Climate Change and Stormwater Management Plan

Del Norte Local Transportation Commission

November 2015

Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

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Chapter 1: Introduction to the Project

Goals

The Climate Change and Stormwater Management Plan project has two goals: to identify transportation assets at risk of climate change impacts and develop adaptation strategies, and to identify current stormwater management needs in Del Norte County. This report is intended to be incorporated in the Del Norte Local Transportation Commission's (DNLTC) next Regional Transportation Plan (RTP). It is the result of following the five-step climate change assessment and adaptation modules outlined in *Addressing Climate Change Adaptation in Regional Transportation Plans* (Cambridge Systematics, Inc., 2013).

Project sub-goals include:

1. Understanding the vulnerability of an agency's overall transportation system to climate change on a general level.
2. Determining potential consequences from particular types of climate impacts.
3. Informing the development and implementation of effective adaptation strategies.
4. Implementing operational or design changes to mitigate climate vulnerabilities.
5. Understanding the scale of climate impacts.
6. Stormwater management strategy.

The planned short and long term capital and maintenance project needs within the county total an estimated $330 million through 2030 for all of the jurisdictions involved. It is the intent of this study to ensure the collective, scarce regional financial resources are directed to the most cost effective projects that are supported by sound data and meet cost benefit thresholds. Many of these valuable assets will be affected by climate change in different ways. In order to protect these assets, a comprehensive understanding of the inventory and the impact of changes in sea level and precipitation must be well understood.

Del Norte County

Del Norte County is located at the far northwest corner of California. It is bordered by Curry County, Oregon to the north, Siskiyou County to the east, Humboldt County to the south, and the Pacific Ocean to the west as shown in Figure 1-1. The topography is relatively flat along the coast between Crescent City and the Smith River delta, but the remainder of the county is forested mountainous terrain associated with the Coastal Range and the Klamath Mountains with elevations ranging from sea level to over 6,400 feet. The county has a total area of 1,230 square miles and 37 miles of coastline.

The county seat and only incorporated city is Crescent City. Other unincorporated communities of interest to this report are Gasquet, Klamath, and Smith River. According to the California Department of Finance, Demographic Research Unit, as of 2013 Del Norte County had a population of 25,403, with 7,243 residing in Crescent City (including incarcerated population). There are four federally recognized Tribes located in the Del Norte region: Elk Valley Rancheria, Smith River Rancheria (also known as Tolowa Dee-ni' Nation), Resighini Rancheria, and the Yurok Tribe.

Figure 1-1. Vicinity Map of Del Norte County

Del Norte Local Transportation Commission

The DNLTC is the Regional Transportation Planning Agency (RTPA) for the Del Norte County region. It is responsible for the development and adoption of the RTP and other transportation programming documents required by law. It is also responsible for fostering coordination and communication between transportation stakeholders, and administering various funding programs that involve cities, counties, and transit operators.

The transportation network in the county is critical to the regional economy and the safety of residents and travelers. There are 3 primary connections to areas outside the County which include US Highway 101 south connecting to Humboldt County; US Highway 101 north connecting to Curry County, Oregon; and US Highway 199 connecting to Grants Pass and Interstate 5 in Oregon.

There are 680 centerline miles of roadway in the county under various jurisdictions. The stakeholders comprise a technical advisory committee and area identified in Table 1-1.

Table 1-1. Stakeholders/Technical Advisory Board for DNLTC

Stakeholder	Contact
Yurok Tribe	Joe James
Smith River Rancheria	Russ Crabtree
Elk Valley Rancheria	Bobbie McGray
County of Del Norte	Heidi Kunstal, Rosanna Bower, Jeff Daniels
Crescent City	Eric Wier, Eric Taylor
Crescent City Harbor District	Charlie Helms
Caltrans District 1	Kevin Tucker
Boarder Coast Regional Airport Authority	Matthew Leitner

Climate Change

Two greenhouse gas emissions scenarios, A2 and B1, are widely used in climate change analyses in California. These are the emissions scenarios used by the Coastal Commission and Caltrans District 1 in recent climate change analyses. The A2 scenario represents the medium-high emission rate projection which assumes economic growth is uneven and the income gap remains large between now-industrialized and developing parts of the world. The B1 scenario represents the low emission rate projection scenario which assumes a future with a high level of environmental and social consciousness combined with a globally coherent approach to more sustainable development. This study is based on the A2 emission scenario because it is the more aggressive projection and the most realistic and conservative choice for decision-makers to use for climate change adaptation planning.

Two future timeframes are focused on for the analysis: 2050 and 2100. The most recent comprehensive climate data (2000) is used as the baseline to which the future time horizons will be compared against and the magnitude of change will be evaluated.

Climate stressors that may pose a potential hazard to transportation assets in Del Norte County are identified as precipitation, sea level rise, and coastal storm surges, all which are projected to increase in frequency or severity in the future. Increases in precipitation will cause increased runoff which will in turn stress drainage networks that serve transportation assets. Sea level is predicted to rise 55 inches along the California coastline by the 2100, leading to increased coastal flooding and shoreline (cliff) erosion. The intensity of coastal storm surges is also projected to increase. This has the potential to cause permanent or periodic inundation of coastal transportation assets, along with damage to these assets brought on by coastal erosion.

Chapter 2: Data Gathering and Analysis

The analysis consists of determining the criticality of transportation assets in Del Norte County and applying climate change data to determine the vulnerability of the asset at the target time frames. This is completed by gathering transportation asset data and climate change data, determining the criticality and vulnerability of those assets, then calculating the risk for each asset.

Data

The basis of this study is the collection and review of studies/reports, climate data, and transportation infrastructure information in Del Norte County. To understand the existing climate adaption efforts in the region the following hazard plans and pilot were reviewed:

- The Federal Highway Administration's Climate Change & Extreme Weather Vulnerability Assessment Framework (December 2012)
- Del Norte County General Plan (January 2003)
- City of Crescent City General Plan (May 2001)
- City of Crescent City General Plan – Local Coastal Plan Extract Policy Document (February 2011)
- Del Norte County, Flood Insurance Study (November 2010)
- Del Norte County and Crescent City Local Roadway Needs Study – Final Report (July 2008)
- California Local Streets and Roads Needs Assessment 2014 Update – (Oct. 2014)
- District 1 Climate Change Vulnerability Assessment and Pilot Studies (December 2014)
- 2014/2015 Overall Work Program Del Norte Local Transportation Commission (May 2014)
- 2011 Del Norte Regional Transportation Plan (June 2011)
- Hydrology Manual for an Area North of Crescent City, Del Norte County (March 1978)

Climate change data was then gathered from various sources, and transportation data was gathered from stakeholders.

Transportation Data

An asset inventory consisting of existing transportation infrastructure data was compiled through the DNLTC stakeholders. This information includes:

- Locally maintained roadways
- Locally maintained bridges
- State maintained roadways
- State maintained bridges
- Transit and school bus fleets

Data received and used in the analysis is listed below in Table 2-1.

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Table 2-1. Asset inventory listed by source

Data	Source
County Road GIS Shapefile	Del Norte County
Flood Drainage Study	Del Norte County
Ortho Data	Del Norte County
Bridges and Culvert Shapefiles	Caltrans District 1
Storm Drain Inlet, Manhole, Pipes Shapefiles	Crescent City
City Road GIS Shapefile	Crescent City
City Utility Mapbook	Crescent City
Coordinated Public Transit-Human Services Transportation Plan	DNLTC

Climate Data

Climate data was gathered for the baseline (2000), 2050, and 2100 timeframes. Climate data on precipitation, sea level rise, and coastal erosion for the A2 emissions scenario was obtained from the sources listed in Table 2-2.

Table 2-2. Climate Data Sources

Source	Data
Federal Emergency Management Agency (FEMA)	Flood maps
Pacific Institute (Pac-Inst)	Coastal hazard maps
Cal-Adapt	Precipitation and runoff data
Coupled Model Intercomparison Project Phase 3 (CMIP3)	Precipitation data
United States Geological Survey (USGS)	Digital terrain model, land cover data
National Oceanic and Atmospheric Administration (NOAA)	Sea level rise

Analysis

The collected data was then analyzed to determine the criticality of transportation assets and the vulnerability to climate change. The most critical transportation assets in Del Norte County were identified and ranked. Climate data was analyzed by comparing the two future time horizons against the baseline to evaluate the magnitude of change and the vulnerability of the transportation assets were assigned and ranked. The risk of each asset was then determined by integrating the criticality and vulnerability.

Criticality of Transportation Assets

Using the asset inventory, critical transportation assets in Del Norte County were identified as:

- Transportation Assets that provide connectivity to points outside the County such as Humboldt County, Grants Pass, Oregon (Interstate 5), and Brookings, Oregon.
- Transportation assets that are part of the established Tsunami evacuation routes.
- Transportation assets that are important to the health and human safety of residents and visitors to Del Norte County.
- Transportation assets that support socioeconomic activity in Del Norte County.

Criticality is based on a combination of functional classification and stakeholder input. The California Road System (CRS) breaks down functional classification to define the type of roadway. CRS, stakeholder awareness of asset performance during past extreme weather conditions, consideration of the tsunami evacuation network, and Average Annual Daily Traffic (AADT) were used to associate criticality with transportation assets.

Of the approximate 680 miles of roadway in Del Norte County, approximately 175 of those miles ranked in the critical range at varying levels. Figure 2-1 shows the miles per criticality level and the percentage of the 175 critically ranked roadways. The most critical assets in Del Norte County are A Street, C Street, Elk Valley Cross Road, Elk Valley Road, H Street, Hwy 199, Lower Lake Drive, and U.S. Hwy 101. A complete list and maps of critically ranked roadways can be found in the Module 2a Technical Memorandum in Appendix B.

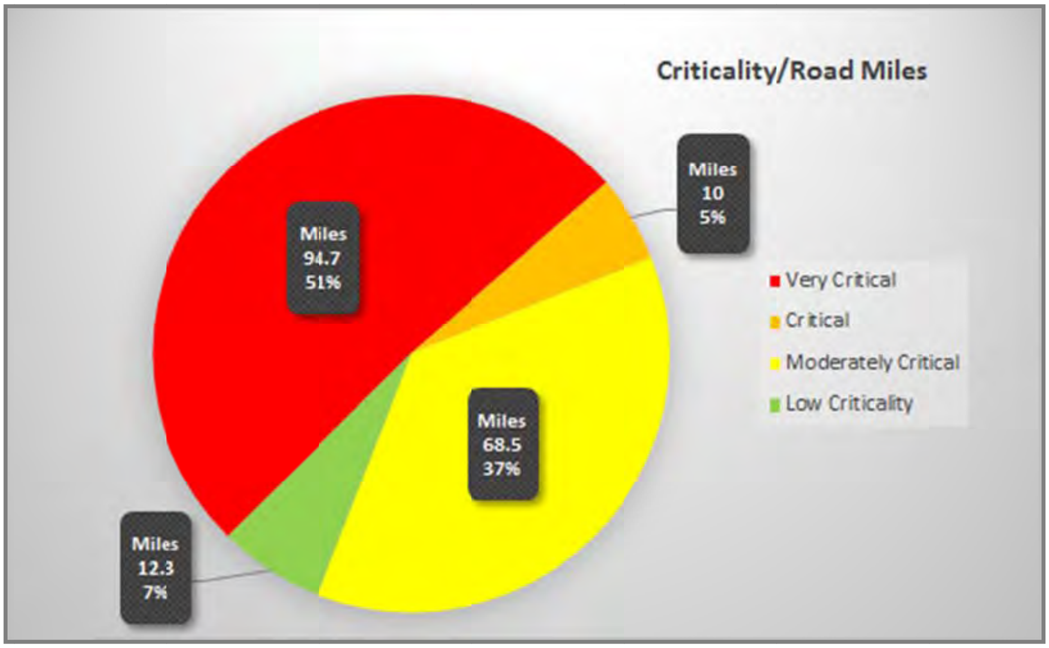

Figure 2-1. Criticality of Transportation Assets in Del Norte County

Climate Data Analysis

To understand the impact climate change will have on the transportation inventory in Del Norte County, climate data were analyzed in terms of the extent and timing of change. The most recent comprehensive climate data (2000) was used as the baseline to which the two future time horizons were compared against and the magnitude of change was evaluated. This data is used to assess the vulnerability of transportation assets to climate change, and determine the level of impact.

Precipitation

The precipitation totals for target years are estimated by calculating an average over 30 year periods. The 2050 timeframe is estimated based on the period from 2035-2064; the 2100 timeframe is estimated based on the period from 2070 to 2099. The baseline, 2000, is estimated based on climate change model results from 1950 to 1999. Annual precipitation totals are projected to decrease by approximately 5% by 2050, and 8% by 2100 in Del Norte County, however monthly averages show an increase in rainfall total over time for the month of February as shown in Table 2-3.

Table 2-3. Change in projected monthly precipitation total in Crescent City

Rank	2050 Change from Baseline	2100 Change from Baseline
January	-0.2%	-0.4%
February	2.0%	3.9%
March	-2.6%	-5.2%
April	-3.0%	-5.9%
May	-9.4%	-18.9%
June	-16.4%	-32.7%
July	-21.0%	-41.9%
August	-22.8%	-45.6%
September	-19.2%	-38.4%
October	-11.5%	-22.9%
November	-3.2%	-6.4%
December	-1.9%	-3.8%

An analysis of extreme precipitation events reveals a predicted increase in magnitude of event. Storms larger than the 98th percentile are anticipated to have rainfall totals 3% greater than baseline in 2050, and 8.1% larger than baseline in 2100 as shown in Table 2-4.

Table 2-4. Change in projected extreme precipitation event total in Crescent City

Analysis Timeframe	Change from Baseline
2050	3.0%
2100	8.1%

Roadway flooding is a common occurrence in various parts of Del Norte County. In particular, along 3rd St in Crescent City, Klamath Beach Road, Lower Lake Road, Kellogg Road, and Highway 101 (between Ehlers Ave and near McMillan Road). Due to the overall decrease in precipitation predicted due to climate change, transportation assets will most likely flood less often. However, due to the increase in extreme precipitation events, transportation assets may experience increased flood depth and duration when flooding does occur.

Sea Level Rise and Coastal Erosion

Sea level is predicted to rise 55 inches along the California coastline by 2100, leading to increased coastal flooding and shoreline erosion. The intensity of coastal storm surges is also projected to increase, which has the potential to cause permanent or periodic inundation of coastal transportation assets, along with damage to these assets brought on by coastal erosion.

Coastal erosion is currently occurring on Pebble Beach Drive in Crescent City, along Highway 101 (between Anchor Way and Humboldt Road) and along Highway 101 at Last Chance Grade in Del Norte County.

Erosion is anticipated to continue to impact most transportation assets that are located along the coast. Likewise, future sea level rise is anticipated to impact most transportation assets that are located along the coast, with impacts spreading inland in low-lying areas. Areas of particular concern are along the southern extents of Crescent City to 3rd Street and encroaching into the Elk Creek watershed, along Highway 101 near the mouth of the Klamath River, and near the mouth of the Smith River.

Vulnerability of Transportation Assets

A ranking system was developed to assign climate based vulnerability to an asset, as shown in Table 2-5. Vulnerability is ranked on a scale from 0 to 10, with 0 indicating no anticipated climate change impact and 10 assuming indicating an assumed loss of asset. This ranking system was developed assuming no repairs will be made to the system during the analysis timeframe.

Table 2-5. Ranking system: Vulnerability of an asset based on climate change

Rank	Description	General ranking methodology
0	No anticipated impact on asset	No impact
2	Mild	Flooding only
4	Mild-Moderate	Erosion only in future
6	Moderate	Current + Future erosion, no flooding
8	Heavy	Current + Future erosion, flooding
10	Loss of an asset	Substantial Current + Future erosion, flooding

A full description of the vulnerability of assets along with figures can be found in the Module 2b Technical Memorandum included in Appendix B. In general, the most vulnerable transportation assets are located along the coast of the Pacific Ocean and the mouths of the Smith and Klamath Rivers.

Risk Assessment of Transportation Assets

A risk assessment integrates the severity or consequence of an impact with the probability or likelihood that an asset will experience the impact. To do this, criticality and climate based vulnerability of the transportation assets were integrated to derive a measure of risk for transportation assets that will be potentially impacted by climate change. A ranking system was developed to assign risk based on vulnerability and criticality of an asset, as shown in 2-6. High priority transportation facilities with high vulnerability to climate change are designated high risk, whereas high priority facilities with low vulnerability to climate change were designated lower risk. Transportation facilities that are already subject to excess rainfall and/or tidal flooding were designated higher risk than facilities that are not currently subject to flooding but will be in future climate change scenarios.

Table 2-6. Ranking system: Risk of an asset based on vulnerability and critically

Rank	Risk	General ranking methodology
1	Low	Only Critical or only vulnerable to climate change (no intersection)
2 - 3	Mild	Low criticality and low vulnerability to climate change
4 - 5	Mild-Moderate	Low criticality and moderate vulnerability to climate change
6 - 7	Moderate	Moderate criticality and moderate vulnerability to climate change
8 - 9	Heavy	Moderate criticality and high vulnerability to climate change
10	Severe	High criticality and high vulnerability to climate change

In general, the most at risk transportation assets to climate change are located along the coast. This includes the major county thoroughfare, US Hwy 101, which spans the county parallel to the coast. In Crescent City, sections of roads located near the coast and Elk Creek are designated high risk. Pebble Beach Road, which is a major residential thoroughfare, is currently subject to coastal erosion. Last

Chance Grade, a highly studied section of US Hwy 101 just north of the Klamath River, is currently subject to coastal erosion which is predicted to increase due to climate change. It is a major principal arterial and is considered the most critical, vulnerable, and at risk segment in Del Norte County. The most at-risk transportation assets in Del Norte County are listed in Table 2-7. The full risk assessment including figures can be found in the Module 3 Technical Memorandum included in Appendix C.

Table 2-7. High risk transportation assets (a risk of 7 or greater)

Asset	Risk	Description
US Hwy 101, Maranda Ln (near Clifford Kamph Memorial Park) to Oregon Border	7	Principal arterial vulnerable to coastal erosion and sea level rise
US Hwy 101, Dr. Fine Bridge over Smith River	7	Major river crossing on principal arterial vulnerable to flooding and sea level rise
Kellogg Rd, Tell Blvd to Public Fishing Access	8	Provides coastal access, vulnerable to coastal erosion and sea level rise
Sandmine Road	8	Connector between Hwy 101 and Humboldt Road vulnerable to sea level rise and coastal erosion
US HWY 199	7	Major highway vulnerable to flooding, landslides.
US Hwy 101, Citizens Dock Road to Enderts Beach Road	8-10	Principal arterial vulnerable to coastal erosion and sea level rise
3rd Street, J St to Hwy 101	7	Major road in Crescent City vulnerable to sea level rise and flooding
US Hwy 101, 2nd St to 3rd St	9	Principal arterial vulnerable to sea level rise and flooding
A Street, Front St to the Pacific Ocean	7	Coastal access vulnerable to sea level rise and coastal erosion
A Street, Front St to 3rd St	8	Tsunami evacuation route vulnerable to sea level rise
South Pebble Beach Drive, A Street to end	7	Major road in Crescent City located adjacent to the coast. Vulnerable to coastal erosion and sea level rise
US Hwy 101, Last Chance Grade	10	Principal arterial vulnerable to coastal erosion
US Hwy 101, Hwy 169 to the north end of Klamath Blvd	8-9	Principal arterial vulnerable to flooding and sea level rise
Klamath Beach Road (adjacent to Klamath River)	7	Major road located adjacent to the mouth of the Klamath River, currently experiences flooding.

Front Street, Crescent City

Chapter 3: Adaptation Strategies

Adaptation measures were investigated for high risk assets (risk level of 7 or higher). An adaptation measure is an action that minimizes risks from climate change, which includes sea level rise, coastal erosion, and increased intensity of precipitation events.

Adaptation Methodology

Adaptation measures were developed for transportation assets that are ranked as high risk, i.e. as both highly vulnerable to climate change and considered critical assets. The expected consequence of climate change impacts on transportation assets must be considered when prioritizing adaptation strategies. The consequences have been categorized into four types: no impact, disruption, deterioration, and damage.

Adaptation Measures for Del Norte

Adaptation measures are categorized into four different approaches: defend, accommodate, changes in policies or practices, and retreat. There are several adaptation options that fall within each approach, as detailed in Table 3-1.

Table 3-1 - Adaptation Options

Approach	Adaptation Option
Defend	Floodwalls/Levees
	Coastal Erosion Countermeasure
Accommodate	Raise Asset Elevation
	Bridge Modifications
	Drainage Modifications
Retreat	Relocate Asset
	Mitigated Retreat
Changes in Policies or Practices	Update Standard Details
	Increase Maintenance & Inspection Interval, Monitor Assets
	Adopt a Storm Drain Master Plan

Defend, accommodate, and retreat are location specific adaptation options. There are often several adaption option alternatives for each location, and it may be appropriate to select different adaptation options depending on time frame. For example, it may make financial sense to defend an asset vulnerable to coastal erosion by using a coastal erosion countermeasure in the short term, then retreat from the original asset location by relocating or abandoning the asset in the long term.

Changes in policies or practices are adaptation options than can be adopted by stakeholders and are not necessarily location specific. Options in this approach include updating standard construction details; increasing maintenance and inspection intervals, and increasing monitoring of assets; and adopting a storm drain master plan. Increasing maintenance and inspection intervals and increasing the monitoring of assets is an option that can be undertaken by all stakeholders. Ideally, inspection, maintenance, and monitoring records will be compiled and stored in a centralized asset management system that the DNLTC can use when updating the Regional Transportation Plan. Adoption of a Storm Drain Master Plan (SDMP) is an option that either the City or County can undertake. The master plan will be useful in determining existing system deficiencies and prioritizing improvements needed to bring the system up to an acceptable level of service, as well as determine the improvements required to mitigate rising sea levels and the intensification of precipitation events.

Stormwater Management

The changes in policies or practices adaptation options can be used as stormwater management options in the current timeframe. Updating standard details to include low impact development guildelines and details is an action many communities in California are taking in order to comply with the recent update of the NPDES Permit issued by the Regional Board. Crescent City is currently exempt from this permit due to population size, but there is a possibility that it may be lose its exemption in the future either through population growth or the elimination of population limits in future permit updates.

A Storm Drain Master Plan (SDMP) is useful tool in setting a level of service of a community and determining the improvements required in order to reach and maintain that level of service. Flooding during storm events is frequently documented at low spots in Crescent City, and a SDMP would provide a systemic approach to mitigating flooding issues. It can also be utilized to determine the best approach for improving water quality in the region.

Planning Level Cost Estimates

The planning level cost estimates were developed as an overall guideline for the DNLTC and its stakeholders to use in preparing annual budgets, updating the Regional Transportation Plan, and to identify funding opportunities for larger projects. Exigent circumstances and future in-field experiences may necessitate deviations from the adaptation options presented in this report. This study and proposed adaptation options are merely the starting point. It is anticipated that the DNLTC and its stakeholders will perform a more detailed study or alternatives analysis to find more affordable or effective improvements with information gathered as part of the design process (detailed topography, easements, etc.).

Changes to Policies or Practices

Making changes to policies or practices is the first step in adapting transportation assets for climate change impacts. Changes can be made quickly and are the most affordable adaptation options. The cost to hire a consultant to complete a SDMP can range from $100,000 to $300,000 depending on the area to be analyzed, the number of storms to be considered, and the amount of data gathering required in order to build a computer model of the storm drain system. Hiring a consultant to update standard details is estimated to cost approximately $25,000. It is difficult to estimate the cost to increase maintenance and inspection intervals. It is likely that maintenance crews are already visiting transportation assets on a regular basis, and only a change in the method of recording information is required.

Defend, Accommodate, and Retreat

Levee and coastal erosion countermeasure costs have been estimated using information from other projects, cost estimating guidelines (2014 *Current Construction Costs*, Saylor Publications, Inc.), and engineering judgment and are in 2014 dollars. Costs include a 75% contingency to cover design, permitting, land acquisition, etc. Levee costs are detailed in Table 3-2. Erosion countermeasure adaptation costs are detailed in Table 3-3.

Table 3-2. Estimated Cost for Levee Adaptation Option

Levee Location	Height (ft)	Top Width (ft)	Length (ft)	Cost
Crescent City waterfront (W of harbor)	10	5	8,000	$ 15,600,000
Crescent City, harbor to Humboldt Rd	10	5	7,300	$ 14,200,000
Crescent City, A St.	10	5	5,000	$ 12,500,000*
Requa Road	10	5	3,200	$ 15,000,000*
Hwy 101, Klamath	10	5	5,900	$ 11,500,000
Klamath Beach Road	10	5	3,300	$ 10,000,000*
Hwy 199	10	5	5,000	$ 9,700,000
Total			**37,700**	**$ 73,400,000**

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Table 3-3. Estimated Cost for Erosion Countermeasure Adaptation Option

Coastal Erosion Location	Length	Cost
Crescent City, from 9th/Pebble Beach to end of A St.	5,300 ft	$ 11,600,000
Hwy 101, Maranda Ln to Oregon border	12,000 ft	$ 36,800,000
Kellogg Rd.	500 ft	$ 400,000
Hwy 101, Last Chance Grade	3-16 mi	$ 1 billion+
Hwy 199	20,000 ft	$ 17,500,000
Total	**56,300 ft**	**$ 1,066,300,000**

It is estimated that local roadway assets recognized in the criticality ranking are in need of an estimated $30 million (2014 dollars) for maintenance and rehabilitation. The following matrix (Table 3-4) identifies the specific roadway assets identified in Module 3 that are also currently recommended for treatment. These costs do not necessarily match up with the more design specific project costs reflected in the Regional Transportation Plan on a project basis, but roughly align on an overall comparison of project costs vs. magnitude. The 2014 cost only includes the pavement maintenance costs. The 2050 and 2100 costs include the levee/floodwall or erosion countermeasure that will be required in order to keep the road in functional order. The 2050 and 2100 costs are intended to provide the true cost required to maintain the road within those timeframes, and may be useful when determining whether it is more cost effective to abandon the road through mitigated retreat.

Table 3-4. Current, 2050, and 2100 Road Maintenance Costs

Asset Name	2014 Road Maintenance Cost Preventative Cost/sq./yd >70 (7-10)) $ 4.61	AC Overlay Cost/sq./yd. 25-69 (3-7) $ 23.24	Reconstruction Cost/sq./yd. <25 (1-3) $ 60.31	Total 2014 Maintenance Cost	2050 Road Cost	2100 Road Cost
3rd St	$ 87,129	$ 439,235	$ 1,140,000	$ 1,690,000	See Front street	See Front street
A St	$ 83,817	$ 422,540	$ 1,100,000	$ 1,630,000	$ 3,330,000	$ 3,540,000
Front St	$ 68,689	$ 346,277	$ 900,000	$ 1,340,000	$ 18,530,000	$ 3,250,000
H St	$ 51,571	$ 259,979	$ 670,000	$ 1,000,000	See Front street	See Front street
Humboldt Rd	$ 126,529	$ 637,861	$ 1,660,000	$ 2,460,000	Protected by 101 Levee	Protected by 101 Levee
Kellog Rd	$ 110,063	$ 554,850	$ 1,440,000	$ 2,140,000	$ 2,180,000	$ 4,050,000
Klamath Beach Rd	$ 372,309	$ 1,876,889	$ 4,870,000	$ 7,230,000	$ 14,320,000	$ 9,140,000
Morehead Rd	$ 149,360	$ 752,956	$ 1,950,000	$ 2,900,000	See Kellog Rd	See Kellog Rd
Moseley Rd	$ 143,288	$ 722,345	$ 1,870,000	$ 2,780,000	See Kellog Rd	See Kellog Rd
Pebble Beach Dr	$ 280,682	$ 1,414,978	$ 3,670,000	$ 5,450,000	$ 14,250,000	$ 7,360,000
Requa Rd	$ 69,349	$ 349,605	$ 910,000	$ 1,350,000	$ 8,250,000	$ 3,260,000
Sandmine Rd	$ 25,652	$ 129,317	$ 340,000	$ 500,000	Protected by 101 Levee	Protected by 101 Levee

Adaptation options and the associated planning level costs are detailed in the Module 4 Technical Memorandum which is included as Appendix D.

Chapter 4: Future Steps

The DNLTC is the central communication hub between stakeholders and can take the lead in ensuring that stormwater management and climate change are considered during the planning phase of policy changes and improvement projects that involve transportation investments. With the identification of the most at risk transportation assets and adaptation measures to address the effect of climate change on these assets, the next steps involve incorporation of these adaptation measures into formal plans and processes. This involves monitoring, stakeholder communication, developing a risk register, finding budget and funding sources, and short-term amendments. Effective adaptation requires an ongoing, iterative process of understanding transportation infrastructure resiliency, conducting a vulnerability and risk assessment, and then selecting adaptation actions.

The Climate Change and Stormwater Management Plan is recommended to be updated every 20 years. This accounts for long term evaluation of the effects of climate change through the update of data and maps. Del Norte County updates the Regional Transportation Plan (RTP) every 5 years in compliance with California law and the RTP Guidelines. In order to include climate change adaptation strategies into the required policy, action and financial elements of the RTP, the monitoring elements should be evaluated for changes that impact the transportation assets in the region every 5 years. Changes in information, data, and project status may require flexibility in the planning process and changes should be noted through the recommended short term amendment process.

