedback

Appendix G: Tag criticality feedback

Category	Criticality Factors	Scaled Average Importance (1-10)
Socioeconomic: Contribution to the social viability of the community and support of the local economy.	Commuter Route	4
	Route for Goods Movement	8
	Functions as Community Connection	5
	Lacks System Redundancy	7
	Serves District 1 Regional Economic Center	4
Operational: Supports uses and capacity and reflects facility value	Functional Classification (interstate, state route highway, local arterial, etc.)	3
	Usage based on Average Daily Traffic	5
	Level of Service (LOS)	1
	Replacement Cost	5
	Ability to re-route/detour & cost impacts associated with re-route	6
	Time to rebuild if damaged	6
Health & Safety: Importance in emergency planning.	Identified Evacuation Route	9
	Provides Access to Health Facilities	6
	Age of Asset	2
	Structural Design	2
	Materials Used	1
	Remaining Service Life (at goal Life of Service)	3
	Potential for Loss of Life	10

Appendix G: Tag criticality feedback

Asset Type	**Average Importance Rating (1-3)**
Highways	3
Bridges	3
Overpasses and underpasses	3
Barriers	2
Stormwater Management Facilities	2
Rest areas	1
Vista points and park & ride sites	1
Weigh station and ag inspection stations	1
Maintenance and office buildings	2
Signals and Traffic Control System	2
Ramps	2
Signs	2
Pullouts	1
Lighting	1
Retaining Walls	2
Other Land Holdings/ROW	1
Designated Roads (i.e scenic hwys, bike routes, etc.)	1
Call Boxes	1

Attachment H

Pairwise Analysis

Attachment H: Pairwise Analysis

	Level of Access (System Redundancy Measure 1)	Ability to Reroute (System Redundancy Measure 2)	Composite ADT	Composite peak hour volume	Total population in census block groups	Total population density in census block groups (ppl/sm)	Total population in census tracts	Total population density in census tracts (ppl/sm)	Number of commercial land use parcels with 1-mile buffer	Number of residential land use parcels with 1-mile buffer	Number of industrial land use parcels with 1-mile buffer	Number of non-park municipal land use parcels with 1-mile buffer	Number of critical nodes	Total miles of segment	Functional classification	Miles of access control highway per mile of segment	Average number of lanes/mile	Miles of designated bike routes per mile of segment	Miles of designated bus route per mile of segment	Miles of officially designated scenic highway per mile of segment	Miles of eligible scenic highway per mile of segment	Miles of designated network truck route per mile of segment	Number of bridges over water longer than 100 feet	Number of bridges over water shorter than 100 feet	Number of overpasses and underpasses
Level of Access (System Redundancy Measure 1)		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ability to Reroute (System Redundancy Measure 2)	0		0	0	1	1	1	1	0	1	1	0	0	1	1	0	1	1	0	1	1	0	0	1	1
Composite ADT	0	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Composite peak hour volume	0	1	0		1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
Total population in census block groups	0	0	0	0		1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Total population density in census block groups (ppl/sm)	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total population in census tracts	0	0	0	0	1	1		1	0	0	1	0	0	1	0	0	1	1	1	1	1	0	0	1	1
Total population density in census tracts (ppl/sm)	0	0	0	0	0	1	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of commercial land use parcels with 1-mile buffer	0	1	0	0	1	1	1	1		1	1	0	0	1	0	0	1	1	1	1	1	0	0	0	0
Number of residential land use parcels with 1-mile buffer	0	0	0	0	1	1	1	1	0		1	0	0	1	0	0	1	1	0	1	1	0	0	0	0
Number of industrial land use parcels with 1-mile buffer	0	0	0	0	1	1	0	1	0	0		0	0	1	0	0	1	1	0	1	1	0	0	0	0
Number of non-park municipal land use parcels with 1-mile buffer	0	1	0	0	1	1	1	1	1	1	1		0	1	0	0	1	1	1	1	1	1	0	0	0
Number of critical nodes	0	1	0	0	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	0	1	0
Total miles of segment	0	0	0	0	1	1	0	1	0	0	0	0	0		0	0	0	1	0	1	1	0	0	0	0
Functional classification	0	0	0	1	1	1	1	1	1	1	1	1	0	1		1	1	1	1	1	1	1	1	1	1
Miles of access control highway per mile of segment	0	1	0	0	1	1	1	1	1	1	1	1	0	1	0		1	1	1	1	1	0	0	1	1
Average number of lanes/mile	0	0	0	0	1	1	0	1	0	0	0	0	0	1	0	0		1	1	1	1	0	0	1	0
Miles of designated bike routes per mile of segment	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0		0	1	1	0	0	0	0
Miles of designated bus route per mile of segment	0	1	0	0	1	1	0	1	0	1	1	0	0	1	0	0	0	1		1	1	0	0	1	0
Miles of officially designated scenic highway per mile of segment	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0		1	0	0	0	0
Miles of eligible scenic highway per mile of segment	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
Miles of designated network truck route per mile of segment	0	1	0	0	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1		0	1	1
Number of bridges over water longer than 100 feet	0	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1		1	1
Number of bridges over water shorter than 100 feet	0	0	0	0	0	1	0	1	1	1	1	1	0	1	0	0	0	1	0	1	1	0	0		1
Number of overpasses and underpasses	0	0	0	0	0	1	0	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	0	0	
Number of stormwater inlets, outfalls, and ditches	0	1	0	0	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1	0	0	1	1
Number of stormwater culverts	0	1	0	0	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1	0	0	1	1
Number of rest areas	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Number of park & ride sites	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Number of vista points	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Number of weigh station and agrigultural inspection stations	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Number of maintenance facilities	0	0	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0	1	0	1	1	0	0	0	0
Number of Caltrans office buildings	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Number of traffic signals (congestion management systems)	0	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Number of closed circuit television systems	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of extinguishable message signs	0	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	0	1	1	0	0	1	1
Number of highway advisory radio systems	0	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	1
Number of road weather information systems	0	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	0	1	1	1	0	1	1
Number of call boxes	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Attachment H: Pairwise Analysis

	Number of stormwater inlets, outfalls, and ditches	Number of stormwater culverts	Number of rest areas	Number of park & ride sites	Number of vista points	Number of weigh station and agrigultural inspection stations	Number of maintenance facilities	Number of Caltrans office buildings	Number of traffic signals (congestion management systems)	Number of closed circuit television systems	Number of extinguishable message signs	Number of highway advisory radio systems	Number of road weather information systems	Number of call boxes	Count	Weight	Weighting Rank
Level of Access (System Redundancy Measure 1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	39	0.050	1
Ability to Reroute (System Redundancy Measure 2)	0	0	1	1	1	1	1	1	1	1	1	1	1	1	27	0.035	12
Composite ADT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	38	0.049	2
Composite peak hour volume	1	1	1	1	1	1	1	1	1	1	1	1	1	1	35	0.045	3
Total population in census block groups	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0.006	36
Total population density in census block groups (ppl/sm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.001	39
Total population in census tracts	0	0	1	1	1	1	0	1	1	1	1	1	1	1	24	0.031	13
Total population density in census tracts (ppl/sm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.003	38
Number of commercial land use parcels with 1-mile buffer	0	0	1	1	1	1	0	1	0	1	0	0	0	1	21	0.027	19
Number of residential land use parcels with 1-mile buffer	0	0	1	1	1	1	0	1	0	1	0	0	0	1	18	0.023	23
Number of industrial land use parcels with 1-mile buffer	0	0	1	1	1	1	0	0	0	1	0	0	0	1	15	0.019	26
Number of non-park municipal land use parcels with 1-mile buffer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	30	0.039	9
Number of critical nodes	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34	0.044	5
Total miles of segment	0	0	1	1	1	1	0	1	1	1	1	1	1	1	18	0.023	23
Functional classification	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34	0.044	5
Miles of access control highway per mile of segment	1	1	1	1	1	1	1	1	1	1	1	1	1	1	32	0.041	7
Average number of lanes/mile	0	0	1	1	1	1	1	1	1	1	1	1	1	1	22	0.028	16
Miles of designated bike routes per mile of segment	0	0	1	0	1	1	0	1	1	1	0	1	0	1	14	0.018	27
Miles of designated bus route per mile of segment	0	0	1	1	1	1	1	1	1	1	1	1	1	1	24	0.031	13
Miles of officially designated scenic highway per mile of segment	0	0	1	1	1	1	0	0	0	1	0	0	0	1	11	0.014	29
Miles of eligible scenic highway per mile of segment	0	0	0	0	0	0	0	0	0	1	0	0	0	1	6	0.008	35
Miles of designated network truck route per mile of segment	1	1	1	1	1	1	1	1	1	1	1	1	0	1	31	0.040	8
Number of bridges over water longer than 100 feet	1	1	1	1	1	1	1	1	1	1	1	1	1	1	35	0.045	3
Number of bridges over water shorter than 100 feet	0	0	1	1	1	1	1	1	1	1	0	0	0	1	21	0.027	19
Number of overpasses and underpasses	0	0	1	1	1	1	1	1	1	1	0	0	0	1	23	0.030	15
Number of stormwater inlets, outfalls, and ditches		1	1	1	1	1	1	1	1	1	1	1	1	1	30	0.039	9
Number of stormwater culverts	0		1	1	1	1	1	1	1	1	1	1	1	1	29	0.037	11
Number of rest areas	0	0		1	1	1	0	0	0	0	0	0	0	0	8	0.010	31
Number of park & ride sites	0	0	0		1	1	0	0	0	0	0	0	0	0	8	0.010	31
Number of vista points	0	0	0	0		0	0	0	0	0	0	0	0	0	5	0.006	36
Number of weigh station and agrigultural inspection stations	0	0	0	0	1		0	1	0	0	0	0	0	0	7	0.009	34
Number of maintenance facilities	0	0	1	1	1	1		1	0	1	1	1	1	1	22	0.028	16
Number of Caltrans office buildings	0	0	1	1	1	0	0		0	1	0	0	0	1	12	0.015	28
Number of traffic signals (congestion management systems)	0	0	1	1	1	1	1	1		1	0	0	0	1	17	0.022	25
Number of closed circuit television systems	0	0	1	1	1	1	0	0	0		0	0	0	0	8	0.010	31
Number of extinguishable message signs	0	0	1	1	1	1	0	1	1	1		1	0	1	21	0.027	19
Number of highway advisory radio systems	0	0	1	1	1	1	0	1	1	1	0		1	1	20	0.026	22
Number of road weather information systems	0	0	1	1	1	1	0	1	1	1	1	0		1	22	0.028	16
Number of call boxes	0	0	1	1	1	1	0	0	0	1	0	0	0		9	0.012	30

Attachment I

Criticality Weights Obtained from Pairwise Analysis

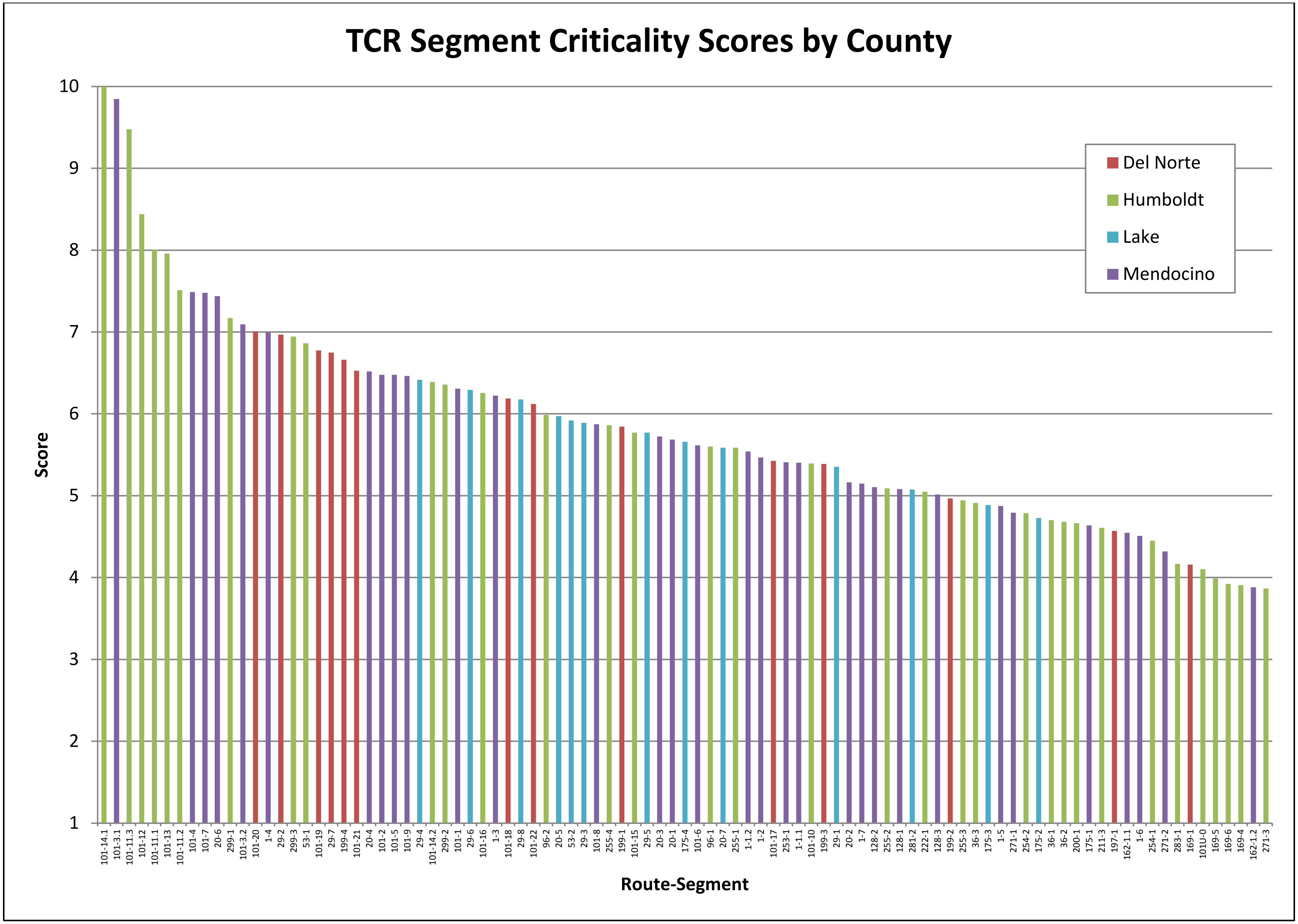
Attachment I: Criticality factor weights obtained from the pairwise analysis

Criticality Factor	TAG Score	Overall Weight	Scaled Weight	Priority Ranking
Level of Access (System Redundancy Measure 1)	7 to 9	39	10.0	1
Composite ADT	5	38	9.8	2
Composite peak hour volume	5	35	9.1	3
Number of bridges over water longer than 100 feet	9	35	9.1	3
Functional classification	3	34	8.8	5
Number of critical nodes	7 to 9	34	8.8	5
Miles of access control highway per mile of segment	7	32	8.4	7
Miles of designated network truck route per mile of segment	8	31	8.2	8
Number of non-park municipal land use parcels with 1-mile buffer	6	30	7.9	9
Number of stormwater inlets, outfalls, and ditches	6	30	7.9	9
Number of stormwater culverts	6	29	7.7	11
Ability to Reroute (System Redundancy Measure 2)	7 to 9	27	7.2	12
Total population in census tracts	5	24	6.5	13
Miles of designated bus route per mile of segment	3	24	6.5	13
Number of overpasses and underpasses	9	23	6.3	15
Number of maintenance facilities	6	22	6.1	16
Average number of lanes/mile	6	22	6.1	16
Number of road weather information systems	6	22	6.1	16
Number of extinguishable message signs	6	21	5.8	19
Number of commercial land use parcels with 1-mile buffer	4	21	5.8	19
Number of bridges over water shorter than 100 feet	9	21	5.8	19
Number of highway advisory radio systems	6	20	5.6	22
Total miles of segment	5	18	5.2	23
Number of residential land use parcels with 1-mile buffer	5	18	5.2	23
Number of traffic signals (congestion management systems)	6	17	4.9	25
Number of industrial land use parcels with 1-mile buffer	4	15	4.5	26
Miles of designated bike routes per mile of segment	3	14	4.2	27
Number of Caltrans office buildings	6	12	3.8	28
Miles of officially designated scenic highway per mile of segment	3	11	3.5	29
Number of call boxes	3	9	3.1	30
Number of rest areas	3	8	2.8	31
Number of park & ride sites	3	8	2.8	31
Number of closed circuit television systems	3	8	2.8	31
Number of weigh station and agrigultural inspection stations	3	7	2.6	34
Miles of eligible scenic highway per mile of segment	3	6	2.4	35
Total population in census block groups	5	5	2.2	36
Number of vista points	3	5	2.2	36
Total population density in census tracts (ppl/sm)	5	2	1.5	38
Total population density in census block groups (ppl/sm)	5	1	1.2	39

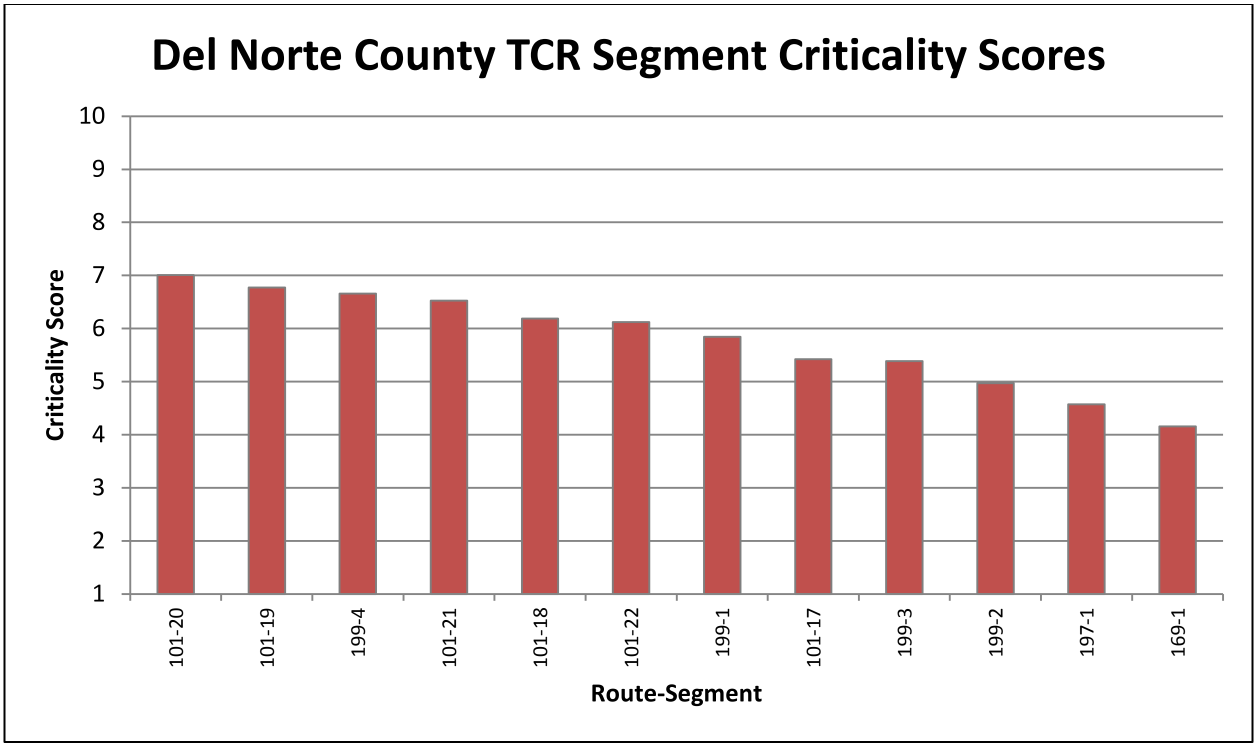
Attachment J

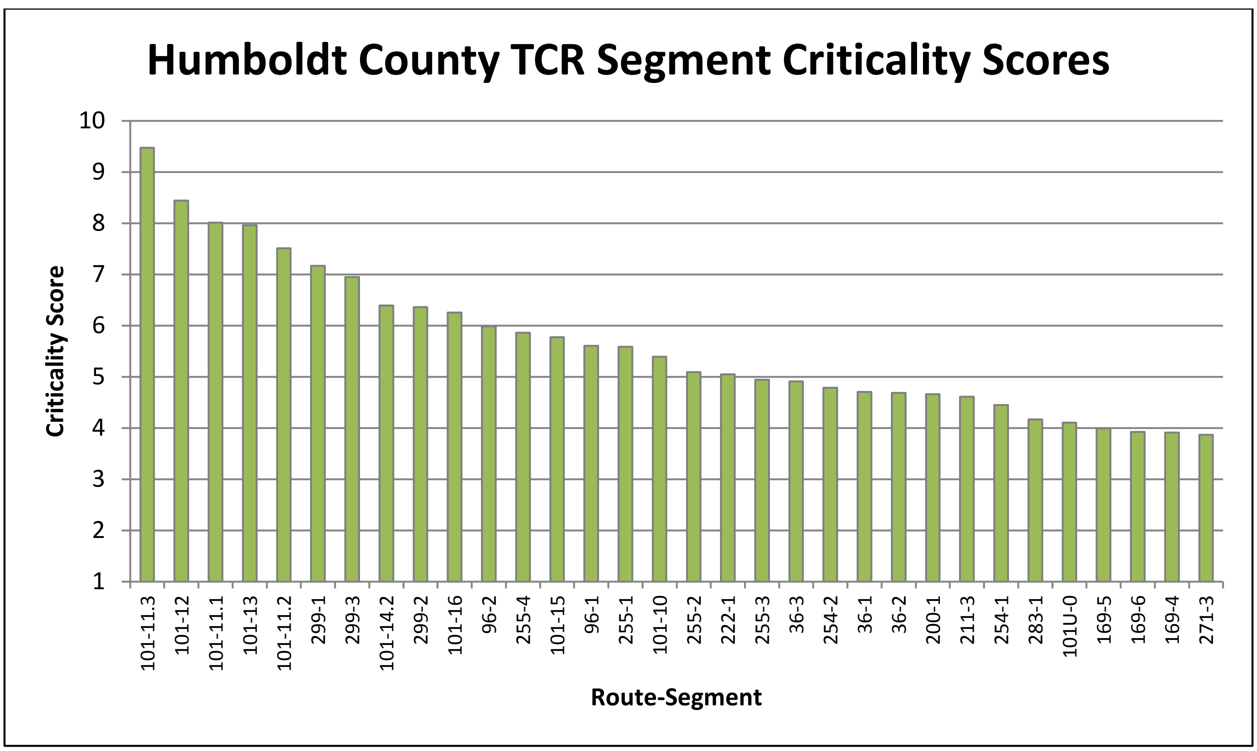
Comparison Graph Criticality Scores

Attachment J: Comparison graph of the scaled TCR segment criticality scores

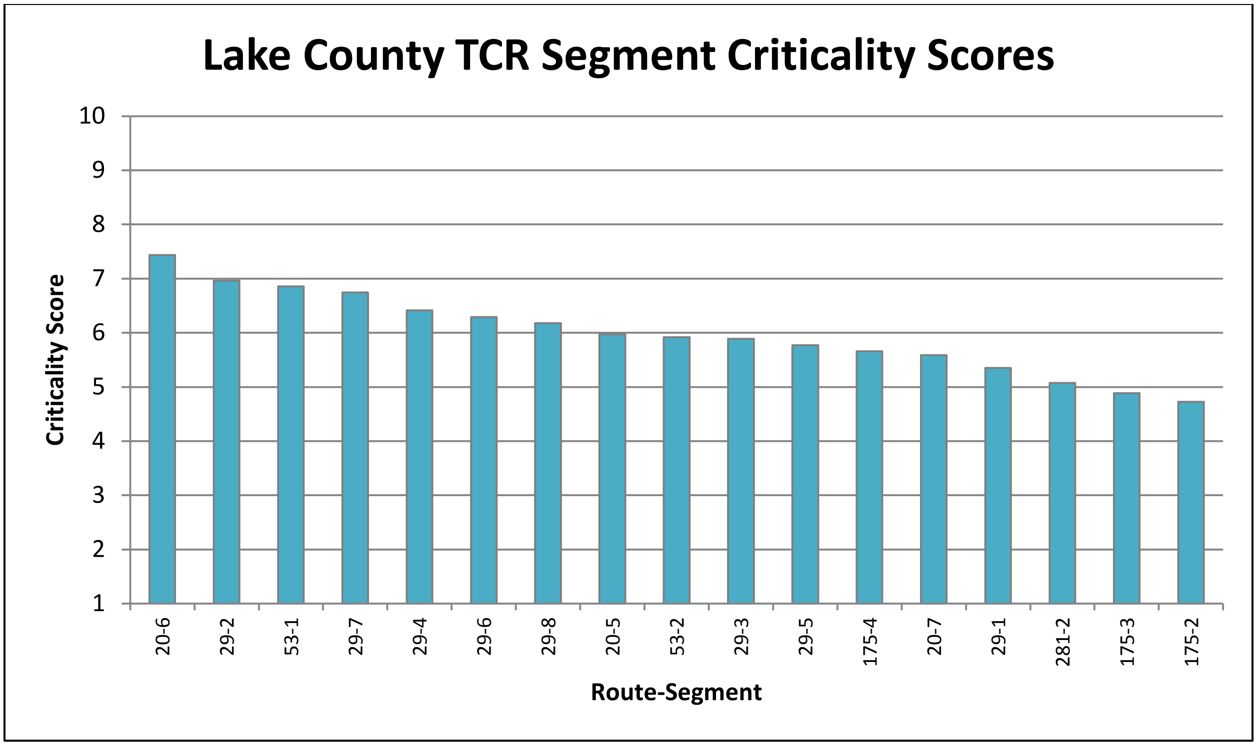


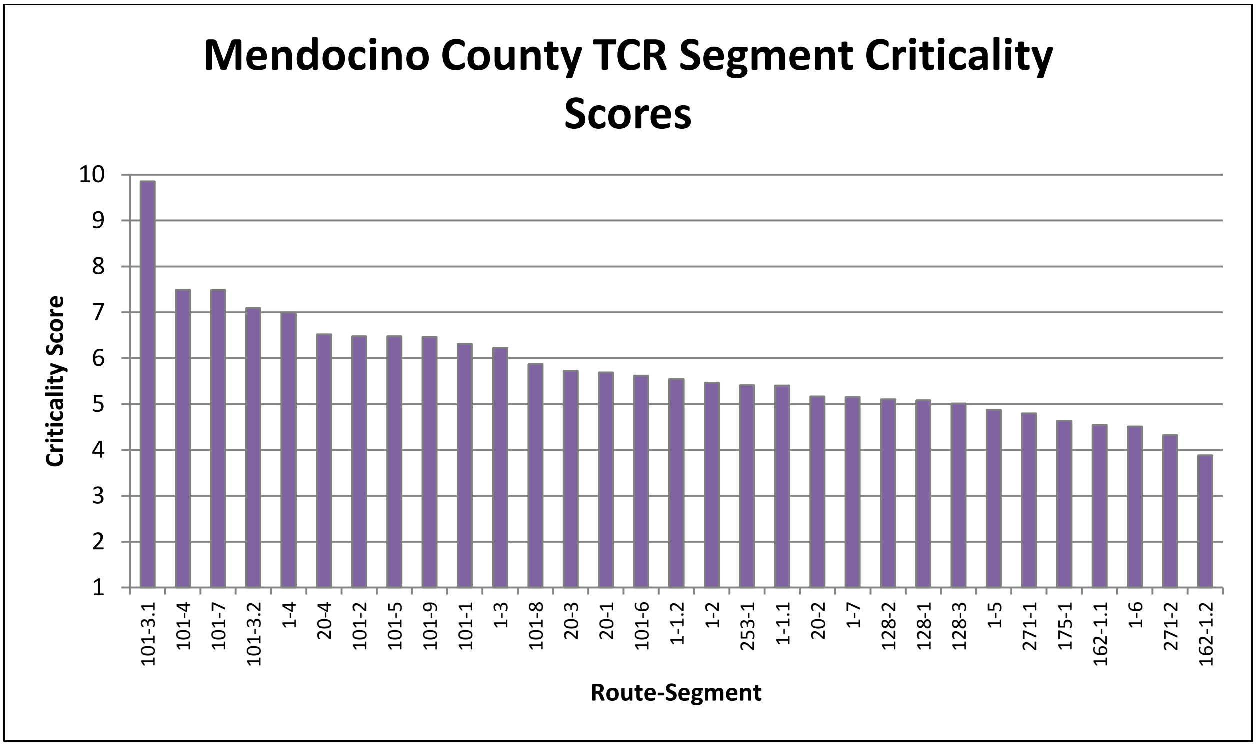
Attachment J: Comparison graph of the scaled TCR segment criticality scores





Attachment J: Comparison graph of the scaled TCR segment criticality scores





Attachment K

Comparison Table of the Scaled TCR Segments

Attachment K: Comparison table of the scaled TCR segment criticality scores

Rank	Score	County	Route	Segment	Description
1	10.0	HUM	101	14.1	Jct 255 to Airport
2	9.8	MEN	101	3.1	South of Ukiah to Rte 20
3	9.5	HUM	101	11.3	north of Rio Dell to South Eureka Urban boundary
4	8.4	HUM	101	12	South Eureka Urban boundary to near North Eureka city limits
5	8.0	HUM	101	11.1	North of Richardson Grove to Weott
6	8.0	HUM	101	13	Near North Eureka city limits to Jct. Rte 255
7	7.5	HUM	101	11.2	Weott to north of Rio Dell
8	7.5	MEN	101	4	South of Willits to Arnold
9	7.5	MEN	101	7	Bell Springs Rd. to Jct. Rte. 1 at Leggett
10	7.4	LAK	20	6	Route 29 to Route 53
11	7.2	HUM	299	1	Route 101 To The City Of Blue Lake
12	7.1	MEN	101	3.2	Rte 20 to South of Willits
13	7.0	DN	101	20	South of Crescent City to North of Crescent City
14	7.0	MEN	1	4	So. Fort Bragg City limits to No. Fort Bragg City limit
15	7.0	LAK	29	2	Junction Route 175 to Junction Route 53
16	6.9	HUM	299	3	Community Of Willow Creek To Humboldt/Trinity Line
17	6.9	LAK	53	1	Junction SR 29 to 40th Ave. City of Clearlake
18	6.8	DN	101	19	Wilson Creek to South of Crescent City.
19	6.7	LAK	29	7	0.5 mile South of Lakeport City limit to0.7 mile North of Lucerne Cutoff
20	6.7	DN	199	4	Near Idlewild to the Calif./Oregon Border
21	6.5	DN	101	21	North of Crescent City to Jct. Rte. 199
22	6.5	MEN	20	4	Route 101 to MEN/LAK Co. Line
23	6.5	MEN	101	2	Pieta Creek to South of Ukiah
24	6.5	MEN	101	5	Arnold to South of Laytonville
25	6.5	MEN	101	9	Red Mountain Creek to MEN/HUM County line
26	6.4	LAK	29	4	North of Diener Dr to North of Junction Rte. 175
27	6.4	HUM	101	14.2	Airport to Big Lagoon
28	6.4	HUM	299	2	City Of Blue Lake To Community Of Willow Creek
29	6.3	MEN	101	1	SON/MEN Co. line to Pieta Creek
30	6.3	LAK	29	6	Kelseyville to 0.5 mile South of Lakeport (w/ Rte 175)
31	6.3	HUM	101	16	Redwood National Park Bypass
32	6.2	MEN	1	3	Little River to south Fort Bragg City limit
33	6.2	DN	101	18	Del Norte Redwoods State Park Area
34	6.2	LAK	29	8	0.7 mile North of Lucerne Cutoff to Junction Route 20
35	6.1	DN	101	22	Jct. Rte. 199 to Oregon border
36	6.0	HUM	96	2	1.3 km (0.8 mi) south Rock Chute Viaduct to HUM Co. line.
37	6.0	LAK	20	5	MEN/LAK Co. Line to Route 29
38	5.9	LAK	53	2	40th Ave to Junction SR 20
39	5.9	LAK	29	3	Junction Route 53 to North of Diener Drive
40	5.9	MEN	101	8	Jct. Rte. 1 at Leggett to Red Mountain Creek
41	5.9	HUM	255	4	Arcata Urban Limits to Junction Rte. 101
42	5.8	DN	199	1	Route 101 to near Gasquet
43	5.8	HUM	101	15	Big Lagoon to Redwood National Park Bypass
44	5.8	LAK	29	5	No. of Junction Rte. 175 to Kelseyville
45	5.7	MEN	20	3	Broaddus Creek to Route 101 at Willits
46	5.7	MEN	20	1	From Route 1 at Fort to Summer Lane
47	5.7	LAK	175	4	From the community of Cobb to Route 29 in the community of Middletown
48	5.6	MEN	101	6	South of Laytonville to Bell Springs Rd.
49	5.6	HUM	96	1	Rte. 299 to 1.3 km (0.8 mi) south of Rock Chute Viaduct.
50	5.6	LAK	20	7	Route 53 to LAK/COL Co. Line
51	5.6	HUM	255	1	Route 101 to Eureka Urban Limits
52	5.5	MEN	1	1.2	Point Arena (north) to Route 128
53	5.5	MEN	1	2	Junction Route 128 to Little River
54	5.4	DN	101	17	HUM/DN Co. line to Kamp Klamath
55	5.4	MEN	253	1	Rte 128 at Boonville to iunction Rte 101 near Ukiah
56	5.4	MEN	1	1.1	Sonoma/Mendocino County line to Point Arena (north)

Attachment K: Comparison table of the scaled TCR segment criticality scores

Rank	Score	County	Route	Segment	Description
57	5.4	HUM	101	10	MEN/HUM County line to North of Richardson Grove
58	5.4	DN	199	3	West of Patrick Creek to near Idlewild
59	5.4	LAK	29	1	Napa/Lake Co. line to Junction Route 175
60	5.2	MEN	20	2	Summer Lane to Broaddus Creek
61	5.1	MEN	1	7	North Westport to Junction Rte. 101 at Leggett
62	5.1	MEN	128	2	Indian Creek Bridge to Route 253
63	5.1	HUM	255	2	Eureka Urban Limits to 0.2 mi. North Mad River Slough Br. #4-257
64	5.1	MEN	128	1	Route 1 to Indian Creek Bridge
65	5.1	LAK	281	2	Near Konoctl Bay to Route 29
66	5.0	HUM	222	1	Rte. 101 to East Site Road in Talmage
67	5.0	MEN	128	3	Route 253 to the Sonoma County Line
68	5.0	DN	199	2	Near Gasquet to west of Patrick Creek
69	4.9	HUM	255	3	0.2 Mi. North Mad River Slough Br. #257 to Arcata Urban Limits
70	4.9	HUM	36	3	Bridgeville to Trinity Co. Line
71	4.9	LAK	175	3	Route 29 South of the community of Kelseyville to the community of Cobb
72	4.9	MEN	1	5	No. Fort Bragg City limits to Little Valley Road
73	4.8	MEN	271	1	Route 101 to Route 1
74	4.8	HUM	254	2	Myers Flat to Route 101 at Jordan Road
75	4.7	LAK	175	2	MEN/LAK County Line to Route 29 South of the City of Lakeport
76	4.7	HUM	36	1	Rte 101 to Hely Creek Bridge
77	4.7	HUM	36	2	Hely Creek Bridge
78	4.7	HUM	200	1	Jct. Rte. 101 to Jct. Rte. 299
79	4.6	MEN	175	1	Route 101 to MEN/LAK County Line
80	4.6	HUM	211	3	Ocean Ave. in Ferndale to Route 101
81	4.6	DN	197	1	Route 199 to Route 101
82	4.5	MEN	162	1.1	Route 101 to PM 16.76
83	4.5	MEN	1	6	Little Valley Road to North Westport
84	4.5	HUM	254	1	Route 101 to Myers Flat
85	4.3	MEN	271	2	1.5 miles so. of Reynolds Overcrossing to the MEN/HUM County line
86	4.2	HUM	283	1	Rte 101 to end of Eel River Bridge #4-15
87	4.2	DN	169	1	Route 101 to Klamath Glen
88	4.1	HUM	101U	0	101U: SON/MEN Co. line to Jct. Rte. 101
89	4.0	HUM	169	5	Ke'pel Road to Martins Ferry
90	3.9	HUM	169	6	Martins Ferry to Weitchpec
91	3.9	HUM	169	4	Wautec to Ke'pel Road
92	3.9	MEN	162	1.2	PM 16.76 to Short Creek Bridge
93	3.9	HUM	271	3	MEN/HUM Co. line to Route 101

Appendix 2

Climate Data Projections for Caltrans District 1 Climate Change Pilot Study

ESA PWA

550 Kearny Street
Suite 900
San Francisco, CA 94108
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415.896.0332 fax

www.esassoc.com

memorandum

date July 21, 2014

to Rob Holmlund (GHD)

from Louis White, PE

subject Climate Data Projections for Caltrans District 1 Climate Change Pilot Study

1. Introduction

This memorandum describes climate change data sets that were compiled and processed for use in the Caltrans District 1 Climate Change Pilot Study (D1CCPS). The purpose of the project is to evaluate the vulnerability of Caltrans transportation assets in District 1 to various climate change impacts and develop adaptation strategies for the most vulnerable assets. The various climate change data sets prepared for this project, and included in the GIS geodatabase, will be combined with an inventory of Caltrans assets in District 1 to evaluate the vulnerability of those assets. This analysis is based on existing information and does not include any additional modeling. Data was processed to create metrics to describe the level of exposure of the assets to a particular climate change impact relative to a threshold or trigger at specific time intervals.

The following sections describe the information that is included in the geodatabase and the metrics used to characterize exposure of each climate stressor and hazard.

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2. Definition of Terms and Climate Change Background

The science of climate change and modeling of future scenarios has been extensively described (IPCC, 2013). In general, global temperature is driven by concentrations of greenhouse gases (GHGs) such as carbon dioxide, methane, and water vapor which absorb energy radiating from Earth back into space. Global emissions of greenhouse gases have rapidly increased following the industrial revolution in the mid-1700s primarily due to the burning of fossil fuels such as coal, oil, and natural gas. Emissions continue to grow as nations modernize and consume greater amounts of fossil fuels. Acknowledging this pattern, many national and statewide initiatives have been advanced to curb GHG emissions as well as respond to the anticipated impacts of climate change already underway.

Present day concentrations of carbon dioxide (CO_2) in Earth's atmosphere represent the highest ever measured, which is a key driver of increasing global temperatures, precipitation patterns, and rising sea levels. The anticipated rise in temperatures is expected to continue beyond year 2100, even if the CO_2 emissions are reduced by 2050 (Figure 1). The increased global temperature acts to warm ocean temperatures, and also has been shown to increase the rate of melting of the large ice sheets near the poles. Sea level rise (SLR) results from a combination of melting of land-based ice and thermal expansion of the oceans due to increased temperatures. The magnitude of the impact of global warming on climate change is influenced by various complex interactions in the earth-ocean-atmosphere system. Many processes and feedbacks must be accounted for in order to realistically project climate changes resulting from particular GHG emission scenarios. These complications are the source of much of the debate which has occurred about the likely magnitude and timing of climate changes due to the enhanced GHG effect.

The following sections provide background and descriptions of several terms that are used in this memorandum to describe climate change data and climate modeling.

2.1. Emissions Scenarios

Projecting potential climate trends and extremes requires first establishing future scenarios of GHG emissions that will influence future climate patterns. Due to the high level of uncertainty in the evolution of these factors, a series of qualitative storylines describing the evolution of possible trajectories of heat-trapping GHG emissions were developed by the International Panel on Climate Change (IPCC) for the IPCC Fourth Assessment Report (AR4) (IPCC 2007). These were used to guide climate change modeling efforts in AR4 upon which most of the available climate impact modelling has been based. The IPCC's (2000) special report on emissions scenarios (SRES) provides six scenario groups of plausible global emissions pathways, with no assigned probabilities of occurrence. Two of these scenarios, A2 and B1, have been selected to represent medium-high and relatively low (or "best-case") emissions projections respectively (Cayan et al. 2012). These emissions scenarios are defined as follows:

- **A2**. Medium-high emissions resulting from continuous population growth coupled with internationally uneven economic and technological growth. Under this scenario, emissions increase through the 21st century and by 2100 atmospheric carbon dioxide (CO2) levels are approximately three-times greater than pre-industrial levels.

- **B1**. Lower emissions than A2, resulting from a population that peaks mid-century and declines thereafter, with improving economic conditions and technological advancements leading to more efficient utilization of resources. Under this scenario, emissions peak mid-century and then decline, leading to a net atmospheric CO2 concentration approximately double that of pre-industrial levels. This scenario is often referred to as a "best-case" scenario.

2.2. General Circulation Models (GCMs)

General circulation models (GCMs) are used for predicting climate change. They model how the atmosphere, oceans, land surface, and ice interact to create weather and climate over long periods of time (decades and centuries) over the whole globe. GCMs subdivide the Earth's surface, atmosphere, and oceans into a 3D grid of thousands of cells. Standard physical equations for the transfer of heat, water, and momentum are solved for each grid cell to predict temperature, precipitation, and winds. Many relevant processes are well represented at the scale of these grid cells, such as the large-scale westerly flow of moisture from the Pacific Ocean. Due to the spread of climate projections over the various models, data is often averaged over multiple GCMs to avoid biasing towards any one model.

To identify the GCMs that best suited to predicting climate phenomena in the State of California, Cayan et al. (2012) selected six models from AR4 based on data availability and on historic skill in representing climate patterns in California, including seasonal precipitation and temperature, annual variability of precipitation, and the El Niño/Southern Oscillation (ENSO) phenomenon. Data was obtained for six GCMs considered representative of climate trends in California. Each model has multiple runs with 16 total runs for the A2 scenario, and 17 total runs for the B1 scenario. Runs represent different initial conditions in the GCMs. The six models selected for the assessment were:

1. The NCAR Parallel Climate Model (PCM);

2. The NOAA Geophysical Fluids Dynamics Laboratory (GFDL) model, Version 2.1;

3. The NCAR Community Climate System Model (CCSM);

4. The Max Plank Institute 5th generation ECHAM model (ECHAM5/MPI OM);

5. The medium-resolution model from the Center for Climate System Research of the University of Tokyo and collaborators (MIROC 3.2); and

6. The French Centre National de Recherches Météorologiques (CNRM) models.

Data for a series of climate stressors downscaled to the 12-kilometer (7.5-mile) scale has been archived and made available for public use on the World Climate Research Programme's (WCRP) Coupled Model Intercomparison Project Phase 3 (CMIP3) website (http://gdo-dcp.ucllnl.org). This data has been widely applied for evaluating climate trends in California. The CMIP3 archive presents compiled data from a joint effort between the US Department of the Interior's Bureau of Reclamation, Lawrence Livermore National Laboratory, Santa Clara University, Scripps, Climate Central, and the USGS. This archive includes downscaled geographic gridded data for temperature and precipitation for a number of GCMs and emissions scenarios as well as daily hydrologic projections of precipitation and other hydrologic stressors derived from the downscaled GCM data. We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on Coupled Modelling (WGCM) for their roles in making available the WCRP CMIP3 multi-model dataset. Support of this dataset is provided by the Office of Science, U.S. Department of Energy.

The CMIP3 dataset represents GCM data developed for AR4 driven by the SRES emissions trajectories. The downscaled GCM data has been used to develop additional datasets including surface water projections (USBR, 2011), and fire risk projections (Westerling, A. L., Bryant, B. P. 2008). For the Fifth Assessment Report (AR5), the IPCC has developed new emissions scenarios called Representative Concentration Pathways (RCPs). There are four RCPs which represent different amounts of anticipated radiative forcing by the end of the century. The emissions trajectories and GHG concentrations for the RCPs deviate from the previous scenarios. The RCPs have been used to develop new GCM output and a downscaled dataset for Phase 5 of the CMIP (CMIP5) has been published online by the WCRP. This dataset was not used for this report for two primary reasons

1. The most recent statewide assessment of climate change in California used CMIP3 data and emissions scenarios. To remain consistent with existing projection information for California the CMIP3 data was also used for this report.

2. The downscaled CMIP5 dataset is currently available for temperature and precipitation projections only. Secondary datasets such as hydrologic projections have yet to be developed using CMIP5 data.

As further data becomes available for CMIP5, projection information should be updated to reflect the most recent climate projection information.

2.3. Downscaling

GCMs are designed to represent climate change processes at the global scale. Models can show differences in the rate of climate change at different locations, but only on the continental scale. The size of the GCM grid cells, and thus the spatial resolution of the climate projections, is limited by the computing power necessary to solve the equations for all of the grid cells at hourly (or shorter) time steps for runs which may span 100 years or more. Thus, the climate models at the time of the latest IPCC report in 2007 produced output at spatial scales of roughly 120 to 180 miles.

Particularly in mountainous regions, such as the California coastal ranges and the Sierra Nevada, this scale is too coarse to capture the many important effects of topography on climate. For example, because the elevations of mountain ranges are averaged with the elevation of adjacent valleys, the Sierra Nevada, as represented in the GCMs, tops out at around 6,000 feet. The scale of GCM output is also too coarse to use as input for many models predicting environmental impacts, such as basin-scale hydrologic and water system models, or wildlife habitat models. Therefore, techniques to reduce the spatial scale of the GCM output (that is, downscaling) are needed for most user applications.

- **Statistical downscaling**. Statistical relationships between the regional circulation and aspects of the local climate (e.g., temperature, precipitation, wind) are used to apply GCM results to a particular place.

- A **regional climate model** (RCM) uses output from a general circulation model, but simulates processes at much higher resolution over the particular region. A RCM is very much like a GCM, except that it uses much finer resolution and covers a limited area. So a regional model may have a 10-mile grid spacing over specific regions, compared with 120 to 180 miles for a GCM.

When making use of downscaled climate projections, as with the underlying GCM output, a range of projections should be considered rather than one or two. In the case of statistical downscaling, several GCM projections are typically downscaled using the same method. Likewise with RCM downscaling, it is important to consider projections produced by multiple RCM-GCM combinations.

2.4. Uncertainty

Natural sources of uncertainty are inherent in climate processes due to fluctuating and chaotic processes, but the act of modeling using numerical algorithms and its required assumptions introduces two more main sources of uncertainty: method uncertainty and emissions uncertainty. The three types of uncertainty that appear in this memorandum are as follows:

- **Method uncertainty** is introduced from differences in model algorithms, techniques, and how the climate processes are considered. GCMs simulate climate phenomenon using a three-dimensional grid typically run with a spatial resolution of hundreds of kilometers. Smaller scale processes such as cloud interactions must be spatially averaged and this is managed differently between GCMs. Physical climate interactions such as ocean circulation, and water vapor and heat transport can be handled differently between models. The consequence of this is that GCMs may produce differing results for the same emissions pathway. For this reason, it is standard to evaluate multiple GCMs to estimate the range of potential changes in climate conditions.

- **Emissions uncertainty** is a function of the future pathways of global emissions which are, by definition, hypothetical, and based on assumptions of population growth, socioeconomic composition, and technological innovation. The emissions pathways are projections, not predictions, of possible future conditions and how those conditions relate to carbon emissions worldwide. It is standard to choose multiple emissions scenarios to estimate the range of projected climate conditions. However, measured global emissions have exceeded nearly all of the projected emissions pathways developed under AR4 (Le Quéré et al. 2010).

- **Natural variability** also influences climate trends lending another source of uncertainty. Even without external forcing from increasing greenhouse gases, climate variability will occur over space and time due to natural interactions within the climate system. This natural variability will continue in the future while external forcing will also induce variability. The two sources of variability lead to uncertainty in estimating the impact of radiative forcing on climate patterns independent of natural variations.

3. Geodatabase of Climate Information

The GIS geodatabase attached includes a series of raster files containing climate data processed from downscaled CMIP3 data. Datasets of temperature, precipitation, and runoff for 1950-2100 at a spatial resolution of 12 km by 12 km (7.5x7.5 miles) were downloaded from the CMIP3 archive for the A2 and B1 emissions scenarios. The timestamp for these online datasets is August, 2011. The datasets in the geodatabase developed for this project are horizontally referenced to the World Geodetic System of 1984 (WGS 1984). The climate datasets in the geodatabase and key parameters are summarized in Attachment 1 and described in more detail below.

3.1. Temperature

Daily maximum air temperature data was obtained from the CMIP3 archive and processed to illustrate average trends, as well as projections of extreme conditions. The annual average of daily maximum temperature for District 1 is projected to increase by approximately 4.1°F and 6.7°F for the B1 and A2 emissions scenarios, respectively, by 2100 (Figure 2). This time series represents a spatial average of temperatures across all of District 1 and is presented as a 10-year moving average to remove noise. The solid line represents an ensemble average of the results over all model runs, and the shading indicates the range in projections due to method uncertainty between models. The general trend is that the average temperatures in District 1 will increase over the coming century. Changes in the annual average of the daily maximum temperature are similar for all four counties, and close to the District 1 average (Table 1).

TABLE 1
CHANGE IN ANNUAL AVERAGE OF DAILY MAXIMUM AIR TEMPERATURE FROM HISTORIC AVERAGE (°F)

Year	2050		2100	
Emissions Scenario	A2	B1	A2	B1
District 1	3.3	3.0	6.7	4.1
Del Norte	3.2	2.8	6.7	4.0
Humboldt	3.3	2.9	6.7	4.0
Lake	3.5	3.2	6.9	4.4
Mendocino	3.4	3.0	6.7	4.2

For this study, extreme temperature is defined as the number of days per year exceeding 95° F, referred to here as "heat days." The two future conditions datasets (2050 and 2100) represent the change in number of heat days relative to a historic 30-year average (1970-2000) from the CMIP3 model data. This variable is averaged over a 30-year period (2035-2065 for 2050, and 2070-2100 for 2100) and then averaged over the GCMs.

The change in the number of projected heat days for 2050 and 2100 vary spatially throughout District 1, and tend to show a larger change for emissions scenario A2 compared to scenario B1 (Figures 3 and 4, respectively). Maps of the projected data show that inland areas have the greatest change in the number of extreme heat days, while little or no increase in the number of extreme heat days is expected in the coastal areas. Although the projections show an increase of approximately 15 to 20 extreme heat days per year by 2050, up to an additional 40 days per year are projected for inland areas. This is particularly the case in Lake County and the eastern portions of Mendocino and Humboldt Counties. A greater increase in heat days is projected for the A2 emissions scenario as compared to the B1 emissions scenario.

Method uncertainty introduced by the different model runs indicates that the number of additional heat days for the district could be significantly higher or lower (Figure 5). The number of extreme heat days presented in Figures 3 and 4 correspond to an average of all model runs, which tends to hide the model disagreement. The time series in the top panel of Figure 5 shows a running 30-year average of the additional number of heat days per year, where the solid line represents the average of all models, and the shaded areas correspond to the spread of the model projections. Note that this data is for a district average, as compared to the spatial data shown in the preceding figures. The lower panel of Figure 5 presents box plots that illustrate the distribution of model projections, where the blue box indicates the 25th percentile of the model projections, the red box indicates the 75th percentile, and the outer limits represent the maximum and minimum model projections.

3.2. Precipitation

Daily maximum precipitation data was obtained from the CMIP3 archive and processed to illustrate average trends, as well as projections of extreme conditions. The relative change of the total annual precipitation compared to the historic average is projected to decrease by approximately 2% to 7% for the B1 and A2 emissions scenarios, respectively, by 2100 (Table 2). The values in Table 2 represent a spatial average of precipitation across all of District 1 and was estimated using a 30-year moving average to remove noise in the signal. Figure 6 presents a time series graphic of the modeled precipitation data, where the solid line represents an ensemble average of the results over all model runs and the shading indicates the range in projections due to method uncertainty between models. The time series is presented using a 10-year moving average. The general trend of the data indicates that the changes in total annual precipitation in District 1 over the coming century are very uncertain, as shown by the wide range of model projections. However, the GCM averaged relative change in the total annual precipitation as a spatial average over each county yields similar results close to the District 1 average (Table 2).

TABLE 2
PERCENT CHANGE IN TOTAL ANNUAL PRECIPITATION FROM HISTORIC AVERAGE (%)

Year	2050		2100	
Emissions Scenario	A2	B1	A2	B1
District 1	-4.1	-0.5	-6.5	-2.0
Del Norte	-3.0	0.0	-5.6	-0.6
Humboldt	-3.9	-0.4	-6.5	-1.8
Lake	-5.1	-1.2	-6.8	-3.0
Mendocino	-4.6	-0.8	-6.8	-2.6

The District 1 average of the total annual precipitation for the ensemble average of models was compared to a selected “wet” model (PCM) and a selected “dry” model (GFDL) to illustrate the range in projections (Table 3). The results of the wet model indicate an increase in the total annual precipitation of up to approximately 9% greater than the historic average (for B1 scenario at 2100), while the dry model shows a decrease of up to approximately 15% (for A2 scenario at 2100). These results indicate that careful interpretation and selection of future climate projections need to be considered when applying to assessing the vulnerability of assets as well as the selection of an appropriate emissions scenario.

TABLE 3
PERCENT CHANGE IN TOTAL ANNUAL PRECIPITATION FOR DIFFERENT MODELS

Year	2050		2100	
Emissions Scenario	A2	B1	A2	B1
Model Average	-4.1	-0.5	-6.5	-2.0
Wet Model	-0.7	7.1	-1.3	8.6
Dry Model	-5.0	1.1	-15.1	-8.3

Note: Data represents spatial average over all of District 1

For this study, extreme precipitation was characterized by the 98th percentile daily precipitation event over 30-year periods for 2050 and 2100. The 2050 timeframe was estimated based on the period from 2035 to 2064; the 2100 timeframe was estimated based on the period from 2070 to 2099. The 98th percentile is a statistical measure of the extreme occurrence which may be exceeded 2% of the time over a given period. The 98th percentile is used as an indication of the extreme events for this study rather than the 100-year recurrence because:

- The projections of extreme precipitation are highly uncertain due to modeling, downscaling, and may not be in agreement with the historical observations of precipitation;

- The use of recurrence requires an assumption of "stationarity[1]," in which the precipitation patterns are not changing.

However, the magnitude of the relative changes of the 98th percentile values may be correlated to changes in the 100-year event as an indication of changes in extremes. For example, an increase in the 98th percentile precipitation may be indicative of an increase of the 100-year event by a similar amount.

Maps of the ensemble average of extreme precipitation generally show a decrease for the A2 scenario (Figure 7) and a slight increase for the B1 scenario (Figure 8). However, Figures 7 and 8 represent the ensemble average over all models, which tend to indicate a low degree of change although the different models tend to show a significant amount of change.

Similar maps were generated to show the range in projected changes in extreme precipitation resulting from the wet and dry models. The wet model projects a District-wide increase in extreme precipitation for both emissions scenarios A2 (Figure 9) and B1 (Figure 10). The dry model projections show a significant decrease in extreme precipitation event for the A2 emissions scenario (Figure 11). However, results from the B1 emissions scenario for the dry model show that a decrease in extreme precipitation is limited to the southern portion of District 1 by 2050, and then expanding northward by 2100 (Figure 12). A general conclusion that can be made from these figures is that the projections of extreme precipitation are greater in the B1 emissions scenario than the A2 scenario.

The projections of changes in precipitation have a large amount of uncertainty due to disagreement between the different models (Figure 13). The box and whisker plots in Figure 13 show the distribution of the model projections for extreme precipitation as a District average for 2050 and 2100. The black diamond represents the 98th percentile value for the wet model, and the gray diamond represents the 98th percentile value for the dry model. Generally, the model agreement on projecting the extreme precipitation decreases for the A2 emissions scenario, as shown by the increasing spread of values. A similar range in values is projected for the B1 scenario, except that the majority of models tend to be greater than the average A2 values. A range in the percent change, from negative to positive, is projected for both the A2 and B1 emissions scenarios. However, the spatial distribution, as illustrated in the maps in Figures 7 through 12, is an important consideration in applying the projected changes to evaluate the vulnerability of the assets.

3.3. Runoff

Similar to the precipitation, daily maximum runoff data was obtained from the CMIP3 archive and processed to illustrate average trends, as well as projections of extreme conditions. Daily runoff projections were calculated using a simple water balance model that is driven by the projections of precipitation and temperature. The relative change of the total annual runoff compared to the historic average is projected to decrease by approximately 2% to 4% for the B1 and A2 emissions scenarios, respectively, by 2100 (Figure 14). This time series represents a spatial average of runoff across all of District 1 and is presented as a 10-year moving average to remove noise. The solid line represents an ensemble average of the results over all model runs, and the shading indicates the range in projections due to method uncertainty between models, which is noticeably large. The general trend

[1] Stationarity is defined as a quality of a process in which the statistical parameters, such as the mean and standard deviation, of the process do not change with time.

indicates that the changes in total annual precipitation in District 1 over the coming century are very uncertain, as shown by the wide range of model projections. The relative change in the total annual runoff is similar for Del Norte, Humboldt and Mendocino Counties, which are close to the District 1 average, although Lake County values tend to suggest relatively greater amount of runoff (Table 2). The table also suggests that, on average, runoff decreases for the A2 emissions scenario, but increases for the B1 emissions scenario.

TABLE 4
PERCENT CHANGE IN TOTAL ANNUAL RUNOFF FROM HISTORIC AVERAGE (%)

Year	2050		2100	
Emissions Scenario	A2	B1	A2	B1
District 1	-3.1	2.6	-4.1	2.2
Del Norte	-3.1	1.9	-4.3	2.6
Humboldt	-3.1	2.4	-4.2	2.1
Lake	-3.0	4.2	-1.9	3.9
Mendocino	-3.3	3.0	-4.5	1.8

The average percent change in total annual runoff for District 1 exhibits similar characteristics to the precipitation, in that there is a wide range in projections that show increase up to 150-200% and decrease up to 150-200% (Figure 14). The uncertainty is due to the different results from the several models used in the projections. The results are greatly affected by the different emissions scenarios, which project an increase in runoff by 2100 for the B1 scenario, and a decrease by 2100 for the A2 scenario (Table 4). However, the spatial results show a decrease in the total annual runoff from the historic values when averaged over all GCMs, particularly by 2100 (Figure 15).

The District 1 average of the total annual runoff for the ensemble average of models was compared to a selected “wet” model (PCM) and a selected “dry” model (GFDL) to illustrate the range in projections (Table 5). The results of the wet model indicate an increase in the total annual precipitation of up to approximately 30% greater than the historic average (for B1 scenario at 2100), while the dry model shows a decrease of up to approximately 15% (for A2 scenario at 2100). These results indicate that careful interpretation and selection of future climate projections need to be considered when applying to assessing the vulnerability of assets as well as the selection of an appropriate emissions scenario, and that method uncertainty poses a major challenge to providing management recommendations.

TABLE 5
PERCENT CHANGE IN TOTAL ANNUAL RUNOFF FOR DIFFERENT MODELS (%)

Year	2050		2100	
Emissions Scenario	A2	B1	A2	B1
Model Average	-3.1	2.6	-4.1	2.2
Wet Model	3.6	19.5	6.4	29.9
Dry Model	-3.3	5.7	-14.5	-10.4

Note: Data represents spatial average over all of District 1

For this study, extreme runoff was characterized by the 98th percentile daily runoff event over 30-year periods for 2050 and 2100, similar to how extreme precipitation is characterized and described above. The 2050 timeframe was estimated based on the period from 2035 to 2064; the 2100 timeframe was estimated based on the period from 2070 to 2099. Maps of the ensemble average of extreme runoff generally show a decrease for the A2 and B1 scenarios (Figures 15 and 16, respectively).

Similar to the analysis of extreme precipitation, maps were generated to show the range in projected changes in extreme runoff resulting from the wet and dry models. The wet model shows little changes District-wide for the A2 scenario (Figure 17), but suggests that areas in Lake County, northern portions of Mendocino County, and most of Humboldt and Del Norte Counties, may experience an increase in extreme runoff for the B1scenario (Figure 18). The dry model projections are somewhat different, and, by 2050, show a decrease to no change in extreme runoff north of Mendocino County, but a significant increase in extreme runoff throughout Lake County and most of Mendocino County for the A2 emissions scenario (Figure 19). However, by 2100, the dry model results suggest a District-wide decrease in the extreme runoff for the A2 scenario. Results from the B1 emissions scenario for the dry model show an increase in runoff by 2050, followed by a decrease by 2100 (Figure 20).

The projections of changes in runoff have a large amount of uncertainty due to disagreement between the different models (Figure 21). The box and whisker plots in Figure 21 show the distribution of the model projections for extreme runoff as a District average for 2050 and 2100. The black diamond represents the 98th percentile value for the wet model, and the gray diamond represents the 98th percentile value for the dry model. Generally, the model agreement on projecting the extreme precipitation decreases for the A2 emissions scenario, as shown by the increasing spread of values. A similar range in values is projected for the B1 scenario, overall, except that the majority of models tend to be greater than the average A2 values. A range in the percent change, from negative to positive, is projected for both the A2 and B1 emissions scenarios. However, the spatial distribution, as illustrated in the maps in Figures 15 through 20, is an important consideration in applying the projected changes to evaluate the vulnerability of the assets.

3.4. Fire Risk

3.4.1. Cal-Adapt Data

The projected fire risk data was obtained through Cal-Adapt.org. The data provided through Cal-Adapt represents projected increase in burned area as a ratio relative to existing fire risk for three GCMs for the A2 and B1 emissions scenarios averaged for 30-year time periods ending in 2020, 2050, and 2085. The three GCMs available for the Fire Risk data are:

1. The NCAR Parallel Climate Model (PCM);
2. The NOAA Geophysical Fluids Dynamics Laboratory (GFDL) model, Version 2.1;
3. The French Centre National de Recherches Météorologiques (CNRM) models.

The data provided in the geodatabase represents an average over the three GCMs for the 2050 and 2085 periods. The Cal-Adapt fire risk data projects an increase in fire risk for the whole district by 2100 (Figure 22).

3.4.2. Department of Water Resources Fire Exposure Data

A separate set of projections of wildfire exposure for early-, mid- and late-century were provided by the California Department of Water Resources (DWR). Fire exposure was estimated by DWR (2013) to evaluate vulnerability of their assets throughout the state, and was based on an extensive study of fire risk projections for California (Krawchuk and Moritz 2012). The Krawchuck and Moritz (2012) study estimated the change in probability of one or more fires occurring within a 30-year time period for three future periods (2010-2039; 2040-2069; and 2070-2099) as compared to the historic period (1971-2000). The future projections of wildfire risk were completed using two GCMs (PCM and GFDL), two emissions scenarios (A2 and B1), and two land use projections (business-as-usual and smart-growth. The final results of projected wildfire risk report the maximum modeled probability to represent a conservative estimate of future wildfire. DWR selected curves of five exposure categories from very low to very high to relate the future change in probability to existing probability of fire risk. For this study we used the exposure rating curves developed by DWR (2013).

The wildfire exposure data for mid- and late-century in District 1 is shown in Figure 23, and indicates that fire exposure increases for most areas by 2100, particularly the inland areas of Lake and Mendocino Counties.

3.5. Landslides

Projections of future landslide risk due to climate change are not available for the District 1 area. Existing information on the risk of deep-seated landslides is available from the California Geologic Survey (Wills et al. 2011). The study classifies deep-seated landslide susceptibility as a function of slope class and rock strength, with increasing susceptibility with slope and in weaker rocks. Much of District 1 is classified as high susceptibility to deep-seated landslides. We are not aware of any studies or date that indicates how the susceptibility may change due to climate change factors such as increased temperature and changes in precipitation.

Shallow landslides, including debris flows, are highly correlated to extreme rainfall events, and may be of the most interest to Caltrans in terms of hazards related to climate change. We understand that numerical and empirical models of shallow landslide susceptibility have been developed by researchers and geologists; however we are unaware of available data for District 1. Efforts to map existing and projected shallow landslide susceptibility for District 1 should be considered as a tool to aid in planning and design.

3.6. Sea Level Rise

Four datasets for sea level rise and coastal erosion were compiled for this project: coastal erosion and flood data from the Pacific Institute (2009) sea level rise study for the coast of California, data from Trinity Associates (2013) shoreline inventory, mapping, and vulnerability rating for Humboldt Bay, recent sea level rise inundation modeling and mapping by Northern Hydrology and Engineering (NHE) (2014) developed for the Humboldt Bay sea level rise vulnerability assessment project, and sea level rise inundation mapping using NOAA’s Coastal Viewer. These datasets are described further below.

3.6.1. Pacific Institute and PWA (2009)

The Pacific Institute (2009) study mapped coastal erosion and flood hazard zones along the coast of California from Santa Barbara County north to the Oregon border.

Storm Flood Zones

Storm flood zones were estimated for the California Coast for existing (year 2000) and future (2100) conditions that assume a sea level rise of 55-inches, in accordance with state guidance at the time (CCC 2011). This sea level rise projection also falls within the range recommended by the updated state guidance (CCC 2013). 2011) The storm flood mapping used a bathtub model approach mapping the 100-yr total water level[2] resulting from 55-inches SLR by 2100. This is an overestimate of the 100-year flood zone in inland areas and is generally more accurate near the coast where wave run-up is occurring. These flood zones do not consider coastal erosion or vertical land motion.

Figure 24 shows an example of the existing and future (2100) 100-year coastal flood zone near Point Arena in Mendocino County. The areas with the blue shading represent the existing flood zones, and the green areas represent flood zones for 2100 that consider sea level rise. Although the bathtub approach used in the study generally tends to provide an overestimate of the flood elevations, areas with river mouths, such as at the mouth of the Garcia River, may be more accurate due to the interactions of fluvial discharge, inlet morphodynamics, and the "perching" of the estuarine water bodies due to the littoral barrier.

Dune and cliff erosion

Dune and cliff erosion hazard areas resulting from low (0.6 meters or 24 inches by 2100) and high (1.4 meters or 55 inches by 2100) sea level rise for years 2025, 2050, and 2100 were also estimated and mapped for the California coast north of Santa Barbara. Some gaps in coverage exist in District 1: Crescent City harbor, ~11 miles of coast near the Del Norte/Humboldt County Line, and from the Mattole River to Humboldt/Mendocino County Line.

A coastal erosion hazard zone represents an area where erosion (caused by coastal processes) has the potential to occur over a certain time period. This does not mean that the entire hazard zone is eroded away; rather, any area within this zone is at risk of damage due to erosion during a major storm event. Actual location of erosion during a particular storm depends on the unique characteristics of that storm (e.g. wave direction, surge, rainfall, and coincident tide). As sea level rises, higher mean sea level will make it possible for wave run-up to reach the dune more frequently, undercutting at the dune toe and causing increased erosion. These hazard zones consider historic trends in erosion, increased erosion due to sea level rise, and potential erosion of a 100-year storm. Figure 24 presents an example of the dune and cliff hazard zone near Point Arena. The red, orange, and yellow areas represent the erosion hazard zones for 2025, 2050, and 2100, respectively. Similar zones extending up and down the coast are included in the geodatabase.

3.6.2. Humboldt Bay Sea Level Rise Adaptation Planning Project (2010-present)

The State Coastal Conservancy (SCC) is funding a multi-phased project to identify sea level rise vulnerabilities and adaptation strategies for Humboldt Bay. This effort began in 2010 after Governor Schwarzenegger issued Executive Order S-13-08, which identified the necessity to plan for sea level rise. The first phase of the project, titled the Humboldt Bay Shoreline Inventory, Mapping and Sea Level Rise Vulnerability Assessment, was completed in January 2013 by Trinity Associates. The 2013 report presented the results of the inventory and

[2] The total water level is the elevation that represents the vertical extent of wave runup plus storm surge. Here the 100-year total water levels were developed using existing FEMA base flood elevations. Where no FEMA flood study was available a 100-year total water level was estimates using engineering judgment.

mapping of existing shoreline conditions, assessed shoreline vulnerability to extreme high water events and sea level rise, and presented an inventory of land uses and infrastructure vulnerable to inundation from overtopping, breaching, and rising sea levels. A shoreline vulnerability rating, a quantitative measure of vulnerability was developed as an addendum to the shoreline vulnerability assessment (2013). Trinity Associates shoreline vulnerability rating and mapping is useful in locating shoreline segments that are likely to fail during extreme high water events and as sea levels approach a critical elevation threshold for shoreline structures such as dikes and railroad grade.

The second phase of the project, titled Humboldt Bay Sea Level Rise Adaptation Planning Project, is sponsored by the Coastal Ecosystems Institute of Northern California (CEINC). There are two components to this project: inundation modeling and mapping by NHE and an adaptation planning working group led by the Humboldt County Public Works and Humboldt Bay Harbor, Recreation and Conservation District, with members from the Local Coastal Program authorities, Coastal Commission and various local and state resource agencies and Wiyot Tribe. Trinity Associates is the adaptation planning consultant for this phase of the project. Preliminary inundation mapping provided by NHE are used and presented herein.

There are nearly 9,000 acres of diked former tidelands adjacent to Humboldt Bay. Inundation maps were generated for existing conditions to illustrate areas subject to flooding if shoreline structures such as earthen dikes are compromised. 100-year storm flood maps were also developed for Humboldt Bay for existing conditions and four sea level rise scenarios: 0.5 meters (1.6 ft), 1.0 meter (3.3 ft), 1.5 meters (4.9 ft), and 2.0 meters (6.6 ft). The mapping identifies areas adjacent to Humboldt Bay and the adjoining sloughs that are below the 100-year extreme water surface elevation. Figure 25 presents an example of the preliminary model results and mapping by NHE that shows inundation from 100-year extreme water level variations within different portions of the Humboldt Bay for existing conditions and for 1.5 meters of sea level rise. These maps are based on preliminary model results provided by NHE as part of the State Coastal Conservancy funded Phase II Humboldt Bay Sea Level Rise Adaptation Planning Project. The geodatabase also includes information on the following flood zones for existing and sea level rise scenarios: 100-yr, 10-yr, and mean higher high water[3] (MHHW). These elevations comprise the base tidal elevations used to assess shoreline vulnerability in the Humboldt Bay Sea Level Rise Adaptation Planning Project.

3.6.3. NOAA SLR Viewer Data

Sea level rise inundation mapping data is available online using the NOAA Coastal Services Center's Sea Level Rise and Coastal Flooding Impacts Viewer (SLR Viewer). The SLR Viewer is an online tool that is helpful in graphically presenting potential impacts of sea level rise to coasts of the United States of America. The SLR Viewer provides a simple visual tool with a user interface that illustrates the potential impacts of sea level rise on the coast. A slider bar is used to see how various levels of sea level rise will impact the area of interest. The base elevation of the data is the MHHW elevation, which is 6.52 ft NAVD[4] in the vicinity of Humboldt Bay. The SLR Viewer presents several levels of high tide inundation with 1-foot incremental increases in sea level rise. The inundated areas is presented in a map with shades of blue, where darker blue represents hydrologically connected

[3] Mean higher high water (MHHW) is a tidal datum that is calculated as an average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch (approximately 19 years).

[4] NOAA NOS Station 9418767, North Spit, CA

greater depths, lighter blue represents hydrologically connected shallow areas, and green shading represents low-lying areas that are not hydrologically connected but may flood.

The data is limited in that several natural processes associated with sea level rise are not included. The data presented in the maps is based on projected water surface elevations and mapped onto a digital elevation model (DEM). The mapping represents a bathtub mapping effort for existing conditions, when in fact natural processes associated with sea level rise, including erosion, marsh migration, fluvial-tidal interactions, and lagoon dynamics, are not included in establishing the inundation limits. Furthermore, other processes including storm surge and waves could present additional flood pathways that are not considered in the mapping. The confidence of the mapping is not 100%, as with all sea level rise mapping exercises, and user should evaluate the uncertainties in the extent of mapped inundation resulting from errors in the elevation data and the tidal corrections. Other hydrologic features, such as canals, ditches and stormwater infrastructure, may not be included to completely capture the area's hydrology.

More information on the SLR Viewer is summarized in documentation that is available on the website.[5,6]

4. Summary of Sea Level Rise Guidance for Caltrans District 1

This section summarizes California state guidance on sea level rise adaptation planning and design. Federal guidance also exists (USACE 2011); however, the California guidance incorporates recent science specific to the West Coast and is tailored to California planning processes. In 2008, Executive Order S-13-08 directed state agencies to plan for sea-level rise and other climate change impacts. It also directed the California Natural Resources Agency, in coordination with other state agencies and the National Research Council (NRC) of the National Academy of Sciences, to assess sea level rise for the Pacific Coast and create official sea level rise estimates for state agencies in California, Oregon and Washington.

In March 2011[7], the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT) presented interim guidance to state agencies for incorporating the risks posed by sea level rise into project and program plans (OPC 2011). The guidance was targeted towards state agencies and non-state entities implementing projects or programs funded by the state or on state property.

In May 2011, Caltrans published specific guidance on when and how to implement sea level rise guidance in transportation planning and design (Caltrans 2011). The guidance included the sea level rise projections from the interim state guidance and stated that the Caltrans guidance would be revised when the NRC study (below) was complete. The guidance has not been updated as of May 2014.

In 2012, the National Research Council (NRC) released a report titled "Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future" (NRC 2012). This report provides global and regional sea level rise projections and likely ranges at four locations along the West Coast. The report splits the West Coast into two tectonic regions when incorporating vertical land motion into regional sea level rise

[5] NOAA 2012, Method Description: Detailed Methodology for Mapping Sea Level Rise Inundation, May 2012.
[6] NOAA 2014, Frequent Questions: Digital Coast Sea Level Rise and Coastal Flooding Impacts Viewer, March 2014.
[7] Prior to completion of the NRC 2012 report

estimates: North of Cape Mendocino (uplift, 1 ± 1.5 mm/year) and South of Cape Mendocino (subsidence, -1 ± 1.3 mm/year).

In March 2013, the Ocean Protection Council (OPC) staff presented an update to the interim guidance (OPC 2013). The purpose of the document remained the same but was updated to include the range of sea level rise projections NRC 2012 study. The guidance document seeks to enhance consistency across agencies as each develops its respective approach to planning for sea level rise. It will be updated regularly, to keep pace with scientific advances associated with sea level rise.

In October 2013, the California Coastal Commission released draft guidance to help local governments apply the OPC 2013 guidance in new and updated Local Coastal Programs and Coastal Development Permits (CCC 2013). The draft document is currently out for public comment, and is expected to be finalized in early summer 2014. A series of technical appendices provide examples, adaptation strategies, and detailed instructions for estimating local hazard conditions. This guidance recommends modifying the regional sea level rise projections in the vicinity of Humboldt Bay and the Eel River, where vertical land motion differs significantly from that assumed by NRC 2012 (and adopted in OPC 2013).

Caltrans District 1 includes regions north of Cape Mendocino, south of Cape Mendocino, and Humboldt Bay to the Eel River. Therefore, according to draft CCC 2013 guidance, three different sea level rise projections should be considered. Table 6 presents the range of sea level rise projections for each of these regions, as presented in OPC 2013 for North and South of Cape Mendocino and as estimated by ESA for Humboldt Bay according to CCC 2013 draft guidance[8].

TABLE 6
SEA LEVEL RISE PROJECTIONS FOR CALIFORNIA, RELATIVE TO YEAR 2000

Year	North of Cape Mendocino (OPC 2013)	South of Cape Mendocino (OPC 2013)	Vicinity of Humboldt Bay (ESA analysis, based on CCC 2013)
2030	-4 to 23 cm (-0.13 to 0.75 ft)	4 to 30 cm (0.13 to 0.98 ft)	13 to 33 cm (5 to 13 in)
2050	-3 to 48 cm (-0.1 to 1.57 ft)	12 to 61 cm (0.39 to 2.0 ft)	25 to 65 cm (9.8 to 25.7 in)
2100	10 to 143 cm (0.3 to 4.69 ft)	42 to 167 cm (1.38 to 5.48 ft)	66 to 177 cm (25.8 to 69.7 in)

5. Selection of Climate Stressors for Asset Exposure Analysis

Evaluation of the exposure of critical Caltrans transportation assets in District 1 to a range of climate stressors is a key component of the vulnerability assessment. As described in Section 2.4, many sources of uncertainty accompany the climate model outputs, including method uncertainty from climate models, implications of different emissions scenarios, and the natural and spatial variability of the projections. Therefore, this section screens the climate data to select climate stressor datasets that represent the “worst-case” scenarios in terms of asset exposure and that yield the most conservative results.

[8] Vertical land motion at North Spit was estimated by NOAA 2013 (-3.42 mm/yr ± 0.54 mm/yr). This estimate (including the uncertainty) was added to the regional sea level projections for Newport, OR (the nearest regional projection, assume vertical land motion removed) in NRC 2012 to give an estimate of relative sea level rise at North Spit.

5.1. Temperature

Evaluating the exposure of assets to temperature should consider the climate scenarios that project the greatest increase in the number of extreme heat days. The results shown by the box plot in Figure 5 suggest that the A2 emissions scenario yields the most conservative results with the greatest change in number of extreme heat days per year.

5.2. Precipitation

Although the projections of extreme precipitation show a wide range in relative change, the exposure analysis will focus on the dataset that shows the greatest increase in extreme daily rainfall event. The focus on the "wet" conditions will allow the exposure analysis to consider the potential impacts of flooding that may result from increased heavy precipitation events. Out of the three sets of model results, the "wet" model (PCM) run for the B1 emissions scenario yields the greatest change in the extreme daily rainfall. The wet model is represented by the black diamond in the box plot in Figure 13, and is consistent with projecting more wet conditions.

5.3. Runoff

Similar to the extreme precipitation, extreme runoff projections varied greatly across models and emissions scenarios. The greatest change in extreme daily runoff results from the "wet" model with the B1 emissions scenario. The wet model is represented by the black diamond in the box plot in Figure 21. Note that although the results vary considerably spatially, and that some specific areas may show large changes for a particular model or emissions scenario, the analysis is focused on the entirety of District 1 suggesting that the "wet" model with B1 emissions scenario best represents the extreme runoff condition.

5.4. Wildfire

Evaluation of the exposure of transportation assets to wildfire should be accomplished using the DWR (2013) dataset, which was previously screened by DWR to consider the "worst-case" conditions resulting from the A2 and B1 emissions scenarios. Furthermore, DWR already rated the exposure of the original fire risk projections made by Krawchuk and Moritz (2012) in a semi-quantitative scale that can easily be applied to this vulnerability assessment.

5.5. Sea Level Rise

Exposure of assets to sea level rise should be completed using separate datasets for areas along the open coast of District 1 and for the interior of Humboldt Bay. This is partly due to the availability of the data. For example, the Pacific Institute study covers most of the shoreline of District 1, while the Humboldt Bay Sea Level Rise Adaptation Planning Project is focused only on the shores of Humboldt Bay. These represent the best available data for this assessment. For more frequent events (i.e. daily to annual occurrences) we understand that data from the NOAA SLR Viewer will be used to assess the exposure of assets to flooding.

5.5.1. Open Coast

The Pacific Institute study data should be applied along stretches of the open coast in all available areas besides within Humboldt Bay. The conditions along the open coast are subject to large waves and elevated tides which result in flooding and erosion. Erosion hazard maps show the areas that may be impacted by increased erosion from sea level rise at years 2050 and 2100. These zones can be applied to the exposure analysis to determine if an asset is impacted or not. Similarly, existing and future (year 2100) flood zones that represent the approximate 100-year flood elevation can be used to assess the exposure of the assets to potential coastal flooding. Intermediate conditions at year 2050 can be inferred from results of the existing and future extreme conditions.

5.5.2. Humboldt Bay

Flooding within Humboldt Bay should use the data developed by the Humboldt Bay Sea Level Rise Adaptation Planning Project that show areas of inundation resulting from different amounts of sea level rise. Specifically, extreme flooding in Humboldt Bay should consider the different projections of inundation of the simulated 100-year recurrence flood projections.

Because the inundation mapping was conducted for discrete amounts of sea level rise, and the exposure will be conducted for the planning horizons of 2050 and 2100, the following datasets should be used:

- Year 2050: Use the 0.5 meter projection with the 100-year recurrence water level to infer the extreme water level at 2050;

- Year 2100: Use the 1 and 1.5 meter projections of the 100-year recurrence water level to develop a range in the anticipated extreme water level at 2100.

This dataset represents the best available flood mapping that considers increased water surface elevation resulting from sea level rise. Assessing the range of potential sea level rise for 2100 is important because of the non-uniform rates of vertical land motion that are observed in Humboldt Bay, and suggest that areas along the southern shore of Humboldt Bay may be experiencing greater rates of relative sea level rise than in the north (Cascadia GeoSciences 2013). Site specific and design-level analyses may need to use sanctioned rates and estimates of sea level rise in accordance with the National Geodetic Survey and National Ocean Service.

5.5.3. NOAA SLR Viewer Data

We understand the SLR Viewer data will be used to assess frequent tidal inundation for existing and future conditions with sea level rise. Table 7 summarizes the recommended data mapping layers to be applied in evaluation of the asset exposure. The table presents three planning horizons: existing conditions at 2010; future conditions at 2050; and future conditions at 2100. For each of the three planning horizons we identify two inundation frequencies that can be used for the evaluation: daily high tide and annual high tide. Here, we assume that the MHHW elevation can be representative of the daily high tide without storm surge and without the effects of waves and wave runup. The annual high tide elevation was assumed to include an additional 2 feet of storm surge above the MHHW elevation, but does not include the effects of waves. We selected an annual storm surge of 2 feet as a conservative estimate based on review of tidal records at Point Arena, North Spit in Humboldt Bay, and at Crescent City.

TABLE 7
RECOMMENDED DATA LAYERS FOR EVALUATING INUNDATION FREQUENCY

Year	Frequency of Inundation	Assumptions	Mapping Layer
2010 (Existing)	Daily High Tide	MHHW	CA_EKA_slr_0ft
2010 (Existing)	Annual High Tide	MHHW + 2 feet of storm surge	CA_EKA_slr_2ft
2050	Daily High Tide	MHHW + 2 feet SLR	CA_EKA_slr_2ft
2050	Annual High Tide	MHHW + 2 feet SLR + 2 feet storm surge	CA_EKA_slr_4ft
2100	Daily High Tide	MHHW + 4 feet SLR	CA_EKA_slr_4ft
2100	Annual High Tide	MHHW + 4 feet SLR + 2 feet storm surge	CA_EKA_slr_6ft

Note: Assumes no wave action; assumes storm surge limited to 2 feet;

Applying the data layers listed in Table 7 to the asset exposure analysis will help to inform the level of impact that may occur for a range of inundation magnitudes. The level of impact to an asset will be a function of the level or frequency of inundation that occurs. For example, an asset that experiences shallow flooding approximately once per year may have a moderate impact, or in a “temporary closure” category of impacts. However, an asset that is flooded on a daily to monthly frequency likely implies a higher degree of impact, such as the “temporary closure” or “complete failure” categories.

Use of the NOAA SLR Viewer data is considered acceptable in the absence of other available data that considers other important factors, such as waves and erosion. The geomorphic changes to the shore associated with sea level rise play an important role in erosion hazard determination and flood routing, which have major implications on assessing vulnerability. In evaluating the vulnerability of the assets, the data should be used in combination with the separate sea level rise and erosion data sets provided. Additional assumptions were made by ESA regarding the degree of storm surge associated with a flood event with an approximately annual recurrence, but is based on tidal records in the vicinity of District 1. Further, the NOAA data does not include waves when it is known waves play an important role in coastal flooding along the exposed and open coast in California. Other interactions between fluvial and tidal processes, including the water surface elevation of coastal lagoons, should be considered a special case and may need additional site specific evaluation. We recommend associating the annual high tide inundation with the “reduced capacity” category of impacts and the daily high tide inundation with the “temporary closure” or “complete failure” impact categories.

6. References

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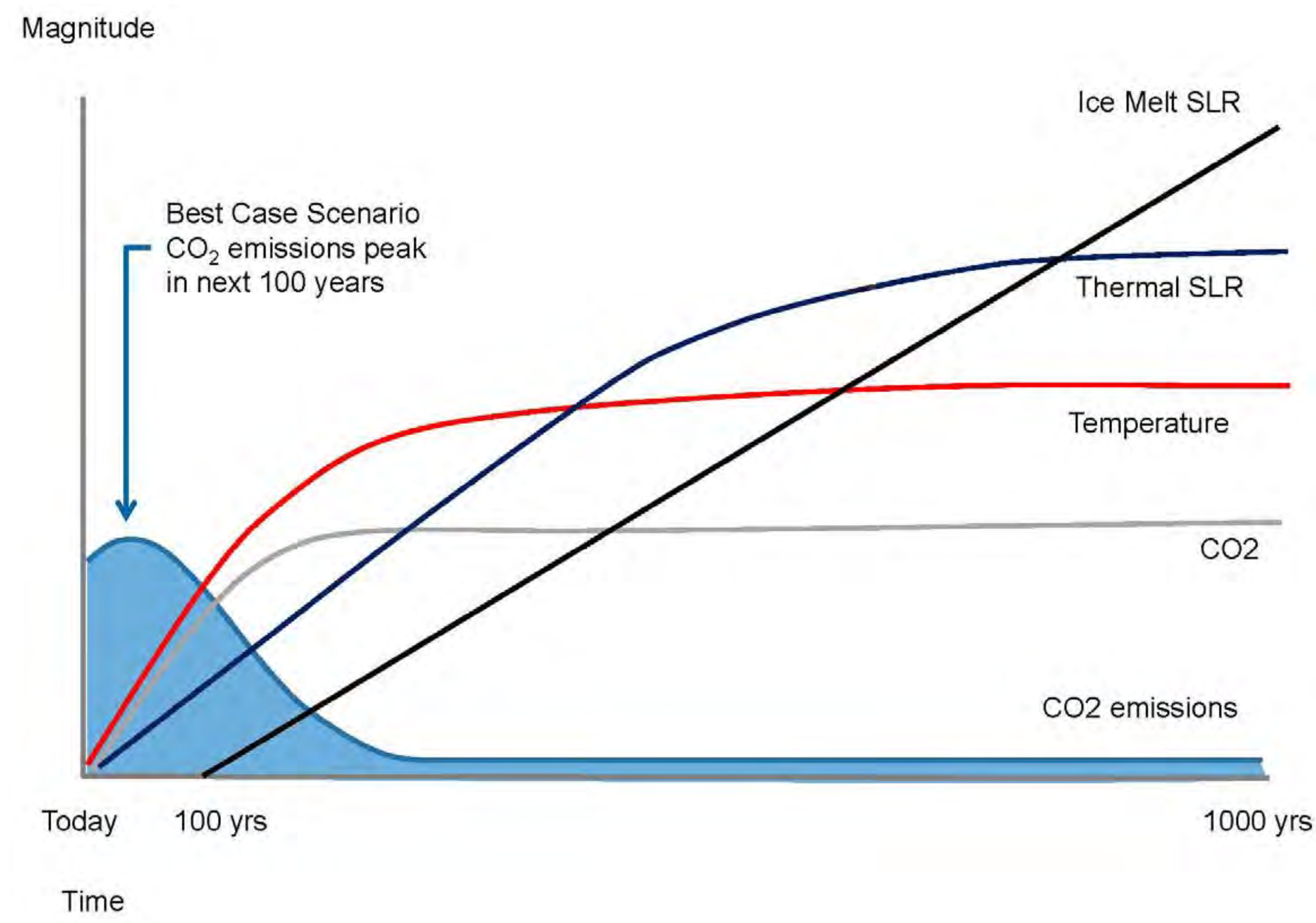
7. Figures

Figure 22. Fire Risk: Increase in Area Burned

Figure 23. Fire Exposure Level (DWR 2014)

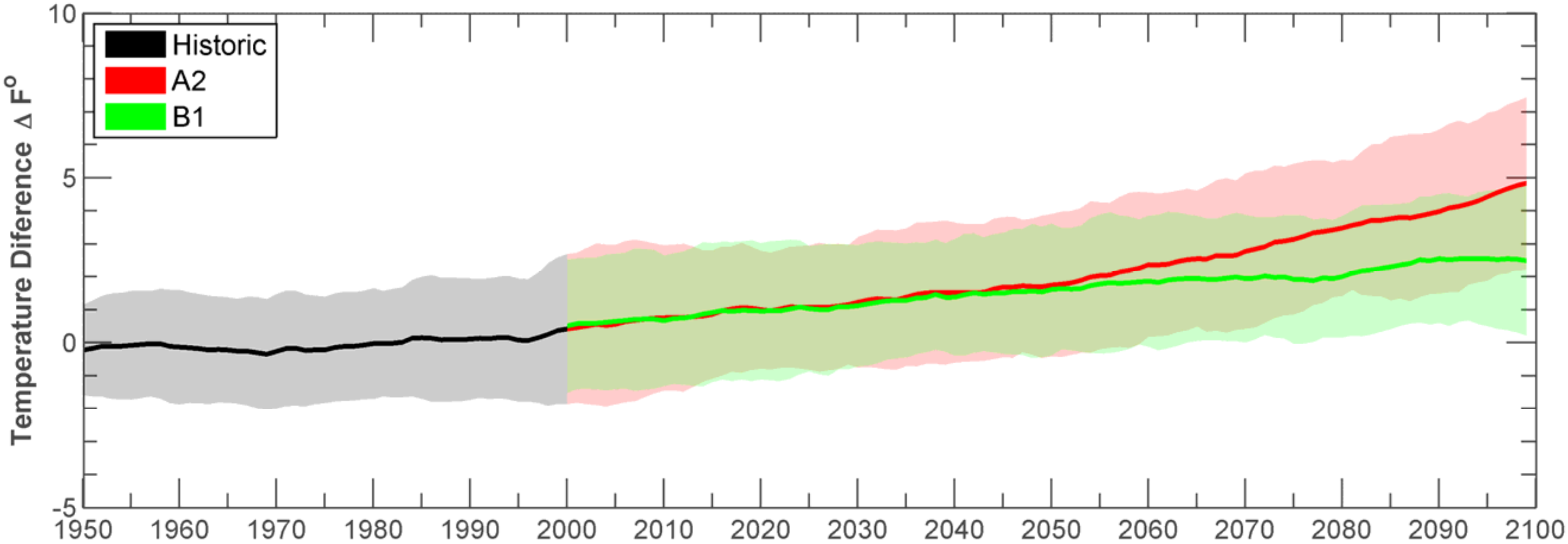
Figure 24. Example of Coastal Hazard Zones at Point Arena

Figure 25. Example of Coastal Flood Zones in Humboldt Bay (NHE 2014)



SOURCE: After IPCC 2007

Figure 1
Residual Climate Effects Continue Beyond 2100



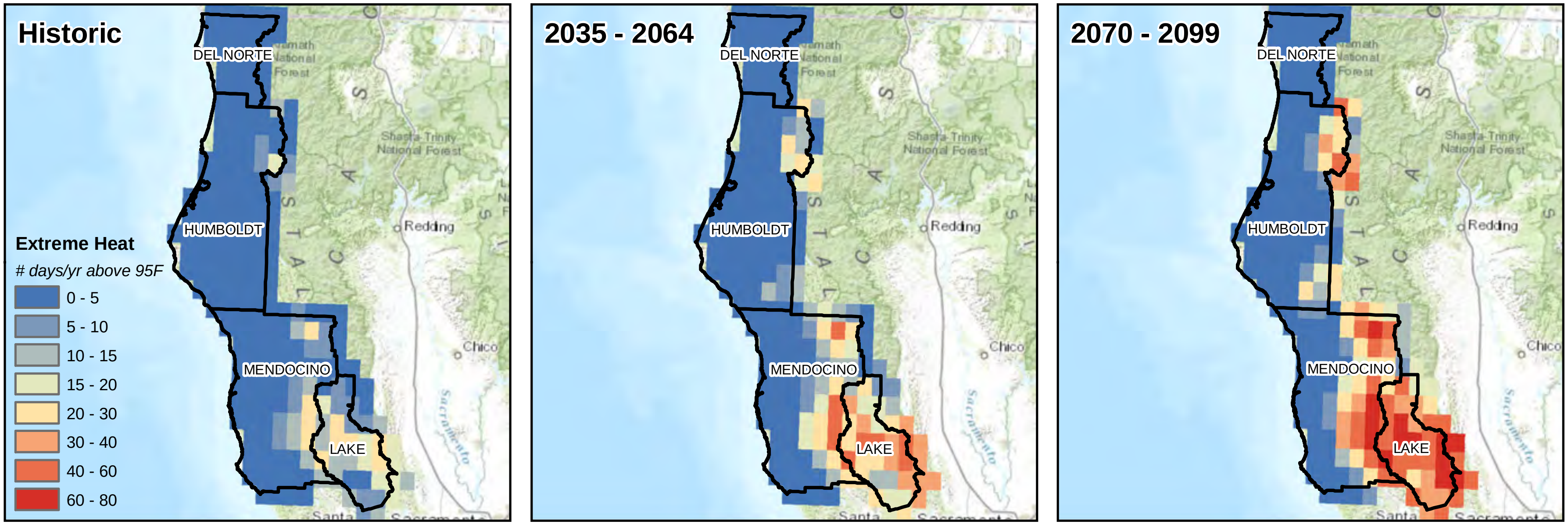
SOURCE: CMIP3

NOTES: 10-year moving average; spatially averaged over District 1;
solid lines are ensemble average;
shading represents range of individual GCMs

Caltrans District 1 Climate Change Pilot Study . D130588.00

Figure 2

Change in Annual Average of Daily Maximum Temperature from Historic Average for A2 and B1 Emissions Scenarios



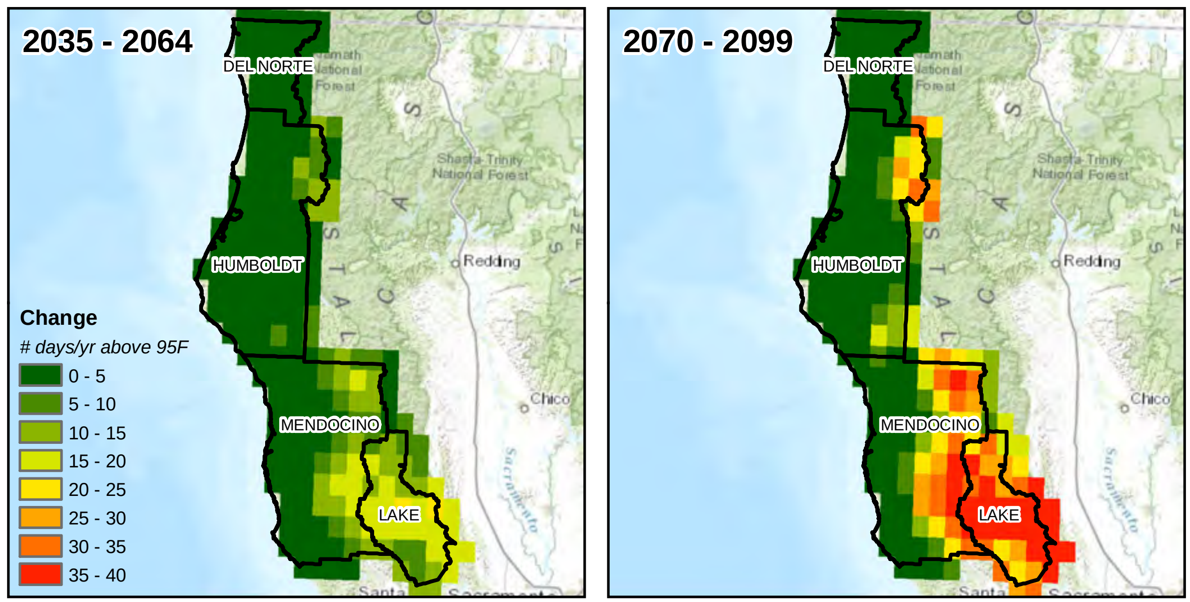
Climate scenario:
A2 (high medium-high emissions)

Climate model(s):
Average of all GCMs

N

0 25 50 Miles

Description:
The annual number of extreme heat days (days above 95F) was estimated for a historic period (1970 - 1999 or "Historic") and two future periods (2035 - 2064 and 2070 - 2099) for each global climate model (GCM). The top panel presents the annual number of extreme heat days averaged for all GCMs. The bottom panel shows the change in number of extreme extreme heat days relative to the historic time period.



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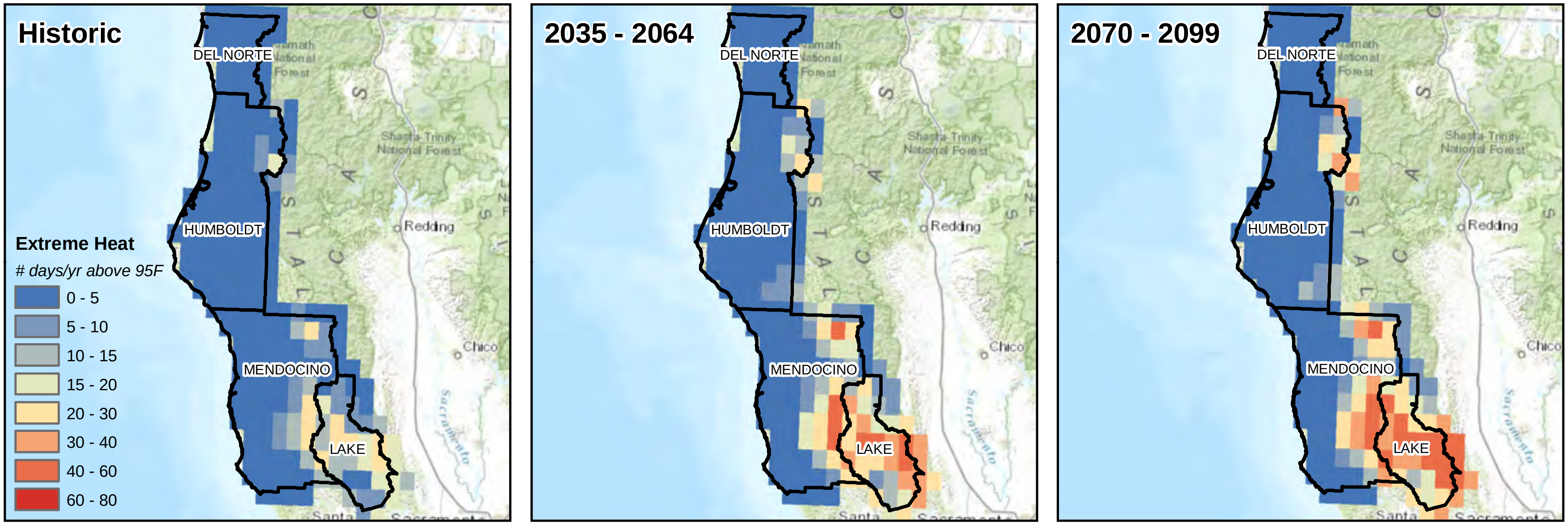
SOURCE: Cal Adapt, 2014

Caltrans District 1 Climate Change Pilot Study . 130588.00

Figure 3

Extreme Temperatures: Days Above 95F for Scenario A2, All Models

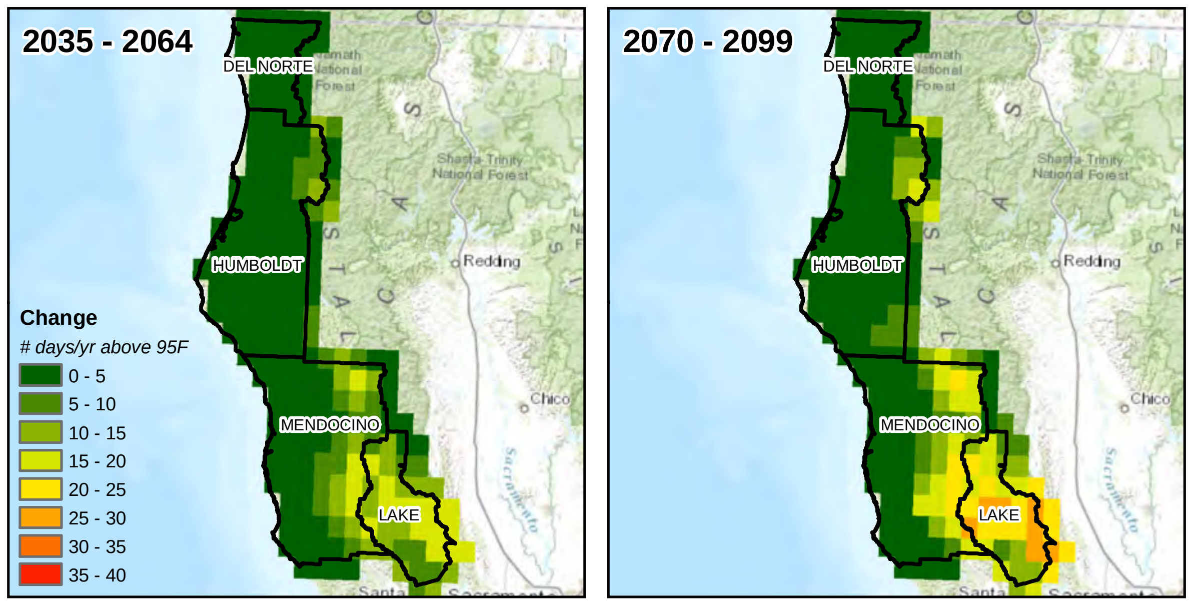


Climate scenario:
B1 (low emissions)

Climate model(s):
Average of all GCMs

N
0 25 50 Miles

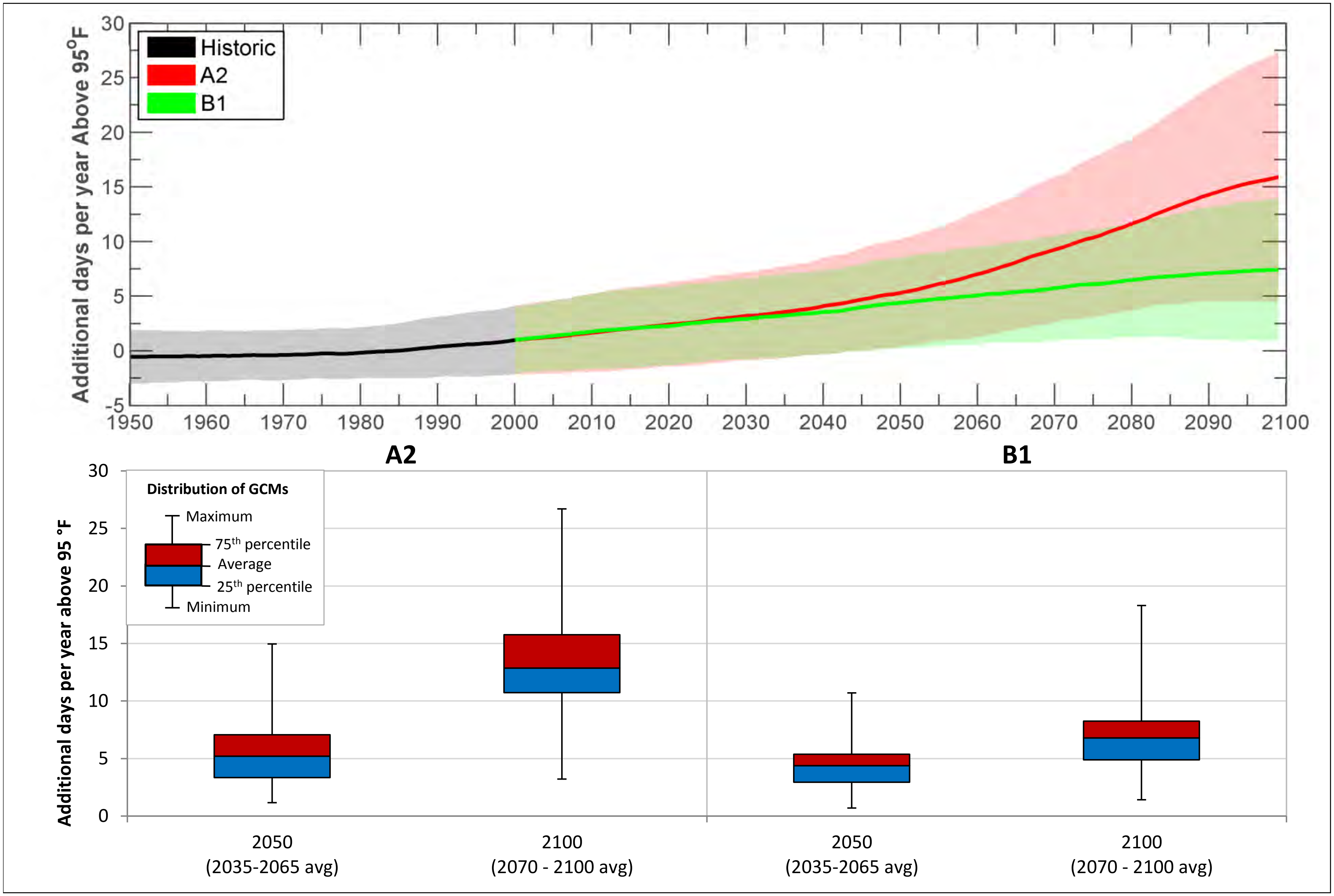
Description:
The annual number of extreme heat days (days above 95F) was estimated for a historic period (1970 - 1999 or "Historic") and two future periods (2035 - 2064 and 2070 - 2099) for each global climate model (GCM). The top panel presents the annual number of extreme heat days averaged for all GCMs. The bottom panel shows the change in number of extreme extreme heat days relative to the historic time period.



G:\130588_HCAOG-ClimateChange\MXDs\Figures\Temperature_Above95F_16Jun2014.mxd

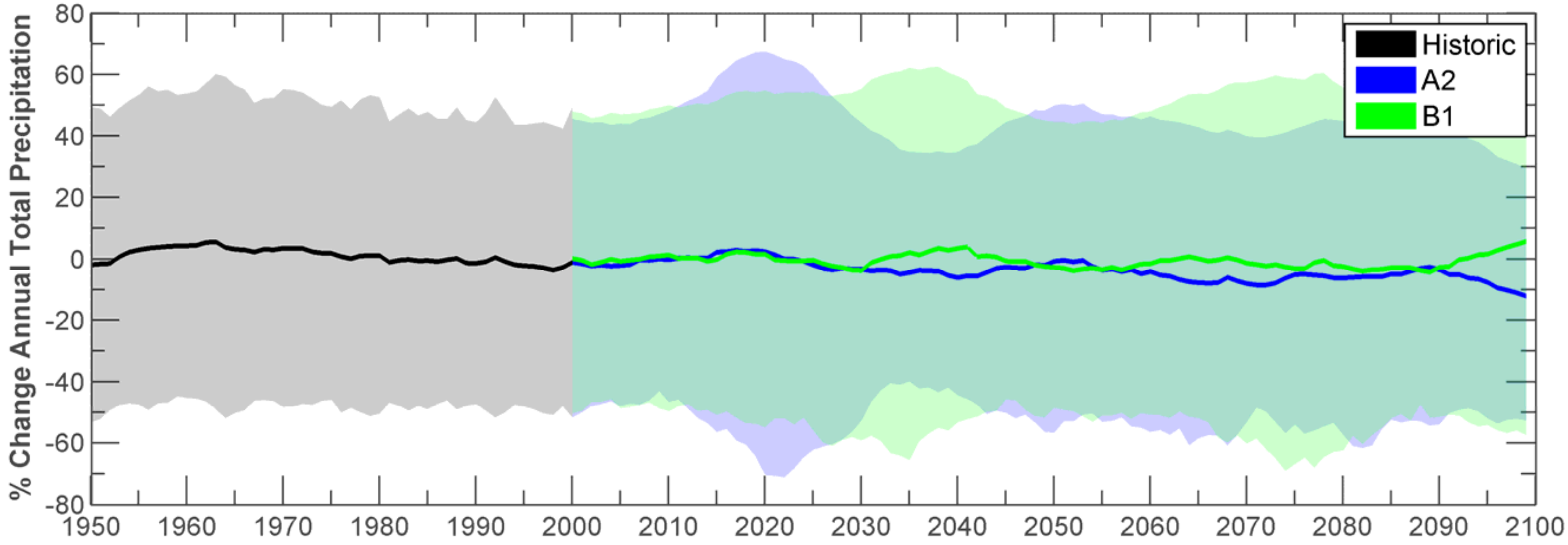
SOURCE: Cal Adapt, 2014

Figure 4
Extreme Temperatures: Days Above 95F for Scenario B1, All Models



SOURCE: WCRP CMIP3 downscaled data
NOTE: The top plot shows a time series of the change in number of days per year exceeding 95 °F relative to a historic average (1970-2000). The range of GCMs is shown for historic (grey), A2 (red), and B1 (green) conditions. Solid lines represent an average of the GCMs. The lines are smoothed using a moving 30-year average. The bottom plot shows the range of GCMs for A2 and B1 emissions for 30-year averages for 2050 and 2100.

Figure 5
Change in Extreme Temperature Over Time for Multiple GCMs - District 1 Average



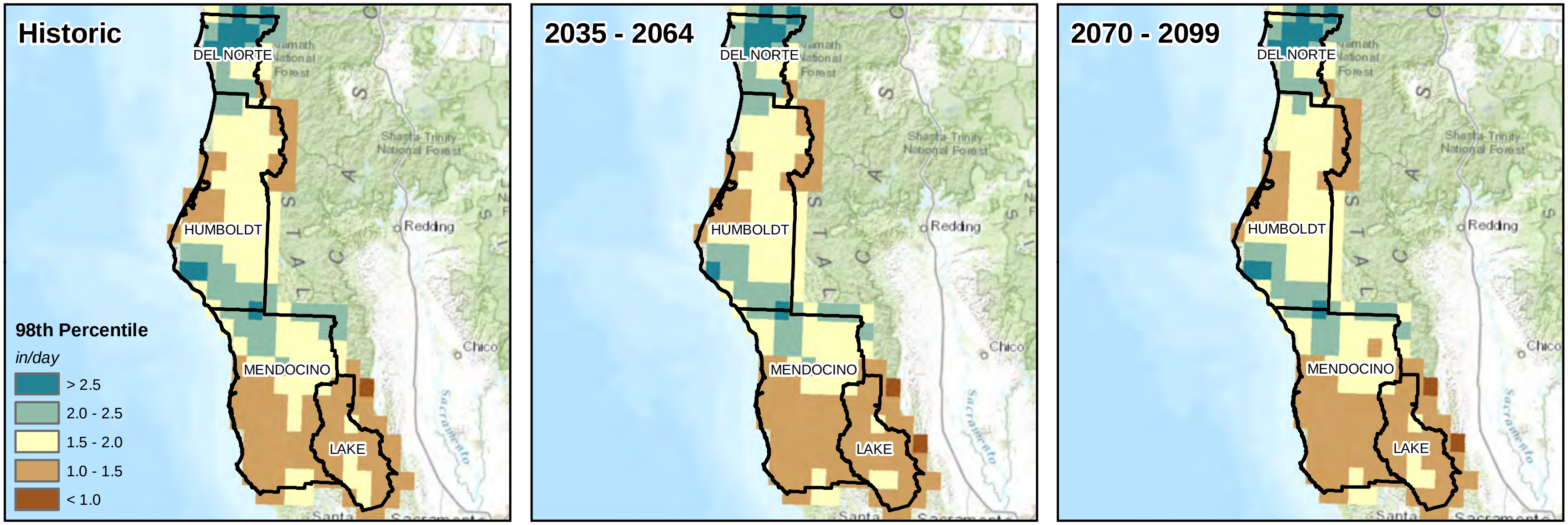
SOURCE: CMIP3

NOTES: 10-year moving average; spatially averaged over District 1;
solid lines are ensemble average;
shading represents range of individual GCMs

Caltrans District 1 Climate Change Pilot Study . D130588.00

Figure 6

Percent Change of Total Annual Precipitation from Historic Average
for A2 and B1 Emissions Scenarios

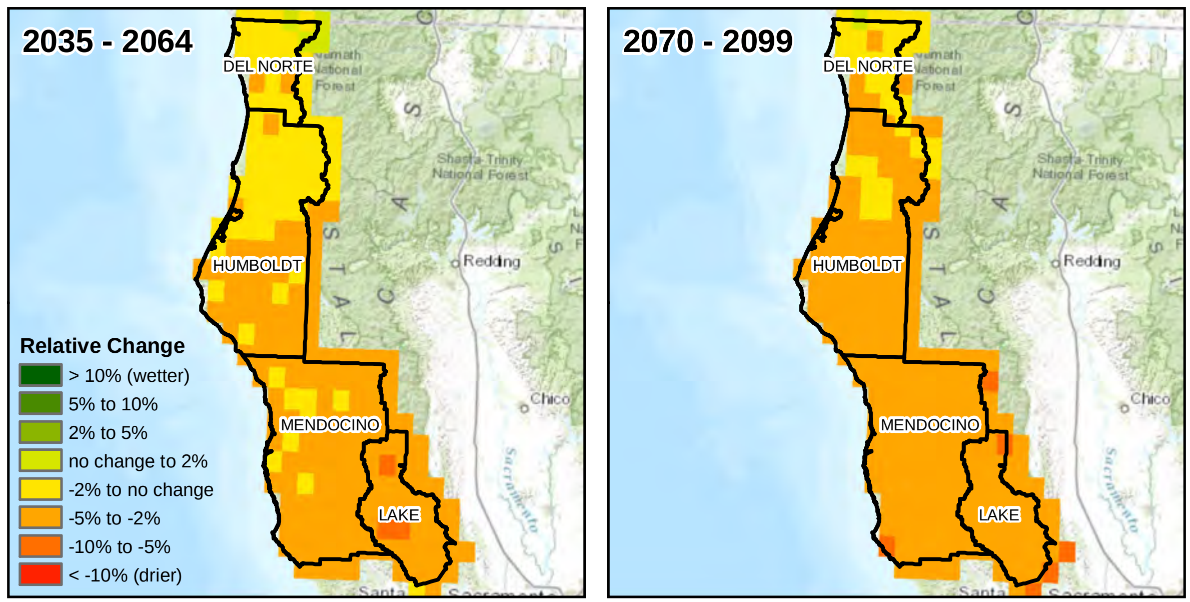


Climate scenario:
A2 (high medium-high emissions)

Climate model(s):
Average of all GCMs

N
0 25 50 Miles

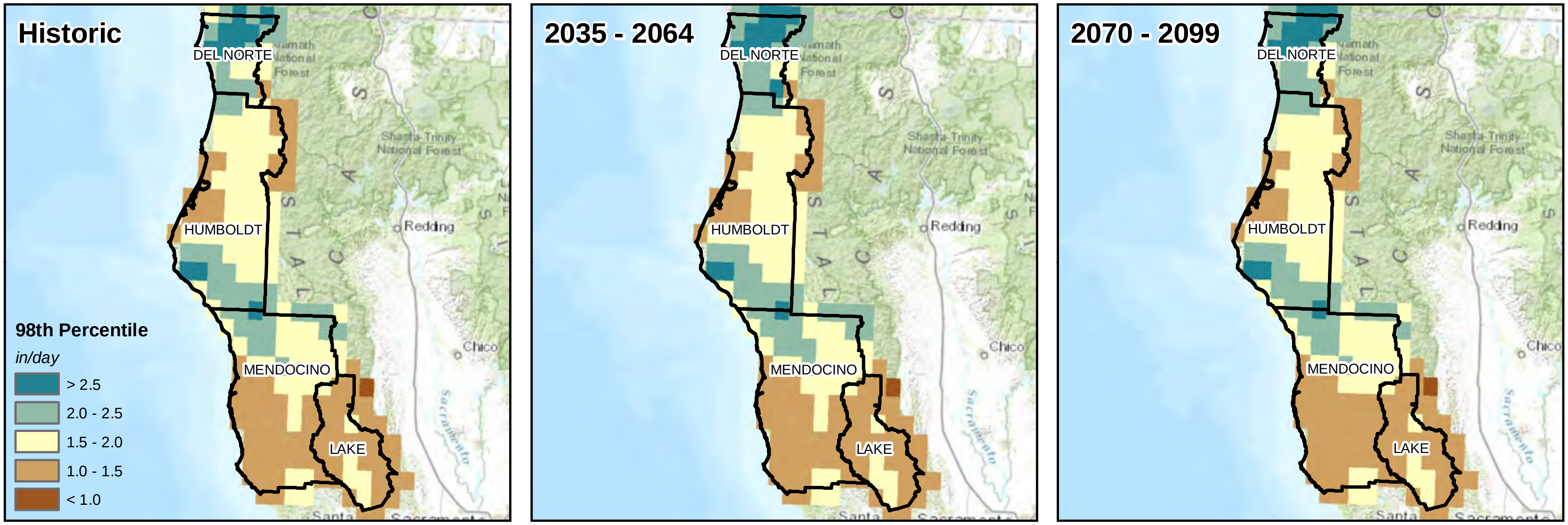
Description:
The 98th percentile precipitation was estimated for a historic period (1970 - 1999 or "Historic") and two future periods (2035 - 2064 and 2070 - 2099) for each global climate model (GCM). The top panel presents the 98th percentile precipitation averaged for all GCMs. The bottom panel shows the percent change relative to the historic time period.



G:\130588_HCAOG-ClimateChange\MXDs\Figures\Precip_98Percentile_11Jun2014.mxd

SOURCE: Cal Adapt, 2014

Figure 7
98th Percentile Precipitation: Average Values and Relative Change for Scenario A2, All Models



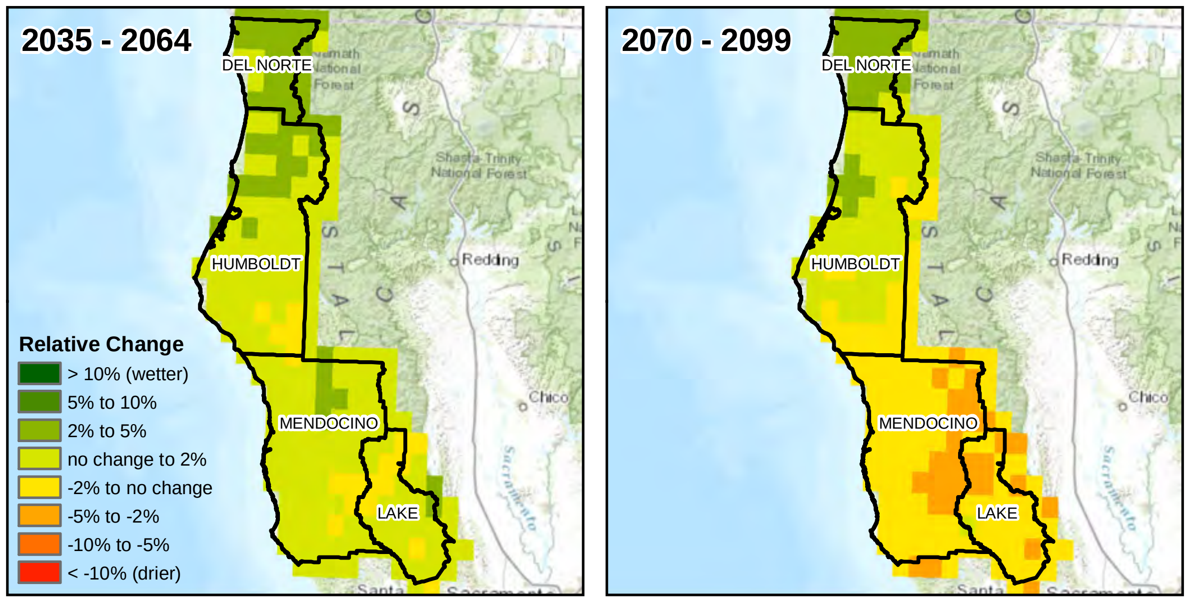
Climate scenario:
B1 (low emissions)

Climate model(s):
Average of all GCMs

N

0 25 50 Miles

Description:
The 98th percentile precipitation was estimated for a historic period (1970 - 1999 or "Historic") and two future periods (2035 - 2064 and 2070 - 2099) for each global climate model (GCM). The top panel presents the 98th percentile precipitation averaged for all GCMs. The bottom panel shows the percent change relative to the historic time period.