The DNLTC plays a central role in mitigating the impact of climate change on the transportation assets in Del Norte County. This study is a critical step in the evaluation of the transportation investments made at all levels of government. It can be a centralized source of information and can assist stakeholders in coordinating planning and budgeting efforts. In order to get the most value out of this Climate Change and Stormwater Management Study, periodic updates must be performed. Those updates should include acknowledgement of new climate data and new methods for mitigating climate change impacts. Additionally, information regarding the region's transportation assets should be updated on a regular basis.

US Hwy 101 along the Del Norte County Coastline

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TECHNICAL MEMORANDUM

TO: Tamera Leighton **DATE:** March 13, 2015

FROM: Schaaf & Wheeler **JOB #:** DNLT.15.01

SUBJECT: Module 1 – Mission, Goals, and Objectives for the Climate Change and Stormwater Management Plan

Mission

The transportation network in Del Norte County is critical to the regional economy and the safety of residents and travelers. There are 3 primary connections to areas outside the County including US Highway 101 south connecting to Humboldt County, US Highway 101 north connecting to Curry County Oregon, and US Highway 199 connecting to Grants Pass and Interstate 5 in Oregon. These routes are historically susceptible to closure and therefore affect commerce and travel in and out of the County.

There are approximately 680 centerline miles of roadway in the county under various jurisdictions. The planned short and long term capital and maintenance project needs within the county total $330 million through 2030 for all of the jurisdictions involved. It is the intent of this study to ensure the collective, scarce regional financial resources are directed to the most cost effective projects that are supported by sound data and meet cost benefit thresholds. Many of these valuable assets will be affected by climate change in different ways. In order to protect these assets, a comprehensive understanding of the inventory and the impact of changes in sea level and precipitation must be well understood.

Goals

The goal of this study is to identify transportation assets that are vulnerable to climate change and related stormwater impacts, and develop adaptation strategies. Project sub-goals include:

1. Understanding the vulnerability of an agency's overall transportation system to climate change on a general level.
2. Determining potential consequences from particular types of climate impacts.
3. Informing the development and implementation of effective adaptation strategies.
4. Implementing operational or design changes to mitigate climate vulnerabilities.
5. Understanding the scale of climate impacts.
6. Stormwater Management Strategy

Objectives

Two climate change scenarios, A2 and B1, are widely used in climate change analysis in California. A2 represents the medium-high emission projection scenario and B1 represents the low emission projection scenario. For this study, the exposure of transportation assets to forecasted climate change will be based on the A2 emissions scenario. This scenario was chosen because it is the more aggressive projection and is the more realistic choice for decision-makers to use for climate adaptation planning. The A2 emission scenario assumes that there is no decrease in carbon emissions resulting from continuous population growth.

The level and growth of greenhouse gas (GHD) emissions are directly correlated to the following three variables: population, income, and intensity of emissions. For most countries, population and income are rising faster than intensity is declining, so emissions are rising. This is occurring even with reductions in greenhouse gas emissions resulting from energy conservation, increased energy efficiency, and use of energy sources that emit less or no CO2 as these emission reductions have been offset by the increase in total energy use associated with population and economic growth.

Two future timeframes will be focused on: 2050 and 2100. The most recent comprehensive climate data (2000) will be used as the baseline to which the two future time horizons will be compared against and the magnitude of change will be evaluated.

Climate stressors have been identified that will pose a potential hazard to transportation assets in Del Norte County. These climate stressors include precipitation, sea level rise, and coastal storm surges, which are projected to increase in frequency or severity in the future. Precipitation is projected to increase by 9% by 2050, and 16% by 2100. Increases in precipitation will cause increased runoff which will in turn lead to more flooding. This will directly impact the drainage capacities of transportation assets which will be more susceptible to flooding and damage or failure in the future. Sea level is predicted to rise 55 inches along the California coastline by the 2100, leading to increased coastal flooding and shoreline (cliff) erosion. The intensity of coastal storm surges is also projected to increase. This has the potential to cause permanent or periodic inundation of coastal transportation assets, along with damage to these assets brought on by coastal erosion. Therefore, stormwater and sea level rise impacts on transportation assets in Del Norte County from climate change will be addressed in this study.

A vital aspect of this study is engaging stakeholders that have key interests in the transportation infrastructure in Del Norte County. A team of stakeholders and a technical advisory committee have been identified, which includes members from Caltrans, Crescent City, Crescent City Harbor District, Del Norte County, Del Norte County Regional Airport (limited to ground transportation), and regional Tribes. These members have direct planning, operations, or design responsibilities that would consider climate adaptation in their practices. A preliminary list of contacts is shown in Table 1.

Table 1. Stakeholders/Technical Advisory Board for Del Norte County

Stakeholder	Contact
Yurok Tribe	Joe James
Smith River Rancheria	Russ Crabtree
Elk Valley Rancheria	Bobbie McGray
County of Del Norte	Heidi Kunstal, Rosanna Bower, Jeff Daniels
Crescent City	Eric Wier
Crescent City Harbor District	Charlie Helms
Caltrans District 1	Kevin Tucker
Boarder Coast Regional Airport Authority	Matthew Leitner

The next phase of this study includes collecting and reviewing studies/reports, climate data, and transportation infrastructure information in Del Norte County. To understand the existing climate adaption efforts in the region, available hazard plans and pilot studies completed in the region will be reviewed. Thus far we have obtained the following studies:

- The Federal Highway Administration's Climate Change & Extreme Weather Vulnerability Assessment Framework (December 2012)
- Del Norte County General Plan (January 2003)
- Del Norte County, Flood Insurance Study (November 2010)
- Del Norte County and Crescent City Local Roadway Needs Study – Final Report (July 2008)
- California Local Streets and Roads Needs Assessment 2014 Update – (Oct. 2014)
- District 1 Climate Change Vulnerability Assessment and Pilot Studies (December 2014)
- 2014/2015 Overall Work Program Del Norte Local Transportation Commission (May 2014)
- 2011 Del Norte Regional Transportation Plan (June 2011)

Climate data for the baseline scenario (2000) and for the two future scenarios (2050 and 2100) have been collected from the sources listed in Table 2. This data will be used to assess the vulnerability of transportation assets to climate change and to determine the potential consequence of climate change on these assets.

Table 2. Climate data sources

Source	Data
Federal Emergency Management Agency (FEMA)	Flood maps
Pacific Institute (Pac-Inst)	Coastal hazard maps
Cal-Adapt	Precipitation and runoff data
Coupled Model Intercomparison Project Phase 3 (CMIP3)	Precipitation data
United States Geological Survey (USGS)	Digital terrain model, land cover data
National Oceanic and Atmospheric Administration (NOAA)	Sea level rise

Existing transportation infrastructure data (asset inventory) will be complied through the stakeholders. The information received as of February 12th, 2015 is listed below in Table 3.

Table 3. Asset inventory listed by source

Data	Source
County Road GIS Shapefile	Del Norte County
Hydrology Manual	Del Norte County
Flood Drainage Study	Del Norte County
Ortho Data	Del Norte County
Bridges and Culvert Shapefiles	Caltrans District 1
Storm Drain Inlet, Manhole, Pipes Shapefiles	Crescent City
City Road GIS Shapefile	Crescent City

Using the climate data and transportation asset inventory collected, a risk assessment of existing transportation infrastructure will be conducted. Risk will be analyzed by assessing asset criticality (i.e. how essential an asset is) using qualitative criteria and by determining the potential for a transportation segment to be impacted by a climate event. Transportation segments and facilities will be ranked or prioritized by vulnerability for adaptation action.

Based on the identified vulnerabilities, appropriate adaptation strategies will be evaluated. The identified vulnerabilities will be used to develop a series of projects that stakeholders can implement to adapt to changing climate conditions. This process is summarized in Table 4.

Table 4. Evaluate adaptation strategies

Step	Adaptation Assessment	Description
1	Identify adaptation options	These adaptation strategies will be flexible, cost effective, and address the specifics of the climate change impact.
2	Develop adaptation assessment criteria	These criteria can include: total capital investment, usable life, level of performance, flexibility, environmental considerations, and social considerations.
3	Create adaptation assessment methodology	This methodology will be built around a uniform scoring system that will measure the ability of the adaptation option to address the vulnerability of the asset. (i.e. qualitative cost benefit analysis)
4	Prepare cost analysis for adaptation options	The highest priority options in Del Norte County will be further evaluated in terms of potential planning and implementation costs.

Finally, based on the results from this study, climate impact considerations will be incorporated into future long-range transportation planning and investment decisions. This will occur through project prioritization, acknowledgement of these impacts, and a commitment to ongoing study.

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TECHNICAL MEMORANDUM

TO:	Tamera Leighton, Del Norte Local Transportation Commission	DATE:	September 21, 2015
FROM:	Emily Straley, P.E.	JOB#:	DNLT.15.01
SUBJECT:	Module 2 – Assemble Asset Inventory and Screen Criticality, and Apply Climate Information		

Introduction

Module 2 of the Climate Change Assessment consists of gathering transportation and climate change data, and assessing the criticality and vulnerability of those assets. This module consists of two sub-modules: Module 2a in which the transportation assets are inventoried and assigned a criticality; and Module 2b in which climate change data is gathered and the transportation assets are assigned a vulnerability ranking. The Module 2a and Module 2b technical memorandum and contained herein.

TECHNICAL MEMORANDUM MODULE 2A

To: Tamera Leighton

From: Green DOT Transportation Solutions

Date: April 13, 2015

Screening for Criticality

The first step in screening for criticality is to identify what the critical assets are to the region and communities within Del Norte County (Cambridge Systematics, 2013). Since this study focuses on transportation assets, our project team is evaluating roadways, bridges, culverts (to some degree), and the area's school bus and transit fleet inventory (for emergency evacuation situations). Critical transportation assets in Del Norte County have been identified as:

- Transportation Assets that provide connectivity to points outside the County such as Humboldt County, Grants Pass Oregon (Interstate 5), and Brookings, Oregon.
- Transportation assets that are part of the established Tsunami evacuation routes.
- Transportation assets that are important to health and human safety of residents and visitors to Del Norte County.
- Transportation assets that support socioeconomic activity in Del Norte County.

Asset Inventory

Transportation assets within Del Norte County have been identified in Module 1 and include the following:

- Locally maintained roadways
- Locally maintained bridges
- State maintained roadways
- State maintained bridges
- Transit and school bus fleets

Categorizing Assets and Criticality Screening

This study is aimed at educating the local decision makers, stakeholders and the community overall about the vulnerability and value of the transportation assets in Del Norte County. To do this, our project team has aggregated the region's assets into recognizable groups.

Group 1-Roadways

In order to categorize transportation assets, our project team (with concurrence from the stakeholders) used functional classification as a metric for screening criticality on roadway segments. Functional classification is the process in which streets and highways are grouped into classes, or systems, according to the character of traffic service that they are intended to provide. There are three highway functional classifications: arterial, collector, and local roads. All streets and highways are grouped into one of these classes, depending on the character of the traffic (i.e. local or long distance) and the degree of land access that they allow. The classifications are described by FHWA in Table 1 below.

Table 1-FHWA Standard Classifications

Functional System	Services Provided
Arterial	Provides the highest level of service at the greatest speed for the longest uninterrupted distance with some degree of access control.
Collector	Provides a less highly developed level of service at a lower speed for shorter distances by collecting traffic from local roads and connecting them with arterials.
Local	Consists of all roads not defined as arterials or collectors; primarily provides access to land with little or no through movement.

For further breakdown, the California Road System (CRS) breaks down functional classification even further than the federal system. This helps to define the type of roadway being analyzed. Our project team used this system to associate criticality with transportation assets. Table 2 below is the CRS functional classification system we are using for this project.

Table 2-CRS Functional Classifications

Functional Classification Legend	
Interstate	1
Other Freeways or Expressways	2
Other Principal Arterial	3
Minor Arterial	4
Major Collector	5
Minor Collector	6
Local	7

In order to assess the criticality of each roadway asset on individual merit, our team developed a hybrid of two FHWA criticality screening approaches (FHWA, Climate Adaptation, 2014) defined as:

1. Desk Review-This approach emphasizes objectivity and uses quantitative information that is based on readily available data sources and requires little local knowledge to apply in asset ranking.
2. Stakeholder Elicitation-This approach uses stakeholders that understand the value of the assets at risk and are likely the implementers of future adaptation strategies. Additionally, stakeholder awareness of asset performance during past extreme weather conditions will be considered.

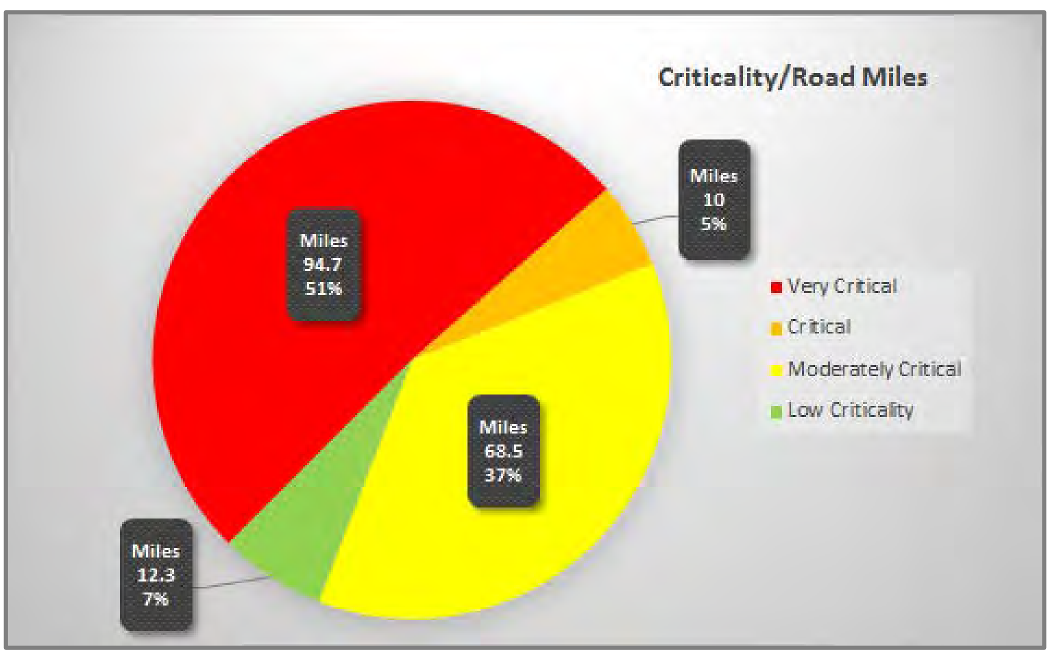
Our hybrid methodology utilized both approaches to define roadway segment criticality based on the functional classification which, in Del Norte County, is closely related to Average Annual Daily Traffic (AADT). This was deemed an appropriate criticality screening criteria. We have also added two additional modifiers to the Criticality screening for roadway assets. If a roadway asset is part of the tsunami evacuation network (Attachment A), it will be given an additional point of criticality. Also, we provided the flexibility of an asset to have an AADT modifier in case of a roadway with criticality based on functional classification doesn't match the high AADT shown in recent traffic counts. Below is the roadway criticality screening tool.

Table 3-Roadway Criticality Screening

Functional Classification	Criticality of Asset		Tsunami Modifier	ADT Modifier
Principal Arterial	5	Very Critical	+0	+1
Minor Arterial	4	Critical	+1	+1
Major Collector	3	Moderately Critical	+2	+1
Minor Collector	2	Low Criticality	+3	+1
Local Road	1	Very Low	+4	+1

Of the approximate 680 miles of roadway in Del Norte County, approximately 175 of those miles ranked in the critical range at varying levels. Table 4 below shows the miles per criticality level and the percentage of the 175 critically ranked roadways. A complete list and maps of critically ranked roadways can be found in Attachment B and C respectively.

Table 4-Del Norte County Roadway Criticality



Group 2-Bridges

There are approximately 40 Caltrans bridges in Del Norte County on the State and local roadway system (see Attachment D). Similar to roadway assets, bridges are an important component of the roadway network and critical to connectivity. These assets have similar vulnerabilities to roadways and will be screened for criticality along with roadway segments using the FHWA hybrid screening methodology. The screening aligns with the roadway screening on the criticality maps in Attachment A. In addition to using the desk review and stakeholder elicitation for value understanding, we will compare current bridge rehabilitation and replacement methodologies as a balance for prioritization.

Group 3-Culverts

Culverts play an integral role supporting the roadway network. The City and County do not have culvert documentation, so only Caltrans culverts will be included in the criticality screening of roadway assets as recommended by the FHWA (FHWA, Climate Change & Extreme Weather Vulnerability Assessment Framework, 2012).

Group 4-Emergency Evacuation Assets (Transit and School Buses)

Emergency evacuations may be necessary on a more frequent basis due to increased precipitation and flooding potential. Buses play a critical role in emergency evacuation situations and must be considered as an asset to the transportation system. Del Norte County has two resources for buses; Redwood Coast Transit (13 vehicles-see Table 5) and the Del Norte Unified School District (9 vehicles). All vehicles in the bus fleet available for emergency evacuation will be given the same criticality rating of 5 and assessed accordingly.

Table 5-Redwood Coast Transit Fleet Roster

Vehicle No.	Year	Chassis Make	Body Make	Fuel	Fixed Seats	Folding Seats	Wheelchair Positions	Bike Rack Capacity	Length	12/31/06 Mileage	Replacement Schedule
268	1998	Ford	Eldorado	Gas	12	0	1	NA	23'	236879	2005/06
269	1998	Ford	Eldorado	Diesel	16	6	1	NA	25'	236420	2006/07
270	1999	Ford	Eldorado	Diesel	12	6	1	NA	23'	229251	2006/07
271	2002	Ford	Eldorado	Diesel	16	4	1	NA	23'	143867	2009/10
272	2003	Ford	Eldorado	Diesel	16	4	1	2	23'	178905	2010/11
273	2003	Ford	Eldorado	Diesel	16	4	1	2	23'	185895	2010/11
274	2003	Ford	Eldorado	Diesel	16	4	1	2	23'	181138	2010/11
275	2003	Ford	Eldorado	Diesel	16	4	1	2	23'	173351	2010/11
276	2003	Ford	Eldorado	Diesel	16	4	1	2	23'	147154	2010/11
277	2005	Ford	Eldorado	Gas	12	6	2	NA	23'	69285	2012/13
278	2005	Ford	Eldorado	Gas	12	6	2	NA	23'	59383	2012/13
280	2007	Chevy	Eldorado	Diesel	18	6	2	2	32'	48038	2013/14
Ordered	2008	Chevy	Eldorado	Diesel	18	6	2	NA	32'	NA	2013/14

Source: RCTA March 2008

BIBLIOGRAPHY

Cambridge Systematics. (2013). *Addressing Climate Change Adaptation in Regional Transportation Plans.* Sacramento: California Department of Transportation.

FHWA. (2012). *Climate Change & Extreme Weather Vulnerability Assessment Framework.* Washington DC: FHWA.

FHWA. (2014, May 24). *Climate Adaptation*. Retrieved from Assessing Criticality in Transportation Adaptation Planning: http://www.fhwa.dot.gov/environment/climate_change/adaptation/adaptation_framework/modules/criticality_guidance/

ATTACHMENT A-TSUNAMI EVACUATION ROUTES

About Tsunamis

A tsunami is a series of waves or surges usually caused by an earthquake beneath the sea floor. Tsunamis can cause great loss of life and property damage where they come ashore.

- **The first wave is almost never the largest**
- **Successive waves may be spaced ten or more minutes apart and continue arriving for many hours**

Two Ways to Find Out a Tsunami May be Coming:

Natural Warning

Strong ground shaking, a loud ocean roar, or the water receding unusually far exposing the sea floor, are all Nature's warnings that a tsunami may be coming. If you observe any of these natural warning signs, immediately move to higher ground or inland. Safe areas are shown in gray on the map on the reverse side. Stay away from low areas until told by emergency personnel that the danger has passed. A tsunami may arrive within minutes of any of these natural warning signs and may last for 8 hours or longer.

Official Warning

You may be notified that a Tsunami Warning has been issued by: TV and radio stations, door-to-door contact by emergency responders, NOAA weather radios, or in some cases, by outdoor sirens. Move away from the beach and seek more information without using a phone. Tune into local radio or television stations for more information. Follow the directions of emergency personnel who may ask you to evacuate low lying coastal areas.

Both Natural and Official warnings are equally important. Respond to whatever you hear or observe first!

What Areas are at Risk?

Beaches and low lying areas close to the coast such as lagoons, bays and river mouths are at greatest risk. The map on the reverse side shows areas you should leave after feeling an earthquake with strong ground shaking. **If you are in a safe area, stay where you are.**

What If I am Outside the Map Area?

Go to an area 100 feet above sea level or 2 miles inland, away from the coast. If you cannot get this far, go as high as possible. Every foot inland or upwards can make a difference.

How Do I Know If an Earthquake is Big Enough to Cause a Tsunami?

Protect yourself during the earthquake.

- If you are on the beach and feel an earthquake, no matter how small, immediately move inland or to high ground.
- In other low lying areas, **COUNT** how long the earthquake lasts. If you count 20 seconds or more of very strong ground shaking and are located in a tsunami hazard zone, evacuate **as soon as it is safe to do so.**

GO ON FOOT. Roads and bridges may be damaged by strong ground shaking. Avoid downed power lines. If evacuation is impossible, go to the upper floor of a sturdy building or climb a tree—this should only be used as a last resort.

Be Prepared

- Know the best evacuation route
- Walk your route – practice walking your route at night and in stormy weather
- Discuss emergency plans with family, coworkers and neighbors
- Consider how to evacuate pets – such as dogs on leashes and cats in crates
- Prearrange assistance from neighbors if you need help evacuating
- Prepare a disaster emergency kit
- Take first aid and CPR training – learn more about disaster preparedness

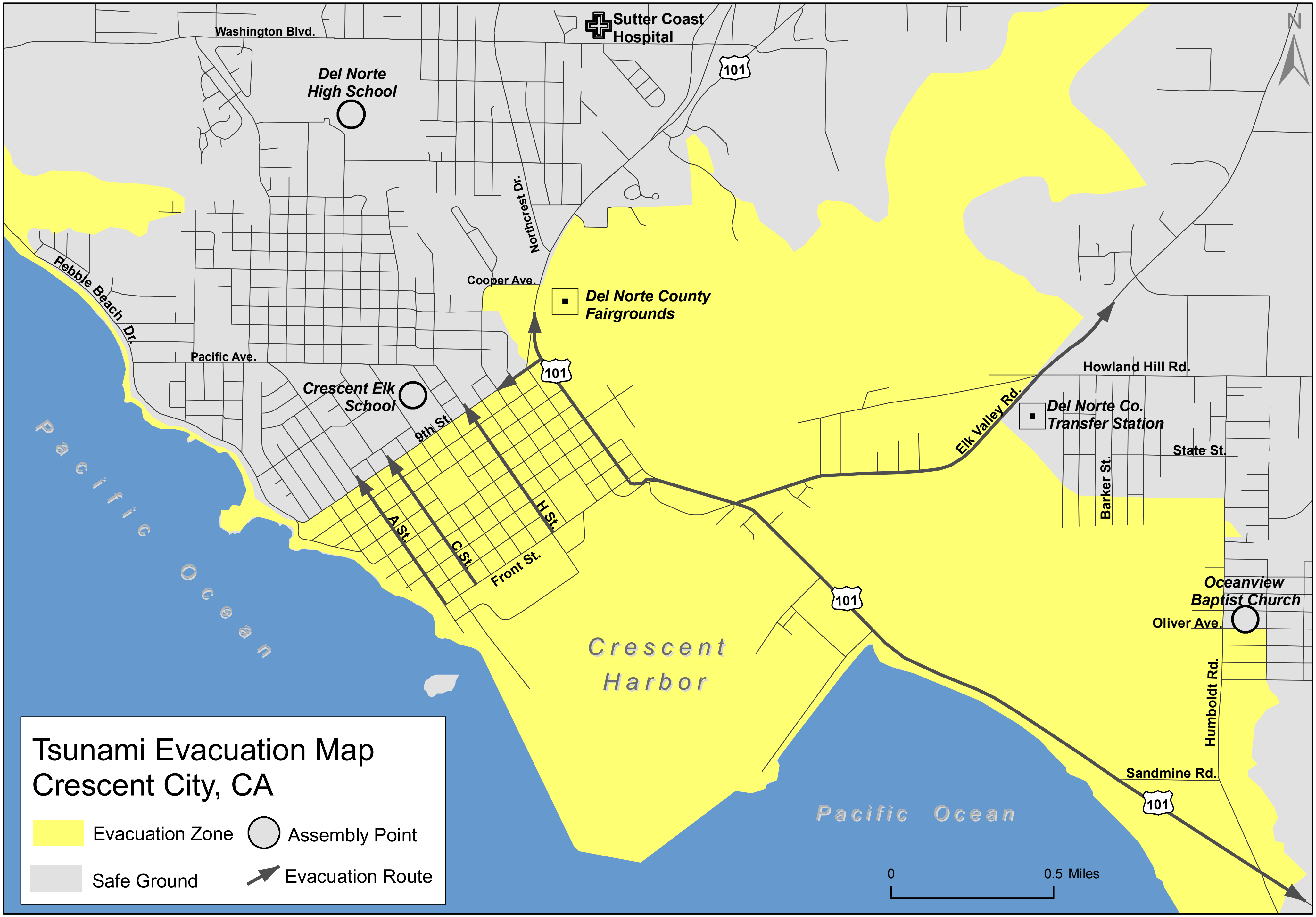
HOW TO SURVIVE A TSUNAMI IN CRESCENT CITY

PROTECT YOURSELF DURING THE EARTHQUAKE

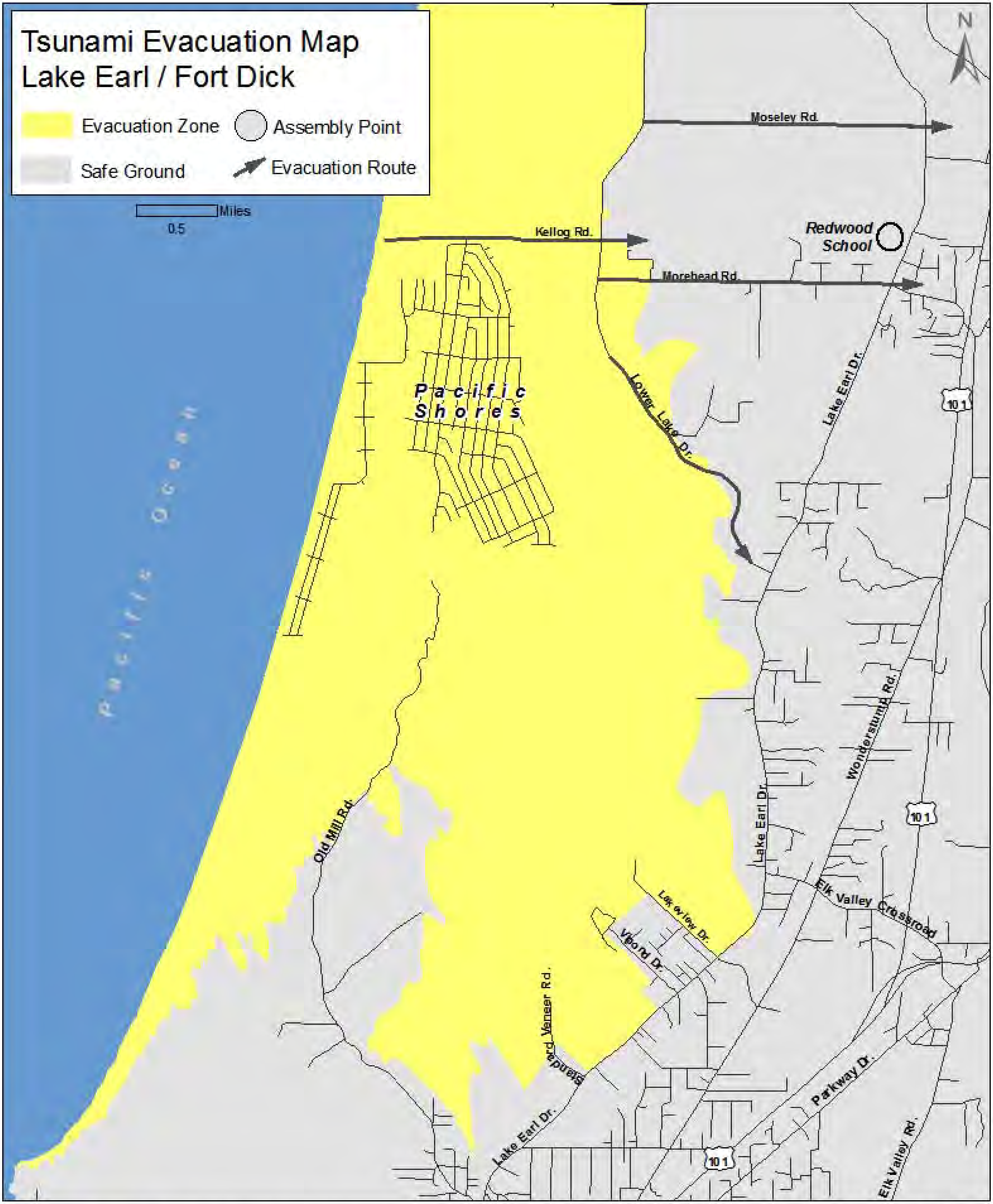
MOVE TO HIGH GROUND OR INLAND AS SOON AS YOU CAN

DO NOT WAIT FOR AN OFFICIAL WARNING

STAY THERE
Remain on high ground. Waves from a tsunami may arrive for 8 hours or longer

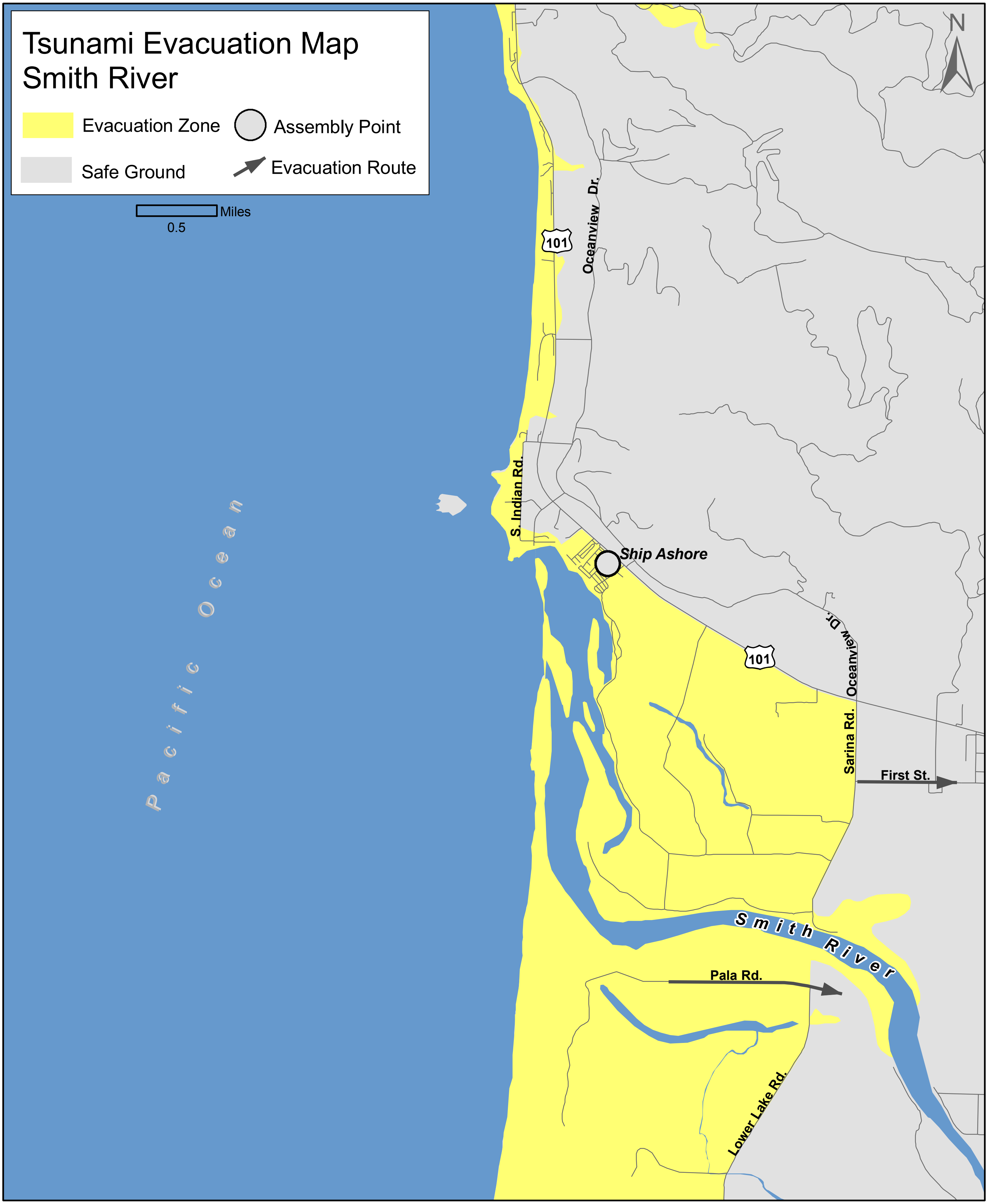


Note: This evacuation map is based on the State of California inundation projections and the best currently available scientific information.
It is intended for emergency planning purposes only. This map may be revised as new information becomes available.



Note: This evacuation map is based on the State of California inundation projections and the best currently available scientific information. It is intended for emergency planning purposes only.
This map may be revised as new information becomes available.

Klamath Tsunami Evacuation Zone



Note: This evacuation map is based on the State of California inundation projections and the best currently available scientific information. It is intended for emergency planning purposes only.
This map may be revised as new information becomes available.

COUNTY OF DEL NORTE 1857

ATTACHMENT B-CRITICALLY RANKED ROADWAYS IN DEL NORTE COUNTY

Critically Ranked Roadways in Del Norte County

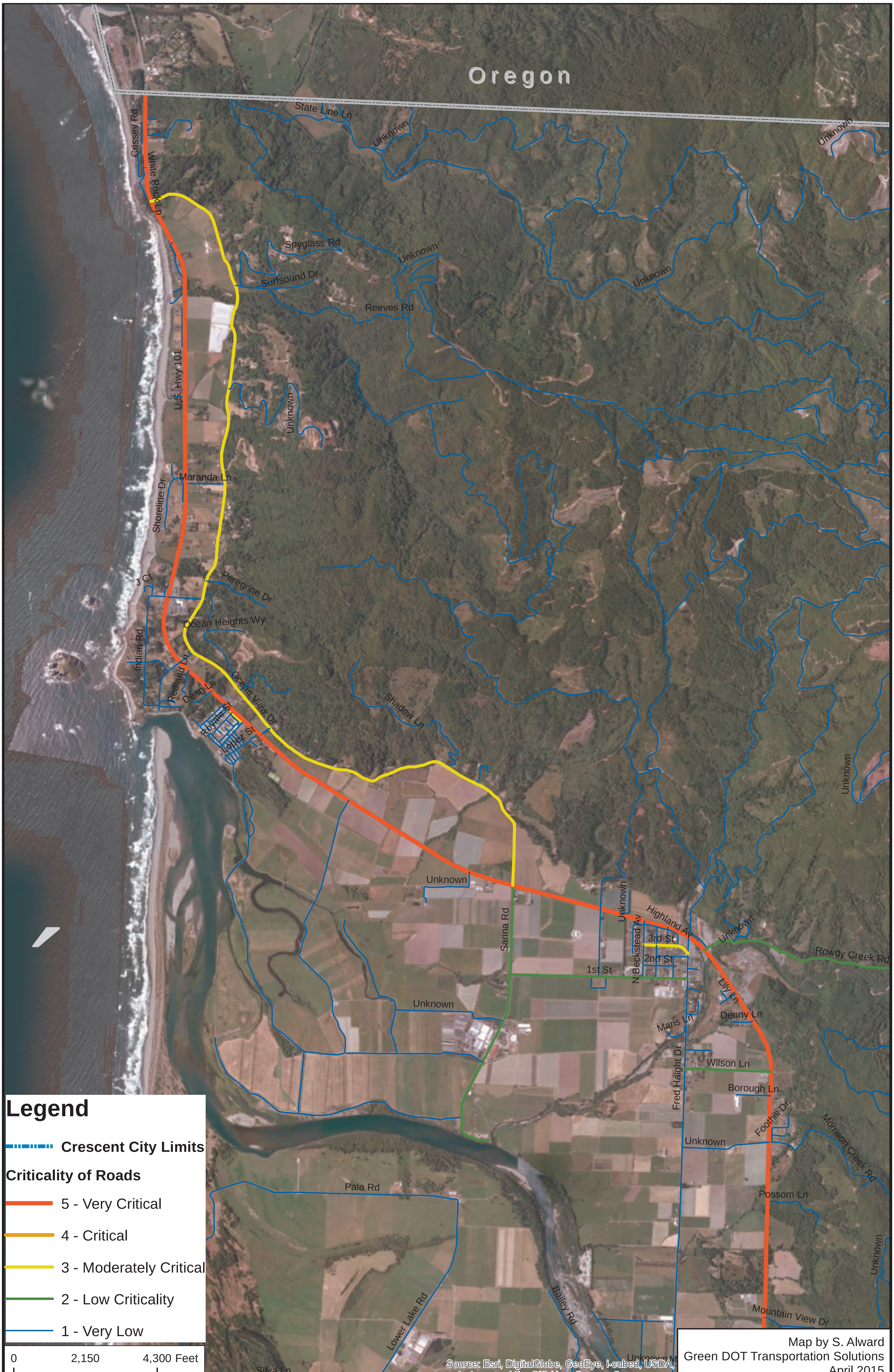
Name	Functional Class	Evacuation Route	Criticality of Asset
A St	5	Y	5
C St	5	Y	5
Elk Valley Crsrd	5	Y	5
Elk Valley Rd	5	Y	5
H St	5	Y	5
Highway 199	3	N	5
Kellog Rd	6	Y	5
Lower Lake Dr	5	Y	5
Morehead Rd	6	Y	5
Moseley Rd	6	Y	5
U.S. Hwy 101	1	Y	5
North Bank Rd	4	N	4
Washington Blvd	4	N	4
3rd St	5	N	3
5th St	5	N	3
9th St	5	N	3
Cooper Ave	5	N	3
El Dorado St	5	N	3
Fred Haight Dr.	5	N	3
Front St	5	N	3
Harding Ave	5	N	3
Highway 169	5	N	3
Howland Hill Rd	5	N	3
Humboldt Rd	5	N	3
Inyo St	5	N	3
Kings Valley Rd	5	N	3
Klamath Beach Rd	5	N	3
Lake Earl Dr	5	N	3
Meridian St	5	N	3
Northcrest Dr	5	N	3
Ocean View Dr	5	N	3
Pacific Ave	5	N	3
Parkway Dr	5	N	3
Patrick J Murphy Me	5	N	3
Pebble Beach Dr	5	N	3
Requa Rd	5	N	3
Sand Mine Rd	5	N	3
Small Ave	5	N	3
South Fork Rd	5	N	3
Taylor St	5	N	3
Unkown	5	N	3
Wonder Stump Rd	5	N	3
1st St	6	N	2
Rowdy Creek Rd	6	N	2
Sarina Rd	6	N	2
South Bank Rd	6	N	2
Unkown	6	N	2
Wilson Ln	6	N	2

Attachment B

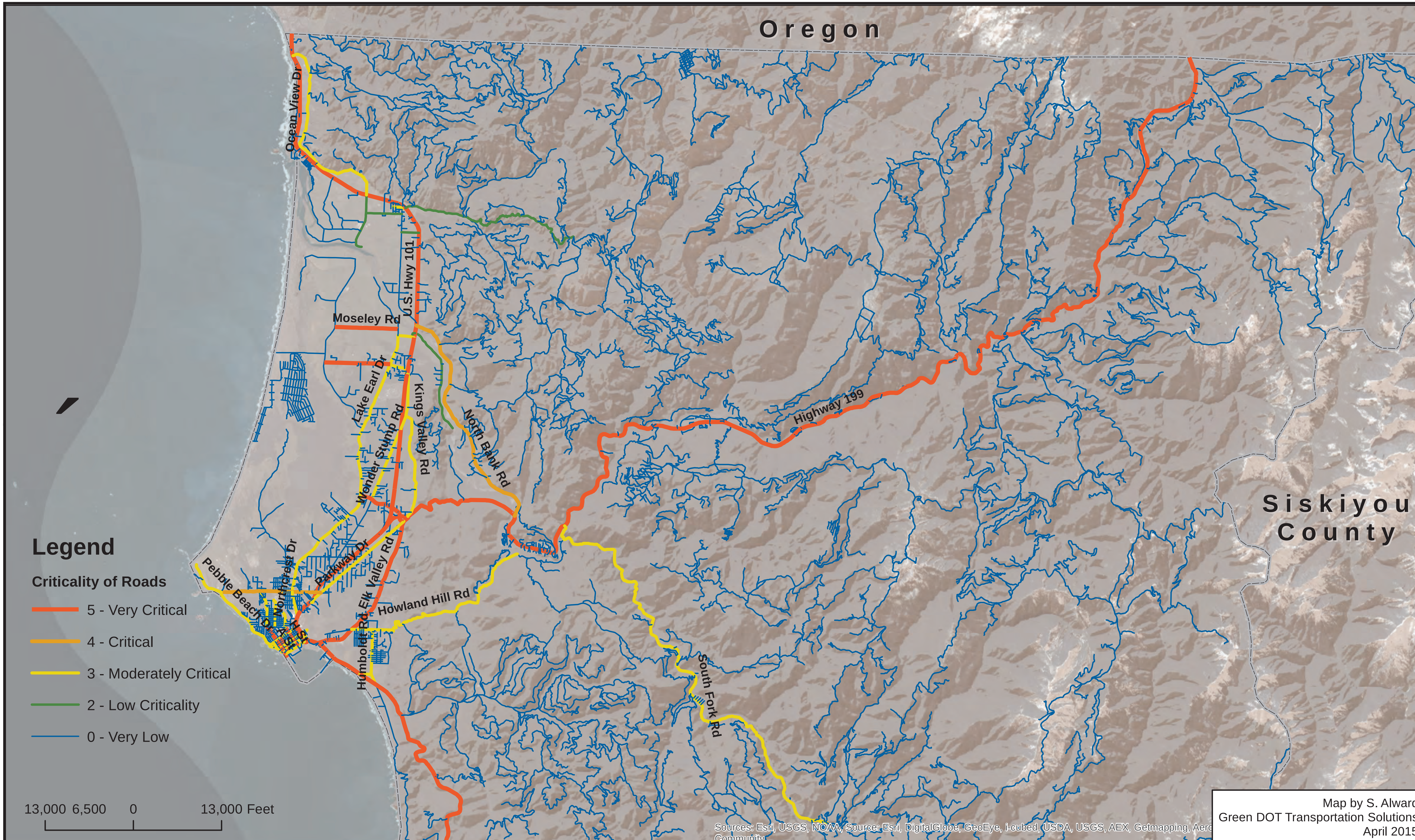
ATTACHMENT C-ROADWAY CRITICALITY MAPS

CRESCENT CITY CRITICALITY OF ROADS

GREEN DOT transportation solutions



NORTHERN BORDER CRITICALITY OF ROADS



NORTHERN COUNTY CRITICALITY OF ROADS

SOUTHERN BORDER CRITICALITY OF ROADS

GREEN DOT transportation solutions

ATTACHMENT D-BRIDGES

Del Norte County

District 01

California Dept of Parks and Recreation

Bridge Number	Feature Intersected	Facility Carried	Location	NBI Bridge	SD/FO	Suff Rating	Health Index	PCI	Year Built	ADT	Lanes	Road Width	Length	On/Off Federal Aid System	On/Off NHS Highway	Permit Rating
01P0005	MILL CREEK	BREEN MEMORIAL RD	JEDEDIAH SMITH STATE PARK	NBI Bridge	FO	59.8	96.35		1949	100	1	3.5	45	Off	Off	GOOOO
01P0010	MILL CREEK	MILL CREEK CMPGRND	DEL NORTE STATE PARK	NBI Bridge	SD	35.7	73.46		1989	200	1	5.4	27	Off	Off	XXXXX
01P0011	WEST BRANCH MILL CREEK	HAMILTON ROAD	2.1 MILES EAST OF US 101	NBI Bridge	SD	35.1	69.57		1950	10	1	5.3	27	Off	Off	XXXXX
01P0012	EAST FORK MILL CREEK	HAMILTON ROAD	2.8 MILES EAST OF US 101	NBI Bridge	SD	27.7	74.34		1950	10	1	5.2	26	Off	Off	XXXXX
01P0014	FIRST GULCH	HAMILTON ROAD	3.1 MILES EAST OF US 101	NBI Bridge	SD	36.2	49.93		1950	10	1	5.4	15	Off	Off	PPPPP
01P0015	EAST FORK MILL CREEK	ROCK CREEK ROAD	4.1 MILES EAST OF US 101	NBI Bridge	SD	23.7	73.88		1950	10	1	4.9	27	Off	Off	XXXXX
01P0016	CHEWY CREEK	WEST BRANCH ROAD	4.7 MILES EAST OF US 101	NBI Bridge	SD	39.7	56.29		1950	10	1	4.2	12	Off	Off	PPPPP
01P0017	WEST BRANCH MILL CREEK	WEST BRANCH ROAD	5.4 MI S OF HAMILTON ROAD	NBI Bridge	SD	47.8	0		1950	10	1	5.5	18	Off	Off	PPPPP
01P0018	BUMMER LAKE CREEK	CHILD'S HILL ROAD	4.5 MI EAST OF US 101	NBI Bridge		79.9	58.41		1950	10	1	6.1	19	Off	Off	PPPPP
01P0019	JANE CREEK	CHILD'S HILL ROAD	10.3 MI SE OF HAMILTON RD	NBI Bridge		61.7	50		1950	5	1	5.6	19	Off	Off	OXXXX
01P0020	ROCK CREEK	CHILD'S HILL ROAD	8.8 MI SE OF HAMILTON RD	NBI Bridge		46.9	83.19		1950	10	1	5.5	27	Off	Off	XXXXX
01P0021	EAST FORK MILL CREEK	CHILD'S HILL ROAD	5.3 MILES EAST OF US 101	NBI Bridge		64.9	58.86		1950	10	1	4.1	18	Off	Off	PPPPP

Del Norte County

District 01

County of Del Norte

Bridge Number	Feature Intersected	Facility Carried	Location	NBI Bridge	SD/FO	Suff Rating	Health Index	PCI	Year Built	ADT	Lanes	Road Width	Length	On/Off Federal Aid System	On/Off NHS Highway	Permit Rating
01C0001	HOPPOW CREEK	KLAMATH MILL ROAD	500' E OF RT 101/169 SEP	NBI Bridge		85.6	100		1965	1395	2	8.5	18	Off	Off	PPPPP
01C0002	HOPPOW CREEK	CHAPMAN STREET	WEST OF ROUTE 101/169 SEP	NBI Bridge	SD	55.2	75.1		1965	20	2	9.5	31	Off	Off	PPPPP
01C0005	SOUTH FORK SMITH RIVER	SOUTH FORK ROAD	0.4 MI SE OF US 199	NBI Bridge	SD	33.4	57.79	42.18	1948	334	2	7.3	63	On	Off	OOOOO
01C0006	MIDDLE FORK SMITH RIVER	SOUTH FORK ROAD	0.05 MI SE JCT SR199	NBI Bridge		68.2	79.56	50	1956	350	2	6.7	79	On	Off	PPGGG
01C0008	GILBERT CREEK	OCEAN VIEW DRIVE	0.8 MI S OF RT 101	NBI Bridge	FO	55.3	91.41		1947	670	2	6.1	29	On	Off	OOOOO
01C0009	ROWDY CREEK	ROWDY CREEK ROAD	1.75 MI E OF RTE 101	NBI Bridge		96.7	100		1962	145	2	8.5	25	Off	Off	PPPPP
01C0010	MIDDLE FORK SMITH RIVER	GASQUET FLAT ROAD	0.1 MILE N/O RTE 199	NBI Bridge		84.3	81.3	50	1960	400	2	8.5	61	Off	Off	PPPPP
01C0011	HUNTER CREEK	REQUA ROAD	0.1 MI WEST OF RT101	NBI Bridge	SD	20.4	84.6		1949	1110	2	8.4	42	Off	Off	XXXXX
01C0012	SALT CREEK	REQUA ROAD	0.4 MI WEST OF RTE 101	NBI Bridge		73.8	100		1958	1110	2	0.0	7	Off	Off	PPPPP
01C0015	ROWDY CREEK	FRED D. HAIGHT DR.	1/2 MI S OF RTE 101	NBI Bridge		96.6	92.91		1989	2600	2	11.0	43	Off	Off	POOXX
01C0017	JORDAN CREEK	LAKE EARL DRIVE	3.7 MI N OF RTE 101	NBI Bridge		84.1	88.16		1954	4150	2	12.5	9	On	Off	PPPPP
01C0018	ELK CREEK	OREGON MOUNTAIN RD	0.1 MILE NE/O RTE 199	NBI Bridge		97.0	94.82		1925	40	2	10.4	9	Off	Off	PPPPP
01C0020	SALT CREEK	SALT CREEK RD	0.1 MI N/O REQUA RD	NBI Bridge	SD	41.5	47.37		1975	5	1	3.8	16	Off	Off	OOOOO
01C0022	SHEEP PEN CREEK	DOUGLAS PARK ROAD	0.74 MI S/O SOUTH FORK RD	NBI Bridge		84.5	97.65		1975	140	2	8.7	12	Off	Off	OOOOO
01C0026	HURDYGURDY CREEK	SOUTH FORK ROAD	14.2 MI SE OF JCT RTE 199	NBI Bridge	FO	56.6	56.99	46.2	1955	300	1	4.3	53	On	Off	PPPPP
01C0027	SOUTH FORK SMITH RIVER	SOUTH FORK ROAD	13.0 MI SE JCT SR199	NBI Bridge	FO	76.9	96	75	1955	334	1	4.6	101	On	Off	PGOOO
01C0031	HURDYGURDY CREEK	BIG FLAT ROAD	2.6 MI N/O S FORK ROAD	NBI Bridge	SD	38.5	30.49	25	1948	40	1	3.7	39	Off	Off	PPPPP
01C0032	EIGHTEEN MILE CREEK	OLD GASQUET TOLL	5 MI FROM ROUTE 199	NBI Bridge		71.9	93.5		1970	20	1	4.7	8	Off	Off	PPPPP
01C0033	WEST FORK PATRICKS CREEK	OLD GASQUET TOLL	3.5 MI FROM RTE 199	NBI Bridge		60.2	100		1960	30	1	4.3	34	Off	Off	XXXXX
01C0034	SHELLY CREEK	PATRICK'S CREEK RD	2.3 MILE N/O RTE 199	NBI Bridge		83.8	94.9		1976	50	1	4.2	20	Off	Off	PPPPP
01C0035	SHELLY CREEK	COUNTY ROAD 316	9.3 MI NORTH OF RTE 199	NBI Bridge		81.3	100		1975	50	1	4.3	8	Off	Off	PPPPP
01C0036	NORTH FORK SMITH RIVER	COUNTY ROAD 305	12 MI E JCT ROWDY CREK RD	NBI Bridge		96.5	100		1981	10	2	7.3	47	Off	Off	PPPPP
01C0037	SOUTH FORK SMITH RIVER	SOUTH FORK ROAD	6.1 MILE SE OF RTE 199	NBI Bridge		96.8	100		1981	334	2	9.8	144	On	Off	PPPPP
01C0038	SOUTH FORK SMITH RIVER	SOUTH FORK ROAD	6.5 MI SE JCT RTE 199	NBI Bridge		96.8	100		1981	334	2	9.8	136	On	Off	PPPPP

Del Norte County

District 01

County of Del Norte

Bridge Number	Feature Intersected	Facility Carried	Location	NBI Bridge	SD/FO	Suff Rating	Health Index	PCI	Year Built	ADT	Lanes	Road Width	Length	On/Off Federal Aid System	On/Off NHS Highway	Permit Rating
01C0039	CLARKS CREEK	WALKER ROAD	0.2 MI NORTH OF RTE 199	NBI Bridge		74.3	92.63	75	2002	25	1	6.1	21	Off	Off	OOOOO
01C0040	MYNOT CREEK	MINOT CREEK ROAD	0.1 MI E OF RTE 101	NBI Bridge		97.0	100		2005	85	2	7.2	12	Off	Off	PPPPP
01C0041	ROCK CREEK	SOUTH FORK ROAD	8.1 MI SE JCT US 199	NBI Bridge		96.8	100		2009	334	2	9.6	35	On	Off	POOOO
01C0042	BOULDER CREEK	SOUTH FORK ROAD	9.2 MI SE JCT US 199	NBI Bridge		93.7	100		2009	344	2	9.5	32	On	Off	POOOO

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TECHNICAL MEMORANDUM

TO:	Tamera Leighton, Del Norte Local Transportation Commission	DATE:	September 21, 2015
FROM:	Emily Straley, P.E.	JOB#:	DNLT.15.01
SUBJECT:	Module 2b – Apply Climate Information		

Introduction

The transportation asset inventory for Del Norte County and the criticality of each asset are presented in Module 2a. The purpose of Module 2b is to present the extent and timing of climate change impact on the transportation assets. This module summarizes the precipitation, sea level rise, and coastal erosion climate change data, how that data is applied to the transportation assets, and the impact of climate change on those assets.

Climate Data Sources

As discussed in Module 1, the exposure of transportation assets to forecasted climate change is based on the A2 emissions scenario, focusing on two future timeframes: 2050 and 2100. The most recent comprehensive climate data (2000) is used as the baseline to which the two future time horizons are compared against and the magnitude of change is evaluated. Climate data on precipitation, sea level rise, and coastal erosion has been collected from the sources listed in Table 1. This data is used to assess the vulnerability of transportation assets to climate change, and determine the level of impact of climate change on these assets based on the ranking system discussed herein.

Table 1 - Climate data sources

Source	Data
Federal Emergency Management Agency (FEMA)	Flood maps
Pacific Institute (Pac-Inst)	Coastal hazard maps
Cal-Adapt	Precipitation and runoff data
Coupled Model Intercomparison Project Phase 3 (CMIP3)	Precipitation data
United States Geological Survey (USGS)	Digital terrain model, land cover data
National Oceanic and Atmospheric Administration (NOAA)	Sea level rise

Ranking of Vulnerability

A ranking system was developed to assign climate based vulnerability to an asset, as shown in Table 2. Vulnerability is ranked on a scale from 0 to 10, with 0 indicating no anticipated climate change impact and 10 assuming indicating an assumed loss of asset. This ranking system was developed assuming no repairs will be made to the system during the analysis timeframe.

Table 2 - Ranking system: Vulnerability of an asset based on climate change

Rank	Description	General ranking methodology
0	No anticipated impact on asset	No impact
2	Mild	Flooding only
4	Mild-Moderate	Erosion only in future
6	Moderate	Current + Future erosion, no flooding
8	Heavy	Current + Future erosion, flooding
10	Loss of an asset	Substantial Current + Future erosion, flooding

Using the climate data compiled from the various agencies along with observational data gathered from stakeholders, vulnerability was assigned to the asset inventory in an ArcGIS database.

Impact of Climate Change on Transportation Assets

Precipitation

The precipitation totals for target years are estimated by calculating an average over 30 year periods. The 2050 timeframe is estimated based on the period from 2035-2064; the 2100 timeframe is estimated based on the period from 2070 to 2099. The baseline, 2000, is estimated based on climate change model results from 1950 to 1999.

Annual precipitation totals are projected to decrease by approximately 5% by 2050, and 8% by 2100 in Del Norte County. Table 3 summarizes the projected changes in annual precipitation totals for the future timeframes as compared to the baseline at three locations of interest in the County.

Table 3 – Change in projected annual precipitation total in Del Norte County

Location	Analysis timeframe	Change from baseline
Crescent City	2050	-4.9%
	2100	-7.7%
mouth of Klamath R.	2050	-5.0%
	2100	-7.9%
Gasquet	2050	-4.6%
	2100	-7.4%

Monthly averages were calculated to determine a decrease in precipitation can be anticipated in general, or if the change in precipitation will vary by season. As shown in Table 4, every month except for February is predicated to experience a decrease in precipitation, with January predicated to remain nearly constant. This indicates that while Del Norte is predicted to receive less rain annually, February could be 2% to 3.9% than the year 200 baseline.

Table 4 - Change in projected monthly precipitation total in Crescent City

Rank	2050 Change from Baseline	2100 Change from Baseline
January	-0.2%	-0.4%
February	2.0%	3.9%
March	-2.6%	-5.2%
April	-3.0%	-5.9%
May	-9.4%	-18.9%
June	-16.4%	-32.7%
July	-21.0%	-41.9%
August	-22.8%	-45.6%
September	-19.2%	-38.4%
October	-11.5%	-22.9%
November	-3.2%	-6.4%
December	-1.9%	-3.8%

The next step is determining the impact of climate change on the intensity of precipitation events. Drainage structures are generally designed to convey the flow from larger storm events, so if precipitation is predicted to increase, the size of drainage structures will increase as well. As February precipitation is predicated to increase, it's likely that the intensity of precipitation events will increase as well. This was confirmed by computing the 98th percentile daily precipitation event over the target year timeframe period. The 98th percentile is a statistical measure of the extreme occurrence which may be exceeded 2% of the time over a given period. It is used as an indication of extreme events over 100-year recurrence because the use of a recurrence assumes precipitation patterns are not changing. However, a change in the 98th percentile value may correlate to changes in the 100-year event. An increase in extreme precipitation is predicted for the Crescent City area as shown in Table 5. This indicates that storms larger than the 98th percentile will have rainfall totals 3% greater than baseline in 2050, and 8.1% larger than baseline in 2100.