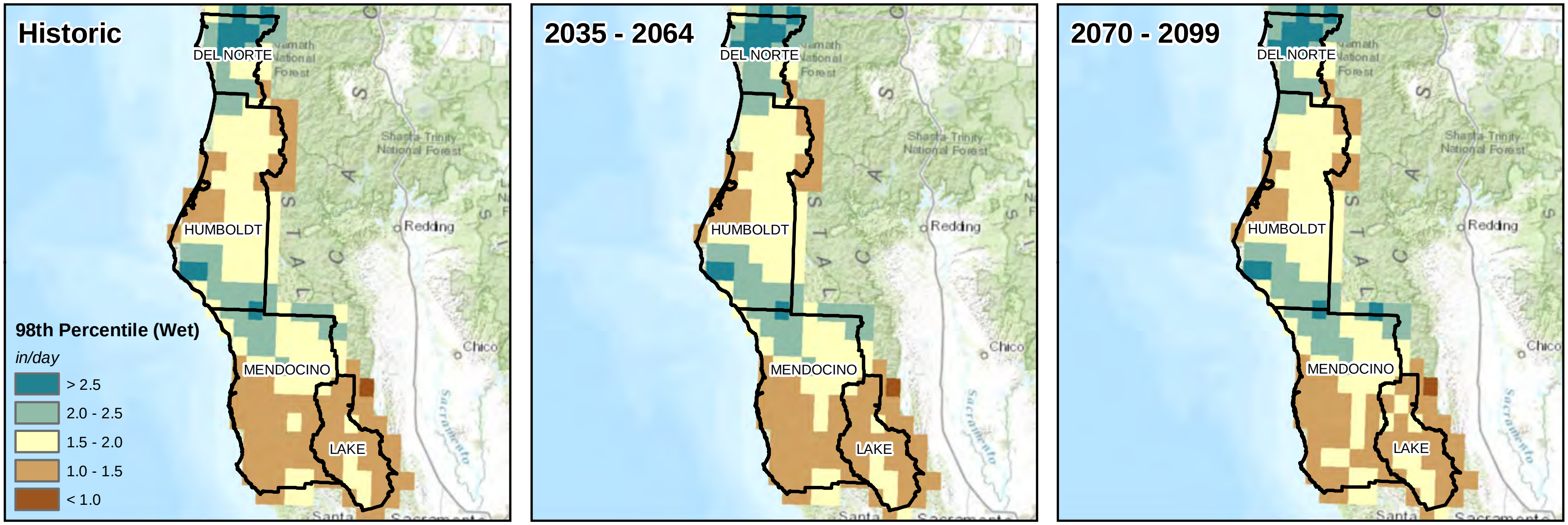


G:\130588_HCAOG-ClimateChange\MXDs\Figures\Precip_98Percentile_11Jun2014.mxd

SOURCE: Cal Adapt, 2014

Caltrans District 1 Climate Change Pilot Study . 130588.00

Figure 8
98th Percentile Precipitation: Average Values and Relative Change for Scenario B1, All Models

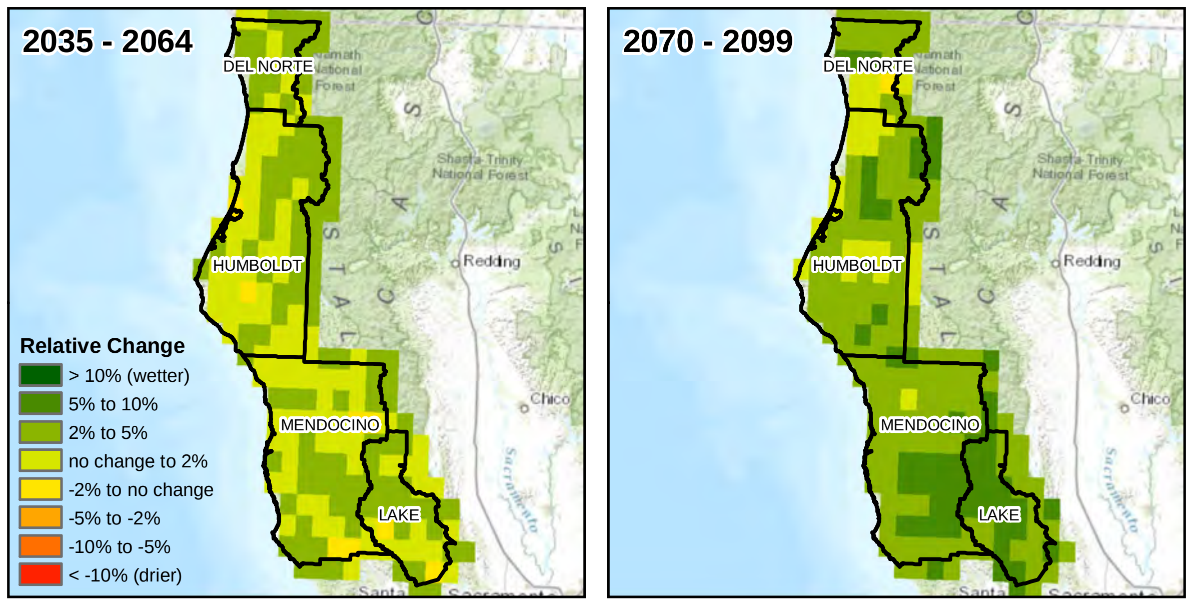


Climate scenario:
A2 (high medium-high emissions)

Climate model(s):
Wet GCM (PCM)

N
0 25 50
Miles

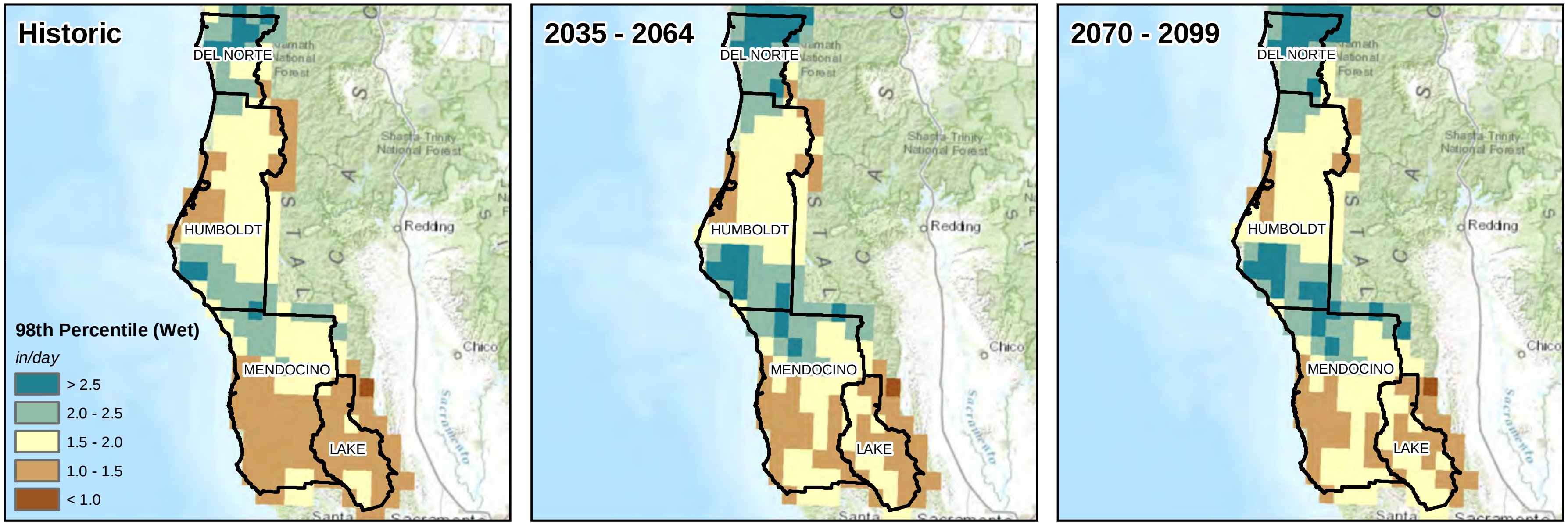
Description:
The 98th percentile precipitation was estimated for a historic period (1970 - 1999 or "Historic") and two future periods (2035 - 2064 and 2070 - 2099) for a wet global climate model (GCM). The top panel presents the 98th percentile precipitation for the wet GCM. The bottom panel shows the percent change relative to the historic time period.



G:\130588_HCAOG-ClimateChange\MXDs\Figures\Precip_98Percentile_11Jun2014.mxd

SOURCE: Cal Adapt, 2014

Figure 9
98th Percentile Precipitation: Average Values and Relative Change for Scenario A2, Wet Model

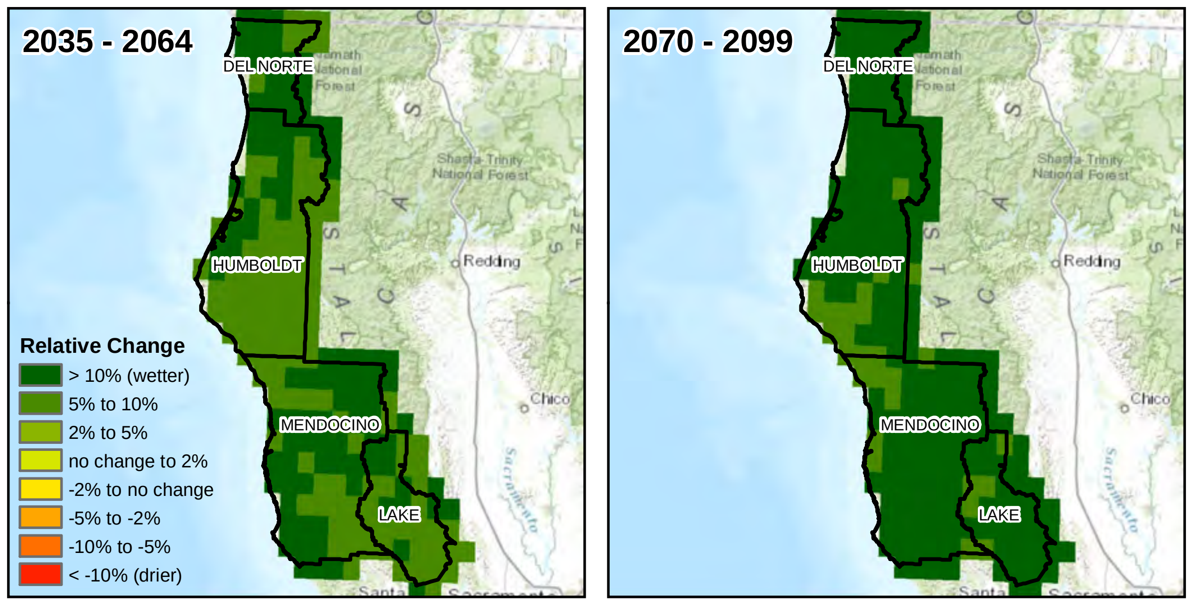


Climate scenario:
B1 (low emissions)

Climate model(s):
Wet GCM (PCM)

N
0 25 50 Miles

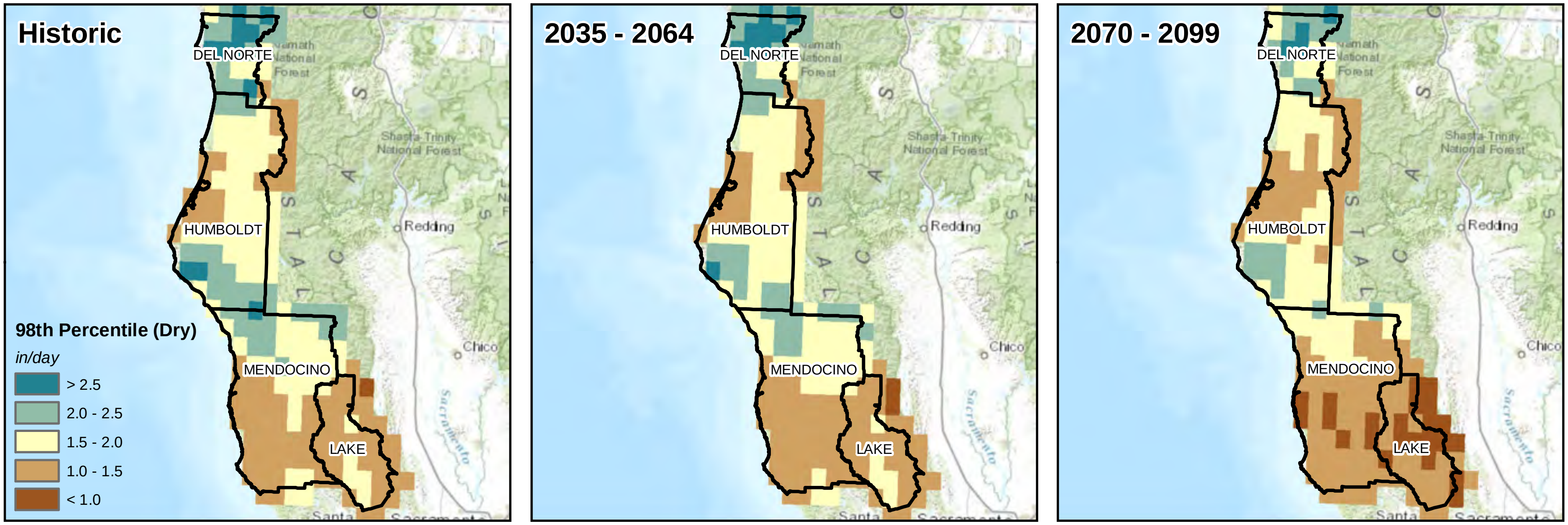
Description:
The 98th percentile precipitation was estimated for a historic period (1970 - 1999 or "Historic") and two future periods (2035 - 2064 and 2070 - 2099) for a wet global climate model (GCM). The top panel presents the 98th percentile precipitation for the wet GCM. The bottom panel shows the percent change relative to the historic time period.



G:\130588_HCAOG-ClimateChange\MXDs\Figures\Precip_98Percentile_11Jun2014.mxd

SOURCE: Cal Adapt, 2014

Figure 10
98th Percentile Precipitation: Average Values and Relative Change for Scenario B1, Wet Model

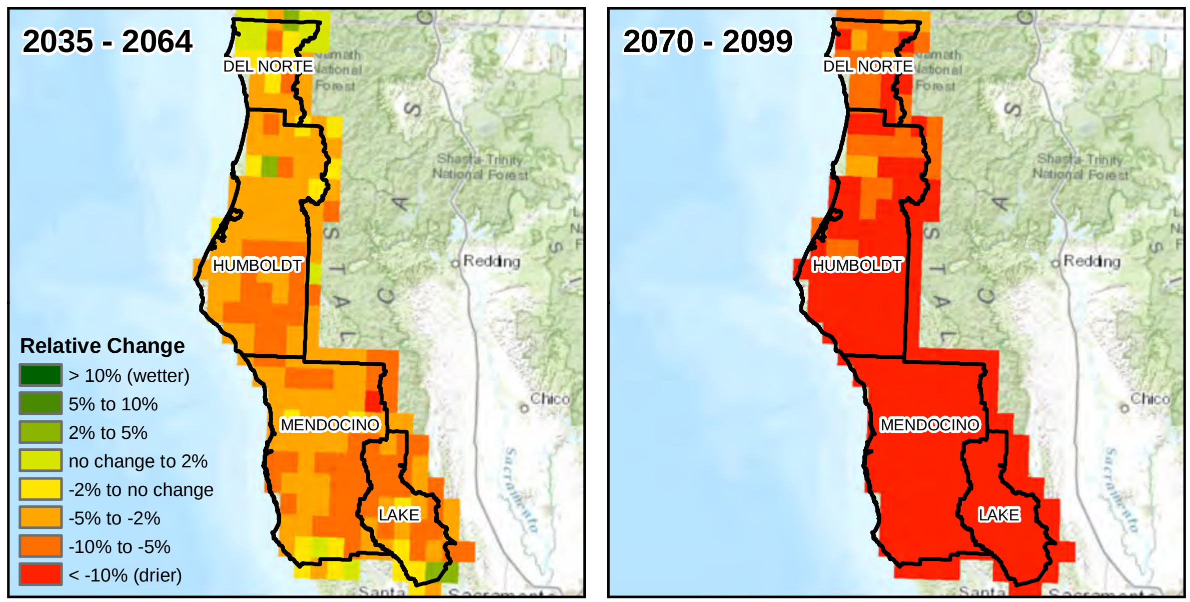


Climate scenario:
A2 (high medium-high emissions)

Climate model(s):
Dry GCM (GFDL)

N
0 25 50 Miles

Description:
The 98th percentile precipitation was estimated for a historic period (1970 - 1999 or "Historic") and two future periods (2035 - 2064 and 2070 - 2099) for a dry global climate model (GCM). The top panel presents the 98th percentile precipitation for the dry GCM. The bottom panel shows the percent change relative to the historic time period.



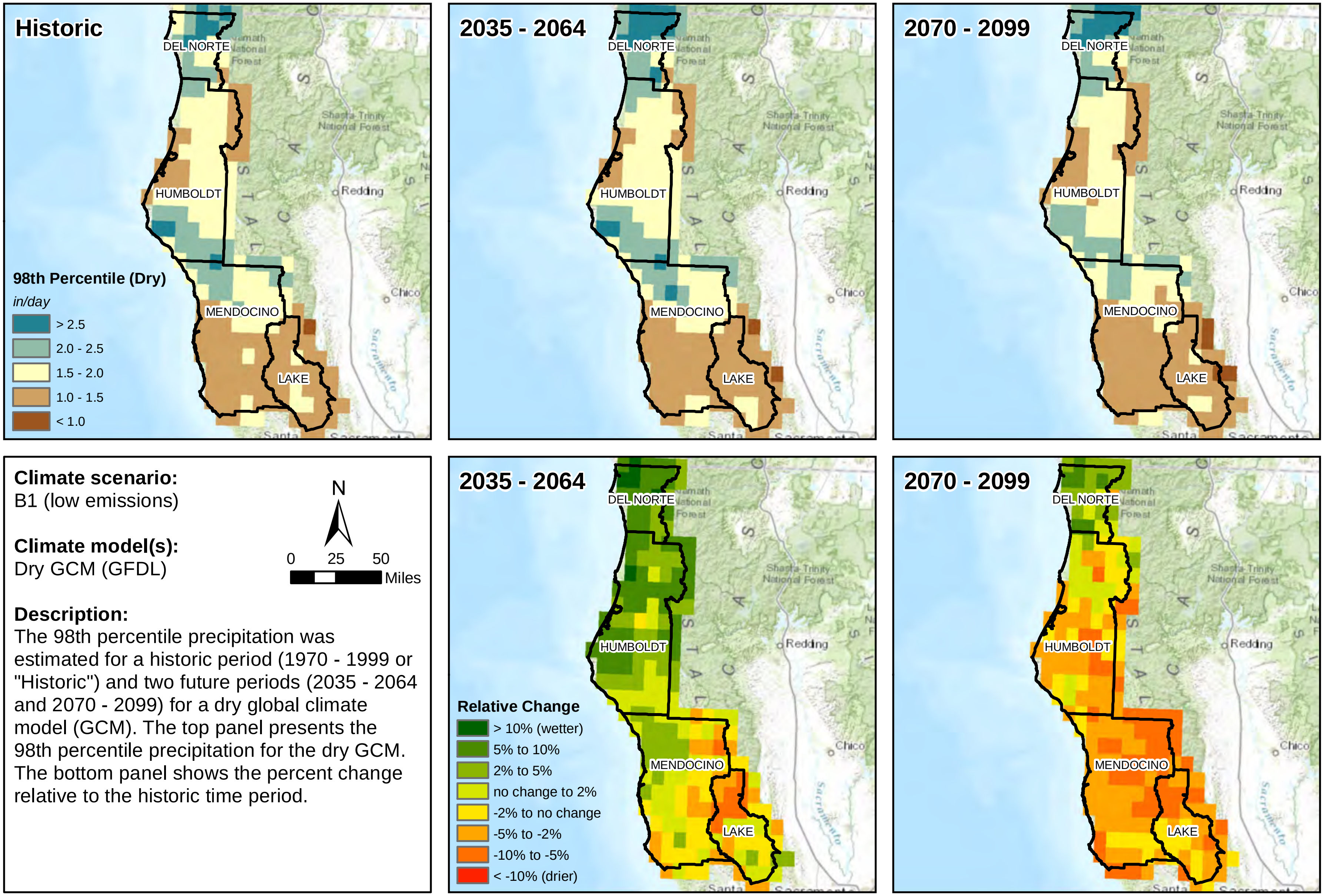
G:\130588_HCAOG-ClimateChange\MXDs\Figures\Precip_98Percentile_11Jun2014.mxd

SOURCE: Cal Adapt, 2014

Caltrans District 1 Climate Change Pilot Study . 130588.00

Figure 11

98th Percentile Precipitation: Average Values and Relative Change for Scenario A2, Dry Model



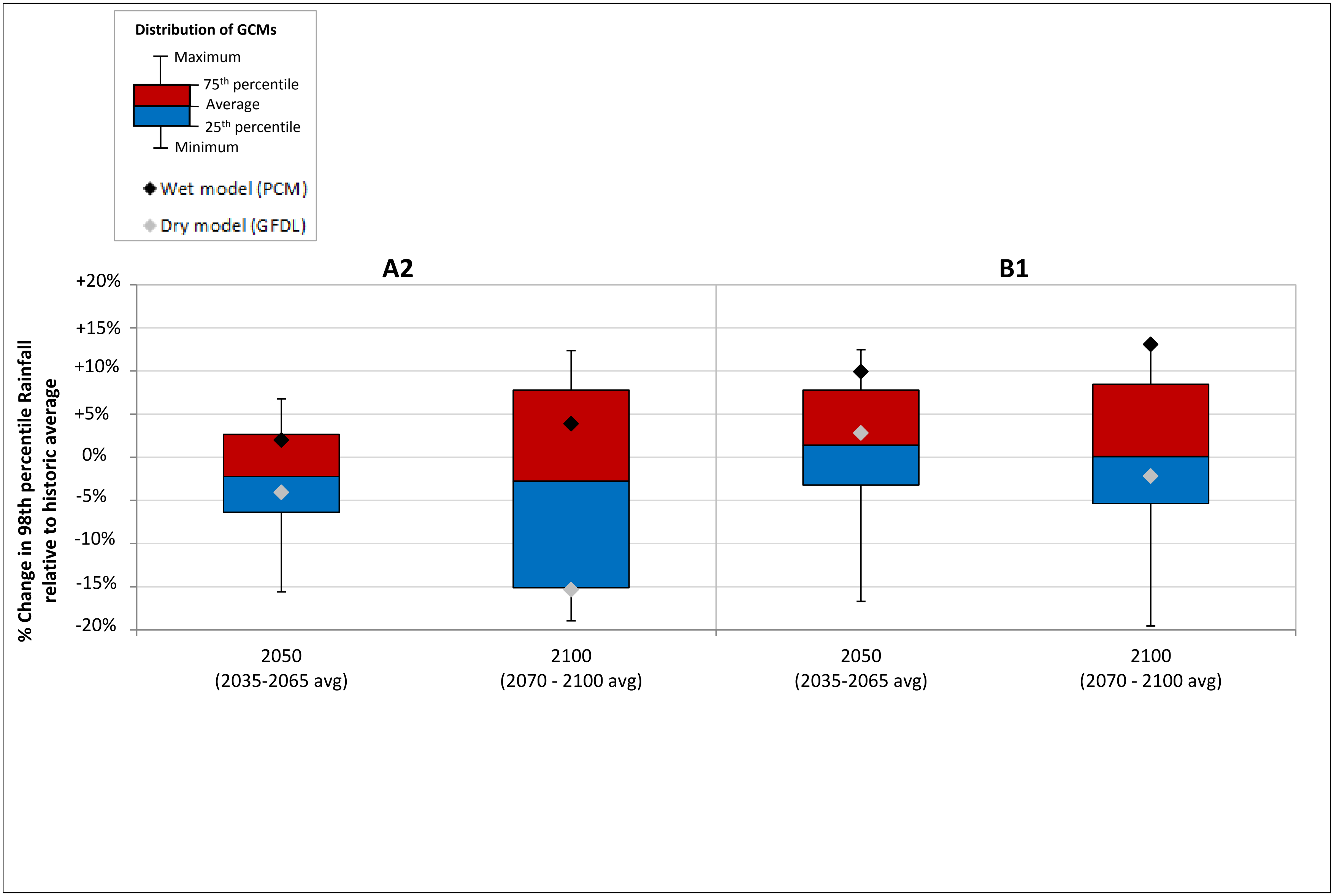
G:\130588_HCAOG-ClimateChange\MXDs\Figures\Precip_98Percentile_11Jun2014.mxd

SOURCE: Cal Adapt, 2014

Caltrans District 1 Climate Change Pilot Study . 130588.00

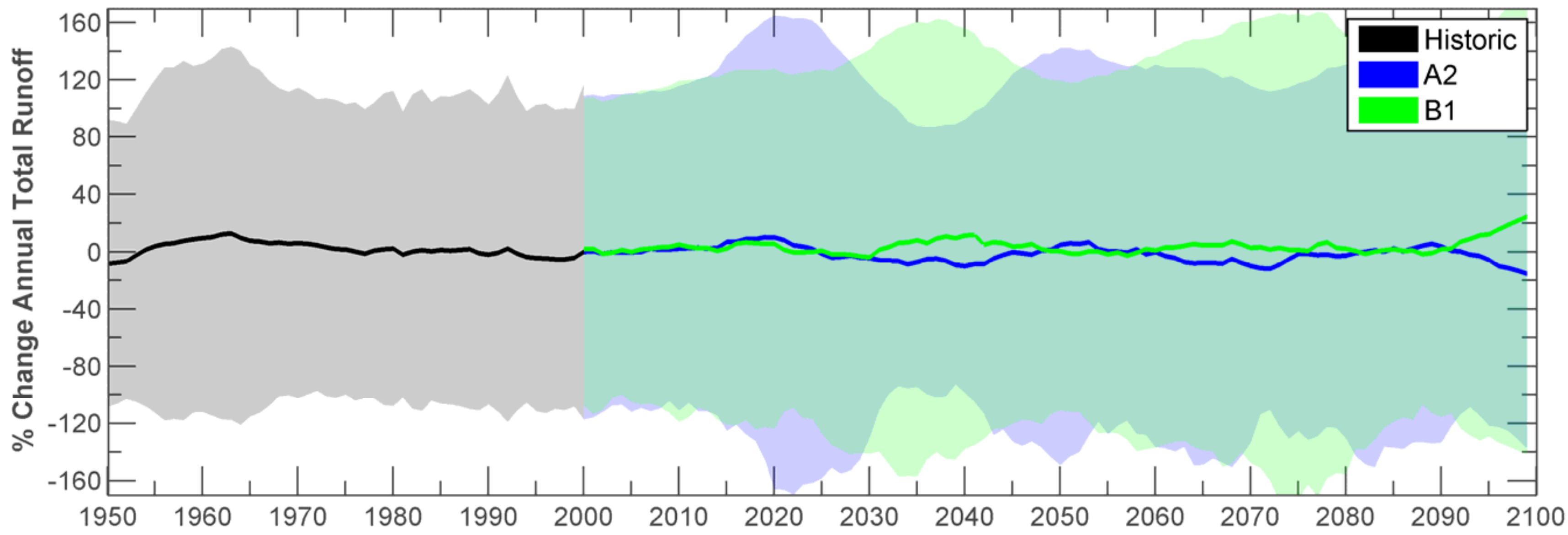
Figure 12

98th Percentile Precipitation: Average Values and Relative Change for Scenario B1, Dry Model



SOURCE: WCRP CMIP3 downscaled data

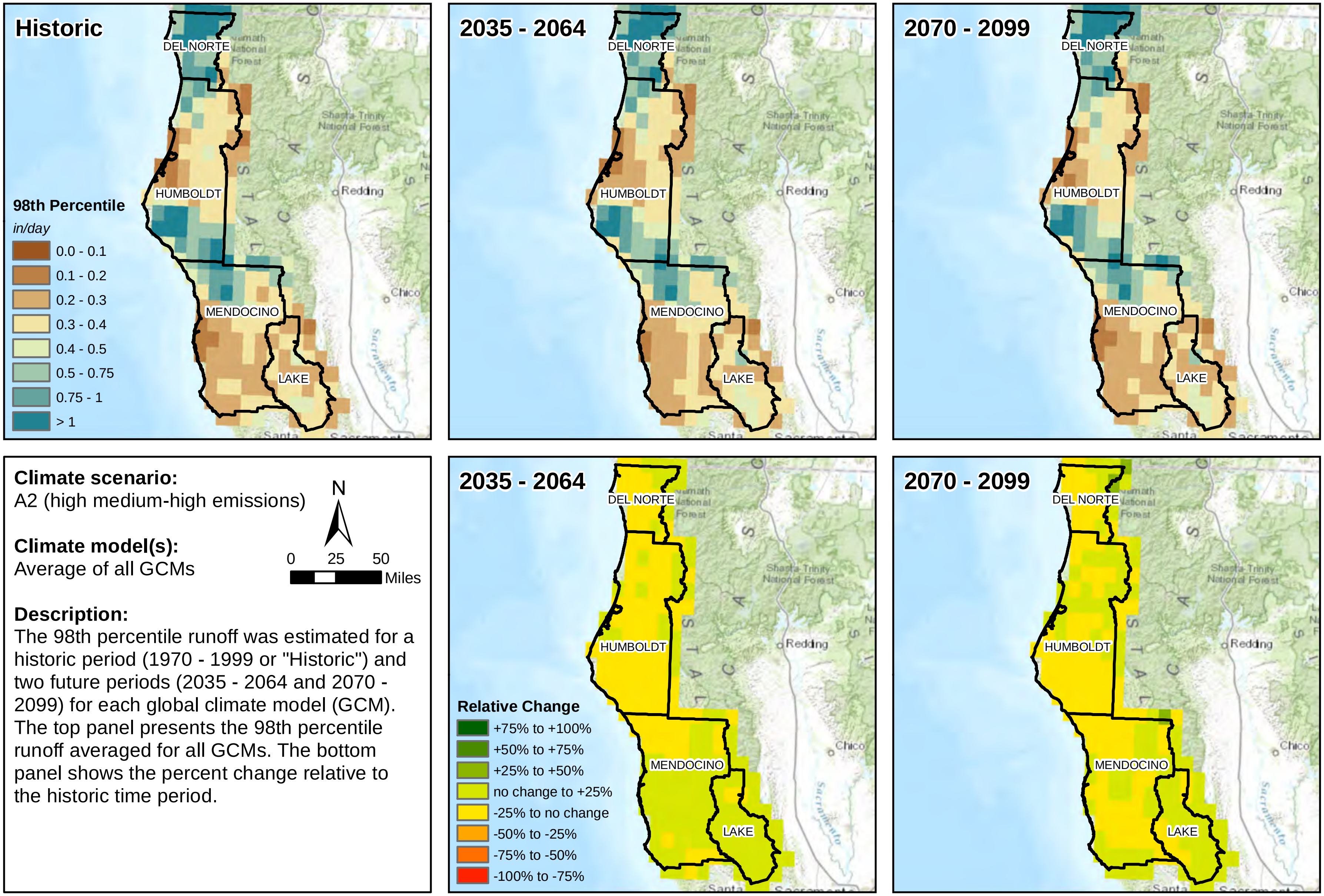
Figure 13
Change in Extreme Precipitation Over Time for Multiple GCMs - District 1 Average



SOURCE: CMIP3

NOTES: 10-year moving average; spatially averaged over District 1;
solid lines are ensemble average;
shading represents range of individual GCMs

Figure 14
Percent Change in Total Annual Runoff from Historic Average for A2 and B1 Emissions Scenarios



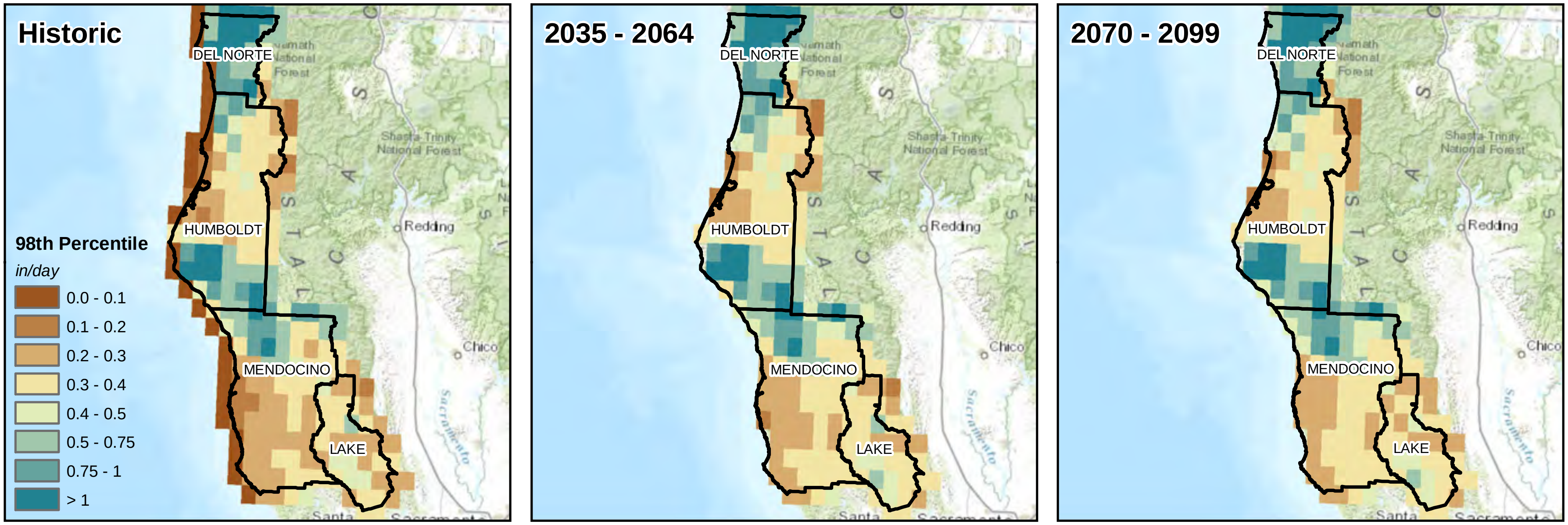
S:\GIS\130588_HCAOG-ClimateChange\MXDs\Figures\Runoff_98Percentile_16Jun2014.mxd

SOURCE: Cal Adapt, 2014

Caltrans District 1 Climate Change Pilot Study . 130588.00

Figure 15

98th Percentile Runoff: Average Values and Relative Change for Scenario A2, All Models

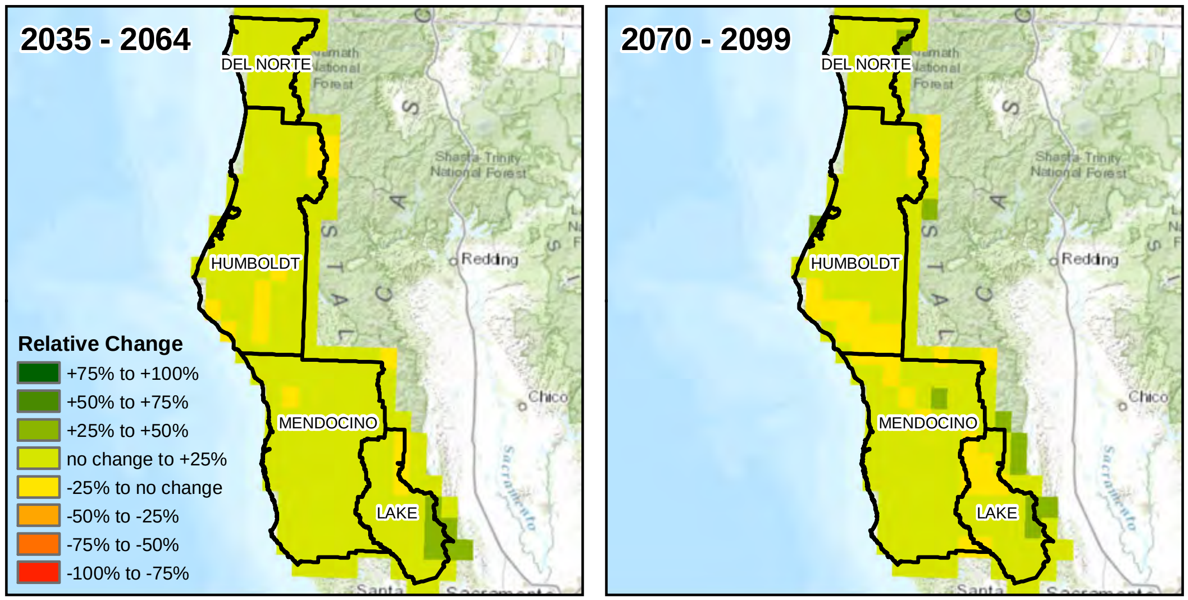


Climate scenario:
B1 (low emissions)

Climate model(s):
Average of all GCMs

N
0 25 50
Miles

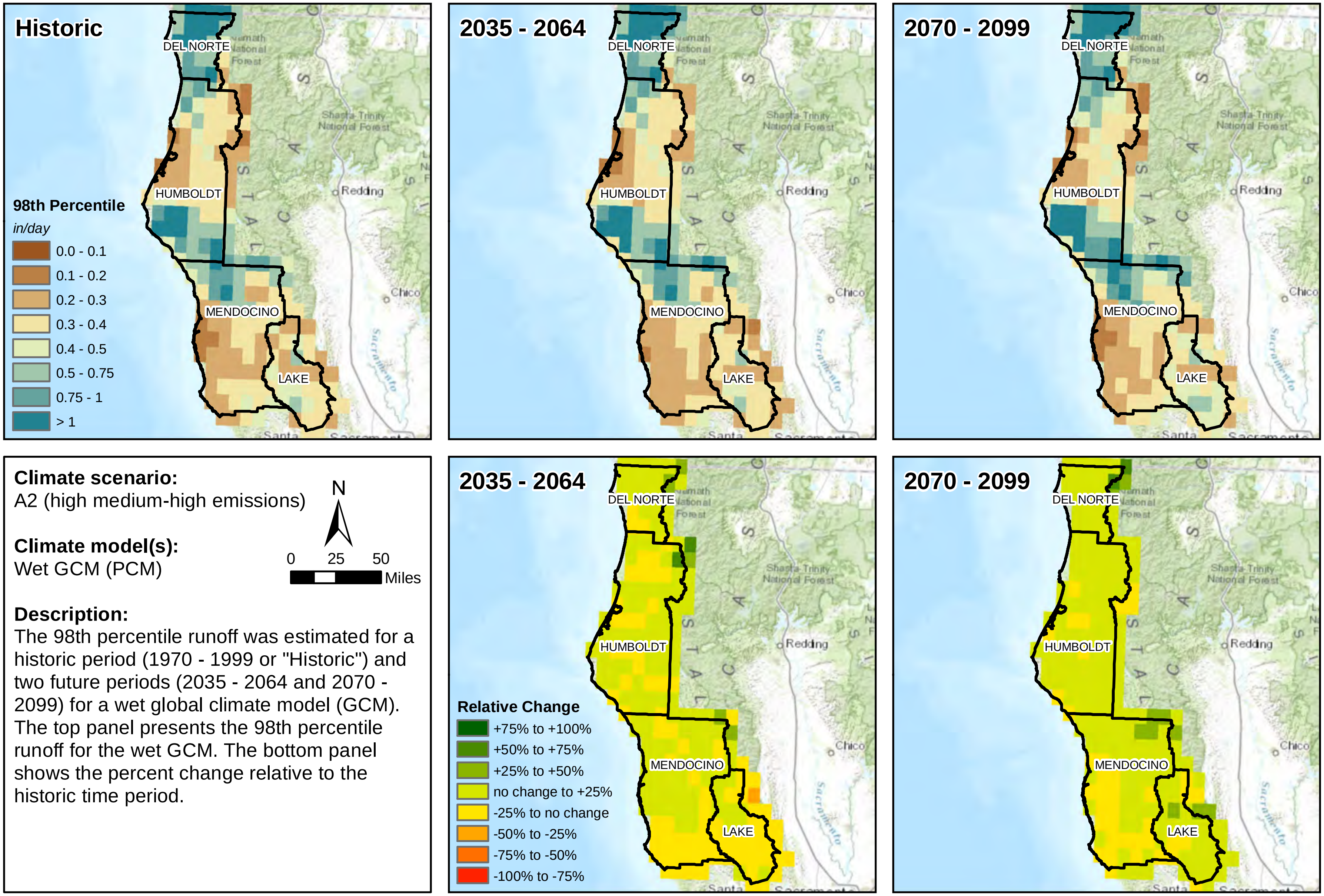
Description:
The 98th percentile runoff was estimated for a historic period (1970 - 1999 or "Historic") and two future periods (2035 - 2064 and 2070 - 2099) for each global climate model (GCM). The top panel presents the 98th percentile runoff averaged for all GCMs. The bottom panel shows the percent change relative to the historic time period.



S:\GIS\130588_HCAOG-ClimateChange\MXDs\Figures\Runoff_98Percentile_16Jun2014.mxd

SOURCE: Cal Adapt, 2014

Figure 16
98th Percentile Runoff: Average Values and Relative Change for Scenario B1, All Models



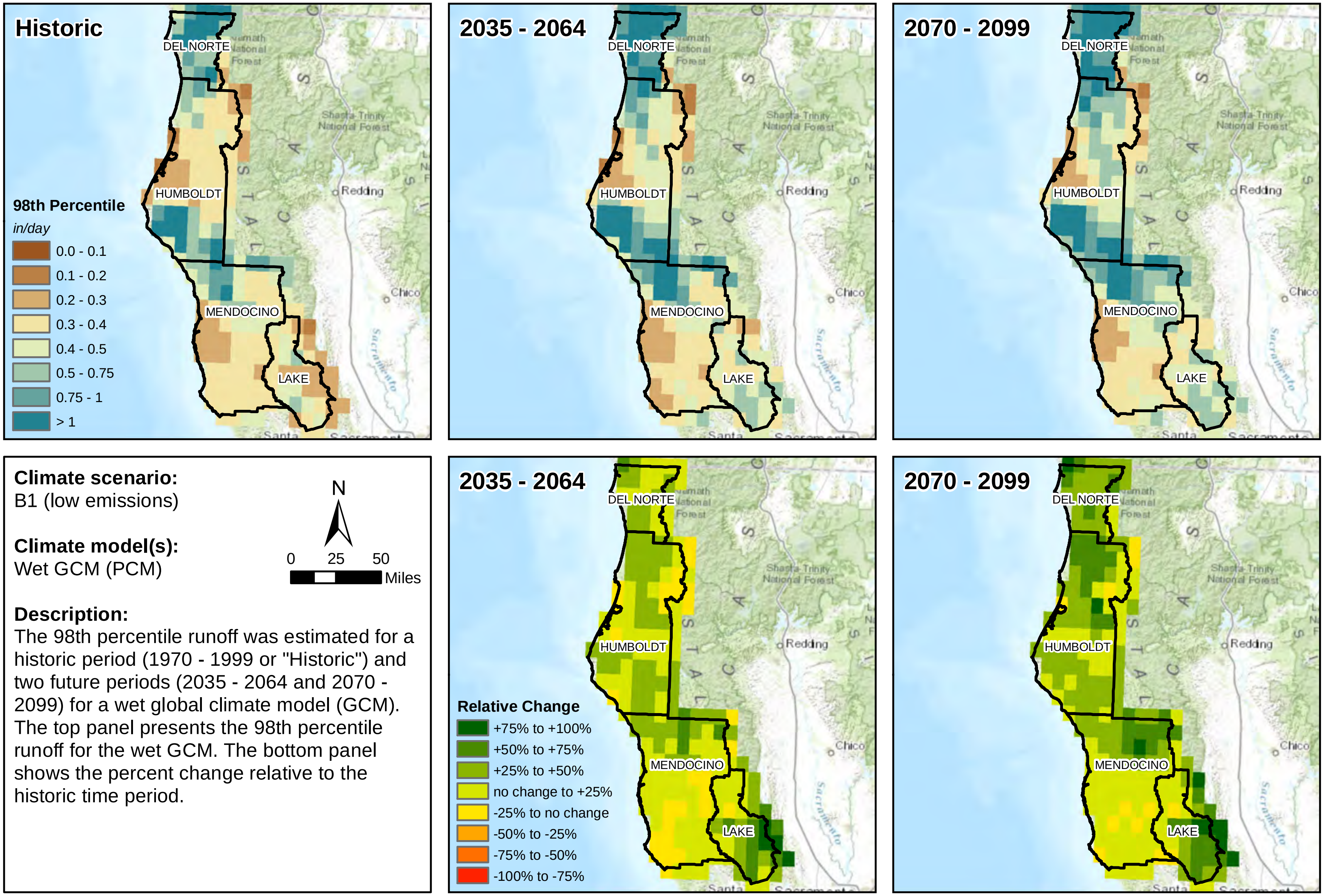
S:\GIS\130588_HCAOG-ClimateChange\MXDs\Figures\Runoff_98Percentile_16Jun2014.mxd

SOURCE: Cal Adapt, 2014

Caltrans District 1 Climate Change Pilot Study . 130588.00

Figure 17

98th Percentile Runoff: Average Values and Relative Change for Scenario A2, Wet Model

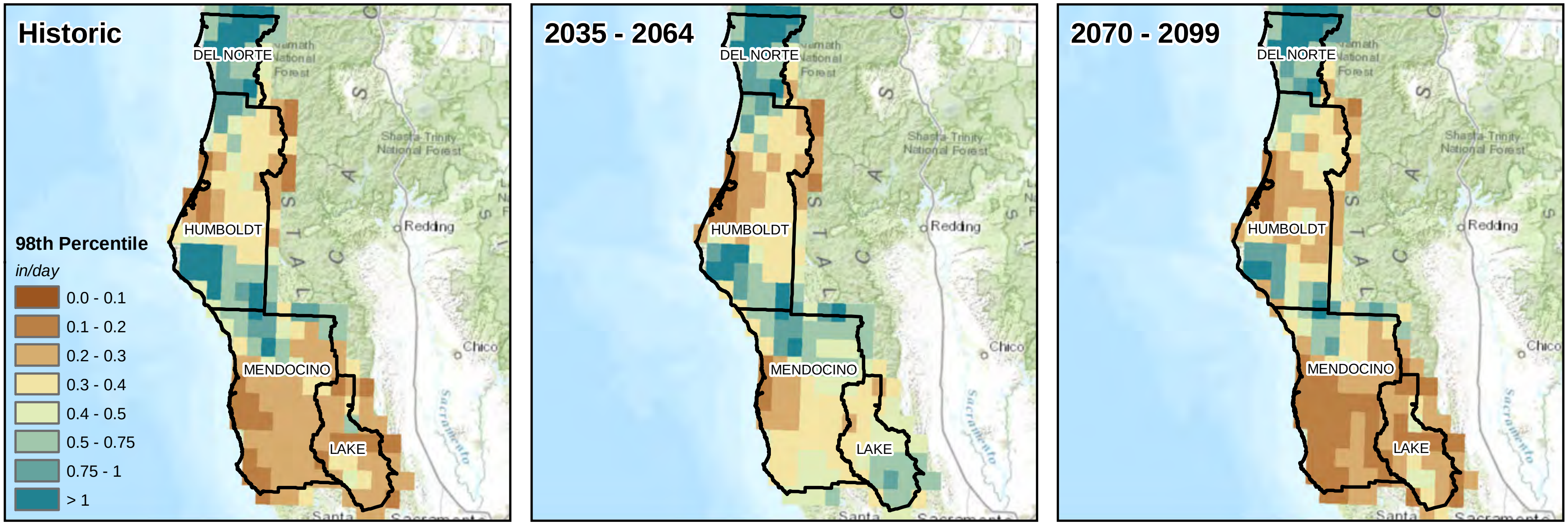


S:\GIS\130588_HCAOG-ClimateChange\MXDs\Figures\Runoff_98Percentile_16Jun2014.mxd

SOURCE: Cal Adapt, 2014

Figure 18

98th Percentile Runoff: Average Values and Relative Change for Scenario B1, Wet Model

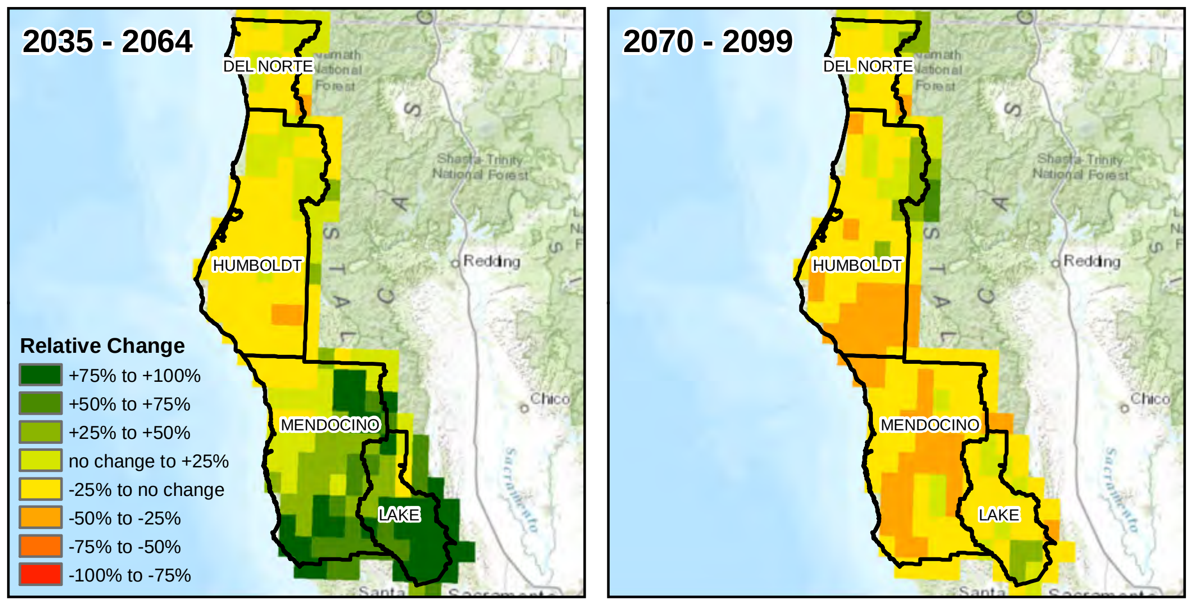


Climate scenario:
A2 (high medium-high emissions)

Climate model(s):
Dry GCM (GFDL)

N
0 25 50
Miles

Description:
The 98th percentile runoff was estimated for a historic period (1970 - 1999 or "Historic") and two future periods (2035 - 2064 and 2070 - 2099) for a dry global climate model (GCM). The top panel presents the 98th percentile runoff for the dry GCM. The bottom panel shows the percent change relative to the historic time period.



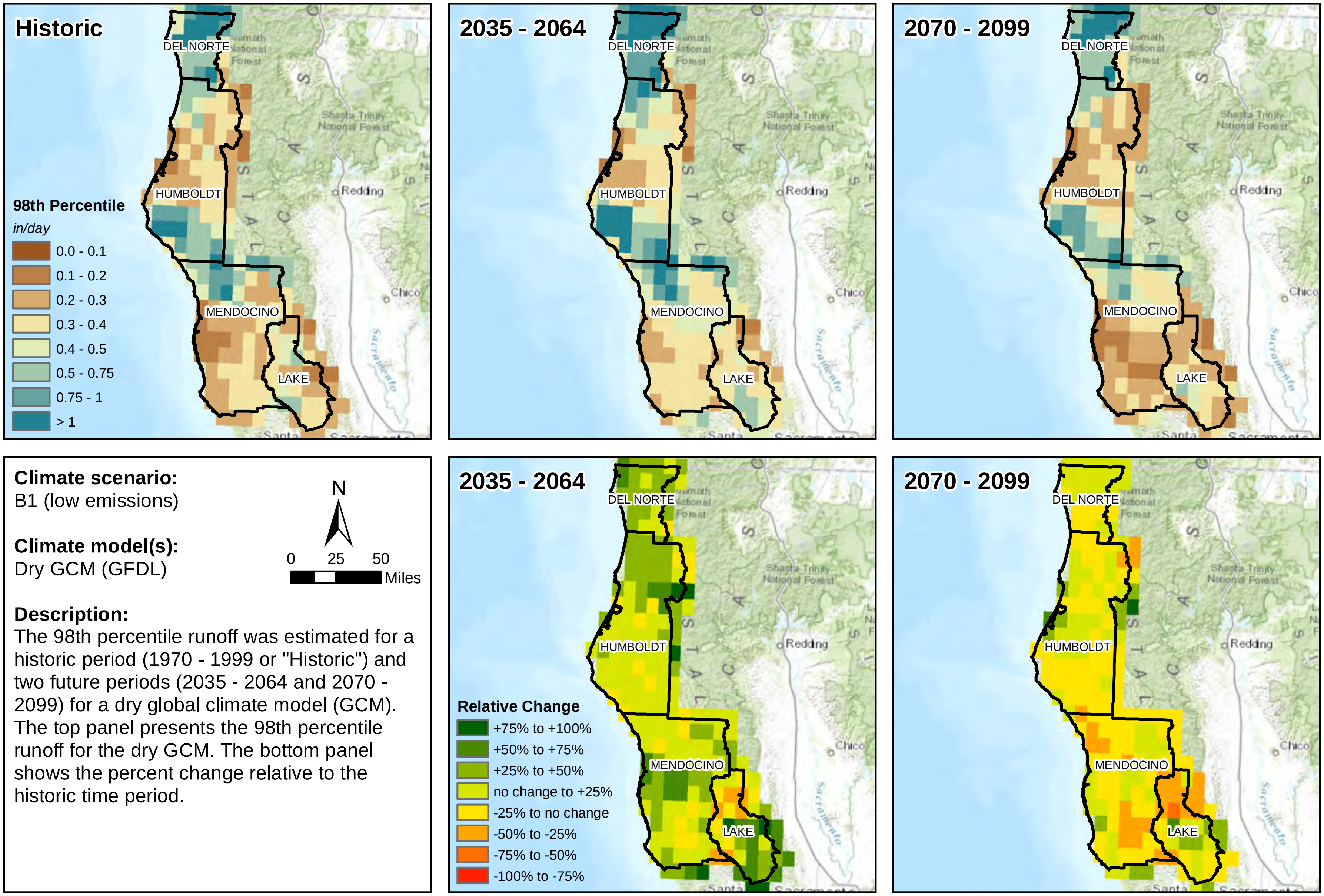
S:\GIS\130588_HCAOG-ClimateChange\MXDs\Figures\Runoff_98Percentile_16Jun2014.mxd

SOURCE: Cal Adapt, 2014

Caltrans District 1 Climate Change Pilot Study . 130588.00

Figure 19

98th Percentile Runoff: Average Values and Relative Change for Scenario A2, Dry Model



Climate scenario:
B1 (low emissions)

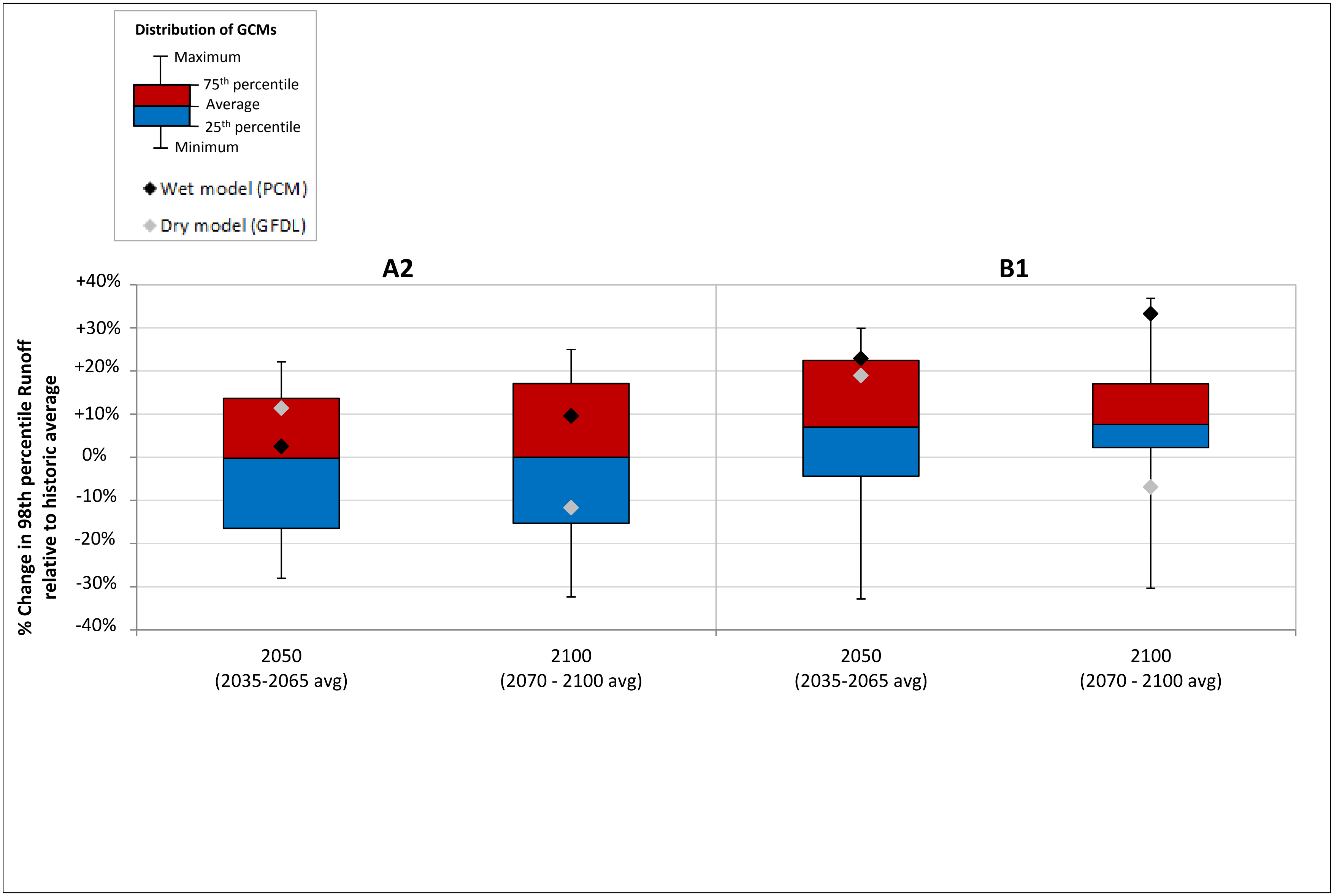
Climate model(s):
Dry GCM (GFDL)

Description:
The 98th percentile runoff was estimated for a historic period (1970 - 1999 or "Historic") and two future periods (2035 - 2064 and 2070 - 2099) for a dry global climate model (GCM). The top panel presents the 98th percentile runoff for the dry GCM. The bottom panel shows the percent change relative to the historic time period.

S:\GIS\130588_HCAOG-ClimateChange\MXDs\Figures\Runoff_98Percentile_16Jun2014.mxd

SOURCE: Cal Adapt, 2014

Figure 20
98th Percentile Runoff: Average Values and Relative Change for Scenario B1, Dry Model



SOURCE: WCRP CMIP3 downscaled data

Caltrans District 1 Climate Change Pilot Study . 130588.00

Figure 21
Change in Extreme Runoff Over Time for Multiple GCMs - District 1 Average

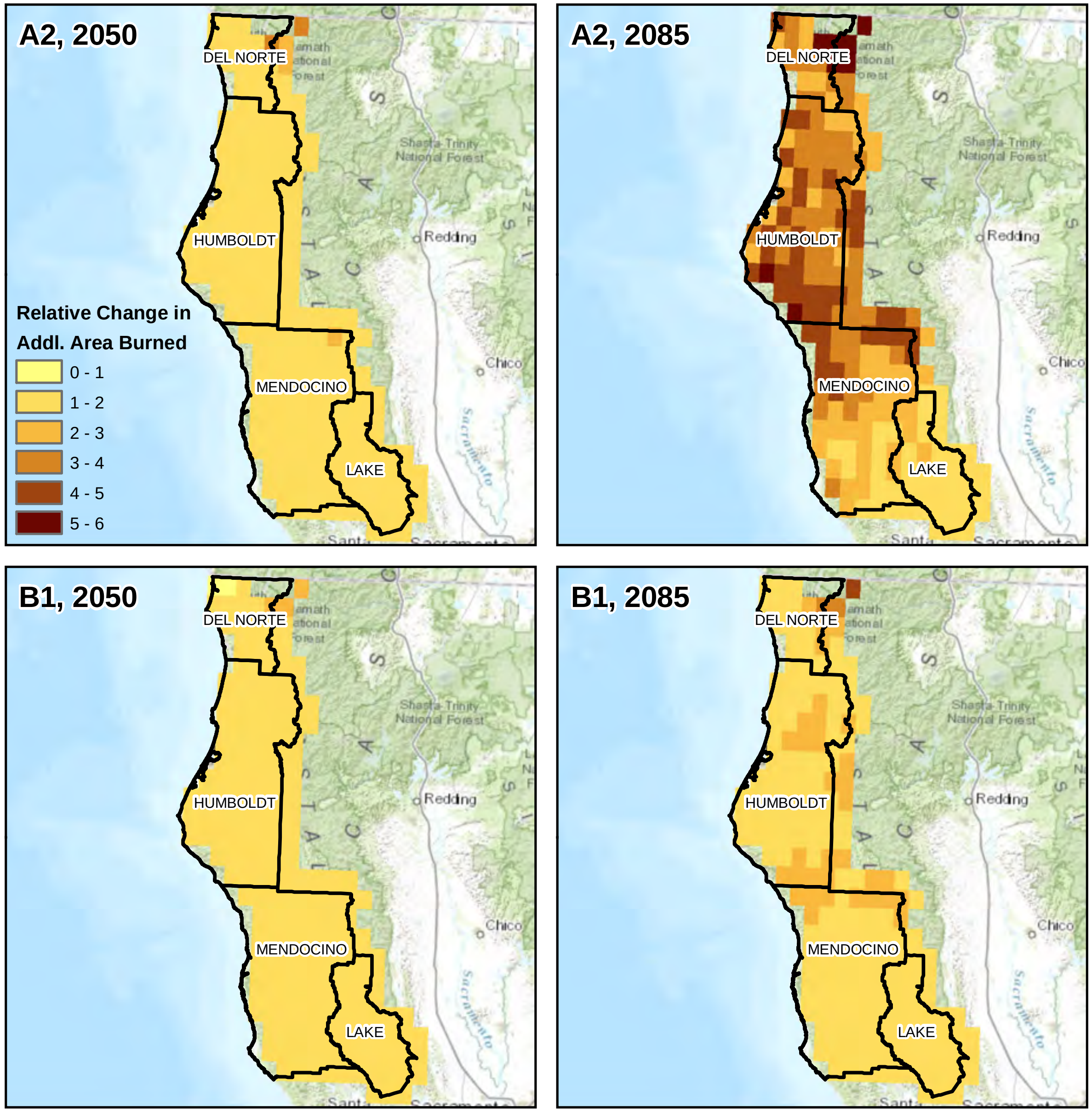
Climate scenario:
top panel: A2 (high medium-high emissions)
bottom panel: B1 (low emissions)

Climate model(s):
Average of three models

Description:
These maps show the relative change in burned area compared to existing fire risk, based on the average of three global climate model (GCM) projections.

N
0 25 50 Miles

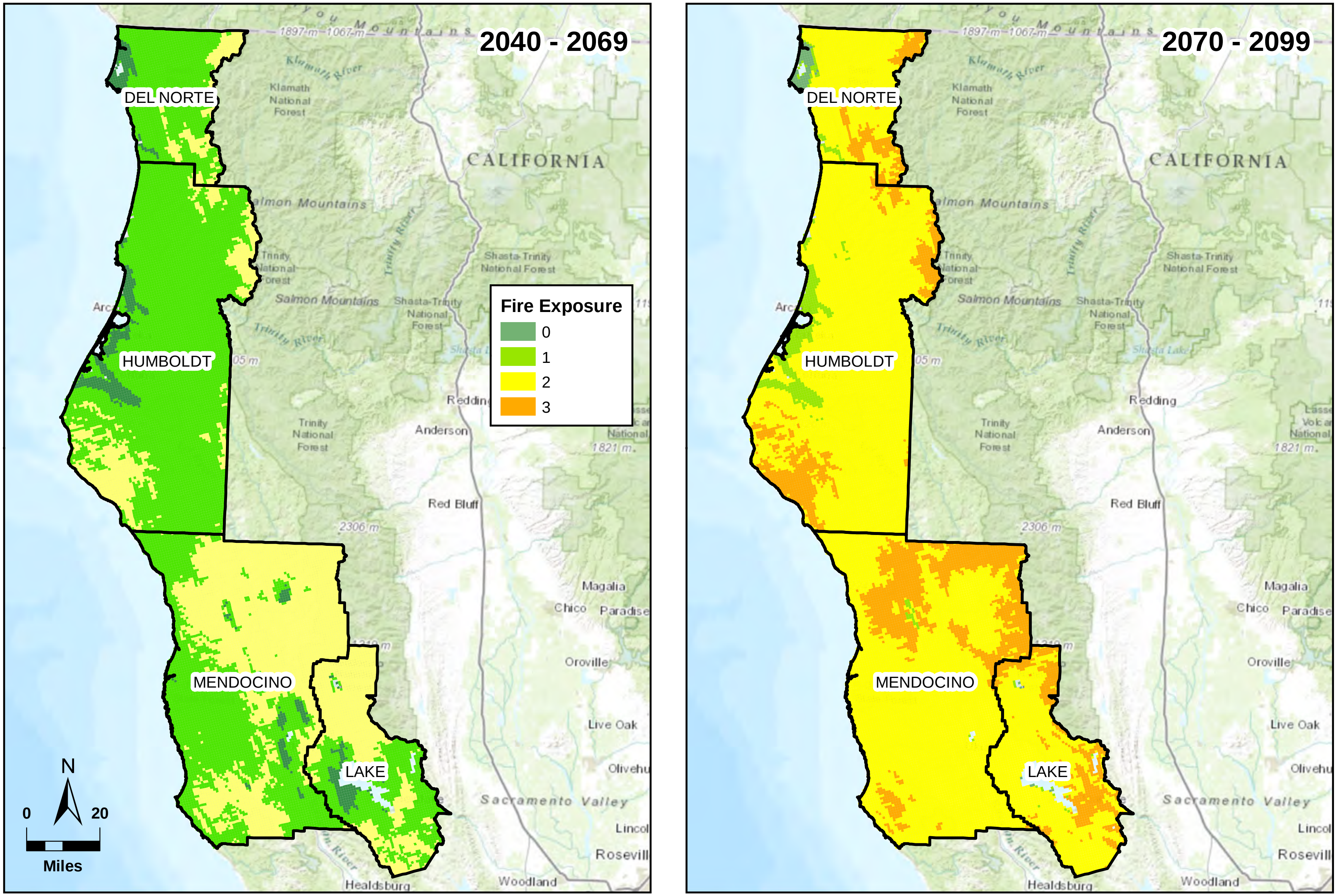
Note:
Fire risk data was downloaded from the CalAdapt website (http://cal-adapt.org/fire/). Only relative change (i.e. 3-fold increase in burned area) was available for download. These results were modeled solely on climate projections and do not take landscape and fuel sorces into account.



S:\GIS\130588_HCAOG-ClimateChange\MXDs\Figures\Fire Risk_16Jun2014.mxd

SOURCE: Cal Adapt, 2014

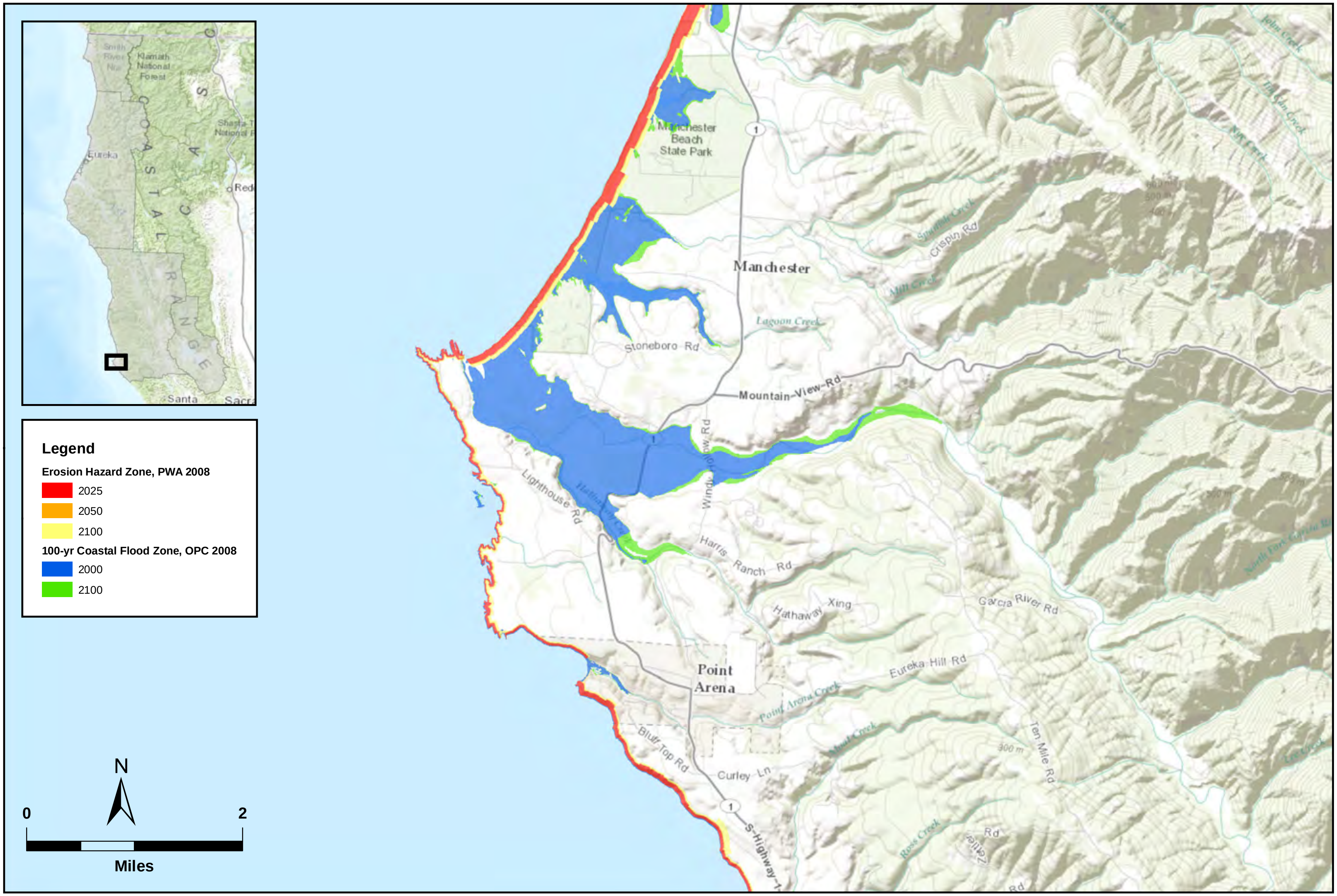
Figure 22
Fire Risk: Increase in Area Burned



G:\130588_HCAOG-ClimateChange\MXDs\Figures\Fire Exposure_23May2014.mxd

SOURCE: DWR 2014

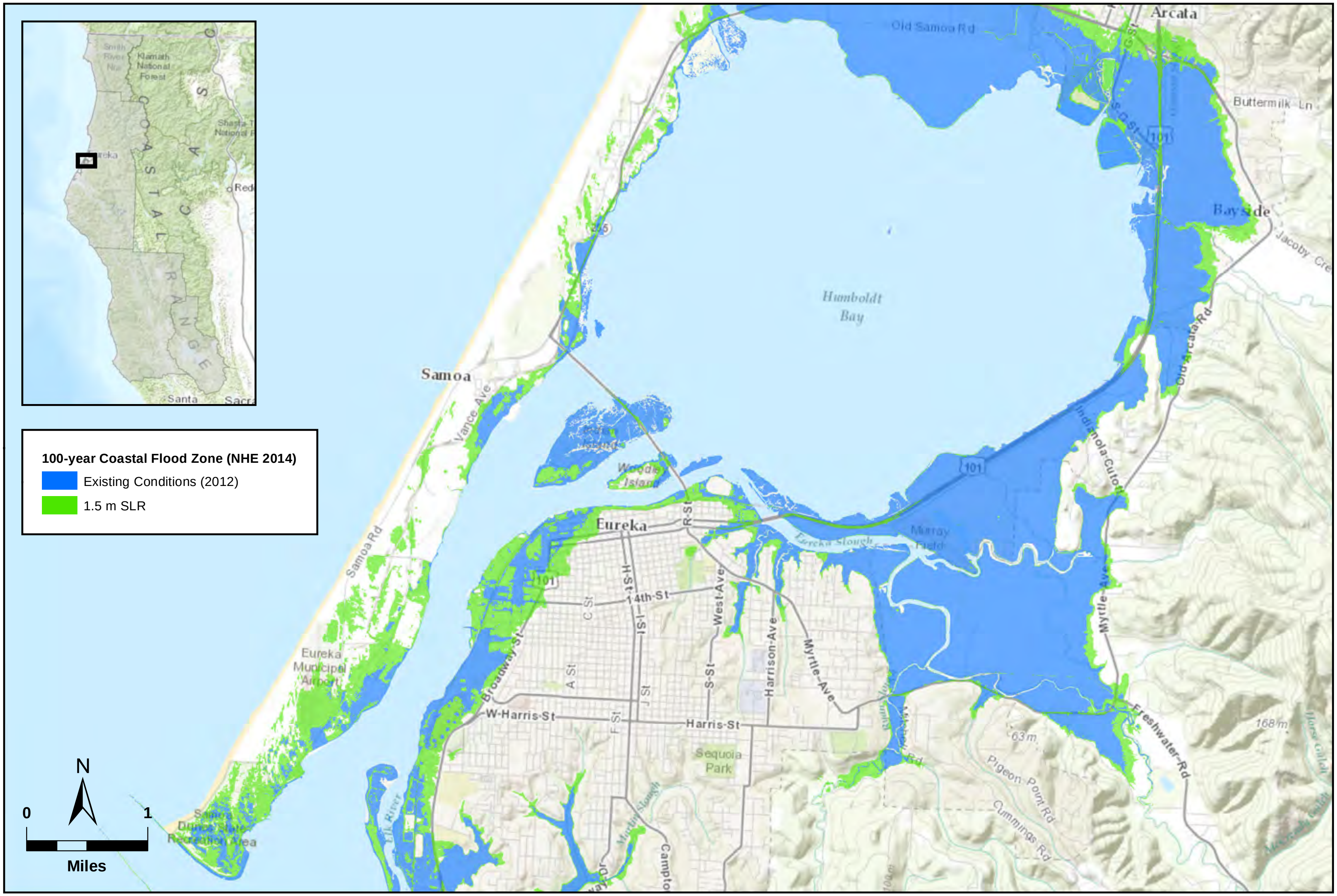
Figure 23
Fire Exposure Level (DWR 2014)



SOURCE: PWA 2008 and Pacific Institute 2009

Climate Change Adaptation Pilot Strategy for Critically Vulnerable Assets in NW California . 130588.00

Figure 24
Example of Coastal Hazard Zones at Point Arena



Climate Change Adaptation Pilot Strategy for Critically Vulnerable Assets in NW California . 130588.00

SOURCE: NHE 2014. Flood zones also available for 0.5m, 1.0m, 1.5m, and 2.0m of sea level rise for MHHW, the 10-yr storm, and the 100-yr storm

Figure 25
Example of Coastal Flood Zones in Humboldt Bay (NHE 2014)

Attachment 1. Summary of Climate Information and Datasets included in Geodatabase

Variable	Climate/Storm Conditions	Metric	Time period (s)	Sea Level Rise	Emissions scenario	Climate Model	Filename (FeatureClass/Filename)	Original Data Source	Data Resolution
Temperature	Extreme	Number of days per year with T>95° F	2000	-	A2	Average of 6 models	TempDays95_ModelAvg_A2_Historic	WCRP CMIP3 downscaled data[1]	12km x 12km
			2050				TempDays95_ModelAvg_A2_2050		
			2100				TempDays95_ModelAvg_A2_2100		
			2000		B1		TempDays95_ModelAvg_B1_Historic		
			2050				TempDays95_ModelAvg_B1_2050		
			2100				TempDays95_ModelAvg_B1_2100		
		Change in extreme heat days relative to historic average	2050		A2		TempDays95_ModelAvg_A2_2050		
			2100				TempDays95_ModelAvg_A2_2100		
			2050		B1		TempDays95_ModelAvg_B1_2050		
			2100				TempDays95_ModelAvg_B1_2100		
Precipitation	Extreme	98th Percentile Total Inches/Day	2000		A2	Average of 6 models	Precip98Percentile_ModelAvg_A2_Historic		
			2050				Precip98Percentile_ModelAvg_A2_2050		
			2100				Precip98Percentile_ModelAvg_A2_2100		
			2000		B1		Precip98Percentile_ModelAvg_B1_Historic		
			2050				Precip98Percentile_ModelAvg_B1_2050		
			2100				Precip98Percentile_ModelAvg_B1_2100		
			2000		A2	NCAR PCM1 (wet model)	Precip98Percentile_PCMwet_A2_Historic		
			2050				Precip98Percentile_PCMwet_A2_2050		
			2100				Precip98Percentile_PCMwet_A2_2100		
			2000		B1		Precip98Percentile_PCMwet_B1_Historic		
			2050				Precip98Percentile_PCMwet_B1_2050		
			2100				Precip98Percentile_PCMwet_B1_2100		
			2000		A2	NOAA GFDL (dry model)	Precip98Percentile_GFDLdry_A2_Historic		
			2050				Precip98Percentile_GFDLdry_A2_2050		
			2100				Precip98Percentile_GFDLdry_A2_2100		
			2000		B1		Precip98Percentile_GFDLdry_B1_Historic		
			2050				Precip98Percentile_GFDLdry_B1_2050		
			2100				Precip98Percentile_GFDLdry_B1_2100		
		Percent change in 98th percentile daily rainfall relative to hitoric average	2050		A2	Average of 6 models	Precip98PercentileChange_ModelAvg_A2_2050		
			2100				Precip98PercentileChange_ModelAvg_A2_2100		
			2050		B1		Precip98PercentileChange_ModelAvg_B1_2050		
			2100				Precip98PercentileChange_ModelAvg_B1_2100		
			2050		A2	NCAR PCM1 (wet model)	Precip98PercentileChange_PCMwet_A2_2050		
			2100				Precip98PercentileChange_PCMwet_A2_2100		
			2050		B1		Precip98PercentileChange_PCMwet_B1_2050		
			2100				Precip98PercentileChange_PCMwet_B1_2100		
			2050		A2	NOAA GFDL (dry model)	Precip98PercentileChange_GFDLdry_A2_2050		
			2100				Precip98PercentileChange_GFDLdry_A2_2100		
			2050		B1		Precip98PercentileChange_GFDLdry_B1_2050		
			2100				Precip98PercentileChange_GFDLdry_B1_2100		

Attachment 1. Summary of Climate Information and Datasets included in Geodatabase

Variable	Climate/Storm Conditions	Metric	Time period (s)	Sea Level Rise	Emissions scenario	Climate Model	Filename (FeatureClass/Filename)	Original Data Source	Data Resolution
Runoff	Extreme	98th Percentile Total Inches/Day	2000	-	A2	Average of 6 models	Runoff98Percentile_ModelAvg_A2_Historic	WCRP CMIP3 downscaled data[1]	12km x 12km
			2050				Runoff98Percentile_ModelAvg_A2_2050		
			2100				Runoff98Percentile_ModelAvg_A2_2100		
			2000		B1		Runoff98Percentile_ModelAvg_B1_Historic		
			2050				Runoff98Percentile_ModelAvg_B1_2050		
			2100				Runoff98Percentile_ModelAvg_B1_2100		
			2000		A2	NCAR PCM1 (wet model)	Runoff98Percentile_PCMwet_A2_Historic		
			2050				Runoff98Percentile_PCMwet_A2_2050		
			2100				Runoff98Percentile_PCMwet_A2_2100		
			2000		B1		Runoff98Percentile_PCMwet_B1_Historic		
			2050				Runoff98Percentile_PCMwet_B1_2050		
			2100				Runoff98Percentile_PCMwet_B1_2100		
			2000		A2	NOAA GFDL (dry model)	Runoff98Percentile_GFDLdry_A2_Historic		
			2050				Runoff98Percentile_GFDLdry_A2_2050		
			2100				Runoff98Percentile_GFDLdry_A2_2100		
			2000		B1		Runoff98Percentile_GFDLdry_B1_Historic		
			2050				Runoff98Percentile_GFDLdry_B1_2050		
			2100				Runoff98Percentile_GFDLdry_B1_2100		
		Percent change in 98th percentile daily runoff relative to historic average	2050		A2	Average of 6 models	Runoff98PercentileChange_ModelAvg_A2_2050		
			2100				Runoff98PercentileChange_ModelAvg_A2_2100		
			2050		B1		Runoff98PercentileChange_ModelAvg_B1_2050		
			2100				Runoff98PercentileChange_ModelAvg_B1_2100		
			2050		A2	NCAR PCM1 (wet model)	Runoff98PercentileChange_PCMwet_A2_2050		
			2100				Runoff98PercentileChange_PCMwet_A2_2100		
			2050		B1		Runoff98PercentileChange_PCMwet_B1_2050		
			2100				Runoff98PercentileChange_PCMwet_B1_2100		
			2050		A2	NOAA GFDL (dry model)	Runoff98PercentileChange_GFDLdry_A2_2050		
			2100				Runoff98PercentileChange_GFDLdry_A2_2100		
			2050		B1		Runoff98PercentileChange_GFDLdry_B1_2050		
			2100				Runoff98PercentileChange_GFDLdry_B1_2100		
Fire Risk	Average	Relative Change in Burned Area compared to existing fire risk	2050		A2	Average of 3 models	FireRisk_AddtlAreaBurned_ModelAvg_A2_2050	Cal-Adapt[2]	
					B1		FireRisk_AddtlAreaBurned_ModelAvg_B1_2050		
			2085		A2		FireRisk_AddtlAreaBurned_ModelAvg_A2_2085		
					B1		FireRisk_AddtlAreaBurned_ModelAvg_B1_2085		
Wildfire Exposure (DWR)		Exposure rating - Very low to Very High	2010 - 2039, 2040 - 2069, 2070 - 2099		A2, B1		FireExposure_DWR	DWR[3]	Developed from 1km x 1km fire risk data

Attachment 1. Summary of Climate Information and Datasets included in Geodatabase

Variable	Climate/Storm Conditions	Metric	Time period (s)	Sea Level Rise	Emissions scenario	Climate Model	Filename (FeatureClass/Filename)	Original Data Source	Data Resolution
Inundation - Humboldt Bay	MHW_SHORELINE	Existing MHW Shoreline	2012	0 m	-	-	Inundation_HumboldtBay/YEAR2012_MHW_SHORELINE_140326	Jeff Anderson/NHE[4]	Varies
	100YR	Existing Extreme 100-year WSE	2012	0 m	-	-	Inundation_HumboldtBay/YEAR2012_100YR_140326		
	10YR	Existing Extreme 10-year WSE	2012	0 m	-	-	Inundation_HumboldtBay/YEAR2012_10YR_140326		
	MHHW	Existing MHHW Shoreline	2012	0 m	-	-	Inundation_HumboldtBay/YEAR2012_MHHW_140326		
	100YR	~2050 Extreme 100-year WSE	N/A	0.5 m	-	-	Inundation_HumboldtBay/YEAR2000_w0p5MSLR_100YR_140326		
	10YR	~2050 Extreme 10-year WSE	N/A	0.5 m	-	-	Inundation_HumboldtBay/YEAR2000_w0p5MSLR_10YR_140326		
	MHHW	~2050 MHHW shoreline	N/A	0.5 m	-	-	Inundation_HumboldtBay/YEAR2000_w0p5MSLR_MHHW_140326		
	100YR	2100 Extreme 100-year WSE - low SLR scenario	N/A	1 m	-	-	Inundation_HumboldtBay/YEAR2000_w1MSLR_100YR_140326		
	10YR	2100 Extreme 10-year WSE - low SLR scenario	N/A	1 m	-	-	Inundation_HumboldtBay/YEAR2000_w1MSLR_10YR_140326		
	MHHW	2100 MHHW Shoreline - low SLR scenario	N/A	1 m	-	-	Inundation_HumboldtBay/YEAR2000_w1MSLR_MHHW_140326		
	100YR	2100 Extreme 100-year WSE - mid SLR scenario	N/A	1.5 m	-	-	Inundation_HumboldtBay/YEAR2000_w1p5MSLR_100YR_140326		
	10YR	2100 Extreme 10-year WSE - mid SLR scenario	N/A	1.5 m	-	-	Inundation_HumboldtBay/YEAR2000_w1p5MSLR_10YR_140326		
	MHHW	2100 MHHW Shoreline - mid SLR scenario	N/A	1.5 m	-	-	Inundation_HumboldtBay/YEAR2000_w1p5MSLR_MHHW_140326		
	100YR	2100 Extreme 100-year WSE - high SLR scenario	N/A	2 m	-	-	Inundation_HumboldtBay/YEAR2000_w2MSLR_100YR_140326		
	10YR	2100 Extreme 10-year WSE - high SLR scenario	N/A	2 m	-	-	Inundation_HumboldtBay/YEAR2000_w2MSLR_10YR_140326		
	MHHW	2100 MHHW Shoreline - mid high scenario	N/A	2 m	-	-	Inundation_HumboldtBay/YEAR2000_w2MSLR_MHHW_140326		
Inundation - Open Coast	100YR	Existing 100-year total water level (extreme storm surge + waves)	2000	0 m	-	-	Inundation_AllDistrict1/YEAR2000_w0MSLR_100YR	Pacific Institute/PWA[5,6]	Developed using transects spaced at 500m intervals
	100YR	Future 100-year total water level (extreme storm surge + waves) at 2100	2100	1.4 m	-	-	Inundation_100YR_AllDistrict1/YEAR2000_w1p4MSLR_100YR		
	100YR Base Flood Elevation		2000	0 m		-	Inundation_100YR_AllDistrict1/Coastal_BFE		
Dune Erosion Hazard Zone - Open Coast	-	high end erosion at 2025	2025	1.4 m by 2100	-	-	ErosionHazardZones/DHZ_high_2025_final		
	-	high end erosion at 2050	2050	1.4 m by 2100	-	-	ErosionHazardZones/DHZ_high_2050_final		
	-	high end erosion at 2100	2100	1.4 m by 2100	-	-	ErosionHazardZones/DHZ_high_2100_final		
	-	low end erosion at 2025	2025	0.6 m by 2100	-	-	ErosionHazardZones/DHZ_low_2025_final		
	-	low end erosion at 2050	2050	0.6 m by 2100	-	-	ErosionHazardZones/DHZ_low_2050_final		
	-	low end erosion at 2100	2100	0.6 m by 2100	-	-	ErosionHazardZones/DHZ_low_2100_final		
Cliff Erosion Hazard Zone - Open Coast	-	high end erosion at 2025	2025	1.4 m by 2100	-	-	ErosionHazardZones/CHZ_high_2025_final		
	-	high end erosion at 2050	2050	1.4 m by 2100	-	-	ErosionHazardZones/CHZ_high_2050_final		
	-	high end erosion at 2100	2100	1.4 m by 2100	-	-	ErosionHazardZones/CHZ_high_2100_final		
	-	low end erosion at 2025	2025	0.6 m by 2100	-	-	ErosionHazardZones/CHZ_low_2025_final		
	-	low end erosion at 2050	2050	0.6 m by 2100	-	-	ErosionHazardZones/CHZ_low_2050_final		
	-	low end erosion at 2100	2100	0.6 m by 2100	-	-	ErosionHazardZones/CHZ_low_2100_final		
Landslide Susceptibility	-	Relative susceptibility - low to high	Existing	-	-	-	LandslideSusceptibility_north	CGS[7]	10m x 10m
	-	Relative susceptibility - low to high		-	-	-	LandslideSusceptibility_south		

1 World Climate Research Programme Coupled Model Intercomparison Project Phase 3 http://gdo-dcp.ucllnl.org/
2 Cal-Adapt.org compilation of fire risk data from UC Merced Climate Applications Lab http://cal-adapt.org/fire/
3 DWR, 2013. Draft Fire Exposure Assessment Methdology and GIS Mapping Products
4 Northern Hydrology Engineering, 2014. Humboldt Bay Sea Level Rise Adaptation Planning Project, Preliminary Sea-Level Rise Inundation Mapping Products
5 Pacific Institute, 2009. The Impacts of Sea-Level Rise on the California Coast
6 PWA, 2009. California Coastal Erosion Response to Sea Level Rise - Analysis and Mapping
7 California Geological Survey, 2011. Susceptibility to Deep-Seated Landslides in California. Map Sheet 58

Appendix 3

Caltrans TCR Segment Potential for Impact

Memorandum

15 October, 2014

To	Rex Jackman, Chief, Transportation Planning Caltrans District 1		
Copy to	Brad Mettam (Caltrans), Jamie Hostler (Caltrans), Marcella Clem (HCAOG)		
From	Rebecca Crow	Tel	707-443-8326
Subject	Caltrans TCR Segment Potential for Impact	Job no.	84/10842/20

1 Introduction

This memorandum describes the methods and results of an analysis to evaluate the potential for impact of transportation assets owned and maintained by the California Department of Transportation (Caltrans) District 1 in support of the project entitled "Caltrans District 1 Climate Change Pilot Study" (D1CCPS). The purpose of the overall project is to evaluate the vulnerability of Caltrans transportation assets in District 1 to various climate change factors and develop adaptation strategies for the most vulnerable assets. Vulnerability is defined by the Intergovernmental Panel on Climate Change (IPCC) as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes".

Vulnerability takes into consideration criticality (including consideration of socioeconomic, operational, and health and safety importance) and potential for impact (including consideration of exposure, sensitivity, and adaptive capacity). This memorandum presents the analysis of the potential for impact, while supporting memoranda present criticality and vulnerability.

In this memorandum, potential for impact is presented in terms of an impact score which is a function of climate change projections and resulting climate characteristics, how these characteristics can result in impacts to assets, as well as the sensitivity of those assets to the impact factors.

1.1 List of Attachments

The technical work within this memorandum is supported with additional more detailed information provided as attachments including the following:

Attachment A: Figure B1

Attachment B: Asset Sensitivity Matrix

Attachment C: ArcGIS Model Builder – Climate Data Analysis and Historical Data Analysis

Attachment D: Potential Impact Scoring Worksheet

Attachment E: Potential Impact Scores by climate factor and historic event

Attachment F: Comparison Graphs of the TCR Segment Potential Impact Scores, Climate Horizon 2050 A2.

Attachment G: Tabular TCR Segment Potential Impact Scores for Each Climate Projection

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2 Methodology

Transportation assets were grouped into highway Transportation Concept Report (TCR) segments based on Caltrans descriptions, which was discussed in the Technical Memo titles, Caltrans TCR Segment Criticality. The segments and existing assets were evaluated for the presence and magnitude of impact factors related to climate characteristics as well historical maintenance requirements. Potential impact factors were scored on a scale of 0 to 10 based upon criteria identified in the spreadsheets. The highest score for any single factor became the score for the segment. This is because any single factor can be the cause of the highest probable impact, rather than the cumulative impacts of different factors. This is much like the evaluation of sound intensity where the maximum intensity is the result of the loudest cause, not the addition of all the causes of sound.

The methodology began with the collection and organization of relevant data for the analysis.

2.1 Data Collection and Organization

2.1.1 Asset Sensitivity

Sensitivities of assets and the services the assets provide were evaluated based on feedback from technical staff at Caltrans as well as from historical emergency maintenance records provided by Caltrans. Caltrans' technical staff commented on general design standards, design life, considerations with regard to changes in climate scenarios (past and future), and anticipated climate impacts to assets. Historical emergency maintenance data were incorporated to supplement the information provided by Caltrans technical design staff. A summary of asset sensitivity with regards to traffic, bridges, stormwater facilities and roadway infrastructure is provided in the Asset Sensitivity Matrix in Attachment B. These sensitivities were used in the development of potential impact scoring worksheets, discussed in Section 2.3, Potential Impact Analysis.

2.1.2 Historical Emergency Maintenance Data

Historical emergency maintenance activities resulting from climate-related events were quantified to supplement and confirm information in the Asset Sensitivity Matrix, and to identify locations of historical emergency maintenance events. These data were categorized by the impact factor that caused the emergency maintenance event, and by the impact score, which relates to the severity of the effect of the emergency event. Locations of the maintenance needs resulting from events were also analyzed. The shorter the distance between events, the more events per mile existed and the greater the potential for impact due to an event.

Emergency maintenance information was gathered from State Highway Operation and Protection Program (SHOPP) from 1996 to 2014, Emergency Projects from 2004 to 2014 and maintenance supervisors' descriptions of chronic issues. The data generally included location, year, program/categorization codes, cost, and brief description of event, cause, and/or work done. The data were compiled and key words were used to categorize the events by climate related impact factors. Key words including drainage, erosion, slope movement, sea level, fire, and other non-climate or unknown events were used. Table 1 describes the type of events included in each impact factor category.

Table 1: Categorization of maintenance events was conducted using key description words.

Climate Impact Factor Category	Keywords
Drainage	Culvert, debris dam, drain, drainage, sink, washout, flood, flooded,
Erosion	Slope erosion, RSP, eroded
Fire	Fire damage, fire
Sea Level Rise	Tides, waves
Slope Movement	Slope, slip, slide, slipout, fill slope, landslide, shoulder failure, stabilization
Other	No description/lacking detail, earthquake, fish passage, mitigation, decommission, facilities, traffic

2.1.3 Climate Characteristics

Climate data compiled and processed for this D1CCPS were used to evaluate the exposure of critical Caltrans transportation assets in District 1 to a range of climate impact factors. Climate data is discussed in more detail in the Climate Data Projections for Caltrans District 1 Climate Change Pilot Study memorandum. Projections for each climate impact factor vary depending on the emission scenario, climate projection, and climate model.

Emissions Scenarios.

Two emissions scenarios were selected for use in this project representing different levels of global atmospheric carbon concentration:

The A2 emissions scenario projects mid-to-high emissions assuming continuous population growth and uneven economic and technological growth, resulting in tripling of the atmospheric carbon concentration by the end of the century.

The B1 emissions scenario represents lower projected emissions assuming carbon emissions peak by 2050 and then decrease by 2100. The B1 scenario results in a doubling of the atmospheric carbon concentration by the end of the century. This has been described as a “best case” scenario.

Climate Projections

Projections of 2050 and 2100 were used for the analysis and supplemented with other similar dates or ranges when these specific projection dates were not available.

Use of Climate Models

Climate models vary. Some show a decrease in climate characteristics such as precipitation, while others show an increase given the same emissions scenario and climate projection. Because Caltrans has an inherent need to protect its assets planning assumes worst case scenarios. Models reflecting these worst cases were used. For example, a model that showed an increase in precipitation was used to analyze the relative increase in precipitation along a segment and the Department of Water Resources’ “worst case” scenario for fire risk was used to analyze potential climate impacts of fire along a segment.

2.2 Data Analysis

The overall data analysis process to develop potential impact scores, depicted in Figure 1, consists of the following three major steps:

1. Perform a spatial analysis for each TCR segment with respect to asset types, historical events, and climate impact factors,
2. Quantify and extract the analysis data for potential impact scoring, and
3. Score the potential impacts for each TCR segment.

Asset data provided by Caltrans, consisting of TCR Segments (Roads), bridges and culverts were evaluated with climate data using ArcGIS software. An ArcGIS model was created to associate climate scenario projections (e.g. 2050 A2) with the geographic location of assets. An additional ArcGIS model was created to associate the historical maintenance events with the assets and TCR segments. From each ArcGIS model, a database file was generated containing a table for each spatial analysis of the projected climate scenarios or historical conditions. See Attachment C for the ArcGIS models.

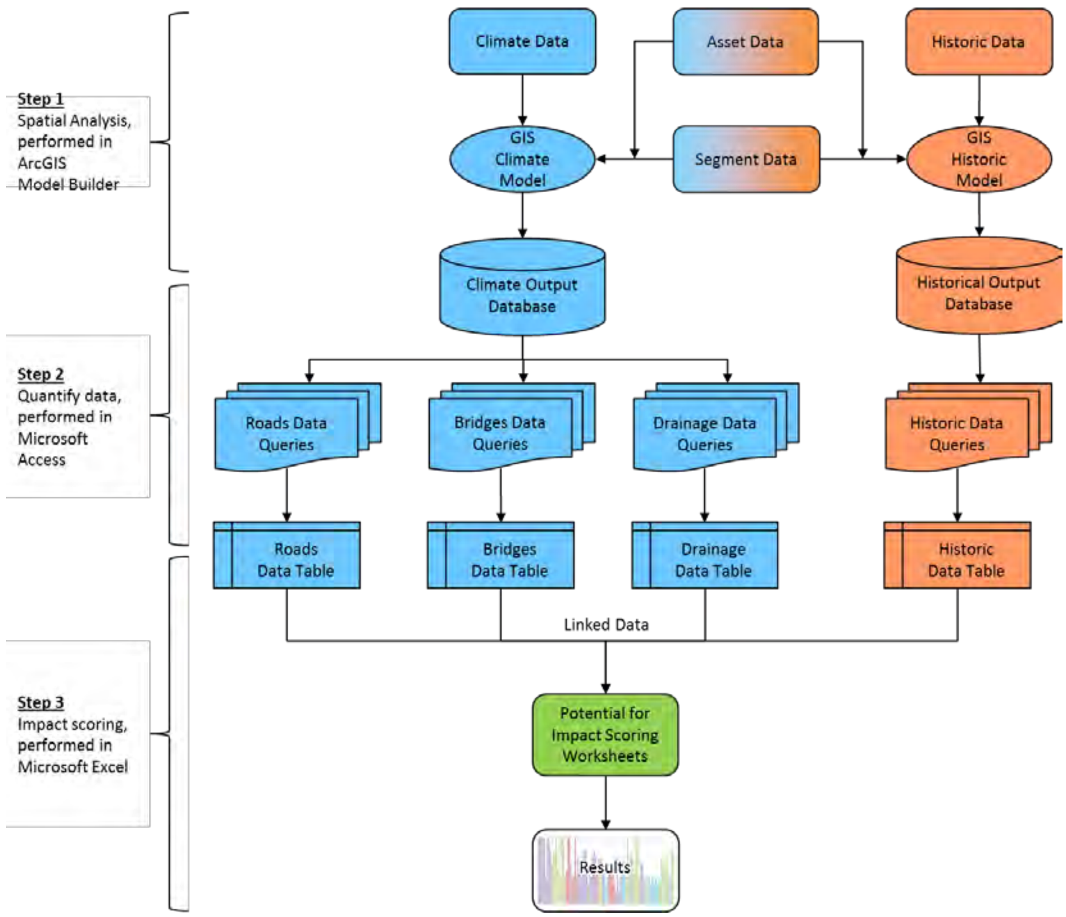
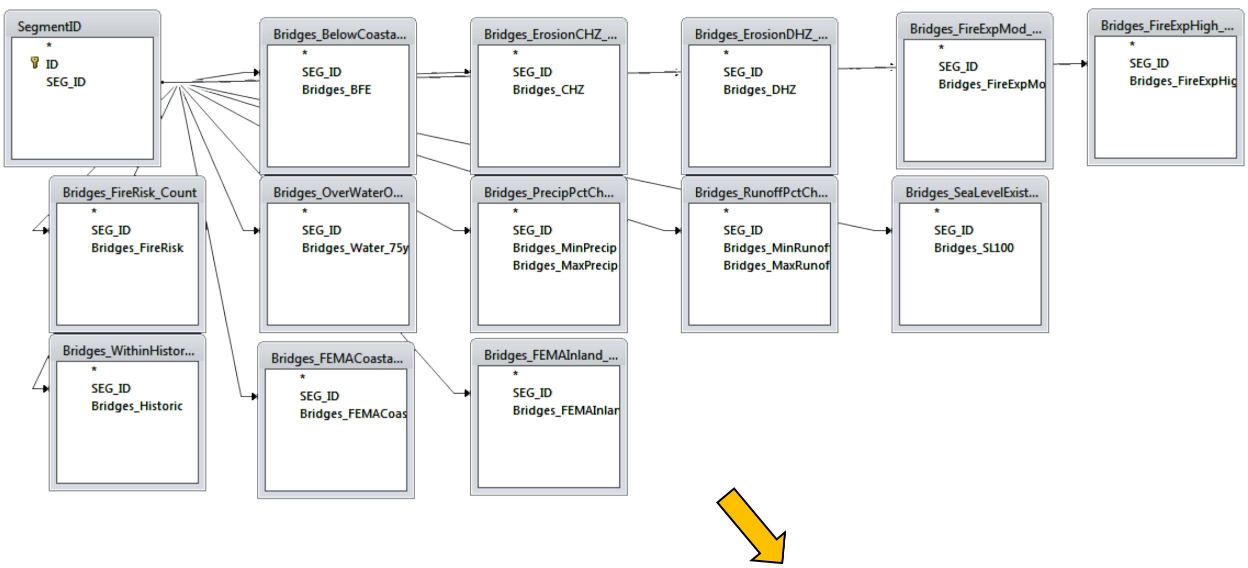


Figure 1: Models were created in ArcGIS to associate assets, climate impact factors and historical maintenance information in a database.

The database files generated from the spatial analyses were post-processed in Microsoft Access. Data queries were developed to quantify and extract tables containing the pertinent information for each TCR segment based on the assets and their various levels of exposure to projected future climate scenarios and historical maintenance events. Figure 2 illustrates a sample set of queries that quantify the exposure to bridges for each TCR segment. The advantage of the database approach was that geodatabase files created by ArcGIS were natively supported by Access. This allows data queries to the database without affecting the original spatial analysis data. Additionally, data query results were automatically updated when updates were made to the ArcGIS models.



ALL_BRIDGES

SEG_ID	Bridges_MinPrecip	Bridges_MaxPrecip	Bridges_Min	Bridges_Ma›
200_1	0.947179973125458	2.16140007972717	-8.9870996475	1.66059994698
211_3	0.746290028095245	1.27390003204346	-8.9870996475	7.91890001297
222_1	2.42350006103516	3.42319989204407	-3.4583001137	3.63070011139
253_1	1.52129995822906	2.42350006103516	-9.2122001648	3.63070011139
254_1	1.10230004787445	2.92810010910034	6.38119983673	7.91890001297
254_2	-0.0176439993083477	3.2386999130249	-0.9100999832	11.2749996185
255_1	-0.856610000133514	0.744889974594116	-8.9870996475	-5.1584000587
255_2	-0.856610000133514	-0.856610000133514	-8.9870996475	-8.9870996475
255_3				
255_4	-0.856610000133514	0.376419991254807	-8.9870996475	2.58139991760
271_1	1.10230004787445	1.32389998435974	-3.1398999691	0.44348999858
271_2	1.41999995708466	1.41999995708466	1.66059994698	1.66059994698
271_3	1.41999995708466	1.41999995708466	1.66059994698	1.66059994698
281_2				
283_1	2.1907000541687	2.1907000541687	5.72230005264	5.72230005264
29_1	-0.319489985704422	4.07509994506836	-5.7747998238	-5.7747998238

Figure 2: Access data queries joined to create a bridge exposure data table that quantifies the climate impacts for each TCR segment.

The information obtained from the queries was then linked to Potential Impact Scoring Worksheets to populate the worksheets for each segment.

2.3 Potential Impact Analysis

The Potential for Impact is assessed by evaluating both modeled climate change factors and historical maintenance events that point to road segments exacerbated by climate change events. The worksheets allow each segment of roadway (TCR segment) to be scored based on individual factors. The levels of potential impact previously defined as reduced capacity, temporary operational failure, and complete asset failure were evaluated by factors that could be rated on a scale of 0-10. Figure 3 lists the characteristics of the three classifications of potential impacts and are discussed in Section 2.3.1 and 2.3.2.

Reduced capacity impacts were given a score of 1 to 3. Reduced capacity is considered to have little-to-no impact to an asset with and only minor effects on the services provided by the assets consistent with routine maintenance activities. Reduced capacity is characterized by potential minor roadway speed reduction, brief traffic control measures, brief delays in access, potentially resulting in a reduced level of service.

Temporary operational failure potential impacts were given a score of 4 to 6, which is considered to be moderate impact to the assets. Temporary operational failure is characterized by minor repairs, traffic delays and/or traffic control measures for extended periods (hours to days), temporary re-rerouting of traffic, and potential for vehicle stranding.

Complete asset failure potential impacts were given a score of 7 to 10. Complete asset failure is considered to be a significant impact requiring reconstruction of all or a portion of an asset. Complete asset failure is characterized by extensive rehabilitation of assets, significant reduction of travel for extended periods of time and significant safety and stranding issues.

POTENTIAL FOR IMPACT TO DISTRICT INFRASTRUCTURE		
REDUCED CAPACITY	TEMPORARY OPERATIONAL FAILURE	COMPLETE FAILURE
1 2 3	4 5 6	7 8 9 10
• Minor repairs consistent with routine maintenance. • Potential minor roadway speed reduction, brief traffic control measures and brief delays in access.	• Moderate repairs and replacements required • Traffic delays and/or traffic control measures for extended periods (hours to days), temporary re-rerouting of traffic, and potential for vehicle stranding.	• Significant impact requiring reconstruction of a part of whole asset. • Extensive rehabilitation of assets, significant reduction of travel for extended periods of time and significant safety and stranding issues

Image 3: General characteristics potential impacts levels to District 1 infrastructure.

The worksheets are based upon the assessment of locally-derived data, and presented in Attachment D. Factors that could impact a road segment were classified according their potential to impact service, and the tables were developed so that scoring of factors would relate to a Potential for Impact score (0 to 10). Each segment would be evaluated with the two sets of criteria, presented in this memo as separate worksheets for clarity. The actual work is captured on two spreadsheets. One spreadsheet is used to capture raw data for each segment, which is linked to a second spreadsheet that is used to populate scores for each factor and segment. A highest score column is used to select the single highest Potential for Impact score for each segment.

By evaluating both potential climate change impacts and the historical maintenance events, it is possible to capture the variability of potential impacts. For example, a road segment on high ground is unlikely to be significantly impacted by climate-induced increased rainfall; however a segment with a history of drainage problems is quite likely to be impacted by this increase, and the severity of impact can be estimated by considering the record of prior costs.

2.3.1 Potential Climate Impact to Roadway (Potential Climate Impact) Scoring Worksheet

The Roadway Scoring Worksheet, also labelled Potential Climate Impact Scoring Worksheet associates scoring with each climate impact factor based on the information provided in the Asset Sensitivity Matrix. Climate impact factors such as fire, precipitation, runoff, and temperature were assigned potential impact scores within the range of 1 to 3, all categorized as reduced capacity. These climate impact factors, without association to specific assets and infrastructure are anticipated to make travel more difficult but do not indicate lasting damage to assets. How severely a climate impact factor affects an asset is gauged by its impact score. For example, temporary, rare impacts to assets are associated with the 100 year FEMA and coastal flood zones and would tend to have a low score for that asset. On the other hand, assets located in areas that are at an elevation below the projected mean higher high water (MHHW) or within a coastal erosion zone are considered to have the potential for complete failure due to regular inundation and/or erosion of structural components and bases and hence would have a much higher impact score.

2.3.2 Potential Historical Impact Indicators Scoring Worksheet

The scoring associated with each historical indicator was developed based on the information provided in the Asset Sensitivity Matrix and maintenance records. Maintenance data categorized by drainage, erosion, and slope movement was sorted by cost and general ranges were assigned to correspond to the potential impact categories. Maintenance issues are assumed to continue with or without the effect of climate change factors. For the purposes of this analysis, costs of damage events were categorized as follows:

- Less than $600,000: minor repairs not significantly disrupting service,
- Between $600,000 and $2,000,000: Replacements of single assets and can cause short term lane closures,
- More than $2,000,000: Replacement and repair of multiple assets and can cause long term traffic impacts including road closures.

For erosion related events, the following categorization was used:

- Less than $1,000,000: Additional or replacement of erosion protection measures,
- More than $1,000,000: More extensive work or multiple assets being replaced or protected.

Segments identified as chronic issues generally tended to have temporary operational issues that may be exacerbated by climate change factors. Those historical events with higher costs will tend to have a higher impact score.

A few design features were noted to be particularly vulnerable to impacts. These include plastic culverts within high risk fire zones could melt and cause minor service impacts, and bridges within erosion hazard zones have the potential for complete failure due to the erosion potential of structural elements.

3 Results

Figure 4 displays the results of the potential impact scoring process of the 93 TCR segments and subsegments in District 1 for climate projection 2050 A2. Results for climate projections 2100 A2, 2050 B1 and 2100 B1 demonstrate slight variability in potential impact scores for select segments. These differences are presented in Section 3.1. A detailed listing of the potential climate impact scores for each segment, for each climate projections, due to climate impact factors and historical events is listed in Attachment E. Graphical results for all of District 1 are presented in Attachment F. Attachment F also includes the results of criticality scoring as grouped by county. Tabular results for all of District 1 are presented in Attachment G. Attachment A Figure B1 displays these results on a District-wide map.

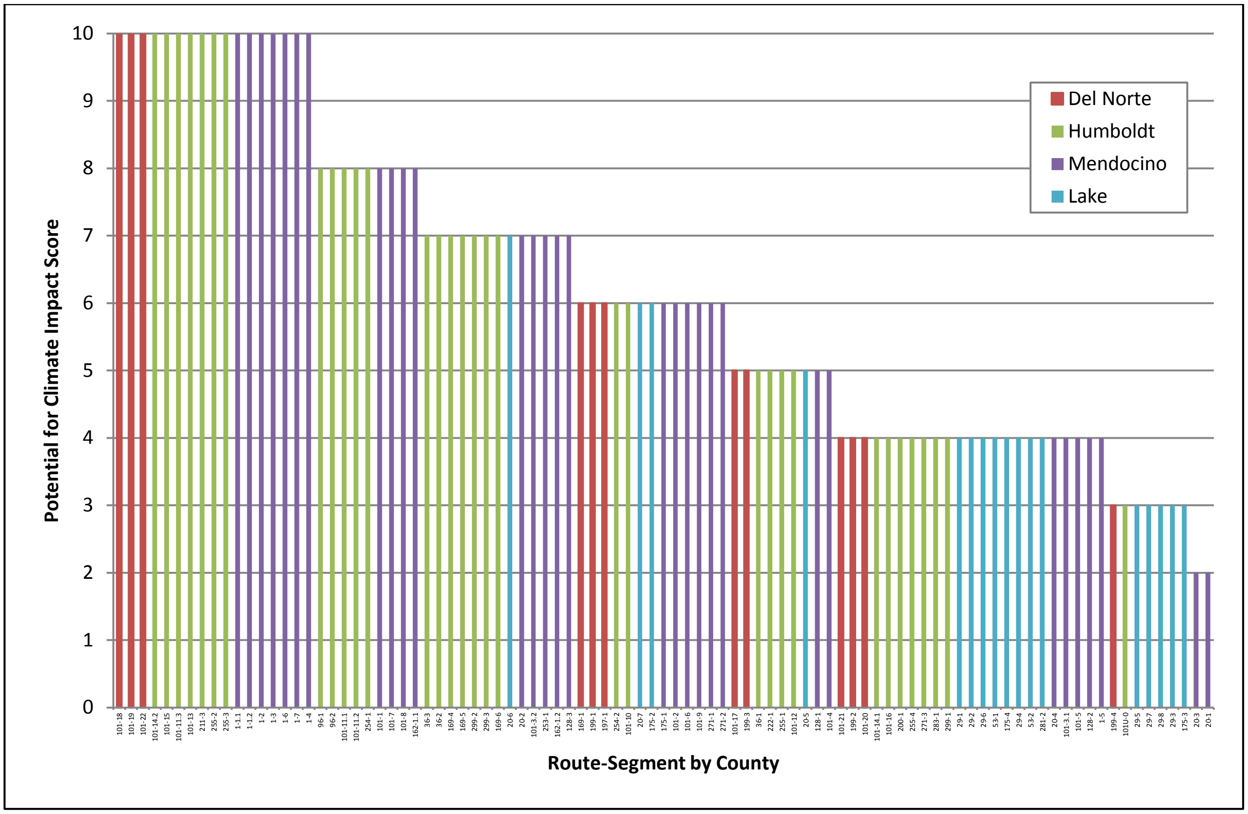


Figure 4: Potential for Climate Impact scores by county for all TCR segments under the 2050 A2 climate horizon.

As shown in Figure 4, the potential for impact scores range from 2 to 10. Figure 5 shows the distribution of potential climate impact scores by climate impact category. Nine of the 93 segments (10% of the total) have the potential for impacts that would cause a reduced capacity, 45 segments (48%) have the potential for temporary operational failure, and 39 segments (42%) have the potential for complete failure.

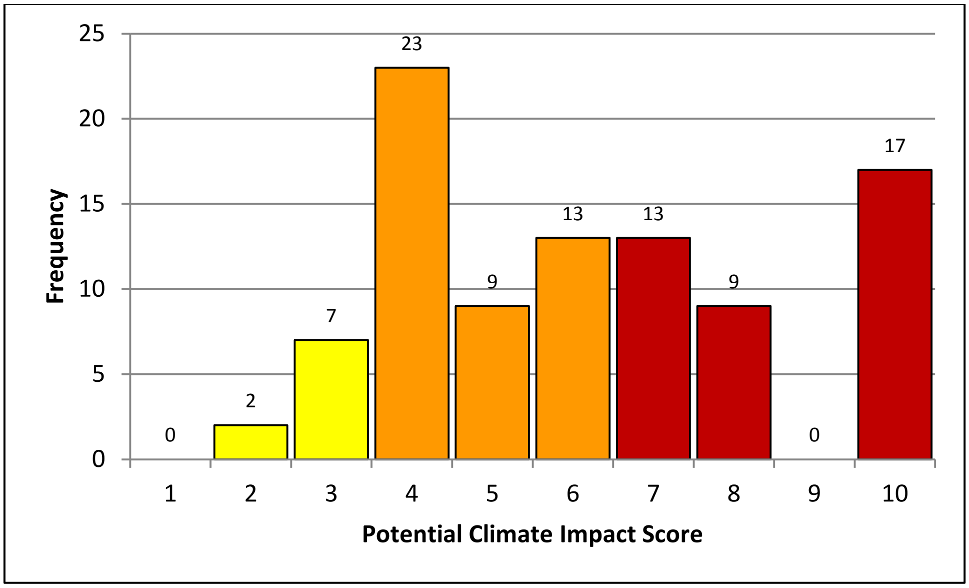


Figure 5: Distribution of the potential climate impact scores by category; reduced capacity (yellow), temporary operational failure (orange), and complete failure (red).

Figure 6 presents a summary of the number of segments that fall into each Level of Potential Impact for each Climate Impact Factor.

	Climate Impact Factors							
Level of Potential Impact	Historic Event Frequency	Increase in 95°F Temps	Increase in Runoff	100-Year Flood Events	Sea level rise	Chronic Drainage Issues	Historic Event Cost	Total segments in each Level of Potential Impact
Reduced Capacity	4,	4,	1,					9,
Temporary Operational Failure	13,			23,	2,	7,		45,
Complete Failure	13,				17,		9,	39,

Figure 6: Summary of Segments by Level of Potential Impact and Climate Events.

The potential climate impacts that would cause temporary operational failures include flooding events, historical events, and sea level impacts. Segments were identified as being impacted by potential flooding events where segments intersected either a 100-year coastal or FEMA floodplain. The segments with potential impacts associated with historical events had events spaced between 0.5 and 1.5 square miles.

The segments with sea level impacts were due to their potential exposure to annual high tides as a result of the projected sea level rise.

The potential climate impacts that may cause complete failure were due to significant historical events, erosion hazard zones, and sea level impacts. The segments with potential impacts associated with historical events had events spaced less than 0.5 square miles apart. The segments with potential impacts associated historical event costs had significant historical maintenance costs as a result of drainage and slope movement events. These costs ranged between $2-4 million per event for both types of events. The segments with potential sea level impacts included segments with a portion of the roadway or a bridge that was within a cliff or dune erosion hazard zone. In some instances, the sea level impacts also included exposure to the annual high tides. Seven of the segments intersect the projected annual high tide due to sea level rise. Of those seven, four of them intersect the existing annual high tide.

3.1 Comparison of Climate Projections

The previous results were based upon the A2 climate projection for 2050, in addition to historical events. The remaining climate projections 2050 B1, 2100 A1, and 2100 B1 were also used to model levels of potential impact. While the resulting potential impact scores model mostly agreed regardless of the model used, there were five segments whose scores differed between models as presented in Table 2.

Table 2: Changes in segment potential impact scores across climate projections.

Segment	Climate Projection Potential Impact Score			
	2050 A2	**2050 B1**	**2100 A2**	**2100 B1**
20-1	2	2	1	2
20-3	2	2	3	3
29-5	3	2	3	3
101-12	4	4	5	4
255-1	5	5	10	10

This was mainly due to the differing climate projections of the climate scenarios, in which extreme precipitation and extreme temperatures vary as presented in Table 3.

Table 3: Variation between models

<table>
<tr><th colspan="2">Climate Scenario</th><th>Increase in extreme precipitation</th><th>Increase in extreme temperature (average estimate)</th></tr>
<tr><td rowspan="2">A2</td><td>2050</td><td>4%</td><td>5</td></tr>
<tr><td>2100</td><td>8%</td><td>12.5</td></tr>
<tr><td rowspan="2">B1</td><td>2050</td><td>15%</td><td>+/- 4.5</td></tr>
<tr><td>2100</td><td>19%</td><td>+/- 7</td></tr>
</table>

Two segments had changes in their potential impact as a result of sea level rise, and three were due to other climate factors. Table 4 summarizes by segment the variation in the climate model that resulted in a differing score. “ALL” is used to denote that the change applies to both the A2 and B1 climate scenarios.

Table 4: Changes in the general potential impact to a segment by climate projections.

Segment	Climate Projections	General Change in Climate Factor
20-1	2050 A2 *to* 2100 A2	Change in runoff decreased below 10%
20-3	2050 *to* 2100 ALL	Number of 95°F days increased from 5-10 days to greater than 10 days
29-5	2050 A2 *to* 2050 B1	Number of 95°F days decreased to less than 10
	2050 B1 *to* 2100 ALL	Number of 95°F days increased to greater than 10
101-12	2050 ALL *to* 2100 A2	Intersects with annual high tide events due to sea level rise
255-1	2050 ALL *to* 2100 ALL	Intersects with daily high tide events due to sea level rise

4 Discussion

The potential climate impact scores for each segment were derived from the asset sensitivity, historical data, and climate impact factors. Review of the data suggests that potential climate impact is generally a function of proximity to the coast and historical events.

Segments along the coast are exposed to potential impacts from erosion and/or inundation associated with rising sea level. The presence of these potential exposures was evaluated based on the intersection of any portion of the roadway with the estimated extent of erosion and sea level inundation. Sea level inundation was coarsely estimated for post miles under 10 feet elevation. Segments with close proximity to existing daily high tides were further investigated where more detailed elevation data were available. These post miles were often located near tidally influenced sloughs and creeks. Differences of up to 5 feet were noted between the coarse elevations and more detailed topography. However, while these portions of the roadway may not be inundated on a daily basis, they are in low lying areas, within close proximity to areas of daily tidal inundation and are susceptible to the compounding effects of the freshwater-tidal processes.

Historical event frequency and magnitude of events were used to indicate segments with existing issues related to climate factors. Areas with costly and/or a high frequency of maintenance events are assumed to likely continue to experience impacts with any increases in climate factors and in fact may be exacerbated through increased precipitation, for example.

The potential impact score related to sea level was found to be relatively consistent between climate scenarios. This is because impact was indicated at the scale of a road segment. While sea elevation changed in the models, segments affected by the results of one model, tended to be affected (although to a different degree) by another model. The one exception was a segment of Highway 255 around Humboldt Bay, which was found to be affected by the 2100 models, but not the 2050 models due to the particular topographic issues. There were also instances where the coastal erosion zones increased in area due to sea level rise, but the adjacent segment potential impacts did not change. There was no change to these segments because they already intersected the erosion zone and thus any additional portions of the seg-ment within the zone did not affect the resulting completed failure impact. These types of findings point to the need to use this analysis tool for macro scale screening and then complete more detailed site specific analyses for areas where a greater understanding is desired or where project decisions need to be made.

5 Conclusions

Segments with high potential impact scores are typically located along the coast with sea level, flood or erosion hazards, or have demonstrated costly or high frequency maintenance efforts. Fire, precipitation, runoff and temperature climate factors in the absence of historical events are not anticipated to have significant potential for impact to transportation assets. However, the magnitude and frequency of impacts related to climate factors is assumed to continue if existing conditions are maintained or any increase in climate factors is anticipated.

6 References

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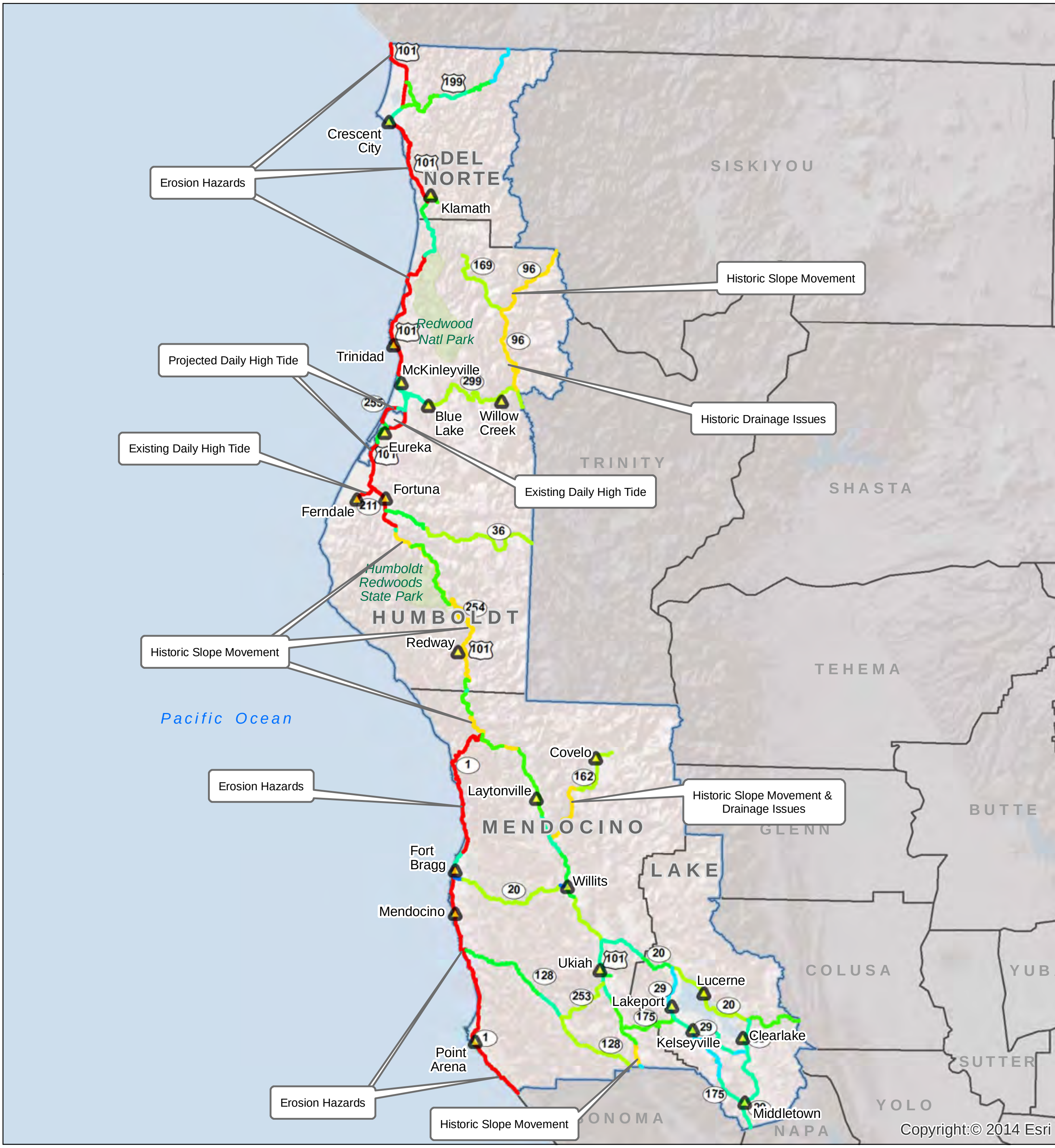
US Department of Transportation (September 2012). Assessing the Sensitivity of Transportation Assets to Climate Change in Mobile, AL. Task 2.4. FHWA-HEP-12-045.

ESA/PWA. (2014). Climate Data Projections for Caltrans District 1 Climate Change Pilot Study.

Attachment A

Figure B1



Potential For Impact Score
Low = 1, High = 10

1
2
3
4
5
6
7
8
9
10

City
National or State Park
District 1 Boundary
County Boundary
Outside of District 1

Paper Size 8.5" x 11" (ANSI A)

0 10 20 30 40 50
Miles
Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

N

GHD ESA

Caltrans District 1 and HCAOG
District 1 Climate Change Pilot Study

Job Number | 84-11905
Revision | A
Date | 01 Jul 2014

Climate Horizon 2050 A2
Potential for Impact Score Per TCR Segment

Figure B1

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\\ghdnet\ghd\US\Eureka\Projects\11905 HumCoAssocGovernments\8410842 HCAOG_CCVA_District 1\08-GIS\Maps\Working\ReportFigures\84_10842_FXX_PotentialForImpact_2050_A2.mxd

Attachment B

Asset Sensitivity Matrix

Attachment B: Asset Sensitivity Matrix

Asset or Service	Adaptive Capacity/Design Life	Temperature	Precipitation	Runoff	Fire	Erosion	Sea Level Rise
Traffic Flow		None anticipated	Light Rain: 2-4% roadway speed reduction Heavy Rain: 4-7% roadway speed reduction	Excess runoff may increase hazardous conditions, and potential for accidents.	Throttles or blocks flow of traffic. Often requires traffic detours via nearest safe alternate route. Sensitivity depends on scale of fire and level redundancy.	Throttles or blocks flow of traffic. Often requires traffic detours via nearest safe alternate route. Sensitivity depends on scale of fire and level of redundancy.	Blocks flow of traffic. Sensitivity depends on elevation of alternate routes.
Bridges (Overpasses, Railroad, Water Crossings)	Low Adaptive Capacity Do not tend to see issues with drainage and exposure to climate due to large, intense, conservative design measures. In the past a 50 year design life was used. Modern design life is 75 years and occasionally 100 years.	Negligible to atmospheric temperature changes. Designed with a safety factor of 1.5-1.8 and would require an increase of 30°F-50°F above normal to have an effect.	None noted	Occasional debris may hit bridge	Average wildfire surface temp is 800°C (1472°F). Extreme fire surface temperatures can reach 1200°C (2,192°F). Temperatures of 1000°F to 1200°F begin to change crystal structure of steel materials in bridge.	Embankments may be damaged. Scour associated with large storm events.	Not a serious concern with a SLR of 3 feet.
Storm Water Facilities	Adaptive capacity varies. Culverts are replaced as needed. Fish passage design incorporates increased capacity. Many culverts in the district are at the end of their life span. Designed on a case-by-case basis. Often check with maintenance staff	None anticipated	Culverts are based on NOAA rainfall data. Latest Atlas 14 was implemented in 2012 and a 15-20% increase was noted. The 10 and 100 year storms are analyzed for cross culverts. Culverts may fail due to slope failure, washout/overwhelmed, debris,	Cross Culverts are designed for the 25 year run-off event. Extreme events are considered and incorporated. Tributary Drainage Areas (TDAs): Associated with discharge point. TDAs are defined by Caltrans ROW boundaries and investigation of drainage features, highway slope, and other indicators.	Plastic drains are susceptible to fire exposure. HDPE and PVC culverts may fail under exposure to fire.	Landslides and debris prevents or limits drainage capacity	May cause backwatering where stormwater outfalls to sea. Issues with tide debris and high tides.