Table 5 - Change in projected extreme precipitation event total in Crescent City

Analysis Timeframe	Change from Baseline
2050	3.0%
2100	8.1%

Roadway flooding is a common occurrence in various parts of Del Norte County. In particular, along 3rd St in Crescent City and on Klamath Beach Road and Highway 101 (between Ehlers Ave and near McMillian Road). Due to the overall decrease in precipitation predicted due to climate change, transportation assets will most likely flood less often However, due to the increase in extreme precipitation events, transportation assets may experience increased flood depth and duration when flooding does occur.

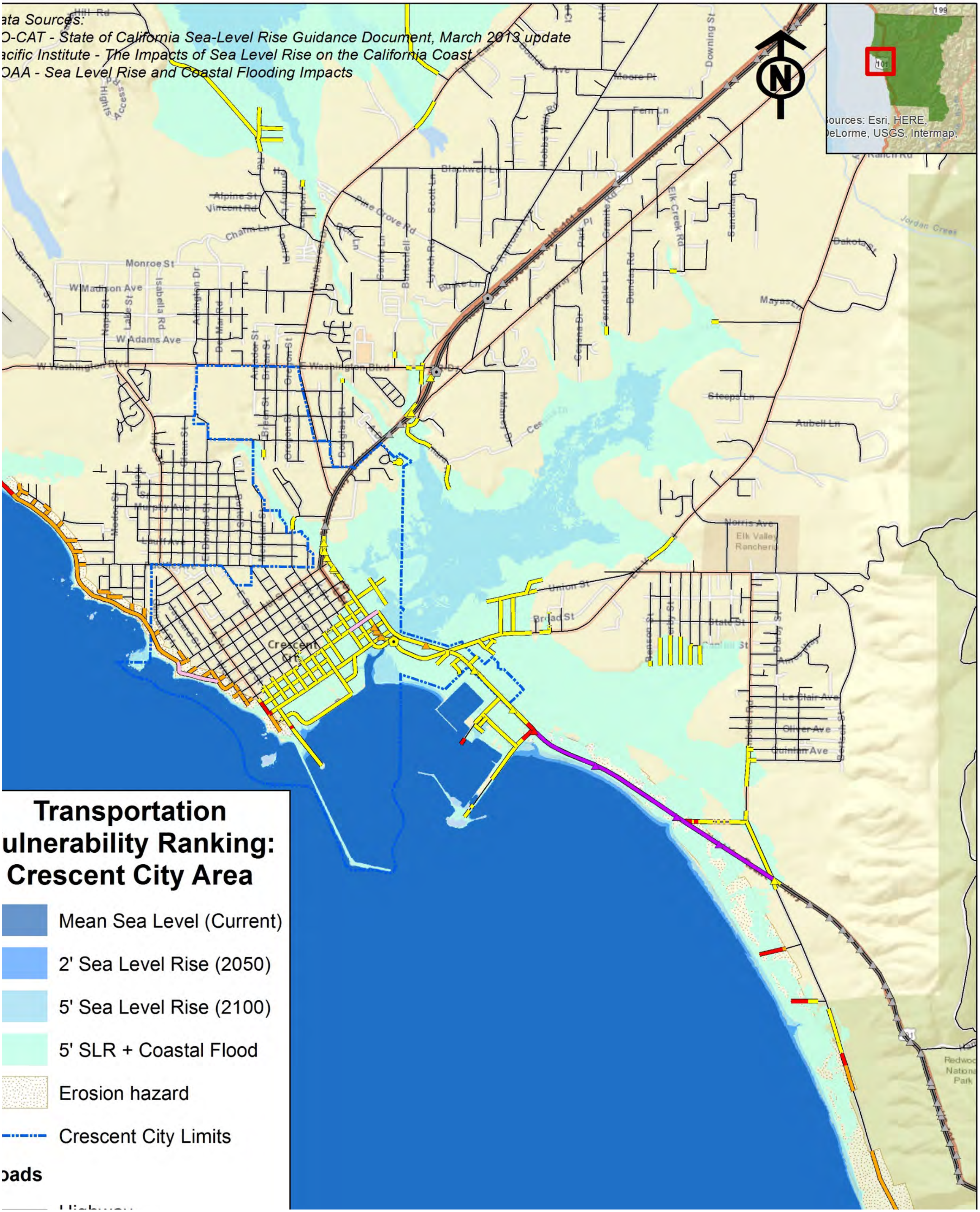
Sea Level Rise and Coastal Erosion

Sea level is predicted to rise 55 inches along the California coastline by 2100, leading to increased coastal flooding and shoreline erosion. The intensity of coastal storm surges is also projected to increase, which has the potential to cause permanent or periodic inundation of coastal transportation assets, along with damage to these assets brought on by coastal erosion.

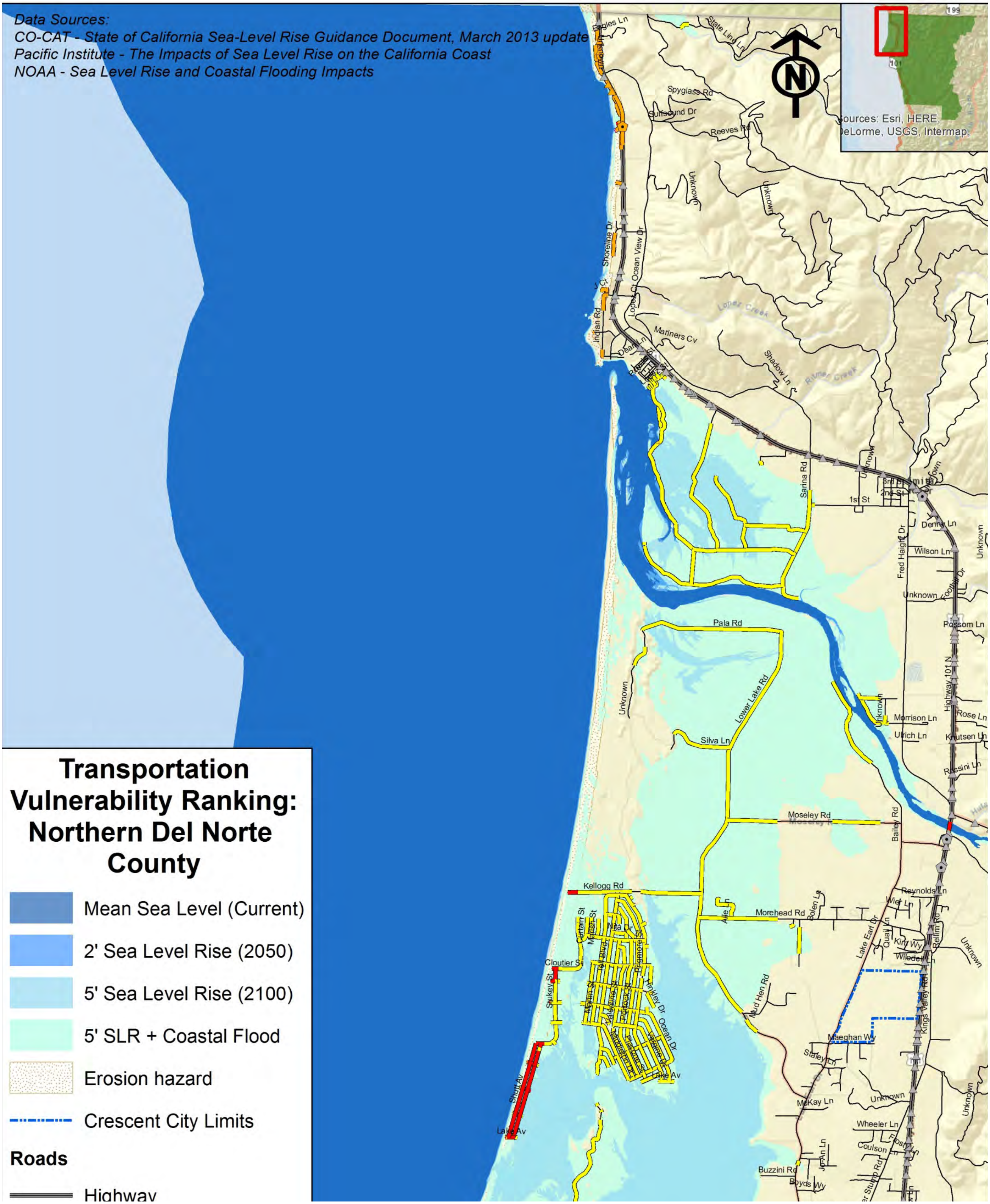
Coastal erosion is currently occurring on Pebble Beach Drive in Crescent City, along Highway 101 (between Anchor Way and Humboldt Road) and along Highway 101 at Last Chance Grade in Del Norte County. These assets are assigned a vulnerability ranking of 10, as coastal erosion is predicted to become more severe. Furthermore, there are currently 7 bridges and 46 culverts owned and maintained by Caltrans in the current flood zone. It is unknown how many City and County owned and maintained bridges and culverts are located in the current flood zone. By year 2100, coastal flooding and erosion is anticipated to impact 3 additional bridges and an additional 47 culverts. If nothing is done to mitigate the erosion at these locations, it is anticipated that there will be a complete loss of these assets by 2100. Erosion is anticipated to impact most transportation assets that are located along the coast.

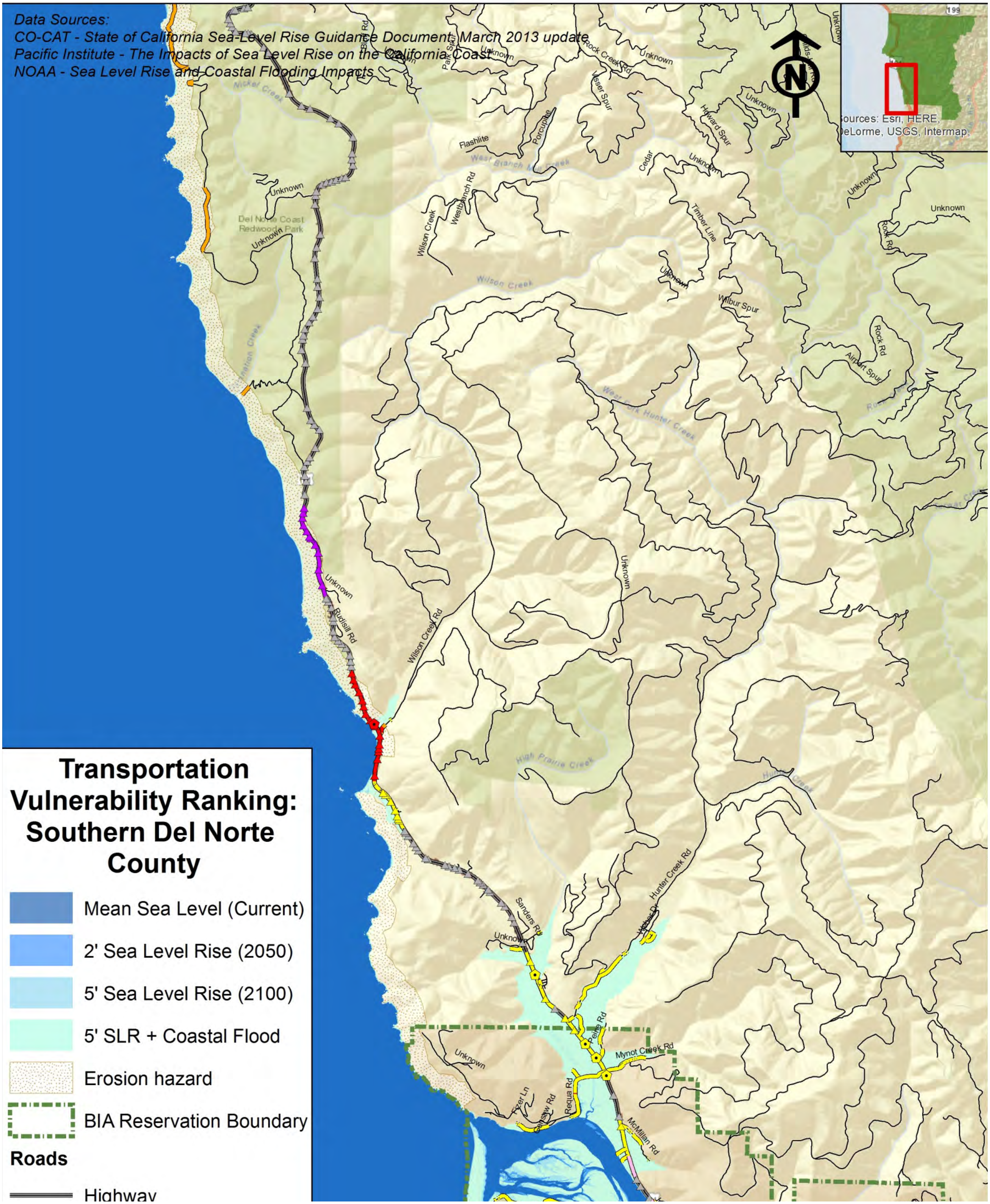
Likewise, future sea level rise is anticipated to impact most transportation assets that are located along the coast with impacts spreading inland in low-lying areas. Areas of particular concern are along the southern extents of Crescent City to 3rd Street and encroaching into the Elk Creek watershed, along Highway 101 near the mouth of the Klamath River, and near the mouth of the Smith River.

Figure 1 (Crescent City), Figure 2 (Northern Del Norte County), and Figure 3 (Southern Del Norte County) show the sea level rise and coastal erosion impact areas and the vulnerability ranking of the transportation asset inventory. In general, the most vulnerable transportation assets are located along the coast of the Pacific Ocean and the mouths of the Smith and Klamath Rivers.



ata Sources:
O-CAT - State of California Sea-Level Rise Guidance Document, March 2013 update
acific Institute - The Impacts of Sea Level Rise on the California Coast
OAA - Sea Level Rise and Coastal Flooding Impacts
ources: Esri, HERE,
eLorme, USGS, Intermap,
N
Transportation
ulnerability Ranking:
Crescent City Area
Mean Sea Level (Current)
2' Sea Level Rise (2050)
5' Sea Level Rise (2100)
5' SLR + Coastal Flood
Erosion hazard
Crescent City Limits
oads
Monroe St
W Madison Ave
W Adams Ave
W Washington Blvd
E Washington Blvd
Blackwell Ln
Pine Grove Rd
Alpine St
Vincent Rd
Moore Pt
Fern Ln
Elk Creek Rd
Steeps Ln
Aubell Ln
Dakota St
Norris Ave
Elk Valley Rancheria
Union St
State St
Le Clair Ave
Oliver Ave
Quinlan Ave
Crescent City
Jordan Creek
Redwood National Park


Data Sources:
CO-CAT - State of California Sea-Level Rise Guidance Document, March 2013 update
Pacific Institute - The Impacts of Sea Level Rise on the California Coast
NOAA - Sea Level Rise and Coastal Flooding Impacts
Transportation Vulnerability Ranking: Northern Del Norte County
Mean Sea Level (Current)
2' Sea Level Rise (2050)
5' Sea Level Rise (2100)
5' SLR + Coastal Flood
Erosion hazard
Crescent City Limits
Roads
Highway
N
Sources: Esri, HERE, DeLorme, USGS, Intermap
199
101
State Line Ln
Spyglass Rd
Reeves Rd
Shoreline Dr
Ocean View Dr
Indian Rd
Mariners Cv
Lopez Creek
Shadow Ln
Sarina Rd
1st St
2nd St
Denny Ln
Wilson Ln
Fred Haight Dr
Pala Rd
Lower Lake Rd
Silva Ln
Morrison Ln
Ulrich Ln
Knutsen Ln
Rose Ln
Possom Ln
Rossini Ln
Highway 101 N
Moseley Rd
Bailey Rd
Kellogg Rd
Morehead Rd
Reynolds Ln
Cloutier St
Stukey St
Nita Dr
Hinkley Dr
Ocean Dr
Lake Av
Shutt Av
Mud Hen Rd
Lake Earl Dr
Kings Valley Rd
Maeghan Wy
Staley Ln
McKay Ln
Wheeler Ln
Coulson Ln
Buzzini Rd
Boyds Wy
Unknown



Data Sources:
CO-CAT - State of California Sea-Level Rise Guidance Document, March 2013 update
Pacific Institute - The Impacts of Sea Level Rise on the California Coast
NOAA - Sea Level Rise and Coastal Flooding Impacts
N
Sources: Esri, HERE, DeLorme, USGS, Intermap,
199
Transportation Vulnerability Ranking: Southern Del Norte County
Mean Sea Level (Current)
2' Sea Level Rise (2050)
5' Sea Level Rise (2100)
5' SLR + Coastal Flood
Erosion hazard
BIA Reservation Boundary
Roads
Highway
Del Norte Coast Redwoods Park
Nickel Creek
Wilson Creek
West Branch Mill Creek
West Fork Hunter Creek
High Prairie Creek
Hunter Creek
Flashlite
Porcupine
Cedar
Timber Line
Wilbur Spur
Rock Rd
Airport Spur
Howard Spur
Rock Creek Rd
Westbranch Rd
Wilson Creek Rd
Rudisill Rd
Sanders Rd
Hunter Creek Rd
Peins Rd
Mynot Creek Rd
Requa Rd
McMillan Rd
Unknown

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TECHNICAL MEMORANDUM

TO:	Tamera Leighton, Del Norte Local Transportation Commission	DATE:	September 21, 2015
FROM:	Emily Straley, P.E.	JOB#:	DNLT.15.01
SUBJECT:	Module 3 – Conduct Vulnerability and Risk Assessment		

Introduction

The transportation asset inventory for Del Norte County and the criticality of each asset were presented in Module 2a. Module 2b presented the extent and timing of climate impact on these transportation assets. Module 3 brings together these two modules to develop a risk assessment of the transportation asset inventory in Del Norte County. A risk assessment integrates the severity or consequence of an impact with the probability or likelihood that an asset will experience the impact. To do this, criticality and climate based vulnerability of the transportation assets were integrated to derive a measure of risk for transportation assets that will be potentially impacted by climate change. This module summarizes the risk assessment process, the ranking of risk, and high risk transportation assets.

Risk Assessment Process

Risk of a transportation asset to climate change is based on the criticality and vulnerability of an asset. As discussed in the Module 2 memos, the criticality and vulnerability of the transportation assets were developed independently. Criticality is based on a combination of functional classification and stakeholder input. Vulnerability is based on climate impacts assuming the A2 emission scenario and the 2100 future timeframe. To integrate these two attributes to determine risk, the data were overlain in ArcGIS. These two attributes were intersected and the risk was assigned based averaging the criticality and vulnerability of a given asset.

Ranking of Risk

A ranking system was developed to assign risk based on vulnerability and criticality of an asset, as shown in Table 1. High priority transportation facilities with high vulnerability to climate change are designated high risk, whereas high priority facilities with low vulnerability to climate change were designated lower risk. Transportation facilities that are already subject to excess rainfall and/or tidal flooding were designated higher risk than facilities that are not currently subject to flooding but will be in future climate change scenarios.

Table 1. Ranking system: Risk of an asset based on vulnerability and critically

Rank	Risk	General ranking methodology
1	Low	Only Critical or only vulnerable to climate change (no intersection)
2 - 3	Mild	Low criticality and low vulnerability to climate change
4 - 5	Mild-Moderate	Low criticality and moderate vulnerability to climate change
6 - 7	Moderate	Moderate criticality and moderate vulnerability to climate change
8 - 9	Heavy	Moderate criticality and high vulnerability to climate change
10	Severe	High criticality and high vulnerability to climate change

Prioritized List of Transportation Assets

In general, the most at risk transportation assets to climate change are located along the coast. This includes the major county thoroughfare, US Hwy 101, which spans the county parallel to the coast. A disruption along US Hwy 101 can result in detours of several hours and have a significant impact on the economy in Del Norte County. This highway is classified as high risk in sections because it is a principal arterial that is currently subject to coastal erosion, and is projected to be impacted by increased coast erosion as well as sea level rise and flooding due to climate change. Risk along US Hwy 101 ranges between 5 and 10, with higher risk sections found generally along the coast.

In Crescent City, sections of roads located near the coast and Elk Creek are designated high risk. Pebble Beach Road, which is a major residential thoroughfare, is currently subject to coastal erosion. Coastal erosion is anticipated to worsen in this area due to climate change. A Street, which provides coastal access and is a tsunami evacuation route between Front Street and 3rd Street, is subject to coastal erosion and 2100 coastal flood. 3rd Street and US Hwy 101 between 2nd and 3rd Street is currently subject to frequent flooding during precipitation events. This area is vulnerable to sea level rise and coastal flooding by 2100, although the flooding due to precipitation events will continually worsen as the sea level rises. US Hwy 101 between Citizens Dock Road and Enderts Beach Road, which is along the major connector between Crescent City and all areas to the south, is vulnerable to coastal erosion and sea level rise. Although mean sea level isn't expected to encroach upon the roadway until 2100, it is likely that the 100-year tide will impact the roadway before then. A more detailed study is required to determine when this section of roadway will require mitigation in order to remain outside the FEMA floodplain.

The southern section of Del Norte County is also as risk due to climate change. Last Chance Grade, a highly studied section of US Hwy 101 just north of the Klamath River, is currently subject to coastal erosion which is predicted to increase due to climate change. US Hwy 101 through Klamath is subject to flooding due to overtopping from the Klamath River. This is anticipated to worsen due to sea level rise and the intensification of storm events. Klamath Beach Road, an important access road for the Yurok Tribe, is subject to similar impacts. Particularly vulnerable is the section of Klamath Beach Road adjacent to the Klamath River near the intersection of Alder Camp Road. This section is on an outside bend of the river and is subject to increased erosion.

US HWY 199 is a major highway that connects Del Norte County to inland highways and population centers. It is currently subject to frequent landslides which are documented to occur most often after rainfall events. It is vulnerable to storms of increased intensity which are predicted to occur due to climate change.

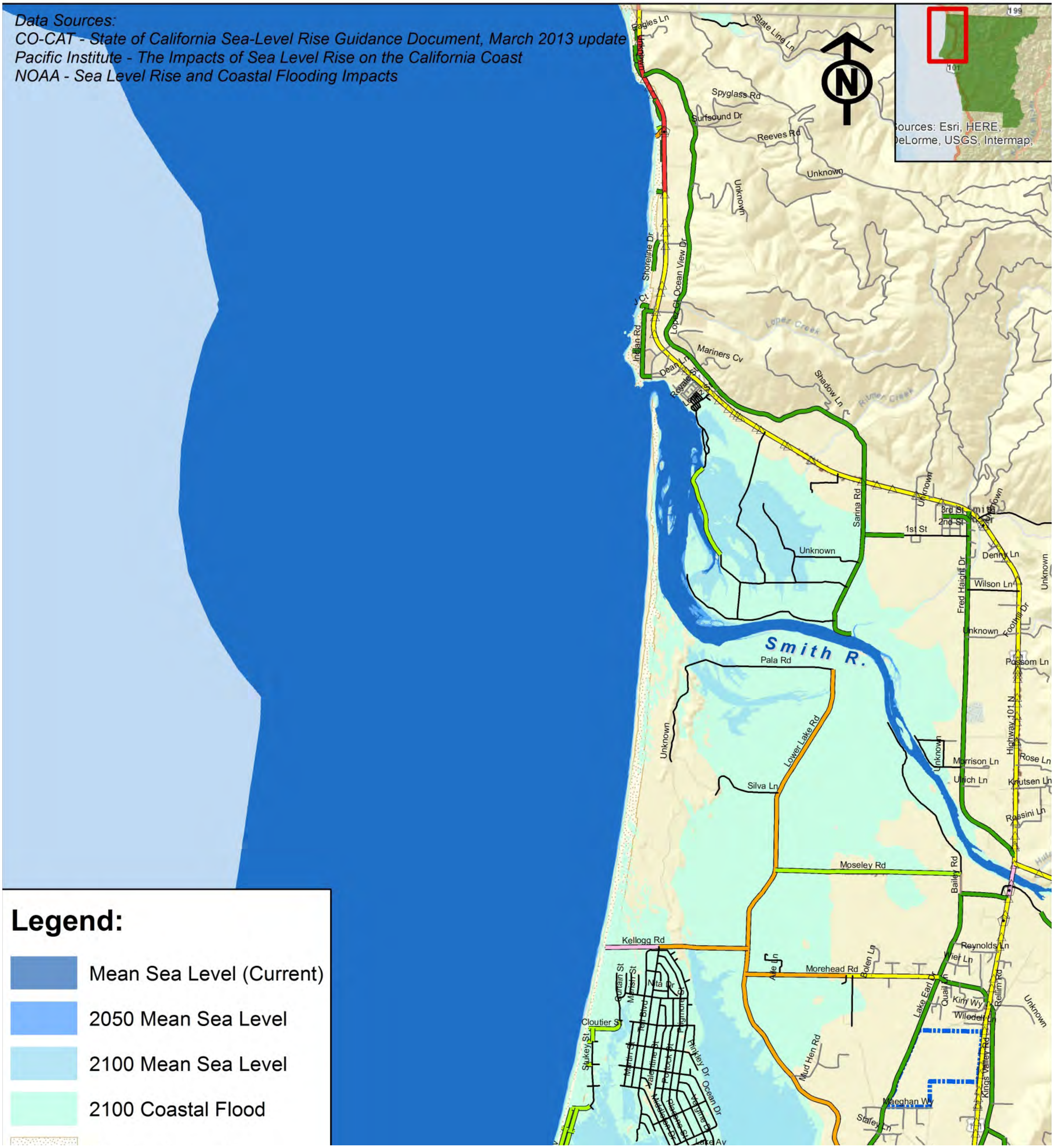
Table 2 summarizes the high risk transportation assets in Del Norte County.

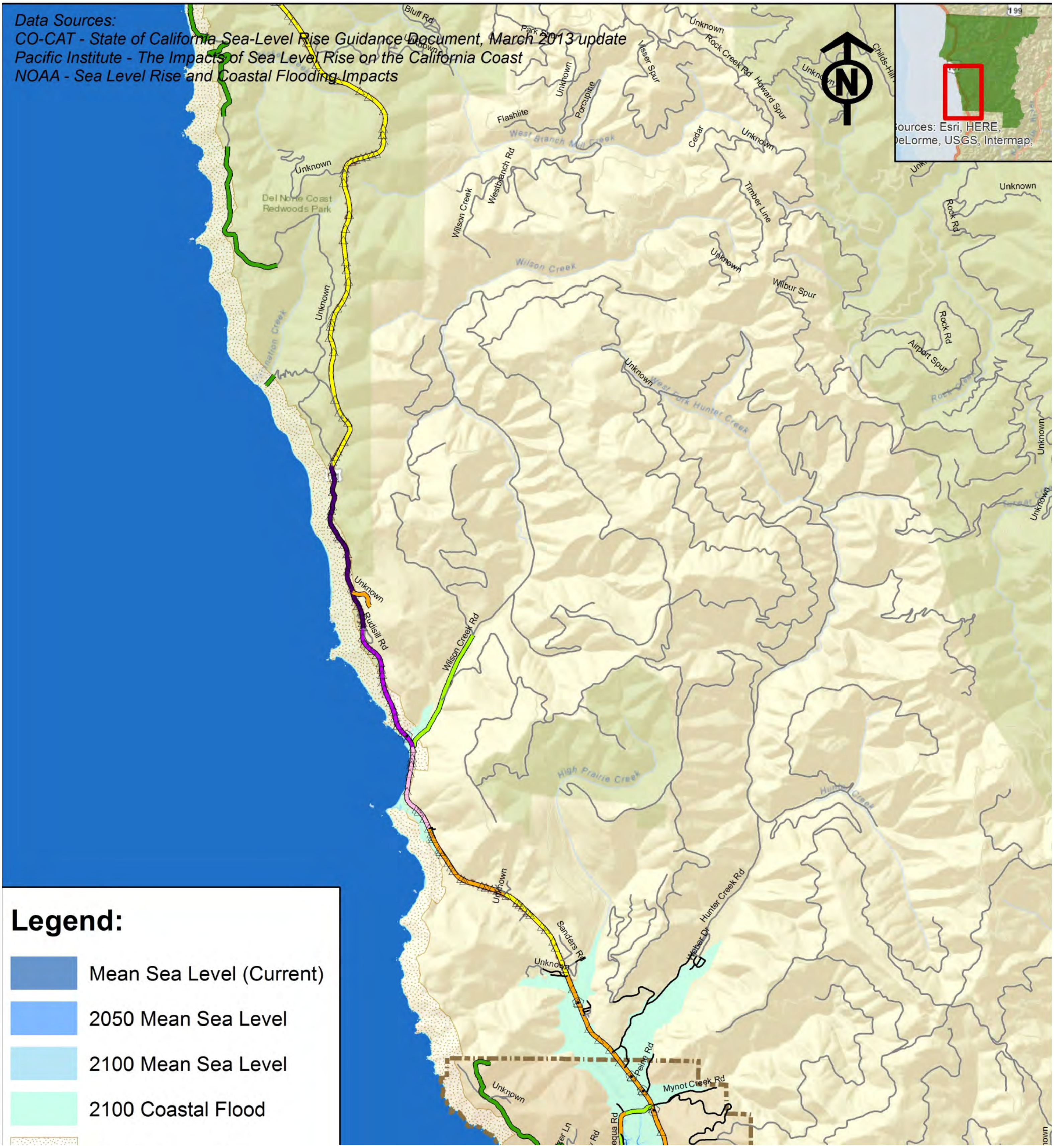
Table 2. High risk transportation assets (a risk of 7 or greater)

Asset	Risk	Description
US Hwy 101, Maranda Ln (near Clifford Kamph Memorial Park) to Oregon Border	7	Principal arterial vulnerable to coastal erosion and sea level rise
US Hwy 101, Dr. Fine Bridge over Smith River	7	Major river crossing on principal arterial vulnerable to flooding and sea level rise
Kellogg Rd, Tell Blvd to Coast	8	Provides coastal access, vulnerable to coastal erosion and sea level rise
Sandmine Road	8	Connector between Hwy 101 and Humboldt Road vulnerable to sea level rise and coastal erosion
US HWY 199	7	Major highway vulnerable to flooding, landslides.
US Hwy 101, Citizens Dock Road and Enderts Beach Road	8-10	Principal arterial vulnerable to coastal erosion and sea level rise
3rd Street, J St to Hwy 101	7	Major road in Crescent City vulnerable to sea level rise and flooding
US Hwy 101, 2nd St to 3rd St	9	Principal arterial vulnerable to sea level rise and flooding
A Street, Front St to the Pacific Ocean	7	Coastal access vulnerable to sea level rise and coastal erosion
A Street, Front St to 3rd St	8	Tsunami evacuation route vulnerable to sea level rise
South Pebble Beach Drive (entire length)	7	Major road in Crescent City located adjacent to the coast. Vulnerable to coastal erosion and sea level rise
US Hwy 101, Last Chance Grade	10	Principal arterial vulnerable to coastal erosion
US Hwy 101, Hwy 169 to north end of Klamath Blvd	8-9	Principal arterial vulnerable to flooding and sea level rise
Klamath Beach Road (adjacent to Klamath River)	7	Major road located adjacent to the mouth of the Klamath River, currently experiences flooding.

The pilot study, *District 1 Climate Change Vulnerability Assessment and Pilot Studies*, completed in December 2014, identifies and classifies the potential vulnerabilities of state owned transportation assets to climate change throughout Caltrans District 1, which includes Del Norte County. Specifically, the report identifies the top three most vulnerable segments in Del Norte County which are all on US HWY 101. The pilot study considers Last Chance Grade (south of Crescent City and Wilson Creek) as the most vulnerable segment in Del Norte County, with an impacting ranking of 10. Similarly, this module ranks Last Chance Grade as highly critical and vulnerable with a risk ranking of 10. The second most vulnerable segment, per the pilot study is considered the segment of US HWY 101 that runs through the Del Norte Redwoods State Park area which is north of Klamath. This module also considers this segment of US HWY 101 as highly critical and vulnerable, with a risk ranking of 8 to 9. Finally the pilot study rates the segment of US HWY 101 between US HWY 199 and the Oregon border as the third most vulnerable segment in the county. As well, this module ranks this segment of highway as highly critical and moderately vulnerable with a risk ranking of 7.


Data Sources:
CO-CAT - State of California Sea-Level Rise Guidance Document, March 2013 update
Pacific Institute - The Impacts of Sea Level Rise on the California Coast
NOAA - Sea Level Rise and Coastal Flooding Impacts
N
Sources: Esri, HERE, DeLorme, USGS, Intermap,
Elk Creek
Crescent City
Elk Valley Rancheria
Jordan Creek
Monroe St
W Madison Ave
W Adams Ave
Blackwell Ln
Pine Grove Rd
Moore Pl
Fern Ln
Boulder Ave
Downing St
Elk Ranch Rd
Dakota St
Mayas Ln
Steeps Ln
Aubell Ln
Norris Ave
Union St
Broad St
State St
Le Clair Ave
Oliver Ave
Quintan Ave
Murphy Ave
Alpine St
Vincent Rd
Chalm Ln
Riverside St
Isabella Rd
Arlington Dr
Burke Ln
Elk Creek Rd
Sandmann Rd
Darby St
Amos Way
Bertsch St
Legend:
Mean Sea Level (Current)
2050 Mean Sea Level
2100 Mean Sea Level
2100 Coastal Flood


Data Sources:
CO-CAT - State of California Sea-Level Rise Guidance Document, March 2013 update
Pacific Institute - The Impacts of Sea Level Rise on the California Coast
NOAA - Sea Level Rise and Coastal Flooding Impacts
Sources: Esri, HERE, DeLorme, USGS, Intermap,
N
Legend:
Mean Sea Level (Current)
2050 Mean Sea Level
2100 Mean Sea Level
2100 Coastal Flood
Smith R.
Spyglass Rd
Surfsound Dr
Reeves Rd
State Line Ln
Shoreline Dr
Ocean View Dr
Mariners Cv
Shadow Ln
Lopez Creek
Rowdy Creek
Indian Rd
Sarina Rd
1st St
2nd St
3rd St
Fred Haight Dr
Dennis Ln
Wilson Ln
Foothill Dr
Possom Ln
Highway 101 N
Morrison Ln
Rose Ln
Ulrich Ln
Knutsen Ln
Rossini Ln
Pala Rd
Lower Lake Rd
Silva Ln
Moseley Rd
Bailey Rd
Kellogg Rd
Morehead Rd
Bolen Ln
Reynolds Ln
Wier Ln
Lake Earl Dr
Quail Ln
Kim Wy
Wilodell Ct
Relim Rd
Kings Valley Rd
Mud Hen Rd
Maeghan Wy
Staley Ln
Cloutier St
Stukey St
Ocean Dr
Hinkley Dr
Unknown



Data Sources:
CO-CAT - State of California Sea-Level Rise Guidance Document, March 2013 update
Pacific Institute - The Impacts of Sea Level Rise on the California Coast
NOAA - Sea Level Rise and Coastal Flooding Impacts
N
Sources: Esri, HERE, DeLorme, USGS, Intermap,
Bluff Rd
Park Rd
Unknown
Rock Creek Rd
Howard Spur
Visser Spur
Porcupine
Flashlite
West Branch Mill Creek
Cedar
Del Norte Coast Redwoods Park
Wilson Creek
Westbranch Rd
Timber Line
Rock Rd
Wilbur Spur
Airport Spur
West Fork Hunter Creek
Rudisill Rd
Wilson Creek Rd
High Prairie Creek
Hunter Creek
Sanders Rd
Hunter Creek Rd
Heber Dr
Peňa Rd
Mynot Creek Rd
Legend:
Mean Sea Level (Current)
2050 Mean Sea Level
2100 Mean Sea Level
2100 Coastal Flood

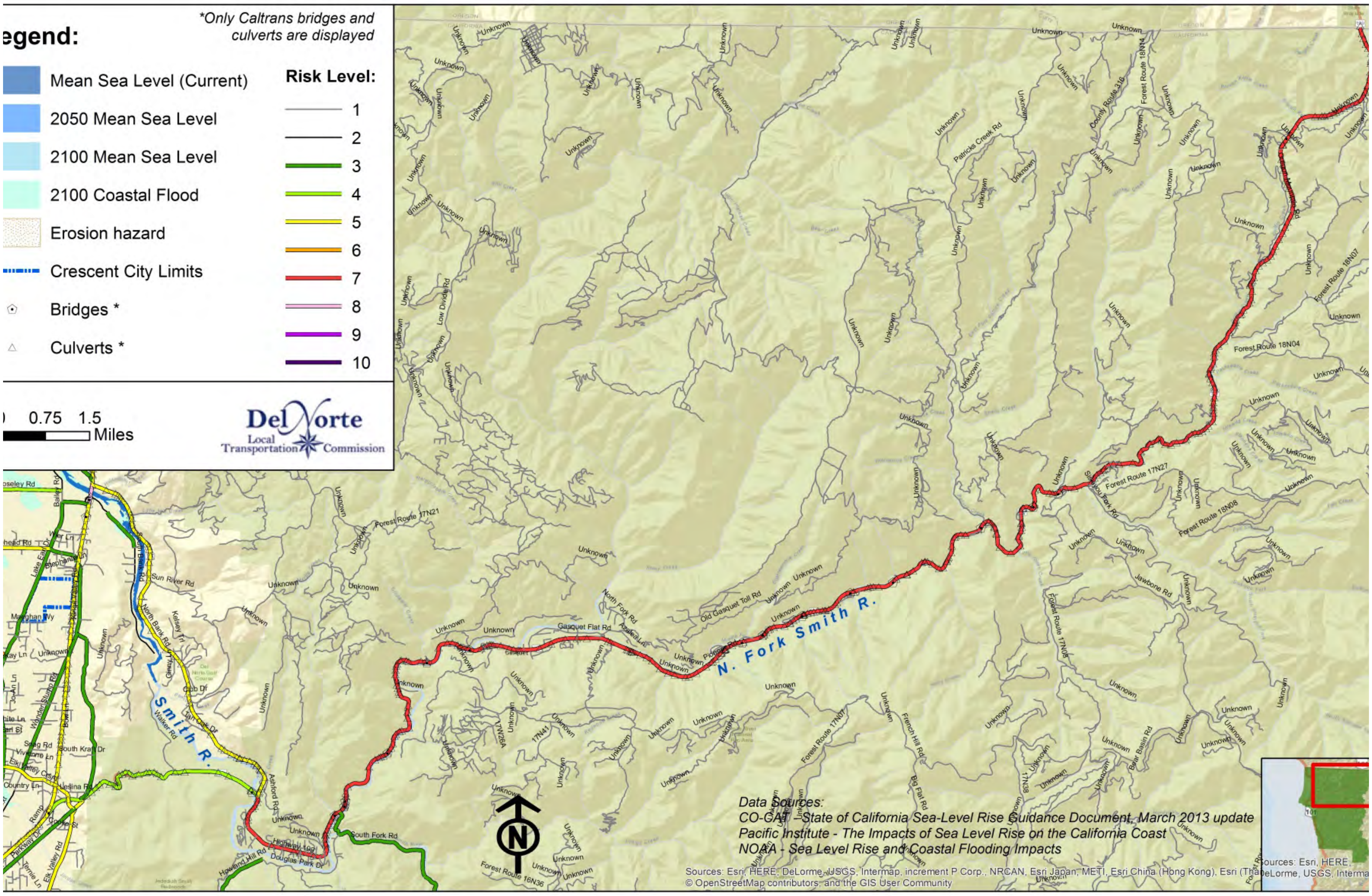


Figure 4 - Eastern Del Norte County Risk Rankings

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TECHNICAL MEMORANDUM

TO:	Tamera Leighton, Del Norte Local Transportation Commission	DATE:	September 21, 2015
FROM:	Emily Straley, P.E., Schaaf & Wheeler	JOB#:	DNLT.15.01
SUBJECT:	Module 4 – Develop Adaptation Strategies		

Introduction

Transportation assets that are ranked as both highly vulnerable to climate change and considered critical assets were identified in Module 3. This group of assets was assigned a risk level of 7 or greater. In this Module, adaptation measures for each of these transportations assets are discussed. An adaptation measure is an action that minimizes risks from climate change, which includes sea level rise, coastal erosion, and increased intensity of precipitation events.

Adaptation Methodology

Adaptation strategies are modeled after existing strategies adopted by other coastal regions in California and applied to fit the specific infrastructure of Del Norte County. The strategies address potential transportation impacts through planning, design, and operations/maintenance response. A matrix of adaptation strategies has been developed for each high risk location described in Module 3. The matrix identifies when each adaptation strategy is needed by; how long planning, design, and implementation is anticipated to take; the anticipated lifespan of the adaptation strategy; and a planning level cost estimate. Funding availability is considered, and strategies will be developed to align with short and long range projects in the Regional Transportation Plan and other planning and programming documents. Adaptation strategies are based on constrained and unconstrained resources with prioritization of projects identified in both categories.

Climate Consequences

The expected consequence of climate change impacts on transportation assets must be considered when prioritizing adaptation strategies. The consequences have been categorized into four types: no impact, disruption, deterioration, and damage. Transportation assets with no anticipated impact have been removed from further analysis during Module 3. Another consequence of climate change is disruption. Disruption is an impact that disrupts or impedes transportation operations, such as standing water, which has the potential to temporarily cause road closures, decrease traffic speeds, and decrease the level of service of a roadway. Deterioration occurs as a result of repeated exposure to climate stressors and can include increased bridge and culvert scour, pavement cracking and deformation, etc. Deterioration can decrease the life of a transportation asset. Damage is a catastrophic impact to a transportation asset that can lead to long-term disruption or closure of an asset and may require extensive planning and design to repair. The consequences of climate change impacts can be used to prioritize adaptation options.

Adaptation Measures for Del Norte

Adaptation measures are categorized into four different approaches: defend, accommodate, changes in policies or practices, and retreat. There are several adaptation options that fall within each approach, as detailed in Table 1.

Table 1 - Adaptation Options

Approach	Adaptation Option
Defend	Floodwalls/Levees
	Coastal Erosion Countermeasure
Accommodate	Raise Asset Elevation
	Bridge Modifications
	Drainage Modifications
Retreat	Relocate Asset
	Mitigated Retreat
Changes in Policies or Practices	Update Standard Details
	Increase Maintenance & Inspection Interval, Monitor Assets
	Adopt a Storm Drain Master Plan

Defend, Accommodate, and Retreat

Defend, accommodate, and retreat are location specific adaptation options. Adaptation options that fall under these approaches are assigned to locations based on which climate stressor the asset in that location is vulnerable to. For example, floodwalls/levees are an option for assets vulnerable to sea level rise or river flooding, and coastal erosion countermeasure is an option for assets vulnerable to coastal erosion. There are often several adaption option alternatives for each location, and it may be appropriate to select different adaptation options depending on time frame. For example, it may make financial sense to defend an asset vulnerable to coastal erosion by using a coastal erosion countermeasure in the short term, then retreat from the original asset location by relocating or abandoning the asset in the long term. Adaptation options by location are summarized in Tables 5 through 15 on Pages 6 through 11.

Changes in Policies or Practices

Changes in policies or practices are adaptation options than can be adopted by stakeholders and are not necessarily location specific. Options in this approach include updating standard construction details; increasing maintenance and inspection intervals, and increasing monitoring of assets; and adopting a storm drain master plan. Updating standard construction details is an adaptation option that can be undertaken by Crescent City, Del Norte County, or both. The purpose is to ensure road that are built or improved in the future are designed to withstand the additional deterioration that can be caused by intensified precipitation events or standing water due to sea level rise. Sample standard details adopted by Mendocino County can be found in Attachment A, and include concrete lined ditch, trench section, and low impact to hydrology guidelines/alternative design standards.

Increasing maintenance and inspection intervals and increasing the monitoring of assets is an option that can be undertaken by all stakeholders. Ideally, inspection, maintenance, and monitoring records will be compiled and stored in a centralized asset management system that the DNLTC can use when updating the Regional Transportation Plan. These records can be used to track disruption, deterioration, and damage either directly or indirectly caused by influence, which can then be used to select and prioritize adaptation options.

Adoption of a Storm Drain Master Plan (SDMP) is an option that either the City or County can undertake. The master plan will be useful in determining existing system deficiencies and prioritizing improvements needed to bring the system up to an acceptable level of service. The SDMP can also determine the improvements required to mitigate rising sea levels and the intensification of precipitation events. The cost to hire a consultant to complete a SDMP can range from $100,000 to $300,000 depending on the area to be analyzed, the number of storms to be considered, and the amount of data gathering required in order to build a computer model of the storm drain system.

Planning Level Cost Estimates

The planning level cost estimates provided in this section are intended for use as an overall guideline for the DNLTC and its stakeholders to use in preparing annual budgets, updating the Regional Transportation Plan, and identifying funding opportunities for larger projects. Exigent circumstances and future in-field experiences may necessitate deviations from the adaptation options presented in this report. This study and proposed adaptation options are merely the starting point. It is anticipated that the DNLTC and its stakeholders will perform a more detailed study or alternatives analysis to find more affordable or effective improvements with information gathered as part of the design process (detailed topography, easements, etc.).

Changes in Policies or Practices

Making changes to policies or practices is the first step in adapting transportation assets for climate change impacts. Changes can be made quickly and are the most affordable adaptation options. The cost to hire a consultant to complete a SDMP can range from $100,000 to $300,000 depending on the area to be analyzed, the number of storms to be considered, and the amount of data gathering required in order to build a computer model of the storm drain system. Hiring a consultant to update standard details is estimated to cost approximately $25,000. It is difficult to estimate the cost to increase maintenance and inspection intervals. It is likely that maintenance crews are already visiting transportation assets on a regular basis, and only a change in the method of recording information is required.

Defend, Accommodate, and Retreat

Levee and coastal erosion countermeasure costs have been estimated using information from other projects, cost estimating guidelines (2014 *Current Construction Costs*, Saylor Publications, Inc.), and engineering judgment and are in 2014 dollars. Costs include a 75% contingency cost to cover design, permitting, land acquisition, etc. Levee costs are estimated by assuming a top width of 5-feet and a height of 10-feet, and are detailed in Table 2. Erosion countermeasure adaptation costs are detailed in Table 3.

Table 2 - Estimated Cost for Levee Adaptation Option

Levee Location	Height (ft)	Top Width (ft)	Length (ft)	Cost
Crescent City waterfront (W of harbor)	10	5	8,000	$ 15,600,000
Crescent City, harbor to Humboldt Rd	10	5	7,300	$ 14,200,000
Crescent City, A St.	10	5	5,000	$ 12,500,000*
Requa Road	10	5	3,200	$ 15,000,000*
Hwy 101, Klamath	10	5	5,900	$ 11,500,000
Klamath Beach Road	10	5	3,300	$ 10,000,000*
Hwy 199	10	5	5,000	$ 9,700,000
Total			**37,700**	**$ 73,400,000**

* *Project cost provided by County.*

Table 3 – Estimated Cost for Erosion Countermeasure Adaptation Option

Coastal Erosion Location	Length	Cost
Crescent City, from 9th/Pebble Beach to end of A St.	5,300 ft	$ 11,600,000
Hwy 101, Maranda Ln to Oregon border	12,000 ft	$ 36,800,000
Kellogg Rd.	500 ft	$ 400,000
Hwy 101, Last Chance Grade	3-16 mi	$ 1 billion+
Hwy 199	20,000 ft	$ 17,500,000
Total	**56,300 ft**	**$ 1,066,300,000**

It is estimated that local roadway assets recognized in the criticality ranking are in need of an estimated $30 million (2014 dollars) for maintenance and rehabilitation. These estimates are based on recommended treatment costs for three categories of pavement condition (based on pavement condition index or PCI). The categories are defined in Table 4.

Table 4 - Pavement Maintenance Unit Costs

Preventative Maintenance	AC Overlay	Reconstruction
PCI 70 or greater	PCI 25-69	PCI below 25
$4.61	$23.24	$60.31

The following matrix (Table 5) identifies the specific roadway assets identified in Module 3 that are also currently recommended for treatment. The planning level costs in this matrix are calculated on an estimated cost per square yard of roadway segment within the vulnerability zone. Assumptions include costs based on the *California Local Streets and Roads Needs Assessment* and an average 30 foot wide pavement section. These costs do not necessarily match up with the more design specific project costs reflected in the Regional Transportation Plan on a project basis, but roughly align on an overall comparison of project costs vs. magnitude. The 2014 cost only includes the pavement maintenance costs. The 2050 and 2100 costs include the levee/floodwall or erosion countermeasure that will be required in order to keep the road in functional order. The 2050 and 2100 costs are intended to provide the true cost required to maintain the road within those timeframes, and may be useful when determining whether it is more cost effective to abandon the road through mitigated retreat.

Table 5 - Current, 2050, and 2100 Road Maintenance Costs

	2014 Road Maintenance Cost					
Asset Name	Preventative Cost/sq./yd >70 (7-10)) $ 4.61	AC Overlay Cost/sq./yd. 25-69 (3-7) $ 23.24	Reconstruction Cost/sq./yd. <25 (1-3) $ 60.31	Total 2014 Maintenance Cost	2050 Road Cost	2100 Road Cost
3rd St	$ 87,129	$ 439,235	$ 1,140,000	$ 1,690,000	See Front street	See Front street
A St	$ 83,817	$ 422,540	$ 1,100,000	$ 1,630,000	$ 3,330,000	$ 3,540,000
Front St	$ 68,689	$ 346,277	$ 900,000	$ 1,340,000	$ 18,530,000	$ 3,250,000
H St	$ 51,571	$ 259,979	$ 670,000	$ 1,000,000	See Front street	See Front street
Humboldt Rd	$ 126,529	$ 637,861	$ 1,660,000	$ 2,460,000	Protected by 101 Levee	Protected by 101 Levee
Kellog Rd	$ 110,063	$ 554,850	$ 1,440,000	$ 2,140,000	$ 2,180,000	$ 4,050,000
Klamath Beach Rd	$ 372,309	$ 1,876,889	$ 4,870,000	$ 7,230,000	$ 14,320,000	$ 9,140,000
Morehead Rd	$ 149,360	$ 752,956	$ 1,950,000	$ 2,900,000	See Kellog Rd	See Kellog Rd
Moseley Rd	$ 143,288	$ 722,345	$ 1,870,000	$ 2,780,000	See Kellog Rd	See Kellog Rd
Pebble Beach Dr	$ 280,682	$ 1,414,978	$ 3,670,000	$ 5,450,000	$ 14,250,000	$ 7,360,000
Requa Rd	$ 69,349	$ 349,605	$ 910,000	$ 1,350,000	$ 8,250,000	$ 3,260,000
Sandmine Rd	$ 25,652	$ 129,317	$ 340,000	$ 500,000	Protected by 101 Levee	Protected by 101 Levee

Conclusion

Module 4 has presented a variety of adaptation options and their planning level costs for at risk transportation assets in Del Norte County. Module 5, the final module in the Caltrans Five-Step Climate Change Assessment and Adaptation Modules, will discuss how the DNLTC and its stakeholders apply this information in future planning steps.

Table 6 - Hwy 101 - Maranda Lane to Oregon Border Adaptation Options

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate
Coastal Erosion Countermeasure	Use engineering solutions to stabilize areas of current or impending coastal erosion to prevent deterioration and/or damage to transportation assets.	Defend	Medium	2050	2100	$37,000,000
Relocate Asset	Reroute Hwy 101 inland, to a distance far enough from the coast to avoid current and anticipated future coastal erosion hazards.	Retreat	Long	2050-2100	2100+	$80,000,000

Table 7 - Hwy 101 – Dr. Fine Bridge (Smith River) Adaptation Options

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate
Bridge Modifications	Consider bridge modifications to prevent increased scour, bridge overtopping, and deterioration due to increased salinity.	Accommodate	Medium - Long	2050-2100	2100	NA

Table 8 - Pacific Shores - Kellog Road, Lake Earl Drive, Moseley Road, Morehead Road

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate
Coastal Erosion countermeasure	Use engineering solutions to stabilize areas of current or impending coastal erosion to prevent deterioration and/or damage to transportation assets.	Defend	Long	Current - 2050	2100	$400,000
Raise Roadway Elevations	Raise roadway and other transportation assets to an elevation sufficient to prevent current and anticipated coastal floods	Accommodate	Medium	Current - 2050	Current - 2050	$3,300,000
Mitigated retreat	Allow areas at the western end of Kellogg Road to erode with the surrounding bluffs. Manage traffic to avoid areas of impacted roadway.	Retreat	Short	2050	2050	NA

Table 9 – Hwy 199

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate
Erosion countermeasure	Use engineering solutions to stabilize areas of current or impending coastal erosion to prevent deterioration and/or damage to transportation assets.	Defend	Long	2050-2100	2100	Unknown
Floodwall/Levees	Design floodwalls or levees to be located between Hwy 101 and the Smith River. Structures should be of sufficient height to prevent current and future river flooding from inundating roadway.	Defend	Long	2050-2100	2100	Unknown

* A more detailed, location specific study is required in order to determine project costs.

Table 10 - Sandmine Road

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate
Floodwall/Levee	Construct a seawall or levee between the coast and Hwy 101 between Anchor Way and Enderts Beach Road to remove the roadway from the 100-year floodplain. Seawall or levee design should allow increased height required by sea level rise.	Defend	Long	2050	2100	Protected by Hwy 101 Levee
Raise Roadway Elevations	Raise the roadbed of Sandmine Road to an elevation sufficient to avoid current and anticipated coastal floods.	Accommodate	Long	2050	2100+	$15,000,000
Mitigated retreat	Focus roadway improvements inland (such as Humboldt Road) and allow roadway to deteriorate with eventual abandonment. Monitor at 10-year increments.	Retreat	Long	2050	2100+	NA

Table 11 - Crescent City - Hwy 101 from Elk Valley Road, Citizens Dock Road, 3rd Street, A Street, Pebble Beach Drive, H Street

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate
Raise Roadway Elevations	Raise roadway and other transportation assets to an elevation sufficient to prevent current and anticipated coastal floods.	Accommodate	Medium	Current - 2050	2100	$87,000,000
Floodwall/Levees	Construct a seawall or levee along the coast from the Harbor to near A Street to remove portions of Hwy 101 and Crescent City from the current 100-year floodplain. Seawall or levee design should allow extension and increased height required by sea level rise. A pump station(s) may be required to prevent precipitation flooding on the landward side of the seawall or levee.	Defend	Medium	Current - 2050	2100	$25,000,000
Coastal Erosion countermeasure	Use engineering solutions to stabilize areas of current or impending coastal erosion to prevent deterioration and/or damage to transportation assets.	Defend	Medium	Current - 2050	2100	$12,000,000
Mitigated retreat	Focus roadway improvements inland and allow roadways adjacent to the coast to deteriorate with eventual abandonment. Monitor at 10-year increments.	Retreat	Long	2050 - 2100	2100+	NA

Table 12 - Hwy 101 - Anchor Way to Enderts Beach Road

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate
Floodwall/Levee	Construct a seawall or levee between the coast and Hwy 101 between Anchor Way and Enderts Beach Road to remove the roadway from the 100-year floodplain. Seawall or levee design should allow increased height required by sea level rise.	Defend	Medium	Current	2100	$16,000,000
Relocate Roadway	Reroute Hwy 101 and connecting roadways inland, to a distance far enough from the coast to avoid the current 100-year floodplain and anticipated future sea level rise and coastal erosion hazards.	Retreat	Long	Current - 2050	2100+	$28,000,000

Table 13 - Hwy 101 - Last Chance Grade

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate*
Relocate Roadway	Reroute Hwy 101 inland, to a distance far enough from the coast to avoid current and anticipated future coastal erosion hazards.	Retreat	Long	Current - 2050	2100+	$300 million to $1 billion
Major structural protection	Provide a high technology solution including retaining walls, minor realignments, and bridges or tunnels	Defend	Long	Current - 2050	2100+	$1 billion or more

* Costs from Caltrans District 1 Climate Change Pilot Study (December 2014)

Table 14 - Hwy 101 between Klamath Blvd and Hwy 169 Interchange

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate
Floodwall/Levees	Construct a seawall or levee between the Klamath River and Hwy 101 to remove the roadway from the 100-year floodplain. Seawall or levee design should allow increased height required by sea level rise.	Defend	Medium	Current	2100	$12,000,000
Raise road elevations	Raise the roadbed of Hwy 101 to an elevation sufficient to avoid current and anticipated future river and coastal floods. A raised roadbed woud also act as a levee to protect structures and local roadways in the town of Klamath from flooding.	Accommodate	Long	Current-2050	2100+	$40,000,000
Reroute road	Reroute Hwy 101 to the northeast of Klamath, to a distance and elevation far enough from the Klamath River to avoid current and anticipated future river and coastal floods.	Retreat	Long	Current-2050	2100+	$40,000,000

Table 15 - Klamath Beach Road

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate
Floodwall/Levees	Design a floodwall to be located between Klamath Beach Road and the Klamath River. Floodwall should be of sufficient height to prevent current and future river and coastal floods from spilling onto roadway.	Defend	Medium	current-2050	2100	$10,000,000*
Raise road elevations	Raise the roadbed of Klamath Beach Road to an elevation sufficient to avoid current and anticipated future river and coastal floods.	Accommodate	Long	2050	2100+	$22,000,000
Reroute road	Reroute Klamath Beach Road to the south of its current location, to a distance and elevation far enough from the Klamath River to avoid current and anticipated future river and coastal floods.	Retreat	Long	2050	2100+	$22,000,000

** Project cost provided by County.*

Table 16 - Requa Road

Adaptation Option	Description	Approach	Length of Planning/Design	Needed By	Option Effective Until	Planning Level Estimate
Floodwall/Levees	Design a seawall or floodwall between the roadway and the Klamath River to remove the roadway from the 100-year floodplain. Seawall or levee design should allow extension and increased height required by sea level rise.	Defend	Medium	Current - 2050	2100	$15,000,000*
Raise road elevations	Raise the roadbed to an elevation sufficient to avoid current and anticipated future river and coastal floods.	Accommodate	Long	Current - 2050	2100+	$22,000,000
Reroute road	Reroute roadways to a distance and elevation avoid current and anticipated future river and coastal floods.	Retreat	Long	Current - 2050	2100+	$22,000,000

** Project cost provided by County*

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TECHNICAL MEMORANDUM

TO:	Tamera Leighton, Del Norte Local Transportation Commission	DATE:	October 9, 2015
FROM:	Emily Straley, PE, Schaaf & Wheeler Jeff Schwein, AICP CTP, Green DOT Transportation Solutions	JOB#:	DNLT.01.15
SUBJECT:	Module 5 – Monitoring and Evaluation Plan		

Introduction

A range of adaptation measures and associated planning level costs for highly vulnerable and critical transportations assets in Del Norte County were discussed in detail in Module 4. Module 5, the final module in the Caltrans Five-Step Climate Change Assessment and Adaptation Modules, presents recommendations for how the adaptation measures can be integrated into long and short term planning steps.