Attachment B: Asset Sensitivity Matrix

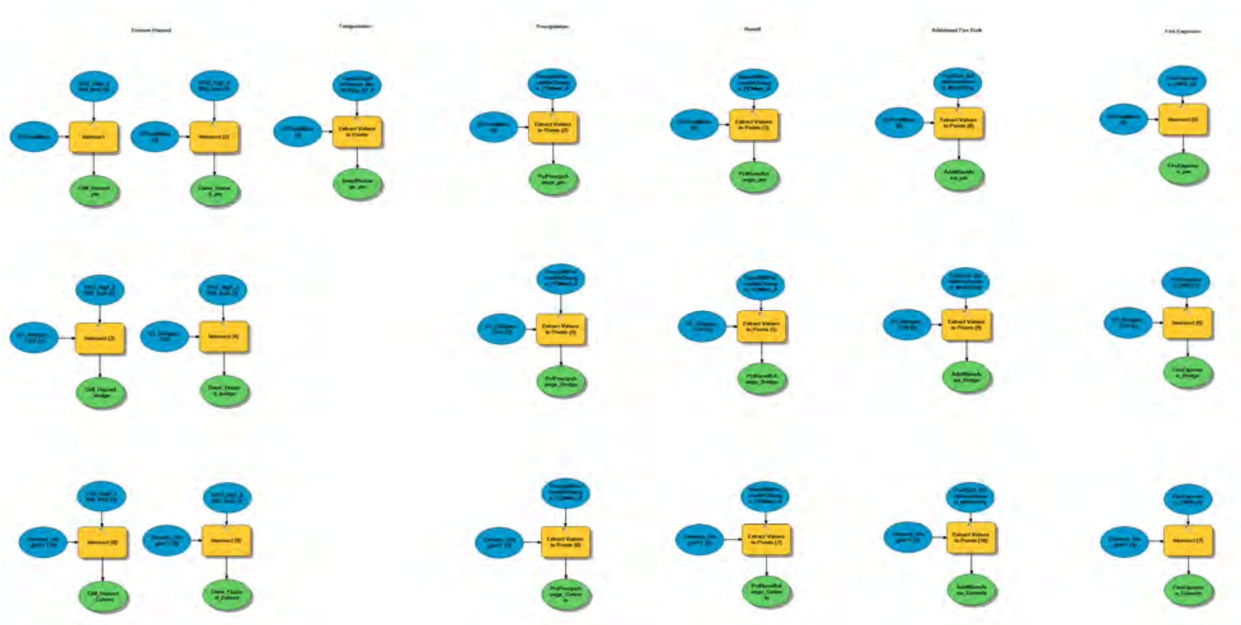
Asset or Service		Adaptive Capacity/Design Life	Temperature	Precipitation	Runoff	Fire	Erosion	Sea Level Rise
Roadway	Pavement	Generally a 20 year planning horizon. Design life of overlay is 7-10 years, asphalt is 20 years, and PCM is 40+ years. Quarry materials are becoming more scarce and higher costs are anticipated. Design is based on climate regions.	Based on Climate Regions. Climate region boundaries are subject to change and thus design as climate changes.	Structural section/Fill prism influenced by infiltration of water into the cross section causing sinks and other failures on shoulders and slopes	Structural section could also be influenced by infiltration of water into the cross section. Can contribute to failure of retaining walls with instability in slopes and erosion Washout and/or damage to substructure	Wooden guardrails and other wooden or plastic assets may be destroyed	RSP is used on slope to armor against erosion. Can contribute to failure of retaining walls Washout and/or damage to substructure	RSP is used on slope to armor against wave run-up Structural section could also be influenced by infiltration of water into the cross section
Roadway	Amenities and Buildings		Critical maintenance engine/equipment heat stress at 105-110F, and >110F restricts maintenance operation	None noted	Amenity structures may be rendered temporarily inaccessible	Amenity structures may be damaged or destroyed	Amenity structures may be damaged from landslides and rendered temporarily inaccessible	Amenity structures may be damaged or destroyed
Roadway	Traffic Control Systems		None noted	Heavy rainfall can limit signal visibility	Flooding may damage electrical components causing traffic signal and other electrical equipment to malfunction	Traffic operating systems may be destroyed	Traffic operating systems may be unearthed if foundation/footings are not buried deep enough.	Signals no longer operable

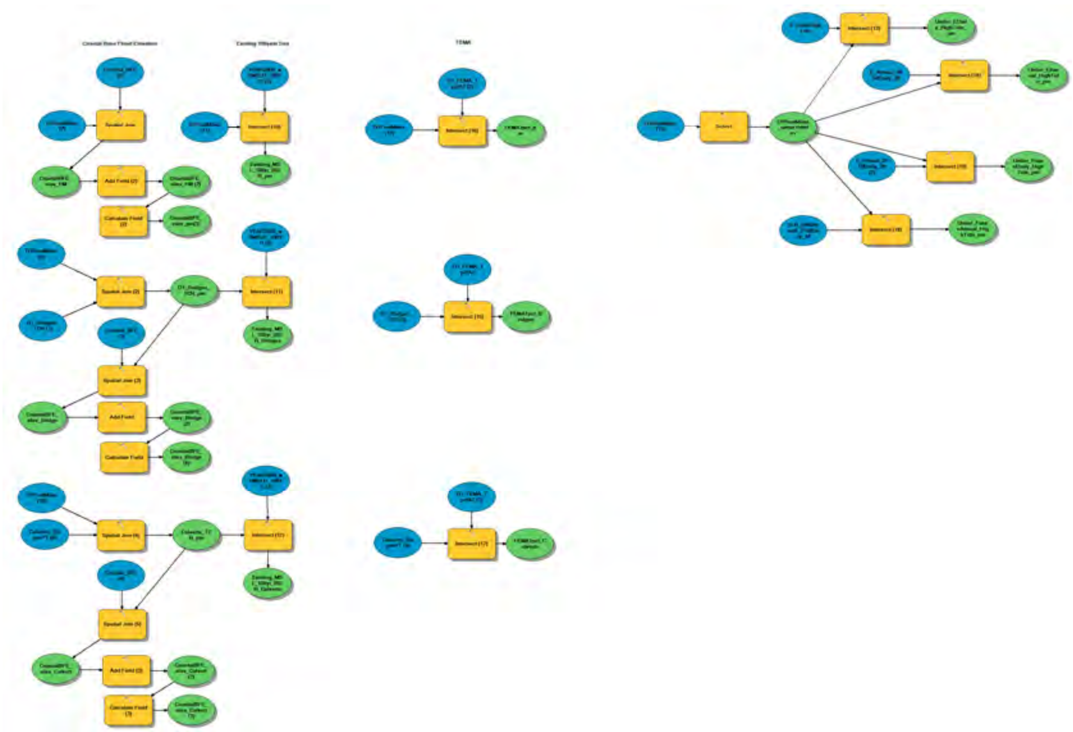
Attachment C

ArcGIS Model Builder – Climate Data Analysis and Historical Data Analysis

Attachment C: ArcGIS Model Builder

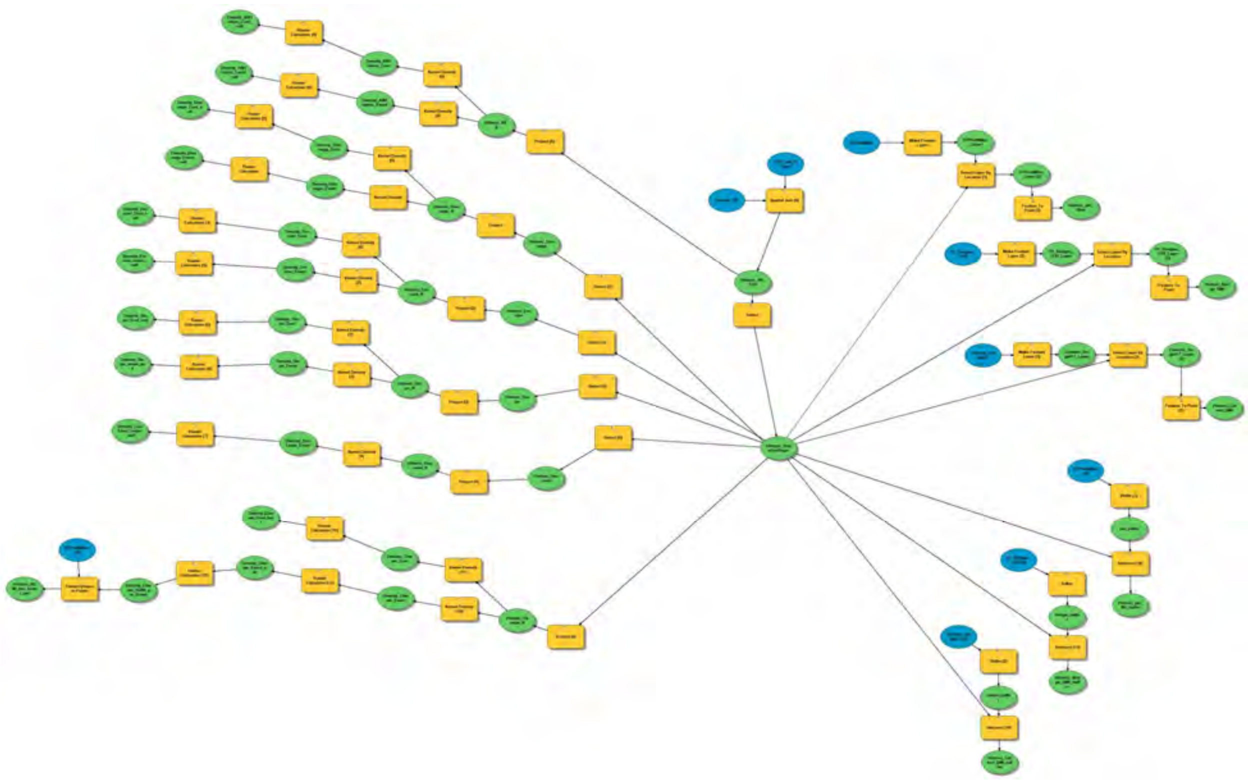
Climate Data Analysis (Part 1)





Attachment C: ArcGIS Model Builder

Historic Data Analysis



Attachment D

Potential Impact Scoring Worksheet

POTENTIAL CLIMATE IMPACT SCORING WORKSHEET

Factors / Impact Scores	No Impact	Reduced Capacity			Temporary Operational Failure			Complete Failure				Factor Score
	0	1	2	3	4	5	6	7	8	9	10	
ROADWAY SEGMENTS												
Max Fire (Fire Risk)	None	Moderate		High								
Max Precipitation (% change in 98^{th} percentile storm)	<0%	0-10	>10									
Max Runoff (% change in 98^{th} percentile storm)	<0%	0-10	>10									
Max Temperature (change in number of days >95°F)	<0 days	0-5	5-10	>10								
Intersects 100 year effective FEMA Floodplain(s)	No				Yes							
Intersects within 100-year Coastal Flooding	No				Yes							
Intersects with Annual High Tide due to Sea Level Rise	No					Yes						
Intersects with Daily High Tide due to Sea Level Rise	No										Yes	
Intersects Coastal (Dune or Cliff) Erosion Hazard Zone	No										Yes	
CULVERTS												
Plastic Culverts within High Risk Fire Zone	None		High									
BRIDGES												
Bridge within Erosion Hazard Zone (Dune or Cliff)	No										Yes	
								Maximum Factor Score				

POTENTIAL HISTORICAL IMPACT INDICATORS SCORING WORKSHEET												
Impact Scores / Factors	No Impact	Reduced Capacity			Temporary Operational Failure			Complete Failure				Factor Score
	0	1	2	3	4	5	6	7	8	9	10	
Maximum Cost of Historic Drainage Events w/ increase in Precipitation or runoff	$0	$0-200K	$200-400K	$400-600K	$600-800k	$800K-1M	$1-2M	$3-4M	>$4M			
Maximum Cost of Historic Erosion Events w/ increase in Precipitation or runoff	$0		$0-1M				>$1M					
Maximum Cost of Historic Slope Movement Events w/ increase in Precipitation or runoff, or within High Fire Risk	$0	$0-200K	$200-400K	$400-600K	$600-800k	$800K-1M	$1-2M	$3-4M	>$4M			
Historic drainage, erosion, slope failure event density as square miles per event at culvert location	>20 mi^2	10-20	5-10	2-5	1.5-2	1-1.5	0.5-1	<0.5				
Segment intersects with Existing Daily High Tide	No										Yes	
Segment within Identified Chronic Drainage Issue Areas	No					Yes						
Segment within Identified Chronic Slope Movement Areas	No			Yes								
Segment within Identified Chronic Sea Level Issue Areas	No					Yes						
								Maximum Factor Score				

Attachment E

Potential Impact Scores by Climate Factor and Historic Event

Attachment E: Potential impact scores by climate factor and historic event

Highway	TCR Segment	Segment Description	Potential Climate Impact To Roadway Scoring Worksheet											Potential Historical Impact Indicators Scoring Worksheet								Potential Impact Score (Max)
			Roadway Segments									Culverts	Bridges									
			Max Fire (Fire Risk)	Max Precipitation (% change in 98th percentile storm)	Max Runoff (% change in 98th percentile storm)	Max Temperature (change in number of days >95°F)	Intersects 100 year effective FEMA Floodplain(s)	Intersects within 100-year Coastal Flooding	Intersects with projected Annual High Tide due to Sea Level Rise	Intersects with projected Daily High Tide due to Sea Level Rise	Intersects with Coastal (Dune or Cliff) Erosion Hazard Zone	Plastic Culverts within High Risk Fire Zone	Bridge within Erosion Hazard Zone (Dune or Cliff)	Maximum Cost of Historic Drainage Events w/ increase in Precipitation or runoff	Maximum Cost of Historic Erosion Events w/ increase in Precipitation or runoff	Maximum Cost of Historic Slope Movement Events w/ increase in Precipitation or runoff, or within High Fire Risk	Historic drainage, erosion, slope failure event density as square mile per event at culvert location	Segment intersects with Existing Daily High Tide	Segment within Identified Chronic Drainage Issue Areas	Segment within Identified Chronic Slope Movement Areas	Segment within Identified Chronic Sea Level Issue Areas	
1	1.1	Sonoma/Mendocino County line to Point Arena (north)	0	1	0	1	4	4	0	0	10	0	0	7	0	2	5	0	0	0	5	**10**
	1.2	Point Arena (north) to Route 128	0	1	1	1	4	4	0	0	10	0	0	5	6	6	6	0	0	0	0	**10**
	2	Junction Route 128 to Little River	0	1	1	1	4	4	0	0	10	0	0	0	0	0	3	0	0	0	0	**10**
	3	Little River to south Fort Bragg City limit	0	1	2	1	4	4	0	0	10	0	10	0	0	0	3	0	0	0	0	**10**
	4	So. Fort Bragg City limits to No. Fort Bragg City limit	0	1	2	0	4	4	5	10	0	0	0	0	0	0	0	0	0	0	0	**10**
	5	No. Fort Bragg City limits to Little Valley Road	0	1	2	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**
	6	Little Valley Road to North Westport	0	1	2	0	4	4	5	10	10	0	0	2	0	8	6	10	5	0	5	**10**
	7	North Westport to Junction Rte. 101 at Leggett	0	1	2	1	4	4	0	0	10	0	10	7	6	6	6	0	0	0	0	**10**
20	1	From Route 1 at Fort to Summer Lane	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
	2	Summer Lane to Broaddus Creek	1	1	2	2	0	0	0	0	0	0	0	2	0	7	6	0	0	0	0	**7**
	3	Broaddus Creek to Route 101 at Willits	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
	4	Route 101 to MEN/LAK Co. Line	1	1	1	3	4	0	0	0	0	0	0	1	0	0	3	0	0	0	0	**4**
	5	MEN/LAK Co. Line to Route 29	1	1	1	3	4	0	0	0	0	0	0	0	0	0	4	0	5	0	0	**5**
	6	Route 29 to Route 53	0	1	1	3	4	0	0	0	0	0	0	0	0	7	4	0	5	0	0	**7**
	7	Route 53 to LAK/COL Co. Line	1	1	0	3	4	0	0	0	0	0	0	0	0	6	5	0	5	0	0	**6**
29	1	Napa/Lake Co. line to Junction Route 175	1	1	0	3	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	**4**
	2	Junction Route 175 to Junction Route 53	1	1	0	2	4	0	0	0	0	0	0	0	2	4	4	0	0	0	0	**4**
	3	Junction Route 53 to North of Diener Drive	1	1	0	2	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	**3**
	4	North of Diener Dr to North of Junction Rte. 175	0	1	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**
	5	No. of Junction Rte. 175 to Kelseyville	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
	6	Kelseyville to 0.5 mile South of Lakeport (w/ Rte 175)	0	0	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**
	7	0.5 mile South of Lakeport City limit to 0.7 mile North of Lucerne Cutoff	0	1	1	3	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	**3**
	8	0.7 mile North of Lucerne Cutoff to Junction Route 20	0	1	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
36	1	Rte 101 to Hely Creek Bridge	0	1	1	1	4	0	0	0	0	0	0	0	0	0	5	0	5	0	0	**5**
	2	Hely Creek Bridge	0	1	1	1	4	0	0	0	0	0	0	6	0	7	5	0	0	0	0	**7**
	3	Bridgeville to Trinity Co. Line	0	1	2	2	4	0	0	0	0	0	0	7	0	7	7	0	0	0	0	**7**
53	1	Junction SR 29 to 40th Ave. City of Clearlake	1	1	0	3	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	**4**
	2	40th Ave to Junction SR 20	1	1	0	3	4	0	0	0	0	0	0	1	0	0	3	0	0	0	0	**4**
96	1	Rte. 299 to 1.3 km (0.8 mi) south of Rock Chute Viaduct.	0	1	2	3	0	0	0	0	0	0	0	8	0	3	6	0	5	0	0	**8**
	2	1.3 km (0.8 mi) south Rock Chute Viaduct to HUM Co. line.	0	1	2	3	0	0	0	0	0	0	0	6	0	8	6	0	0	0	0	**8**

Attachment E: Potential impact scores by climate factor and historic event

Highway	TCR Segment	Segment Description	Potential Climate Impact To Roadway Scoring Worksheet											Potential Historical Impact Indicators Scoring Worksheet								Potential Impact Score (Max)
			Roadway Segments									Culverts	Bridges									
			Max Fire (Fire Risk)	Max Precipitation (% change in 98th percentile storm)	Max Runoff (% change in 98th percentile storm)	Max Temperature (change in number of days >95°F)	Intersects 100 year effective FEMA Floodplain(s)	Intersects within 100-year Coastal Flooding	Intersects with projected Annual High Tide due to Sea Level Rise	Intersects with projected Daily High Tide due to Sea Level Rise	Intersects with Coastal (Dune or Cliff) Erosion Hazard Zone	Plastic Culverts within High Risk Fire Zone	Bridge within Erosion Hazard Zone (Dune or Cliff)	Maximum Cost of Historic Drainage Events w/ increase in Precipitation or runoff	Maximum Cost of Historic Erosion Events w/ increase in Precipitation or runoff	Maximum Cost of Historic Slope Movement Events w/ increase in Precipitation or runoff, or within High Fire Risk	Historic drainage, erosion, slope failure event density as square mile per event at culvert location	Segment intersects with Existing Daily High Tide	Segment within Identified Chronic Drainage Issue Areas	Segment within Identified Chronic Slope Movement Areas	Segment within Identified Chronic Sea Level Issue Areas	
101	0	101U: SON/MEN Co. line to Jct. Rte. 101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	**3**
	1	SON/MEN Co. line to Pieta Creek	0	1	0	3	4	0	0	0	0	0	0	4	0	8	7	0	0	3	0	**8**
	2	Pieta Creek to South of Ukiah	0	1	0	3	4	0	0	0	0	0	0	0	0	2	6	0	0	0	0	**6**
	3.1	South of Ukiah to Rte 20	0	1	1	3	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	**4**
	3.2	Rte 20 to South of Willits	1	1	1	3	4	0	0	0	0	0	0	7	0	6	7	0	0	3	0	**7**
	4	South of Willits to Arnold	1	1	1	2	4	0	0	0	0	0	0	0	0	0	5	0	0	0	0	**5**
	5	Arnold to South of Laytonville	1	1	1	1	4	0	0	0	0	0	0	0	0	0	4	0	0	0	0	**4**
	6	South of Laytonville to Bell Springs Rd.	1	1	1	1	4	0	0	0	0	0	0	0	0	0	6	0	0	0	0	**6**
	7	Bell Springs Rd. to Jct. Rte. 1 at Leggett	1	1	1	1	4	0	0	0	0	0	0	2	0	8	6	0	0	0	0	**8**
	8	Jct. Rte. 1 at Leggett to Red Mountain Creek	0	1	1	1	4	0	0	0	0	0	0	0	0	8	5	0	0	0	0	**8**
	9	Red Mountain Creek to MEN/HUM County line	0	1	1	1	4	0	0	0	0	0	0	4	0	4	6	0	0	0	0	**6**
	10	MEN/HUM County line to North of Richardson Grove	0	1	2	3	0	0	0	0	0	0	0	0	0	0	6	0	5	0	0	**6**
	11.1	North of Richardson Grove to Weott	0	1	1	2	4	0	0	0	0	0	0	7	0	8	7	0	0	0	0	**8**
	11.2	Weott to north of Rio Dell	0	1	1	0	4	0	0	0	0	0	0	1	0	8	6	0	0	0	0	**8**
	11.3	North of Rio Dell to South Eureka Urban boundary	0	1	2	0	4	4	5	10	0	0	0	1	0	2	4	0	5	0	0	**10**
	12	South Eureka Urban boundary to near North Eureka city limits	0	1	2	0	4	4	5	0	0	0	0	0	0	0	3	0	0	0	0	**5**
	13	Near North Eureka city limits to Jct. Rte 255	0	1	0	0	4	4	5	10	0	0	0	0	0	0	3	10	0	0	5	**10**
	14.1	Jct 255 to Airport	0	1	1	0	4	4	0	0	0	0	0	2	0	0	4	0	0	0	0	**4**
	14.2	Airport to Big Lagoon	0	1	1	0	4	4	0	0	10	0	10	2	0	0	3	0	0	0	0	**10**
	15	Big Lagoon to Redwood National Park Bypass	0	1	1	1	4	4	0	0	10	0	0	7	0	8	7	0	0	0	5	**10**
	16	Redwood National Park Bypass	0	1	1	1	4	0	0	0	0	0	0	0	0	0	4	0	0	0	0	**4**
	17	HUM/DN Co. line to Kamp Klamath	0	1	0	0	4	4	0	0	0	0	0	0	0	0	5	0	0	0	0	**5**
	18	Del Norte Redwoods State Park Area	0	1	0	0	4	4	0	0	10	0	0	0	0	0	7	0	5	0	0	**10**
	19	Wilson Creek to South of Crescent City.	0	1	1	0	0	4	0	0	10	0	10	6	0	8	7	0	5	0	5	**10**
	20	South of Crescent City to North of Crescent City	0	1	1	0	0	4	0	0	0	0	0	1	0	0	3	0	0	0	0	**4**
	21	North of Crescent City to Jct. Rte. 199	0	1	1	0	4	4	0	0	0	0	0	0	0	0	3	0	0	0	0	**4**
	22	Jct. Rte. 199 to Oregon border	0	1	1	1	4	4	0	0	10	0	0	0	0	0	3	0	0	0	0	**10**
128	1	Route 1 to Indian Creek Bridge	0	1	1	1	4	4	0	0	0	0	0	1	0	0	4	0	5	0	0	**5**
	2	Indian Creek Bridge to Route 253	1	1	0	1	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	**4**
	3	Route 253 to the Sonoma County Line	1	1	0	2	4	0	0	0	0	0	0	7	0	7	6	0	0	0	0	**7**
162	1.1	Route 101 to PM 16.76	1	1	1	1	4	0	0	0	0	0	0	8	0	8	7	0	5	0	0	**8**
	1.2	PM 16.76 to Short Creek Bridge	1	1	2	3	4	0	0	0	0	0	0	0	6	3	7	0	5	0	0	**7**

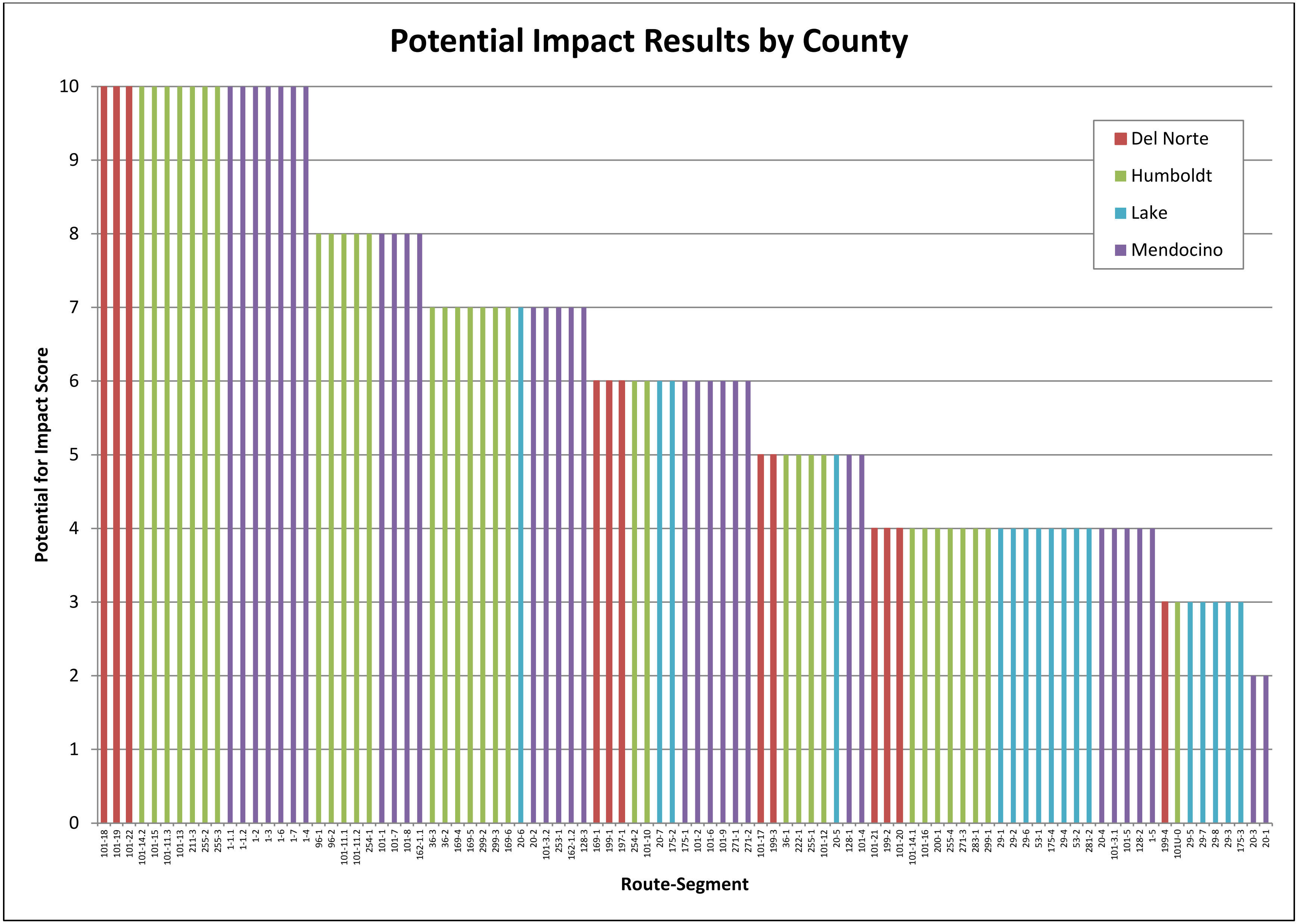
Attachment E: Potential impact scores by climate factor and historic event

Highway	TCR Segment	Segment Description	Potential Climate Impact To Roadway Scoring Worksheet											Potential Historical Impact Indicators Scoring Worksheet								Potential Impact Score (Max)
			Roadway Segments									Culverts	Bridges									
			Max Fire (Fire Risk)	Max Precipitation (% change in 98th percentile storm)	Max Runoff (% change in 98th percentile storm)	Max Temperature (change in number of days >95°F)	Intersects 100 year effective FEMA Floodplain(s)	Intersects within 100-year Coastal Flooding	Intersects with projected Annual High Tide due to Sea Level Rise	Intersects with projected Daily High Tide due to Sea Level Rise	Intersects with Coastal (Dune or Cliff) Erosion Hazard Zone	Plastic Culverts within High Risk Fire Zone	Bridge within Erosion Hazard Zone (Dune or Cliff)	Maximum Cost of Historic Drainage Events w/ increase in Precipitation or runoff	Maximum Cost of Historic Erosion Events w/ increase in Precipitation or runoff	Maximum Cost of Historic Slope Movement Events w/ increase in Precipitation or runoff, or within High Fire Risk	Historic drainage, erosion, slope failure event density as square mile per event at culvert location	Segment intersects with Existing Daily High Tide	Segment within Identified Chronic Drainage Issue Areas	Segment within Identified Chronic Slope Movement Areas	Segment within Identified Chronic Sea Level Issue Areas	
169	1	Route 101 to Klamath Glen	0	0	0	0	4	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6
	4	Wautec to Ke'pel Road	0	1	1	1	0	0	0	0	0	0	0	7	2	7	6	0	0	0	0	7
	5	Ke'pel Road to Martins Ferry	0	1	0	1	0	0	0	0	0	0	0	1	0	7	7	0	0	0	0	7
	6	Martins Ferry to Weitchpec	0	1	0	1	0	0	0	0	0	0	0	1	0	1	7	0	0	0	0	7
175	1	Route 101 to MEN/LAK County Line	0	1	0	3	4	0	0	0	0	0	0	0	0	1	6	0	5	0	0	6
	2	MEN/LAK County Line to Route 29 South of the City of Lakeport	0	1	0	3	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6
	3	Route 29 South of the community of Kelseyville to the community of Cobb	1	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	4	From the community of Cobb to Route 29 in the community of Middletown	1	1	1	3	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	4
197	1	Route 199 to Route 101	0	1	1	0	4	0	0	0	0	0	0	4	0	3	6	0	0	0	0	6
199	1	Route 101 to near Gasquet	0	1	1	0	4	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6
	2	Near Gasquet to west of Patrick Creek	0	1	1	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	4
	3	West of Patrick Creek to near Idlewild	0	1	1	1	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	5
	4	Near Idlewild to the Calif./Oregon Border	0	1	1	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3
200	1	Jct. Rte. 101 to Jct. Rte. 299	0	1	1	0	4	0	0	0	0	0	0	0	0	0	4	0	0	0	0	4
211	3	Ocean Ave. in Ferndale to Route 101	0	1	1	0	4	4	5	10	0	0	0	0	0	0	3	10	5	0	0	10
222	1	Rte. 101 to East Site Road in Talmage	0	1	1	3	4	0	0	0	0	0	0	0	0	0	3	0	5	0	0	5
253	1	Rte 128 at Boonville to iunction Rte 101 near Ukiah	1	1	1	3	0	0	0	0	0	0	0	6	0	7	7	0	0	0	0	7
254	1	Route 101 to Myers Flat	0	1	1	2	4	0	0	0	0	0	0	1	0	8	7	0	5	0	0	8
	2	Myers Flat to Route 101 at Jordan Road	0	1	1	1	4	0	0	0	0	0	0	6	0	6	6	0	0	0	0	6
255	1	Route 101 to Eureka Urban Limits	0	1	0	0	0	0	5	0	0	0	0	0	0	0	1	0	0	0	0	5
	2	Eureka Urban Limits to 0.2 mi. North Mad River Slough Br. #4-257	0	0	0	0	4	4	5	10	0	0	0	0	0	0	3	10	0	0	5	10
	3	0.2 Mi. North Mad River Slough Br. #257 to Arcata Urban Limits	0	0	0	0	4	4	5	10	0	0	0	0	0	0	3	0	0	0	0	10
	4	Arcata Urban Limits to Junction Rte. 101	0	0	0	0	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	4
271	1	Route 101 to Route 1	1	1	1	1	4	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6
	2	1.5 miles so. of Reynolds Overcrossing to the MEN/HUM County line	0	1	1	1	4	0	0	0	0	0	0	1	0	0	6	0	0	0	0	6
	3	MEN/HUM Co. line to Route 101	0	1	1	1	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	4
281	2	Near Konoctl Bay to Route 29	0	1	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
283	1	Rte 101 to end of Eel River Bridge #4-15	0	1	0	0	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	4
299	1	Route 101 To The City Of Blue Lake	0	1	1	0	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	4
	2	City Of Blue Lake To Community Of Willow Creek	0	1	1	0	4	0	0	0	0	0	0	7	0	7	6	0	0	3	0	7
	3	Community Of Willow Creek To Humboldt/Trinity Line	0	1	2	2	0	0	0	0	0	0	0	1	0	7	5	0	0	0	0	7

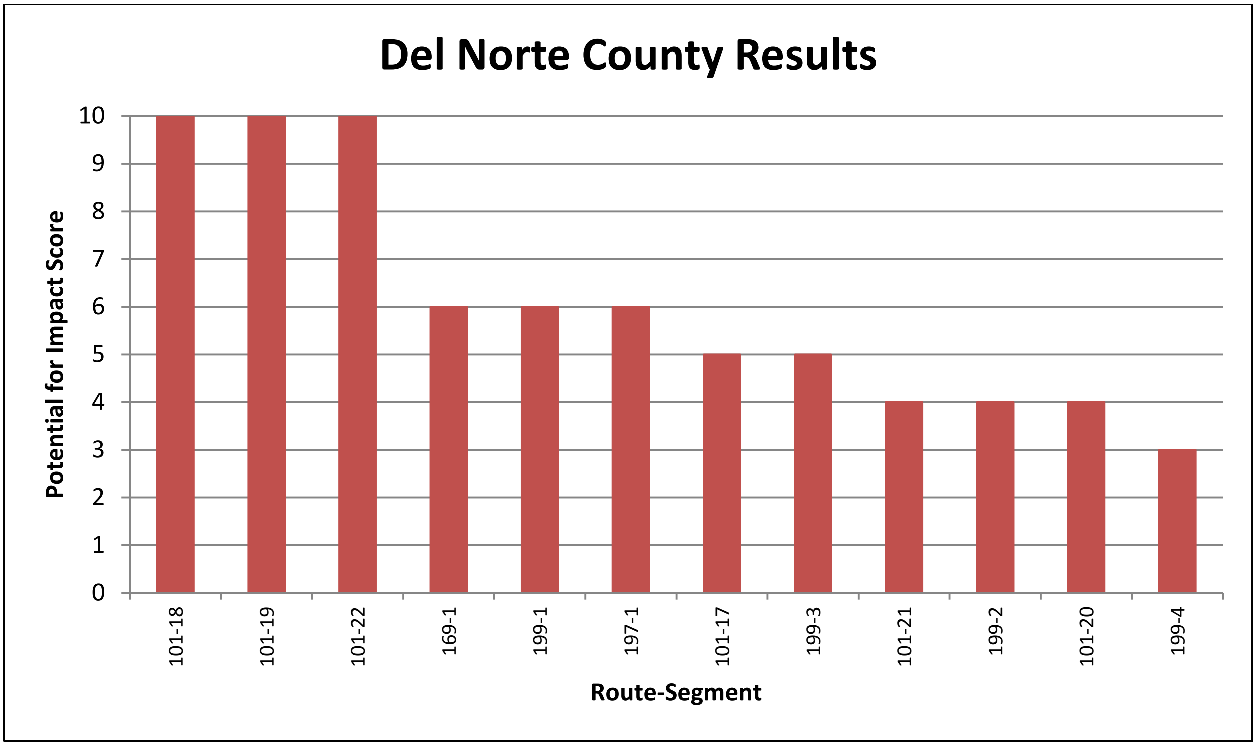
Attachment F

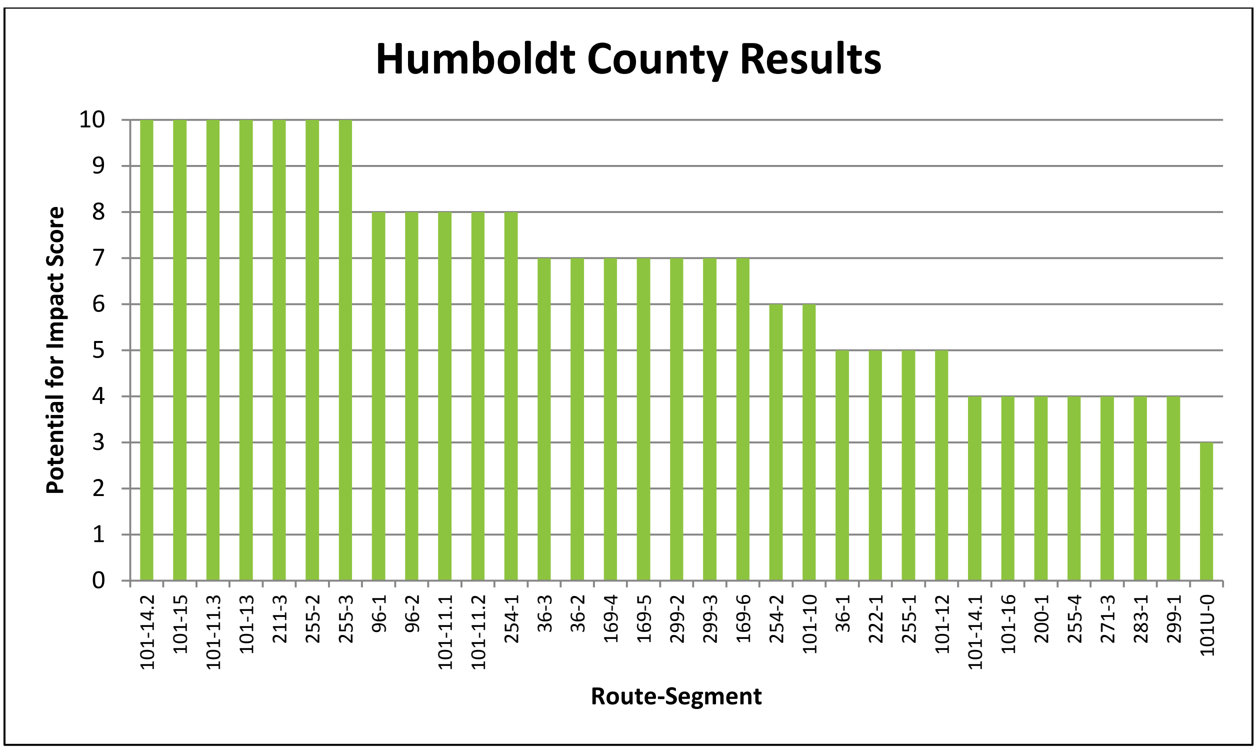
Comparison Graphs of the TCR Segment Potential Impact Scores, Climate Horizon 2050 A2

Attachment F: Comparison graphs of the TCR segment potential impact scores for climate horizon 2050 A2

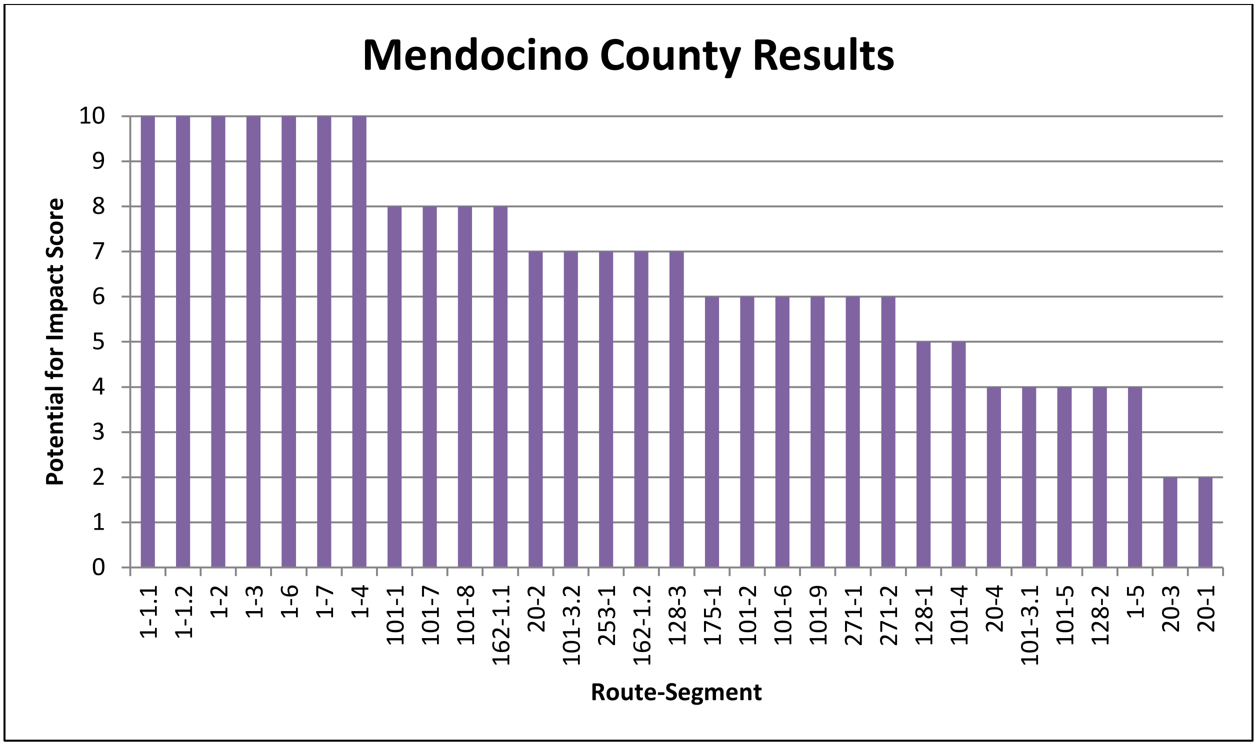


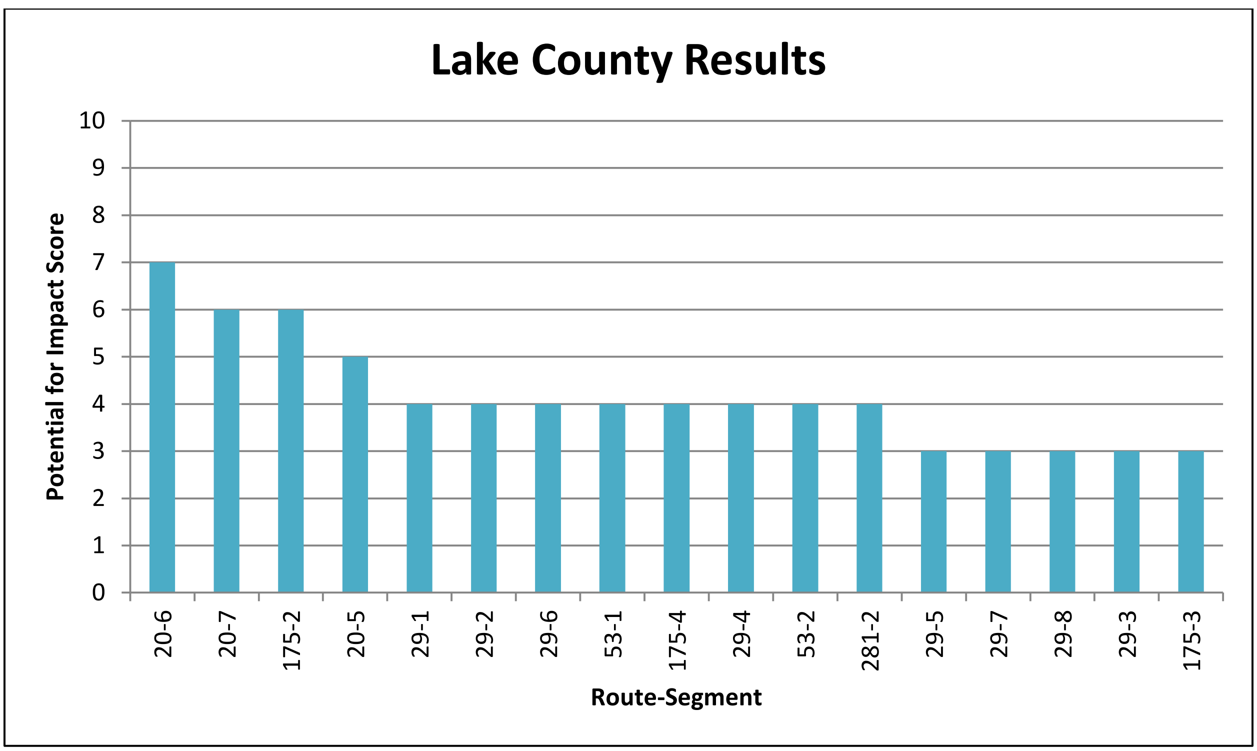
Attachment F: Comparison graphs of the TCR segment potential impact scores for climate horizon 2050 A2





Attachment F: Comparison graphs of the TCR segment potential impact scores for climate horizon 2050 A2





Attachment G

Tabular TCR Segment Potential Impact Scores for Each Climate Projection

Attachment G: Tabular TCR segment potential impact scores for each climate projection

County	Route	Segment	Climate Projection Potential for Impact Scores			
			2050 A2	2050 B1	2100 A2	2100 B1
MEN	1	1.1	10	10	10	10
MEN	1	1.2	10	10	10	10
MEN	1	2	10	10	10	10
MEN	1	3	10	10	10	10
MEN	1	4	10	10	10	10
MEN	1	6	10	10	10	10
MEN	1	7	10	10	10	10
HUM	101	11.3	10	10	10	10
HUM	101	13	10	10	10	10
HUM	101	14.2	10	10	10	10
HUM	101	15	10	10	10	10
DN	101	18	10	10	10	10
DN	101	19	10	10	10	10
DN	101	22	10	10	10	10
HUM	255	2	10	10	10	10
HUM	255	3	10	10	10	10
HUM	96	1	8	8	8	8
HUM	96	2	8	8	8	8
MEN	101	1	8	8	8	8
MEN	101	7	8	8	8	8
MEN	101	8	8	8	8	8
HUM	101	11.1	8	8	8	8
HUM	101	11.2	8	8	8	8
MEN	162	1.1	8	8	8	8
HUM	254	1	8	8	8	8
MEN	20	2	7	7	7	7
LAK	20	6	7	7	7	7
HUM	36	2	7	7	7	7
HUM	36	3	7	7	7	7
MEN	101	3.2	7	7	7	7
MEN	128	3	7	7	7	7
MEN	162	1.2	7	7	7	7
HUM	169	4	7	7	7	7
HUM	169	5	7	7	7	7
HUM	169	6	7	7	7	7
HUM	200	1	7	7	7	7
MEN	253	1	7	7	7	7
HUM	299	2	7	7	7	7
HUM	299	3	7	7	7	7
LAK	20	7	6	6	6	6
MEN	101	2	6	6	6	6
MEN	101	6	6	6	6	6
MEN	101	9	6	6	6	6
HUM	101	10	6	6	6	6
DN	101	20	6	6	6	6

Attachment G: Tabular TCR segment potential impact scores for each climate projection

County	Route	Segment	Climate Projection Potential for Impact Scores			
			2050 A2	2050 B1	2100 A2	2100 B1
MEN	175	1	6	6	6	6
LAK	175	2	6	6	6	6
HUM	254	2	6	6	6	6
MEN	271	1	6	6	6	6
MEN	271	2	6	6	6	6
LAK	20	5	5	5	5	5
LAK	29	1	5	5	5	5
LAK	29	6	5	5	5	5
HUM	36	1	5	5	5	5
MEN	101	4	5	5	5	5
MEN	128	1	5	5	5	5
LAK	175	3	5	5	5	5
DN	199	1	5	5	5	5
DN	199	3	5	5	5	5
HUM	211	3	5	5	5	5
HUM	222	1	5	5	5	5
HUM	255	1	5	5	10	10
MEN	1	5	4	4	4	4
MEN	20	4	4	4	4	4
LAK	29	2	4	4	4	4
LAK	29	4	4	4	4	4
LAK	53	1	4	4	4	4
LAK	53	2	4	4	4	4
MEN	101	3.1	4	4	4	4
MEN	101	5	4	4	4	4
HUM	101	12	4	4	5	4
HUM	101	14.1	4	4	4	4
HUM	101	16	4	4	4	4
DN	101	17	4	4	4	4
DN	101	21	4	4	4	4
MEN	128	2	4	4	4	4
DN	169	1	4	4	4	4
LAK	175	4	4	4	4	4
DN	197	1	4	4	4	4
HUM	255	4	4	4	4	4
HUM	271	3	4	4	4	4
LAK	281	2	4	4	4	4
HUM	283	1	4	4	4	4
HUM	299	1	4	4	4	4
LAK	29	3	3	3	3	3
LAK	29	5	3	2	3	3
LAK	29	7	3	3	3	3
LAK	29	8	3	3	3	3
HUM	101U	0	3	3	3	3
DN	199	2	3	3	3	3
DN	199	4	3	3	3	3
MEN	20	1	2	2	1	2
MEN	20	3	2	2	3	3

Appendix 4

Caltrans TCR Segment Vulnerability

Memorandum

15 October 2014

To	Rex Jackman, Chief, Transportation Planning Caltrans District 1		
Copy to	Brad Mettam (Caltrans), Jamie Hostler (Caltrans), Marcella Clem (HCAOG)		
From	Rebecca Crow	Tel	707 443 8326
Subject	Caltrans TCR Segment Vulnerability	Job no.	84/10842/20

1 Introduction

This memorandum describes the methods and results of an analysis to evaluate the vulnerability of transportation assets owned and maintained by the California Department of Transportation (Caltrans) District 1 in support of the project entitled “Caltrans District 1 Climate Change Pilot Study” (D1CCPS). The purpose of the project is to evaluate the vulnerability of Caltrans transportation assets in District 1 to various climate change factors and develop adaptation strategies for the most vulnerable assets. Vulnerability is defined by the Intergovernmental Panel on Climate Change (IPCC) as “the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes”. Vulnerability takes into consideration criticality (including consideration of socioeconomic, operational, and health and safety importance discussed under a separate memorandum) and potential for impact (including consideration of exposure, sensitivity, and adaptive capacity also discussed under a separate memorandum). This memorandum analyzes vulnerability, while supporting memoranda analyze the criticality and potential for impact.

1.1 List of Attachments

The technical work within this memorandum is supported with additional more detailed information provided as attachments including the following:

- A: Tabular TCR segment vulnerability scores for each climate projection
- B. Plots of vulnerability scores for each climate projection
- C: Vulnerability scores for climate projection 2050 A2
- D: Overall Vulnerability Scoring per TCR Segment, Climate Horizon 2050 A2

2 Methodology

Transportation assets were grouped into highway Transportation Concept Report (TCR) segments based on Caltrans descriptions. This segmentation scheme is consistent with the criticality and potential for impact analyses discussed in the separate memoranda. Vulnerability was evaluated as a product of criticality and potential for impact. The criticality and potential for impact scores (each score ranging between 1 and 10) for each TCR segment were multiplied together to calculate a resulting score up to 100. The lower the score, the lower the resulting vulnerability.

Image 1 provides a visual of the relationship between Criticality on the horizontal axis and Impact on the Vertical axis with increasing Vulnerability moving towards the upper right hand corner in the red zone.

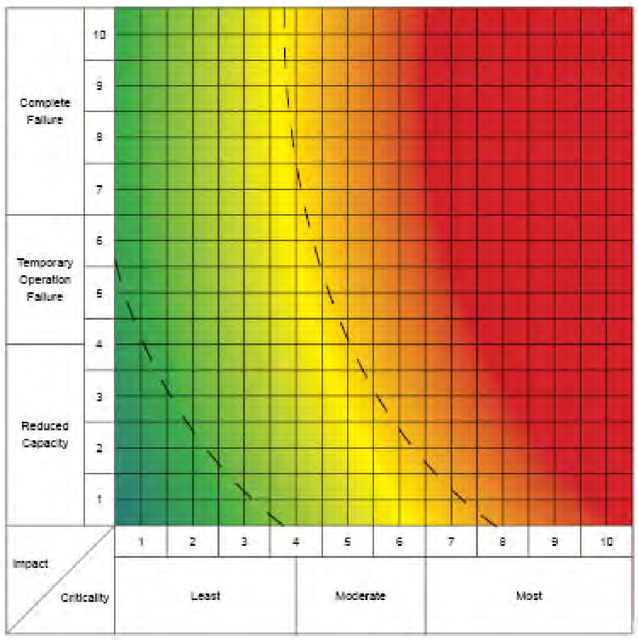


Image 1: Relationship Between Impact and Criticality and Resulting Vulnerability

Based on the Criticality and the Impact calculated in previous memoranda for each asset segment, the resulting Vulnerability scores were calculated for each climate projection and emission scenario. Climate projections for each climate impact factor vary depending on the emission scenario, climate projection and climate model.

The A2 emissions scenario projects mid-to-high emissions assuming “business as usual” that results in tripling of the atmospheric carbon concentration by the end of the century.

The B1 emissions scenario represents low projected emissions assuming the “best case” scenario in which carbon emissions continue to increase until 2050 and then decrease by 2100. The B1 scenario results in a doubling of the atmospheric carbon concentration by the end of the century.

Climate data is discussed in more detail in the Climate Data Projections for Caltrans District 1 Climate Change Pilot Study memorandum.

3 Results

Image 2 displays the results of the vulnerability scoring of the 93 TCR segments and subsegments in District 1 for the 2050 A2 climate projection.

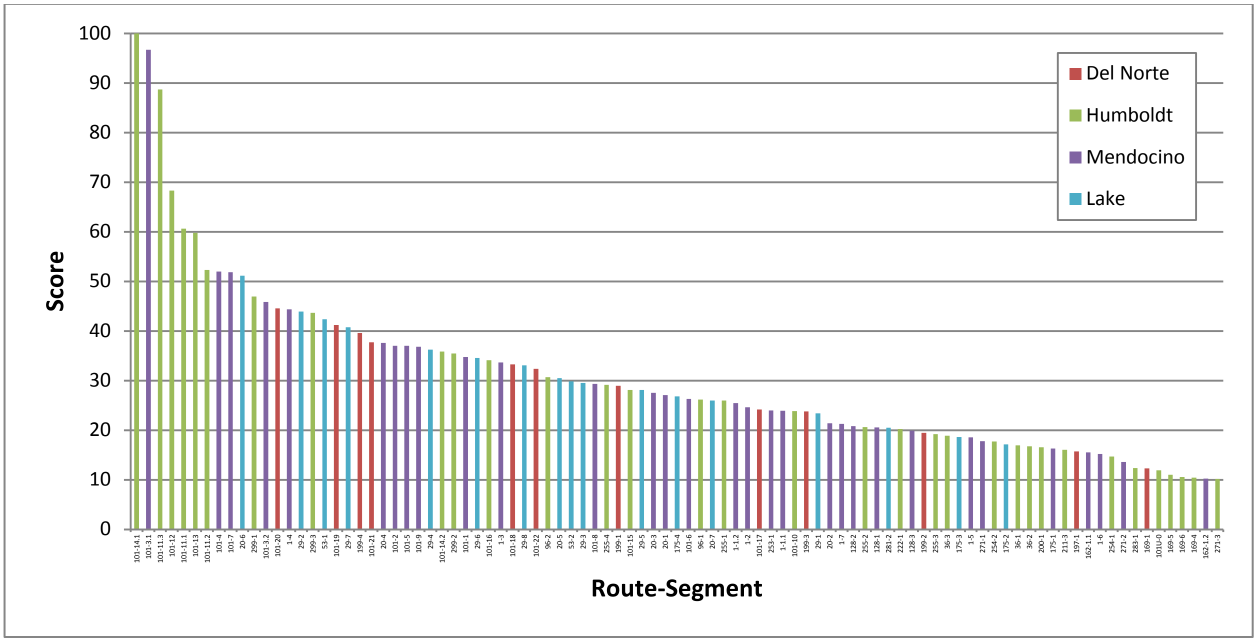


Image 2: Segment Vulnerability Scores for the 2050 A2 Climate Projection

As described in the Potential for Impact memo, results for climate projections 2100 A2, 2050 B1 and 2100 B1 resulted in relatively consistent impact scores regardless of the projection used, with the exception of only five segments. Of those five segments, only one segment's score changed significantly, which was a segment of Highway 255 around Humboldt Bay, which was found to be affected by the 2100 models, but not the 2050 due to the particular topographic issues. Table 1 shows the changes in segment vulnerability scores for each climate projection. A detailed listing of the vulnerability scores for each segment and climate projection is listed in Attachment A. Graphical results for all of District 1 are presented in Attachment B. Due to the marginal variability across climate projections, Attachment C includes the results of vulnerability scoring as grouped by county for only the 2050 A2 climate projection. Attachment D displays these results on a District-wide map.

Table 1: Changes in Segment Potential Impact Scores Across Climate Projections

	Climate Projection Vulnerability Score			
Segment	**2050 A2**	**2050 B1**	**2100 A2**	**2100 B1**
20-1	10.4	10.4	5.2	10.4
20-3	10.5	10.5	15.7	15.7
29-5	15.9	10.6	15.9	15.9
101-12	33.1	33.1	41.3	33.1
255-1	25.5	25.5	51.0	51.0

Image 3 shows the distribution of vulnerability scores for District 1. The majority of the segments received low vulnerability scores: 85% received a score of less than 50, and 95% received less than 60

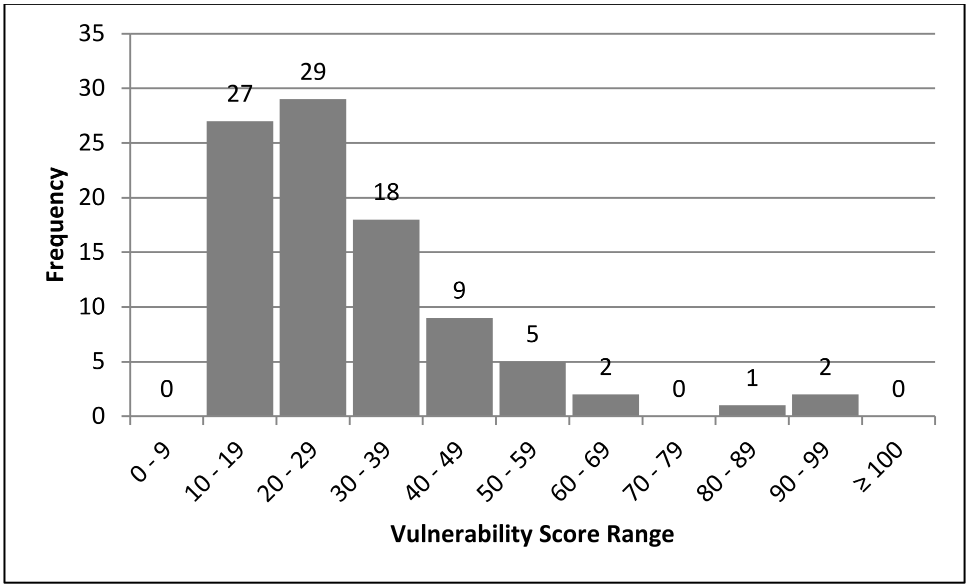


Image 3: Distribution of Vulnerability Scores for Climate Projection 2050 A2

This distribution of vulnerability scores suggests that there are a relatively small number of assets that have both a high criticality and a high potential for impact and hence a high vulnerability. This means that while all assets need to be maintained to continue to meet their service objectives, the primary areas of focus for addressing the most pressing climate change issues to result in the greatest good are relatively few.

The following sections outline the top three most vulnerable segments in each county and highlight the key factors that contributed to each segment's vulnerability score. Changes in potential impact across the climate projections did not affect the scores for the top three most vulnerable segments in each county. Therefore, regardless of the climate change models used, the assets warranting the main attention remain the same. However, the various climate change models forecast differing levels of sea level rise, which will affect the final configuration of adaptation options that are implemented. Therefore, further work beyond this planning pilot study is needed to make final decisions on how to address climate change for these asset segments.

3.1 Del Norte County

US 101 Segment 19

The segment that was rated most vulnerable in Del Norte County is US 101 Segment 19 between Wilson Creek and south of Crescent City, which received a vulnerability score of 64. The segment received a criticality score of 6.4 and a potential impact score of 10. The criticality factors that contributed to the high vulnerability score included low redundancy, higher route classifications, and presence of traffic operating systems. The potential impact score is due to a portion of the segment being within an erosion hazard zone. This particular location is referred to as Last Chance Grade and has historically been exposed to frequent slope failure and erosion issues.

US 101 Segment 18

The segment that was rated second most vulnerable in Del Norte County is US 101 Segment 18 in the Del Norte Redwoods State Park area, which received a vulnerability score of 58. The segment received a criticality score of 5.8 and a potential impact score of 10. The criticality factors that contributed to the high vulnerability score included its lack of redundancy, presence of bridges, and higher route classifications. The potential impact factor was that the segment contains a portion of the roadway within the erosion hazard zone.

US 101 Segment 22

The segment that was rated third most vulnerable in Del Norte County is US 101 Segment 22 between the junction with US 199 and the Oregon border, which received a vulnerability score of 57. The segment received a criticality score of 5.7 and a potential impact score of 10. The criticality factors that contributed to the high vulnerability score included its high route classification and moderate redundancy. The potential impact factor was that the segment contains a portion of the roadway within the erosion hazard zone.

3.2 Humboldt County

US 101 Segment 11.3

The segment that was rated most vulnerable in Humboldt County is US 101 Segment 11.3 between Rio Dell and the south Eureka urban boundary, which received a vulnerability score of 94. The segment received a criticality score of 9.4 and a potential impact score of 10. The criticality factors that contributed to the high vulnerability score included its number of bridges, length, low redundancy, relatively high ADT, and high route classifications. The potential impact factor was the segment's coastal proximity with portions of low elevation that has the potential for tidal inundation.

US 101 Segment 13

The segment that was rated second most vulnerable in Humboldt County is US 101 Segment 13 in Humboldt County between the north Eureka city limits and the junction with Route 255 (South Arcata), which received a vulnerability score of 77. The segment received a criticality score of 7.7 and a potential impact score of 10. The criticality factors that contributed to the high vulnerability score included high ADT, large population, high number of municipal non-park parcels, and route classifications. The potential impact factor was the segment's coastal proximity with low elevation that has the potential for tidal inundation.

US 101 Segment 11.1

The segment that was rated third most vulnerable in Humboldt County is US 101 Segment 11.1 in Humboldt County between Richardson Grove and Weott, which received a vulnerability score of 62. The segment received a criticality score of 7.8 and a potential impact score of 8. The criticality factors that contributed to the high vulnerability score included low redundancy, presence of bridges over water, high number of stormwater facilities, presence of critical nodes, and high route classifications. The potential impact factor was the segment's frequent historical slope movement due to drainage issues.

3.3 Lake County

SR 20 Segment 6

The segment that was rated most vulnerable in Lake County is SR 20 Segment 6 between junctions with SR 29 and SR 53, which received a vulnerability score of 50. The segment received a criticality score of 7.2 and a potential impact score of 7. The criticality factors that contributed to the high vulnerability score included low level of redundancy, high number of stormwater and maintenance facilities, proximity to commercial and residential parcels, and high route classifications. The potential impact factor was the frequent and high-cost historical slope movement events, as well as chronic drainage issues.

SR 20 Segment 7

The segment that was rated second most vulnerable in Lake County is SR 20 Segment 7 between the junction with SR 53 and the Lake/Colusa County line, which received a vulnerability score of 31. The segment received a criticality score of 5.1 and a potential impact score of 6. The criticality factors that contributed to the high vulnerability score included its moderately low level of redundancy and high route classification. The potential impact factor was the frequent and high cost historical slope movement events.

SR 29 Segment 6

The segment that was rated third most vulnerable in Lake County is SR 29 Segment 6 between Kelseyville and 0.5 miles south of Lakeport (intersection with SR 175), which received a vulnerability score of 29. The segment received a criticality score of 5.9 and a potential impact score of 5. The criticality factors that contributed to the high vulnerability score included high route classification and the number of critical nodes present. The potential impact factor was exposure to frequent historical slope movement, drainage, and erosion events.

3.4 Mendocino County

SR 1 Segment 4

The segment that was rated most vulnerable in Mendocino County is SR 1 Segment 4 between the northern and southern city limits of Fort Bragg, which received a vulnerability score of 67. The segment received a criticality score of 6.7 and a potential impact score of 10. The criticality factors that contributed to the high vulnerability score included lack of significant redundancy, moderate ADT, presence of maintenance facilities, and high route classifications. The potential impact factor was the potential for inundation from the daily high tide due to sea level rise in 2050 related to the segment’s low elevation at the mouth of Pudding Creek near the coast.

SR 1 Segment 3

The segment that was rated second most vulnerable in Mendocino County is SR 1 Segment 3 between Little River and the southern Fort Bragg city limit, which received a vulnerability score of 58. The segment received a criticality score of 5.8 and a potential impact score of 10. The criticality factors that contributed to the high vulnerability score include a lack of redundancy, moderate ADT, higher number of bridges, and designation as a bus route. The potential impact factor was that the segment contains both a portion of the roadway and a bridge that is within the erosion hazard zone.

US 101 Segment 7

The segment that was rated third most vulnerable in Mendocino County is US 101 Segment 7 between Bell Springs Road and the junction with SR 1 at Leggett, which received a vulnerability score of 58. The segment received a criticality score of 7.2 and a potential impact score of 8. The criticality factors that contributed to the high vulnerability score included very low level of redundancy, road length, and high number of critical nodes. The potential impact factor was frequent and high-cost historical slope movement events.

4 Discussion

Vulnerability scores are a product of the criticality and potential impact scores. The maximum possible score is 100. Segments scoring in the top 5^{th} percentile, a score above 60, generally scored above 6 in criticality and a 10 in potential impact. No relationship between criticality and potential impact scores were noted. Segments scoring above 6 in criticality ranged in potential impact score from 3 to 10, resulting in vulnerability scores ranging from 18 to 95. Segments with potential impact scores of 10 ranged in criticality scores of 3.9 to 9.5, resulting in vulnerability scores from 39 to 95 respectively.

Vulnerability scores throughout the District varied by geographic location. Coastal segments were among the most vulnerable due to the high potential impact associated with rising sea levels. Vulnerability associated with significant historical slope instability, drainage and erosion issues exist throughout the district. Routes with higher asset criticality such as lacking redundancy, high use, high route classification, and critical nodes were present throughout the District.

Each county has varying climate exposure risk and asset criticality due to geographic location, projected changes in climate, historical issues and infrastructure or assets required for continued service.

5 Conclusions

The vulnerability analysis helps focus future efforts to address the most important assets at the greatest risk to climate change factors. This analysis shows a relatively small number of assets with high vulnerability scores. Understanding vulnerability is necessary to know where to concentrate adaptation efforts. Within this planning tool, considering adaptation options to address the climate change risks helps users further their planning in a proactive manner before climate change effects become severe. Adaptation options are considered under a separate memorandum by identifying one pilot study location in each county.

The pilot study locations are meant to highlight the use of the adaptation tool and further the understanding of issues and opportunities at a particular location, but are not intended to be the final answer. In fact, the implementation of an adaptation option may be many years in the future and many policy, permitting, technical, funding, and stakeholder issues may need to be addressed prior to selection of the most appropriate approach and actual implementation. Considering pilot study locations is one of the first steps in the overall process to help focus future effort.

Based on the vulnerability findings and with the intent of evaluating different types of situations in different geographic areas, the following pilot study locations are suggested:

Del Norte County Pilot Study Location

The most vulnerable segments in Del Norte County are coastal segments that exhibited potential for impact exposure to frequent slope failure and erosion hazard zones. These segments generally demonstrate low redundancy and higher route classifications.

The recommended Pilot Study location in Del Norte County is the area known as Last Change Grade on Highway 101 segment 19. This location is representative of the typical hazards, challenges and service needs in Del Norte County. This segment serves as the only southern access route without significant detours.

Humboldt County Pilot Study Location

The most vulnerable segments in Humboldt County are coastal segments along the open coast and Humboldt Bay subject to tidal inundation and historical slope movement and drainage issues. These segments generally demonstrate high ADT, high route classifications and low redundancy.

The recommended Pilot Study location in Humboldt County is the area known as the Safety Corridor between Eureka and Arcata on Highway 101 Segment 13. This location represents challenges associated with adapting to sea level rise, large geographic area with alternate routes subject to inundation and maintaining a high level of service as the main route between large population centers.

Lake County Pilot Study Location

The most vulnerable segments in Lake County are located in areas subject to large and/or frequent slope movement, drainage and erosion events. These segments generally have a low level of redundancy and high route classification.

The recommended Pilot Study location in Lake County is an area near North Lakeport in the vicinity of the junction of Highway 20 and Highway 29. This area represents challenges with drainage, erosion and slope movement events as well as limited redundancy and high rout classification.

Mendocino County Pilot Study Location

The most vulnerable segments in Mendocino County are coastal segments or connections to coastal segments subject to tidal inundation, erosion hazards and frequent, high-cost historical slope movement events. These segments have low redundancy and moderate ADT.

The recommended Pilot Study location in Mendocino County is a segment on Highway 1 that is exposed to effects of rising sea and/or frequent, high-cost maintenance events. The area selected is to include challenges with re-routing and serve as a critical route or connection to other state highways.

Attachment A

Tabular TCR Segment Vulnerability Scores for Each Climate Projection

Attachment A: Tabular TCR segment vulnerability scores for each climate projection

County	Route	Segment	Climate Projection Vulnerability Scores			
			2050 A2	2050 B1	2100 A2	2100 B1
HUM	101	11.3	94.2	94.2	94.2	94.2
HUM	101	13	77.3	77.3	77.3	77.3
MEN	1	4	66.6	66.6	66.6	66.6
DN	101	19	64.2	64.2	64.2	64.2
HUM	101	11.1	62.3	62.3	62.3	62.3
HUM	101	14.2	59.9	59.9	59.9	59.9
MEN	1	3	58.0	58.0	58.0	58.0
HUM	101	11.2	57.9	57.9	57.9	57.9
DN	101	18	57.7	57.7	57.7	57.7
MEN	101	7	57.6	57.6	57.6	57.6
DN	101	22	56.9	56.9	56.9	56.9
HUM	101	15	53.0	53.0	53.0	53.0
MEN	1	1.2	50.4	50.4	50.4	50.4
LAK	20	6	50.1	50.1	50.1	50.1
MEN	1	2	49.6	49.6	49.6	49.6
MEN	1	1.1	48.9	48.9	48.9	48.9
MEN	101	3.2	47.4	47.4	47.4	47.4
MEN	101	1	47.2	47.2	47.2	47.2
HUM	299	3	46.2	46.2	46.2	46.2
MEN	1	7	46.1	46.1	46.1	46.1
HUM	255	2	45.4	45.4	45.4	45.4
HUM	96	2	44.3	44.3	44.3	44.3
HUM	255	3	43.8	43.8	43.8	43.8
MEN	101	8	43.3	43.3	43.3	43.3
HUM	299	2	41.7	41.7	41.7	41.7
HUM	96	1	40.9	40.9	40.9	40.9
DN	101	20	40.1	40.1	40.1	40.1
HUM	101	14.1	40.0	40.0	40.0	40.0
MEN	101	3.1	39.3	39.3	39.3	39.3
MEN	1	6	39.0	39.0	39.0	39.0
MEN	101	2	36.5	36.5	36.5	36.5
MEN	101	9	36.4	36.4	36.4	36.4
MEN	101	4	36.0	36.0	36.0	36.0
MEN	253	1	34.3	34.3	34.3	34.3
HUM	101	12	33.1	33.1	41.3	33.1
MEN	20	2	32.4	32.4	32.4	32.4
MEN	162	1.1	31.5	31.5	31.5	31.5
MEN	128	3	31.2	31.2	31.2	31.2
MEN	101	6	30.8	30.8	30.8	30.8
HUM	254	1	30.7	30.7	30.7	30.7
LAK	20	7	30.6	30.6	30.6	30.6
HUM	36	3	30.4	30.4	30.4	30.4
LAK	29	6	29.4	29.4	29.4	29.4
HUM	101	10	29.3	29.3	29.3	29.3
HUM	36	2	28.6	28.6	28.6	28.6
HUM	200	1	28.5	28.5	28.5	28.5
LAK	20	5	27.6	27.6	27.6	27.6
HUM	299	1	27.4	27.4	27.4	27.4
DN	199	1	26.9	26.9	26.9	26.9

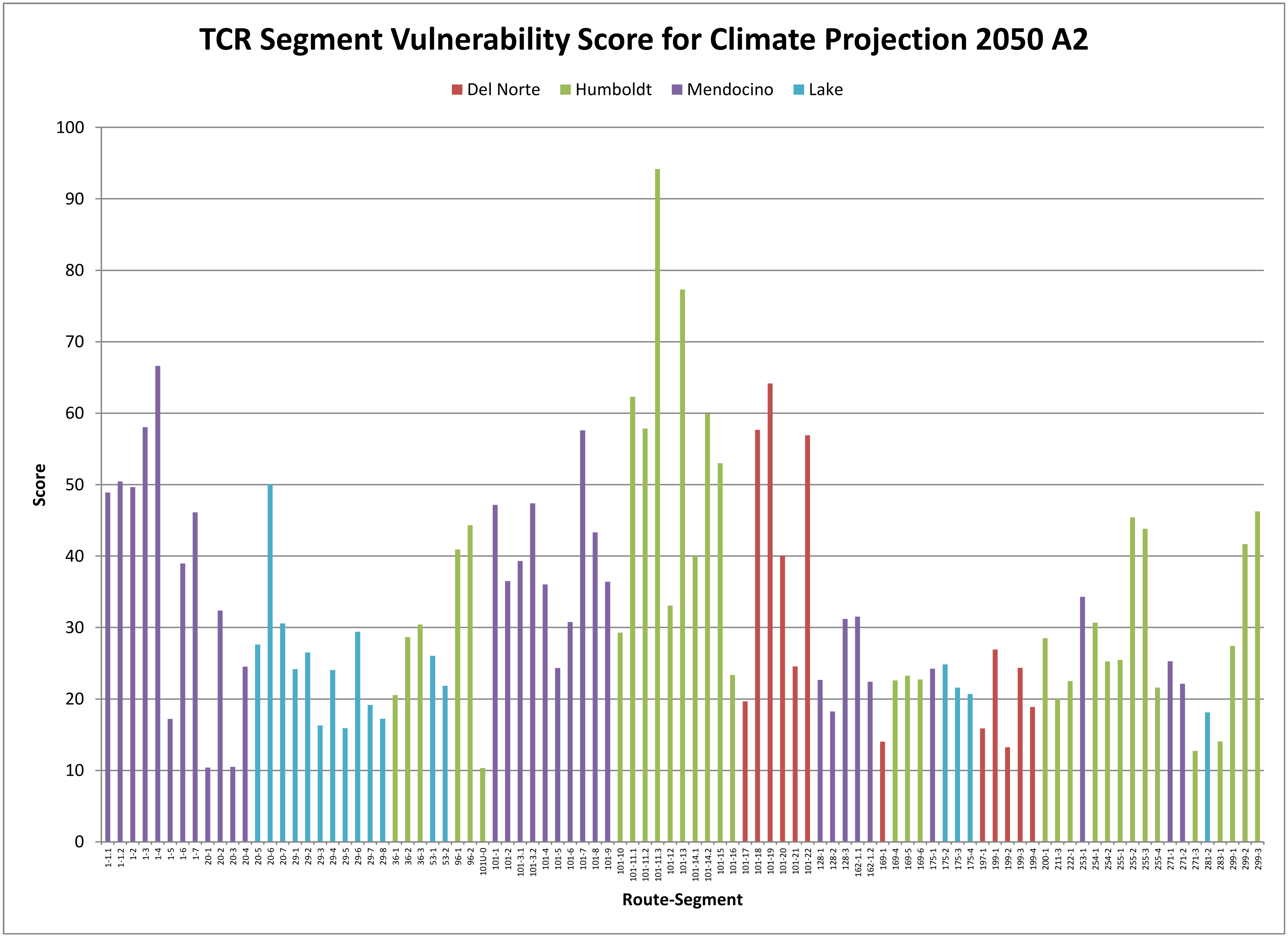
Attachment A: Tabular TCR segment vulnerability scores for each climate projection

County	Route	Segment	Climate Projection Vulnerability Scores			
			2050 A2	2050 B1	2100 A2	2100 B1
LAK	29	2	26.5	26.5	26.5	26.5
LAK	53	1	26.0	26.0	26.0	26.0
HUM	255	1	25.5	25.5	51.0	51.0
MEN	271	1	25.3	25.3	25.3	25.3
HUM	254	2	25.2	25.2	25.2	25.2
LAK	175	2	24.8	24.8	24.8	24.8
DN	101	21	24.6	24.6	24.6	24.6
MEN	20	4	24.5	24.5	24.5	24.5
DN	199	3	24.4	24.4	24.4	24.4
MEN	101	5	24.3	24.3	24.3	24.3
MEN	175	1	24.2	24.2	24.2	24.2
LAK	29	1	24.2	24.2	24.2	24.2
LAK	29	4	24.1	24.1	24.1	24.1
HUM	101	16	23.4	23.4	23.4	23.4
HUM	169	5	23.3	23.3	23.3	23.3
HUM	169	6	22.7	22.7	22.7	22.7
MEN	128	1	22.7	22.7	22.7	22.7
HUM	169	4	22.6	22.6	22.6	22.6
HUM	222	1	22.5	22.5	22.5	22.5
MEN	162	1.2	22.4	22.4	22.4	22.4
MEN	271	2	22.1	22.1	22.1	22.1
LAK	53	2	21.9	21.9	21.9	21.9
HUM	255	4	21.6	21.6	21.6	21.6
LAK	175	3	21.6	21.6	21.6	21.6
LAK	175	4	20.7	20.7	20.7	20.7
HUM	36	1	20.6	20.6	20.6	20.6
HUM	211	3	20.0	20.0	20.0	20.0
DN	101	17	19.7	19.7	19.7	19.7
LAK	29	7	19.2	19.2	19.2	19.2
DN	199	4	18.9	18.9	18.9	18.9
MEN	128	2	18.2	18.2	18.2	18.2
LAK	281	2	18.1	18.1	18.1	18.1
LAK	29	8	17.3	17.3	17.3	17.3
MEN	1	5	17.2	17.2	17.2	17.2
LAK	29	3	16.3	16.3	16.3	16.3
LAK	29	5	15.9	10.6	15.9	15.9
DN	197	1	15.9	15.9	15.9	15.9
HUM	283	1	14.1	14.1	14.1	14.1
DN	169	1	14.0	14.0	14.0	14.0
DN	199	2	13.2	13.2	13.2	13.2
HUM	271	3	12.7	12.7	12.7	12.7
MEN	20	3	10.5	10.5	15.7	15.7
MEN	20	1	10.4	10.4	5.2	10.4
HUM	101U	0	10.3	10.3	10.3	10.3

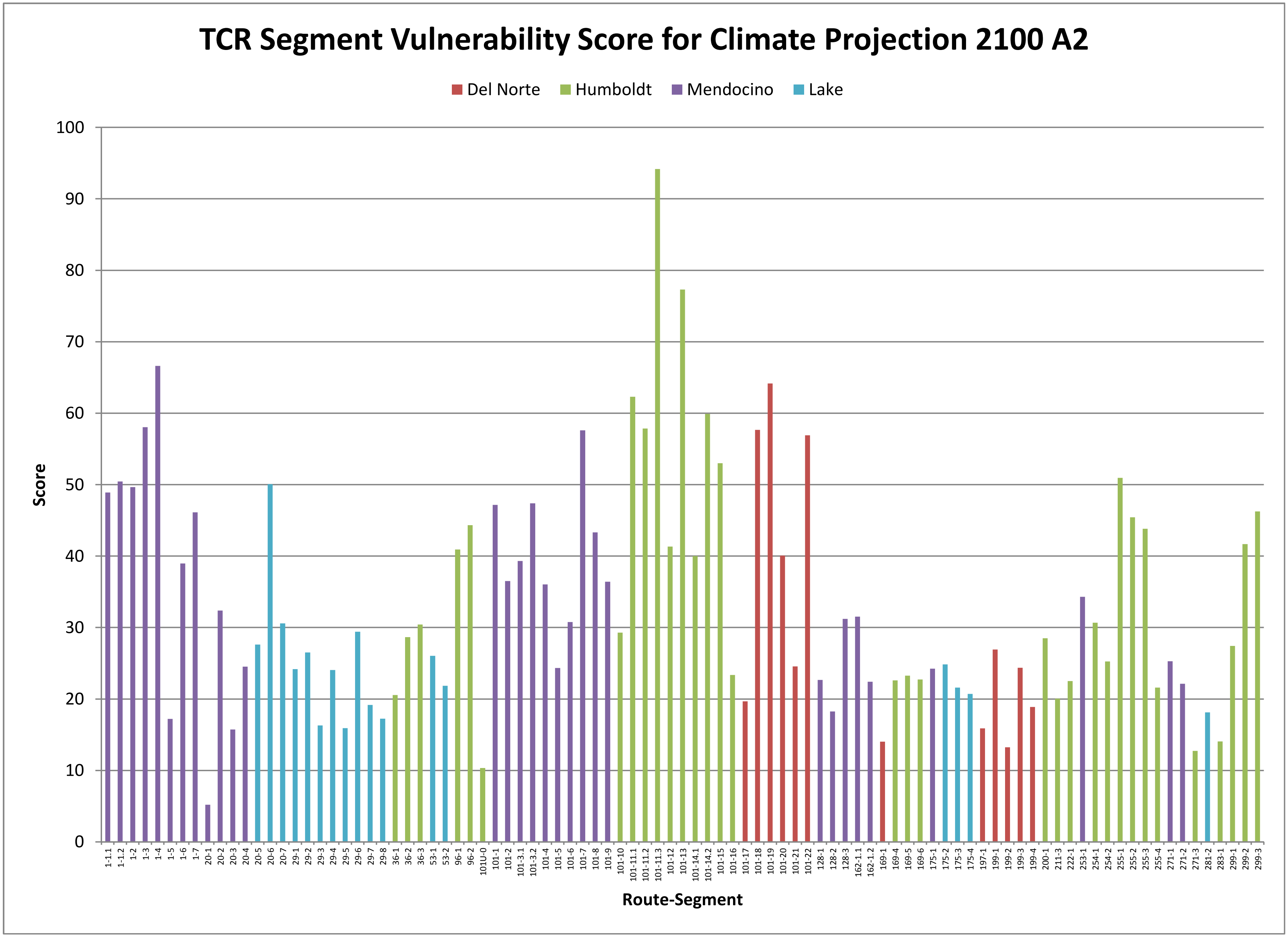
Attachment B

Plots of Vulnerability Scores for Each Climate Projection

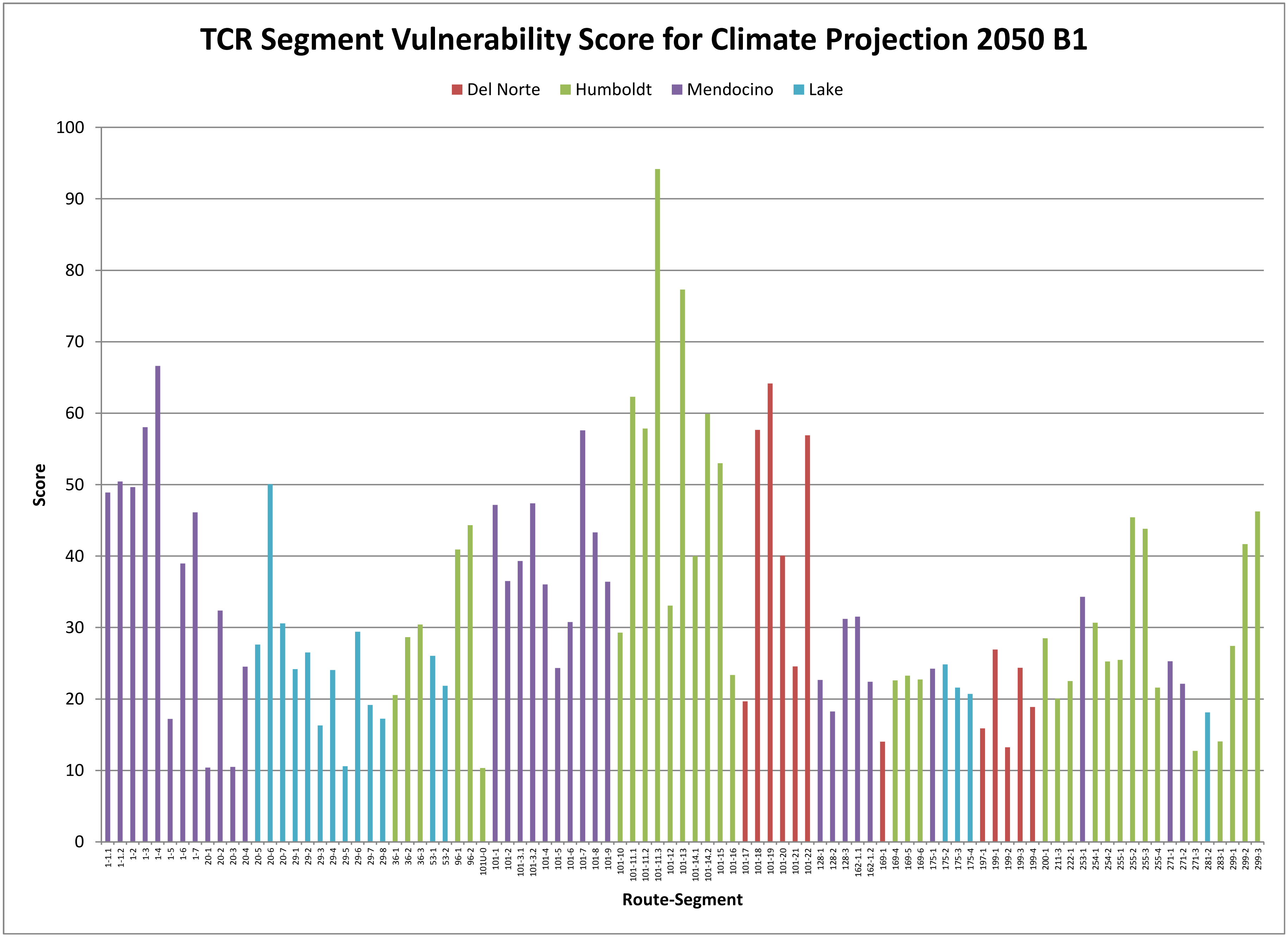
Attachment B: Plots of vulnerability scores for each climate projection



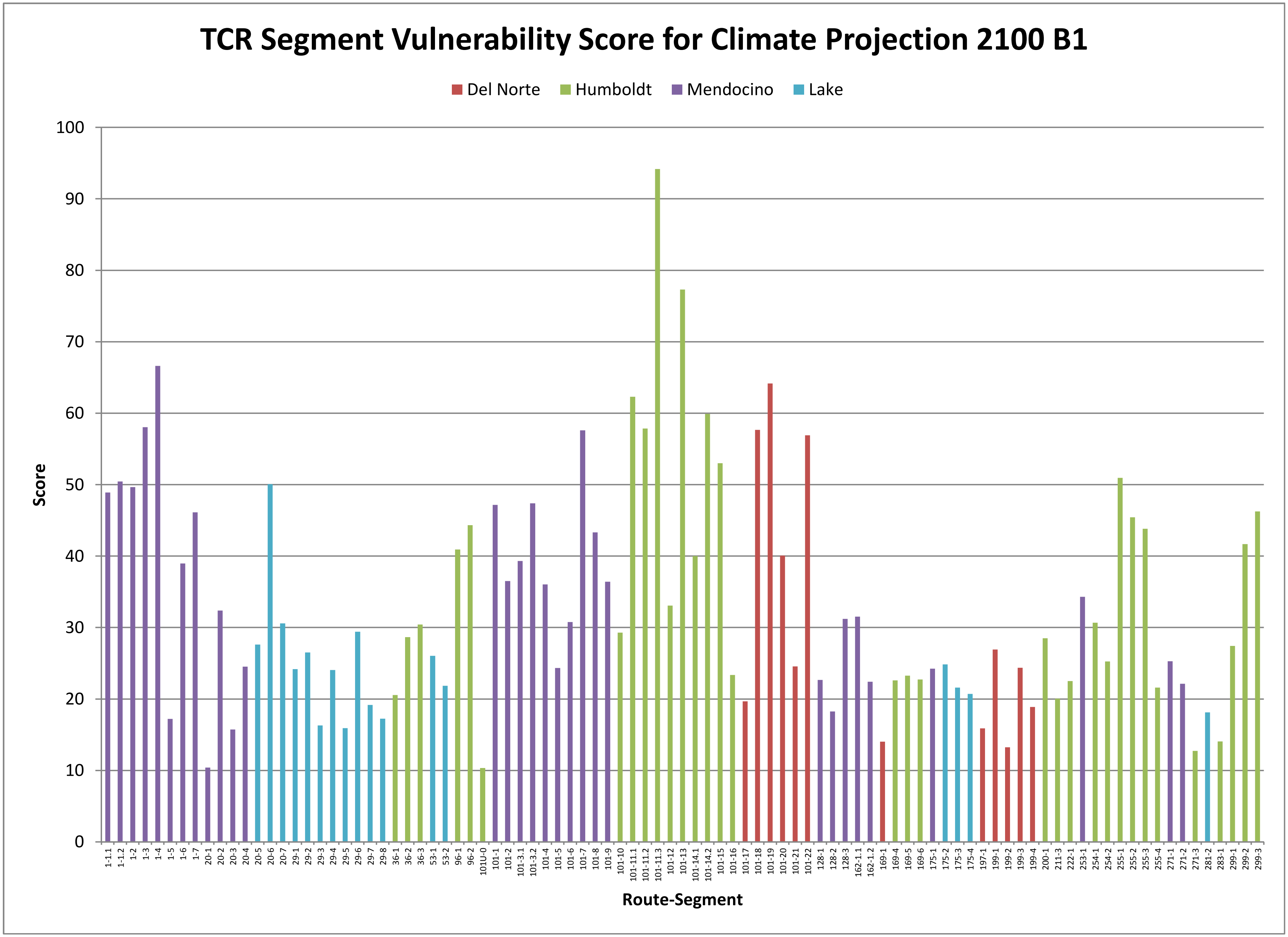
Attachment B: Plots of vulnerability scores for each climate projection



Attachment B: Plots of vulnerability scores for each climate projection



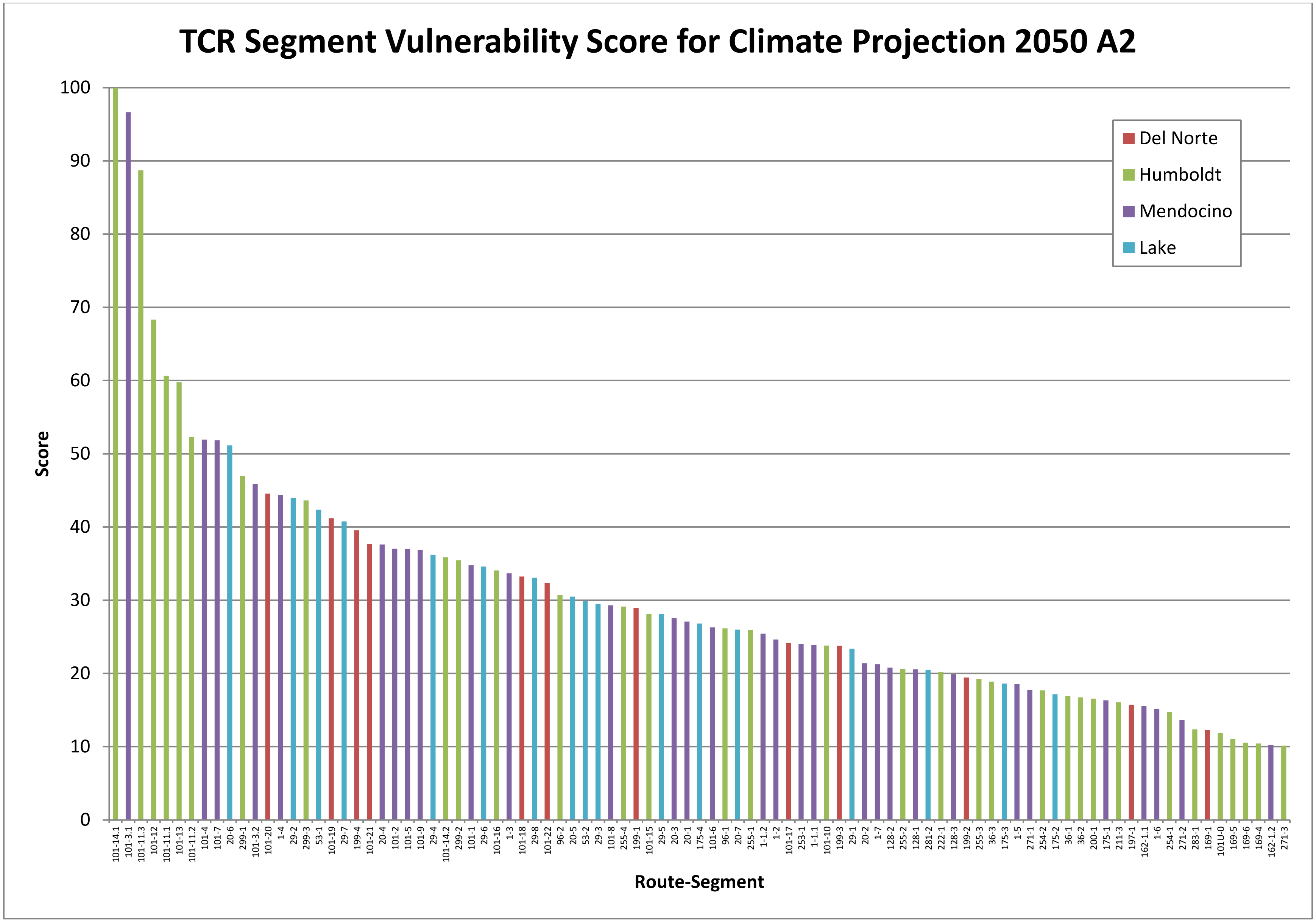
Attachment B: Plots of vulnerability scores for each climate projection



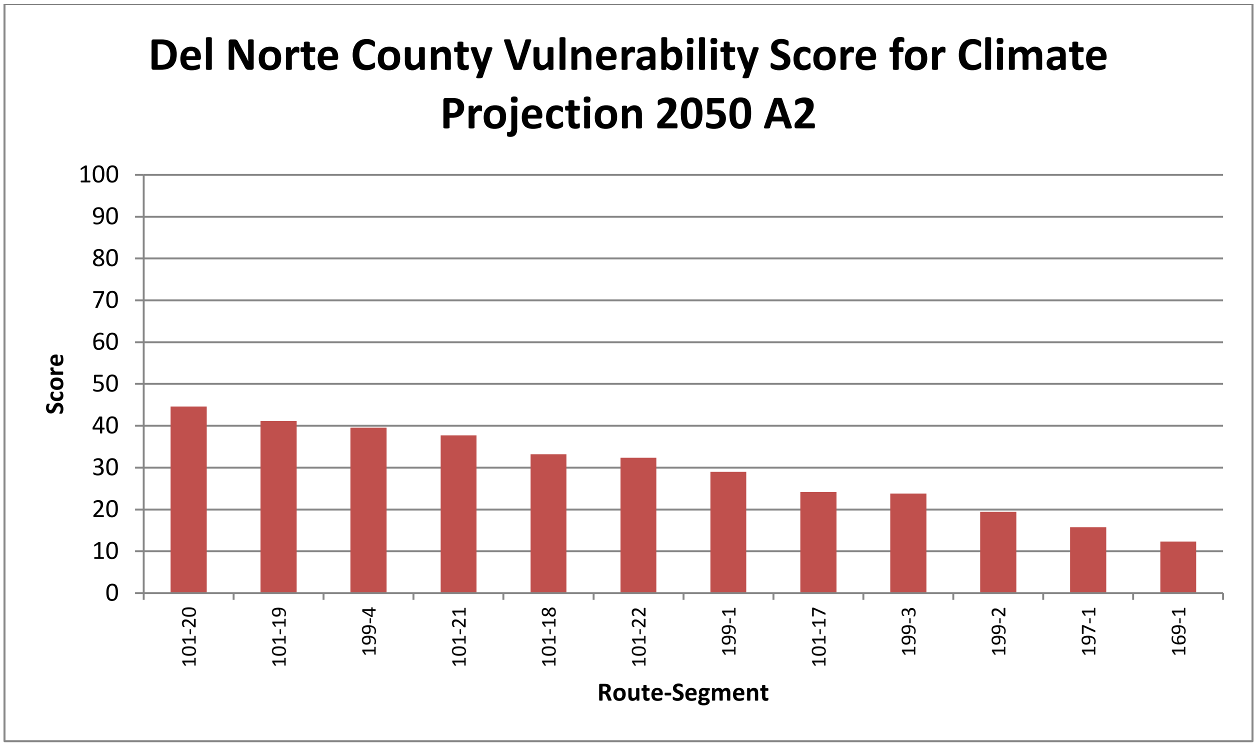
Attachment C

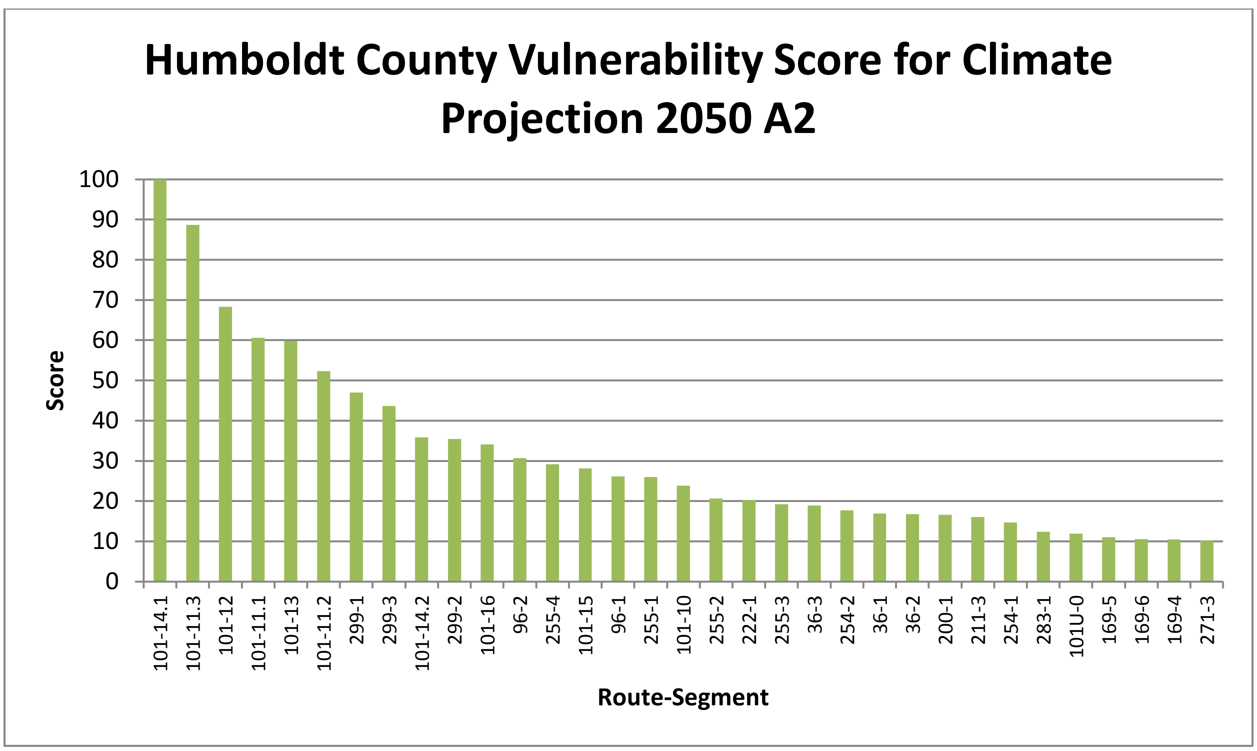
Vulnerability Scores for Climate Projection 2050 A2

Attachment C: Vulnerability scores for climate projection 2050 A2

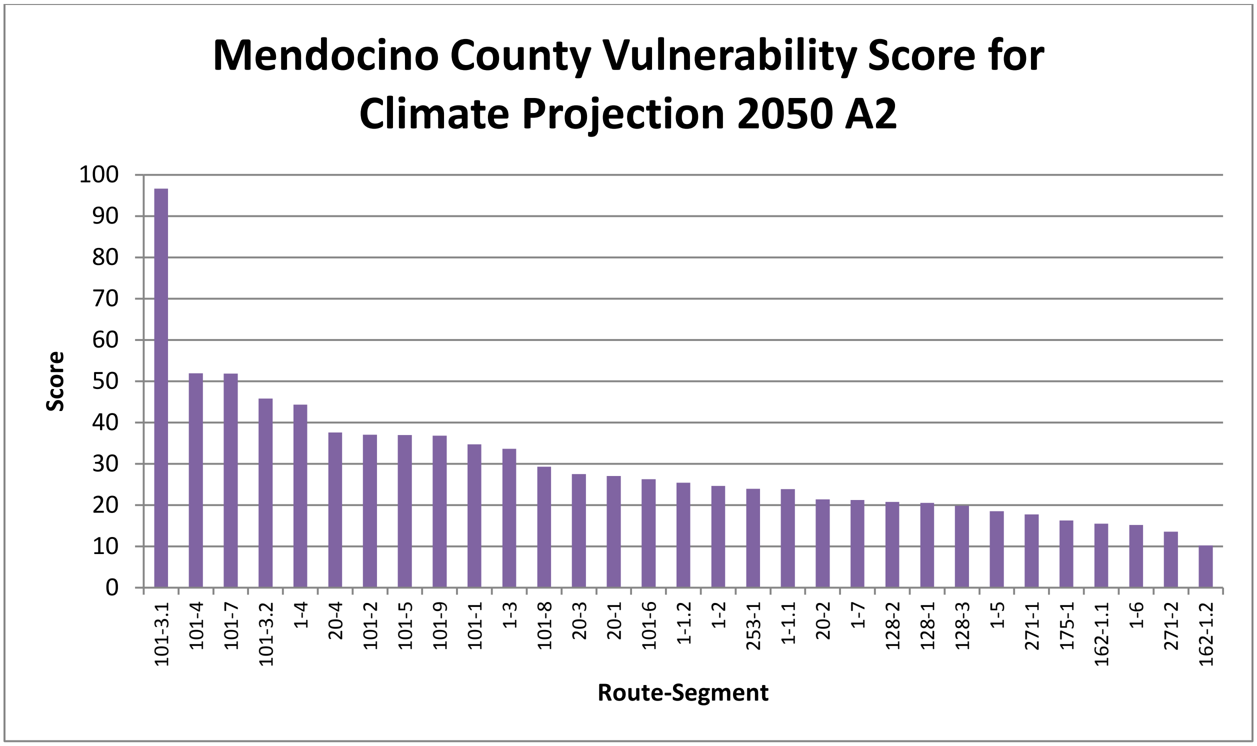


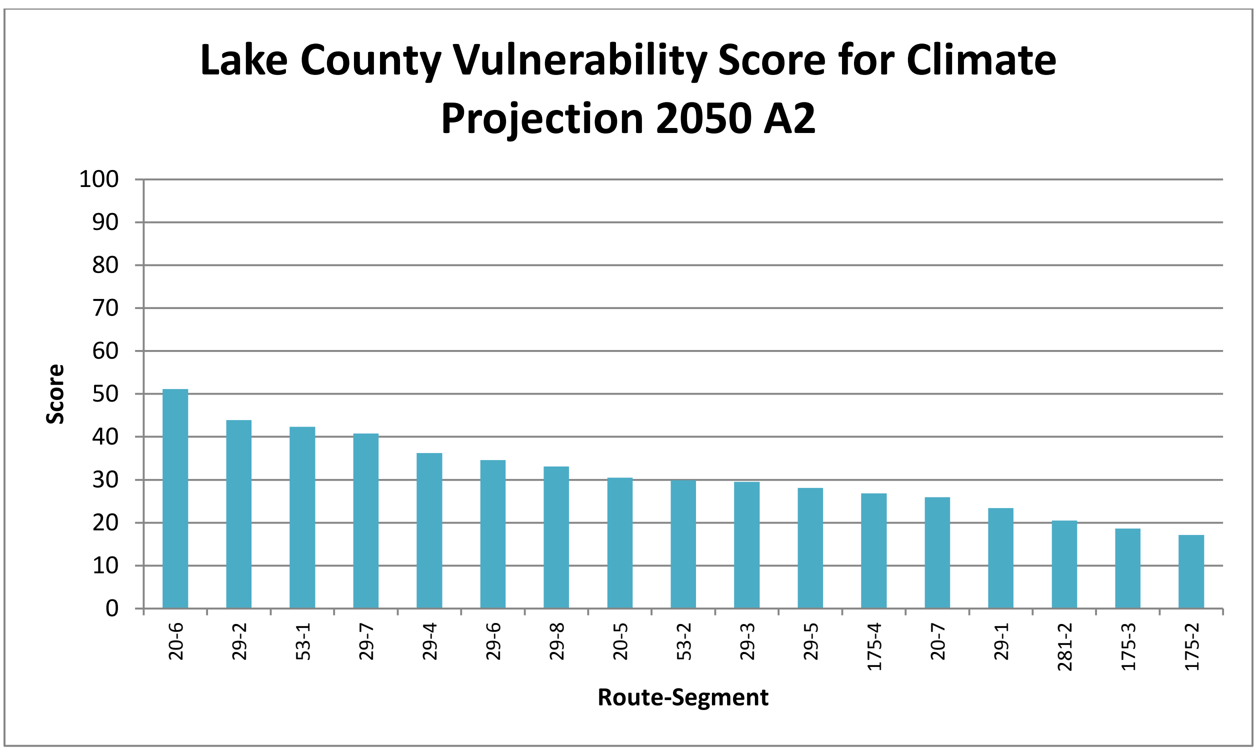
Attachment C: Vulnerability scores for climate projection 2050 A2





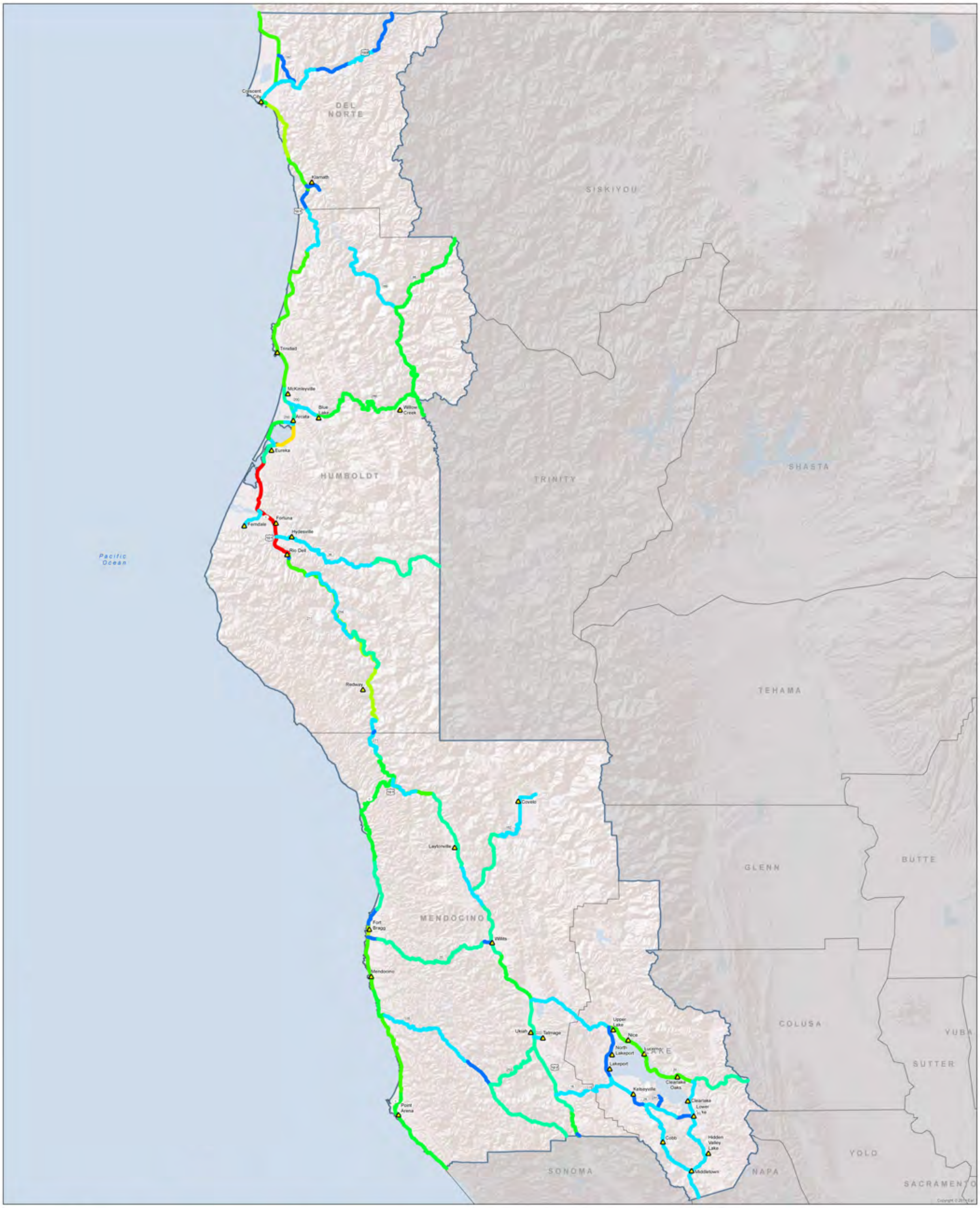
Attachment C: Vulnerability scores for climate projection 2050 A2





Attachment D

Climate Horizon 2050 A2 Overall Vulnerability Scoring per TCR Segment



Overall Vulnerability Score
1 = Low, 100 = High

Vulnerability$.Vulnerability_2050_A2

- 1-10
- 10.1 - 20.0
- 20.1 - 30.0
- 30.1 - 40.0
- 40.1 - 50.0
- 50.1 - 60.0
- 60.1 - 70.0
- 70.1 - 80.0
- 80.1 - 90.0
- 90.1 - 100.0
- City
- County Boundary
- District 1 Boundary
- Outside of District 1

Paper Size 30" x 42" (ARCH E1)

10 5 0 10
Miles

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere

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GHD ESA

Caltrans District 1 and HCAOG
District 1 Climate Change Pilot Study

Climate Horizon 2050 A2
Overall Vulnerability Scoring Per TCR Segment

Job Number 84-10842-20
Revision A
Date 17 Jul 2014

Figure 12

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718 Third Street Eureka CA 95501 USA T 707 443 8326 F 707 444 8330 E eureka@ghd.com W www.ghd.com

Data source: Data Custodian: Locations, road assets, PM Points, Culvert, Strom Drain - Feb 2014; ESRI world shaded relief - Feb 2013; Data Custodian: Roads - Feb 2014. GHD: Asset Criticality, 2014. Created by: bvivyan

Appendix 5

Caltrans Asset Adaptation Assessment Methodology

Memorandum

12 November 2014

To	Rex Jackman, Chief, Transportation Planning Caltrans District 1		
Copy to	Brad Mettam (Caltrans), Jamie Hostler (Caltrans), Marcella Clem (HCAOG)		
From	Rebecca Crow	Tel	707 443 8326
Subject	Caltrans Asset Adaptation Assessment Methodology	Job no.	84/10842/30

1 Introduction

This memorandum describes the methods and results of a process to identify and evaluate adaptation options for transportation assets owned and maintained by the California Department of Transportation (Caltrans) District 1 in support of the project entitled “Caltrans District 1 Climate Change Pilot Study” (D1CCPS). The Federal Highways Administration defines adaptation as “any activity that reduces the vulnerability of transportation systems to future changes in climate.” (FHWA, 2013)

The purpose of the overall project is to evaluate the vulnerability of Caltrans transportation assets in District 1 to various climate change factors and develop adaptation strategies for the most vulnerable assets. Prior memoranda assessed vulnerability of assets based on criticality and potential for impact resulting from regional climate change. These separate memoranda should be reviewed to provide context for this memorandum, and are listed below for reference.

The most vulnerable road segments were identified and four representative prototype locations were selected to test the tools and further the adaptation planning. One prototype location was identified in each of the four counties in Caltrans District 1 (Del Norte, Humboldt, Mendocino, and Lake) and highlight different types of assets, climate change hazards, and adaptation options. This memorandum summarizes the process used to identify and evaluate candidate adaptation options based on a number of factors including cost, effectiveness, flexibility, benefits, and social and environmental factors. The process begins with a range of potential adaptation options and through an evaluation and prioritization process, narrows the options to help focus future evaluation and selection processes.

When considering adaptation options, it is important to understand that climate change is a long term phenomenon with a multitude of short and long term effects. Appropriate adaptations need to be implemented within a timeframe that provides protection when it is needed. An adaptation option should be initiated based on a forecasted trigger condition such as a particular sea level elevation. In some cases, the trigger condition could occur decades in the future and so the evaluation, selection, and implementation of the most appropriate solution should be based on information that is most relevant and up to date. This memo provides a framework for considering adaptation options and the use of the pilot study areas are intended as examples of how the process can work rather than as a final decision of what should be done to adapt to climate change in any particular location.

1.1 List of Attachments

Attachments provide additional detail and illustrations in addition to the information and analysis provided in the text of this memorandum. The relevant supplemental attachments are as follows:

- Attachment A: Assessment Criteria
- Attachment B: Assessment Criteria Weighting Input, Pairwise Analysis, and Worksheet
- Attachment C: Summary of Climate Change Factors, Secondary Effects, and Adaptation Objectives
- Attachment D: Adaptation Options Scoring Worksheet
- Attachment E: Adaptation Options Summary Page
- Attachment F: Prototype Location Vicinity Map
- Attachment G: List of Adaptation Options

1.2 List of Supporting Documentation

This memo builds off work completed previously under separate cover as part of the overall Caltrans District 1 Climate Change Pilot Project. The following memos should be referenced for additional supporting information.

- Caltrans TCR Segment Criticality, GHD October 2014
- Caltrans TCR Segment Potential for Impact, GHD October 2014
- Caltrans TCR Segment Vulnerability, GHD October 2014
- Climate Data Projections for Caltrans District 1 Climate Change Pilot Study, ESA July 2014

2 Methodology

The project methodology to arrive at the assessment of adaptation options builds on the foundation presented in previous memoranda that culminated in the identification of the vulnerability of assets and identification of one prototype location within each of the four counties in District 1 that represents a higher vulnerability road segment. This memorandum highlights the methodology developed to identify and prioritize adaptation strategies at each of the prototype locations. A separate memorandum was developed for each of the prototype locations detailing the actual adaptation strategies developed for each of the sites.

2.1 Vulnerability Assessment Summary

The Vulnerability Assessment was based on an evaluation of road segment criticality, climate change impacts derived from regional models, and a potential for impact assessment. The criticality study evaluated road segments for their relative importance compared to other road segments. Criteria to assess criticality were both quantitative and qualitative. Transportation Concept Report (TCR) segments were used as the primary unit of study to assess vulnerability.

Climate change impacts were evaluated under two emissions scenarios and two timeframes (2050 and 2100):

- The A2 emissions scenario projects mid-to-high emissions assuming continuous population growth and uneven economic and technological growth, resulting in tripling of the atmospheric carbon concentration by the end of the century.

- The B1 emissions scenario represents lower projected emissions assuming carbon emissions peak by 2050 and then decrease by 2100. The B1 scenario results in a doubling of the atmospheric carbon concentration by the end of the century. This has been described as a "best case" scenario.

An assessment of the level of exposure of Caltrans assets to climate change impacts under these scenarios, and a review of historical maintenance events were combined to arrive at potential for impact scores. The product of the scores for potential for impact and criticality resulted in the overall vulnerability score.

Four sites were selected, one in each of District 1's counties, for adaptation option assessment. The selected sites represented typical vulnerabilities for their regions, and allowed the project team to examine a range of climate change factors and adaptation options in development of the methodology. A map of the four selected sites is included Attachment F.

2.2 Adaptation Option Development

The adaptation option development methodology used to identify and prioritize adaptation options is presented in this section. Prior transportation-related adaptation planning documents were reviewed for their processes and prioritization criteria. Certain activities, such as the identification of impacts and vulnerabilities, listing of adaptation options, and selected priority options, were common to many of the studies. However, criteria for selecting options and identifying timeframes for implementation was not always clearly described and so this analysis intends to carry the state of practice of clime change planning a step further. The methodology proposed in this memorandum provides evaluation criteria that can be customizes to reflect the priorities and values of the planning participants, and also provides a framework for estimating planning and implementation timeframes to help plan for adaptation investments.

A model was developed based upon the process shown in Figure 1: Overall Adaptation Process Flowchart. Specific sites were evaluated for physical and climate factors; a range of adaptation options developed; and criteria for preliminary evaluation were considered. This process was formalized within a spreadsheet, producing a range of options with scores based upon weighted criteria.

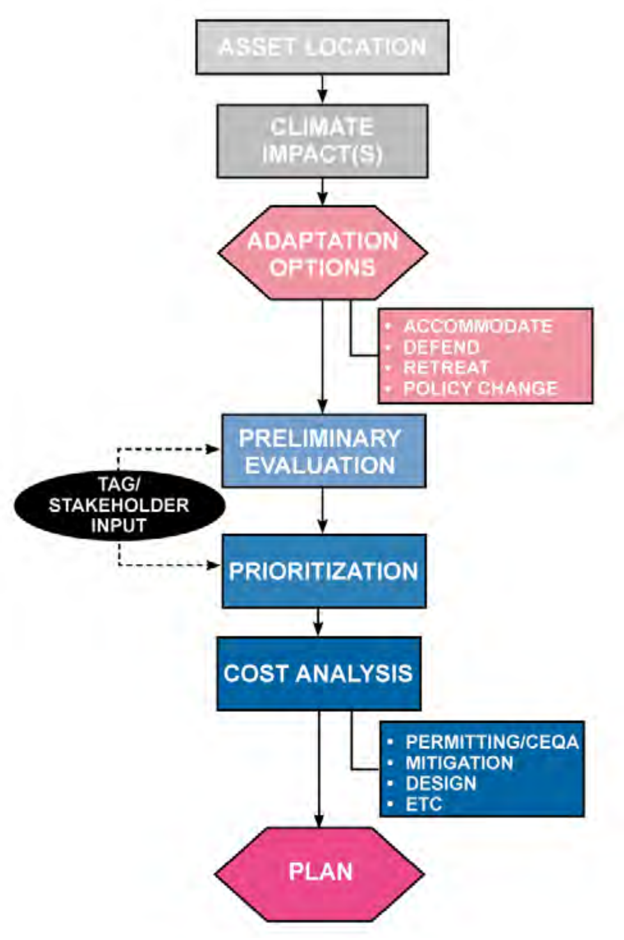

Figure 1: Overall Adaptation Process Flowchart

Development of the adaptation methodology began with an assessment of categories of Climate Change Factors, and their Primary and Secondary Effects. For example, a Climate Change Factor is global temperature increase, a Primary Effect is sea level rise, and a Secondary Effect is tidal flooding. In the context of this study, it is these Secondary effects that impact transportation assets. These concepts are further discussed in the following sections.

2.2.1 Climate Change Factors and Effects

Primary Effects of climate change factors are a general indicator of the potential for large-scale impacts to an asset. Figure 2 outlines the Primary Effects of the three climate change factors identified for District 1 transportation assets, sea level, temperature increase, and precipitation changes. Sea level rise has the potential to increase erosion to coastal lands due to wave run-up, to inundate coastal assets from tidal flooding, and raise the water table of coastal lands. Extreme temperature increases have the potential to alter the composition and health of forest and rangeland areas (CNRA 2012), and dry out fuels that feed wildfires. As a result, the increased temperatures have the potential to increase the frequency and severity of wildfires (CNRA 2009). Increases in air temperature, particularly when in conjunction with changes in atmospheric circulation, affect the development of storms and the potential for heightened cyclone activity (FHWA 2013). Precipitation changes can increase runoff magnitudes, which may overwhelm existing assets. Further, precipitation changes can cause soil conditions to remain saturated longer than anticipated, triggering landslides or otherwise damaging structures.

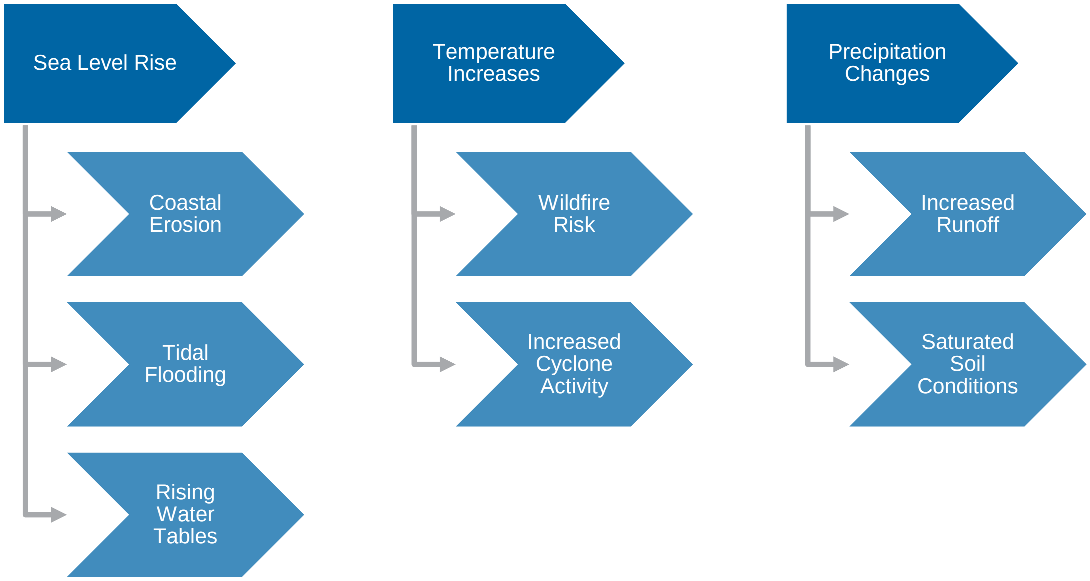

Figure 2: Climate Change Factors and Primary Effects Addressed in This Study

The Secondary Effects are a result of how the Primary Effects impact an asset. They describe specific hazards that may threaten a structure, facility, or natural resource, such as damage due to flood, fire, or erosion. Existing protection measures, such as levees or drainage structures, may currently mute the magnitude of these impacts. Other site conditions, such as local geology, could exacerbate the damage. Secondary Effects may be minimal or extreme, and should be analyzed for individual sites. An example of how Climate Change Factors and their Effects can be mitigated through setting Adaptation Objectives and identifying Adaptation Options is shown in Figure 3.