Monitoring

It is recommended to update the Climate Change and Stormwater Management Plan every 20 years. This accounts for long term evaluation of the effects of climate change through the update of data and maps. Each new report will also reflect changes in legislation, regulations, science and technology. The following items should be monitored for change and evaluated for their effect on transportation assets every 20 years:

Table 1-Monitoring Elements

Element (Data)
Flood Maps-Federal Emergency Management Agency (FEMA)
Coastal Hazard Maps-Pacific Institute ((Pac-Inst)
Precipitation and Runoff Data-Cal-Adapt
Precipitation Data-Coupled Model Intercomparison Project Phase 3 (CMIP3)
Sea Level Rise Data-National Oceanic and Atmospheric Administration
Element (Reports)
Climate Change and Extreme Weather Vulnerability Assessment Framework (Federal Highway Administration, Dec, 2012)
District 1 Climate Change Vulnerability Assessment and Pilot Studies (Dec, 2014)
Addressing Climate Change in Regional Transportation Plans-A Guide for California MPOs and RTPAs

In addition to monitoring foundational elements utilized to develop the plan, information and data within the Climate Change and Stormwater Management Plan must be monitored for change and updated as well. This includes the following elements:

Table 2-Required Updates

Data and Maps
Criticality of Assets
Vulnerability Ranking and Risk Levels
Prioritized Ranking of Regional and Local Assets

Del Norte County updates the Regional Transportation Plan (RTP) every 5 years in compliance with California law and the RTP Guidelines. In order to include climate change adaptation strategies into the required policy, action and financial elements of the RTP, the monitoring elements should be evaluated for changes that impact the transportation assets in the region every 5 years. Changes in climate data, funding programs and the introduction of new studies are critical elements of adapting to climate change. In addition to information and data changes, regional and local policy changes and project delivery may have an impact on future RTP components. Changes in information, data, and project status may require flexibility in the planning process and changes should be noted through the recommended short term amendment process (described below).

Stakeholder Communication

The DNLTC is the central communication hub between stakeholders and can take the lead in ensuring that stormwater management and climate change are considered during the planning phase of policy changes and improvement projects that involve transportation investments. The DNLTC Technical Advisory Committee is currently utilized for guiding RTP development and is made up of the appropriate stakeholders for this report. Therefore, the TAC should remain as the primary stakeholder group and be involved in communications regarding monitoring and changes to the report. Stakeholders should report changes in information that have an effect on future projects to the TAC on a regular basis. This will provide cohesion during the short term evaluation (5 year) and long term update of the report.

Risk Register

The DNLTC has taken the lead in assessing climate change impacts on transportation assets in Del Norte County, and can continue to maintain the list of risks and adaptation options. The DNLTC plans to update the Climate Change and Stormwater Management Plan every 20 years, but the vulnerability of transportation assets and associated adaptation options can be reassessed on a more frequent basis as new information is gathered or funding sources become available. Maintenance and monitoring information can be considered during each Regional Transportation Planning (RTP) process. Adaptation strategies can be reprioritized during this process depending on the impact climate change has had on the asset in question during the interim. Available funding priorities may also be used to determine the priority of adaptation measures.

During transportation project development, the project specific risk register functions as an assessment tool. This risk register is a required as part of the Project Initiation Document or Project Study Report. Each risk register for projects in the Del Norte Region should contain assessment items for climate change impacts. This identification of risks early on in the project development process will improve the value of transportation investments in the region.

Budget and Funding Sources

Projects related to climate change include administrative projects (such as planning) and infrastructure projects. Funding the recommended adaptation strategies will take a cooperative effort amongst stakeholders. The financial element in the RTP identifies near (1-10 year) and long term (11-20 year) funding resources for the 20 year RTP period. In order to include the most recent climate change data and evaluate the impacts on projects to be included in the RTP, some funding should be identified as a resource for this task. Additionally, funding to update the Climate Change and Stormwater Management Plan on a 20 year basis should be budgeted on the regional level with participation from partnering agencies.

Short-Term Amendment Process

During the development of the RTP and recommended evaluation of the Climate Change and Stormwater Management Plan elements, new data, reports and maps that are identified as having an effect on transportation planning should be updated and amended into the report. The amendment can be a simple, on-going list of items to be formally amended into the report at the 20 year long term update of the Climate Change and Stormwater Management Plan. This amendment should be accepted by the stakeholders and attached to the report.

Conclusion

The DNLTC plays a central role in mitigating the impact of climate change on the transportation assets in Del Norte County. This study is a critical step in the evaluation of the transportation investments made at all levels of government. It can be a centralized source of information and can assist stakeholders in coordinating planning and budgeting efforts .In order to get the most value out of this Climate Change and Stormwater Management Study, periodic updates must be performed. Those updates should include acknowledgement of new climate data and new methods for mitigating climate change impacts. Additionally, information regarding the region's transportation assets should be updated on a regular basis.

ATTACHMENT A

Sample Standard Details

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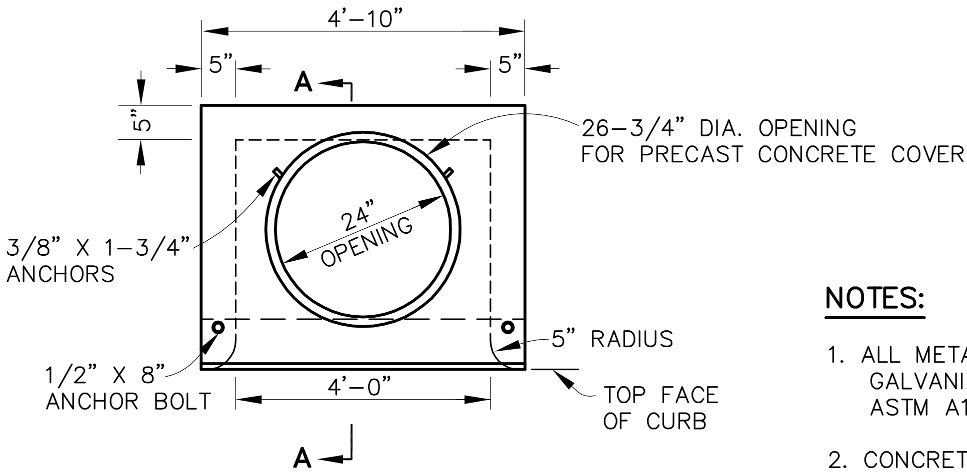
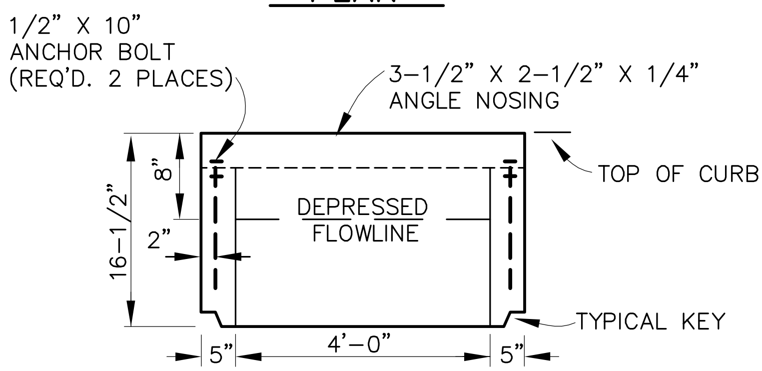


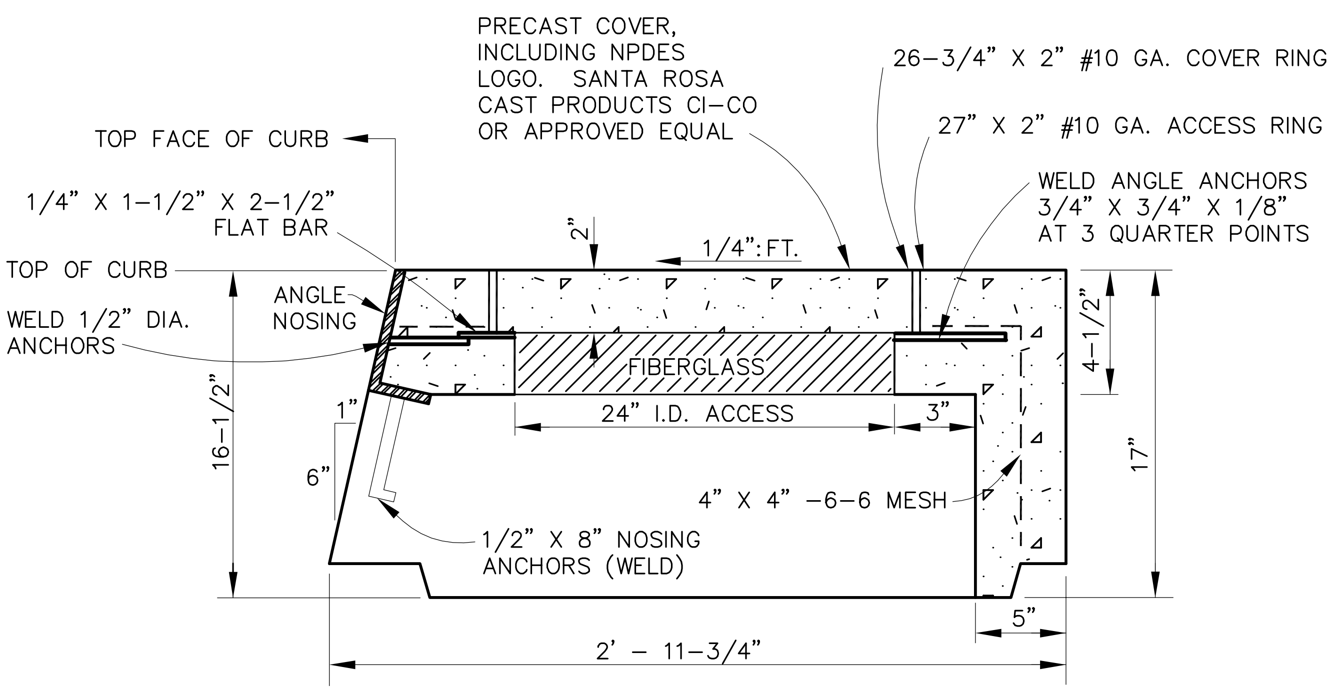
PLAN



ELEVATION

NOTES:

1. ALL METAL PARTS SHALL BE HOT DIPPED GALVANIZED AFTER FABRICATION PER ASTM A123.
2. CONCRETE SHALL TEST 3000 PSI AT 28 DAYS.
3. ALL REINFORCING SHALL BE 4" X 4" – 6-6 MESH.
4. WEIGHT OF UNIT COMPLETE = 1500± LBS. COVER ONLY = 100± LBS.
5. 3/4" GALVANIZED STEEL GUARD ROD FOR OPENINGS IN EXCESS OF 9".
6. BASE MAY BE PRECAST OR CAST IN PLACE TO SUIT.
7. PRECAST UNIT SHALL BE SANTA ROSA PRECAST 4AC OR APPROVED EQUAL.



SECTION A–A

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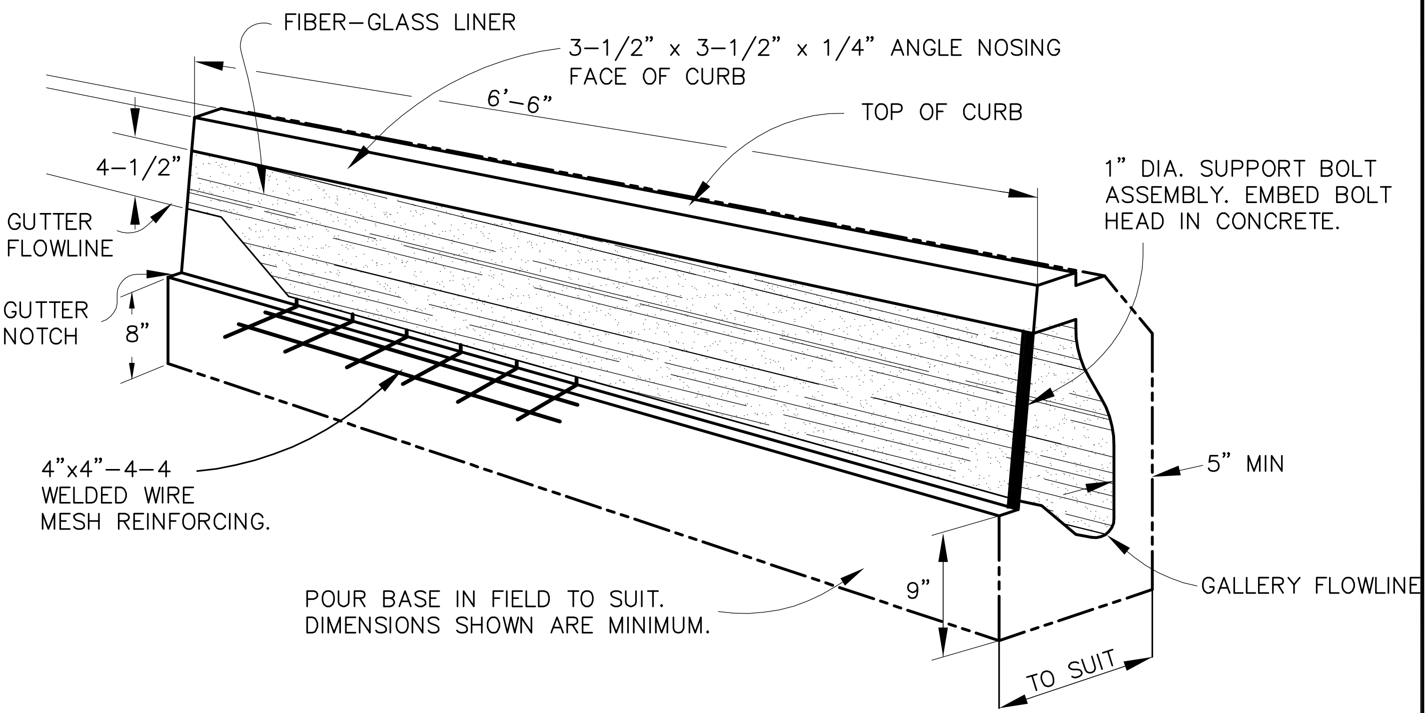
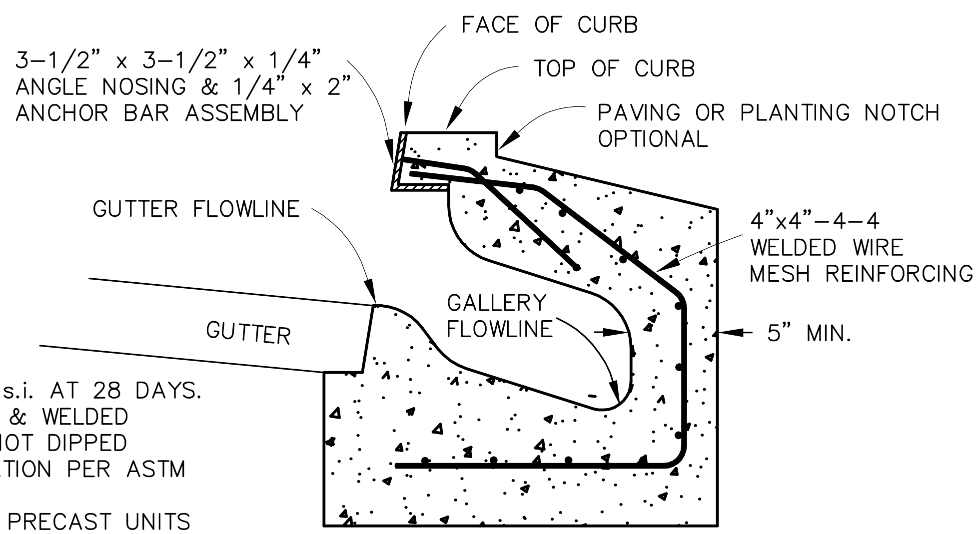
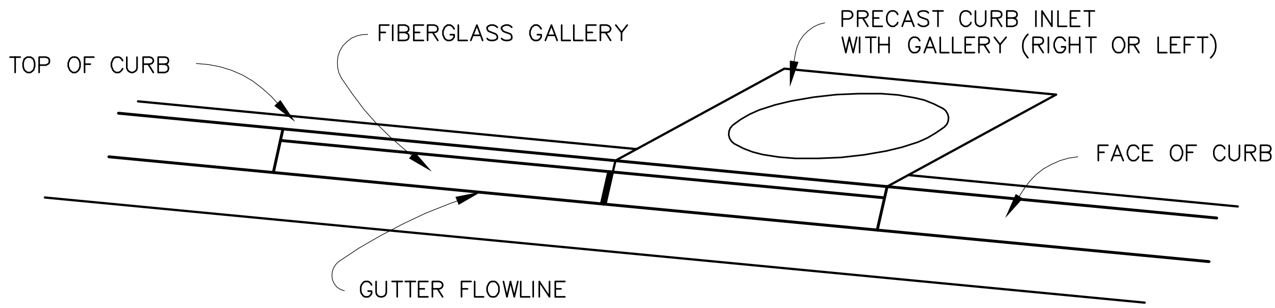




NOTES:

1. CONCRETE SHALL BE 3000p.s.i. AT 28 DAYS.
2. NOSING ASSEMBLY (ANGLED & WELDED ANCHOR BARS) SHALL BE HOT DIPPED GALVANIZED AFTER FABRICATION PER ASTM SPEC. A123-59.
3. EITHER CAST-IN-PLACE OR PRECAST UNITS ARE ACCEPTABLE.



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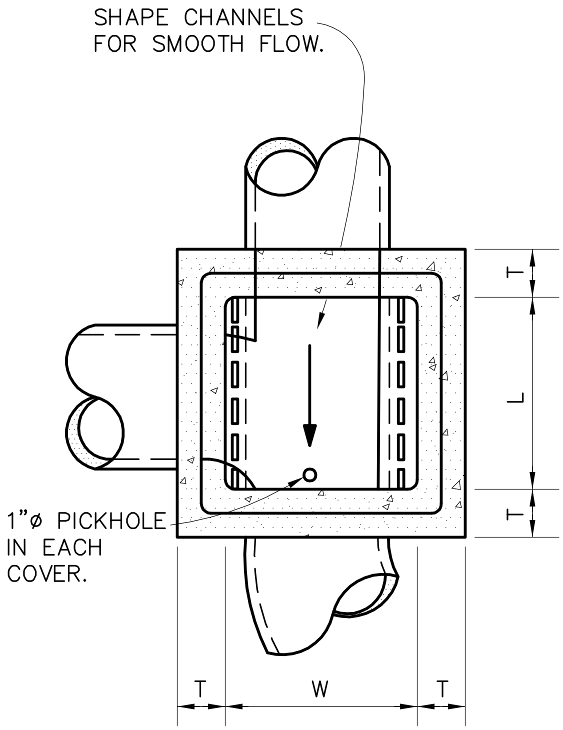
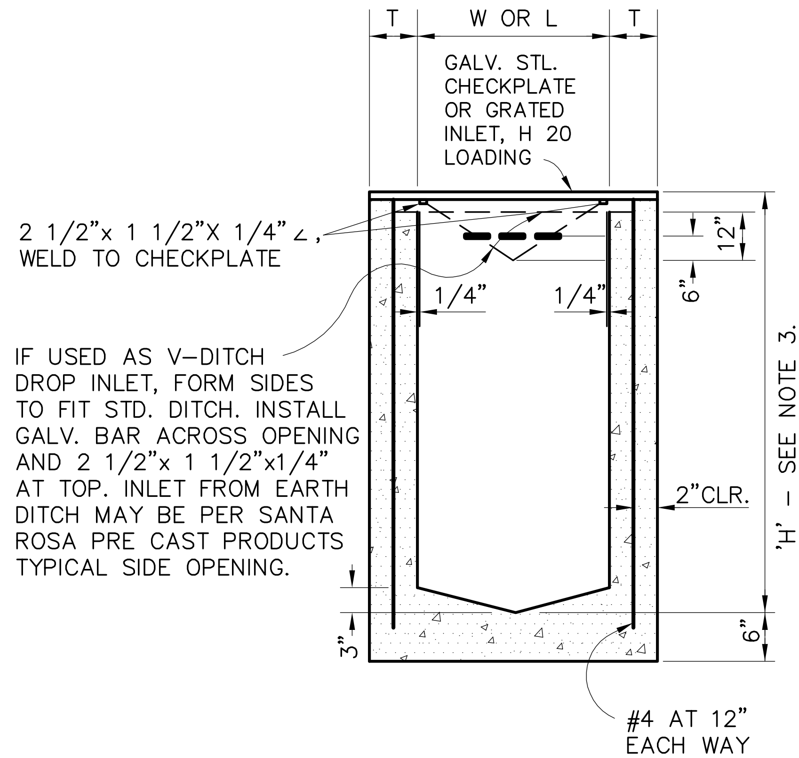


PLAN SECTION



PROFILE SECTION

DEPTH	L	W	T	COVER(S)
3' OR LESS	24"	24"	6"	1 – 36"x 36"
OVER 3' TO 8'	36"	36"	6"	2 – 24"x 48"
OVER 8' TO 12'	SEE NOTE 3		8"	2 – 30"x 48"
OVER 12'	CUSTOM STRUCTURE			

NOTE:

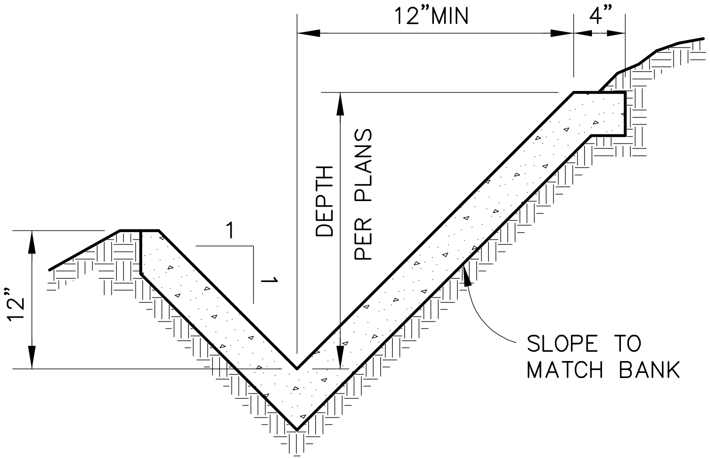
1. SEE MENDOT STD D20 FOR GENERAL NOTES, REINFORCING, AND STEP REQUIREMENTS.
2. DROP INLET MAY BE PRECAST OR CAST IN PLACE, AT CONTRACTOR'S OPTION. PRECAST INLET SHALL BE SANTA ROSA CAST PRODUCTS (SRCP) MODEL 2K, 1M, OR 3M OR APPROVED EQUAL.
3. PROVIDE 40" MANHOLE BASE WHERE 'H' IS GREATER THAN 8' AND LESS THAN OR EQUAL TO 12', USE SRCP REDUCER SLAB 48MH-IM OR APPROVED EQUAL.

DROP INLET AND TURNING STRUCTURE

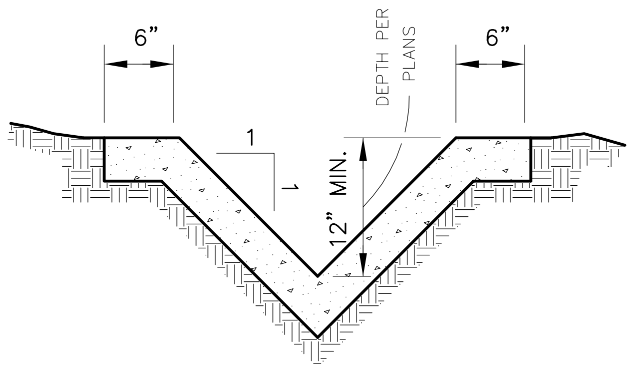
MENDOT STD. NO. **D32**

SCALE: NONE | DESIGN: RCW | DRAWN: CLG | OCT. 2000

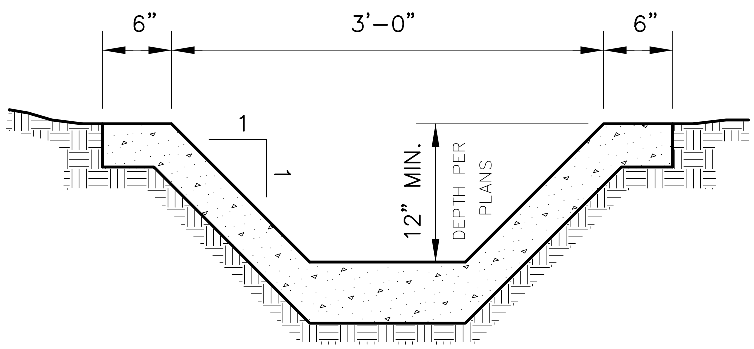
PLOT DATE: 29-AUG-00



TYPE "A"



TYPE "B"



TYPE "C"

NOTE:

1. ALL SECTIONS SHALL BE AT LEAST 4" THICK.
2. CONCRETE SHALL BE CLASS "2" (5 SACK). REINFORCING, #4 AT 24" O.C. EACH WAY, SHALL BE PROVIDED.
3. BOTH SIDES OF THE DITCH SHALL BE FORMED WITH 2"x4" LUMBER, UNLESS OTHERWISE SHOWN ON PLANS.
4. CONCRETE FINISH SHALL BE ORDINARY SURFACE FINISH PER SECTION 51-1.18A OF THE CALTRANS STANDARD SPECIFICATIONS.
5. DITCH SIDES SHALL BE BACKFILLED AND COMPACTED IMMEDIATELY AFTER THE REMOVAL OF SIDE FORMS.
6. NO CONCRETE SHALL BE PLACED PRIOR TO FORM INSPECTION BY THE DOT INSPECTOR.
7. NO DITCH IS TO BE CONSTRUCTED ON FILLED GROUND PRIOR TO CERTIFICATION OF THE FILL TO THE DOT BY THE SOIL ENGINEER.
8. NO EXPANSION JOINTS SHALL BE REQUIRED.
9. CONCRETE-LINED DITCHES SHALL ONLY BE USED OUTSIDE OF THE ROADWAY CLEAR ZONE.

DITCHES, CONCRETE LINED

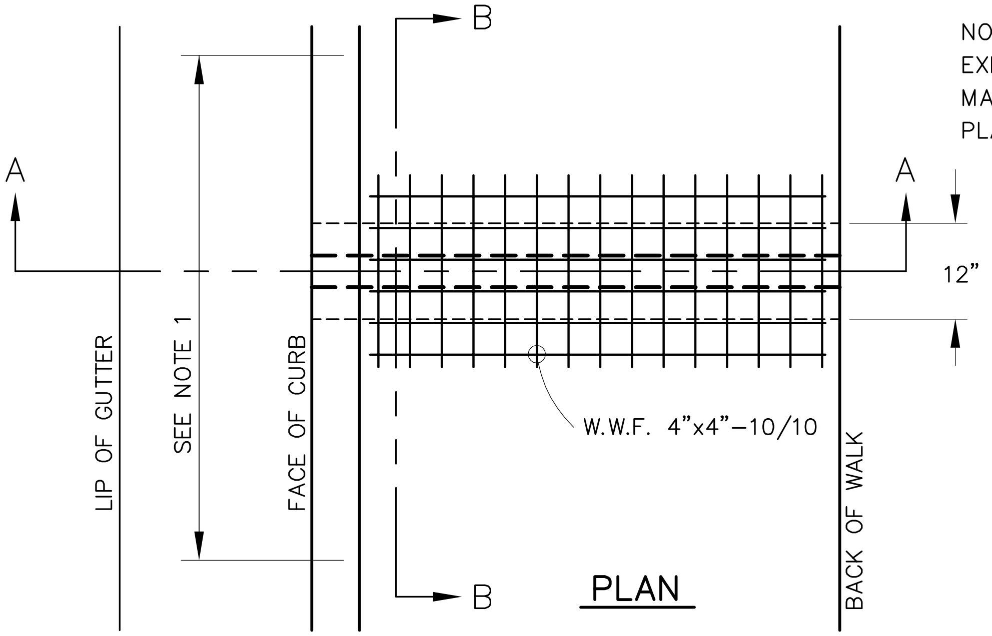
MENDOT STD. NO. **D61**

SCALE: NONE	DESIGN: RCW	DRAWN: LMM	OCT. 2000	PAGE: A-73

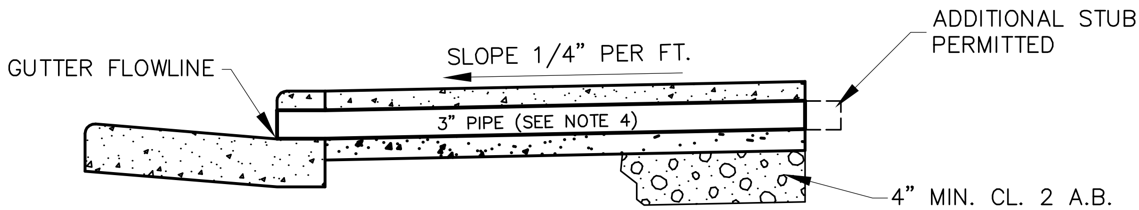
FILE: CLFS1:\LDD PROJECTS\22301\MEN-D61.DWG

PLOT DATE: 16-AUG-00

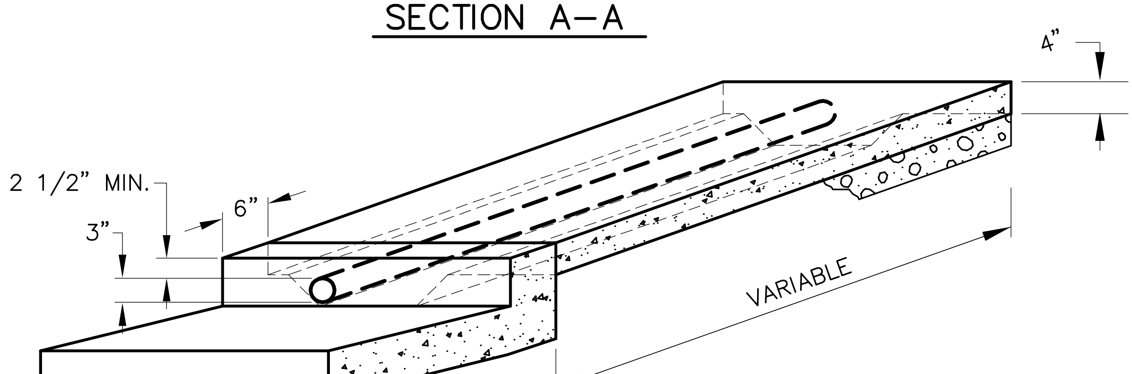
NOTE: IF SIDEWALK IS EXISTING, A 12" SECTION MAY BE SAW CUT TO PLACE 3" P.V.C. & W.W.F.



PLAN



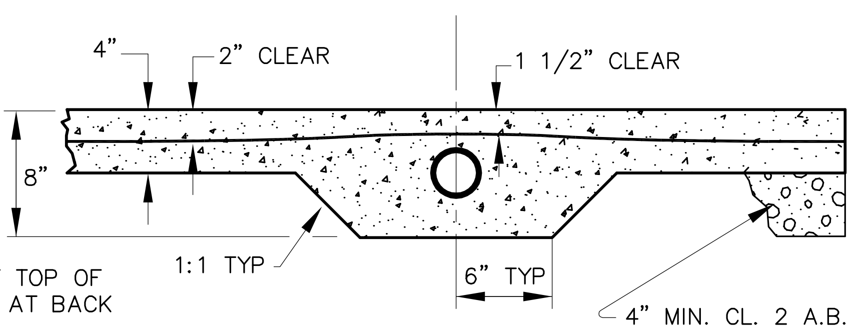
SECTION A–A



CURB OPENING DETAIL

NOTES:

1. WIRE MESH SHALL BE 2' WIDE. LENGTH SHALL EQUAL SIDEWALK WIDTH MINUS 4". IF SIDEWALK EXISTING, SEE NOTE ABOVE.
2. ON SITE DRAINAGE AND LOCATION OF CURB OUTLETS SHALL BE BY THE OWNER TO THE SATISFACTION OF THE COUNTY.
3. DRAIN PIPE SHALL BE INSTALLED SO THAT TOP OF PIPE IS 2 1/2" MIN. BELOW FINISH GRADE AT BACK OF SIDEWALK
4. SIDEWALK DRAIN TO BE 3" SCH 40 HEAVY WALL RIGID POLYVINYL CHLORIDE PIPE OR APPROVED SUBSTITUTE.



SECTION B–B

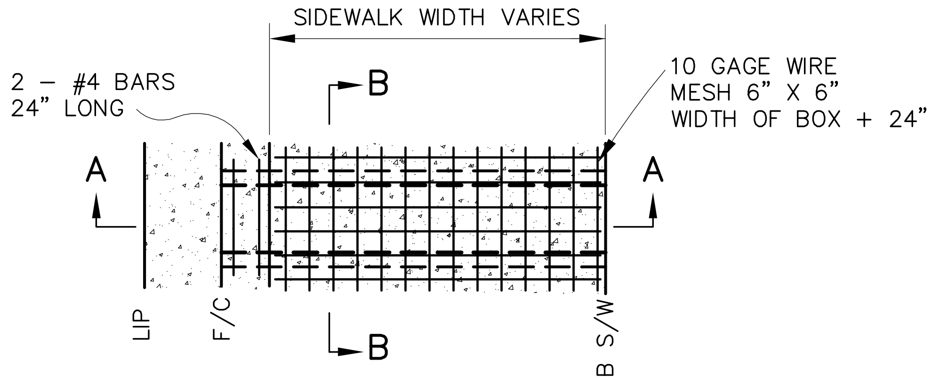
CURB OUTLET TYPE "A"

MENDOT STD. NO. D50

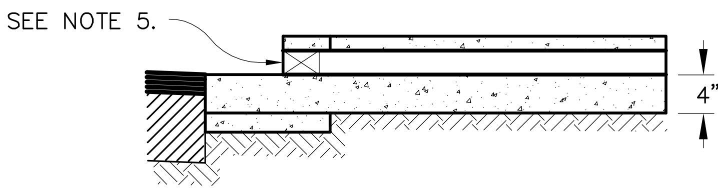
SCALE: NONE	DRAWN: LMM	APPVD: RCW	OCT. 2000	PAGE: A–70

FILE: CLFS1:\LDD PROJECTS\22301\MEN-D50.DWG

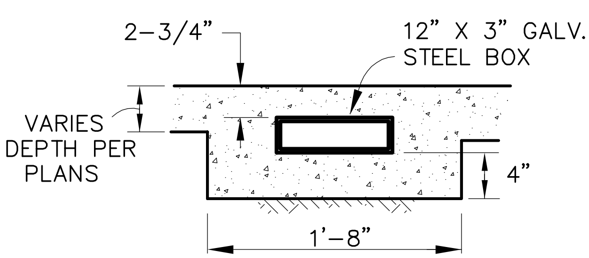
PLOT DATE: 16-AUG-00



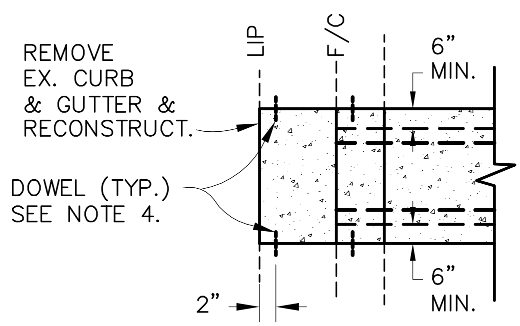
PLAN



SECTION A–A



SECTION B–B



EX. SIDEWALK

NOTES:

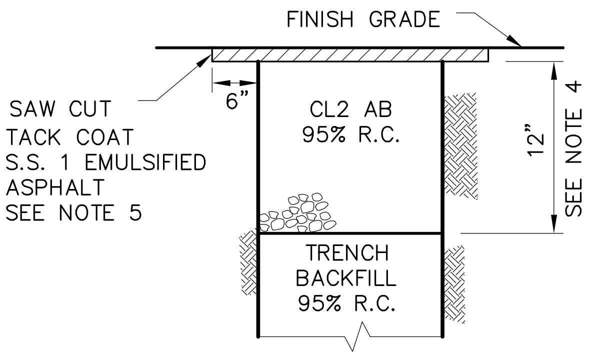
1. WITH APPROVAL OF THE DOT DIRECTOR, WIDTH OF BOX MAY BE REDUCED TO 6" FOR LOW FLOW LOCATIONS.
2. STEEL SHALL BE 16 GAGE AND SHALL BE HOT DIPPED GALVANIZED.
3. ALL CONCRETE SHALL BE CLASS "1" (6 SACKS PER CUBIC YARD).
4. IF CURB & GUTTER IS EXISTING, CONTRACTOR SHALL SAWCUT & REMOVE THE CURB & GUTTER AND INSTALL 1/2" x 8" DOWELS PER THE EX. SIDEWALK DETAIL.
5. PROVIDE TEMPORARY BLOCKING AT CURB FACE WHILE PLACING CONCRETE TO PREVENT CRUSHING. ENDS OF SHEET METAL BOX SHALL BE SMOOTH AND SQUARE, WITH NO PROTRUDING EDGES. END OF SHEET METAL BOX SHALL BE 1/4" BEHIND CURB FACE.
6. TYPE "B" CURB OUTLET SHALL NOT BE USED IN LOCATIONS WITH A PLANTER STRIP.
7. SEE MENDOT STD. A40 FOR GENERAL NOTES AND DETAILS NOT SHOWN.

FILE: CLFS1:\LDD PROJECTS\22301\MEN-D51.DWG

CURB OUTLET TYPE "B"

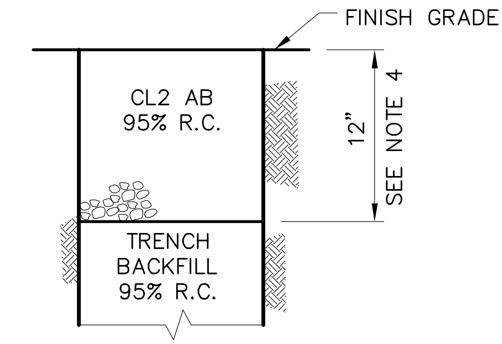
MENDOT STD. NO. **D51**

SCALE: NONE	DESIGN: RCW	DRAWN: LMM	OCT. 2000	PAGE: A-71



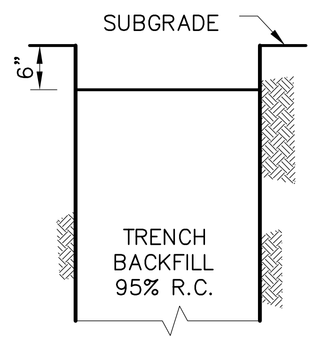
TYPE A

(EXISTING ROAD OR PAVED SHOULDERS)



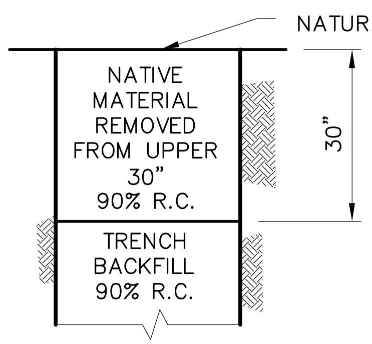
TYPE B

(UNPAVED SHOULDER AREAS)



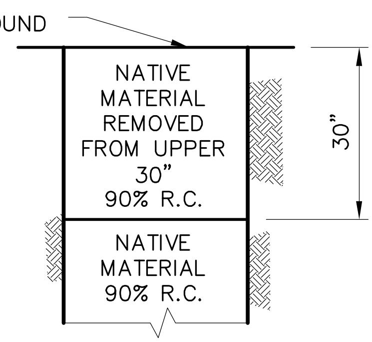
TYPE C

(ROADS UNDER CONSTRUCTION)



TYPE D

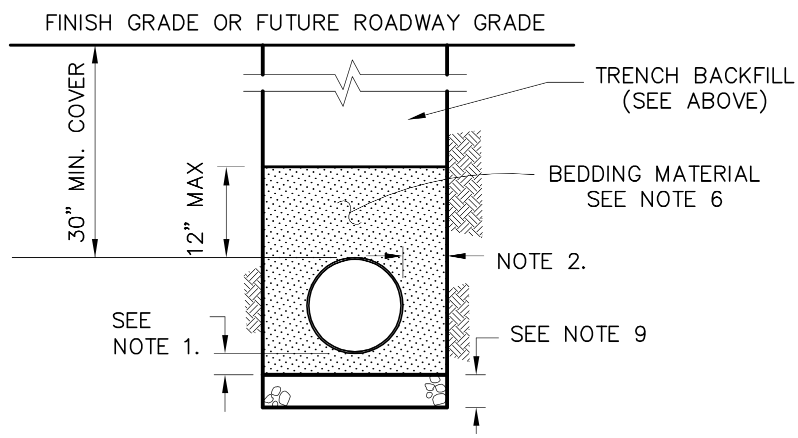
(PUBLIC UTILITY EASEMENTS)
(OUTSIDE ROAD AREA)



TYPE E

(PUBLIC UTILITY EASEMENTS)
(UNDEVELOPED AREAS)

TRENCH BACKFILL AND SURFACING



PIPE BEDDING

NOTE:

SEE MENDOT STD. A60B AND A60C FOR ALL TRENCH RESTORATION NOTES.

TRENCH RESTORATION SECTIONS

MENDOT STD. NO. **A60A**

SCALE: NONE	DESIGN: HND	DRAWN: HND	FEB. 2008	PAGE: A-44

TRENCH RESTORATION NOTES:

1. BEDDING BELOW PIPE SHALL BE AS REQUIRED BY UTILITY OR AGENCY THAT OWNS THE FACILITY.

2. 12" MIN., OR 6" MIN. IF SLURRY CEMENT BACKFILL IS USED. SEE NOTE 10.

3. RELATIVE COMPACTION DESIGNATED R.C.

4. THE MINIMUM ROAD STRUCTURAL SECTION SHALL BE A MIN. OF 3" A.C. ON 12" CL. 2 A.B. OR SHALL MATCH EXISTING PAVEMENT THICKNESS WHICHEVER IS THICKER, UNLESS OTHERWISE SHOWN ON THE PLANS. STRUCTURAL SECTION IN SHOULDERS SHALL MATCH EXISTING AND SHALL BE A MIN. OF 8" CL. 2 A.B.

5. NEATLY CUT PAVEMENT SIX INCHES FROM EDGE OF TRENCH AFTER TRENCH IS BACKFILLED. SS1 DESIGNATES SS1 ASPHALTIC EMULSION PER CALTRANS STANDARD SPECIFICATION, SECTION 94, ASPHALTIC EMULSION.

6. **MATERIAL SPECIFICATIONS**

6a. DRAIN ROCK SHALL BE EITHER OF THE NOMINAL SIZES DESIGNATED AS 1-1/2" BY 3/4" OR 2-1/2" BY 1-1/2".

6b. PIPE BEDDING AND TRENCH BACKFILL MATERIAL SHALL BE A WELL GRADED GRAVEL/SAND MATERIAL AND SHALL HAVE A MINIMUM SAND EQUIVALENT VALUE OF 20 AND SHALL CONFORM TO THE FOLLOWING GRADINGS:

PERCENT PASSING

	3"	3/4"	3/8"	NO. 4	NO. 16	NO. 30	NO. 200
PIPE BEDDING		100	80-100	10-50	5-30		0-4
TRENCH BACKFILL	100			35-100		20-100	

6c. IN ADDITION, WHEN TESTED WITH THE FOLLOWING SERIES OF SIEVES, NO MORE THAN 25% OF THE MATERIAL WILL BE RETAINED BETWEEN ANY ADJACENT SIEVES: 3", 2-1/2", 2", 1-1/2", 1", 3/4", 1/2", 3/8", NO. 4, NO. 8, NO. 16, NO. 30, NO. 50, NO. 100, AND NO. 200.

6d. **AGGREGATE BASE** CL 2 A.B. DESIGNATES CLASS 2 AGGREGATE BASE AND SHALL CONFORM TO THE PROVISIONS OF SECTION 26 OF THE COUNTY STANDARD SPECIFICATIONS.

6e. **NATIVE MATERIAL** SHALL NOT CONTAIN ROCKS LARGER THAN 3".

TRENCH RESTORATION NOTES

MENDOT STD. NO.

A60B

SCALE: NONE | DESIGN: HND | DRAWN: HND | FEB. 2008

7. **COMPACTION REQUIREMENTS:** (AS SHOWN ON A60A AND IN THE FOLLOWING MODIFICATIONS)

7a. **DRAIN ROCK** SHALL BE CONSOLIDATED WITH VIBRATORY COMPACTION EQUIPMENT TO A MINIMUM R.C. OF 90%.

7b. **PIPE BEDDING MATERIAL** SHALL BE CONSOLIDATED WITH VIBRATORY COMPACTION EQUIPMENT TO A MINIMUM R.C. OF 90%.

7c. **GENERAL:** THE COMPACTION REQUIREMENTS SHALL BE ACHIEVED UTILIZING METHODS AND EQUIPMENT APPROVED BY THE COUNTY. ANY METHOD OF COMPACTION WHICH FAILS TO UNIFORMLY ACHIEVE THE REQUIRED LEVELS OF COMPACTION THROUGHOUT THE LENGTH AND DEPTH OF TRENCHES SHALL BE DISCONTINUED. COMPACTION METHODS AND EQUIPMENT SHALL BE SUCH AS NOT TO DAMAGE THE INSTALLED PIPE, EXCEED ITS LOADING CAPACITY OR DISTURB ITS ALIGNMENT. FLOODING, PONDING OR JETTING WILL NOT BE ALLOWED.

7d. **MECHANICAL COMPACTION:** TRENCH BACKFILL SHALL BE PLACED IN UNIFORM, HORIZONTAL LAYERS NOT EXCEEDING EIGHT (8) INCHES IN THICKNESS BEFORE COMPACTION. EACH LAYER SHALL BE COMPACTED, USING MECHANICAL MEANS, TO THE SPECIFIED DENSITY SHOWN ON THE PLANS.

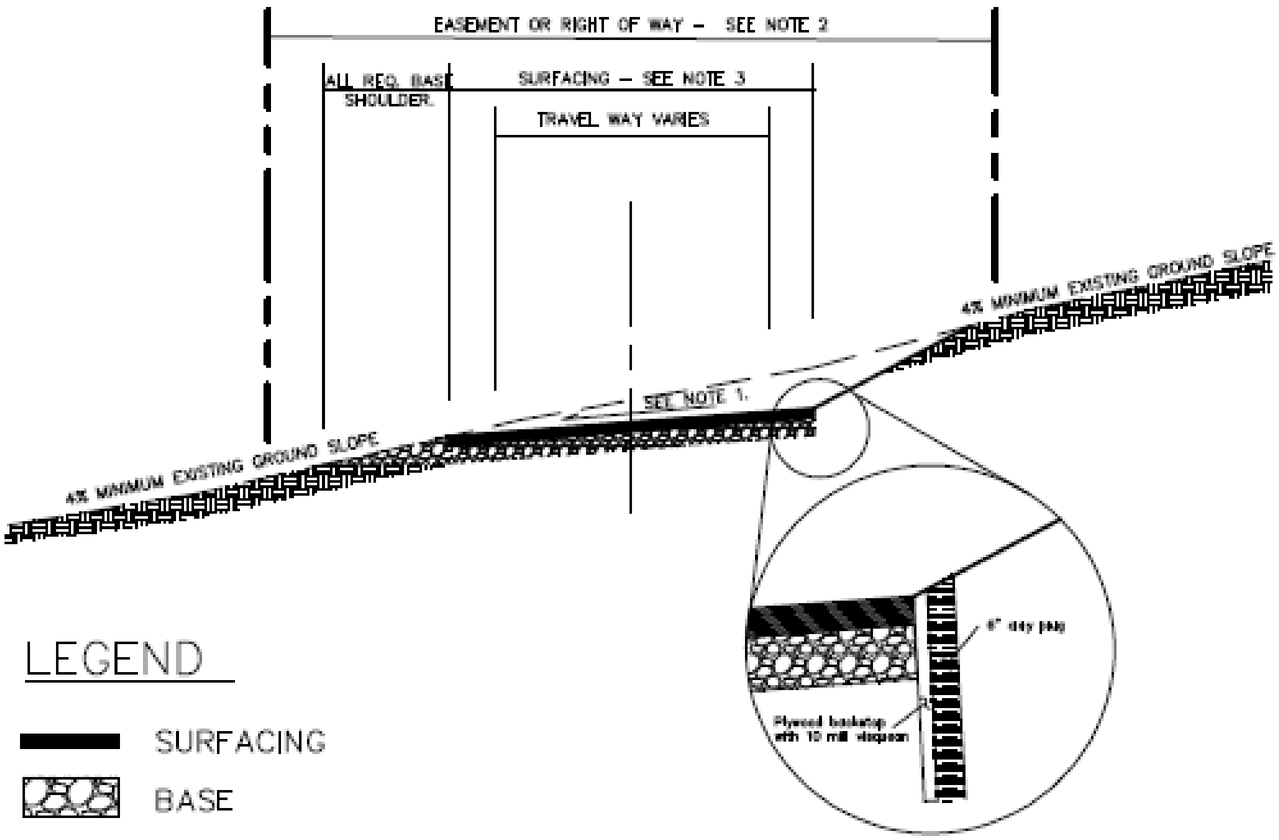
THE CONTRACTOR MAY, AT CONTRACTOR'S SOLE OPTION AND AT CONTRACTOR'S SOLE EXPENSE, CONSTRUCT A TEST TRENCH SECTION WHICH DEMONSTRATES METHODS, EQUIPMENT, OR MATERIALS WHICH WILL RELIABLY ACHIEVE THE REQUIRED COMPACTION IN LIFTS GREATER THAN 8 INCHES. AT ITS SOLE DISCRETION, THE COUNTY MAY INCREASE THE MAXIMUM ALLOWABLE LIFT THICKNESS PERMITTED BASED UPON THE RESULTS DEMONSTRATED BY THE TEST TRENCH SECTION. SHOULD SUBSEQUENT TESTING DEMONSTRATE THAT THE REQUIRED COMPACTION IS NOT BEING RELIABLY ACHIEVED, THE COUNTY MAY, AT ITS SOLE DISCRETION, REDUCE THE MAXIMUM LIFT THICKNESS TO ITS ORIGINAL VALUE OF 8 INCHES.

8. **TRENCHING METHODS:** ROCK WHEEL TRENCHING SHALL BE ALLOWED FOR TRENCH CONSTRUCTION IN COUNTY ROADS. INSTALLATION OF CABLE USING THE PLOW METHOD SHALL NOT BE ALLOWED.

9. **TRENCH BASE:** TRENCH BASE SHALL BE STABILIZED USING ADDITIONAL PIPE BEDDING; DRAIN ROCK, OR OTHER SUITABLE MATERIAL AS DIRECTED BY UTILITY, COUNTY DOT, OR CIVIL ENGINEER IN RESPONSIBLE CHARGE OF THE WORK.

10. **SLURRY CEMENT BACKFILL:** SLURRY CEMENT BACKFILL MAY BE USED FOR TRENCH BACKFILL ONLY AS AUTHORIZED BY COUNTY DOT, BUT SHALL BE REQUIRED WHEN TRENCH WIDTHS OF LESS THAN 12 INCHES ARE REQUESTED. SLURRY CEMENT BACKFILL SHALL MEET THE REQUIREMENTS OF SECTION 19-3.062, SLURRY CEMENT BACKFILL, OF THE CALTRANS STANDARD SPECIFICATIONS, UNLESS COUNTY DOT DIRECTOR APPROVES A SPECIFIC MIX DESIGN.

PLOT DATE: 28-AUG-00



LEGEND

SURFACING

BASE

SEE Note 5. Water Barrier

NOTES:

1. DESIGN OF CROSS SLOPE SHALL CONFORM TO Tab Ca – Alternate Design Standards.

2. MINIMUM PRIVATE EASEMENT OR PUBLIC RIGHT OF WAY WIDTH SHALL CONFORM TO THE ROAD DESIGNATION.

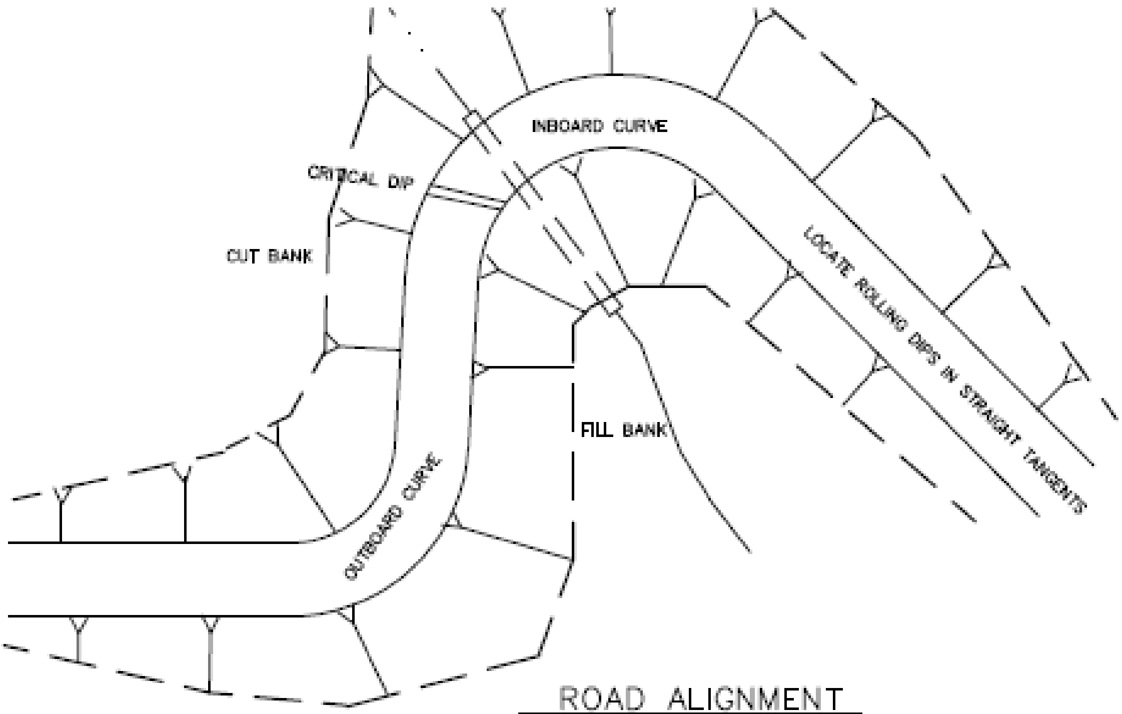
3. SURFACING WIDTH SHALL CONFORM TO THE APPROPRIATE STD. NOS. A10G &H; HOWEVER FULL SHOULDER WIDTH MUST ALL BE PLACED ON THE OUTSLOPED PORTION.

4. PAVEMENT AND/OR BASE THICKNESS' SHALL CONFORM TO THE REQUIRED ROAD DESIGNATION.

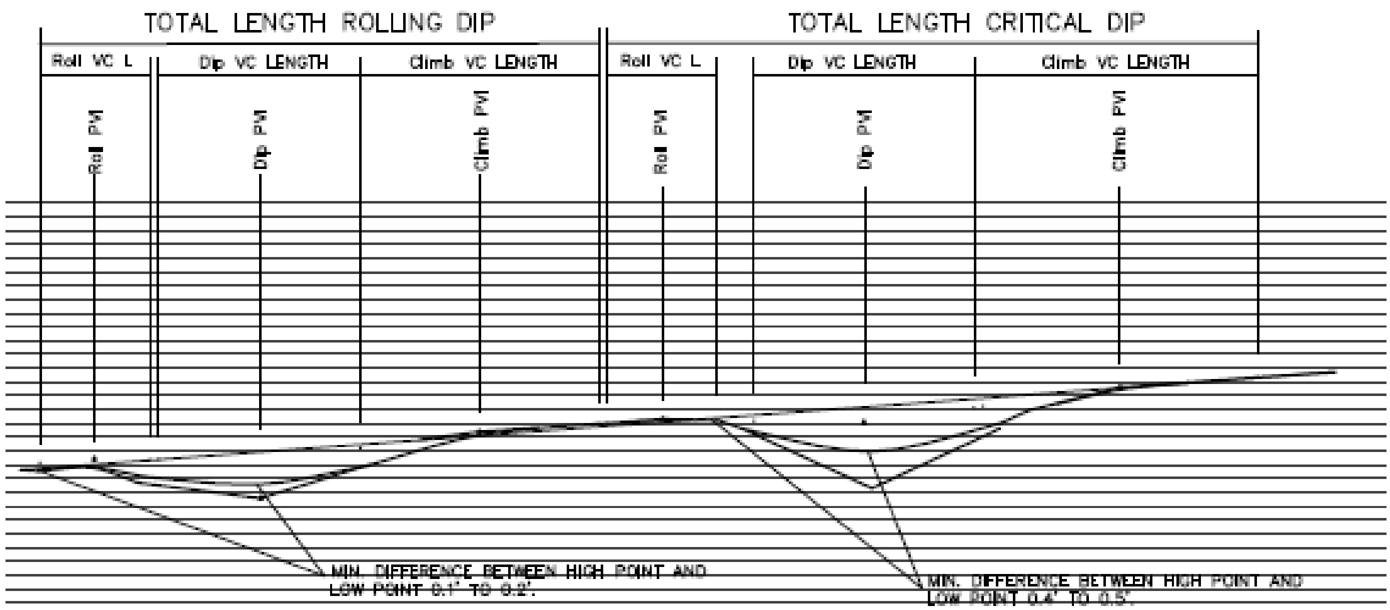
5. DEVELOPERS DESIRING TO USE THIS ALTERNATE STANDARD SHALL PROVIDE A WATER BARRIER UNLESS THE PROJECT SOILS INVESTIGATION INDICATES THAT SUBSOIL WATER WILL NOT MIGRATE INTO THE BASE LAYER IN SUFFICIENT AMOUNTS TO CAUSE PAVEMENT DAMAGE.