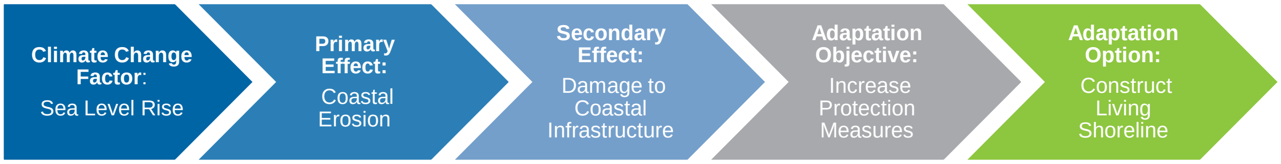

Figure 3: Example of Climate Factors and Related Adaptation Objectives and Options

Adaptation Objectives to address Secondary Effects are developed to identify overarching approaches to address the climate change impacts on assets. . Each Adaptation Objective could have multiple Adaptation Options. The same objective may also apply to multiple secondary effects. A summary of climate change factors, secondary effects, and adaptation objectives evaluated in this study are included in Attachment C.

2.2.2 Adaptation Approach

Adaptation options represent a spectrum of approaches to meet the challenge of climate change, characterized as “defend, accommodate, planned retreat, and forced retreat.” Policy changes are also often considered along with adaptation options. Options that “defend” an asset increase protection around the asset. An example of defend option is to build a seawall to protect an asset against sea level rise. Options that “accommodate” modify the asset to allow the impact to pass through the system without harming it. A typical example of an “accommodate” strategy is installation of a causeway that allows floodwaters to pass beneath a coastal road. Planned retreat strategies relocate an asset outside of a hazard zone before the Secondary Effects disable the asset. Forced retreat is the consequence of taking no action and the Secondary Effects render the asset unusable. Forced retreat can be a deliberate strategy while other strategies are in preparation, or can be the result of no or poor planning. The category “changes in policies or practices” was also added to represent the range of maintenance, planning, or regulatory changes that can improve management of assets under climate change threats. This “defend-accommodate-retreat” framework was helpful in thinking through options that represented a range of solutions, but is not itself significant to the adaptation project selection process.

Table 1: Examples of Adaptation Option Categories

Adaptation Category	Adaptation Option Example
Defend	Construct a levee or dike
Accommodate	Establish alternate routes for use during closures
Retreat (planned)	Remove, restore site and rebuild infrastructure at a different location
Retreat (forced)	Abandon asset and vacate property
Changes in Policies or Practices	Modify land use policies to discourage development in the at risk zones

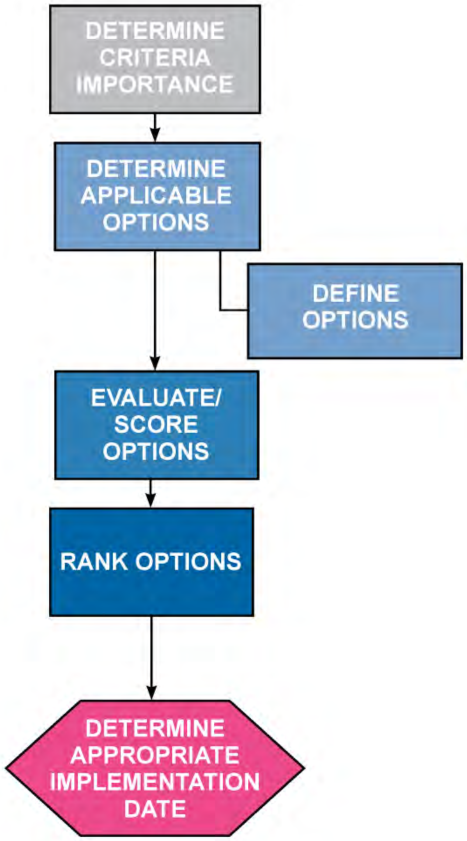

Figure 4: Evaluation Process Flowchart

Criteria for evaluating the adaptation options involved project finances, timelines, performance, and consequences of a project. These criteria were based upon a review of prior climate change adaptation studies, and project team discussions. Attachment A provides a list of the criteria, definitions and scoring ranges.

These criteria were weighted using a pairwise analysis to reflect local priorities and values. Adaptation criteria were ranked for potential weighting through Stakeholder and public meetings. Stakeholders were asked to prioritize criteria. At public meetings, participants were given three stickers to use for voting in any combination on their preferred criteria. The opinion on criteria ranking was explored to understand how community and stakeholder values and priorities could be translated into the tool. Final weighting of criteria are presented in the next section.

Developing thresholds for project selection and implementation timing was also incorporated into the model. The relative design life of adaptation options was programmed into the spreadsheets, allowing users to iteratively explore how different options may be desirable for different climate change projections, target design thresholds for expensive projects with long design lives, or identify maintenance triggers for upgrading to more expensive adaptation options.

For example, a bridge may have a design life of 80-100 years, but could become unusable in less time by climate change effects. In such a scenario, managers may choose to maintain existing assets for an extended period ("defend" scenario) while planning for replacement of the asset as climate impacts are better documented and projections become more accurate, or managers may choose to design the project according to current projections for the forecasted worst case scenario in 2100.

The process creates a way to rapidly winnow a large field of potential adaptation options to a more manageable list. It is not a substitute for the balancing of technical, sociological, ecological, and political decisions that must be made through dialogue, but rather a means of refining priorities.

3 Adaptation Option Selection and Evaluation

This section describes the process of selecting and evaluating adaptation options undertaken in the D1CCPS in greater detail.

3.1 Adaptation Option Selection

Many adaptation options can be considered for every climate change event and situation. The intent of the tool developed in this study is not to capture every possibility, but to identify a variety of general options ranging from the “no project” approach to relocation, protection, or reconstruction.

Nine primary adaptation options are included within the adaptation tool. These adaptation options were developed through an evaluation of Climate Change Factors, and Primary and Secondary Effects along with associated Adaptation Objectives. The final list represents primary types of Climate Change Adaptation projects. The adaptation tool provides specific examples of adaptation options that fall within each primary category. Table 2 shows the adaptation options included within the tool. Attachment G includes the full list of example adaptations under each option.

Table 2: Adaptation Tool Adaptation Options

Approach	Adaptation Option
Defend	Provide major structural protection
	Provide protection at existing elevations/locations
Accommodate	Elevate the infrastructure above the impact zone
	Enhance drainage to minimize closure time and/or deterioration levels
Retreat	Abandon Infrastructure
	Relocate infrastructure (horizontally)
	Temporarily restrict use of infrastructure
Changes in policies or practices	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate
	Modify land use and development policies to account for future impacts

Once the primary adaptation options are chosen, the adaptation tool automatically carries over those options into a scoring sheet and a more detail description is entered in the adaptation tool. The more detailed description is developed based on a review of the example adaptations and site specific characteristics.

3.2 Preliminary Evaluation

The preliminary evaluation process is intended to objectively compare a number of adaptation options based on a list of predetermined assessment criteria. The process begins by determining the appropriate assessment criteria and the level of each criterion’s importance. When compared against one another, each criterion is weighted. A higher weight represents greater relative importance. Next, options that were pre-selected through the prior steps are then evaluated (numerically scored) based on each assessment criterion. The total weighted score for each option is calculated. Estimating the timeframe for each option is then performed to identify the impacts form different implementation dates.

3.2.1 Assessment Criteria

The following seven assessment criteria were selected to independently score each option:

1. Total Capital Investment
2. Average Annual Cost

3. Usable Life
4. Level of Performance
5. Flexibility
6. Environmental Considerations
7. Social Considerations

Factors relating to cost, effectiveness, flexibility, benefits and impacts were considered and then weighted based on importance level. The criteria are defined specifically to relate to the climate change impacts and terminology used in this study. Each criterion is given a numerical range of scores to choose from. Attachment A contains detailed descriptions of the Assessment Criteria and their range of scores.

3.2.2 Level of Criteria Importance

The assessment criteria are weighted with respect to one another and used to emphasize importance of one or more criteria. Input on the level of importance was obtained from TAG and Stakeholder feedback as well as the public. Attachment B presents a summary of the public input received in the August 2014 public meetings and the feedback received from the TAG and Stakeholder groups on the ranking of criteria. The input from the TAG and Stakeholder groups was used as the basis for the pairwise analysis completed to determine the final weighting. Attachment B also shows the final criteria ranking and weighting developed using the pairwise matrix to compare the criteria one-to-one basis. Lastly, Attachment B includes the criteria scoring worksheet used to obtain feedback on the importance level of each criterion. For a more detailed discussion on obtaining weights from a pairwise analysis, refer to the Caltrans TCR Segment Criticality Technical Memo (GHD, 2014).

After the initial selection of options has been made, a secondary table shows only the selected options for the purposes of scoring (Figure 5)

Project Location: HYW 101 Humboldt Bay			Assumed Values	
			Assumed Design Service Life	Assumed Total Capital Investment
No.	**Adaptation Option (Select from List)**	**Enter Description or Comment**		**Weight >>**
1	Provide protection at existing elevations/locations	*Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height to 1 ft above 2050 water level at a King tide*	100	107,958,000
2	Elevate the infrastructure above the impact zone	*Increase the height of the roadway by building up the fill prism 1 ft above 2050 water level at a King tide for 6 miles*	100	93,702,000
3	Elevate the infrastructure above the impact zone	*Construct a causeway, 6 miles, at a height of 5 ft above 2050 water level at a King tide*	100	343,676,000

Figure 5: Sample of List of Applicable Options.

The choices for adaptation options within the tool are intended to be relatively general in nature. Prior to more detailed evaluation of each option further planning should be undertaken including conceptual planning limits of work, level of protection, materials used, etc. For example, an appropriate description might be to "*Create a living shoreline averaging 350' long by 40' wide with an oyster reef breakwater, vegetative salt marsh and riparian buffer.*" If this option is chosen and implemented, a significant amount of additional detail will be necessary for the final evaluation and selection as well as for the design and construction. However, for planning purposes only the basic configuration need be entered. The description of the conceptual plan should be entered into the "Enter Description or Comment" box.

3.3 Adaptation Option Evaluation

Once the adaptation options are entered and the description completed, the assessment criteria are scored. The first two assessment criteria are based on user input for Design Service Life and Total Capital Investment cost. The Design Service Life can vary depending on the infrastructure, but essentially it is the "life" of the infrastructure until major deterioration begins to occur. For the purposes of the study, the design service life of an asset assumes that regular, routine maintenance occurs (e.g. overlays, crack sealing, etc.). The Total Capital Investment is based on the estimated cost for full implementation of the option (from planning through construction).

Based on the information provided, the first two criteria (Total Capital Investment and Average Annual Cost) are automatically calculated and scored (Figure 6). The remaining criteria require input based on the conditions of the location and/or the option being evaluated. Attachment D displays an example complete scoring worksheet. When evaluating the option, the definition of each criterion should be reviewed and used to consider the appropriate scoring of the option. In some cases, the scores available may not seem applicable or appropriate to the situation. Specific notes and examples are provided for each of the criteria in Attachment A, and it also provides assistance on how to appropriately score the option given the situation. Once decided, the score can be chosen from the dropdown menu provided under each criterion.

Assessment Criteria							Total Score	Rank
Total Capital Investment	Annual Average Cost	Usable Life	Level of Performance	Flexibility	Environmental Considerations	Social Considerations		
3.7	11.1	18.5	25.9	7.4	14.8	18.5		
0: > $100M	0: >$100,000/yr	2: Acceptable	3: Enhanced	3: Likely (or unnecessary)	-1: Very little net impact	2: Some net improvement	159	2
1: $10M - $100M	0: >$100,000/yr	2: Acceptable	3: Enhanced	1: Unlikely	-2: Some net impact	2: Some net improvement	133	3

Figure 6: Sample Scoring of Option Based on the Criteria

When all of the criteria have been scored, the weighted score is calculated and displayed under "Total Score" (Figure 7). As each option is scored, the ranking will automatically be updated to indicate the highest scoring options. The five highest ranking options are then displayed separately for further evaluation (Figure 7).

Top Scoring Adaptation Options			
Rank	Adaptation Option	Project Description	Score
1	Elevate the infrastructure above the impact zone	Construct a causeway, 6 miles, at a height of 5 ft above 2050 water level at a King tide	174
2	Provide protection at existing elevations/locations	Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including	159
3	Elevate the infrastructure above the impact zone	Increase the height of the roadway by building up the fill prism 1 ft above 2050 water level at a King tide for 6 miles	133
4	Temporarily restrict use of infrastructure	Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information	93
5	Increase the infrastructure's maintenance and inspection interval and continue to	Equivalent to the No project alternative. Only temporary measures inacted and repairs made on an as needed basis.	93

Figure 7: Sample of Top Scoring Options Table

3.3.1 Timeline and Summary

A summary page is created for up to five of the highest ranking options (Attachment E). The summary includes information such as climate factors and impacts, description of the option, input data, and criteria scores. In addition, assumptions can be made to estimate the various stages of development and desired implementation date. Similar to the scoring, a drop-down menu displays the top five option descriptions. Once the option is selected, previously input information will automatically be inserted in the appropriate cells. Figure 8 displays a sample of the location, climate factor, and adaption option information that is populated upon selecting one of the options from the menu.

Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2050
Adaptation Option	Provide protection at existing elevations/locations
Project Description	**Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height to 1 ft above 2050 water level at a King tide**

Figure 8: Sample of Upper Portion of the Summary Page

Next, timeframes associated with planning, permitting, design, and construction are estimated in order to assess the usable life of the project in light of climate change adaptation initiation dates. An initiation date is when the formal implementation process is planned to begin. Depending on the option and level of complexity, planning, permitting, design and construction timeframes may vary significantly. Lastly, the desired implementation date should be added. Once completed, the timeline will automatically update to reflect the timeframe associated with the overall process. Figure 9 displays a sample summary of the example adaptation option selected in Figure 8.

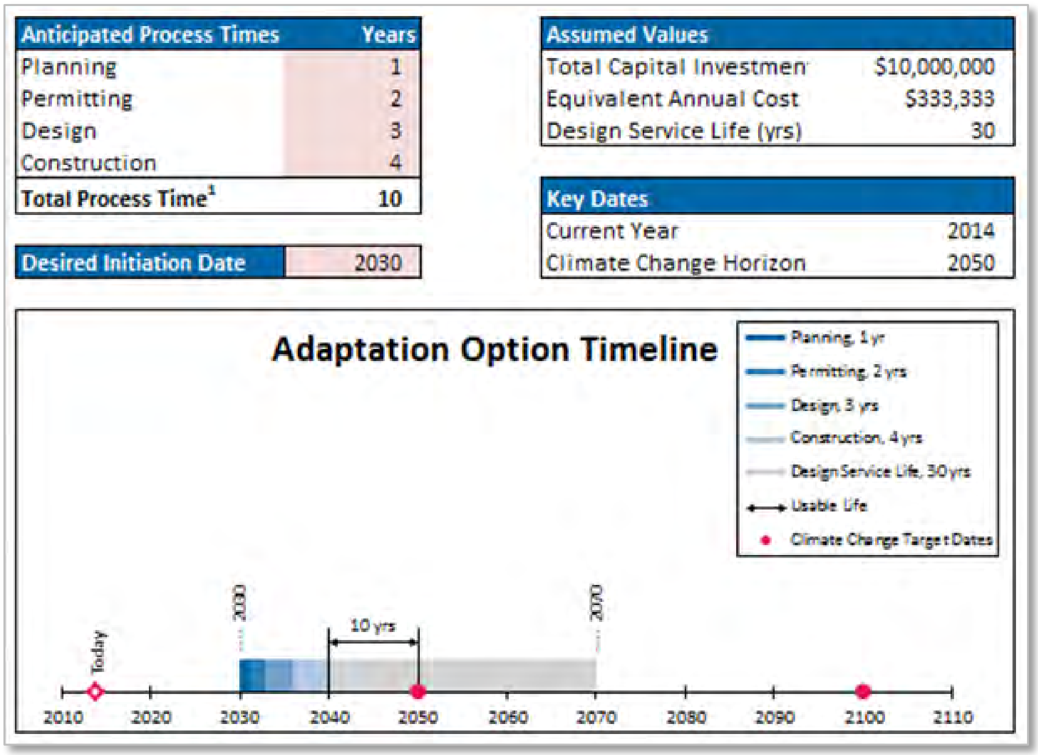

Figure 9: Sample of Lower Portion of the Summary Page

Depending on the outcome, the project initiation date can be modified and adjusted as needed to achieve the desired usable life with respect to climate change target dates (2050 or 2100). In addition, the timeline can be used to identify shortcomings, such as significant investments that would have short usable lives based on climate change horizons. The intent of this component of the tool is to identify preferred implementation timelines for each option and allow comparison of the life or protection of each option.

4 Climate Change Variability and Implementation

The results of this study address climate change impacts and projections obtained from existing models, but as the science and understanding of the impacts of climate change improve, the model projections are likely to change. For these reasons, adaptation strategies should consider how the inherent uncertainty of climate projections affects the adaptation initiation date. Figure 10 depicts how uncertainty or variability in the rate of climate change can affect the initiation date. For example, if the existing projection of sea level rise is found to underestimate water elevations by 2050 and 2100, coastal adaptation strategies will have to be initiated at an earlier date than was initially considered. Conversely, if sufficient emissions reductions are achieved such that global temperatures stabilize implementation of adaptation strategies may be delayed or have a longer useful life.

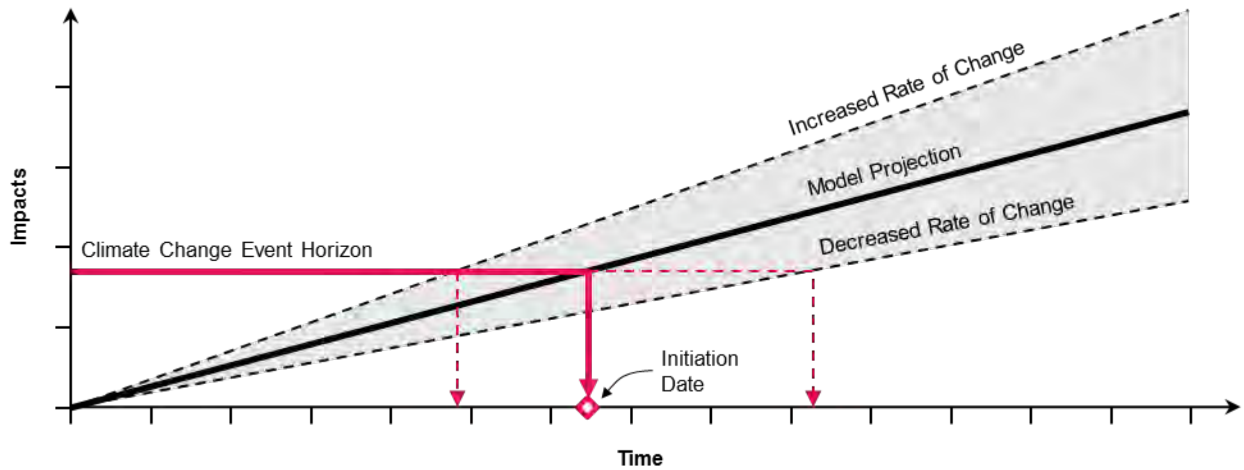

Figure 2: Need for Initiation of Adaptation Strategies May Depend upon the Rate of Climate Change

The existing timeline of an adaptation strategy assumes that an improvement or new asset will be designed to withstand projected climate impacts, but its usable life may depend on the projected climate change event horizon. Figure 11 depicts a typical timeline of an adaptation strategy from project initiation to the end of an asset's design life.

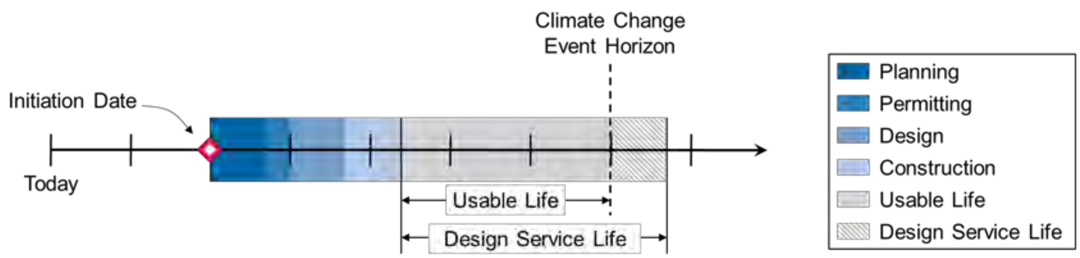

Figure 11: Typical Timeline of an Adaptation Strategy

The initiation timing of an adaptation strategy varies depending upon the rate of climate change. As previously discussed, if a climate change effects are found to occur at a rate other than projected, adaptation strategies may need to be changed or may need to be initiated sooner or could be delayed. Figure 12 depicts how the uncertainty of climate effects can change the initiation date.

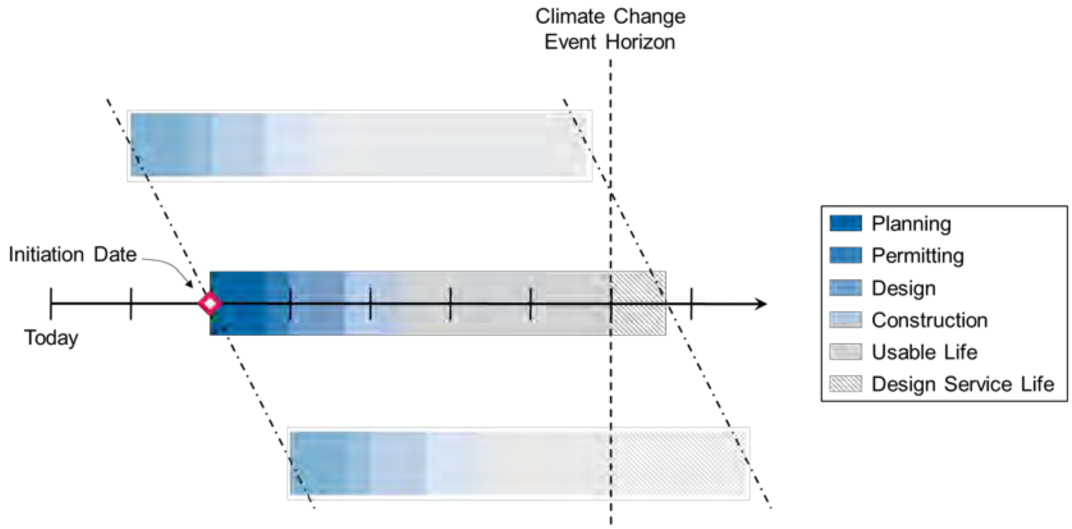

Figure 3: Changes in Adaptation Initiation Dates Due to Uncertainty of the Rate of Climate Change

5 Conclusions

This technical memo presented the methodology for assessing adaptation strategies. This methodology was used to develop and evaluate adaptations at the four prototype locations, which are presented in a separate technical memorandum.

6 References

Environmental Science Associates (ESA), 2014, Climate Data Projections for Caltrans District 1 Climate Change Pilot Study, Memorandum Prepared by Louis White, PE (ESA) for Rob Holmlund (GHD), July 21, 2014.

California Natural Resources Agency (CNRA). (2009). California Climate Adaptation Strategy. State of California Executive Order S-13-2008.

California Natural Resources Agency (CNRA). (July 2012). California Adaptation Planning Guide: Identifying Adaptation Strategies.

GHD, 2014, Caltrans TCR Segment Criticality, Memorandum Prepared by Rebecca Crow (GHD) for Rex Jackman (Caltrans), October 15, 2014.

Federal Highway Administration (FHWA). (March 2013). Planning for Systems Management & Operations as part of Climate Change Adaptation.

Federal Highway Administration (FHWA). (October 2013).Assessment of the Body of Knowledge on Incorporating Climate Change Adaptation Measures into Transportation Projects.

Attachment A

Assessment Criteria

Assessment Criteria

Total Capital Investment

The estimated total cost of implementation of the adaptation option including, but not limited to the costs associated with planning, permitting, design and construction.

Scoring range:

0 – Greater than $100M

1 – $10M to $100M

2 – $1M to $10M

3 – Less than $1M

Average Annual Cost

Average annual cost is the total capital investment cost of implementing the adaptation option with respect to the design service life.

Example: If the estimated total cost of the option is $1.6 million but the design service life is 50 years, the ratio would be $36,000/year.

Scoring range:

0 – More than $100,000/year

1 – $50,001/year to 100,000/year

2 – $10,001/year to $50,000/year

3 – Less than $10,000/year

Usable Life

Usable life is the comparison of the adaptation option's design service life, with respect to the climate change event horizon.

Example: Re-routing of traffic may only be a short term solution due to the capacity or strength of the available route to handle the full ADT of the impacted route. In the case where the specified climate horizon is beyond the life expectancy of the adaptation option, the score should be deemed "Considerable, but insufficient".

Scoring range:

0 – Minimal (or Temporary)

1 – Considerable, but insufficient

2 – Acceptable

3 – Surpasses

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Note: In the case where only policy changes are proposed and no project is specified, the score should reflect the estimated usable life of the existing infrastructure.

Note: Regular maintenance activities such as overlays, in-kind replacement, etc. should not be used to determine the useful life.

Level of Performance

Level of performance is the existing level of protection compared to the anticipated level of protection, at the specified climate change event horizon.

Example: An adaptation option that would allow for occasional, temporary flooding of a roadway that currently does not flood, would be considered to be "1 – Decreased" level of performance.

Scoring range:

0 – Minimum (or none)

1 – Decreased

2 – Equivalent

3 – Enhanced

Note: In the case where "Do Nothing" is the option, the score should reflect the change in performance of the existing infrastructure during the climate change event horizon, as compared to the existing conditions.

Note: Consideration should be made to the performance of the option only. In the case of wildfires, the adaptation option may be used to protect/enhance the signs or roads however, road closures due to smoke should not be considered due to the fact that the smoke is in no way, a result of the option chosen.

Flexibility

Flexibility is the ability of the adaptation option (at any stage in development) to be modified to provide a higher level of protection against impacts or to be updated as new data models for climate change are developed. Flexibility also considers the potential for the adaptation option to be phased or completed in segments over a longer period of time. The benefit to phasing (for the purposes of scoring this criterion) is that the total capital investment cost can be distributed over a period of many years.

Scoring range:

0 – None

1 – Unlikely

2 – Potentially

3 – Likely (or unnecessary)

Note: In the case where "Do Nothing" is the option, the recommended score would be "2 - Potentially" with the idea that this option will result in a reduced (or no) level of protection therefore, future options for protection have a high level of flexibility …except in the case where enough time has elapsed eliminating any opportunities for future improvement or development.

Environmental Considerations

Environmental considerations accounts for the potential of the adaptation option to improve or impact the existing environmental conditions with respect to integrity, diversity, or abundance of the natural ecosystem's functions and/or habitat.

Scoring range:

-3 – Significant impact

-2 – Some impact

-1 – Very little impact

0 – No change (or balance of improvements vs. impacts)

1 – Very little improvement

2 – Some improvement

3 – Significant improvement

Example: Benefits may include opportunities for new environmental restoration,

Example: Environmental impacts may have a potential for negative or adverse consequences with respect to impacts to sensitive habitats or species. Impacts are limited to those caused by proposed adaptation project, and do not consider impacts which would otherwise occur under the no project scenario. For example if an area would be flooded under a climate change scenario and the adaptation option elevates transportation infrastructure but allows the same level of climate change induced flooding, the option would be ranked " no change".

Social Considerations

Social considerations accounts for the potential of the adaptation option to improve or impact the communities social welfare.

Example: Benefits may include the potential for cooperation or collaboration efforts towards the implementation of the adaption option, which may include the sharing of costs, permitting, design ideas, public communication efforts, etc.

Example: Social impacts may have the potential for negative or adverse impacts with respect to livelihood, health, safety, culture, or economic development of the surrounding communities.

Scoring range:

-3 – Significant impact

-2 – Some impact

-1 – Very little impact

0 – No change (or balance of improvements vs. impacts)

1 – Very little improvement

2 – Some improvement

3 – Significant improvement

Attachment B

Assessment Criteria Weighting Input, Pairwise Analysis, and Worksheet

Summary of Tag, Stakeholder and Criteria Weighting

	Humboldt County	Del Norte	Mendocino County	Lake County	All Counties	TAG/SHG	Final Score -for TAG weighting
Total Capital Investment	3	4	1	3	2	1	3.7
Average Annual Cost	6	2	3	1	3	3	11.1
Usable Life	6	3	5	7	6	6	18.5
Level of Performance	4	7	4	5	7	7	25.9
Flexibility	7	1	6	5	5	2	7.4
Environmental Considerations	2	5	7	6	4	4	14.8
Social Considerations	1	6	3	3	2	5	18.5

Notes:

- Highest ranked criterion
- Second highest ranked criterion
- Third highest ranked criterion

Criteria Weighting Pairwise Matrix
Enter the numbers ""1 or "0" in the upper right (red) portion of the matrix. The lower (gray) portion will be automatically populated with the opposite value.

Enter a "1" if the critieria in the row (left) is more important than the critieria in the column (top), or

Enter a "0" if the row is less important than the column.

	Total Capital Investment	Annual Cost	Usable Life	Level of Performance	Flexibility	Environmental Considerations	Social Considerations	Weight	Percent	Weighting Rank
Total Capital Investment		0	0	0	0	0	0	0.037	3.7%	7
Annual Cost	1		0	0	1	0	0	0.111	11.1%	5
Usable Life	1	1		0	1	1	1	0.185	18.5%	2
Level of Performance	1	1	1		1	1	1	0.259	25.9%	1
Flexibility	1	0	0	0		0	0	0.074	7.4%	6
Environmental Considerations	1	1	0	0	1		0	0.148	14.8%	4
Social Considerations	1	1	0	0	1	1		0.185	18.5%	2
Weight	0.037	0.111	0.185	0.259	0.074	0.148	0.185			
Percent	3.7%	11.1%	18.5%	25.9%	7.4%	14.8%	18.5%			
Weighting Rank	7	5	2	1	6	4	2			

D1 CLIMATE CHANGE PILOT STUDY: TAG/STAKEHOLDER ADAPTATION OPTION CRITERIA SCORING WORKSHEET

Name: County:

Agency:

Background: The importance of the critieria used to evaluate an adaptation option is a key factor in determining which options to consider. The purpose of this ranking exercise is to obtain input from the Technical Advisory Group and Stakeholders on which factors are most important to consider when looking at Caltrans District 1 assets.

Return to: **Jessica Hall at GHD, 718 Third St. Eureka, CA 95501 or email to** jessica.hall@ghd.com Please return by: **September 2, 2014**

Instructions: Please rank the importance of the adaptation option criteria listed below from most important (8) to least important (1). These relative importance values will be used to develop weighting for the adaptation option criteria.

Criteria	Description	Importance	Comments*
Total Capital Investment	The estimated total cost of implementation of the adaptation option including, but not limited to the costs associated with planning, permitting, design and construction.		
Equivalent Annual Cost	Equivalent annual cost is the total capital investment cost of impementing the adaptation option with respect to the design service life.		
Implementation Timeline	Implementation timeline considers the potential for the adaptation option to be phased or completed in segments over a longer period of time. The benefit to phasing (for the purposes of scoring this criterion) is that the total capital investment cost to be expended over a period of many years.		
Usable Life	Usable life is the comparison of the adaptation option's design service life, with respect to the climate change event horizon.		
Level of Performance	Level of performance is the existing level of protection compared to the anticipated level of protection, at the specified climate change event horizon.		
Flexibility	Flexibility is the ability of the adaptation option (at any stage in development) to be modified to provide a higher level of protection against impacts or to be updated as new data models for climate change are developed.		
Environmental Considerations	Environmental considerations accounts for the potential of the adaptation option to improve or impact the existing environmental conditions with respect to integrity, diversity, or abundance of the natural ecosystem's functions and/or habitat.		
Social Considerations	Social considerations accounts for the potential of the adaptation option to improve or impact the communities social welfare.		

* Please list any additional criteria you believe should be considered or provide clarification as needed for your importance rating.

Attachment C

Summary of Climate Change Factors, Secondary Effects, and Adaptation Objectives

Summary of Climate Change Factors, Secondary Effects, and Adaptation Objectives

Climate Change Factor	Secondary Effect	Adaptation Objectives
Sea Level Rise	Risk of damage to coastal infrastructure from erosion	Provide localized protection from erosion before it causes damage to the infrastructure
		Add or increase protection from erosion, from a distance
		Increase localized protection but move the risk of damage away from the active areas
		Temporarily do nothing and reevaluate the infrastructure at a later date
		Relocate infrastructure
		Permanently do nothing, close or vacate the infrastructure
		Stop or reduce the level of future impacts to the properties within the at risk zone
		Increase localized protection from erosion before it causes damage to the existing protective structure
		Add or increase secondary protection from erosion to the existing protective structure
		Temporarily do nothing, maintain use and reevaluate the protective structure at a later date
		Relocate protective structure
		Stop or reduce the level of future impacts to the properties within the at risk zone
	Risk of damage to coastal infrastructure from seawater flooding	Provide localized protection from flooding before it causes damage to the infrastructure
		Add or increase protection from flooding, from a distance
		Provide localized protection from flooding before it causes damage to the infrastructure
		Temporarily increase localized protection from flooding before it enters the roadway
		Elevate the infrastructure above the estimated flood impact zone
		Enhance drainage to minimize closure time and deterioration levels
		Temporarily restrict use of infrastructure and provide alternate route
		Increase awareness and provide advance notification to drivers
		Temporarily do nothing, maintain use and reevaluate the infrastructure at a later date
		Relocate infrastructure
		Permanently do nothing, close or vacate the infrastructure
		Stop or reduce the level of future impacts to the properties within the at risk zone
	Risk of damage to protective structures from flooding	Increase localized protection from flooding before it causes damage to the existing protective structure
		Add or increase secondary protection from flooding to the existing protective structure
		Temporarily do nothing and reevaluate the protective structure at a later date
		Relocate protective structure
		Stop or reduce the level of future impacts to the properties within the at risk zone

Sea Level Rise	Risk of damage to coastal infrastructure from corrosion	Increase localized protection from corrosion before it causes damage to the existing protective structure
		Add or increase protection from corrosion, from a distance
		Elevate the infrastructure above the estimated corrosion zone
		Temporarily do nothing and reevaluate the infrastructure at a later date
		Relocate infrastructure
		Permanently do nothing, close or vacate the infrastructure
	Risk of damage to structural integrity from rising water table	Increase drainage to lower the water table in the immediate area
		Increase drainage in the area to lower the water table surrounding the infrastructure
		Elevate the infrastructure above the estimated impact zone
		Temporarily do nothing and reevaluate the infrastructure at a later date
		Relocate infrastructure
		Permanently do nothing, close or vacate the infrastructure
Increased temperatures	Risk of damage to infrastructure from fire	Provide localized protection from heat/fire before it causes damage to the infrastructure
		Temporarily restrict use of infrastructure and provide alternate route
		Increase awareness and provide advance notification to drivers
		Relocate infrastructure
		Permanently do nothing, close or vacate the infrastructure
	Risk of damage to infrastructure from high winds	Provide localized protection from high winds before it causes damage to the infrastructure

Precipitation Changes	Risk of damage to infrastructure from stormwater flooding	Provide localized protection from flooding before it causes damage to the infrastructure
		Temporarily increase localized protection from flooding before it enters the roadway
		Increase localized protection but move the risk of damage away from the active areas
		Increase drainage within the area
		Elevate the infrastructure above the estimated flood impact zone
		Temporarily restrict use of infrastructure and provide alternate route
		Temporarily do nothing, maintain use and reevaluate the infrastructure at a later date
		Relocate infrastructure
		Permanently do nothing, close or vacate the infrastructure
		Stop or reduce the level of future impacts to the properties within the at risk zone
		Stop or reduce the level of future impacts to the environment
	Risk of damage to infrastructure from landslides	Add or increase the stability of the slope to reduce the risk of landslides
		Increase awareness and provide advance notification to drivers
		Provide localized protection from landslides before it causes damage to the infrastructure
		Temporarily restrict use of infrastructure during extreme event
		Relocate infrastructure
		Permanently do nothing, close or vacate the infrastructure

Attachment D

Adaptation Options Scoring Worksheet

			Assumed Values		Assessment Criteria								
Project Location: HYW 101 Humboldt Bay PM.79.3R and 85.3 2050			Assumed Design Service Life	Assumed Total Capital Investment	Total Capital Investment	Annual Average Cost	Usable Life	Level of Performance	Flexibility	Environmental Considerations	Social Considerations	Total Score	Rank
No.	**Adaptation Option (Select from List)**	**Enter Description or Comment**		**Weight >>**	3.7	11.1	18.5	25.9	7.4	14.8	18.5		
1	Provide protection at existing elevations/locations	*Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height to 1 ft above 2050 water level at a King tide*	100	107,958,000	0: > $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	2: Potentially	-1: Very little net impact	3: Significant net improvement	189	1
2	Elevate the infrastructure above the impact zone	*Increase the height of the roadway by building up the fill prism 1 ft above 2050 water level at a King tide for 6 miles*	100	93,702,000	1: $10M - $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	1: Unlikely	-2: Some net impact	2: Some net improvement	152	2
3	Elevate the infrastructure above the impact zone	*Construct a causeway, 6 miles, at a height of 5 ft above 2050 water level at a King tide*	100	343,676,000	0: > $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	0: None	-1: Very little net impact	1: Very little net improvement	137	3
4	Temporarily restrict use of infrastructure	*Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information*	25	100,000	3: <$1M	3: <$10,000/yr	0: Minimal (or temporary)	1: Decreased	3: Likely (or unnecessary)	-1: Very little net impact	-2: Some net impact	41	5
5	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.*	25	100,000	3: <$1M	3: <$10,000/yr	0: Minimal (or temporary)	0: Minimum (or none)	3: Likely (or unnecessary)	-1: Very little net impact	-2: Some net impact	15	6
6	Relocate infrastructure (horizontally)	*Assumed 8 mile re-route to the east of the existing Hwy 101 - does not include all of the northern portion as not inundated at 2050 average annual king tide*	100	294,000,000	0: > $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	0: None	-3: Significant net impact	2: Some net improvement	126	4
7	Abandon Infrastructure	*Not a viable alternative due to need for connectivity*											
8	Enhance drainage to minimize closure time and/or deterioration levels	*Not a viable alternative due to tidal influence*											

Top Scoring Adaptation Options			
Rank	**Adaptation Option**	**Project Description**	**Score**
1	Provide protection at existing elevations/locations	Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height	189
2	Elevate the infrastructure above the impact zone	Increase the height of the roadway by building up the fill prism 1 ft above 2050 water level at a King tide for 6 miles	152
3	Elevate the infrastructure above the impact zone	Construct a causeway, 6 miles, at a height of 5 ft above 2050 water level at a King tide	137
4	Relocate infrastructure (horizontally)	Assumed 8 mile re-route to the east of the existing Hwy 101 - does not include all of the northern portion as not inundated at 2050	126
5	Temporarily restrict use of infrastructure	Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information	41

Attachment E

Adaptation Options Summary Page

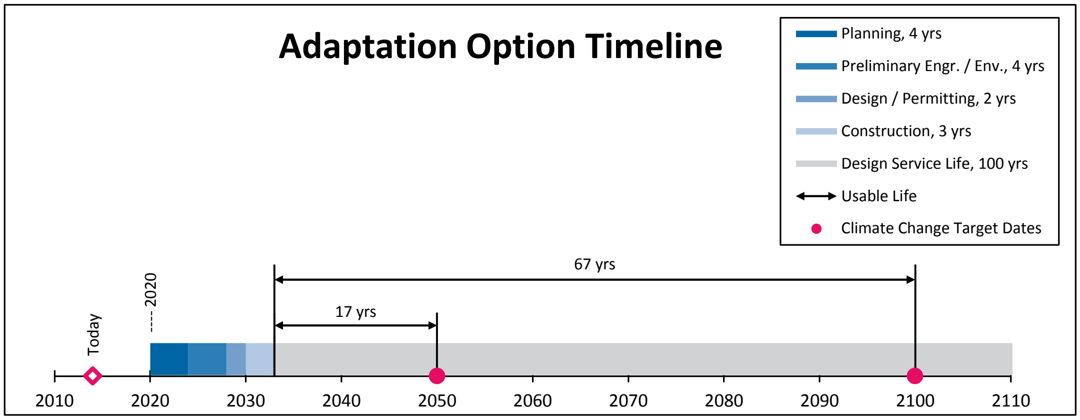
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2050
Adaptation Option	Provide protection at existing elevations/locations
Project Description	**Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height to 1 ft above 2050 water level at a King tide**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

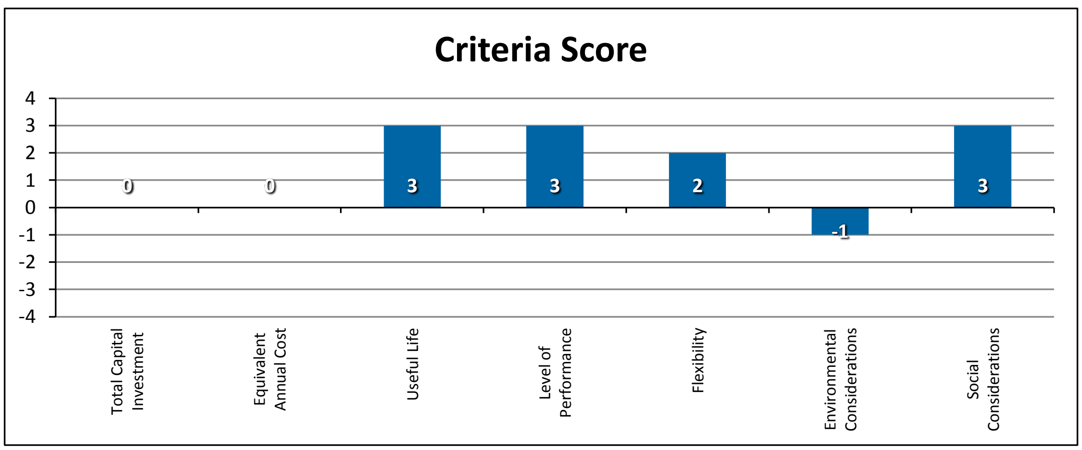
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$107,958,000
Equivalent Annual Cost	$1,079,580
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2050



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67

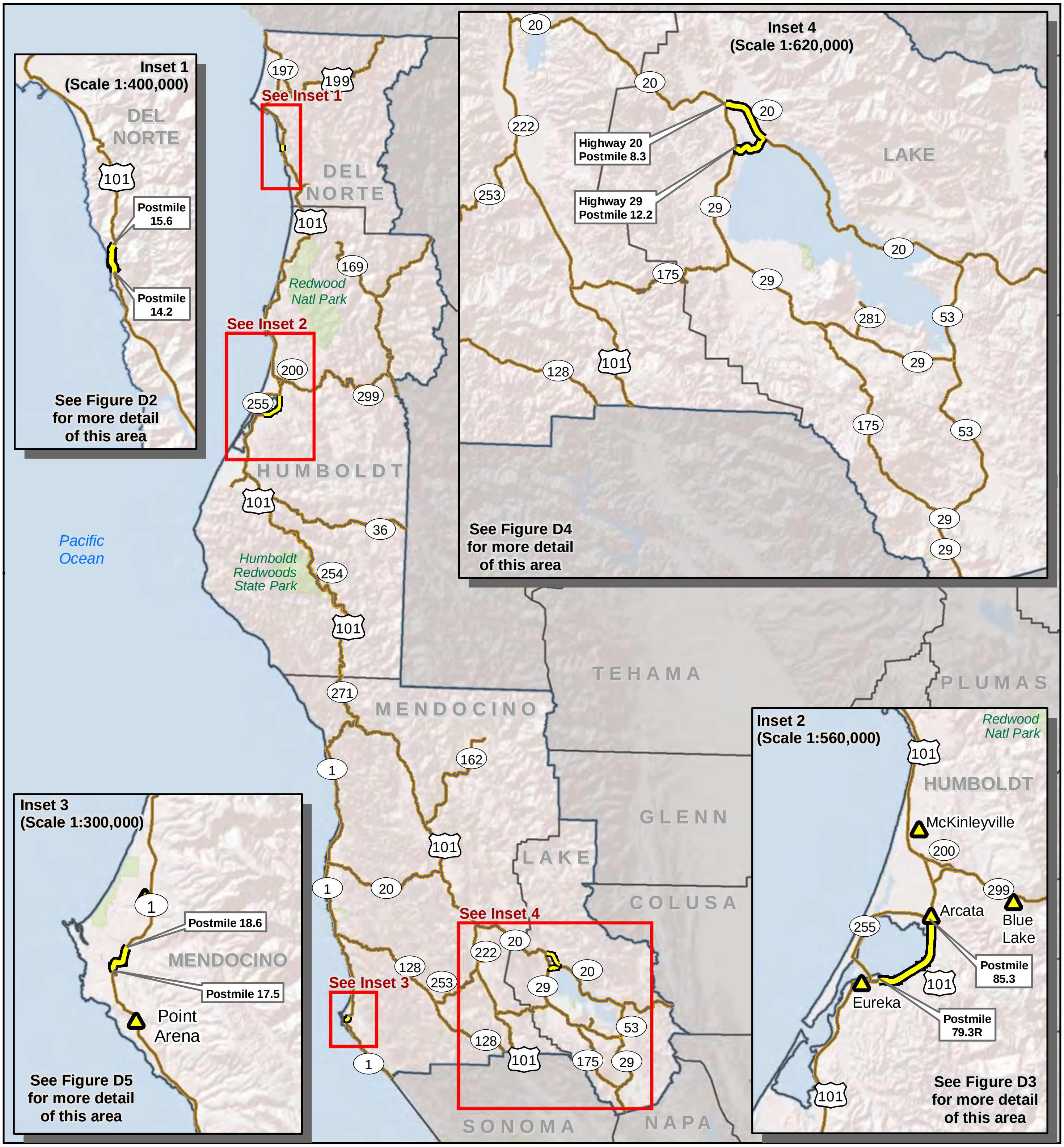


Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

Attachment F

Prototype Location Vicinity Map



Prototype Location
Roadways
City
National or State Park
County Boundary
District 1 Boundary
Outside of District 1

Paper Size 8.5" x 11" (ANSI A)
0 10 20 30 40
Miles
Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

N

GHD ESA

Caltrans District 1 and HCAOG
District 1 Climate Change Pilot Study

Vicinity
Prototype Locations

Job Number	8410842.30
Revision	A
Date	11 Nov 2014

Figure 1

718 Third Street Eureka CA 95501 USA T 707 443 8326 F 707 444 8330 E eureka@ghd.com W www.ghd.com

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Attachment G

List of Adaptation Options

Approach	Adaptation Option	Adaptation Examples
Defend	Provide protection at existing elevations/locations	Add a protective exterior coating
		Add curbing along the edge of pavement
		Add or increase the width of the paved shoulders in the high risk zones
		Add Rock Slope Protection along the effected bank of the protective structure
		Add Rock Slope Protection along the shoulder, edge of pavement or edge of property within the high risk zones.
		Construct a living shoreline of the protective structure
		"Dry" flood-proof the building
		"Wet" flood-proof the building
		Implement or develop reusable breakaway devices for sign posts
		Increase maintenance of surrounding vegetation to reduce burnable materials
		Increase the size (or mass) of the protective structure
		Install and maintain vegetation appropriately along the slopes
		Rebuild portions of the effected structure with corrosion resistant materials
		Rebuild the protective structure with corrosion resistant materials
		Rebuild the protective structure with newer, more resilient materials
		Replace plastic culverts with metal or concrete
		Replace weaker signal poles and/or sign posts with stronger more resilient materials
		Replace wooden or asphalt exterior building materials with tile, slate or metal
		Replace wooden sign and guardrail posts with non-flammable materials
		Underground existing wiring
		Work with or require other utility owners to underground or strengthen infrastructure effected by high winds
	Provide major structural protection	Add wire reinforcing and soil nails
		Construct a levee or dike
		Construct a retaining wall along the shoulder, edge of pavement or edge of property within the high risk zones.
		Construct a seawall along the shoulder, edge of pavement or edge of property within the high risk zones.
		Increase the size (or mass) of the protective structure
		Install a retaining wall at the base of the slope

Accommodate	Elevate the infrastructure above the impact zone	Construct a causeway
		Disassemble, restore site and rebuild infrastructure at a different location
		Raise the elevation of the building or structure
		Raise the elevation of the infrastructure
		Raise the fill prism of the road or building
	Enhance drainage to minimize closure time and/or deterioration levels	Add culverts or French drains to convey water
		Construct drainage channels or swales
		Improve subsurface drainage with perforated soil nails (or similar)
		Improve surface drainage by modifying the redirecting runoff
		Increase offsite retention with swales or ponds outside the right of way
		Increase onsite retention with swales or ponds within the right of way
		Increase drainage capacity by lengthening bridges or building elevated viaduct segments
		Increase the size and/or number of culverts in the flood impact zone
Retreat	Relocate infrastructure (horizontally)	Disassemble, restore site and rebuild infrastructure at a different location
		Remove, restore site and rebuild infrastructure at a different location
		Remove, restore site and rebuild the protective structure at a different location
	Temporarily restrict use of infrastructure	Establish alternate routes for use during closures
		Increase signage and warning information
		Install ITS infrastructure to recommend use of alternate route
	Abandon Infrastructure	Remove infrastructure, restore and retain property for future mitigation
		Remove infrastructure, restore and vacate property
Changes in policies or practices	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	Increase the infrastructure's maintenance and inspection interval
		Increase the protective structure's maintenance and inspection interval
	Modify land use and development policies to account for future impacts	Modify development requirements to account for the impacts anticipated in the at risk zones
		Modify land use policies to discourage development in the at risk zones
		Strengthen erosion and sediment controls/requirements for construction activity

Appendix 6

Caltrans Asset Adaptation Assessment Del Norte County Prototype Location

Memorandum

12 November 2014

To	Rex Jackman, Chief, Transportation Planning Caltrans District 1		
Copy to	Brad Mettam (Caltrans), Jamie Hostler (Caltrans), Marcella Clem (HCAOG)		
From	Rebecca Crow, PE GHD Louis White, PE ESA	Tel	707 443 8326
Subject	Caltrans Asset Adaptation Assessment Del Norte County Prototype Location	Job no.	84/10842/30

1 Introduction

This memo presents a summary of the climate data and adaptation analysis and options for the Del Norte County prototype location. The selected prototype location is along Highway 101 along the coast, immediately north of Wilson Creek and False Klamath Beach and approximately 9 miles south of Crescent City. This area, known as Last Chance Grade and located between PM.14.2 and 15.6, is shown in Figure 1 of Attachment A. The key Caltrans assets at this prototype location along Highway 101 include the roadway and associated infrastructure. Several erosion mitigation and structural modifications have recently been installed to stabilize the roadway, as this area is subject to frequent damage from weather events and inherent land instability.

1.1 List of Attachments

Attachments provide additional detail and illustrations in addition to the information and analysis provided in the text of this memorandum. The relevant supplemental attachments are as follows:

- Attachment A: Figures
- Attachment B: Adaptation Option Scoring
- Attachment C: Adaptation Option Cost Estimates
- Attachment D: Adaptation Option Summary/Timeline Evaluation

1.2 List of Supporting Documentation

This memo builds off work completed previously under separate cover as part of the overall Caltrans District 1 Climate Change Pilot Project. The following memos should be referenced for additional supporting information:

- Caltrans TCR Segment Criticality, GHD October 2014
- Caltrans TCR Segment Potential for Impact, GHD October 2014

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- Caltrans TCR Segment Vulnerability, GHD October 2014
- Climate Data Projections for Caltrans District 1 Climate Change Pilot Study, ESA July 2014
- Caltrans Asset Adaptation Assessment Methodology, GHD November 2014

2 Climate Data Summary

This section provides a summary of the climate data used in the analysis. Climate change is a very complex issue and there are many implications for managing infrastructure in the face of climate change. It is important to recognize that numerous climate change models and scenarios have been developed by various entities based on differing assumptions. Various models forecast various ranges of future climate conditions. These future climate conditions influence the infrastructure management strategies that can be implemented. No one model is “right” in part because climate is not a steady-state phenomenon, but rather a highly dynamic interaction of forces that periodically result in very significant and often damaging events. It is not possible to precisely forecast when certain types of episodic events will occur and how severe they will be, and so the results of models should be used to provide general guidance rather than precise predictions.

Also, just as is the case today, in the future there will be “average” or typical conditions as well as more severe conditions. No matter what practical level of climate change one plans for, there will be periodic problematic conditions that will cause inconvenience, damage, or worse. Therefore, climate change projections should be considered in the context of adapting to potential changes rather than attempting to completely avoid all negative consequences of climate change.

2.1 Geomorphic Setting

A segment of Highway 101 known as Last Chance Grade traverses a steep and high coastal bluff between Wilson Creek and Crescent City (Figure 1). The segment is particularly prone to landslides, especially 2.5 miles north of Wilson Creek, which includes several distinct types of landslides that are historically active and have disrupted the highway (Wills 2000). Geologically, the area is characterized by formations that are particularly weak and prone to landslides. Wills (2000) describes four predominant types of landslides that have been documented and mapped at Last Chance Grade, including:

- **Rock slides** that occur on relatively steep slopes, often moving and sliding on one or several shear surfaces called slide planes. These slides are sensitive to a rise in the water table that may occur in years with high rainfall, decreasing the stability of the overall slope. These are often slow slides.
- **Earth flows** are composed of fine grained soil and weathered bedrock, and movement occurs on many discontinuous shear surfaces. These are more common on less steep slopes, but can be found where landslide toes are being eroded. The movement of earth flows is generally slow, but can accelerate under certain circumstances. Earth flows can be affected by changes along the entire slope or a disturbance to any part of the slope, including changes to the water table.
- **Debris slides** occur in coarse-grained soil that is likely to include surface deposits, rock fragments and vegetation on very steep slopes. Initially they may move as one intact slab of earth and vegetation, but break up quickly into rock and soil flows. Debris slides usually occur in areas where the base of a slope is undercut by erosion. Debris slides are often triggered by periods of intense rainfall or by undercutting and erosion of the base of the slope, and can be renewed into a new slide when the scar is impacted by similar disturbing processes.

- **Debris flows** are similar to debris slides except that the mass of coarse grained material flows downslope as a slurry. These often begin as a shallow slide from high pore water pressures following periods of intense rain, at a time scale much shorter than those that affect deeper slides.

Figure 1: An oblique view of Last Chance Grade shows the very steep and exposed landslides that are impacted by rain and wave action (source: Google Earth).

2.2 Primary Impacts

The roadway along Last Chance Grade is often impacted by landslides and earth movement. Delays and closures result from landslides which are most often induced during or after large storms with intense precipitation.

Several factors influence the stability of landslides, including the inclination of the slope, the type of rock and geologic structures, landforms, rainfall, and erosion or undercutting at the toe of the slope (Wills 2000). Along this segment of road, the slopes tend to be fairly steep and weathered, and composed of weak and erodible materials. The other major drivers of the landslides are hydrologic: precipitation and wave action. The area of Last Chance Grade tends to become more destabilized after periods of intense rainfall – both for short-duration, intense storms and for seasons with exceptionally high totals of rainfall. Waves also act at the base of the landslides to remove materials by wave erosion, and tend to maintain steep slopes that are prone to sliding.

2.3 Effects of Climate Change

The landslide issues will likely get worse when considering the effects of climate change. Two of the primary drivers described above, precipitation and wave action, will likely change due to climate change. Landslides should be expected to continue, and their frequency of occurrence and magnitudes may increase in the future due to potential for increased precipitation and waves impacting the slopes higher due to sea level rise and potentially more intense or more frequent storms. Increased precipitation amounts will continue to destabilize the slope, and the incidence of more intense and frequent storms may cause damaging debris slides and flows to impact the highway. Similarly, waves will impact the bluff face higher on the slope as sea level rises which may accelerate the erosion. Erosion hazard zones that consider the effects of sea level rise show that the area is vulnerable to ongoing coastal erosion that was estimated independently of the active and ongoing landslide processes at the site (Figure 2). Figure 3 demonstrates the geologic interaction in relation to climate change impacts.

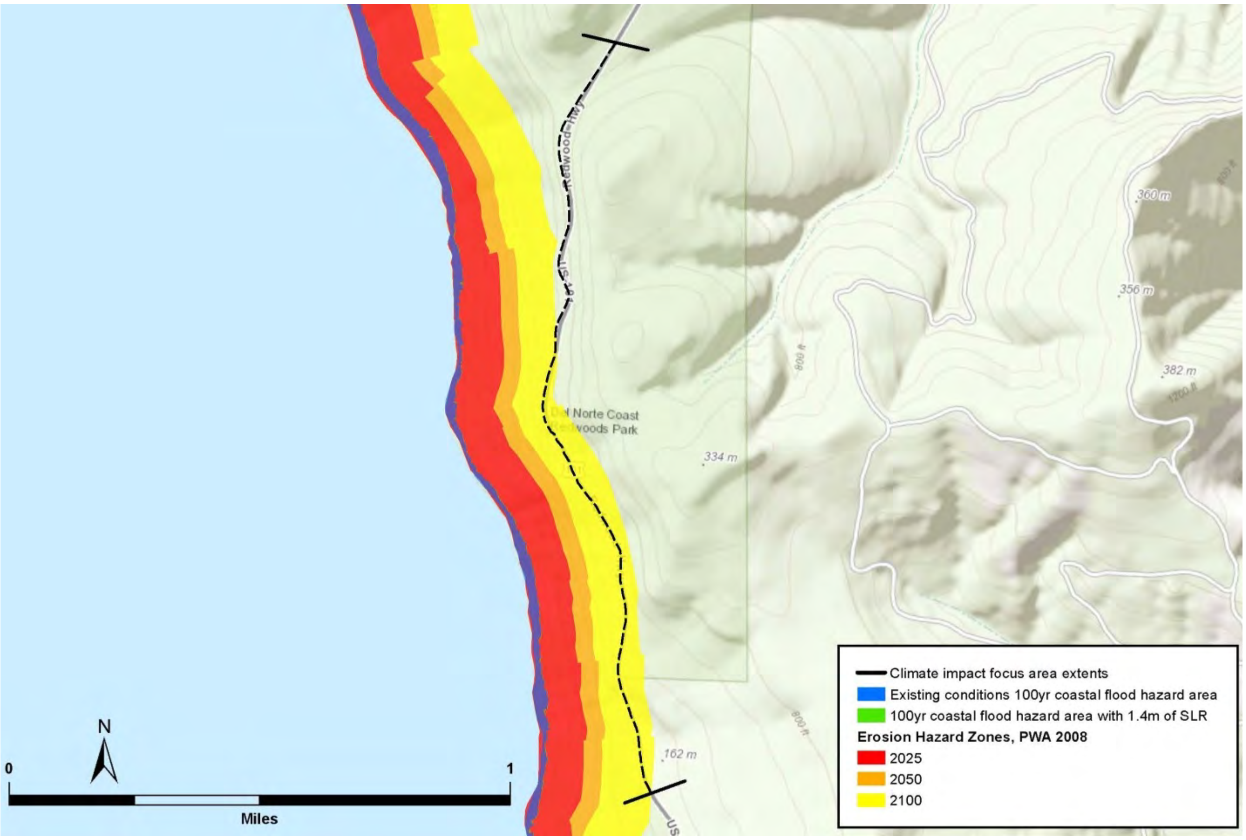


Figure 2: Erosion hazard zones that consider the effects of sea level rise indicate that impacts to Highway 101 may accelerate.

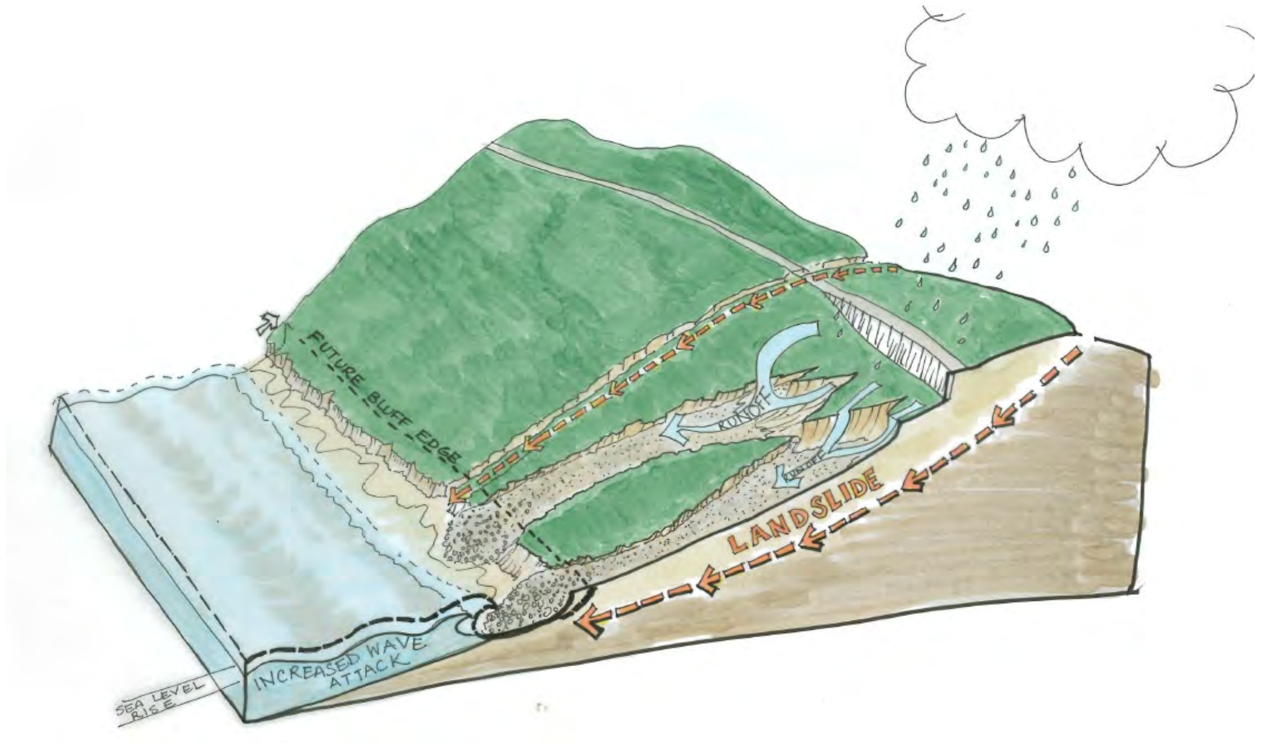


Figure 3: Section view shows geologic and climate forces acting at the Last Chance Grade site.

ESA (2014) analyzed and summarized downscaled climate model data and anticipated rates of sea level rise for the Caltrans District 1 Climate Change Pilot Study. Table 1 summarizes the projected rise in sea level and projected changes in extreme precipitation and runoff for the Del Norte Prototype Location at Last Chance Grade. The combination of increased precipitation and rising sea level will likely increase the frequency and magnitude of episodic erosion and landslide events that impact Highway 101.

Table 1. Projected changes in sea level and extreme precipitation and runoff at 2050 and 2100 for the Del Norte County Prototype Site: Highway 101 at Last Chance Grade.

Climate Factor	Change at 2050	Change at 2100
Sea Level Rise[1]	-1 to 19 inches	4 to 56 inches
Extreme Precipitation[2,4]	2 to 9%	1 to 16%
Extreme Runoff[3,4]	-6 to 5%	-6 to 6%

1 OPC (2013)

2 Projected change in extreme precipitation (98th percentile) calculated using the PCM (wet) model.

3 Projected change in extreme runoff (98th percentile) calculated using average of all model runs.

4 Percent change is presented for 2050 and 2100 relative to a historic period from 1970 to 2000.

The range in projections shown in Table 1 represents uncertainty associated with the global emissions of greenhouse gases (GHG). The ranges in the projected relative sea level rise are a combination of several factors, including increased temperatures, thermal expansion of the oceans, changes in land ice melt, vertical land motion, and the future global emissions of GHG. For periods beyond 2050, the uncertainty increases and yields a larger range in projected sea level rise. Similarly, the percent change in extreme precipitation and extreme runoff increases from the A2 to the B1 emissions scenario. As discussed in greater detail in the accompanying memorandum “Climate Data Projections for Caltrans District 1 Climate Change Pilot Study,” the A2 and B1 emissions scenarios were selected to represent medium-high and relatively low (or “best-case”) emissions projections, respectively (ESA 2014). These emissions scenarios were originally developed and described by the IPCC (IPCC 2000; Cayan et al. 2012). The A2 and B1 emissions scenarios are defined as follows:

- **A2.** Medium-high emissions resulting from continuous population growth coupled with internationally uneven economic and technological growth. Under this scenario, emissions increase through the 21^{st} century and by 2100 atmospheric carbon dioxide (CO2) levels are approximately three-times greater than pre-industrial levels.
- **B1.** Lower emissions than A2, resulting from a population that peaks mid-century and delicnes thereafter, with improving economic conditions and technological advancements leading to more efficient utilization of resources. Under this scenario, emissions peak mid-century and then decline, leading to a net atmospheric CO2 concentration approximately double that of pre-industrial levels. This scenario is often referred to as a “best-case” scenario.

The effects of the respective scenario on the percent change in projected extreme precipitation and runoff for years 2050 and 2100 is due to a combination of increased temperatures and changes to the hydrologic cycle. The A2 scenario results in a more rapid increase in average temperatures, which increases evapo-ration and causes soil moisture to decrease, and in turn reduces the volume of runoff during precipitation events. Less rainfall is projected for the A2 scenario overall. Likewise, reduction of GHG emissions under the B1 scenario results in a rise in average temperature that occurs less rapidly which would tend to have a less significant effect on evaporation and soil moisture as compared to the A2 scenario. The annual precipitation is projected to increase for the B1 scenario and the magnitude of extreme events will likely increase as well. Results of projected climate change factors at 2050 and 2100 for the A2 and B1 emissions scenarios for District 1 and its four counties are summarized more completely in ESA (2014). Projected changes in relative sea level rise can be associated with low and high emissions scenarios, but the projections of sea level rise presented here do not directly represent the A2 or B1 emissions scenarios.

3 Adaptation Evaluation

The Last Chance Grade site has a history of instability. Over the years, Caltrans has put significant effort into evaluating options to address the instability, and is currently completing the Last Chance Grade Feasibility Study. The current Caltrans feasibility study includes collection and evaluation of data including geotech-nical, physical and economic data, review of previous studies, development of a range of alternatives, feasibility evaluation, and recommendations. The study includes an important public outreach element with a series of 3 meetings scheduled for January 26^{th}, 27^{th}, and 28^{th} 2015. The level of detail for the Caltrans feasibility study is greater than that included in the D1CCPS for this or the other 3 prototype location. Thus, new adaptation measures and costs were not developed for this site. Generalized adaptation measures were developed based on the categories of projects that may be pursued at the site.

While a preferred implementation project to address existing instability has not been identified, the site continues to experience degradation and accumulate costs for small and large maintenance projects to keep the highway open. Thus, there is a cost associated with the “no project” option, which could also be called a “business as usual” option. For this adaptation evaluation, the cost of the “no project” alternative was compared with other adaptation measures. .

Table 2 below shows the four adaptation options considered for this prototype location. The adaptation option to abandon the road segment presented in Table 2 was considered not viable. This section of Highway is the sole access to the urban portions of Del Norte County and is a critical emergency route. There is no alternate route if this section of road becomes unusable. Thus, it cannot be abandoned.

Table 2: Seven Adaptation Options Considered for Last Chance Grade – Del Norte County

Project Location: HYW 101 Last Chance Grade PM 14.2 to 15.6 2050		
No.	**Adaptation Option**	**Description**
1	Provide major structural protection	*Provide a high technology solution approximately within the existing road right of way, possibly including retaining walls, minor re-alignments, and bridges or tunnels.*
2	Relocate infrastructure (horizontally)	*Construct a full bypass.*
3	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis. Includes cumulative average annual repair costs for 20 years and assumes appropriate signage for road restrictions added.*
4	Abandon Infrastructure	*Not considered a viable alternative*

Each of the potentially viable adaptation options, 1 through 3, is discussed in the following sections. Due to limited information about future solutions, only a 2050 scenario is presented for each of the adaptation options for last chance grade. The complete scoring sheets for 2050 are included in Appendix B. Due to uncertainties in the configuration of options, rages are provided for some of the assessment criteria values presented below. Attachment B includes the more conservative values, but the summary table at the end of this section includes the range of final scores.

3.1 Adaptation Option 1

Provide major structural protection	*Provide a high technology solution approximately within the existing road right of way, possibly including retaining walls, minor re-alignments, and bridges or tunnels.*

Adaptation Option 1 focuses on high technology solutions to protect the existing roadway. The high technology solution may include a combination of retaining walls, minor re-alignments, and bridges or tunnels. The high technology solution is anticipated to be higher cost, but lower environmental impact than full re-alignment. Consideration in the future should be given to how climate induced increased wave action which will continue to erode the toe of the slope will affect the feasibility of solutions near the existing road right of way. Table 3 presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. The complete scoring sheets for 2050 are included in Appendix B.

Table 3: Last Chance Grade Adaptation Option 1 Summary

Assessment Criteria	**Value**	**Comments**
Assumed Design Service Life	50 to 100 years	Design service life will depend on the final configuration of the option selected
Assumed Total Capital Investment	$ $1 billion or more	Cost range estimated from on-going Caltrans feasibility study
Usable Life	2: Acceptable (2050)	The usable life satisfies the 2050 planning horizon, but additional effort may be needed for a solution to satisfy the 2100 horizon useful life
Level of Performance	3: Enhanced	This option provides enhanced protection of the asset in comparison with the existing condition
Flexibility	1: Unlikely	This option could be flexible, depending on the final configuration, however structural solutions are often difficult to modify once constructed.
Environmental Considerations	-1: Very little net impact -2: Some net impact	It is assumed that some sensitive habitat would be disturbed with this alternative but less than the re-routing options
Social Considerations	3: Significant net improvement	It is assumed this option (if feasible) can address the landslide/erosion issues and would keep the highway open, providing a significant social improvement.

3.2 Adaptation Option 2

Relocate infrastructure (horizontally)	*Construct a full bypass*

Adaptation Option 2 falls under the category of retreat. A new bypass would be constructed. The actual location is not known, however, all theLast Chance Grade bypass alternatives would be located within the vicinity of the Redwoods National and State Parks and potential culturally sensitive sites. Table 4 below presents the qualitative evaluation of a representative alternative used for scoring the criteria in the adaptation planning tool. The complete scoring sheet for 2050 is included in Appendix B.

Table 4: Last Chance Grade Adaptation Option 2 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	100 years	High end of the design life of concrete structures. Assumed structures are properly maintained to protect integrity
Assumed Total Capital Investment	$ 300 Million to $1 Billion	Cost range estimated from on-going Caltrans feasibility study
Usable Life	3: Surpasses	The usable life is beyond the 2100 scenario, thus, the option surpasses the climate horizon in its useful life
Level of Performance	3: Enhanced	This option provides enhanced protection of the asset in comparison with the existing condition
Flexibility	0: None	This option would not be flexible once constructed. It could not be relocated
Environmental Considerations	-3: Significant net impact	It is assumed that some disturbance to the Redwood National and State Park would occur and there is the potential for disturbance of cultural sites.
Social Considerations	3: Significant net improvement	It is assumed this option can feasibly address the landslide/erosion issues and would keep the highway open, providing a significant social improvement.

3.3 Adaptation Option 3

Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the "No Project" alternative. Only temporary measures enacted and repairs made on an as needed basis. Includes cumulative average annual repair costs for 20 years and assumes appropriate signage for road restrictions added*

Adaptation Option 3 presents a wait-and-see approach, with no new infrastructure constructed and only management changes implemented. Table 5 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. The complete scoring sheets for 2050 are included in Appendix D.

Table 5: Last Chance Grade Adaptation Option 3 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	20 years	A design life of 20 years was used
Assumed Total Capital Investment	$ 26,500,000	Cost estimated as the 20 year present worth of annual maintenance costs based on historic costs plus the cost of ITS infrastructure at 4 locations
Usable Life	0: Minimal (or temporary)	The usable life is less than the 2050 time frames
Level of Performance	1: Decreased	This option provides reduced performance relative to the existing condition, given increased impacts from climate change
Flexibility	3: Likely	This option allows flexibility to further evaluate climate impacts and allows for any option to be implemented in the future
Environmental Considerations	-2: Some net impact	The continued instability will result in the continued need for emergency projects, each with their own environmental impacts
Social Considerations	-3: Significant net impact	This option would not address lane closures that currently occur due to earth movement. This option leaves open the possibility of a catastrophic failure of the road segment isolating Del Norte County, cutting off and emergency route, and the possibility of loss of life.

3.4 Cost Assumptions

Attachment C includes information on how were developed for the six adaptation options. Future work should include more detailed cost analysis of preferred options to allow for the further analysis of feasibility of appropriate adaptation strategies. This is anticipated to be included in the Last Chance Grade Feasibility Study being completed by Caltrans, due to be finished in June 2015.

3.5 Top Scoring Adaptation Options and Implementation Timeline

The adaptation planning tool summarizes the three potentially viable adaptation options considered. Table 6 presents the final scores for the adaptation options, including a range where several possible criteria values were possible. These options are then carried over into the timeline analysis portion of the adaptation planning tool. The adaptation tool timeline summary page for each of the three adaptation options is included in Attachment D. It should be noted that the difference in total score between Option 1, high technology, and Option 2, full bypass, may be as little as 4 points, thus these options should be considered equivalent. The cost criteria range does not account for such large costs, and should be given further consideration as planning for improvement continues.

Table 6: Summary of Del Norte County Prototype Location Adaptation Scoring for 2050 Planning Horizon

Top Scoring Adaptation Options			
Rank	**Adaptation Option**	**Project Description**	**Score 2050**
1	Provide major structural protection	Provide a high technology solution approximately within the existing road right of way, possibly including retaining walls, minor re-alignments, and bridges or tunnels	148 to 163
2	Relocate infrastructure (horizontally)	Construct a full bypass	144
3	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	Equivalent to the “No Project” alternative. Only temporary measures enacted and repairs made on an as needed basis. Includes cumulative average annual repair costs for 20 years and assumes appropriate signage for road restrictions added	-33

4 Next Steps

Last Chance Grade represents a challenging segment of Highway 101 under current conditions and the challenges are likely to increase due to climate change. The current strategy of maintaining the roadway requires significant resources due to debris removal and repairs due to land instability. Intuitively the cost of road maintenance should have some correlation to precipitation, and the maintenance data does indicate a strong correlation between high precipitation levels and repairs. Earth movement results from a complex combination of factors over a long term with precipitation being just one. Climate change and increase sea level, storm events, and precipitation are expected to exacerbate the existing coastal uplift geology challenges, but it is not possible to precisely predict how and when these issues will manifest.

An event may occur which will significantly damage the roadway to the point that reconstruction in kind is impractical or cost prohibitive. Therefore, Caltrans should continue with more detailed analysis and plans for alternatives to the existing roadway and implement the preferred alternative when deemed necessary and feasible.

5 References

Caltrans, 2002, Value Analysis Report – SR101 Roadway Stabilization, prepared by Value Management Strategies, Inc., October 2002.

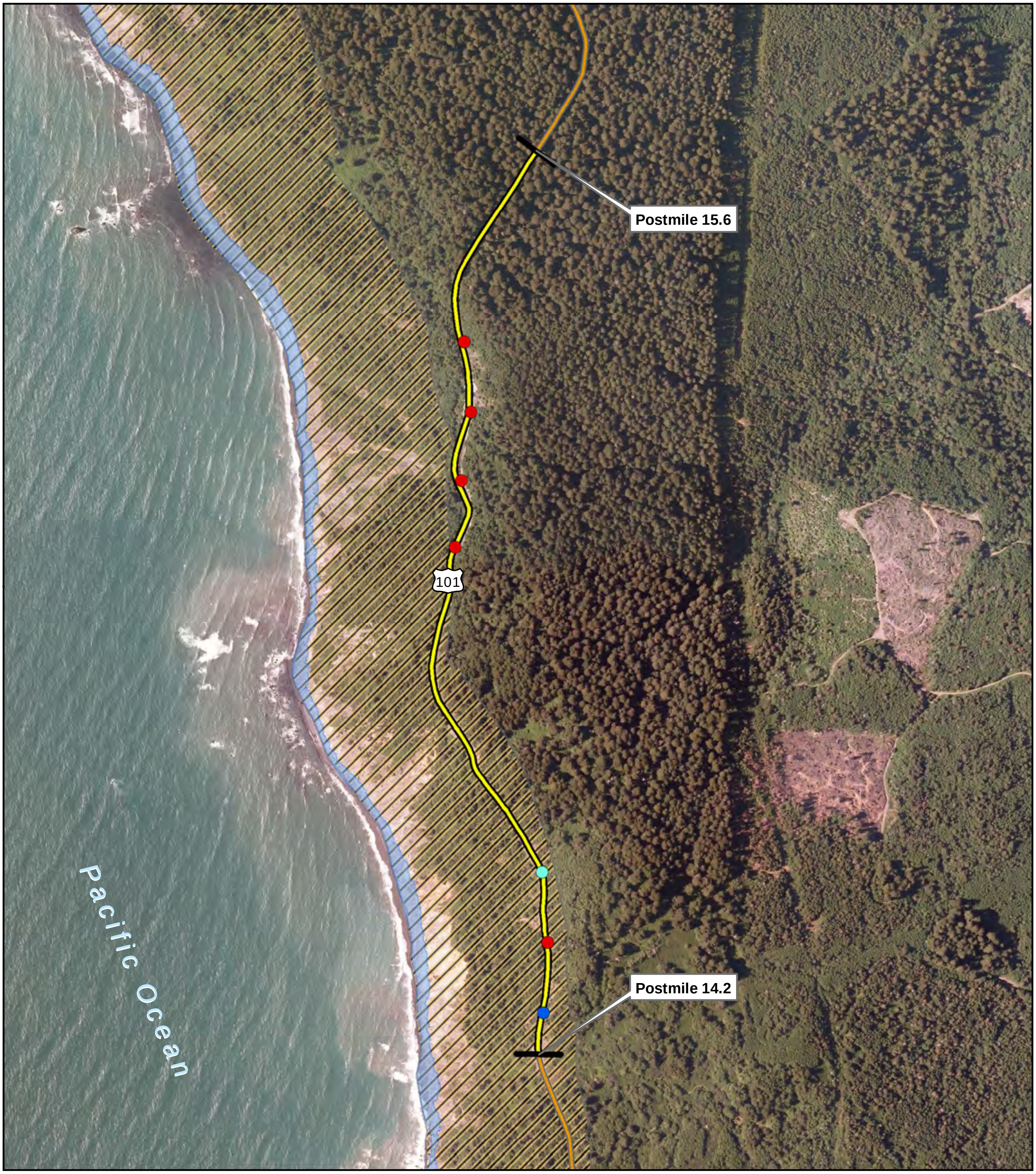
Environmental Science Associates (ESA), 2014, Climate Data Projections for Caltrans District 1 Climate Change Pilot Study, Memorandum Prepared by Louis White, PE (ESA) for Rob Holmlund (GHD), July 21, 2014.

Ocean Protection Council (OPC), 2013, State of California Sea-Level Rise Guidance Document, Developed by the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), with science support provided by the Ocean Protection Council's Science Advisory Team and the California Ocean Science Trust, March 2013 update, Accessed online [August 2014]: http://www.opc.ca.gov/webmaster/ftp/pdf/docs/ 2013_SLR_Guidance_Update_FINAL1.pdf.

Wills, C.J., 2000, Landslides in the Highway 101 Corridor Between Wilson Creek and Crescent City, Del Norte County, California, Special Report 184, Prepared California Department of Transportation, Department of Conservation, California Geological Survey, Sacramento, CA, Available Online [Accessed September 10, 2014]: http://www.conservation.ca.gov/cgs/rghm/landslides/SR_184/ Documents/CT101dn.pdf.

Attachment A

Figures



Chronic Slope Movement Area
Chronic Drainage Issue Area
Chronic Sea Level Issue Area
100-year Coastal Flooding
Coastal Cliff Erosion Hazard Zone
Prototype Limits
Prototype Location
Roadways

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Map Projection: Albers
Horizontal Datum: North American 1983
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GHD ESA

Caltrans District 1 and HCAOG
District 1 Climate Change Pilot Study

Job Number	8410842.30
Revision	A
Date	11 Nov 2014

Del Norte County
Prototype Locations

Figure 1

718 Third Street Eureka CA 95501 USA T 707 443 8326 F 707 444 8330 E eureka@ghd.com W www.ghd.com

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Attachment B

Adaptation Option Scoring

Project Location: HYW 101 Last Chance Grade PM 14.2 to 15.6 2050			Assumed Values		Assessment Criteria							Total Score	Rank
			Assumed Design Service Life	Assumed Total Capital Investment	Total Capital Investment	Annual Average Cost	Usable Life	Level of Performance	Flexibility	Environmental Considerations	Social Considerations		
No.	**Adaptation Option (Select from List)**	**Enter Description or Comment**		**Weight >>**	3.7	11.1	18.5	25.9	7.4	14.8	18.5		
1	Provide major structural protection	*Provide a high technology solution approximately within the existing road right of way, possibly including retaining walls, minor re-alignments, and bridges or tunnels*	50	1,500,000,000	0: > $100M	0: >$100,000/yr	2: Acceptable	3: Enhanced	1: Unlikely	-2: Some net impact	3: Significant net improvement	148	1
2	Relocate infrastructure (horizontally)	*Construct a full bypass*	100	1,000,000,000	0: > $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	0: None	-3: Significant net impact	3: Significant net improvement	144	2
3	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis. Includes cumulative average annual repair costs for 20 years and assumes appropriate signage for road restrictions added*	20	26,500,000	1: $10M - $100M	0: >$100,000/yr	0: Minimal (or temporary)	1: Decreased	3: Likely (or unnecessary)	-2: Some net impact	-3: Significant net impact	-33	3
4	Abandon Infrastructure	*Not considered a viable alternative*											

Top Scoring Adaptation Options			
Rank	**Adaptation Option**	**Project Description**	**Score**
1	Provide major structural protection	Provide a high technology solution approximately within the existing road right of way, possibly including	148
2	Relocate infrastructure (horizontally)	Construct a full bypass	144
3	Increase the infrastructure's maintenance and inspection interval and continue to	Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an	-33

Attachment C

Adaptation Option Cost Estimates

HWY 101 Last Chance Grade PM 14.2 to 15.6

HWY 101 Last Chance Grade PM 14.2 to 15.6 Historic Maintenance Costs

Year	Emergency Maintenance	Annual Maintenance	Total Maintenance
1981	$ 240,000	$ 250,000	$ 490,000
1982	$ 1,083,000	$ 250,000	$ 1,333,000
1983	$ 120,000	$ 250,000	$ 370,000
1984	$ 566,000	$ 250,000	$ 816,000
1985	$ 85,000	$ 250,000	$ 335,000
1986	$ 1,356,000	$ 250,000	$ 1,606,000
1987	$ 78,000	$ 250,000	$ 328,000
1988	$ 196,000	$ 250,000	$ 446,000
1989	$ 100,000	$ 250,000	$ 350,000
1990	$ 1,056,000	$ 250,000	$ 1,306,000
1991	$ 773,000	$ 250,000	$ 1,023,000
1996	$ 100,000	$ 250,000	$ 350,000
1997	$ 478,542	$ 250,000	$ 728,542
1998	$ 4,156,539	$ 250,000	$ 4,406,539
1999	$ 63,281	$ 250,000	$ 313,281
2000	$ 95,718	$ 250,000	$ 345,718
2008	$ 1,038,070	$ 250,000	$ 1,288,070
2009	$ 13,764,187	$ 250,000	$ 14,014,187
2011	$ 6,900,433	$ 250,000	$ 7,150,433
2012	$ 1,222,421	$ 250,000	$ 1,472,421
TOTAL			**$ 38,472,191**
ANNUAL AVERAGE			**$ 1,923,610**

Present Worth of Annual Maintenance Costs

Years	Year	Present Worth ($)	Present Worth ($) Rounded
0	2014	$0	$0
10	2024	$15,602,197	$15,600,000
20	2034	$26,142,482	$26,100,000
30	2044	$33,263,120	$33,300,000
40	2054	$38,073,569	$38,100,000

Present worth based on a 4% discount rate

Attachment D

Adaptation Option Summary/Timeline Evaluation

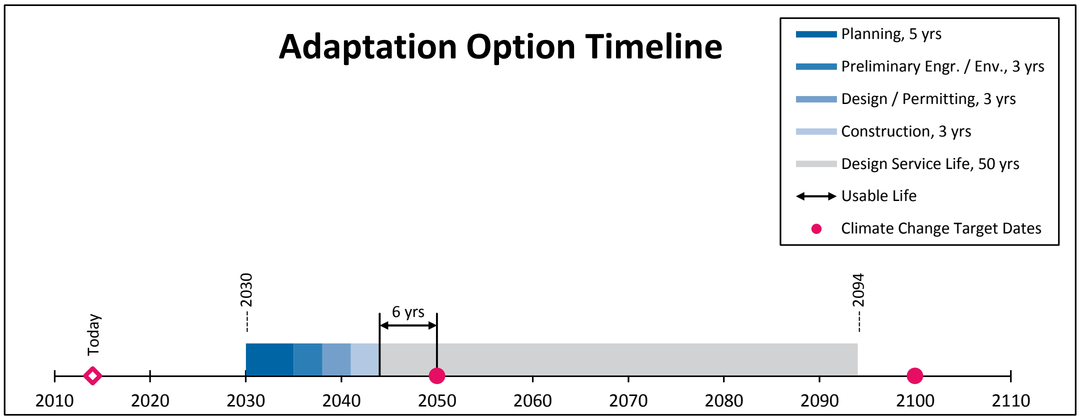
Project Location	HYW 101 Last Chance Grade PM 14.2 to 15.6 2050
Adaptation Option	Provide major structural protection
Project Description	**Provide a high technology solution approximately within the existing road right of way, possibly including retaining walls, minor re-alignments, and bridges or tunnels**

Anticipated Process Times	Years
Planning	5
Preliminary Engr. / Env.	3
Design / Permitting	3
Construction	3
Total Process Time[1]	**14**

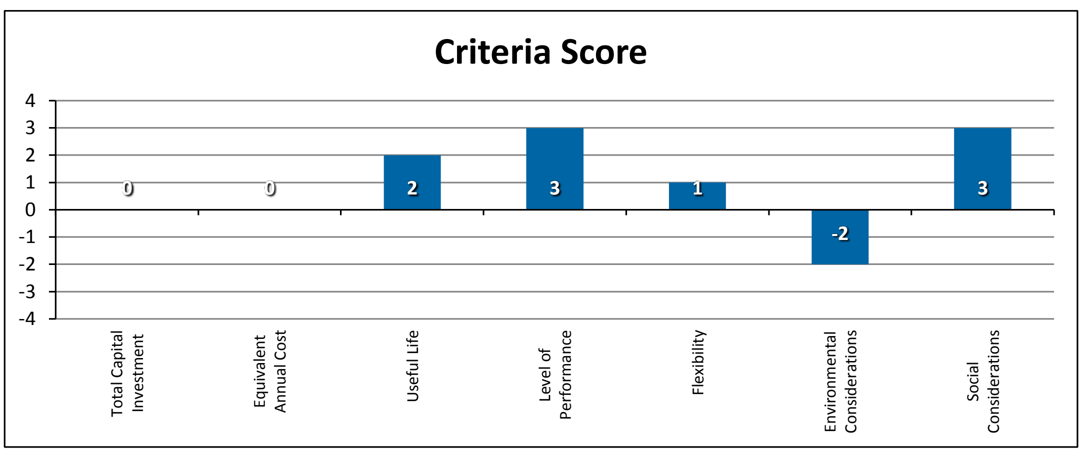
Desired Initiation Date	2030

Assumed Values	
Total Capital Investment	$1,500,000,000
Equivalent Annual Cost	$30,000,000
Design Service Life (yrs)	50

Key Dates	
Current Year	2014
Climate Change Horizon	2050



Usable life if designed for	Years
2050 Climate Projection	6
2100 Climate Projection	56



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

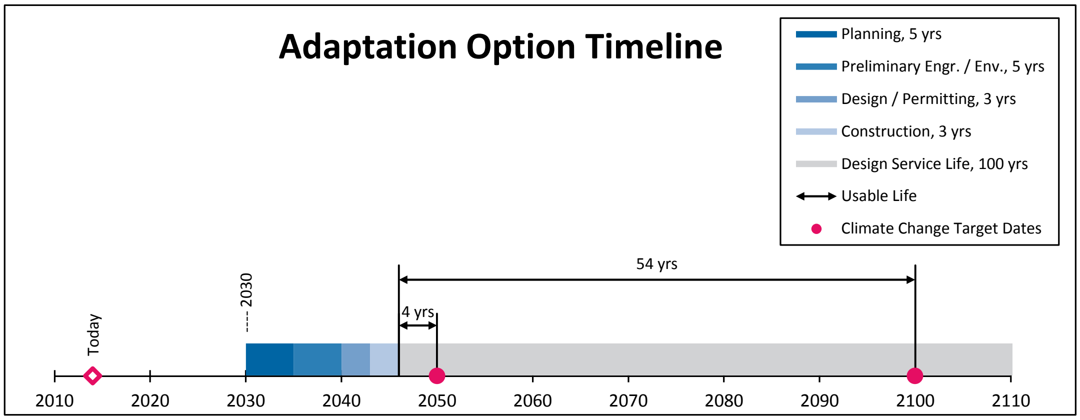
Project Location	HYW 101 Last Chance Grade PM 14.2 to 15.6 2050
Adaptation Option	Relocate infrastructure (horizontally)
Project Description	**Construct a full bypass**

Anticipated Process Times	Years
Planning	5
Preliminary Engr. / Env.	5
Design / Permitting	3
Construction	3
Total Process Time[1]	**16**

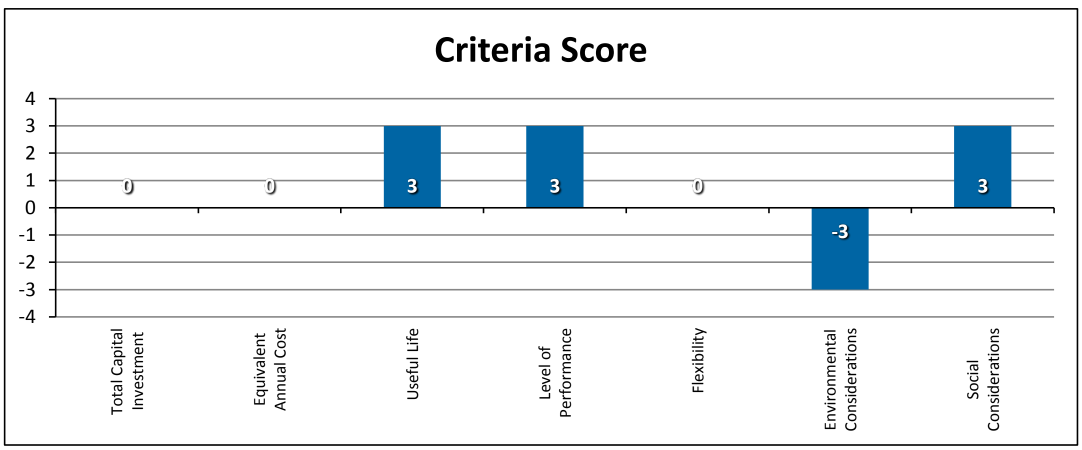
Desired Initiation Date	2030

Assumed Values	
Total Capital Investment	$1,000,000,000
Equivalent Annual Cost	$10,000,000
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2050



Usable life if designed for	Years
2050 Climate Projection	4
2100 Climate Projection	54



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

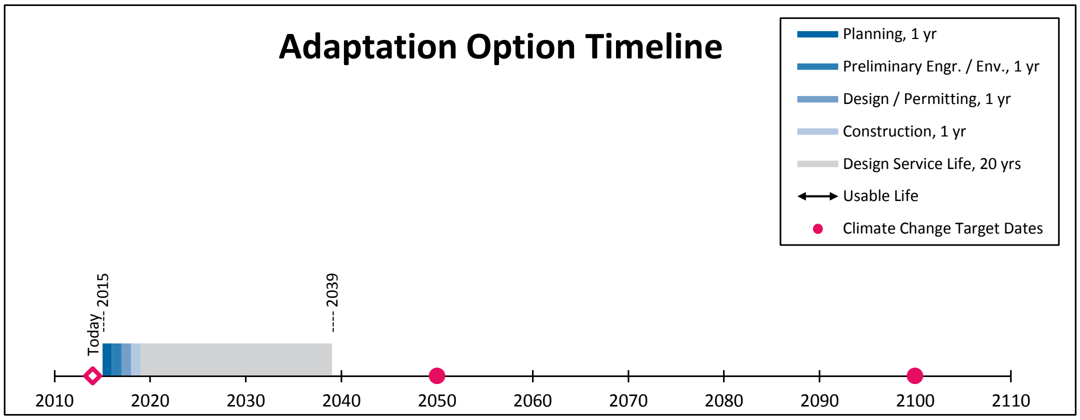
Project Location	HYW 101 Last Chance Grade PM 14.2 to 15.6 2050
Adaptation Option	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate
Project Description	**Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis. Includes cumulative average annual repair costs for 20 years and assumes appropriate signage for road restrictions**

Anticipated Process Times	Years
Planning	1
Preliminary Engr. / Env.	1
Design / Permitting	1
Construction	1
Total Process Time[1]	**4**

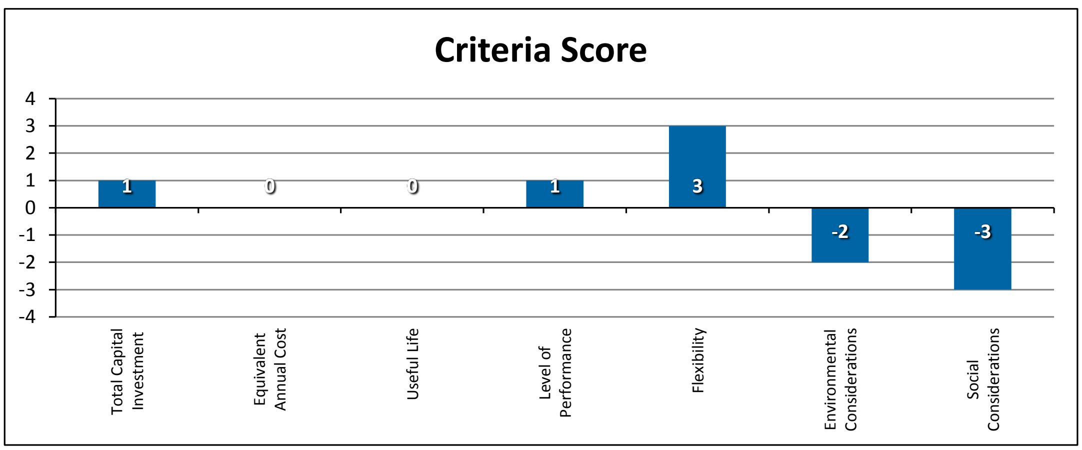
Desired Initiation Date	2015

Assumed Values	
Total Capital Investment	$26,500,000
Equivalent Annual Cost	$1,325,000
Design Service Life (yrs)	20

Key Dates	
Current Year	2014
Climate Change Horizon	2050



Usable life if designed for	Years
2050 Climate Projection	31
2100 Climate Projection	81



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

Appendix 7

Caltrans Asset Adaptation Assessment
Humboldt County Prototype Location

Memorandum

12 November 2014

To	Rex Jackman, Chief, Transportation Planning Caltrans District 1		
Copy to	Brad Mettam (Caltrans), Jamie Hostler (Caltrans), Marcella Clem (HCAOG)		
From	Rebecca Crow, PE, GHD Louis White, PE, ESA	Tel	707 443 8326
Subject	Caltrans Asset Adaptation Assessment Humboldt County Prototype Location	Job no.	84/10842/30

1 Introduction

This memo presents a summary of the climate data and adaptation analysis and options for the Humboldt County prototype location. The selected prototype location is along Highway 101 between Eureka and Arcata along the eastern edge of Arcata Bay, the north basin of Humboldt Bay between PM.79.3R and 85.3, and is shown in Figure 1 in Attachment A. The key Caltrans assets at the prototype site along Highway 101 include the roadway and embankment, bridges, and water control structures that connect marsh areas, creeks, and watersheds from the east to Arcata Bay.

1.1 List of Attachments

Attachments provide additional detail and illustrations in addition to the information and analysis provided in the text of this memorandum. The relevant supplemental attachments are as follows:

- Attachment A: Figures
- Attachment B: Technical Memo: Application of Humboldt Bay Sea Level Rise Adaptation Planning Project to Caltrans District 1 Climate Change Pilot Study, Humboldt County Highway 101 Study Site
- Attachment C: Projected Water Surface Elevations
- Attachment D: Projected Water Surface Elevations with Adaptation Options
- Attachment E: Adaptation Option Cost Estimates
- Attachment F: Adaptation Option Scoring
- Attachment G: Adaptation Option Summary/Timeline Evaluation

1.2 List of Supporting Documentation

This memo builds off work completed previously under separate cover as part of the overall Caltrans District 1 Climate Change Pilot Project. The following memos should be referenced for additional supporting information.

- Caltrans TCR Segment Criticality, GHD October 2014
- Caltrans TCR Segment Potential for Impact, GHD October 2014

GHD Inc.
718 Third Street Eureka CA 95501 USA
T 1 707 443 8326 F 1 707 444 8330 E eureka@ghd.com W www.ghd.com

- Caltrans TCR Segment Vulnerability, GHD October 2014
- Climate Data Projections for Caltrans District 1 Climate Change Pilot Study, ESA July 2014
- Caltrans Asset Adaptation Assessment Methodology, GHD November 2014

2 Climate Data Summary

This section provides a summary of the climate data used in the analysis. Climate change is a very complex issue and there are many implications for managing infrastructure in the face of climate change. It is important to recognize that there are numerous climate change models and scenarios that have been developed by various entities based on differing assumptions. Various models forecast various ranges of future climate conditions. These future climate conditions influence infrastructure management strategies that may be implemented. No one model is "right" in part because climate is not a steady state phenomenon, but rather a highly dynamic interaction of forces that periodically result in very significant, and often damaging events. It is not possible to precisely forecast when and how severe certain types of episodic events will be and so the results of models should be used to provide general guidance rather than precise predictions.

Also, just like today, there will be future "average" or more typical conditions and periodic more severe conditions. No matter what practical level of climate change one plans for, there will be periodic problematic conditions that will cause inconvenience, damage, or worse. Therefore climate change projections should be considered in the context of adapting to potential changes rather than attempting to completely avoid all negative consequences of climate change.

2.1 Geomorphic Setting

The segment of Highway 101 between Eureka and Arcata is located on a low lying coastal area at the eastern edge of Arcata Bay. The roadway in several locations runs parallel to a railroad grade adjacent to open water and mudflats that are exposed during periods of low tide. Several miles of unmaintained railway is located directly west of the highway, and currently provides some protection to the highway from tidal inundation, coastal flooding and wave induced erosion, although the lack of maintenance has resulted in degradation of the railway prism including breaches in a number of areas. Agricultural and wetland areas are located directly east of Highway 101 on former tidelands, with several drainages that connect to the tidal bay through sloughs and water control structures that extend beneath the highway. Several miles of agricultural dikes provide some degree of flood protection to Highway 101 from tidal inundation and flooding from the eastern watersheds and storm runoff. The right bank dikes on Eureka and Fay Slough provide substantial flood protection to the lower reach of Highway 101.

Humboldt Bay, including the prototype site, has experienced significant and spatially varying rates of vertical land motion due to tectonic subsidence, with greatest rates of subsidence in the southern reaches of Humboldt Bay and decreasing in magnitude to the north (Cascadia GeoSciences 2013). Relative sea level rise, interpreted as the combination of vertical land motion and regional sea level rise, for Humboldt Bay is estimated at approximately 18.6 inches for the last 100 years (Cascadia GeoSciences 2013). Projections of future sea level rise presented below incorporate estimates of vertical land motion published by NOAA, which are similar to estimates by Cascadia GeoSciences (2013).

2.2 Primary Impacts

The primary potential climate change impacts to the site are (permanent) tidal inundation from shoreline failure and rising sea levels, shoreline erosion and (temporary) flooding from elevated coastal water levels during extreme tidal events (astronomical tides, El Nino, low pressure systems, strong winds, and storm surges) and (temporary) flooding from extreme precipitation and stormwater runoff (Trinity Associates 2014; NHE 2014). The floodpath of coastal waters from the west to the prototype site is from Arcata Bay. The floodpaths from the east include tidewater from Eureka/Fay Sloughs, and Gannon Slough and storm runoff from extreme precipitation events in combination with elevated coastal water levels which would prohibit drainage through the culverts into Arcata Bay. The roadway embankments are vulnerable to inundation if existing protective shoreline structures fail and during extreme events for existing conditions (Trinity Associates 2014; NHE 2014). By 2050, if 0.5 meters of relative sea level rise (RSLR) are realized then the southern portion of the roadway is vulnerable to being tidally inundated and the northern portion is vulnerable to flooding during extreme events. By 2100, the northern portion is vulnerable to being tidally inundated with 1.0 meters of RSLR (Trinity Associates 2014; NHE 2014).

2.3 Effects of Climate Change

Tidal inundation and flood risks at the prototype site and adjacent lands will increase as the likelihood of extreme weather events increases along with projected sea level rise. An increase in extreme precipitation events could also increase the impacts, including the frequency and magnitude, of combined coastal and storm water runoff flooding. Inundation mapping completed as part of the Humboldt Bay Sea Level Rise Vulnerability Project shows that a rise in sea level by 0.5 to 1.0 meters will significantly impact the roadway, and would occur sooner during extreme storm events (Trinity Associates 2014; NHE 2014). Mapping of inundation areas is included in “Application of Humboldt Bay Sea Level Rise Adaptation Planning Project to Caltrans District 1 Climate Change Pilot Study, Humboldt County Highway 101 Study Site” in Attachment B.

ESA (2014) analyzed and summarized downscaled climate model data and anticipated rates of sea level rise for the Caltrans District 1 Climate Change Pilot Study. Table 1 summarizes the projected rise in sea level and projected changes in extreme precipitation and runoff for the Humboldt Prototype Site along Arcata Bay. The combination of increased precipitation and rising sea level will likely increase the frequency and magnitude of flooding-related impacts on Highway 101 between Eureka and Arcata.

Table 1: Projected changes in sea level, and extreme precipitation and runoff at 2050 and 2100 for the Humboldt County Prototype Site: Highway 101 between Eureka and Arcata.

Climate Factor	Change at 2050	Change at 2100
Sea Level Rise[1]	10 to 26 inches	26 to 70 inches
Extreme Precipitation[2,4]	1 to 11%	2 to 14%
Extreme Runoff[3,4]	-1 to 9%	4 to 12%

1 ESA Analysis for Eureka, based on CCC (2013)

2 Projected change in extreme precipitation (98th percentile) calculated using the PCM (wet) model.

3 Projected change in extreme runoff (98th percentile) calculated using average of all model runs.

4 Percent change is presented for 2050 and 2100 relative to a historic period from 1970 to 2000.

The range in projections that is shown in Table 1 represents uncertainty associated with the global emissions of greenhouse gases (GHG). The ranges in the projected relative sea level rise are a combination of several factors, including increased temperatures, thermal expansion of the oceans, changes in land ice melt, vertical land motion, and the future global emissions of GHG. For periods beyond 2050, the uncertainty increases and yields a larger range in projected sea level rise. Similarly, the percent change in extreme precipitation and extreme runoff increases from the A2 to the B1 emissions scenario. As discussed in greater detail in the accompanying memorandum “Climate Data Projections for Caltrans District 1 Climate Change

Pilot Study," the A2 and B1 emissions scenarios were selected to represent medium-high and relatively low (or "best-case") emissions projections, respectively (ESA 2014). These emissions scenarios were originally developed and described by the IPCC (IPCC 2000; Cayan et al. 2012). The A2 and B1 emissions scenarios are defined as follows:

- **A2.** Medium-high emissions resulting from continuous population growth coupled with internationally uneven economic and technological growth. Under this scenario, emissions increase through the 21st century and by 2100 atmospheric carbon dioxide (CO2) levels are approximately three-times greater than pre-industrial levels.
- **B1.** Lower emissions than A2, resulting from a population that peaks mid-century and declines thereafter, with improving economic conditions and technological advancements leading to more efficient utilization of resources. Under this scenario, emissions peak mid-century and then decline, leading to a net atmospheric CO2 concentration approximately double that of pre-industrial levels. This scenario is often referred to as a "best-case" scenario.

The effects of the respective scenario on the percent change in projected extreme precipitation and runoff for years 2050 and 2100 is due to a combination of increased temperatures and changes to the hydrologic cycle. The A2 scenario results in a more rapid increase in average temperatures, which increases evaporation and causes soil moisture to decrease, and in turn reduces the volume of runoff during precipitation events. Less rainfall is projected for the A2 scenario overall. Likewise, reduction of GHG emissions under the B1 scenario results in a rise in average temperature that occurs less rapidly which would tend to have a less significant effect on evaporation and soil moisture as compared to the A2 scenario. The annual precipitation is projected to increase for the B1 scenario and the magnitude of extreme events will likely increase as well. Results of projected climate change factors at 2050 and 2100 for the A2 and B1 emissions scenarios for District 1 and its four counties are summarized more completely in ESA (2014). Projected changes in relative sea level rise can be associated with low and high emissions scenarios, but the projections of sea level rise presented here do not directly represent the A2 or B1 emissions scenarios.

3 Adaptation Evaluation

The information presented above was used in combination with information developed by Trinity Associates in Attachment B to this memo to develop adaptation options for the Humboldt County prototype location. Eight adaptation options were initially identified which encompassed the 4 primary types of adaptation (defend, accommodate, retreat, and changes in policies or practices).

Table 2 below shows the eight adaptation options considered. These adaptation options were based on the projected elevation of the king tide plus the maximum sea level rise presented in Table 1 above and in the "Climate Data Projections for Caltrans District 1 Climate Change Pilot Study" Technical Memorandum (ESA, 2014). This separate memo should be referenced for additional details. Attachment C includes cross sections at three locations along the Eureka Arcata Corridor showing projected water surface elevations. Projections are for 2050 and 2100 for both the low and high estimates of sea level rise presented in Table 1. Projections are also presented using both the mean maximum monthly high water (MMMW) and average king tide as the base elevation.

It should be noted that other situations will periodically arise where the sea level would be higher than projected even if the projections were completely accurate under the circumstances considered. This is because there could be a situation where there could be other combinations of forces in addition to the basis of sea level projection. These higher sea level conditions could occur for example if there were a combination of extreme precipitation and storm surge occurring during a king tide event. Although perhaps relatively unlikely, these more extreme events are statistically possible. Future work should focus on evaluating the potential for simultaneous events that could result in even higher episodic sea level events. These more extreme events may simply result in temporary inconvenience, but could also result in damage. For the purposes of this analysis, however, the more unlikely extreme combinations of forces are not considered.

The evaluation of options focused on the segment of roadway from the Eureka Slough Bridge to the Highway 255 off ramp. Climate change affects other portions of Highway 101 as well including the area of 101 south of the Eureka Slough Bridge through the City of Eureka, and Highway 101 along South Bay. These other areas were not the focus of this study, but based on the general sea level rise characteristics, there will likely need to be adaptation measures implemented to address sea level rise effects along Highway 101 south of the Eureka Slough Bridge at the 2050 and 2100 project climate change scenario. The analysis of other portions of Highway 101 should be further considered in future studies.

Two adaptation options presented in Table 2 were considered not viable. The first non-viable option was enhancing drainage to minimize closure time and/or deterioration levels. This was considered not viable as the primary climate effect is flooding due to sea level rise, and increased drainage would not reduce flooding caused by rising sea level. It is assumed that appropriate drainage would be incorporated into options including new berms and raising the roadway prism, but drainage improvements alone would not address sea level rise impacts. The second non-viable option was abandoning the road segment, which would result in Old Arcata Road as the only coastal road connection between Arcata and Eureka. Old Arcata Road in its current state cannot handle the current traffic load on Highway 101. Highway 101 between Arcata and Eureka is a highly utilized section of road that provides important connectivity between the two cities and so abandonment was deemed impractical.

Table 2: Eight Adaptation Options Considered for Humboldt Bay in 2050/2100

Project Location: HYW 101 Humboldt Bay		
No.	**Adaptation Option**	**Description**
1	Provide protection at existing elevations/locations	*Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 11.26 miles, including increasing height to 1 ft above 2050/2100 water level at a King tide*
2	Elevate the infrastructure above the impact zone	*Increase the height of the roadway by building up the fill prism 1 ft above 2050/2100 water level at a King tide for 6 miles*
3	Elevate the infrastructure above the impact zone	*Construct a causeway, 6 miles, at a height of 5 ft above 2050/2100 water level at a King tide*
4	Temporarily restrict use of infrastructure	*Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information*
5	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.*
6	Relocate infrastructure (horizontally)	*Assumed 8 mile re-route to the east of the existing Hwy 101 - does not include all of the northern portion as not inundated at 2050 average annual king tide*
7	Abandon Infrastructure	*Not a viable alternative due to need for connectivity*
8	Enhance drainage to minimize closure time and/or deterioration levels	*Not a viable alternative due to tidal influence*

Each of the potentially viable adaptation options 1 through 6 is discussed in the following sections.

3.1 Adaption Option 1

Provide protection at existing elevations/locations	*Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 11.26 miles, including increasing height to 1 ft above 2050/2100 water level at a King tide*

Adaptation Option 1 focuses on strengthening the existing system of protective structures, including publically owned but unmaintained railroad grade, and publically and privately owned and maintained dikes. The protective structures would be strengthened and raised to 1 foot above either the 2050 or 2100 projected average king tide elevation. Table 3 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix F.

Table 3: Humboldt Bay Adaptation Option 1 Summary

Assessment Criteria	**Value**	**Comments**
Assumed Design Service Life	100 years	High end of the design life of an earthen structure. Assumed structure is properly maintained to protect integrity
Assumed Total Capital Investment	$ 121,310,000 (2050) $ 121,460,000 (2100)	Assumed protective structure raised to 1 ft above the high estimate of 2050/2100 Sea Level Rise. For 2050 scenario, less railroad reconstruction assumed due to less impact in 2050
Usable Life	3: Surpasses	The usable life is beyond the 2100 scenario, thus, the option surpasses the climate horizon in its useful life
Level of Performance	3: Enhanced	This option provides enhanced protection of the asset in comparison with the existing condition
Flexibility	2: Potentially	This option could be flexible, in that additional height could be added to the protective structure at a later date. It would be more difficult in areas where new railroad has been placed.
Environmental Considerations	-1: Very little net impact	It is assumed that some wetlands would be impacted with a bigger fill footprint needed for a higher berm, but that it would be less than raising the whole road.
Social Considerations	3: Significant net improvement	The use of the highway would be maintained, and this option, would include coordinated protection of other social assets past the berm, such as telephone, gas, and water lines.

3.2 Adaption Option 2

Elevate the infrastructure above the impact zone	*Increase the height of the roadway by building up the fill prism 1 ft above 2050/2100 water level at a King tide for 6 miles*

Adaptation Option 2 focuses on elevating the existing roadway in its present location. The roadway would be raised to 1 foot above either the 2050 or 2100 projected average king tide elevation. Table 4 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix F.

Table 4: Humboldt Bay Adaptation Option 2 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	100 years	High end of the design life of an earthen structure. Assumed structure is properly maintained to protect integrity, and regular roadway overlays are implemented.
Assumed Total Capital Investment	$ 60,570,000 (2050) $ 117,630,000 (2100)	Assumed protective structure raised to 1 ft above the high estimate of 2050/2100 Sea Level Rise. For 2050 3.36 miles of road assumed to be elevated, which excludes northern section not inundated, and for 2100 7.09 miles of road assumed to be elevated.
Usable Life	3: Surpasses	The usable life is beyond the 2100 scenario, thus, the option surpasses the climate horizon in its useful life
Level of Performance	3: Enhanced	This option provides enhanced performance relative to the existing condition.
Flexibility	1: Unlikely	With the costs and effort involved in constructing the new roadway on the raised fill prism, it would be difficult to add additional height in the future.
Environmental Considerations	-2: Some net impact	It is assumed that some wetlands would be impacted with a bigger fill footprint needed for an elevated road, and it would be more that raising the height of protective structures.
Social Considerations	3: Some net improvement	The use of the highway would be maintained, which provides a social benefit, however this option does not necessarily protect other social assets, such as telephone, gas, and water lines.

3.3 Adaption Option 3

Elevate the infrastructure above the impact zone	*Construct a causeway, 6 miles, at a height of 5 ft above 2050/2100 water level at a King tide*

Adaptation Option 3 focuses on elevating the existing roadway in its present location. The roadway would be raised to 5 feet above either the 2100 projected average king tide elevation. Table 5 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix F.

Table 5: Humboldt Bay Adaptation Option 3 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	100 years	Caltrans design standard for bridges
Assumed Total Capital Investment	$ 173,680,000 (2050) $ 368,040,000 (2100)	For 2050 3.36 miles of causeway assumed, which excludes northern section of roadway not inundated, and for 2100 7.09 miles of causeway is assumed.
Usable Life	3: Surpasses	The usable life is beyond the 2100 scenario, thus, the option surpasses the climate horizon in its useful life
Level of Performance	3: Enhanced	This option provides enhanced performance relative to the existing condition.
Flexibility	0: None	Once a causeway is built, it would be very difficult to increase the height or add other protective measures at a later date.
Environmental Considerations	-1: Very little net impact (2050) 0: No net change (2100)	Under the 2050 scenario, a causeway would allow some bay inundation in areas that are currently protected by the 101 corridor. In the 2100 scenario, the 101 corridor does not provide protection from inundation, thus there is no inundation impact from the project.
Social Considerations	1: Very little net improvement	The use of the highway would be maintained, which provides a social benefit, however this option does not necessarily protect other social assets, such as telephone, gas, and water lines, and would not prevent flooding of properties east of the 101.

3.4 Adaption Option 4

Temporarily restrict use of infrastructure	*Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information*

Adaptation Option 4 focuses on increasing notifications and directing vehicles to use alternate routes. Table 6 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix F.

Table 6: Humboldt Bay Adaptation Option 4 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	20 years	Typical useful life of ITS infrastructure is 20 years.
Assumed Total Capital Investment	$ 1,080,000 (same for 2050 and 2100)	The capital investment includes the ITS infrastructure. Also added to this option is the estimated annual cost of added maintenance and staff time for assisting with alternate routes ($50,000/ year for 20 years).
Usable Life	0: Minimal or temporary	The usable life is less than the 2050 or 2100 time frames and will allow flooding at King tides under existing conditions.
Level of Performance	1: Decreased	This option provides reduced performance relative to the existing condition.
Flexibility	3: Likely	This option allows flexibility to further evaluate climate impacts and allows for any option to be implemented in the future.
Environmental Considerations	-1: Very little net impact	Some flooding would occur under both the 2050 and 2100 scenarios
Social Considerations	-2: Some net impact (2050) -3: significant net impact (2100)	Alternate routes would be needed, creating delays for the traveling public. Delays would increase as time goes on with almost no access by 2100.

3.5 Adaption Option 5

Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.*

Adaptation Option 5 presents a wait-and-see approach, with no new infrastructure constructed and only management changes implemented. Table 7 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix F.

Table 7: Humboldt Bay Adaptation Option 5 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	20 years	This alternative is assumed to last until 2050, at which time, the roadway will be inundated too often to allow use of an alternate route on a temporary basis. A design life of 20 years was used for comparison with Option 4.
Assumed Total Capital Investment	$ 950,000 (same for 2050 and 2100)	There is not capital investment for this option. Costs for this option include the estimated annual cost of added maintenance and staff time for assisting with alternate routes without ITS (estimated at $70,000/year)
Usable Life	0: Minimal or temporary	The usable life is less than the 2050 or 2100 time frames and will allow flooding at King tides under existing conditions.
Level of Performance	1: Decreased	This option provides reduced performance relative to the existing condition.
Flexibility	3: Likely	This option allows flexibility to further evaluate climate impacts and allows for any option to be implemented in the future.
Environmental Considerations	-1: Very little net impact	Some flooding would occur under both the 2050 and 2100 scenarios
Social Considerations	-2: Some net impact (2050) -3: significant net impact (2100)	Alternate routes would be needed, creating delays for the traveling public. Delays would increase as time goes on with almost no access by 2100.

3.6 Adaption Option 6

Relocate infrastructure (horizontally)	*Assumed 8 mile re-route to the east of the existing Hwy 101 - does not include all of the northern portion as not inundated at 2050 average annual king tide*

Adaptation Option 5 focuses on relocating the roadway out of the inundation/ flooding area. This potion only looks at the prototype section of Highway 101. However, it is likely that if relocation were to be considered it would encompass a longer section of highway stretching south of the City of Eureka. Historic attempts to relocate 101 through Eureka have been unsuccessful. Thus, it there is significant risk of failure if this option is is selected for implementation. Table 8 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool.

Table 8: Humboldt Bay Adaptation Option 6 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	100 years	High end of the design life of an earthen structure. Assumed structure is properly maintained to protect integrity, and regular roadway overlays are implemented.
Assumed Total Capital Investment	$350,000,000 (same for 2050 and 2100)	Relocation costs based on Willits bypass project including mitigation.
Usable Life	3: Surpasses	The usable life is beyond the 2100 scenario, thus, the option surpasses the climate horizon in its useful life
Level of Performance	3: Enhanced	This option provides enhanced performance relative to the existing condition.
Flexibility	0: None	Once a new roadway is built, it cannot be moved. Also if it were to be subject to climate change impacts in the future, it would be difficult to increase the roadway elevation.
Environmental Considerations	-3: Significant net impact	Difficult to determine environmental impacts without a specific alignment. For this study, a new road outside existing right of way is assumed to have impacts to wetlands.
Social Considerations	2: Some net improvement	A new highway will maintain connectivity between Eureka and Arcata, however this option does not necessarily protect other social assets, such as telephone, gas, and water lines, and would not prevent flooding of properties east of the 101.

3.7 Overall Cost Assumptions Applicable to All Options

Attachment E includes planning level cost estimates for many of the proposed adaptation options, including costs for Project Approval & Environmental Document (PA&ED), Plans, Specifications and Estimates (PS&E), right-of-way, Mitigation, and Construction Engineering. The purpose of the cost estimates is gauging the relative magnitude of cost between options, rather than to provide costs for budgeting purposes. Future work should include more detailed cost analysis of preferred options to allow for the further analysis of feasibility of appropriate adaptation strategies.

The cost estimates are based on many assumptions, including; the anticipated means and methods of construction, assumed soil conditions, limited topographic survey, opinion of manufacturers, suppliers, contractors, bid results from recently bid projects, Caltrans average unit cost estimating database, and other estimating guides. These assumptions reflect the experience of GHD working on similar types of projects.

Cost estimates for developed for specific options can be found in Attachment E and include anticipated construction item quantities, unit prices, and the extended total. There is a subtotal with the sum of all of the anticipated construction items followed by other implementation costs calculated as a percentage of the anticipated construction cost. An estimating contingency of 25% was added to each estimate to provide an allowance for some amount of uncertainty in the market and for unforeseen costs which may be required to construct the project. The northern and southern sections of the 101 Eureka Arcata corridor are affected by climate change at different elevations. There may be opportunities to phase some of the adaptation options over time. This was not accounted for in the cost estimates.

The Mitigation portion of the estimate accounts for potential land acquisition, design and construction costs to create wetlands, and to offset impacts to existing wetlands and Environmentally Sensitive Habitat Areas (ESHA). Unit costs per acre for pre-construction and construction of estuarine wetland, palustrine wetland and ESHA were based on similar previous types of project estimates.

3.8 Top Scoring Adaptation Options and Implementation Timeline

The adaptation planning tool summarizes the six potentially viable adaptation options, There were a total of six adaptation options scored. There was a tie for fifth place. Table 9 presents the final scores for the adaptation options. These options are then carried over into the timeline analysis portion of the adaptation planning tool. The adaptation tool timeline summary page for each of the six adaptation options is included in Attachment G.

Table 9: Summary of Humboldt County Prototype Location Adaptation Scoring for 2050 Planning Horizon

Top Scoring Adaptation Options				
Rank	Adaptation Option	Project Description	Score 2050	Score 2100
1	Provide protection at existing elevations/locations	Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height to 1 ft above 2050/2100 water level at a King tide	189	189
2	Elevate the infrastructure above the impact zone	Increase the height of the roadway by building up the fill prism 1 ft above 2050/2100 water level at a King tide for 6 miles	152	148
3	Elevate the infrastructure above the impact zone	Construct a causeway, 6 miles, at a height of 5 ft above 2050 water level at a King tide	137	137
4	Relocate infrastructure (horizontally)	Assumed 8 mile re-route to the east of the existing Hwy 101	126	126
5	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.	30	30
6	Temporarily restrict use of infrastructure	Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information	15	15

4 Next Steps

As previously discussed, the evaluation of options focused on the segment of roadway from the Eureka Slough Bridge to the Highway 255 off ramp. Climate change affects other portions of Highway 101 including the area of 101 south of the Eureka Slough Bridge through the City of Eureka. Adaptation planning should consider impacts along Highway 101 for the entire coast for Humboldt Bay including Arcata Bay and South Bay at the 2050 and 2100 projected climate change scenarios.

Also the adaptation options developed in this study are relatively general in nature. Options should be further developed to account for the variability in impacts between the northern and southern portions of the corridor. Additional coordination should be conducted with other agencies impacted by sea level rise in the vicinity of the Eureka Arcata corridor, including Humboldt County, the Cities of Arcata and Eureka, PG&E, and North Coat Railroad Authority.

5 References

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Cascadia GeoSciences, 2013, Tectonic Land Level Changes and their Contribution to Sea-Level Rise, Humboldt Bay Region, Northern California.

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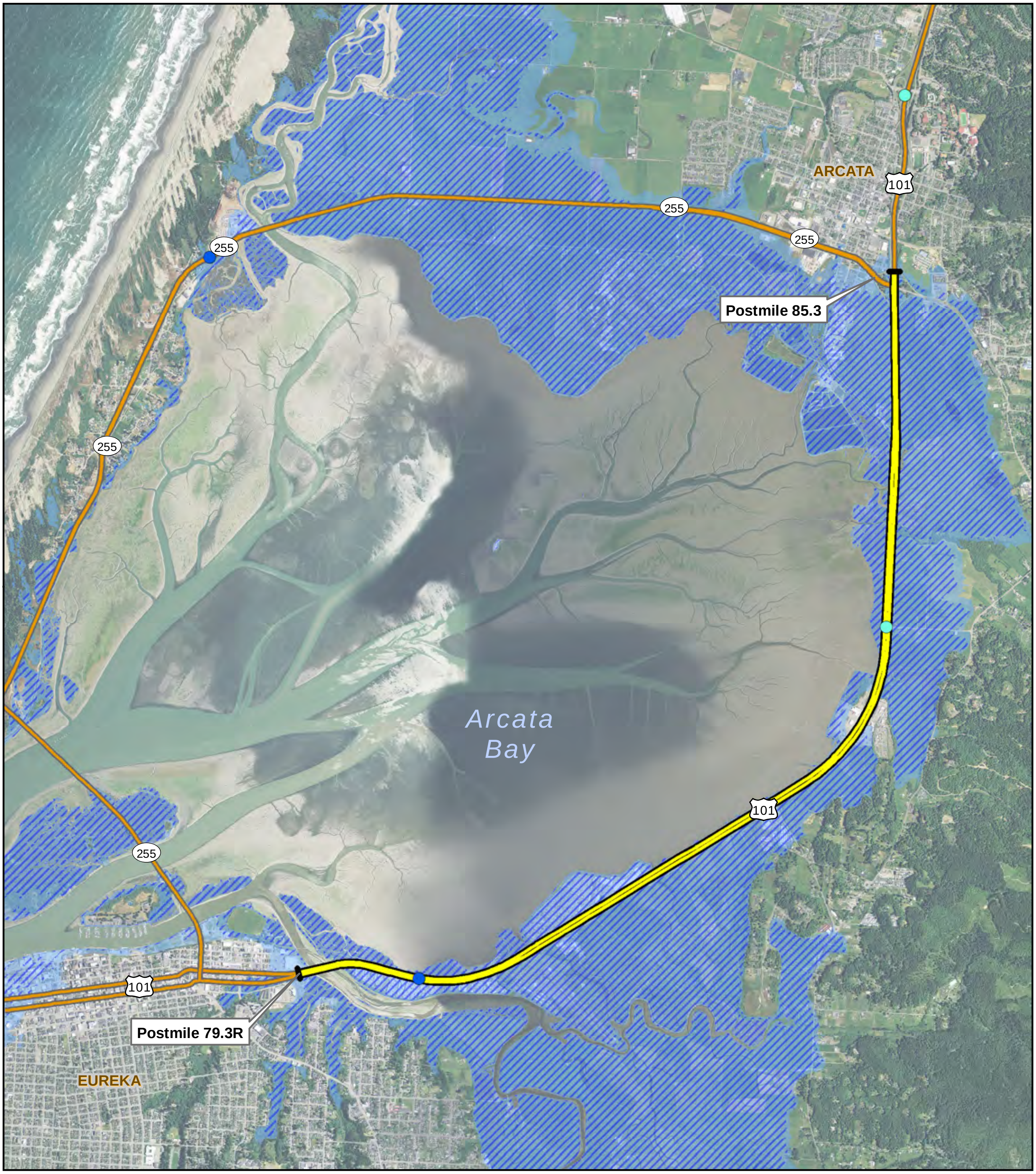
Trinity Associates, 2014, Application of Humboldt Bay Sea Level Rise Adaptation Planning Project to Caltrans District 1 Climate Change Pilot Study, Humboldt County Highway 101 Study Site, Memorandum Prepared by Aldaron Laird, for Rob Holmlund (GHD), August 24, 2014.

Attachment A

Figures



Chronic Drainage Issue Area

Chronic Sea Level Issue Area

Projected Daily High Tide due to Sea Level Rise

Projected Annual High Tide due to Sea Level Rise

Prototype Limits

Prototype Location

Roadways

Streams

Paper Size 8.5" x 11" (ANSI A)

0 1,000 2,000 3,000 4,000 5,000

Feet

Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

N

GHD ESA

Caltrans District 1 and HCAOG
District 1 Climate Change Pilot Study

Humboldt County
Prototype Location

Job Number	8410842.30
Revision	A
Date	11 Nov 2014

Figure 1

718 Third Street Eureka CA 95501 USA T 707 443 8326 F 707 444 8330 E eureka@ghd.com W www.ghd.com

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Attachment B

Technical Memo: Application of Humboldt Bay Sea Level Rise Adaptation Planning Project to Caltrans District 1 Climate Change Pilot Study, Humboldt County Highway 101 Study Site

TRINITY ASSOCIATES

Specializing in
Environmental and Sea Level Rise Adaptation Planning

Memorandum

Date: October 27, 2014

To: Rebecca Crow, GHD

From: Aldaron Laird
Environmental and Sea Level Rise Adaptation Planner

Subject: Application of Humboldt Bay Sea Level Rise Adaptation Planning Project to Caltrans District 1 Climate Change Pilot Study, Humboldt County Highway 101 Study Site

980 7th Street, Suite K, Arcata, CA 95518 • (707) 845-6877 • riverplanner@gmail.com

Caltrans District 1 Climate Change Pilot Study

The Caltrans District 1 Climate Change Pilot Study (D1CCPS) has selected a 5.9 mile segment of U.S. Highway 101 between the cities of Eureka and Arcata as a focused sea level vulnerability assessment and adaptation planning case study. This study site is representative of highway segments that traverse low lying coastal areas that are susceptible to inundation by sea level rise and flooding from extreme events (100 year still water elevation) (Figure 1). Other coastal areas susceptible to sea level rise impacts may experience coastal erosion or backwater flooding in the lower reaches of streams and rivers.

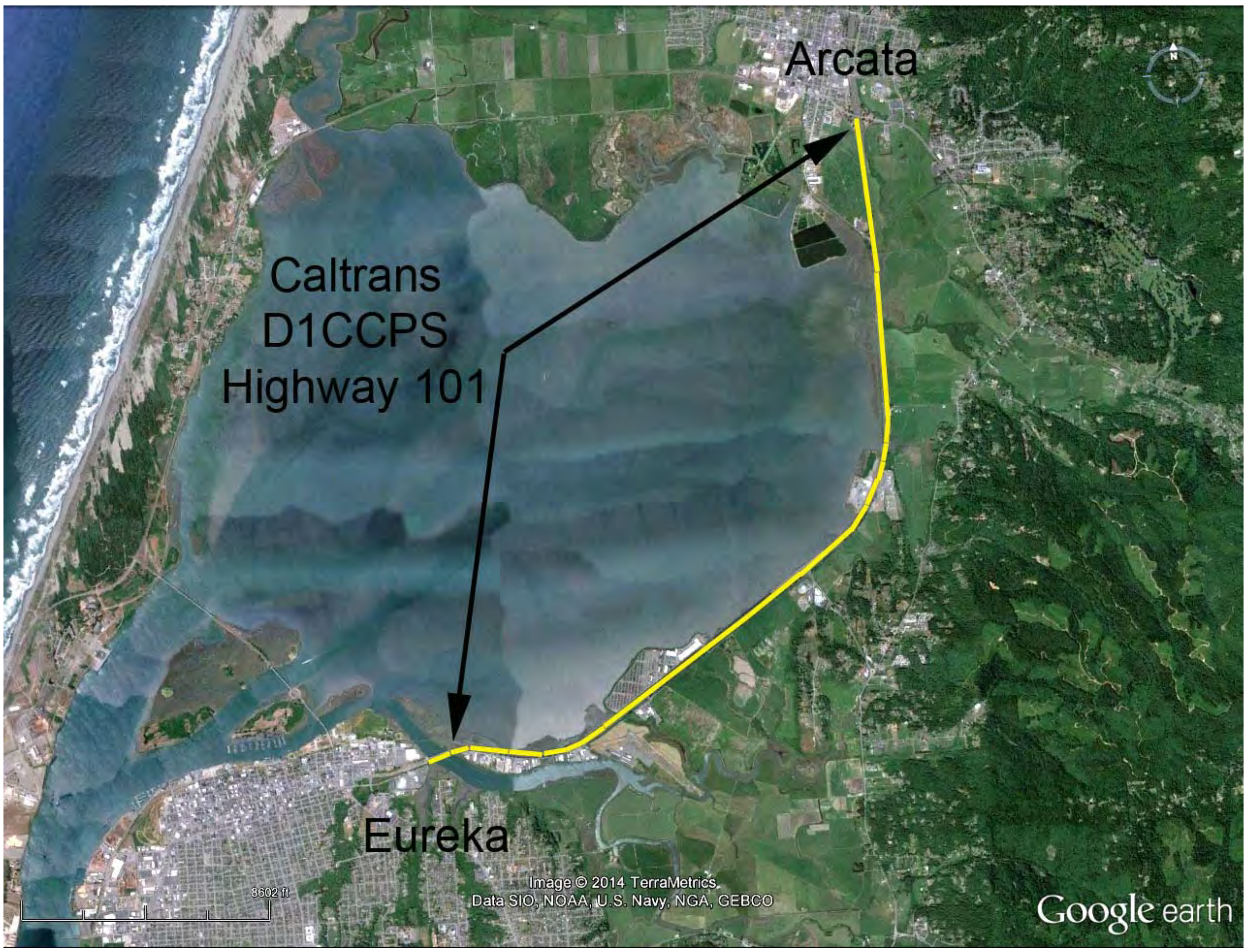


Figure 1. Caltrans' District 1 climate change pilot study, Humboldt County site, Highway 101 on Arcata Bay.

The State Coastal Conservancy funded a climate change planning project known as the Humboldt Bay Sea Level Rise Adaptation Planning Project (HBSLRAP). The HBSLRAP project consisted of two phases that entailed: 1) a shoreline inventory, mapping, and vulnerability assessment (Laird 2013 and Powell 2013), and 2) inundation modeling and mapping (NHE 2014). The HBSLRAP also convened an adaptation planning working group (APWG) to develop a regional adaptation plan for Humboldt Bay (2013-2014). The body of work prepared by the HBSLRAP project provides site specific vulnerability assessment and adaptation planning information for the development of adaptation strategies and measures for transportation assets on Humboldt Bay. In addition, the D1CCPS also produced a memo describing climate change data sets including one for relative sea level rise on Humboldt Bay that will be useful in assessing vulnerability Caltrans assets (White 2014).

Vulnerability Assessment

The HBSLRAP utilized vulnerability assessment methodology described in the California Adaptation Planning Guide (2012) that has been modified in the process of developing an adaptation plan for Humboldt Bay. The HBSLRAP vulnerability assessment methodology entails assessing asset exposure, sensitivity, and significance (Figure 2).

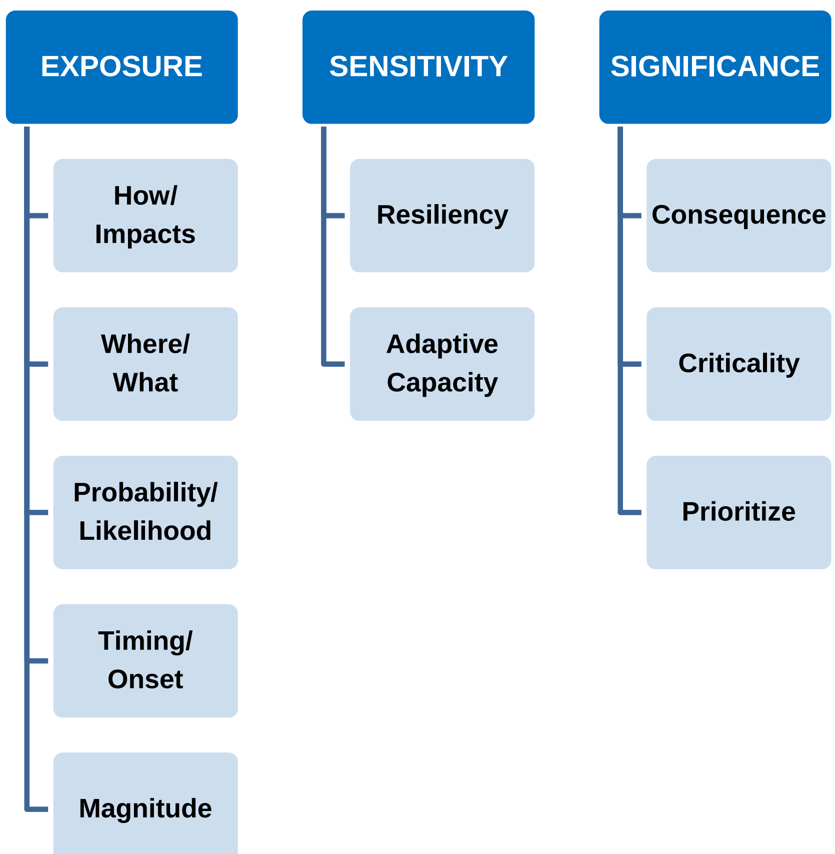


Figure 2. Vulnerability assessment methodology entails assessing exposure, sensitivity and significance.

What follows in this memo is an exposure assessment based on the HBSLRAP GIS shoreline vulnerability assessment (Laird 2013) and inundation-flood vulnerability modeling/mapping for Humboldt Bay (NHE 2014), Humboldt County, California. Assessing sensitivity and significance of the U.S. 101 corridor on Arcata Bay is being addressed in other technical memos for the D1CCPS.

Sea level rise will impact transportation assets that are located in low lying coastal areas such as Highway 101 on Arcata Bay. These can manifest as direct impacts such as erosion of highway fill, bridge abutments and/or flooding of highway surfaces and drainage structures, as well as indirect impacts such as rising groundwater, and saltwater intrusion. When assessing exposure to sea level rise for planning purposes, it is useful to differentiate between permanent saltwater inundation versus frequent inundation and infrequent extreme hazard floods.

The first phase of the HBSLRAP project inventoried, mapped, and assessed the vulnerability of the current shoreline of Humboldt Bay. The segment of Highway 101 between Eureka and Arcata does not actually form a shoreline on the Bay; instead publicly and privately owned structures form 11.26 miles of protective shorelines to the west and east of Highway 101. These shorelines primarily consist of a publically owned but unmaintained railroad grade, spanning 4.55 miles, and publically and privately owned and maintained dikes over 5.35 miles (Figure 3 and 4). Currently 0.45 miles of these shorelines are exposed, 7.44 miles are unfortified, and 3.40 miles are fortified (Figure 5 and 6). At present, 5.48 miles of shoreline protecting Highway 101 have been rated highly vulnerable to breaching because they are overtopping by extreme tides (100 year event) up to 2 feet above the tidal baseline elevation (Figure 7 and 8). The HBSLRSP project's baseline is the mean monthly maximum water (MMMW) (7.74 feet NAVD 88 as measured at NOAA's North Spit Tide Gage). Moderate vulnerability rating was given to shoreline segments that are 2 to 4 feet above MMMW elevations and low for segments that are 4 to greater than 6 feet above. Eroding shoreline segments at any elevation were rated highly vulnerable. Unfortified shoreline segments that are in the 1 to 3 foot elevation range were also rated highly vulnerable. The same staggered ranking occurs from 2 to 5 feet based on shoreline cover resulting in a higher rating than what would be if elevation is just considered (Laird 2013).

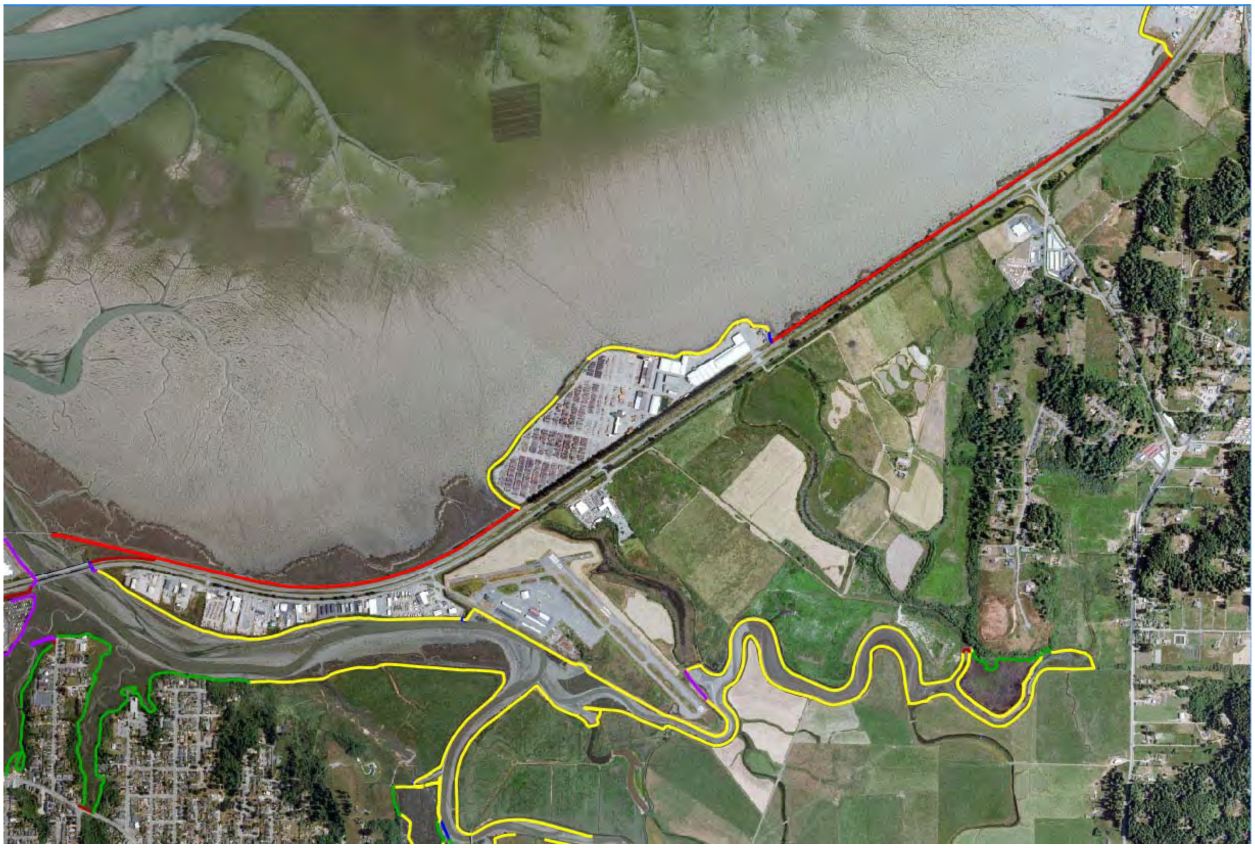


Figure 3. Shoreline structure of the lower reach of Highway 101: railroad (red), dike (yellow), fortified (purple), and natural (green) (Laird 2013).

Figure 4. Shoreline structure of the upper reach of Highway 101: railroad (red), dike (yellow), natural (green), fortified (purple), roadway (maroon), and bridge abutments (blue) (Laird 2013).

Figure 5. Shoreline cover of the lower reach of Highway 101: eroding (red), vegetated (yellow), and fortified (brown) (Laird 2013).

Figure 6. Shoreline cover of the upper reach of Highway 101: eroding (red), vegetated (yellow), and fortified (brown) (Laird 2013).

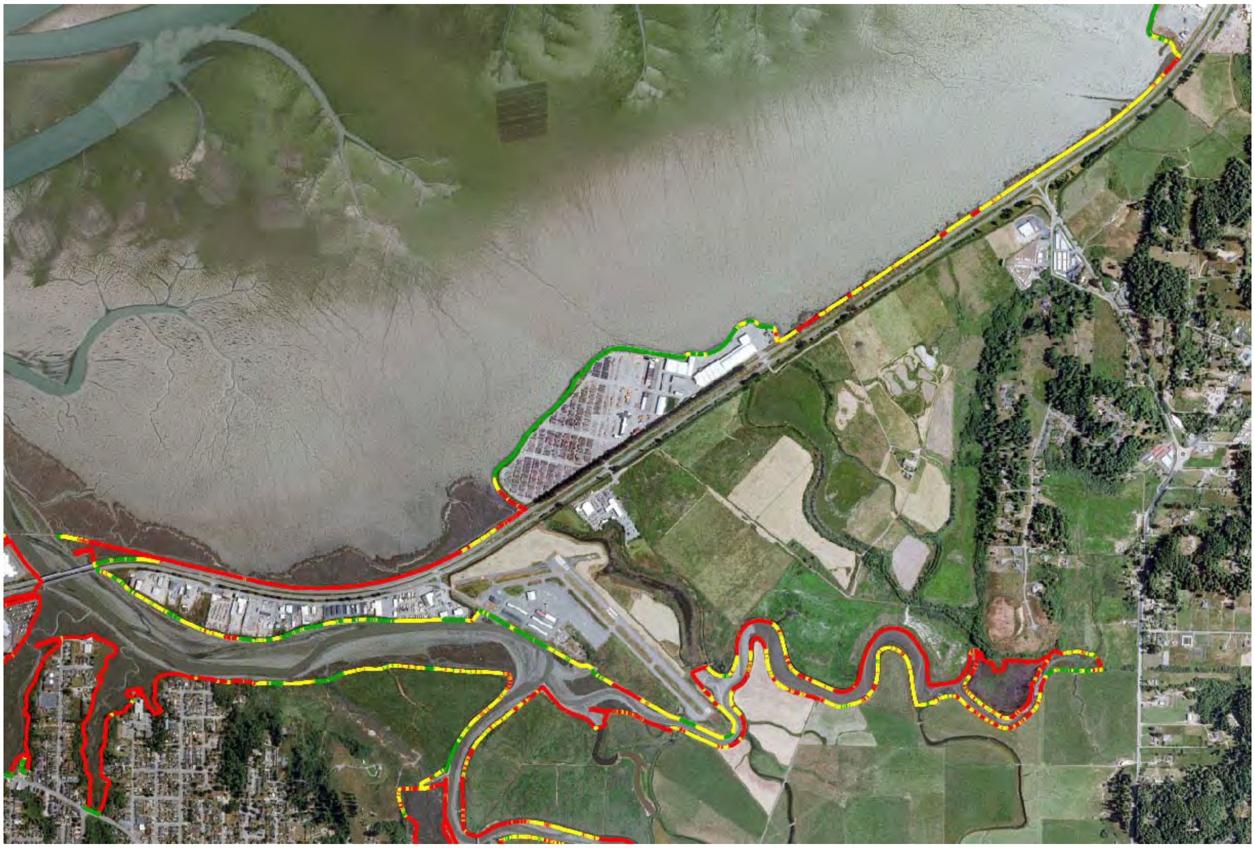


Figure 7. Shoreline vulnerability rating of the lower reach of Highway 101: high (red), moderate (yellow), and low (green) (Laird 2013).

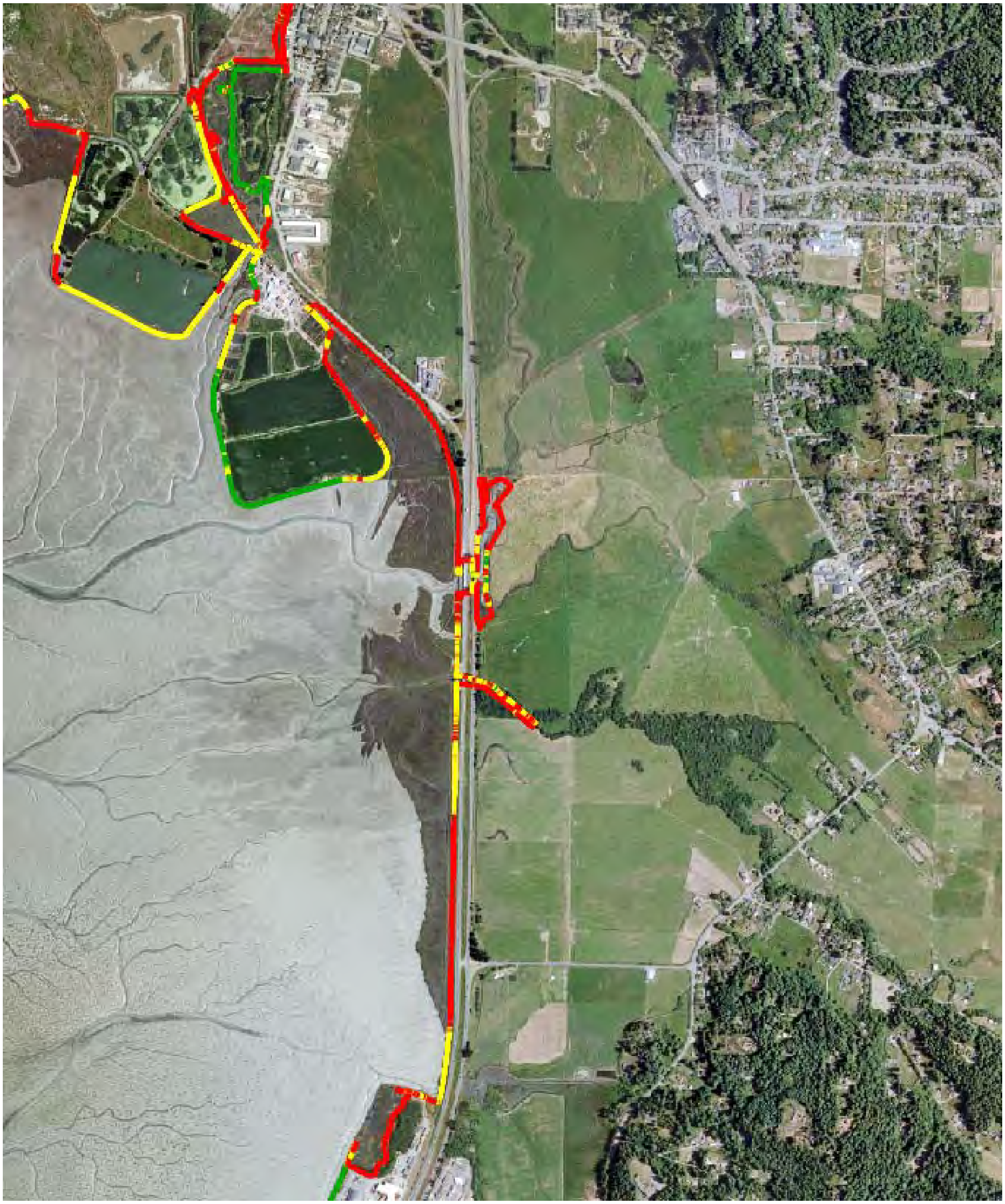


Figure 8. Shoreline vulnerability rating of the upper reach of Highway 101: high (red), moderate (yellow), and low (green) (Laird 2013).

The shorelines to the west and east that protect Highway 101 from tidal inundation also have multiple public and privately owned and maintained tide gates, while Highway 101 has multiple culverts and bridges that convey stormwater runoff from the watersheds to the east. On Arcata Bay, Highway 101 traverses several tributaries that drain from the east to the Bay or Eureka Slough (Figure 9). Stormwater runoff from these watersheds can overwhelm water control and drainage structures, resulting in overbank flows that flood areas bordering Highway 101 to the east.

Figure 9. Highway 101 traverses several tributaries and streams to Arcata Bay.

Under MMMW conditions, if the protective shorelines to the west and east are compromised by erosion or overtopping, the existing Highway 101 would become a causeway, similar in function to a dike, traversing Arcata Bay. The Highway would continue as a causeway until it becomes inundated by rising tides. In contrast, a viaduct would be an elevated roadway that allows water to pass beneath. If the water control and drainage structures located in the protective shoreline to the east or beneath Highway 101 fail or are impaired, flooding of lands behind the protective shorelines may occur, which can flood the road prism and surface of Highway 101.

The lands adjacent to Humboldt Bay are vulnerable to tidal inundation and rising ground water because they are former tidelands and therefore lie within the tide range. Additionally, these lands are at risk of inundation and flooding as a consequence of historical land uses, subsidence, and from sea level rise. In 1870, when the U.S. Coast Survey first mapped Humboldt Bay, it encompassed 27,000 acres. Today, Humboldt Bay occupies 17,000 acres. From 1890 to 1910, approximately 9,000 acres of salt marsh on Humboldt Bay was diked off, drained, and converted to agricultural uses. Many of the critical assets for the Humboldt Bay region, including this segment of Highway 101, were subsequently located on these diked former tidelands, which have compacted by as much as 3 feet due to oxidation of organic material in the former salt marsh soil. Currently, 75 percent of the shoreline on Humboldt Bay is artificial, composed mostly of earthen dikes on 41 miles and railroad grade on 11 miles. If these dikes and railroad grade were breached or overtopped today, Humboldt Bay could expand by 52 percent in areal extent, inundating nearly 9,000 acres of former salt marsh. Compared to Humboldt Bay's reclamation of its former tidelands, if the shoreline fails, sea level rise to 2.0 meters will increase the footprint of Humboldt Bay by 22 percent for a cumulative total of or 74 percent (Figure 10). The rate of increase with sea level rise reflects the steeper upland topography adjacent to the low-lying former tidelands. While the area extent at risk will not change rapidly; those areas in the existing hazard zone will likely be flooded more frequently and to greater depth, increasing the risk to assets in those areas.

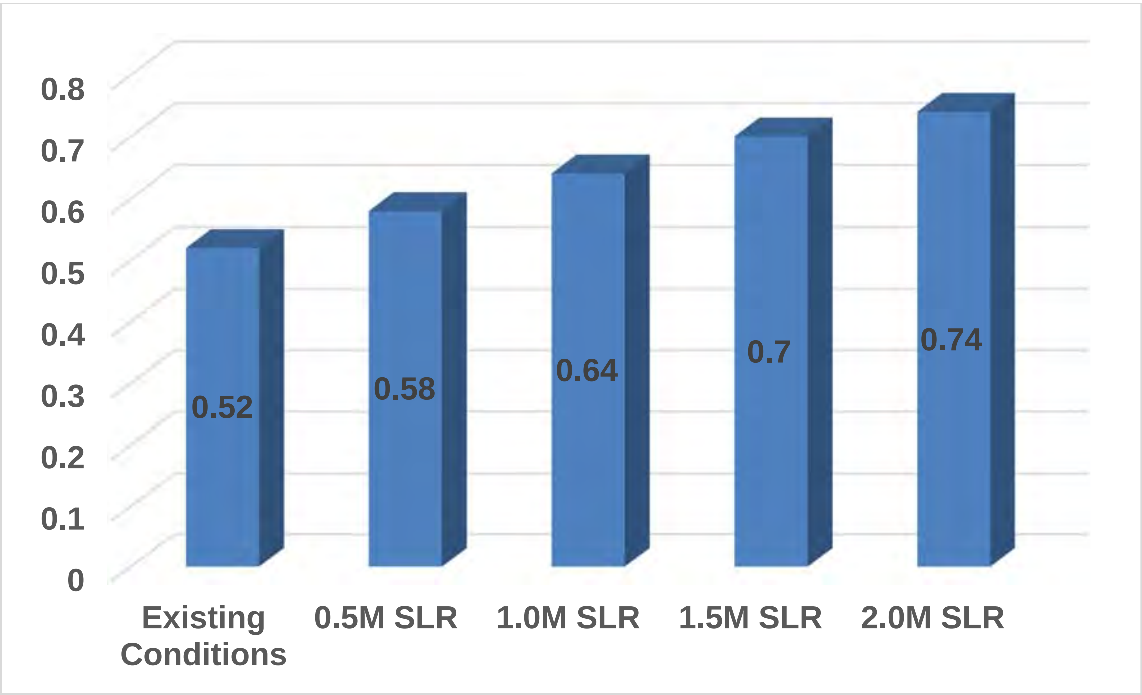


Figure 10. Percent increase in Bay footprint as result of shoreline failure and sea level rise.

Low lying former tidelands, and the assets located thereon, adjacent to Humboldt Bay are most at risk from shoreline failure today under existing tidal conditions, while sea level rise will increase the frequency and the depth of tidal inundation as well as the footprint incrementally.

Adaptation planning to mitigate the impacts from tidal inundation must account for the projected time frame of exposure for inundation. Many critical assets on and adjacent to Humboldt Bay are at risk from failure of the current artificial shoreline. Adaptation planning must focus on the asset at risk and develop specific adaptation measures scaled to projected exposure thresholds and magnitudes.

As mentioned previously, the segment of Highway 101 between Eureka and Arcata is protected from coastal erosion and tidal inundation by 11.26 miles of intervening shorelines to the west and east. When these protective shorelines are compromised, the highway will become the new shoreline that will need to be protected from tides, wind generated waves, and extreme events. This segment of Highway 101 is currently at risk of flooding during extreme tidal events, storm surge, and periods of heavy stormwater runoff. On Humboldt Bay, average King Tide reaches 8.78 feet (NAVD 88) at the North Spit tide gage. However, King Tide on New Year's Eve in 2005 reached 9.55 feet and a "state of disaster" was declared on Humboldt Bay in response to shoreline erosion, overtopping, and flooding.

California requires that sea level rise assessments be performed for conditions that are likely to occur in 2030, 2050, and 2100. Relative sea level rise (RSLR), combines rates of both vertical ground movement and regional sea level rise. Phase II of the HBSLRAP project estimates that RSLR at the North Spit tide gage, relative to 2000, will reach 0.56 feet by 2030, 1.09 feet by 2050, and 3.24 feet by 2100 (NHE 2014). On Humboldt Bay, a shoreline elevation threshold exists between 9.74 and 10.74 feet (NAVD 88), 2.0 to 3.0 feet above MMMW elevation, the project's baseline water elevation. At this threshold significant portions of the diked shoreline (28% to 58%) and railroad shoreline (15% to 66%) are overtopped by MMMW elevation and may result in permanent tidal inundation of lands behind the dikes and railroad (Laird 2013). However, during storm surges and episodes of severe wind waves these shoreline structures will likely be overtopped much earlier than when RSLR exceeds this MMMW elevation threshold. A RSLR estimate of 2.0 feet is expected by 2075 (NHE 2014). The D1CCPS assesses exposure at 2050 and 2100.

Based on the HBSLRAP project's Phase II inundation and flood mapping (NHE 2014), this segment of Highway 101 can be segregated in to two reaches that are vulnerable to inundation and flooding at different elevations: 1) south of Bracut (Brainard's Point) is generally lower in elevation, and 2) north of Bracut is higher.

The HBSLRAP project's Phase II produced maps of the areal extent of inundation and flooding during extreme events in meters. It is possible, with the GIS dataset that was prepared for inundation and flood models, for future projects to identify the depth of inundation or flooding at any specific location. There are 6 hydrologic units on Humboldt Bay: Arcata, Eureka and South Bays, and Mad River, Eureka and Elk River Sloughs. These hydrologic units can be stratified into 27 hydrologically separate sub-units or flood cells.

Existing Conditions

<u>Inundation</u> @ MMMW (7.74 ft. NAVD 88) (Figures 11 and 12):

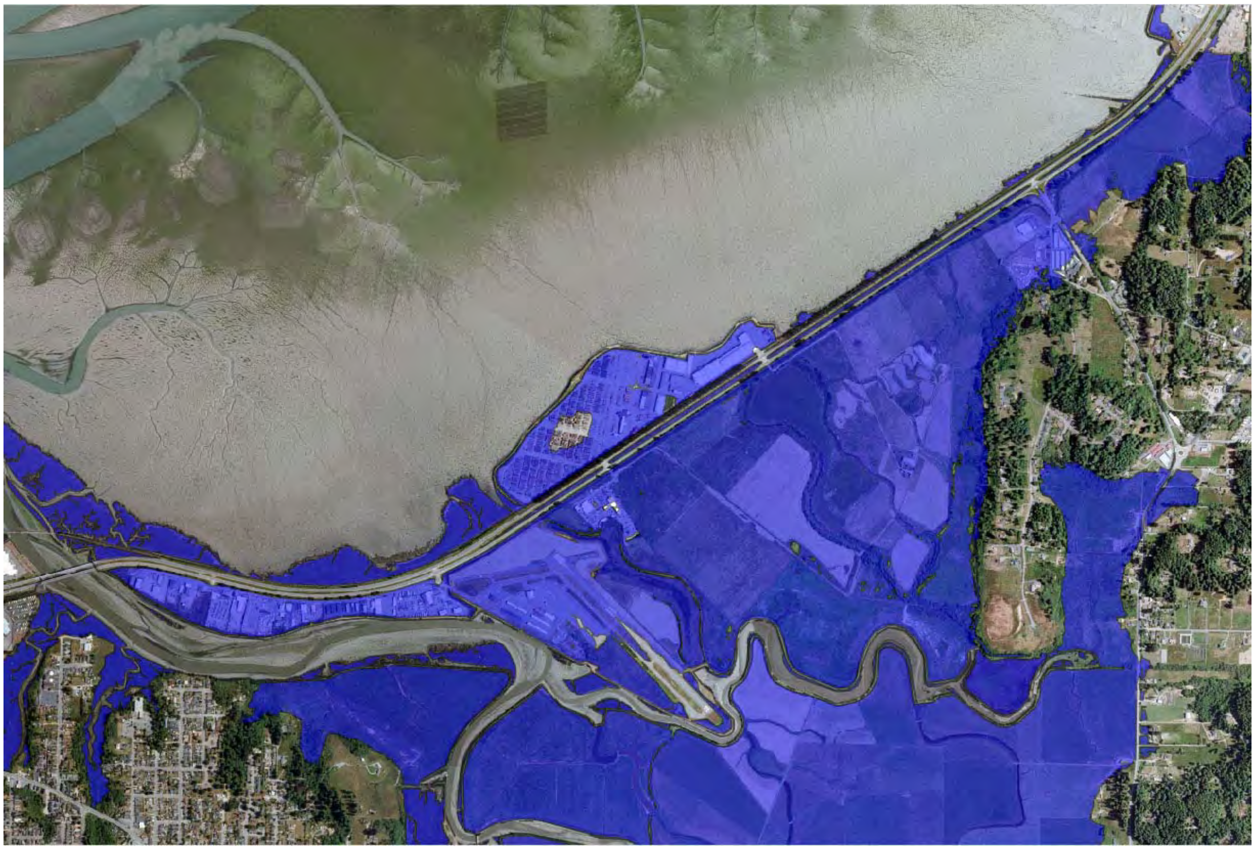


Figure 11. Lower Reach: the land adjacent to the road prism is inundated to the west and east of Highway 101. Erosion of the road embankment is possible if exposed to waves and integrity maybe compromised prior to inundation or flooding. Erosion related impacts will increase as water depth increases.

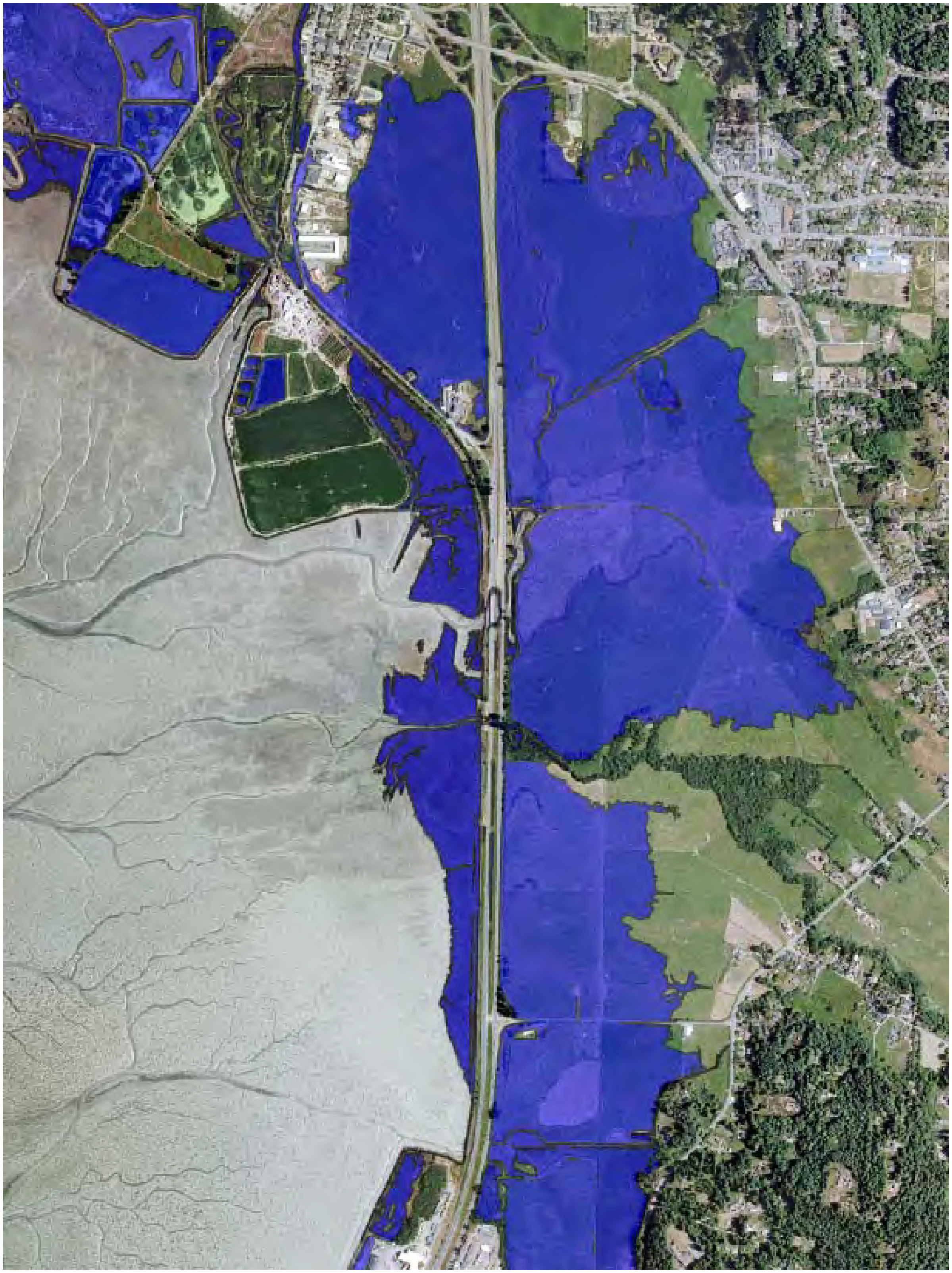


Figure 12. Upper Reach: the land adjacent to the road prism is inundated to the west and east of Highway 101.

<u>Flooding</u> @ MMMW + 100 year still water level (9.24 ft. NAVD 88) (Figures 13 and 14):

Figure 13. Lower Reach: North of Airport Rd. both north and south bound lanes are flooded.

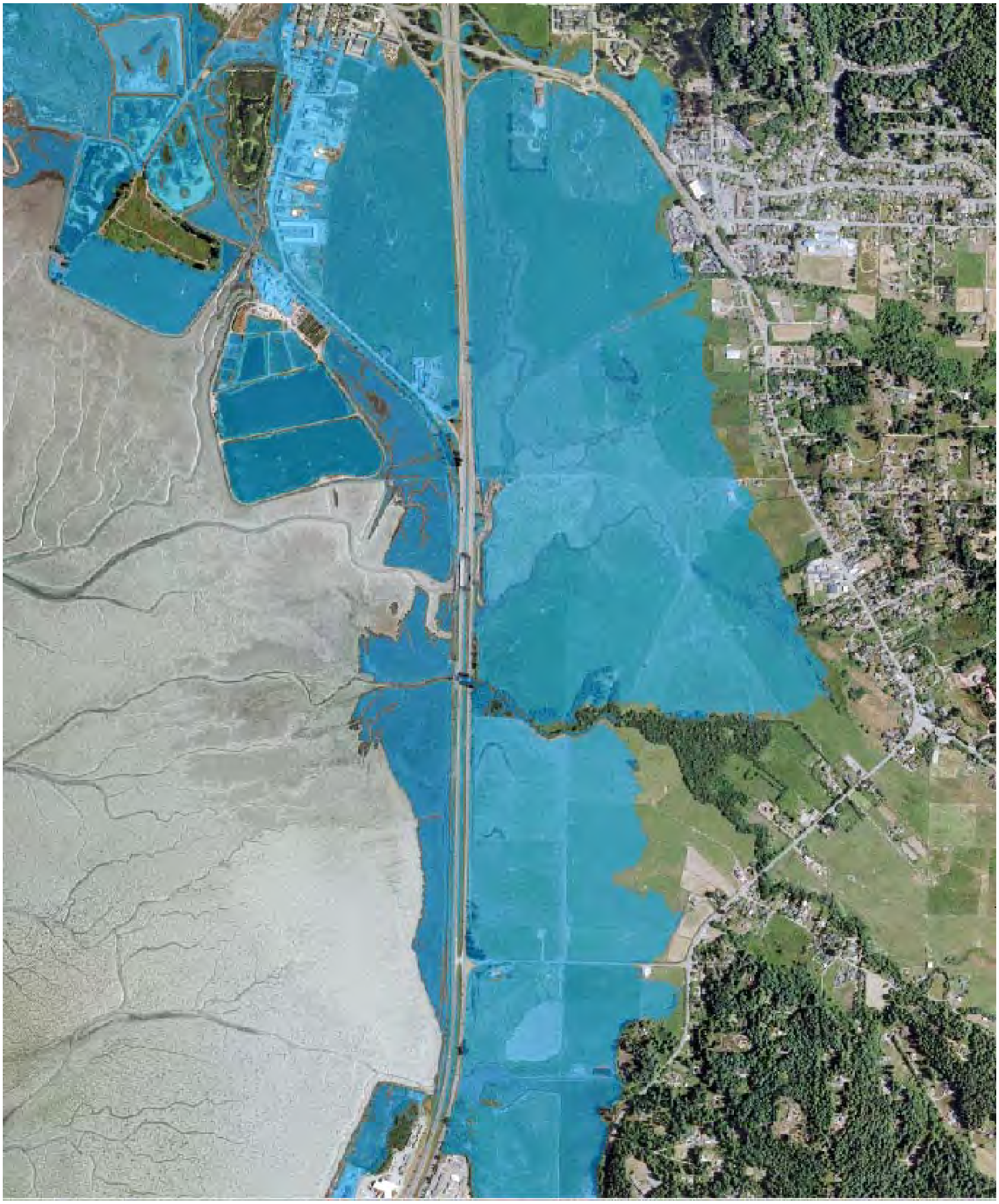


Figure 14. Upper Reach: the land adjacent to the road prism is flooded to the west and east of Highway 101.

2014 to 2050:

<u>Inundation</u> @ MMMW + 0.5 meter (9.38 ft. NAVD 88) (Figures 15 and 16):

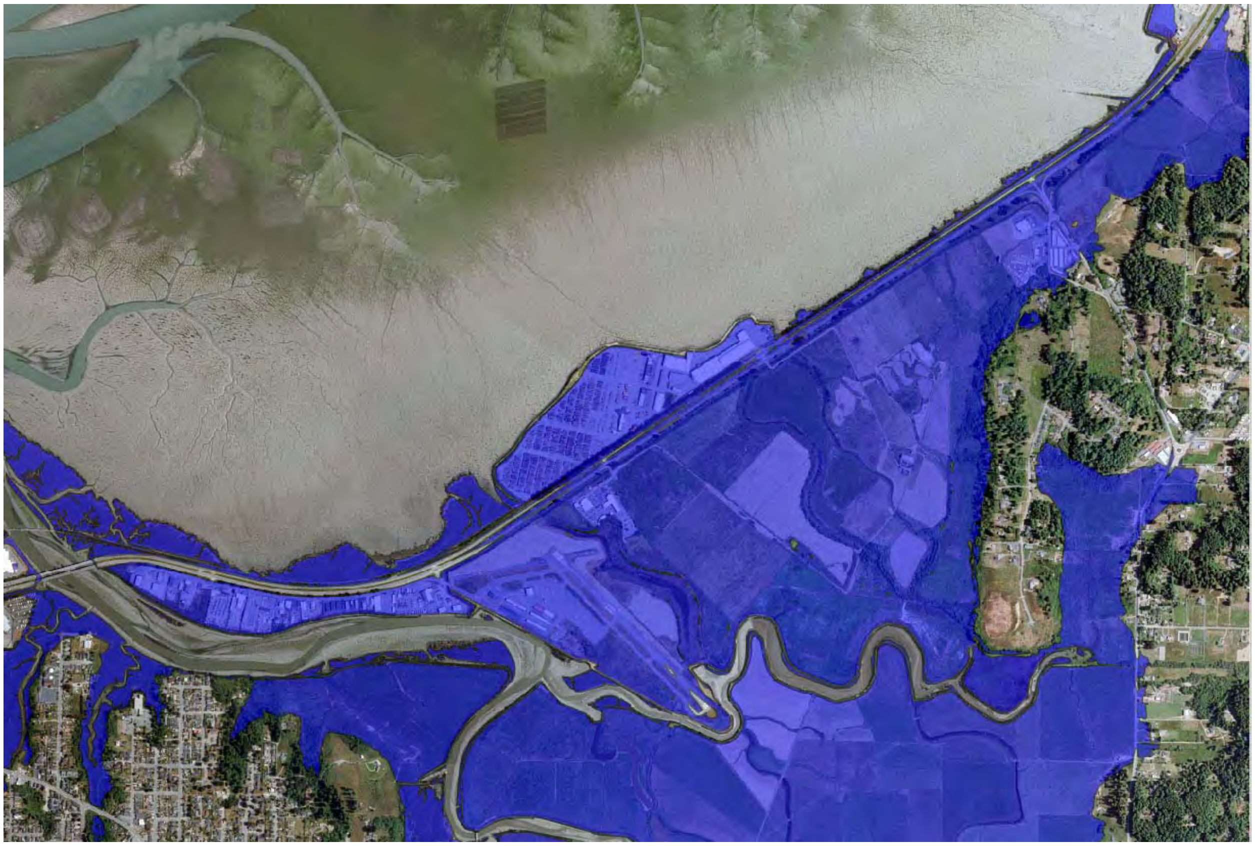


Figure 15. Lower Reach: North of Airport Rd. both north and south bound lanes are inundated.

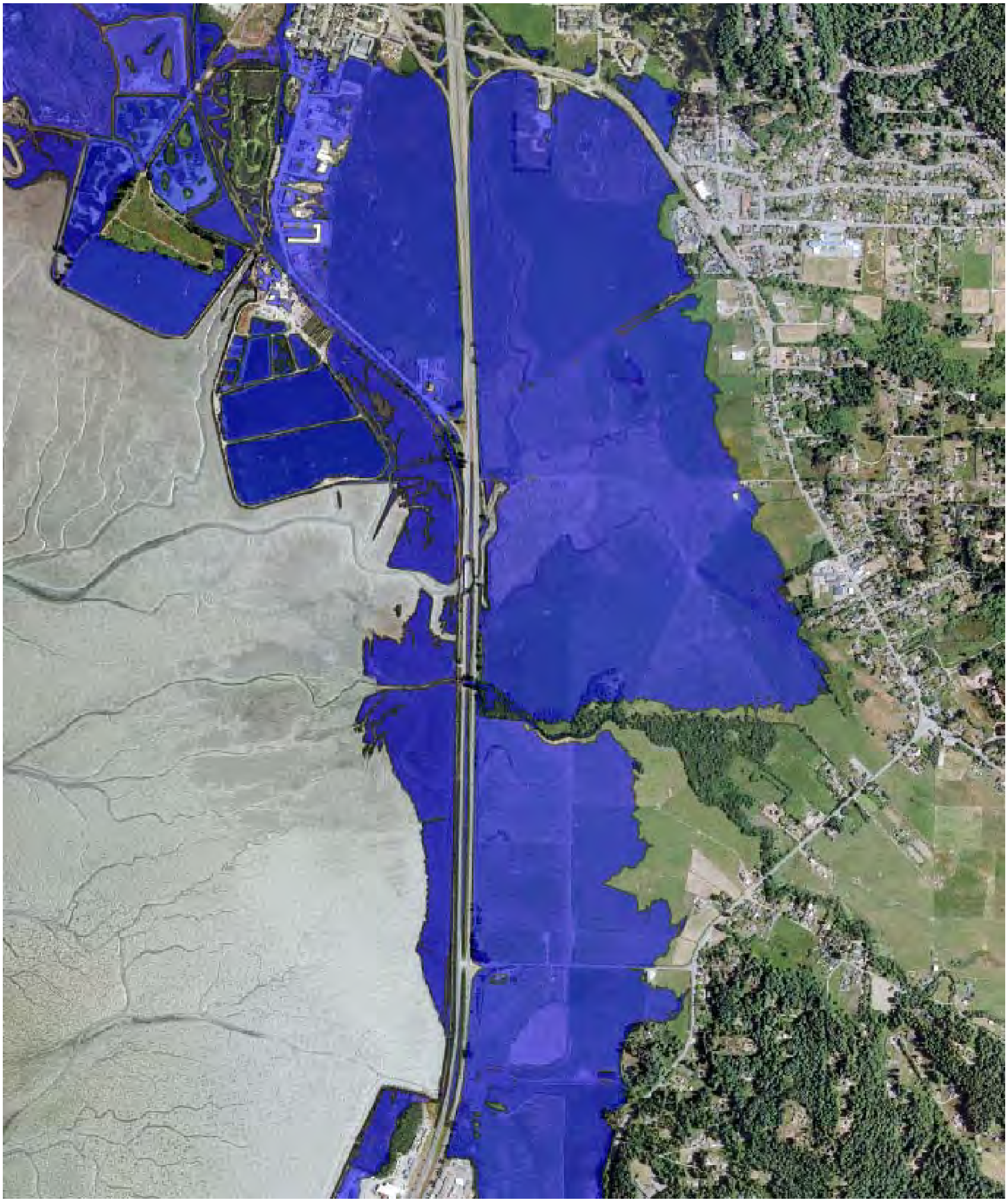


Figure 16. Upper Reach: the land adjacent to the road prism is inundated to the west and east of Highway 101.

<u>Flooding</u> @ MMMW + 0.5 meter + 100 year (10.88 ft. NAVD 88) (Figures 17 and 18):

Figure 17. Lower Reach: Eureka Slough north to Airport Rd. partial flooding of north bound lanes and south bound lanes, North of Airport Rd. both north and south bound lanes are flooded.

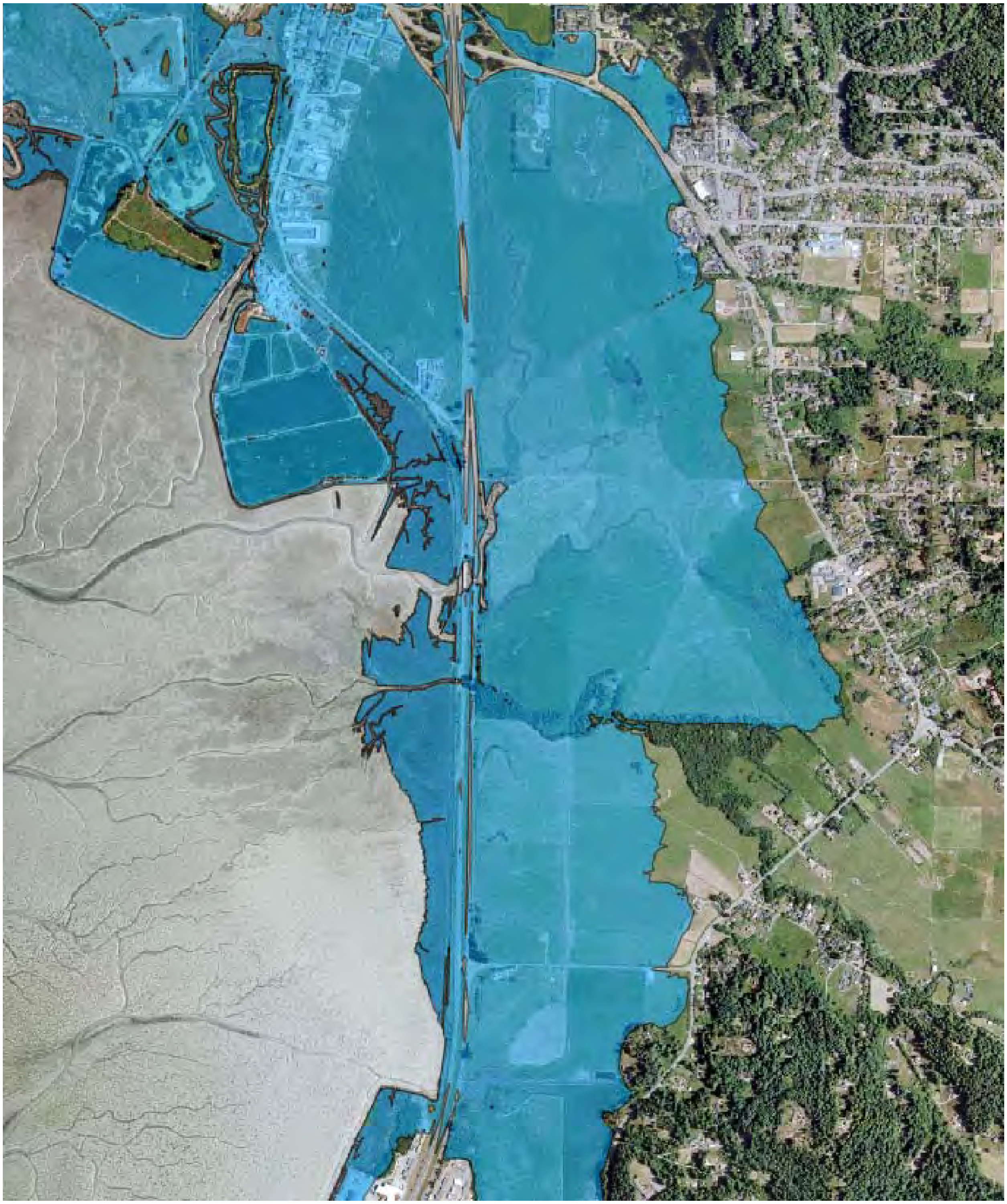


Figure 18. Upper Reach: both north and south bound lanes are flooded, nearly the entire length of this reach.

2050 to 2100:

<u>Inundation</u> @ MMMW + 1.0 meter (11.02 ft. NAVD 88) (Figures 19 and 20):

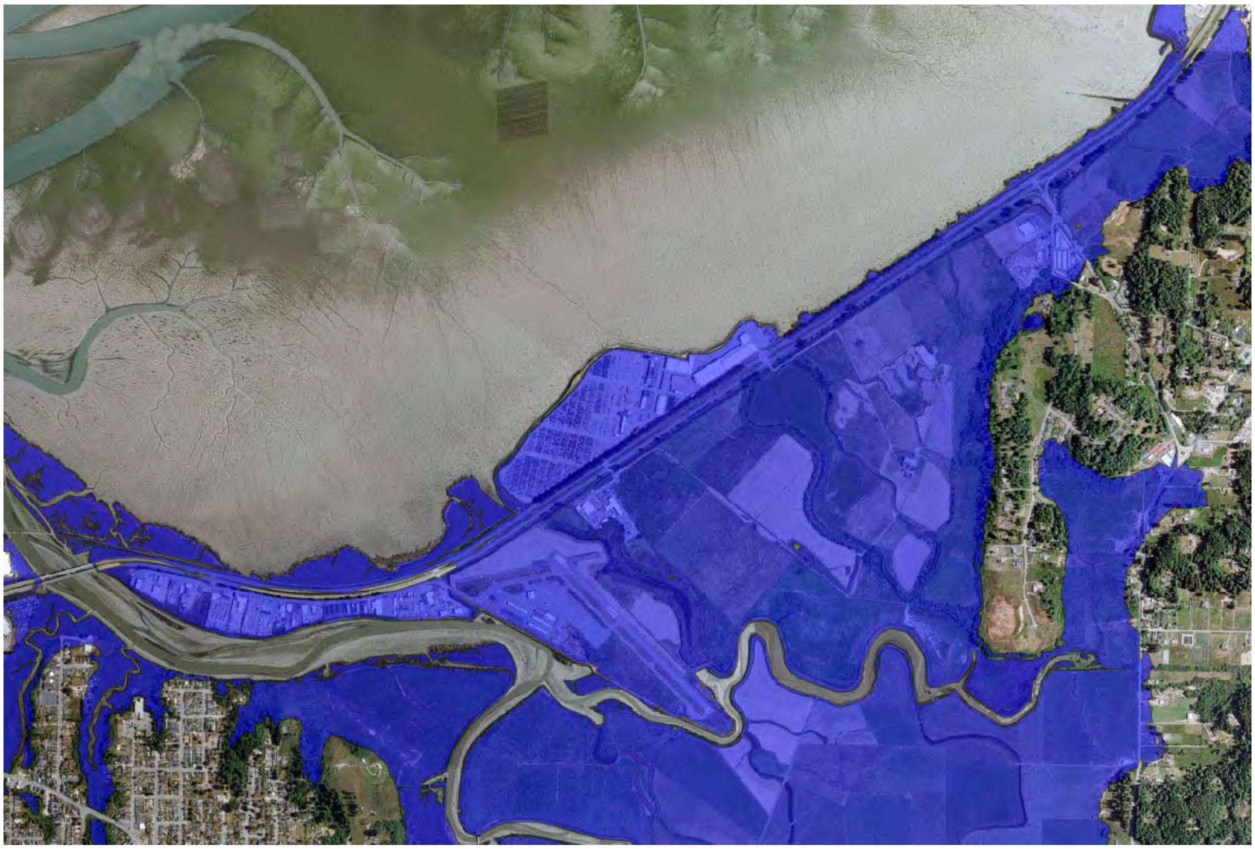


Figure 19. Lower Reach: Eureka Slough north to Airport Rd. partial inundation of north bound lanes and south bound lanes are inundated, North of Airport Rd. both north and south bound lanes are inundated.

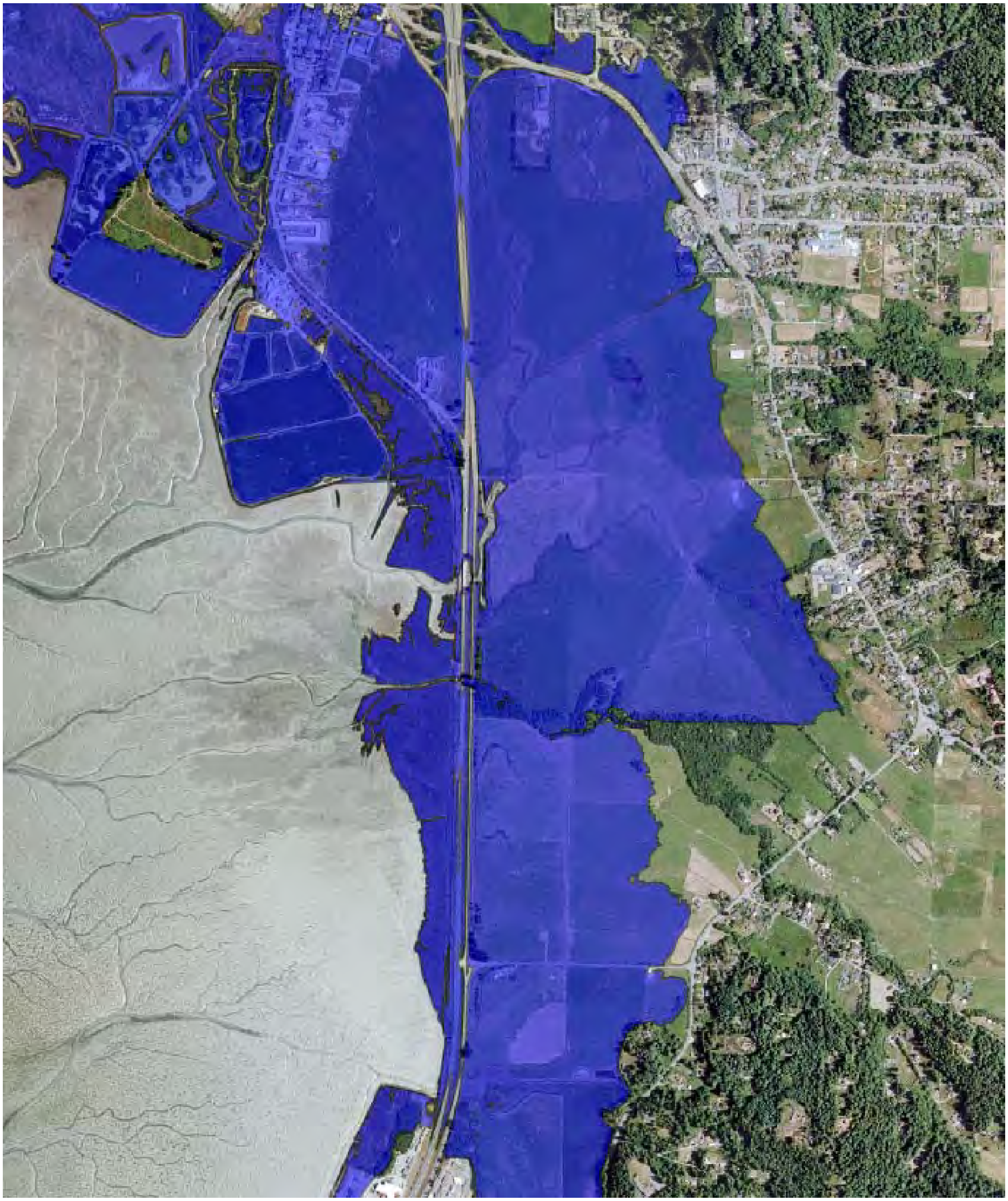


Figure 20. Upper Reach: south bound lanes are inundated approximately 50 percent of the length of this reach and the north bound lanes inundated approximately 25 percent of length of this reach.

Flooding @ MMMW + 1.0 meter + 100 year (12.52 ft. NAVD 88) (Figures 21 and 22):

Figure 21. Lower Reach: both north and south bound lanes are flooded.

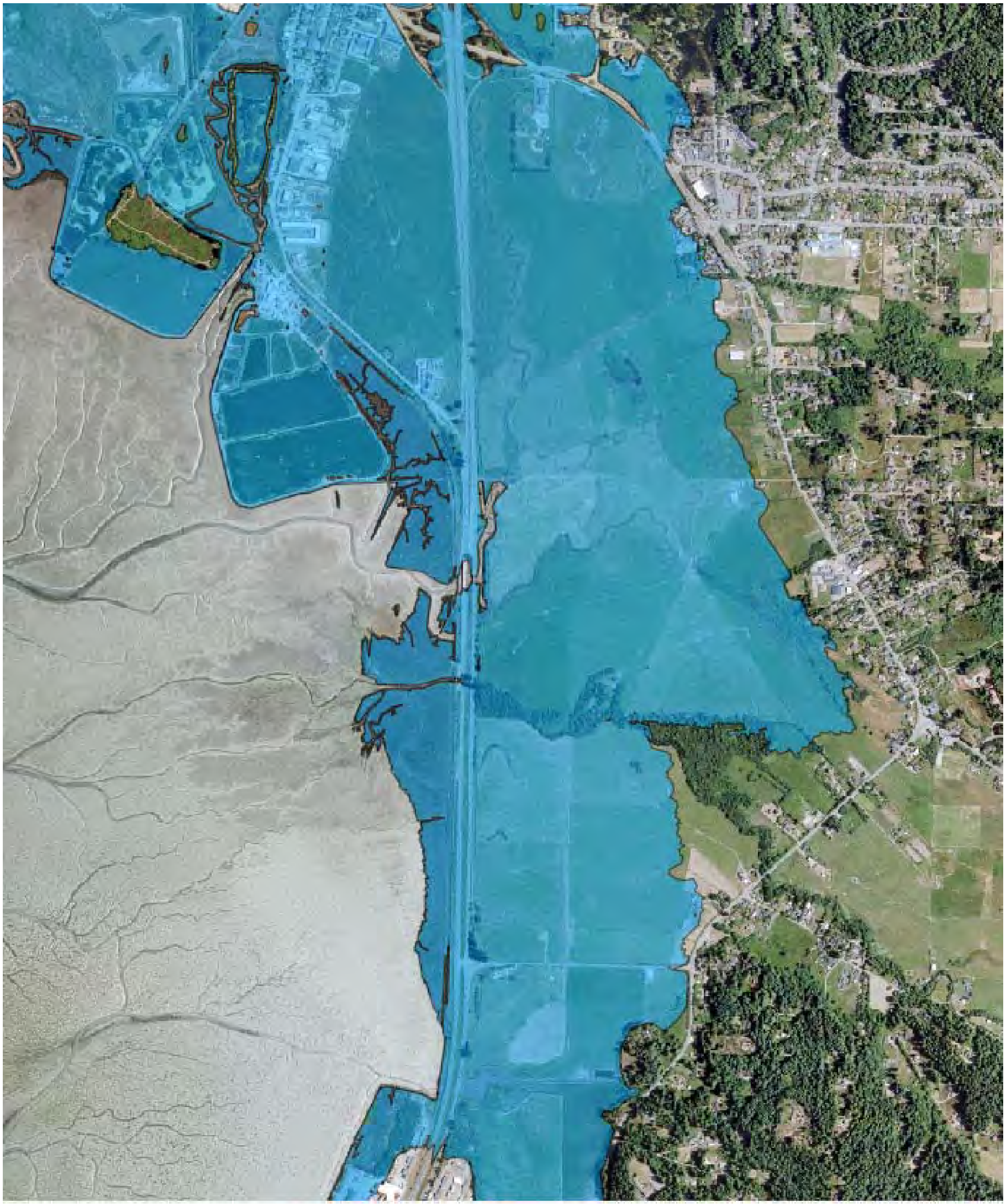


Figure 22. Upper Reach: both north and south bound lanes are flooded.

In summary, if the current shorelines were to be breached, the land adjacent to the road prisms in both the lower and upper reaches would be inundated by tidewater, flooded during extreme storm events, and vulnerable to erosion under existing conditions. The lower reach road surface would be inundated when RSLR rises to 0.5 meters. In the upper reach with 1.0 meter of RSLR, nearly 50 percent of the south bound lanes would be inundated and 25 percent of the north Bound lanes. The road surfaces in the upper reach would be completely inundated with 1.5 meters of RSLR. Today, a 100 year tidal event would flood the road surfaces in the lower reach, and, with 0.5 meter of RSLR, the same extreme event would flood the road surfaces in the upper reach.

Adaptation Strategies

Adaptation to sea level rise impacts will likely require a combination of strategies to be employed at different stages of an asset's vulnerability. The D1CCPS has chosen to address sea level rise impacts and adaptation strategies from 2014 to 2050 and 2050 to 2100. Projected RSLR for 2050 is 1.1 feet and 3.2 feet by 2100 (NHE 2014). However, the range of estimated RSLR for example by 2050, is 0.7 feet to 1.9 feet, projections and estimates beyond 2050 are less certain but are likely underestimated at this time; 2100 is 2.0 to 5.3 feet.

In general, adaptation strategies available to transportation authority's fall under several categorical approaches regarding sea level rise impacts to assets at risk: no new actions, protect, accommodate, or relocate. Regulatory reform of some statutes could facilitate the adaptive capacity of transportation authority's to respond to impacts from sea level rise. For the D1CCPS on Humboldt Bay the following adaptation strategies could be employed in their respective time frames (Table 1).

No New Actions

2014 to 2050: If the diked or railroad grade shorelines that protect Highway 101 are breached, then the lower and upper reaches of Highway 101 would become a tidally inundated causeway. This causeway could act as a barrier to stormwater runoff and could be eroded, overtopped and flooded. Further, the road base for Highway 101 may not have been designed or built to be inundated, settling of the road base and surface may occur. During extreme events, such as a 100 year event, if the shoreline fails both north and south bound lanes in the lower reach would flood. Flooding would require traffic to be temporarily blocked or re-routed to other roads that are open. By 2050, if 1.0 feet of RSLR has occurred then the lower and upper reaches of Highway 101 will be flooded annually during multiple King Tides and by extreme tidal events, requiring traffic to be temporarily blocked or re-routed to other roads.

2050 to 2100: The lower reach of the Highway 101 will be inundated by MMMW with 0.5 meters of RSLR, which could occur by 2066 (NHE 2014), an alternate route will be needed. The upper reach with 0.5 meters of RSLR will be flooded during extreme events, requiring traffic to be temporarily blocked or re-routed to local service roads. By 2100, significant portions of the upper reach of Highway 101, nearly 50 percent of the south bound lanes and 25 percent of the north bound lanes may be inundated daily with 1.0 meters of RSLR, and an alternate route will be needed.

The road surfaces in the upper reach will be completely inundated by MMMW with 1.5 meters of RSLR.

Protect

2014 to 2050: Initially partnering with shoreline property owners to improve shoreline protective structures could prevent tidal inundation of the roadway from up to 2.0 feet of RSLR. Fortification (living shorelines or harden structures) and increases of shoreline elevation on 5.48 miles of highly vulnerable sections of shoreline protecting Highway 101 (0.45 miles to breaching, 5.03 miles to overtopping) could protect against inundation of the road prism and North and South bound lanes. Raising 5.89 miles of roadway surfaces and embankments is an alternative to improving shoreline protective structures.

King Tides and extreme events would temporarily flood both North and South Bound lanes, requiring traffic to be temporarily blocked or re-routed to local service roads.

2050 to 2100: Protective shoreline structures that are 1.0 to 1.5 meters higher than current protective shoreline may be required. These structures could be constructed on existing shorelines (11.26 miles) or parallel to the Highway (11.78 miles = 5.89 miles x 2) to create a secure transportation corridor. The existing North and South bound lanes may also need to be elevated if rising groundwater inside the shoreline structures could cause long-term inundation. In a new corridor there would be an opportunity to locate other critical assets such as gas and water lines, and other transportation routes (trail and rail) which could lead to the cost of adaptation being borne by multiple entities. Again, raising 5.89 miles of roadway surfaces and embankments is an alternative to improving shoreline protective structures.

Protecting existing shorelines or constructing new shorelines as discussed would be a huge and expensive undertaking. The useful life of these protective adaptation options will need to be weighed in light of expected accelerated rate of RSLR, and other adaptation options.

Accommodate

The benefit of this adaptation strategy, as with the protection strategy, is to continue to maintain the transportation corridor in its existing right-of-way.

2014 to 2050: Constructing, more bridges or extending the length of existing bridges, elevated piled causeways, and installing more culverts could increase drainage capacity to convey stormwater runoff to prevent overtopping and flooding of the Highway if the existing shorelines become compromised.

Constructing an elevated causeway could be achieved in stages or by choosing one option based on capital expenditure and usable life: first increasing the footprint of the road prism and raising the elevation of the existing road surface, and then by installing pilings and suspending the roadway like a viaduct above extreme flood elevations.

The lower reach of Highway 101 is at greater risk of inundation and flooding than the upper reach. An elevated causeway could be constructed in the 3.22 miles of lower reach between Eureka Slough and Bracut to prevent up to 2.0 meters, or as high as you want to pay for, of tidal inundation and flooding of the road bed from extreme events, and up to 1.5 meters of RSLR. During this time period it may be more economically feasible to protect the upper reach with shoreline improvement discussed previously.

2050 to 2100: The 2.21 miles of the upper reach of Highway 101 between Bracut and Highway 255 on- and off-ramps could accommodate up to 2.0 meters of RSLR if it was reconstructed as an elevated causeway to prevent up to 2.0 meters of tidal inundation and flooding from extreme events, and up to 1.5 meters of RSLR. An elevated causeway could be constructed to accommodate any elevation of RSLR necessary.

Relocate

2014 to 2050: Measures to protect Highway 101 in the study area or to accommodate RSLR up to

Based on RSLR estimates 0.5 meters of RSLR should not occur in the study area before 2050.

If protective or accommodative strategies are not pursued the lower half of Highway 101 in the study area will need to be relocated with 0.5 meters or more of RSLR, and the upper half with 1.0 meters.

There are 2 segments of Highway 101 is at risk of inundation at MMMW elevation from 0.5 meters and greater of RSLR that traverse the shoreline of Humboldt Bay: South Bay and Arcata Bay, the study site. With 1.5 meters and greater of RSLR the Elk River Slough segment of Highway 101 is at risk of inundation at MMMW elevation.

Relocation of Highway 101 to the east of Humboldt Bay could proceed in phases as the need arises or all at once. However, the environmental and social consequences and expense of relocating a major highway to the east of Humboldt Bay will be significant.

Regulate

Modifications of existing environmental and land use regulations could greatly enable the feasibility of proposed alternative adaptation strategies by removing or reducing regulatory constraints. For example the placement of fill in waters of the U.S and State, such as Humboldt Bay and its diked former tidelands, if allowed, to expand the footprint of protective shoreline structures or road bed currently would require compensatory mitigation that may be difficult or impossible to secure.

Table 1. Arcata Bay Pilot Study Site adaptation strategies and options: lower and upper reaches, 2014-2050, 2030-2050, and 2050-2100.

ADAPTATION STRATEGIES	2014-2050	2030-2050	2050-2100
NO NEW ACTIONS			
Lower Reach			
	Existing Conditions Shoreline Breaches = tidally inundates highway embankments and adjacent lands	***RSLR 0.5 meters = tidally inundates north and south bound lanes***	
	Increased maintenance of highway embankment and road surface	Will need to be abandoned and relocated or utilize alternative route	
	Existing Conditions Shoreline Breaches = 100 year event floods north and south bound lanes		
	Temporary closures and increased maintenance of highway embankment and road surface		
Upper Reach			
	Existing Conditions Shoreline Breaches = tidally inundates road embankments and adjacent lands	*RSLR 0.5 meters = tidally inundates highway embankments and adjacent lands*	***RSLR 1.0 meters = tidally inundates north and south bound lanes***
	Increased maintenance of highway embankment and road surface	Increased maintenance of highway embankment and road surface	Will need to be abandoned and relocated or utilize alternative route
	Existing Conditions Shoreline Breaches = 100 year event floods road embankments and adjacent lands		
	Increased maintenance of highway embankment and road surface		
PROTECT			

Lower Reach			
	Existing Conditions Shoreline Breaches = tidally inundates road embankments and adjacent lands	***RSLR 0.5 meters = tidally inundates north and south bound lanes***	
	Increased maintenance of highway embankment and road surface	Construct levee corridor with other transportation modes and utilities	
	Enhance existing shoreline structure elevation and/or cover to minimize breaching	Enhance existing shoreline structure elevation and/or cover to minimize breaching	
	Fortify road embankments and raise road surface elevation	Fortify highway embankments and raise road surface elevation	
	Existing Conditions Shoreline Breaches = 100 year event floods north and south bound lanes		
	Temporary closures and increased maintenance of highway embankment and road surface		
Upper Reach			
	Existing Conditions Shoreline Breaches = tidally inundates road embankments and adjacent lands	*RSLR 0.5 meters = tidally inundates highway embankments and adjacent lands*	***RSLR 1.0 meters = inundates north and south bound lanes***
	Increased maintenance of highway embankment and road surface	Increased maintenance of Highway embankments and road surfaces	Construct levee corridor with other transportation modes and utilities
	Enhance existing shoreline structure elevation and/or cover to minimize breaching	Enhance existing shoreline structure elevation and/or cover to minimize breaching	Enhance existing shoreline structure elevation and/or cover to minimize breaching
	Fortify road embankments and raise road surface elevation	Fortify highway embankments and raise road surface elevation	Fortify highway embankments and raise road surface elevation

	Existing Conditions Shoreline Breaches = 100 year event floods north and south bound lanes	***RSLR 0.5 meters + 100 year event = floods north and south bound lanes***	
	Temporary closures and increased maintenance of highway embankment and road surface	Temporary closures and increased maintenance of highway embankment and road surface	
ACCOMMODATE			
Lower Reach			
	Existing Conditions Shoreline Breaches = tidally inundates road embankments and adjacent lands	***RSLR 0.5 meters = tidally inundates north and south bound lanes***	
	Increase drainage capacity by lengthening bridges or building elevated viaduct segments	Construct elevated viaduct for lower reach	
	Existing Conditions Shoreline Breaches = 100 year event floods north and south bound lanes		
	Temporary closures and increased maintenance of highway embankment and road surface		
	Increase drainage capacity by lengthening bridges or building elevated viaduct segments		
Upper Reach			
	Existing Conditions Shoreline Breaches = tidally inundates road embankments and adjacent lands	*RSLR 0.5 meters = tidally inundates highway embankments and adjacent lands*	***RSLR 1.0 meters = inundates north and south bound lanes***
	Increase drainage capacity by lengthening bridges or building elevated viaduct segments	Increase drainage capacity by lengthening bridges or building elevated viaduct segments	Construct elevated viaduct for upper reach

	Existing Conditions Shoreline Breaches = 100 year event floods north and south bound lanes		
	Temporary closures and increased maintenance of highway embankment and road surface		
	Increase drainage capacity by lengthening bridges or building elevated viaduct segments		
RELOCATE			
Lower Reach			
	Existing Conditions Shoreline Breaches = tidally inundates road embankments and adjacent lands	***RSLR 0.5 meters = tidally inundates north and south bound lanes***	
	No action, Protect, or Accommodate	Relocate lower reach to Myrtle Ave./Old Arcata Road alignment and then to Brainard's Point and upper reach	
		Relocate lower reach along Highway 255	
	Existing Conditions Shoreline Breaches = 100 year event floods north and south bound lanes		
	Temporary closures and increased maintenance of highway embankment and road surface		
	Increase drainage capacity by lengthening bridges or building elevated viaduct segments		
Upper Reach			

Existing Conditions Shoreline Breaches = tidally inundates road embankments and adjacent lands	*RSLR 0.5 meters = tidally inundates highway embankments and adjacent lands*	***RSLR 1.0 meters = inundates north and south bound lanes***
No action, Protect, or Accommodate	No action, Protect, or Accommodate	Relocate upper reach along Old Arcata Rd. alignment and Bayside Ave to Arcata
	Relocate with lower reach along Highway 255	Relocate with lower reach along Highway 255

References

California Natural Resources Agency. 2012. California Adaptation Planning Guide.

Laird, Aldaron, Brian Powell. 2013. Humboldt Bay shoreline inventory, mapping, and sea level rise vulnerability assessment and Addendum: Shoreline Vulnerability Ratings. Prepared for the State Coastal Conservancy.

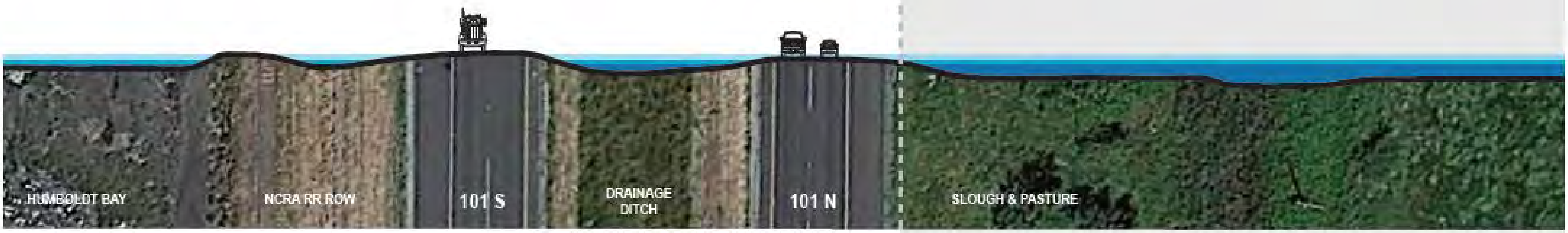
Northern Hydrology and Engineering. 2014. Estimates of local or relative sea level rise for Humboldt Bay region. Prepared for the California State Coastal Conservancy.

Northern Hydrology and Engineering. 2014. Preliminary data release for the Humboldt Bay sea level rise vulnerability assessment: Humboldt Bay sea level rise inundation mapping. Prepared for the California State Coastal Conservancy.

Attachment C

Projected Water Surface Elevations

HWY 101 PM 84.7 NEAR GANNON SLOUGH



HWY 101 PM 82.4 NEAR INDIANOLA CUTOFF

HWY 101 PM 80.5 NEAR JACOBS AVENUE

GHD

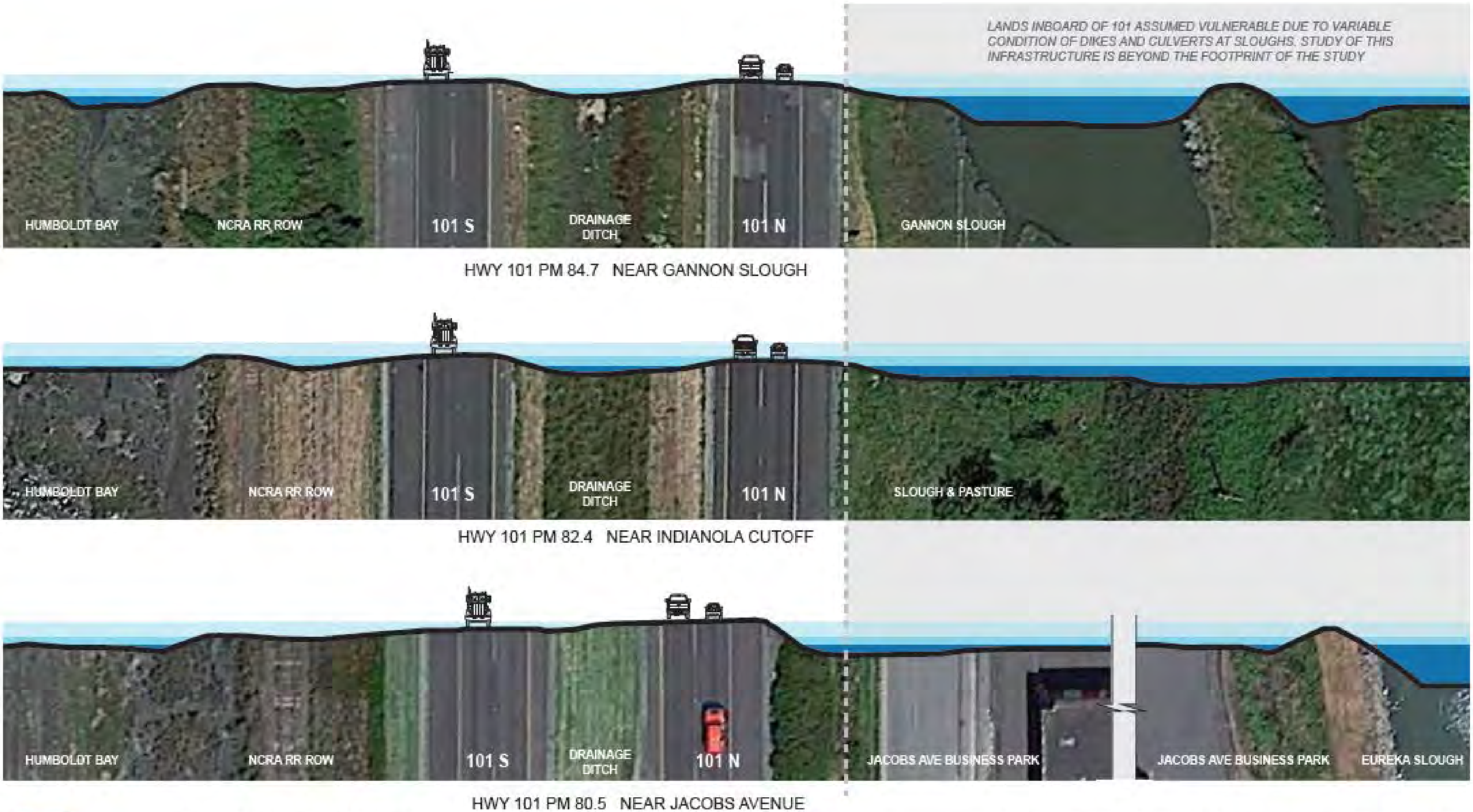
MEAN MONTHLY MAXIMUM WATER & SEA LEVEL RISE: 2050

PROJECTED WATER SURFACE ELEVATIONS

2050 HIGH: 9.91'

2050 LOW: 8.57'

MMMW (2014): 7.74'



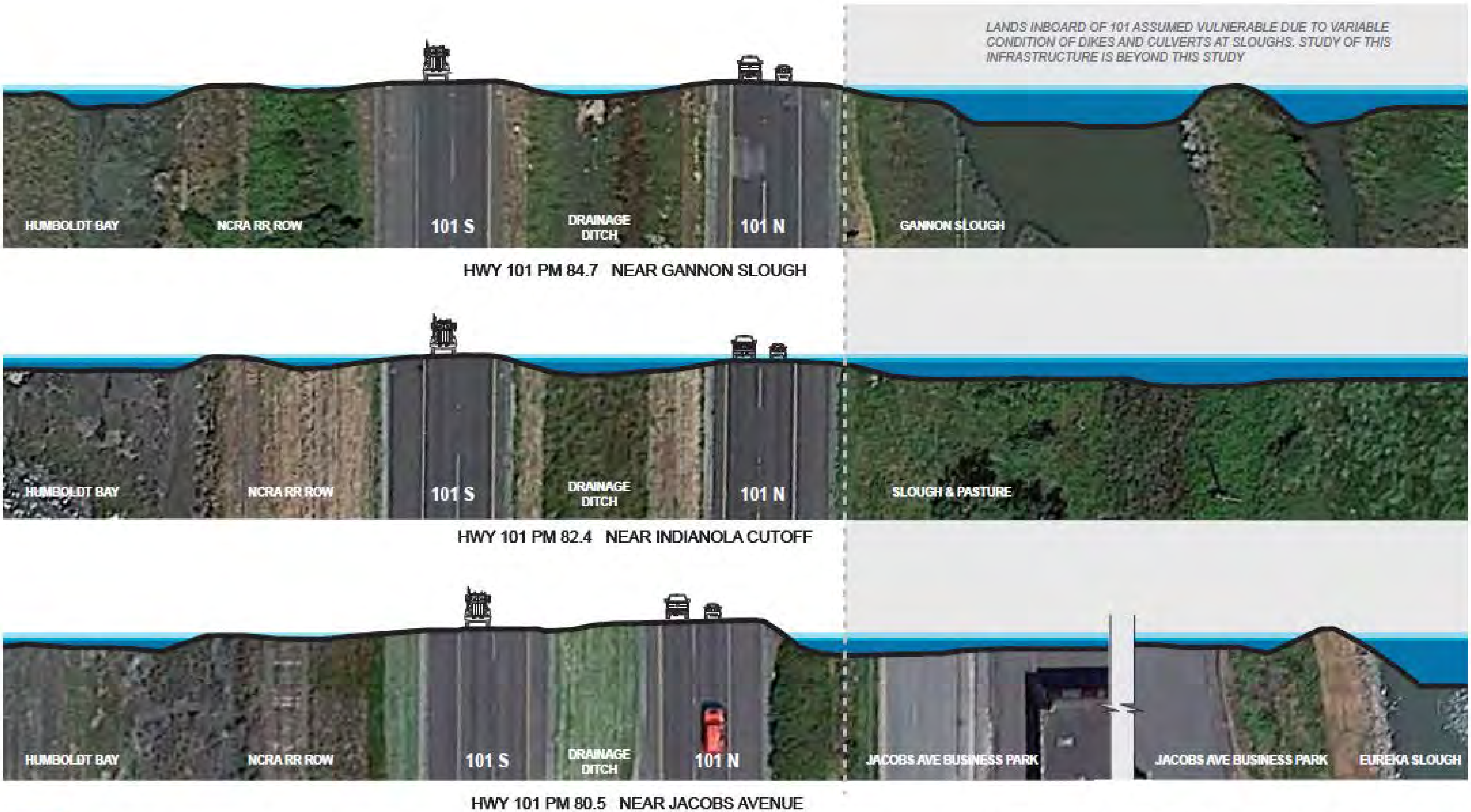
MEAN MONTHLY MAXIMUM WATER & SEA LEVEL RISE: 2100

PROJECTED WATER SURFACE ELEVATIONS

2100 HIGH: 13.57'

2100 LOW: 9.91'

MMMW (2014): 7.74'



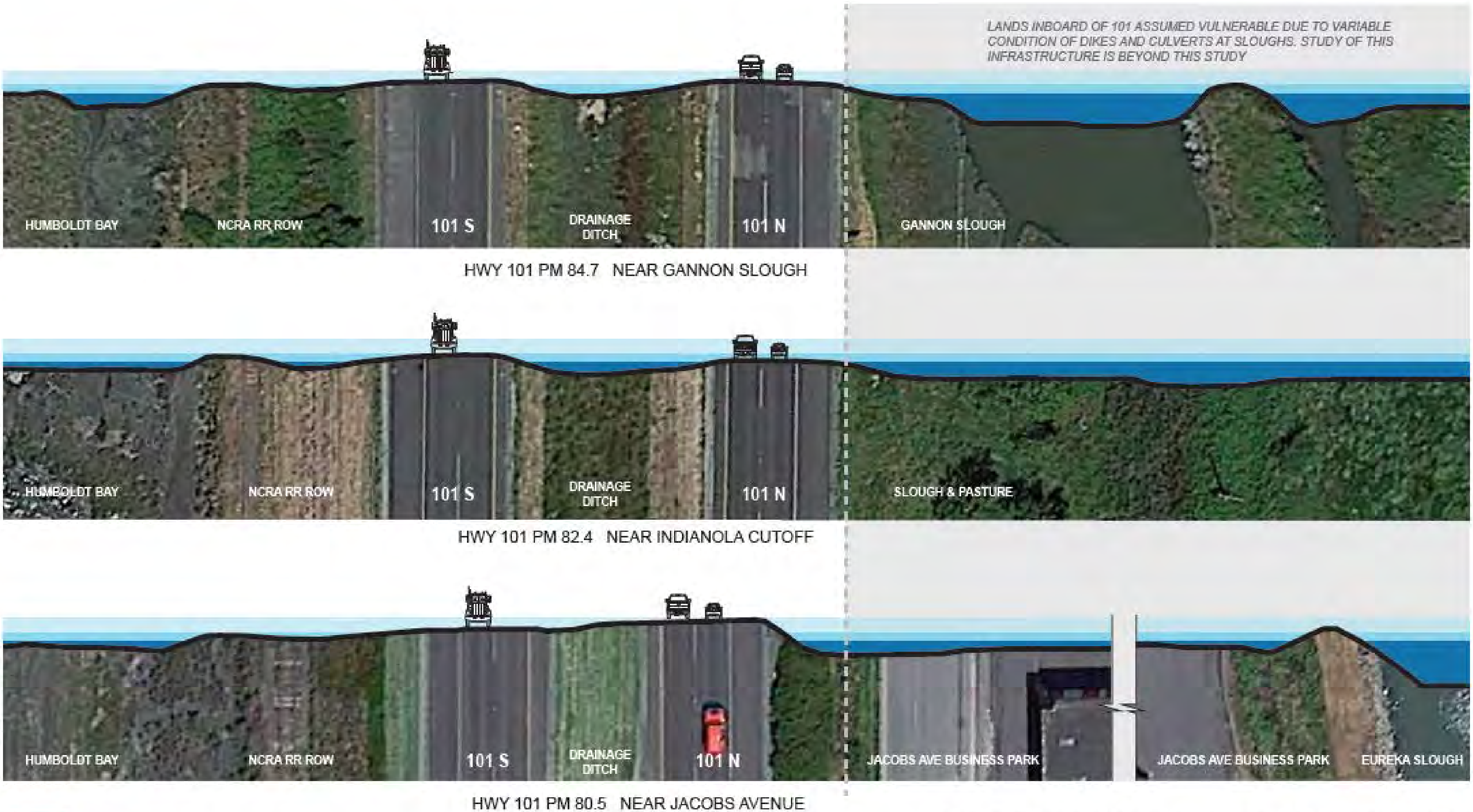
KING TIDES & SEA LEVEL RISE: 2050

PROJECTED WATER SURFACE ELEVATIONS

2050 HIGH: 10.95'

2050 LOW: 9.61'

AVERAGE KING TIDE (CURRENT): 8.78'



KING TIDES & SEA LEVEL RISE: 2100

PROJECTED WATER SURFACE ELEVATIONS

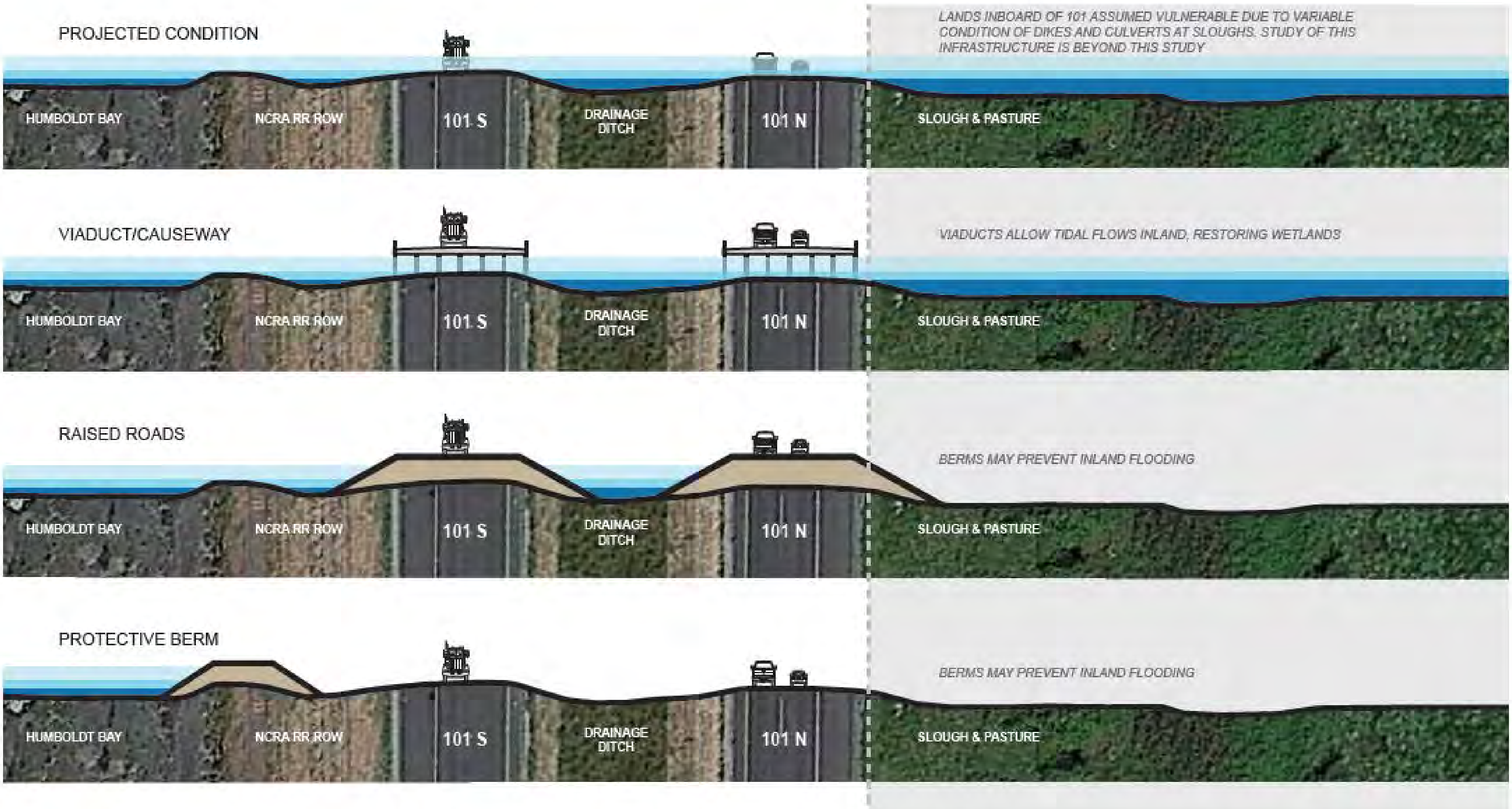
2100 HIGH: 14.61'

2100 LOW: 10.95'

AVERAGE KING TIDE (CURRENT): 8.78'

Attachment D

Projected Water Surface Elevations with Adaptation Options



ADAPTATION STRATEGIES: HUMBOLDT BAY

HWY 101 NEAR PM 82.4

2100 KING TIDE WATER ELEVATIONS

2100 HIGH: 14.81'
2100 LOW: 10.95'
AVERAGE KING TIDE (CURRENT): 8.78'

Attachment E

Adaptation Option Cost Estimates

Humboldt County

HWY 101 Humboldt Bay PM 79.3 to 85.3 - 2050 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Strengthen Existing Berm - Option No. 1				
Demo Existing Railroad	Mi	5.78	$500,000	$2,890,000
Embankement	CY	292,860	$10	$2,928,600
Rip Rap / Geotextile Fabric	SY	47,562	$195	$9,274,590
Reconstruct Railroad	Mi	5.78	$1,000,000	$5,780,000
Seed and mulch	SY	217,995	$0.80	$174,396
Misc driveway /entrance reconstruction work	Ea	6	$17,500	$105,000
Reconstruct bridge at 2 sloughs (combined lengths)	SF	28,000	$33	$924,000
Environmental Mitigation	Ac	94	$400,000	$37,600,000
SUBTOTAL (Non-Percentage Items)				**$59,676,586**
Mobilization	-	10%	$59,676,586	$5,967,659
Clear and Grub	-	10%	$59,676,586	$5,967,659
Erosion Control	-	1%	$59,676,586	$596,766
Maintenance of Traffic	-	5%	$59,676,586	$2,983,829
SUBTOTAL (Percentage Items)				**$15,515,912**
CONSTRUCTION TOTAL				**$75,192,498**
Project Approval & Environmental Documentation	-	8%	$75,192,498	$6,015,400
Plans, Specifications, & Estimates	-	10%	$75,192,498	$7,519,250
Construction Engineering	-	10%	$75,192,498	$7,519,250
PLANNING AND ENGINEERING COSTS				**$21,053,900**
TOTAL ESTIMATED COSTS				**$96,246,398**
Contingency	-	25%		$24,061,599
GRAND TOTAL				**$120,307,997**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$120,310,000**

Humboldt County

HWY 101 Humboldt Bay PM 79.3 to 85.3 - 2050 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Elevate the Road Prism - Option No. 2				
Mill and mix the existing roadway into subgrade	SY	177,160	$5.50	$974,380
Embankment	CY	85,299	$10	$852,990
Class II Aggregate Base (8")	CY	41,324	$40	$1,652,960
Asphalt (Type A) (6")	TN	72,836	$120	$8,740,320
Drainage culverts and swales	LS	1	$1,500,000	$1,500,000
Utility Relocation	LF	17,716	$225	$3,986,100
Reconstruct bridge at 2 sloughs (combined lengths)	SF	28,000	$33	$924,000
Pavement Markings and Signage	LS	17,716	$42	$744,072
Misc driveway /entrance reconstruction work	Ea	15	$25,000	$375,000
Seed and Mulch	SY	248,024	$0.80	$198,419
remove and reconstruct guardrail	LF	10,200	$40.00	$408,000
Environmental Mitigation	Ac	12.2	$400,000.00	$4,880,000
SUBTOTAL (Non-Percentage Items)				**$25,236,241**
Mobilization	-	20%	$25,236,241	$5,047,248
Clear and Grub	-	20%	$25,236,241	$5,047,248
Erosion Control	-	5%	$25,236,241	$1,261,812
Maintenance of Traffic	-	5%	$25,236,241	$1,261,812
SUBTOTAL (Percentage Items)				**$12,618,121**
CONSTRUCTION TOTAL				**$37,854,362**
Project Approval & Environmental Documentation	-	8%	$37,854,362	$3,028,349
Plans, Specifications, & Estimates	-	10%	$37,854,362	$3,785,436
Construction Engineering	-	10%	$37,854,362	$3,785,436
PLANNING AND ENGINEERING COSTS				**$10,599,221**
TOTAL ESTIMATED COSTS				**$48,453,583**
Contingency	-	25%		$12,113,396
GRAND TOTAL				**$60,566,979**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$60,570,000**

Humboldt County

HWY 101 Humboldt Bay PM 79.3 to 85.3 - 2050 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Construct a Causeway - Option No. 3				
Demo and restore existing roadbed	SY	177,160	$4	$620,060
Construct Causeway	SF	1,417,280	$86	$121,886,080
Overlay portion	TN	11,716	$120	$1,405,920
Frontage Roads / On ramps / Driveway Reconstruction	SF	180,000	$33	$5,940,000
Utility relocation and lighting built into above costs			$0	$0
SUBTOTAL (Non-Percentage Items)				$129,852,060
Mobilization	-	0%	$129,852,060	$0
Clear and Grub	-	0%	$129,852,060	$0
Erosion Control	-	0%	$129,852,060	$0
Maintenance of Traffic	-	0%	$129,852,060	$0
SUBTOTAL (Percentage Items)				$0
CONSTRUCTION TOTAL				$129,852,060
Project Approval & Environmental Documentation	-	3%	$129,852,060	$3,895,562
Plans, Specifications, & Estimates	-	2%	$129,852,060	$2,597,041
Construction Engineering	-	2%	$129,852,060	$2,597,041
PLANNING AND ENGINEERING COSTS				$9,089,644
TOTAL ESTIMATED COSTS				$138,941,704
Contingency	-	25%		$34,735,426
GRAND TOTAL				$173,677,130
GRAND TOTAL ROUNDED (to the nearest 10,000)				$173,680,000

Included in Sq. Ft. Cost Above

Humboldt County

HWY 101 Humboldt Bay PM 79.3 to 85.3 - 2050 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Install ITS Infrastructure - Option No. 4				
ITS System	LS	4	$100,000	$400,000
20 -year O&M rounded	LS	1	$680,000	$680,000
TOTAL				**$1,080,000**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$1,080,000**

Increase Maintenance - Option No.5				
20 -year O&M rounded	LS	1	$950,000	$950,000
TOTAL				**$950,000**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$950,000**

Relocate Horizontally - Option No. 6				
Roadway Relocation	Mi	8	$35,000,000	$280,000,000
SUBTOTAL (Non-Percentage Items)				**$280,000,000**
Mobilization	-		$280,000,000	$0
Clear and Grub	-		$280,000,000	$0
Erosion Control	-		$280,000,000	$0
Mitigation	-		$280,000,000	$0
SUBTOTAL (Percentage Items)				**$0**
CONSTRUCTION TOTAL				**$280,000,000**
Project Approval & Environmental Documentation	-		$280,000,000	$0
Plans, Specifications, & Estimates	-		$280,000,000	$0
Construction Engineering	-		$280,000,000	$0
PLANNING AND ENGINEERING COSTS				**$0**
TOTAL ESTIMATED COSTS				**$280,000,000**
Contingency	-	25%		$70,000,000
GRAND TOTAL				**$350,000,000**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$350,000,000**

Included in Per Mile Cost

Included in Per Mile Cost

Humboldt County

HWY 101 Humboldt Bay PM 79.3 to 85.3 - 2100 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Strengthen Existing Berm - Option No. 1				
Demo Existing Railroad	Mi	6.16	$500,000	$3,080,000
Embankement	CY	292,860	$10	$2,928,600
Rip Rap / Geotextile Fabric	SY	47,562	$195	$9,274,590
Reconstruct Railroad	Mi	6.16	$1,000,000	$6,160,000
Seed and mulch	SY	217,995	$0.80	$174,396
Misc driveway /entrance reconstruction work	Ea	6	$17,500	$105,000
Reconstruct bridge at 2 sloughs (combined lengths)	SF	28,000	$33	$924,000
Environmental Mitigation	Ac	94	$400,000	$37,600,000
SUBTOTAL (Non-Percentage Items)				**$60,246,586**
Mobilization	-	10%	$60,246,586	$6,024,659
Clear and Grub	-	10%	$60,246,586	$6,024,659
Erosion Control	-	1%	$60,246,586	$602,466
Maintenance of Traffic	-	5%	$60,246,586	$3,012,329
SUBTOTAL (Percentage Items)				**$15,664,112**
CONSTRUCTION TOTAL				**$75,910,698**
Project Approval & Environmental Documentation	-	8%	$75,910,698	$6,072,856
Plans, Specifications, & Estimates	-	10%	$75,910,698	$7,591,070
Construction Engineering	-	10%	$75,910,698	$7,591,070
PLANNING AND ENGINEERING COSTS				**$21,254,996**
TOTAL ESTIMATED COSTS				**$97,165,694**
Contingency	-	25%		$24,291,423
GRAND TOTAL				**$121,457,117**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$121,460,000**

Humboldt County

HWY 101 Humboldt Bay PM 79.3 to 85.3 - 2100 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Elevate the Road Prism - Option No. 2				
Mill and mix the existing roadway into subgrade	SY	374,190	$5.50	$2,058,045
Embankment	CY	403,377	$10	$4,033,770
Class II Aggregate Base (8")	CY	87,283	$40	$3,491,320
Asphalt (Type A) (6")	TN	129,095	$120	$15,491,400
Drainage culverts and swales	LS	1	$1,500,000	$1,500,000
Utility Relocation	LF	37,419	$225	$8,419,275
Reconstruct bridge at 2 sloughs (combined lengths)	SF	28,000	$33	$924,000
Pavement Markings and Signage	LS	37,419	$42	$1,571,598
Misc driveway /entrance reconstruction work	Ea	15	$25,000	$375,000
Seed and Mulch	SY	526,886	$0.80	$421,509
remove and reconstruct guardrail	LF	10,200	$40.00	$408,000
Environmental Mitigation	Ac	26	$400,000	$10,320,000
SUBTOTAL (Non-Percentage Items)				**$49,013,917**
Mobilization	-	20%	$49,013,917	$9,802,783
Clear and Grub	-	20%	$49,013,917	$9,802,783
Erosion Control	-	5%	$49,013,917	$2,450,696
Maintenance of Traffic	-	5%	$49,013,917	$2,450,696
SUBTOTAL (Percentage Items)				**$24,506,958**
CONSTRUCTION TOTAL				**$73,520,875**
Project Approval & Environmental Documentation	-	8%	$73,520,875	$5,881,670
Plans, Specifications, & Estimates	-	10%	$73,520,875	$7,352,088
Construction Engineering	-	10%	$73,520,875	$7,352,088
PLANNING AND ENGINEERING COSTS				**$20,585,845**
TOTAL ESTIMATED COSTS				**$94,106,720**
Contingency	-	25%		$23,526,680
GRAND TOTAL				**$117,633,400**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$117,630,000**

Humboldt County

HWY 101 Humboldt Bay PM 79.3 to 85.3 - 2100 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Construct a Causeway - Option No. 3				
Demo and restore existing roadbed	SY	3,367,710	$4	$11,786,985
Construct Causeway	SF	2,993,520	$86	$257,442,720
Frontage Roads / On ramps / Driveway Reconstruction	SF	180,000	$33	$5,940,000
Utility relocation and lighting built into above costs			$0	$0
SUBTOTAL (Non-Percentage Items)				$275,169,705
Mobilization	-	0%	$275,169,705	$0
Clear and Grub	-	0%	$275,169,705	$0
Erosion Control	-	0%	$275,169,705	$0
Maintenance of Traffic (Included in Sq. Ft. Cost Above)	-	0%	$275,169,705	$0
SUBTOTAL (Percentage Items)				$0
CONSTRUCTION TOTAL				$275,169,705
Project Approval & Environmental Documentation	-	3%	$275,169,705	$8,255,091
Plans, Specifications, & Estimates	-	2%	$275,169,705	$5,503,394
Construction Engineering	-	2%	$275,169,705	$5,503,394
PLANNING AND ENGINEERING COSTS				$19,261,879
TOTAL ESTIMATED COSTS				$294,431,584
Contingency	-	25%		$73,607,896
GRAND TOTAL				$368,039,480
GRAND TOTAL ROUNDED (to the nearest 10,000)				$368,040,000

Humboldt County

HWY 101 Humboldt Bay PM 79.3 to 85.3 - 2100 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Install ITS Infrastructure - Option No. 4				
ITS System	LS	4	$100,000	$400,000
20 -year O&M rounded	LS	1	$680,000	$680,000
TOTAL				**$1,080,000**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$1,080,000**

Item Description	Units	Quantity	Unit Cost	Total
Increase Maintenance - Option No.5				
20 -year O&M rounded	LS	1	$950,000	$950,000
TOTAL				**$950,000**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$950,000**

Item Description	Units	Quantity	Unit Cost	Total
Relocate Horizontally - Option No. 6				
Roadway Relocation	Mi	8	$35,000,000	$280,000,000
SUBTOTAL (Non-Percentage Items)				**$280,000,000**
Mobilization	-		$280,000,000	$0
Clear and Grub	-		$280,000,000	$0
Erosion Control	-		$280,000,000	$0
Mitigation	-		$280,000,000	$0
Included in Per Mile Cost				
SUBTOTAL (Percentage Items)				**$0**
CONSTRUCTION TOTAL				**$280,000,000**
Planning	-		$280,000,000	$0
Engineering	-		$280,000,000	$0
Construction Management	-		$280,000,000	$0
Permitting	-		$280,000,000	$0
Included in Per Mile Cost				
PLANNING AND ENGINEERING COSTS				**$0**
TOTAL ESTIMATED COSTS				**$280,000,000**
Contingency	-	25%		$70,000,000
GRAND TOTAL				**$350,000,000**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$350,000,000**

Attachment F

Adaptation Option Scoring

Project Location:
HYW 101 Humboldt Bay PM.79.3R and 85.3
2050

No.	Adaptation Option (Select from List)	Enter Description or Comment	Assumed Values: Assumed Design Service Life	Assumed Values: Assumed Total Capital Investment	Assessment Criteria: Total Capital Investment	Assessment Criteria: Annual Average Cost	Assessment Criteria: Usable Life	Assessment Criteria: Level of Performance	Assessment Criteria: Flexibility	Assessment Criteria: Environmental Considerations	Assessment Criteria: Social Considerations	Total Score	Rank
				Weight >>	3.7	11.1	18.5	25.9	7.4	14.8	18.5		
1	Provide protection at existing elevations/locations	*Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height to 1 ft above 2050 water level at a King tide*	100	121,310,000	0: >$100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	2: Potentially	-1: Very little net impact	3: Significant net improvement	189	1
2	Elevate the infrastructure above the impact zone	*Increase the height of the roadway by building up the fill prism 1 ft above 2050 water level at a King tide for 6 miles*	100	60,570,000	1: $10M - $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	1: Unlikely	-2: Some net impact	2: Some net improvement	152	2
3	Elevate the infrastructure above the impact zone	*Construct a causeway, 6 miles, at a height of 5 ft above 2050 water level at a King tide*	100	173,680,000	0: >$100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	0: None	-1: Very little net impact	1: Very little net improvement	137	3
4	Temporarily restrict use of infrastructure	*Install ITS infrastructure to recommend use of alternate route and increase signage and warning information*	20	1,080,000	2: $1M - $10M	1: $50,001-100,000/yr	0: Minimal (or temporary)	1: Decreased	3: Likely (or unnecessary)	-1: Very little net impact	-2: Some net impact	15	6
5	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.*	20	950,000	3: <$1M	2: $10,001-50,000/yr	0: Minimal (or temporary)	1: Decreased	3: Likely (or unnecessary)	-1: Very little net impact	-2: Some net impact	30	5
6	Relocate infrastructure (horizontally)	*Assumed 8 mile re-route to the east of the existing Hwy 101*	100	350,000,000	0: >$100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	0: None	-3: Significant net impact	2: Some net improvement	126	4
7	Abandon Infrastructure	*Not a viable alternative due to need for connectivity*											
8	Enhance drainage to minimize closure time and/or deterioration levels	*Not a viable alternative due to tidal influence*											

Top Scoring Adaptation Options

Rank	Adaptation Option	Project Description	Score
1	Provide protection at existing elevations/locations	Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height	189
2	Elevate the infrastructure above the impact zone	Increase the height of the roadway by building up the fill prism 1 ft above 2050 water level at a King tide for 6 miles	152
3	Elevate the infrastructure above the impact zone	Construct a causeway, 6 miles, at a height of 5 ft above 2050 water level at a King tide	137
4	Relocate infrastructure (horizontally)	Assumed 8 mile re-route to the east of the existing Hwy 101	126
5	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.	30

Project Location:
HYW 101 Humboldt Bay PM.79.3R and 85.3
2100

No.	Adaptation Option (Select from List)	Enter Description or Comment	Assumed Values: Assumed Design Service Life	Assumed Values: Assumed Total Capital Investment	Assessment Criteria: Total Capital Investment	Annual Average Cost	Usable Life	Level of Performance	Flexibility	Environmental Considerations	Social Considerations	Total Score	Rank
				Weight >>	3.7	11.1	18.5	25.9	7.4	14.8	18.5		
1	Provide protection at existing elevations/locations	*Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height to 1 ft above 2100 water level at a King tide*	100	121,460,000	0: > $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	2: Potentially	-1: Very little net impact	3: Significant net improvement	189	1
2	Elevate the infrastructure above the impact zone	*Increase the height of the roadway by building up the fill prism 1 ft above 2100 water level at a King tide for 6 miles*	100	117,630,000	0: > $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	1: Unlikely	-2: Some net impact	2: Some net improvement	148	2
3	Elevate the infrastructure above the impact zone	*Construct a causeway, 6 miles, at a height of 5 ft above 2100 water level at a King tide*	100	368,040,000	0: > $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	0: None	-1: Very little net impact	1: Very little net improvement	137	3
4	Temporarily restrict use of infrastructure	*Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information*	20	1,080,000	2: $1M - $10M	1: $50,001-100,000/yr	0: Minimal (or temporary)	1: Decreased	3: Likely (or unnecessary)	-1: Very little net impact	-2: Some net impact	15	5
5	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.*	20	950,000	3: <$1M	2: $10,001-50,000/yr	0: Minimal (or temporary)	1: Decreased	3: Likely (or unnecessary)	-3: Significant net impact	-2: Some net impact	0	6
6	Relocate infrastructure (horizontally)	*Assumed 8 mile re-route to the east of the existing Hwy 101*	100	350,000,000	0: > $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	0: None	-3: Significant net impact	2: Some net improvement	126	4
7	Abandon Infrastructure	*Not a viable alternative due to need for connectivity*											
8	Enhance drainage to minimize closure time and/or deterioration levels	*Not a viable alternative due to tidal influence*											

Top Scoring Adaptation Options

Rank	Adaptation Option	Project Description	Score
1	Provide protection at existing elevations/locations	Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height	189
2	Elevate the infrastructure above the impact zone	Increase the height of the roadway by building up the fill prism 1 ft above 2100 water level at a King tide for 6 miles	148
3	Elevate the infrastructure above the impact zone	Construct a causeway, 6 miles, at a height of 5 ft above 2100 water level at a King tide	137
4	Relocate infrastructure (horizontally)	Assumed 8 mile re-route to the east of the existing Hwy 101	126
5	Temporarily restrict use of infrastructure	Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information	15

Attachment G

Adaptation Option Summary/Timeline Evaluation

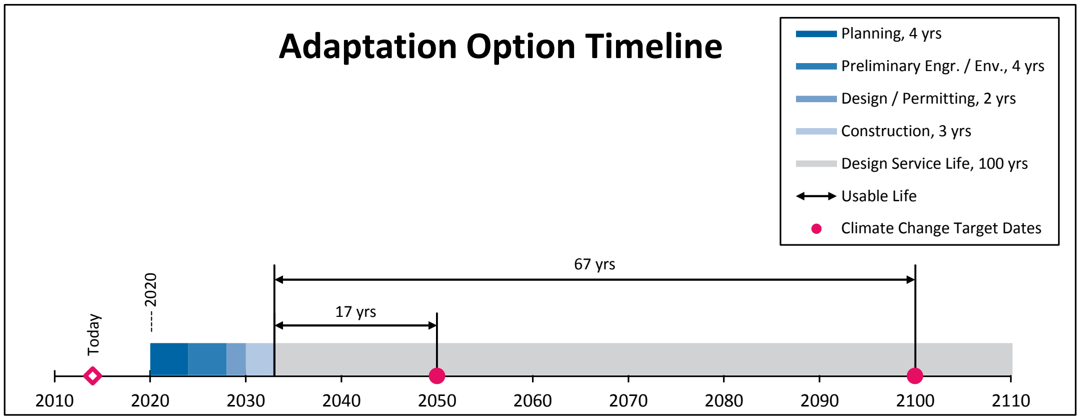
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2050
Adaptation Option	Provide protection at existing elevations/locations
Project Description	**Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height to 1 ft above 2050 water level at a King tide**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

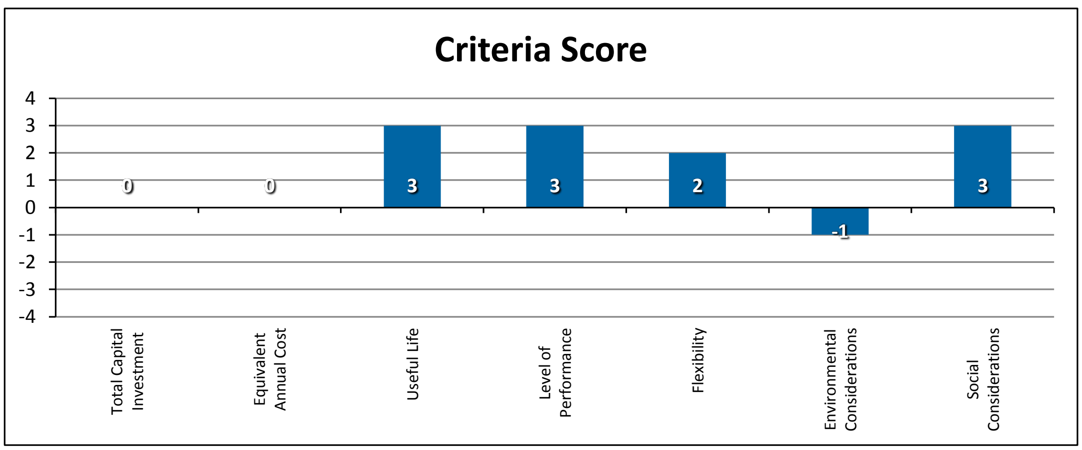
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$121,310,000
Equivalent Annual Cost	$1,213,100
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2050



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

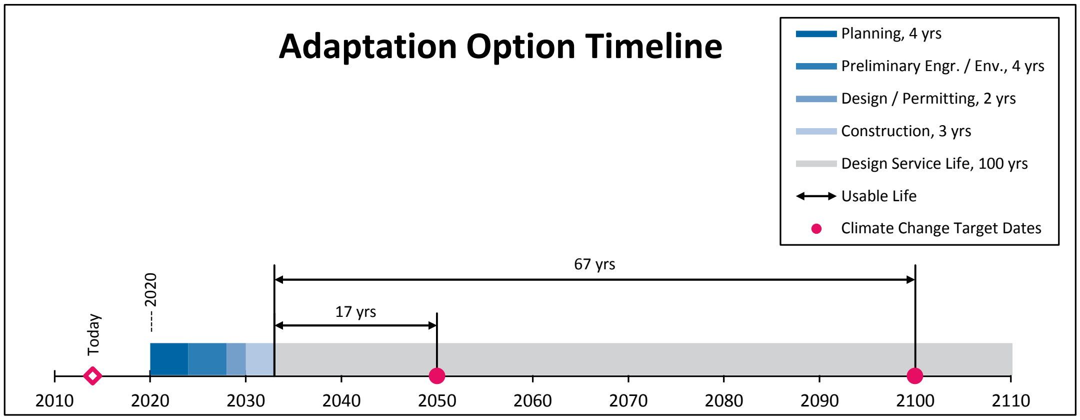
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2050
Adaptation Option	Elevate the infrastructure above the impact zone
Project Description	**Construct a causeway, 6 miles, at a height of 5 ft above 2050 water level at a King tide**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

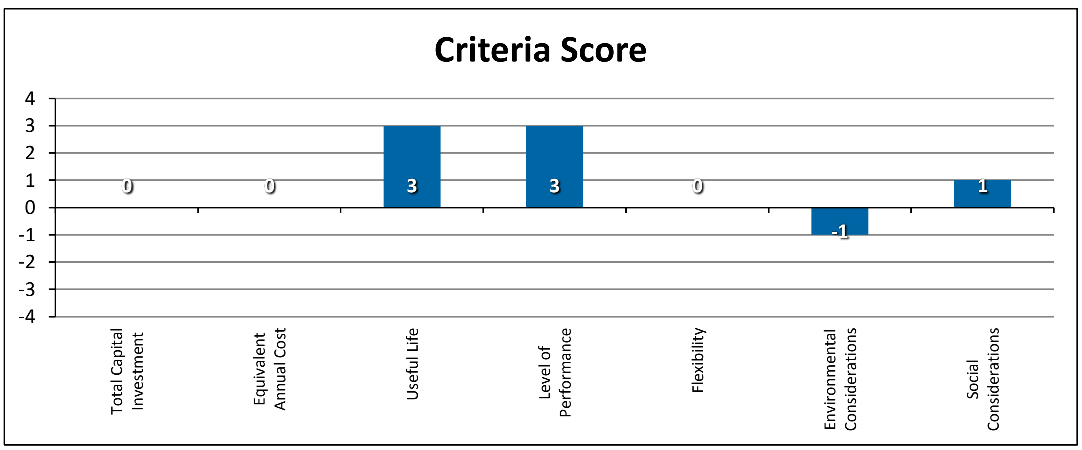
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$173,680,000
Equivalent Annual Cost	$1,736,800
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2050



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

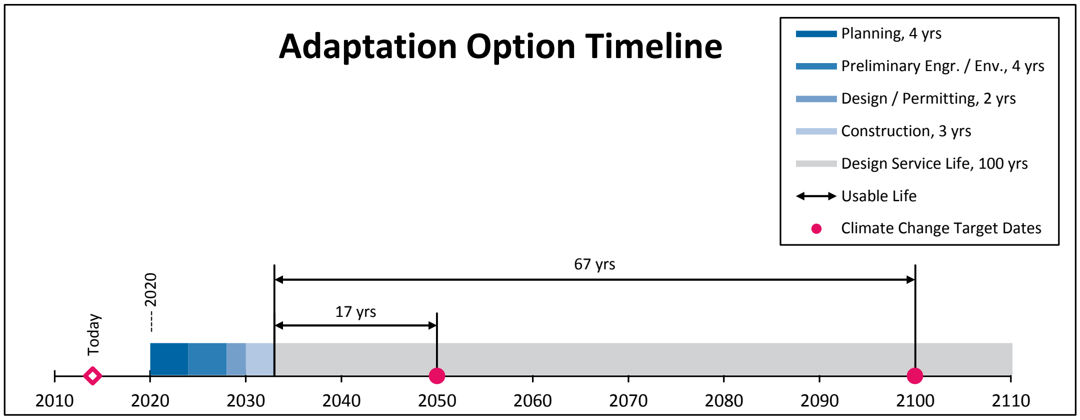
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2050
Adaptation Option	Elevate the infrastructure above the impact zone
Project Description	**Increase the height of the roadway by building up the fill prism 1 ft above 2050 water level at a King tide for 6 miles**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

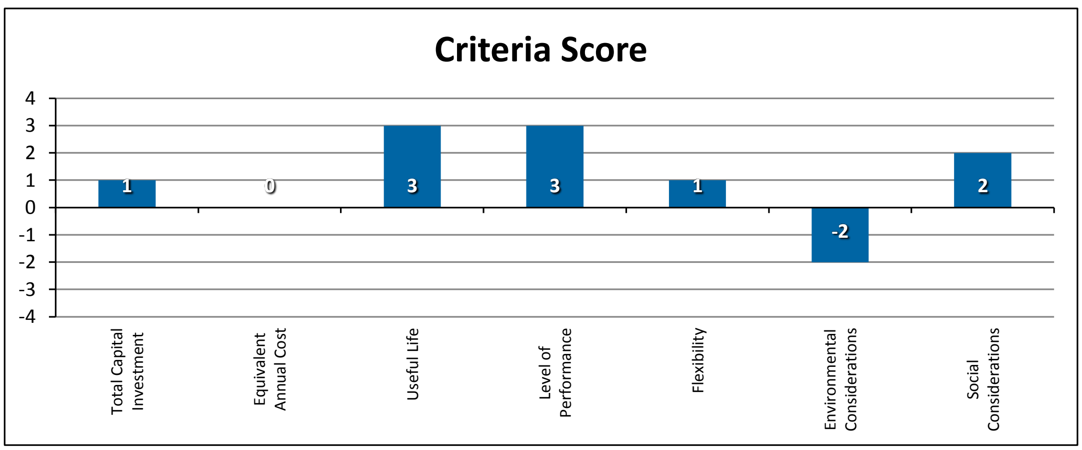
Assumed Values	
Total Capital Investment	$60,570,000
Equivalent Annual Cost	$605,700
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2050

Desired Initiation Date	2020



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

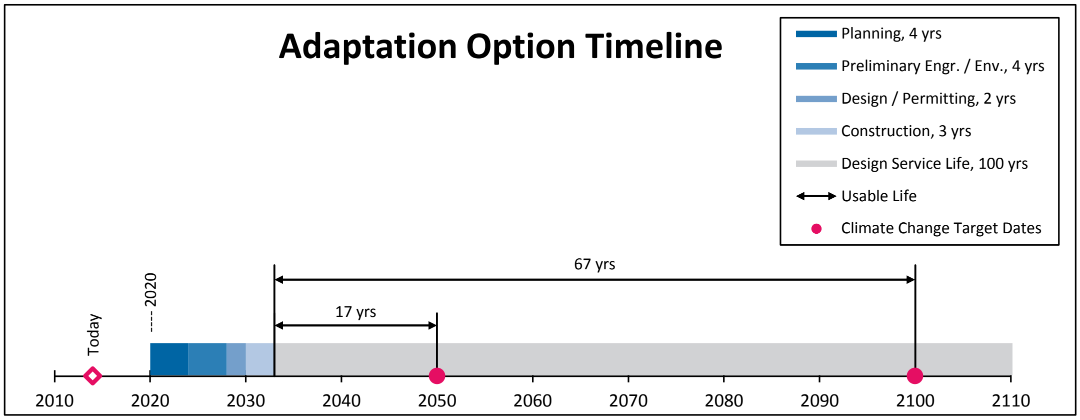
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2100
Adaptation Option	Elevate the infrastructure above the impact zone
Project Description	**Construct a causeway, 6 miles, at a height of 5 ft above 2100 water level at a King tide**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

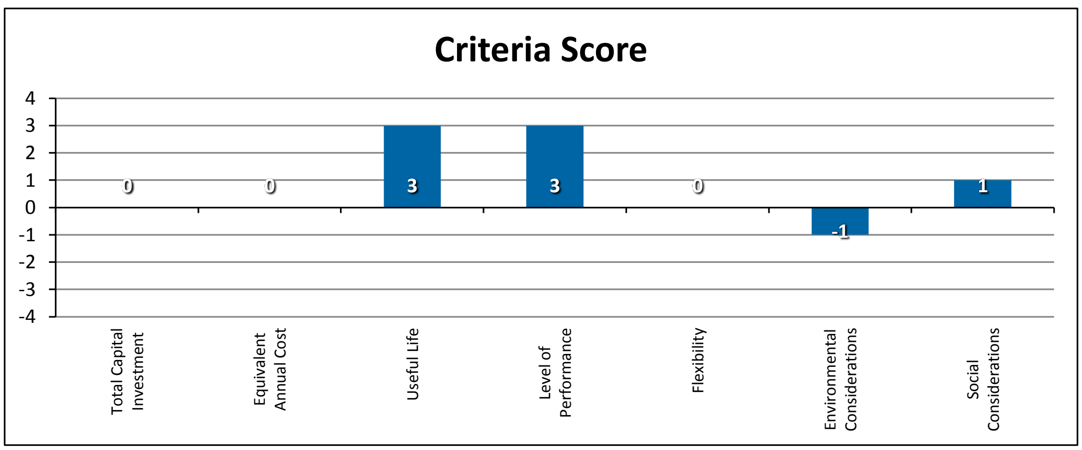
Assumed Values	
Total Capital Investment	$368,040,000
Equivalent Annual Cost	$3,680,400
Design Service Life (yrs)	100

Desired Initiation Date	2020

Key Dates	
Current Year	2014
Climate Change Horizon	2100



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

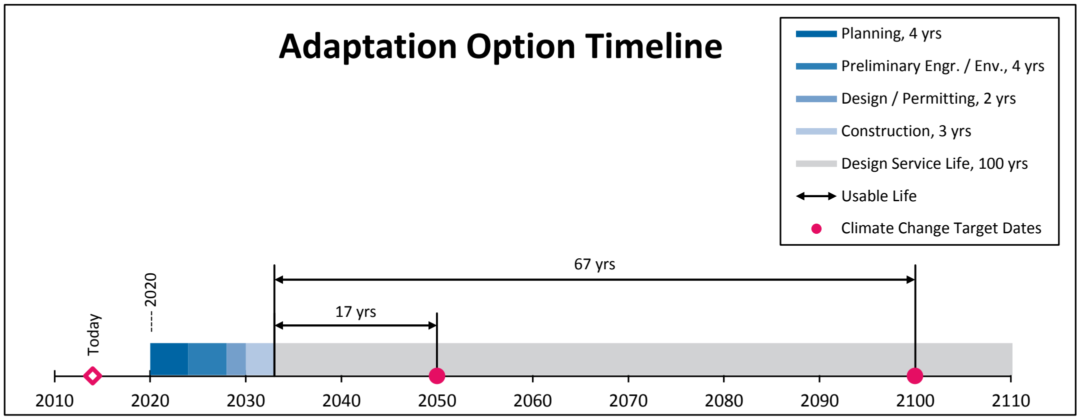
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2100
Adaptation Option	Elevate the infrastructure above the impact zone
Project Description	**Increase the height of the roadway by building up the fill prism 1 ft above 2100 water level at a King tide for 6 miles**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

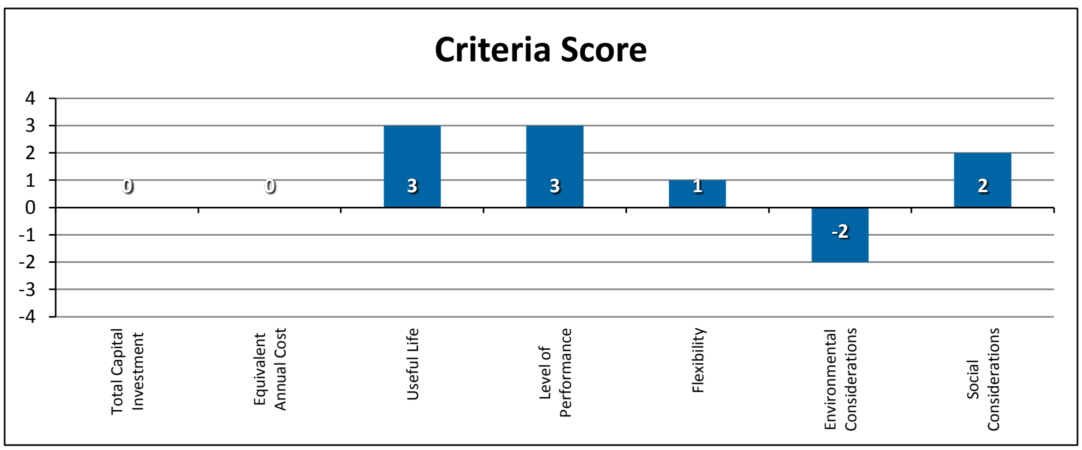
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$117,630,000
Equivalent Annual Cost	$1,176,300
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2100



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

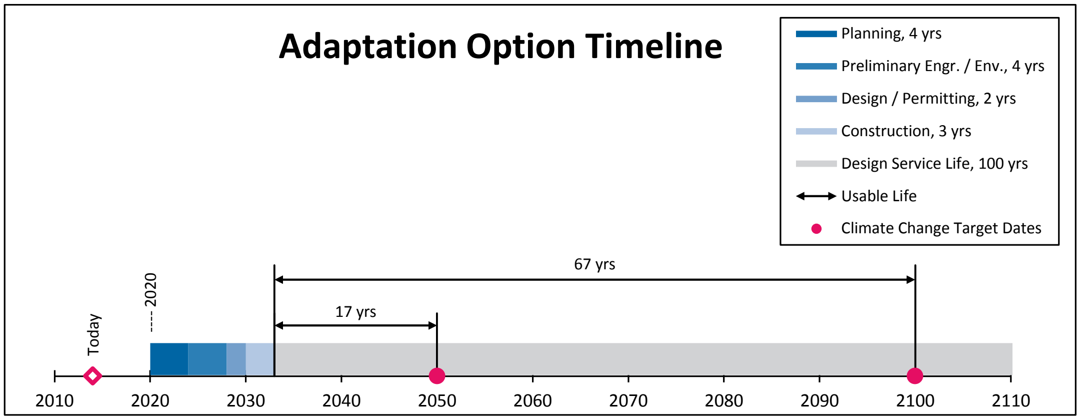
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2100
Adaptation Option	Provide protection at existing elevations/locations
Project Description	**Strengthen/ add protection to existing protective structures (RR berm, dikes, and fill areas) for 10 miles, including increasing height to 1 ft above 2100 water level at a King tide**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

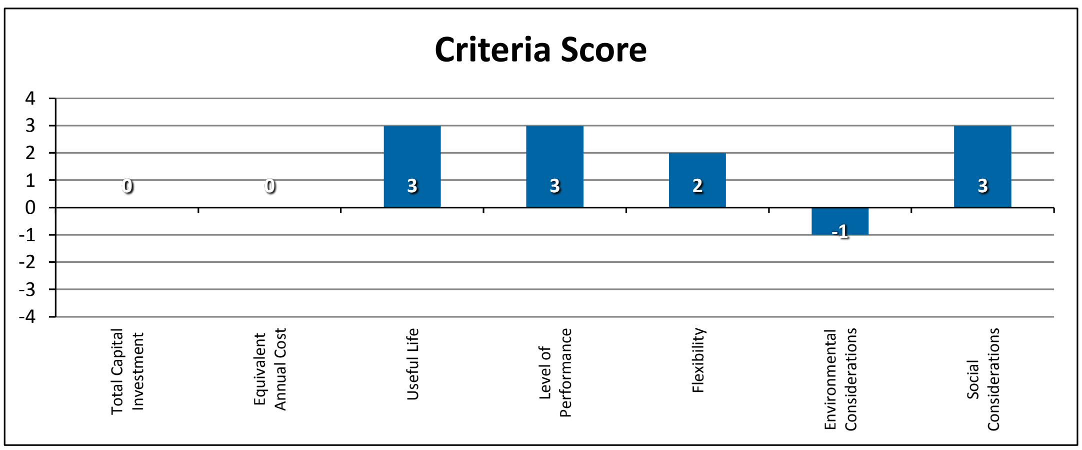
Assumed Values	
Total Capital Investment	$121,460,000
Equivalent Annual Cost	$1,214,600
Design Service Life (yrs)	100

Desired Initiation Date	2020

Key Dates	
Current Year	2014
Climate Change Horizon	2100



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

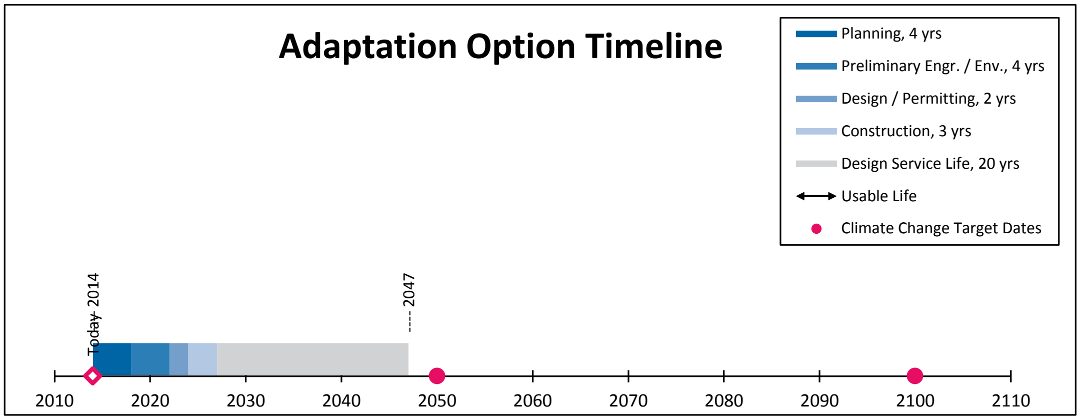
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2050
Adaptation Option	Temporarily restrict use of infrastructure
Project Description	**Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

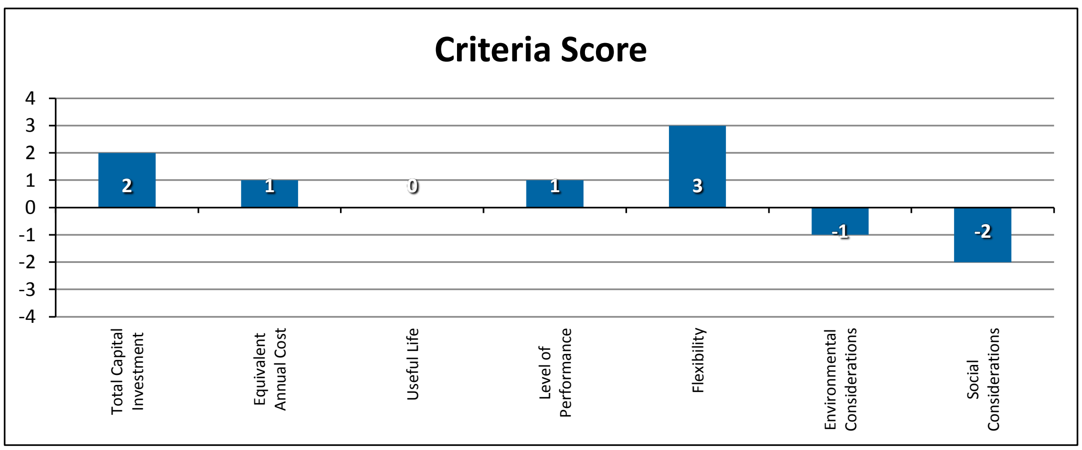
Desired Initiation Date	2014

Assumed Values	
Total Capital Investment	$1,080,000
Equivalent Annual Cost	$54,000
Design Service Life (yrs)	20

Key Dates	
Current Year	2014
Climate Change Horizon	2050



Usable life if designed for	Years
2050 Climate Projection	23
2100 Climate Projection	73



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

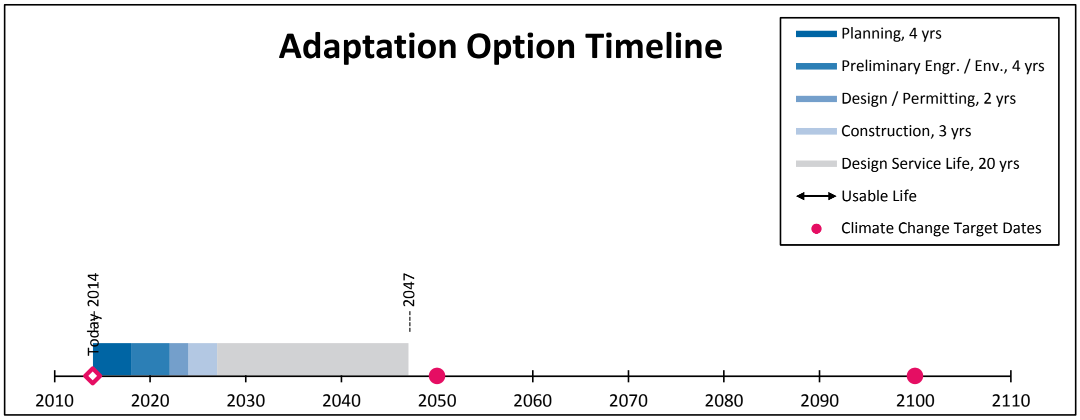
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2050
Adaptation Option	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate
Project Description	**Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

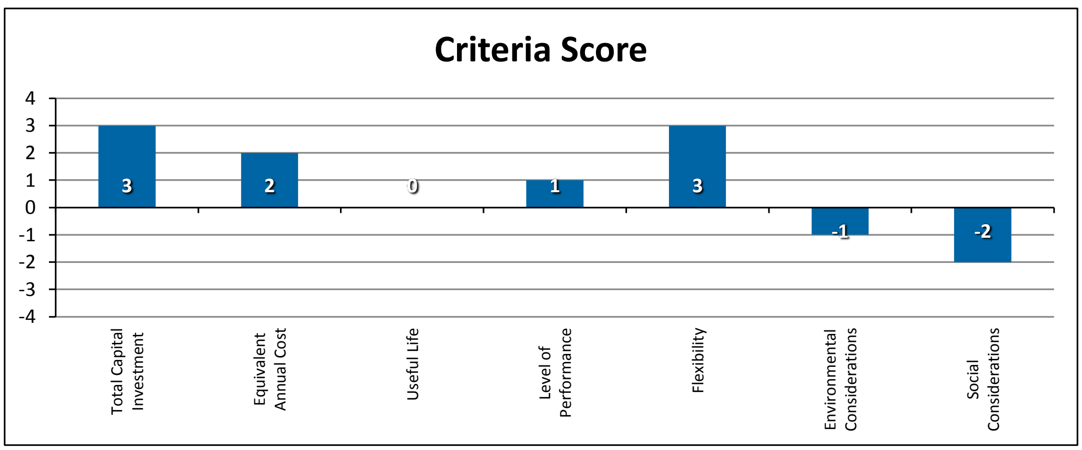
Desired Initiation Date	2014

Assumed Values	
Total Capital Investment	$950,000
Equivalent Annual Cost	$47,500
Design Service Life (yrs)	20

Key Dates	
Current Year	2014
Climate Change Horizon	2050



Usable life if designed for	Years
2050 Climate Projection	23
2100 Climate Projection	73



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

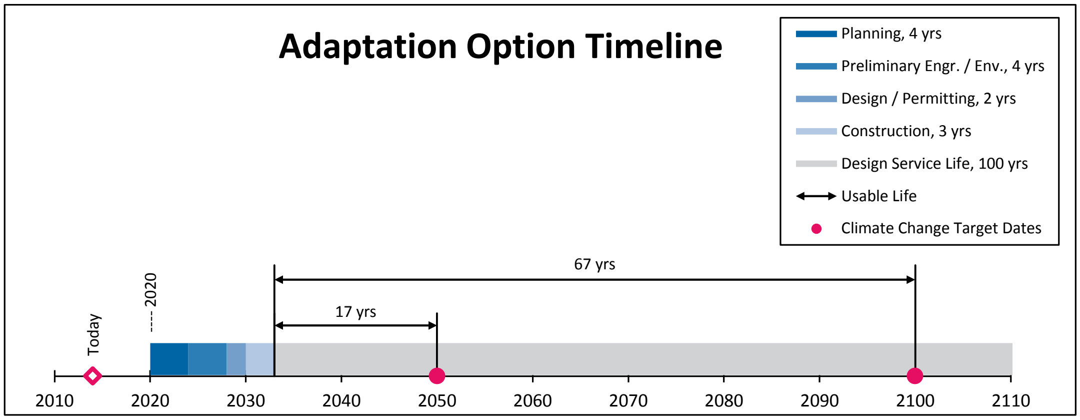
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2050
Adaptation Option	Relocate infrastructure (horizontally)
Project Description	**Assumed 8 mile re-route to the east of the existing Hwy 101 - does not include all of the northern portion as not inundated at 2050 average annual king tide**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

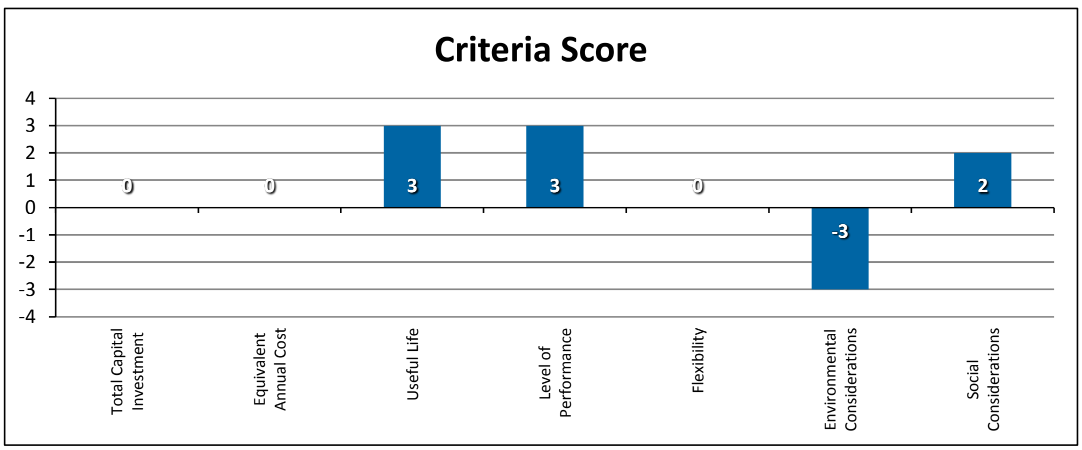
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$350,000,000
Equivalent Annual Cost	$3,500,000
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2050



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

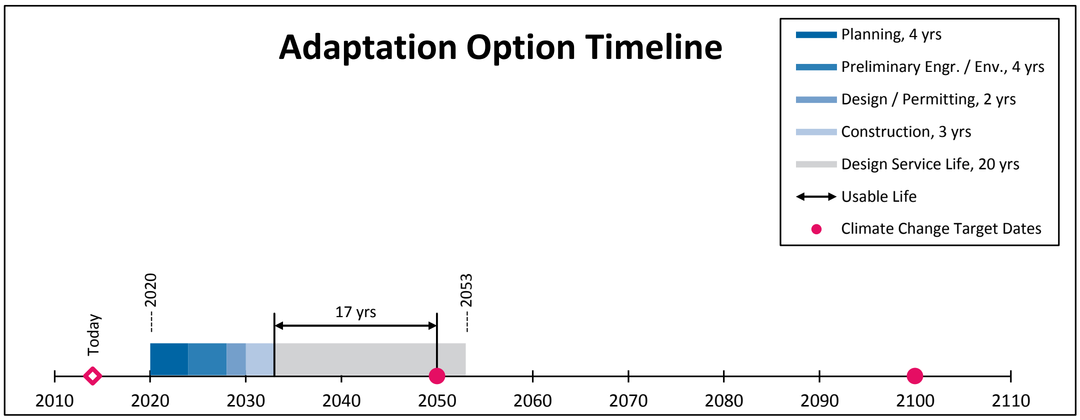
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2100
Adaptation Option	Temporarily restrict use of infrastructure
Project Description	**Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

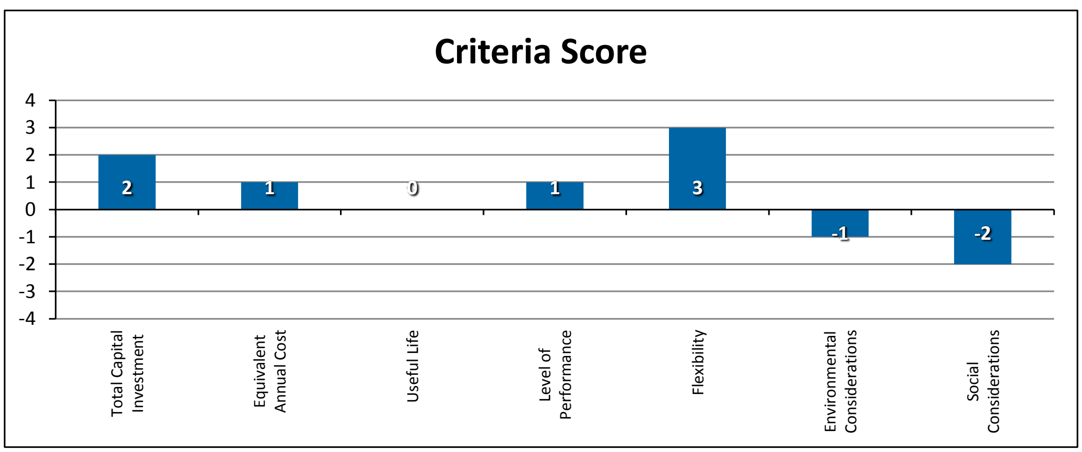
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$1,080,000
Equivalent Annual Cost	$54,000
Design Service Life (yrs)	20

Key Dates	
Current Year	2014
Climate Change Horizon	2100



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

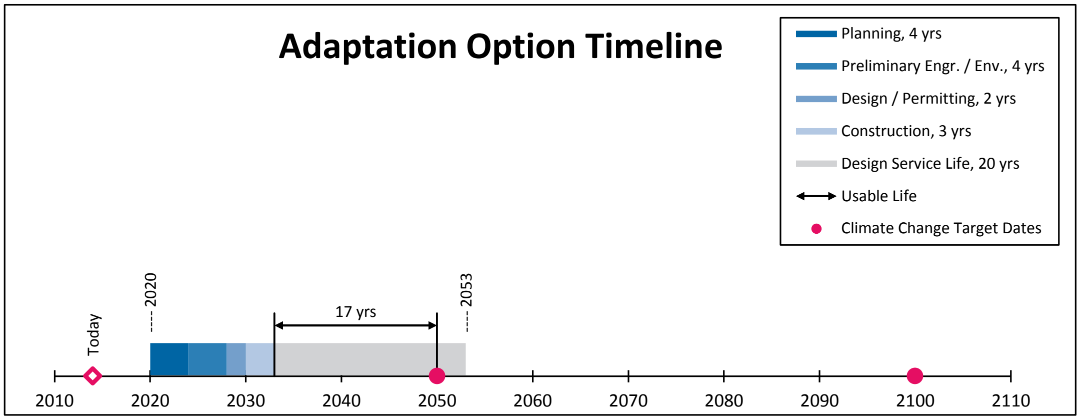
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2100
Adaptation Option	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate
Project Description	**Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

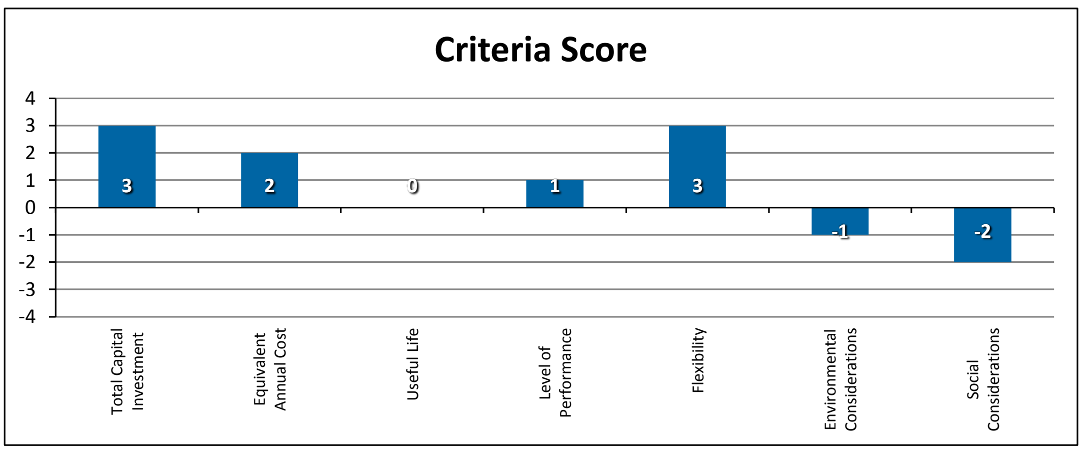
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$950,000
Equivalent Annual Cost	$47,500
Design Service Life (yrs)	20

Key Dates	
Current Year	2014
Climate Change Horizon	2100



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

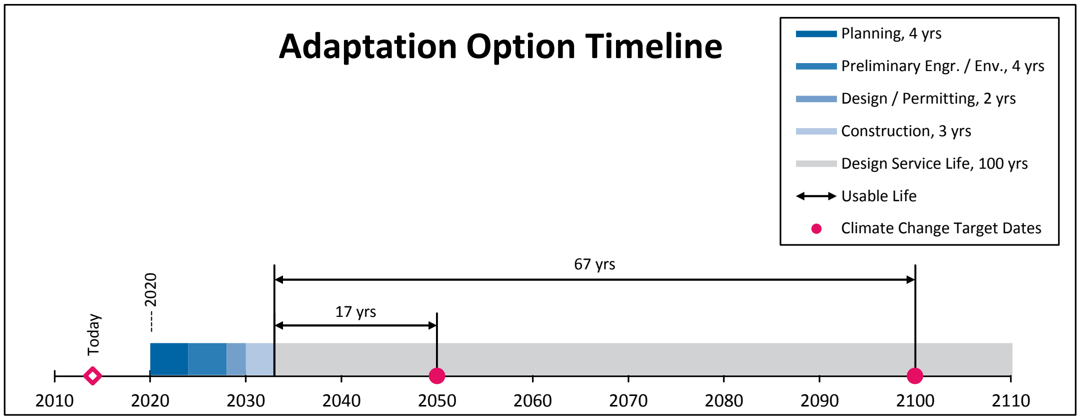
Project Location	HYW 101 Humboldt Bay PM.79.3R and 85.3 2100
Adaptation Option	Relocate infrastructure (horizontally)
Project Description	**Assumed 8 mile re-route to the east of the existing Hwy 101**

Anticipated Process Times	Years
Planning	4
Preliminary Engr. / Env.	4
Design / Permitting	2
Construction	3
Total Process Time[1]	**13**

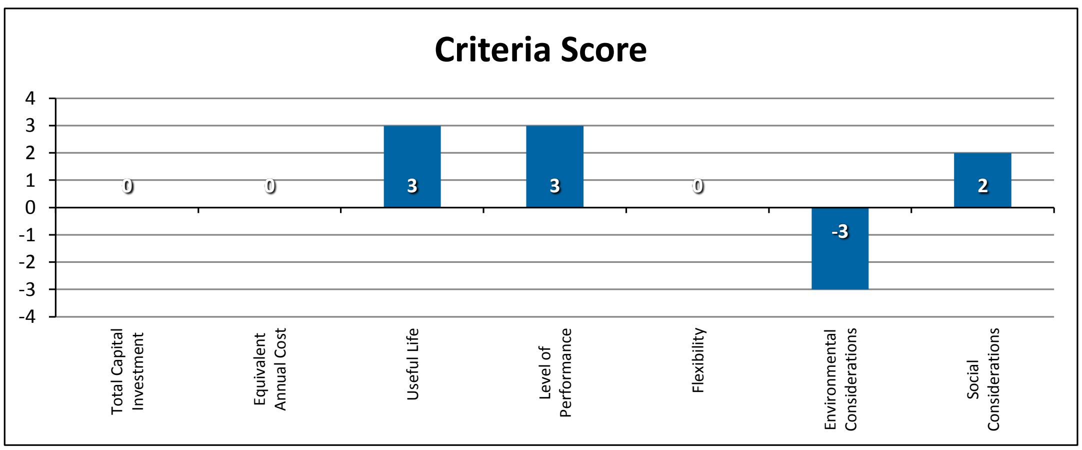
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$350,000,000
Equivalent Annual Cost	$3,500,000
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2100



Usable life if designed for	Years
2050 Climate Projection	17
2100 Climate Projection	67



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

Appendix 8

Caltrans Asset Adaptation Assessment

Lake County Prototype Location

Memorandum

12 November 2014

To	Rex Jackman, Chief, Transportation Planning Caltrans District 1		
Copy to	Brad Mettam (Caltrans), Jamie Hostler (Caltrans), Marcella Clem (HCAOG)		
From	Rebecca Crow, PE, GHD Louis White, PE, ESA	Tel	707 443 8326
Subject	Caltrans Asset Adaptation Assessment Lake County Prototype Location	Job no.	84/10842/30

1 Introduction

This memo presents a summary of the climate data and adaptation analysis and options for the Lake County prototype location. The selected prototype location for Lake County was identified as Highway 20 from PM 8.3 to the southeast of Upper Lake to County Road 407 (Nice-Lucerne Cutoff Road), including CR 407, located at the Northern edge of Clear Lake along the downstream reach of Middle Creek and Rodman Slough, shown in Figure 1 in Attachment A and in Figure 2 below.

The key Caltrans assets at the Lake County prototype location include Highways 29 and 20 near Upper Lake. County Road 407 is a key connection between Highways 29 and 20 and is discussed in this memo. Additional assets operated by, or in the interest of Caltrans, include roadways and embankments, a bridge over Rodman Slough along County Road 407, and water control structures.

1.1 List of Attachments

Attachments provide additional detail and illustrations in addition to the information and analysis provided in the text of this memorandum. The relevant supplemental attachments are as follows:

- Attachment A: Figures
- Attachment B: Overview of Middle Creek Flood Damage Reduction and Ecosystem Restoration Project
- Attachment C: Adaptation Option Cost Estimates
- Attachment D: Adaptation Option Scoring
- Attachment E: Adaptation Option Summary/Timeline Evaluation

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T 1 707 443 8326 F 1 707 444 8330 E eureka@ghd.com W www.ghd.com

1.2 List of Supporting Documentation

This memo builds off work completed previously under separate cover as part of the overall Caltrans District 1 Climate Change Pilot Project. The following memos should be referenced for additional supporting information.

- Caltrans TCR Segment Criticality, GHD October 2014
- Caltrans TCR Segment Potential for Impact, GHD October 2014
- Caltrans TCR Segment Vulnerability, GHD October 2014
- Climate Data Projections for Caltrans District 1 Climate Change Pilot Study, ESA July 2014
- Caltrans Asset Adaptation Assessment Methodology, GHD November 2014

2 Climate Data Summary

This section provides a summary of the climate data used in the analysis. Climate change is a very complex issue and there are many implications for managing infrastructure in the face of climate change. It is important to recognize that there are numerous climate change models and scenarios that have been developed by various entities based on differing assumptions. Various models forecast different ranges of future climate conditions. These future climate conditions influence infrastructure management strategies that may be implemented. No one model is "right" in part because climate is not a steady state phenomenon, but rather a highly dynamic interaction of forces that periodically result in very significant, and often damaging events. It is not possible to precisely forecast when and how severe certain types of episodic events will be and so the results of models should be used to provide general guidance rather than precise predictions.

Also, just like today, there will be future "average" or more typical conditions and periodic more severe conditions. No matter what practical level of climate change one plans for, there will be periodic problematic conditions that will cause inconvenience, damage, or worse. Therefore climate change projections should be considered in the context of adapting to potential changes rather than attempting to completely avoid all negative consequences of climate change.

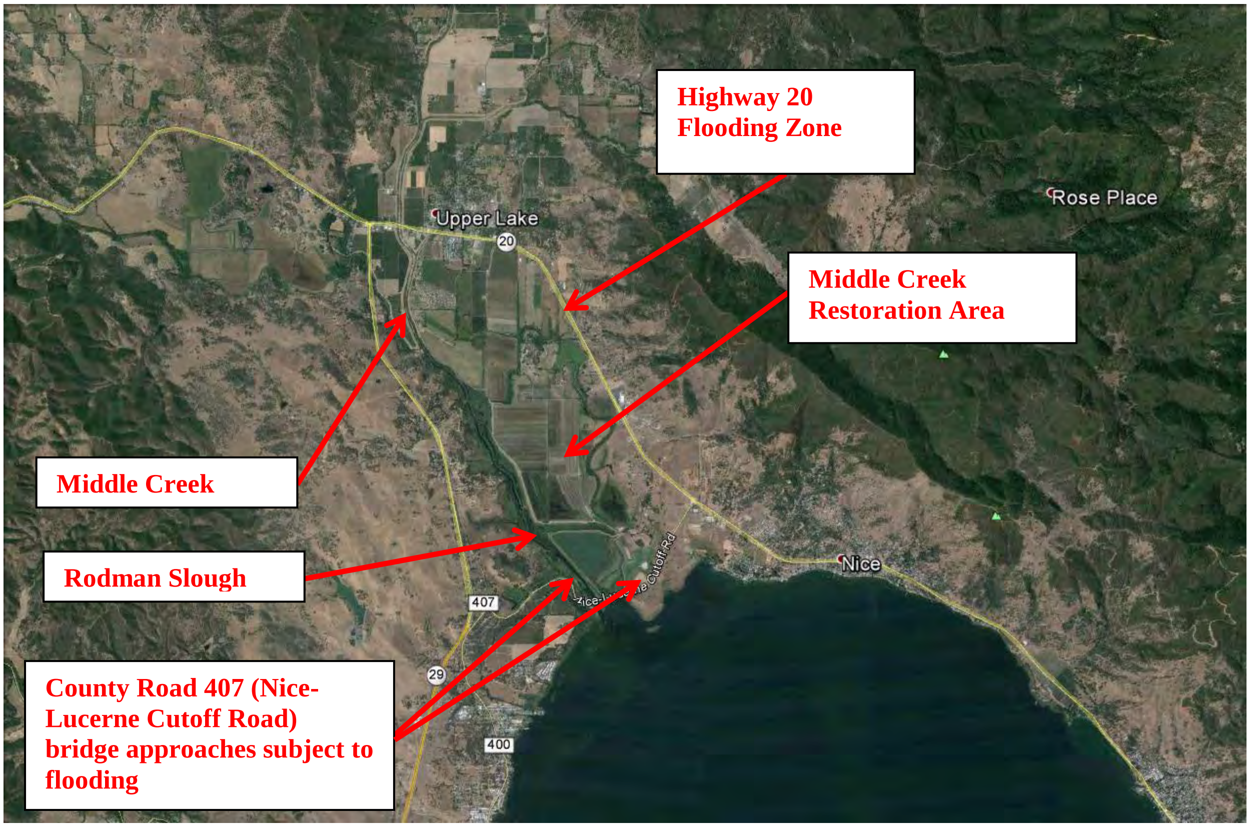

Figure 1. Aerial Image of Northern Edge of Clear Lake Showing Low-lying Agricultural Lands That Were Historically Freshwater Wetlands (Photo from Google Earth).

2.1 Geomorphic Setting

The northern shore of Clear Lake is a low-lying area that was converted from freshwater wetlands to agricultural and residential areas between 1900 and 1940 (Lake County 2012). Levees were constructed to provide protection from elevated waters level in Clear Lake and streamflow routed to Clear Lake through Rodman Slough. These levees have settled up to three feet below design grade in areas and are not constructed to current design standards. The low-lying area is prone to flooding during high lake water levels and periods of runoff resulting from heavy rainfall (Figure 2). The U.S. Army Corps of Engineers determined that the levees currently provide four-year level of protection against flooding. Plans are being developed by the Army Corps of Engineers and Lake County to implement ecological and habitat restoration as well as enhance flood protection to the area. Caltrans comments on the plan to the U.S. Army Corps of Engineers in 2002 indicate that areas of Highway 20 are mapped in the FEMA 100-year flood plain, and may change under the restored project conditions (Caltrans 2002).

2.2 Primary Impacts

The primary impact to Northern Clear Lake is flooding of the roadways due to elevated lake water levels and rainfall runoff that overtops the Middle Creek and Rodman Slough banks (Figure 3). Lake elevation rises with rainfall and can stay high for considerable periods of time. In 1983, the flood waters took 60 days to recede; and 40 days is not uncommon. Clear Lake has a natural outlet at Cashe Creek which control the Lake elevation. There is a dam approximately 5 miles downstream which is managed by the Yolo County Flood Control and Water Conservation District.

Figure 2: Aerial Image of Rodman Slough and Middle Creek During a Flood Event (Source: Thomas Smythe)

Highway 20 and County Road 407 flood due to different reasons: levee overtopping and low road elevation. The levee on Middle Creek protecting Highway 20 is relatively low, due in part to subsidence and currently provides a four-year level of protection. The highway floods when Middle Creek is high and the levee is overtopped. With possible anticipated increases in extreme precipitation and runoff, it is expected that overtopping of the levee will become more frequent.

Middle Creek, together with Scott Creek flow into Rodman Slough. County Road 407 on either side of Rodman Slough bridge is low and high flows in the creeks together with high lake levels causes flooding on the low lying sections. Flooding events results in road closures and rerouting of traffic to Highway 53 and 29. Local traffic then has to use county roads which are narrow, step and generally unsuited to high volumes of traffic.

There are proposals by the County to restore 1600 acres of wetlands along Middle Creek, expanding the area of Clear Lake, re-establishing stream channels and expanding a riparian corridor. This would involve breaching the Middle Creek levee increasing inundation areas along Highway 20 and potentially increasing the extent and frequency of flooding (Figure 3). The proposed restoration could also impact County Road 407. A full description of the restoration project is included in Attachment C.

Figure 3: FEMA 100-year flood plain in the vicinity of the Lake County Pilot Site shows portions of Highway 20 and most of County Road 407 are located within the floodplain. Restoration of the site may cause the limits of the 100-year flooding to change and impact additional area of roads.

In addition to flooding, landslides are common in the area and an ongoing management problem for roads throughout Lake County. Local geology is primarily sandstone and has been described colloquially as “hard mud”. Increased rainfall intensity may exacerbate this existing problem. Even with monitoring, it may be difficult to identify exactly where landslide events would occur.

2.3 Effects of Climate Change

The degree to which climate change will further impact these roads is uncertain. Average total rainfall is projected to decrease however intensity the of precipitation and runoff during individual storms may increase. Table 1 summarizes the projected changes in extreme precipitation and runoff for Northern Clear Lake (ESA 2014). The increased precipitation and runoff amounts will likely increase in frequency and magnitude resulting in flooding-related impacts on Highway 20 and County Road 407.

Table 1. Projected Changes in Extreme Precipitation and Runoff at 2050 and 2100 for the Lake County Pilot Site: Highway 20 and County Road 407 at Northern Clear Lake.

Climate Factor	Change at 2050	Change at 2100
Extreme Precipitation[1,3]	**4 to 10%**	**6 to 12%**
Extreme Runoff[2,3]	**6 to 51%**	**6 to 69%**

1 Projected change in extreme precipitation (98th percentile) calculated using the PCM (wet) model.

2 Projected change in extreme runoff (98th percentile) calculated using average of all model runs.

3 Percent change is presented for 2050 and 2100 relative to a historic period from 1970 to 2000.

The range in projections that is shown in Table 1 represents uncertainty associated with the global emissions of greenhouse gases (GHG). Specifically, the percent change in extreme precipitation and extreme runoff increases from the A2 to the B1 emissions scenario. As discussed in greater detail in the accompanying memorandum “Climate Data Projections for Caltrans District 1 Climate Change Pilot Study,” the A2 and B1 emissions scenarios were selected to represent medium-high and relatively low (or “best-case”) emissions projections, respectively (ESA 2014). These emissions scenarios were originally developed and described by the IPCC (IPCC 2000; Cayan et al. 2012). The A2 and B1 emissions scenarios are defined as follows:

- **A2.** Medium-high emissions resulting from continuous population growth coupled with internationally uneven economic and technological growth. Under this scenario, emissions increase through the 21^{st} century and by 2100 atmospheric carbon dioxide (CO2) levels are approximately three-times greater than pre-industrial levels.
- **B1.** Lower emissions than A2, resulting from a population that peaks mid-century and declines thereafter, with improving economic conditions and technological advancements leading to more efficient utilization of resources. Under this scenario, emissions peak mid-century and then decline, leading to a net atmospheric CO2 concentration approximately double that of pre-industrial levels. This scenario is often referred to as a “best-case” scenario.

The effects of the respective scenario on the percent change in projected extreme precipitation and runoff for years 2050 and 2100 is due to a combination of increased temperatures and changes to the hydrologic cycle. The A2 scenario results in a more rapid increase in average temperatures, which increases evaporation and causes soil moisture to decrease, and in turn reduces the volume of runoff during precipitation events. Less rainfall is projected for the A2 scenario overall. Likewise, reduction of GHG emissions under the B1 scenario results in a rise in average temperature that occurs less rapidly which would tend to have a less significant effect on evaporation and soil moisture as compared to the A2 scenario. The annual precipitation is projected to increase for the B1 scenario and the magnitude of extreme events will likely increase as well. These differences in climate for the A2 and B1 scenarios can likely explain why the runoff is much higher for the B1 scenario as compared to the A2 scenario. Results of projected climate change factors at 2050 and 2100 for the A2 and B1 emissions scenarios for District 1 and its four counties are summarized more completely in ESA (2014).

Mitigation of the anticipated flood conditions in the future may be resolved by elevating the roadway or improving the amount of structural protection, such as increasing the levee heights, which surround the highway infrastructure.

3 Adaptation Evaluation

The information presented above was used in combination with information developed by Lake County and the Army Corps of Engineers (County of Lake, 2012) in Attachment B to this memo to develop adaptation options for the Lake County prototype location. Seven adaptation options were initially identified which encompassed the 4 primary types of adaptation (defend, accommodate, retreat, and changes in policies or practices). Table 2 below shows the seven adaptation options considered.

Table 2: Seven Adaptation Options Considered for Lake County in 2050/2100

Project Location: Middle Creek/ Rodman Slough, Highway 20 (PM to 8.3 to 12.1/ County Road 407 Lake County 2050/2100		
No.	**Adaptation Option**	**Description**
1	Elevate the infrastructure above the impact zone	*Increase height of roadway 2 ft above 100 yr flood hazard zone elevation. Project would incorporate new culverts and drainage features*
2	Relocate infrastructure (horizontally)	*Assumed 4 mile re-route to the east of the existing Hwy 20 -Does not address CR 407*
3	Temporarily restrict use of infrastructure	*Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information*
4	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.*
5	Modify land use and development policies to account for future impacts	*Coordinate with Yolo County to alter natural lake outlet to improve drainage and prevent flooding at the north end of the Lake*
6	Abandon Infrastructure	*Not Considered feasible without re-route*
7	Provide major structural protection	*Install flood protection berms along roadway above 100 flood hazard elevation. Project would incorporate new culverts and pump stations*

Three of the adaptation options were considered not viable or not considered in this analysis as described below:

- Option 5: The adaptation of coordinating with Yolo County to modify the natural outlet of Clear Lake was considered beyond the scope of this study. The potential feasibility of this alternative is unknown and neither are the costs. This option represents a large policy issue that would involve multiple stakeholders from several counties, state and deferral agencies, and the public.
- Option 6: The adaptation of abandoning the infrastructure was considered not viable. The segment of Highway 20 that is subject to flooding could not be abandoned without some type or re-route, as this is a vital corridor and the local roads cannot handle the traffic.
- Option 7: The adaptation of protecting the roadway with berms was also considered not viable. Flooding in this area comes from both runoff as well as backwatering from Clear Lake. A berm project would result in isolating the roadway from rising water, however it would interrupt the hydrology of the system creating the need for extensive drainage improvements and possible pump stations.

Each of the potentially viable adaptation options, 1 through 4, is discussed in the following sections.

3.1 Adaption Option 1

Elevate the infrastructure above the impact zone	*Increase height of roadway 2 ft above 100 yr flood hazard zone elevation. Project would incorporate new culverts and drainage features*

Adaptation Option 1 focuses on elevating the existing roadway in its present location. The roadway would be raised to 2 feet above either the 100 year flood hazard zone elevation. Table 3 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix D.

Table 3: Lake County Adaptation Option 1 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	100 years	High end of the design life of an earthen structure. Assumed structure is properly maintained to protect integrity, and regular roadway overlays are implemented.
Assumed Total Capital Investment	$ 49,810,000	Assumed road is raised to above flood hazard elevation. Due to limited data on coastal flooding elevations, one cost was developed for 2050 and 2100
Usable Life	3: Surpasses	The usable life is beyond the 2100 scenario, thus, the option surpasses the climate horizon in its useful life
Level of Performance	3: Enhanced	This option provides enhanced performance relative to the existing condition.
Flexibility	1: Unlikely	With the costs and effort involved in constructing the new roadway on the raised fill prism, it would be difficult to add additional height in the future.
Environmental Considerations	-2: Some net impact	It is assumed that some wetlands would be impacted with a bigger fill footprint needed for an elevated road, and it would be more that raising the height of protective structures.
Social Considerations	3: Some net improvement	The use of the highway would be maintained, which provides a social benefit, however this option does not necessarily protect other social assets, such as telephone, gas, and water lines.

3.2 Adaption Option 2

Relocate infrastructure (horizontally)	*Assumed 4 mile re-route to the east of the existing Hwy 20 - Does not address CR 407*

Adaptation Option 2 focuses on relocating the roadway out of the inundation/ flooding area. This option may not be viable due to limited areas for road relocation, however it was included here for comparison purposes. Table 4 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix D.

Table 4: Lake County Adaptation Option 2 Summary

Assessment Criteria	**Value**	**Comments**
Assumed Design Service Life	100 years	High end of the design life of an earthen structure. Assumed structure is properly maintained to protect integrity, and regular roadway overlays are implemented.
Assumed Total Capital Investment	$ 140,000,000	Relocation costs based on Willits bypass project including mitigation
Usable Life	3: Surpasses	The usable life is beyond the 2100 scenario, thus, the option surpasses the climate horizon in its useful life
Level of Performance	3: Enhanced	This option provides enhanced performance relative to the existing condition
Flexibility	0: None	Once a new roadway is built, it cannot be moved. Also if it were to be subject to climate change impacts in the future, it would be difficult to increase the roadway elevation
Environmental Considerations	-2: Some net impact	Difficult to determine environmental impacts without a specific alignment. For this study, a new road outside existing right of way is assumed to have impacts to wetlands and other sensitive habitats
Social Considerations	2: Some net improvement	A new highway will maintain connectivity between, however this option does not necessarily protect other sections of Highway 20

3.3 Adaption Option 3

Temporarily restrict use of infrastructure	*Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information*

Adaptation Option 4 focuses on increasing notifications and directing vehicles to use alternate routes. Table 5 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix D.

Table 5: Lake County Adaptation Option 3 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	20 years	Typical useful life of ITS infrastructure is 20 years.
Assumed Total Capital Investment	$ 1,080,000	The capital investment includes the ITS infrastructure. Also added to this option is the estimated annual cost of added maintenance and staff time for assisting with alternate routes ($50,000/ year for 20 years).
Usable Life	0: Minimal or temporary	The usable life is less than the 2050 or 2100 time frames
Level of Performance	1: Decreased	This option provides reduced performance relative to the existing condition.
Flexibility	3: Likely	This option allows flexibility to further evaluate climate impacts and allows for any option to be implemented in the future.
Environmental Considerations	-1: Very little net impact	Some flooding would occur under both the 2050 and 2100 scenarios
Social Considerations	-2: Some net impact	Alternate routes would be needed, creating delays for the traveling public. Delays would increase as time goes on.

3.4 Adaption Option 4

Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.*

Adaptation Option 4 presents a wait-and-see approach, with no new infrastructure constructed and only management changes implemented. Table 6 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix F.

Table 6: Lake County Adaptation Option 4 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	20 years	This alternative is assumed to last until 2050, at which time, the roadway will be inundated too often to allow use of an alternate route on a temporary basis. A design life of 20 years was used for comparison with Option 4.
Assumed Total Capital Investment	$ 950,000	There is not capital investment for this option. Costs for this option include the estimated annual cost of added maintenance and staff time for assisting with alternate routes without ITS (estimated at $70,000/year)
Usable Life	0: Minimal or temporary	The usable life is less than the 2050 or 2100 time frames
Level of Performance	1: Decreased	This option provides reduced performance relative to the existing condition
Flexibility	3: Likely	This option allows flexibility to further evaluate climate impacts and allows for any option to be implemented in the future.
Environmental Considerations	-1: Very little net impact	Some flooding would occur under both the 2050 and 2100 scenarios
Social Considerations	-2: Some net impact	Alternate routes would be needed, creating delays for the traveling public. Delays would increase as time goes on

3.5 Overall Cost Assumptions Applicable to All Options

Attachment C includes planning level cost estimates for many of the proposed adaptation options, including costs for Project Approval & Environmental Document (PA&ED), Plans, Specifications and Estimates (PS&E), right-of-way, Mitigation, and Construction Engineering. The purpose of the cost estimates is gauging the relative magnitude of cost between options, rather than to provide costs for budgeting purposes. Future work should include more detailed cost analysis of preferred options to allow for the further analysis of feasibility of appropriate adaptation strategies.

The cost estimates are based on many assumptions, including; the anticipated means and methods of construction, assumed soil conditions, limited topographic survey, opinion of manufacturers, suppliers, contractors, bid results from recently bid projects, Caltrans average unit cost estimating database, and other estimating guides. These assumptions reflect the experience of GHD working on similar types of projects.

Cost estimates for developed for specific options can be found in Attachment C and include anticipated construction item quantities, unit prices, and the extended total. There is a subtotal with the sum of all of the anticipated construction items followed by other implementation costs calculated as a percentage of the anticipated construction cost. An estimating contingency of 25% was added to each estimate to provide an allowance for some amount of uncertainty in the market and for unforeseen costs which may be required to construct the project.

The Mitigation portion of the estimate accounts for potential land acquisition, design and construction costs to create wetlands, and to offset impacts to existing wetlands and Environmentally Sensitive Habitat Areas (ESHA). Unit costs per acre for pre-construction and construction of estuarine wetland, palustrine wetland and ESHA were based on similar previous types of project estimates.

3.6 Top Scoring Adaptation Options and Implementation Timeline

The adaptation planning tool summarizes the top viable adaptation options. There were a total of four adaptation options scored. Table 7 presents the final scores for the adaptation options. These options are then carried over into the timeline analysis portion of the adaptation planning tool. The adaptation tool timeline summary page for each of the six adaptation options is included in Attachment E. Due to the limited data on flood elevations and lack of modelling to determine increases in flood elevations due to changes in precipitation and run off only one set of options was evaluated for 2050 and 2100.

Table 7: Summary of Humboldt County Prototype Location Adaptation Scoring for 2050 Planning Horizon

Top Scoring Adaptation Options			
Rank	**Adaptation Option**	**Project Description**	**Score**
1	Elevate the infrastructure above the impact zone	Increase height of roadway 2 ft above 100 yr flood hazard zone elevation. Project would incorporate new culverts and drainage features	163
2	Relocate infrastructure (horizontally)	Assumed 4 mile re-route to the east of the existing Hwy 20 -Does not address CR 407	141
3	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.	30
4	Temporarily restrict use of infrastructure	Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information	15

4 Next Steps

The analysis conducted for this prototype location considered ranges for precipitation and runoff changes. This informs planners as to possible impacts from climate change, however, additional analysis is necessary for selecting a preferred approach. It is recommended that a site specific hydrologic/ hydraulic model be developed to further understand the flooding at this location and changes in flooding from climate impacts. Similar work was done for the Humboldt prototype location. This would provide planners more accurate information on the water surface elevations that need to be planned for at the site. Adaptations should also be coordinated with the Middle Creek Restoration Project, which if implemented will change the flood patters and elevations in the area.

5 References

- Caltrans, 2002, Middle Creek Ecosystem Restoration, Letter to Mr. Jerry Fuentes, USACE, from Rex Jackman, Caltrans District 1, May 29, 2002.
- County of Lake, 2012, Overview: Middle Creek Flood Damage Reduction and Ecosystem Restoration Project, October 3, 2012, Accessed Online [November 6, 2014]: http://www.co.lake.ca.us/Assets/WaterResources/docs/Middle+Creek+Restoration+Project.pdf.
- Environmental Science Associates (ESA), 2014, Climate Data Projections for Caltrans District 1 Climate Change Pilot Study, Memorandum Prepared by Louis White, PE (ESA) for Rob Holmlund (GHD), July 21, 2014.

Attachment A

Figures

100-year Effective FEMA Floodplain(s) | Prototype Limits | Roadways
Prototype Location | Streams

Paper Size 8.5" x 11" (ANSI A)
0 1,000 2,000 3,000 4,000
Feet
Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

N

Caltrans District 1 and HCAOG
District 1 Climate Change Pilot Study

Job Number 8410842.30
Revision A
Date 11 Nov 2014

Lake County
Prototype Location

Figure 1

718 Third Street Eureka CA 95501 USA T 707 443 8326 F 707 444 8330 E eureka@ghd.com W www.ghd.com

G:\11905 HumCoAssocGovernments\8410842 HCAOG_CCVA_District 1\08-GIS\Maps\Figures\Report_8410842_30\8410842-30_Lake.mxd

Attachment B

Overview of Middle Creek Flood Damage Reduction and Ecosystem Restoration Project

OVERVIEW
MIDDLE CREEK FLOOD DAMAGE REDUCTION AND ECOSYSTEM RESTORATION PROJECT
October 3, 2012

INTRODUCTION

The Middle Creek Flood Damage Reduction and Ecosystem Restoration Project (Project) will eliminate flood risk to 18 residential structures, numerous outbuildings and approximately 1,650 acres of agricultural land and will restore damaged habitat and the water quality of the Clear Lake watershed. Reconnection of this large, previously reclaimed area, as a functional wetland is anticipated to have a significant affect on the watershed health and the water quality of Clear Lake.

The Project is located at the north end of Clear Lake in the area bounded by State Highway 20 and Rodman Slough, see Figure 1. Clear Lake is a large, natural, shallow, eutrophic lake. It is the headwaters of Cache Creek, a tributary of the Bay-Delta. The Scotts Creek and Middle Creek watersheds, which comprise approximately one half of the Clear Lake watershed, drain through Rodman Slough adjacent to the Project area. These two watersheds provide 57 percent of the inflow and 71 percent of the phosphorus loading to Clear Lake. Fourteen hundred acres of "reclaimed" wetlands are located in the Project area.

BACKGROUND AND PROJECT DESCRIPTION

The Project area was "reclaimed" between 1900 and 1940 by constructing levees, creating a slough and reclaiming approximately 1,200 acres of lake bottom and shoreline wetlands for agricultural purposes. In 1958, the U.S. Army Corps of Engineers (Corps) added to the levee system, reclaiming an additional 200 acres of shoreline wetlands. These projects resulted in the physical isolation of over 1,650 acres of wetland and floodplain from the largest tributaries of Clear Lake. Figures 2 and 3 show the 1916 and current configurations of the Project area.

The levees in the Project area have settled up to three feet below design grade, are prone to slope failure and have inadequate cross-section. These levees were never constructed to proper standards and are the most prone to failure during a major flood event. The pumping station is 49 years old and in need of major repairs, primarily due to age and levee settlement. The Corps has determined that the levees provide only a four-year level of protection (the levees were designed to provide a 50-year level of protection) and will overtop during a 35-year flood event, unless emergency flood fight measures are implemented. The area was evacuated in 1983, 1986 and 1998, with evacuation imminent in 1995. Reconstruction of the levees and pump station repair are estimated to be in excess of $6,000,000. Since the reconstruction costs exceed the benefits received (reduced flood damages), neither the State or Federal governments are authorized to participate in the repair of the levees.

In 1994, the EPA Clean Lakes Diagnostic/Feasibility Study for Clear Lake was completed. Sediment nutrients are primarily responsible for the cultural eutrophication of Clear Lake and the resulting chronic blue-green algal blooms. The Clean Lakes Study identified a significant degradation in Clear Lake's water quality between 1920 and 1940. Sediment cores collected by the University of California, Davis (UCD), shows an abrupt increase in sedimentation rates around 1927, corresponding to the beginning of the large-scale reclamation of the Project area, start of strip mining at the Sulphur Bank Mine, and other major construction projects in the Clear Lake watershed. The Clean Lakes Study recommends numerous actions be taken to reduce the frequency and magnitude of the blue-green algal blooms, including erosion control and wetland and riparian restoration. The County of Lake adopted an Implementation Plan on July 19, 1994 identifying the recommended actions and a time line for their implementation. The Plan is to improve the watershed health of the Clear Lake watershed and improve the quality of Clear Lake.

The District is currently implementing stream bank and wetland rehabilitation projects and actively encouraging the implementation of erosion control projects within the Clear Lake watershed. The District is cooperating with the USDA Forest Service, USDA Natural Resources Conservation Service, the USDI Bureau of Land Management, East Lake and West Lake Resource Conservation Districts, and local watershed groups to improve management of the watershed. Restoration of the Project area is one of the recommendations as it would restore the largest damaged wetland located at the base of the largest sediment source within the watershed, serving as the single largest recommended water quality improvement project.

In 1995, Lake County requested the Corps assist the County in evaluating the project to reduce flood risk and to improve water quality. The Corps undertook the Project under the environmental restoration authority, where it is authorized to provide up to sixty-five percent of the construction cost. The Project consists of reconnecting Scotts and Middle Creek to the historic wetland and floodplain areas by acquiring the reclaimed land, and breaching the existing levee system to create inlets that direct flows into the historically flooded area. The Project removes the flood risk from the properties behind the levee, provides significant water quality benefits and restores large areas of shoreline and riparian habitat that were lost over two-thirds of a century ago.

In May 1997, a Reconnaissance Study was completed by the Corps that established that the Project was practical and there was a federal interest in pursuing the Project further.

In June 1999, the Corps began a Feasibility Study that evaluated six alternative projects, including the No Action, three restoration alternatives, and a non-structural and a structural flood damage reduction alternative. The restoration alternatives all include reconnecting the area adjacent to Clear Lake and Rodman Slough, with the primary difference being the northern limit of the Project area. The pure flood damage reduction alternatives were not cost-effective. During the Feasibility Study that reviewed flood damage reduction, habitat and other benefits, it was determined the most beneficial project would be full restoration of the Project area, see Figure 4. Environmental review as required by NEPA and CEQA was conducted concurrent with the Feasibility Study. The Final Feasibility Study/Environmental Impact Statement/Environmental Impact Report was completed in October 2003. The CEQA process was completed in May 2004. The Project was approved by the Corps in November 2004. The Project was authorized by the Water Resources Development Act (WRDA) in November 2007.

In April, 2008, the Corps began working on resolving some issues remaining from the Feasibility Study. They were required to complete a Cultural Resource study, evaluate the Project impacts on methyl mercury generation, and evaluate the Project impacts on the endangered red legged frog. The latter two special studies were requested by the U.S. Fish and Wildlife Service (USFWS) after their review of the NEPA document. These two studies were approved by USFWS in 2012. The Cultural Resource study will be completed during the design. At this time, the Corps can approve the Record of Decision, completing the NEPA process. Funds then have to be appropriated to start the Project Design.

PROJECT BENEFITS

The Project will provide the following Flood Damage Reduction benefits:

- Reduce flood risk by removing structures and property at risk of severe flooding as a result of levee failure. There are 18 homes and numerous outbuildings subject to flooding should the levees fail. Approximately 1,650 acres of agricultural land would be flooded. Because flood depths are great (over 5 feet in most locations) and would extend for extended periods, potential flood damages are high.

- Protect over three miles of public roads and a major, high voltage PG&E transmission line that cross the Project area and are currently vulnerable to flood damage by elevating or retrofitting the existing structures.

- The California Department of Water Resources (DWR) currently maintains the Middle Creek Flood Control Project in the Project area. The Project would remove approximately three miles of substandard levees, one pumping station and one weir structure from the Flood Control Project. The Project would result in lower O&M ($110,000 to $160,000 per year) and emergency response costs (estimated in excess of $300,000 per major flood event) for DWR and cooperating State and Federal agencies[1].

The Project will reduce the amount of sediment and nutrient inputs to Clear Lake producing the following water quality benefits:

- Sediment is the primary nutrient source (97 percent of Clear Lake's total phosphorus load is sediment bound) contributing to the cultural eutrophication of Clear Lake. It has been estimated that the current sediment and phosphorus load is twice the pre-European sediment load. Approximately 71 percent of the sediment and phosphorus entering Clear Lake is from Scotts and Middle Creek watersheds. It has been estimated that the Project would remove up to 40 percent of phosphorus entering Clear Lake from Middle and Scotts Creeks. Reduced phosphorus concentrations in Clear Lake would potentially reduce the chlorophyll concentrations by 33 percent. A corresponding reduction in total organic carbon would also be realized;

- Wetlands are known to efficiently remove nitrogen from the water column. Because the Project area is hydraulically connected to Clear Lake, it would provide some nitrogen removal benefits to Clear Lake. These benefits are unknown and have not been quantified;

- Improved water quality in Clear Lake will reduce the cost of treating lake water to drinking water standards; and

- Recreation and tourism will be enhanced by improving the water quality in Clear Lake. In 1994, the USDA Soil Conservation Service estimated that $7 million in tourism is lost annually due to water quality issues in Clear Lake.

The Project would provide the following habitat benefits:

- Restore up to 1,400 acres of the 7,520 acres of historic wetlands in the Clear Lake Basin that have either been lost or severely impacted. This is a 79 percent increase in the Basin’s existing wetland habitat. Of the historic 9,300 acres of freshwater wetlands that existed in the Clear Lake Basin, approximately 7,520 acres (80 percent) have been lost or severely impacted. Restored habitat includes open water, seasonal wetlands, instream aquatic habitat, shaded aquatic habitat, and perennial wetlands. Additional upland habitat will be protected adjacent to the wetland and stream areas.

- Provide a significant increase in habitat for fish and wildlife. This Project would greatly improve the bird-nesting habitat and increase the available spawning habitat for native and non-native fish. The area is currently used extensively by migratory waterfowl.

- Preserve the fish and wildlife resources and the cultural resources in the project area.

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[1] The 10.8 miles of levee on Scotts, Middle, Clover an Alley Creeks in the Upper Lake area are maintained by the District and are not affected by the Project.

- Several special-status wildlife species could benefit from the creation of wetland, open water, and riparian habitats in the expanded floodplain. Some species include the northwestern pond turtle, American white pelican, double-crested cormorant, western least bittern, osprey, white-tailed kite, bald eagle, northern harrier, Cooper's hawk, American peregrine falcon, California yellow warbler, yellow-breasted chat, tricolored blackbird, fringed myotis, long-eared myotis, long-legged myotis, pallid bat, and Townsend's western big-eared bat.

The Project will have an unknown, and possibly beneficial, impact on vector control issues in the area. A diverse wetland and riparian community will replace several hundred acres of rice fields and flood-irrigated pasture. Natural predators may result in lower insect populations in the area.

It is anticipated that the Project will impact the Clear Lake ecosystem quickly. The project area was active freshwater marsh less than 100 years ago and already has significant quantities of native wetland vegetation in the Project area. The existing vegetation and the inherent soil properties will facilitate rapid re-establishment of the native habitat. Pilot plantings will be used in the Project area to supplement natural revegetation.

Water quality improvement in Clear Lake should be fully realized within 10 years, with some improvement almost immediately apparent. Improved regulation of instream gravel mining was implemented in 1980, with instream mining decreasing each year until 1991, when essentially all instream mining ceased. The clarity of Clear Lake improved significantly in 1991, and has been the clearest in the last fifty years records. We anticipate the reduced phosphorus loading to Clear Lake after the Project is constructed to become apparent within a similar time frame.

THE NEXT STEP

With completion of the Feasibility Study and all environmental documentation, the following phases remain in the Project:

- The Project has been authorized by WRDA. Limited Federal funds have been appropriated. Additional funds must be appropriated to complete the design.

- Several parcels in the Project area are held by the United States In-Trust for the Robinson Rancheria Band of Pomo Indians. The Corps does not have the authority to adversely impact these In Trust lands with the Project. The District is working with the Rancheria to have the “trust” transferred to other parcels owned by the Rancheria outside the Project area and have developed a mutually agreeable mitigation Plan to address the remaining “trust” property.

- Design: Detailed plans and specifications will be developed by the Corps for the alternative selected in the Feasibility Study.

- Significant land acquisition will be required, including relocation of up to 22 residents. Land acquisition and relocation will be according to Federal requirements. In August 2003, the District was awarded a $5.214 million grant by DWR to begin acquiring residential properties within the Project area. Properties may only be acquired from willing sellers with these funds. In December 2006, the grant amount was increased to $5.714 million. As of November 2008, seven residential parcels have been acquired and structures demolished. In December 2008, these funds were frozen by the State, with no estimate of when the funds will be made available. After funds were frozen, one parcel was acquired and the structures demolished. In April 2011, a grant amendment for an additional $7 million was approved. Four residential parcels have been acquired with these funds. Six additional residential parcels are proposed for acquisition in 2012-2013. Purchase of agricultural land will also begin in 2013, with up to 1,390 acres of land, depending on land values.

- The California Department of Fish and Game (DFG) has prepared a Clear Lake Wildlife Area Conceptual Area Protection Plan (CAPP) that includes acquisition of all of the property required for the Project. If the DFG proceeds with the CAPP, the District will work closely with DFG to meet the mutual goals of each agency.

- Construction: The Project will be constructed. The USACE will administer the construction contract, while contracting out the actual construction work.

Under current funding guidelines, approximately 35 percent of the costs for future phases of the project are the responsibility of the Project Sponsor, the District. These costs are beyond the District's ability to pay. The District is currently developing partnerships to assist in completion of the Project. Current and potential partners include:

•U. S. Army Corps of Engineers
•Central Valley Flood Protection Board
•California Department of Fish and Game/Wildlife Conservation Board
•California State Water Resources Control Board
•Central Valley Regional Water Quality Control Board
•California Bay-Delta Authority
•California Department of Water Resources
•Local Native American Tribes
•Resource Conservation Districts
•Lake County Special Districts
•Lake County watershed groups
•Nonprofit organizations

PROJECT COST	
Federal Share	$31,300,000
Non-Federal Share	$16,700,000
Total Cost	$48,000,000
PROJECT SCHEDULE	
Reconnaissance Study	1996-1997
Feasibility Study/EIS/EIR	1998-2004
Chief of Engineers Report	2004
Design	2012-2014
Construction	2014-2016

REFERENCES

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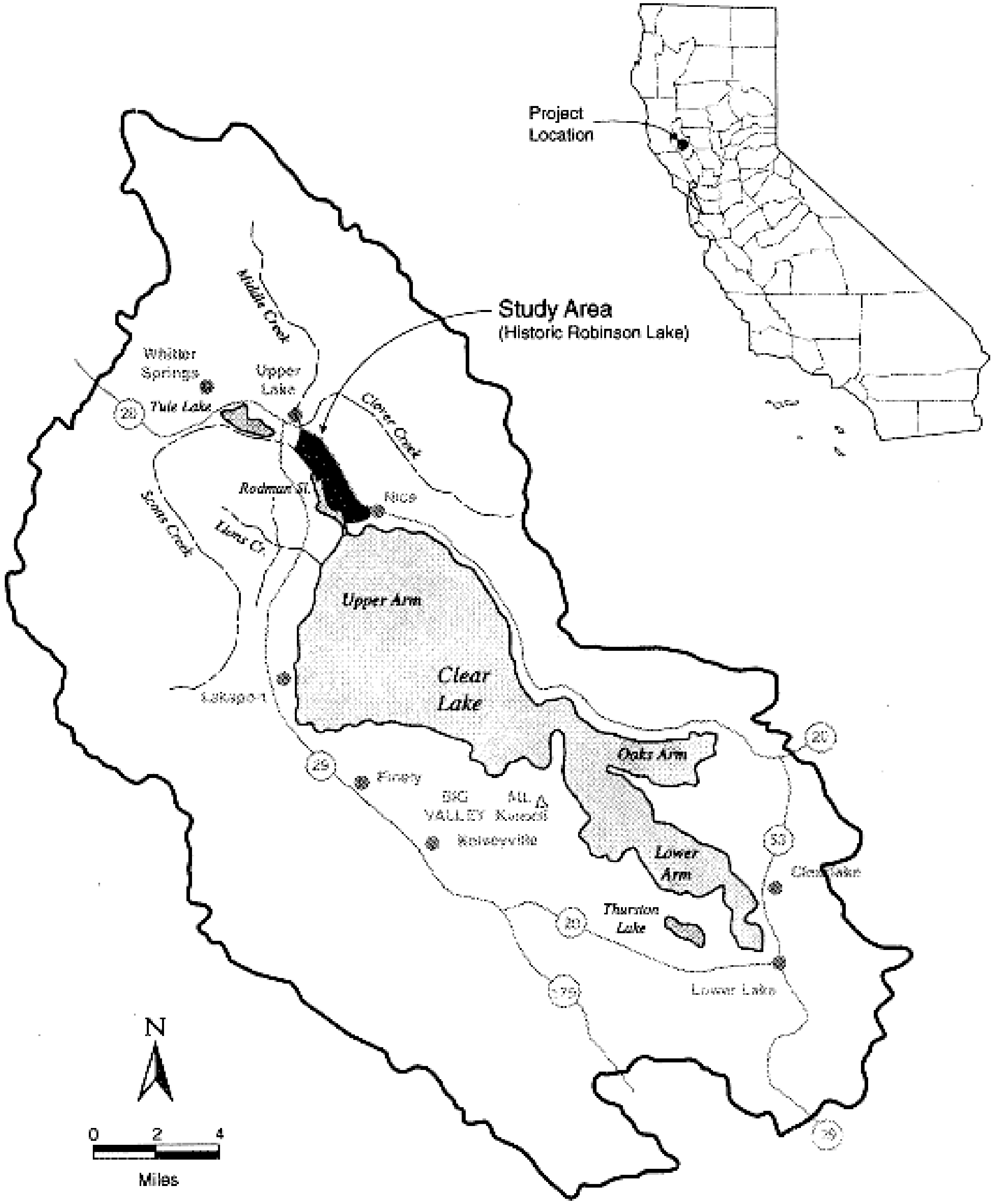
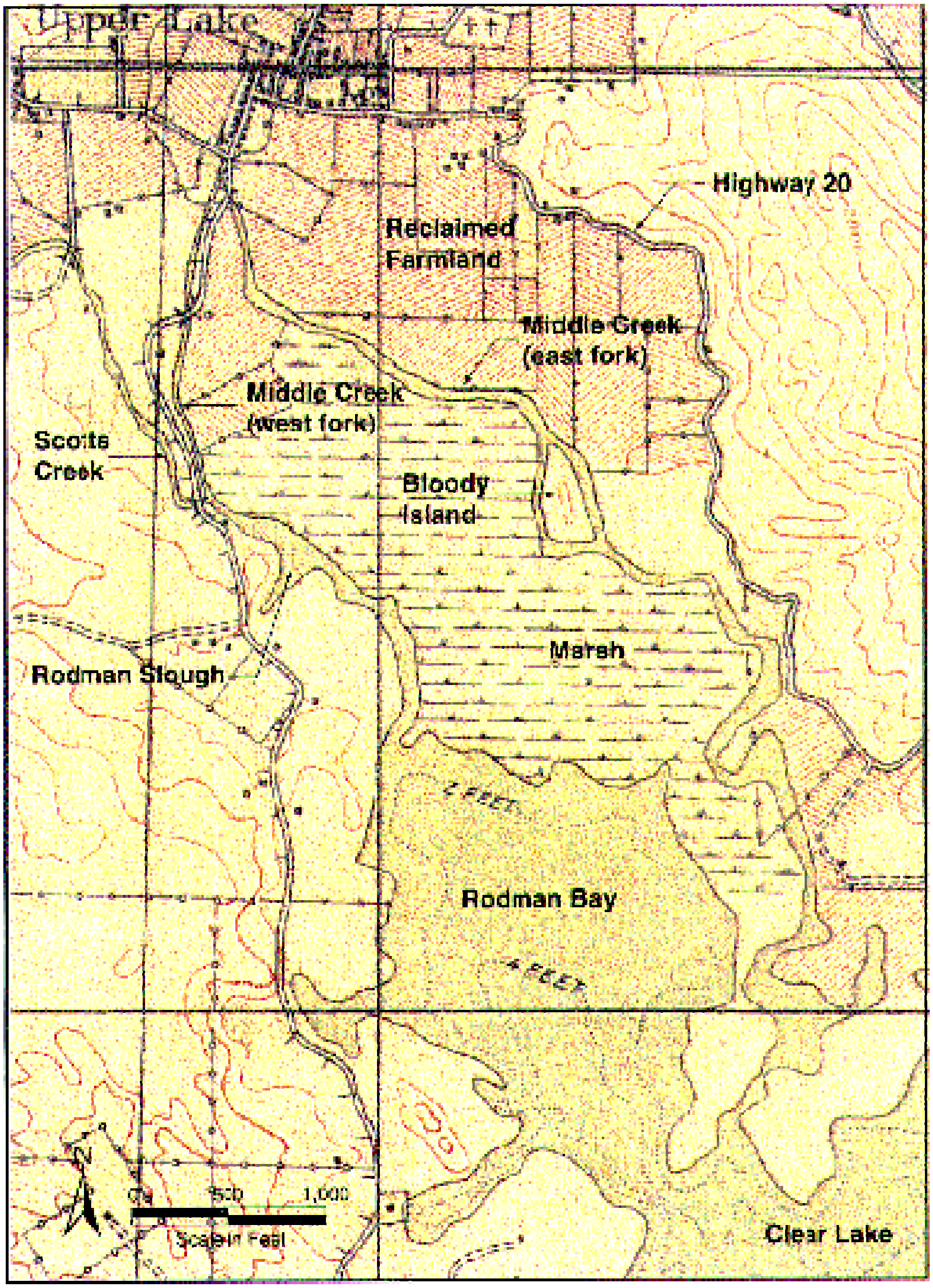


Figure 2.1
Project Study Area Location Map



Source: USGS Lakeport, California quadrangle 1924 (surveyed in 1916).

Figure 2

Historic Conditions of the Study Area, 1916

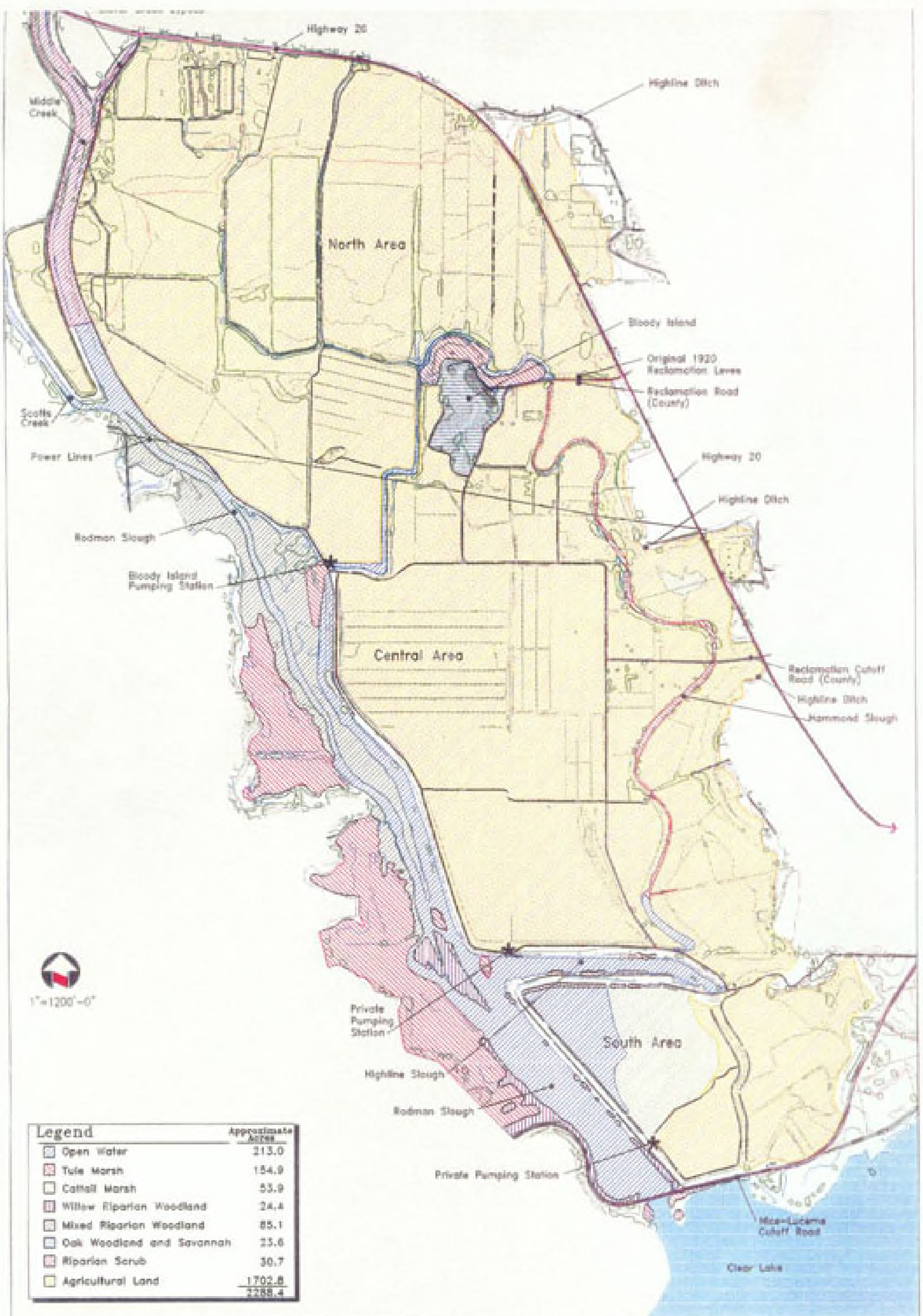
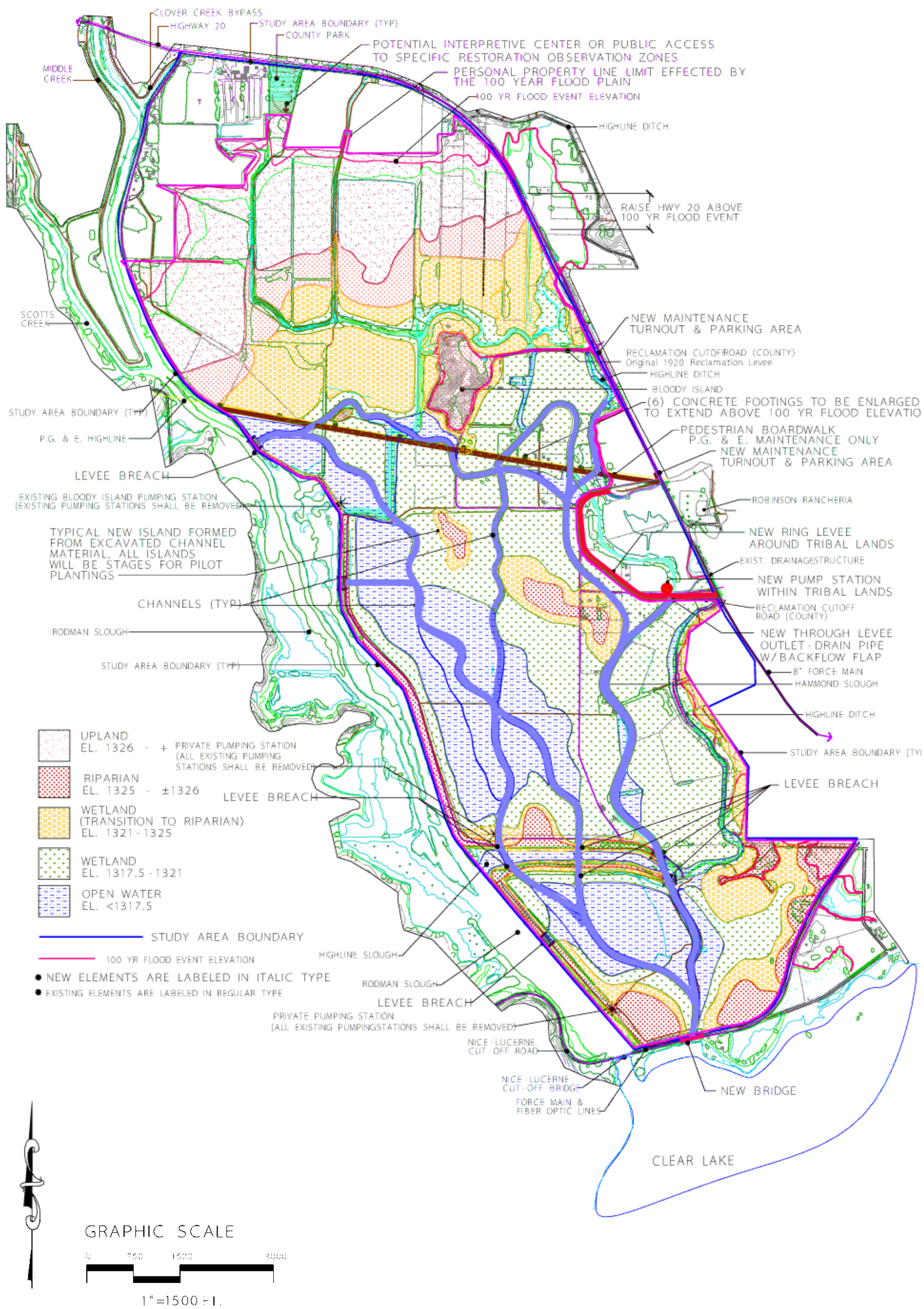


Figure 2.9
Existing Vegetation and Wildlife Habitat in the Study Area

Figure 3



MIDDLE CREEK, LAKE COUNTY, CALIFORNIA

FLOOD DAMAGE REDUCTION AND ECOSYSTEM RESTORATION

Restore Entire Robinson Lake Flood Plain

ALTERNATIVE 2

Figure 4

US Army Corps of Engineers
Sacramento District

Attachment C

Adaptation Option Cost Estimates

Lake County

HWY Middle Creek / Rodman Slough, HWY 20 (PM 8.3 to 12.1/CR 407) - 2050 & 2100 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Elevate the Road Prism - Option No. 1				
Mill and mix the existing roadway into subgrade	SY	56800	$5.50	$312,400
Embankment	CY	74750	$10	$747,500
Class II Aggregate Base (8")	CY	3125	$40	$125,000
Asphalt (Type A) (6")	TN	19600	$110	$2,156,000
Drainage culverts and swales	LS	1	$1,000,000	$1,000,000
Pavement Markings and Signage	LF	13450	$30	$403,500
Misc driveway /entrance reconstruction work	Ea	5	$10,000	$50,000
Seed and Mulch	SY	104850	$80	$8,388,000
New bridge reconstruction	SF	14000	$86	$1,204,000
Environmental Mitigation	Ac	11.2	$400,000	$4,480,000
SUBTOTAL (Non-Percentage Items)				**$18,866,400**
Mobilization	-	40%	$18,866,400	$7,546,560
Clear and Grub	-	15%	$18,866,400	$2,829,960
Erosion Control	-	5%	$18,866,400	$943,320
Maintenance of Traffic	-	5%	$18,866,400	$943,320
SUBTOTAL (Percentage Items)				**$12,263,160**
CONSTRUCTION TOTAL				**$31,129,560**
Project Approval & Environmental Documentation	-	8%	$31,129,560	$2,490,365
Plans, Specifications, & Estimates	-	10%	$31,129,560	$3,112,956
Construction Engineering	-	10%	$31,129,560	$3,112,956
PLANNING AND ENGINEERING COSTS				**$8,716,277**
TOTAL ESTIMATED COSTS				**$39,845,837**
Contingency	-	25%		$9,961,459
GRAND TOTAL				**$49,807,296**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$49,810,000**

Lake County

HWY Middle Creek / Rodman Slough, HWY 20 (PM 8.3 to 12.1/CR 407) - 2050 & 2100 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Relocate Horizontally - Option No. 2				
Roadway Relocation	Mi	4	$35,000,000	$140,000,000
		1	$0	$0
SUBTOTAL (Non-Percentage Items)				**$140,000,000**
Mobilization	-		$140,000,000	$0
Clear and Grub	-		$140,000,000	$0
Erosion Control	-		$140,000,000	$0
Maintenance of Traffic	-		$140,000,000	$0
SUBTOTAL (Percentage Items)				**$0**
CONSTRUCTION TOTAL				**$140,000,000**
Planning	-		$140,000,000	$0
Engineering	-		$140,000,000	$0
Construction Management	-		$140,000,000	$0
Permitting	-		$140,000,000	$0
PLANNING AND ENGINEERING COSTS				**$0**
TOTAL ESTIMATED COSTS				**$140,000,000**
Contingency	-	25%		$35,000,000
GRAND TOTAL				**$175,000,000**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$175,000,000**

Included in Per Mile Cost

Included in Per Mile Cost

Install ITS Infrastructure - Option No. 3				
ITS System	LS	4	$100,000	$400,000
20 -year O&M rounded	LS	1	$680,000	$680,000
TOTAL				**$1,080,000**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$1,080,000**

Increase Maintenance - Option No. 4				
20 -year O&M rounded	LS	1	$950,000	$950,000
TOTAL				**$950,000**
GRAND TOTAL ROUNDED (to the nearest 10,000)				**$950,000**

Attachment D

Adaptation Option Scoring

Project Location: Middle Creek/ Rodman Slough, Highway 20 (PM to 8.3 to 12.1/ County Road 407 Lake County 2050/2100			Assumed Values		Assessment Criteria								
			Assumed Design Service Life	Assumed Total Capital Investment	Total Capital Investment	Annual Average Cost	Usable Life	Level of Performance	Flexibility	Environmental Considerations	Social Considerations	Total Score	Rank
No.	Adaptation Option (Select from List)	Enter Description or Comment		Weight >>	3.7	11.1	18.5	25.9	7.4	14.8	18.5		
1	Elevate the infrastructure above the impact zone	*Increase height of roadway 2 ft above 100 yr flood hazard zone elevation. Project would incorporate new culverts and drainage features*	100	49,810,000	1: $10M - $100M	0: >$100,000/yr	2: Acceptable	3: Enhanced	3: Likely (or unnecessary)	-1: Very little net impact	2: Some net improvement	163	1
2	Relocate infrastructure (horizontally)	*Assumed 4 mile re-route to the east of the existing Hwy 20 -Does not address CR 407*	100	140,000,000	0: > $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	0: None	-2: Some net impact	2: Some net improvement	141	2
3	Temporarily restrict use of infrastructure	*Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information*	20	1,080,000	2: $1M - $10M	1: $50,001-100,000/yr	0: Minimal (or temporary)	1: Decreased	3: Likely (or unnecessary)	-1: Very little net impact	-2: Some net impact	15	4
4	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.*	20	950,000	3: <$1M	2: $10,001-50,000/yr	0: Minimal (or temporary)	1: Decreased	3: Likely (or unnecessary)	-1: Very little net impact	-2: Some net impact	30	3
5	Modify land use and development policies to account for future impacts	*Coordinate with Yolo County to alter natural lake outlet to improve drainage and prevent flooding at the north end of the Lake*											
6	Abandon Infrastructure	*Not considered feasible without re-route*											
7	Provide major structural protection	*Install flood protection berms along roadway above 100 flood hazard elevation. Project would incorporate new culverts and pump stations*											

Top Scoring Adaptation Options

Rank	Adaptation Option	Project Description	Score
1	Elevate the infrastructure above the impact zone	Increase height of roadway 2 ft above 100 yr flood hazard zone elevation. Project would incorporate new culverts and drainage features	163
2	Relocate infrastructure (horizontally)	Assumed 4 mile re-route to the east of the existing Hwy 20 -Does not address CR 407	141
3	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.	30
4	Temporarily restrict use of infrastructure	Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information	15

Attachment E

Adaptation Option Summary/Timeline Evaluation

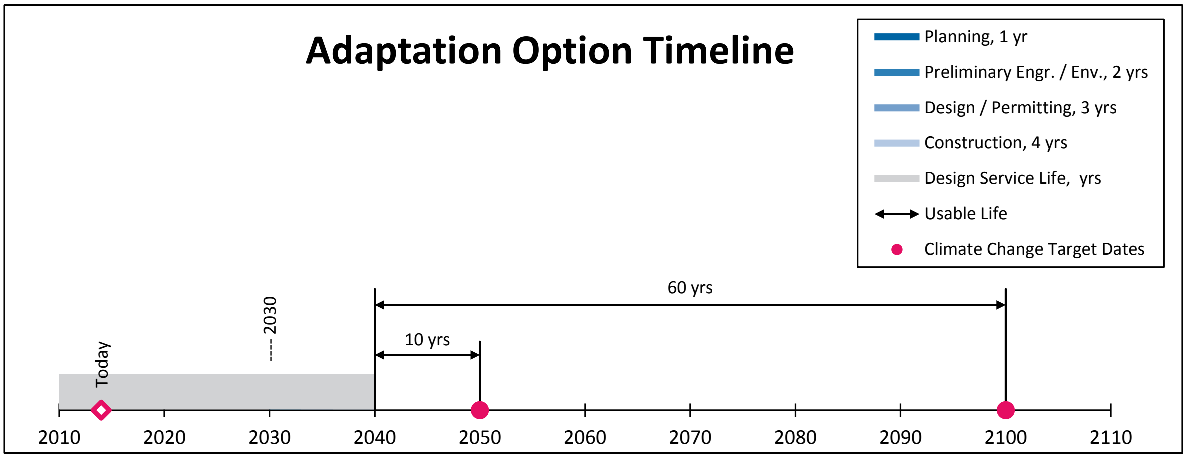
Project Location	Middle Creek/ Rodman Slough, Highway 20 (PM to 8.3 to 12.1/ County Road 407 Lake County
Adaptation Option	#N/A
Project Description	**Construct a viaduct, 6 miles, at a height of 5 ft above 2050 water level at a King tide**

Anticipated Process Times	Years
Planning	1
Preliminary Engr. / Env.	2
Design / Permitting	3
Construction	4
Total Process Time[1]	**10**

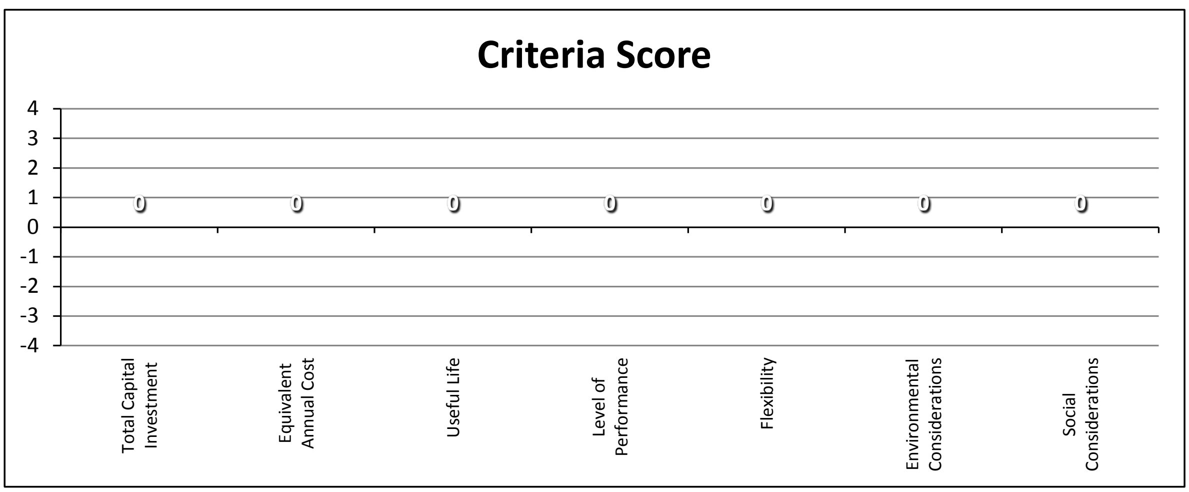
Desired Initiation Date	2030

Assumed Values
Total Capital Investment
Equivalent Annual Cost
Design Service Life (yrs)

Key Dates	
Current Year	2014
Climate Change Horizon	2050/2100



Usable life if designed for	Years
2050 Climate Projection	10
2100 Climate Projection	60



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

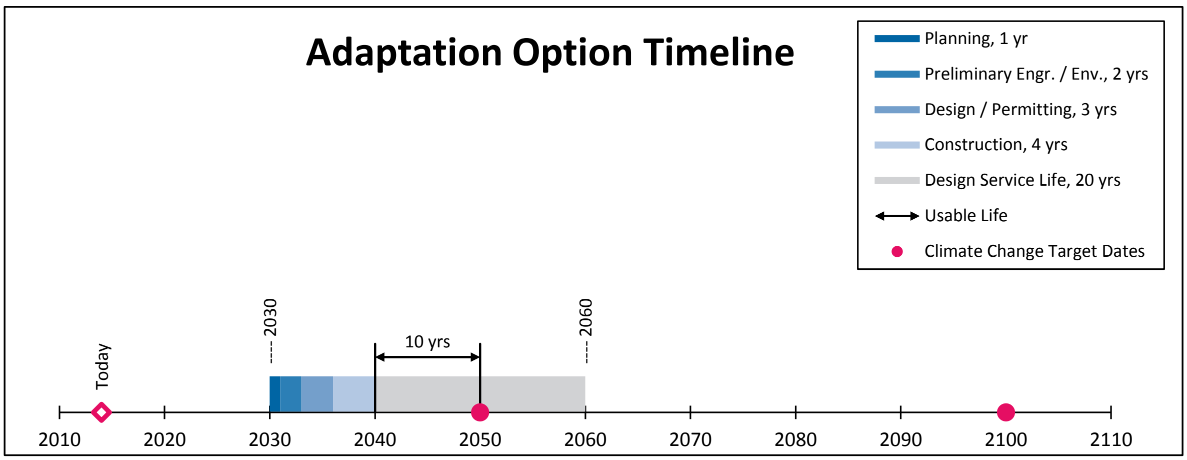
Project Location	Middle Creek/ Rodman Slough, Highway 20 (PM to 8.3 to 12.1/ County Road 407 Lake County
Adaptation Option	Temporarily restrict use of infrastructure
Project Description	**Install ITS infrastructure to recommend use of alternate route and Increase signage and warning information**

Anticipated Process Times	Years
Planning	1
Preliminary Engr. / Env.	2
Design / Permitting	3
Construction	4
Total Process Time[1]	**10**

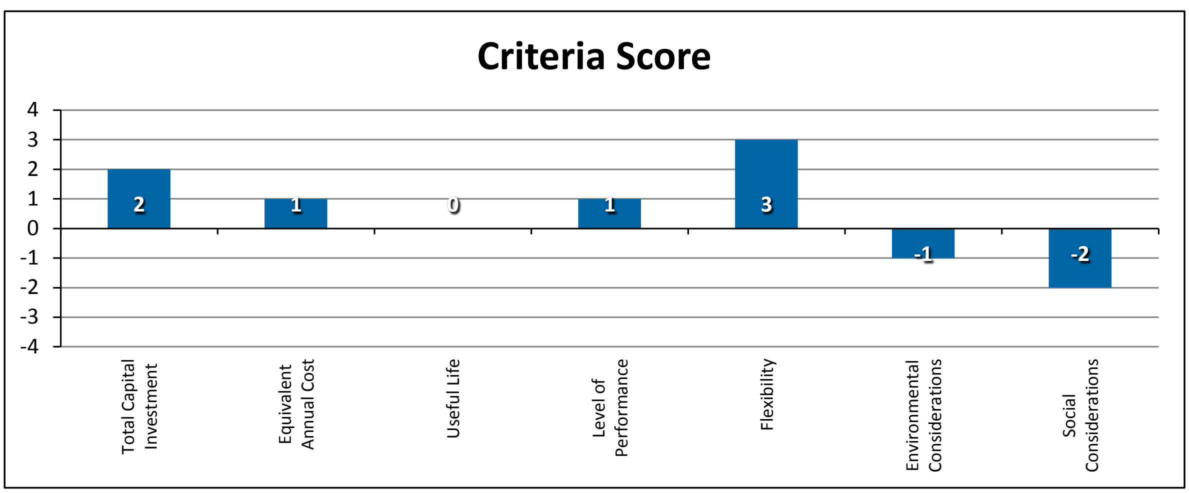
Desired Initiation Date	2030

Assumed Values	
Total Capital Investment	$1,080,000
Equivalent Annual Cost	$54,000
Design Service Life (yrs)	20

Key Dates	
Current Year	2014
Climate Change Horizon	2050/2100



Usable life if designed for	Years
2050 Climate Projection	10
2100 Climate Projection	60



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

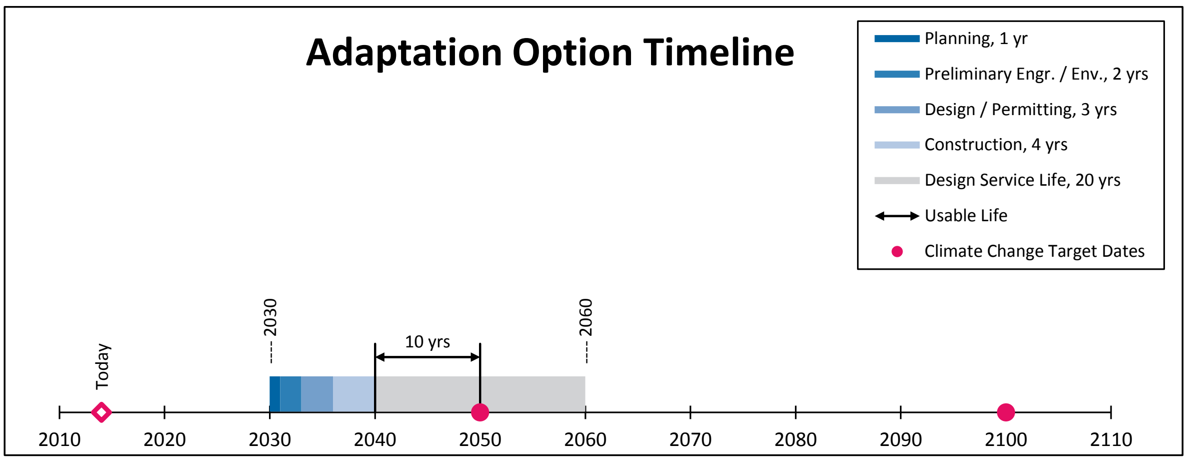
Project Location	Middle Creek/ Rodman Slough, Highway 20 (PM to 8.3 to 12.1/ County Road 407 Lake County
Adaptation Option	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate
Project Description	**Equivalent to the No project alternative. Only temporary measures enacted and repairs made on an as needed basis.**

Anticipated Process Times	Years
Planning	1
Preliminary Engr. / Env.	2
Design / Permitting	3
Construction	4
Total Process Time[1]	**10**

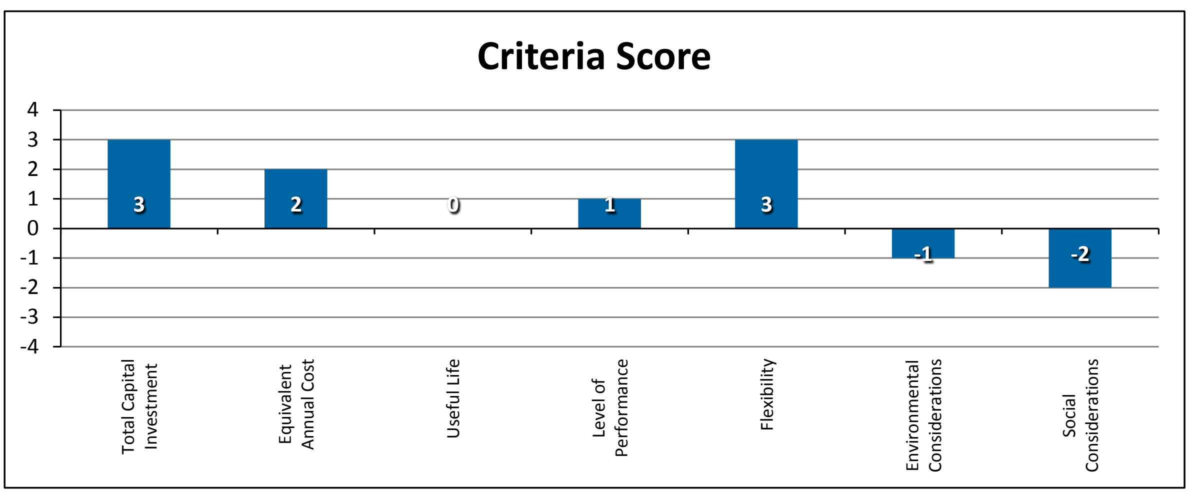
Desired Initiation Date	2030

Assumed Values	
Total Capital Investment	$950,000
Equivalent Annual Cost	$47,500
Design Service Life (yrs)	20

Key Dates	
Current Year	2014
Climate Change Horizon	2050/2100



Usable life if designed for	Years
2050 Climate Projection	10
2100 Climate Projection	60



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

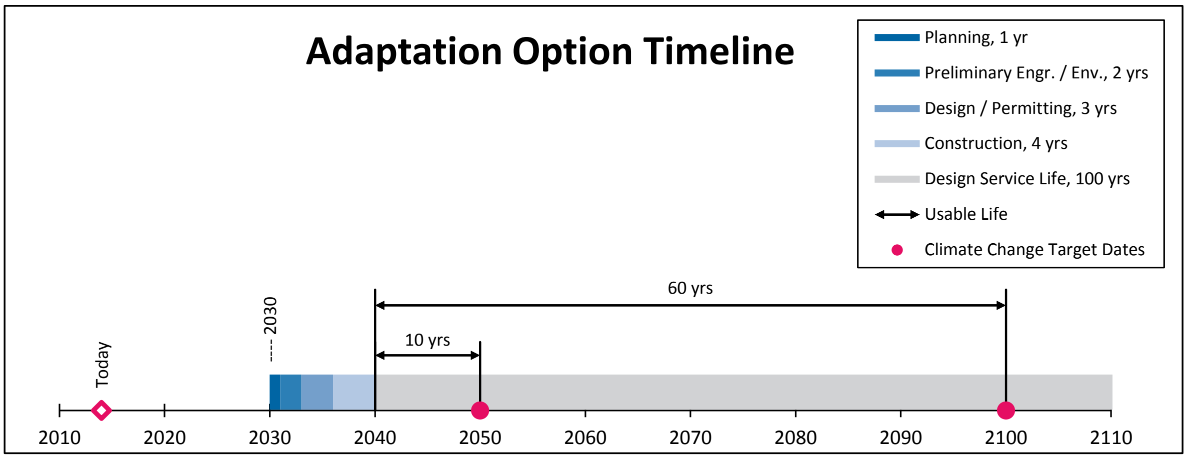
Project Location	Middle Creek/ Rodman Slough, Highway 20 (PM to 8.3 to 12.1/ County Road 407 Lake County
Adaptation Option	Relocate infrastructure (horizontally)
Project Description	**Assumed 4 mile re-route to the east of the existing Hwy 20 -Does not address CR 407**

Anticipated Process Times	Years
Planning	1
Preliminary Engr. / Env.	2
Design / Permitting	3
Construction	4
Total Process Time[1]	**10**

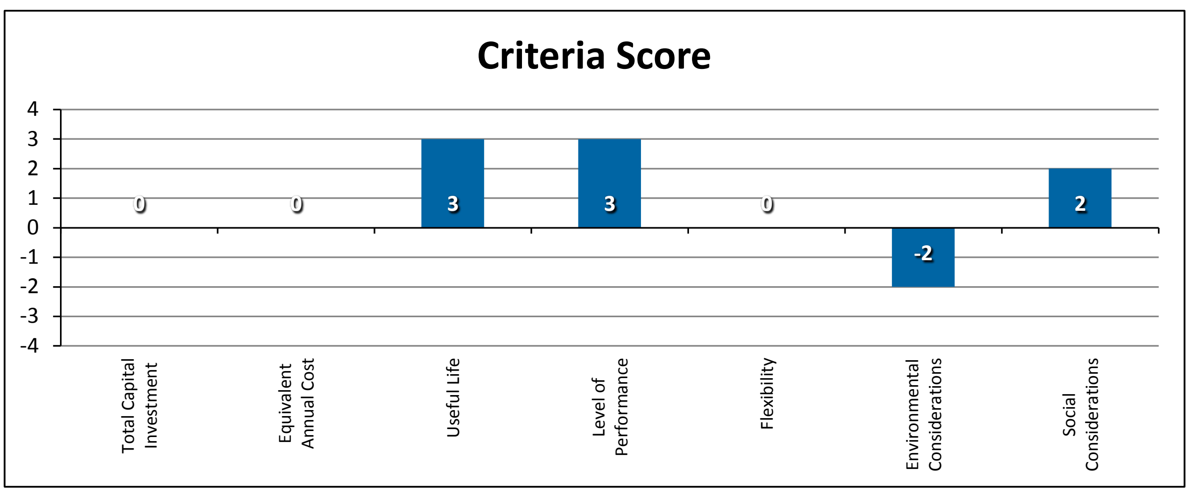
Desired Initiation Date	2030

Assumed Values	
Total Capital Investment	$140,000,000
Equivalent Annual Cost	$1,400,000
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2050/2100



Usable life if designed for	Years
2050 Climate Projection	10
2100 Climate Projection	60



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

Appendix 9

Caltrans Asset Adaptation Assessment

Mendocino County Prototype Location

Memorandum

12 November 2014

To	Rex Jackman, Chief, Transportation Planning Caltrans District 1		
Copy to	Brad Mettam (Caltrans), Jamie Hostler (Caltrans), Marcella Clem (HCAOG)		
From	Rebecca Crow, PE GHD Louis White, PE ESA	Tel	707 443 8326
Subject	Caltrans Asset Adaptation Assessment Mendocino County Prototype Location	Job no.	84/10842/30

1 Introduction

This memo presents a summary of the climate data and adaptation analysis and options for the Mendocino County prototype location. The selected prototype location is along Highway 1 at the Garcia River crossing approximately 2 miles east of Manchester Beach, immediately north of Point Arena between PM 17.5 and 18.6, and is shown in Figure 1 in Attachment A. The key Caltrans assets at the Mendocino prototype site along Highway 1 include the roadway and embankment, bridge over the main-stem of the Garcia River, and a crossing over Hathaway Creek.

1.1 List of Attachments

Attachments provide additional detail and illustrations in addition to the information and analysis provided in the text of this memorandum. The relevant supplemental attachments are as follows:

- Attachment A: Figures
- Attachment B: Excerpts from Windy Hollow Road Over the Garcia River, Final Bridge Feasibility Study
- Attachment C: Adaptation Option Cost Estimates
- Attachment D: Adaptation Option Scoring
- Attachment E: Adaptation Option Summary/Timeline Evaluation

1.2 List of Supporting Documentation

This memo builds off work completed previously under separate cover as part of the overall Caltrans District 1 Climate Change Pilot Project. The following memos should be referenced for additional supporting information.

- Caltrans TCR Segment Criticality, GHD October 2014
- Caltrans TCR Segment Potential for Impact, GHD October 2014

GHD Inc.
718 Third Street Eureka CA 95501 USA
T 1 707 443 8326 F 1 707 444 8330 E eureka@ghd.com W www.ghd.com

- Caltrans TCR Segment Vulnerability, GHD October 2014
- Climate Data Projections for Caltrans District 1 Climate Change Pilot Study, ESA July 2014
- Caltrans Asset Adaptation Assessment Methodology, GHD November 2014

2 Climate Data Summary

This section provides a summary of the climate data used in the analysis. Climate change is a very complex issue and there are many implications for managing infrastructure in the face of climate change. It is important to recognize that there are numerous climate change models and scenarios that have been developed by various entities based on differing assumptions. Various models forecast various ranges of future climate conditions. These future climate conditions influence infrastructure management strategies that may be implemented. No one model is “right” in part because climate is not a steady state phenomenon, but rather a highly dynamic interaction of forces that periodically result in very significant, and often damaging events. It is not possible to precisely forecast when and how severe certain types of episodic events will be and so the results of models should be used to provide general guidance rather than precise predictions.

Also, just like today, there will be future “average” or more typical conditions and periodic more severe conditions. No matter what practical level of climate change one plans for, there will be periodic problematic conditions that will cause inconvenience, damage, or worse. Therefore climate change projections should be considered in the context of adapting to potential changes rather than attempting to completely avoid all negative consequences of climate change.

2.1 Geomorphic Setting

The lower reach of the Garcia River is characterized as a perched tidal lagoon-estuary system. The water levels in the lagoon are tidally influenced, with high water levels that match the high tides along the open coast and low water levels elevated above the low tides on the open coast (this is inferred from inspection of aerial images and familiarity with similar coastal lagoons in the area). Tidal influence appears to extend up to the Highway 1 Bridge, approximately 2 miles upstream of the mouth (CDFG 1978).

The estuary represents the second largest coastal salt marsh in Mendocino County (CDFG 1978). The estuary is composed primarily of fine sediments with sand and gravels. Coarse gravel and sand tend to settle upstream of the site. Most of the bluffs, marshes, and pasture in the immediate vicinity are privately owned. The pasture and agricultural lands in the vicinity of the lower Garcia River are separated by strips of riparian vegetation, are not diked, and act as a floodplain during flood conditions. However the Highway 1 road prism tends to act as a flow barrier across the floodplain thereby elevating the flood water surface elevation.

Most studies for the estuary have been focused on fisheries, effects of timber harvest, sedimentation (Jackson 1998, 1999), gravel mining (PWA 1996), agriculture, and restoration of floodplain and bank stabilization (see krisweb.com/biblio/ biblio_garcia.htm). In addition to gravel sourcing, the estuary plays a major role in fisheries and avian habitat. The salt marsh and estuary is a stopover for waterfowl, which rest and feed in the areas surrounding the estuary. The coastal areas are utilized by harbor seals and other marine wildlife. The estuary is heavily utilized by salmon and steelhead, and provides critical rearing habitat for juveniles.

The lower estuary is bounded along the southwestern edge by high bluffs, and the river mouth is located on the northern side of Point Arena, discharging to the Pacific Ocean at the southern end of Manchester Beach.

The inlet is formed by a balance of tidal and fluvial flows that tend to scour the inlet and coastal processes and waves which tend to close the inlet by depositing sand into the entrance.

2.2 Primary Impacts

The roadway and crossings are periodically impacted by flooding, initiating temporary closures that range from periods of hours to days. Closure of the road causes disruption to travel north and south along the coast, preventing people from traveling to and from their homes, schools, shopping and employment (MCOG 2011). A Regional Transportation Plan for Mendocino County indicates that this segment of highway must be closed during times of heavy rains and high tide, sometimes several times a year for hours at a time (MCOG 2011).

Fluvial flood events initiated by storms with significant precipitation in combination with elevated coastal water elevations during periods of high tide and/or large swells tend to perch the lagoon water levels. The high water levels in the lagoon cause fluvial discharge to backwater and flood the banks of the Garcia River and Hathaway Creek (Figure 2).

Another complicating factor that contributes to flooding of the site is the effects of the inlet morphology at the beach berm. The tidal inlet and the beach berm constrict flows at the mouth, which tends to elevate water levels in the lagoon and upstream. Although the beach berm and inlet likely are scoured and breached during significant fluvial events, some degree of constriction will still be present. The elevation of the beach berm and the tidal inlet are formed and controlled by the coastal water levels and wave action.

Figure 1. Hathaway Creek is a tributary of the Garcia River, with its confluence on the west side of Highway 1. The top image shows dry or normal conditions of the creek; the bottom photograph shows flood waters backed up by the road prism of Highway 1 just above where it joins the Garcia River estuary (Top photo: Google Earth; Bottom photo by Craig Bell, accessed at krisweb.com).

2.3 Effects of Climate Change

The flooding problems at the prototype site will increase in the future with climate changes related sea level rise and increased precipitation. Increased precipitation during storms, as well as increased frequency in storms, may cause a greater amount of flooding-related road impacts. Sea level rise will cause the beach berm and tidal inlet elevations to increase and to migrate landward, thereby increasing the water surface elevation of the estuary in typical and flood conditions (Figure 3). This implies that significant flood events (greater than 2- to 5-year flood events) will continue to impact the roadway and crossings, and that smaller and more frequent flood events may also start having greater impact on the roadway. Overall, flooding of Highway 1 will likely occur more frequently, and inundate larger areas than existing. Figure 4 demonstrates the interactions between climate change effects and hydrological processes in vicinity of the Garcia River at the Highway 1 crossing.

ESA (2014) analyzed and summarized downscaled climate model data and anticipated rates of sea level rise for the Caltrans District 1 Climate Change Pilot Study. Table 1 summarizes the projected rise in sea level and projected changes in extreme precipitation and runoff for the Mendocino Prototype Site at the Garcia River. The combination of increased precipitation and rising sea level will likely increase the frequency and magnitude of flooding-related impacts on Highway 1 at the Garcia River.

Table 1. Projected changes in sea level, and extreme precipitation and runoff at 2050 and 2100 for the Mendocino County Prototype Site: Highway 1 in vicinity of the Garcia River.

Climate Factor	Change at 2050	Change at 2100
Sea Level Rise[1]	5 to 24 inches	16 to 66 inches
Extreme Precipitation[2,4]	2 to 4%	4 to 11%
Extreme Runoff[3,4]	5.6 to 10.8%	0.3 to 15.8%

1 OPC (2013)

2 Projected change in extreme precipitation (98th percentile) calculated using the PCM (wet) model.

3 Projected change in extreme runoff (98th percentile) calculated using average of all model runs.

4 Percent change is presented for 2050 and 2100 relative to a historic period from 1970 to 2000.

MCOG (2011) suggests a possible solution to the flooding problems is to construct a County Bridge across the Garcia River on Windy Hollow Road, located approximately 0.5 miles east of Highway 1. A feasibility study has been completed to assess the best type of bridge structure for the crossing, which would be located on tribal lands owned by the Manchester-Point Arena Rancheria.

The range in projections that is shown in Table 1 represents uncertainty associated with the global emissions of greenhouse gases (GHG). The ranges in the projected relative sea level rise are a combination of several factors, including increased temperatures, thermal expansion of the oceans, changes in land ice melt, vertical land motion, and the future global emissions of GHG. For periods beyond 2050, the uncertainty increases and yields a larger range in projected sea level rise. Similarly, the percent change in extreme precipitation and extreme runoff increases from the A2 to the B1 emissions scenario. As discussed in greater detail in the accompanying memorandum "Climate Data Projections for Caltrans District 1 Climate Change Pilot Study," the A2 and B1 emissions scenarios were selected to represent medium-high and relatively low (or "best-case") emissions projections, respectively (ESA 2014). These emissions scenarios were originally developed and described by the IPCC (IPCC 2000; Cayan et al. 2012). The A2 and B1 emissions scenarios are defined as follows:

- **A2.** Medium-high emissions resulting from continuous population growth coupled with internationally uneven economic and technological growth. Under this scenario, emissions increase through the 21st century and by 2100 atmospheric carbon dioxide (CO2) levels are approximately three-times greater than pre-industrial levels.

- **B1.** Lower emissions than A2, resulting from a population that peaks mid-century and delicnes thereafter, with improving economic conditions and technological advancements leading to more efficient utilization of resources. Under this scenario, emissions peak mid-century and then decline, leading to a net atmospheric CO2 concentration approximately double that of pre-industrial levels. This scenario is often referred to as a “best-case” scenario.

The effects of the respective scenario on the percent change in projected extreme precipitation and runoff for years 2050 and 2100 is due to a combination of increased temperatures and changes to the hydrologic cycle. The A2 scenario results in a more rapid increase in average temperatures, which increases evaporation and causes soil moisture to decrease, and in turn reduces the volume of runoff during precipitation events. Less rainfall is projected for the A2 scenario overall. Likewise, reduction of GHG emissions under the B1 scenario results in a rise in average temperature that occurs less rapidly which would tend to have a less significant effect on evaporation and soil moisture as compared to the A2 scenario. The annual precipitation is projected to increase for the B1 scenario and the magnitude of extreme events will likely increase as well. Results of projected climate change factors at 2050 and 2100 for the A2 and B1 emissions scenarios for District 1 and its four counties are summarized more completely in ESA (2014). Projected changes in relative sea level rise can be associated with low and high emissions scenarios, but the projections of sea level rise presented here do not directly represent the A2 or B1 emissions scenarios.

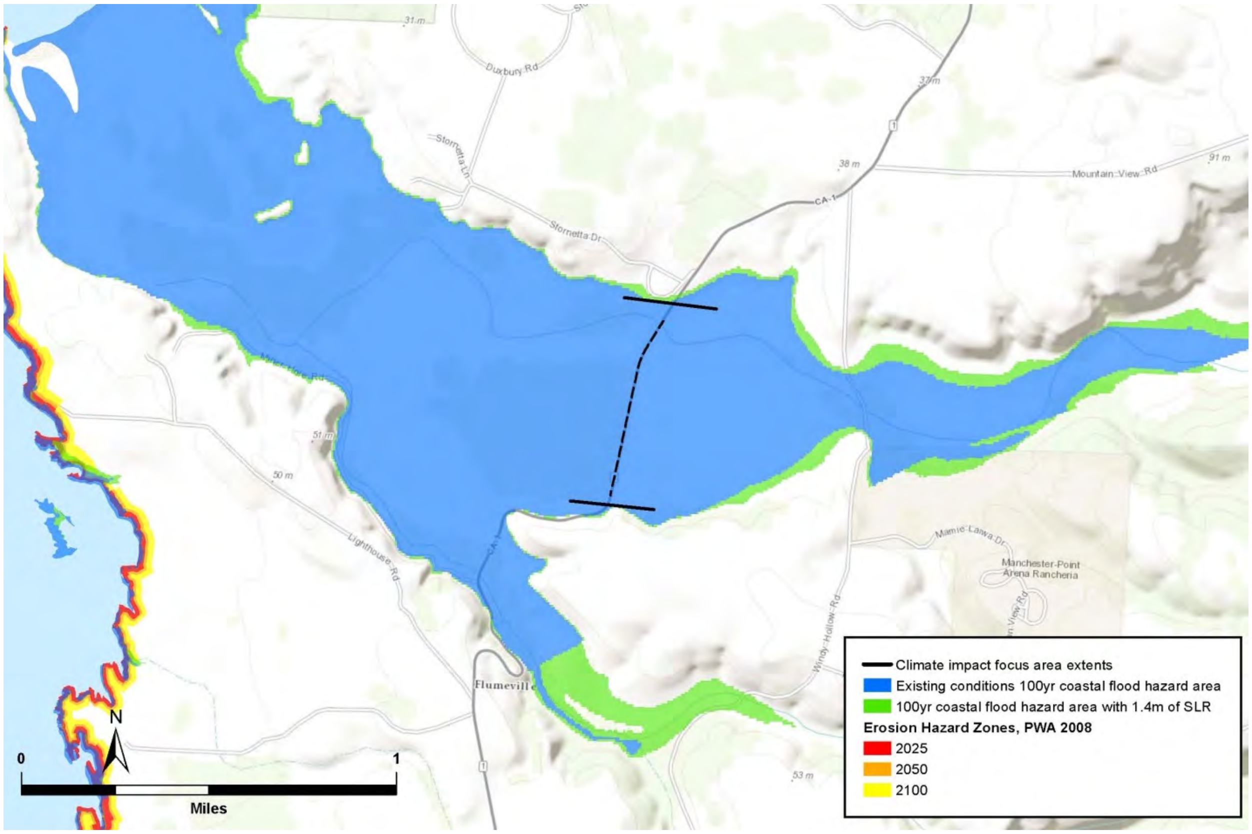


Figure 2: Flood of Highway 1 in vicinity of the Garcia River will likely increase in frequency and magnitude because of sea level rise.

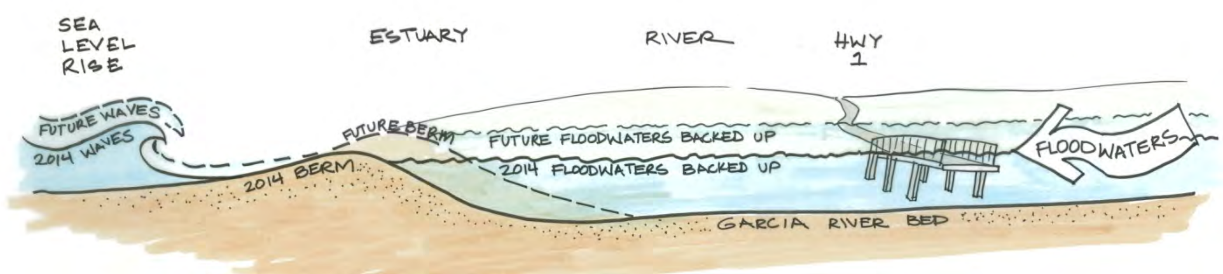


Figure 4: Interactions between climate change effects and hydrological processes in vicinity of the Garcia River at the Highway 1 crossing

3 Adaptation Evaluation

The information presented above was used in combination with information developed for the Windy Hollow Bridge Feasibility Study (Tylin International, 2007) (see excerpts in Attachment B) to develop adaptation options for the Mendocino County prototype location. Seven adaptation options were initially identified which encompassed the 4 primary types of adaptation (defend, accommodate, retreat, and changes in policies or practices).

Table 2 below shows the seven adaptation options considered for this prototype location. Two adaptation options presented in Table 2 were not considered viable alternatives. The first non-viable option was installing flood protection berms along the roadway. Flooding in this area comes from both runoff upstream as well as tidal backwatering. A berm project would result in isolating the roadway from rising water, however it would interrupt the hydrology of the system creating the need for extensive tides gates and possible pump stations. The second non-viable option was abandoning the roadway. This road currently provides the only connectivity across the Garcia River and the alternate route is 125 miles, which is not practical to serve the community.

No.	Adaptation Option	Description
1	Elevate the infrastructure above the impact zone	*Increase height of roadway 2 ft above 100 yr coastal hazard elevation. Project would incorporate new culverts and raising/ replacing Hathaway Creek Bridge*
2	Elevate the infrastructure above the impact zone	*Construct a causeway, across the Garcia River Flood plain and Hathaway Creek at a height of 5 ft above 100 yr coastal hazard elevation*
3	Relocate infrastructure (horizontally)	*Re-route Highway 1 along Windy Hollow Rd*
4	Temporarily restrict use of infrastructure	*Temporarily re-route Highway 1 long Windy Hollow Rd during periods of flooding*

5	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Temporary close/ reroute during flooding*
6	Provide major structural protection	*Install flood protection berms along roadway above 100 yr. coastal hazard elevation. Project would incorporate new culverts, tide gates, and raising/ replacing Hathaway Creek Bridge – Not considered viable*
7	Abandon Infrastructure	*Not Considered further due to lack of existing nearby redundant route*

Each of the potentially viable adaptation options 1 through 5 is discussed in the following sections.

3.1 Adaption Option 1

Elevate the infrastructure above the impact zone	*Increase height of roadway 2 ft above 100 yr coastal hazard elevation. Project would incorporate new culverts and raising/ replacing Hathaway Creek Bridge*

Adaptation Option 1 focuses on increasing the height of the road above the coastal flooding hazard elevation, through building up the road prism.

Table 3 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix D.

Table 3: Garcia River Adaptation Option 1 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	100 years	High end of the design life of an earthen structure. Assumed structure is properly maintained to protect integrity
Assumed Total Capital Investment	$ 14,420,000	Assumed road is raised to 2 feet above coastal hazard elevation including 24 inches of SLR in 2050 and 66 inches in 2100. Due to limited data on coastal flooding elevations, one cost was developed for 2050 and 2100
Usable Life	2: Acceptable	The usable life is beyond the 2100 scenario. However due to uncertainties in the future flooding conditions, this criteria was ranked as acceptable.

Level of Performance	3: Enhanced	This option provides enhanced protection of the asset in comparison with the existing condition
Flexibility	1: Unlikely	With the costs and effort involved in constructing the new roadway on the raised fill prism, it would be difficult to add additional height in the future.
Environmental Considerations	-2: Some net impact	It is assumed that some wetlands would be impacted, and hydrologic functions affected as well
Social Considerations	3: Significant net improvement	The use of the highway would be maintained, resulting in significant connectivity improvement

3.2 Adaption Option 2

Elevate the infrastructure above the impact zone	*Construct a causeway, across the Garcia River Flood plain and Hathaway Creek at a height of 5 ft above 100 yr coastal hazard elevation*

Adaptation Option 2 focuses on increasing the height of the road above the coastal flooding hazard elevation, through the installation of a causeway.

Table 3 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix D.

Table 3: Garcia River Adaptation Option 2 Summary

Assessment Criteria	Value	Comments
Assumed Design Service Life	100 years	High end of the design life of an earthen structure. Assumed structure is properly maintained to protect integrity
Assumed Total Capital Investment	$ 15,520,000	Assumed road is raised to 2 feet above coastal hazard elevation including 24 inches of SLR in 2050 and 66 inches in 2100. Due to limited data on coastal flooding elevations, one cost was developed for 2050 and 2100
Usable Life	3: Surpasses	The usable life is beyond the 2100 scenario and additional height to account for the uncertainty in future flooding conditions was incorporated
Level of Performance	3: Enhanced	This option provides enhanced protection of the asset in comparison with the existing condition

Flexibility	0: None	Once a causeway is built, it would be very difficult to increase the height or add other protective measures at a later date
Environmental Considerations	-1: Very Little net impact	It is assumed that some wetlands may be impacted, but much less than building up the road prism
Social Considerations	3: Significant net improvement	The use of the highway would be maintained, resulting in significant connectivity improvement

3.3 Adaption Option 3

Relocate infrastructure (horizontally)	*Re-route Highway 1 along Windy Hollow Rd*

Adaptation Option 3 focuses on re-routing the highway along Windy Hollow Road and construction a new bridge over the Garcia River. This would be a permanent re-route. Table 4 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix D.

Table 4: Garcia River Adaptation Option 3 Summary

Assessment Criteria	**Value**	**Comments**
Assumed Design Service Life	100 years	High end of the design life of an earthen structure. Assumed structure is properly maintained to protect integrity
Assumed Total Capital Investment	$ 35,570,000	Road is permanently re-aligned, which is assumed to address both the 2050 and 2100 scenarios. Only one cost was developed
Usable Life	3: Surpasses	The usable life is beyond the 2100 scenario
Level of Performance	3: Enhanced	This option provides enhanced performance in comparison with the existing condition
Flexibility	3: Likely or Unnecessary	The new alignment would be out of the hazard zone, and thus, would not need to be flexible.
Environmental Considerations	-2: Some net impact	It is assumed that some wetlands may be impacted where Windy Hollow Road would be widened
Social Considerations	3: Significant net improvement	The use of the highway would be maintained, resulting in significant connectivity improvement. In addition, the new bridge would connect the Manchester Point Arena tribal lands.

3.4 Adaption Option 4

Temporarily restrict use of infrastructure	*Temporarily re-route Highway 1 long Windy Hollow Rd during periods of flooding*

Adaptation Option 4 focuses on re-routing the highway along Windy Hollow Road on an as-needed basis. This option would include construction of a new bridge over the Garcia River. However the road improvements would be reduced as it is anticipated the existing Highway 1 alignment would remain in service. Table 5 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Appendix D.

Table 5: Garcia River Adaptation Option 4 Summary

Assessment Criteria	**Value**	**Comments**
Assumed Design Service Life	50 years	This option includes reduced improvements to the Windy Hollow roadway, and thus it is anticipated that major improvements would be needed after 50 years.
Assumed Total Capital Investment	$ 25,410,000	Road is permanently re-aligned, which is assumed to address both the 2050 and 2100 scenarios. Only one cost was developed
Usable Life	2: Acceptable (2050) 1: Considerable, but insufficient (2100)	The usable life is beyond the 2050 scenario, but not the 2100 scenario
Level of Performance	3: Enhanced	This option provides enhanced performance in comparison with the existing condition
Flexibility	3: Likely or Unnecessary	The new alignment would be out of the hazard zone, and thus, would not need to be flexible
Environmental Considerations	-1: Very little net impact	It is assumed that some wetlands may be impacted where Windy Hollow Road would be widened, but less than for the permanent re-location
Social Considerations	3: Significant net improvement	The use of the highway would be maintained, resulting in significant connectivity improvement. In addition, the new bridge would connect the Manchester Point Arena tribal lands.

3.5 Adaption Option 5

Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Temporary close/ reroute during flooding*

Adaptation Option 5 presents a wait-and-see approach, with no new infrastructure constructed and only management changes implemented. This creates an immediate challenge for this prototype site in comparison to the other sites. Under existing conditions, the road must be closed several times a year due to flooding. There is an economic impact to the community for the full loss of use of this road. The cost estimate for this option reflects the economic value of the time the road is not in service, including vehicle miles to detours.. Table 6 below presents the qualitative evaluation of the alternative used for scoring the criteria in the adaptation planning tool. Where applicable, values for the 2100 planning horizon are presented. The complete scoring sheets for 2050 and 2100 are included in Attachment D.

Table 6: Garcia River Adaptation Option 4 Summary

Assessment Criteria	**Value**	**Comments**
Assumed Design Service Life	36 years	The useful life is based on the no action until 2050, and is consistent with the costs developed for economic loss due to road closures
Assumed Total Capital Investment	$ 25,410,000	Road is permanently re-aligned, which is assumed to address both the 2050 and 2100 scenarios. Only one cost was developed
Usable Life	0: Minimal or temporary	The usable life is less than the 2050 and 2100 scenarios
Level of Performance	1: Decreased	This option provides reduced performance relative to the existing condition, ad flooding is expected to increase
Flexibility	3: Likely	This option allows flexibility to further evaluate climate impacts and allows for any option to be implemented in the future.
Environmental Considerations	-1: Very little net impact	Some flooding would occur under both the 2050 and 2100 scenarios
Social Considerations	-3: significant net impact (2100)	Alternate routes would be needed, creating delays for the traveling public. Delays would increase as time goes on

3.6 Cost Assumptions

Attachment C includes information on how were developed for the six adaptation options. Future work should include more detailed cost analysis of preferred options to allow for the further analysis of feasibility of appropriate adaptation strategies. The values for loss of use of the road were taken from the Final BCA Reference Guide (FEMA, 2009).

3.7 Top Scoring Adaptation Options and Implementation Timeline

The adaptation planning tool summarizes the five potentially viable adaptation options. Table 7 presents the final scores for the adaptation options. The adaptation tool timeline summary page for each of the six adaptation options is included in Attachment E. Without more detailed data it was difficult to determine the difference in many of the criteria for the 2050 and 2100 planning horizons. Thus, only one set of adaptation options was developed.

Table 7: Summary of Mendocino County Prototype Location Adaptation Scoring

Top Scoring Adaptation Options			
Rank	**Adaptation Option**	**Project Description**	**Score (2050)**
1	Elevate the infrastructure above the impact zone	Construct a causeway, across the Garcia River Flood plain and Hathaway Creek at a height of 5 ft above 100 yr coastal hazard elevation including 24 inches of SLR A2 Scenario @2050).	178
2	Relocate infrastructure (horizontally)	Re-route Highway 1 along Windy Hollow Rd	167
3	Elevate the infrastructure above the impact zone	Increase height of roadway 2 ft above 100 yr coastal hazard elevation including 24 inches of SLR (A2 Scenario @2050). Project would incorporate new culverts and raising/ replacing Hathaway Creek Bridge	152
4	Temporarily restrict use of infrastructure	Temporarily re-route Highway 1 long Windy Hollow Rd during periods of flooding	85
5	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	Temporary close/ reroute during flooding (Assume closure 6 times per year in 2050 @ 12 hours average and 12 per year in 2100 @ 18 hours average)	-22

4 Next Steps

This prototype location experiences closures during existing conditions more frequently than the three other prototype locations. The evaluation of the potential economic cost of closures of the road, plus the nature of existing flooding problems at the site demonstrate the importance of planning for near-term improvements at this site.

The analysis conducted for this prototype location considered ranges for sea level rise, precipitation changes and runoff changes. This informs planners as to possible impacts from Climate change, but additional analysis is necessary for selecting a preferred approach. It is recommended that a site specific hydrologic/ hydraulic model be developed to further understand the interaction between seal level rise and coastal flooding at this location. Similar work was done for the Humboldt prototype location. This would provide planners more accurate information on the water surface elevations that need to be planned for at the site. This planning should occur in the near term because periodic flooding already causes road closures and this situation will steadily worsen with climate change.

5 References

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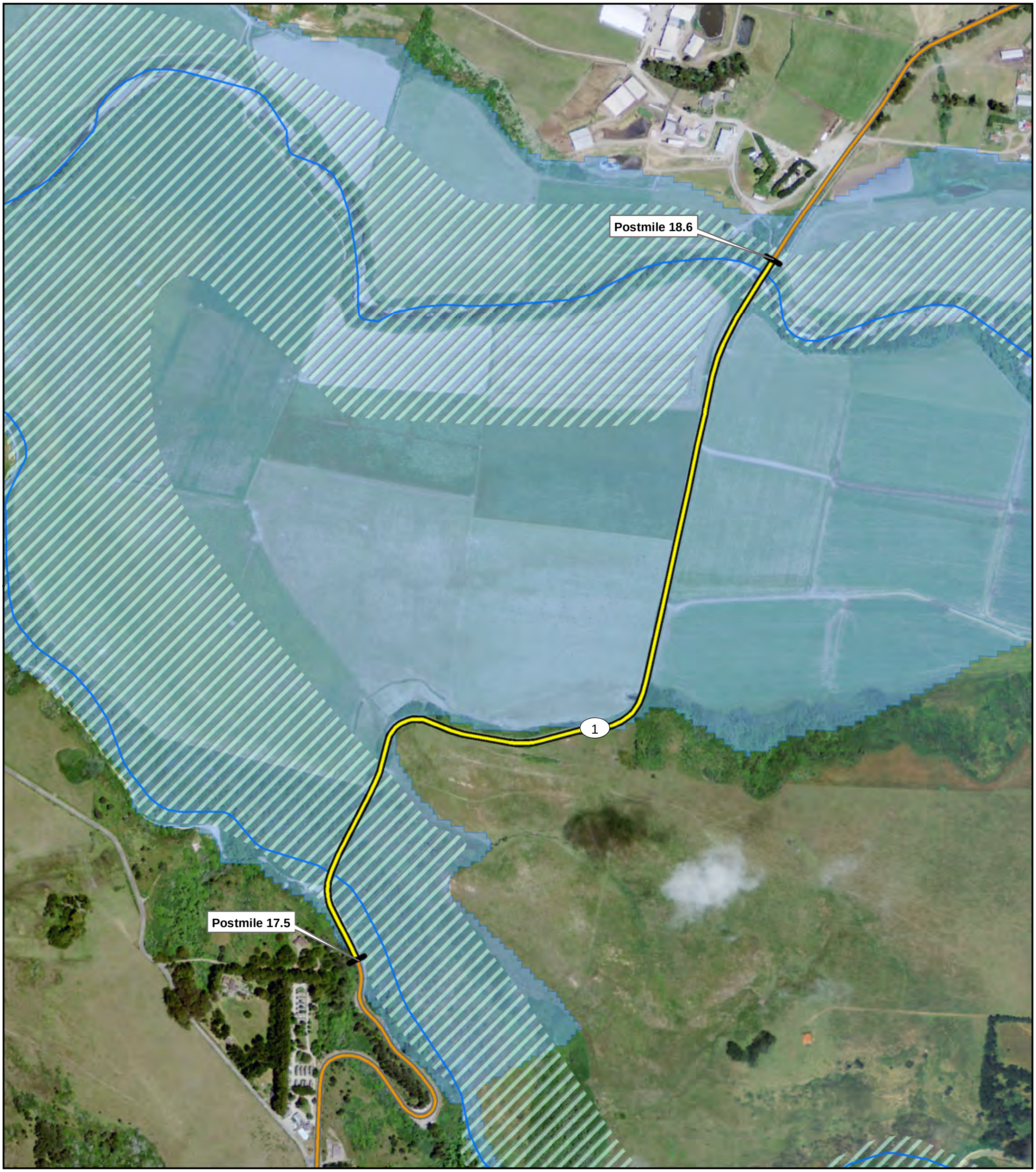
Attachment A

Figures



Chronic Erosion Issue Area
Chronic Sea Level Issue Area
100-year Effective FEMA Floodplain(s)
100-year Coastal Flooding
Prototype Limits
Prototype Location
Roadways
Streams

Paper Size 8.5" x 11" (ANSI A)
0 150 300 450 600 750
Feet
Map Projection: Albers
Horizontal Datum: North American 1983
Grid: NAD 1983 California Teale Albers

N

GHD ESA

Caltrans District 1 and HCAOG
District 1 Climate Change Pilot Study

Mendocino County
Prototype Location

Job Number 8410842.30
Revision A
Date 11 Nov 2014

Figure 1

718 Third Street Eureka CA 95501 USA T 707 443 8326 F 707 444 8330 E eureka@ghd.com W www.ghd.com

G:\11905 HumCoAssocGovernments\8410842 HCAOG_CCVA_District 1\08-GIS\Maps\Figures\Report_8410842_30\8410842-30_Mendocino.mxd

 Data source: Aerial, NAIP 2010, 1 m resolution; FEMA, 2014. Created by:jrousseau

Attachment B

Excerpts from Windy Hollow Road Over the Garcia River, Final Bridge Feasibility Study

WINDY HOLLOW ROAD OVER THE GARCIA RIVER
FINAL
BRIDGE FEASIBILITY REPORT

PREPARED FOR:

ACTION NETWORK

THROUGH AN ENVIRONMENTAL JUSTICE GRANT
FOR
THE MANCHESTER-POINT ARENA BAND OF POMO INDIANS

FEBRUARY 28, 2007

PREPARED BY:

TYLININTERNATIONAL

10365 OLD PLACERVILLE ROAD, STE 200
SACRAMENTO, CALIFORNIA 95827

Table Of Contents

1. Executive Summary

The communities of Point Arena and Manchester, on the southern coast of Mendocino County, California, are located on opposite sides of the Garcia River. Today, there is only one road that connects these two communities, State Route 1, which is also the backbone of the transportation network in that coastal region. During heavy rains, the Garcia River overtops State Route 1, which isolates the two communities and severs the only north-south route in the region. This interruption of the regional transportation network occurs almost every year, and can last from hours to several days at a time during each episode. The closure of State Route 1 impacts public safety and causes hardship on the local residents, interfering with employment, social services and mobility.

Windy Hollow Road is on higher ground upstream of State Route 1, and would be an excellent road to use during flood events, but there is currently no bridge to cross the Garcia River. Community leaders have sponsored this feasibility study to construct a permanent bridge for year-round use on Windy Hollow Road. This is a much needed improvement project that would provide for community safety, disaster responsiveness and will improve the local transportation network and enhance the region's livability.

Prior to this feasibility study, regional transportation studies were developed through funding provided by the Caltrans Community Based Transportation Planning Grant Program. The studies identified the Windy Hollow Bridge as the second highest priority transportation project for the area. As a follow up to this recommendation, an Environmental Justice Grant was received by the Manchester-Point Arena Band of Pomo Indians to further study the concept of building a bridge for Windy Hollow Road across the Garcia River.

Action Network, as administrators of the Environmental Justice Grant for the Manchester-Point Arena Band of Pomo Indians, selected T.Y. Lin International to study the concept of a new bridge crossing on Windy Hollow Road. The results of the study indicate that a new bridge could be built at the site using conventional bridge types and construction methods. In addition to a new bridge, approximately one mile of the existing Windy Hollow Road will need to be rebuilt to current standards.

A public outreach event was held in January 2007 to seek input from local residents regarding the bridge concept. The event was well attended, with both favorable and dissenting opinions, as is expected for any significant change to a road system. While the majority sentiment from this meeting was positive and in favor of the bridge, there were strong messages from all viewpoints that the local residents must be involved and engaged in the project development process.

The estimated cost of the new bridge and roadwork in current (2007) dollars is $10.8 million. The recommendations of this study call for elevating this project from the local level into the regional transportation planning process.

2. Overview

Windy Hollow Road connects with Riverside Road in Point Arena and with State Route 1 south of Manchester. Windy Hollow Road dead-ends on both sides of the Garcia River and a bridge is needed to make this a through road. A bridge across the Garcia River on Windy Hollow Road would offer an alternative to the only existing crossing of the Garcia River on State Route 1. State Route 1 is subject to periodic flooding from the Garcia River that closes the road and severs traffic between Point Arena and Manchester for days at a time. Community leaders have determined that a feasibility study is needed to evaluate the suitability of constructing permanent bridge for year-round use to provide for community safety, disaster responsiveness and improve the local transportation network to enhance the region's livability.

It is beyond the scope of this study to consider alternative routes or alignments. There have been studies and workshops conducted, as cited in the "Guiding Documents" section, that recommend this particular study.

This bridge feasibility study is funded through an Environmental Justice Grant from the California State Highway Account administered by Caltrans. The Environmental Justice Grants are offered to promote community involvement in planning to improve mobility, access, and safety while promoting economic opportunity, equity, environmental protection, and affordable housing for low-income, minority, and Native American communities. The grant was awarded to the Manchester-Point Arena Band of Pomo Indians to be administered by Action Network, a local non-profit organization committed to building a thriving, healthy community.

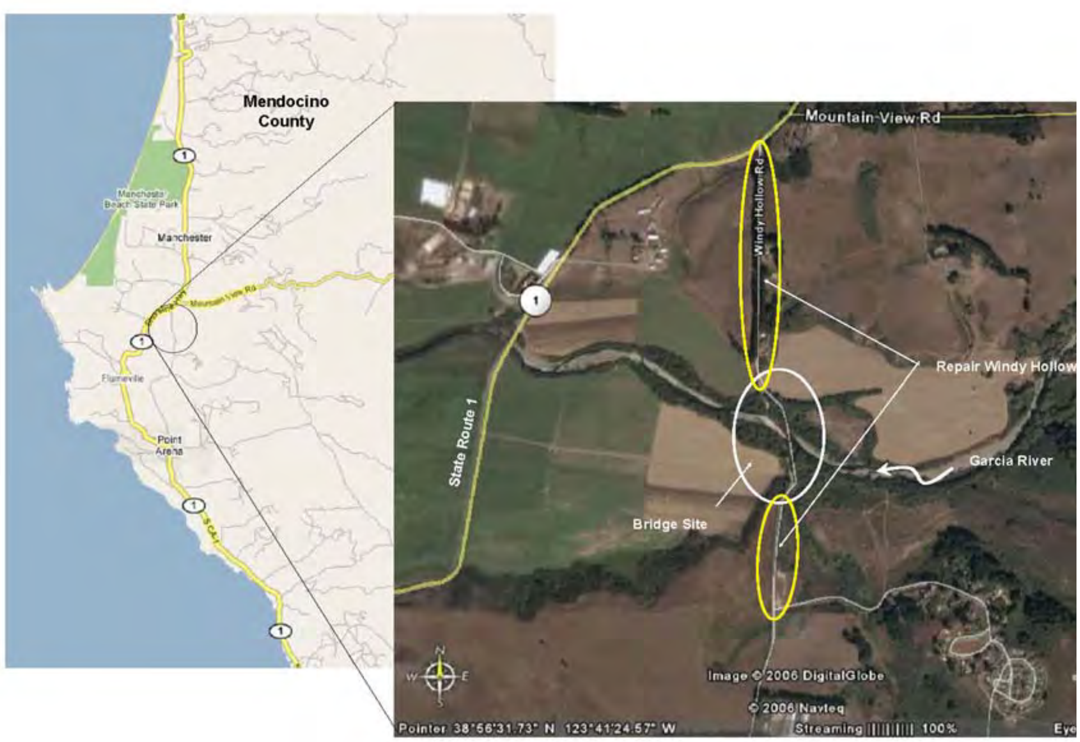


Figure 1 - Project Location

5. Roadway Design Considerations

The existing Windy Hollow Road is in very poor condition. The portion on the south side of the Garcia River, from Mamie Laiwa Drive to the river is currently closed to though traffic with a locked gate. The roadbed is cracked and overgrown, and will need complete rebuilding from the intersection with Mamie Laiwa Drive to the river, a distance of approximately 1,800 feet. On the north side of the river, the existing roadbed is also in very poor condition, with significant cracks and potholes. This roadway will need at minimum a new overlay, and depending on the subgrade condition, it may also require a complete rebuild. The distance from the river to the intersection with Highway 1 is approximately 2,800 feet.

The Windy Hollow Road approaches to the bridge at the Garcia River will need to be raised up to 15 feet to meet the new bridge deck elevation. Windy Hollow Road on the north side of the river is currently subject to flooding, so obviously the roadway approach on the north will need to be re-graded to eliminate the sag vertical curve in near the river. The Plan and Profile layout sheet shows the anticipated rise in the roadway surface.

For cost estimation purposes, it is assumed that the roadway cross section will be rebuilt to Mendocino County standards for a two-lane minor collector rural road. This is the current designation for Windy Hollow Road, and is consistent with the character of the roadway, especially after the bridge is constructed. The roadway will need a partial widening and rehab of the existing roadway, estimated at $8.50 per square foot of the gross roadway area. The total cost for the roadway work is estimated to be $1,600,000.

Right-of-Way

On the north side of the river, the county has a 40-foot wide right-of-way for Windy Hollow Road. The minor collector standard requires a minimum 70-foot right-of-way, so 30 feet of right-of-way will need to be acquired for the length of the road on the north side of the river. This road is approximately 2,800 feet long, so 84,000 square feet of right-of-way is needed. Assuming a cost of $50,000 per acre ($1.25/sf), this will add $100,000 to the project cost for the north side of the river.

The right-of-way on the south side of the river is entirely within the MPA Rancheria, so the availability for the county to build and maintain improvements depends on agreements with the Rancheria and the BIA. It is assumed that agreements are or will be made to operate and maintain this road, but if not, a cost to acquire right-of-way just outside of the Rancheria will be added to the project estimate. The road could be moved to the west approximately 150-feet to the west, for a distance of approximately 1800 feet. This would result in a right-of-way acquisition cost of $157,500 for the south approach.

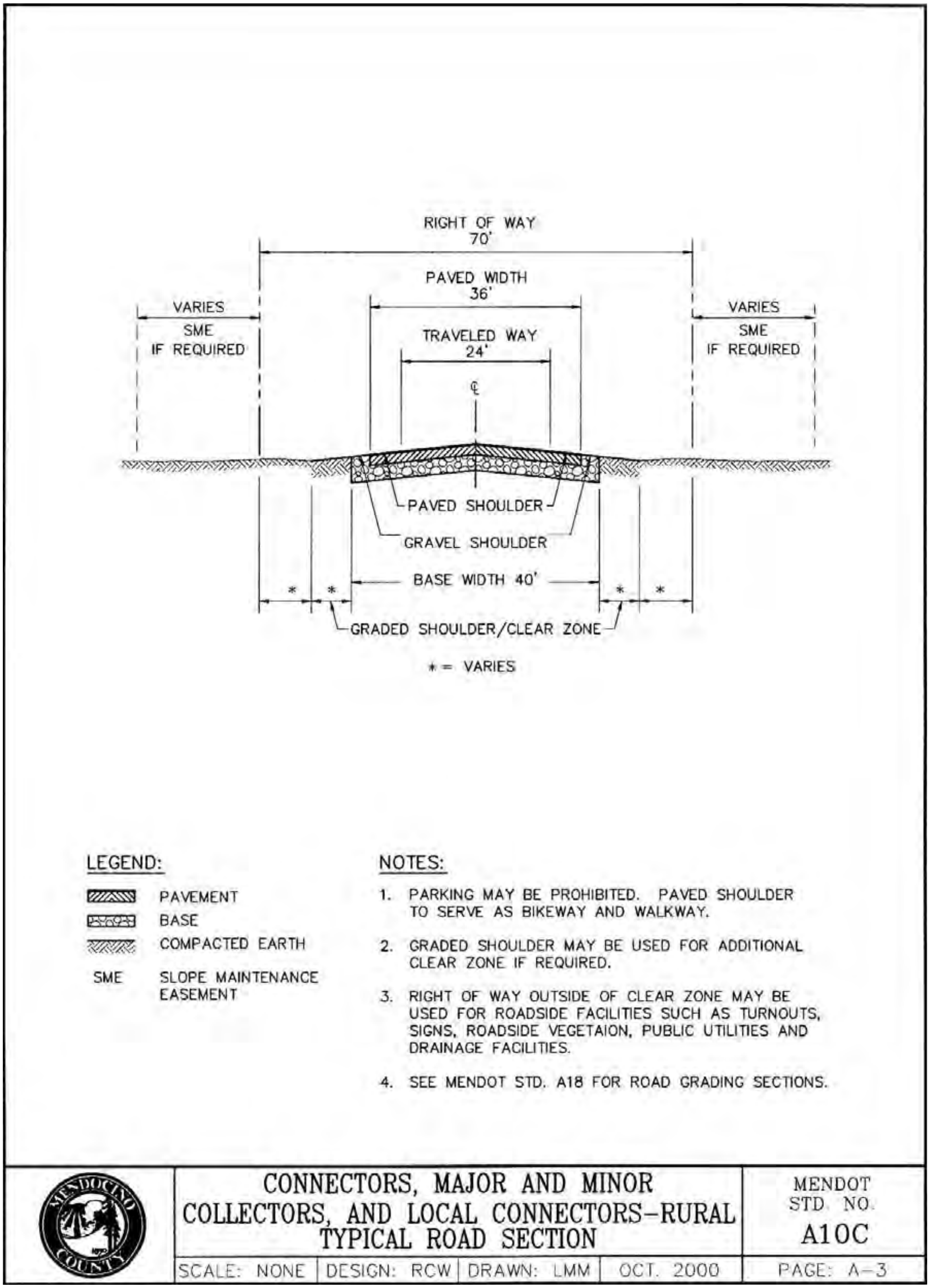


Figure 2 - Roadway Typical Section – Collectors

8. Cost Estimates

The following summary of estimated cost shows current costs based on 2006 data, and costs projected out to 2011 by applying a 25% cost escalation factor (5% per year). This estimate assumes a 690-foot long bridge over the river, widening and overlay for 4,600 feet of roadway and associated right-of-way and engineering support costs.

Project Cost Estimate (1,000's)			
		2007	**2011**
Bridge Items		$ 6,640	$ 8,330
Roadway Items		$ 1,400	$ 1,756
Total Construction Contract		$ 8,040	$ 10,086
Right-of-Way		$ 258	$ 258
Total Capital Costs		$ 8,298	$ 10,344
Support Costs			
Planning/Pre-Design	5%	$ 402	$ 504
Environmental	3%	$ 241	$ 303
Final Design	12%	$ 965	$ 1,210
ROW App/Acq	1%	$ 80	$ 101
Construction Engineering	10%	$ 804	$ 1,009
Total Support Costs		$ 2,492	$ 3,127
Total Project Cost		$ 10,790	$ 13,537

Figure 3- Windy Hollow Road Bridge Project Estimated Costs

It should be noted that these costs are higher than the costs shown at the poublic outreach meeting on January 20, 2007. The higher project cost is due to recent updates by Caltrans for construction cost data for the final quarter of 2006. Also, right-of-way costs were not considered in the prior estimate shown at the public meeting.

Attachment C

Adaptation Option Cost Estimates

Mendocino County

HWY 1 at the mouth of the Garcia River (PM 17.5 to 18.6) - 2050 Scenario

Item Description	Units	Quantity	Unit Cost	Total
Elevate the Road Prism - Option No. 1				
Mill and mix the existing roadway into subgrade	SY	9333	$7.50	$69,998
Embankment	CY	46670	$15	$700,050
Class II Aggregate Base (8")	CY	2225	$60	$133,500
Asphalt (Type A) (6")	TN	3220	$160	$515,200
Drainage culverts and swales	LS	1	$750,000	$750,000
Pavement Markings and Signage	LF	3500	$15	$52,500
Misc driveway /entrance reconstruction work	Ea	3	$4,000	$12,000
Seed and Mulch	SY	11670	$1.00	$11,670
Reconstruct livestock Fencing	LF	5000	$8	$40,000
Environmental mitigation	AC	7.23	$400,000	$2,892,000
Reconstrict small bridge	SF	4000	$66	$264,000
remove and reinstall guardrail	LF	400	$50	$20,000
SUBTOTAL (Non-Percentage Items)				$5,460,918
Mobilization	-	40%	$5,460,918	$2,184,367
Clear and Grub	-	15%	$5,460,918	$819,138
Erosion Control	-	5%	$5,460,918	$273,046
Maintenance of Traffic	-	5%	$5,460,918	$273,046
SUBTOTAL (Percentage Items)				$3,549,596
CONSTRUCTION TOTAL				$9,010,514
Project Approval & Environmental Documentation	-	8%	$9,010,514	$720,841
Plans, Specifications, & Estimates	-	10%	$9,010,514	$901,051
Construction Engineering	-	10%	$9,010,514	$901,051
PLANNING AND ENGINEERING COSTS				$2,522,944
TOTAL ESTIMATED COSTS				$11,533,458
Contingency	-	25%		$2,883,364
GRAND TOTAL				$14,416,822

Attachment D

Adaptation Option Scoring

No.	Adaptation Option (Select from List)	Enter Description or Comment	Assumed Values: Assumed Design Service Life	Assumed Values: Assumed Total Capital Investment	Assessment Criteria: Total Capital Investment	Assessment Criteria: Annual Average Cost	Assessment Criteria: Usable Life	Assessment Criteria: Level of Performance	Assessment Criteria: Flexibility	Assessment Criteria: Environmental Considerations	Assessment Criteria: Social Considerations	Total Score	Rank
Project Location: HYW 1 Mendocino County PM PM 17.5 to 18.6 2050/2100				Weight >>	3.7	11.1	18.5	25.9	7.4	14.8	18.5		
1	Elevate the infrastructure above the impact zone	*Increase height of roadway 2 ft above 100 yr coastal hazard elevation including 24 inches of SLR (A2 Scenario @2050). Project would incorporate new culverts and raising/ replacing Hathaway Creek Bridge*	100	14,420,000	1: $10M - $100M	0: >$100,000/yr	2: Acceptable	3: Enhanced	1: Unlikely	-2: Some net impact	3: Significant net improvement	152	3
2	Elevate the infrastructure above the impact zone	*Construct a causeway, across the Garcia River Flood plain and Hathaway Creek at a height of 5 ft above 100 yr coastal hazard elevation including 24 inches of SLR A2 Scenario @2050).*	100	15,520,000	1: $10M - $100M	0: >$100,000/yr	3: Surpasses	3: Enhanced	0: None	-1: Very little net impact	3: Significant net improvement	178	1
3	Relocate infrastructure (horizontally)	*Re-route Highway 1 along Windy Hollow Rd*	100	35,570,000	1: $10M - $100M	0: >$100,000/yr	2: Acceptable	3: Enhanced	3: Likely (or unnecessary)	-2: Some net impact	3: Significant net improvement	167	2
4	Temporarily restrict use of infrastructure	*Temporarily re-route Highway 1 long Windy Hollow Rd during periods of flooding*	50	25,410,000	1: $10M - $100M	0: >$100,000/yr	1: Considerable, but insufficient	1: Decreased	2: Potentially	-1: Very little net impact	2: Some net improvement	85	4
5	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate	*Temporary close/ reroute during flooding (Assume closure 6 times per year in 2050 @ 12 hours average and 12 per year in 2100 @ 18 hours average)*	20	219,600,000	0: > $100M	0: >$100,000/yr	0: Minimal (or temporary)	1: Decreased	3: Likely (or unnecessary)	-1: Very little net impact	-3: Significant net impact	-22	5
6	Provide major structural protection	*Install flood protection berms along roadway above 100 yr. coastal hazard elevation including 24 inches of SLR (A2 Scenario @2050). Project would incorporate new culverts and raising/ replacing Hathaway Creek Bridge*											
7	Abandon Infrastructure	*Not Considered further due to lack of existing redundant route*											

Top Scoring Adaptation Options

Rank	Adaptation Option	Project Description	Score
1	Elevate the infrastructure above the impact zone	Construct a causeway, across the Garcia River Flood plain and Hathaway Creek at a height of 5 ft above 100 yr coastal hazard	178
2	Relocate infrastructure (horizontally)	Re-route Highway 1 along Windy Hollow Rd	167
3	Elevate the infrastructure above the impact zone	Increase height of roadway 2 ft above 100 yr coastal hazard elevation including 24 inches of SLR (A2 Scenario @2050). Project	152
4	Temporarily restrict use of infrastructure	Temporarily re-route Highway 1 long Windy Hollow Rd during periods of flooding	85
5	Increase the infrastructure's maintenance and inspection interval and continue to	Temporary close/ reroute during flooding (Assume closure 6 times per year in 2050 @ 12 hours average and 12 per year in 2100 @ 18	-22

Attachment E

Adaptation Option Summary/Timeline Evaluation

Attachment F: Adaptation option summary

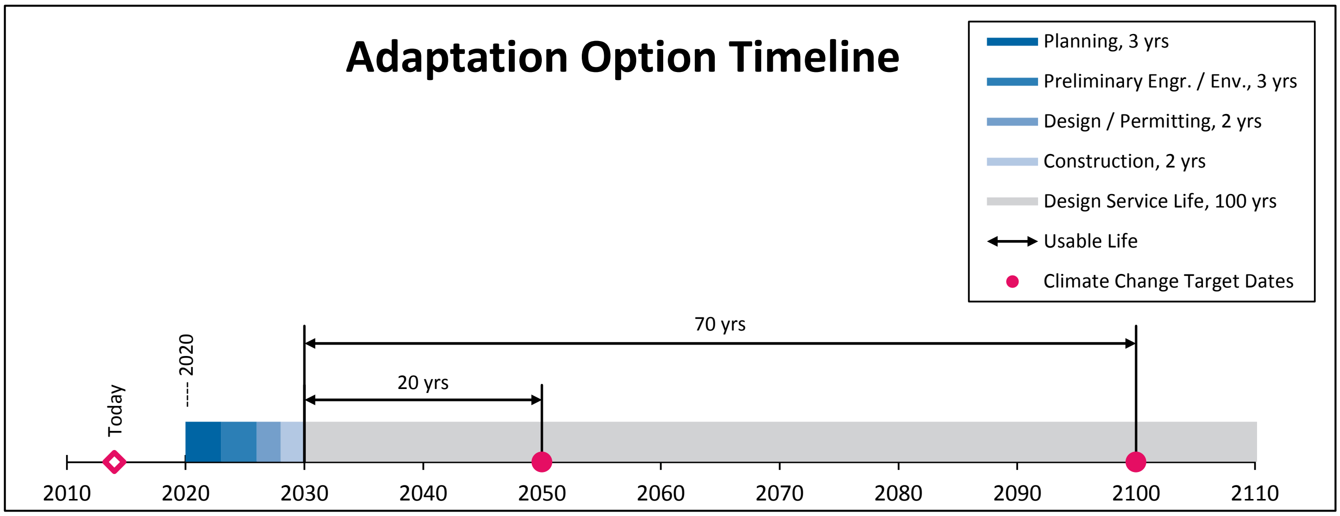
Project Location	HYW 1 Mendocino County PM PM 17.5 to 18.6 2050/2100
Adaptation Option	Relocate infrastructure (horizontally)
Project Description	**Re-route Highway 1 along Windy Hollow Rd**

Anticipated Process Times	Years
Planning	3
Preliminary Engr. / Env.	3
Design / Permitting	2
Construction	2
Total Process Time[1]	**10**

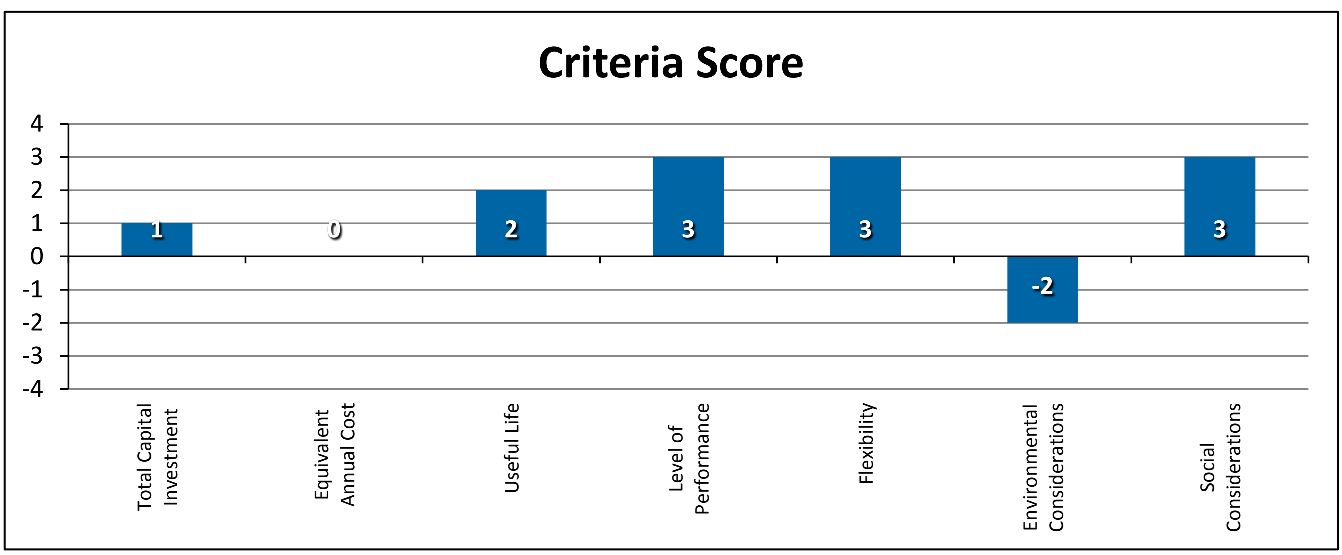
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$35,570,000
Equivalent Annual Cost	$355,700
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2100



Usable life if designed for	Years
2050 Climate Projection	20
2100 Climate Projection	70



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

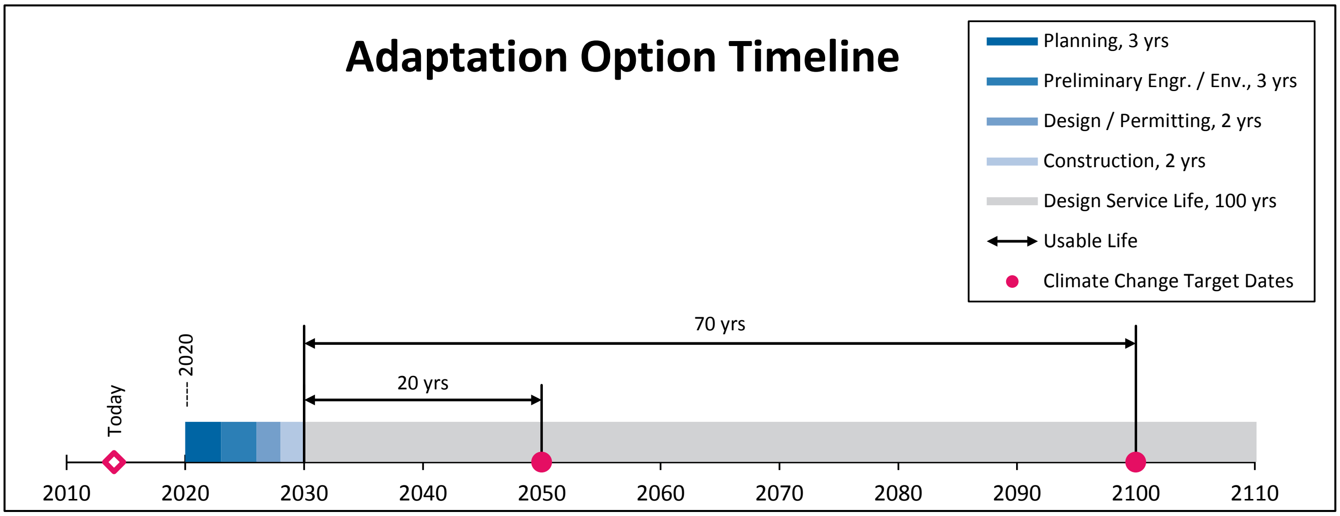
Project Location	HYW 1 Mendocino County PM PM 17.5 to 18.6 2050/2100
Adaptation Option	Elevate the infrastructure above the impact zone
Project Description	**Construct a causeway, across the Garcia River Flood plain and Hathaway Creek at a height of 5 ft above 100 yr coastal hazard elevation including 24 inches of SLR A2 Scenario @2050).**

Anticipated Process Times	Years
Planning	3
Preliminary Engr. / Env.	3
Design / Permitting	2
Construction	2
Total Process Time[1]	**10**

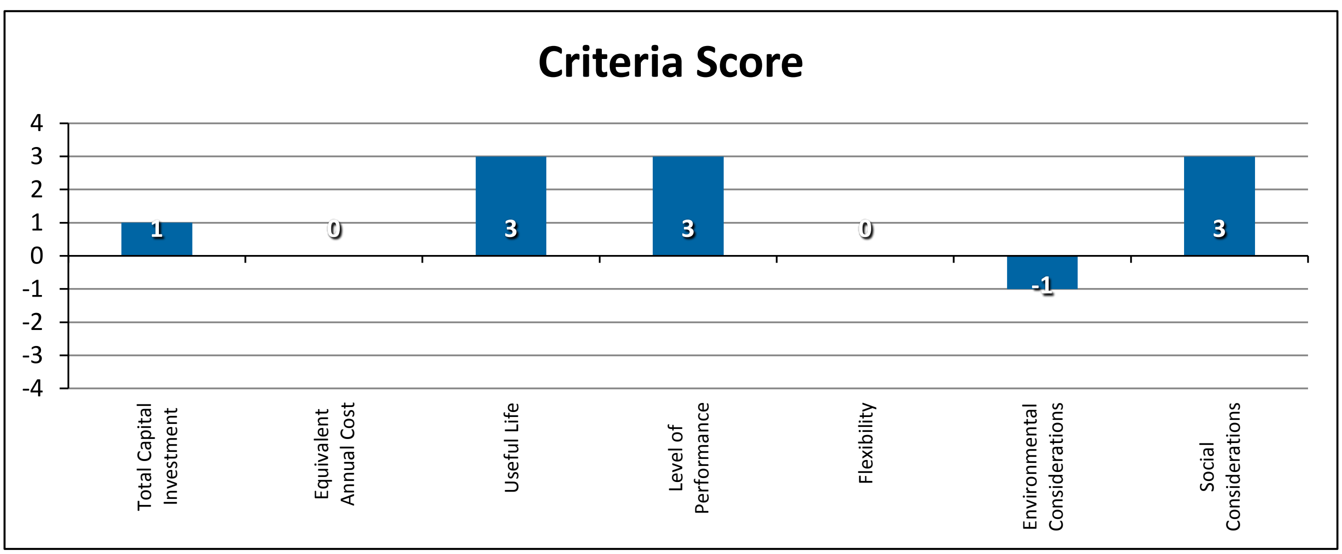
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$15,520,000
Equivalent Annual Cost	$155,200
Design Service Life (yrs)	100

Key Dates	
Current Year	2014
Climate Change Horizon	2100



Usable life if designed for	Years
2050 Climate Projection	20
2100 Climate Projection	70



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

Attachment F: Adaptation option summary

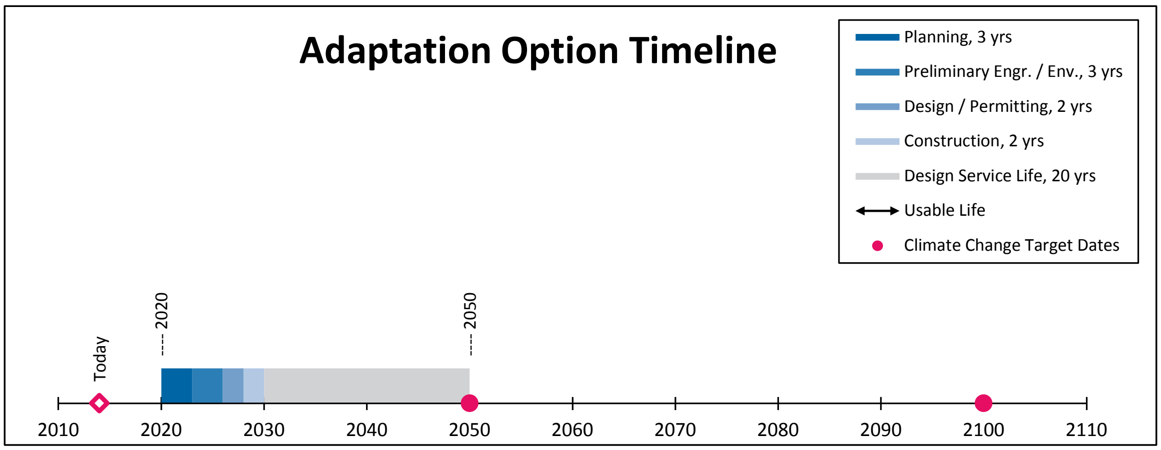
Project Location	HYW 1 Mendocino County PM PM 17.5 to 18.6 2050/2100
Adaptation Option	Increase the infrastructure's maintenance and inspection interval and continue to monitor/evaluate
Project Description	**Temporary close/ reroute during flooding (Assume closure 6 times per year in 2050 @ 12 hours average and 12 per year in 2100 @ 18 hours average)**

Anticipated Process Times	Years
Planning	3
Preliminary Engr. / Env.	3
Design / Permitting	2
Construction	2
Total Process Time[1]	**10**

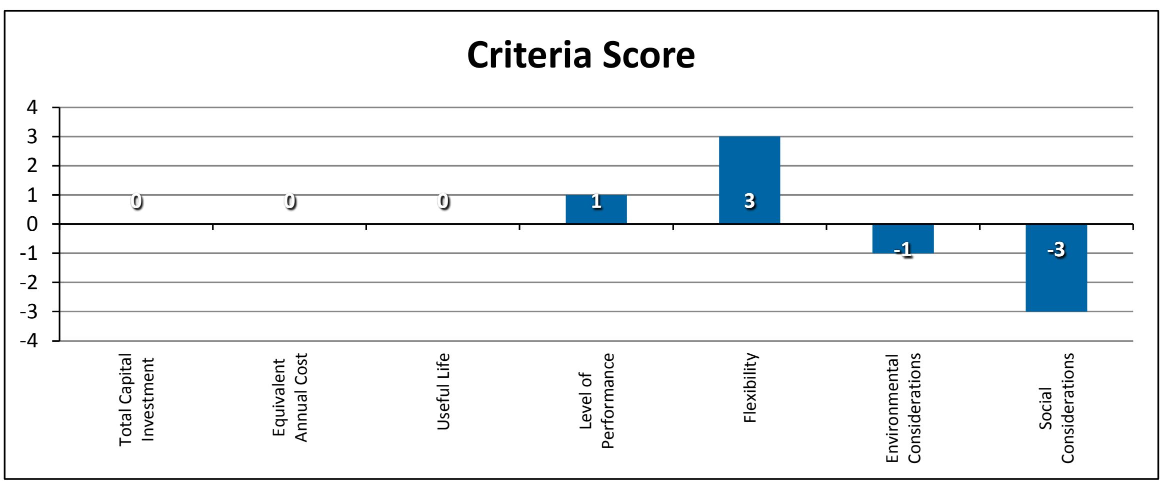
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$219,600,000
Equivalent Annual Cost	$10,980,000
Design Service Life (yrs)	20

Key Dates	
Current Year	2014
Climate Change Horizon	2100



Usable life if designed for	Years
2050 Climate Projection	20
2100 Climate Projection	70



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

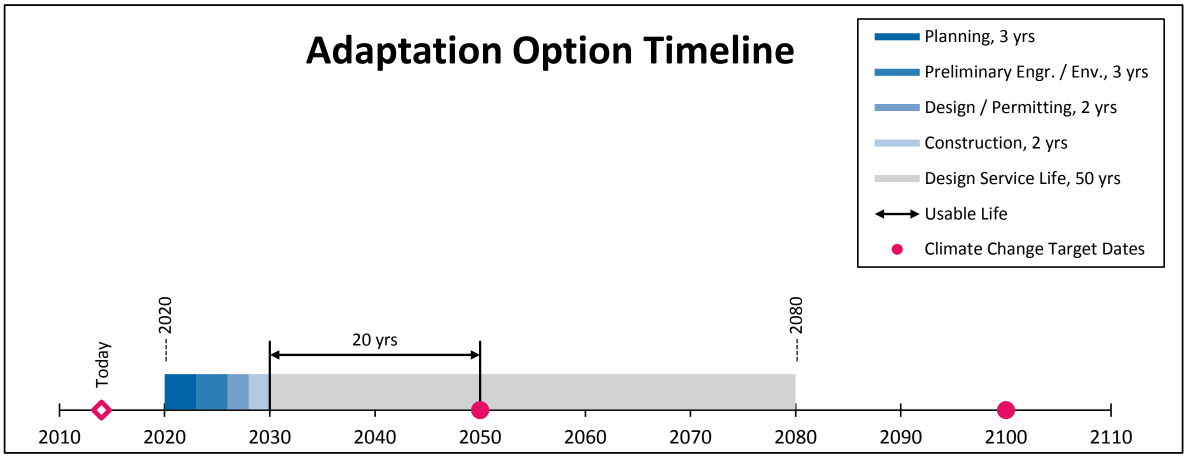
Project Location	HYW 1 Mendocino County PM PM 17.5 to 18.6 2050/2100
Adaptation Option	Temporarily restrict use of infrastructure
Project Description	**Temporarily re-route Highway 1 long Windy Hollow Rd during periods of flooding**

Anticipated Process Times	Years
Planning	3
Preliminary Engr. / Env.	3
Design / Permitting	2
Construction	2
Total Process Time[1]	**10**

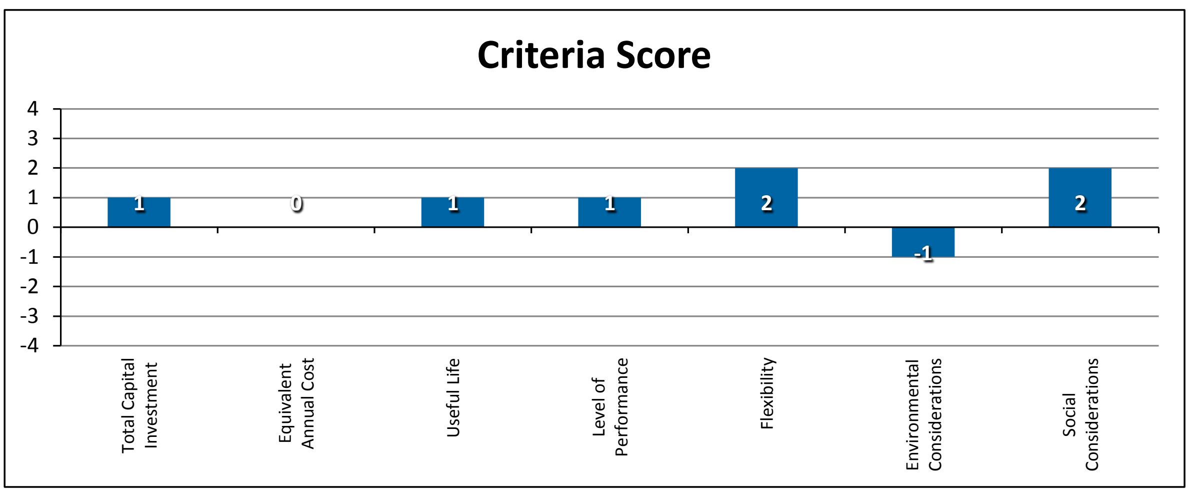
Desired Initiation Date	2020

Assumed Values	
Total Capital Investment	$25,410,000
Equivalent Annual Cost	$508,200
Design Service Life (yrs)	50

Key Dates	
Current Year	2014
Climate Change Horizon	2100



Usable life if designed for	Years
2050 Climate Projection	20
2100 Climate Projection	70



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

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Design / Permitting	2
Construction	2
Total Process Time[1]	**10**

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Key Dates	
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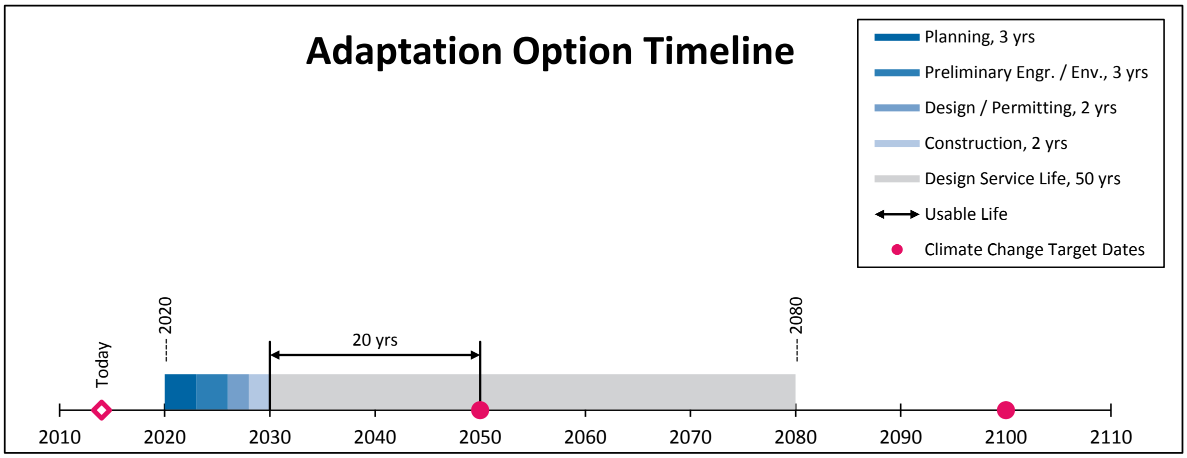
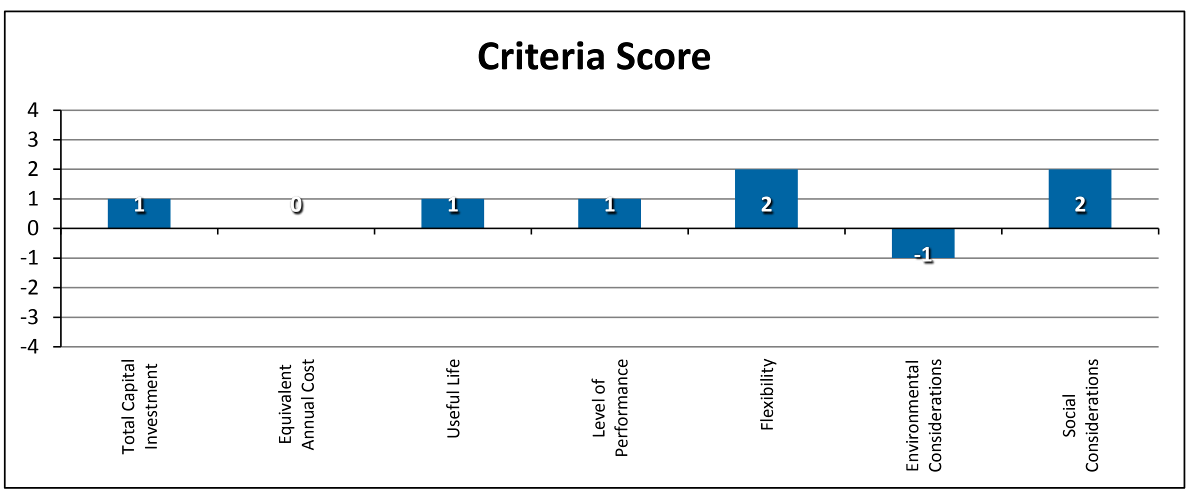


Usable life if designed for	Years
2050 Climate Projection	20
2100 Climate Projection	70



Notes:

1. Process times will likely overlap. Adjust as necessary to represent the estimated length of time for the total length of process time.

Appendix 10

Stakeholder and Public Meeting Summary

Stakeholder and Public Meeting Summary

Stakeholder Meeting Notes

1. **Introductions (5 mins)**
   a. Project team and stakeholders present
   b. Review project objectives

   Project team and stakeholders were introduced, and the project's objectives were reviewed. An update of the project status and process was briefly explained.
2. **Review schedule and process (10 minutes)**
   a. Review roles/responsibilities of Stakeholders.

   This part of the agenda was provided in case any stakeholders needed clarification or reminders of roles. This was not needed at any of the locations.
3. **Adaptation criteria (15 minutes)**
   a. Description of adaptation process
   b. Review adaptation criteria
   c. Adaptation option criteria scoring

   The adaptation options selection process was described, and the role of the criteria scoring sheet explained. Stakeholders were walked through examples of how to prioritize criteria and were asked to rank them on a scale of 1-8, where 8 is most important and 1 is least. Stakeholders were asked to return completed score sheets by September 2.

Public Meeting Notes

6:00 PM: Welcome and Introductions

Brad Mettam introduced the project study team at the Humboldt, Lake, and Mendocino meetings. At the Del Norte meeting, Tamera Leighton opened the meeting and then handed it over to Brad, who then introduced the project study team.

6:10 PM: Presentation

At the Del Norte, Lake, and Mendocino meetings, Rob Holmlund and Jessica Hall walked the audience through the project purpose and background, projected climate change impacts, prototype planning sites, and adaptation options. At the Humboldt meeting, Aldaron Laird joined Holmlund and Hall in this presentation to focus on sea level rise impacts to Humboldt Bay.

6:50 PM: Discussion

While there was some question/answer during the presentations, the study team broke the audience up to vote on adaptation options and scoring criteria. At the Humboldt meeting, small group discussions were conducted followed by free-form voting with stickers. Stickers were color-coded to the different displays. After this meeting, it was decided that a clearer way to conduct this portion of the meeting is to have an "expert" stationed at both the adaptation options and the scoring criteria – the expert would engage the public in question/answers on a one-on-one or small group basis. The audience would then be enabled to roam freely between adaptation and criteria displays, voting with less time pressure. It was also decided to use 3 stickers for each set of displays, forcing the audience to prioritize. This approach was taken for the Del Norte, Lake, and Mendocino County meetings.

7:20 PM: Final Q & A, Closing comments

At the Humboldt meeting, it was noted that it was difficult to bring the group to closure with the small groups, voting, and mingling happening simultaneously. At the following meetings, the approach was adapted to study team mingling with audience members until the announcing of the scores of the voting.

7:30 PM: Adjourn Meeting

Meeting were all adjourned by 7:30pm.

Comments from the Meetings

Some comments were taken during presentations. Stakeholders and members of the public were also invited to provide written feedback on comment sheets posted around the room, as well as on the displays for the adaptation options and adaptation criteria scoring. These comments are transcribed below, as well as the counts for the sticker-voting to prioritize adaptation options and adaptation criteria.

8/25 – Humboldt

Stakeholder's Meeting

Scoring discussion unclear- 0 to 3 or 1 to 3?

Questions raised about implementation timeframe and short term projects, how valued

Ranking of environmental scoring.

Public Meeting

Rating criteria seemed linked, "kind of squishy" and too vague.

Criteria seemed to overlap

Will Caltrans really consider all these criteria?

Missing criteria:

> Impacts to other roadways/network. Not necessarily impacted by climate change, but about traffic re-routing
>
> Impacts to other means of transporation
>
> Break out social considerations

Criteria vs. infrastructrure/property control

Can you really look at criteria without knowing adaptation options?

Paradigm of present – car-centric. No mention of shift to other mode. Work with other agencies?

What would be alternate routes?

Offshore armoring and baffles with wetland buffer west of highway

(look to) examples elsewhere

Roads getting larger/size of vehicles (speaker was objecting to this trend)

Work with regulatory agencies to expedite permitting

Farmland protection.

Criteria Votes

Criteria	Comment	Votes
Equivalent Annual Cost	"considers life cycle costs"	12
Social Considerations	"Please consider those for whom transportation issues complicate their access to needed resources specifically those populations impacted by socio-economic/geographic factors. (Are these voices being invited/represented during these discussions?)"	22

	"Impacts to other roadways" "Other transportation options"	
Environmental Considerations	"Develop transportation options away from auto-centric."	22
Level of Performance		19
Flexibility	"Get regulatory agencies to come up with better or transfer landowners" *(sic)*	23
Usable Life		5
Implementation Timeline		5
Total Capital Investment		4

Options

Option	**Comment**	**Votes**
Raise bridges and road	"seems practical"	25
Protect roads with armoring/living shorelines	"win/win if combined"	74
Manage with closure – no changes		18
Causeway	"to stylish" *(sic)*	52
Re-route road	"very expensive and splits habitat"	34

8/26 – Del Norte

Geologic events – earthquake impacts on roads

What county in the Bay Area did the FHWA study? (we said we will post to web)

Is it safe to assume that larger cut slopes in road work are safer/not safe when you think of climate change?

Storm surges already affecting South Beach

Many geologic events, not just Last Chance Grade

Dr. Klein bridge design life

2012 IPCC criticized – its worst case scenario is too conservative

Limited population here. How balance criteria? What mechanism would be used? Equilibrium in ranking needed.

- No alternate route
- Not a question of if but when
- Serves region not just Del Norte County

Consider a tunnel for Last Chance Grade. This would save a lot of erosion.

Consider earthquakes. Plan around the Cascadia event.

Hold off large projects due to eqs.

Tunnel not feasible. Too expensive

Use state park/Mill Creek/Yurok lands to re-route

Add “safety” to criteria.

Changing state of the art of climate change modeling

LCG could fail at any time.

Criteria Votes

Criteria	**Comment**	**Votes**
Equivalent Annual Cost		6
Social Considerations		3
Environmental Considerations		4
Level of Performance	“does this include safety?”	24
Flexibility		2
Usable Life		11
Implementation Timeline		1
Total Capital Investment		12

Options-Last Chance Grade

Option	Comment	Votes
Defend road		0
Re-route road	"move Last Chance Grade inland. The state park known as mill creek is owned by the state. The Yurock Reservation lands are adjoining at Wilson Creek" *(sic)*	63

Options-Coastal i.e. South Beach

Option	Comment	Votes
Raise bridges and road		6
Protect roads with armoring/living shorelines	"Concrete sea wall board walk south beach"	2 (hard armoring) / 7 (living shorelines)
Manage with closure – no changes	"Manage with closure until verification a problem exists"	0
Causeway		5
Re-route road	"move 101 up to Oceanview Drive"	39

8/27 – Lake

Comments

18 wheelers on Highway 20 are hard on the road between here (Lakeport) and Clearlake Oaks. Road will give way. Economic reason to go down 20 and cost?

> *A response made by a local stakeholder is that there is a fairly recent change to shift large trucks to Highway 29. Arterial route 53 to 29 coming in 2-3 years. This will include passing opportunities to make that road more desirable. Also likely to also see traffic calming on Highway 20.*

Criteria Votes

Criteria	**Comment**	**Votes**
Equivalent Annual Cost		2
Social Considerations		1
Environmental Considerations	"too many problems caused by not evaluating impacts on environmental resources"	13
Level of Performance		6
Flexibility	"like how it can be adapted to future conditions"	6
Usable Life		7
Implementation Timeline		2
Total Capital Investment		2

Options

Option	**Comment**	**Votes**
Raise bridges and road (explained in this context as levees with roads atop)		14
Manage with closure – no changes		1
Causeway	"like how it won't block water flow" "smaller footprint than other choices"	28
Re-route road		3

8/28 - Mendocino

Better community notice

Get Caltrans to stop clearing trees, destroying wetlands, and building freeways near oceans. No more mountaintop removal please, as in Willits Bypass.

Criteria Votes

Criteria	Comment	Votes
Equivalent Annual Cost		0
Social Considerations	“does the community feel it is necessary?” “is it needed?” “do you have their approval or consent or do they disapprove?” “what are their thoughts and ideas?”	2
Environmental Considerations	“impacts on all aspects” “required by NEPA/CEQA already”	5
Level of Performance		3
Flexibility		6
Usable Life	“invest in something that will last”	9
Implementation Timeline		2
Total Capital Investment		2

Options

Option	Comment	Votes
Raise bridges and road		1
Manage with closure – no changes	“required to be studied (do nothing) but creates “road blocks” after predicted events in future service life”	
Causeway	“viaduct that allows normal esuary functions, build to survive (minimal damage) max cred. earthquake" (*sic)*	13
Re-route road	“always possible but would be costly”	16

Public Meeting Attendance Counts

Meeting	Stakeholder	Public	Caltrans Employees at Public Mtg *(counted in total)*
8/25 Humboldt	16	54	14
8/26 Del Norte	15	33	3
8/27 Lake	9	21	4
8/28 Mendocino	11	11	4
Total	51	119	25

PUBLIC WORKSHOP ANNOUNCEMENT

CLIMATE CHANGE

HOW WILL IT AFFECT YOU?

JOIN US at a **public workshop** about climate change impacts to our state road system. The workshop will also present potential strategies for adapting to climate change.

How are climate change factors likely to impact our region?

Which transportation facilities are the most vulnerable to climate change?

What are some potential solutions?

How will we adapt to ***coastal erosion at Last Chance Grade?***

WHEN & WHERE

Tuesday, August 26
6:00-7:30pm
Elk Valley Rancheria
Community Center
2298 Norris Avenue
Crescent City, CA

WORKSHOP DETAILS

6:00 pm:	Presentation on regional Climate Change impacts and vulnerability
6:45 pm:	Public breakout sessions

This project is funded by the Federal Highway Administration and Caltrans and is conducted in partnership with Regional Transportation Planning Agencies.

Caltrans · Del Norte Local Transportation Commission · Humboldt County Association of Governments · LAKE APC · MCOG

Prepared by:

GHD

For more information, contact:
Jessica Hall at GHD, (707) 443-8326

PUBLIC MEETING

Climate Change Vulnerability Assessment & Pilot Project

Tuesday, August 26, 2014
6:00-7:30 PM

Elk Valley Rancheria Community Center
2298 Norris Avenue,
Crescent City, CA

AGENDA

6:00 PM:	Welcome and Introductions
6:10 PM:	Presentation
6:50 PM:	Discussion
7:20 PM:	Final Q & A, Closing comments
7:30 PM:	Adjourn Meeting

The Climate Change Vulnerability Assessment and Pilot Project is a study funded by the Federal Highways Administration, led by Caltrans and the Humboldt County Association of Governments, with the involvement of the Del Norte Local Transportation Commission and other North Coast Regional Transportation Planning Authorities.


CLIMATE CHANGE
Vulnerability Assessment & Pilot Project
Photo: Caltrans
Prepared for:
Prepared by:

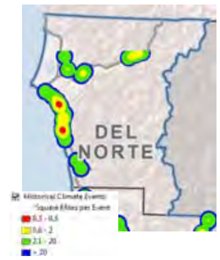

NBC NEWS
Scientists More Certain Than Ever on Climate Change, Report Says

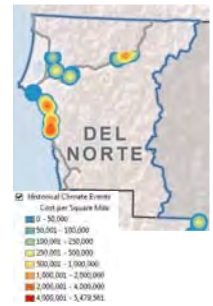

Courtesy of CALTRANS

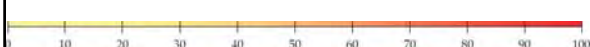

Photo: Brian Birke, Creative Commons Attribution License

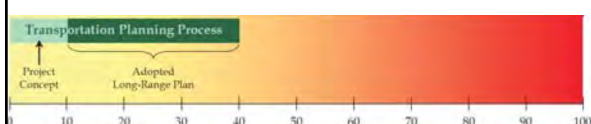

Photo: laffy4k, Creative Commons Attribution License

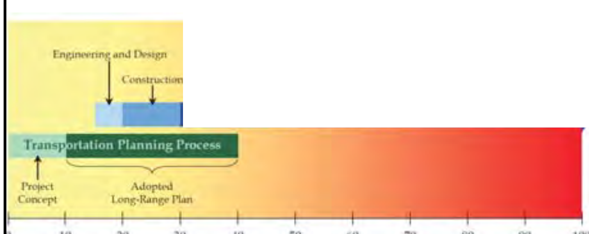
Historic Maintenance Events

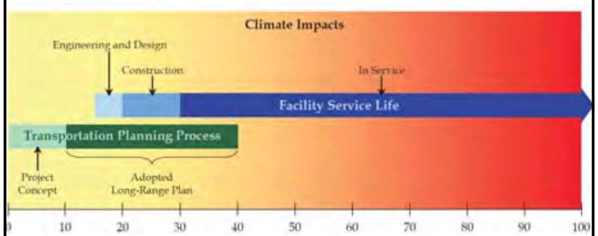


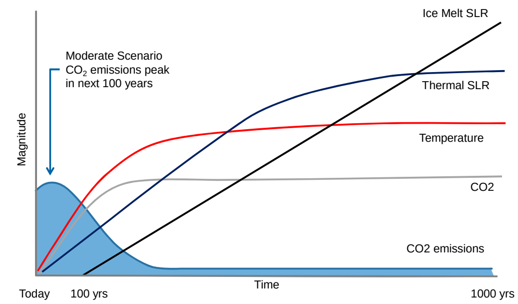












Climate Change Scenarios

2050

Extreme Climate Change Models

Moderate Climate Change Models

PROJECT HISTORY

2008 Gulf Coast Study

↓

FHWA Conceptual Model for Climate Change Vulnerability Assessments

↓

2010 Pilot Studies (5)

↓

FHWA Climate Change & Extreme Weather Vulnerability Assessment Framework

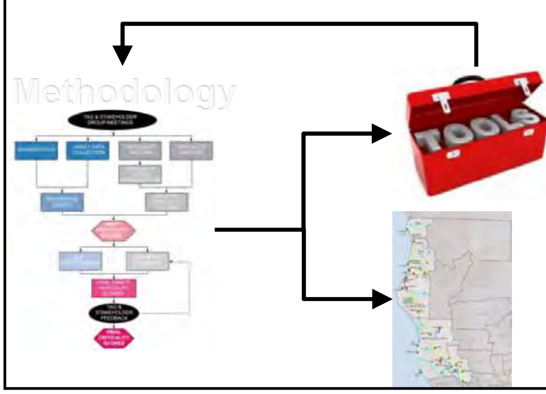
↓

2013 Pilot Studies (19)

↓

?

D1CCPS Project: Process vs. Product

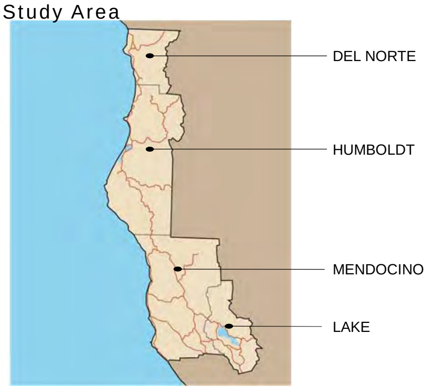


Project Objectives

1. Identify **Vulnerabilities**

2. Analyze **Adaptation Options**

Study Area



Identify vulnerabilities

What is *vulnerability?*

Exposure

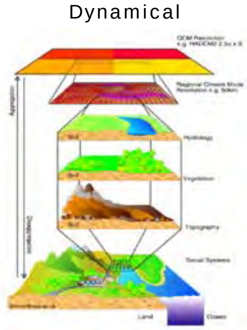
Climate Change Effects

- Temperature
- Precipitation
- Runoff
- Sea level rise
- Coastal erosion hazards
- Wildfire

Moderate & Extreme changes at 2050 and 2100

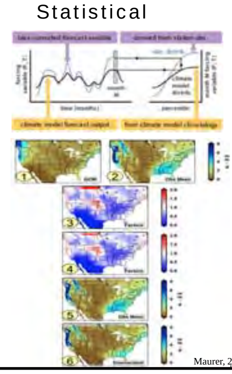
How do we know?

Dynamical



David Viner, Climatic Research Unit, University of East Anglia, UK

Statistical

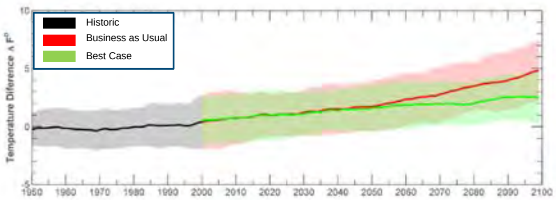


Maurer, 2008

RESULTS OF EXPOSURE ANALYSIS

Climate Change Effects

Changes in Average Daily
Maximum Temperature



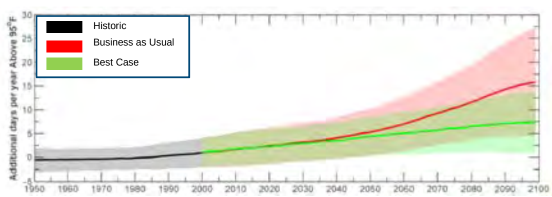
Del Norte County

DEL NORTE
+2.8 to 3.2°F - 2050
+4.0 to 6.7°F - 2100

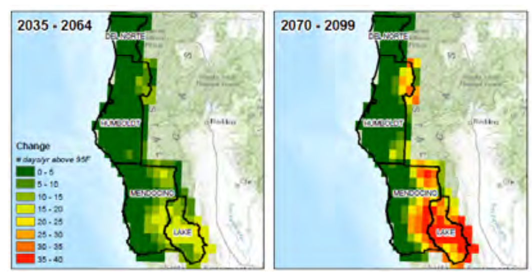
Increased average temperature

Climate Change Effects

Extreme Temperature
(additional days above 95F)



Extreme Temperatures



Increased days above 95°F.

Sea Level Rise

King Tides Rising

Sea Level Rise

2000 0 in

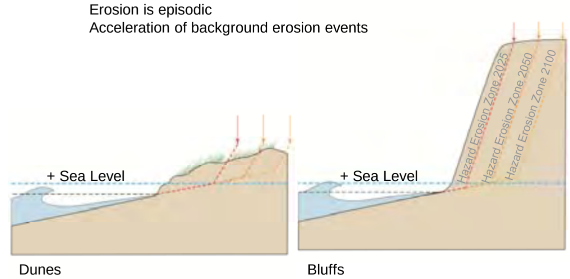
2050
12-14 in

2100
36-55 in

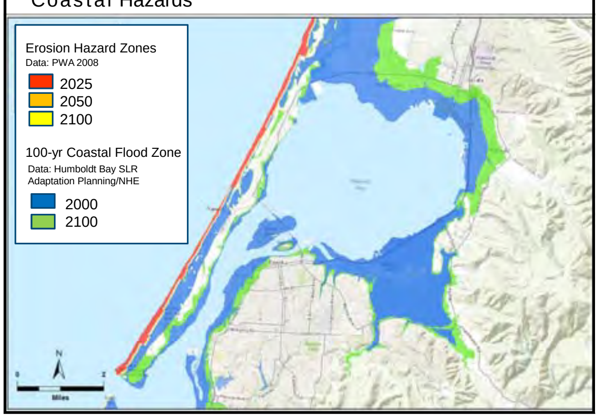
2100+ ?? in

Coastal Erosion

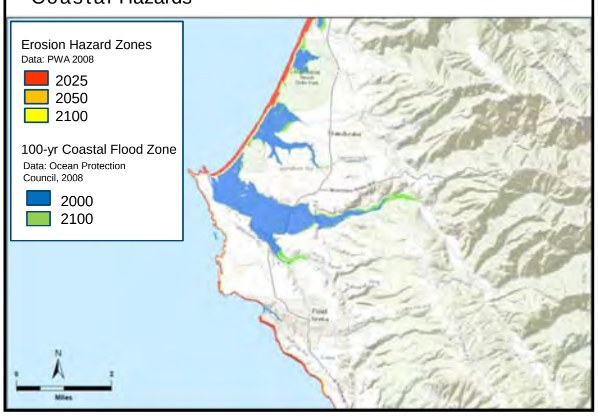
Erosion is episodic
Acceleration of background erosion events



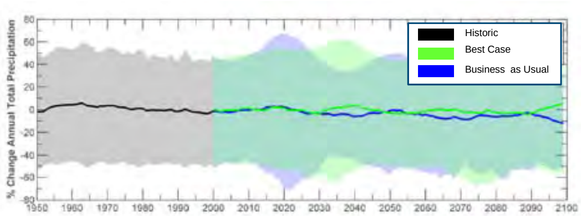
Coastal Hazards



Coastal Hazards



Rainfall change



Del Norte County

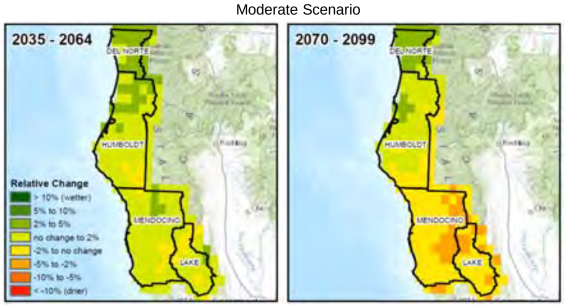
DEL NORTE

-3% to 0%	2050
-5.6 to 0.6%	2100

Changes in average rainfall

Extreme Precipitation

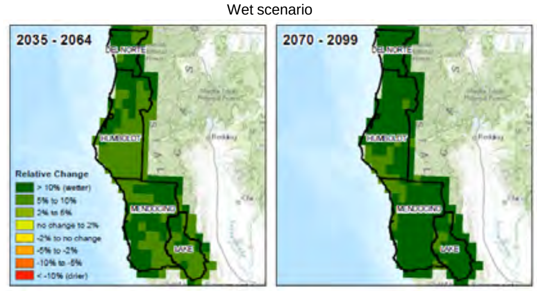
Moderate Scenario



Changes in extreme rainfall

Extreme Precipitation

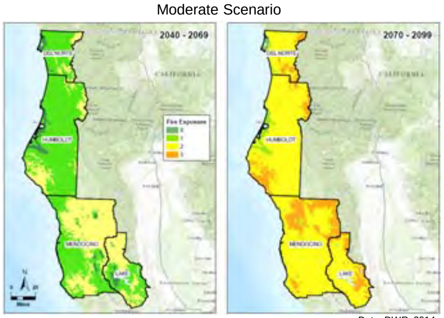
Wet scenario



Changes in extreme rainfall

Wildfire Exposure

Moderate Scenario



Changes wildfire risk

Data: DWR, 2014

What is "Potential for Impact"

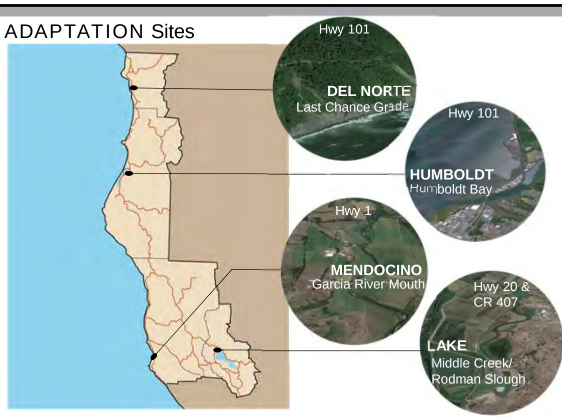
Delay

Temporary Closure – Damage

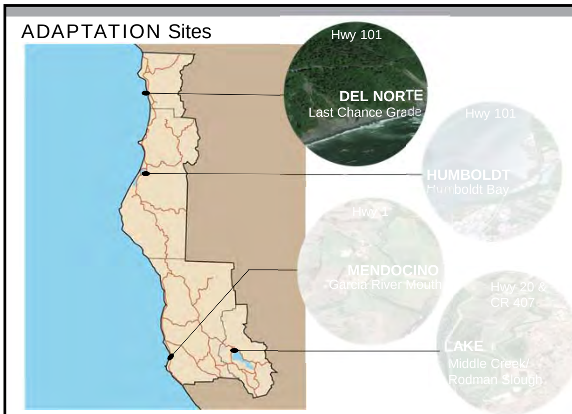
Failure

ADAPTATION Prototype Sites

ADAPTATION Sites



ADAPTATION Sites

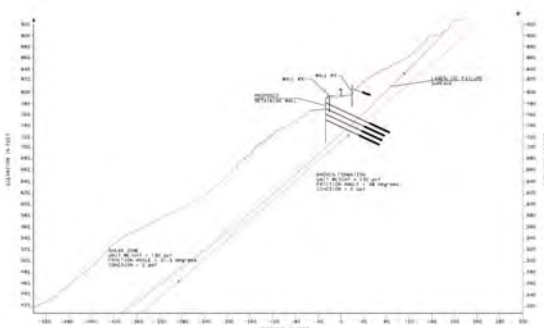


Del Norte County

Last Chance Grade

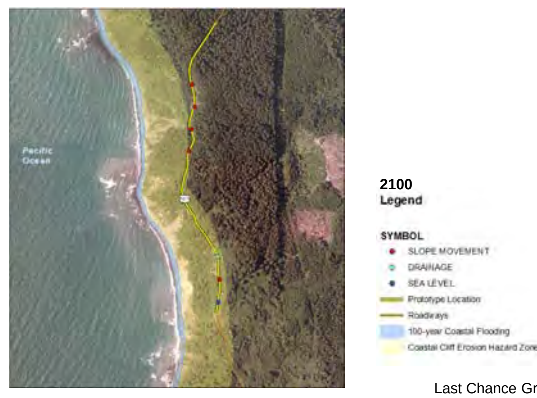
Del Norte County

Last Chance Grade



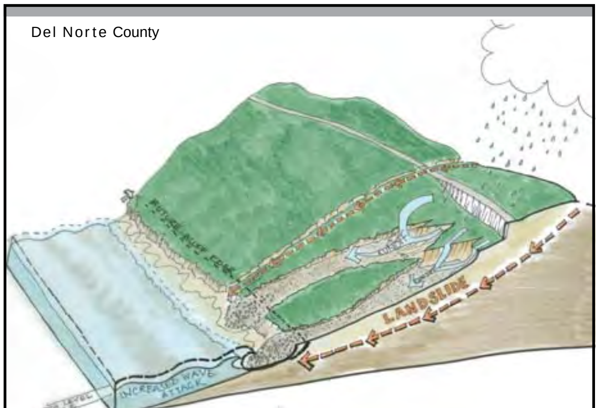
The ELB wall design attempted to go behind the presumed slide plane.

Del Norte County



Last Chance Grade

Del Norte County



Last Chance Grade

Del Norte County

Del Norte County

Del Norte County

Del Norte County

Del Norte County

Del Norte County

Del Norte County

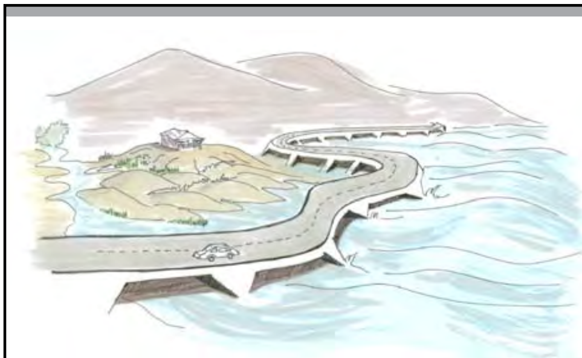
ADAPTATION Options

Adaptation approaches

Existing

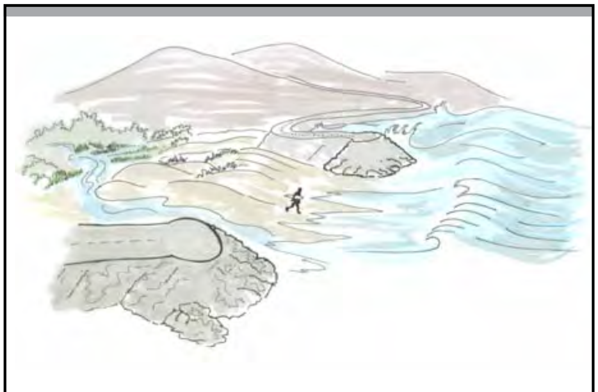
Adaptation approaches

Defend



Adaptation approaches

Adapt

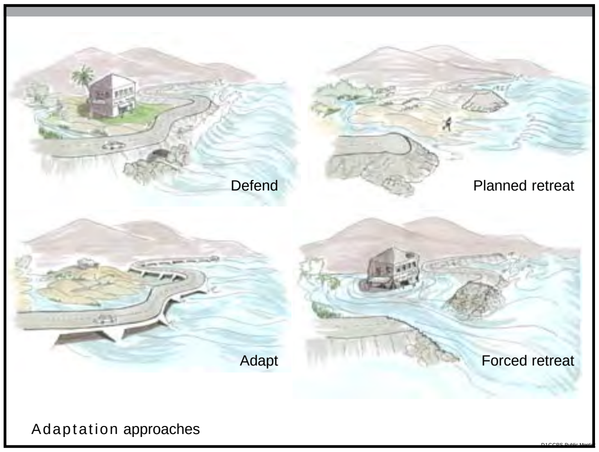


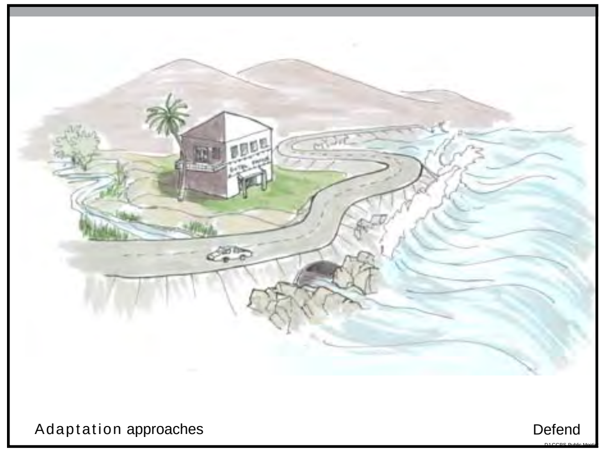
Adaptation approaches

Planned Retreat

Adaptation approaches

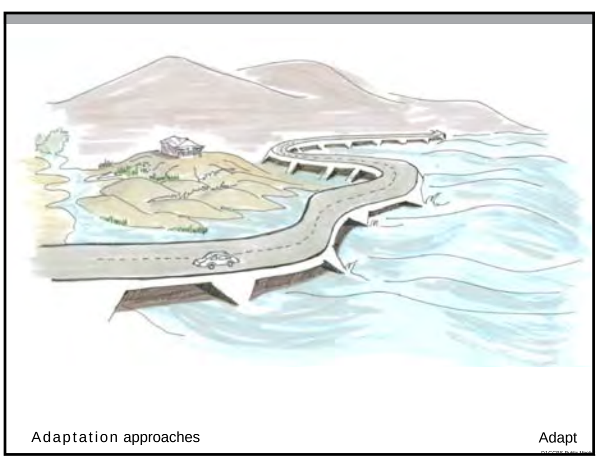
Forced Retreat

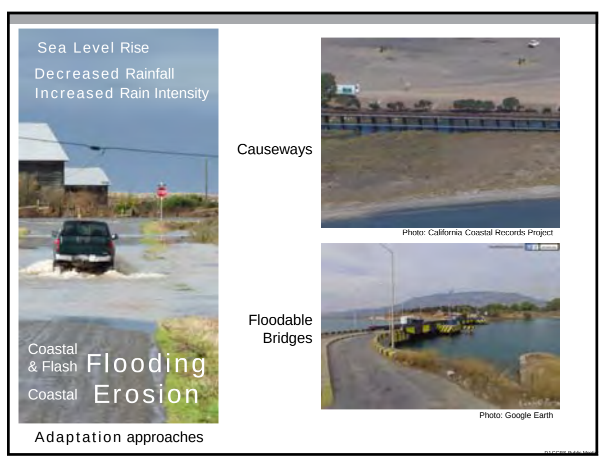

Defend
Planned retreat
Adapt
Forced retreat
Adaptation approaches

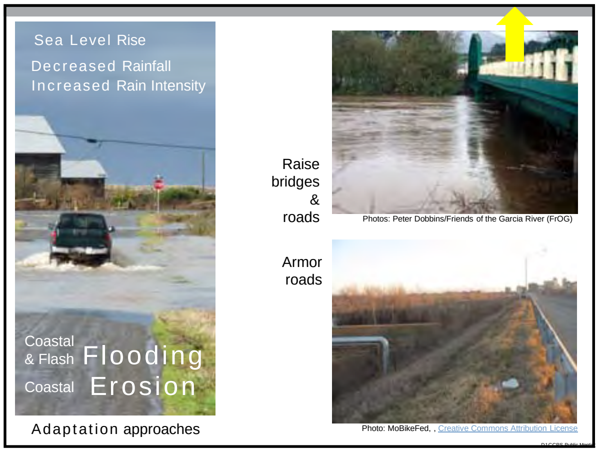

Adaptation approaches
Defend


Sea Level Rise
Decreased Rainfall
Increased Rain Intensity
Coastal & Flash Flooding
Coastal Erosion
Flood Walls
Sea Walls
Levees
Dikes
Living shoreline
Adaptation approaches
Photo: GoogleEarth

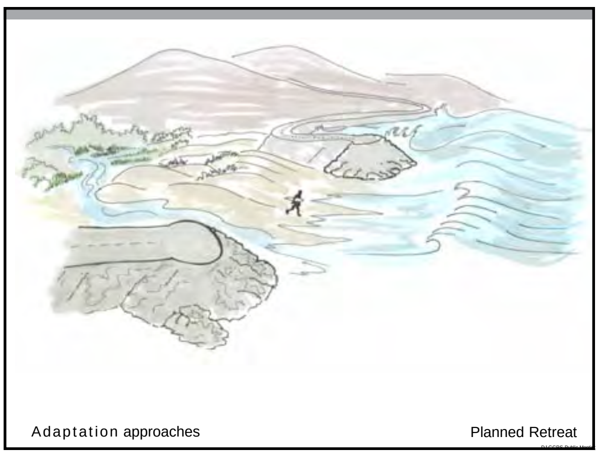

Sea Level Rise
Decreased Rainfall
Increased Rain Intensity
Wave attack
Runoff
Erosion on
Landslide
Soil nails
&
Retaining walls
Adaptation approaches
Photos: Google Earth
Structural modification until failure

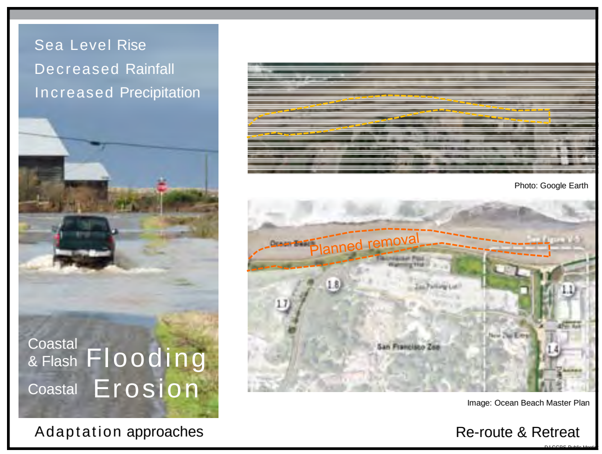

Adaptation approaches
Adapt

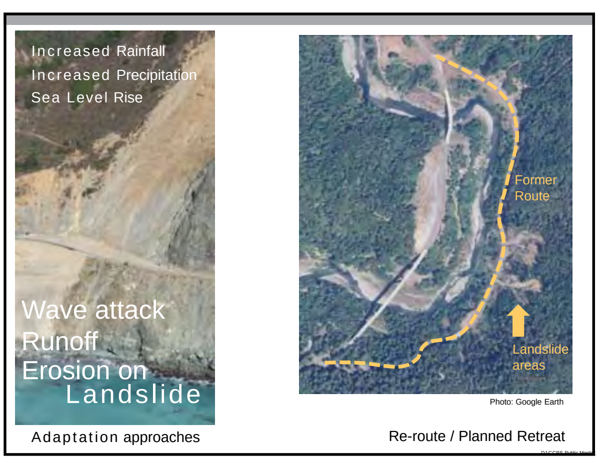

Sea Level Rise
Decreased Rainfall
Increased Rain Intensity
Coastal & Flash Flooding
Coastal Erosion
Causeways
Photo: California Coastal Records Project
Floodable Bridges
Photo: Google Earth
Adaptation approaches

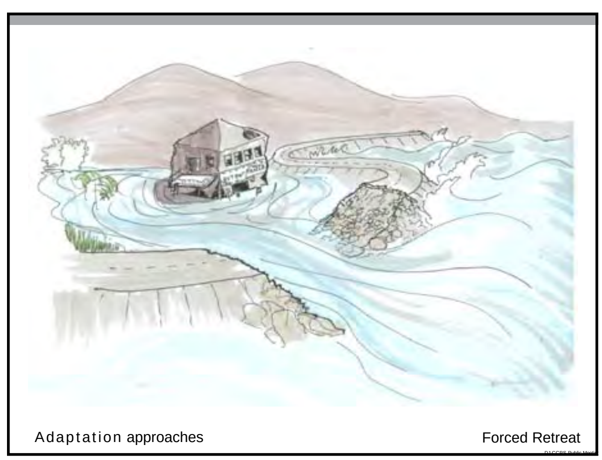

Sea Level Rise
Decreased Rainfall
Increased Rain Intensity
Coastal & Flash Flooding
Coastal Erosion
Adaptation approaches
Raise bridges & roads
Photos: Peter Dobbins/Friends of the Garcia River (FrOG)
Armor roads
Photo: MoBikeFed, , Creative Commons Attribution License


Sea Level Rise
Decreased Rainfall
Increased Rain Intensity
Wave attack
Runoff
Erosion on
Landslide
Adaptation approaches
Bridge over
Tunnel under
Photos: California Coastal Records Project


Adaptation approaches
Planned Retreat


Sea Level Rise
Decreased Rainfall
Increased Precipitation
Coastal & Flash Flooding
Coastal Erosion
Adaptation approaches
Photo: Google Earth
Planned removal
Image: Ocean Beach Master Plan
Re-route & Retreat

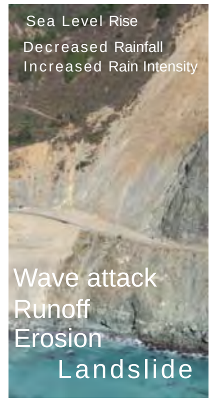

Increased Rainfall
Increased Precipitation
Sea Level Rise
Wave attack
Runoff
Erosion on
Landslide
Adaptation approaches
Former Route
Landslide areas
Photo: Google Earth
Re-route / Planned Retreat


Adaptation approaches
Forced Retreat

No Action:

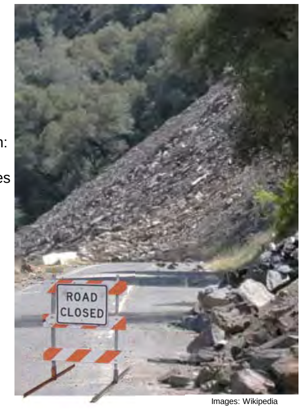
Flooding & Road Closures

Adaptation approaches



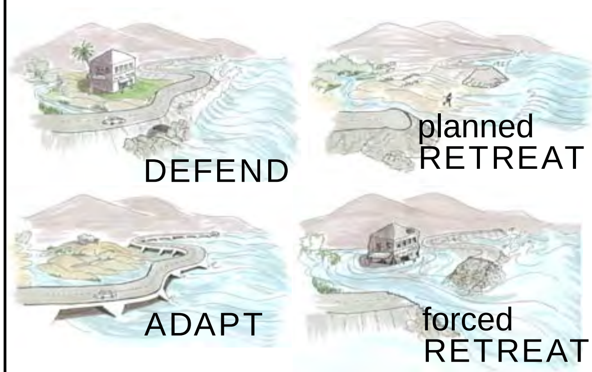
No Action:

Landslides & Road Closures



Images: Wikipedia

Adaptation approaches



Adaptation approaches

Adaptation Assessment Criteria

- Total Capital Investment
- Usable Life
- Equivalent Annual Cost
- Effectiveness (level of performance)
- Implementation Timeline
- Flexibility
- Environmental Considerations
- Social Considerations

Group Discussions

What are your top priorities for adapting to climate change impacts?

- Total Capital Investment
- Usable Life
- Equivalent Annual Cost
- Effectiveness (level of performance)
- Implementation Timeline
- Flexibility
- Environmental Considerations
- Social Considerations

What adaptation options do you feel are most appropriate for the Eureka to Arcata 101 Corridor?

Last Change Grade Adaptation Options

Defend: Structural modification and maintenance

Re-route / Planned Retreat

Project website

http://www.northcoastclimatechange.com

Photo: A. Laird

JOIN US

at a public workshop about climate change impacts to our state road system.

The workshop will also present potential strategies for adapting to climate change.

How are climate change factors likely to impact our region?

Which transportation facilities are the most vulnerable to climate change?

What are some potential solutions?

How will we adapt to sea level rise on ***Hwy 101 between Arcata and Eureka***?

WHEN & WHERE

Monday, August 25
6:00-7:30pm
Wharfinger Building
Great Room
1 Marina Way
Eureka, CA

WORKSHOP DETAILS

6:00 pm: Presentation on regional cimate change impacts and vulnerability

6:45 pm: Public breakout sessions

This project is funded by the Federal Highway Administration and Caltrans and is conducted in partnership with Regional Transportation Planning Agencies.

Prepared by:

GHD

For more information, contact:
Jessica Hall at GHD, (707) 443-8326

Caltrans · Del Norte Local Transportation Commission · Humboldt County Association of Governments · LAKE APC · MCOG

PUBLIC MEETING

Climate Change Vulnerability Assessment & Pilot Project

Monday, August 25, 2014
6:00-7:30 PM

Wharfinger Building Great Room
1 Marina Way,
Eureka, CA

AGENDA

6:00 PM:	Welcome and Introductions
6:10 PM:	Presentation
6:50 PM:	Discussion
7:20 PM:	Final Q & A, Closing comments
7:30 PM:	Adjourn Meeting

The Climate Change Vulnerability Assessment and Pilot Project is a study funded by the Federal Highways Administration, led by Caltrans and the Humboldt County Association of Governments, with the involvement of North Coast Regional Transportation Planning Authorities.


CLIMATE CHANGE
Vulnerability Assessment & Pilot Project
Photo: Aldaron Laird
Prepared for:
Del Norte Local Transportation Commission
LAKE APC
MCOG
Prepared by:
ESA PWA
GHD

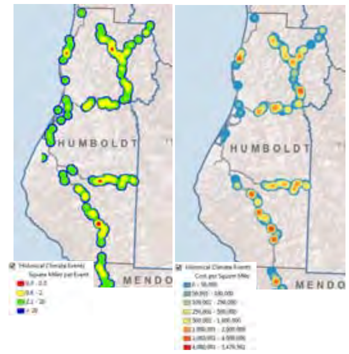

NBC NEWS
ENVIRONMENT
Scientists More Certain Than Ever on Climate Change, Report Says

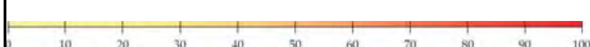

Courtesy of CALTRANS

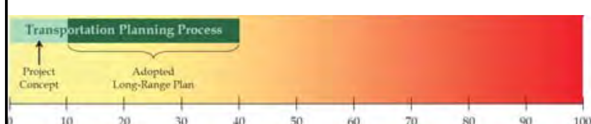
Photo: Brian Birke, Creative Commons Attribution License

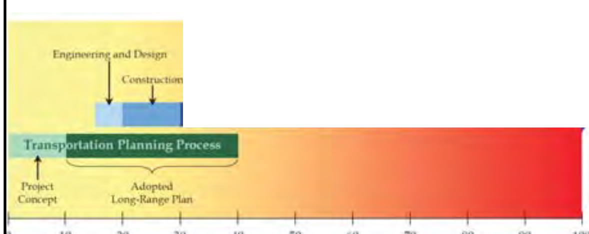
Photo: laffy4k, Creative Commons Attribution License

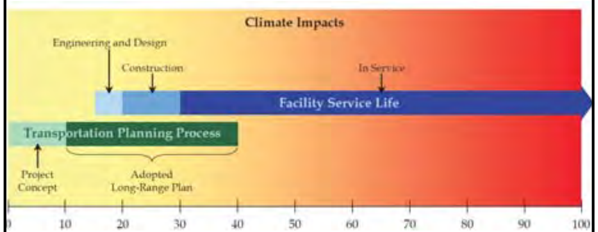
Historic Maintenance Events

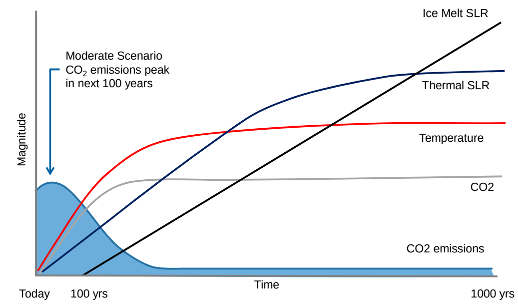












Climate Change Scenarios

2050

Extreme Climate Change Models

Moderate Climate Change Models

PROJECT HISTORY

2008 Gulf Coast Study

↓

FHWA Conceptual Model for Climate Change Vulnerability Assessments

↓

2010 Pilot Studies (5)

↓

FHWA Climate Change & Extreme Weather Vulnerability Assessment Framework

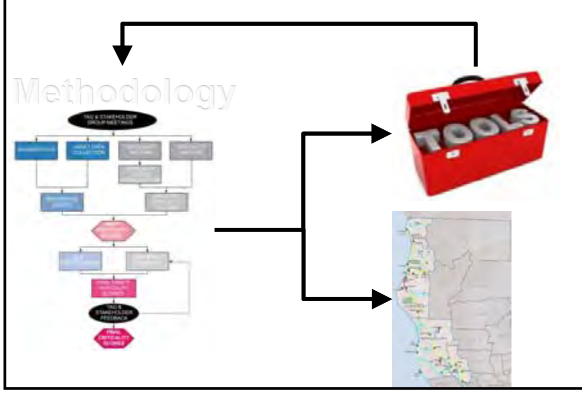
↓

2013 Pilot Studies (19)

↓

?

D1CCPS Project: Process vs. Product

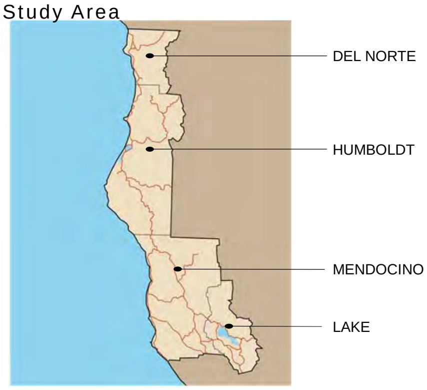


Project Objectives

1. Identify **Vulnerabilities**

2. Analyze **Adaptation Options**

Study Area



Identify vulnerabilities

What is *vulnerability?*

Criticality	How critical is this facility?
+	
Exposure	What is the impact affecting it?
+	
Sensitivity	How does it handle the impact?
=	
Vulnerability	

What is "Criticality"

Photo: Google Earth

What is "Criticality"

Photo: Google Earth

What is "Criticality"

Photo: Google Earth

What is "Criticality"

Photo: Google Earth

What is "Criticality"


Photo: Google Earth

What is "Criticality"


Photo: Google Earth

Exposure

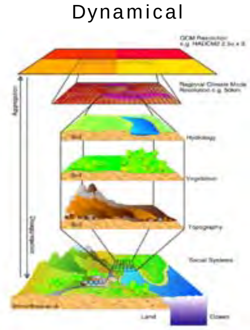
Climate Change Effects

- Temperature
- Precipitation
- Runoff
- Sea level rise
- Coastal erosion hazards
- Wildfire

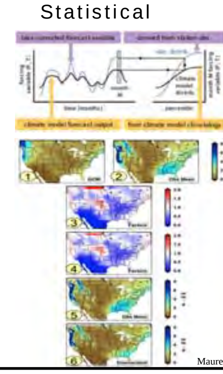
Moderate & Extreme changes at 2050 and 2100

How do we know?

Dynamical



Statistical



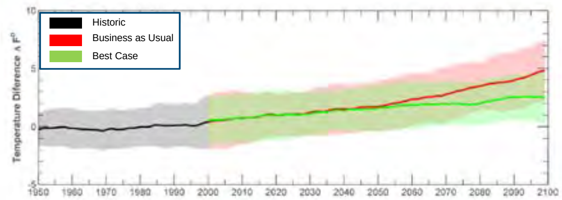
David Viner, Climatic Research Unit, University of East Anglia, UK

Maurer, 2008

RESULTS OF EXPOSURE ANALYSIS

Climate Change Effects

Changes in Average Daily Maximum Temperature



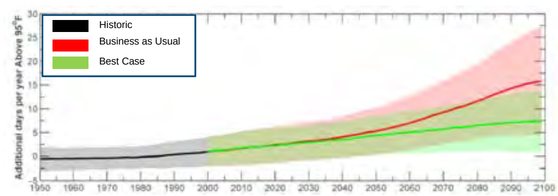
Humboldt County

HUMBOLDT
+2.9 to 3.3°F - 2050
+4.0 to 6.7°F – 2100

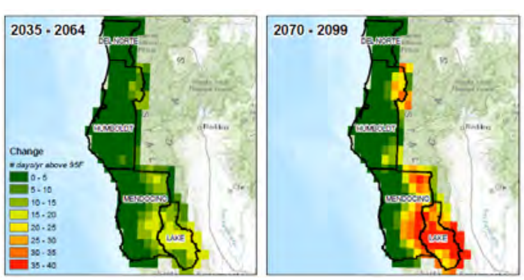
Increased average temperature

Climate Change Effects

Extreme Temperature (additional days above 95F)



Extreme Temperatures



Increased days above 95°F.

Sea Level Rise

King Tides Rising

Sea Level Rise

2000 0 in

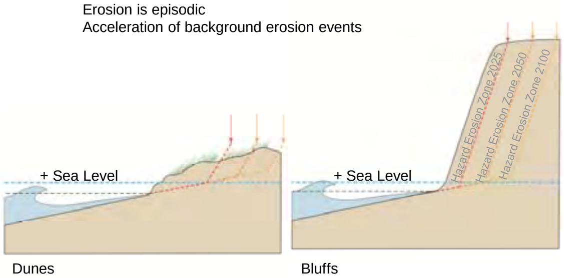
2050
12-14 in

2100
36-55 in

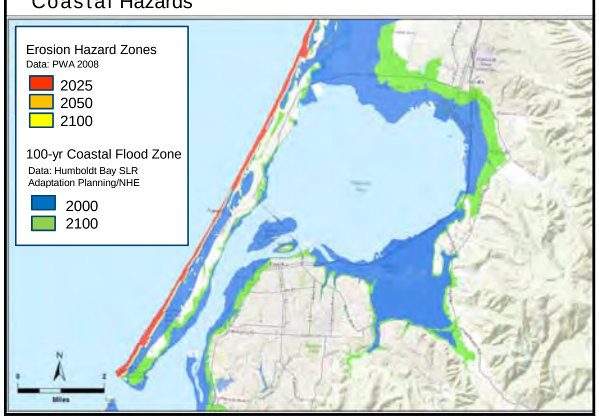
2100+ ?? in

Coastal Erosion

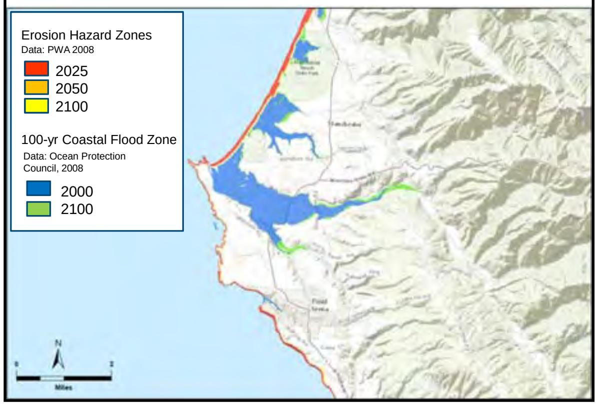
Erosion is episodic
Acceleration of background erosion events



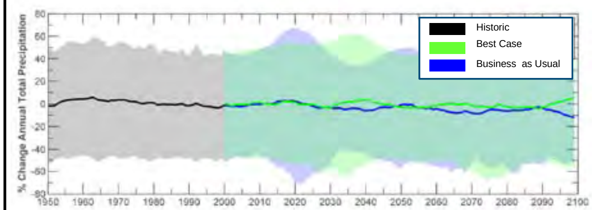
Coastal Hazards



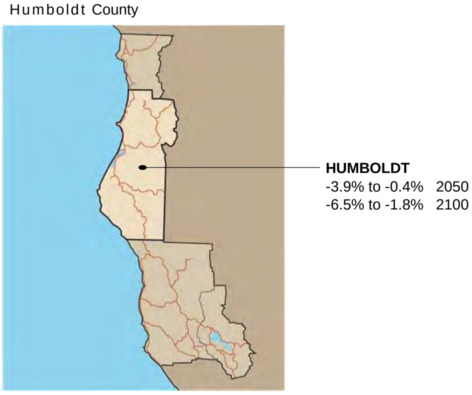
Coastal Hazards



Rainfall change



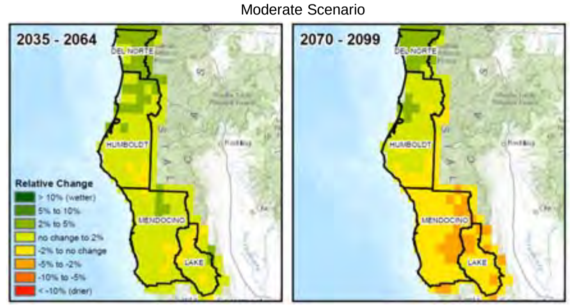
Humboldt County



Changes in average rainfall

Extreme Precipitation

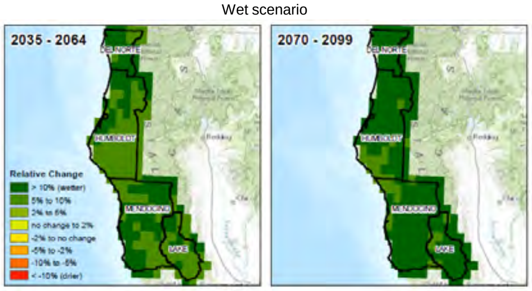
Moderate Scenario



Changes in extreme rainfall

Extreme Precipitation

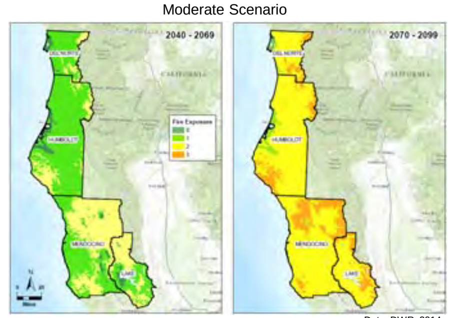
Wet scenario



Changes in extreme rainfall

Wildfire Exposure

Moderate Scenario



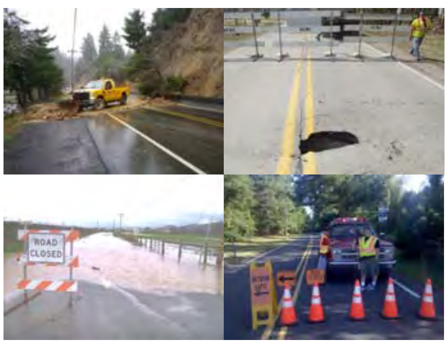
Changes wildfire risk

Data: DWR, 2014

What is "Potential for Impact"

Delay

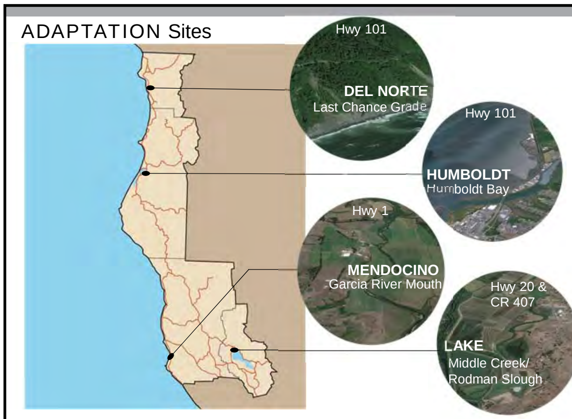
Temporary Closure – Damage



Failure

ADAPTATION Prototype Sites

ADAPTATION Sites



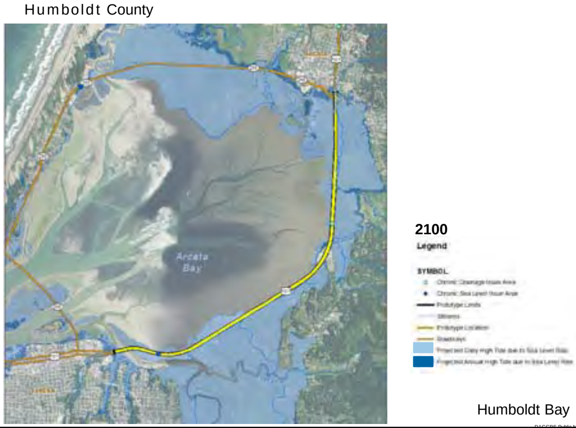
ADAPTATION Sites

Humboldt County

Photo: GoogleEarth

Humboldt Bay

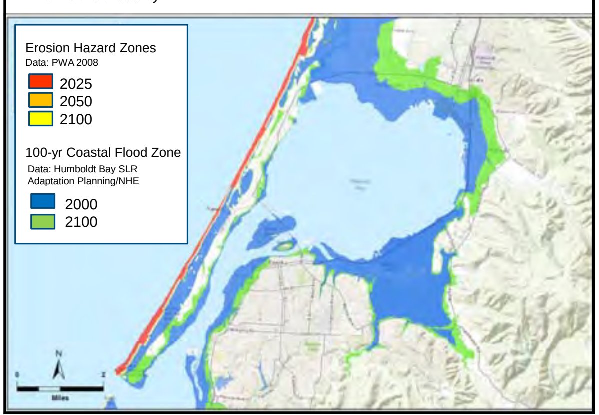
Humboldt County



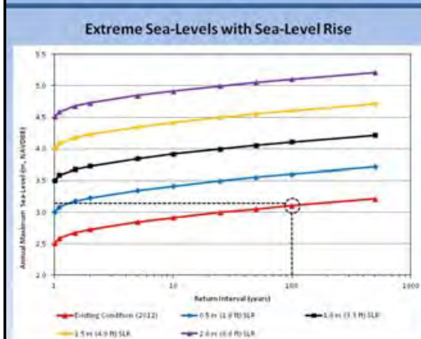
Humboldt Bay

Findings in the Eureka/Arcata Corridor

Humboldt County



Humboldt Bay North Spit Sea-Levels



Why should we be concerned with Sea-Level Rise

- Immediate concerns are related to coastal flooding
- Sea-level rise gradually increases extreme water levels (not static like 100-yr riverine flood levels)
- For example, the 100-yr extreme sea-level becomes the 1-yr level with 0.5 m SLR
- To put this into perspective, since 1912 the North Spit Tide Gauge has seen about 0.47 m of SLR
- So what was a 100-yr extreme sea-level in 1912 is today the 1-yr level or about the mean monthly high tide


Figure 3. Shoreline structure of the lower reach of Highway 101: railroad (red), dike (yellow), fortified (purple), and natural (green) (Laird 2013).

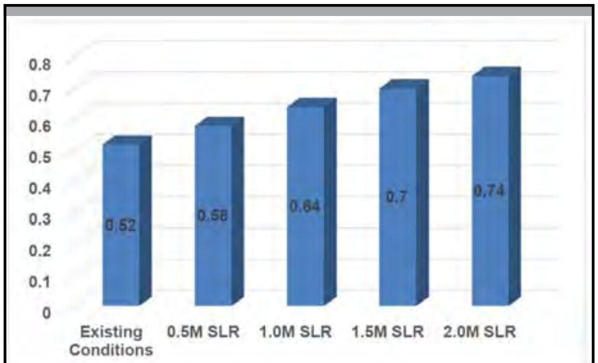
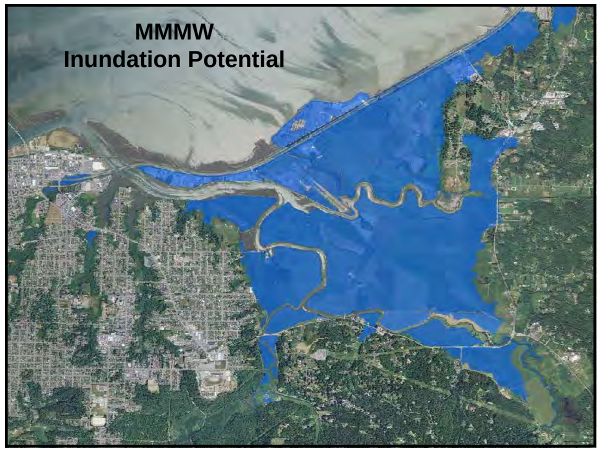
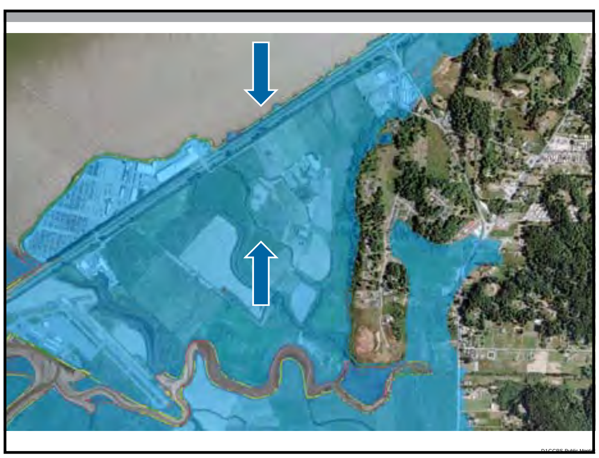
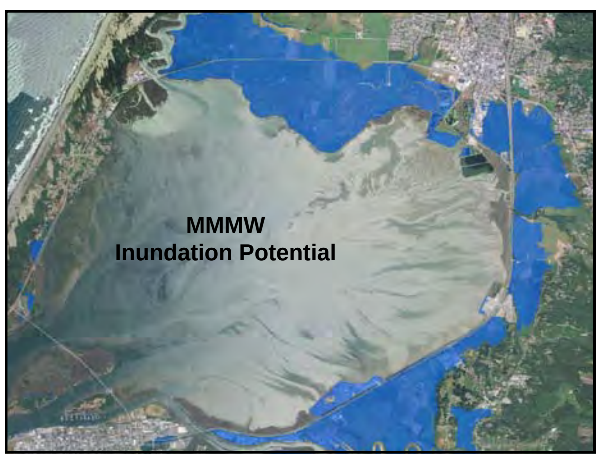


Figure 10. Percent increase in Bay footprint as result of shoreline failure and sea level rise.







West of Highway 101-Unmaintained NWP Railroad Grade

East of Highway 101-King Tide Flooding-Bayside Cut-off

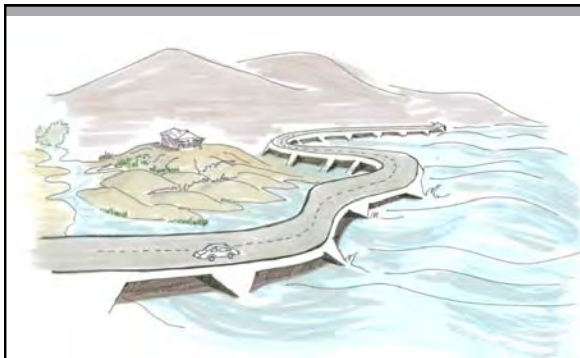
ADAPTATION Options

Adaptation approaches

Existing

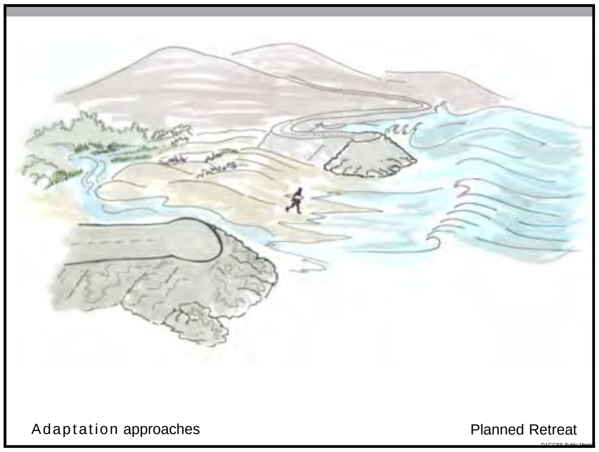
Adaptation approaches

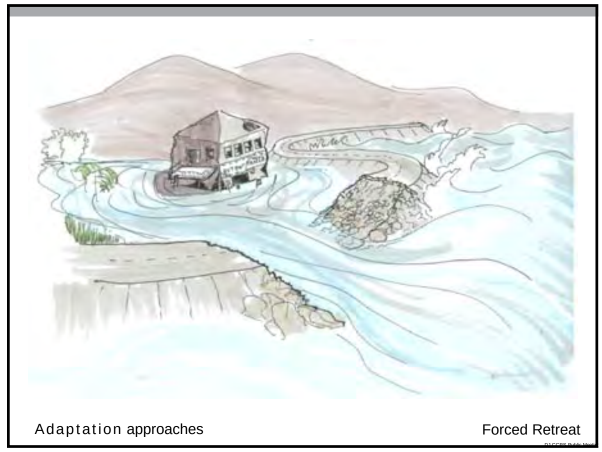
Defend

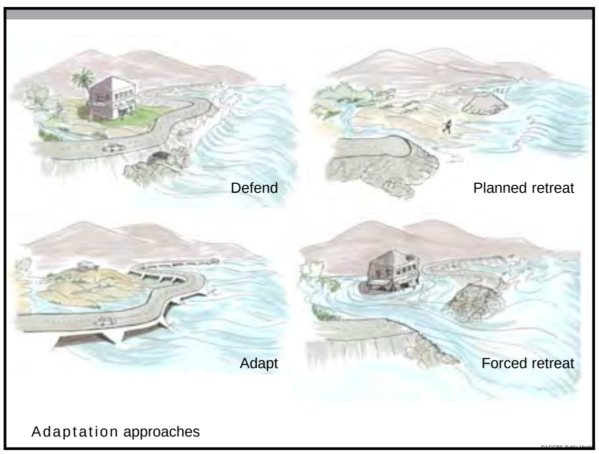


Adaptation approaches

Adapt

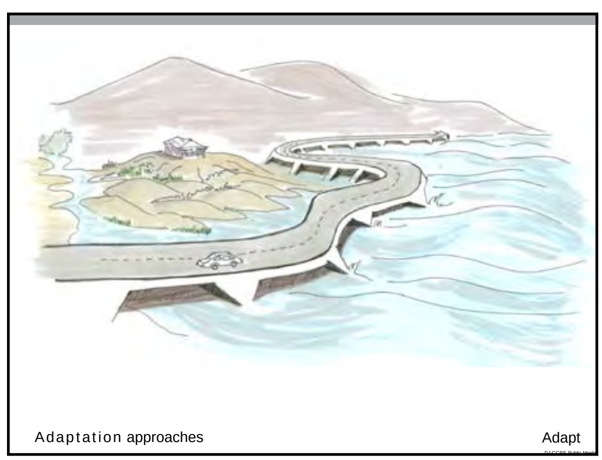

Adaptation approaches
Planned Retreat

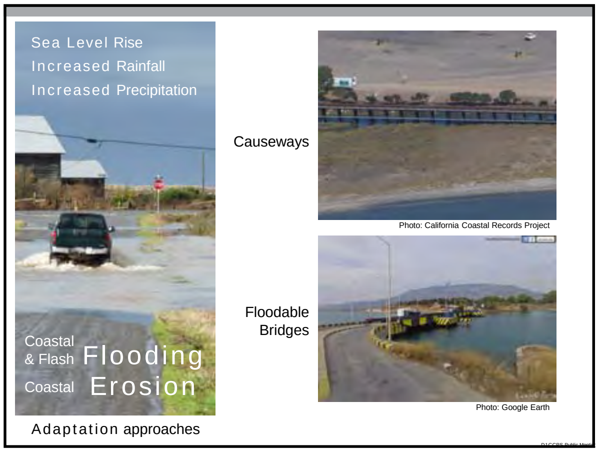

Adaptation approaches
Forced Retreat

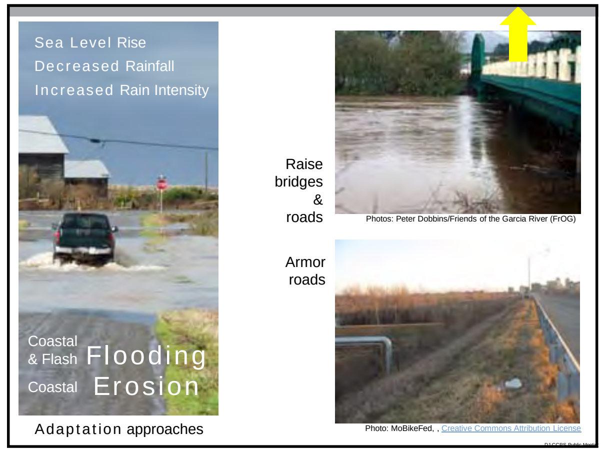

Defend
Planned retreat
Adapt
Forced retreat
Adaptation approaches

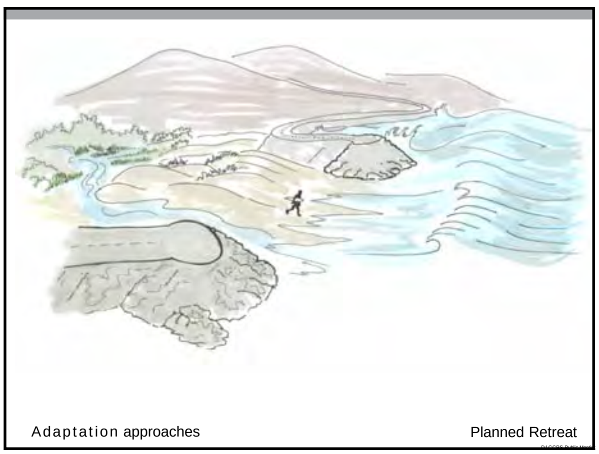

Adaptation approaches
Defend

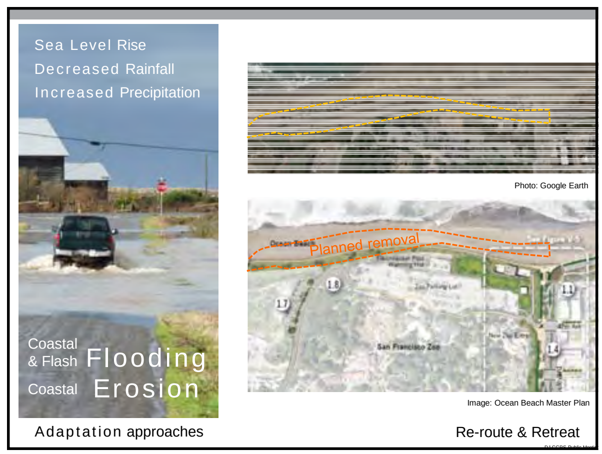

Sea Level Rise
Decreased Rainfall
Increased Rain Intensity
Coastal & Flash Flooding
Coastal Erosion
Flood Walls
Sea Walls
Levees
Dikes
Living shoreline
Adaptation approaches
Photo: GoogleEarth

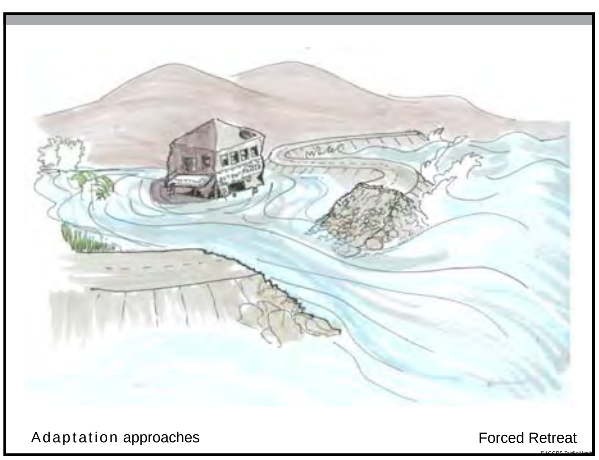

Adaptation approaches
Adapt

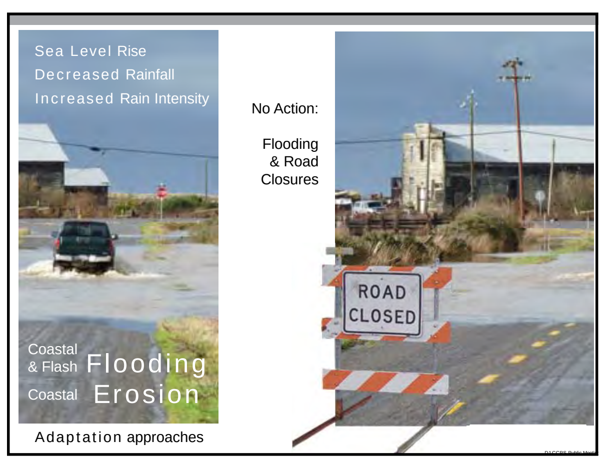

Sea Level Rise
Increased Rainfall
Increased Precipitation
Coastal & Flash Flooding
Coastal Erosion
Adaptation approaches
Causeways
Photo: California Coastal Records Project
Floodable Bridges
Photo: Google Earth

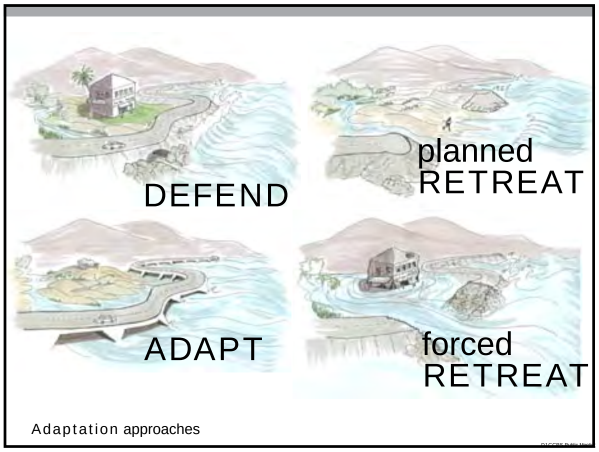

Sea Level Rise
Decreased Rainfall
Increased Rain Intensity
Coastal & Flash Flooding
Coastal Erosion
Adaptation approaches
Raise bridges & roads
Photos: Peter Dobbins/Friends of the Garcia River (FrOG)
Armor roads
Photo: MoBikeFed, , Creative Commons Attribution License

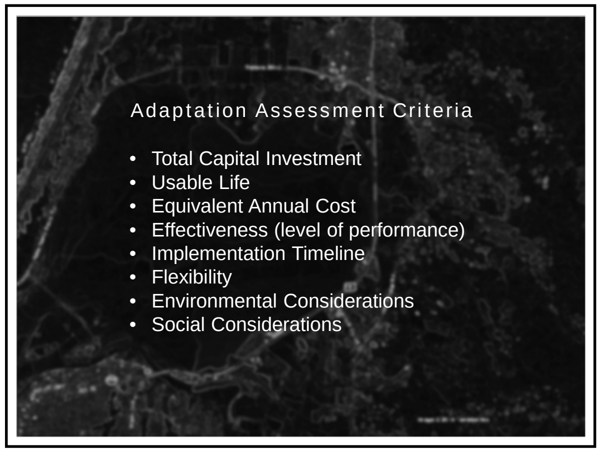

Adaptation approaches
Planned Retreat


Sea Level Rise
Decreased Rainfall
Increased Precipitation
Coastal & Flash Flooding
Coastal Erosion
Photo: Google Earth
Planned removal
Image: Ocean Beach Master Plan
Adaptation approaches
Re-route & Retreat


Adaptation approaches
Forced Retreat


Sea Level Rise
Decreased Rainfall
Increased Rain Intensity
Coastal & Flash Flooding
Coastal Erosion
Adaptation approaches
No Action:
Flooding & Road Closures
ROAD CLOSED





Project website

http://www.northcoastclimatechange.com


DISTRICT ONE CLIMATE CHANGE PILOT STUDY

CLIMATE CHANGE ADAPTATION PILOT STRATEGY FOR CRITICALLY VULNERABLE ASSETS IN A NORTHWEST CALIFORNIA PROJECT

DISTRICT ONE – CLIMATE CHANGE – PILOT STUDY – (D1CCPS) | TECHNICAL ADVISORY GROUP | STAKEHOLDERS GROUP

RELATED LINKS

CalTrans District One

DISTRICT ONE – CLIMATE CHANGE – PILOT STUDY – (D1CCPS)

Project Background

The planning department of Caltrans District 1 applied for and received a grant from the Federal Highway Administration to study the potential vulnerabilities of transportation assets to climate change throughout District 1 (Del Norte, Humboldt, Mendocino, and Lake Counties) and to identify and evaluate a range of adaption options to address the identified vulnerabilities at four prototype locations.

The study will begin with an inventory of transportation assets in District 1 and a subsequent analysis to determine which assets are critically vulnerable. Following this task, four pilot sites ("prototype locations") will be selected for further analysis during the "adaptation assessment" phase of the project. The adaptation assessment will identify options for adapting Caltrans infrastructure to the various climate change factors and will evaluate the level of protection, flexibility, relative costs, acceptability,

Photo: A. Laird

JOIN US

at a public workshop about climate change impacts to our state road system. The workshop will also present potential strategies for adapting to climate change.

How are climate change factors likely to impact our region?

Which transportation facilities in Lake County are the most vulnerable to climate change?

What are some potential solutions?

How will we adapt to ***increasingly intense flooding around Clear Lake?***

WHEN & WHERE

Wednesday, August 27
6:00-7:30pm
Board Chambers
Lake County Courthouse
255 N. Forbes Avenue
Lakeport, CA

WORKSHOP DETAILS

6:00 pm: Presentation on regional climate change impacts and vulnerability

6:45 pm: Public breakout sessions.

This project is funded by the Federal Highway Administration and Caltrans and is conducted in partnership with Regional Transportation Planning Agencies.

Prepared by: GHD

For more information, contact:
Jessica Hall at GHD, (707) 443-8326

Caltrans | Del Norte Local Transportation Commission | Humboldt County Association of Governments | LAKE APC | MCOG

PUBLIC MEETING

Climate Change Vulnerability Assessment & Pilot Project

Wednesday, August 27, 2014
6:00-7:30 PM

Board Chambers, Lake County Courthouse
255 North Forbes Avenue,
Lakeport, CA

AGENDA

6:00 PM:	Welcome and Introductions
6:10 PM:	Presentation
6:50 PM:	Discussion
7:20 PM:	Final Q & A, Closing comments
7:30 PM:	Adjourn Meeting

The Climate Change Vulnerability Assessment and Pilot Project is a study funded by the Federal Highways Administration, led by Caltrans and the Humboldt County Association of Governments, with the involvement of the Lake City/County Area Planning Council and other North Coast Regional Transportation Planning Authorities.


CLIMATE
CHANGE
Vulnerability Assessment
& Pilot Project
Photo: Thomas Smythe
Prepared for:
Prepared by:
PWA
GHD
LAKE APC
MCOG

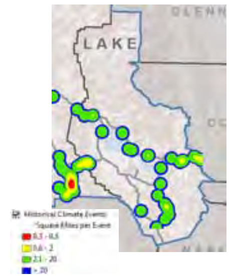

NBC NEWS
Scientists More Certain Than Ever on Climate Change, Report Says

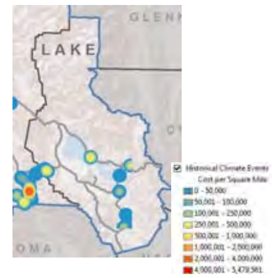

Courtesy of CALTRANS

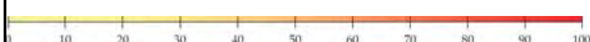
Photo: Brian Birke, Creative Commons Attribution License

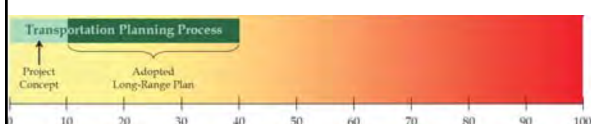
Photo: laffy4k, Creative Commons Attribution License

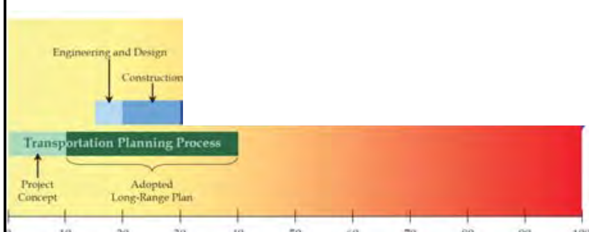
Historic Maintenance Events

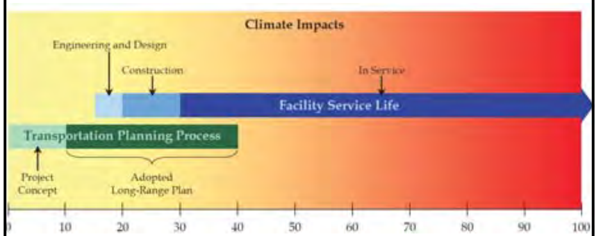


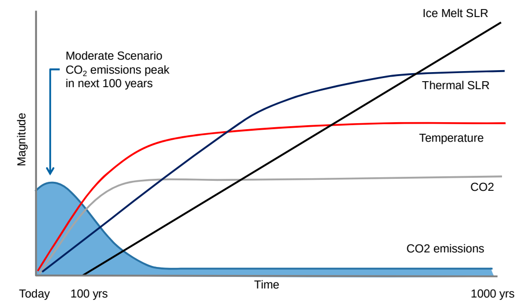












Climate Change Scenarios

2050

Extreme Climate Change Models

Moderate Climate Change Models

PROJECT HISTORY

2008 Gulf Coast Study

↓

FHWA Conceptual Model for Climate Change Vulnerability Assessments

↓

2010 Pilot Studies (5)

↓

FHWA Climate Change & Extreme Weather Vulnerability Assessment Framework

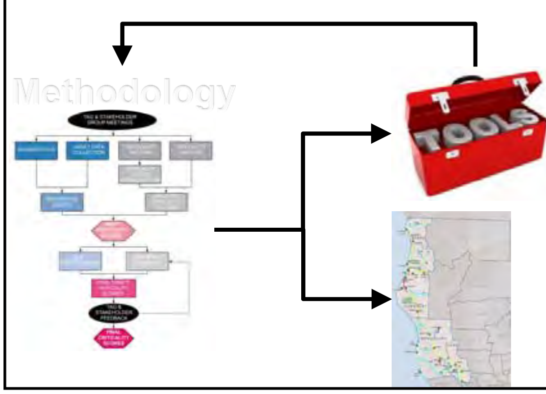
↓

2013 Pilot Studies (19)

↓

?

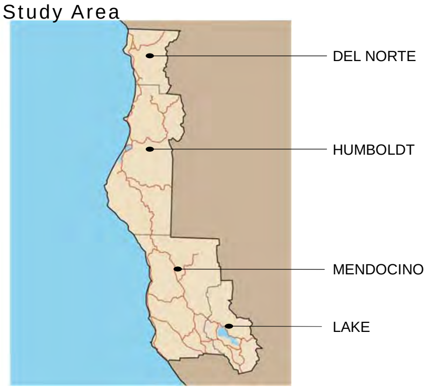
D1CCPS Project: Process vs. Product



Project Objectives

1. Identify **Vulnerabilities**
2. Analyze **Adaptation Options**

Study Area



Exposure

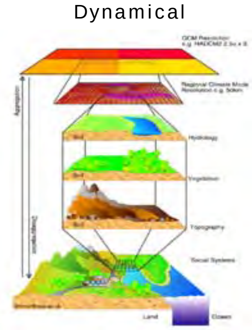
Climate Change Effects

- Temperature
- Precipitation
- Runoff
- Sea level rise
- Coastal erosion hazards
- Wildfire

Moderate & Extreme changes at 2050 and 2100

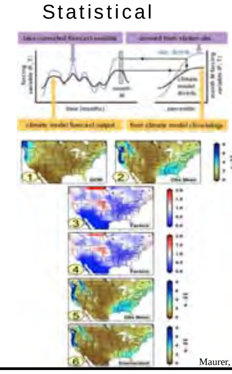
How do we know?

Dynamical



David Viner, Climatic Research Unit, University of East Anglia, UK

Statistical

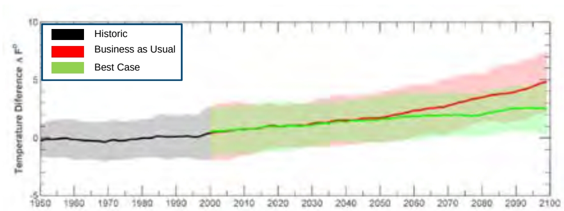


Maurer, 2008

RESULTS OF EXPOSURE ANALYSIS

Climate Change Effects

Changes in Average Daily Maximum Temperature

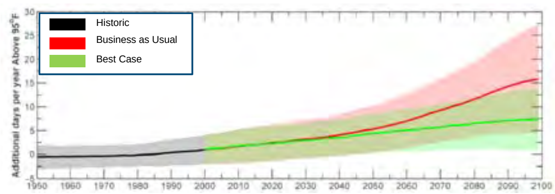


Lake County

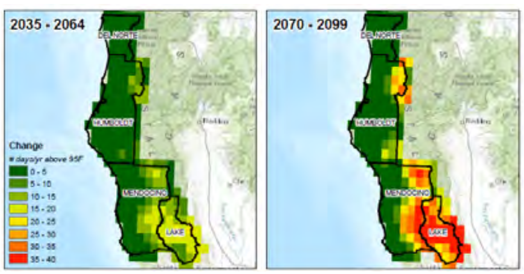
Increased average temperature

Climate Change Effects

Extreme Temperature
(additional days above 95F)



Extreme Temperatures



Increased days above 95°F.

Sea Level Rise

Photo: Aldaron Laird

King Tides Rising

Sea Level Rise

2000 0 in

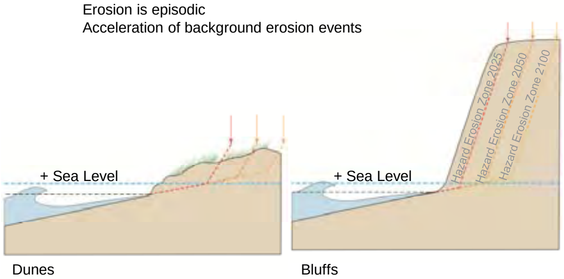
2050
12-14 in

2100
36-55 in

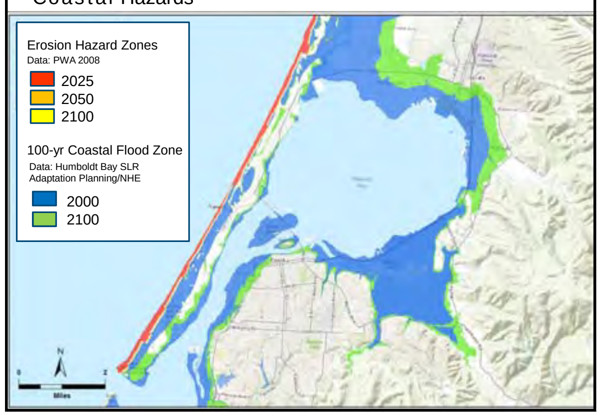
2100+ ?? in

Coastal Erosion

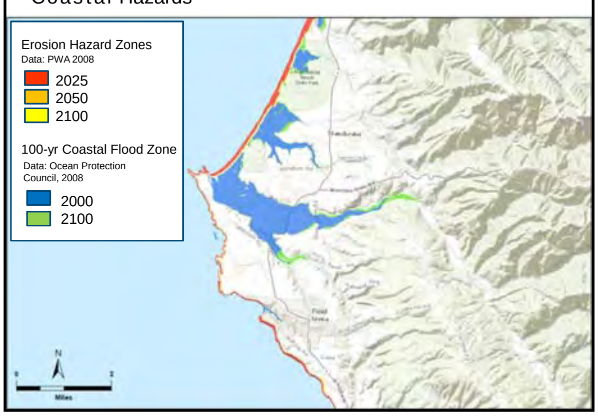
Erosion is episodic
Acceleration of background erosion events



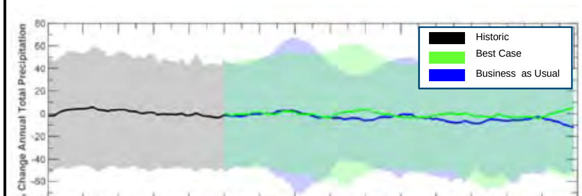
Coastal Hazards



Coastal Hazards



Rainfall change



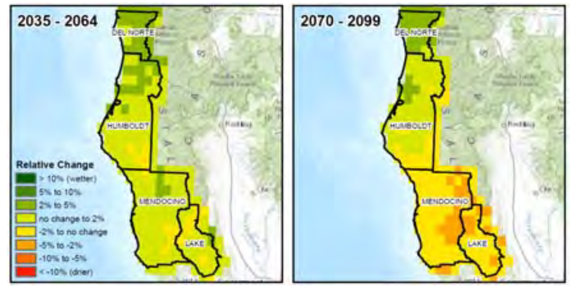
Lake County

LAKE
-5.1% to -1.1% 2050
-6.8% to -2.6% 2100

Changes in average rainfall

Extreme Precipitation

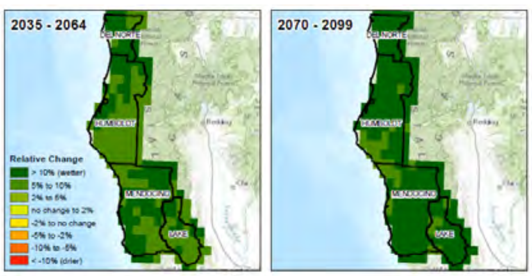
Moderate Scenario



Changes in extreme rainfall

Extreme Precipitation

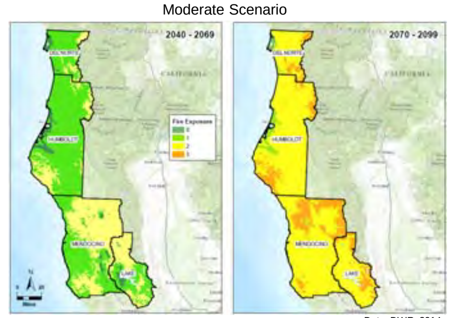
Wet scenario



Changes in extreme rainfall

Wildfire Exposure

Moderate Scenario



Changes wildfire risk

Data: DWR, 2014

What is "Potential for Impact"

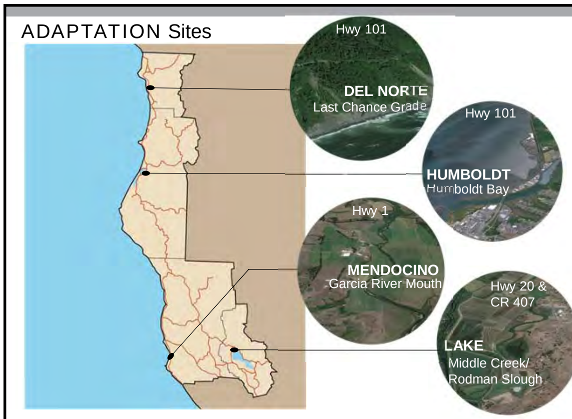
Delay

Temporary Closure – Damage

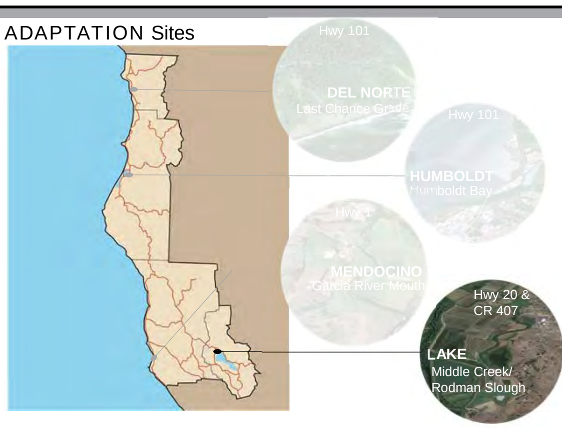
Failure

ADAPTATION Prototype Sites

ADAPTATION Sites



ADAPTATION Sites



Lake County

Rodman Slough/Middle Creek

Lake County

Rodman Slough/Middle Creek

Photo: Thomas Smythe

Rodman Slough/Middle Creek

Photo: Thomas Smythe

Rodman Slough/Middle Creek

Photo: Thomas Smythe

Rodman Slough/Middle Creek

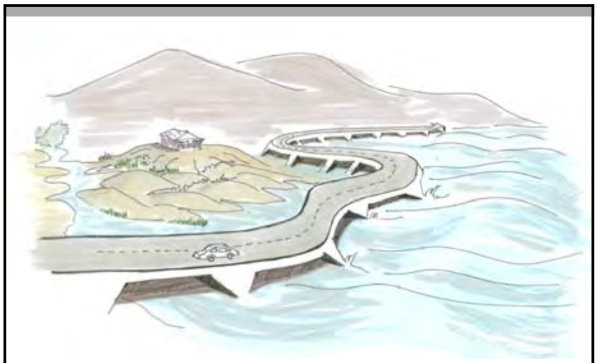
ADAPTATION Options

Adaptation approaches

Existing

Adaptation approaches

Defend



Adaptation approaches

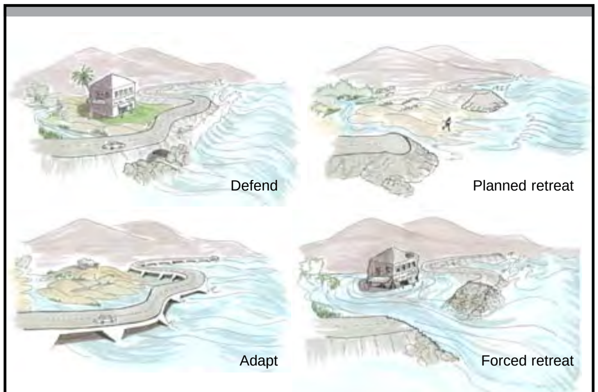
Adapt

Adaptation approaches

Planned Retreat

Adaptation approaches

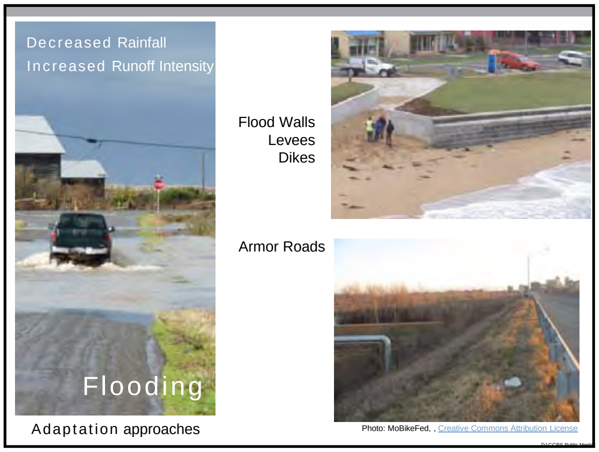
Forced Retreat

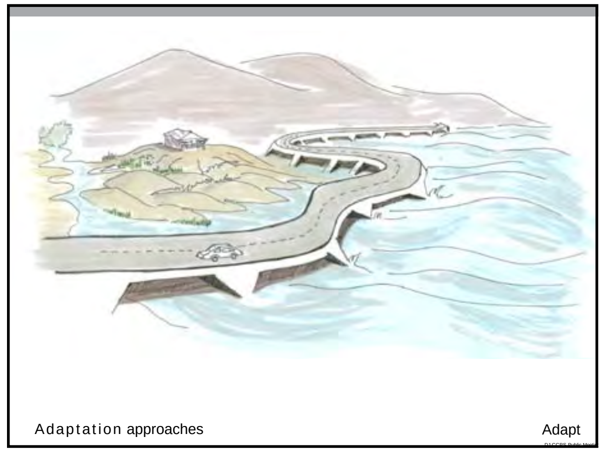


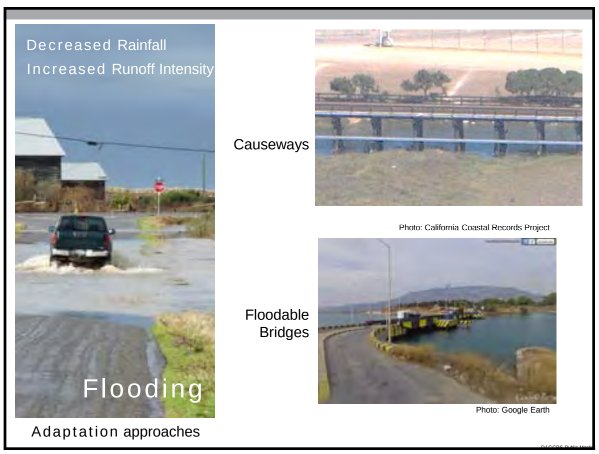
Adaptation approaches

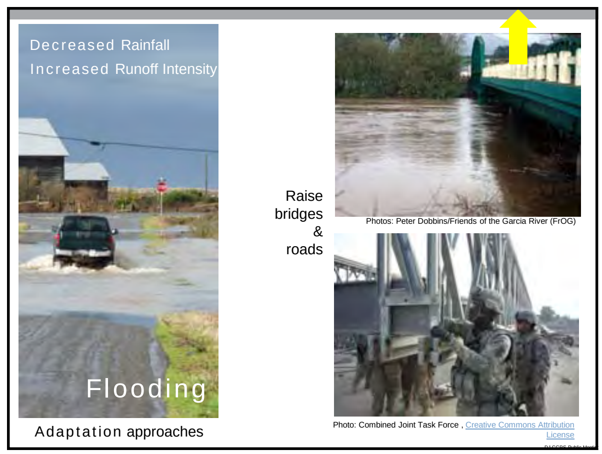
Adaptation approaches

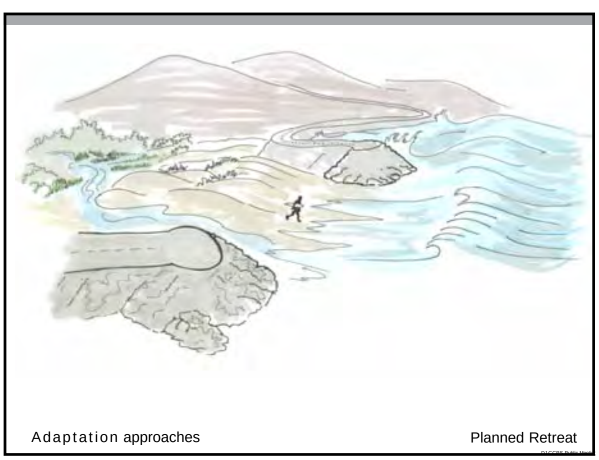
Defend

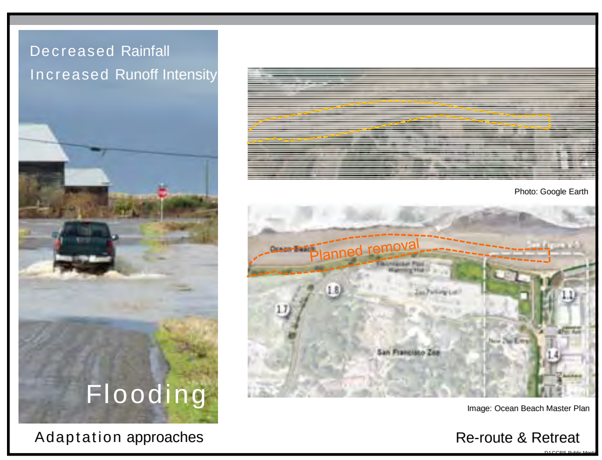

Decreased Rainfall
Increased Runoff Intensity
Flooding
Flood Walls
Levees
Dikes
Armor Roads
Photo: MoBikeFed, , Creative Commons Attribution License
Adaptation approaches


Adaptation approaches
Adapt


Decreased Rainfall
Increased Runoff Intensity
Flooding
Causeways
Photo: California Coastal Records Project
Floodable
Bridges
Photo: Google Earth
Adaptation approaches


Decreased Rainfall
Increased Runoff Intensity
Flooding
Raise
bridges
&
roads
Photos: Peter Dobbins/Friends of the Garcia River (FrOG)
Photo: Combined Joint Task Force , Creative Commons Attribution License
Adaptation approaches


Adaptation approaches
Planned Retreat


Decreased Rainfall
Increased Runoff Intensity
Flooding
Photo: Google Earth
Planned removal
Image: Ocean Beach Master Plan
Adaptation approaches
Re-route & Retreat

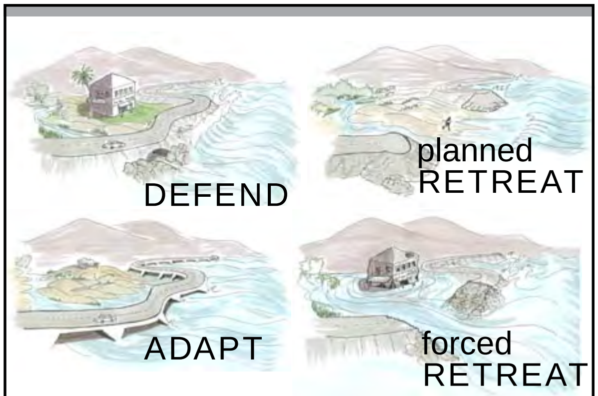
Adaptation approaches

Forced Retreat

No Action:

Flooding & Road Closures

Adaptation approaches



Adaptation approaches

Adaptation Assessment Criteria

- Total Capital Investment
- Usable Life
- Equivalent Annual Cost
- Effectiveness (level of performance)
- Implementation Timeline
- Flexibility
- Environmental Considerations
- Social Considerations

Group Discussions

What are your top priorities for adapting to climate change impacts?

- Total Capital Investment
- Usable Life
- Equivalent Annual Cost
- Effectiveness (level of performance)
- Implementation Timeline
- Flexibility
- Environmental Considerations
- Social Considerations

What adaptation options do you feel are most appropriate for the Eureka to Arcata 101 Corridor?

Project website

http://www.northcoastclimatechange.com


DISTRICT ONE CLIMATE CHANGE PILOT STUDY
CLIMATE CHANGE ADAPTATION PILOT STRATEGY FOR CRITICALLY VULNERABLE ASSETS IN A NORTHWEST CALIFORNIA PROJECT
DISTRICT ONE - CLIMATE CHANGE - PILOT STUDY - (D1CCPS)
TECHNICAL ADVISORY GROUP
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RELATED LINKS
CalTrans District One
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PUBLIC WORKSHOP ANNOUNCEMENT

CLIMATE CHANGE

HOW WILL IT AFFECT YOU?

JOIN US

at a public workshop about climate change impacts to our state road system.

The workshop will also present potential strategies for adapting to climate change.

How are climate change factors likely to impact our region?

Which transportation facilities are the most vulnerable to climate change?

What are some potential solutions?

How will we adapt to ***increased coastal flooding around the Garcia River mouth?***

WHEN & WHERE

Thursday, August 28
6:00-7:30pm
Fort Bragg Branch Library
Community Room
499 East Laurel Street
Fort Bragg, CA

WORKSHOP DETAILS

6:00 pm:	Presentation on regional climate change impacts and vulnerability
6:45 pm:	Public breakout session

This project is funded by the Federal Highway Administration and Caltrans and is conducted in partnership with Regional Transportation Planning Agencies.

Prepared by:

GHD

For more information, contact:
Jessica Hall at GHD, (707) 443-8326

Caltrans | Del Norte Local Transportation Commission | Humboldt County Association of Governments | LAKE APC | MCOG

PUBLIC MEETING

Climate Change Vulnerability Assessment & Pilot Project

Thursday, August 28, 2014

6:00-7:30 PM

Fort Bragg Community Library Community Room,

499 East Laurel Street

Fort Bragg, CA

AGENDA

6:00 PM:	Welcome and Introductions
6:10 PM:	Presentation
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CLIMATE CHANGE
Vulnerability Assessment & Pilot Project
Photos: Peter Dobbins/Friends of the Garcia River (FrOG)
Prepared for:
Prepared by:
PWA
GHD

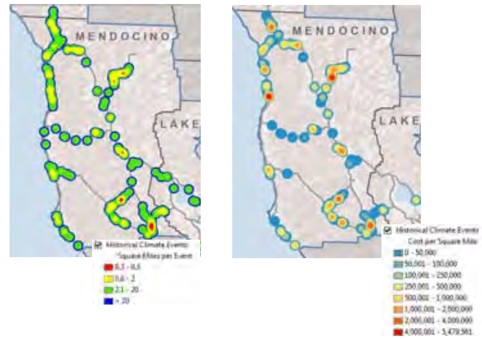

NBC NEWS
Scientists More Certain Than Ever on Climate Change, Report Says

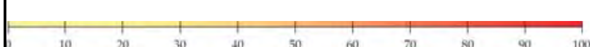

Courtesy of CALTRANS

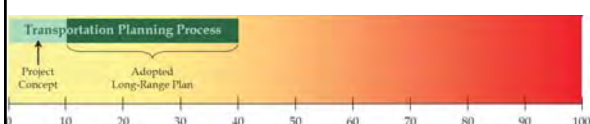
Photo: Brian Birke, Creative Commons Attribution License

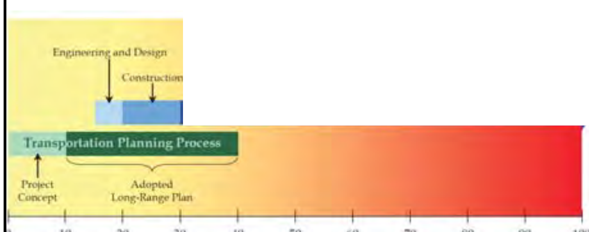
Photo: laffy4k, Creative Commons Attribution License

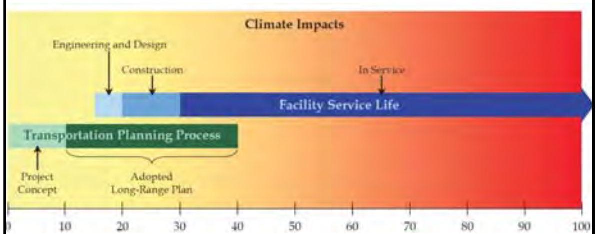
Historic Maintenance Events

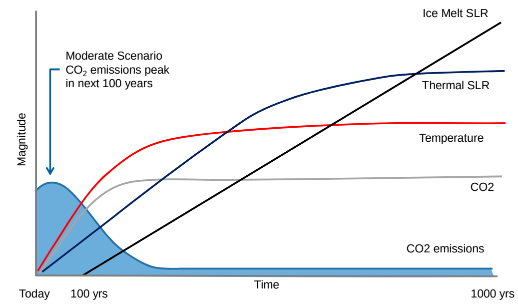












Climate Change Scenarios

2050

Extreme Climate Change Models

Moderate Climate Change Models

PROJECT HISTORY

2008 Gulf Coast Study

↓

FHWA Conceptual Model for Climate Change Vulnerability Assessments

↓

2010 Pilot Studies (5)

↓

FHWA Climate Change & Extreme Weather Vulnerability Assessment Framework

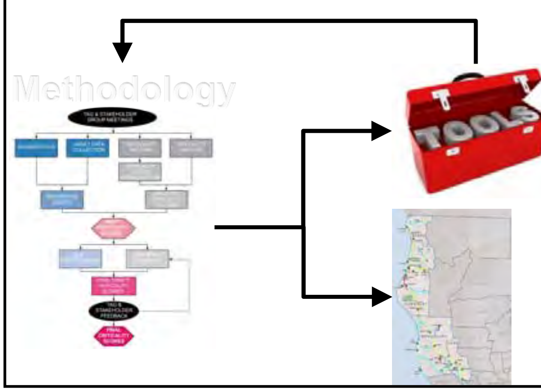
↓

2013 Pilot Studies (19)

↓

?

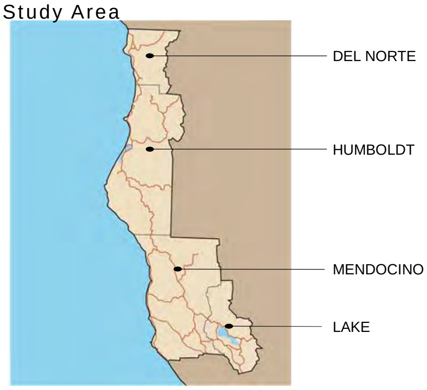
D1CCPS Project: Process vs. Product



Project Objectives

1. Identify **Vulnerabilities**
2. Analyze **Adaptation Options**

Study Area



Exposure

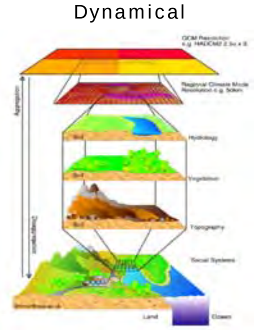
Climate Change Effects

- Temperature
- Precipitation
- Runoff
- Sea level rise
- Coastal erosion hazards
- Wildfire

Moderate & Extreme changes at 2050 and 2100

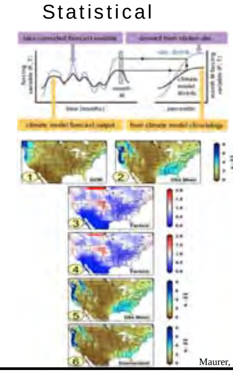
How do we know?

Dynamical



David Viner, Climatic Research Unit, University of East Anglia, UK

Statistical

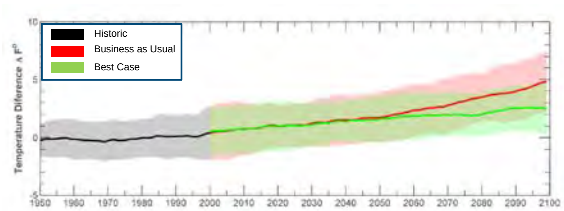


Maurer, 2008

RESULTS OF EXPOSURE ANALYSIS

Climate Change Effects

Changes in Average Daily Maximum Temperature



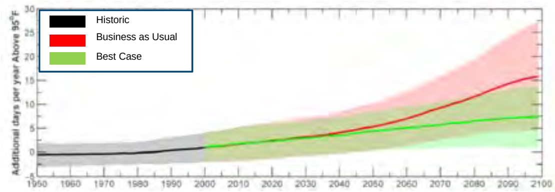
Mendocino County

MENDOCINO
+3.0 to 3.4°F - 2050
+4.0 to 6.7°F - 2100

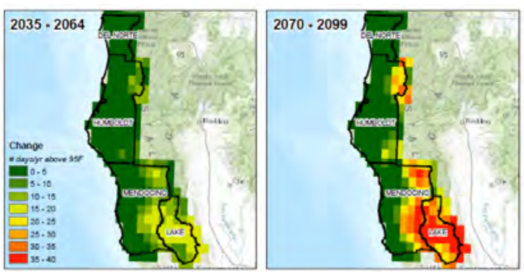
Increased average temperature

Climate Change Effects

Extreme Temperature
(additional days above 95F)



Extreme Temperatures



Increased days above 95°F.

Sea Level Rise

King Tides Rising

Sea Level Rise

2000 0 in

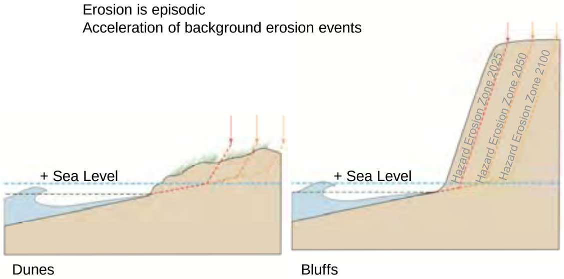
2050
12-14 in

2100
36-55 in

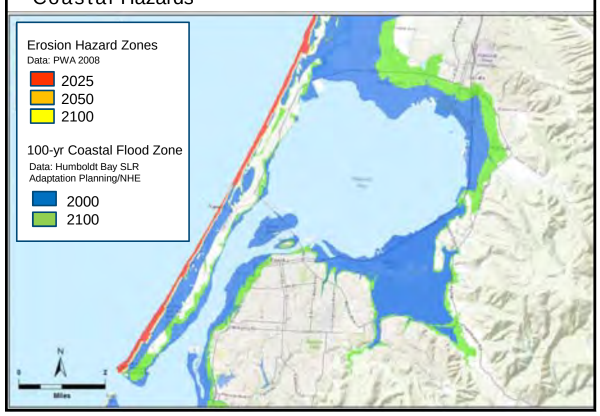
2100+ ?? in

Coastal Erosion

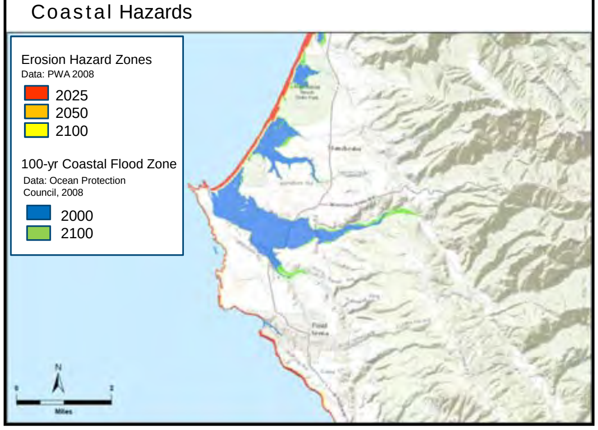
Erosion is episodic
Acceleration of background erosion events



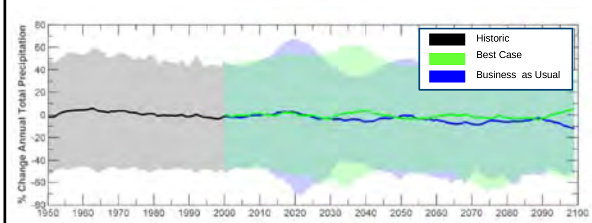
Coastal Hazards



Coastal Hazards



Rainfall change



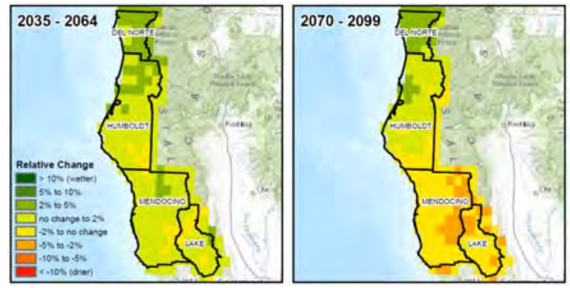
Mendocino County

MENDOCINO
-4.6% to -0.8% 2050
-6.8% to -3% 2100

Changes in average rainfall

Extreme Precipitation

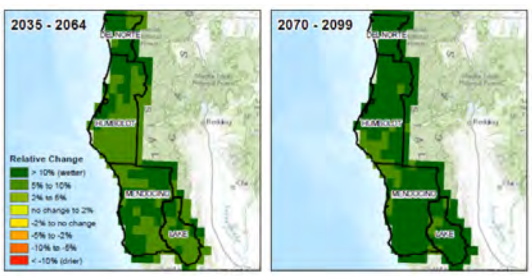
Moderate Scenario



Changes in extreme rainfall

Extreme Precipitation

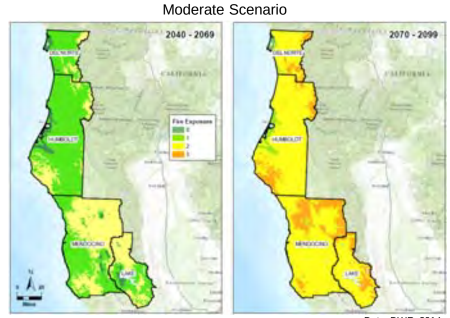
Wet scenario



Changes in extreme rainfall

Wildfire Exposure

Moderate Scenario



Changes wildfire risk

Data: DWR, 2014

What is "Potential for Impact"

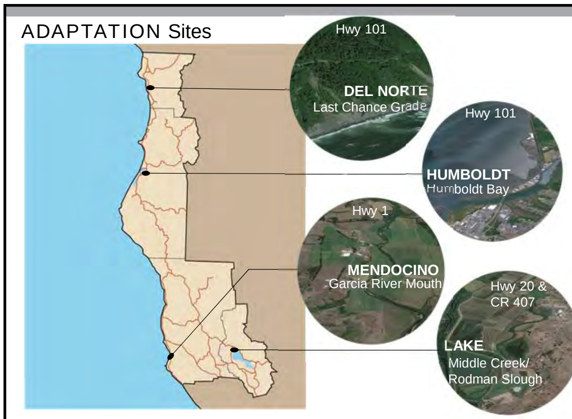
Delay

Temporary Closure – Damage

Failure

ADAPTATION Prototype Sites

ADAPTATION Sites

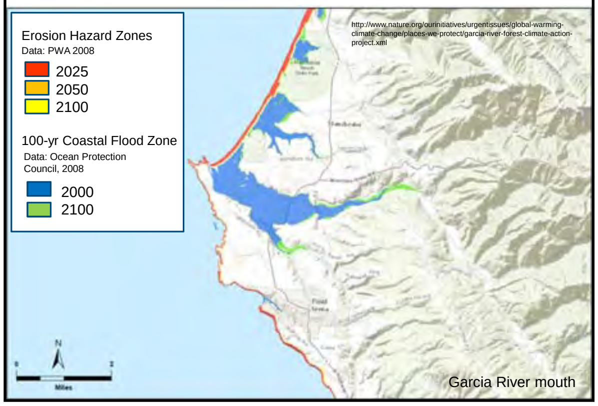


ADAPTATION Sites

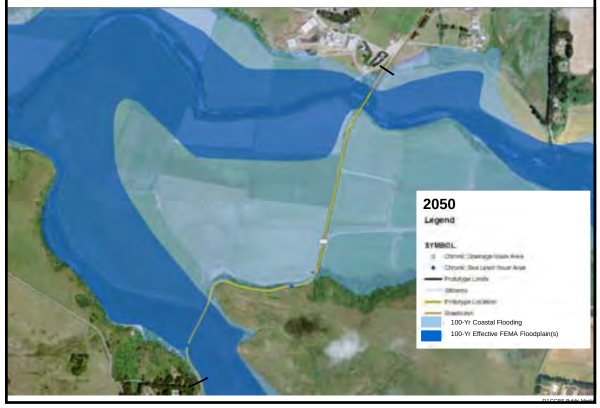
Mendocino County

Garcia River mouth

Mendocino County



Mendocino County



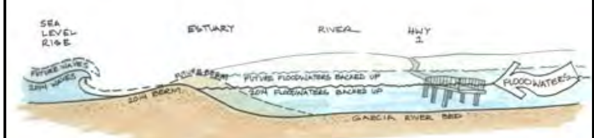
Mendocino County

2002 high flows and low flows

Photos: Peter Dobbins/Friends of the Garcia River (FrOG)

Garcia River mouth

Mendocino County



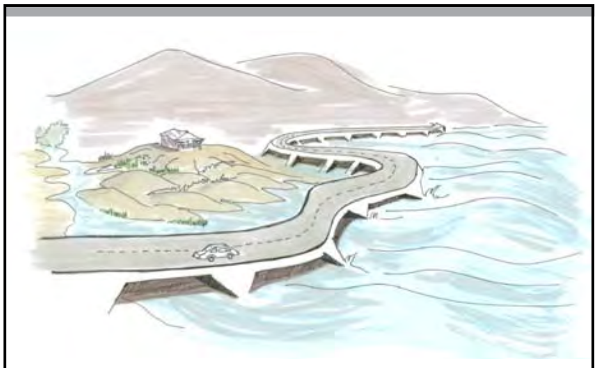
ADAPTATION Options

Existing

Adaptation approaches

Adaptation approaches

Defend



Adaptation approaches

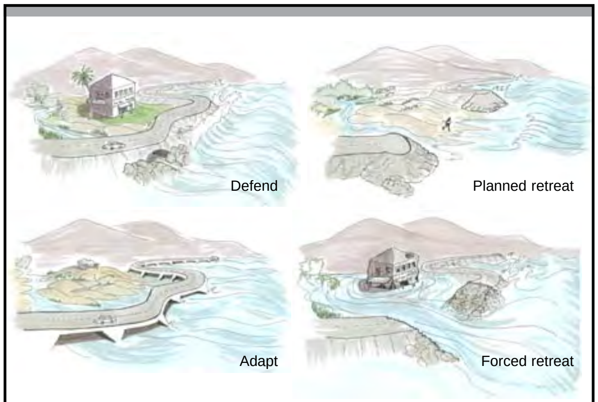
Adapt

Adaptation approaches

Planned Retreat

Adaptation approaches

Forced Retreat

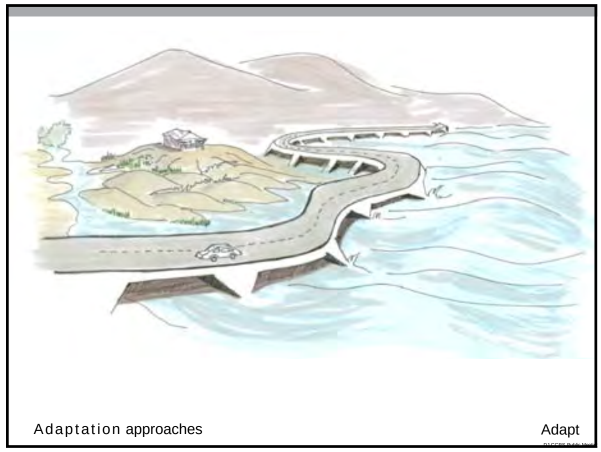


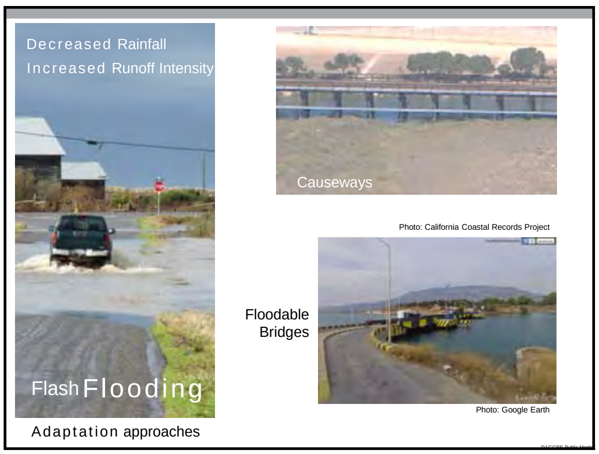
Adaptation approaches

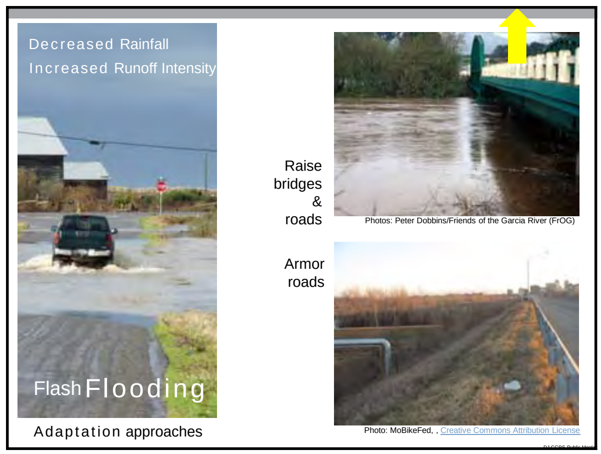
Adaptation approaches

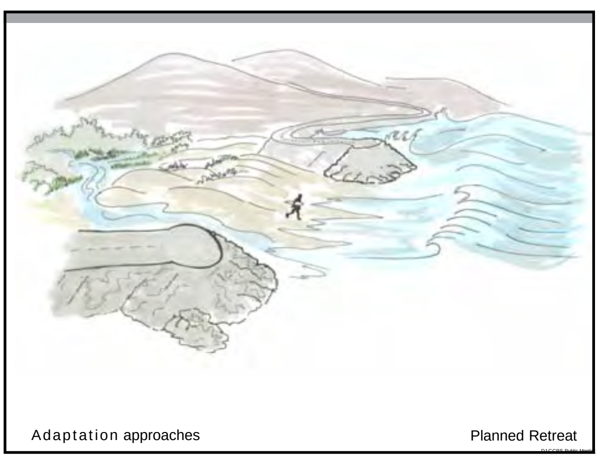
Defend

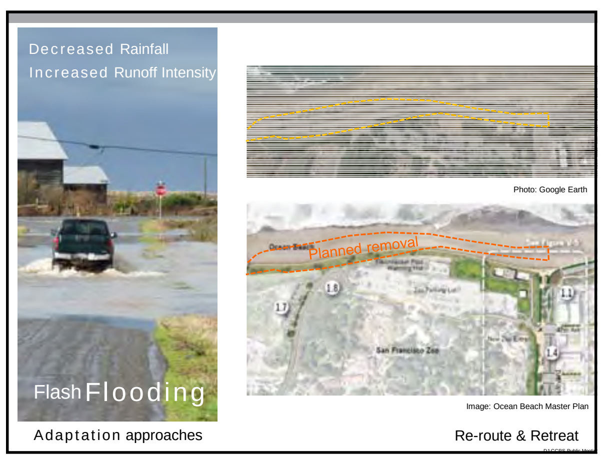

Decreased Rainfall
Increased Runoff Intensity
Flash Flooding
Flood Walls
Levees/
Dikes
Adaptation approaches

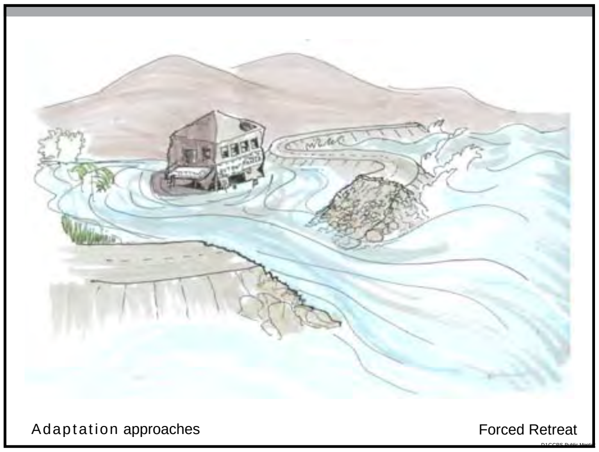

Adaptation approaches
Adapt

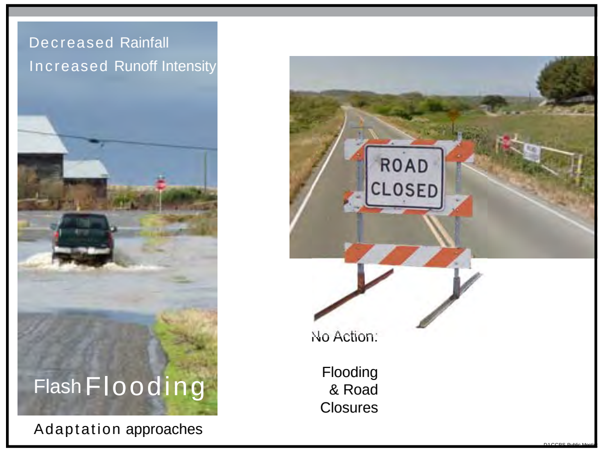

Decreased Rainfall
Increased Runoff Intensity
Flash Flooding
Causeways
Photo: California Coastal Records Project
Floodable
Bridges
Photo: Google Earth
Adaptation approaches

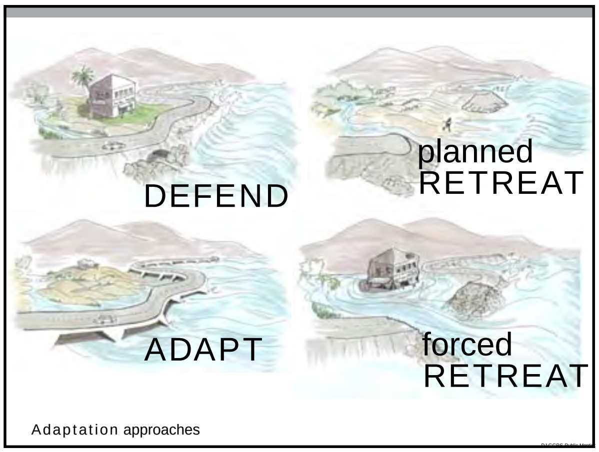

Decreased Rainfall
Increased Runoff Intensity
Flash Flooding
Raise
bridges
&
roads
Photos: Peter Dobbins/Friends of the Garcia River (FrOG)
Armor
roads
Photo: MoBikeFed, , Creative Commons Attribution License
Adaptation approaches

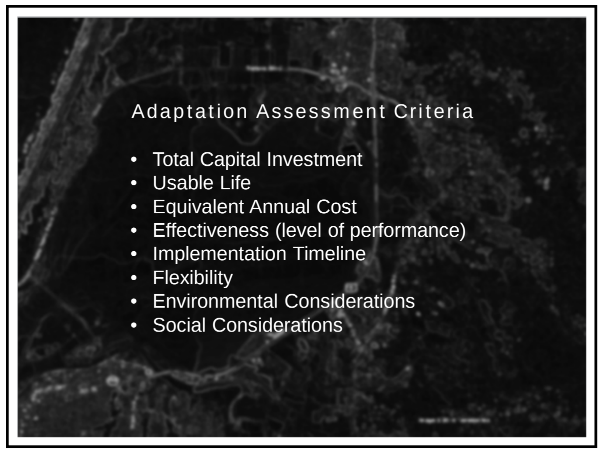

Adaptation approaches
Planned Retreat


Decreased Rainfall
Increased Runoff Intensity
Flash Flooding
Photo: Google Earth
Planned removal
Image: Ocean Beach Master Plan
Adaptation approaches
Re-route & Retreat









Project website

http://www.northcoastclimatechange.com


DISTRICT ONE CLIMATE CHANGE PILOT STUDY
CLIMATE CHANGE ADAPTATION PILOT STRATEGY FOR CRITICALLY VULNERABLE ASSETS IN A NORTHWEST CALIFORNIA PROJECT
DISTRICT ONE - CLIMATE CHANGE - PILOT STUDY - (D1CCPS)
TECHNICAL ADVISORY GROUP
STAKEHOLDERS GROUP
RELATED LINKS
CalTrans District One
DISTRICT ONE – CLIMATE CHANGE – PILOT STUDY – (D1CCPS)
Project Background
The planning department of Caltrans District 1 applied for and received a grant from the Federal Highway Administration to study the potential vulnerabilities of transportation assets to climate change throughout District 1 (Del Norte, Humboldt, Mendocino, and Lake Counties) and to identify and evaluate a range of adaption options to address the identified vulnerabilities at four prototype locations.
The study will begin with an inventory of transportation assets in District 1 and a subsequent analysis to determine which assets are critically vulnerable. Following this task, four pilot sites ("prototype locations") will be selected for further analysis during the "adaptation assessment" phase of the project. The adaptation assessment will identify options for adapting Caltrans infrastructure to the various climate change factors and will evaluate the level of protection, flexibility, relative costs, acceptability,

Appendix 11

Scope of Work

EXHIBIT B

CLIMATE CHANGE ADAPTATION PILOT STRATEGY FOR
CRITICALLY VULNERABLE ASSETS IN NORTHWEST CALIFORNIA PROJECT

SCOPE OF WORK

The following terms are defined here for the purposes of the following scope:

- CONSULTANT – GHD
- CLIENT – Caltrans and HCAOG
- Project Management Team (PM Team) – Up to a total of four individuals from HCAOG and Caltrans directly associated with the day-to-day management of the project.
- Technical Advisory Group (TAG) – Individuals from a total of up to 15 federal, state, and local governmental/regulatory organizations/agencies that will provide project guidance and will have review-authority throughout the project. These individuals will attend quarterly TAG meetings, review each draft and final submittal, attend TAG meetings, and attend stakeholder meetings. TAG meetings will occur approximately quarterly. This group will be limited to governmental entities.
- Stakeholder Group – Individuals from a total of up to 50 federal, state, and local agencies that have an interest in the vulnerability assessments and adaptation methodologies developed as part of the project as well as an interest in the environment or services affected by Caltrans District 1 transportation facilities. These individuals will provide high-level guidance at scheduled points in the project and that will participate in up to four meetings. This group will be limited to governmental entities.
- Interested-Parties – Individuals that are not in any of the above groups but that may have an interested in the project. These individuals will be contacted via email at periodic intervals (up to six times) and will be invited to all public meetings.
- Regional Transportation Planning Agency (RTPA) – Del Norte Local Transportation Commission (DNLTC), Humboldt County Association of Governments (HCAOG), Mendocino Council of Governments (MCOG), and Lake County/City Area Planning Council.

Task 1: Technical Advisory Group, Verification & Outreach

This task captures the interaction between the Project Management Team (PM Team) and advisory and guidance groups, preparation of public meetings, and development of a public website.

Task 1A: Form Technical Advisory Group

Task 1A involves four primary actions on the part of the CONSULTANT:

(1) Organization of the TAG;
(2) Coordination and facilitation of quarterly TAG meetings;
(3) Development of a list of stakeholders; and
(4) Coordination with the Humboldt Bay Sea Level Rise Adaptation Planning Working Group (APWG).

The TAG will be comprised of representatives from all four Regional Transportation Planning Agencies (RTPA), Caltrans, and other federal, state, and local governmental/regulatory organizations/agencies.

CONSULTANT will develop a list of organizations and individuals' names from those organizations and present the list to the PM Team. The PM Team will approve the TAG list or recommend alterations. CONSULTANT will contact each of the approved individuals/organizations and facilitate their involvement as TAG members.

TAG meetings will be held in Eureka. CONSULTANT will manage TAG communications via phone calls, emails, and via an information exchange page on the project website (described below under Task 1C). CONSULTANT will organize and facilitate an inception meeting early in the project to establish a collaborative environment between the TAG and the PM Team. On an approximately quarterly basis, CONSULTANT will organize and facilitate four (4) additional meetings (for a total of five TAG meetings). Due to the fact that TAG members are dispersed throughout the geographic extent of District 1, CONSULTANT will set up teleconferencing and video conference services for each TAG meeting in order to enable maximum participation of the TAG members.

CONSULTANT will schedule and coordinate meeting logistics. CONSULTANT will prepare meeting agenda, meeting materials, and presentations. The TAG will be provided an opportunity to review all correspondence or documentation produced prior to release to Stakeholders or the public.

As a part of task 1A, CONSULTANT will coordinate with the Humboldt Bay Sea Level Rise Adaptation Planning Working Group (APWG) to exchange information and expertise on existing adaptation studies in the Humboldt Bay region. APWG updates will be presented to the TAG at their quarterly meeting and to the PM Team following each bi-monthly APWG meeting.

CONSULTANT will also compile a list of stakeholders and interested parties. The list of stakeholders is proposed to be utilized to solicit participation in the meetings identified in Task 5A and for the on-site training described in Task 5B.

CONSULTANT will consult with Caltrans District 1 Native American Liaison to contact Tribal Governments and to invite them to participate as a stakeholder so that they may represent tribal interests in the project.

Task 1B: Public Meetings

CONSULTANT will organize and hold eight public meetings to provide local communities an opportunity to learn about the project. CONSULTANT will utilize presentations and visual aids to inform stakeholders and the public about potential climate change impacts to Caltrans transportation facilities in District 1 and proposed adaptation measures to increase transportation facility resiliency to climate change and severe weather. Time will be allotted for the public to provide comments and ask questions of TAG members present, PM Team, and CONSULTANT.

CONSULTANT will schedule and coordinate meeting logistics. CONSULTANT will prepare meeting agenda, meeting materials, and presentations. The TAG will be provided an opportunity to review correspondence or documentation produced prior to release to Stakeholders or the public.

The first four public meetings will be held near the middle of the project timeline and will be held in four different locations: one in Del Norte County, one in Humboldt County, one in Mendocino County, and one in Lake County. The last four public meetings will be held near the end of the project timeline. These four final public meetings will consist of live webcasts that will be broadcast in four different locations: one in Del Norte County, one in Humboldt County, one in Mendocino County, and one in Lake County. CONSULTANT will work the four RTPAs to coordinate the live webcasts. CONSULTANT will conduct the live webcasts in Eureka, while each of the RTPAs will facilitate the meeting locations and audio-visual materials.

CONSULTANT will advertise each of the eight public meetings at least three weeks in advance using local newspapers, community radio announcements, and website links. CONSULTANT will post digital copies of outreach materials, notices, attendee list, meeting agenda and minutes as well as presentation materials and a summary of each public meeting on project website (see Task 1C).

Task 1C: Website

CONSULTANT will create a project logo, web design, content, and secure site permissions. The website will have two access restricted web pages, one to facilitate information exchange for the TAG and one for the PM Team. The website will host online links to videos of the public meetings, and presentations. Deliverables approved by the TAG will be posted online for public view. The website will be hosted on a private server for the duration for the duration of the project. At completion of the project the website will be packaged for upload to either Caltrans District 1 or HCAOG website so that the project information will be accessible after the project is completed.

TASK 1 DELIVERABLES:

- *Draft lists of TAG members and Stakeholders members*
- *Final lists of TAG members and Stakeholders member, and their contact information*
- *Draft meeting agendas for all PM, TAG, Stakeholder, and Public meetings*
- *Final meeting agendas, minutes, sign in sheets, and all other related materials prepared by CONSULTANT for TAG meetings, Stakeholder meetings, and Public meetings*
- *Five TAG meetings*
- *Eight public meetings*
- *Live project website*

CONSULTANT FEE FOR TASK 1: $52,000

Task 2: Vulnerability Confirmation

Task 2 will assess the criticality and vulnerability of Caltrans-owned transportation assets in District 1 to the following anticipated climate change effects:

- sea-level rise
- severe weather storms,
- inland flooding
- coastal bluff erosion
- landslides
- prolonged drought
- wildfire

CLIENT has identified four potential locations to serve as “Prototype Pilot Locations” (prototype locations) that we be evaluated in this task for their appropriateness for serving as the locations to be analysed in Task 3. The four sites identified by CLIENT are:

- Post Mile (PM) 14.8 to PM 15.6 on US 101 in Del Norte County, commonly known as “Last Chance Grade.”
- PM 18.1 to PM 18.6 on State Route (SR) 1 in Mendocino County near the Garcia River.
- PM 79.6 to PM 85.6 on US 101 in Humboldt County between the Cities of Eureka and Arcata.
- A corridor on the northwest shore of Clear Lake in Lake County (near SR 20).

CONSULTANT will conduct an assessment in Task 2 that will be used to confirm the appropriateness of these four prototype locations for analysis in the adaptation methodology component of the project (Task 3).

CONSULTANT will use existing data from Caltrans and other State sources, the Climate Change and Extreme Weather Vulnerability Assessment Framework (FHWA, 2012) and a qualitative methodology as described in the Climate Change and Extreme Weather Vulnerability Assessment Framework (FHWA, 2012).

CONSULTANT will approach Task 2 in six steps:

1. Conduct an inventory of Caltrans-owned transportation assets in District 1.
2. Gather information from generally accepted sources on climate change projections of sea level rise, temperature changes, precipitation changes, and storm surge together with associated hazards such as erosion, flooding, landslide, and fire within District 1. CONSULTANT will provide the PM Team the opportunity to review and approve the sources gathered by CONSULTANT.
3. Consult with Caltrans staff regarding prior extreme weather impacts and identify Caltrans facilities and highway segments that have known extreme weather vulnerabilities.

4. Establish qualitative criteria for initial screening for both asset criticality and vulnerability based on guidance provided by the "*Climate Change and Extreme Weather Vulnerability Assessment Framework, Federal Highways Administration, December 2012"* (FHWA, 2012) (which is an updated version of the methodology provided in Washington State DOT's 2011 study "Climate Impacts Vulnerability Assessment").
5. Utilize feedback from PM Team, TAG, Stakeholders, public and other appropriate subject matter experts to undertake qualitative screening, to assess/prioritize asset criticality, and to estimate vulnerability.
6. Create GIS maps showing the results of asset inventory, criticality assessment, and vulnerability assessment.
7. Confirm and refine the four prototype locations.

Task 2A: Data Collection & Vulnerability Assessment

A targeted inventory of Caltrans-owned transportation assets in District 1 will be conducted. The initial approach will be to collect pertinent information from the Caltrans GIS Data Library (http://www.dot.ca.gov/hq/tsip/gis/datalibrary/gisdatalibrary.html), and then augment with additional information from other existing Caltrans datasets, provided by Caltrans. CONSULTANT anticipates that the inventory will include several different transportation asset types, including road segments, bridges and tunnels, culverts and storm sewers, rest stops, and maintenance and office buildings. CONSULTANT assumes that the required data sets are available in a geo-referenced digital format that can be incorporated into GIS.

For linear features, such as highways, CONSULTANT will identify segments based on terrain and potential exposure to climate change hazards. CONSULTANT will consolidate the associated highway system infrastructure (highway, bridges, bridge approaches, rest stops, culverts, adjacent slopes) into segments.

CONSULTANT will compile existing GIS-based climate change information on sea level rise, storm surge temperature, and precipitation for both mean and extreme conditions. In addition, CONSULTANT will include information on projected changes in hazards such as erosion, flooding, landslide, and fire that are associated with climate change. This will be overlaid on the asset data to evaluate the vulnerability. After initial assessment of available climate data and assumptions, CONSULTANT's findings will be reviewed and approved by the PM Team.

Consultation with key Caltrans District 1 staff such as maintenance area superintendents will be undertaken by CONSULTANT to gather information on historic extreme weather events. This will be used to provide an understanding of existing vulnerabilities.

CONSULTANT will describe the climate change information and characterize the uncertainties, consistent with the FHWA Risk Model and based on discussions with the TAG. CONSULTANT will obtain agreement from the PM Team on the planning horizons over which projections will be made to correlate with other planning efforts and to maximize the use of existing data. CONSULTANT will use the Caltrans Guidance on Incorporating Sea Level Rise (Caltrans 2011) to properly assess the criteria for including sea level rise, and to inform planning horizons. CONSULTANT will comply with the FHWA conceptual model of risk analysis, which requires consideration of the likelihood and magnitude of future climate change scenarios by identifying several different levels of sea level rise and other climate change stressors, such as increased temperature and changes to precipitation patterns. CONSULTANT will discuss the different scenarios and projections that are available with the TAG. CONSULTANT will illustrate how climate uncertainty creates four main scenarios: high likelihood and high magnitude, high likelihood but low magnitude, low likelihood but high magnitude, and low likelihood and low magnitude.

CONSULTANT will use climate data that can be accessed and viewed from several publicly available sources, including Cal-Adapt, Coupled Model Intercomparison Project (CMIP) Archive, and the Pacific Institute GIS Data (Pacific Institute 2009). Other guidance for applying climate projections will also be used, including existing guidance established by Caltrans. CONSULTANT will review the following sources of climate data and projections:

- Reports on the Third Assessment from the California Climate Change Center, 2012
- Climate Change and Sea Level Rise Scenarios for California Vulnerability and Adaptation Assessment (Cayan et al. 2012)
- Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future (NRC 2012)
- The Impacts of Sea-Level Rise on the California Coast (Pacific Institute 2009)
- Simulation of Climate Change in San Francisco Bay Basins, California: Case Studies in the Russian River Valley and Santa Cruz Mountains (Flint and Flint 2012)
- State of California Multi-Hazard Mitigation Plan (Adopted 2010)
- Draft California State Hazard Mitigation Plan (In Progress 2013)
- 2013 Draft State (California) Multi-Hazard Mitigation Plan Public (currently in public review process)
- Crescent City/Del Norte County Hazard Mitigation Plan
- The 2008 Humboldt Operational Area Hazard Mitigation Plan (Approved 2008)
- 2013 Update Humboldt Operational Area Hazard Mitigation Plan (in progress)
- The 2008 Mendocino County Multi-Hazard Mitigation Plan (Approved 2008)
- 2013 Update Mendocino County Multi-Hazard Mitigation Plan (currently in public review process)
- Lake County Natural Hazard Mitigation Plan (2012)

The criticality of assets and level of impact will be established based on previously developed methods (FHWA, 2012 and "*Climate Impacts Vulnerability Assessment Report, Washington State Department of Transportation, November 2011"* (WSDOT 2011)). The criticality evaluation will include a primarily qualitative assessment of whether the particular asset is classified as being low, moderate, or very critical, and a basic quantitative technique to establish a simple numerical scale from 1 to 10. The criticality criteria will include factors such as level of roadway classification (e.g. interstate, lifeline), traffic volumes, and the presence of alternate routes. Determinations of criticality will incorporate input received at public meetings on use of the asset. Impact ratings of assets will assess the potential consequences associated with climate change impacts on a simple numerical scale from 1 to 10. The impact scale will be divided into three major categories: Complete Failure, Temporary Operational Failure, and Reduced Capacity (FHWA, 2012; WSDOT 2011). The qualitative criteria for asset criticality and vulnerability will be agreed upon with the TAG prior to its use.

CONSULTANT will undertake a preliminary screening of assets to assess and prioritize asset criticality and vulnerability which will be illustrated graphically. Graphic illustrations will then be taken to the TAG to confirm qualitative screening by appropriate subject matter experts. During these meetings, the findings of both the asset inventory and climate change impacts will be described and discussed. CONSULTANT will coordinate with Caltrans staff and RTPA staff to compile historical knowledge of extreme events and their impacts.

Assessing the change in asset vulnerability over time will be completed for the planning horizons previously agreed upon. CONSULTANT will use the climate projections to establish how impacts to assets will change over time, and then compare to criticality, to determine the change in vulnerability. Once vulnerability has been established for transportation assets, CONSULTANT will prioritize highly vulnerable assets in order of criticality. This list will assist in evaluation and confirmation of the appropriateness of the previously selected prototype locations.

The methodology and results of the process undertaken in Task 2A will be presented in Technical Memorandum #1. As a part of this memorandum, CONSULTANT will create one or more GIS based map(s) of Caltrans-owned assets in District 1 and specify vulnerable locations and facilities. These maps will be based on a geodatabase of the compiled GIS layers, which will be provided to CLIENT with Technical Memorandum #1. The final map(s) will include layers showing facility type, impact type, and criticality of the facility. The map(s) will include background layers showing terrain, rivers and streams, coastline, and mean and extreme climate change stressors.

Task 2B: Confirm & Refine Project Areas for Adaptation Work

The prototype locations identified above will be analysed based on the data collected under Task 2A. The sites will be analysed for their appropriateness for use throughout Task 3 of this scope. If necessary, the spatial boundaries of the prototype locations will be refined to ensure that they include areas that are in the "highly vulnerable" category and over areas which an adaptation strategy can be developed. If necessary, CONSULTANT will propose new prototype locations to the PM Team.

Once the prototype locations have been approved by the PM Team, focused downscaled climate change information (previously developed in Task 2A for the whole of District 1) will be refined for the four prototype locations. These will serve as key inputs to the discussion on adaptation strategies. The GIS map(s) will be updated to include this and additional existing information on the assets that is relevant to the development of adaptation strategies. The methodology and results of the process undertaken in Task 2B will be presented in Technical Memorandum #2.

TASK 2 DELIVERABLES:

- *Draft Technical Memorandum #1 (Vulnerability)*
- *Final Technical Memorandum #1 (Vulnerability)*
- *Draft Technical Memorandum #2 (Confirmation/Refinement of Prototype Locations)*
- *Final Technical Memorandum #2 (Confirmation/Refinement of Prototype Locations)*
- *Draft GIS maps (associated with Technical Memorandum #2)*
- *Final GIS maps (associated with Technical Memorandum #2)*
- *Final Geodatabase of GIS data (associated with GIS maps)*

CONSULTANT FEE FOR TASK 2: $55,000

Task 3: Adaptation Assessment

CONSULTANT will conduct an adaptation assessment that will identify options for adapting to climate change and that will evaluate the benefits, costs, effectiveness, efficiency, and feasibility of those adaptation options. This assessment will include:

- Identification of appropriate adaptation options/actions
- Development of criteria that will be used to evaluate feasibility, including: benefits, costs, and effectiveness
- Methodology to evaluate adaptation options

In this task, CONSULTANT will identify adaptation strategies for the vulnerabilities identified at the prototype locations. CONSULTANT will develop adaptation actions that may provide Caltrans with feasible options for adapting critical infrastructure to changing climate conditions. Adaptation strategies will focus on engineering based solutions, including structural modifications, operational strategies, design standards, and technology improvements. In addition, opportunities to incorporate ecosystem-based adaptation, such as using wetlands and beaches to reduce sea level rise impacts, as well as non-structural solutions, such as traffic routing, may be investigated as appropriate.

CONSULTANT will describe each adaptation strategy using an implementation timeline, relative cost, flexibility, and potential for multiple benefits. CONSULTANT will develop a set of criteria to evaluate the applicability of different strategies to the climate change impacts identified at the prototype locations. The criteria will allow comparison of the different strategies (including a no action scenario) in terms of relative costs, useful life, environmental constraints, public acceptability, and other criteria identified in coordination with the TAG. Once the adaptation strategies and assessment criteria have been established, CONSULTANT will develop a rating and ranking system to identify the most feasible option to pursue for implementation at each of the four prototype locations. Finally, CONSULTANT will develop a planning level cost estimate for the priority adaptation strategy at each prototype location.

Task 3A: Identify Adaptation Options

CONSULTANT will identify climate adaptation strategies that could be implemented at the four prototype locations in order to adapt Caltrans facilities within those four locations to climate change.

A preliminary list of adaptation options will be developed based on CONSULTANT's existing knowledge base, information from the literature review, and consultation with the PM Team, the TAG, and Stakeholders.

CONSULTANT will identify the following types of engineering-based adaptation strategies:

- Increased frequency and/or alternate approaches to facility maintenance
- Structural modifications to roadways, bridges, facilities, and other assets
- Changes to maintenance approach, including frequency and types of maintenance activities
- Culvert repairs and replacements
- Elevating of roadways
- Replacement of low-lying roadways with bridges
- Realignment of roadways
- Installation of retaining structures
- Redesigns of facilities utilizing alternate construction materials
- Utilization advanced warning systems
- Incorporating climate change modelling outputs into adaptation assessments

CONSULTANT will develop the following types of descriptive information for each adaptation option:

- Climate Factor: This is the climate change impact the adaptation methodology addresses; for example: sea level rise, changes in precipitation, or changes in stream flows.
- Anticipated Effect: This is the effect on the asset that is anticipated from the climate change factor. There will likely be more than one effect on an asset from climate change in both type and magnitude over time.
- Adaption Option: This is the adaptation option to be assessed; for example: temporary road closures, raising flood protection levee, roadway realignment, etc.
- Planning Horizon: Differentiates between measures appropriate for short-term planning, including minor modification at lower costs and fewer constraints, and long-term planning for major improvements with higher costs and greater regulatory, political, or legal constraints.
- Implementation Timeline: Estimated lengths of time required to plan and implement the option, or estimated time until a new technology is expected to be available.

Adaptation improvement options will be thoroughly described and categorized into long and short term options.

The information will be summarized in table format (presented in Technical Memorandum #3) and will feature more detailed descriptions of the adaptation options. The methodology and results of the process undertaken in Task 3A will be presented in Technical Memorandum #3.

Task 3B: Develop Adaptation Assessment Criteria

CONSULTANT will develop a preliminary list of criteria to evaluate the feasibility of adaptation options. CONSULTANT will then facilitate feedback from the TAG and PM Team to review the list and help refine or add criteria that will be important to understand when assessing the options. In addition to development of the list of adaptation criteria, CONSULTANT will facilitate input from the TAG regarding how the criteria should be defined and how to apply the criteria to the adaptation options. The preliminary list of criteria includes:

- Relative Cost: Order of magnitude estimate of potential costs for implementation of the adaptation option as well as the potential cost of no action.
- Level of Confidence: Estimates the probability that the measure will provide the desired resiliency and reduced vulnerability.

- Asset Severity: Determines the level of impact that would be experienced by a complete failure of the asset
- Effectiveness: The likelihood that the adaptation option will reduce the risk of impact
- Potential Restraints: Regulatory, political, environmental, or physical factors that may imped implementation
- Implementation Timeline: Consideration of phasing and timeline impacts
- Supplemental Benefits: Benefits that may be experienced beyond protection of Caltrans assets
- Useful life: Looks at the length of time the option will be functional for climate adaptation; for example: temporary road re-routing may have a limited life due to eventual need to replace a road.
- Level of Protection: Minimum level of service, existing level of service, and enhanced level of service to be provided by the adaptation option
- Flexibility: Ability of the option to be modified as new data and models for climate change are developed and changes at the local level are better understood
- Site Specific Constraints: Evaluation of potential regulatory, environmental, and political constraints that may affect implementation of the adaptation option
- Public Acceptability: Estimate of the reaction of the public to the adaptation option.
- Integrated Benefits: Secondary benefits that may be provided beyond protection of the transportation asset, such as public access and trails, habitat improvements, and mitigation of impacts using the natural environment (e.g., wetland restoration for reducing wave heights and impacts) which may increase support for the measure and influence funding opportunities

CONSULTANT will facilitate feedback from the TAG and Stakeholders regarding the needs and priorities at each of the prototype locations. CONSULTANT will then compare the list of adaptation options compiled in Task 3A with the needs and priorities at each of the prototype locations. A maximum of 5 adaptation strategies will be evaluated for each prototype location. CONSULTANT will develop a set of criteria to evaluate the applicability of different strategies to the climate change impacts identified at the prototype locations. The criteria will allow comparison of the different adaptation options (including a no action scenario) to adapt assets to improve their resiliency to climate change.

CONSULTANT will document the process of developing and refining the adaptation criteria, and the input used to determine the importance of inclusion or exclusion of specific criteria, to facilitate ability of other organizations to apply the methodology to similar transportation assets at risk located throughout the state and country. The methodology and results of the process undertaken in Task 3B will be presented in Technical Memorandum #4.

Task 3C: Adaptation Assessment Methodology

CONSULTANT will develop an objective comparison and ranking of adaption options that may reduce the vulnerability of specific assets by combining the suite of adaptation implementation options with the criteria against which the options will be assessed. Information from Task 2A on the impacts of loss of use of the asset and the remaining useful life of the asset will be incorporated at this point in the evaluation.

CONSULTANT will develop a priority adaptation option selection methodology that includes a matrix ranking the most feasible options with the greatest effect on reducing the vulnerability of assets. Weights will be assigned to assessment criteria. A score will be assigned to each assessment criteria for each adaption option and multiplied by the criteria weight to result in a total weighted criteria score.

CONSULTANT will develop a uniform scoring system to measure the ability of the adaptation option to address the vulnerability of the asset. The scoring system and weighting factors will be based on technical research conducted in Task 3A and supported by opinions from relevant experts from the TAG and stakeholders. A sensitivity analysis on the criteria weightings will be conducted to assure a reasonable balance of weights to avoid dominance by a single assessment criterion.

While the assessment methodology will be applied to the four prototype locations as part of this study, it will also be developed in a logical step by step manner such that it can be used by others after the study is complete. The methodology and results of the process undertaken in Task 3C will be presented in Technical Memorandum #5.

Task 3D: Cost Analysis for Adaptation Options
After prioritization of the adaptation options, the highest priority option at each pilot location will be further evaluated in terms of potential planning and implementation costs and possible funding sources. The adaptation option cost analysis is anticipated to take into consideration; permitting, California Environmental Quality Act documentation, mitigation, design, purchase of lands and rights-of-way, and construction costs. The methodology and results of the process undertaken in Task 3D will be presented in Technical Memorandum #6.

TASK 3 DELIVERABLES:
- *Draft Technical Memorandum #3 (Adaptation Options)*
- *Final Technical Memorandum #3 (Adaptation Options)*
- *Draft Technical Memorandum #4 (Adaptation Criteria)*
- *Final Technical Memorandum #4 (Adaptation Criteria)*
- *Draft Technical Memorandum #5 (Adaptation Assessment Methodology)*
- *Final Technical Memorandum #5 (Adaptation Assessment Methodology)*
- *Draft Technical Memorandum #6 (Cost Analysis for Selected Adaptation Option)*
- *Final Technical Memorandum #6 (Cost Analysis for Selected Adaptation Option)*

CONSULTANT FEE FOR TASK 3: $173,000

Task 4: Final Report
CONSULTANT will develop a final report, which will include a summary documenting the work completed, an overview of the methodologies developed in each of the six technical memorandums, and the procedures for estimating costs of adaptation options. In addition, the final report will include:
- A summary of the work performed and deliverables produced
- A description of the groups involved, including the TAG, PM Team, stakeholders, and the public; the roles and responsibilities of each of these groups will also be described
- Prioritized list of adaptation options for the assets at the prototype locations
- Recommendations for future actions to improve climate change adaptation process and procedure for transportation agencies
- Best practices, lessons learned, issues encountered, and procedures used to address the issues

CLIENT will distribute final report to peer agencies including State Departments of Transportation and other interested parties.

TASK 4 DELIVERABLES:
- *Administrative Draft Report*
- *Draft Final Report*
- *Final Report*
- Ten (10) hard copies and three (3) DVD copies of the final report

CONSULTANT FEE FOR TASK 4: $20,000

Task 5: Training & Presentations

Task 5A: Stakeholder Meetings & Presentations
CONSULTANT will develop a list of potential stakeholders. The list will consist of organizations and individuals' names from those organizations. The PM Team will approve the Stakeholder list or

recommend alterations. CONSULTANT will contact each of the approved individuals/organizations by email and solicit their involvement as Stakeholders.

CONSULTANT will utilize presentations and visual aids to inform stakeholders about potential climate change impacts to Caltrans transportation facilities in District 1 and proposed adaptation measures to increase transportation facility resiliency to climate change and severe weather.

CONSULTANT will schedule and coordinate meeting logistics. CONSULTANT will prepare meeting agendas, meeting materials, and presentations. The TAG will be provided an opportunity to review all correspondence or documentation produced prior to release to Stakeholders.

CONSULTANT will organize and facilitate six stakeholder meetings. Four of the stakeholder meetings will be held in different locations: one in Del Norte County, one in Humboldt County, one in Mendocino County, and one in Lake County. The other two stakeholder meetings will consist of live webcasts that stakeholders can join remotely.

CONSULTANT will consult with Caltrans District 1 Native American Liaison to contact Tribal Governments and to invite them to participate as a stakeholder so that they may represent tribal interests in the project.

Task 5B: On-Site Training

CONSULTANT will provide 8 hours of on-site training in Eureka to interested TAG members and stakeholders on preparing vulnerability and adaptation assessments that address climate change impacts and increase transportation facility resiliency to climate change and severe weather. Due to the fact that TAG and Stakeholder members are dispersed throughout the geographic extent of District 1, CONSULTANT will set up teleconferencing and video conference services in order to enable maximum participation in the Training.

TASK 5 DELIVERABLES:

- *Six stakeholder meetings and presentations*
- *Draft agendas for each Stakeholder meeting*
- *Final meeting agendas, minutes, and all other related materials prepared by CONSULTANT for each of the six Stakeholder meetings*
- *Draft agenda for the eight-hour training*
- *Eight hours of on-site training (hosted in the City of Eureka)*
- *Final meeting agendas, minutes, and all other related materials prepared by CONSULTANT for the training*

CONSULTANT FEE FOR TASK 5: $50,000

TASK 6: Project Management & Contract Administration

Upon receipt of a signed contract, CONSULTANT will work with CLIENT to coordinate a kickoff meeting. CONSULTANT will review and refine the contract scope and schedule and develop a strategic plan for completing this project within the required timeline. The meeting may be held at the Caltrans District 1 office, HCAOG Office, or CONSULTANT's Eureka Office.

The PM Team will meet bi-weekly to conduct status meetings. CONSULTANT will refer to these meetings as the "PM Team Meetings." CONSULTANT will attend every PM Team Meeting, and technical staff from CONSULTANT's sub-consultants will attend specific PM Team Meetings when needed.

For each PM Team Meeting, CONSULTANT will create and distribute an agenda at least 24 hours prior to each meeting. CONSULTANT will coordinate all logistics regarding meeting locations, teleconferencing, and video teleconferencing. Following each meeting, CONSULTANT will distribute a list of minutes and action items.

CONSULTANT will work closely with CLIENT to ensure completion of all tasks and deliverables identified in the approved scope of work/ proposal. CONSULTANT will use accounting software to prepare and submit invoices for reimbursable expenses (including detailed description of expenditures per task and supporting documentation) monthly to HCAOG for processing and payment. Each invoice will include a progress report of work performed.

TASK 6 DELIVERABLES:
- *Bi-weekly status report notes*
- *Monthly invoices; invoices will be changed at the Task level*

CONSULTANT FEE FOR TASK 6: $50,000

ASSUMPTIONS

CONSULTANT assumes the following:

- This study will only apply to Caltrans facilities and Caltrans roadways. This project will not apply to non-Caltrans facilities/roads such as County roads.
- In situations where a Caltrans facility has a design alteration that is programmed for implementation, the project will assess existing conditions unless Caltrans can provide all of the following associated with the programmed design alternation:
    - Engineered design plans (at the 30% level or greater)
    - Georeferenced topographic survey data in either GIS, AutoCAD, or Microstation format
    - CEQA documentation
    - Project Study Report
- The Project Management Team (PM Team) will be limited to a total of four individuals from HCAOG and Caltrans.
- The Technical Advisory Group (TAG) will be limited to a total of 15 federal, state, and local governmental/regulatory organizations/agencies.
- The TAG will be limited to governmental entities.
- The Stakeholder Group will be limited to a total of 50 federal, state, and local agencies.
- The Stakeholder Group will be limited to governmental entities.
- The quarterly TAG meetings will be held in Eureka; live video webcast will be available for TAG members that cannot travel to Eureka.
- The PM Team and TAG will be invited to attend stakeholder meeting/presentations and public meetings.
- Four of the eight public meetings will be held in specific locations: one in Del Norte County, one in Humboldt County, one in Mendocino County, and one in Lake County. The other four public meetings will consist of live webcasts that will be broadcast in four different locations: one in Del Norte County, one in Humboldt County, one in Mendocino County, and one in Lake County. Each of the four RTPAs will coordinate these live webcasts. CONSULTANT will conduct the live webcasts in Eureka, while each of the RTPAs will facilitate the meeting locations and audio-visual materials.
- Four of the six Stakeholder Meetings will occur in specific locations: one in Del Norte County, one in Humboldt County, one in Mendocino County, and one in Lake County. The other two stakeholder meetings will be held in Eureka and will consist of live video webcasts that stakeholders can join remotely.
- The live training will occur in Eureka.
- Two of the six stakeholder meetings will occur on the same day and at the same location as two TAG meetings. The stakeholder meetings will be separate from the TAG meetings; the two sets of meetings will be back-to-back.

- Four of the eight public meetings will occur on the same day and at the same location as four of the Stakeholder meetings. The public meetings will be separate from the stakeholder meetings; the two sets of meetings will be back-to-back.
- A draft of each technical memorandum will be provided to the TAG for review. Drafts will be provided in Microsoft Word format. The TAG will review draft products within two weeks of receiving the products. Reviews will occur using the "Tracked Changes" feature of Microsoft Word. Each agency will compile its comprehensive comments into a single Word Document (with tracked changes).
- No more than five adaptation strategies will be developed for each prototype location.
- Within two weeks of receipt of a signed contract, Caltrans will provide to CONSULTANT all existing georeferenced data (GIS, AutoCAD, Microstation, etc) associated with Caltrans facilities in District 1, including all data from the Caltrans GIS Data Library, and other data not in the Caltrans GIS Data Libaray such as data regarding Caltrans facilities in District 1, including road centrelines, roadway segments, bridges, retaining walls, culverts and storm sewers, rest stops, and maintenance and office buildings.
- The data sets provided by Caltrans will be in a geo-referenced digital format that can be incorporated into GIS, and include metadata on the coordinate system and data source. CONSULTANT will not scan, rubber sheet, or digitize paper data.
- For linear features (such as roadways), data will be compiled into segments.
- The criticality of assets and level of impact will be established based on previously developed methods (FHWA, 2012; WSDOT 2011).
- No new climate modelling will be completed as part of this scope. The vulnerability of assets will be based on existing climate models and data agreed to by the TAG.
- The vulnerability of assets will be evaluated under a maximum of two planning horizons and a mean and extreme climate scenario for each planning horizon.

SUMMARY OF CONSULTANT FEE BY TASK

TASK	Total Fee
TASK 1: Technical Advisory Group, Verification and Outreach	$61,000
TASK 2: Vulnerability Confirmation	$96,000
TASK 3: Adaptation Assessment	$164,000
TASK 4: Final Report	$38,000
TASK 5: Training and Presentations	$11,000
TASK 6: Project Management and Contract Administration	$29,989
TOTAL	**$399,989**

Caltrans District 1 Climate Change Pilot Study Comments on the Draft Final Report

December 2014

The commenters are listed below. If comments were submitted by email only, they are included below. If a separate comment document was attached, it is included in this Appendix separately.

Melissa Kraemer, Supervising Planner California Coastal Commission

See Comment Letter

Tamera Leighton, Executive Director Del Norte Local Transportation Commission

See Comment Letter

Jesse Roberson – Senior Transportation Planner, Dow & Associates/ Lake Area Planning Commission

- Thank you for considering my input into the District 1 Climate Change Pilot Study. The following comments are based on my first introduction to the project and should be considered accordingly in light of my lack of previous participation with the project.
- The introduction jumps into the results of facility “criticality” without providing a definition. The explanation of criticality is better explained in the body of the report. Please revise the introduction for clarity to avoid confusion for the readers. The explanation of “Exposure” and “Potential for Impact” is also lacking. It isn’t until the explanation of “Vulnerability” that adequate explanation is provided. The lack of context for the reader needs to be addressed before the second half of page 2.
- Pages 10 and 49 make incorrect references to the Mendocino County Association of Governments. The name of the Regional Transportation Planning Agency is the Mendocino Council of Governments. Please correct.
- Neither the Garcia River Bridge, nor (Lake) County Road 407 made the top 3 priorities for either Lake or Mendocino County.
- The inclusion of a discussion about State Route 1 north of Point Arena, near the mouth of the Garcia River, as an at-risk location currently as well as for greater impacts under a future scenario involving sea-level rise and increases in precipitation would appear to merit a more significant problem or risk. The substantial out of direction travel associated with existing road closures points to a significant lack of redundancy. While areas surrounding Fort Bragg may experience a similar inconvenience under future scenarios, the lack of existing concern in these areas suggests that community size may be weighted too heavily.
- On Page 43, the price attached to the improvements to raise County Road 407 is substantial and it seems likely that the County would be unable to pro-actively improve this segment without financial assistance. An appendix item for funding sources to improve local roads to address climate change impacts would be helpful.
- On Page 45, the adaptation option in the chart to build an earthen structure does not match the bridge replacement description in the introductory discussion immediately preceding the chart. Please verify that the comments portion of the chart and the discussion point to the same option. It appears that the discussion in the appendix has an option #3 that matches the discussion in the text of the document. Please review this section for accuracy and edit as necessary.
- Other edits for typographical errors are needed, as I noted more than one. For time considerations, specific typos are not called out.

Appendix 12

Draft Final Report Comments

STATE OF CALIFORNIA -- NATURAL RESOURCES AGENCY EDMUND G. BROWN, JR, *Governor*

CALIFORNIA COASTAL COMMISSION
NORTH COAST DISTRICT OFFICE
1385 EIGHTH STREET • SUITE 130
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December 8, 2014

Rebecca Crow, PE, Project Manager
GHD, Inc.
718 Third Street
Eureka, CA 95501

RE: Comments on District 1 Climate Change Vulnerability Assessment and Pilot Studies FHWA Climate Resilience Pilot Final Report

Dear Ms. Crow:

Thank you for sharing the draft *District 1 Climate Change Vulnerability Assessment and Pilot Studies FHWA Climate Resilience Pilot Final Report* for our review. We applaud Caltrans' work to proactively address climate change issues for California's transportation system through this pilot. We also appreciate being included in the Technical Advisory Group for the effort.

Our following comments pertain to sections of the report that deal with the identification of vulnerable features and evaluation of adaptation measures, as well as our recommendations for ensuring that these exercises are integrated into related local and regional planning contexts.

With regard to the methodology to identify vulnerable features, we note several admirable aspects of the report, including:

- coverage of a range of climate change topics (not just sea level rise);
- analyses of both a low and high impact scenarios;
- identification of transportation corridors by what appear to be logical segments;
- examination of many highway-related assets (not just roadways).

The report rightly acknowledges that the methodologies used are not and cannot be a "perfect science." The "Lessons Learned" chapter (#5) clearly outlines the evolving nature of the methodologies and the difficulty of accurately and consistently quantifying the various "criticality" considerations. Any time many different variables are applied over a range of potential future projections, the resulting conclusions are speculative as to what actually may come to pass. Moreover, weighting several variables also may mask seemingly small but potentially significant considerations. Nonetheless, planning for the future of public investments and resources requires attempting to identify and apply sound techniques, and the best available information, to the decision-making process.

Relative to this effort, there does appear to some notable corroboration for the project's approach, in that the vulnerabilities projected from the quantitative methodologies were similar to the concerns identified by experts familiar with the studied transportation corridors. And, indeed, use of experienced expert opinion, such as employing the Delphi method, is an accepted predictive methodology. Therefore, given the complexity and cost of the report's tested methodologies, it may be prudent for Caltrans to consider pursuing a more streamlined hybrid approach to identify vulnerabilities throughout the rest of the state and over time. For example, this could take the form of having those familiar with the transportation system perform a first-cut listing of the most likely vulnerable assets. Quantitate methods subsequently could be applied to those selected areas to more specifically predict which effects might happen when, and at what magnitude, and then to determine priorities for the most vulnerable areas based on identified criticality factors. Commission staff supports Caltrans' commitment to address vulnerable transportation infrastructure through scientifically acceptable, predictive methodologies and looks forward to working together to address important infrastructure issues raised by climate change effects in the coastal zone.

The next section of the report illustrates how strategies might be developed for adapting priority vulnerable segments to climate change. We appreciate that the report presents:

- a range of possible measures to address each vulnerable segment;
- environmental and social impacts to factor into the assessments;
- costs;
- advantages and disadvantages of various adaptation strategies; and
- clear maps and graphics of the measures.

The resulting rated adaptation measures can be useful to Caltrans as it moves ahead with its long-term planning. However, we believe that the results of these applied methodologies will need further consideration in both project-specific and larger planning contexts.

Any time scoring is used, it is subject to bias based on the variables chosen for scoring and the different weights given to them. While the scoring system, and subsequent scores assigned, in this pilot effort may reflect Caltrans' mission, it may not adequately account for other State policies and programs. For example, the Coastal Act has mandates to limit shoreline armoring and avoid construction in wetlands and sensitive habitats. Although the report's scoring accounts for environmental factors, it may not give sufficient weight to Coastal Act objectives for subsequent projects in the coastal zone to be found consistent with the Coastal Act or relevant local coastal program (LCP). Relative to cost considerations, we also are concerned that careful attention be given to ensuring that the full spectrum of short- and long-term economic, social, and environmental costs and benefits (not just capital construction costs and benefits) of various options are appropriately analyzed in in these methodologies.

Also, given limited funding, the scoring may need adjustments when considering the potential universe of Caltrans projects. The scoring appears weighted toward structural solutions, which is understandable from a single project's long-term stability perspective. But, from a financial perspective, pursuing less costly, non-structural alternatives could allow more projects to be implemented. This strategy may be necessary to follow if severe or widespread effects of climate change continue to emerge.

More significantly, we encourage Caltrans to integrate its assessment processes with ongoing local and regional planning efforts, including LCP updates, before making final determinations of adaptation strategies to pursue. In terms of choosing which projects to prioritize, it would be beneficial for all stakeholders to consider the universe of vulnerable infrastructure (e.g., utilities, institutional buildings, public recreational facilities, local roads, etc.) in addition to State transportation assets. This will enable various agencies to coordinate approaches and potentially realize cost sharing approaches. For example, Caltrans might choose to move part of a threatened roadway inland, as opposed to strengthen it in place, if there are adjacent utility lines, public works facilities, and/or public pathways that other agencies are planning to relocate as well.

Collaborative planning also can help ensure that climate change threats are not addressed in isolation and that various public objectives can be achieved, such as environmental sustainability, economic health, and social well-being. Such planning may suggest different transportation infrastructure approaches, such as relocating highways, reconfiguring roadways into complete streets, or emphasizing transit or bicycles over automobiles. Thus, for example, while the report's methodology may result in scoring armoring a section of highway over relocation, relocation may better fit into a comprehensive planning solution that accounts for other factors as well as climate change. Additionally, although Caltrans needs to adapt to climate change impacts, because these impacts are in large part driven by our current transportation system, there should also be a major effort to create and invest in a transportation system that also furthers the State's goals to reduce the emission of greenhouse gases.

In conclusion, we applaud Caltrans for examining approaches to address climate change through this pilot effort. Testing and reporting on methodologies that may be appropriate for use elsewhere (and by other parties) should prove valuable. Further discussing a range of possible adaptation strategies and presenting all of this material in a clear and understandable format will aid the many climate change efforts underway in the North Coast. Again, we hope that Caltrans will bring all the information being generated to the table to collaborate with us and other interested agencies, particularly as we deal with related efforts, such as the proposed improvements to the Eureka-Arcata 101 corridor.

We also look forward to working with you and request that you keep us apprised and involved as you move forward with this initiative for potential application elsewhere in the state. Please feel free to contact us if you wish to discuss any of these comments further.

Again, thank you for the opportunity to comment, and feel free to contact Bob Merrill or me with questions (707-826-8950) or contact Tami Grove, our Statewide Development and Transportation Program Manager (831-427-4863).

Sincerely,

Melissa B. Kraemer
Supervising Planner

1301 Northcrest Drive, Ste B PMB 16
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Del Norte Local Transportation Commission

Tamera Leighton, Executive Director
Tamera@DNLTC.org
Desk: (707) 465-3878
Cell: (707) 218-6424

December 8, 2014

Rebecca Crow
GHD Inc.
718 Third Street
Eureka CA 95501 USA

Re: Caltrans District 1 Climate Change Pilot Study (D1CCPS)

Dear Ms. Crow and project team,

On behalf of Del Norte Local Transportation Commission and our region, we are thankful for any increase in knowledge about Last Chance Grade, which is the focus area of study for this pilot study in the Del Norte region.

This 547-page document was difficult to review in the limited time provided – two weeks and during a major holiday: Thanksgiving. While I appreciate your recommendation to focus on Section 4 Prioritization of Actions, I think that a basic review of the entire document is important and I haven't had the opportunity to do so in this limited time.

Throughout this study there have been challenges in obtaining adequate access to information and viable participation. For example, prior to the July 1 TAG meeting I asked Caltrans staff Rex Jackman whether I should drive to Eureka for the meeting. I was assured that the meeting would accommodate a high level of participation via the Internet and call-in. Unfortunately, there were technology issues at the July 1 meeting and all of the participants calling in were put on listen-only mode. This is one of several instances when there were barriers to adequate participation for TAG members outside the Humboldt County area.

I am also concerned about how the TAG was formed. Throughout the document there is mention of TAG participation but up until about July 2014, the TAG was very limited. In the June DNLTC Technical Advisory Committee public meeting, we asked District 1 staff about Tribal participation and were told that there wasn't direct Tribal participation at that time. While Tribal participation and broader participation happened later in the process, I believe that a higher level of consideration to the makeup of the TAG was warranted. While the final list is diverse and robust, this is not the list that was in place through much of the study period.

One of the Key Conclusions states:

> *Through the timeline and implementation tool, this study demonstrated that, regardless of the adaptation option selected, advance planning including environmental permitting is critical to having a strategy on line when needed and receiving the most value for the investment.*

I wholeheartedly agree with this conclusion but I don't believe that adequate consideration has been given to the complexities of the environmental permitting. We seem to have a new phase in highway development in District 1, the litigation phase, and a 10-year project development time frame appears to be unrealistic even if we have a greater level of collaboration between permitting authorities and project proponents.

The study recommends that:

> *The process of engagement should be started early and the broad spectrum of effects and adaptations should be considered so that robust long-term solutions can be developed. The greatest value comes from looking forward and planning future efforts. Your recommendations for priorities and future actions that should be taken by Caltrans to further evaluate, select, and implement climate adaptation strategies will help complete this piece of work and set the direction for future efforts.*

To this end, Del Norte Local Transportation Commission and many interested citizens have written letters in support of long-term solutions to Last Chance Grade, which is the focus project in Del Norte for this study. I have attached these letters for District 1 consideration for next steps.

I also find the Lessons Learned section of the document informative and interesting. The study states:

> *The criticality assessment is challenging because it is essentially a value judgment: what is critical for one person may not be critical for someone else. It is difficult to quantify this context and relativity.*
>
> *In attempting to better focus on criticality to address the challenge noted above, many potential measures were studied and weighed, building in redundancies. It created a false sense of detail and in overemphasizing some criteria, potentially had the effect of skewing weightings.*

While I believe that the final draft has reasonable conclusions, there were many challenges in process. When the measures are studied and weighted but the conclusions don't ring true, we all must be willing to step away from the studies and weights and focus on basic good sense. I applaud the GHD team in its willingness to do step back from the data and consider basic good sense, but I am concerned that a formula can so easily lead to overemphasizing some criteria with the effect of skewing weightings.

Also of interest:

> *This highly involved process led to a ranked list of vulnerable assets. The process often validated what was already understood by the managers of the assets. There were few surprises regarding locations of vulnerability. This also highlights the observation that, in light of the limitations of site specific data, it may be more productive in regions where vulnerable assets are well understood to focus funding on more specific site/asset assessments.*

In the Del Norte region, we often know and understand our vulnerable assets because we experience the impact resulting from vulnerability regularly. Our lifeline, US Highway 101 at Last

Chance Grade was a narrow one-lane road for over a year while a comparatively small section of retaining wall was built. I believe that it is more productive to focus funding on site/asset assessments rather than focus funding on highly involved processes.

The project intent was to create a framework for an analysis process and a platform for future development and I am thankful for the efforts by all involved; however, I am left feeling wary and cautious of an overemphasis and dependence on analytical tools in this highly involved process, especially for rural areas that are lacking detailed data. I am concerned that the risk of overemphasis on the analytical tools may overshadow basic good sense.

I do believe that there should be more time available to review this 547-page document. I understand the project limitations but I don't believe that a compressed review time is an appropriate solution. In this regard, I anticipate that District 1 will continue to evaluate the document and the input from stakeholders over time. This document should be a beginning and not an end to creating a framework for an analysis process and platform.

Sincerely,

Tamera Leighton, Executive Director
Del Norte Local Transportation Commission

Appendix 13

Guide to Digital Resources

Guide to Digital Resources

The Caltrans District 1 Climate Change Pilot Study (D1CCPS), included several digital deliverables. This guide was developed to clarify what they digital deliverables wer that were produced as part of the project. The electronic files can be found on the CD that accompanies the main document.

Climate Data Geodatabase

The data used in the exposure analysis was compiled in a geodatabase as part of the District 1 Climate Change Pilot Study (D1CCPS). Full details on the data are included in the ESA memorandum "Climate Data Projections for Caltrans District 1 Climate Change Pilot Study". This memorandum was Appendix Xx to the D1CCPS final report. A copy of the geodatabase data summary table is attachment 1 to this appendix and the digital copy of this appendix includes the geodatabase file entitled "ClimateData_2014_6-16.gdb"

Asset data

Transportation Asset data was compiled from the Caltrans GIS Data Library (http://www.dot.ca.gov/hq/tsip/gis/datalibrary/gisdatalibrary.html), and supplemented with additional data from Caltrans. Asset data GIS files are not included with this digital Appendix, as the original data sources should be referenced for the most accurate information.

Maintenance data

A .mxd and geodatabase of feature classes related to historical maintenance data are included. Historical maintenance data consists of the following:

- Maintenance_Area_Roads- District 1 roads categorized by maintenance area (North, Central, South)
- Maintenance_Data- Historical Maintenance Data from Emergency Openings (EO), Damage Assessment Forms (DAF), Maintenance Staff Testimonies, and SHOP
- Historical_Cost_of_Events- Cost of Maintenance per Mile (approximate)
- Density_Historical_Number_of_Events- Number of Events per Mile (approximate)

Also included is a spreadsheet that compiles the historical maintenance data received to develop the GIS layers (Historical_Data_Summary.xlsx).

Vulnerability data

The vulnerability data includes maps and data for Criticality, Potential for Impact and Vulnerability. The data provided is as follows:

Criticality

- 84_10842_Criticality.mxd- map of Criticality with base map layers and criticality of TCR segments
- Criticality.mdb
  - Criticality_TCR_Segments- Criticality Evaluation of TCR Segments
- CriticalityMatrix.xlsx- Spreadsheet with Criticality Evaluation and Summaries

Potential for Impact

- 84_10842_Potential_for_Impact.mxd- map of Potential for Impact with base map layers and Potential for Impact of TCR segments for each climate scenario and horizon
- Impact.mdb
  - Impact_2050_A2- Potential for Impact of TCR Segments for high emissions (A2) 2050
  - Impact_2050_B1- Potential for Impact of TCR Segments for low emissions (B1) 2050
  - Impact_2100_A2- Potential for Impact of TCR Segments for high emissions (A2) 2100
  - Impact_2100_B1- Potential for Impact of TCR Segments for low emissions (B1) 2100
- Impact_2050_A2.xlsx- Potential for Impact evaluation of TCR Segments for high emissions (A2) 2050

- Impact_2050_B1.xlsx- Potential for Impact evaluation of TCR Segments for low emissions (B1) 2050
- Impact_2100_A2.xlsx- Potential for Impact evaluation of TCR Segments for high emissions (A2) 2100
- Impact_2100_B1.xlsx- Potential for Impact evaluation of TCR Segments for low emissions (B1) 2100

Adaptation Tool

As part of the D1CCPS, an excel based adaptation planning tool was developed. Included with this digital appendix are the completed adaptation tool workbooks for the prototype locations in the D1CCPS as well as a blank version for use in other applications. All versions include and introduction worksheet and how to use worksheet. The adaptation tool files are as follows:

- D1CCPS_AdaptationTool_V17.xlsx: This is the base adaptation tool excel file without any data inputted for initial use by others.

- Adaptv17_Humboldt_2050.xlsx: This version of the adaptation tool reflects the final adaptation option analysis for the Humboldt County Prototype location for the year 2050 climate horizon.

- Adaptv17_Humboldt_2100.xlsx: This version of the adaptation tool reflects the final adaptation option analysis for the Humboldt County Prototype location for the year 2100 climate horizon.

- Adaptv17-delnorte-2100.xlsx: This version of the adaptation tool reflects the final adaptation option analysis for the Del Norte County Prototype location. A separate 2050 analysis was not completed for this site due to limited data on flood depths in 2050 compared to 2100.

- Adapt_V17_Mendocino_2100.xlsx: This version of the adaptation tool reflects the final adaptation option analysis for Mendocino County. A separate 2050 analysis was not completed for this site due to limited data on flood depths in 2050 compared to 2100.

- Adapt_V17_Lake County_2100.xlsx: This version of the adaptation tool reflects the final adaptation option analysis for Lake County. A separate 2050 analysis was not complete for this site due to limited data on flood depths in 2050 compared to 2100.

Adaptation Tool Training

As part of the D1CCPS a training on how to use the adaptation tool was presented. A webex recording of the raining is included as part of the digital resources.

- D1CCPS Adaptation Tool Training.ARF: WebEx adaptation tool training recording

- nbr2player.msi: Webex recording viewer install file for windows www.ghd.com