FILE: CLFS1:\LDD PROJECTS\22301\MEN-A10G.DWG

MENDOCINO COUNTY 1859	LOW IMPACT TO HYDROLOGY GUIDELINES / ALTERNATE DESIGN STANDARDS	MENDOT STD. NO. A10J
	SCALE: NONE · DESIGN: HND · DRAWN: HND · JAN. 2008	PAGE: A–8d



ROAD ALIGNMENT
NO SCALE



ROAD PROFILE
NO SCALE

NOTES:

1. DESIGN OF CROSS SLOPE SHALL CONFORM TO Tab Ca – Alternate Design Standards.

MENDOCINO COUNTY 1850	LOW IMPACT TO HYDROLOGY GUIDELINES / ALTERNATE DESIGN STANDARDS			MENDOT STD. NO. A10K
	SCALE: NONE	DESIGN: HND	DRAWN: HND	JAN. 2008

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s&w@swsv.com

TECHNICAL MEMORANDUM

TO:	Tamera Leighton, Del Norte Local Transportation Commission	DATE:	October 30, 2015
FROM:	Emily Straley, PE, Schaaf & Wheeler	JOB#:	DNLT.01.15
SUBJECT:	Del Norte County IDF Curve Development		

Objective

The current document detailing hydrology methodology in Del Norte County is the *Hydrology Manual for an Area North of Crescent City, Del Norte County* (County Manual) by CH2M Hill dated March 1978. The methodology prescribed in the manual is the Stanford Watershed Model. The Stanford Watershed Model (SWM) was developed from 1959 through 1966, and was the first computer program to integrate the processes of overland flow, base flow, infiltration and soil moisture, and evaporation and transpiration and perform calculations on a short (hourly) time step. This model is the predecessor of the Hydrological Simulation Program - Fortran (HSPF), a non-proprietary system of simulation modules developed for and with support of the U.S. Environmental Protection Agency (EPA). Since the release of HSPF, hydraulic and hydrologic modeling programs has undergone a continual series of code and algorithm enhancements, leading to the production of the current EPA SWMM modeling program, along with a host of proprietary modeling programs.

The information given in the County Manual is not applicable to hydrology methods widely used today, such as the NRCS Curve Number Method or the Rational Method. Intensity-Duration-Frequency (IDF) curves are not provided; instead separate Duration-Area-Recurrence Interval curves are provided for different land uses including: upland forest, lowland forest, cleared land, and impervious land. The Del Norte Local Transportation Commission (DNLTC) has tasked Schaaf & Wheeler with developing IDF curves that can be used with a variety of hydrology methods.

IDF Curve Methodology

The data used to calculate IDF curves is obtained from the National Weather Service's National Oceanic and Atmospheric Administration (NOAA). NOAA has developed the Precipitation Frequency Data Server (PFDS), where the platform, NOAA Atlas 14, provides precipitation frequency (PF) estimates, among other information such as ASCII grids of estimates, associated temporal distributions of heavy rainfall, time series data at observation sites, and cartographic maps. These PF estimates are based on historic events and have a 90% confidence interval unless otherwise noted. This information has been endorsed by the Federal Advisory Committee on Water Information's (ACWI) Subcommittee on Hydrology and is de-facto national standard.

NOAA Atlas 14 provides PF estimates for the following durations: 5 minutes, 10 minutes, 15 minutes, 30 minutes, 60 minutes, 2 hour, 3 hour, 6 hour, 12 hour, 24 hour, 2 day, 3 day, 4 day, 7 day, 10 day, 20 day, 30 day, 45 day, and 60 day. Estimates for the following storm frequencies are given as well: 1 year, 2 year, 3 year, 5 year, 10 year, 25 year, 50 year, 100 year, 500 year, and 1000 year. This resource provides data for several gages in the Del Norte area including Crescent City, Gasquet, and Klamath, as well as interpolates data for areas that do not have a rain gage.

Rainfall intensity is dependent on rainfall duration and frequency. The less frequent the rainfall, the larger its intensity. An IDF curve is historical data manipulated into an easy to understand format to help determine the probability of a storm occurring and the intensity of that storm if it were to occur. The historical data provided by NOAA Atlas 14 is used in conjunction with MS Excel to create IDF curves.

IDF Curves

Four gages were identified as suitable for statistical analysis based on location, and length and continuity of record, with two gages highlighted as representative of the region. The location of gages is shown in Figure 1. Data at the Elk Valley gage (04-2749) is located on Hwy 199 just south of the Oregon border in the northeast section of Del Norte County (Lat. 41.9881° Lon. -123.7183°). It is at elevation 1,708' and data has been recorded from 02/1938 – 03/2010. This gage was chosen because it is important for the DNLTC stakeholders to have an IDF curve that reflects hydrologic conditions and high elevations. Gasquet is an area of particular interest due to the frequent flooding that occurs. It is located at elevation 384' along the Smith River, in the Smith River National Recreation Area. The area surrounding Gasquet is steeply sloped wooded hillsides which reach elevations up to 2,000 ft. The National Weather Service maintains a rain gage at Gasquet, but this gage may not reflect the rainfall that occurs in the majority of the watershed. The Elk Valley gage provides data that may be representative of the higher elevations that drain to the Gasquet area.

Data at the Crescent City 3 NNW (04-2147), which is at elevation 43', was recorded from 01/1893 – 05/2010. It is located just north of Crescent City near McNamara Field (Lat. 41.7958° Lon. -124.2147°). Two other gages are located in Crescent City: Crescent City 7 ENE and Crescent City MNTC STN. The Crescent City 7 ENE gage is no longer maintained, with a period of record from 12/1951 – 05/2002. The Crescent City MNTC STN gage is also no longer maintained, with a period of record from 07/1948 – 12/1983. The gage chosen for this analysis, Crescent City 3 NNW, has a period of record of 117 years which is excellent for performing statistical analyses.

The IDF curves for these two gages are provided in Figure 2 and Figure 3. The IDF curve for the Gasquet gage (Lat. 41.8453° Lon. -123.9647°) is provided in Figure 4 as a comparison to the Crescent City and Elk Valley gage. The IDF curve for the Klamath gage (Lat. 41.5786° Lon. -124.0747°) was calculated as well, and is provided in Figure 5, since several high priority projects are recommended in that area in the Module 4 Technical Memorandum.

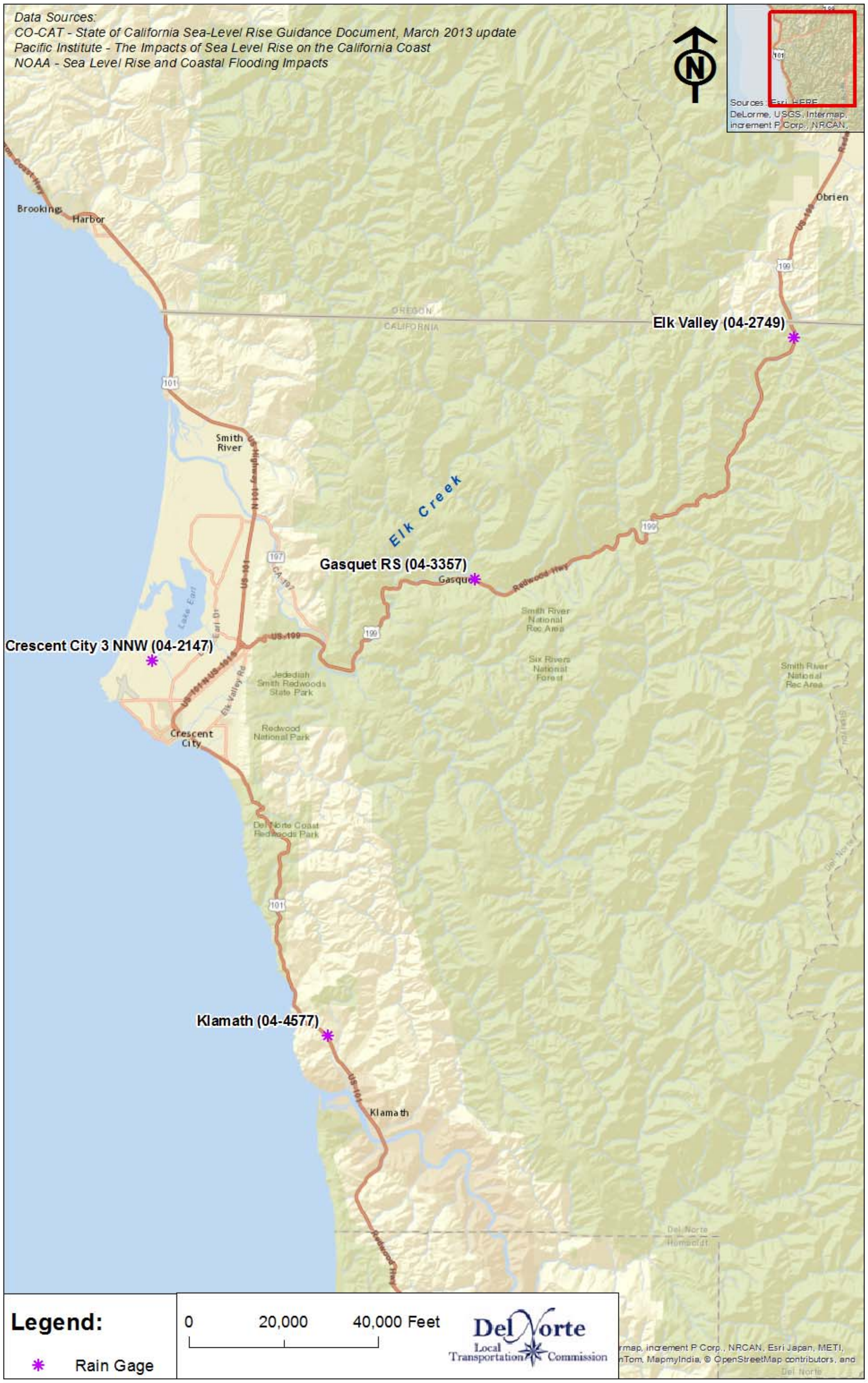

Figure 1. Rain Gage Locations

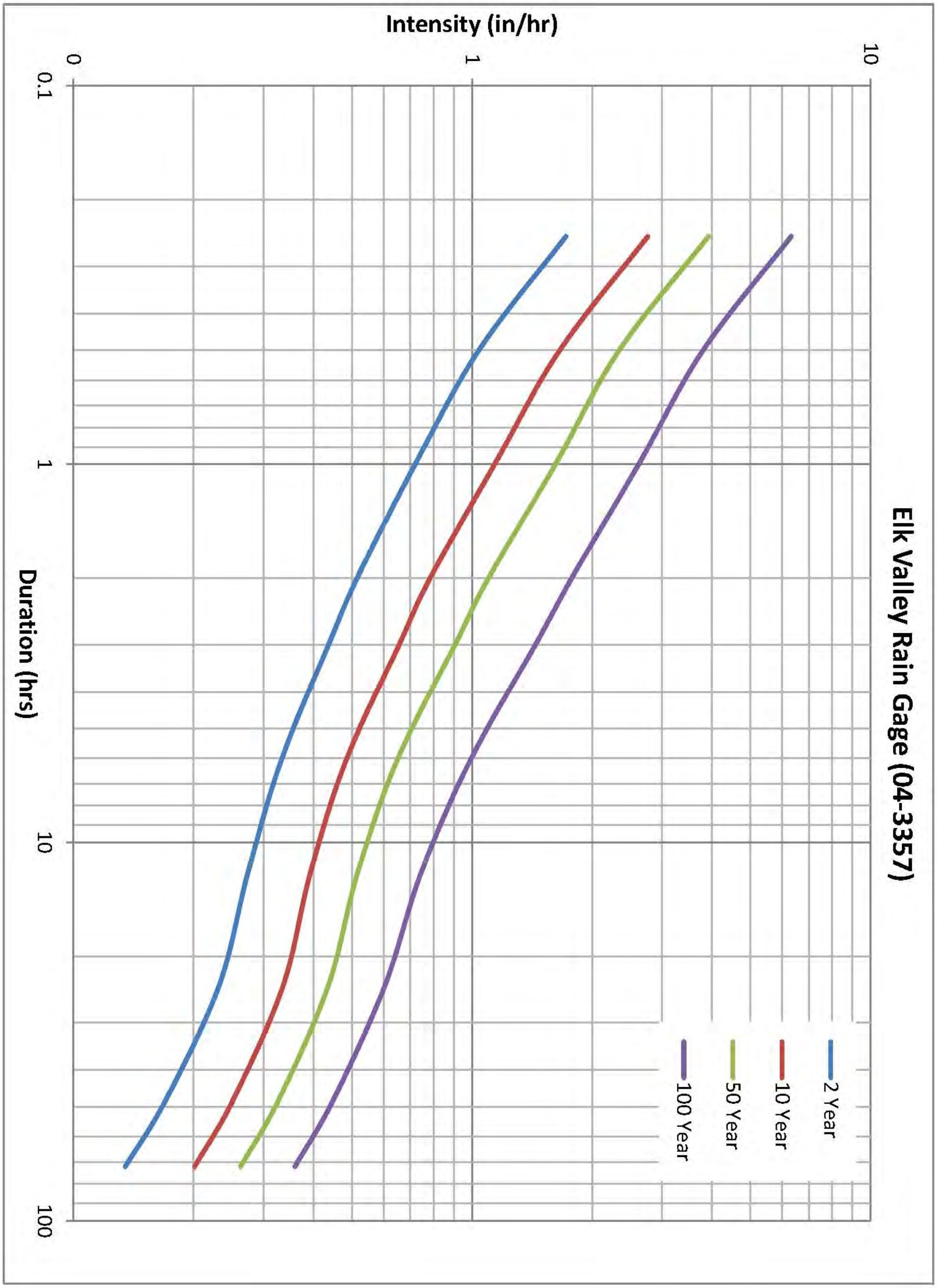

Figure 2. IDF Curve at the Elk Valley Rain Gage

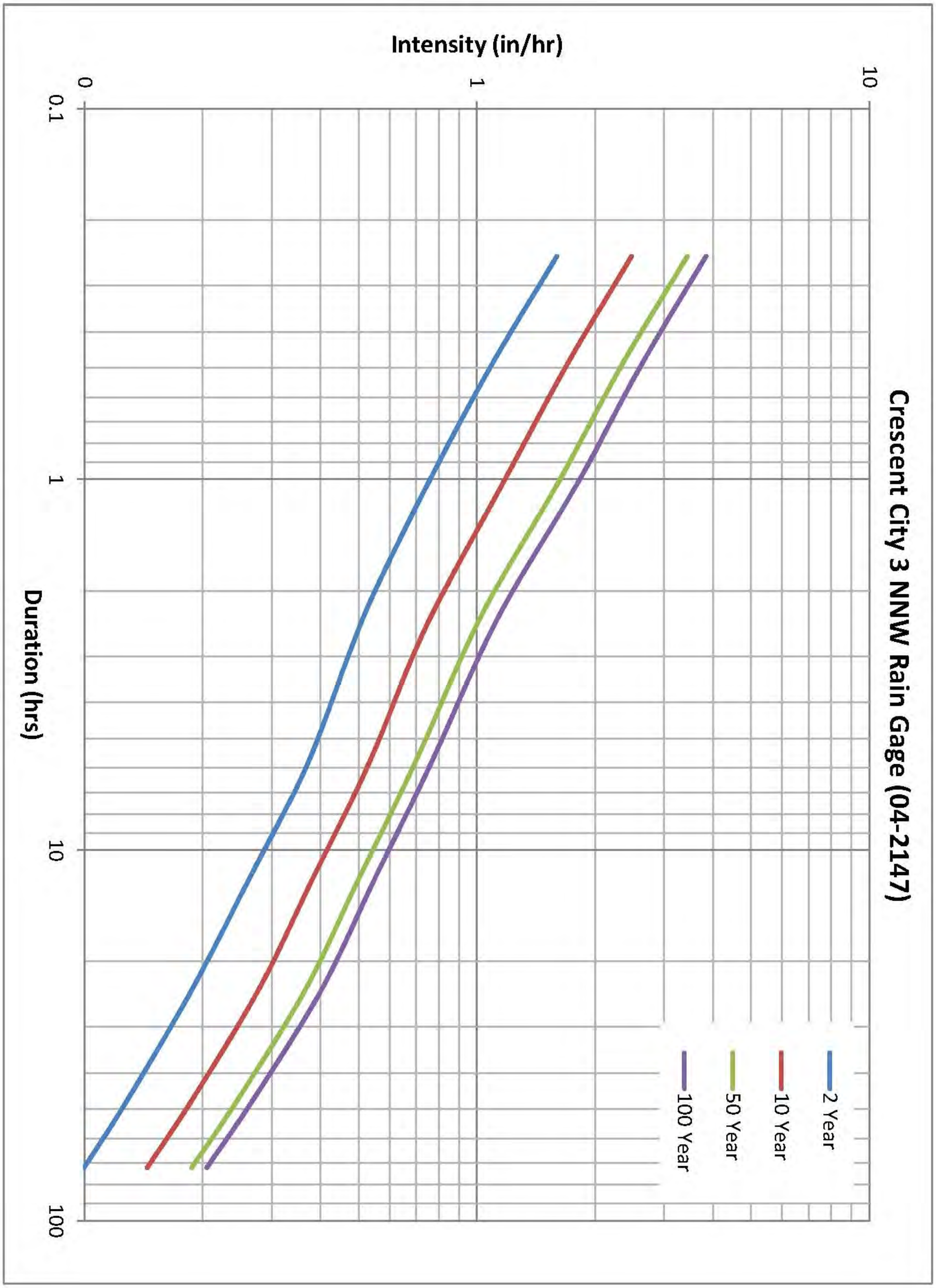

Figure 3. IDF Curve at the Crescent City Rain Gage

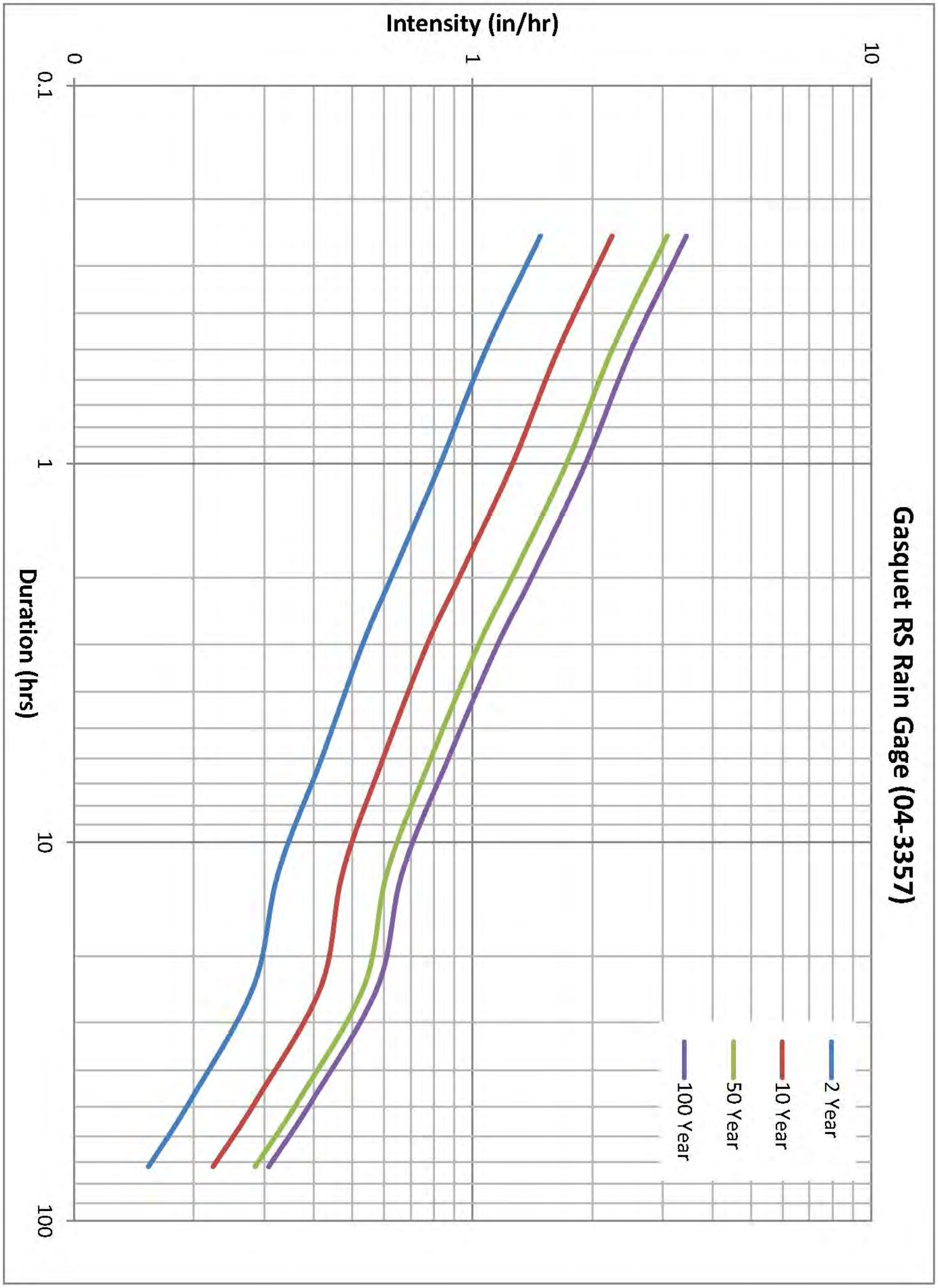

Figure 4. IDF Curve at the Gasquet RS Rain Gage

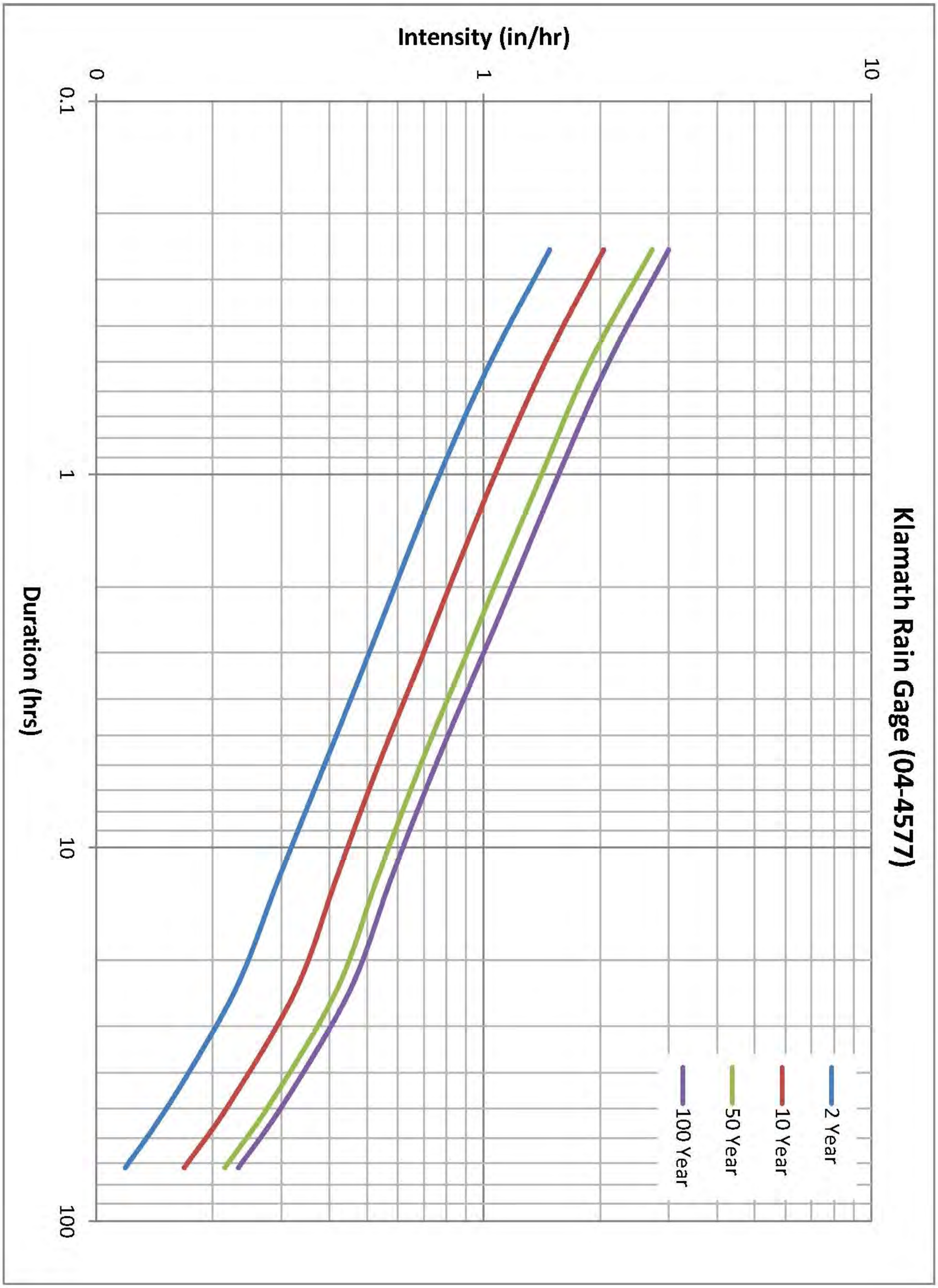

Figure 5. IDF Curve at the Klamath Rain Gage

Calculations using IDF Curves

A brief discussion of common hydrology methodologies is given here to provide information on how to use the IDF curves to calculation the quantity of runoff. This is not intended to be an exhaustive list of methods, or a recommendation of how the quantity of runoff should be calculated in Del Norte County. This section is merely meant to be a source of information since the IDF curves cannot be used with information provided in the County Manual written in 1978.

Rational Method

The Rational Method is a popular method for estimating peak discharges for sites with tributary areas less than or equal to 200 acres where storage effects are not significant. The following methodology shall be used to calculate the quantity of runoff (Q)

The Rational Formula is generally written:

$$Q_T = k\ C\ i_T\ A$$

Where: Q_T = peak discharge (cfs)

T =	recurrence interval (years)
k =	1.008 (generally rounded to 1)
C =	A dimensionless runoff coefficient
i =	The design rainfall intensity in inches/hour for a duration equal to the time of concentration of the watershed
A =	Watershed area in acres.

The runoff coefficient, C, is a function of land use and underlying soil type. Land use can be determined based on zoning, the General Plan, or the USGS. Soil type can also be looked up on USGS. The USGS maintaines a website, http://earthexplorer.usgs.gov/, from which this data can be directly downloaded from. The time of concentration is defined as the travel time of a drop of water from the most hydraulically remote point in the contributing area to the point where the discharge is being determined. The travel time can include overland flow time and the travel time in gutters, storm sewers, channels, and other drainage ways.

Unit Hydrograph Method

The Unit Hydrograph Method is often used to estimate peak discharges for sites with tributary areas greater than 200 acres, to evaluate detention basins, or where a hydrograph (flow vs. time) is required as an output. This method allows the user to account for hydrologic losses including evaporation, transpiration, infiltration, surface routing, storage, and antecedent moisture conditions.

This method is too complex to detail in this technical memorandum, but the basic process is as follows:

- Simulating rainfall from a specified storm
- Simulation rainfall losses due to interception and infiltration
- Simulating the overland flow into creeks, channels, or pipes to provide a runoff hydrograph at concentrated points
- Routing the hydrograph through creeks, channels, or pipes
- Routing the hydrograph through detention basins or reservoirs

A detailed explanation of the hydrograph method can be found in the *Handbook of Applied Hydrology* by V.T. Chow[1], TR-55[2], and other appropriate references.

Conclusion

The IDF curves provided in this memorandum can be used in conjunction with the appropriate hydrologic methodology to calculated peak flows and runoff hydrographs for areas in the vicinity of the individual gages. The IDF curves cannot be used in the same manner as the Duration-Area-Recurance Interval curves provided in the County Manual written in 1978. Instead, more modern hydrology methodologies, such as those discussed herein, should be employed to produce runoff estimates. It should be noted that the IDF curves are only valid for the current timeframe, and do not reflect the impact of climate change. These curves should be recalculted periodically to capture precipitation changes that occur in the future.

This memo specifically enhances the value and usability of the Climate Change Stormwater Management Study performed by Schaaf & Wheeler by providing the information needed for the Del Norte County Community Development Department to generate IDF curves in a simple, straight forward manner. While the methodology is accurate now, the data provided by NOAA Atlas 14 does not include the effect of climate change within it. In the future to come, this data may have to be updated as climate change becomes more evident and has an effect on precipitation as never seen before in historic data however. For further information about the data used to derive these curves, please refer to NOAA's Hydrometeorological Design Studies Center, which is constantly being updated.

[1] Chow, Ven Te, 1964, *Handbook of Applied Hydrology: A Compendium of Water Resources Technology* New York: McGraw-Hill.

[2] United States Department of Agriculture. Natural Resources Conservation Service, Conservation Engineering Division. 1986. *Urban Hydrology for Small Watershed, TR-55*. Retrieved from http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf