Upper Culebra Watershed Assessment Report

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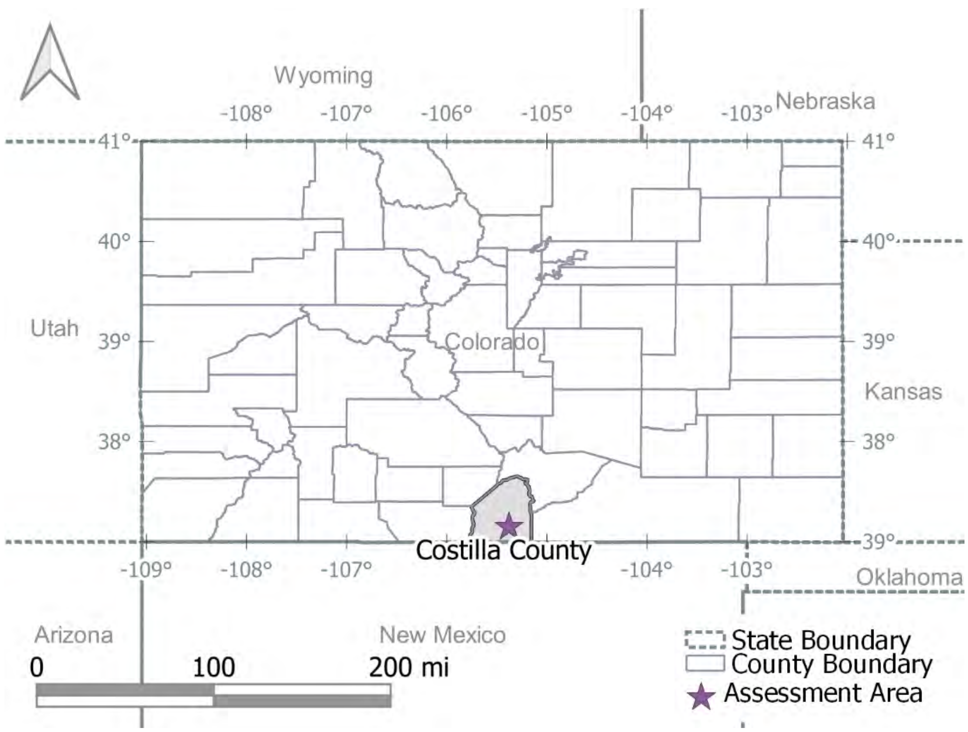
In Progress Draft

Prepared for Costilla County Conservancy District



May 18, 2022

Prepared by

Tailwater Limited

Dedication

This report is dedicated to the people of the Culebra Basin past, present, and future. May we all continue to learn and adapt to develop a sustainable community for the generations to come.

Assessment Team

The following individuals were part of the contracted team that collected, analyzed, and compiled the information contained in this report. This report would not have been possible with the work and expertise of these individuals

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Executive Summary

Author: Tailwater Limited

Culebra Creek is a major tributary to the Rio Grande in Southern Colorado, with a drainage area of 378 square miles. Now disconnected, Culebra Creek has not flowed to the Rio Grande regularly in recent history. The Culebra Basin is often described by its rich cultural history. The basin encompasses the oldest continuously occupied town, San Luis, and the oldest continuously operated ditch, The San Luis People's Ditch. The San Luis People's Ditch has the number one decreed water right in the State of Colorado. The community living in the Culebra Basin uses Acequias to provide water to strips of land called Vara Strips. Vara strips divide the lands to provide access to water, farmlands, and uplands to some of the original settlements within the basin, allowing for a thriving community. Globally, much has changed since settlement, with the widespread use of automobiles, electricity, and computers, to name a few. The Culebra Watershed Assessment was developed and based on the stakeholder identified technical areas listed below. These areas are the key drivers in watershed and community health.

Project Approach

The project team started with a desktop evaluation of available data to evaluate the watershed. Publicly available datasets and other datasets were identified and analyzed for input into the assessment. During this process, data gaps were identified. While processing existing datasets, it became apparent that a lot of the information about the basin was either incomplete or missing altogether. To supplement the missing data, the project team developed sampling plans and protocols for collecting additional data necessary to evaluate the health of the Culebra Watershed.

During the summer of 2021, the project team conducted field investigations to supplement data to evaluate the condition of the Culebra Watershed. The field data collection effort allowed the team to become more familiar with the Culebra Basin and develop many baseline datasets described in the report and are available for future studies. This data was also used to develop recommendations provided at the end of many chapters within the report.

Utilizing all the available information a list of priority projects for the basin was developed. These projects are recommendations to improve the watershed's health or develop a better understanding of the watershed's condition developed from the recommendations from each section. Watershed health, and our understanding of watershed health is dynamic, and monitoring is really the only way to gain any sort of understanding for what is occurring within a watershed. In understanding watershed health, it is crucial to monitor for trends continuously. As practices are put in place to improve the health of a watershed, monitoring of the watershed should be continued to evaluate whether those practices have the desired effects.

Riparian Assessment

- Assessed water influenced areas adjacent to streams and lakes.
- These areas are important to the health of the watershed by providing stability to stream channels and their banks.
- Riparian areas are often very diverse, providing habitat for numerous flora and fauna in an ecosystem.
- Healthy riparian areas provide stream bank stability, reduce water temperatures, provide essential leaf litter

Aquatic Assessment

- Assessed aquatic habitat required to support fish and aquatic invertebrates.
- Aquatic habitat is an excellent indicator of watershed health.
- Assessment develops baseline dataset to fill data gaps.
- A lack of diversity, and/or biomass in aquatic ecosystems indicate degradation within the watershed.

Flow Regimes Assessment

- Assessed water administration and available hydrology records to evaluate how water moves through the watershed.
- Understanding the factors affecting how water moves through the watershed is important for addressing community livelyhood, especially a community dependent on agriculture.

Water Quality Assessment

- Assessed and summarized existing water quality data and regulations.
- Assessment added new water quality sampling data and extended spatial extent of water quality data.
- The quality quality of water directly effects all the people, animals, and plants all depend on water to survive.

Forest Health Assessment

- Assessed health of the forests that make up much of the upper watershed
- Forest health heavily impacts the health of the watershed including the hydrological cycle and wildfire risk.
- Provided on the ground samples of forest composition and health.

Rangeland Assessment

- Evaluated the health of the watershed as it pertains to grazing practices on communal lands.
- Grazing can have both positive and negative impacts on aquatic, riparian, and upland health.
- Rangeland health and grazing practices have impacts on riparian health, aquatic health, water quality, water availability, and forest health.

Geomorphology /Geology Assessment

- Assessed the streams within the basin for stability.
- Disturbances in a watershed are often revealed as change in channel stability.
- A channel that is no longer functioning or is functioning poorly will have negative impacts to the overall health of a watershed.

Infrastructure Assessment

- Assessed existing diversion and water conveyance infrastructure within the basin.
- Assessed roadway and critical infrastructure within floodway.
- Infrastructure impacts flow conveyance and sediment transport affecting water quanity and quality

Historic Land Use Assessment

- Assessed the community connection with the watershed through surveys and interviews.
- Evaluted heritage in the basin to gain an understanding of historic land use practices that may have impacted the overall health of the watershed.
- Assessed historic photographs and documents that may have impacts on the current condition within the watershed.

Safety and Emergency Management

- Evaluated natural hazards that could occur within Culebra Basin.
- Assessed existing conditions that impact safety and emergency management including available assets for handling emergency situations and existing mitigation measures.
- Proposed potential mitigation measures to improve safety and emergency management.

Key Findings

The assessment key findings are summarized by each assessment area.

The riparian assessment was completed by rapidly assessing the conditions across the basin. The rapid assessment identified many degraded areas and areas that should be preserved. Recommendations for improving the riparian habitat include restoring floodplain connection and managing logging, grazing, and weeds.

The aquatic habitat assessment measured 22 sites across the Culebra watershed. This assessment revealed that most sites were impaired concerning habitat measures for riffle/pool ratios and the presence or density of large woody debris. Some of the sites had increased fine sediment deposition. Macroinvertebrate sample results indicated that the water quality within the basin was generally good. Hillslope erosion was not correlated with aquatic habitat quality, suggesting that in-channel erosion, forest health, and other stressors contribute to aquatic habitat degradation. Recommendations for improving aquatic habitat included actions to restore riffle/pool ratios by increasing available large woody debris and adding other complexity to the systems and reducing fine sediment inputs.

The geomorphic assessment evaluated the aquatic habitat sites and sites identified as having instability indicators, such as bank erosion and mid-channel bar formation. The assessment identified the following stressors resulting in geomorphic instability: poor floodplain connection, poor riparian health, modified hydrology, and channelization. Recommendations for projects that could improve reach stability are provided for eleven locations which range from changes in diversions structures, improvements to floodplain connection, channel restoration, and grazing management.

The flow regimes assessment evaluated the available streamflow and diversion data. This assessment identified: gaps in available data that are negatively impacting water administration within the basin, mapped areas that are dewatered for portions of the year, and other administrative actions. The assessment also summarized available modeled estimates of streamflow. Recommendations for projects include increasing monitoring and the availability of streamflow records, installing measurement structures on all points of diversion and within the acequias, pursue community agreeance and understanding of applicable water administration occurring within the basin.

The infrastructure assessment evaluated the diversion structures, culverts and bridges, and roadways for impacts on watershed health. Many of the diversion structures were identified as not meeting measurement rules laid out by the State of Colorado, including measurement structures and lockable headgates. Fish and sediment passage issues were identified at many of the structures. The assessment of culvert crossings revealed many of these structures were installed without adequate downstream scour protection. This lack of scour protection at these locations has resulted in gully formation and road maintenance concerns. Flood hazards were identified for critical infrastructure, including Centennial School and the San Luis WWTP. Recommendations were developed for land use and development activities, diversion structures, and roads.

The water quality assessment evaluated existing water quality data, known degradation within the basin, and water quality regulations. Water quality was sampled at 10 locations across the basin, and field water quality parameters were collected opportunistically throughout the assessment. Concerns related to water quality within the basin included biological mercury concentrations in Sanchez Reservoir and impacts from Battle Mountain Mine. Rito Seco is listed on the 303(d) list. It is listed for E. coli and dissolved Copper. Sanchez Reservoir is on the monitoring and evaluation list for Total Arsenic due to a change in regulation and not a change in the physical water quality. Water quality throughout the remainder of the basin was of good quality. Concerns were identified related to unplanned releases from Battle Mountain Mine, mercury in reservoirs, municipal solid waste disposal, and septic systems. Recommendations for the basin include continued routine sampling, installation of continuous water quality monitoring for Rito Seco, basin education on water quality, and erosion reduction.

The forest health assessment evaluated the health of the forests within the basin by collecting 100 stand exams covering all the forest vegetation types identified within the basin. Desired forest conditions are provided along with the forest inventory results for each of the significant landowners within the basin. Recommended treatments and best management practices for the forests are described, along with mapped recommendations for each stand exam location. The expected outcomes of improved forest management include a more resilient forest that is less prone to extensive insect and disease damage, reduced extreme fire risk, and improved wildlife habitat.

The safety and emergency management assessment evaluated the natural hazards likely to occur within the basin. The basin's readiness for hazard response includes structure risk assessment, firefighting resources, communications, and available response. This assessment included a community meeting with major landowners to discuss their processes and evaluate how these entities work with local and state agencies that would be responding in the event of a disaster. Mitigation strategies are provided for general community preparedness, wildfire, and flood events. Recommendations were made to align the basin with existing plans and policies within the local, state, and federal guidelines to foster an environment of collaboration.

The historical land use assessment evaluated residents' perceptions of the basin with respect to watershed health through a community survey and interviews with select individuals. 75% of landowners felt that the community could work together to improve the overall condition of the watershed. This assessment identified the following management actions that those participants would like to see enforcement of Costilla County Watershed Protection Overlay, updated infrastructure, improved road maintenance, improvements in grazing on the mountain and La Vega, and other recommendations.

The report provides additional analyses detailing the potential for post-wildfire debris flow and hillslope erosion risk throughout the basin. These datasets can be utilized to evaluate land-use decisions within the basin.

Priority Projects

The summaries and recommendations from each assessment area were used to develop a comprehensive list of priority projects for the basin. These projects were grouped into six generalized areas of potential watershed improvements. While numerous projects were identified to improve the watershed's overall health six areas were identified to organize these projects for improving the overall health of the Culebra Watershed and positively impacting the community. Watershed health is complex and dynamic, and while these lists are identified as the priorities, they are not static. They should be adapted as the watershed conditions change and the understanding of the watershed increases. The priority projects are listed on the following page and are described in more detail within the report. The criteria used for selecting priority projects are below.

- Improve community safety and reducing overall community risk from natural hazards,
- Improve water quality,
- Reduce conflict or improve conflict resolution related to natural resources,
- Fill in data gaps that that were identified from the technical sections of this report,
- Increase water yield or water availability, and
- Improve aquatic habitat.

Forest Management and Wildfire Mitigation

Forest Management and Wildfire Mitigation were identified as being one of the most critical factors impacting or potentially impacting the health of the Culebra Basin. Wildfire is the single most likely, and potentially most dangerous natural hazard that can be expected to occur within the Culebra Watershed. As has been seen in recent years and throughout history, wildfires are common in Colorado. A potential fire is prone to burning hotter and more intensely than landscapes that have adapted to fires. A catastrophic fire will degrade water quality and increase sediment loading in the basin.

Water Administration

Water in the West is in limited supply, which is becoming more and more apparent, especially in Colorado. The livelihoods of numerous individuals in the Culebra Basin are dependent on water for raising crops and/or animals. Raising crops and/or animals helps drive the Culebra Basin economy. To better understand how water moves and is administered in the basin, it is important to monitor and track it. Appropriately administering water in the basin will make it possible for people to make informed decisions about how water is used and how changes in the climate impact water availability. Water administration can help to improve relationships between neighbors, keeping everyone up-to-date and informed as to what is occurring regarding water in the Culebra Basin.

Public/Private Infrastructure Not Related to Water Diversions
Priority projects under the "Public/Private Infrastructure Not Related to Water Diversions" heading relate to roads and road crossings, solid waste management, and permits and regulations. While it is important to have roads in the watershed to allow property and resource access, these roads impact the watershed's health and public safety. One basin priority is to adequately maintain roads to reduce their impacts on watershed health. Social roads and paths should be decommissioned and rehabilitated to reduce sediment contributions. Culverts and bridges should be designed appropriately to convey all flows, and they should be designed to reduce the risk of aggradation and/or degradation within their areas of influence. Solid waste disposal is needed to address extensive dumping within the local waterways. Updates to permitting and regulation would improve community understanding.

Sanchez Canal and Reservoir Operations Improvements
The Sanchez Canal and Sanchez reservoir have a large footprint across the Culebra Basin. While being an engineering marvel for the time when it was constructed, there are opportunities to improve its function in numerous places across the valley. Projects involving the Sanchez Canal and Reservoir involve improved water administration, improved canal function, and improved function of the stream channels and valley transected by the canal.

Projects Around Diversion Structures and Ditches and Stream Restoration
Priority projects involving "Improvements Around Diversion Structures and Ditches" identify several projects that could be implemented to improve diversion structures and ditches and streams. These projects will impact water administration, water quality, riparian, and aquatic resources. Improving stream and channel corridors within the basin may positively impact the functions of those systems. Improving stream channels can benefit water quality, riparian, and aquatic resources. A functional channel will also benefit agriculture and livestock, improving foraging opportunities and watering by increasing sub-irrigation.

Rangeland and Vegetation Management
Rangeland and vegetation management priority projects will improve and promote grazing plans and cattle management. Properly managing livestock within the watershed will help to promote stability. Grazing management will increase riparian and aquatic health and increase water quality and channel stability. Vegetation can be managed to promote healthy grazing as well. Vegetation management, or managing noxious weeds, will promote plant diversity in the watershed, provide resiliency against insects and disease and a changing climate.


Priority Projects
Forestry Management and Wildfire Mitigation
Community Projects Including Firewise, Education, and Controlled Burning
Forest Management Including Selective Thinning, Commercial Logging, Mastication, and Controlled Burning.
Water Administration
Streamflow and Diversion Measurement
Acequia Measurement and Record Keeping
Water Quality Monitoring
Cooperative Water Management
Public and Private Infrastructure not related to water
Public Roads Maintenance and Monitoring
Rito Seco Flood Mitigation
Rito Seco Fluvial Hazard Reduction
Solid Waste Management
General Permits and Regulations
Sanchez Canal and Reservoir
Diversion Headgate Improvements
Scour reduction Ventero and Culebra Creek
Tailwater Conveyance
Improvements around Diversion Structures and Ditches and Stream Restoration
Ditch Fish Passage, Floodplain Connection, and Ripairian Habitat
Guadalupe Sanchez Diversion Improvements and Channel Restoration
Culebra Creek Upstream of Sanchez Canal Channel Restoration
San Acacio and Cerritos, Francisco Sanchez, and Island Headgate Improvements
San Francisco Ditch Diversion Dam and Headgate Improvements
Culebra Creek - San Luis WWTP Flood Hazard Reduction
Levee Removal/ Rehabilitation Culebra Creek
El Poso Creek from Sangre de Cristo Ranches to the Confluence with Culebra Creek
Rangeland and Vegetation Management
Jaroso Creek Meadow
Upland revegetation - Vallejos Creek South of Confluence with North Vallejos Creek
Ripairian Vegetation

Chapter 1. Introduction

Author: Tailwater Limited

The Upper Culebra Watershed Assessment is a wide-ranging assessment of the conditions within the Upper Culebra Basin to provide a baseline for identifying priority projects and determining the needs for long-term monitoring. This assessment evaluates technical subject areas defined by the community through stakeholder meetings that began June 21, 2018 and continued through January 2019. The stakeholder meetings included community meetings and smaller stakeholder groups which were used to define the topics for the assessment. Stakeholder groups were identified by topic to help define the scope for this assessment (Figure 1-1). The subject areas include many of the aspects of the basin which rely on water and which the community relies on for their livelihood and quality of life.

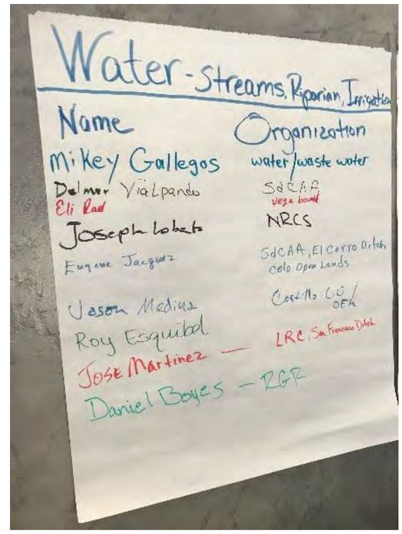


Figure 1-1 Example poster from stakeholder meetings.

The assessment was visioned to take place over the duration of one year incorporating as much existing data as may be identified. During the development of the scopes of this project and discussions, it was determined that significant data gaps exist within the basin and additional watershed scale information would be needed prior to expending the resources to implement any long-term monitoring programs. The assessment team met with the local Technical Advisory Committee May 19, 2021, and from this and the existing available data developed study plans that were circulated the technical advisors June 11, 2021. The field assessment part of the assessment kicked off June 15, 2021.

This assessment was divided into eleven tasks including Riparian Habitat Assessment, Aquatic Habitat Assessment, Flow Regimes Assessment, Water Quality Assessment, Forest Health Assessment, Rangeland Assessment, Historic Land Use Assessment, Geomorphology/Geology Assessment, Infrastructure Assessment, Safety and Emergency Management Assessment, and Priority Projects (Figure 1-2).

This report is the result of long-term efforts within the Upper Culebra Basin to evaluate the current watershed health, with the goal of eventually completing projects to improve conditions within the basin.

1.1 Project Location

The Culebra River is a tributary to the Rio Grande located primarily within Colorado but with a small portion of the southern basin crossing into New Mexico. This watershed lies on the western boundary of the southern Sangre de Cristo Mountain Range (Figure 1-3) draining approximately 378 square miles. The watershed includes one town, San Luis, Colorado and seven villages: San Acacio, Viejo San Acacio, San Pedro, San Pablo, Chama, Los Fuertes (also called San Isidro), and La Valley (also called San Francisco or El Rito).

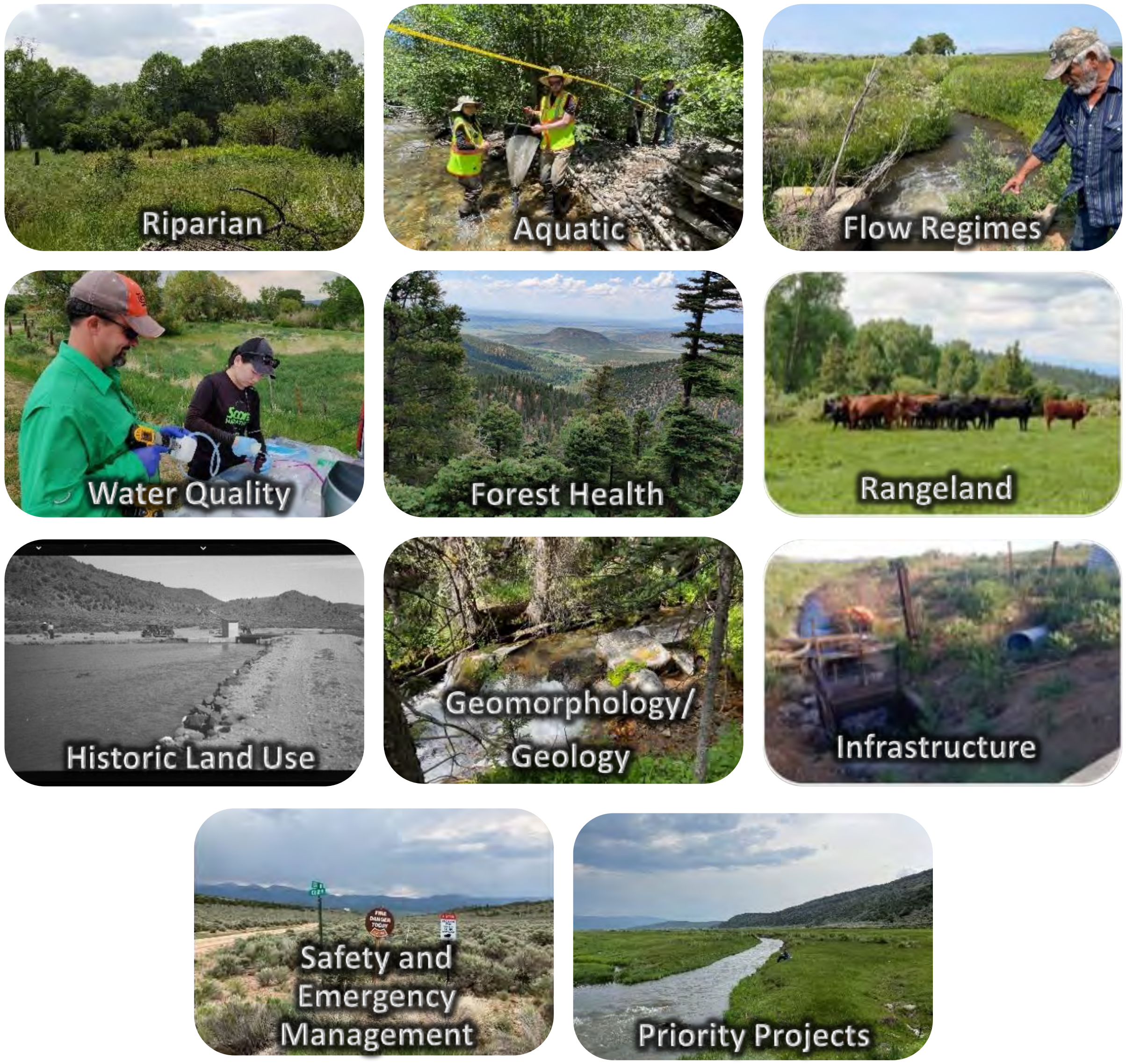


Figure 1-2 Upper Culebra Watershed Assessment Tasks.

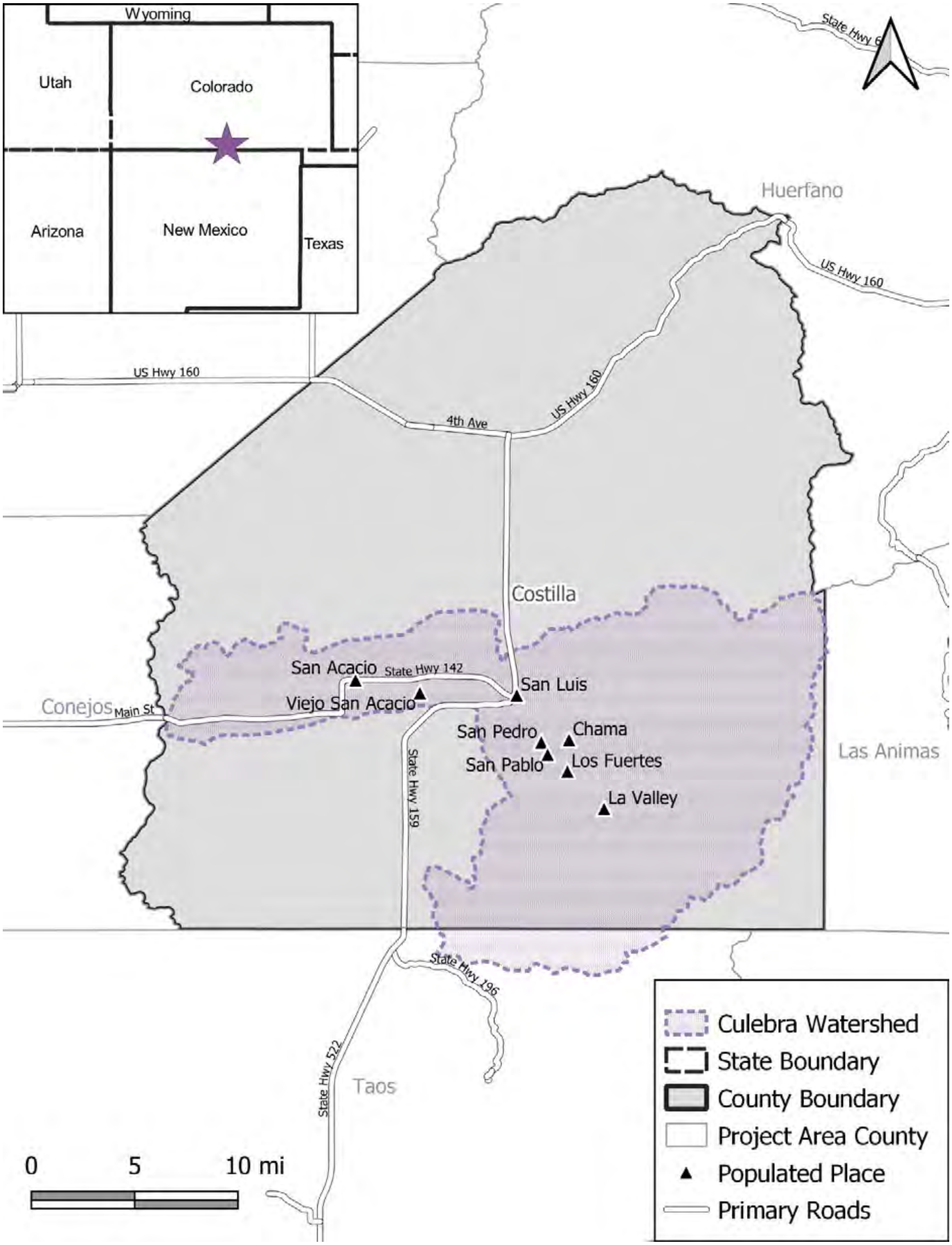


Figure 1-3 Upper Culebra Watershed Location Map.

1.2 Project Goals and Objectives

The following six goals were identified for the Culebra Watershed Assessment. These goals drove the focus of the data collection that was performed, as part of this assessment, and to develop the project list that is included in Chapter 15. In addition to the project goals and objectives, each technical section contains subject area specific goals and objectives.

Goal 1 Increase understanding and document current conditions of natural resources within the Culebra Basin.

Goal 2 Develop understanding of community connections with the natural resources and customs related to natural resources within the Culebra Basin.

Goal 3 Identify causes of water, forest, and rangeland conflict in the Culebra Basin.

Goal 4 Develop understanding of community safety hazards and existing mitigation related to natural disasters including flood, fire, and post-fire debris flows.

Goal 5 Develop plan and projects to increase resiliency and sustainability and decrease degradation of natural resources within the Culebra Basin.

From the identified goals, objectives, which can be thought of as actions, were developed to guide the assessment towards meeting the goals. The objectives were based on feedback from the community about the types of outcomes that are desired from this assessment. The objectives were also developed with the anticipated timeline of one-year from start to finish.

Goals	Objectives
Goal 1. Increase understanding and document current conditions of natural resources within the Culebra Basin.	*Objective 1.1.* Put together interdisciplinary team of technical experts to evaluate the condition of the Culebra Basin. *Objective 1.2.* Perform a measurement-based assessment of the watershed conditions. Technical subjects include riparian habitat, aquatic habitat, flow regimes, water quality, forest health, rangeland health, wildlife habitat, geology/geomorphology, and infrastructure condition. *Objective 1.3.* Document and summarize the assessment findings in a single comprehensive final report and community presentation. *Objective 1.4.* Where possible identify linkage between degradation and causes.
Goal 2. Develop understanding of community connections with the natural resources and customs related to natural resources within the Culebra Basin.	*Objective 2.1* Integrate local knowledge and experiences within the Culebra Basin as part of the assessment. *Objective 2.1* Interview key individuals in the basin to document community connections and customs. *Objective 2.1* Review available documentation to understand community history.
Goal 3. Identify causes of water, forest, and rangeland conflict in the Culebra Basin.	*Objective 3.1* Identify geographic areas of conflict within the basin. *Objective 3.2* Document status of the forest health in basin to educate basin stakeholders and inform decisions.

	Objective 3.3 Document status of rangeland health in common areas within the Culebra Basin to educate basin stakeholders and inform decisions. *Objective 3.4* Review and summarize water administration within the Culebra Basin. *Objective 3.5* Evaluate water related infrastructure within the Culebra Basin. *Objective 3.6* Evaluate existing water quality data from the Culebra Basin. *Objective 3.7* Interview individuals to further understand the basis of conflict within the basin.
Goal 4. Develop understanding of community safety hazards and existing mitigation related to natural disasters including flood, fire, and post-fire debris flows.	*Objective 4.1* Identify areas at risk of damage in the event of flood, fire, and post-fire debris flows. *Objective 4.2* Review and document status of safety and emergency management in Culebra Basin. Document best management practices that are used to reduce risk of natural disasters. *Objective 4.3* Identify areas with current mitigation strategies that reduce risks from flood, fire, or post-fire debris flows.
Goal 5. Develop plan and projects to increase resiliency and sustainability and decrease degradation of natural resources within the Culebra Basin.	*Objective 5.1* Develop project list and strategies for reducing risk of flood, fire, and post-fire debris flows. *Objective 5.2* Develop project list to improve resiliency within the Culebra Basin. *Objective 5.3* Develop and/or document target metrics for healthy natural resources including aquatic habitat, riparian habitat, geomorphology, water quality, forests, rangeland, and infrastructure.

1.3 Background

The Upper Culebra Watershed elevation ranges from 7,461 ft to 14,052 ft (2,274 m to 4,283 m) (USDA/NRCS - National Geospatial Center of Excellence, 2015) with annual precipitation ranging from 8.07 to 43.50 inches (205 mm to 1105 mm) (Northwest Alliance for Computational Science & Engineering, 2018-2022). The United States Census estimated the population of Costilla County to be 3,828 in 2018 (United States Census Bureau, 2020).

Existing datasets were compiled to develop an understanding of the basin. These datasets are used to describe the landforms, the climate, land cover, political and administrative boundaries, and geographic organizational tools that affect and/or describe the conditions within the Culebra Watershed.

1.3.1 Landforms and Topography

The Culebra basin is defined by the Sangre de Cristo Mountains to the east and is formed by San Pedro Mesa to the west with the Culebra River cutting through the gap between San Pedro Mesa to the south and San Pedro Cuesta to the north near the town of San Luis as if flows toward the Rio Grande River. The northern boundary in the lower basin is defined by the San Luis Hills formation (Kirkham, Shaver, Lindsay, & Wallace, 2003).

In 2011, the United States Geological Survey (USGS) collected LiDAR elevation data across the San Luis Valley, this data set covers the lower portion of the Upper Culebra Basin and was delivered at a 1-meter resolution (1 point every meter both longitudinally and laterally), the coverage area is shown in Figure 1-4 (United States Geological Survey, 2011). Reported vertical accuracy of this dataset in is +/- 12.5 cm (0.41 ft).

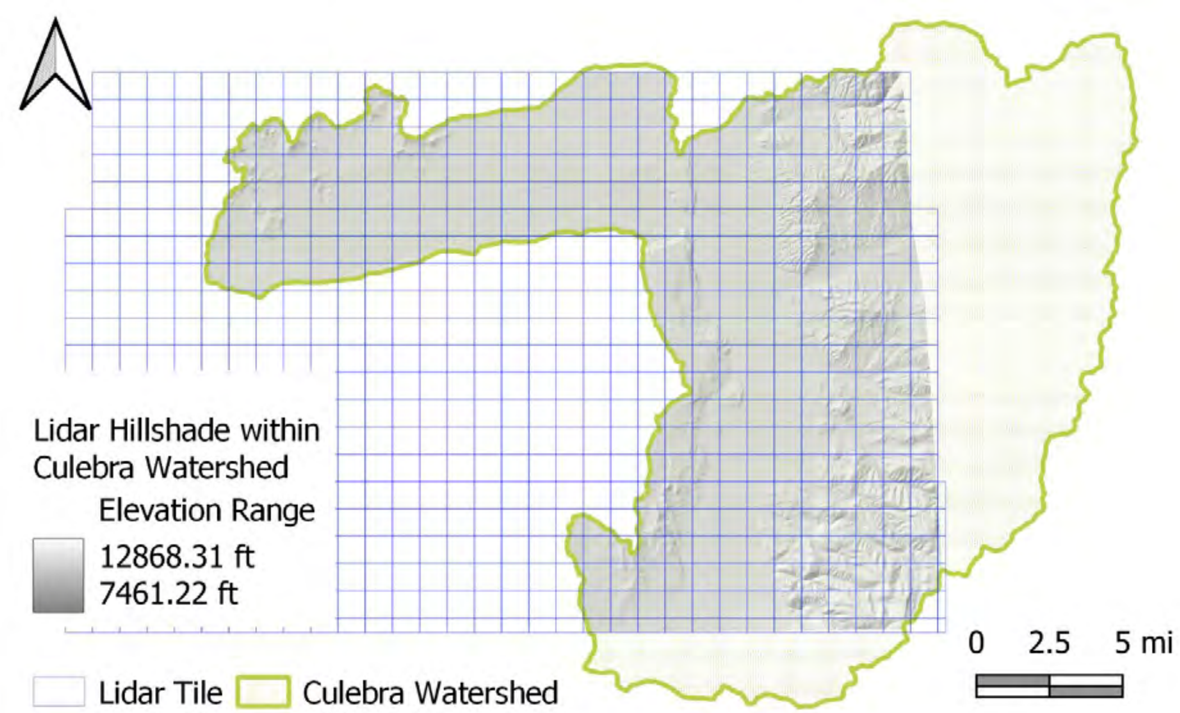


Figure 1-4 2011 USGS Lidar coverage for Culebra Watershed (United States Geological Survey, 2011).

For analysis and visualizations that span the entire basin the 10-meter and 30-meter (approximately 32.8-feet to 98.4-feet) resolution digital elevation models (DEM) were used. Both these datasets cover the entire watershed.

Elevation and derived parameters such as slope, drainage area, and stream networks provide the basis for the initial desktop analysis for many of the tasks. The level of detail used within the desktop analysis is based on the methodology and susceptibility to noise.

The slope of the basin is generally flatter within the valleys and the lower portion of the watershed and steeper in the upper watershed and along the slopes of San Pedro Mesa and San Luis Hills (Figure 1-5).

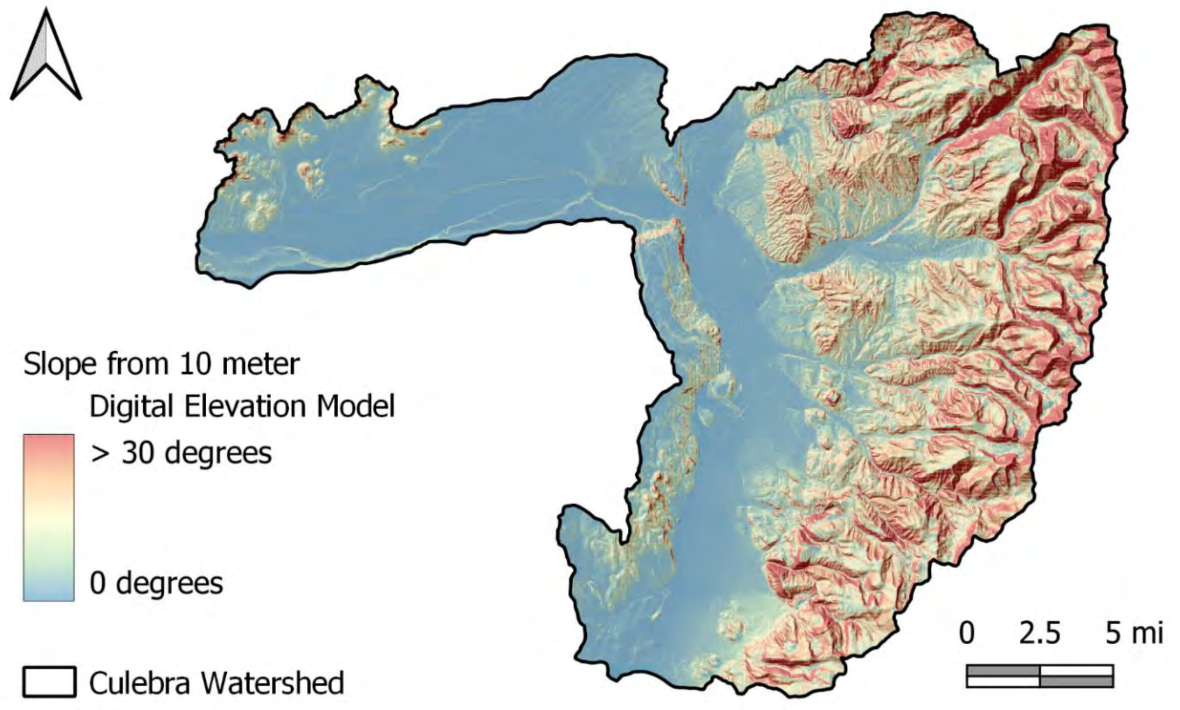


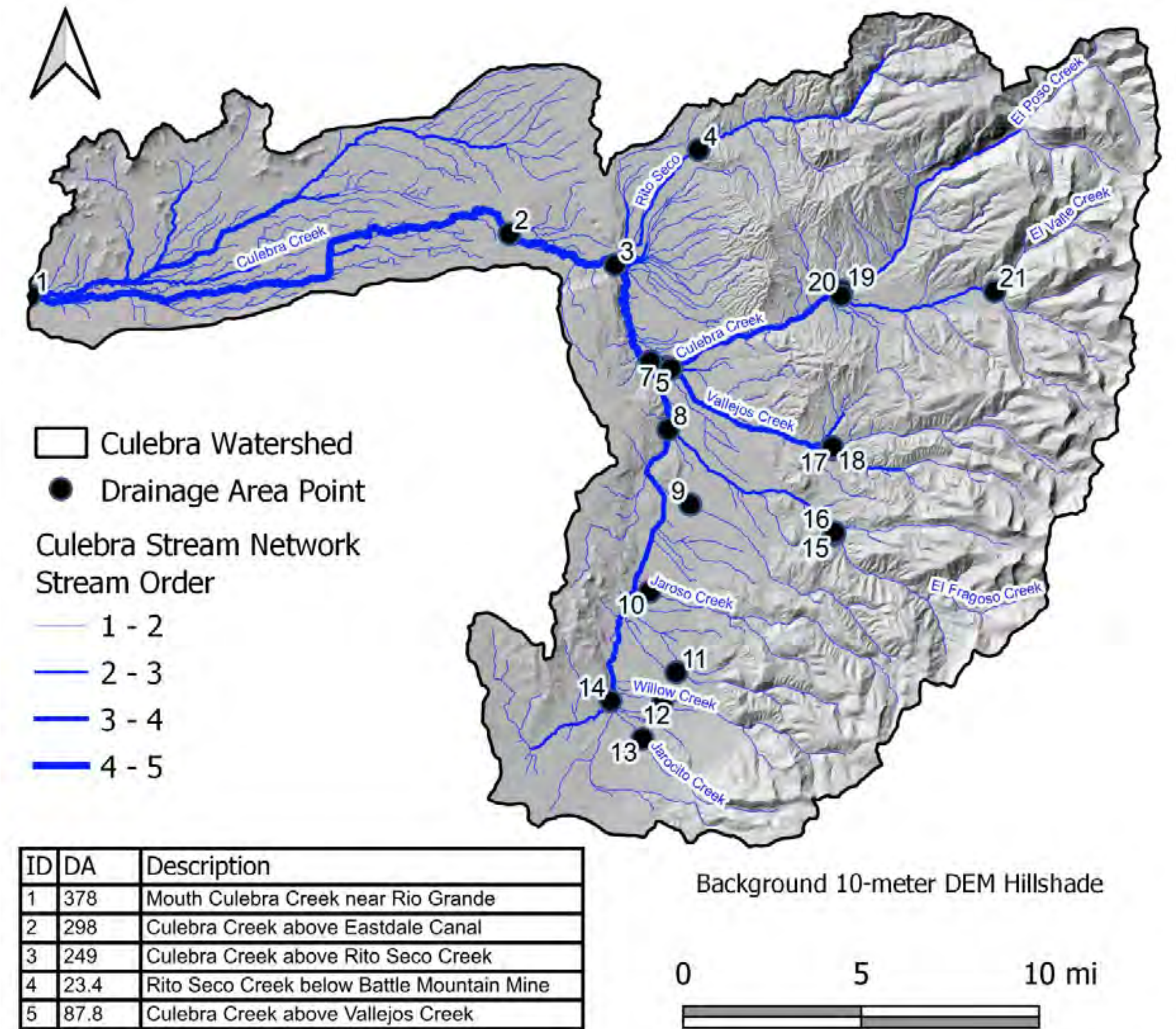
Figure 1-5 Culebra watershed slope map generated from 10-meter digital elevation model. 10-meter digital elevation model hillshade shown in background.

1.3.1.1 Stream Network

The available 10-meter DEM was hydraulically conditioned to remove roadway embankments and other overhead features. This is necessary because aerial data collection techniques are not able to detect passageways under bridges and through culverts. The term for this process is “burning” the stream network into the dem. This 10-meter DEM was then processed using the steps outlined in the TauDEM 5.3 Users Guide (Tarboton, Dash, & Sazib, October 2015) to produce the base stream network and stream order. A threshold of 0.019 square miles (485 cells) was used to determine the starting point for stream formation. This value was based on the stream drop analysis described by Tarboton and others (October 2015) to have a geomorphically objective threshold for stream channel delineation. This analysis resulted in a maximum Strahler stream order of 5 at the outlet with a starting stream order of 1.

The network defined from the 10-meter DEM will differ from the actual stream path in areas due to the sample resolution, which sometimes doesn’t sample small channels within the landscape. The areas where this is particularly apparent are where stream channel does not coincide with valley fall and across alluvial fans where there may be multiple flow paths. The visual display of the network is left un-modified due to the need to maintain the relationship to the underlying data sets, realizing that on the local scale there may be discrepancies from characteristics on the ground. This data set is reasonable on a small to medium scale (1:250,000 to 1:50,000). Parameters may require additional interpretation before making critical decisions.

This stream network is used to evaluate watershed characteristics such as drainage area and mean annual precipitation, distance from outlet at the Rio Grande, highest elevation within the contributing area, an estimation of reach slope, stream order, and reach beginning, middle and end elevations. An example of how this information can be used to summarize drainage areas within the basin is shown in Figure 1-6.



ID	DA	Description
1	378	Mouth Culebra Creek near Rio Grande
2	298	Culebra Creek above Eastdale Canal
3	249	Culebra Creek above Rito Seco Creek
4	23.4	Rito Seco Creek below Battle Mountain Mine
5	87.8	Culebra Creek above Vallejos Creek
6	29.9	Vallejos Creek near Mouth
7	121	Ventero Creek above Culebra Creek
8	25.9	San Francisco Creek at Mouth
9	6.6	Torcido Creek above Sanchez Canal
10	8.9	Jaroso Creek near Mouth
11	5.7	Cuates Creek at CR21
12	0.1	Willow Creek at CR21
13	2.9	Jaroscito Creek
14	13.3	Ventero Creek above Jaroscito Creek
15	13.3	San Francisco Creek above Alamosito Creek
16	5.9	Alamosito Creek at Mouth

ID	DA	Description
18	12.3	North Vallejos Creek at Mouth
19	34.1	El Poso Creek near Mouth
20	32.7	Culebra Creek above El Poso Creek
21	21	Culebra Creek below El Valle Creek and Carneros Creek

DA is drainage area in square miles

Figure 1-6 Stream network with drainage area at select points within the basin.

The stream network reaches were manually processed to include information such as name, where known, and flow regime – perennial, non-perennial, or reservoir. Names were primarily obtained from available digital Topographic maps. Flow regime estimates were adjusted based on field observation for some of the reaches. The flow regime assessment may need further refinement in some of the smaller streams.

The stream network and TauDEM processes were used to identify characteristics within the watershed that provide information such as land cover above a point, vegetation classes expected within the watershed, soils characteristics, etc.

1.3.1.2 Basins

The watershed was divided into basins to allow analysis of characteristics by receiving reach. This information is used to evaluate sediment input from roads and other sources to each stream link in the infrastructure section, Chapter 6.

1.3.2 Climate

Climate is another factor in determining vegetation classification. Precipitation and temperature are some of the key factors in vegetation. Additionally, slope stability is highly correlated to precipitation intensity and duration.

Climate change is affecting temperature and precipitation patterns, Llewellyn and Vaddey (December 2013) found that during the period 1971 through 2011 the Upper Rio Grande Basin's average temperatures rose at a rate of just under 0.7 °F per decade. Projections from this study suggest that temperatures may rise an additional 4 to 6 °F by the end of the 21st century. The report further estimates that available water supplies will decrease on average by one third, earlier snowmelt runoff as well as variations in timing and magnitude resulting in a decrease in summertime flows and uncertainty in the change in wintertime flows, and greater variability in flows.

> ***"The future will depend on numerous societal choices"*** *- (Llewellyn & Vaddey, December 2013)*

The following is a list of available surface station data with temperature or precipitation records. These stations are the stations that were identified through the StateCU interface (CWCB/DWR, 2020-2021).

1.3.2.1 Weather Stations

Weather station datasets that are available within the basin are listed in Table 1-1. The source of each of these datasets is listed in Table 1-2 to assist in locating these datasets.

Table 1-1 Weather station data within the Culebra watershed from Colorado Decision Support System, accessed January 11, 2022.

Station Id	Name	Precipitation Record		Temperature Record	
		Start Year	End Year	Start Year	End Year
USC00051520	CHAMA	2007	2008	2007	2008
05M03S	CULEBRA #2	2009	2021	2009	2021
CCR01	CULEBRA CREEK, 10MI E SAN LUIS	N/A	N/A	2019	2021
USC00054346	JAROSO	1893	1949	1939	1949
US1COCS0005	JAROSO 0.4 ESE	1998	2006	N/A	N/A
SAN01	SAN ACACIO, 2 MI N MESITA	2000	2017	2000	2021
USC00057428	SAN LUIS	1893	1951	1893	1923
USC00057430	SAN LUIS 2 SE[a]	1980	2006	1980	2006
US1COCS0012	SAN LUIS 8.8 SW	2008	2021	N/A	N/A

[a]Also listed as San Luis 1S

Table 1-2 Station data repositories. Global Historical Climatology Network available at https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ncdc:C00861/html and CoAgMet data available at: https://coagmet.colostate.edu/

Station Id	Name	Site Type
USC00051520	CHAMA	Global Historical Climatology Network
05M03S	CULEBRA #2	Snotel Site also available from Global Historical Climatology Network
CCR01	CULEBRA CREEK, 10MI E SAN LUIS	Unknown
USC00054346	JAROSO	Global Historical Climatology Network
US1COCS0005	JAROSO 0.4 ESE	Global Historical Climatology Network
SAN01	SAN ACACIO, 2 MI N MESITA	CoAgMET
USC00057428	SAN LUIS	Global Historical Climatology Network
USC00057430	SAN LUIS 2 SE	Global Historical Climatology Network
US1COCS0012	SAN LUIS 8.8 SW	Global Historical Climatology Network

In addition to those sensors listed within the Culebra watershed, additional snow monitoring data is collected to the north at the Trinchera site, to the east at the Whisky Creek site, to the south at the North Costilla site and to the northeast at the Apishapa/Cucharas Creek site.

1.3.2.2 PRISM

To evaluate the spatial distribution of precipitation throughout the basin the PRISM precipitation raster was used (Northwest Alliance for Computational Science & Engineering, 2018-2022). The PRISM M3 30-year average, 1991 to 2020, shows the average annual precipitation varies from 8.2 inches per year in the lower basin up to 10.2 inches per year in the upper basin (Figure 1-7).

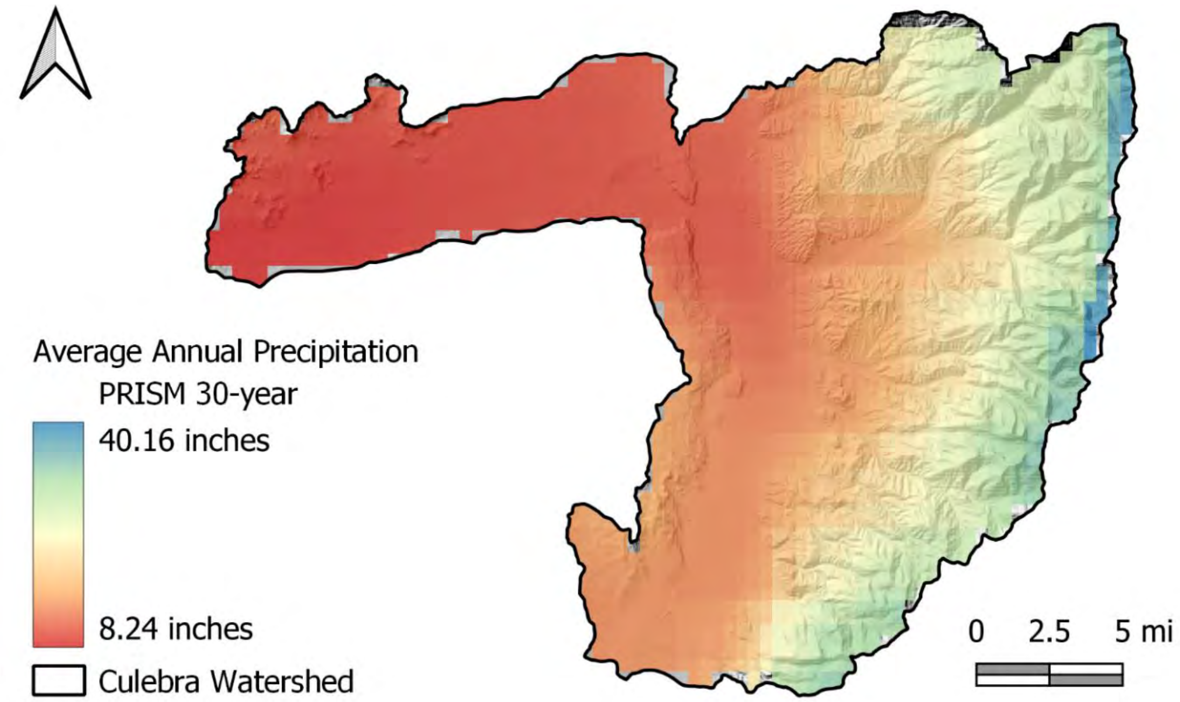


Figure 1-7 Average annual precipitation adapted from PRISM 30-year normal M3 dataset from 1991 to 2020 (Northwest Alliance for Computational Science & Engineering, 2018-2022).

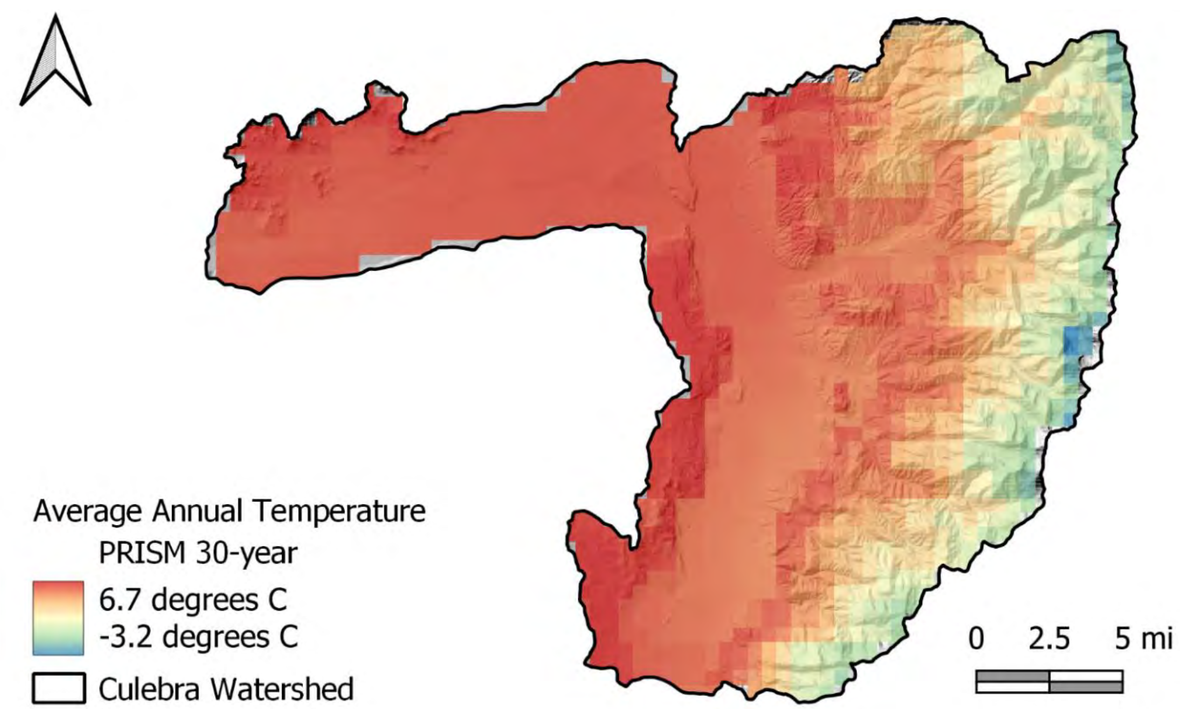


Figure 1-8 Average daily temperature adapted from PRISM 30-year normal M3 dataset from 1991 to 2020 (Northwest Alliance for Computational Science & Engineering, 2018-2022). Average temperature ranges from -3.2 degrees C to 6.7 degrees C (26.2 degrees F to 44.1 degrees F).

The temperature distribution throughout the basin is generally higher in the valleys and lower lying areas and colder as elevation increases (Figure 1-8). The 30-year average daily temperatures range from -3.2 degrees C up to 6.7 degrees C (26.2 degrees F to 44.1 degrees F).

1.3.3 Soils and Geology

The upper portion of the Culebra watershed is comprised of volcanic formations and the lower elevation foothills are generally comprised of sedimentary bedrock (Figure 1-9). San Pedro Mesa is also comprised predominately of rock from volcanic origins. The valley bottoms are composed of alluvial deposits. Deposits in the upper basin are from glacial origin.

Table 1-3 Definition of select terms.

Term	Definition
Alluvium	Clay, silt, sand, gravel, or similar detrital material deposited by running water
Colluvium	Loose sediments deposited at the base of a hillslope from sheetwash, rain-wash, and downslope creep.
Periglacial	Slope deposits that were moved by frost creek.
Eolian	Wind deposited sediments
Sedimentary	Consolidated sediments, this includes sandstones, limestone, and shale.
Lacustrine	Sedimentary rocks formed from ancient lakes.
Paludal	Sediments that accumulated from historic marsh and wetlands.

Large scale soils datasets, STATSGO, divides the basin in to nine major soil groups and water these groups are shown in Figure 1-10 (Schawarz & Alexander, 1995). The hydrologic soils groups provide reference for soil drainage capacity (Figure 1-11). The areas that are generally classified as well drained are the alluvial valley bottom. For site specific information smaller scale mapping and potentially additional site-specific analysis may be necessary.

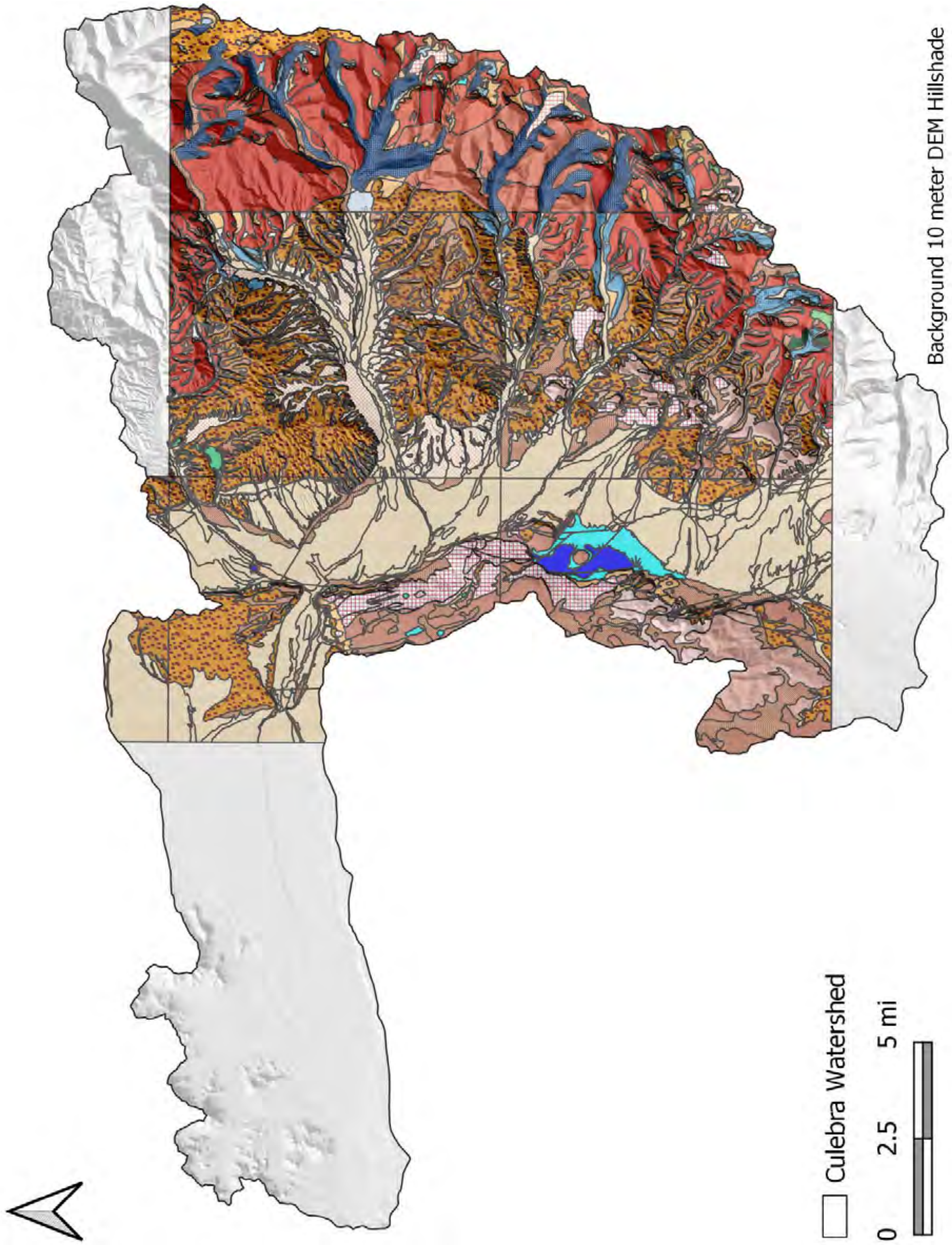


Figure 1-9 Geology of Culebra Watershed adapted from (Kirkham & Heimsoth, Geologic Map of the Fort Garland SW Quadrangle, Costilla County, Colorado, 2003) (Fridrich & Kirkham, 2007) (Kirkham, Keller, Price, & Lindsay, 2005) (Kirkham, Lufkin, Lindsay, & Dickens, Geologic Map of the La Valley Quadrangle, Costilla County, Colorado, 2004) (Kirkham, Shaver, Lindsay, & Wallace, 2003) (Nachette, Thompson, & Drenth, 2008) (Thompson, Machette, & Drenth, 2007).

Water

Artificial

- af - artificial fill
- m - mine deposits
- Qaf - artificial fill

Depositional

Alluvium

- Qa - Alluvium
- Qfp - Floodplain deposits

Alluvium and Colluvium

- Qac - Alluvium and Colluvium
- Qc - Colluvium
- Qcs - Colluvium and sheetwash

Eolian Deposits

- Qdts - Dune deposits
- Qva - Lava Creek B Volcanic as

Fan Deposits

- Qcf - Colluvium and fan deposits
- Qf - Fan Deposits
- Qfy/Qdts - Fan Deposits/Dune deposits

Mass-Wasting Deposits

- Qls - Landslide Deposits
- Qlx - Rock-fall deposits
- Qta - Talus

Glacial deposits

- Qg - Glacial till
- Qgds - Glacially dammed sediments
- Qm - Morainal deposits
- Qrg - Rock glacier deposits
- Qt - Glacial-outwash terrace

Lucustrine

- Qla

Paludal deposits

- Qpa

Periglacial deposits

- Qfe - Flasenmeer
- Qptr - Protalus-rampart deposits
- Qs - Solifluction deposits

Bedrock

Bedrock - sedimentary

- Pm - Limestone
- Psa - Basal siltstone
- QTsf - Servilleta Basalt
- Tsf - Santa Fe Group Sedimentary
- Tsl - Limestone
- Tsr - Redbed sedimentary rocks

Bedrock - volcanic

- PzZg - Gabbro
- Tad - Andesite and dacite
- Tamh - Andesite of Martinez Hill
- Tb - Basalt
- Tbt - Basalt and trachyandesite
- Td - Dacite
- Thb - Hinsdale Formation
- Ti - Hypabyssal intrusive rock
- Tm - Basalt and trachyandesite
- Tr - Rhyolite lavas and andesite lahar deposits
- Trd - Rhyodacite
- Ts - Servilleta Basalt
- Tsb - Servilleta Basalt
- Tsb(ls) - Servilleta Basalt- landslide block
- Tt - Trachybasalt
- Tta - Trachyandesite lava flows
- Xa - Amphibolite
- Xab - Amphibolites of basaltic composition
- Xag - Augen gneiss
- Xagp - Pegmatic leucocratic augen gneiss
- Xap - Aplite
- Xb - Bimodal and metasedimentary
- Xds - Diorite gneiss
- Xds - Dirty metasedimentary rocks
- Xf - Felsic gneiss
- Xfa - Felsic gneiss and amphibolite
- Xfh - Felsic and hornblende gneiss
- Xgg - Gneissic granite
- Xhb - Hornblende-biotite gneiss and amphibolite
- Xhf - Hornblend and felsic gneiss
- Xlg - Leucocratic gneiss
- Xm - Amphibolite
- Xms - Metasedimentary rocks
- Xp - Pegmatiate
- Xq - Orthoquartzite
- Xr - Alkali granite gneiss
- Xt - Tonalite gneiss

Figure 1-9 – continued. Geology legend.

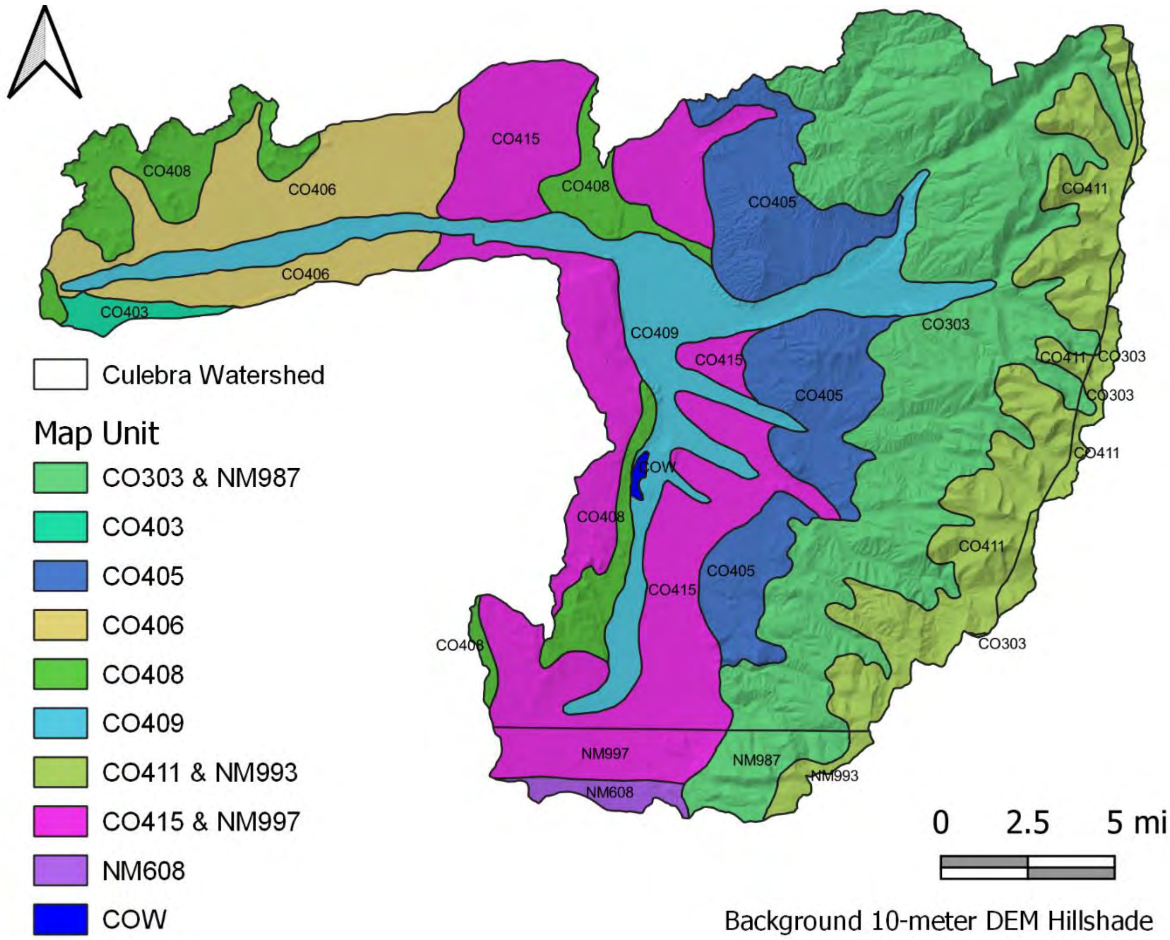


Figure 1-10 Soil map units from STATSGO (Schawarz & Alexander, 1995).

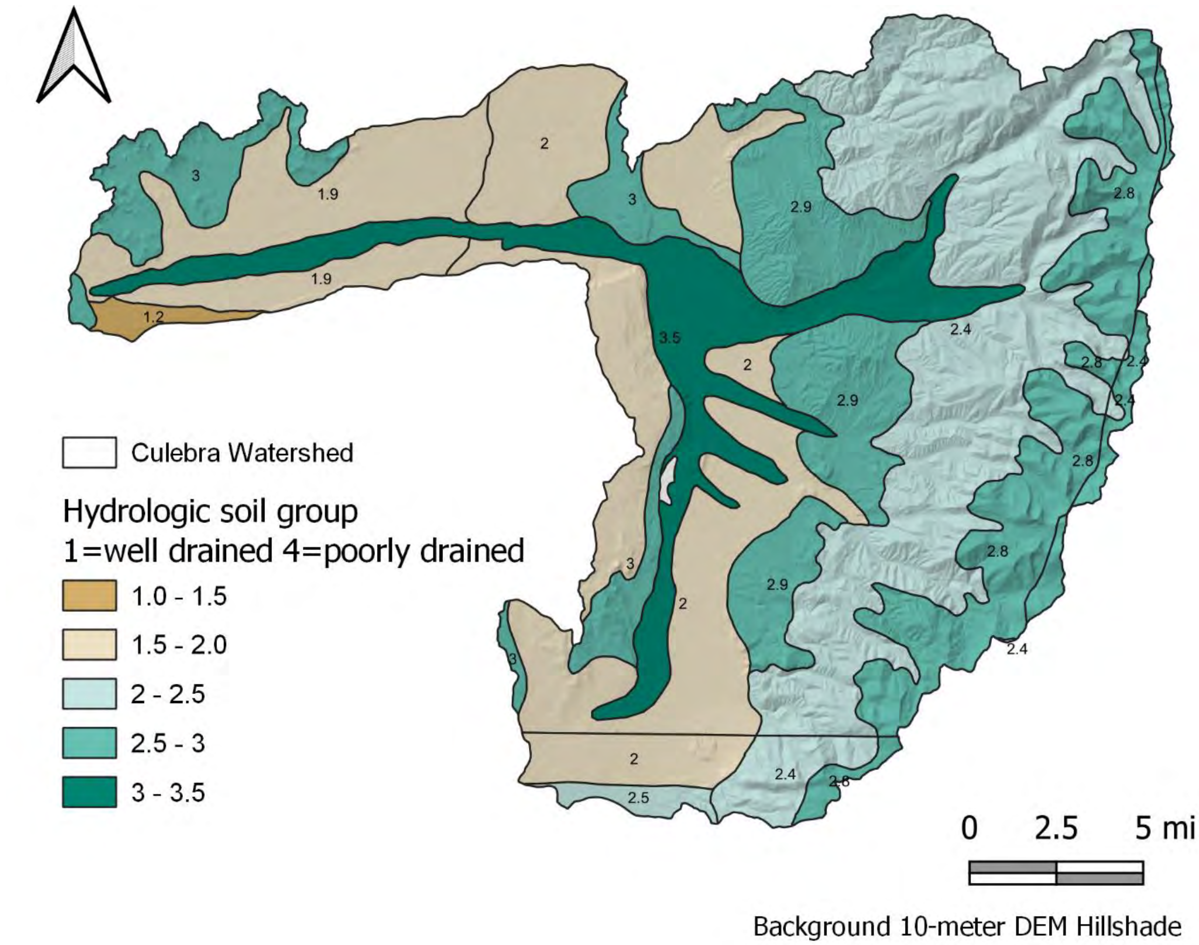


Figure 1-11 Hydrologic soil group from STATSGO database (Schawarz & Alexander, 1995).

1.3.4 Land Cover

Land cover is a determining factor in how water is transported across the landscape. The National Land Cover Database (NLCD) uses Landsat images and processes to estimate the land cover (U. S. Geological Survey, 2019). Generally, the lower basin has shrub and scrub vegetation cover outside of the alluvial valleys, crops within the alluvial valley are pasture and hay with areas of cultivated crops. Acres of coverage by HUC12 are listed Table 1-4 and proportion of cover by HUC12 are listed in Table 1-5. The land cover dataset for the Culebra watershed is shown in Figure 1-12.

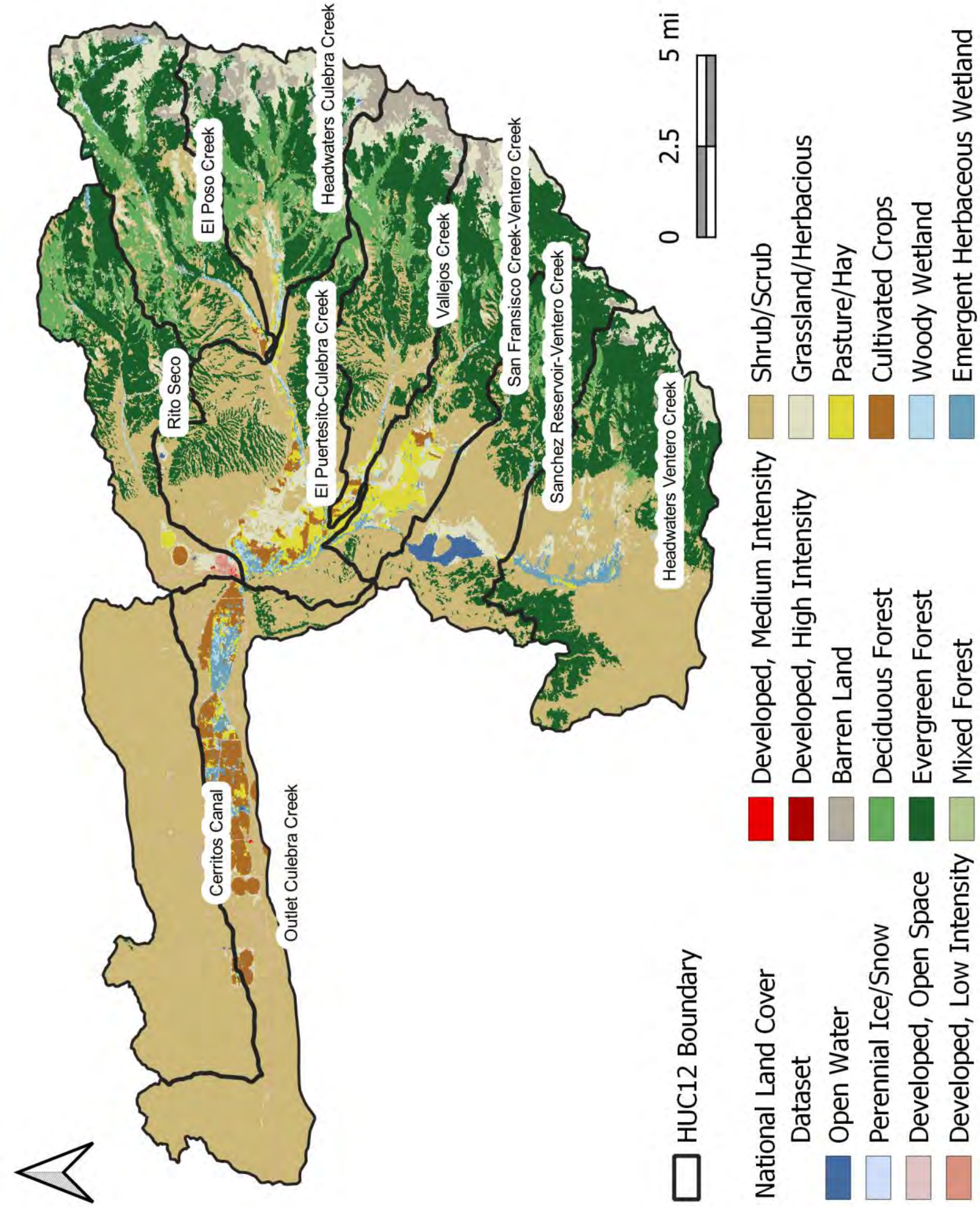


Figure 1-12 National Land Cover Dataset map for Culebra watershed (U. S. Geological Survey, 2019).

Table 1-4 National Land Cover Dataset acres by vegetation cover class (U. S. Geological Survey, 2019).

NLCD Class	HUC 12										
	Headwaters Culebra Creek	**Outlet Culebra Creek**	**Rito Seco**	**Sanchez Reservoir-Ventero Creek**	**El Puertesito-Culebra Creek**	**Vallejos Creek**	**San Fransisco Creek-Ventero Creek**	**El Poso Creek**	**Cerritos Canal**	**Headwaters Ventero Creek**	**Total**
Open Water	10	21	8	748	18	1	-	2	6	-	814
Developed, Open Space	-	571	145	-	17	-	-	-	298	-	1,031
Developed, Low Intensity	-	242	193	-	9	-	-	-	86	-	529
Developed, Medium Intensity	-	4	13	-	-	-	-	-	-	-	18
Developed, High Intensity	-	1	3	-	-	-	-	-	-	-	4
Barren Land	3,160	2	9	77	8	1,678	590	1,095	-	299	6,917
Deciduous Forest	3,828	-	2,147	1,433	486	2,053	1,644	4,042	-	955	16,589
Evergreen Forest	6,567	402	8,120	7,986	6,036	8,646	8,885	8,378	18	13,487	68,525
Mixed Forest	774	-	580	500	82	310	389	762	-	271	3,667
Shrub/Scrub	1,913	18,835	6,344	8,272	13,736	4,866	5,245	4,089	27,375	18,275	108,951
Grassland/Herbaceous	4,188	501	754	1,252	2,194	2,018	3,077	3,176	81	2,751	19,993
Pasture/Hay	172	729	147	79	1,788	377	1,716	63	10	141	5,221
Cultivated Crops	-	3,723	141	-	790	149	155	82	81	-	5,120
Woody Wetlands	309	304	154	67	360	135	215	386	-	216	2,145
Emergent Herbaceous Wetlands	52	1,066	63	29	581	52	240	143	-	839	3,065

Table 1-5 HUC12 National Land Cover Dataset vegetation proportion by vegetation class group (U. S. Geological Survey, 2019).

HUC 12	Water and Ice	Developed	Forest	Shrub/Scrub	Grassland/ Herbaceous	Pasture and Crops	Wetland
Headwaters Culebra Creek	0%	0%	61%	11%	25%	1%	2%
Outlet Culebra Creek	0%	3%	2%	71%	2%	17%	5%
Rito Seco	0%	2%	56%	35%	4%	2%	1%
Sanchez Reservoir-Ventero Creek	4%	0%	47%	42%	6%	0%	0%
El Puertesito-Culebra Creek	0%	0%	25%	53%	8%	10%	4%
Vallejos Creek	0%	0%	58%	27%	11%	3%	1%
San Fransisco Creek-Ventero Creek	0%	0%	50%	25%	15%	9%	2%
El Poso Creek	0%	0%	61%	20%	16%	1%	3%
Cerritos Canal	0%	1%	0%	98%	0%	0%	0%
Headwaters Ventero Creek	0%	0%	39%	50%	8%	0%	3%
Total	**0%**	**1%**	**37%**	**47%**	**9%**	**4%**	**2%**

1.3.5 Administrative Regions

The Culebra watershed falls within Colorado Water Division 3 – Rio Grande Water District 24 – Culebra Creek (Figure 1-13). Administration of water rights within the basin is determined by the laws described in the Colorado Revised Statutes and the adjudicated decrees. Administration within this water division is affected by two interstate compacts, the Rio Grande Compact and the Costilla Creek Compact. In Colorado, water rights are adjudicated within the judicial branch through the Water Courts. There is a Water Court in each of the seven water divisions within the state. Readers wishing to learn more about the water adjudication process are encouraged to read the “Non-Attorney’s Guide to Colorado Water Courts,” available at: https://www.courts.state.co.us/userfiles/file/Court_Probation/Water_Courts/FINAL%20Non-Attorneys%20Guide%20to%20Colorado%20Water%20Courts%20(01_14_20%20fee%20update).pdf

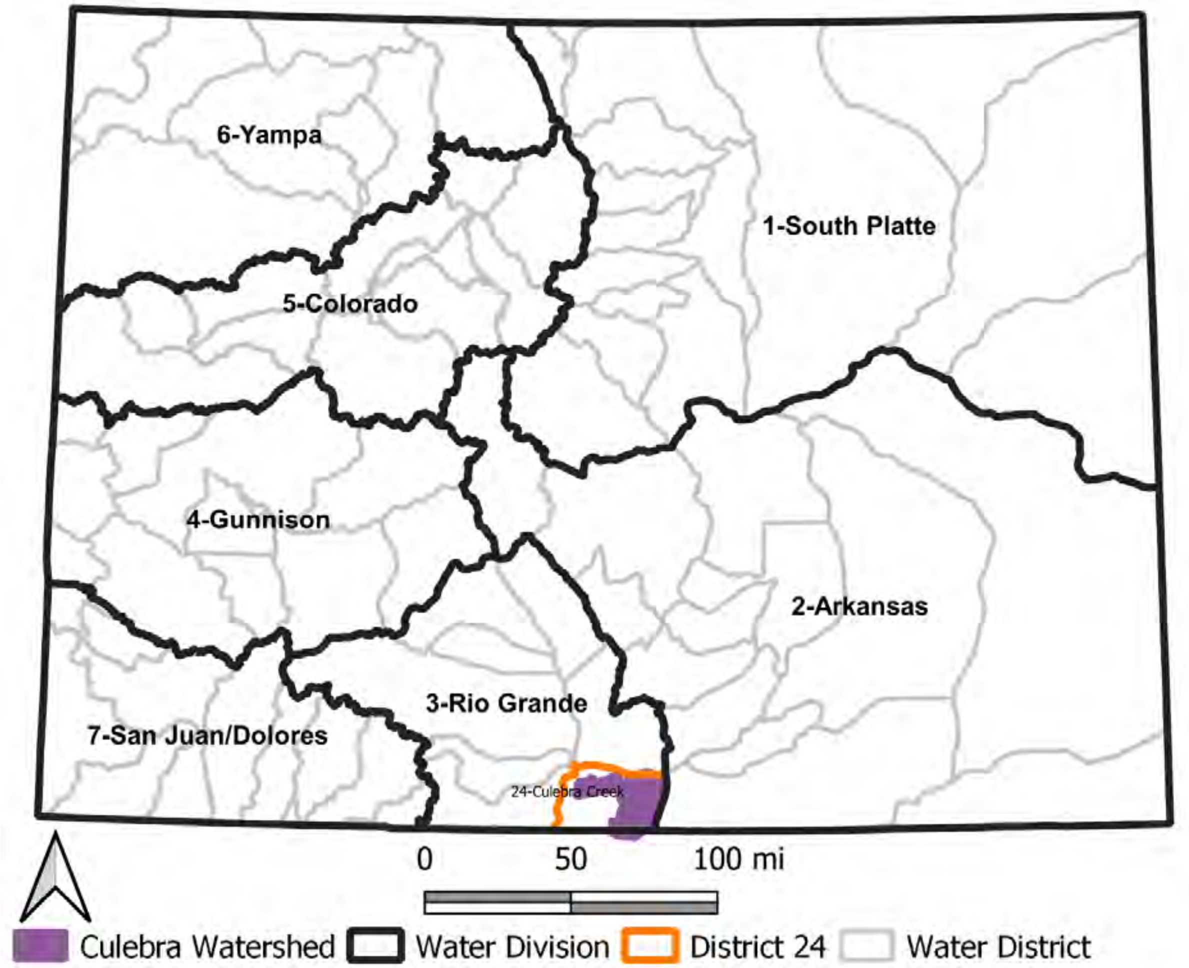


Figure 1-13 Map of Colorado Water Divisions and Districts.

1.3.6 Ecoregion

Ecoregions are defined based on formative processes that have determined the landscape including latitude, elevation, geology, and climate. Ecoregions are defined from a top-down approach which successively divides each region providing more definition (Bailey, 2014).

The concept of an ecoregion recognizes that vegetation can change with time and position (temporally and spatially) and as such the definition of vegetation types are defined through the relatively stable “late successional vegetation”. This vegetation regime is the type of vegetation that is likely to be the endpoint after disturbance events.

Level 1 and 2 ecosystems are defined by the North America Ecosystems, Level 3 is co-defined in both the United States and North America Ecosystems and the level 4 ecosystems are only defined within the United States Ecosystems. These delineations enable comparisons within not only the United States but also globally and at appropriate spatial scales.

Beginning with the top of the hierarchy, Level 1 Ecosystem, the Culebra watershed falls within the Northwestern Forested Mountains (6) and the North American Deserts (10) ecosystem. Continuing to the next level of definition the Level 2 Ecosystems follow the same delineation within the basin as the Level 1 areas with area listed as Northwestern Forested

Mountains lying within the Western Cordillera (6.2) Level 2 ecosystem and areas listed as North American Deserts falling within the Arizona/New Mexico Plateau (10.1) ecosystem. Moving farther down on the list the watershed is divided between the Southern Rockies (6.2.14 or 21) level 3 ecosystem and the Arizona/New Mexico Plateau (10.1.7 or 22) level 3 ecosystem (bearing the same name as the level 2 ecosystem for this region).

The seven level 4 ecoregions within the Culebra watershed are shown in Figure 1-14.Including the following areas within the Southern Rockies level 3 ecosystem:

21a– Alpine Zone, 21b – Crystalline Subalpine Forests, 21d – Foothill Shrublands, 21f- Sedimentary Mid-Elevation Forests, and 21g – Volcanic Subalpine Forests

And the following areas in the Arizona/New Mexico Plateau level 3 ecosystem:

22a – San Luis Shrublands and Hills and 22b – San Luis Alluvial Flats and Wetlands.

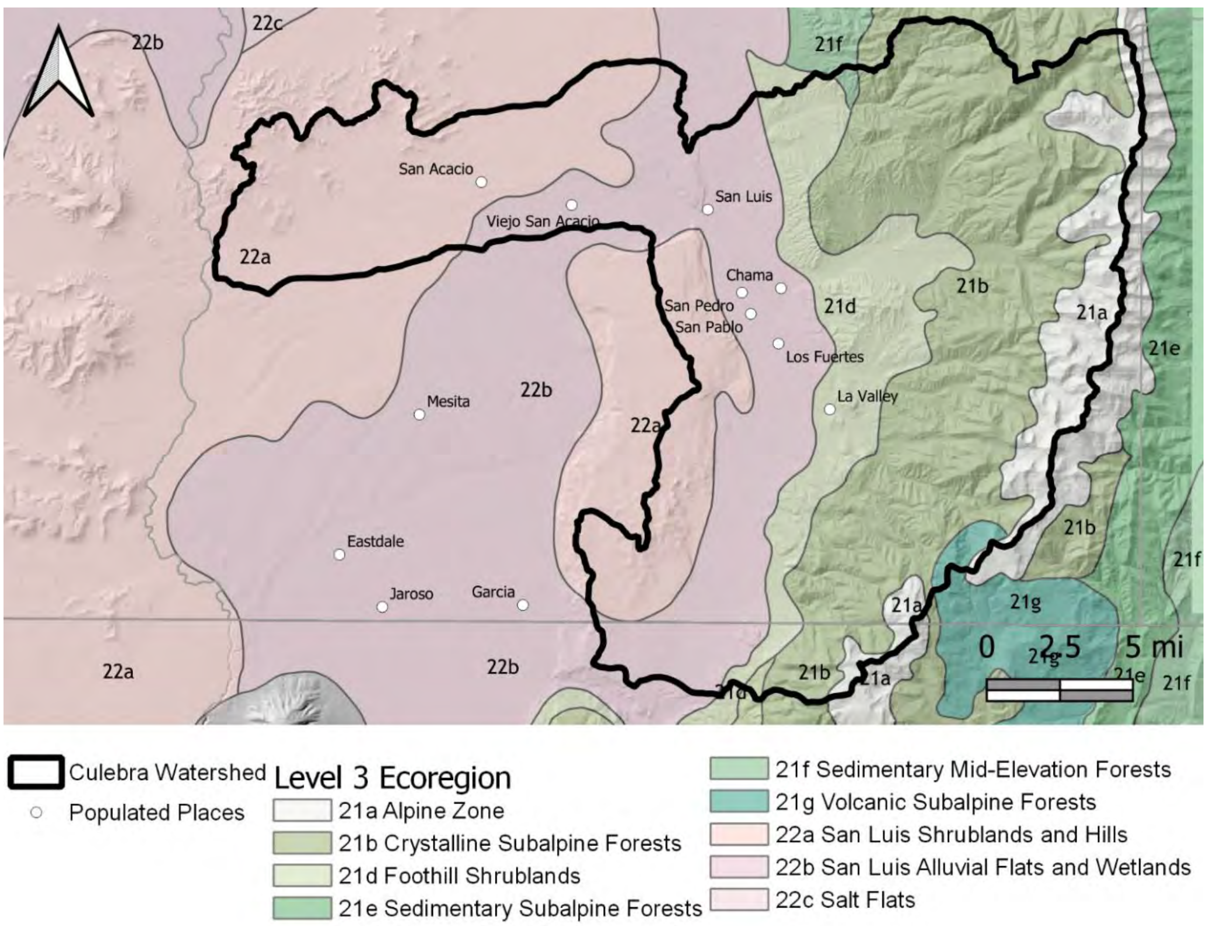


Figure 1-14 Culebra watershed level 4 ecoregions (USEPA).

1.3.7 Transportation

The watershed is intersected by two Colorado State Highways, Highway 159, running north to south from Fort Garland through San Luis and continuing south to Costilla, NM, and Highway 142, beginning in San Luis and running west through San Acacio, until it reaches US Hwy 285 in Romeo (Figure 1-3).

Access is one factor in determining areas within the watershed that are routinely visited by people. Digital street mapping was obtained from the United States Census Line Files (U.S. Census Bureau, 2015). Within the Culebra Basin this digital dataset represented lower basin county roads very well, but poorly represented forest roads and areas that are infrequently traveled. A digital network of roads was developed using the Census Line files as a basis and adding roads, that according to recent aerial imagery, were not delineated, moving roads that were improperly located, and deleting roads that did not exist for use in the assessment. The differences between these two networks are shown in Figure 1-15. These files provide a starting point for building a more complete inventory of roads and could be updated with additional attributes for Safety and Emergency Management Planning.

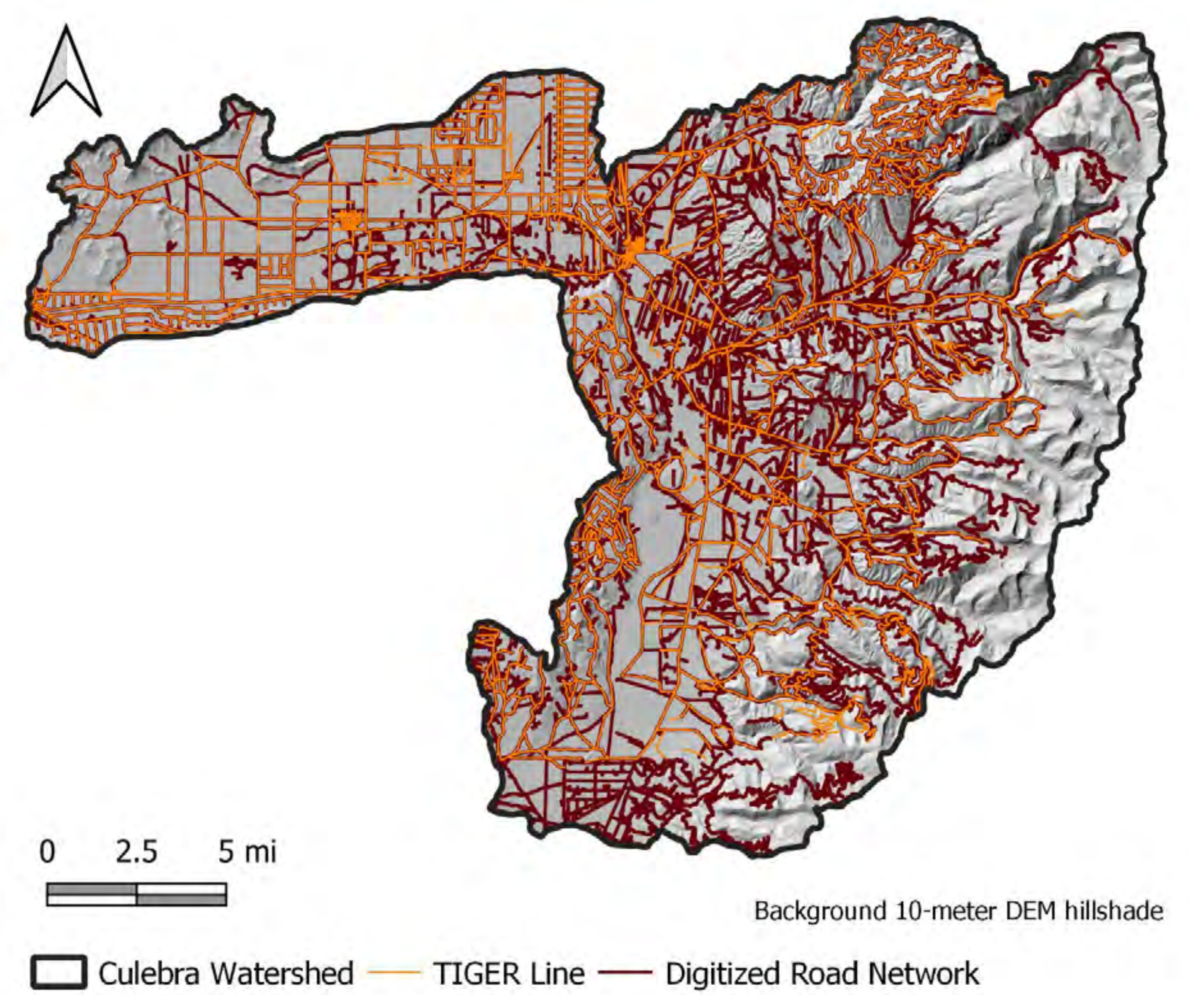


Figure 1-15 Roads and vehicle damaged routes in Culebra Watershed and Tiger Line Files Streets (U.S. Census Bureau, 2015) base map.

1.3.8 Diversion Structure Locations

The first step used to evaluate the diversion structures and ditches was to locate those structures. This task was completed in conjunction with the Flow Regimes task of the assessment. A map of the structures is provided by major tributary in Figure 1-16. The purpose of this map is to compile and document the current location of the actual physical diversion, which in some instances, may not coincide with the decreed point of diversion. Some stream reaches have physically migrated so that the channel is no longer in the same location. The location with respect to section lines may differ from that in the decree due to differences in surveys being referenced and sometimes errors in the originally decreed point of diversion description, differences do not necessarily imply the structure moved. Although significant efforts were taken to develop this map of structures, there may still be errors that need to be corrected in the future. During the development of this shapefile, Colorado Decision Support System files and website (State of Colorado, 2020) (State of Colorado, 2021) were referenced along with acequia locations provided from local archives (Costilla County, 2007). Feedback on locations was requested at the Sangre de Cristo Acequia Association mini-Congreso held on August 20, 2021, and input from knowledgeable persons.

During the assessment it was realized that the locations of the diversion structures were not well documented. Shapefiles that are available from Colorado Decision Support System and previous efforts for the Sangre de Cristo Acequia Association were incomplete and sometimes fraught with errors. GIS parcel information is incomplete for Costilla County, making it challenging to identify whose property the structure is located on to obtain access permission to physically visit the structure.

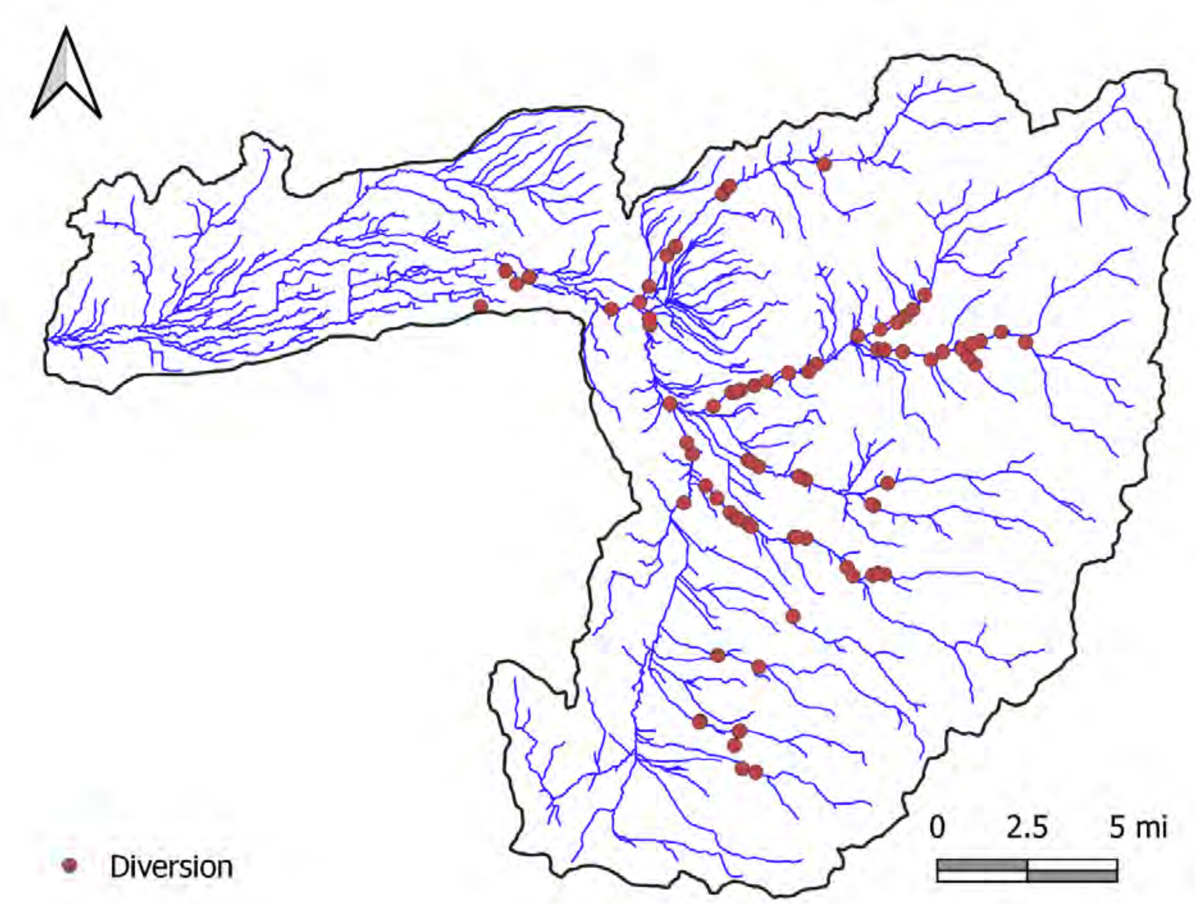


Figure 1-16 Map of diversion structures.

1.4 Sampling Plan Design

Sampling plans and study approaches were compiled for riparian habitat, aquatic habitat, flow regimes, water quality, forest health, historical land use, geology and geomorphology, infrastructure, and safety and emergency management. These documents were provided to the technical advisory representatives via email Friday June 11, 2021, for review. These documents, which provided the basis for field data collection, are provided in Appendix 2.B.

Chapter 2. Riparian Habitat Assessment

Author: AloTerra Restoration Services, LLC

2.1 Introduction

Riparian areas typically occur adjacent to waterways, such as ditches, rivers, and lakes. The soils and vegetation of riparian habitats differ considerably from surrounding areas due to the influence of surface water and groundwater (NRCS, 1996). While riparian areas make up a small portion of habitats in the western US (i.e., less than 1%), they are home to a diverse array of plant species and wildlife, some of which only occur in these areas (NRCS, 1996). In addition to providing essential habitat for wildlife in the form of cover and food, riparian areas also filter out sediment and pollutants by slowing water flow and can minimize the impacts of flooding. Healthy riparian areas can also reduce water temperatures, and provide essential leaf litter into streams, necessary to feed the food chain that supports thriving aquatic life.

The health of riparian areas often depends on the condition of the watershed in which it is found. When a watershed is degraded, the quantity and timing of water into riparian areas can become altered, causing changes in vegetation, habitat structure, the duration of flood events, bank erosion, and other issues (NRCS, 1996). Such changes can result in water moving through the floodplain at a much faster rate, which can reduce the productivity and diversity of the riparian community.

Within the Upper Culebra Watershed, some of the stressors to riparian areas within the watershed include grazing, roadways, logging, and channel incision. Degraded riparian areas can have multiple influences on streams, such as:

- increased stream temperature due to reduced shading,
- excessive sediment loading,
- channel widening or downcutting (i.e., incision),
- change in the amount and diversity of vegetation, and
- lowering of water tables.

2.1.1 Assessment Goals and Objectives

The following three goals were identified for the Riparian Habitat Assessment to guide the development of the assessment to meet the overall watershed assessment goals.

Goal 1 Quantify the degree of degradation of riparian plant communities within the Culebra Watershed.

Goal 2 Develop reference parameters for assessing riparian plant communities within the Culebra Watershed.

Goal 3 Identify strategies for improving riparian plant community health.

Goals	Objectives
Goal 1. Quantify the degree of degradation of riparian plant communities within the Culebra Watershed.	*Objective 1.1* Summarize existing background data. *Objective 1.2* Develop sampling strategy for Culebra Basin that is consistent with project constraints. *Objective 1.3* Collect field data across vegetation life zones to assess degree of degradation. *Objective 1.4* Supplement field sampling with aerial imagery and visual assessment estimate riparian health across perennial streams within the Culebra Basin.
Goal 2. Develop reference parameters for assessing riparian plant communities within the Culebra Watershed.	*Objective 2.1* Identify vegetation life zones for the Culebra Watershed. *Objective 2.2* Evaluate Culebra watershed background data and perform field reconnaissance to identify location of reference plant communities within each vegetation life zones. *Objective 2.3* Perform detailed evaluation of reference plant communities at each reference plant community location.
Goal 3. Identify strategies for improving riparian plant community health.	*Objective 3.1* Summarize assessment data collection to determine factors that could be degrading riparian habitat health within the Culebra Basin. *Objective 3.2* Propose recommendations for improving riparian health within the Culebra Watershed based on experience and reference documentation.

The goal of the Riparian Habitat Assessment was to quantify the level of degradation of riparian plant communities. This was completed using a variety of methods. The following report presents those methods, and synthesis results to inform general management strategies for restoring degraded riparian areas.

2.2 Methods

The assessments were provided in two general classifications: desktop and field. The desktop assessment obtained a variety of existing data, and evaluated that data to generate potential life zones throughout the watershed (i.e., distinct habitats that result from a combination of elevation, climate, and soils), and the quality of riparian habitats within those zones. This was followed by a field assessment, which was used to validate the life zones and the condition of riparian habitats within them. Field methods included a riparian rapid health assessment, visual and aerial surveys, and a more detailed line point intercept method to define reference sites.

2.2.1 Desktop Analysis

Desktop analyses are an efficient way to gather publicly available data regarding a site, and inform field assessments that are necessary to answer important questions about a study area. Field assessments, in turn, fill important gaps in the publicly available data. A search for existing, publicly available data was conducted, and a base map of existing data was prepared. The following geographical information system (GIS) data were cross-referenced as part of the desktop analysis:

- National Land Cover Data (NLCD),
- Level IV Ecoregions (EPA, 2012),
- Eagle View aerial imagery,
- LiDAR/elevation data, and

- National Hydrography Dataset (NHD) (USGS, 2020).

From the above data, a preliminary estimate of vegetation life zones was provided, including alpine, subalpine, montane, foothills, and sagebrush steppe/valley bottom. The Level IV Ecoregion data (EPA, 2012) and hydrogeomorphic (HGM) river classifications (Cooper D. , 1998) were reviewed to establish a classification system and sampling strategy. However, the Level IV Ecoregion data did not line up well with the distribution of life zones encountered in the watershed. In addition, the HGM definitions of riverine areas were not detailed enough to provide a clear classification system of riparian areas within the watershed.

Following the desktop analysis, and a preliminary field assessment, the distribution of life zones was modified based on professional experience, combined with Ackerfield (2015) life zone elevation data for Colorado. The estimated distribution of vegetation life zones was mapped using GIS software and was used as a base map for final field assessments. Following field assessments, the elevation and spatial distribution of vegetation life zones was further modified, to reflect observations on the ground.

Ultimately, six vegetation life zones were identified within the watershed: alpine, subalpine, montane, foothills, foothills willow, and sagebrush steppe/valley bottom (Figure 2-1).

Delineations between the six life zones were made via observations of dominant plant species and the vertical structure of canopy cover. Table 2-1 describes the main characteristics of each life zone and dominant species (Ackerfield, 2015).

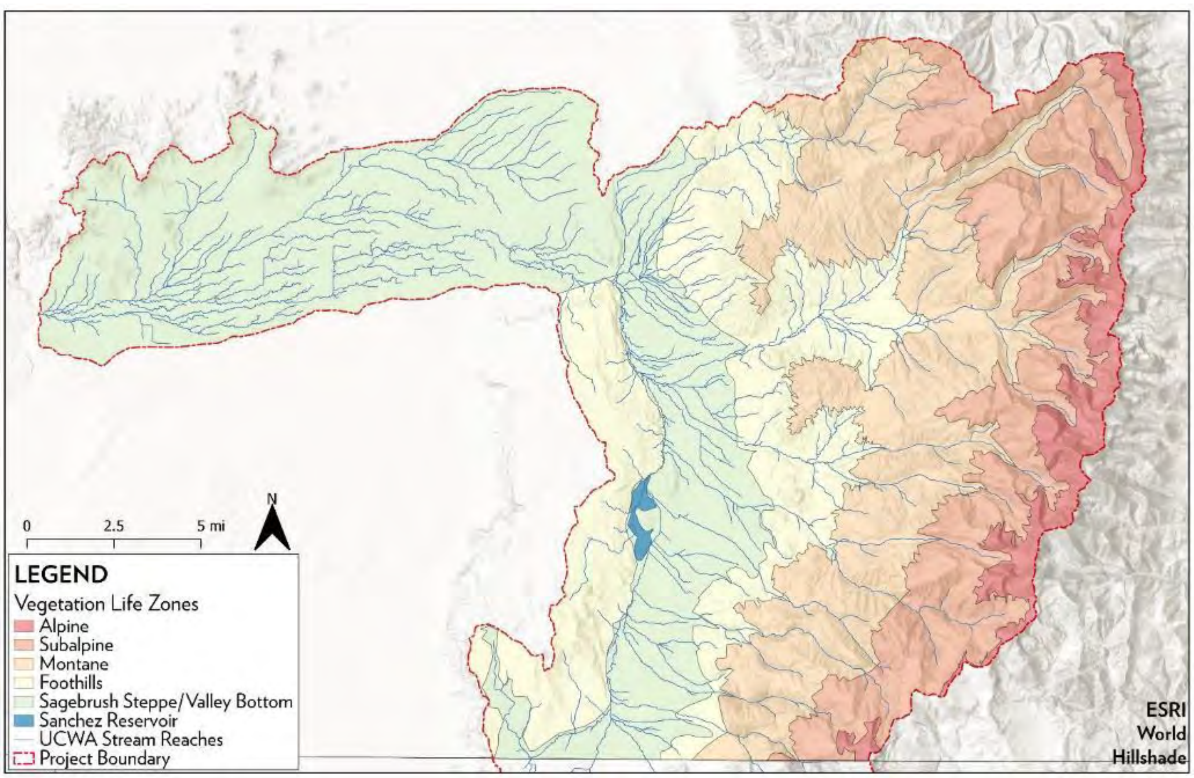


Figure 2-1. Vegetation life zone distributions throughout the Upper Culebra Watershed.

Table 2-1. Characteristics of vegetation life zones found in the Upper Culebra Watershed.

Vegetation Life Zone	Main Characteristics	Dominant Plant Species
Alpine	Little to no canopy layer, dominated by grasses, sedges, rushes, and perennial forbs.	tufted hairgrass alpine timothy alpine meadowrue Whipple's penstemon dwarf clover
Subalpine	Dominated by pine, spruce, and fir trees. Trees in this zone can be shorter than normal or warped in shape due to high winds.	Engelmann spruce subalpine fir marsh marigold buttercups sedges whortleberries
Montane	Riparian areas are dominated by mixed conifer forests, as well as aspens. Herbaceous layers are lush and species rich.	lodgepole pine common juniper Geyer's sedge Oregon grape aspen
Foothills Willow	Riparian areas are dominated by thick, tall, stands of multiple willow species. Shade tolerant grasses and forbs typically grow under the willow canopy.	coyote willow shining willow mountain willow narrowleaf cottonwood sedges
Foothills	Diverse canopy layers that are dominated by pine and juniper species. These areas tend to be drier with the riparian areas being rockier.	pinyon pine ponderosa pine lanceleaf cottonwood sagebrush beardtongue's aster's western wheatgrass narrowleaf cottonwood
Sagebrush Steppe/ Valley Bottom	Landscape is either flat or with rolling hills. Various sagebrush species dominate the area, with little canopy cover taller than 7'. Perennial and annual forbs and grasses fill in the gaps between sagebrush shrubs.	sagebrush blue grama Indian paintbrush scarlet globemallow rabbitbrush oatgrasses bromegrasses

2.2.2 Field Methods

Field data was gathered using three methods, which together allowed for the efficient sampling of the majority of creeks in the watershed: reference site assessments, rapid health assessments, and visual/aerial assessments. These methods are described below.

2.2.2.1 Reference Sites

Reference sites provide an estimate of the pristine (i.e., undisturbed) condition of a particular habitat, and are useful to compare degraded conditions to the expected undisturbed conditions for a particular project. For this project, at least one reference site was identified and analyzed within each life zone (Figure 2-2).

Alpine Reference Site

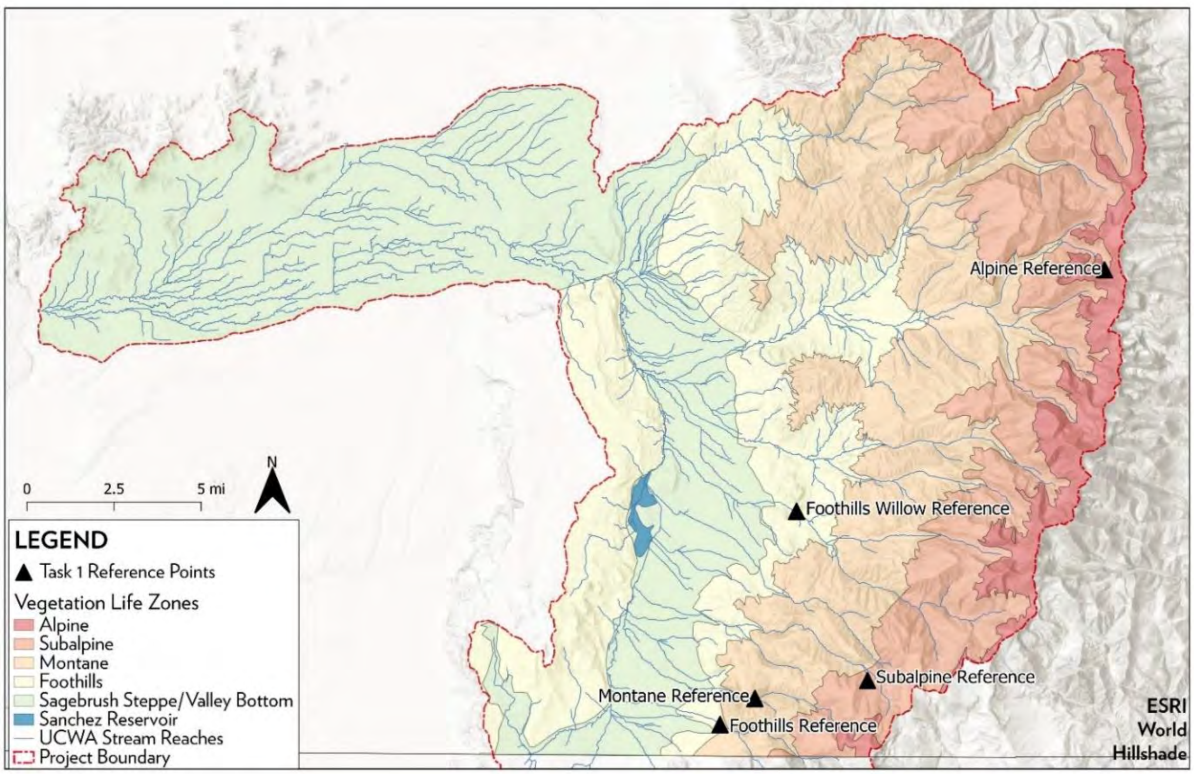


Figure 2-2. Location of reference sites within UCWA. Adequate reference not available for sagebrush steppe/valley bottom.

Several potential reference sites were identified from aerial imagery. During the pre-assessment site visit, final reference sites were determined based on the level of human disturbance at each site, the presence of non-native plant species, and the species richness and structural diversity of the site relative to an expected undisturbed condition. Due to the high level of vegetation and soil alteration of riparian areas in the sagebrush steppe/valley bottom life zone, we were unable to identify an adequate reference area within the watershed for this riparian type. All other life zones contained an adequate reference site.

The line point intercept (LPI) method (Elzinga, 2001) was used to collect cover data at reference sites. The LPI method was completed using a tripod with a periscope for measuring canopy cover, and a laser for measuring ground cover (Figure 2-3). This method provides objective and repeatable sampling for each reference site, reducing bias to data collection. At each reference site, 100-meter long transects were established and sample point data was collected every meter. At each sample point, cover was assessed for herbaceous vegetation, low shrubs, medium shrubs/trees, tall trees, overstory canopy, and groundcover conditions (Table 2-2).

Species that were present within a 2-meter wide “belt transect” along the LPI transect were also recorded, to document those species not encountered with laser points, and are therefore less common.

Table 2-2. Definitions for cover types collected at each meter for LPI assessments.

Cover Type	Definition
Herbaceous vegetation	Non-woody species less than 3’ tall
Low shrubs	Woody species 3-5’ tall
Medium shrubs/trees	Woody species 5-15’ tall
Tall trees	Woody species 15-30’ tall
Overstory canopy	Woody species >30’ tall
Ground surface conditions	Bare ground, rock, litter, downed wood

2.2.2.2 Rapid Health Assessments

Rapid Health Assessments (RHA) provide a balance between efficient data collection and data accuracy, in order to cover the assessment needs of a large watershed such as Culebra. Random sample points were generated via GIS within each life zone (Figure 2-4), where a Rapid Health Assessment would be conducted. Sampling points overlapped with aquatic habitat assessments where possible. Some of the RHA points were changed to visual or aerial assessments in the field due to access issues, the site did not support a riparian area, or for other reasons.

Figure 2-3. Tripod with mounted periscope and laser for LPI sampling.

At each sample point, several observations were taken, in distinct categories, to understand the condition of the site: channel bed, streambanks, degree of floodplain erosion, riparian vegetation in multiple zones within the floodplain (e.g., bank, overbank, and transition), percent of native species, degree of structural diversity, and floodplain impacts (e.g., channel constrictions and floodplain intrusions). Each variable was compared to the reference condition using a rating of 1 through 5, with 1 being non-functioning (i.e., severely degraded) and 5 being the reference standard. Table 2-3 provides a definition of the functional ratings.

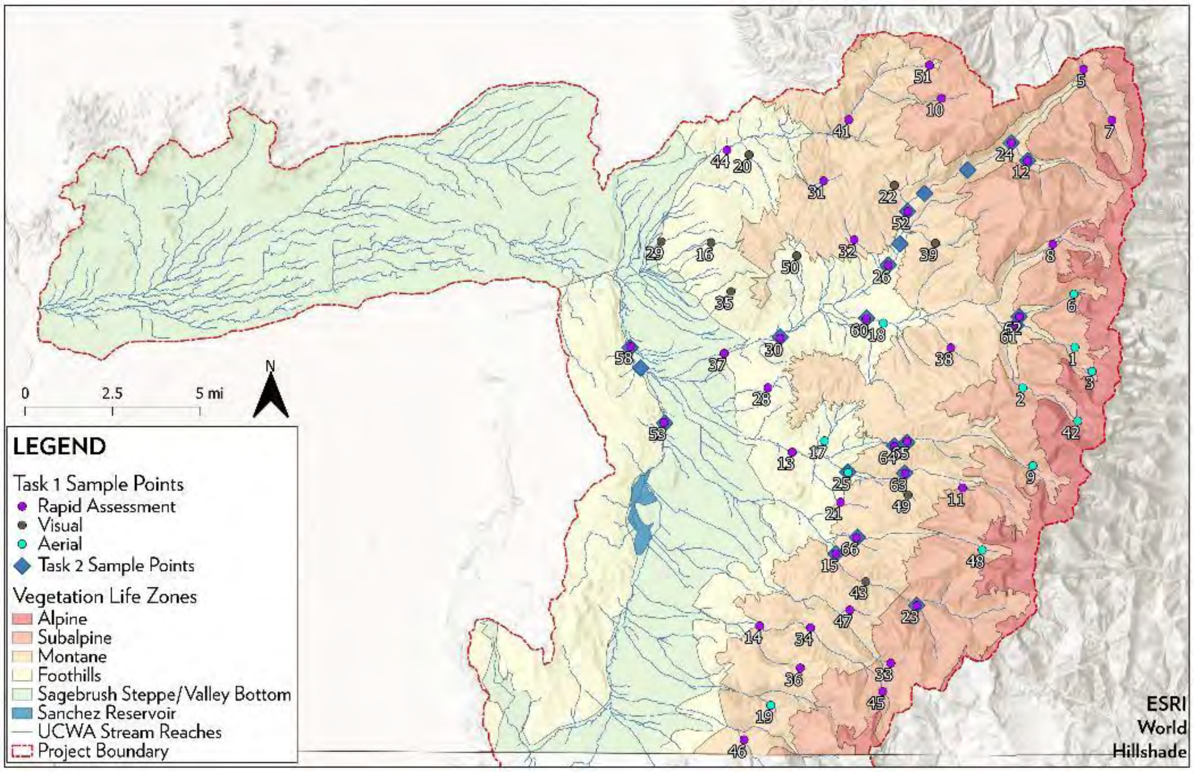


Figure 2-4. Sample point location and type within UCWA.

Table 2-3. Rating classes and definitions.

Rating	Class	Definition
5	Reference Standard	Condition of the variable is self-sustaining and supports functional characteristics appropriate to sustain river health. Limited management to sustain and protect this level of function given stressors from the modern landscape.
4	Highly Functioning	The site can maintain essential qualities that support a high level of ecological function, yet there is some influence of human disturbance at a detectable, yet minor, level. Those stressors vary depending on the variable being measured. Requires some limited management to sustain desirable habitat qualities.
3	Functioning	The condition of the variable has been altered and/or degraded by stressors that influence the variable's functionality. The variable still supports basic, natural, riparian functioning. Management is required to support maintenance of the characteristic functional role of the variable.
2	Functionally Impaired	The condition of the variable is severely altered by stressors that impair its ability to support characteristic functioning and the overall health of the area. Extensive, active management is required to support maintenance of this variable.
1	Non-functioning	The condition of the variable is under the influence of massive alterations/stressors. The level of alteration results in an inability of the variable to support characteristic functioning, or it otherwise makes the area poorly functioning.

2.2.2.3 Visual and Aerial Surveys

In addition to reference site surveys and Rapid Health Assessments, visual and aerial surveys were completed (Figure 2-4) for creek reaches where direct observations were not possible due to private property constraints, access constraints, etc. When combined with the sample assessments, the visual and aerial surveys allowed the riparian assessment to be mapped in a larger portion of the watershed than would have otherwise been possible with the resources available.

Visual surveys were mainly conducted from vehicles. Using Avenza Maps on iPads, surveyed stream reaches were hand digitized onto maps and given a rating of 1 through 5. Aerial surveys (i.e., visual analysis of aerial imagery) were used to assess reaches that were not easily accessible by foot or vehicle, such as remote alpine areas, and private property that was not observable from a nearby road. We used imagery from Eagle View to classify these areas with the same 1 through 5 rating system as was used in the RHA assessments.

2.2.3 Data Analysis

Data from the above methods was analyzed in a number of ways to provide a breadth of information from which management decisions could be made. Besides the general outputs from the RHA evaluation and aerial surveys, the diversity of riparian areas was calculated for riparian areas in all life zones. Biological diversity is a significant contributor to the resilience of an ecosystem, and is closely related to its productivity (i.e., how much plant material/biomass is produced each year). While we did not measure the diversity of wildlife, there is a very strong correlation between the diversity of vegetation and the diversity and abundance of wildlife in a given area. High vegetation diversity supports healthy riparian systems, because multiple functions are being provided. Functions include a) bank and floodplain stability, provided by deep rooted shrubs, trees, and herbaceous vegetation; b) food for wildlife, including pollinators; c) soil fertility provided by nitrogen-producing plants and organic matter inputs; and d) increased resilience against drought, insects, floods, disease, and other natural disturbances (Kimmins, 1997).

Table 2-5 Growth habit codes and definitions.

Growth Habit	Definition
Perennial	lives for 2+ years, usually has a fibrous or rhizomatous root system
Annual	lives for 1 year, usually has a taproot root system
Biennial	takes two growing seasons to reproduce
Grass and Grass-like	grasses, sedges, and rushes
Forb	broadleaf plant that is not a grass, sedge, or rush

Given the importance of diversity, data analysis included a few basic forms of diversity, such as richness (i.e., the number of plant species within an area), functional diversity (i.e., the presence of various life history traits of plant species), structural diversity (i.e., the presence of multiple layers of vegetation, including tree cover, shrub cover, and herbaceous cover), and the number of native species versus non-native species (e.g., Floristic Quality). Life history trait definitions and photo examples can be found below (Table 2-4, Table 2-5, and Figure 2-5).

Cover data from reference sites was analyzed to provide richness, species diversity, and structural diversity. Specific measures included absolute cover by species, relative cover by life history trait, and basic statistics of these measures.

Table 2-4. Life History Trait codes and definitions.

Code	Life History Trait
NPF	Native perennial forb
NAF	Native annual forb
NBF	Native biannual forb
NPG-L	Native perennial grass and grass-like
NAG-L	Native annual grass and grass-like
NS	Native shrub
NT	Native tree
IPF	Introduced perennial forb
IAF	Introduced annual forb
IBF	Introduced biannual forb
IPG-L	Introduced perennial grass and grass-like
IAG-L	Introduced annual grass and grass-like
IS	Introduced shrub
IT	Introduced tree

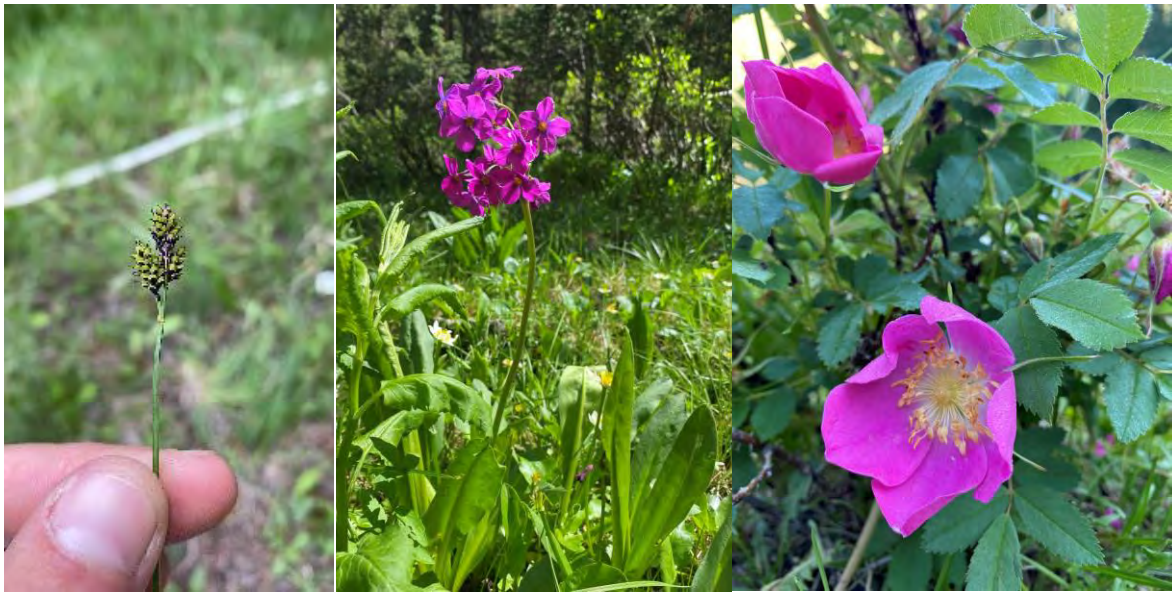


Figure 2-5. Examples of different life history traits found in UCWA. From left to right: Sedge- NPG-L, Parry's primrose- NPF, Wood's rose- NS.

Species richness and evenness was estimated using the Shannon Diversity Index (Shannon, 1948). Species evenness is the relative abundance of species within a community (Shannon, 1948), while the combination of richness and evenness provides the formal measure of diversity. The higher the Shannon Diversity Index, the higher the diversity.

Floristic Quality Index (FQI) was also calculated for each reference site. This index was developed by the Colorado Natural Heritage Program (CNHP) to measure the nativity of vegetation, as well as the relative "commonness" of the species present. FQI summarizes nativity using a "coefficient of conservatism (C)," and assigns each plant species a C value of 0 through 10, with 10 indicating those species that are only found in pristine areas. Those plant species that are never found in pristine areas are given a zero (Smith P. G., 2020). A Mean C was calculated from the species data gathered in each riparian point, indicating the level of disturbance for that site (Smith P. G., 2020).

Table 2-6. C-value ranges as defined by (Smith P. G., 2020). Natural areas = areas with little to no disturbance, pristine; Non-natural = areas that have been altered by human influence, have visible disturbance or degradation.

C-value	Interpretation
0	Non-native species
1-3	Commonly found in non-natural areas
4-6	Equally found in natural and non-natural areas
7-9	Mainly occur in natural areas, but can withstand some habitat degradation
10	Only occur in high quality natural areas

FQI scores are directly correlated to Mean C. A high FQI score (i.e., C values are 7 or higher, Table 2-6) implies a high conservation priority, because the site is dominated by plant species that are typically found in pristine areas (Rocchio, 2007). Because FQI scores are so tightly correlated with species richness, an Adjusted FQI formula was created, which includes non-native species in addition to native species.

$$Mean\ C = \Sigma Ci \div N$$

C = C values; I = individual native species; N = native species richness

$$Adjusted\ FQI = \left(\frac{\overline{C}}{10} \times \frac{\sqrt{N}}{\sqrt{S}}\right)$$

C = average C values; N = native species richness; S = native + non-native species richness; 10 is the maximum C value that can be given to a species

Rapid Health Assessment data was evaluated by site and by tributary. An overall average was calculated for all variables for each site. In addition, a weighted average was calculated, to take into account the channel incision and floodplain intrusions, which were weighted by x2 and x1.5, respectively. This weighting was applied due to the considerable influence these parameters have on the overall health and function of riparian systems.

$$Overall\ Average = \frac{Sum\ of\ Tributary\ Averages}{Number\ of\ RHA\ Points\ in\ Tributary}$$

$$Overall\ Weighted\ Average = \frac{Sum\ of\ Tributary\ Weighted\ Averages}{Number\ of\ RHA\ Points\ in\ Tributary}$$

Rapid health assessment scores were cross referenced with visual and aerial scores to ensure ratings were consistently applied within each reach.

The rapid health assessments, visual surveys, and aerial data were used to develop health rating maps across the watershed, providing a visual snapshot of the variation in the health of riparian areas. Each rating is color coordinated, with red indicating those reaches with the lowest health (ratings between 0 and 1.5), indicating the highest priority for restoration and other management efforts. Reaches that are green (ratings between 4 and 5) are close to reference conditions, which do not require any active restoration treatments.

2.3 Results

The results for the Riparian Habitat Assessment start with the reference sites, followed by the rapid health assessment results, and concluding with the visual and aerial assessments.

2.3.1 Reference Site Results

Reference site results are presented by characteristic measured so that each of the life history categories may be compared. The results are presented as life history categories first followed by structural diversity and concluding with plant diversity, richness, and floristic quality.

2.3.1.1 Life History Categories

In the reference sites, the relative cover of native perennial forbs (NPF) was higher than the relative cover of any other life history category (Figure 2-6). Native species dominated the woody canopy strata (e.g., shrub, tree, overstory, etc.) in all reference sites. The only site where the understory (herbaceous) vegetation was dominated by non-native species was the foothills willow reference. This was not a surprise, as the herbaceous vegetation of lower elevation areas across most of Colorado are highly impacted by non-native species, making a pure reference site near impossible to obtain. That said, the high degree of native cover in all other strata across all sites is an indicator that these sites are relatively undisturbed and highly functioning.

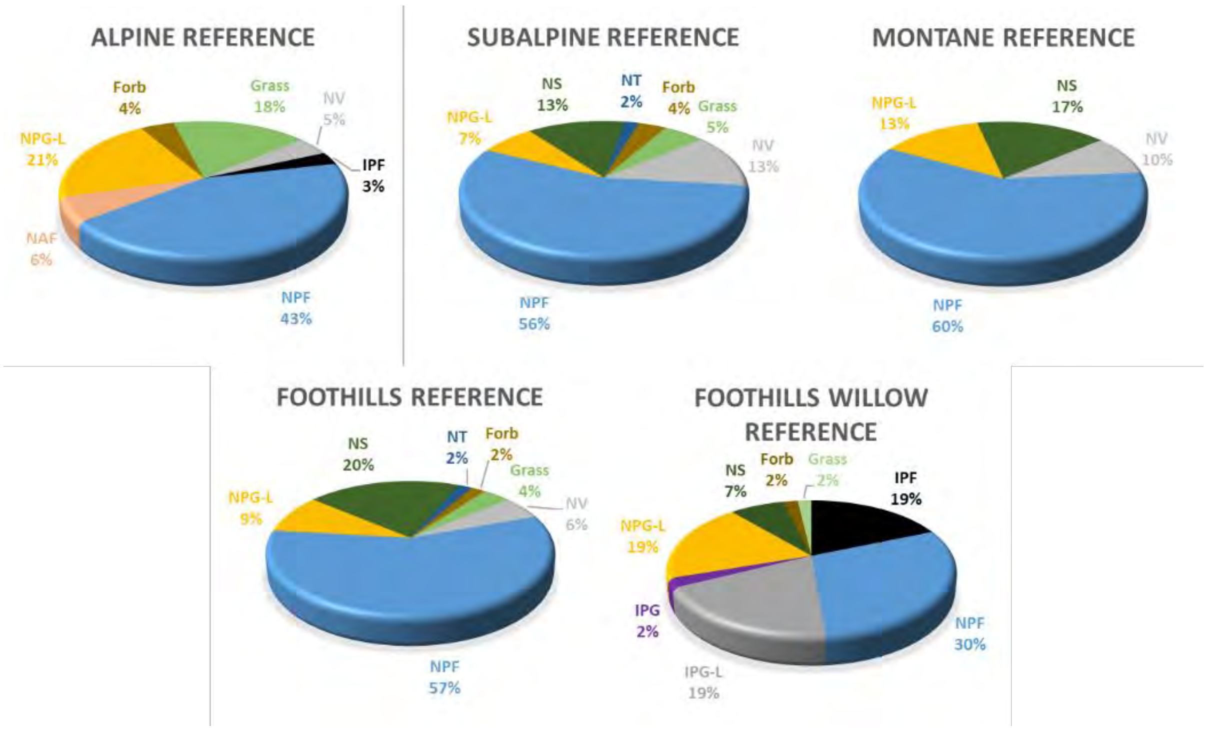


Figure 2-6. Percent relative cover by life history trait for each reference site.

Codes for Life History Traits:

NPF=native perennial forb, NAF=native annual forb, IAF=introduced annual forb, NPG-L=native perennial grass and grass- like, NAG-L=native annual grass and grass-like, IPG= introduced perennial grass, NS=native shrub, NT=native tree, Forb=unidentified forb species, Grass=unidentified grass species.

2.3.1.2 Structural Diversity

Except for the alpine reference sites, all reference sites had high structural diversity. That is, the riparian areas had a high occurrence of herbaceous cover, shrub cover, tree canopy cover, and overstory cover.

The type and degree of canopy cover varied between reference sites, which was expected (Figure 2-7). Foothill's willow was dominated by low shrub species, while subalpine, montane, and foothills sites were dominated by overstory canopy species. The same overstory trees were present throughout the forested portions of the watershed, including aspen (*Populus tremuloides*), Douglas fir *(Pseudotsuga menziesii var. glauca*), alder (*Alnus incana*), white fir (Abies concolor), Engelmann spruce (*Picea engelmannii var. engelmannii*), and cottonwoods (*Populus angustifolia and P. deltoides*). However, plains cottonwood was found only in the lower elevation reference sites (i.e., foothills and foothills willow). The alpine reference, as expected, is dominated by herbaceous species, with no higher canopy strata present. The LPI field data sheets are included in Appendix 3.A. A full list of species observed during the assessment can be found in Appendix 3.C.

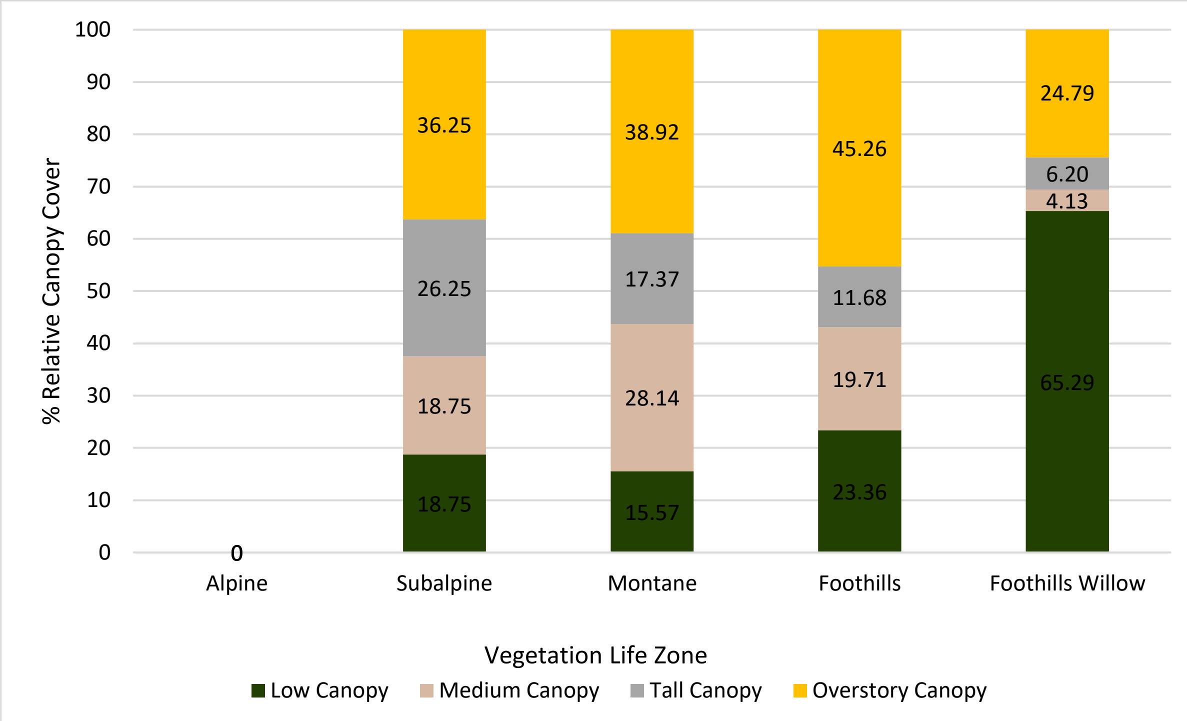


Figure 2-7. Percent relative cover of canopy strata by reference site.

Canopy Definitions:

Low canopy = shrubs/trees 3-5’, Medium canopy = shrubs/trees 5-15’, Tall canopy = trees 15-30’, Overstory canopy = trees >30’

2.3.1.3 Plant Diversity, Richness, and Floristic Quality

The Foothills Willow reference site had the highest plant diversity, while the Montane reference had the lowest diversity (Figure 2-8). The total number of species (i.e., richness) documented in the Foothills Willow reference site was 48, versus 45 total species documented in the Montane reference site. The Alpine reference site had the highest species richness, at 50 species (Figure 2-8). Due to the limited time (one sampling per season, instead of two or three), and the limited number of samplings, these data are likely an under-representation of richness and diversity in the reference areas.

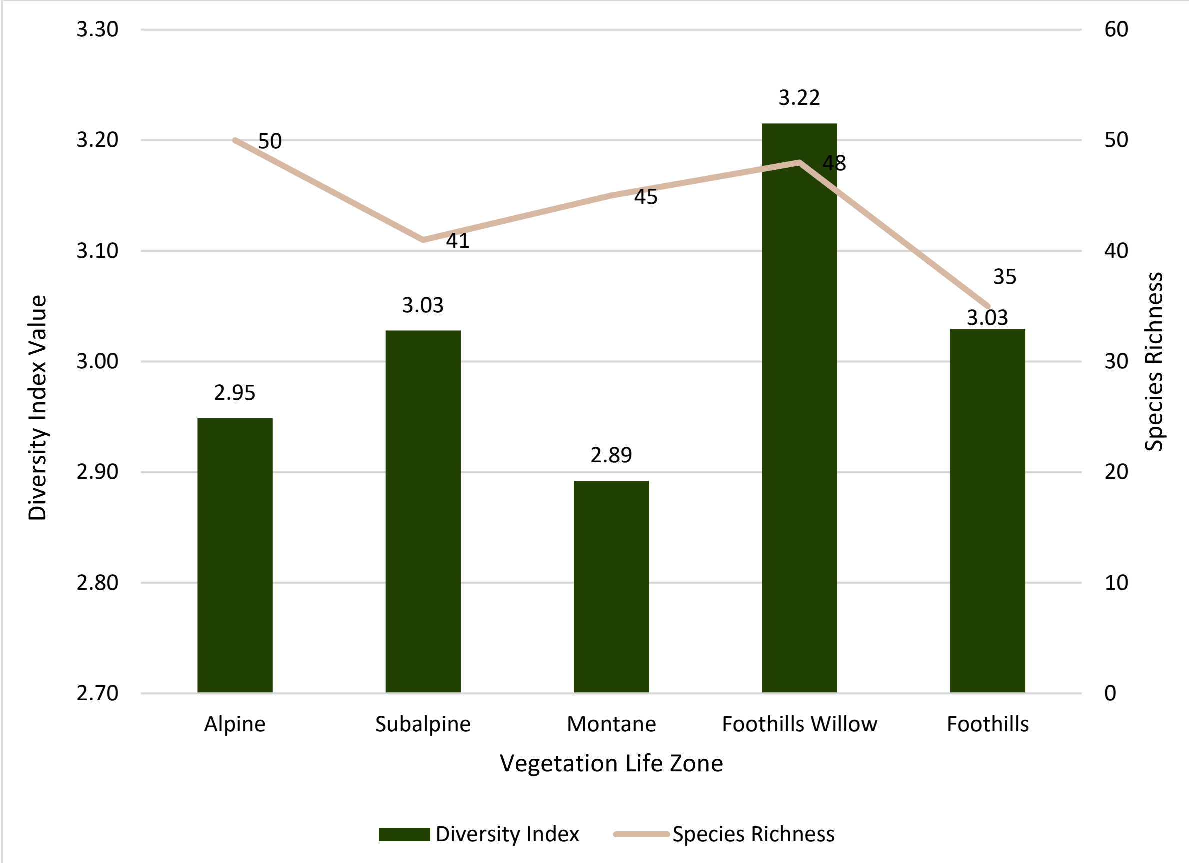


Figure 2-8. Shannon Diversity Index and evenness of each reference site.

The alpine reference had the highest Mean C and Adjusted FQI (Figure 2-9), implying a low level of disturbance. In contrast, the foothills willow reference site had the lowest Mean C and Adjusted FQI (Figure 2-9), implying a higher level of disturbance. Although the foothills willow reference site had the highest species richness, much of that richness was comprised of non-native species, which caused a lower Adjusted FQI score.

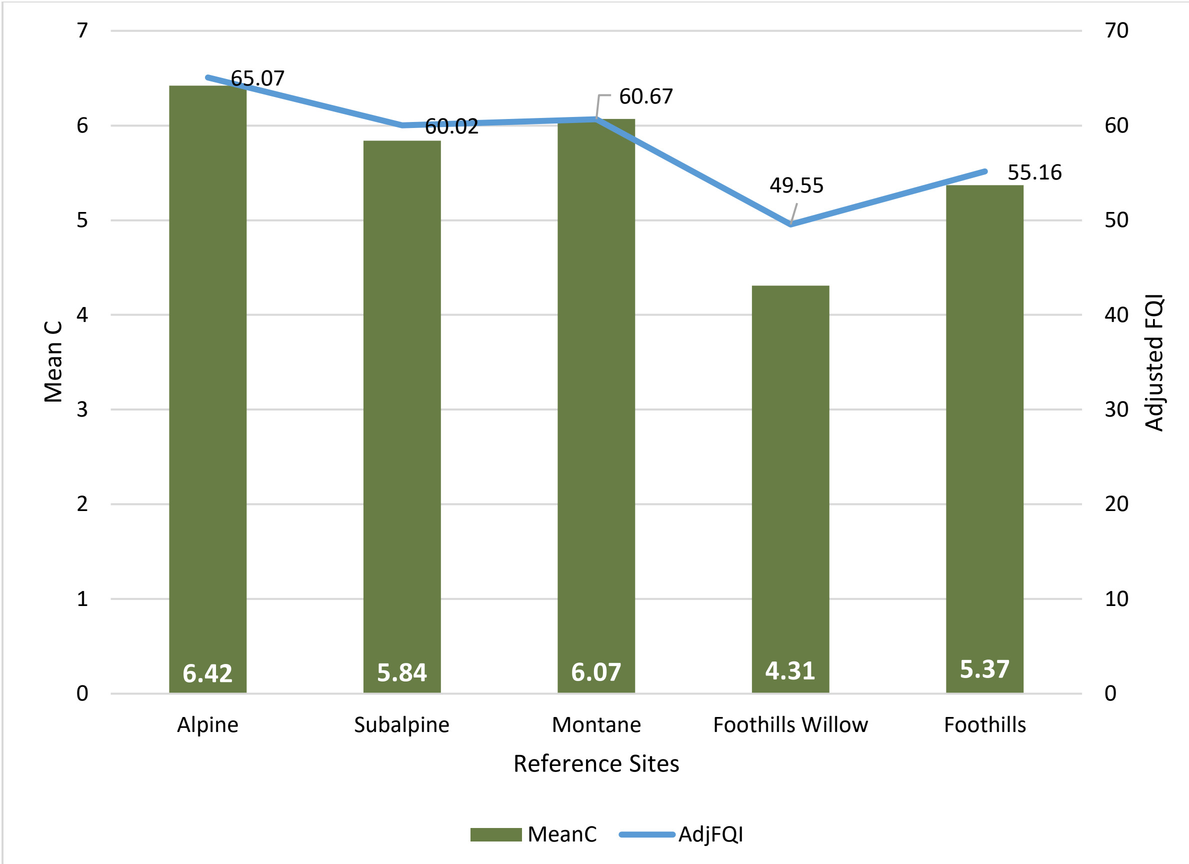


Figure 2-9. Mean conservation coefficient (Mean C) with associated Adjusted Floristic Quality Index (FQI) score for each reference site.

2.3.2 Rapid Health Assessment Results

A total of 38 sites were sampled using the rapid health assessment. The average score for all riparian areas within the Upper Culebra watershed was 4.09. While this implies a relatively healthy watershed in general, multiple reaches and creeks within the watershed had a very low rating (Table 2-7).

Table 2-7. Ratings for Rapid Health Assessment (RHA) Points organized by tributary. Delta is the difference between the weighted average and original average scores (Delta = Weighted Average-Average).

Creek Name	RHA Point	Average	Weighted Average	Delta	Veg Community
El Poso Overall Average= 4.28 Overall Weighted Average= 4.31	5	4.95	4.96	0.01	Subalpine
	7	3.91	3.85	-0.06	Subalpine
	12	4.96	4.96	0.01	Montane
	24	4.42	4.46	0.05	Montane
	26	3.92	4.00	0.08	Foothills
	52	3.50	3.64	0.14	Foothills
Culebra Overall Average= 4.31 Overall Weighted Average= 4.12	8	5.00	5.00	0.00	Montane
	30	2.89	2.96	0.08	Foothills
	37	2.86	2.88	0.01	Foothills
	38	4.36	4.35	-0.02	Montane
	58	3.21	3.39	0.18	Sagebrush
	60	4.67	4.71	0.05	Foothills
	61	4.64	4.69	0.06	Montane
	62	5.00	5.00	0.00	Montane
Jaroso Overall Average= 3.76 Overall Weighted Average= 3.64	14	2.59	2.54	-0.05	Foothills
	34	3.41	3.31	-0.10	Montane
	36	4.10	3.81	-0.29	Montane
	45	4.95	4.92	-0.03	Subalpine
Rito Seco Overall Average= 3.15 Overall Weighted Average= 3.11	10	4.91	4.92	0.01	Subalpine
	31	1.48	1.40	-0.08	Montane
	41	3.14	3.13	0.00	Montane
	44	2.23	2.23	0.00	Foothills
	51	4.00	3.85	-0.15	Montane
San Francisco Overall Average= 4.38 Overall Weighted Average= 4.37	15	3.59	3.58	-0.01	Montane
	23	4.55	4.54	-0.01	Subalpine
	66	5.00	5.00	0.00	Montane
Torcido Overall Average= 4.95 Overall Weighted Average= 4.96	33	5.00	5.00	0.00	Subalpine
	47	4.91	4.92	0.01	Montane
Vallejos and N. Vallejos Overall Average= 4.48 Overall Weighted Average= 4.53	11	4.88	4.88	0.00	Montane
	63	3.86	3.96	0.10	Montane
	64	4.67	4.71	0.05	Montane
	65	4.50	4.58	0.08	Montane
Willow Overall Average= 4.91 Overall Weighted Average= 4.88	46	4.91	4.88	-0.02	Montane

2.3.3 Visual and Aerial Assessment Results

The ratings from visual and aerial assessments were averaged for each reach (Table 2-8 and Figure 2-10). Areas around the Sanchez Reservoir, and creeks in the sagebrush steppe/valley bottom and the lowest rating indicating areas of highest human impacts.

When considering the RHA and Aerial/Visual assessment data as an entire dataset, several creeks were identified for active management. Those creeks that are non-functioning (1.99 or lower) or functionally impaired (2.00 to 2.99) are the highest priority for active restoration, such as to provide the riparian and watershed benefits listed above. These creeks include Ventero, Vallejos, El Pedegroso, Culebra Creek, and reaches immediately above and below Sanchez Reservoir.

Those streams that are rated as functioning (3.00 to 3.99) may require a combination of passive restoration and other management treatments, described generally below. Streams that scored 4.0 or higher should be protected from future human impacts, in order to maintain the watershed benefits they are currently providing.

Table 2-8. Average ratings, by reach, from visual and aerial assessments.

Creek Name	Average Rating
Alamosito	4.37
Bernardino	4.75
Carneros	4.70
Chucilla Alta	4.00
Cuates	4.20
Culebra	2.52
El Fragroso	5.00
El Pedegroso	2.88
El Perdido	5.00
El Poso	3.83
El Rito de Aban	4.00
El Valle	3.68
Jaroso	3.47
North Vallejos	3.59
Rito Agua Azul	3.50
Rito Seco	3.33
San Francisco	3.53
Sanchez Reservoir	1.00
Torcido	4.00
Ventero	1.38
Vallejos	2.88
Willow Creek	5.00

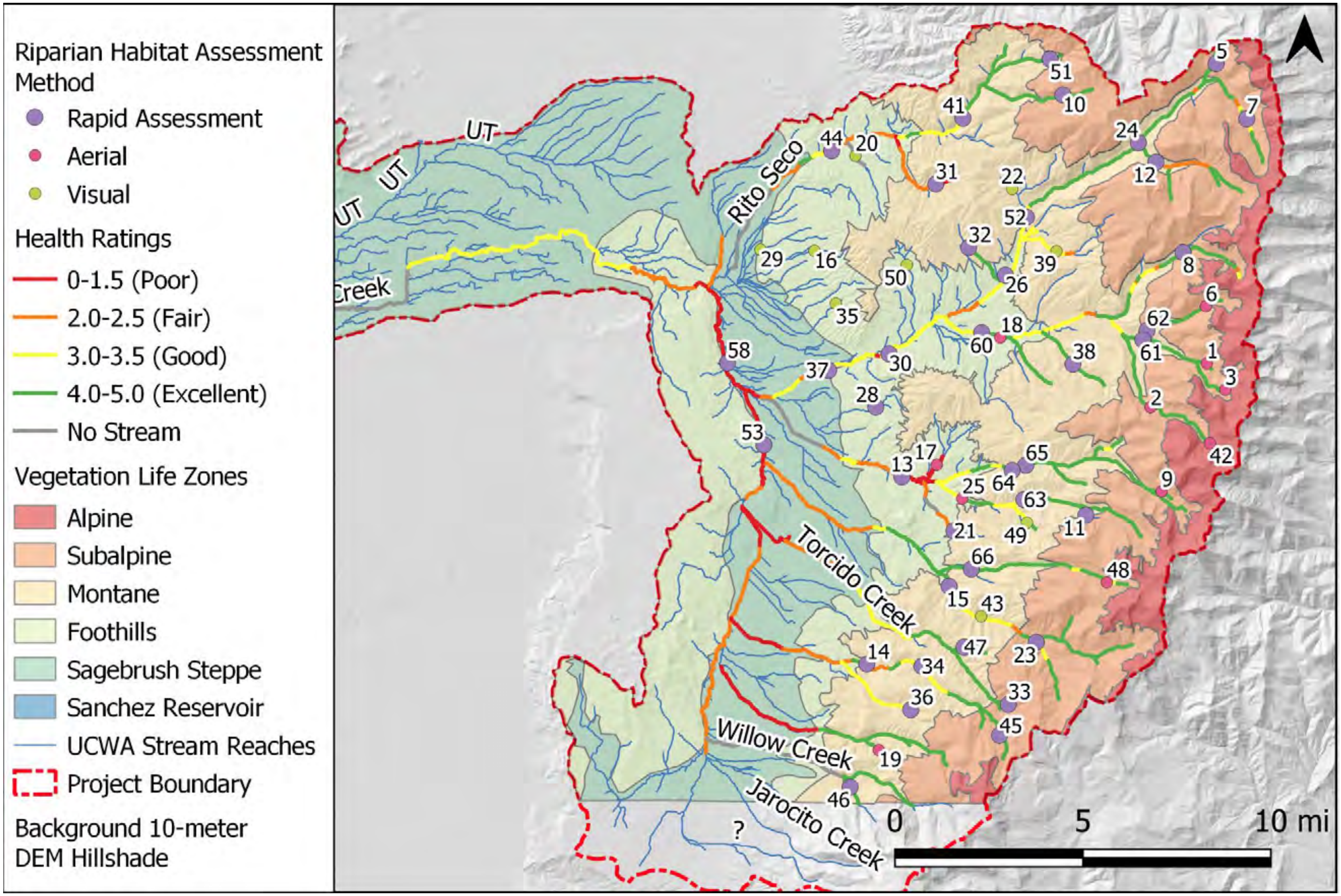


Figure 2-10. Health Ratings Map for entire watershed.

2.3.4 Health Rating Maps by Tributary

The overall health ratings for each tributary are provided within this section.

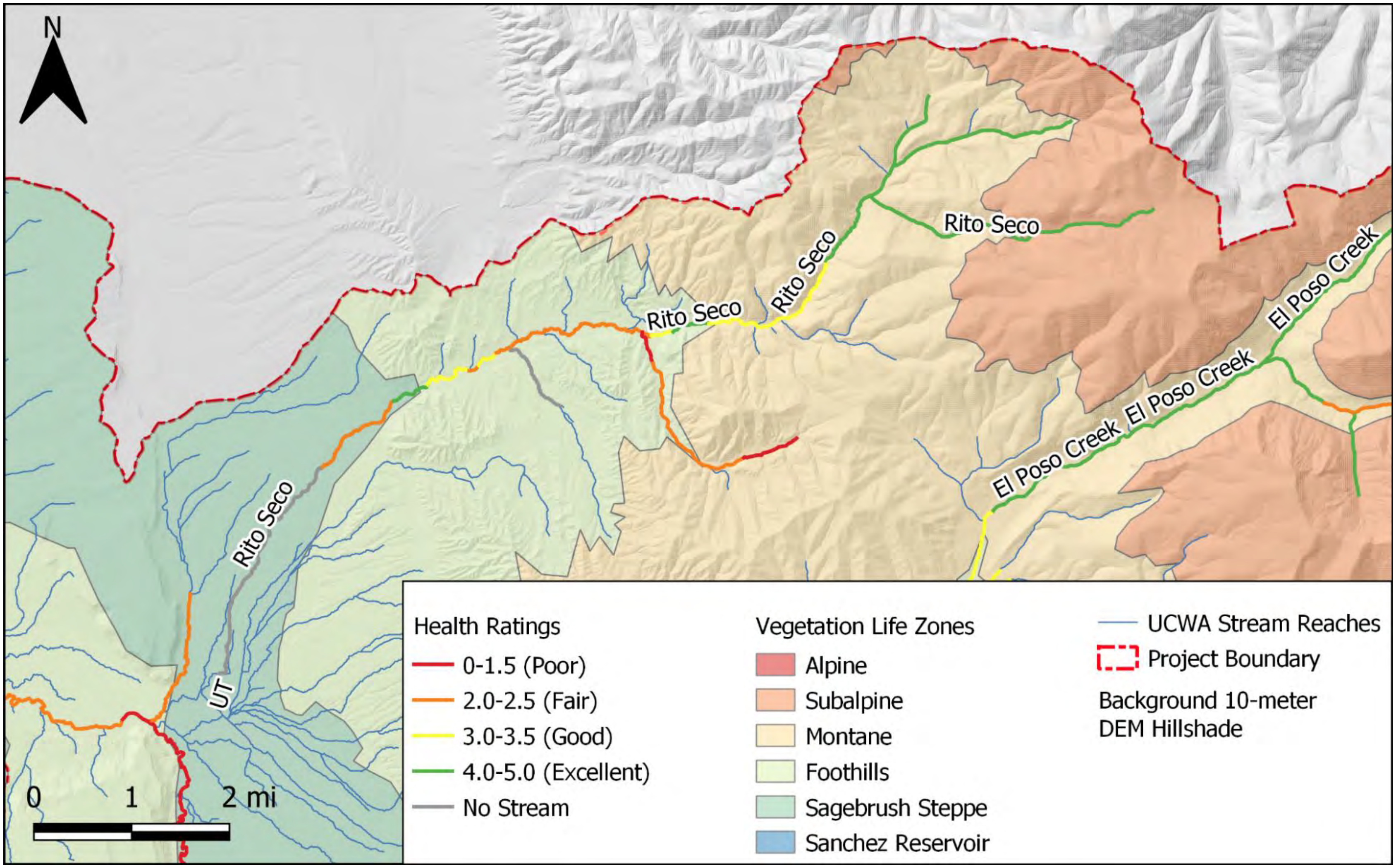


Figure 2-11 Rito Seco riparian health rating map.

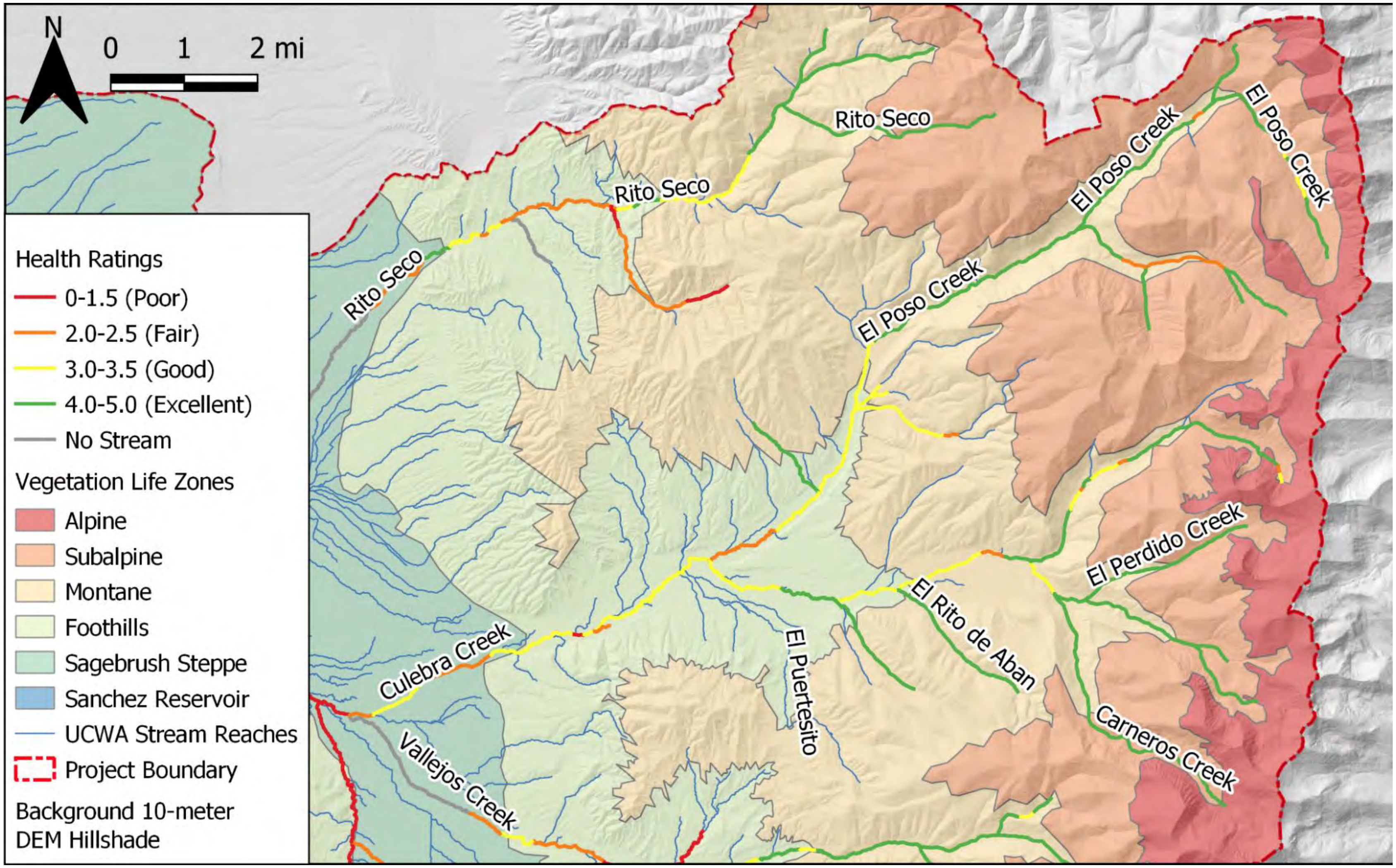


Figure 2-12 El Poso and Upper Culebra Creek riparian health rating map.

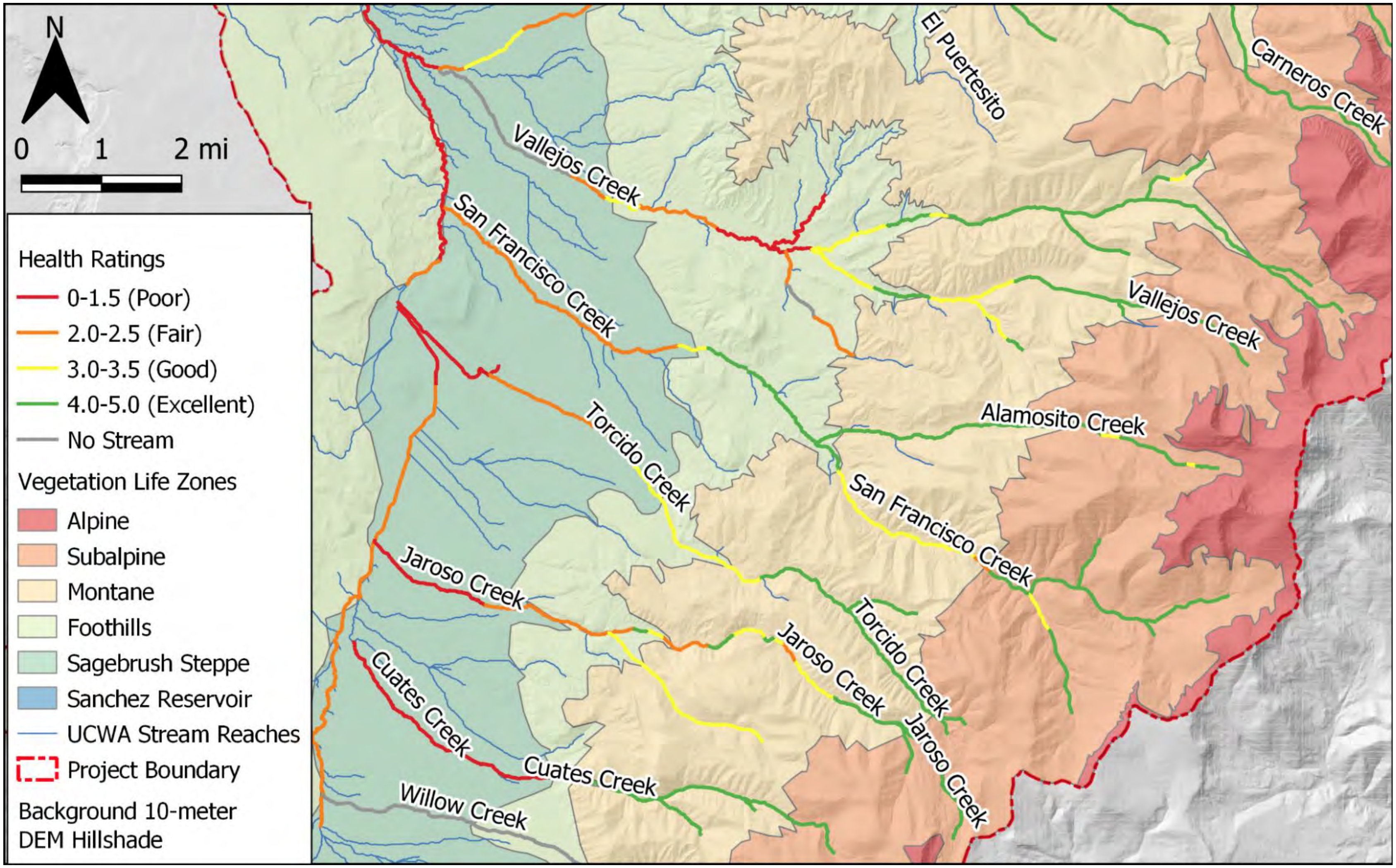


Figure 2-13 Vallejos Creek, North Vallejos Creek, San Francisco Creek, Torcido Creek, and Jaroso Creek riparian health rating map.

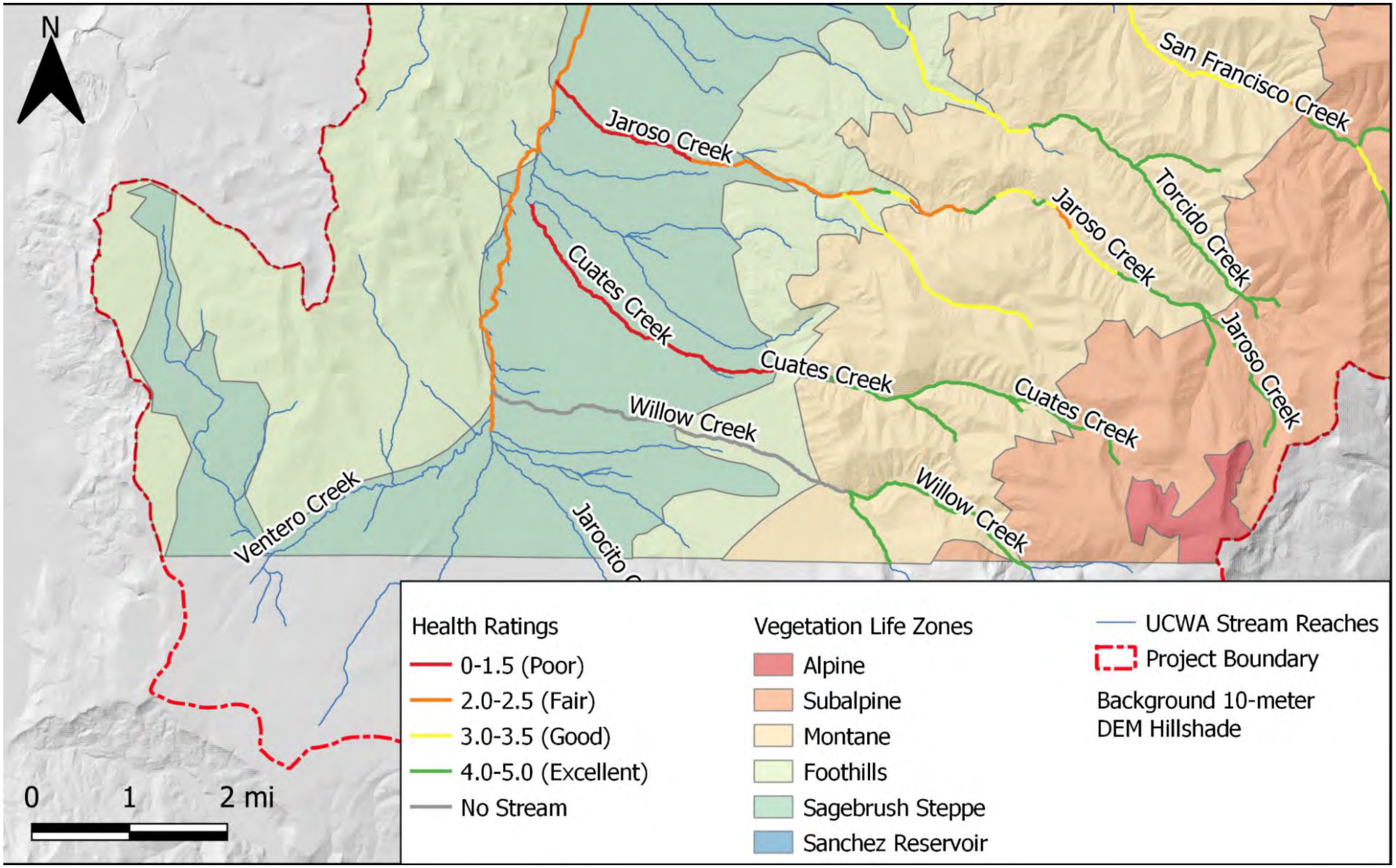


Figure 2-14 Jaroso Creek, Cuates Creek, and Willow Creek riparian health rating map.

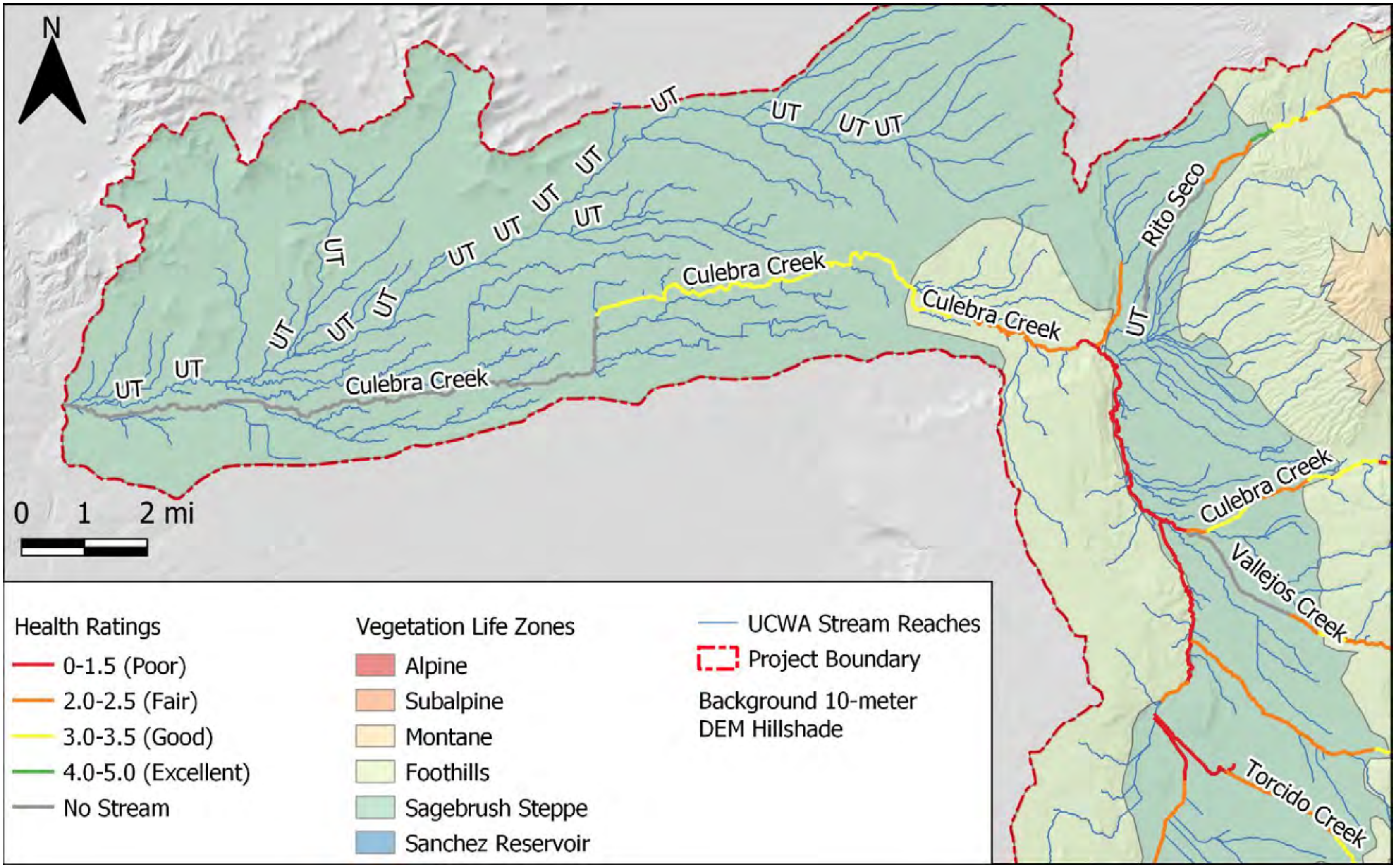


Figure 2-15 Lower Culebra Creek riparian health rating map.

2.4 Discussion

2.4.1 Diversity and Richness or Reference Sites

Based on the LPI and FQI data, reference sites provided a reliable measure against which the condition of all reaches in the watershed could be measured. However, due to the limited focus of this study (i.e., one sample time, rather than two or three sampling dates per site, and the intensity of sampling), species richness and diversity values are an approximation. More sample points, and additional sampling dates, would likely generate a higher species richness and diversity in all riparian areas. The structural diversity of the reference sites represented what was expected for the life zones in question.

2.4.2 Rapid Health Assessments and Visual/Aerial Survey

In general, alpine and subalpine riparian areas scored 4 and higher (Figure 2-10), indicating these riparian areas are healthy, and activities that would degrade these areas (e.g., logging, grazing, roadways, etc.) should be avoided. Creeks in the lower elevations of the watershed, where activities like grazing and agriculture are more prevalent, scored under 4 (Figure 2-10), indicating the need for active and passive management. Specifically, Rito Seco, Jaroso, Culebra, El Pedegroso, Sanchez Reservoir, Ventero Creek, and Vallejos Creek scored the lowest within the UCWA. These creeks and tributaries have been highly impacted by past and current land use. Heavy incision (i.e., downcutting) of creeks, non-native plant species, low canopy structural diversity, and floodplain intrusions are a few of the issues that should be addressed in these reaches to accomplish desired watershed benefits.

2.5 Summary

There are several reaches that should be prioritized for active restoration due to their low ratings, as indicated in Figure 2-10, while higher scoring reaches should be protected. The health rating maps for each tributary highlight areas (Appendix C) provides a visual representation of these reaches. General restoration recommendations are provided below.

Figure 2-16. Examples of degraded riparian areas throughout UCWA. Clockwise starting at top left: heavily incised banks, no structural diversity and incised banks, headgate at the confluence of Vallejos and Culebra Creeks, and floodplain intrusions in the form of homes and roadways.

2.6 General Recommendations

2.6.1 Restoring Floodplain Connectivity in Creeks with High Incision Rates

Reaches with high incision should be priority for active management. Incision directly effects the stability of the entire watershed by compromising water quality, alters the function of streams, and creates ecological and physical stressors on the surrounding environment (Shields Jr., 2009). In some cases, incised streams (i.e., cut downward) can transform thriving and diverse riparian communities into arid uplands with low productivity and diversity. Table 2-9 highlights the point location of streams that had the lowest incision scores (i.e., high rates of incision).

Table 2-9. Rapid Health Assessment Ratings for sample points with the lowest incision ratings.

RAPID ASSESSMENT POINT	7			14			15			31			34			37			38			41			44			51		
	Avg.	RR	RL	Avg.	RR	RL	Avg.	RR	RL	Avg.	RR	RL	Avg.	RR	RL	Avg.	RR	RL	Avg.	RR	RL	Avg.	RR	RL	Avg.	RR	RL	Avg.	RR	RL
Creek Name	El Poso			Jaroso			San Francisco			Rito Seco			Jaroso			Culebra			El Rito de Aban			Rito Seco			Rito Seco			Rito Seco		
Veg Community	Subalpine			Montane			Montane			Montane			Montane			Foothhills			Montane			Montane			Foothills			Montane		
Stream Gradient (%)	2-4			4-10			<2			2-4			2-4			2-4			4-10			4-10			2-4			>10		
CHANNEL, BANKS, EROSION	**Avg.**			**Avg.**			**Avg.**			**Avg.**			**Avg.**			**Avg.**			**Avg.**			**Avg.**			**Avg.**			**Avg.**		
Channel Condition (incising) - or -	2			1.5			3			1			2			3			3.5			3			1.5			3		
Channel Condition (aggrading)	5			2			4			1			4			4			3.5			2			1.5			5		
Riffle imbeddedness	5			3			4			1			4			3			4			2.5			1.5			5		
	Avg.	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**
Bank Stability (including angle and composition)	3	3	2	1	1	2	3.5	4	3	1.5	2	1	2	2	2	3	3	3	4	4	4	3	3	3	1	1	1	3		
Land Erosion (floodplain and immediate uplands)	4	4	4	3	3	3	3.5	4	3	3	3	3	4	4	4	2.5	2	3	5	5	5	3.5	3.5	3.5	2.5	2.5	2.5	4		
RIPARIAN VEGETATION	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**
Bank Zone Condition	3	3	2	1.5	1	2	3.5	4	3	1.25	1	1.5	3	3	3	3	3	3	4	4	4	2.5	2.5	2.5	1	1	1	4	4	4
Overbank Zone Condition		NA	NA	3	3	3	3.5	4	3	2.5	3	2	4	4	4	2.5	2	3	4	4	4	4	4	4	3	3	3	4	4	4
Transition Zone Condition (terrace or other)	3	3	3																											
Riparian area quality (% native)	5	5	5	3.5	3.5	3.5	3	3	3				5	5	5	2.75	2	2.5	5	5	5	4	4	4	3.5	3.5	3.5	5	5	5
Structural Diversity	3	3	3	4	4	4	3.5	3	4	1.5	2	1	2.5	2.5	2.5	2	2	2	5	5	5	3.5	3.5	3.5	3	3	3	5	5	5
FLOODPLAIN IMPACTS	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**	**Avg.**	**RR**	**RL**
Channel Constrictions (bankfull channel)*	5	--	--	3	--	--	4	--	--	1	--	--	3	--	--	3	--	--	5	--	--	3.5	--	--	3	--	--	3	--	--
Floodplain Intrusions (within 100-year)*	5	5	5	3			4	4	4	1			4	4	4	2.75	2	3.5	5			3	3	3	3	3	3	3	3	3
Est. Avg. Depth of Aggradation (feet):	NA			0.5			0.5			0.5			0			0			2			1			1			0		
Est. Avg. Depth of Incision (feet):	1.5			2			1			3			2			1			1			1			3			2		
Number of Knickpoints	0			0			0			1			0			0			0			1			0			0		

2.6.1.1 Active Revegetation and Bioengineering

Most of the riparian areas that are experiencing excessive bank erosion can be treated with a great variety of bioengineering treatments, such as those prescribed in Living Streambanks: a Manual of Bioengineering Treatments for Colorado Streams (link to manual). Most bioengineering treatments can produce results using primarily on-site materials, with limited import of rock or other materials, allowing for cost-effective treatments. In addition to bioengineering, seeding of native grasses and forbs (i.e., insect pollinated herbaceous plants), and installation of native shrub and tree containers and cuttings, can provide for revegetation needs in those reaches that scored a 3 or lower. In reaches with high incision, channel grading may be necessary prior to or in combination with active bioengineering and revegetation treatments.

2.6.2 Logging

Riparian areas where past and current logging has occurred often have low structural diversity and stream shading, which can negatively impact diversity, stream temperatures, wildlife values, and other watershed and stream values. To maintain the stream and watershed benefits those healthy riparian areas provide, we recommend no logging occur within 300 feet of either side of the streambank.

2.6.3 Grazing

Grazing is one of the more challenging land use activities to manage in a watershed the size of Culebra. While limited grazing can be beneficial to some riparian areas, continual and/or intensive grazing can be highly detrimental to riparian areas, degrading their ability to provide key floodplain and watershed benefits. Fencing is not practical in many areas of the watershed. Absent fencing, a deferred rotational grazing system may be most appropriate for the more remote areas of the watershed.

2.6.4 Working (Economical) Watersheds

Through strategic planning, logging, grazing, and restoration can be conducted in a manner that increases the ecological value of the watershed while optimizing the economic value of the watershed. Culebra Watershed provides an excellent opportunity to create a working (economical) watershed.

2.6.5 Weed Management

A number of non-native weed species were identified within the watershed, and warrant treatment. Several non-native plants (weeds) have been identified within the project area, some of which warrant treatment to accomplish project goals. Many weeds can be ecologically, socially, and economically detrimental, while others are known to undermine the success of restoration projects and important wildlife management goals. Many non-native weeds provide low value for native wildlife, and even for domestic animals. Some weeds secrete phytotoxins, which actively inhibit the growth of other native and non-native vegetation. Other invasive species have an advantage over native species, in part, because they lack the full spectrum of biological controls (i.e., insect predators, plant pathogens, etc.) that moderate their populations in their country of origin. As such, they are more likely to spread unabated throughout a project site, displacing native plants and at times forming dense monocultures.

The Colorado Noxious Weed Act (C.R.S. 35-5.5-101-119) defines noxious weeds as:

“An alien plant or parts of an alien plant that have been designated by rule as being noxious or has been declared a noxious weed by a local advisory board, and meets one or more of the following criteria:

- Aggressively invades or is detrimental to economic crops or native plant communities.
- Is poisonous to livestock.
- Is a carrier of detrimental insects, diseases, or parasites.
- The direct or indirect effect of the presence of this plant is detrimental to the environmentally sound management of natural or agricultural ecosystems.”

The Colorado Noxious Weed Act creates a legally binding obligation for the removal/control of noxious species, and prioritizes the control of weeds according to this A, B, and C list:

List A - Species that have not become widely established in the state and may have not even be reported in the state, but are of high concern to the ecological, economic, and/or social interests of Colorado. The goal for these species complete eradication wherever they are found, and to prevent their introduction into Colorado if they are not yet present.

List B - Species already occurring in large populations throughout Colorado, and pose some ecological, economic, or social concerns. The goal is to stop the continued spread of these species into un-infested areas.

List C - These are species that are widespread throughout Colorado, or are not known to pose ecological, social, or economic threats. The goal these species is not to stop their continued spread, but to provide additional education, research, and biological control resources to jurisdictions that desire to manage these species.

Watch List (WL) - Species that have been determined to pose a potential threat to the agricultural productivity and environmental values of the lands of the state, but these weeds currently occur in limited areas. The Watch List encourages the identification and reporting of these species to the Commissioner in order to facilitate the collection of information to assist the Commissioner in determining which species should be designated as noxious weeds.

A great variety of weed management resources are provided by the following entities, including how to create a weed management plan, best management practices for weed management, and more:

Colorado Department of Agriculture website:
https://www.colorado.gov/pacific/agconservation/noxious-weed-publications,

Colorado State University Extension, Weed Resources:
http://www.ext.colostate.edu/sam/weeds.html

Colorado Weed Management Association: https://cwma.org/

2.6.6 Willow Maintenance in Ditches

Residents have identified willows as a concern where they form dense populations in ditches. While some willow species can pose management concerns, willows also provide valuable wildlife habitat, control erosion of ditch embankments, maintain cooler water temperatures where their canopies shade large portions of the ditch, and provide key leaf matter for insect populations, which are important to trout populations. Where willows are not posing a significant concern, we recommend they be left in place, to provide the benefits identified above. Where willows do pose a concern to ditch management needs (e.g., headgate operation, clogged culverts, etc.), a few treatment options are available:

Size Class: Willow saplings and shrubs shorter than 20' tall:

Treatment Method:

- Apply herbicide to actively growing leaves.
- Cut-stump method, where loppers are used to cut the stems to within 4 inches of the ground surface, and herbicide is applied on the stumps within 30 seconds of cutting.
- Preferred Treatment Timing: Spring, Summer, Early Fall. Avoid chemically treating when trees/shrubs are under drought conditions or other environmental stress.
- Chemical: Glyphosate according to manufacturer's recommendations. Due to the proximity to water, an aquatic-safe product must be used, such as Rodeo.

Size Class: Willow trees (crack willow) taller than 20' tall:

Treatment Method:

- Cut-stump method: Use a chain saw or hand saw to cut the trunks to within 18 inches of the ground surface and apply herbicide to the stumps within 30 seconds of cutting. Foliar application of herbicide to resprouts will likely be needed for 2-3 seasons following initial treatment.
- Frill Method: Use an axe or similar cutting tool to make continuous cuts around the base of the stem. The cuts should angle downward and extend into the sapwood. Apply the recommended herbicide to the entire cut area. Be cautious not to girdle the tree as it will prevent the flow of herbicide.
- Cambium injection: Using the cambium injection equipment (ex. Tree IV system from Arborjet), drill holes into the cambium layer of the bark and inject herbicide. Follow manufacture's recommendations for PSI needed, number of holes in cambium needed, as well as quantity of herbicide needed. Manufacture recommendations are based on the DBH of the target tree.
- Preferred Treatment Timing: Timing the treatment when trees are pulling nutrients out of the leaves down toward the roots in preparation for winter dormancy is especially effective. This will pull your applied herbicide straight into the roots, efficiently killing the tree and reducing resprouts. Avoid chemically treating when trees/shrubs are under drought conditions or other environmental stress.
- Chemicals: Glyphosate or Imazapyr, according to manufacturer's recommendations. Due to the proximity to water, an aquatic-safe product must be used, such as Rodeo.

Chapter 3. Aquatic Habitat Assessment

Authors: Redfish Environmental, macroinvertebrate analysis: Dr. Stephanie Parker

3.1 Introduction

Healthy stream corridors are complex. They provide water, food, and shelter for wildlife. Vegetation along their banks shade the streams and help filter pollutants. Within the stream itself there are fish and aquatic invertebrates (insects) with specific requirements for oxygen to breath; substrate of differences sizes, logs, and roots for shelter; vegetation and other invertebrates to eat; and areas with specific characteristics to breed and provide habitat for their young. Aquatic habitat assessments are useful as a tool to identify features and stressors of stream habitats and a method for learning about the aquatic ecosystem and how it is functions. Purposes of aquatic assessments include providing information to determine baseline conditions (i.e., reference condition for future monitoring or track development of restoration projects), identifying areas in degraded condition, and identifying areas where habitat improvements can help enhance aquatic habitat condition.

Aquatic habitat has not been studied in detail at the Culebra Watershed, thus there is little information available to evaluate changes or trends. Because fish are important elements of aquatic ecosystems and indicators of stream habitat condition, the assessment relied on habitat requirements for fish to evaluate stream habitat and limiting factors.

3.1.1 Assessment Goals and Objectives

The following goals were identified for the Aquatic Habitat Assessment to guide the development of the assessment to meet the overall watershed assessment goals.

Goal 1 Determine factors affecting aquatic habitat quality within the Culebra Basin.

Goal 2 Identify strategies for addressing degradation of the aquatic habitat within the Culebra Basin.

Goal 3 Improve understanding and documentation of aquatic habitat condition within the Culebra Basin.

Goals	Objectives
Goal 1 Determine factors affecting aquatic habitat quality within the Culebra Basin.	*Objective 1.1* Perform detailed physical habitat suitability assessment of representative stream reaches within the basin. Targeting the perennial streams within the basin, conduct stream habitat survey at 10-15 sites/reaches (20 to 40 times the channel-wetted width).
Goal 2 Identify strategies for addressing degradation of the aquatic habitat within the Culebra Basin.	*Objective 2.1* Perform physical habitat limiting factors analysis. *Objective 2.2* Summarize factors that are correlated to aquatic habitat health. *Objective 2.3* Develop list of projects to address degradation of the aquatic habitat within the basin.
Goal 3 Improve understanding and documentation of aquatic habitat condition within the Culebra Basin.	*Objective 3.1* Summarize assessment data and provide discussion to synthesize findings.

3.2 Background

Streams in the Culebra Watershed provide habitat for salmonid species (fishes of the Salmonidae family including trout) including brook (*Salvelinus fontinalis*), brown (*Salmo trutta*), rainbow (*Oncorhynchus mykiss*), and cutthroat trout (*O. clarkii spp*). Native Rio Grande cutthroat trout (RGCT, *Oncorhynchus clarkii virginalis*) is a subspecies of cutthroat trout present in the Culebra Watershed, recognized as a species of special concern in Colorado and New Mexico and a sensitive species by the US Forest Service and the Bureau of Land Management in Colorado. Populations of this subspecies have declined drastically in the past 150 years due to anthropogenic factors including the introduction of non-native trout, habitat degradation, and overfishing. Currently RGCT populations occupy a fraction of its native range, particularly headwater streams that only represent marginal trout habitat (Pritchard & Cowley, 2006). In 2003, the RGCT Conservation Team was formed by federal, state, tribal agencies, and other organizations to help improve conservation status of RGCT across its range. Management actions and objectives for RGCT in Colorado and New Mexico are guided by a Conservation Strategy and Agreement (Agreement) that aims at assuring long term viability and genetic diversity of RGCT populations by maintaining areas that currently support RGCT, managing other areas for increased abundance, and establishing new populations where economically and ecologically feasible. Although the primary focus of this Agreement is conservation and enhancement of RGCT and the watersheds upon which they depend, other species (e.g., Rio Grande Sucker – *Catostomus plebeius*, Rio Grande chub – *Gila Pandora*) that occur within or adjacent to RGCT habitat also benefit because the strategy focuses on ecosystem health (RGCT Conservation Team, 2013).

Figure 3-1 Rio Grande cutthroat trout (Onchohynchus clarki virginalis)

The fish population and habitat restoration work conducted by the RGCT Conservation Team has improved conservation status of the RGCT range wide. Between 2006 and 2016, the number of RGCT conservation populations has increased from 42 to 44 in Colorado and from 121 to 129 range wide. Of the 44 conservation populations in Colorado, 43 occur within the Rio Grande Headwaters Geographic Management Unit (GMU) which includes the Culebra Watershed (Bakevich, Paggen, & Felt, 2019). The Colorado Department of Natural Resources, Division of Parks and Wildlife (CPW) has the authority and responsibility for the management of the RGCT on all federal, state, and private land in Colorado.

Many physical, chemical, and biological factors work together to make a stream suitable or not suitable as trout habitat. In streams where fish live and reproduce, habitat requirements are within the suitable range for species present but typically not within optimum range (Bjornn & Reiser, 1991). There are few published studies addressing the biology and ecology of RGCT, however it is likely that many life history traits and habitat requirements are like those of other cutthroat species (Pritchard & Cowley, 2006). Habitat characteristics important for cutthroat trout include availability of cover and number of deep pools, availability of gravels free of sediment for spawning and fry rearing, and summer water temperatures.

The total number of pools in a stream can limit cutthroat trout populations. Lack of deep pools that do not freeze in winter and do not dry in summer or during periods of drought can be a limiting factor in headwater streams (Harig & Fausch, 2002). Pool to riffle ratio is used to assess the stream capability to provide pools for resting and feeding, and rifles to produce food and provide spawning habitat. For cutthroat trout, a ratio of approximately 1 to 1 (50% pool to 50% riffle) is optimal (Hickman & Raleigh, Habitat suitability index models: Cutthroat trout, 1982) (Platts, Megahan, & Minshall, 1983). The percent of pool area used in Alves et al. (2008) as reference condition for cutthroat trout rearing habitat ranged from 35% to 60%.

Large woody debris (LWD) is one of the most important contributors of habitat in forested streams (Meehan, 1991). Cover in the form of overhanging vegetation, banks, deep pools, rocks, debris piles, and LWD is essential for cutthroat trout. Large woody debris can influence channel form, bank stability, the formation of pools, and retention of fine substrate. Kalb and Caldwell (2014) reported 38 to 456 LWD/km at the Rio Ruidoso, New Mexico and indicated that density could provide optimal habitat for RGCT restoration. For a RGCT status assessment, Alves et al. (2008) referenced optimal (natural condition) LWD densities that range widely from 51 to 382 LWD/km according to stream size.

Trout populations also depend on the availability of suitable spawning habitat. Different trout species use different cobble sizes in which to spawn, and preferable spawning gravel size can range from 60 mm-102 mm to 60 mm - 76mm for cutthroat trout and brown trout, respectively (Bjornn & Reiser, 1991). Cutthroat trout have been observed to spawn in substrates ranging from <1mm to 110mm in diameter, but optimum gravel size is somewhere between 12 mm and 85 mm (Pritchard & Cowley, 2006). Fine sediment can fill interstitial spaces between larger substrate particles, reduce inter-gravel flow and oxygen concentrations, and limit embryo survival (Bjornn & Reiser, 1991). Fine substrate can also decrease density and diversity of aquatic insects. Percent fines (substrate <2.3 mm) less than 10% of substrate composition are used as a reference condition value for a RGCT status assessment in Alves et al. (2008).

As noted above, there is little information available on the history of changes in aquatic habitat on the Culebra Watershed. Thus, we rely on habitat requirements for cutthroat trout in general to evaluate stream habitat survey data and assess limiting factors.

3.3 Methods

3.3.1 Aquatic Habitat Survey Site Selection

Stream survey site identification was based the location of previous fisheries surveys conducted by CPW, reach breaks described in section 1.3.1.1, and output from a watershed scale model developed to assess soil erosion potential described in Chapter 15.

The soil erosion potential model (or risk area model), as described in de La Hoz (2020), used to identify potential areas of degradation and identification of areas for field data collection was based on Renard et al. (1997) and Laflen & Flanagan (2013) . The model used different factors to assess soil erosion potential at a watershed scale. These factors consider the effect of topography (slope), soils (soil type and soil erodibility), rain (precipitation), and land cover (vegetative cover, plant litter, and soil surface) on erosion. The distribution of erosion risk potential values generated by the model were used to establish four erosion risk classes (risk, sub-risk, moderate risk, low risk) and a GIS layer based on each of these risk classes was generated (Figure 3-2). A GIS layer of perennial streams within the Upper Culebra Watershed was overlapped on the risk area model and each resulting risk class layer. Subsequently, stream reaches corresponding to each risk class were extracted and a layer of stream reaches in each risk class was generated. Risk, sub-risk, moderate risk, and low risk stream segments accounted for roughly 16%, 22%, 30%, and 31% of the total stream network length, respectively (Figure 3-3). Since each risk class depicts segments of streams that are relatively uniform in character, geology, vegetation, and soils, this classification was used to narrow the natural variability in physical variables affecting attributes of streams.

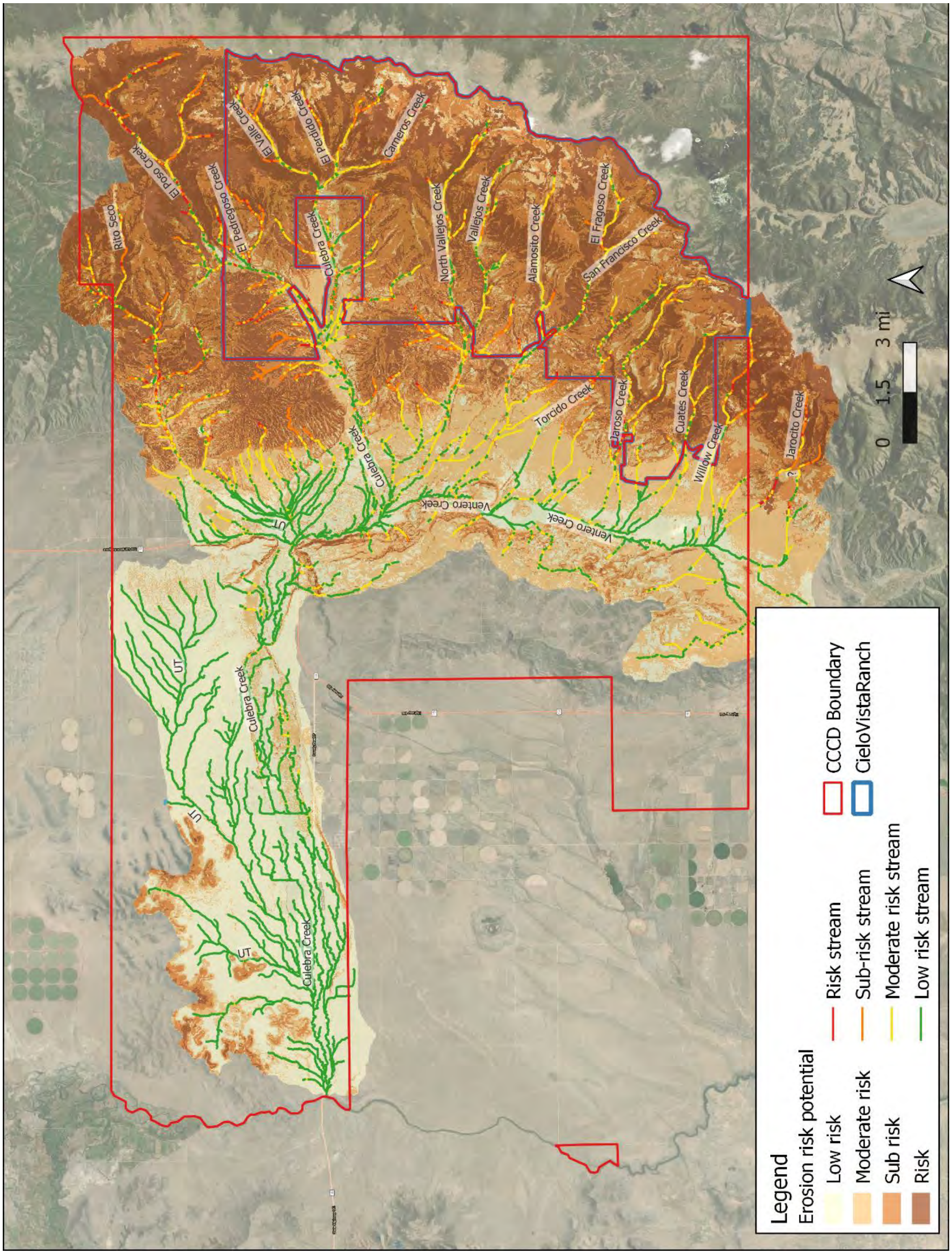
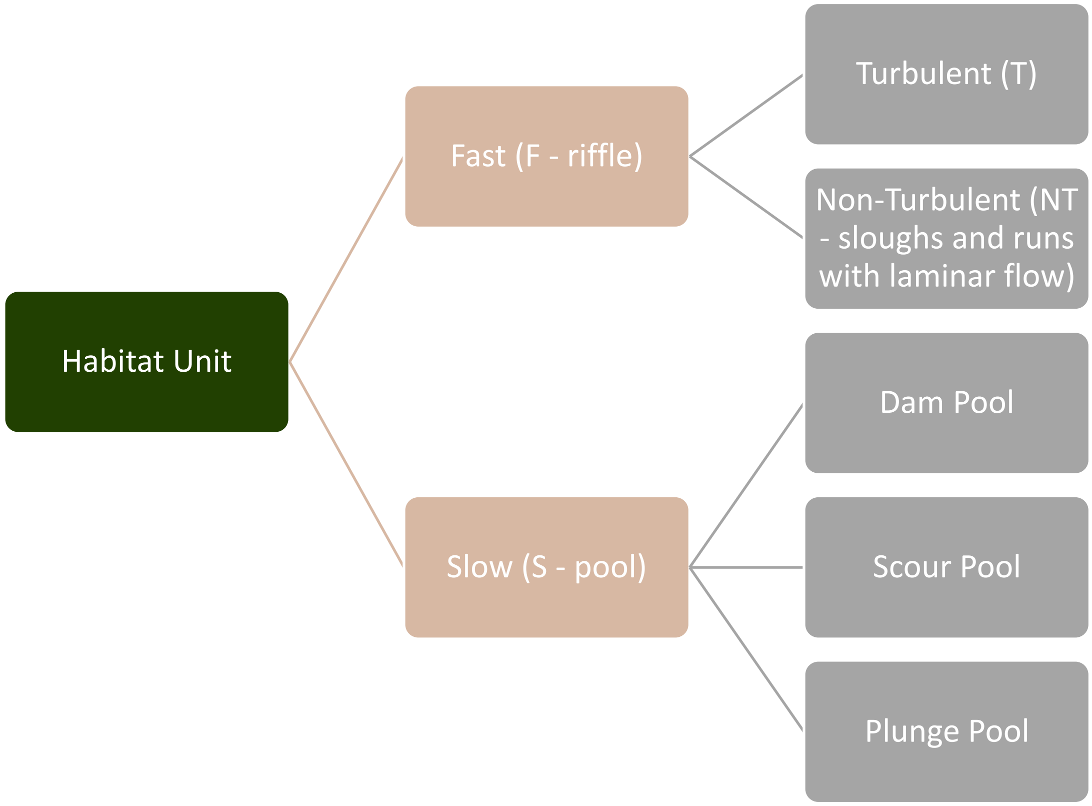


Figure 3-2. Culebra Watershed erosion risk potential classification and corresponding stream reach categories

To examine reaches representative of the watershed, the survey design was stratified by risk area and 16 stream reaches were identified (one reference site and three test sites in each risk area category). Eight additional survey sites were also selected should field crews encountered a site(s) considered non sampleable, not representative of stream condition, or not accessible. Selected reference sites were as free as possible from recent and historic disturbances. Since erosion accelerates sedimentation rates and can lead to loss of stream habitat and biotic diversity, sites at each erosion potential risk class were used to assess the variability in site-specific stream substrate characteristics. Perennial flow is a fish habitat requirement and stream surveys were conducted in stream segments where dewatering does not occur. A map showing dewatered reaches within the watershed is provided in the flow regime section of the watershed assessment. Sampling reaches in each risk class were identified at or in proximity to sites where fish surveys have been conducted by CPW. Reference and test site selection considered presence/absence or relative fish abundance data from previous surveys and length of stream reach. Aquatic habitat survey reach locations are shown in Figure 3-3 and Table 3-2.

3.3.2 Habitat Delineation

Habitat units were identified and delineated at each stream reach surveyed. Habitat units such as pools and riffles are important habitat components for different life stages of fish and having a diversity of habitat units typically increases habitat quality. At each stream reach identified for field survey, data collection started at the lower end of the reach at the first fast water habitat unit that could be crossed safely. Reach length at each site was proportional to the stream channel width. Each site was scouted to determine average channel width, and to be sure that all data collection activities could be performed. Once the reach length was determined (20 to 40 times the channel wetted width), moving upstream from the lowermost end of the reach, habitat types were defined, and their lengths measured. Habitat units were measured with a rangefinder, measuring tape, or GPS unit. Habitat types were determined and numbered in sequential order using the criteria defined by U.S. Department of Agriculture, Forest Service (USFWS, 2014) (USDAFS, 2012). Habitat types were defined only if they were longer than they were wide and comprised more than 50 percent of the channel width. Habitats, as defined by (USDAFS, 2012) are:



Pool to riffle ratios were calculated by dividing the percent of fast water habitat into the percent of slow water habitat within each stream reach surveyed.

3.3.3 Habitat Dimensions

A wetted width and bankfull width were measured at every fast water habitat unit (USDAFS, 2012) (USEPA, 2019). Using best professional judgment, these measurements were made at locations considered representative of the habitat unit.

At every stream reach surveyed, a cross-sectional profile was conducted in a representative fast water turbulent habitat unit. Wetted width, bankfull width, bankfull height, thalweg, and cross-sectional profiles were measured to the nearest X.XX meter (m) as follows:

Wetted width measured from wetted edge to wetted edge including bar habitat but not disconnected pools, using stadia rod, tape measure, range finder, or GPS. Wetted connected undercut is included in wetted width and existing undercut noted.

Bankfull width measured from bankfull indicator to bankfull indicator, using stadia rod, tape measure, range finder, or GPS.

Bankfull height measured from the top of bankfull indicator to the wetted edge using a stadia rod and clinometer.

Thalweg collected for the channel area where bankfull height was measured; the deepest part of the active channel was measured using a stadia rod.

Cross-sectional profile measured at five equally spaced bankfull depths using a stadia rod. Bankfull depth measurements taken from water depth to bankfull height at 0, 25, 50, 75, 100 percent distance of the bankfull width.

For each defined slow water habitat length, maximum wetted width, maximum depth, and crest depth were recorded. Maximum pool depth and crest depth were used to calculate residual pool depth.

Maximum wetted width for each slow water habitat was measured from wetted edge to wetted edge using a stadia rod, tape measure, or range finder. Measured to X.XX m

Maximum depth of each slow water habitat measured using a stadia rod and measured to X.XX m.

Crest depth for each slow water habitat was measured to the nearest X.XX m

Residual pool depth for each slow water habitat units was calculated from the maximum depth minus the maximum tail crest depth.

Table 3-1. Wolman's Pebble Count Size Classification.

Size Bin of B Axis (mm)	Sediment Types
<2	Sand
2-4	Gravel
4-5.7	Gravel
5.7-8	Gravel
8-11.3	Gravel
11.3-16	Gravel
16-22.6	Gravel
22.6-32	Gravel
32-45	Gravel
45-64	Gravel
64-90	Cobble
90-128	Cobble
128-180	Cobble
180-256	Cobble
256-362	Boulders
362-512	Boulders
512-1024	Boulders
1024-2048	Boulders
2048-4096	Boulders

3.3.4 Habitat Unit Mapping

Habitat unit lengths were measured to X.XX m musing a range finder, meter tape, or GPS. A GPS point was recorded at the downstream end of each habitat unit. Representative photographs were taken at each habitat unit.

3.3.5 Pebble Counts

A modified (Wolman, 1954) pebble count was used to assess substrate composition. At each stream reach surveyed, a 100-pebble count was conducted at a representative fast water habitat unit. The count started at bankfull channel edge. Pebbles were randomly selected, measured across the B axis, and binned into Wolman's size bins to the nearest millimeter (mm), as shown in Table 3-1. Wolman's Pebble Count Size Classification. Any pebble selected less than 2mm was recorded as sand. Pebbles were collected at evenly spaced intervals across the entire bankfull width to minimize biasing the count.

3.3.6 Large Woody Debris

All pieces of large woody debris (LWD), defined in (USEPA, 2019) as woody material with a small end diameter of at least 10cm (4in) and a length of at least 1.5m (5ft), were identified and recorded. If pieces met size criteria and any part was within the bankfull channel they were tallied; this included pieces that were partially in the baseflow channel, in the bankfull channel, or spanning above the bankfull channel. Pieces were recorded according to the size classes described in (USEPA, 2019).

3.3.7 Canopy Coverage

Canopy coverage was measured with a densiometer at each stream reach surveyed. Canopy coverage data was taken at the same location where cross-sectional profile data was collected. The densiometer was held level 1m above water surface at the wetted edge of each bank (USEPA, 2019), the percent of overhead area occupied by canopy was recorded facing upstream, downstream, left bank and right bank. The same steps were repeated and recorded for the center of the stream.

3.3.8 Water Quality and Discharge

Dissolved oxygen (DO), pH, water temperature, and conductivity were measured in the middle of each sampling reach with a calibrated multi-parameter water quality meter. As described in USEPA (2019), discharge measurements were conducted at each stream reach during or at the end of each field sampling event, after in situ water quality measurements were recorded. An electromagnetic current meter was used to measure discharge.

3.3.9 Macroinvertebrates

A Surber sampler (0.093 m^2) was used to collect 8 samples per site that were composited to form each individual sample.

3.3.9.1 Macroinvertebrate assessment metrics definitions

Abundance – Number of organisms per benthic area per site.

Taxon richness – Number of taxa per site. Healthy sites tend to have a higher richness.

EPT taxon richness – Number of EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa per site. EPT taxa are more sensitive to stressors and pollution, therefore higher EPT richness typically indicates a healthier stream ecosystem.

Percent EPT taxa – The percent contribution of EPT to the community at a site. This value summarizes the EPT metric.

Percent Chironomidae – Non-biting flies, members of the family Chironomidae, are common macroinvertebrates in nearly all aquatic systems and tend to be tolerant of stressors and pollution. Disproportionate dominance of Chironomidae can indicate poor biotic conditions.

EPT / Chironomidae – The ratio of sensitive taxa (EPT) to tolerant taxa (Chironomidae). Higher EPT/Chironomidae ratios indicate better stream health.

HBI (modified Hilsenhoff Biotic Index) – The Hilsenhoff Biotic Index (Hilsenhoff 1987) summarize the tolerance of benthic organisms to pollution and stressors in the aquatic ecosystem. Several municipalities customize this index to their region; however, this analysis uses a general family-level HBI (Hilsenhoff 1988). This index is considered modified because some taxa were not included in Hilsenhoff’s original taxon list and have been extrapolated for this analysis.

Shannon diversity index – Shannon diversity (H) considers the relative abundance of each taxon per sample or site. Generally, grater taxonomic diversity indicates a healthier ecosystem.

Evenness – Evenness values indicate how evenly the number of individuals is distributed among species. Values range from 0 (no evenness) to 1 (complete evenness).

3.4 Results

A total of 23 sites (stream reaches) were surveyed along 10 streams in the project area between July 7 and July 21, 2021 (Figure 3-3; Table 3-2). Although our objective was to survey 16 stream reaches throughout the watershed, access to sites facilitated survey efforts and habitat data was collected seven additional sites. A total of 4,462 m of stream channel were surveyed and the average reach length was 194 m (range 90-447 m). In this report we provide a summary of the surveys conducted. A database including all data collected, a shapefile format including all referenced GPS waypoints recorded (reach and habitat unit breaks), and representative photos of habitat units delineated along all reaches surveyed are provided electronically. Representative site photos are provided within the results.

Table 3-2. Site location and discharge.

Stream Name	SITE ID	Erosion Risk Category	Latitude	Longitude	Discharge Q (cfs)*
Alamosito Creek	LINKNO981	Moderate Risk	1152609.459	3057447.821	1.37
Canova Creek (Canova Canyon)	LINKNO2652	Risk	1209832.036	3082965.106	13.1
Culebra Creek	LINKNO3068	Sub-Risk	1185188.311	3060950.892	19.1
	LINKNO3644	Low Risk	1182904.733	3045633.595	42.9
	LINKNO3804	Valley Low Risk	1178102.250	3024523.520	82.4
	LINKNO3860	Valley Low Risk	1186603.216	3021442.579	72.8
	LINKNO3932	Valley Low Risk	1195819.318	3004539.424	95.7
El Perdido Creek	LINKNO1244	Sub-Risk	1186173.984	3081809.993	4.53
El Poso Creek	LINKNO379	Risk	1212500.779	3080466.322	13.7
	LINKNO3476	Risk	1208363.093	3073891.173	19.4
	LINKNO3500	Low Risk	1204750.911	3067378.852	19.8
	LINKNO3508	Low Risk	1202046.004	3064833.127	19.1
	LINKNO3524	Moderate Risk	1197116.599	3063677.722	25.8
	LINKNO3532	Risk	1193890.912	3061955.291	28.5
North Vallejos Creek	LINKNO3180-D	Sub-Risk	1166490.090	3063019.709	7.66
	LINKNO3180-U	Low Risk	1167025.157	3064887.747	10.9
Rito Seco	LINKNO315	Risk	1215798.177	3055832.336	3.72
	LINKNO4384	Moderate Risk	1211187.791	3036940.650	3.15
San Francisco	LINKNO925-D	Risk	1150097.972	3054244.506	3.32
	LINKNO925-U	Moderate Risk	1142334.742	3066512.121	3.26
Vallejos Creek	LINKNO1013	Sub-Risk	1162448.459	3055984.321	3.08
	LINKNO933	Moderate Risk	1162329.941	3064584.429	4.68
Ventero Creek	LINKNO3732	Valley Low Risk	1169751.964	3028178.063	96.6

*Discharge recorded during survey

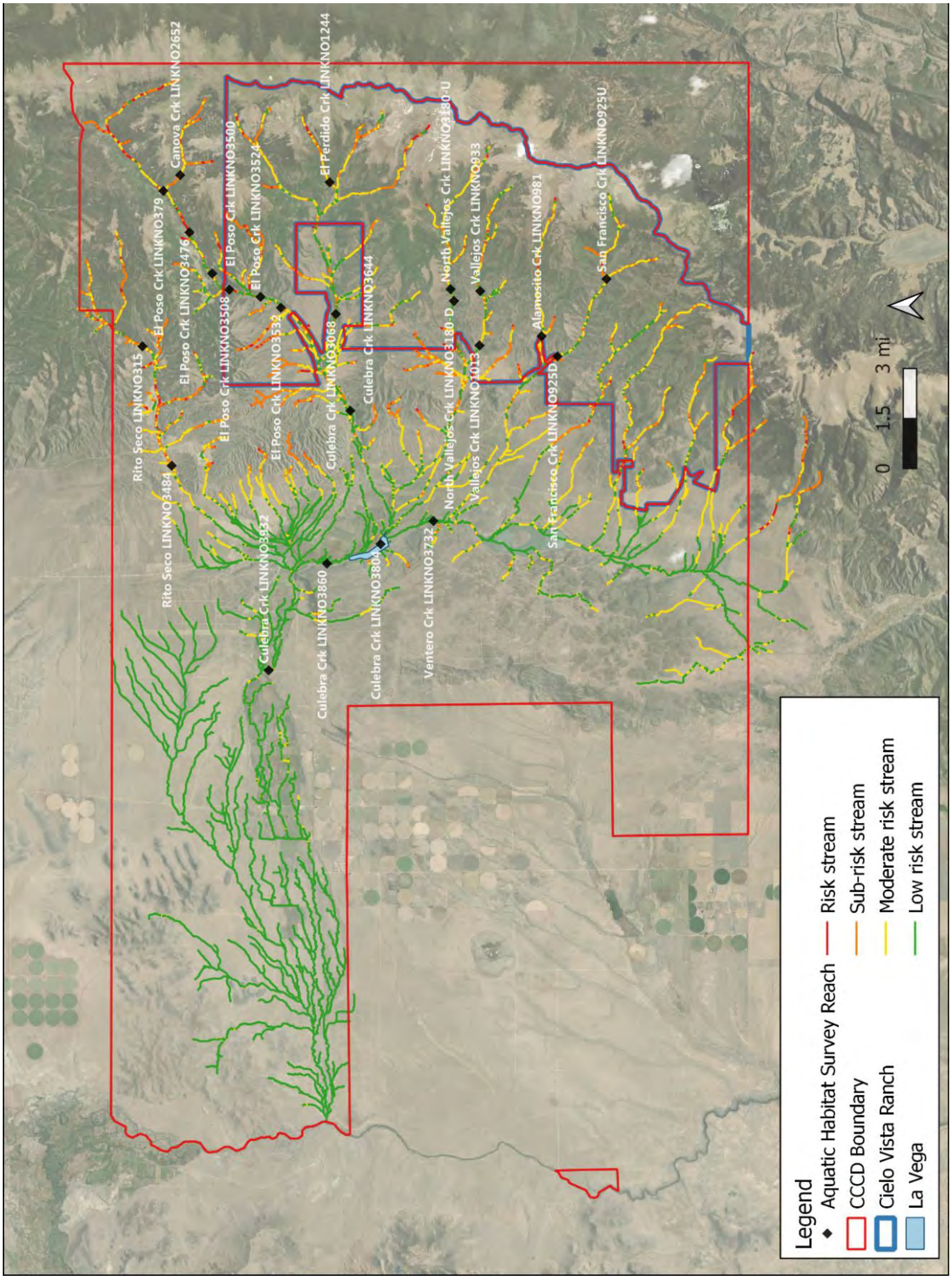
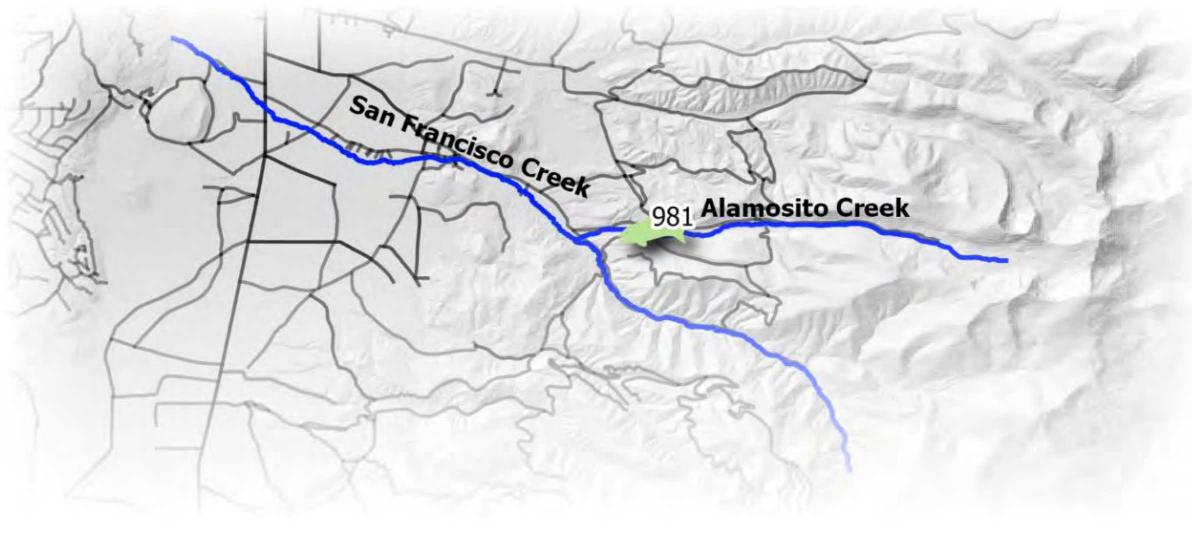


Figure 3-3. UCWA aquatic assessment survey sites (black symbol). Stream layers shown correspond to erosion risk area categories displayed in Figure 1.

The aquatic habitat survey results are presented in tabular and/or graph forms and a summary is provided below. This report provides summary statistics for all parameters recorded on a stream reach-per-reach basis. Summaries include habitat composition per survey reach, tabular summary of pools per reach and average pool crest depth, tabular and graph summary of average substrate composition, and a table summary of LWD densities. A synthesis of results is presented along with a list of potential management actions that could improve aquatic habitat condition, function, and ecosystem health.

3.4.1 Alamosito Creek



3.4.1.1 Habitat Delineation

Alamosito Creek (Site LINKNO981) was surveyed on July 12, 2021. The survey reach was located approximately 1.5km (0.95mi) upstream of its confluence with San Francisco Creek (Figure 3-3). The total length of surveyed stream was 132m (433ft) and water discharge at the time of survey was 1.37cfs (Table 3-2). Barriers to fish movement, defined as natural (e.g., waterfalls, debris jams, excessive water velocities) or manufactured structures that may impede migrating fish were not observed along this survey site.

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
Alamosito Creek	LINKNO981	16	132	100%	1.8	18.9	7.9
	F	9	102	77%	4.2	18.9	11.4
	S	7	30	23%	1.8	6.9	4.3

Figure 3-4 Alamosito Creek, Link no 981, slow water habitat.

Of the 16 habitat units identified along this reach, nine were fast water and six were slow water habitat types. The total length of fast and slow water habitat units along this Alamosito Creek reach were approximately 102m (77%) and 30m (23%), respectively.

Slow water habitat unit lengths at this reach averaged 4.3m (Table 3-4). Four out of seven slow water habitats identified along this channel were delineated as dam pools and three were plunge pools (Table 3-4Table 3-4). By length, 59% and 41% of the pools were dam and plunge pool types, respectively (Figure 3-26). Slow water habitat units had an average wetted width of 3m, an average maximum depth of 0.34m, and average residual pool depth of 0.22 m (Table 3-5).

Stream Name	SITEID	Number of Fast Water Habitat Units	Total Length (m)
Alamosito Creek	LINKNO981	9	102
	NT	3	31
	T	6	71

Fast water habitat units at the Alamosito Creek site totaled in length approximately 31m and 71m, for non-turbulent and turbulent habitat types, respectively. The average fast water habitat unit length was approximately 11m (Table 3-7). Wetted width along fast water habitats ranged from about 2m to 4m and averaged 3m (Table 3-7). A summary of fast water habitat unit characteristics recorded at representative habitats at the Alamosito Creek site are provided in Table 3-8.

3.4.1.2 LWD and Riparian Canopy Cover

The total number of LWD pieces along the Alamosito reach surveyed was 20 (152 LWD/km; Table 3-9). Most of the LWD observed along the reach was less than 5m in length. A single LWD jam was observed (Table 3-10). Riparian vegetation was abundant, and the average total channel canopy cover was 97% (Table 3-11).

3.4.1.3 Substrate

The median substrate size at Alamosito Creek was very coarse gravel (45-64mm; Figure 3-27). Fine particles accounted for 14% of the substrate composition.

3.4.2 Canova Creek

3.4.2.1 Habitat Delineation

Canova Creek (Site LINKNO2652) was surveyed July 8, 2021, at a discharge of 13.1cfs (Table 3-2). The site is located approximately 1.3km (0.8mi) upstream of its confluence with El Poso Creek (Figure 3-3). The total length of surveyed stream was 137m (449ft). Barriers to fish movement were not observed along this survey reach.

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
Canova Creek	LINKNO2652	12	137	100%	3.3	30.0	11.4
	F	5	91	67%	10.0	30.0	18.3
	S	7	45	33%	3.3	13.1	6.5

Figure 3-5 Canova Creek, link no 2652, slow water habitat.

A total of 12 habitat units were identified along this reach; five were fast water and seven were slow water habitat types. The total length of fast and slow water habitat units along this reach were approximately 91m (67%) and 45m (33%), respectively (Figure 3-25).

Slow water habitat unit lengths at this reach averaged approximately 6.5m (Table 3-4). By length, 46% and 54% of the pools were dam and plunge pool types, respectively (Table 3-5). Slow water habitat units had an average wetted width of 3m and an average maximum depth of 0.57m; average residual pool depth was 0.37m (Table 3-5).

Turbulent fast water habitat units at the Canova Creek site totaled in length approximately 78m; only one non-turbulent fast water habitat unit was observed (Table 3-6). The average fast water habitat unit length was 18m (Table 3-3). Wetted width along fast water habitats averaged approximately 4m (Table 3-7). A summary of fast water habitat unit characteristics recoded at representative habitats at the Canova Creek site is provided in Table 3-8.

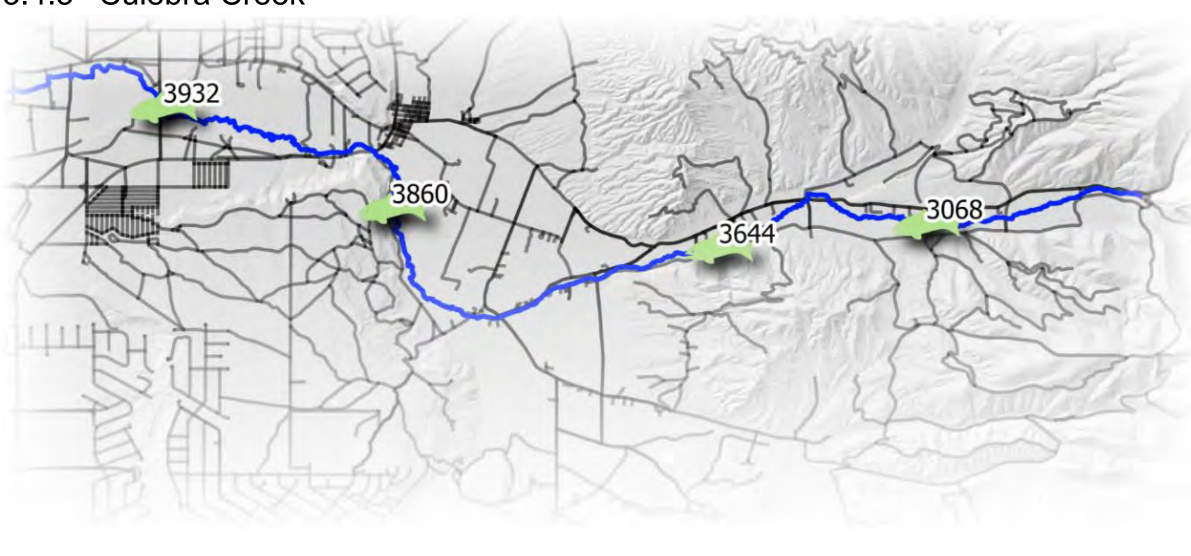
3.4.2.2 LWD and Riparian Canopy Cover

The total number of LWD pieces along the Canova Creek reach surveyed was 32 (234 LWD/km; Table 3-9). Most of the LWD observed along the reach was less than 5m in length. Two LWD jams were observed (Table 3-10). Riparian vegetation was in good condition and the average total channel canopy cover was 79% (Table 3-12).

3.4.2.3 Substrate

The median substrate size at Canova Creek was medium cobble (90-128mm; Figure 3-28). Fine particles were scarce and accounted for 2% of the substrate composition (Figure 3-28).

3.4.3 Culebra Creek



3.4.3.1 Habitat Delineation

Five reaches were surveyed along Culebra Creek between July 13 and July 20, 2021. Listed from highest to lowest elevation, these sites were identified as LINKNO3068, LINKNO3644, LINKNO3804, LINKNO3860, and LINKNO3932. The uppermost site (LINKNO3068) was located approximately 1.9km (1.2mi) downstream of County Road M.5 crossing, and the lowermost site (LINKNO3932) was located approximately 338m (0.2mi) upstream of County Road 16 crossing (Figure 3-3). Stream discharge at Culebra Creek sites ranged from approximately 19 to 96 cfs at the uppermost and lowermost reaches, respectively (Table 3-2). Barriers to fish movement were not observed along these survey reaches.

The total length of surveyed stream reach ranged from 134m at the uppermost site (LINKNO3068) to 447m at one of the lower elevation reaches (LINKNO3860;Table 3-3). A pattern of increasing or decreasing fast to slow habitat unit ratios from upstream to downstream sites was not observed. Fast water habitat units were predominant at all Culebra Creek sites and at sites LINKNO3604 and LINKNO3932, slow water habitats accounted for 10% or less of the reach (Table 3-3, Figure 3-25).

Figure 3-7 Culebra Creek, link no. 3068, slow water habitat.

Figure 3-7 Culebra Creek, link no. 3644, fast water habitat.

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
Culebra Creek	LINKNO3068	13	134	100%	3.9	17.1	10.3
	F	7	85	63%	3.9	17.1	12.1
	S	6	49	37%	4.8	17.1	8.2
	LINKNO3644	12	317	100%	14.5	59.0	26.4
	F	11	297	94%	14.5	59.0	27.0
	S	1	21	6%	20.5	20.5	20.5
	LINKNO3804	10	300	100%	12.0	66.5	30.0
	F	4	195	65%	33.0	66.5	48.8
	S	6	105	35%	12.0	25.5	17.6
	LINKNO3860	10	447	100%	11.0	134.0	44.7
	F	5	283	63%	11.0	134.0	56.5
	S	5	164	37%	19.5	48.0	32.8
	LINKNO3932	4	387	100%	40.5	169.0	96.8
	F	3	347	90%	85.5	169.0	115.6
	S	1	41	10%	40.5	40.5	40.5

Figure 3-9 Culebra Creek, link no. 3860, slow water habitat.

Figure 3-9 Culebra Creek, link no 3804, slow water habitat.

Average slow water habitat unit lengths along Culebra Creek sites ranged from 8.2m at the uppermost site to 40.5m at the lowermost site (Table 3-4). Scour pools were the predominant slow water habitat unit type at all Culebra Creek sites (Table 3-4). Average pool wetted width increased from 5m to 22m from the uppermost to the lowermost site and the average maximum pool depth was greater than 0.5m at all sites (Table 3-5). The average residual pool depth exceeded 0.3m at all sites, except at LINKNO3644 (0.21 m; Table 3-5).

Turbulent fast water habitat units were predominant at the two uppermost Culebra Creek sites (LINKNO3068 and LINKNO3644). Only non-turbulent (runs) fast water habitat units were observed at the three lower sites (LINKNO3804, LINKNO3860, LINKNO3932; Table 3-6). The average fast water habitat unit length ranged from about 12m at the uppermost site to 116m at the lowermost site (Table 3-7). Average wetted width along fast water habitats ranged from 6m at the uppermost site, to 12m at site LINKNO3860 (Table 3-7). The average thalweg depth was over 0.35m at the two upper sites and over 0.45m at the three lower sites (Table 3-8).

3.4.3.2 LWD and Riparian Canopy Cover

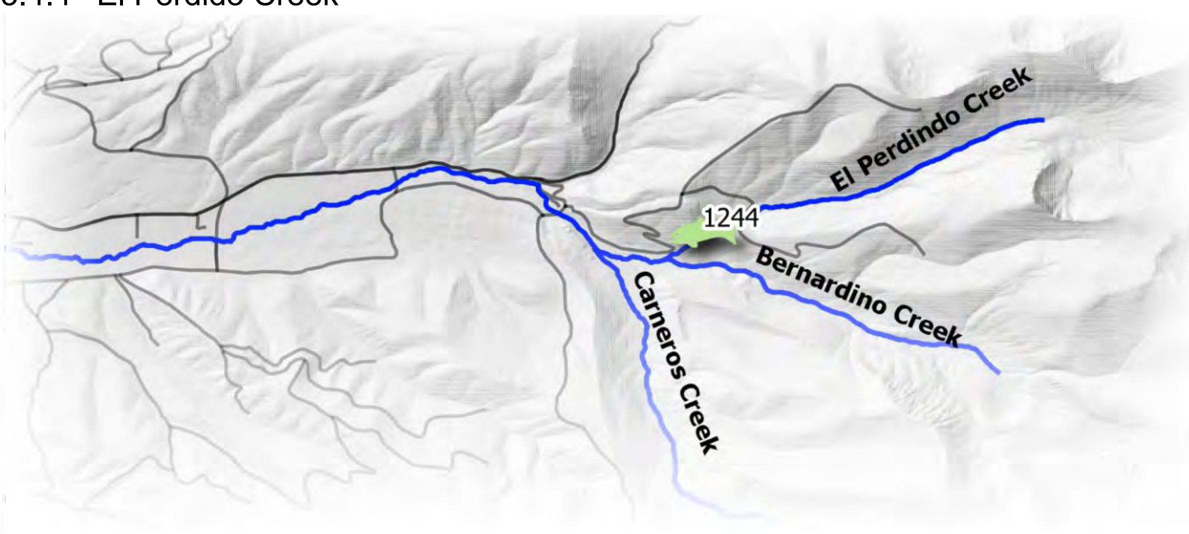
No LWD was observed at the three lower Culebra Creek sites surveyed. Density at the two upper sites was approximately 60 LWD/km and most of the LWD observed was less than 5m in length (Table 3-9). A single LWD jam was observed along the Culebra Creek sites surveyed and was located at the uppermost site (Table 3-10). Riparian vegetation was in good condition at the uppermost Culebra Creek site and the average total channel canopy cover was 90% (Table 3-12). Canopy cover was 40% at LINKNO3644. Riparian vegetation was limited to grass at the three lower sites where there was no channel canopy cover (Table 3-11)

Figure 3-10 Culebra Creek, link no 3932, fast water habitat.

3.4.3.3 Substrate

The median substrate size at the two upper Culebra Creek sites was coarse gravel (16-22.6mm). Small cobble (64-90mm) was the median substrate size at the two lower sites (Figure 3-28). Fine particles accounted for 7% of the substrate composition at LINKNO3644. A higher percentage of fine particles was observed at the other sites accounting for 19%, 20%, and 24% at LINKNO3068, LINKNO3860, and LINKNO3932, respectively.

3.4.4 El Perdido Creek



3.4.4.1 Habitat Delineation

El Perdido Creek (Site LINKNO1244) was surveyed on July 7, 2021, at a discharge of 4.53cfs (Table 3-2). The site is located approximately 426m (0.26mi) upstream of its confluence with Bernardino Creek (Figure 3-3). The total length of surveyed stream was 146m (479ft). Barriers to fish movement were not observed along this survey reach.

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
El Perdido Creek	LINKNO1244	10	146	100%	6.5	34.4	14.6
	F	6	105	72%	7.7	34.4	17.6
	S	4	40	28%	6.5	14.9	10.1

A total of 10 habitat units were identified along this reach; six were fast water units that totaled 105m in length (72% of the reach) and four were slow water habitat types that totaled 40m in length (28% of the reach; Table 3-3, Figure 3-25).

Slow water habitat unit lengths at this reach averaged approximately 10m (Table 3-4) and plunge pools were predominant (Table 3-4). Slow water habitat units had an average wetted width of 5m and an average maximum depth of 0.49m (Table 3-5). Average residual pool depth was 0.32 m (Table 3-5).

Turbulent fast water habitat units at El Perdido Creek reach totaled 105m in length; non-turbulent fast water habitat was not observed (Table 3-6). The average fast water habitat unit length was approximately 18m (Table 3-7). The average wetted width along fast water habitats was 3.8m (Table 3-7) and average thalweg depth was 0.29m (Table 3-8).

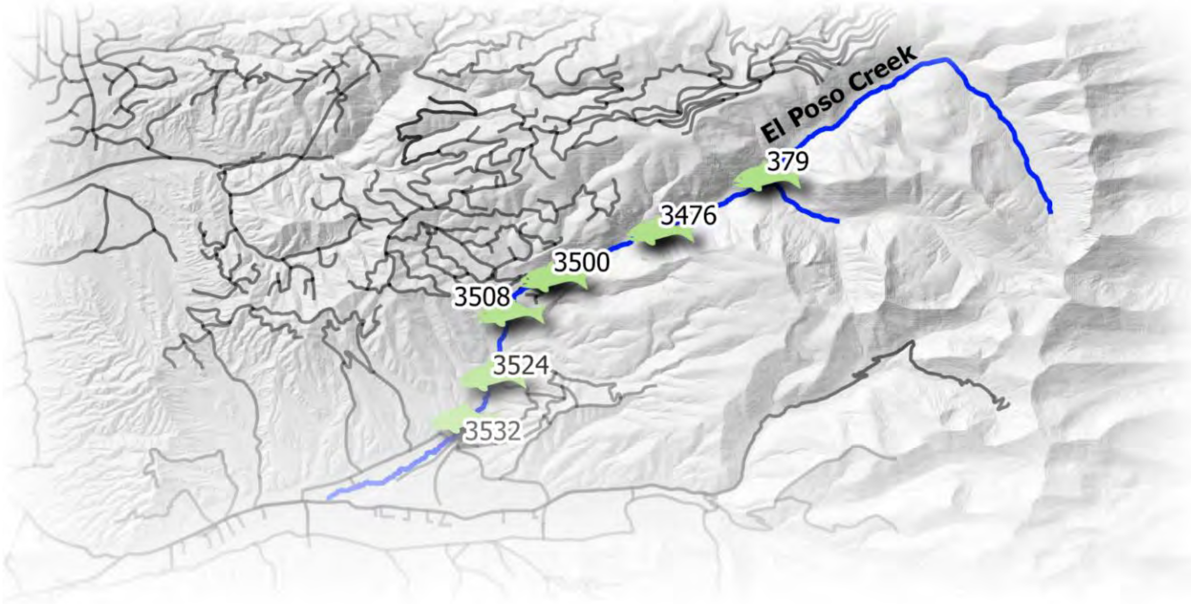
3.4.4.2 LWD and Riparian Canopy Cover

The total number of LWD pieces along El Perdido Creek reach surveyed was 56; this was the highest LWD density observed across all reaches surveyed in the watershed (384 LWD/km; Table 3-9). Most of the LWD observed along the reach was between 5m and 15m in length. A single LWD jam was observed with 12 qualifying pieces (Figure 3-10). Riparian vegetation was in good condition and the average total channel canopy cover was 71% (Table 3-12).

3.4.4.3 Substrate

The median substrate size at this reach was very coarse gravel (32-45mm; Figure 3-28). Fine particles accounted for 11% of the substrate composition.

3.4.5 El Poso Creek



3.4.5.1 Habitat Delineation

Six stream reaches were surveyed along El Poso Creek between July 8 and July 11, 2021. Listed from high to low elevation, these sites were identified as LINKNO379, LINKNO3476, LINKNO3500, LINKNO3508, LINKNO3524, and LINKNO3532. The uppermost site (LINKNO379) was located approximately 267m (0.16 mi) upstream of Canova Creek confluence, and the lowermost site (LINKNO3932) was located approximately 3.4km (2.1miles) upstream of its confluence with Culebra Creek (Figure 3-3). Stream discharge at El Poso Creek reaches ranged from 13.7cfs at the uppermost site to 28.5cfs at the lowermost site (Table 3-2). The total length of surveyed stream reach ranged from 131m at the uppermost (LINKNO379) to 207m at the lowermost (LINKNO3532) sites. Barriers to fish movement were not observed along these survey reaches.

Figure 3-11 El Poso Creek, link no. 3476, slow water habitat.

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
El Poso Creek	LINKNO379	12	131	100%	2.2	25.8	10.9
	F	8	115	88%	8.3	25.8	14.4
	S	4	16	12%	2.2	6.5	4.1
	LINKNO3476	8	167	100%	7.6	40.0	20.8
	F	2	77	46%	37.0	40.0	38.5
	S	6	90	54%	7.6	24.5	14.9
	LINKNO3500	15	206	100%	4.5	28.2	13.7
	F	8	148	72%	11.5	28.2	18.5
	S	7	58	28%	4.5	10.9	8.3
	LINKNO3508	7	156	100%	16.0	45.5	22.2
	F	4	105	68%	18.0	45.5	26.3
	S	3	51	32%	16.0	18.5	16.8
	LINKNO3524	10	145	100%	5.8	25.5	14.5
	F	6	98	68%	6.6	25.5	16.3
	S	4	47	32%	5.8	18.2	11.7
	LINKNO3532	10	207	100%	13.0	36.1	20.7
	F	8	173	84%	13.0	36.1	21.6
	S	2	34	16%	13.5	20.5	17.0

A pattern of increasing or decreasing fast to slow habitat unit ratios from upstream to downstream sites was not observed. Fast water habitat units were predominant at all El Poso Creek sites except at site LINKNO3476 were slow habitat accounted for 54% of the reach length (Table 3-3; Figure 3-25).

Figure 3-12 El Poso Creek, link no. 3532, fast water habitat.

Average slow water habitat unit lengths along El Poso Creek sites ranged from approximately 4m at the uppermost site to 17m at the lowermost site and site LINKNO3508 (Table 3-4). Plunge pools were the predominant slow water habitat unit type at the three upper sites (LINKNO379, LINKNO3476, LINKNO3500;Table 3-5). Dam pools were predominant at sites LINKNO3508 and LINKNO3524, and scour pool was the

Figure 3-14 El Poso Creek, link no. 379, fast water habitat.

Figure 3-13 El Poso Creek, link no. 3500, fast water habitat.

only slow water habitat type encountered at the lowermost site LINKNO3532 (Figure 3-27). Average pool wetted width ranged from 4m at the uppermost site to 6m at the lowermost site and the average maximum pool depth was greater than 0.52m at all sites (Table 3-5). The average residual pool depth at most survey sites was greater than 0.3 m; average residual pool depth was slightly lower (0.29 m) at the uppermost (LINKNO0.79) and lowermost (LINKNO3532) locations (Table 3-5).

Figure 3-15 El Poso Creek, link no. 3508, slow water habitat.

Turbulent fast water habitat units were predominant at El Poso Creek reaches with two exceptions, LINKNO3508 and LINKNO3532, where non-turbulent fast water habitat units accounted for most of the fast water habitat in each reach (Table 3-6). The average fast water habitat unit length ranged from 14.4m at LINKNO379 to 38.5m at site LINKNO3476 (Table 3-6). Average wetted width along fast water habitats ranged from 4m at the uppermost site, to 7m at site LINKNO3500 (Table 3-7). The average thalweg depth ranged from 0.29m at LINKNO3476 to 0.39m at LINKNO379 and LINKNO3508 (Table 3-8).

3.4.5.2 LWD and Riparian Canopy Cover

Density of LWD along El Poso Creek ranged from 479 LWD/km at LINKNO3476 to 68 LWD/km at the lowermost reach (Table 3-9). Small LWD (<5m long) was most common at all sites. Two LWD jams were observed along the reaches surveyed, one at LINKNO3476 and one at the lowermost site (Table 3-9). Riparian vegetation canopy cover ranged from 79% at the lowermost site to 37% at site LINKNO3524 (Table 3-11).

3.4.5.3 Substrate

The median substrate size at the upper three El Poso Creek sites was medium cobble (90-128mm). The median substrate size at the two lower sites was large cobble (128-180mm); very coarse gravel (45-64mm) was the median size at LINKNO3808 (Figure 3-28). There was not much variability in the proportion of fine sediments along the El Poso Creek reaches surveyed. Fine substrates (<2mm) ranged from 2% at LINKNO350 to 8% at LINKNO3508 (Figure 3-28).

3.4.6 North Vallejos Creek

3.4.6.1 Habitat Delineation

Two reaches were surveyed along North Vallejos Creek on July 17, 2021. Stream discharge at the time of survey was 7.7cfs at the lower site (LINKO3180-D) and 10.9cfs at the upper site (LINKNO3190-U; Table 3-2). These sites were located approximately 442m (0.27miles) and 1.1km (0.68mi) upstream of Road K5 crossing (Figure 3-3). The total lengths of stream reach surveyed were 156m and 149m at the lower and upper site, respectively. Barriers to fish movement were not observed along this survey reach.

Fast water habitat units at the lower site accounted for 75% of the reach length; 25% was slow water habitat. Conversely, slow water habitats were predominant at the upper North Vallejos Creek site and accounted for 68% of the reach length (Table 3-3, Figure 3-3).

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
North Vallejos Creek	LINKNO3180-D	12	156	100%	4.0	30.6	13.0
	F	7	116	75%	5.4	30.6	16.6
	S	5	40	25%	4.0	14.0	7.9
	LINKNO3180-U	15	149	100%	4.3	24.0	10.7
	F	3	48	32%	11.2	24.0	16.1
	S	12	101	68%	4.3	12.0	9.2

Slow water habitat units at the lower North Vallejos Creek site included dam (27%), plunge (38%), and scour (35%) pools. Dam and plunge pools accounted for 84% of the upper site (Figure 3-26, Table 3-4). Average pool wetted width was slightly larger at the lower site (6m) than the upper site (4m) and the average max depth at both sites was approximately 0.5m (Table 3-5). Average residual pool depth was 0.36m at the lower site and 0.29m at the upper site (Table 3-5).

Figure 3-16 North Vallejos Creek, link no. 3180-U, slow water habitat.

Fast water habitats were predominantly turbulent at both sites (Table 3-6). Their average length ranged between 16m and 17m and had an average wetted width of 4m (Table 3-7). The average thalweg depth was very similar at both sites, slightly under 0.3m at both sites (Table 3-8).

3.4.6.2 LWD and Riparian Canopy Cover

The density of LWD was 109 LWD/km and 215LWD/km at the lower and upper sites, respectively (Table 3-9). Most of the LWD observed at both sites was less than 5m in length (Table 3-9), and two LWD jam were observed at each North Vallejos Creek site (Table 3-10). Riparian vegetation was in good condition at both sites; the average total channel canopy cover was 82% at the lower site and 77% at the upper site (Table 3-11).

Figure 3-17 North Vallejos Creek, link no. 3180-D, fast water habitat unit.

3.4.6.3 Substrate

Substrate composition at both North Vallejos Creek sites was very similar. Median substrate size at the lower site was very coarse gravel (32mm-45mm) and the median was slightly larger very coarse gravel (45mm-64mm; Figure 3-27). Fine particles accounted for 7% and 8% of the substrate composition at the lower and upper sites, respectively (Figure 3-27).

3.4.7 Rito Seco

3.4.7.1 Habitat Delineation

Two reaches were surveyed along Rito Seco Creek on July 19, 2021. Stream discharge at the time of survey was approximately 3.2cfs at the upper site (LINKO315) and 3.7cfs at the lower site (LINKNO3484; Table 3-2). These sites were located approximately 3km (1.9mi) upstream and downstream of Battle Mountain Gold Mine (Figure 3-3). The total length of stream reach surveyed at the lower site was 165m and 90m were surveyed at the upper site (Table 3-3). Barriers to fish movement were not observed along this survey reach.

Figure 3-18 Rito Seco, link no. 315, fast water habitat unit.

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
Rito Seco	LINKNO315	11	90	100%	3.3	20.0	8.2
	F	3	21	23%	4.5	10.9	6.9
	S	8	69	77%	3.3	20.0	8.6
	LINKNO3484	12	165	100%	9.3	24.5	13.8
	F	3	47	28%	13.0	17.5	15.7
	S	9	118	72%	9.3	24.5	13.1

Figure 3-19 Rito Seco, link no. 3484, slow water habitat unit.

Unlike most of the other stream reaches surveyed throughout the watershed, slow water habitat was predominant and encompassed 72% of the lower reach length and 77% of the upper reach (Tale 3, Figure 3-3). Slow water habitat units at the upper site included dam (33%) and plunge (67%) pools. Dam pools accounted for 78% of the lower site, where plunge (18%) and scour (11%) pools were also observed (Figure 3-26, Table 3-4). Average pool wetted width was approximately 3m at both sites, but average maximum pool depth was greater at the lower site (0.61m) than the upper site (0.34m; Table 3-5). Average residual pool depth was 0.22m at the lower site and 0.46m at the upper site (Table 3-5).

Fast water habitats were predominantly turbulent at the upper site and non-turbulent at the lower site (Table 3-6). Their average length ranged between 7m at the upper site and 16m the lower site and had an average wetted width of 2.4m and 2.8m, respectively (Table 3-6). The average thalweg depth was similar at both sites, 0.21m at the upper site and 0.25m at the lower site (Table 3-7).

3.4.7.2 LWD and Riparian Canopy Cover

The density of LWD ranged from 567 (LWD/km) at the upper site to 42 LWD/km at the lower site (Table 3-9). Most of the LWD observed at both sites was less than 5m in length (Table 3-9). Three LWD jams were observed at the upper site, and none were observed at the lower site (Table 3-10). A breached beaver dam was observed at the lower site without LWD qualifying pieces. Riparian vegetation was in good condition at both sites. The average total channel canopy cover was 96% at the upper site where trees and shrubs were predominant. Grasses and shrubs were predominant at the lower site where average canopy cover was 21% (Table 3-11).

3.4.7.3 Substrate

At the upper Rito Seco site, the median substrate size was very coarse gravel (45mm-64mm), and the percentage of fine sediment (<2mm) was 10% (Figure 3-28). A pebble count was not completed at the lower Rito Seco site, but fine substrate was predominant (sand-silt).

3.4.8 San Francisco Creek

Figure 3-20 San Francisco Creek, link no. 925-D, fast water habitat unit.

3.4.8.1 Habitat Delineation

Two reaches were surveyed along San Francisco Creek on July 12, 2021, at a stream discharge of approximately 3.3cfs (Table 3-2). The lower site (LINKNO925-D) was located approximately 0.8km (0.5mi) above Alamosito Creek confluence, and the upper site (LINKNO925-U) was located approximately 76m (250ft) below the El Fragoso Creek confluence (Figure 3-3). Barriers to fish movement were not observed along these survey reaches.

The total lengths of stream reach surveyed were 129m and 131m at the lower and upper site, respectively (Table 3-3). At the lower site, fast water habitat units accounted for 64% of the reach length and 36% was slow water habitat. At the upper site, fast water habitat comprised 82% of the reach length (Table 3-3, Figure 3-25).

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
San Francisco	LINKNO925-D	14	129	100%	2.7	22.1	9.1
	F	6	83	64%	6.9	22.1	14.9
	S	8	46	36%	2.7	9.3	5.7
	LINKNO925-U	14	131	100%	1.8	26.0	9.4
	F	8	107	82%	5.0	26.0	13.4
	S	6	24	18%	1.8	8.3	4.0

Scour pool was the predominant slow water habitat type at both sites; 80% at the lower reach and 92% at the upper reach (Figure 3-26, Table 3-4). Average pool wetted width was approximately 3m at both sites but the average max depth at the upper site (0.28m) was slightly shallower than the lower site (0.31m; Table 3-5). Average residual crest depth was approximately 0.2m at both sites (Table 3-5).

Figure 3-21 San Francisco Creek, link no. 925-U, fast water habitat unit.

At the lower site, 50m (60%) out of the 83m delineated at fast water habitat were classified as non-turbulent and 33m (40%) were turbulent (Table 3-6). Fast water habitat at the upper site was 100% turbulent. Average wetted width at fast water habitat units was approximately 3m at both reaches (Table 3-7). Their average length ranged between 13.4m and 14.9m and had an average thalweg depth of 0.17m and 0.19m at the upper and lower reaches, respectively (Table 3-8).

3.4.8.2 LWD and Riparian Canopy Cover

Density of LWD was 217 LWD/km at the lower site and 191 LWD/km at the upper site (Table 3-9). No LWD jams were observed at the lower reach and four jams were observed along the upper reach (Table 3-10). Riparian vegetation was in good condition at both sites; the average total channel canopy cover ranged from 74% at the lower site to 64% at the upper site (Table 3-11).

3.4.8.3 Substrate

Median substrate size at the lower San Francisco site was very coarse gravel (32-45mm) and the median pebble size at the upper site was small cobble (90mm-128mm) at the upper site (Figure 3-27). Fine particles (<2mm) accounted for 16% and 7% of the substrate composition at the lower and upper sites, respectively (Figure 3-27).

3.4.9 Vallejos Creek

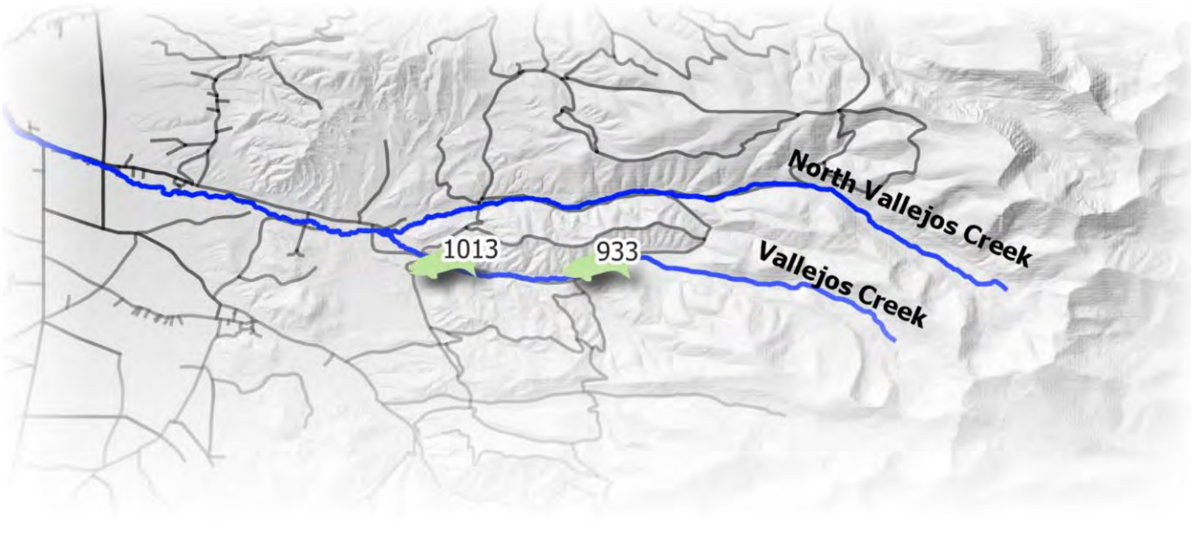


Figure 3-22 Vallejos Creek, link no. 1013, fast water habitat unit.

3.4.9.1 Habitat Delineation

Two reaches were surveyed along Vallejos Creek on July 18, 2021. Stream discharge at the time of survey was approximately 3cfs at the lower site (LINKO1013) and 4.7cfs at the upper site (LINKNO933; Table 3-2). The lower site was located approximately 1.4km (0.8mi) upstream of the North Vallejos Creek confluence and the upper site was located approximately 400m (0.25mi) downstream of the second Road K5 crossing (Figure 3-3). The total lengths of stream reach surveyed were 156m and 136m at the lower and upper site, respectively. Barriers to fish movement were not observed along these survey reaches.

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
Vallejos Creek	LINKNO1013	15	156	100%	2.7	37.2	10.4
	F	8	111	71%	6.7	37.2	13.8
	S	7	45	29%	2.7	13.3	6.5
	LINKNO933	15	136	100%	1.5	22.0	9.0
	F	6	75	55%	6.1	22.0	12.5
	S	9	61	45%	1.5	13.0	6.7

Fast water habitat units at the upper site accounted for 71% of the reach length. The ratio of fast to slow water habitat types was closer to 1:1 at the upper reach where fast water habitat units accounted for 55% of the reach length (Table 3-3, Figure 3-3).

Figure 3-23 Vallejos Creek, link no. 933, fast water habitat unit.

Scour pool (64%) was the predominant slow water habitat type at the lower site. Plunge and scour pool habitat accounted for 42% and 48% of the slow water habitat along the upper reach, respectively (Figure 3-25, Table 3-4). At both sites, average pool wetted width was 2m, average max pool depth was slightly over 0.3m, and average residual pool depth was approximately 0.2m (Table 3-5).

Fast water habitat was predominantly non-turbulent at the lower site (Table 3-6) and had an average wetted width of 2.5m (Table 3-8) and average thalweg depth of 0.19m (Table 3-8). Turbulent fast water habitat was predominant at the upper site, but average habitat unit lengths, wetted widths, and thalweg depths were similar to fast water habitat at the lower site (Table 3-8).

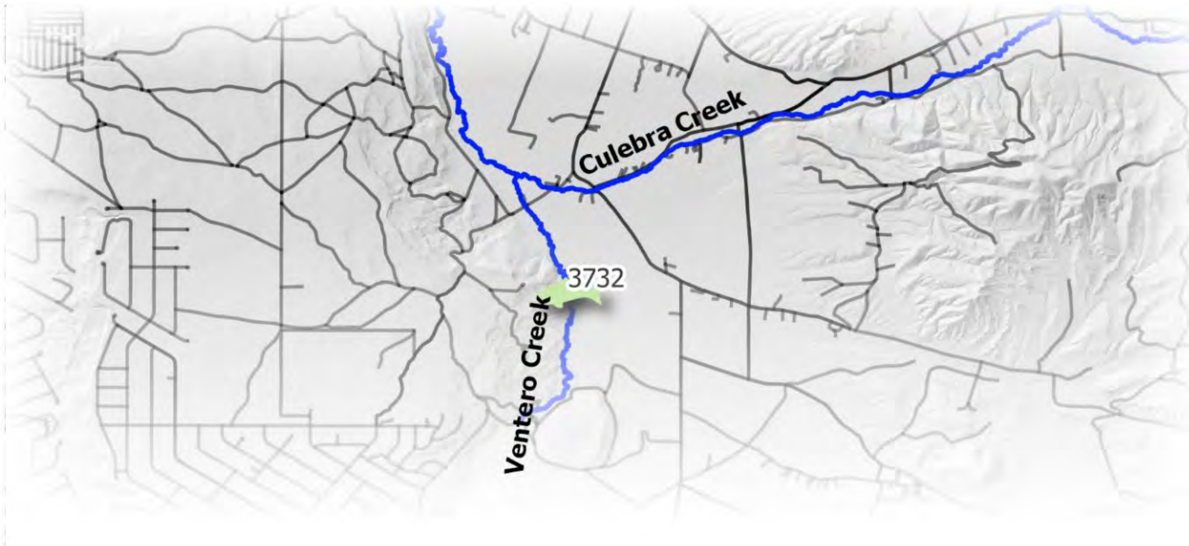
3.4.9.2 LWD and Riparian Canopy Cover

The density of LWD was substantially higher at the upper site (213 LWD/km) than at the lower site (103 LWD/km) and most of the LWD observed at both sites was less than 5m in length (Table 3-9). No LWD jams were observed at the lower site and two were observed the upper site (Table 3-10). Riparian vegetation was in good condition at the lower site. Some areas without ground cover (and eroding) were observed along the upper reach. The average total channel canopy cover ranged from was 95% at the lower site to 70% at the upper site (Table 3-11).

3.4.9.3 Substrate

The substrate composition at both Vallejos Creek sites was similar. Median substrate size at the lower site was very coarse gravel (32mm-45mm) and the median at the upper site was coarse gravel (22.6mm-32mm; Figure 3-27). However, the percentage of fine particles was higher at the upper site than at the lower site; 28% and 14%, respectively (Figure 3-27).

3.4.10 Ventero Creek



3.4.10.1 Habitat Delineation


Figure 3-24 Ventero Creek, link no. 3732, fast water habitat unit.

Ventero Creek (Site LINKNO3732) was surveyed on July 15, 2021. The survey reach was located approximately 2.6km (1.6mi) upstream of its confluence with Culebra Creek; approximately 2.7km (1.7mi) downstream of Sanchez Reservoir (Figure 3-3). Stream discharge at the time of survey was approximately 96.7cfs (Table 3-2). Barriers to fish movement were not observed along this survey reach.

The total length of the survey reach was 340m and of the 13 habitat units identified, seven (59%) were classified as fast water and six (41%) as slow water (Table 3-3, Figure 3-25).

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
Ventero Creek	LINKNO3732	13	340	100%	11.5	45.0	26.1
	F	7	202	59%	15.5	44.5	28.8
	S	6	138	41%	11.5	45.0	23.0

All slow water habitat units were classified as scour pool with an average length of 23m (Table 3-4,Figure 3-26). Slow water habitat average wetted width was 7m, average maximum depth was 1.3m, and average residual pool depth was 0.77m (Table 3-5).

Fast water habitat units at the Ventero Creek reach totaled in length approximately 202m, of which 181m (90%) were non-turbulent. The average fast water habitat unit length approximately 29m and the average wetted width was 5.7m. A summary of fast water habitat unit characteristics recorded at representative habitats at the Ventero Creek site are provided in Table 3-8.

3.4.10.2 LWD and Riparian Canopy Cover
No LWD or LWD jams were observed at this reach (Table 3-9). Riparian vegetation was predominantly grass and sparse shrubs; total channel canopy cover was 0% (Table 3-11).

3.4.10.3 Substrate
The median substrate size at Ventero Creek was very coarse gravel (32mm-45mm; Figure 3-27). Fine particles (<2mm) accounted for 2 % of the substrate composition (Figure 3-28).

3.4.11 Data Summary

3.4.11.1 Habitat Unit Summary

This section contains summaries of the slow and fast water habitats measured by site, number and length of slow habitat units by type, summary of pool characteristics, and number and length of fast habitat units.

Table 3-3. Summary of slow (S) and fast (F) water habitat units by site (total, percent, minimum, maximum, and average length).

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
Alamosito Creek	LINKNO981	16	132	100%	1.8	18.9	7.9
	F	9	102	77%	4.2	18.9	11.4
	S	7	30	23%	1.8	6.9	4.3
Canova Creek	LINKNO2652	12	137	100%	3.3	30.0	11.4
	F	5	91	67%	10.0	30.0	18.3
	S	7	45	33%	3.3	13.1	6.5
Culebra Creek	LINKNO3068	13	134	100%	3.9	17.1	10.3
	F	7	85	63%	3.9	17.1	12.1
	S	6	49	37%	4.8	17.1	8.2
	LINKNO3644	12	317	100%	14.5	59.0	26.4
	F	11	297	94%	14.5	59.0	27.0
	S	1	21	6%	20.5	20.5	20.5
	LINKNO3804	10	300	100%	12.0	66.5	30.0
	F	4	195	65%	33.0	66.5	48.8
	S	6	105	35%	12.0	25.5	17.6
	LINKNO3860	10	447	100%	11.0	134.0	44.7
	F	5	283	63%	11.0	134.0	56.5
	S	5	164	37%	19.5	48.0	32.8
	LINKNO3932	4	387	100%	40.5	169.0	96.8
	F	3	347	90%	85.5	169.0	115.6
	S	1	41	10%	40.5	40.5	40.5
El Perdido Creek	LINKNO1244	10	146	100%	6.5	34.4	14.6
	F	6	105	72%	7.7	34.4	17.6
	S	4	40	28%	6.5	14.9	10.1

Table 3-3. Summary of slow (S) and fast (F) water habitat units by site (total, percent, minimum, maximum, and average length). -- continued

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
El Poso Creek	LINKNO379	12	131	100%	2.2	25.8	10.9
	F	8	115	88%	8.3	25.8	14.4
	S	4	16	12%	2.2	6.5	4.1
	LINKNO3476	8	167	100%	7.6	40.0	20.8
	F	2	77	46%	37.0	40.0	38.5
	S	6	90	54%	7.6	24.5	14.9
	LINKNO3500	15	206	100%	4.5	28.2	13.7
	F	8	148	72%	11.5	28.2	18.5
	S	7	58	28%	4.5	10.9	8.3
	LINKNO3508	7	156	100%	16.0	45.5	22.2
	F	4	105	68%	18.0	45.5	26.3
	S	3	51	32%	16.0	18.5	16.8
	LINKNO3524	10	145	100%	5.8	25.5	14.5
	F	6	98	68%	6.6	25.5	16.3
	S	4	47	32%	5.8	18.2	11.7
	LINKNO3532	10	207	100%	13.0	36.1	20.7
	F	8	173	84%	13.0	36.1	21.6
	S	2	34	16%	13.5	20.5	17.0
North Vallejos Creek	LINKNO3180-D	12	156	100%	4.0	30.6	13.0
	F	7	116	75%	5.4	30.6	16.6
	S	5	40	25%	4.0	14.0	7.9
	LINKNO3180-U	15	149	100%	4.3	24.0	10.7
	F	3	48	32%	11.2	24.0	16.1
	S	12	101	68%	4.3	12.0	9.2
Rito Seco	LINKNO315	11	90	100%	3.3	20.0	8.2
	F	3	21	23%	4.5	10.9	6.9
	S	8	69	77%	3.3	20.0	8.6
	LINKNO3484	12	165	100%	9.3	24.5	13.8
	F	3	47	28%	13.0	17.5	15.7
	S	9	118	72%	9.3	24.5	13.1

Table 3-3. Summary of slow (S) and fast (F) water habitat units by site (total, percent, minimum, maximum, and average length). -- continued

Stream Name	SITEID	Total Habitat Units	Total Length (m)	Total Length (%)	Min of Length (m)	Max of Length (m)	Average of Length (m)
San Francisco	LINKNO925-D	14	129	100%	2.7	22.1	9.1
	F	6	83	64%	6.9	22.1	14.9
	S	8	46	36%	2.7	9.3	5.7
	LINKNO925-U	14	131	100%	1.8	26.0	9.4
	F	8	107	82%	5.0	26.0	13.4
	S	6	24	18%	1.8	8.3	4.0
Vallejos Creek	LINKNO1013	15	156	100%	2.7	37.2	10.4
	F	8	111	71%	6.7	37.2	13.8
	S	7	45	29%	2.7	13.3	6.5
	LINKNO933	15	136	100%	1.5	22.0	9.0
	F	6	75	55%	6.1	22.0	12.5
	S	9	61	45%	1.5	13.0	6.7
Ventero Creek	LINKNO3732	13	340	100%	11.5	45.0	26.1
	F	7	202	59%	15.5	44.5	28.8
	S	6	138	41%	11.5	45.0	23.0
Total			**4,462**				

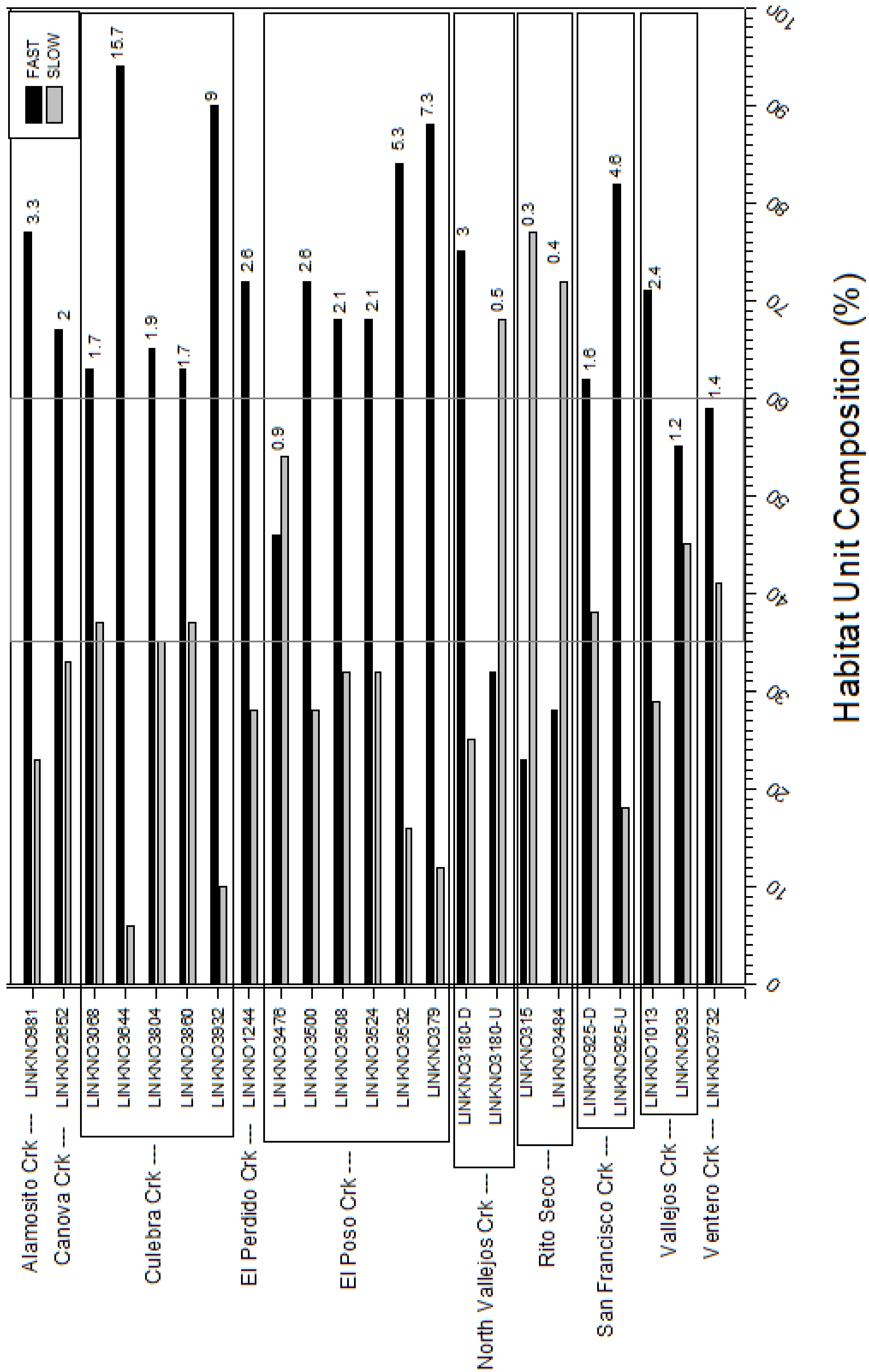


Figure 3-25. Habitat delineation. Fast and Slow habitat composition across Culebra Creek Watershed sites. Numbers on right of bars denote Riffle-Pool ratios. Lines at 35% and 60% denote pool habitat reference condition (Alves J. E., Patten, Brauch, & Jones, 2008).

Table 3-4. Number and length of slow habitat units (pools) by site.

Stream Name	SITEID	Number of Pools	Length (m)	Average of Length (m)
Alamosito Creek	LINKNO981	7	30	4.3
	DAM	4	17.7	4.4
	PLUNGE	3	12.3	4.1
Canova Creek	LINKNO2652	7	45.2	6.5
	DAM	2	20.7	10.3
	PLUNGE	5	24.6	4.9
Culebra Creek	LINKNO3068	6	49.3	8.2
	DAM	1	6.4	6.4
	PLUNGE	2	10.3	5.1
	SCOUR	3	32.7	10.9
	LINKNO3644	1	20.5	20.5
	SCOUR	1	20.5	20.5
	LINKNO3804	6	105.3	17.6
	PLUNGE	1	19.5	19.5
	SCOUR	5	85.8	17.2
	LINKNO3860	5	164.0	32.8
	SCOUR	5	164.0	32.8
	LINKNO3932	1	40.5	40.5
	SCOUR	1	40.5	40.5
El Perdido Creek	LINKNO1244	4	40.4	10.1
	DAM	1	9.0	9.0
	PLUNGE	3	31.5	10.5
El Poso Creek	LINKNO379	4	16.2	4.1
	DAM	1	6.5	6.5
	PLUNGE	3	9.7	3.2
	LINKNO3476	6	89.6	14.9
	DAM	2	33.0	16.5
	PLUNGE	3	35.0	11.7
	SCOUR	1	21.6	21.6
	LINKNO3500	7	58.0	8.3
	DAM	1	8.1	8.1
	PLUNGE	6	49.9	8.3
	LINKNO3508	3	50.5	16.8
	PLUNGE	2	32.0	16.0
	SCOUR	1	18.5	18.5
	LINKNO3524	4	47.0	11.7
	SCOUR	4	47.0	11.7
	LINKNO3532	2	34.0	17.0
	SCOUR	2	34.0	17.0
North Vallejos Creek	LINKNO3180-D	5	39.6	7.9

Stream Name	SITEID	Number of Pools	Length (m)	Average of Length (m)
	DAM	2	10.7	5.4
	PLUNGE	2	14.9	7.4
	SCOUR	1	14.0	14.0
	LINKNO3180-U	12	101.3	9.2
	DAM	5	44.8	9.0
	PLUNGE	5	40.7	10.2
	SCOUR	2	15.8	7.9
Rito Seco	LINKNO315	8	69.1	8.6
	DAM	2	23.0	11.5
	PLUNGE	6	46.1	7.7
	LINKNO3484	9	118.1	13.1
	DAM	6	84.6	14.1
	PLUNGE	2	21.0	10.5
	SCOUR	1	12.5	12.5
San Francisco	LINKNO925-D	8	46.0	5.7
	PLUNGE	2	9.1	4.5
	SCOUR	6	36.9	6.2
	LINKNO925-U	6	23.8	4.0
	PLUNGE	1	1.8	1.8
	SCOUR	5	22.0	4.4
Vallejos Creek	LINKNO1013	7	45.3	6.5
	DAM	2	9.1	4.6
	PLUNGE	1	7.1	7.1
	SCOUR	4	29.1	7.3
	LINKNO933	9	60.7	6.7
	DAM	2	6.0	3.0
	PLUNGE	4	25.3	6.3
	SCOUR	3	29.4	9.8
Ventero Creek	LINKNO3732	6	138.0	23.0
	SCOUR	6	138.0	23.0
Total		**133**	**1432**	

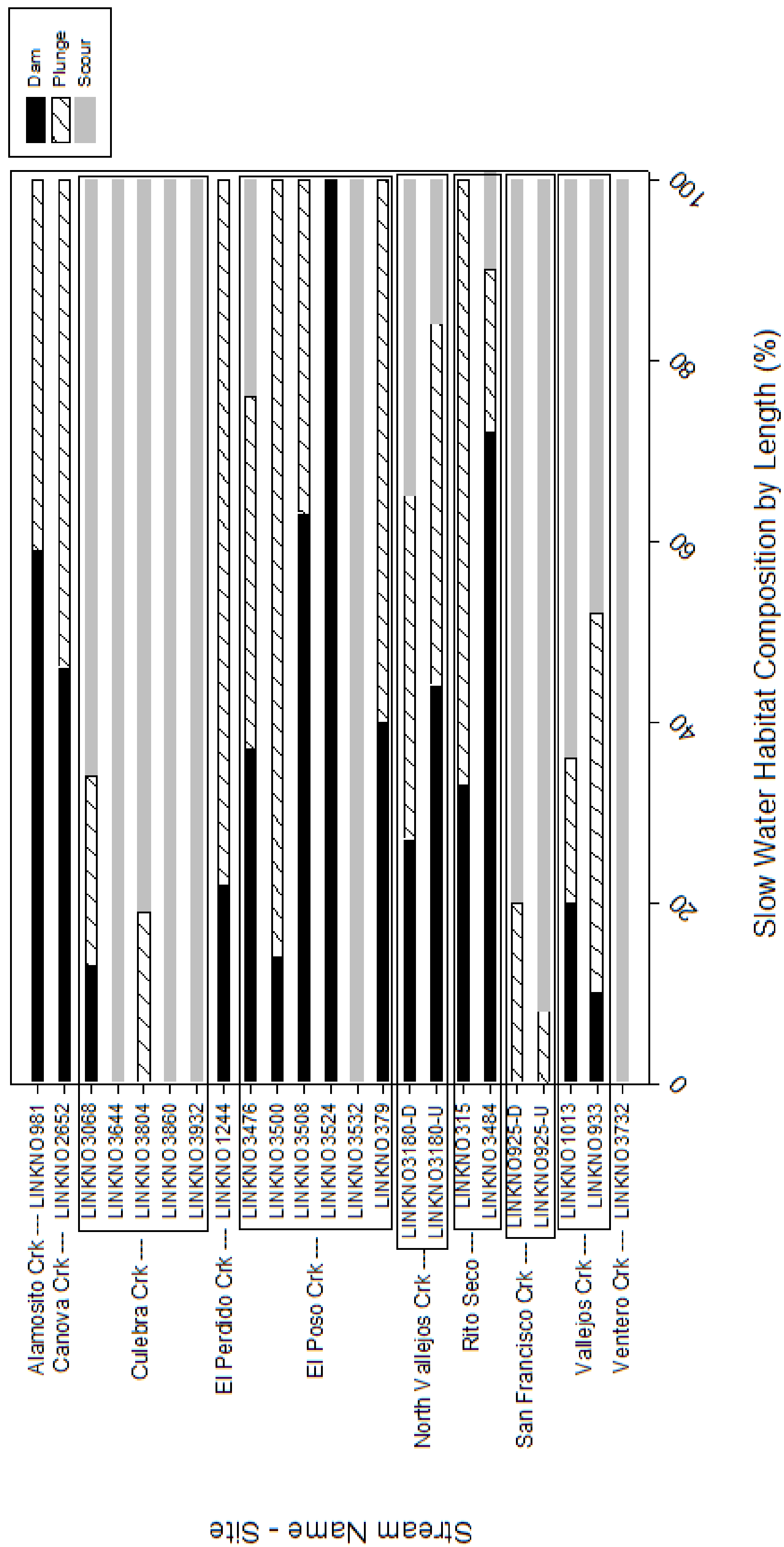


Figure 3-26 Slow water habitat composition across Culebra Watershed sites.

Table 3-5. Summary of pool characteristics by site.

Stream Name	SITEID	No. of Pools	Avg Pool Length (m)	Avg Wetted Width (m)	Avg Crest Depth (m)	Min Depth (m)	Max Depth (m)	Avg of Max Depth (m)	Avg Residual Pool depth (m)
Alamosito Creek	LINKNO981	7	4	3	0.12	0.27	0.40	0.34	0.22
	DAM	4	4	3	0.10	0.27	0.40	0.35	0.25
	PLUNGE	3	4	3	0.14	0.32	0.37	0.34	0.2
Canova Creek	LINKNO2652	7	6	3	0.20	0.40	0.72	0.57	0.37
	DAM	2	10	3	0.19	0.40	0.50	0.45	0.26
	PLUNGE	5	5	3	0.20	0.51	0.72	0.62	0.42
Culebra Creek	LINKNO3068	6	8	5	0.25	0.52	0.68	0.59	0.34
	DAM	1	6	8	0.18	0.60	0.60	0.60	0.42
	PLUNGE	2	5	4	0.25	0.52	0.59	0.56	0.31
	SCOUR	3	11	5	0.27	0.52	0.68	0.60	0.33
	LINKNO3644	1	21	7	0.30	0.51	0.51	0.51	0.21
	SCOUR	1	21	7	0.30	0.51	0.51	0.51	0.21
	LINKNO3804	6	18	7	0.47	0.68	1.21	0.90	0.43
	PLUNGE	1	20	7	0.39	1.06	1.06	1.06	0.67
	SCOUR	5	17	7	0.48	0.68	1.21	0.87	0.39
	LINKNO3860	5	33	16	0.47	0.71	0.95	0.87	0.4
	SCOUR	5	33	16	0.47	0.71	0.95	0.87	0.4
	LINKNO3932	1	41	22	0.38	1.34	1.34	1.34	0.96
	SCOUR	1	41	22	0.38	1.34	1.34	1.34	0.96
El Perdido Creek	LINKNO1244	4	10	5	0.17	0.36	0.59	0.49	0.32
	DAM	1	9	9	0.10	0.59	0.59	0.59	0.49
	PLUNGE	3	10	3	0.20	0.36	0.54	0.45	0.25

Table 3-5. Summary of pool characteristics by site.--continued

Stream Name	SITEID	No. of Pools	Avg Pool Length (m)	Avg Wetted Width (m)	Avg Crest Depth (m)	Min Depth (m)	Max Depth (m)	Avg of Max Depth (m)	Avg Residual Pool depth (m)
El Poso Creek	LINKNO379	4	4	4	0.29	0.54	0.62	0.58	0.29
	DAM	1	7	3	0.40	0.59	0.59	0.59	0.19
	PLUNGE	3	3	4	0.25	0.54	0.62	0.57	0.32
	LINKNO3476	6	15	6	0.21	0.55	0.84	0.72	0.51
	DAM	2	16	5	0.26	0.78	0.84	0.81	0.55
	PLUNGE	3	12	7	0.19	0.55	0.78	0.66	0.47
	SCOUR	1	22	6	0.17	0.70	0.70	0.70	0.53
	LINKNO3500	7	8	6	0.24	0.51	0.91	0.66	0.42
	DAM	1	8	6	0.26	0.91	0.91	0.91	0.65
	PLUNGE	6	8	6	0.23	0.51	0.67	0.62	0.39
	LINKNO3508	3	17	5	0.23	0.55	0.70	0.60	0.37
	PLUNGE	2	16	5	0.24	0.55	0.56	0.56	0.32
	SCOUR	1	19	4	0.23	0.70	0.70	0.70	0.47
	LINKNO3524	4	12	5	0.18	0.47	0.60	0.52	0.34
	SCOUR	4	12	5	0.18	0.47	0.60	0.52	0.34
	LINKNO3532	2	17	6	0.25	0.50	0.58	0.54	0.29
	SCOUR	2	17	6	0.25	0.50	0.58	0.54	0.29
North Vallejos Creek	LINKNO3180-D	5	8	6	0.18	0.40	0.70	0.54	0.36
	DAM	2	5	5	0.20	0.52	0.54	0.53	0.33
	PLUNGE	2	7	5	0.17	0.40	0.70	0.55	0.38
	SCOUR	1	14	9	0.17	0.56	0.56	0.56	0.39
	LINKNO3180-U	12	9	4	0.19	0.39	0.64	0.48	0.29
	DAM	5	9	4	0.21	0.40	0.64	0.49	0.28
	PLUNGE	5	10	4	0.18	0.39	0.50	0.46	0.28
	SCOUR	2	8	6	0.20	0.41	0.55	0.48	0.28

Table 3-5. Summary of pool characteristics by site.--continued

Stream Name	SITEID	No. of Pools	Avg Pool Length (m)	Avg Wetted Width (m)	Avg Crest Depth (m)	Min Depth (m)	Max Depth (m)	Avg of Max Depth (m)	Avg Residual Pool depth (m)
Rito Seco	LINKNO315	8	9	3	0.12	0.26	0.40	0.34	0.22
	DAM	2	12	3	0.09	0.27	0.32	0.30	0.21
	PLUNGE	6	8	3	0.13	0.26	0.40	0.35	0.22
	LINKNO3484	9	13	3	0.15	0.42	1.10	0.61	0.46
	DAM	6	14	3	0.13	0.42	1.10	0.61	0.48
	PLUNGE	2	11	4	0.22	0.53	0.84	0.69	0.47
	SCOUR	1	13	3	0.17	0.45	0.45	0.45	0.28
San Francisco	LINKNO925-D	8	6	3	0.09	0.24	0.40	0.31	0.22
	PLUNGE	2	5	3	0.10	0.29	0.39	0.34	0.24
	SCOUR	6	6	3	0.09	0.24	0.40	0.30	0.21
	LINKNO925-U	6	4	3	0.07	0.24	0.32	0.28	0.21
	PLUNGE	1	2	3	0.08	0.27	0.27	0.27	0.19
	SCOUR	5	4	3	0.06	0.24	0.32	0.29	0.23
Vallejos Creek	LINKNO1013	7	6	2	0.11	0.26	0.37	0.32	0.21
	DAM	2	5	2	0.13	0.30	0.35	0.33	0.2
	PLUNGE	1	7	2	0.10	0.30	0.30	0.30	0.2
	SCOUR	4	7	2	0.11	0.26	0.37	0.32	0.21
	LINKNO933	9	7	2	0.15	0.12	0.49	0.33	0.18
	DAM	2	3	2	0.12	0.29	0.49	0.39	0.27
	PLUNGE	4	6	3	0.17	0.12	0.36	0.29	0.12
	SCOUR	3	10	2	0.13	0.30	0.36	0.33	0.2
Ventero Creek	LINKNO3732	6	23	7	0.53	0.97	1.42	1.30	0.77
	SCOUR	6	23	7	0.53	0.97	1.42	1.30	0.77

Table 3-6. Number and length of turbulent (T) and not turbulent (NT) fast water habitat units by site.

Stream Name	SITEID	Number of Unit Habitats	Length (m)
Alamosito Creek	LINKNO981	9	102
	NT	3	31
	T	6	71
Canova Creek	LINKNO2652	5	91
	NT	1	13
	T	4	78
Culebra Creek	LINKNO3068	7	85
	NT	2	23
	T	5	62
	LINKNO3644	11	297
	NT	4	93
	T	7	204
	LINKNO3804	4	195
	NT	4	195
	LINKNO3860	5	283
	NT	5	283
	LINKNO3932	3	347
	NT	3	347
El Perdido Creek	LINKNO1244	6	105
	T	6	105
El Poso Creek	LINKNO379	8	115
	NT	1	12
	T	7	104
	LINKNO3476	2	77
	T	2	77
	LINKNO3500	8	148
	NT	1	18
	T	7	130
	LINKNO3508	4	105
	NT	3	87
	T	1	18
	LINKNO3524	6	98
	NT	2	43
	T	4	55
	LINKNO3532	8	173
	NT	3	55
	T	5	118

Table 3-6. Number and length of turbulent (T) and not turbulent (NT) fast water habitat units by site.--continued

Stream Name	SITEID	Number of Unit Habitats	Length (m)
North Vallejos Creek	LINKNO3180-D	7	116
	NT	2	20
	T	5	97
	LINKNO3180-U	3	48
	T	3	48
Rito Seco	LINKNO315	3	21
	T	3	21
	LINKNO3484	3	47
	NT	3	47
San Francisco Creek	LINKNO925-D	6	83
	NT	3	50
	T	3	33
	LINKNO925-U	8	107
	T	8	107
Vallejos Creek	LINKNO1013	8	111
	NT	5	78
	T	3	33
	LINKNO933	6	75
	NT	3	28
	T	3	47
Ventero Creek	LINKNO3732	7	202
	NT	6	181
	T	1	21
Total		**137**	**3030**

Table 3-7 Summary of fast water unit characteristics by site.

Stream Name	SITEID	No. Habitat Units (n)	Avg. Length (m)	Min Wetted Width (m)	Max Wetted Width (m)	Avg. Wetted Width (m)
Alamosito Creek	LINKNO981	9	11.4	1.8	4.2	2.9
Canova Creek	LINKNO2652	5	18.3	2.9	4.9	3.8
Culebra Creek	LINKNO3068	7	12.1	5.3	7.8	6.1
	LINKNO3644	11	27.0	7.2	15.0	10.6
	LINKNO3804	4	48.8	6.2	10.5	7.9
	LINKNO3860	5	56.5	10.0	14.5	12.1
	LINKNO3932	3	115.6	8.5	11.5	10.1
El Perdido Creek	LINKNO1244	6	17.6	2.6	6.0	3.8
El Poso Creek	LINKNO379	8	14.4	3.4	4.9	4.0
	LINKNO3476	2	38.5	5.4	7.2	6.3
	LINKNO3500	8	18.5	5.5	9.6	7.0
	LINKNO3508	4	26.3	4.0	6.9	5.4
	LINKNO3524	6	16.3	4.2	6.6	4.8
	LINKNO3532	8	21.6	4.9	6.9	5.8
North Vallejos Creek	LINKNO3180-D	7	16.6	2.9	8.1	4.0
	LINKNO3180-U	3	16.1	2.9	5.1	4.0
Rito Seco	LINKNO315	3	6.9	2.0	2.5	2.2
	LINKNO3484	3	15.7	2.1	2.7	2.4
San Francisco Creek	LINKNO925-D	6	14.9	2.2	3.4	2.8
	LINKNO925-U	8	13.4	1.7	4.2	3.0
Vallejos Creek	LINKNO1013	8	13.8	1.7	3.0	2.5
	LINKNO933	6	12.5	1.9	3.7	2.8
Ventero Creek	LINKNO3732	7	28.8	5.1	6.6	5.7
Total		**137**	**22**	**1.7**	**15**	**5.2**

Table 3-8. Summary of habitat characteristics across representative fast water transects.

Stream Name	SITEID	No. of Fast Water Transects (n)	Avg. Unit Length (m)	Avg. of Bankfull Width (m)	Avg. of Wetted Width (m)	Avg. Bankfull Height (m)	Avg. Thalweg Depth (m)
Alamosito Creek	LINKNO981	9	11.4	3.7	2.9	0.46	0.19
Canova Creek	LINKNO2652	5	18.3	5.4	3.8	0.45	0.41
Culebra Creek	LINKNO3068	7	12.1	8.5	6.1	0.42	0.39
	LINKNO3644	11	27.0	19.1	10.6	0.45	0.35
	LINKNO3804	4	48.8	8.5	7.9	0.13	0.51
	LINKNO3860	5	56.5	13.8	12.1	0.17	0.48
	LINKNO3932	3	115.6	10.6	10.1	0.14	0.46
El Perdido Creek	LINKNO1244	6	17.6	8.7	3.8	0.59	0.29
El Poso Creek	LINKNO379	8	14.4	5.8	4.0	0.57	0.39
	LINKNO3476	2	38.5	9.6	6.3	0.55	0.29
	LINKNO3500	8	18.5	9.3	7.0	0.48	0.38
	LINKNO3508	4	26.3	9.8	5.4	0.29	0.39
	LINKNO3524	6	16.3	8.3	4.8	0.51	0.33
	LINKNO3532	8	21.6	6.7	5.8	0.42	0.37
North Vallejos Creek	LINKNO3180-D	7	16.6	4.3	4.0	0.30	0.28
	LINKNO3180-U	3	16.1	4.6	4.0	0.20	0.27
Rito Seco	LINKNO315	3	6.9	2.8	2.2	0.26	0.21
	LINKNO3484	3	15.7	2.9	2.4	0.25	0.25
San Francisco Creek	LINKNO925-D	6	14.9	3.4	2.8	0.36	0.19
	LINKNO925-U	8	13.4	4.1	3.0	0.35	0.17
Vallejos Creek	LINKNO1013	8	13.8	3.1	2.5	0.27	0.19
	LINKNO933	6	12.5	3.5	2.8	0.24	0.21
Ventero Creek	LINKNO3732	7	28.8	6.3	5.7	0.16	0.63

3.4.11.2 Large Woody Debris Summary

Table 3-9. Summary of large woody debris (lwd) by site.

Stream Name/ SITEID	LWD Length (m)			Total LWD Pieces	Length Surveyed (m)	Total LWD Density (LWD/km)
	1-5	5-15	>15			
Alamosito Creek	16	4	0	20	132	152
LINKNO981	16	4	0	20	132	152
Canova Creek	26	6	0	32	137	234
LINKNO2652	26	6	0	32	137	234
Culebra Creek	26	2	0	28	1585	18
LINKNO3068	8	0	0	8	134	60
LINKNO3644	18	2	0	20	317	63
LINKNO3804	0	0	0	0	300	0
LINKNO3860	0	0	0	0	447	0
LINKNO3932	0	0	0	0	387	0
El Perdido Creek	21	33	2	56	146	384
LINKNO1244	21	33	2	56	146	384
El Poso Creek	156	14	1	183	1012	181
LINKNO379	11	1	0	12	131	92
LINKNO3476	71	9	0	80	167	479
LINKNO3500	23	4	0	27	206	131
LINKNO3508	37	0	1	38	156	244
LINKNO3524	12	0	0	12	145	83
LINKNO3532	13	1	0	14	207	68
North Vallejos Creek	44	5	0	49	305	161
LINKNO3180-D	14	3	0	17	156	109
LINKNO3180-U	30	2	0	32	149	215
Rito Seco	47	11	0	58	255	227
LINKNO315	40	11	0	51	90	567
LINKNO3484	7	0	0	7	165	42
San Francisco Creek	42	11	0	53	260	204
LINKNO925-D	25	3	0	28	129	217
LINKNO925-U	17	8	0	25	131	191
Vallejos Creek	39	6	0	45	292	154
LINKNO1013	16	0	0	16	156	103
LINKNO933	23	6	0	29	136	213
Ventero Creek	0	0	0	0	340	0
LINKNO3732	0	0	0	0	340	0
Total	**403**	**90**	**3**			

Table 3-10. Summary of LWD jams by site. [LWD – large woody debris]

Stream Name	Site id	No. of LWD Jams	Average No. of Qualifying Pieces	Total No. of Qualifying Pieces
Alamosito Creek	LINKNO981	1	2	2
Canova Creek	LINKNO2652	2	8	15
Culebra Creek	LINKNO3068	1	8	8
	LINKNO3644	0	0	0
	LINKNO3804	0	0	0
	LINKNO3860	0	0	0
	LINKNO3932	0	0	0
El Perdido Creek	LINKNO1244	1	12	12
El Poso Creek	LINKNO379	0	0	0
	LINKNO3476	1	14	14
	LINKNO3500	0	0	0
	LINKNO3508	0	0	0
	LINKNO3524	0	0	0
	LINKNO3532	1	9	9
North Vallejos Creek	LINKNO3180-D	2	6	11
	LINKNO3180-U	2	6	11
Rito Seco	LINKNO315	3	5	16
	LINKNO3484	0	0	0
San Francisco Creek	LINKNO925-D	0	0	0
	LINKNO925-U	4	13	50
Vallejos Creek	LINKNO1013	0	0	0
	LINKNO933	2	9	17
Ventero Creek	LINKNO3732	0	0	0
Total		**20**	**5**	**165**

Table 3-11. Summary of large woody debris (lwd) and optimal density for Cutthroat trout rearing habitat.

Stream Name	SITEID	Avg Wetted Width (m)			Total LWD Density (LWD/km)	**Optimal LWD Density (LWD/km)
		Slow habitat	Fast habitat	Overall reach		
Alamosito Creek	LINKNO981*	3	3	3.0	152	275
Canova Creek	LINKNO2652	3	4	3.4	234	275
Culebra Creek	LINKNO3068	5	6	5.6	60	193
	LINKNO3644	7	11	8.8	63	222
	LINKNO3804	7	8	7.5	0	119
	LINKNO3860	16	12	14.1	0	51
	LINKNO3932	22	10	16.1	0	51
El Perdido Creek	LINKNO1244*	5	4	4.4	384	349
El Poso Creek	LINKNO379	4	4	4.0	92	349
	LINKNO3476	6	6	6.2	479	153
	LINKNO3500	6	7	6.5	131	153
	LINKNO3508	5	5	5.2	244	333
	LINKNO3524*	5	5	4.9	83	333
	LINKNO3532*	6	6	5.9	68	333
North Vallejos Creek	LINKNO3180-D*	6	4	5.0	109	333
	LINKNO3180-U*	4	4	4.0	215	349
Rito Seco	LINKNO315	3	2	2.6	567	275
	LINKNO3484	3	2	2.7	42	97
San Francisco Creek	LINKNO925-D	3	3	2.9	217	275
	LINKNO925-U*	3	3	3.0	191	275
Vallejos Creek	LINKNO1013	2	3	2.3	103	275
	LINKNO933*	2	3	2.4	213	275
Ventero Creek	LINKNO3732	7	6	6.4	0	119

* Sites where Rio Grande Cutthroat trout has been previously documented.

** Optimal condition values for cutthroat trout rearing habitat (Alves J. E., Patten, Brauch, & Jones, 2008)

3.4.11.3 Riparian Cover

Table 3-12. Summary of riparian vegetation canopy cover by site.

Stream Name/ SITEID	Number of transects (n)	Average of Left Bank Canopy Cover (%)	Average of Center Canopy Cover (%)	Average of Right Bank Canopy Cover (%)	Total Channel Canopy Cover (%)
Alamosito Creek	9	97	97	96	97
LINKNO981	9	97	97	96	97
Canova Creek	5	76	79	83	79
LINKNO2652	5	76	79	83	79
Culebra Creek	30	40	32	36	36
LINKNO3068	7	91	84	100	92
LINKNO3644	11	50	35	35	40
LINKNO3804	4	0	0	0	0
LINKNO3860	5	0	0	0	0
LINKNO3932	3	0	0	0	0
El Perdido Creek	5	71	66	76	71
LINKNO1244	5	71	66	76	71
El Poso Creek	36	64	51	70	61
LINKNO379	8	69	64	72	68
LINKNO3476	2	69	63	88	73
LINKNO3500	8	69	40	77	62
LINKNO3508	4	40	35	44	40
LINKNO3524	6	35	33	43	37
LINKNO3532	8	84	67	88	79
North Vallejos Creek	10	79	77	85	81
LINKNO3180-D	7	81	79	86	82
LINKNO3180-U	3	75	74	84	77
Rito Seco	6	60	58	58	59
LINKNO315	3	97	95	96	96
LINKNO3484	3	22	22	19	21
San Francisco Creek	14	70	67	69	69
LINKNO925-D	6	77	76	69	74
LINKNO925-U	8	65	59	70	64
Vallejos Creek	14	85	81	85	84
LINKNO1013	8	96	91	97	95
LINKNO933	6	71	67	70	70
Ventero Creek	7	0	0	0	0
LINKNO3732	7	0	0	0	0

3.4.11.4 Substrate Summary

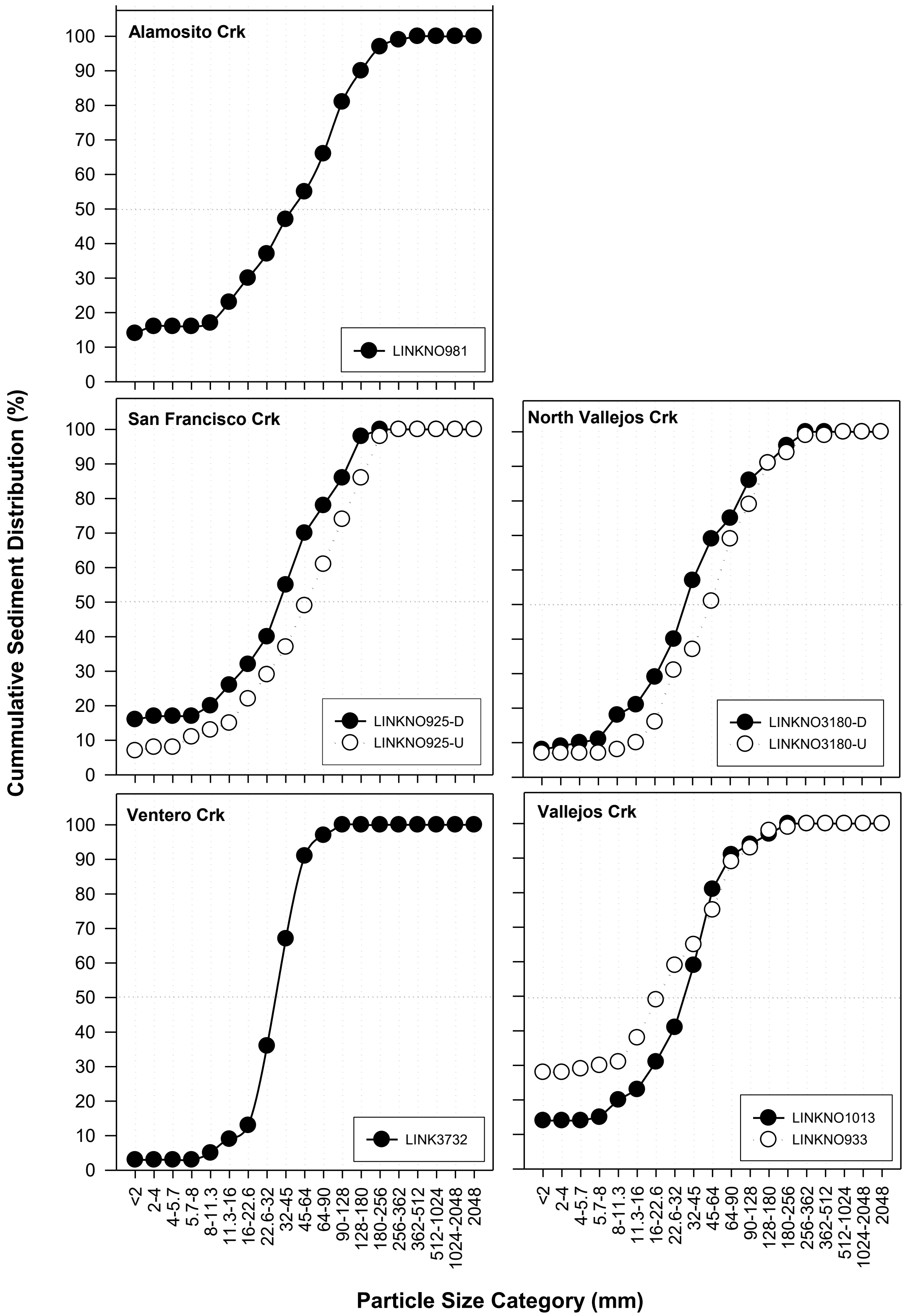


Figure 3-27. Cumulative sediment distribution at survey sites along Alamosito, San Francisco, Ventero, North Vallejos, and Vallejos creeks.

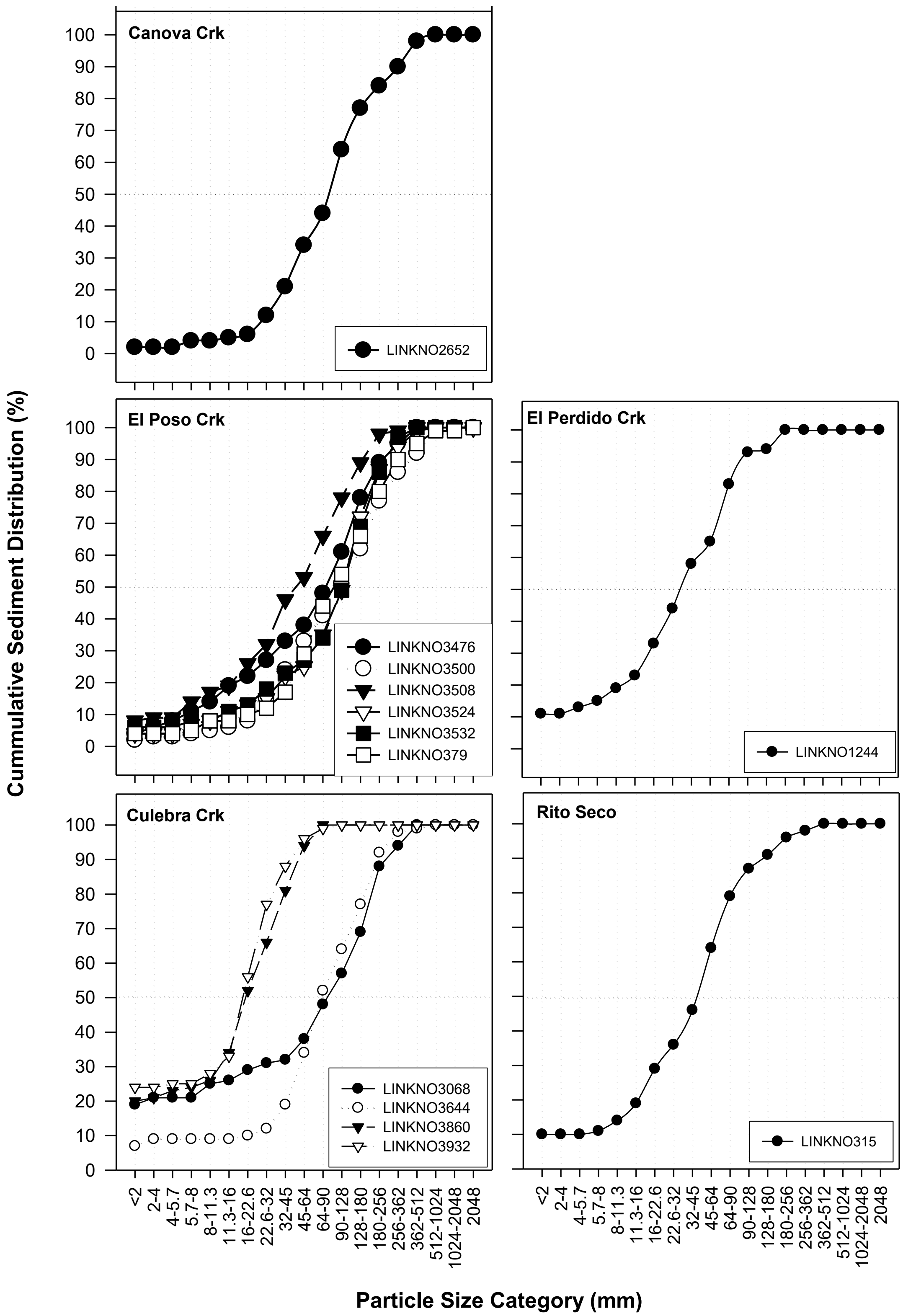


Figure 3-28. Cumulative sediment distribution at survey sites along Canova Creek, El Poso, Culebra, El Perdido, and Rito Seco creeks.

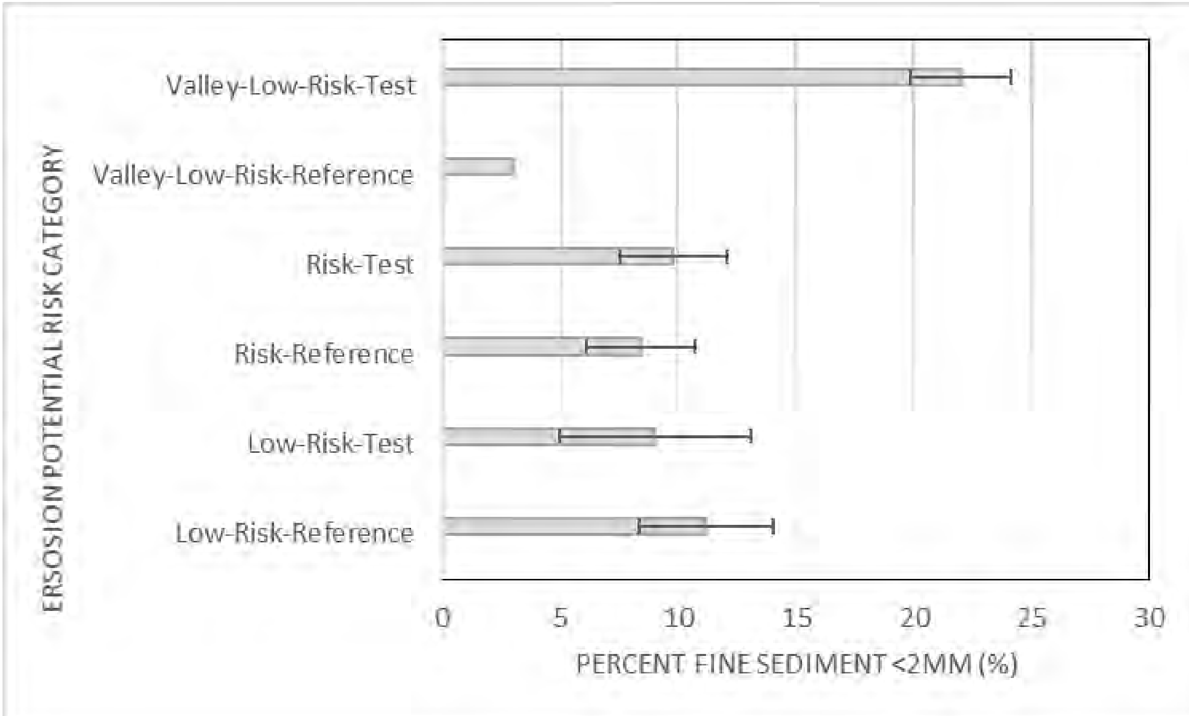


Figure 3-29 Summary of fine sediment (<2mm) in relation to erosion potential risk categories. Error bars denote standard error.

3.4.11.5 Water Quality

Table 3-13 Water quality data summary.

Stream Name	SITEID	DO (mg/l)	Temp (°C)	pH	Cond (µS/cm)
Alamosito Creek	LINKNO981	7.18	11.4	7.01	68
Canova Canyon	LINKNO2652	9.21	10.1	7.13	112
Culebra Creek	LINKNO3068	6.30	14.5	7.10	87
Culebra Creek	LINKNO3644	8.45	12.6	7.08	141
Culebra Creek	LINKNO3860	5.61	20.0	7.31	211
Culebra Creek	LINKNO3804	6.12	21.8	7.21	201
Culebra Creek	LINKNO3932	7.74	15.8	7.44	218
El Perdido Creek	LINKNO1244	6.05	12.5	6.79	71
El Poso Creek	LINKNO3500	9.54	9.8	7.16	174
El Poso Creek	LINKNO3508	8.04	15.7	6.67	174
El Poso Creek	LINKNO3476	8.89	9.0	7.04	176
El Poso Creek	LINKNO3524	7.37	12.2	6.99	163
El Poso Creek	LINKNO3532	6.36	14.5	7.05	164
El Poso Creek	LINKNO379	6.84	8.9	6.88	219
North Vallejos Creek	LINKNO3180- D	8.94	7.2	7.26	65
North Vallejos Creek	LINKNO3180-U	8.09	10.6	7.11	59
Rito Seco	LINKNO4384	6.40	20.1	7.29	127
Rito Seco	LINKNO315	6.38	11.3	7.30	98
San Francisco	LINKNO925-D	8.32	12.8	7.08	71
San Francisco	LINKNO925-U	7.56	8.0	6.95	64
Vallejos Creek	LINKNO933	8.47	8.4	6.98	56
Vallejos Creek	LINKNO1013	7.57	14.3	7.22	59
Ventero Creek	LINKNO3732	7.29	19.7	7.40	198

3.4.11.6 Macroinvertebrate

The macroinvertebrate sample analysis is summarized in Table 3-14 followed by an analysis of each individual metric and the spatial distribution of the samples across the Culebra basin.

Table 3-14 Macroinvertebrate data summary.

Stream	Site id	Density per m^2	Taxon richness	EPT richness	EPT percent	Chironomidae percent
San Francisco Creek	LINKNO925-D	3363	49	18	52.44	11.75
San Francisco Creek	LINKNO925-U	4542	42	18	36.61	35.78
Vallejos Creek	LINKNO1013	3552	43	18	36.44	16.72
El Perdido Creek	LINKNO1244	2745	36	16	43.24	38.30
Canova Creek	LINKNO2652	3636	40	17	75.30	13.60
Culebra Creek	LINKNO3068	2278	43	20	45.60	21.36
Rito Seco	LINKNO315	1613	37	14	35.83	38.42
N. Vallejos Creek	LINKNO3180-D	895	38	16	55.56	30.48
N. Vallejos Creek	LINKNO3180-U	894	41	16	50.38	24.96
El Poso Creek	LINKNO3476	3753	45	21	75.86	11.21
Rito Seco	LINKNO3484	4784	34	10	27.20	16.61
El Poso Creek	LINKNO3500	3401	34	16	43.08	44.58
El Poso Creek	LINKNO3508	1688	47	25	66.40	22.21
El Poso Creek	LINKNO3524	1848	51	25	70.04	12.51
El Poso Creek	LINKNO3532	1401	42	21	68.04	20.06
Culebra Creek	LINKNO3644	5249	39	15	48.60	38.36
Ventero Creek	LINKNO3732	7001	26	4	80.23	7.28
El Poso Creek	LINKNO379	1772	47	17	55.84	14.04
Culebra Creek	LINKNO3804	3501	31	9	53.44	33.47
Vallejos Creek	LINKNO933	675	41	20	57.77	18.33
Alamosito Creek	LINKNO981	2233	41	17	51.90	29.50

Table 3-14 Macroinvertebrate data summary.--continued

Stream	Site id	EPT: Chironomidae	HBI	Diversity (H)	Evenness
San Francisco Creek	LINKNO925-D	4.46	3.64	2.63	0.68
San Francisco Creek	LINKNO925-U	1.02	4.97	2.95	0.79
Vallejos Creek	LINKNO1013	2.18	4.71	2.69	0.72
El Perdido Creek	LINKNO1244	1.13	5.36	2.85	0.80
Canova Creek	LINKNO2652	5.54	4.16	2.48	0.67
Culebra Creek	LINKNO3068	2.14	4.23	2.97	0.79
Rito Seco	LINKNO315	0.93	4.86	3.03	0.84
N. Vallejos Creek	LINKNO3180-D	1.82	4.99	2.85	0.78
N. Vallejos Creek	LINKNO3180-U	2.02	4.72	3.07	0.83
El Poso Creek	LINKNO3476	6.77	3.94	2.75	0.72
Rito Seco	LINKNO3484	1.64	5.14	2.02	0.57
El Poso Creek	LINKNO3500	0.97	5.27	2.85	0.81
El Poso Creek	LINKNO3508	2.99	3.77	3.03	0.79
El Poso Creek	LINKNO3524	5.60	3.42	3.29	0.84
El Poso Creek	LINKNO3532	3.39	3.39	3.10	0.83
Culebra Creek	LINKNO3644	1.27	4.21	2.86	0.78
Ventero Creek	LINKNO3732	11.03	1.82	1.26	0.39
El Poso Creek	LINKNO379	3.98	4.30	3.01	0.78
Culebra Creek	LINKNO3804	1.60	4.39	2.68	0.78
Vallejos Creek	LINKNO933	3.15	4.05	3.00	0.81
Alamosito Creek	LINKNO981	1.76	4.95	3.09	0.83

Abundance

Organisms per square meter of streams bottom ranged from 647.4 in Vallejos Creek to 7,001.3 in Ventero Creek (Figure 3-30,Table 3-14). Thirteen of the 21 sites had >2000 organisms per square meter. This result in Ventero Creek is largely driven by the high number of the mayfly Tricorythodes (4,935 organisms per m^2). The sites with the lowest abundance were the Vallejos Creek sites (Figure 3-31).

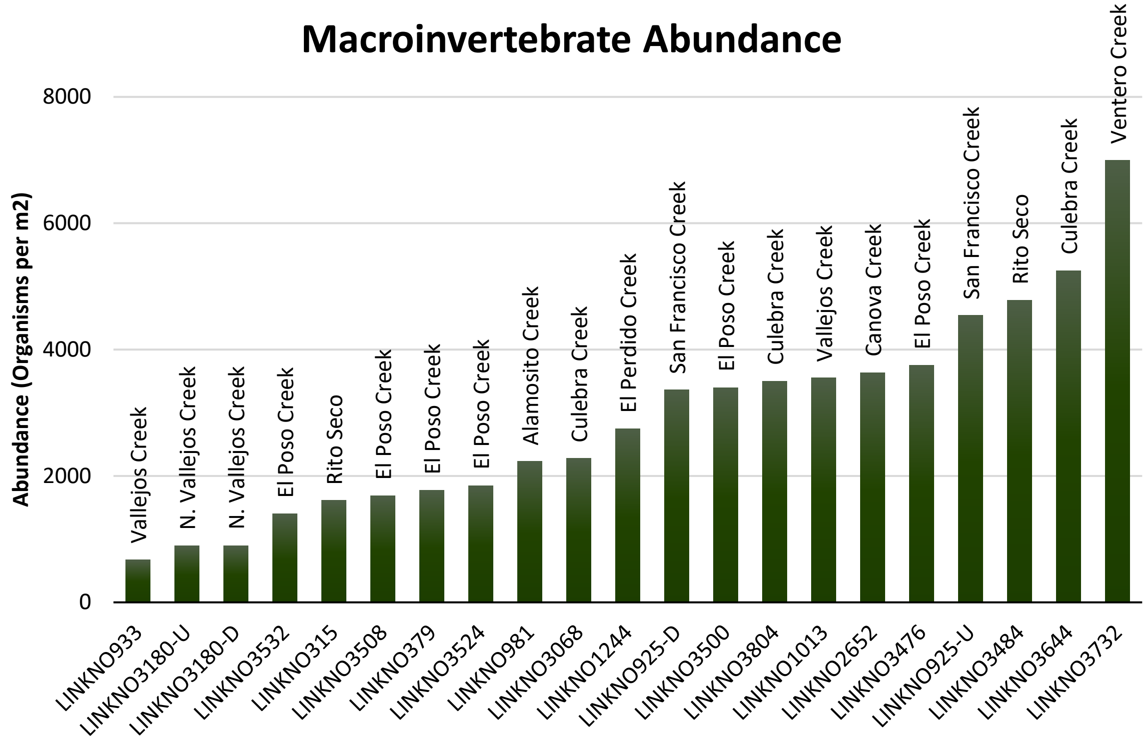


Figure 3-30 Macroinvertebrate abundance per square meter of stream bottom

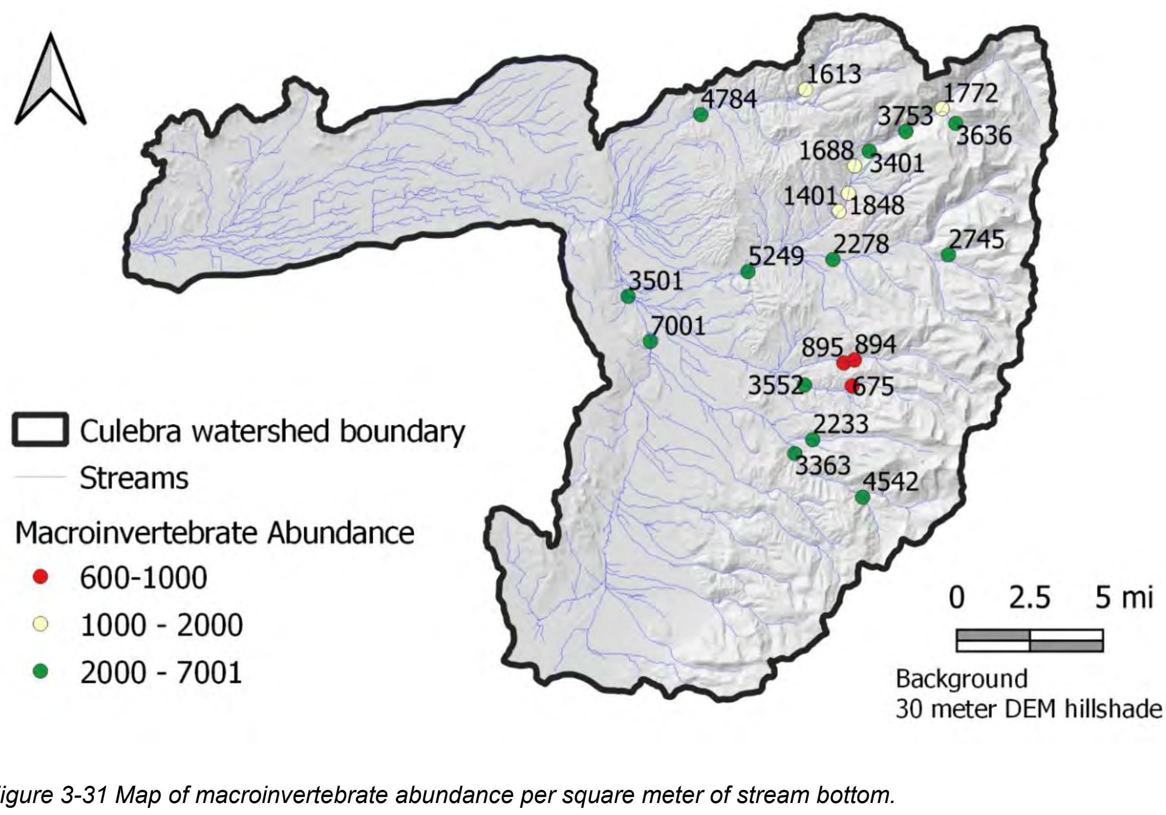


Figure 3-31 Map of macroinvertebrate abundance per square meter of stream bottom.

Taxon richness

Taxon richness often roughly correlates to stream health. Streams with a great number of taxa tend to have not only more taxa in general, but also more sensitive taxa in the stream community. Taxon richness can be skewed by the taxon rank used in analysis, in this analysis, most taxa were identified to genus. Richness ranged from a low of 26 taxa in Ventero Creek, to a high of 51 taxa in El Poso Creek (Figure 3-32 and Figure 3-33). This result is interesting in that Ventero Creek has the lowest taxon richness, but highest macroinvertebrate abundance.

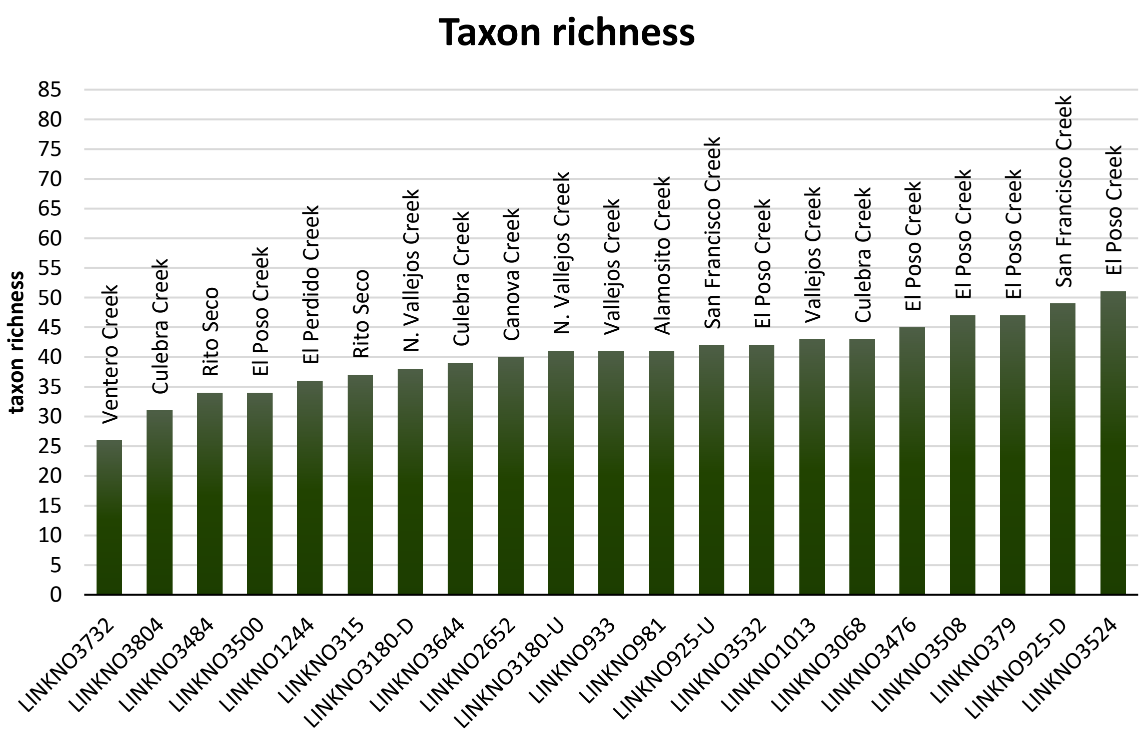


Figure 3-32 Taxon richness per site

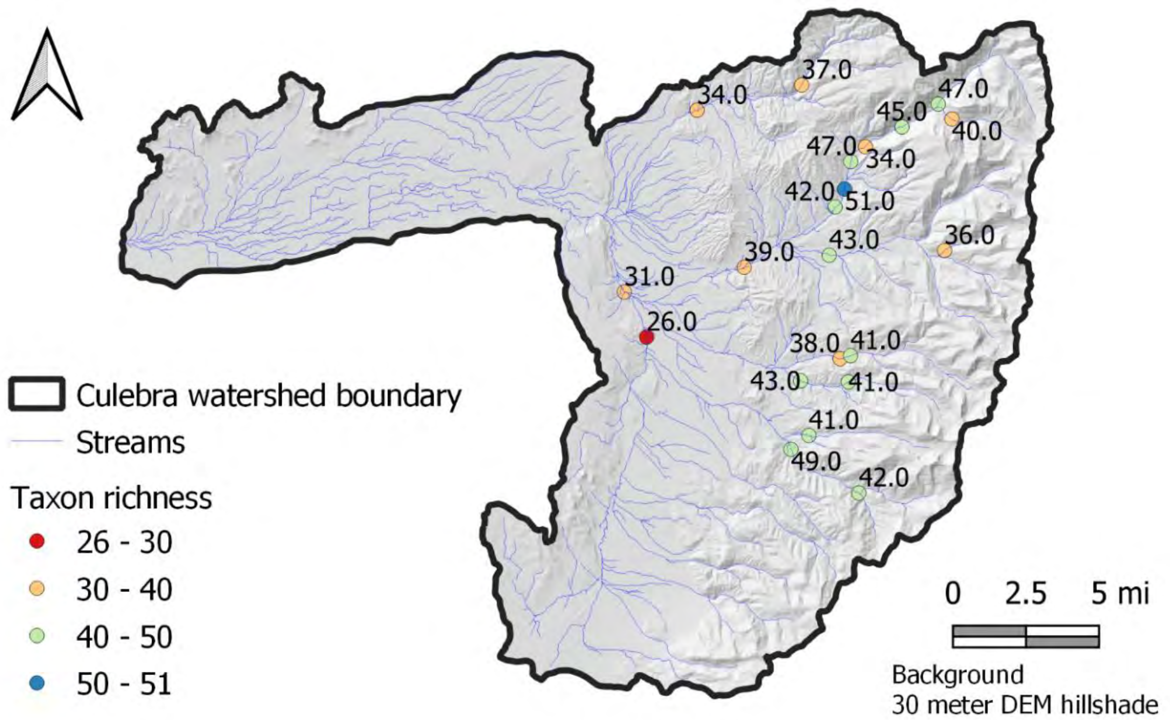


Figure 3-33 Map of taxon richness.

<u>EPT taxon richness</u>

EPT taxon richness indicates taxa that are known to be sensitive to environmental stressors and pollution. In the Upper Culebra Watershed, EPT richness ranges from 4 in Ventero Creek to 25 in two of the El Poso Creek sites (Figure 3-34). High EPT richness is an indicator of good stream health. The lowest EPT taxon richness were also the lowest sites (Figure 3-35).

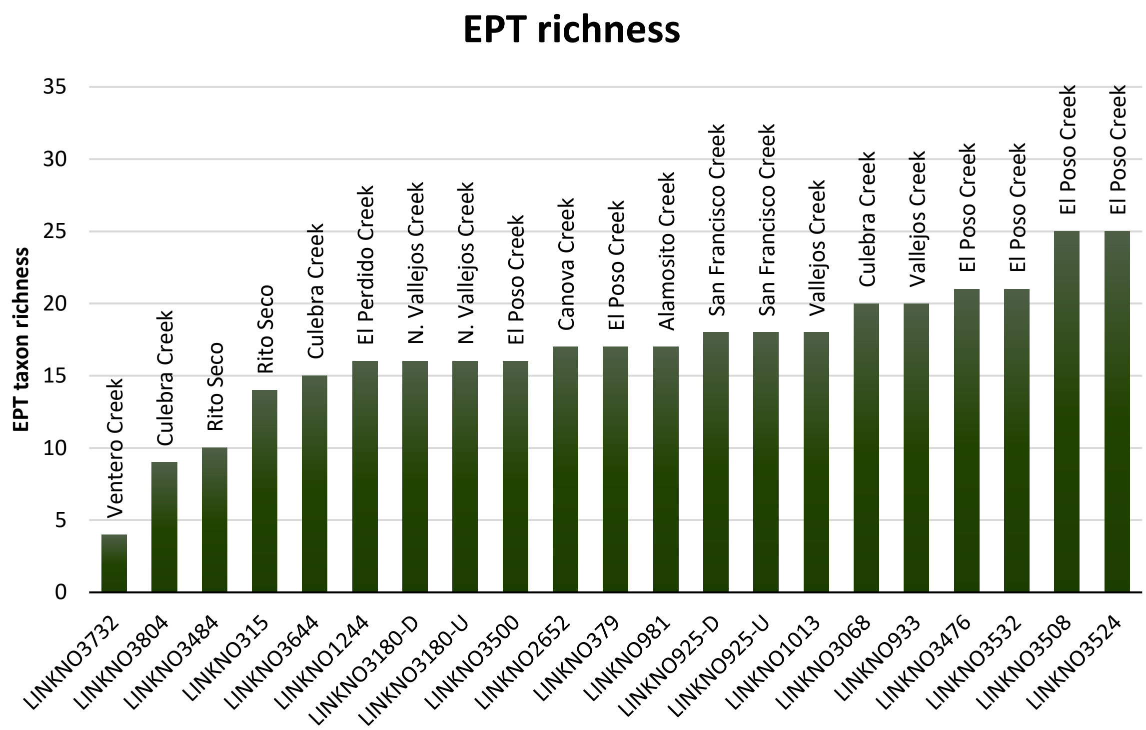


Figure 3-34 EPT taxon richness.

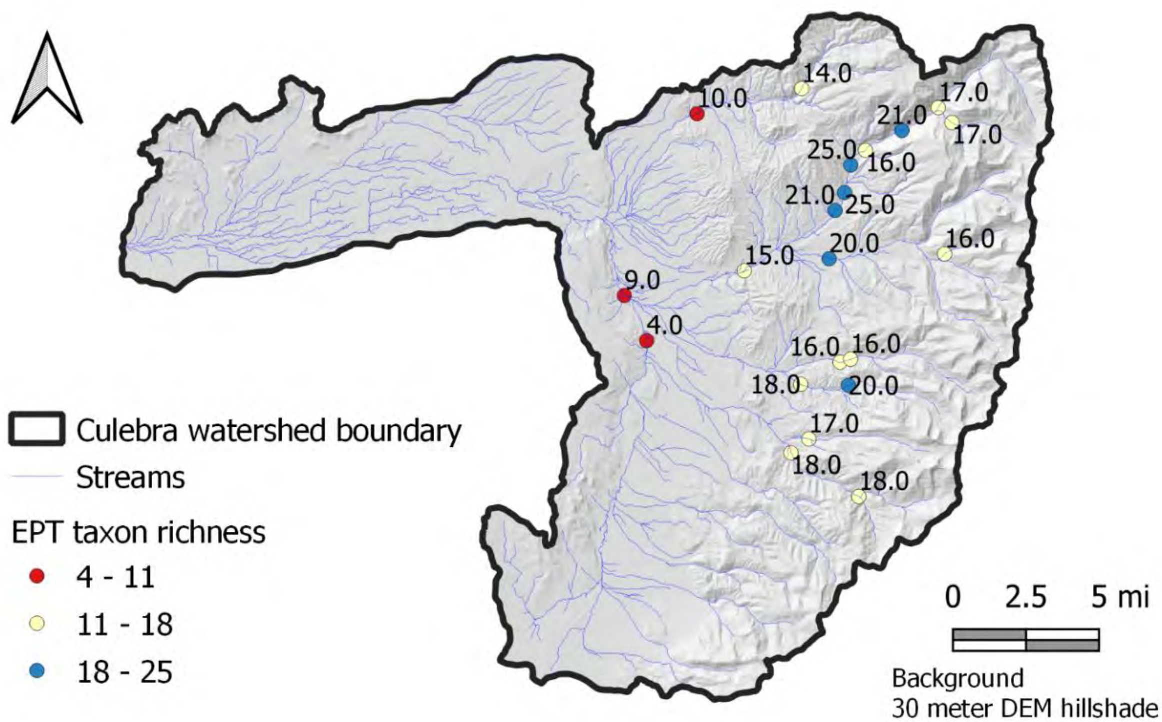


Figure 3-35 Map of EPT taxon richness.

Percent EPT taxa contribution

EPT percent contribution of EPT taxa to macroinvertebrate abundance ranged from 27% in Rito Seco to 80% in Ventero Creek (Figure 3-36 and Figure 3-37). Higher numbers here indicate increased stream health, where individuals from EPT taxa make up a greater portion of the benthic community. Since EPT taxa tend to be more sensitive, their presence in a stream indicates a lack of environmental stress.

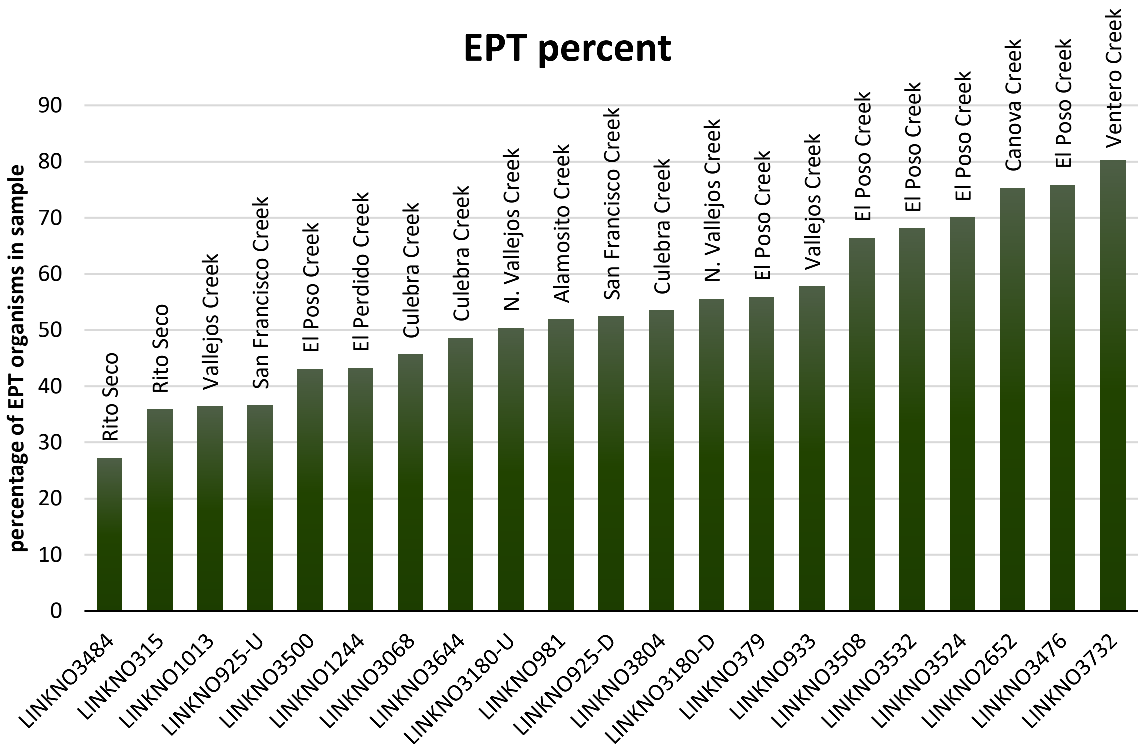


Figure 3-36 Percent EPT taxa contribution

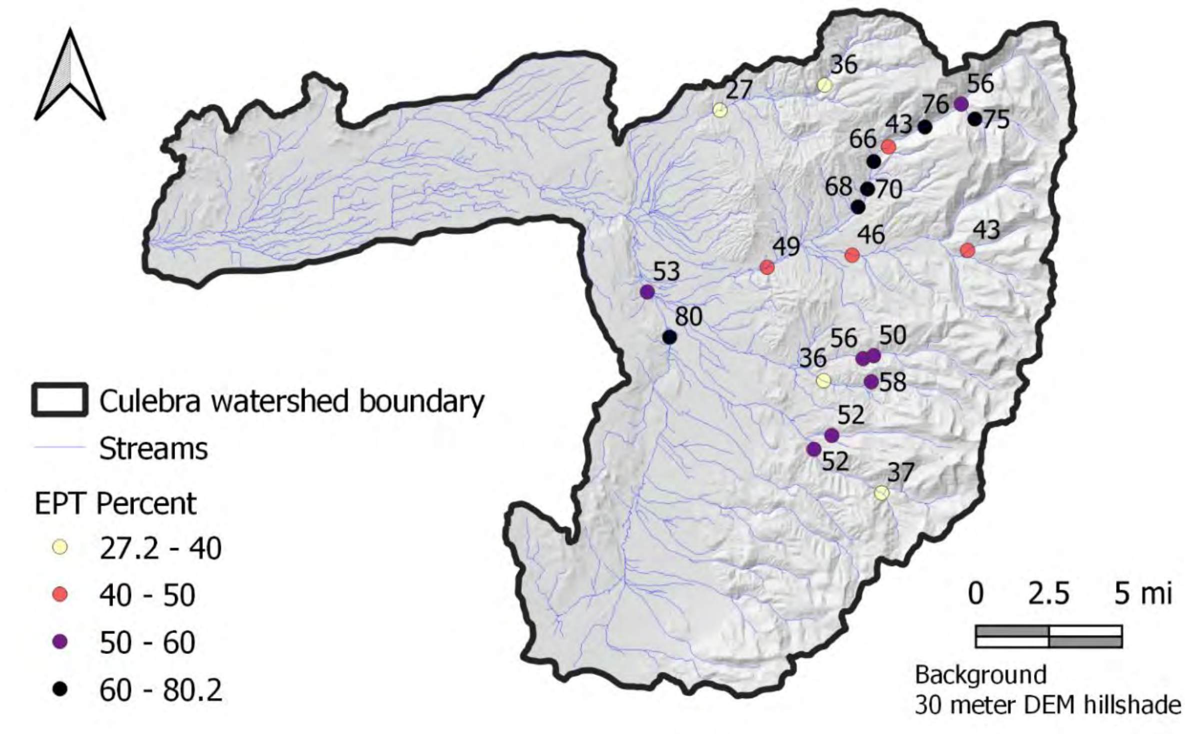


Figure 3-37 Map of percent EPT taxa contribution.

<u>Percent Chironomidae</u>

Percent Chironomidae contribution is the opposite of EPT contribution. Chironomidae are more tolerant to pollution and environmental factors, therefore a greater Chironomid contribution indicates poor stream health. Chironomid contribution ranges from 7.3% in Ventero Creek to 44.6% in El Poso Creek (Figure 3-38 and Figure 3-39).

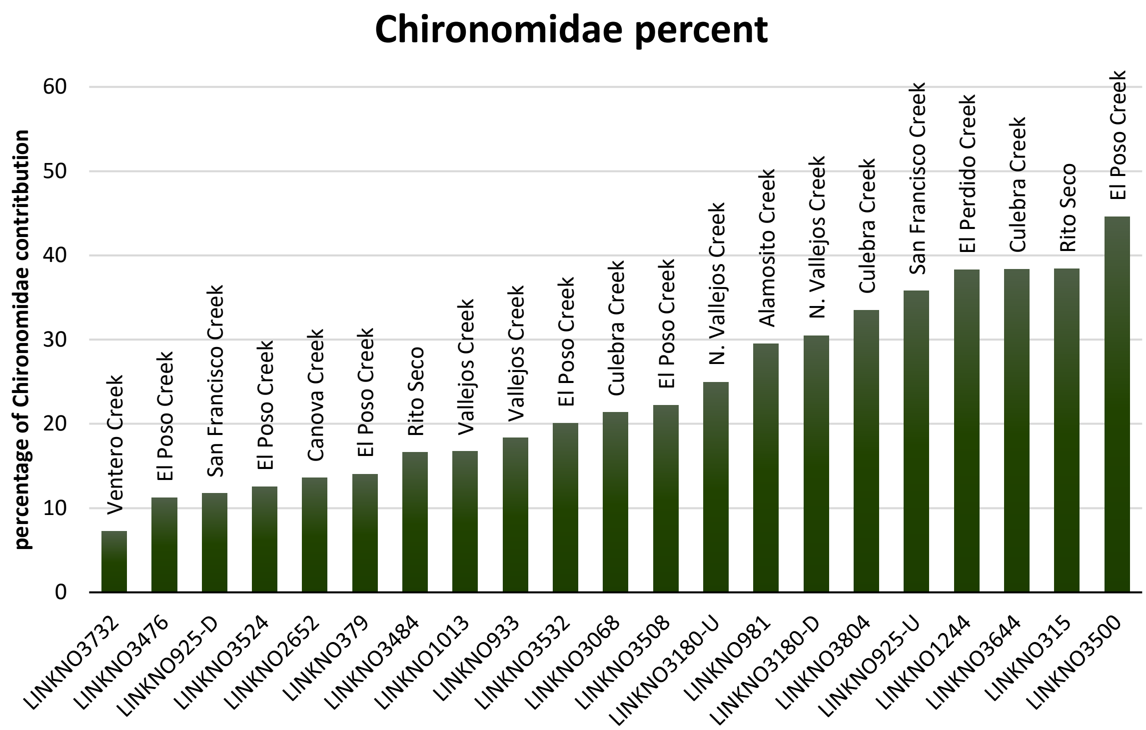


Figure 3-38 Percent Chironomidae taxa contribution

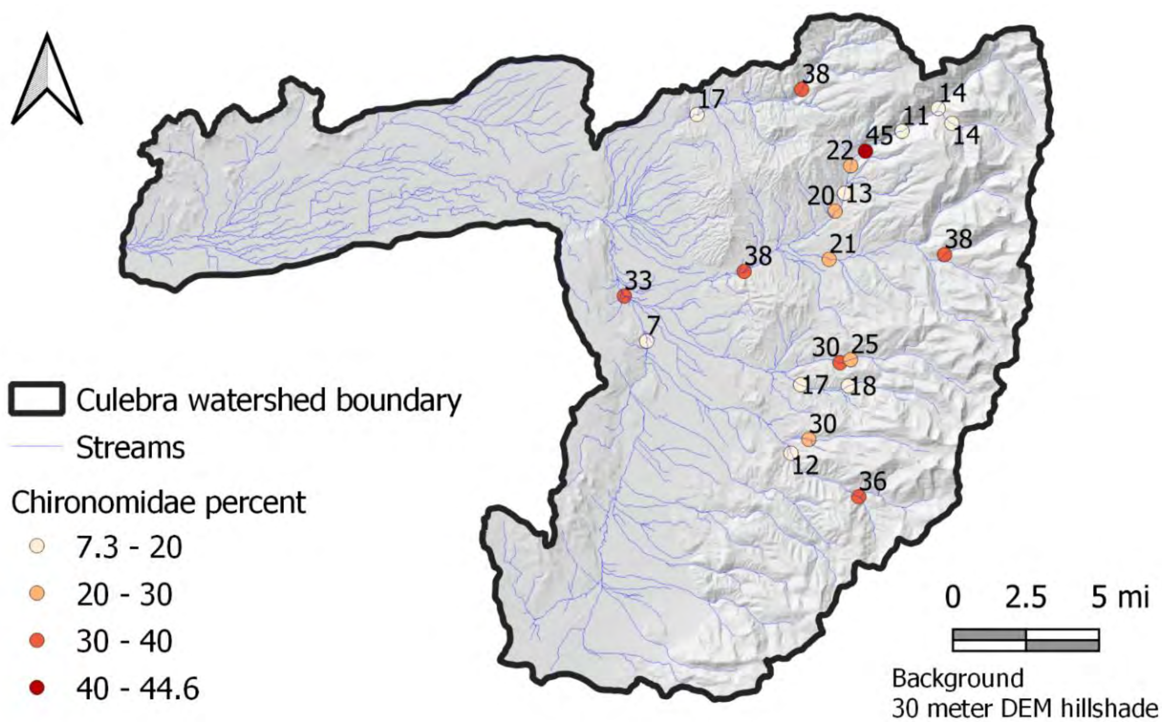


Figure 3-39 Map of percent Chironomidae taxa contribution.

EPT/Chironomidae ratio

The EPT to Chironomidae ratio, similar to EPT richness above, indicated greater stream health where numbers are high. Ventero Creek is the highest at 11, likely due to the large number of mayflies in the samples. The lowest ratios were found at Rito Seco and El Poso Creek, both of which were 0.9 (Figure 3-40 and Figure 3-41). It is interesting to note, however, that other El Poso Creek locations had much higher EPT:Chironomid ratios, so this is location dependent along El Poso Creek.

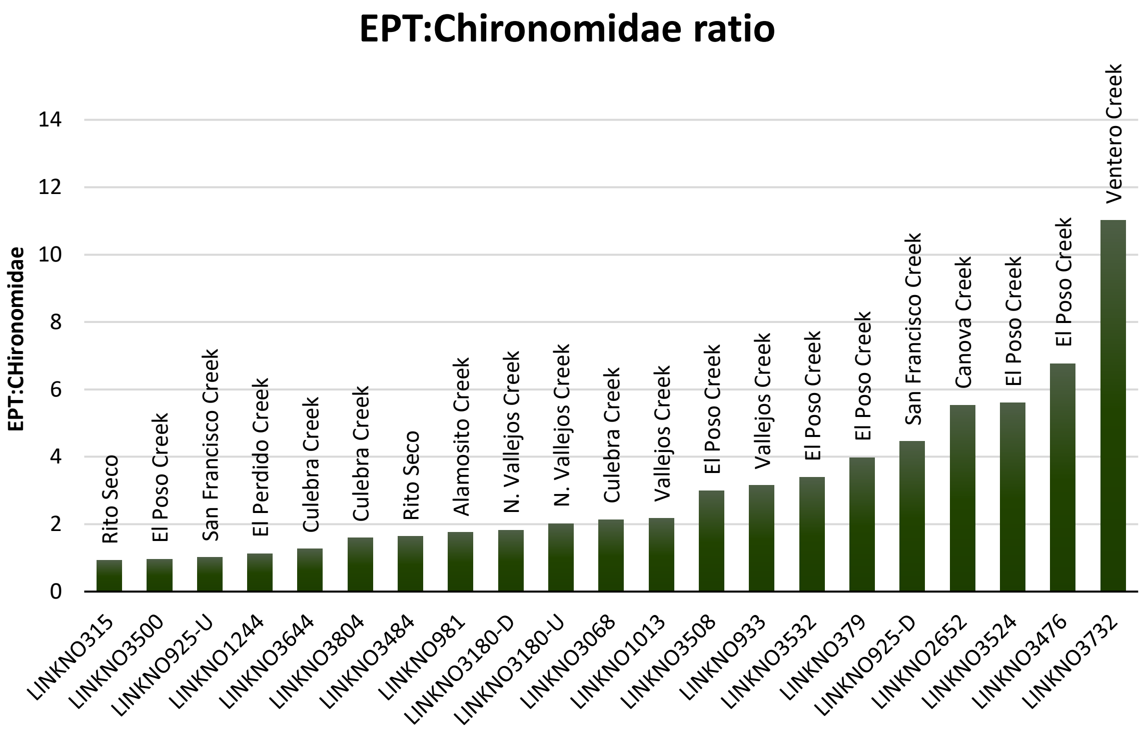


Figure 3-40 EPT: Chironomidae ratio

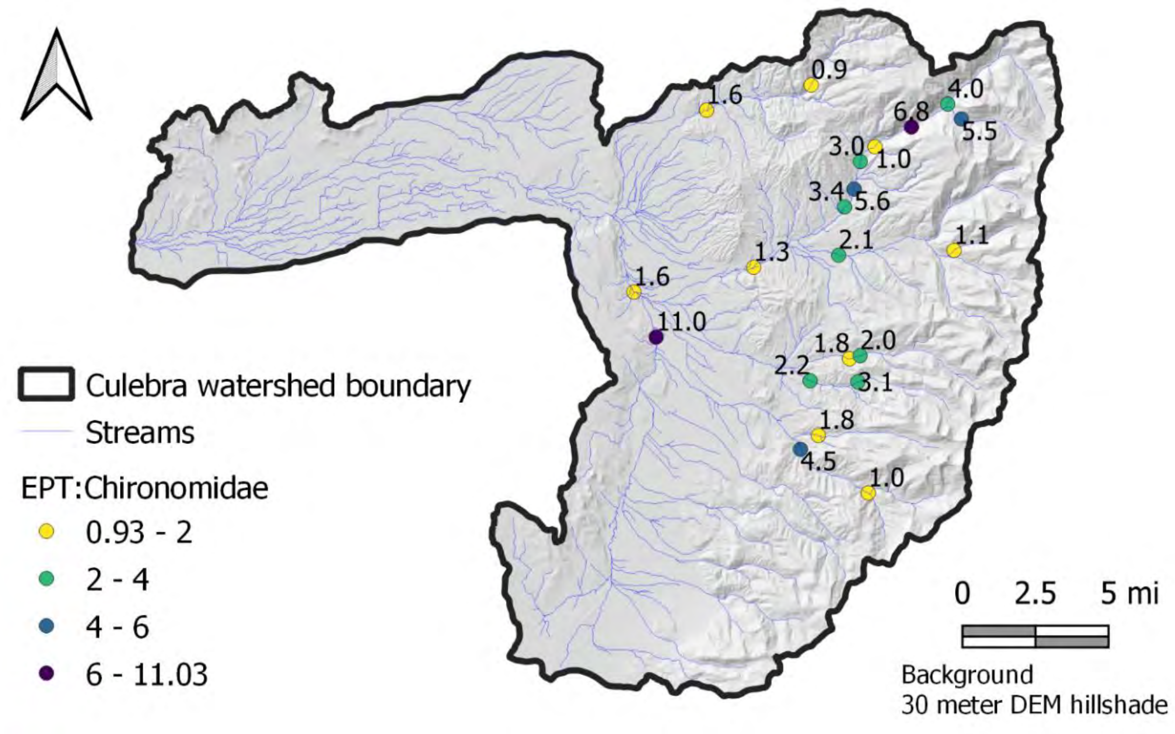


Figure 3-41 Map of percent EPT: Chironomidae.

<u>Hilsenhoff Biotic Index (HBI)</u>

The Hilsenhoff Biotic Index (HBI) is a rapid biological indicator that takes into account the tolerance of different macroinvertebrate taxa. In the Upper Culebra, all 21 samples showed the streams were in relatively good health. 3 streams fell into the "excellent" category (HIB = 0-3.5), 9 streams were classified as "very good" (3.51-4.5), and 9 streams were classified as "good" (4.51-5.5). As with the analyses above, Ventero Creek and two of the El Poso Creek locations were in the excellent category, while one El Poso location and El Perdido Creek had the highest HBI ("good" condition) (Figure 3-42 and Figure 3-43).

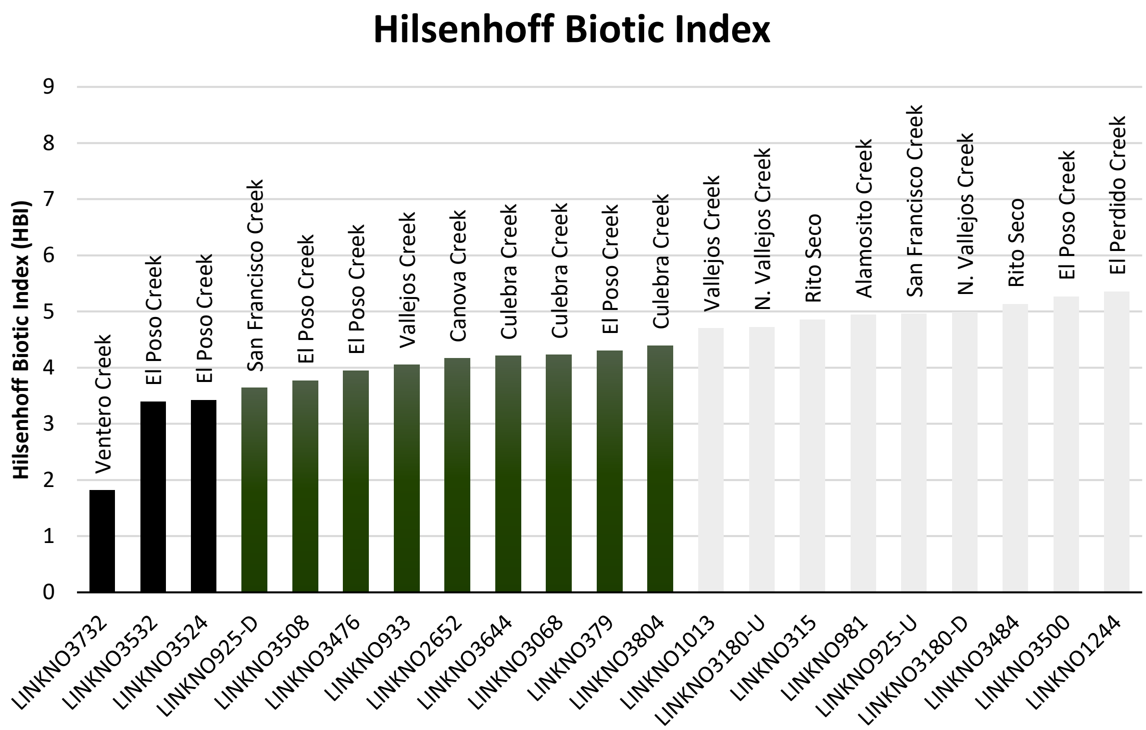


Figure 3-42 Hilsenhoff Biotic Index (HBI): black = excellent, blue = very good, gray = good

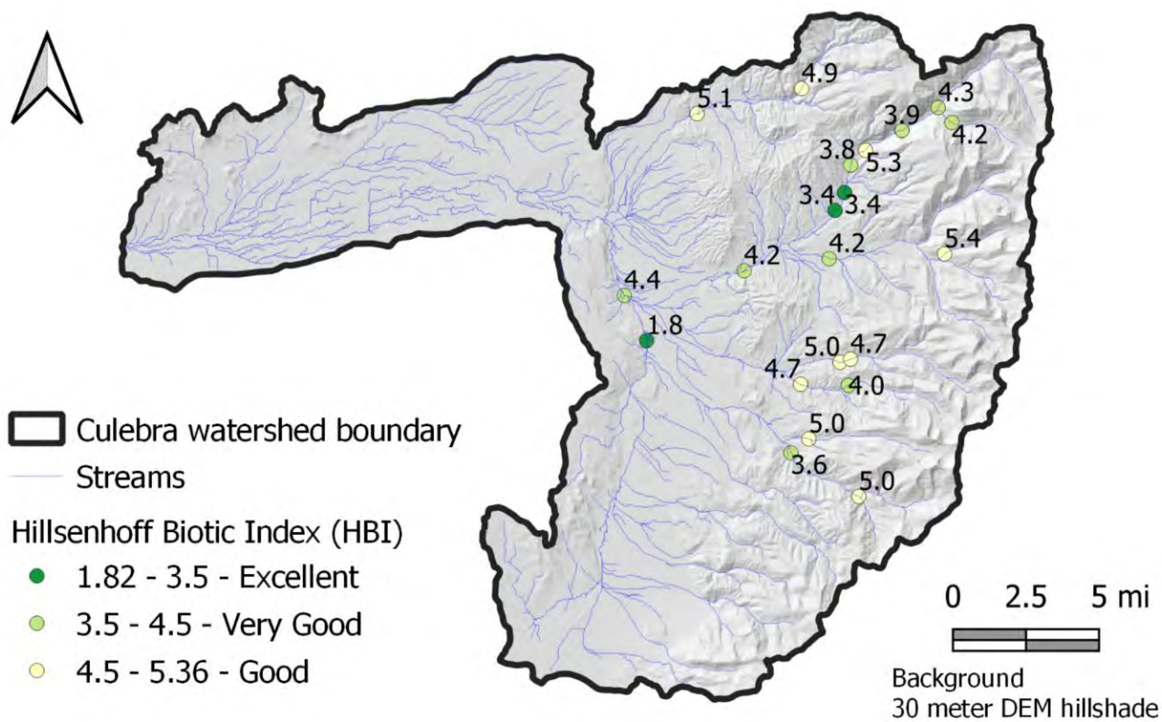


Figure 3-43 Map of Hillsenhoff Biotic Index (HBI).

Shannon diversity index

Similar to the results above, Shannon diversity shows that the lowest diversity was found at Ventero Creek (H = 1.25), while the highest taxonomic diversity was found at Alamosito (3.09) and two El Poso Creek sites (3.10 and 3.29). In general, 18 of 21 sites had diversity metrics greater than 3. These results are plotted in Figure 3-44 and mapped in Figure 3-45. Shannon diversity was calculated using the vegan package in R (Oksanen 2021, R Core Team 2021).

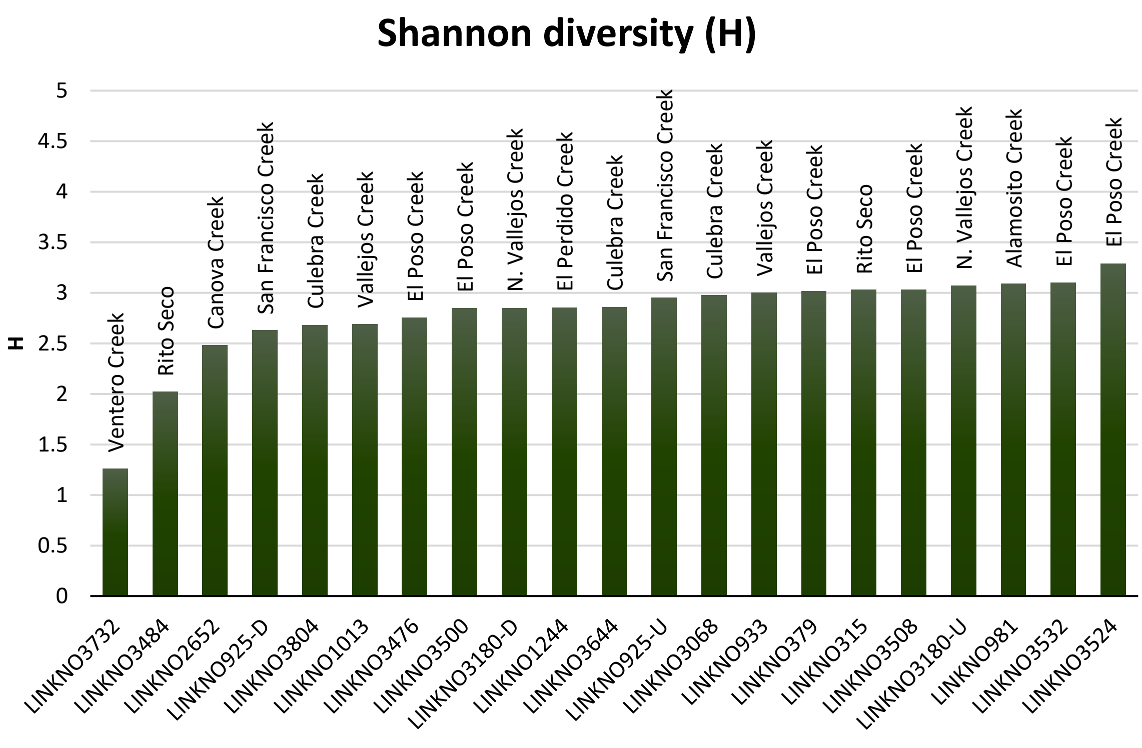


Figure 3-44 Shannon diversity across 21 sites

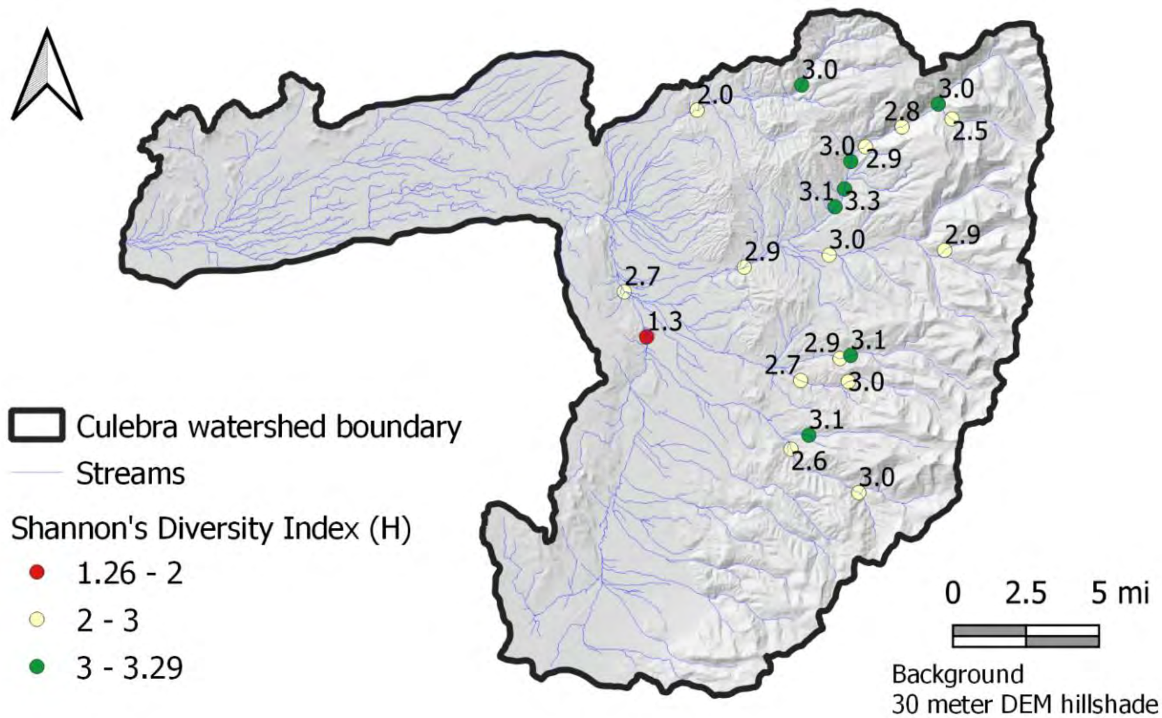


Figure 3-45 Map of Shannon's Diversity Index.

<u>Evenness</u>

Evenness values closer to 1 indicate that the community is more evenly spread across taxa at a site. This is important because sites that are skewed toward having a few dominant taxa may be less stable and more prone to disturbance and stressors. As suggested by the metrics above, evenness is low in Ventero Creek (0.39), where there was a large number of mayflies in the samples. Other sites with low evenness relative to the rest of the watershed are Rito Seco, Canova Canyon, and D. San Francisco Creek. Seventeen of 21 sites had evenness greater than 0.7, indicating relatively evenly distributed taxa in those sites. The results are graphed in Figure 3-46 and mapped in Figure 3-47. Pielou’s evenness was calculated using the Vegan package in R (Oksanen 2021, R Core Team 2021).

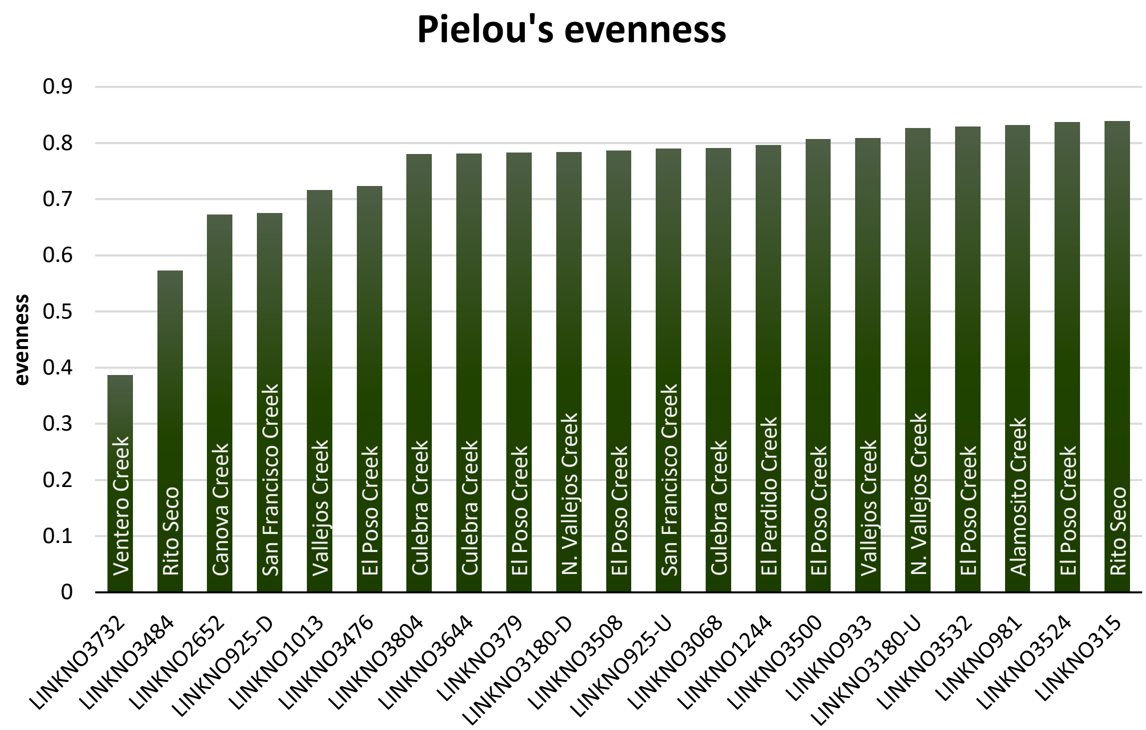


Figure 3-46 Pielou's evenness across 21 sites

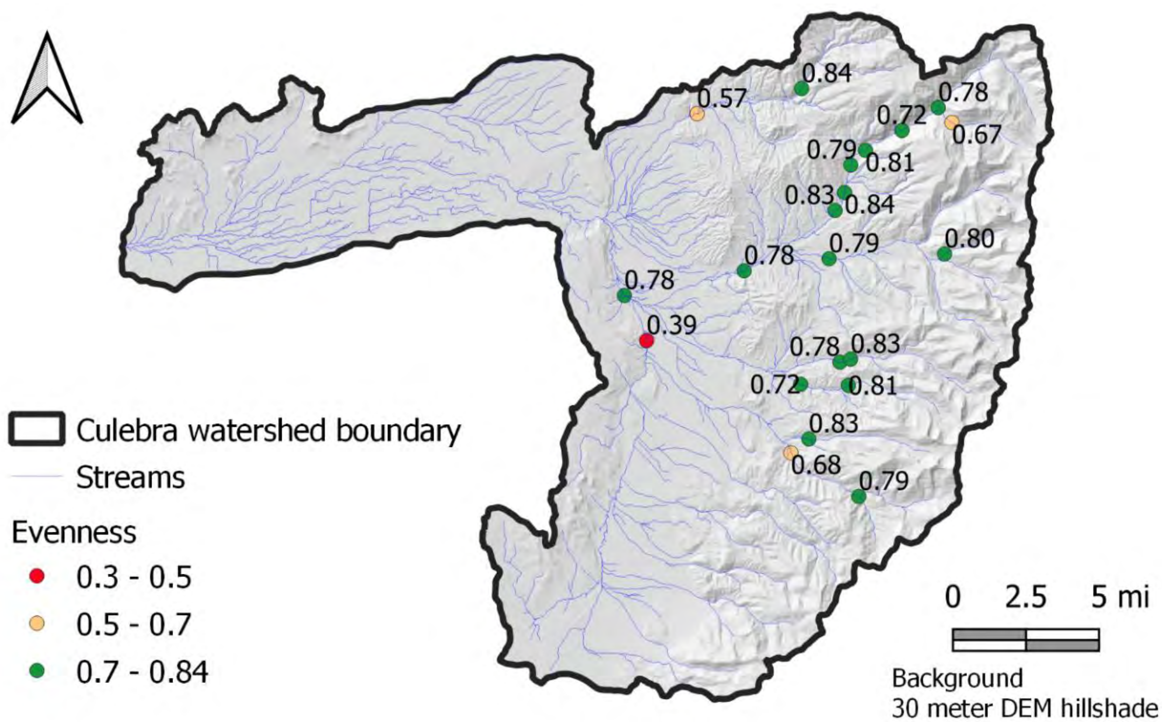


Figure 3-47 Map of Pielou's evenness.

Community composition

Community structure was analyzed using non-metric multidimensional scaling (NMDS) using the Vegan package in R (Oksanen 2021, R Core Team 2021). This analysis creates an ordination that is based on a dissimilarity matrix, in this case, the dissimilarity in the macroinvertebrate community at each site. Figure 3-48 shows a visualization of the macroinvertebrate community at each site, sites that are closer together in the ordination space have more similar communities, while sites such as Ventero Creek (VC_3732), Rito Seco (RS_315), Culebra Creek (CC_3804), and Rito Seco (RS_3484) have greater dissimilarity, and do not group with the majority of sites.

Environmental data can be added to this analysis to determine what the drivers of each axis are. MDS1 is correlated positively with water temperature (R = 0.829) and discharge (0.736). MDS2 was not found to be correlated with any of the environmental variables collected (i.e., dissolved oxygen, water temperature, pH, conductivity, and discharge).

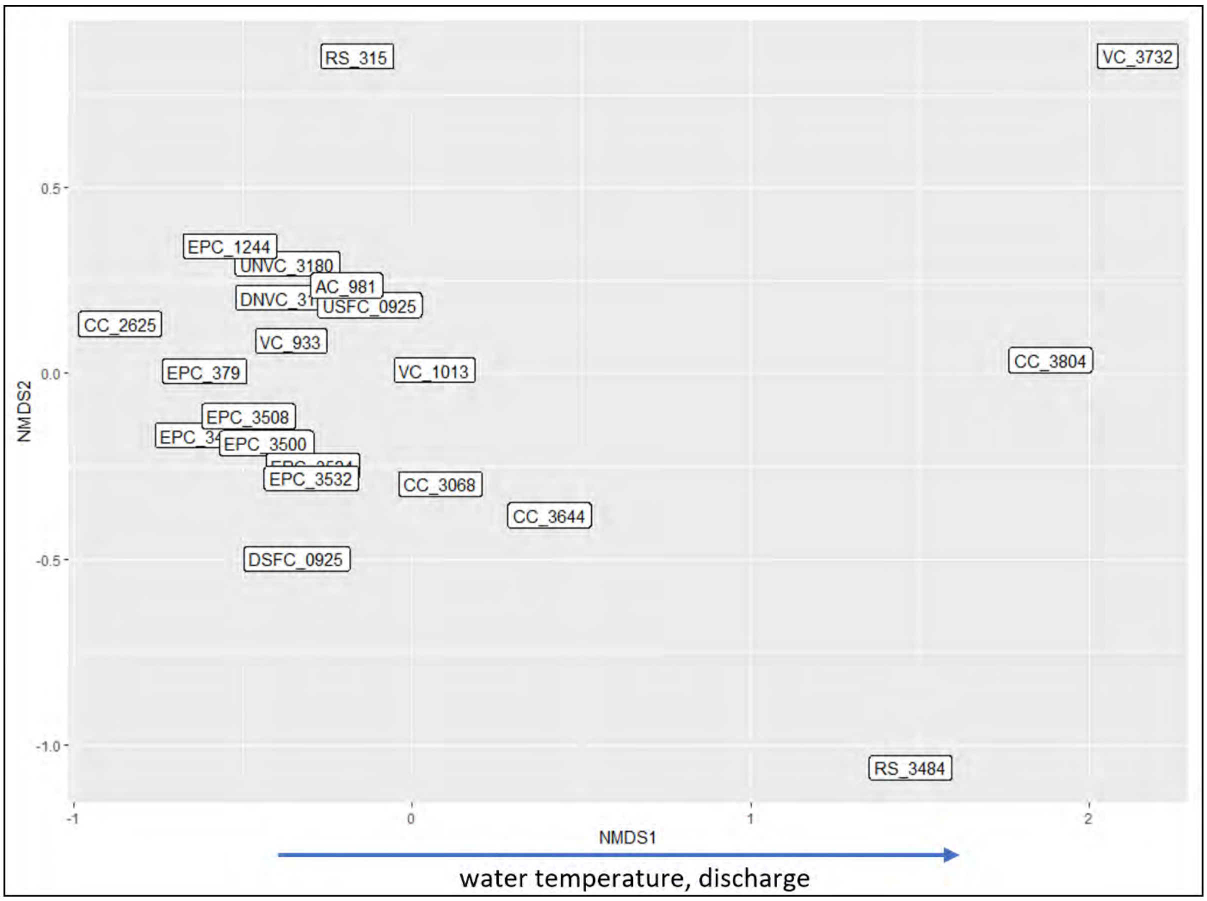


Figure 3-48 NMDS ordination plot for the Culebra watershed streams, based on the macroinvertebrate community (stress = 0.104). MDS1 is correlated with increasing water temperature and increasing discharge.

3.4.11.7 Combined Summary

Table 3-15. Summary of habitat type, pool-riffle ratio, LWD density, fine sediment, fish presence, and soil erosion potential across aquatic habitat survey reaches.

Stream name	Site ID*	Habitat type		Pool/Riffle Ratio	Total LWD Density (LWD/Km)	Optimal LWD Density (LWD/km)	% Fines (<2mm)	Fish present	Soil erosion potential
		% Fast	% Slow						
Culebra Creek	LINKNO3644 (1)	94	6	15.7	63	222	7	NA	Valley-Low-Risk
Culebra Creek	LINKNO3932 (1)	90	10	9	0	51	24	NA	Valley-Low-Risk
El Poso Creek	LINKNO379 (2)	88	12	7.3	92	349	4	0	Risk
El Poso Creek	LINKNO3532 (2)	84	16	5.3	68	333	6	RGNRBT, LOC, BRK	Risk
San Francisco Creek	LINKNO925-U (3)	82	18	4.6	191	275	7	NAT, LOC	Moderate
Alamosito Creek	LINKNO981 (4)	77	23	3.3	152	275	14	RGN, LOC	Moderate
North Vallejos Creek	LINKNO3180-D (5)	75	25	3	109	333	8	RGN, LOC	Sub-Risk
El Perdido Creek	LINKNO1244	72	28	2.6	384	349	11	RGN	Sub-Risk
El Poso Creek	LINKNO3500	72	28	2.6	131	153	2	NA	Low-Risk
Vallejos Creek	LINKNO1013	71	29	2.4	103	275	14	LOC	Sub-Risk
El Poso Creek	LINKNO3508	68	32	2.1	244	333	8	LOC, BRK	Low-Risk
El Poso Creek	LINKNO3524	68	32	2.1	83	333	4	RGN, LOC, BRK	Moderate
Canova Creek	LINKNO2652	67	33	2	234	275	2	NA	Risk
Culebra Creek	LINKNO3804	65	35	1.9	0	119	NA	NA	Low-Risk
San Francisco Creek	LINKNO925-D	64	36	1.8	217	275	16	LOC	Risk
Culebra Creek	LINKNO3860	63	37	1.7	0	51	20	NA	Sub-Risk
Culebra Creek	LINKNO3068	63	37	1.7	60	193	19	NA	Valley-Low-Risk

* Numbers in parenthesis indicate prioritized potential habitat improvement reaches based on pool-riffle ratios and LWD density.

Table 3-15. Summary of habitat type, pool-riffle ratio, LWD density, fine sediment, fish presence, and soil erosion potential across aquatic habitat survey reaches. -- continued

Stream name	Site ID*	Habitat type		Pool/Riffle Ratio	Total LWD Density (LWD/Km)	Optimal LWD Density (LWD/km)	% Fines (<2mm)	Fish present	Soil erosion potential
		% Fast	% Slow						
Ventero Creek	LINKNO3732	59	41	1.4	0	119	3	NA	Valley-Low-Risk
Vallejos Creek	LINKNO933	55	45	1.2	213	275	28	RGN, LOC	Moderate
El Poso Creek	LINKNO3476	46	54	0.9	479	153	4	LOC, BRK	Risk
North Vallejos Creek	LINKNO3180-U	32	68	0.5	215	349	7	RGN, LOC	Low-Risk
Rito Seco	LINKNO3484	28	72	0.4	42	97	NA	NA	Moderate
Rito Seco	LINKNO315	23	77	0.3	567	275	10	NA	Risk

* Numbers in parenthesis indicate prioritized potential habitat improvement reaches based on pool-riffle ratios and LWD density.

3.5 Summary and Discussion

The purpose of this aquatic habitat assessment was to assess the ecological condition of Culebra Creek Watershed, identify causes of concern, and develop a list of prioritized projects that could improve the function of uplands, aquatic, and riparian ecosystems. Aquatic habitat surveys were conducted to assess current stream conditions and to start the process of identifying and prioritizing potential restoration efforts.

Pools, riffles, and habitat lengths were quantified for each stream reach along with a LWD and a log jam count. In addition to the habitat delineation, substrate and riparian canopy cover assessments were also conducted. Pool to riffle ratio is a traditional method of assessing in stream habitat quality and the potential for a stream to have adequate fish habitat. The ratio is used to assess the stream capability of providing resting and feeding pools for fish, and riffles to provide spawning habitats and produce aquatic invertebrates for food. In general, a 1:1 ratio (50% pool to 50% riffle) is considered optimal for a healthy salmonid stream (Platts, Megahan, & Minshall, 1983). Pool habitat accounting for 35% to 60% of the total area is considered suitable rearing habitat for cutthroat trout (Alves J. E., Patten, Brauch, & Jones, 2008).

None of the stream reaches surveyed met the 1:1 pool-riffle ratio criterion suggesting that in-stream restoration efforts could improve habitat availability and quality across the watershed. Of all channels surveyed, the uppermost reach at El Poso (LINKNO3476) was the closest to meet that criterion with a 0.9 ratio, followed by the upper Vallejos Creek site (LINKNO933) and Ventero Creek (LINKNO3732) with 1.2 and 1.4 ratios, respectively (Figure 3-25). The uppermost reach at El Poso, the upper reach at North Vallejos (LINKNO3180-U), and both reaches at Rito Seco (LINKNO0315, LINKNO3484) were the only reaches where pool habitat was predominant (Figure 3-25). At most channels surveyed, more fast water (riffle/run) habitat units than slow water (pool) habitat units were observed and the sites with the lowest proportion of pool habitat were observed at Culebra

Creek (LINKNO3644, LINKNO3932) and El Poso Creek (LINKNO379, LINKNO3532; Figure 3-25). Other sites where the proportion of pool habitats is suitable (between 35% and 60%) for cutthroat trout rearing habitats included the uppermost Culebra Creek reach (LINKNO3068), Culebra Creek LINKNO3860), and the lower reach at San Francisco Creek (LINKNO925-D; Figure 3-25). Mean residual pool depth varied across survey sites but was generally greater than 0.3m and appeared adequate to support fish during periods of low flow conditions (Kalb & Caldwell, 2014) (Harig & Fausch, 2002). Management efforts designed to reduce pool-to-riffle ratios, increase pool frequency, and increase pool depth could help improve habitat condition and function along the Culebra Creek Watershed.

Cover and LWD play a significant role in healthy salmonid streams (Lassettre & Harris, 2001) (Fausch & Northcote, 1992). Large woody debris creates pools, captures nutrients, and provides cover important for both juvenile and adult salmonids. The number and frequency of LWD pieces indicative of a healthy salmonid stream is unique to each stream and depends on variables such as slope and riparian vegetation recruitment (Lassettre & Harris, 2001). Quantifying the amounts of wood that define a healthy stream is difficult as it is highly dependent on the topography, riparian forest management, and watershed processes. Evidence from other studies suggest that densities of LWD at Culebra Watershed streams are adequate at most sites. However, LWD density at sites along the lower Culebra Creek, lower Rito Seco, and Ventero Creek, can be considered low (Table 3-9).

Kalb and Caldwell (2014) conducted an assessment to assess the suitability of the Rio Ruidoso, New Mexico, to support a self-sustaining population of RGCT. They reported a LWD density of 40 to 456 LWD/km and indicated the presence of in-stream woody debris throughout the Rio Ruidoso can support optimal habitat for RGCT. Observed LWD densities throughout sites surveyed at the Culebra Creek Watershed ranged between 0 LWD/km at the three lower Culebra Creek sites (LINKNO3804, LINKNO3860, LINKNO3932) and the Ventero Creek reach (LINKNO3732), to 567 LWD/km at the upper Rito Seco reach (LINKNO315, Table 3-9). High LWD density also occurred at an upper elevation El Poso Creek reach (479 LWD/km, LINKNO3476). It should be noted here that pool habitat was the predominant habitat type observed at these sites with high LWD density (Figure 3-25).

Although the density of LWD along most of the channels surveyed were comparable to those found by Kalb and Caldwell (2014), the LWD density values by channel type and wetted width referenced in Alves et al. (2008), suggest that LWD at most sites surveyed in the Culebra Creek watershed is below optimal for cutthroat trout rearing habitat (Table 3-11). This is particularly important for survey sites in Alamosito Creek (LINKNO0981), North Vallejos Creek (LINKNO3180-D, LINKNO3180-U), San Francisco (LINKNO925-U), and Vallejos Creek (LINKNO0933) where RGCT has been previously documented. The only sites where the estimated LWD density was greater than the optimal referenced by Alves et al. (2008), were located at El Perdido Creek (LINKNO1244), El Poso Creek (LINKNO3476), and Rito Seco (LINKNO315;Table 3-11). Further, the relatively low LWD counts are consistent with the small number of LWD jams observed (Table 3-10). The small number or absence of LWD and log jams was particularly evident at Culebra Creek and Ventero Creek survey reaches; most of the log jams were observed in upper elevation sites (Table 3-9).

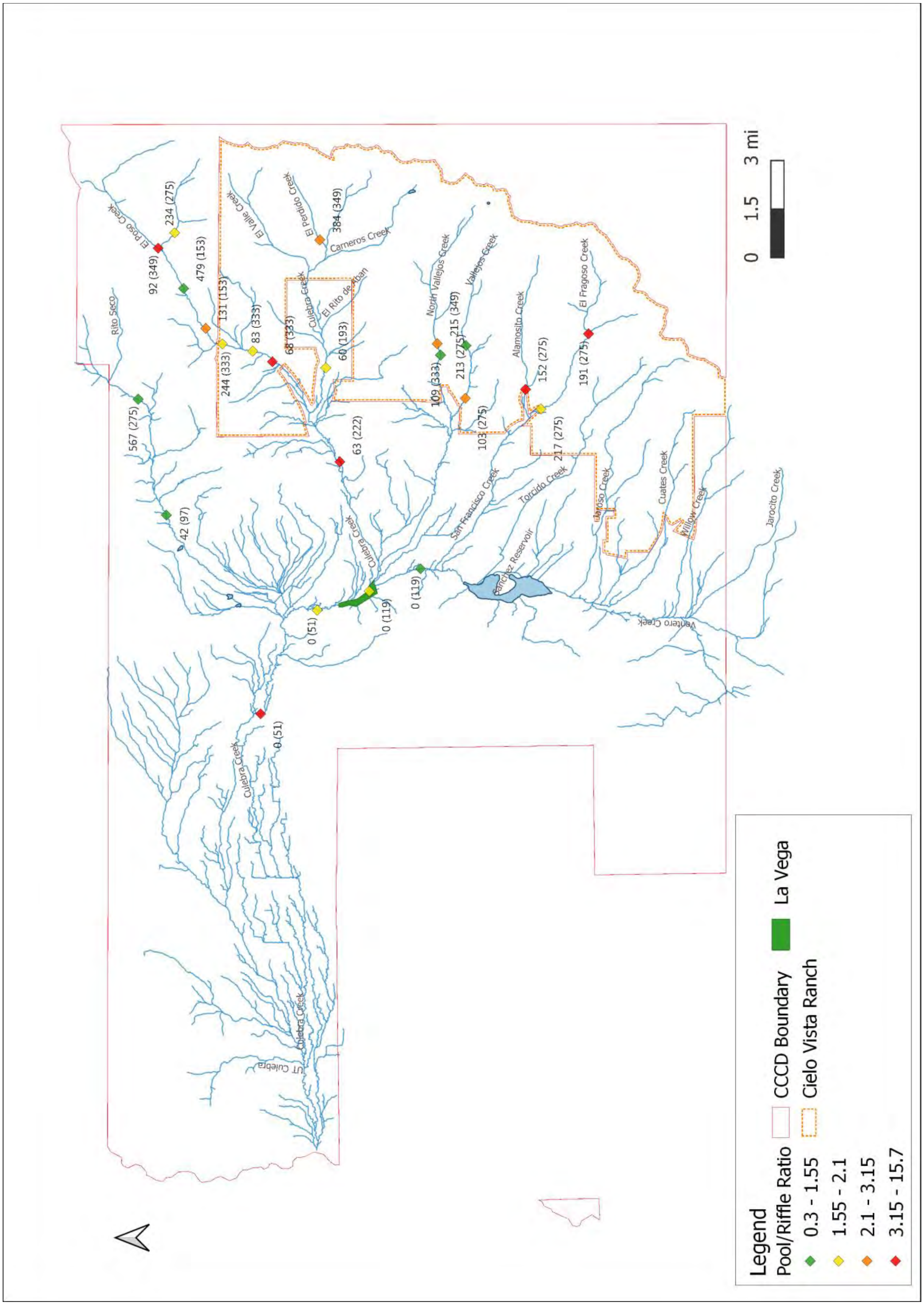


Figure 3-49. Pool-riffle ratios at UCWA aquatic assessment survey sites. numbers denote total LWD density per kilometer. Numbers in parenthesis denote optimal LWD density.

The influence of large stable wood as obstruction to flow, sediment transport, and other channel processes have been well documented (Swanston, 1991) (Montgomery, Collins, Buffington, & Abbe, 2003). The presence of large in-stream woody debris affects salmonids positively by increasing pool frequency, depth, area, and sediment retention (Fausch & Northcote, 1992) (Flebbe & Dolloff, 1995). Woody debris and log jams help dissipate energy that would otherwise transport sediment and contribute to channel incision, particularly in steep channel systems. Although the LWD density at most sites surveyed can be considered suitable for fish habitat, the smallest size class of LWD (1m-5m in length and 0.1m-0.3m in diameter) was predominant throughout the watershed. Large, stable wood can affect the size, type, and frequency of pools (Swanston, 1991) (Kalb & Caldwell, 2014). Given that fast water (run/riffle) was more common than slow (pool) habitats at most survey sites, the small size of LWD observed may explain the relatively sparse number of LWD jams and low frequency of pool habitat. Results from this survey suggest efforts to increase the number and size of LWD and log jams could have a positive effect on trout habitat availability and quality. As noted by Pritchard & Cowley (2006), the introduction of large woody debris or other instream structures in order to increase the number of deep pools is a commonly used technique to improve habitat quality for salmonids; coupled with reducing immigration of non-native trout, LWD could improve habitat for RGCT at the Culebra Creek Watershed.

Riparian forests play a key role in water temperature regulation, influence the maintenance of stream water quality conditions (Kalb & Caldwell, 2014) (Everest & Reeves, 2007) (Platts & Nelson, 1989) and are directly associated to the recruitment of in-stream LWD (Bilby & Bisson, 1998). The assessment of riparian vegetation canopy cover along Culebra Creek watershed streams indicated moderate to heavy tree coverage in the riparian zone, except in low elevation reaches at Culebra (LINKNO3804, LINKNO3860, LINKNO3932), Ventero (LINKNO3732), and Rito Seco (LINKNO3484) creeks (Table 3-12). However, the riparian vegetation was formed primarily by small diameter trees and shrubs. Studies have shown conifer LWD play a greater role in long-term stream structure than deciduous LWD (Ralph, Poole, Conquest, & Naiman, 1994). Large conifer LWD last longer and are also considered more important for the formation of log jams.

Management actions to promote the long-term development of a healthy riparian forest with large-diameter conifer trees, coupled with the development of in-stream engineered jams, could be explored to enhance pool-to-riffle ratios and overall stream habitat quality. A comprehensive literature and data review to assess historical riparian habitat structure and LWD loading in the Culebra Watershed and other streams and rivers across watersheds in South Central Colorado can contribute to the development of relevant targets for potential restoration efforts; values reported in Kalb & Caldwell (2014) and Alves et al. (2008) provide good reference points.

In terms of availability of adequate fish habitat substrate, the substrate median size class across all survey sites ranged between 16mm-22.6mm (coarse gravel) at the lowest Culebra Creek reaches (LINKNO3860, LINKNO3932) to 128mm-180mm (large cobble) at El Poso Creek reaches (LINKNO3508, LINKNO3532) suggesting that suitable spawning substrate is present throughout the streams sampled (Figure 3-27, Figure 3-28). Different trout species use different cobble sizes in which to spawn, and preferable spawning gravel size can range from 60mm-102mm to 60mm-76mm for cutthroat trout and brown trout, respectively (Bjornn & Reiser, 1991). For cutthroat trout habitat, fine sediment (<2.3mm) levels should not exceed 10% of total substrate (Alves J. E., Patten, Brauch, & Jones, 2008). Although spawning substrate occurs throughout the streams surveyed, a high proportion of fine sediment was observed at Alamosito Creek (LINKNO0981), Culebra Creek (LINKNO3068, LINKNO3860, LINKNO3932), San Francisco Creek (LINKNO0925-D), and both Vallejo Creek reaches (LINKNO1013, LINKNO933;Figure 3-27 and Figure 3-28), where high fine-sediments levels can limit fish embryo survival and emergence (Magee, McMahon, & Thurow, 1996) (Bjornn & Reiser, 1991).

In general, differences in the amount of fine sediment between sites located in high and low risk erosion potential areas were not observed (Figure 3-27 to Figure 3-29). The only significant difference in percent fine sediment between reference (Ventero Creek LINKNO3732) and test sites (Culebra Creek LINKNO3804, LINKNO3860, LINKNO3932) was observed in low elevation, low risk sites in the valley. A pattern of high, fine sediment abundance consistent with erosion risk potential areas was not observed, suggesting that hillslope surface erosion is not the main source of fine sediment in stream channels. At low elevation and low gradient reaches, where erosion risk potential is low or moderate, such as the lower Rito Seco reach surveyed, road surface erosion is likely a source of fine sediment (typically <1-2 mm, sand and finer).

This stream habitat assessment suggests that stream channel characteristics can pose limitations to trout populations. As noted above, stream habitat delineations indicated that fast water (riffle, run) was the predominant habitat type along most survey sites. Slow water habitats (pools) are key in habitat complexity; they provide refugia and rest habitat for trout and help regulate water temperature. They also help dissipate stream energy, thus reducing erosion effects on channel morphology. Also limiting channel complexity is the lack of LWD at most of the streams surveyed. Large woody debris provides shelter from aquatic and terrestrial prey and help the formation of instream habitat. The accumulation of fine sediments at some of the streams surveyed can also be considered a factor limiting trout population persistence given the effects of fine sediment on reproduction (fish hatching and emergence success) and survival (loss of food sources).

This stream habitat survey was conducted as part of the CCCD effort to assess Culebra Creek watershed health. The survey results provide a snapshot of current stream habitat conditions that can be used for the subsequent identification of areas with adequate or degraded stream habitat conditions for fish rearing or spawning. The data collected during this survey can also be used as a tool to help identify potential restoration areas, to prioritize stream restoration efforts, and to monitor stream habitat condition.

Aimed towards enhancement in condition and function of aquatic habitat at the watershed scale, below is a list of areas where physical habitat improvements could increase habitat structure, fish habitat availability, stream habitat quality, and overall ecosystem health. Low-technology, process-based restoration (Beechie, et al., 2010) (Wheaton, Bennett, Bouwes, Maestas, & Shahverdian, 2019) opportunities in these areas could be feasible to address aquatic habitat improvements at multiple locations throughout the watershed.

Lower elevation reaches along Culebra Creek (including the section along La Vega) and Ventero Creek below Sanchez Reservoir. Prioritized based on pool-to-riffle ratios and LWD density, LWD can be used in these sections to increase fine sediment retention and increase the frequency and size of pool habitat. Enhancing riparian canopy cover in these areas can also help improve brown trout habitat. A map displaying pool-riffle ratios and LWD density is provided in Figure 3-49.

Alamosito Creek, lower El Poso Creek, lower North Vallejos Creek, and San Francisco Creek where cutthroat trout have been reported. Increasing the density of LWD could improve pool-to-riffle ratios and rearing fish habitat availability (See Figure 3-49). Woody structures can also be designed to increase pool depth.

Lower elevation sections of Rito Seco. Improve riparian buffers to help reduce fine sediment load to the stream. Increase the number of LWD to create scour pools (no damming features) that can help move fine sediment at a modest discharge (See Figure 3-49).

A summary of pool-riffle ratios, LWD density, fine substrate, fish presence, and soil erosion potential is provided in Table 3-15 to help establish priorities for potential habitat improvement sites. Given pool-riffle ratios and the difference in reported and optimal LWD density, sites at Culebra, El Poso, San Francisco, Alamosito, and North Vallejos Creeks are considered of high priority to improve habitat complexity (Table 3-15). However, it should be noted that high priority reaches (or streams) can vary according to criteria used. Depending on overall watershed management objectives, other factors such as the presence/absence of native and non-native fish species, proximity to areas considered at high risk of soil erosion potential (Figure 3-2, Figure 3-3), and broader socio-economic objectives can influence prioritization.

3.5.1 Macroinvertebrate Summary

Macroinvertebrate sampling results showed the streams in the Culebra Watershed are in relatively good condition. Sites that warrant further investigation are Ventero Creek, which had low scores for HBI, diversity, and evenness, but had a large mayfly population that may have skewed results. There also appears to be a gradient within the sites sampled for Rito Seco and El Poso, with a mix of metrics indicating good water quality (e.g., high EPT, excellent HBI) and metrics indicating lower water quality. The majority of sites exhibited similar metrics and grouped together in the NMDS analysis, indicating that they have relatively similar macroinvertebrate community composition.

3.5.2 Monitoring Recommendations and Other Data Gaps

Monitoring is an essential component of natural resource management and successful ecological restoration. Monitoring provides information on the effectiveness of management and/or restoration actions to determine if actions are achieving the intended effects.

Instream habitat and riparian vegetation should be monitored to gauge progress towards desired objectives following changes in management and/or restoration actions and to determine whether recommended actions are effective at improving aquatic habitat conditions. The stream habitat assessment we conducted provides baseline data that can be used to monitor conditions over time. In addition to physical habitat, long-term monitoring should also include temperature.

Monitoring is an essential component of natural resource management and successful ecological restoration.

Fish should continue to be monitored to determine if stable populations are maintained, whether recommended actions have a positive effect on fish populations, and whether fish are using areas where habitat improvements are implemented.

Baseline data on beaver populations should also be established because they play a role in large wood recruitment into the stream channel. Communications with members of the community, as noted in Chapter 14 of this watershed assessment, pointed out that beaver populations have declined.

Lastly, more research is required to assess potential effects of dewatering along reaches identified in the flow regime section of this watershed assessment. Similar to perennial streams, ephemeral and intermittent streams provide landscape hydrologic connection by moving water, nutrients and sediments during high water flows. Ephemeral streams can support aquatic invertebrates and contribute to the biological integrity of the stream network. Although only temporarily, intermittent streams can also support fish. Evaluating the function of dewatered stream reaches as a seasonal migration barrier to fish movement would warrant further study.

Chapter 4. Geomorphic Assessment

Author: Tailwater Limited

"A river cuts through rock not because of its power but because of its persistence." – Jim Watkins

In general terms, fluvial geomorphology is the study of how flowing water shapes the landscape. Fluvial is derived from the Latin word fluvialis, which means "of the river" (Merriam-Webster, n.d.). Geo is derived from the Greek work Ge, meaning "Earth" (Merriam-Webster, n.d.). Morph means "shape" or "form" (Merriam-Webster, n.d.). Logy is derived from the Greek word logia, meaning "the study of" (Word Info, n.d.). This chapter evaluates the fluvial processes defining the shape of the landscape within the Upper Culebra Watershed and how that shape affects the watershed's health. The chapter begins with background and explanations of ideas and concepts used to describe the fluvial landscape transitioning into a discussion of the methods used to evaluate the health of the watershed, followed by a discussion of the results, and concluding with a discussion of potential ways to improve the "shape" of the landscape.

4.1 Introduction

4.1.1 Goal and Objectives

The initial goals laid out for the Task 9 – Geology/Geomorphology Assessment of the Upper Culebra Watershed Assessment were to:

Goal 1 Identify locations of geomorphic instability in the Culebra Basin.

Goal 2 Increase understanding of geomorphology in the Culebra Basin.

Goal 3 Identify projects that could be completed within the Culebra Basin to improve overall watershed health.

Goals	Objectives
Goal 1 Identify locations of geomorphic instability in the Culebra Basin	*Objective 1.1.* Develop map of areas with notable instability including bank erosion and mid-channel bars. *Objective 1.2* Measure geomorphic parameters of reaches with noted instabilities.
Goal 2 Increase understanding of geomorphology in the Culebra Basin.	*Objective 2.1* Develop baseline dataset describing drainage area and rainfall within the basin. *Objective 2.2*. Measure geomorphic parameters including slope and bankfull area for reference relationships. *Objective 2.3*. Evaluate and summarize potential linkages between degradation and probable cause of degradation.
Goal 3 Identify projects that could be completed within the Culebra Basin to improve overall watershed health.	*Objective 3.1* Utilizing information generated within this task generate list of potential strategies for addressing degradation. Objective 3.2 Develop list of projects and strategies that could be utilized to improve geomorphic stability.

To identify the locations within the basin that are in a state of instability, aerial imagery was used to review each perennial stream reach and major non-perennial stream reach for visual signs of instability. Instability was identified by looking for signs of aggradation and degradation within and near the channel. Computational models were used to identify those reaches that may be at risk of instability from proximity to roads, other infrastructure, land use, or topography that may not be visible in aerial imagery due to vegetative cover.

Field assessment was performed on a sample of degraded areas identified from the aerial imagery to perform a more detailed evaluation of departure. Field assessments included collecting cross-sectional and longitudinal profiles, visual assessment, visual and physical assessment of bed material classification, and documentation through a photo log of the site.

Areas at risk of post-fire debris flow are identified through computational models (Cannon, et al., Predicting the probability and volume of postwildfire debris flows in the intermountain westrn United States, 2010) and are described within Chapter 12 of this report.

4.1.2 Fluvial Geomorphology

Several concepts and approaches were used to analyze the health/function of the streams in the Upper Culebra Watershed for the Upper Culebra Watershed Assessment. These approaches are outlined in more detail in the methods sections of this report. The following section explains principles and terms commonly used in geomorphology to help the reader understand the methods, terms, and ideas used throughout the chapter.

4.1.2.1 Channel Classification

River and stream systems are complex environments with physical and biological factors dictating how the water moves across the landscape. To effectively communicate about these complex systems, it often helps to classify river systems and reaches into related categories or classifications. Several methods are available to classify rivers into meaningful groups (Buffington & Montgomery, 2013), and for this study, the Rosgen Classification

System (Rosgen D. , 1996) is used. The Rosgen Classification System is a descriptive classification system that allows for the grouping of similar stream reaches based primarily on the slope (Equation 4-1), sinuosity (Equation 4-2), width-to-depth ratios (Equation 4-3), entrenchment ratios (Equation 4-4), and dominant bed material (Rosgen D. , 1994; Rosgen D. , 1996).

Table 4-1 shows the bases for the Rosgen Classification key. Table 4-2 shows the classification of channel bed materials, or substrate, also used as part of the Rosgen Classification System. Below are equations showing how to calculate the above parameters:

Equation 4-1 Slope

$$S = \frac{rise}{run} = \frac{start\ elevation - end\ elevation}{length}$$

Equation 4-2 Sinuosity

$$\frac{bankfull\ slope}{valley\ slope}$$

Equation 4-3 Width-to-depth ratio (WDR) (NRCS, 2007)

$$WDR = W_{bkf}/D_{bkf}$$

W_{bkf}, is the bankfull width (ft). D_{bkf} is the bankfull depth (ft).

Equation 4-4 Entrenchment ratio. The entrenchment ratio is visually described in (Figure 4-1).

$$Entrenchment\ ratio = \frac{W_{fpa}}{W_{bkf}}$$

W_{fpa}, the width of the floodplain measured at two times the bankfull depth, also known as flood prone area (fpa).

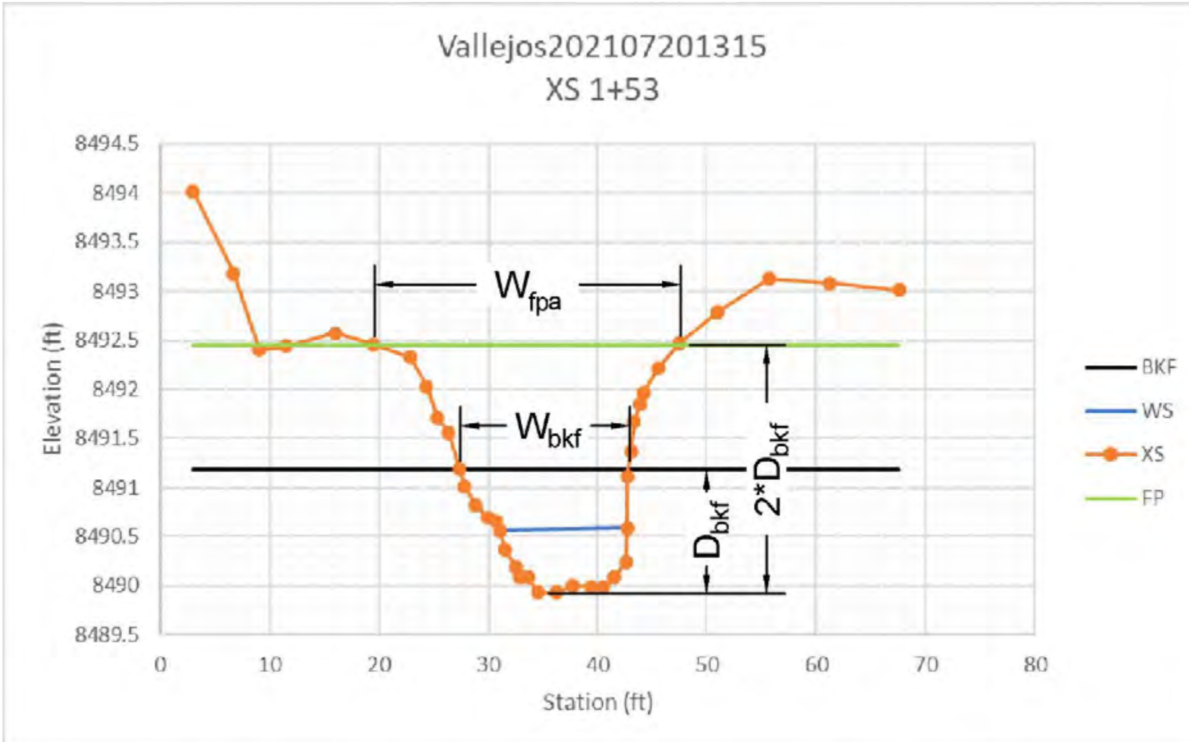


Figure 4-1 Example of entrenchment ratio measurement (Equation 4). Wfpa, flood-prone width, Wbkf, bankfull width, Dbkf Bankfull depth.

Table 4-1 Rosgen Classification System. Adapted from Rosgen (1996).

	Stream Type	Entrenchment Ratio[1,4]	Width to Depth Ratio[2,5]	Sinuosity[3,4]	Bankfull Slope[6]
Single-Thread Channels	A	< 1.4	< 12	1.0-1.2	'a+' > 0.10 0.04 - 0.099
	G	< 1.4	< 12	> 1.2	0.02 - 0.039 'c' < 0.02
	F	< 1.4	> 12	> 1.2	'b' 0.02 - 0.039 < 0.02
	B	1.4 - 2.2	> 12	> 1.2	'a' 0.04 - 0.099 0.02 - 0.039 'c' < 0.02
	E	> 2.2	< 12	> 1.5	'b' 0.02 - 0.039 < 0.02
	C	> 2.2	> 12	> 1.2	'b' 0.02 - 0.039 0.001 - 0.02 'c-' <0.001
Multi-Thread Channels	D	n/a	> 40	n/a	'b' 0.02 - 0.039 0.01 - 0.02 'c-' < 0.001
	DA	>2.2	Variable	Variable	< 0.005

[1]The Entrenchment Ratio is defined as flood-prone area width, or the width of the floodplain measured at two times bankfull max depth divided by the bankfull width (Equation 4-4).

[2]The width-to-depth ratio is defined as the bankfull width divided by the mean bankfull depth of the channel. (Equation 4-3)

[3]The sinuosity is defined as the valley slope divided by the bankfull slope, or the channel length divided by the valley length for the same reach.

[4]Entrenchment and sinuosity ratios can vary by +/- 0.2 units

[5]Width-to-depth ratios can vary by +/- 2.0 units

[6]Stream Classification is typically the stream type followed by bed material number. If the slope is in a specific range the bed material will be followed by the 'value'. For example, a 'B' channel with a gravel substrate and a slope < 0.02 would be classified as a B4c.

Table 4-2 Channel Material size classification. Adapted from NRCS (Part 654, Technical Supplement 3E - Rosgen Stream Classification Technique - Supplemental Materials, 2007).

Channel Material[1]

Type	Classification	Size (mm)
Bedrock	1	> 2048
Boulder	2	256 - 2047.9
Cobble	3	64 - 255.9
Gravel	4	2 to 63.9
Sand	5	0.062 - 1.99
Silt/Clay	6	< 0.062

[1]Channel material is represented by the D50 of reach channel material, or substrate size.

4.1.2.2 Reference Condition

The physical, chemical, and biological processes affect the geomorphic properties or shape of the physical environment. This system of interactions is complicated, especially surrounding stream channels, where the flow of water through the system adds more levels of complexity. Finding reference conditions in stream channels makes it possible to make general inferences about how a stream functions. Once the reference reach condition is determined, a geomorphologist can conduct a departure analysis for similarly classed stream reaches to make determinations about the stream function. Such as, if the reach may be functioning: the channel has a healthy riparian buffer and there is no sign of aggradation or degradation; or they may say that the reach is not functioning: there are signs of aggradation and/or degradation, the riparian community is not healthy or not present. Departure analyses will vary in degrees of complexity evaluated many measured parameters or providing a qualitative assessment.

Using the Natural Channel Design approach, one tries to mimic the natural “functioning” channel and incorporate its dimensions into a channel that is not functioning (NRCS, 2007; Rosgen D. , 1998).

4.1.2.3 Bankfull Channel

Bankfull is defined as the incipient point of flooding, or the stage that the water in a channel is at just before the water leaves its banks and accesses the floodplain (Leopold, Wolman, & Miller, 1964). Stage refers to the height of the water above the channel bed. The discharge associated with the bankfull stage is commonly referred to as the channel forming flow or effective discharge (Leopold L. B., 1994). This flow is significant enough and occurs often enough to be the significant driver in the shape of the channel over time. In theory, this flow moves the most significant quantities of sediment over time. An example of the measured bankfull stage at one of the sites along Vallejos Creek is shown in the cross-section profile in Figure 4-2.

Bankfull dimensions such as bankfull area, bankfull width, and bankfull depth measurements are important in describing and understanding a stream channel. Physical and biological factors affect the channel’s geometry; the more notable factors are the frequency, quantity, and duration of precipitation; drainage slopes; channel substrate; vegetation; and geology. Often, relationships between the drainage area of the channel and the bankfull geometry of a channel are strongly correlated (Leopold L. B., A View of the River, 1994). This relationship is especially true in channels found in similar regions. Regional curves show the relationship between the drainage area contributing to a particular reach and its bankfull area or the channel's area within the bankfull stage. Regional curves are useful for evaluating departure from the reference condition for stream channels. A reference condition is a river segment representing a stable channel within a particular valley morphology. Regional curves are also used to aid in sizing a channel for a restoration project.

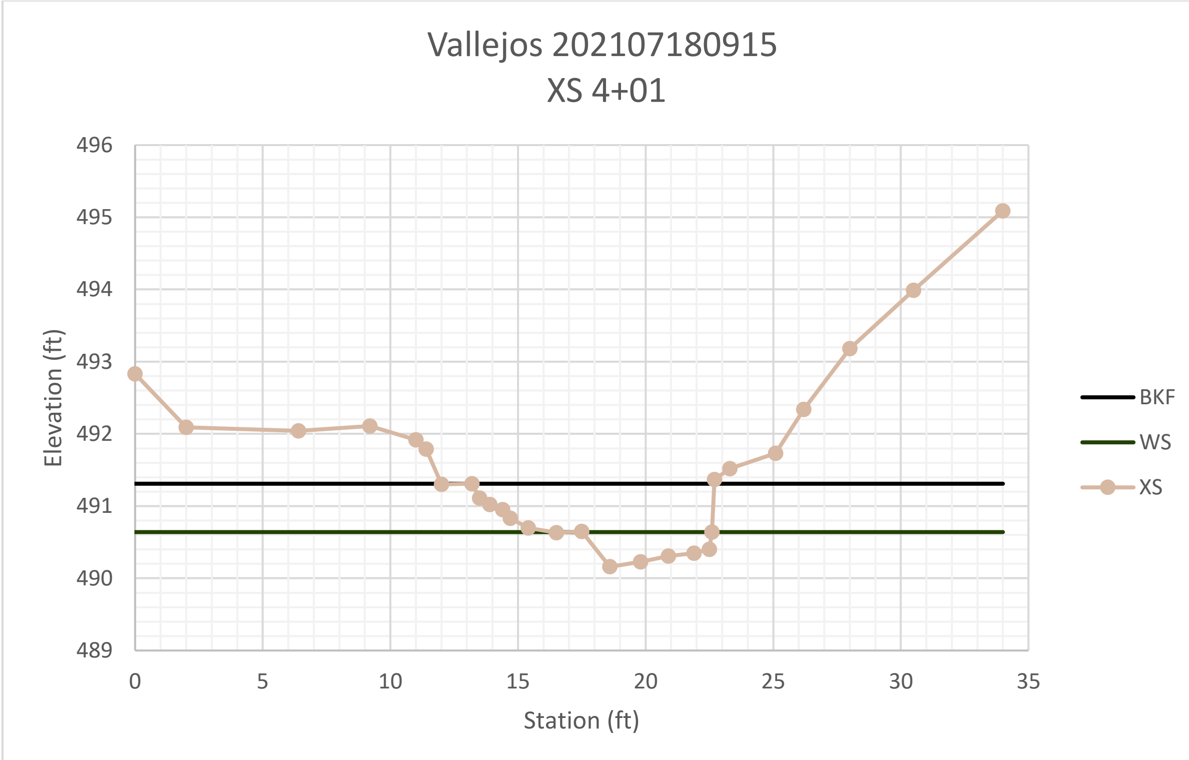


Figure 4-2 Example of bankfull stage measured at Vallejos Creek July 18, 2021. The black line is the bankfull stage (BKF) the blue line is the water surface elevation (WS) recorded at the time of the survey, and the orange line is the relative ground surface elevation (XS)

4.1.2.4 Channel Pattern and Profile

Reference sinuosity is correlated to fluvial landscape and degree of confinement (Rosgen D. , Applied River Morphology, 1996). The lowest possible sinuosity is 1, which is a channel that is aligned with the valley with no meandering. In confined valleys, stream sinuosity between 1.1 and 1.3 are considered good and sinuosity less than 1.1 and greater than 1.3 are considered fair to poor. In unconfined valleys, sinuosity between 1.19 and 1.5 are good and sinuosity less than 1.15 or greater than 1.5 considered fair (Colorado Stream Quantification Tool Steering Committee (CSQT SC), 2019). Channelization increases velocity, decreases length, accelerates bank and bed erosion, results in loss of habitat (riffles and pools), diminishes floodplain connection, reduces nutrient retention, and hyporheic exchange (Bernhardt, et al., 2005).

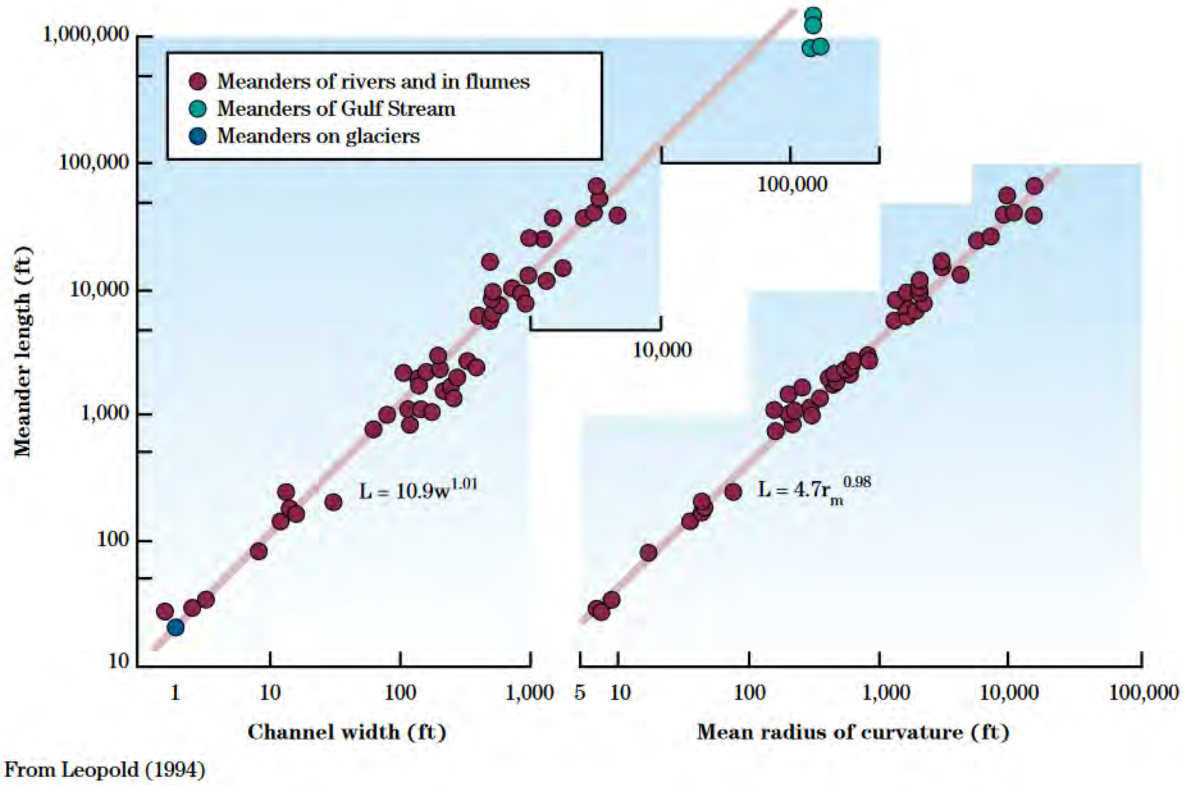


Figure 4-3 Relationship between meander wavelength and channel width and radius of curvature (NRCS, 2007).

Radius of curvatures within natural systems are typically between 1.5 and 4.5 times the bankfull width (NRCS, 2007). A cumulative distribution plot of 263 sites, shown in Figure 4-4, was compiled and analyzed and is included in Chapter 12 of the National Engineering Handbook (2007).

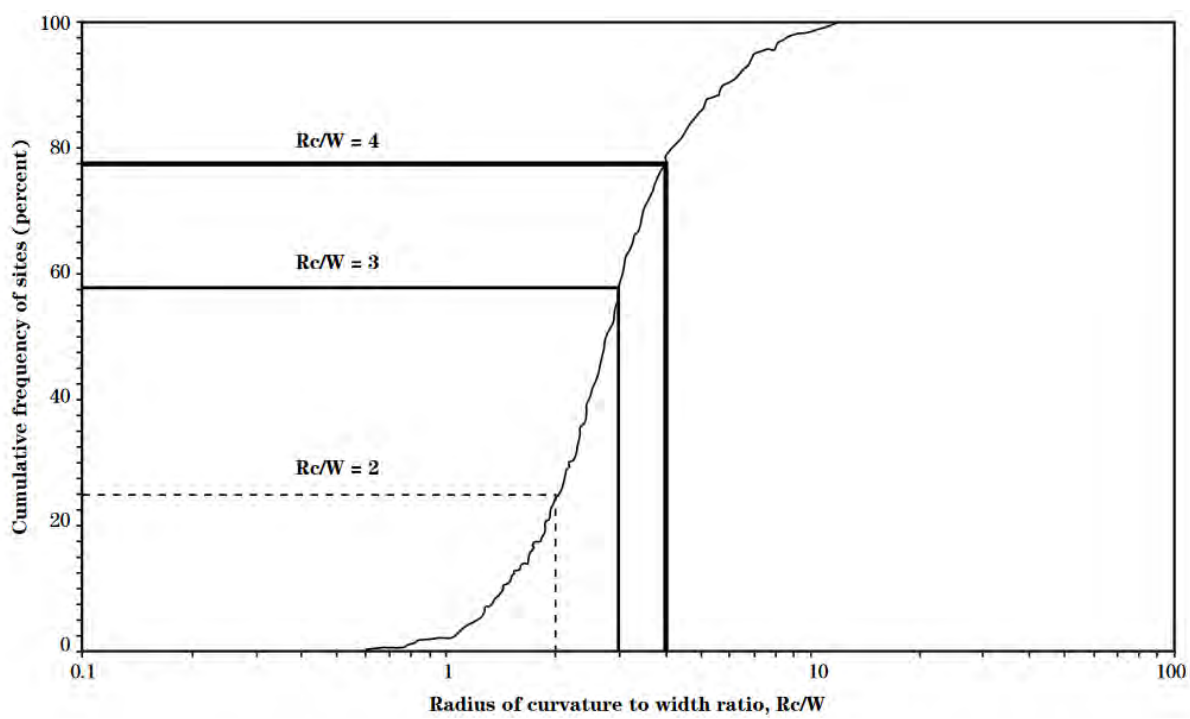


Figure 4-4 Frequency distribution for radius of curvature (Rc) scaled by bankfull width (W) (NRCS, 2007).

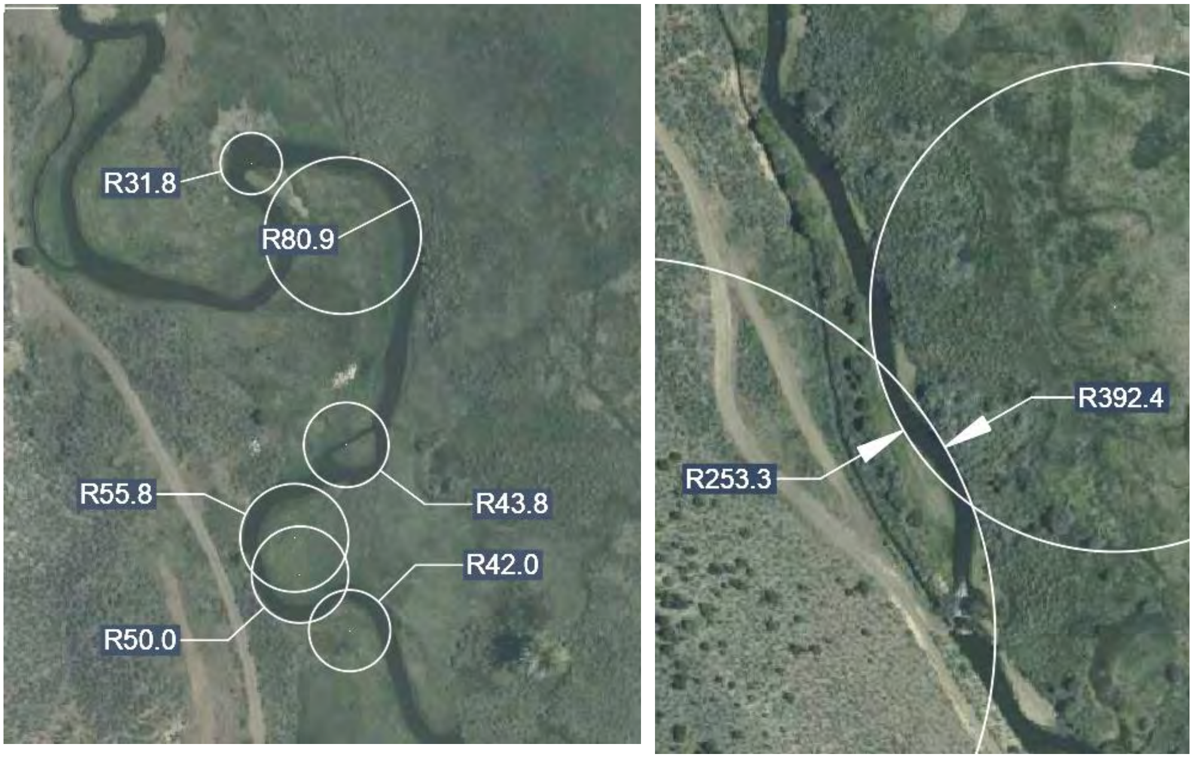


Figure 4-5 Example radius of curvature measurements from Ventero Creek above Culebra Creek near ventero202107150915, bankfull width 19.5-23 ft. Note the erosion near bend with 31.8 ft radius. Left photo upstream of straightened reach shown in right photo.

4.1.3 Sediment

Figure 4-6 Example of gully erosion below stock pond in Colorado Rocky Mountains.

Stream channels transport sediment in addition to water. Traditionally, stream channels were looked at primarily as conduits for transporting water. Over time, however, channels constructed only on the principle of transporting water often fail to consider sediment, resulting in unintended changes to the landscape. Figure 4-6 shows the changes to the landscape that resulted from a stock pond causing sediments to be deposited (i.e., aggradation), and leaving additional transport capacity below the structure (i.e., degradation).

4.1.3.1 Sediment Transport

Lane's Balance (Equation 8 and Figure 4-7) describes how sediment moves through a system. Shear stress (Equation 5), unit stream power (Equation 6), and the continuity equation (Equation 7) describe the forces acting on and within stream channels. It is these forces that enable flowing water to move sediments. Below are equations used to describe these terms.

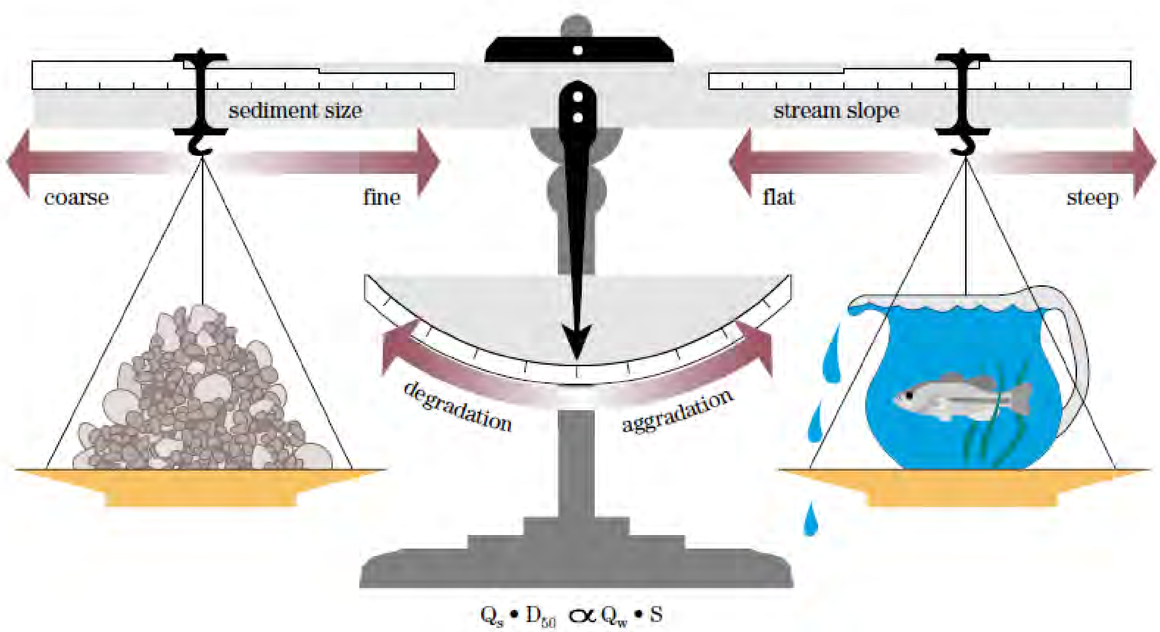


Figure 4-7 Lane's balance as represented in Federal Interagency Stream Restoration Working Group (FIRWG) (1998) in NRCS National Engineering Handbook Part 654 Chapter 13 (NRCS, August 2007).

Shear stress (Equation 4-5) describes the forces being applied and acting on the channel bottom. Shear stress is related to the depth of water/cross-sectional area (hydraulic radius), the slope of the stream bed, and water weight. When the water depth or slope is increased, the shear stress increases, thus increasing the size of sediment that the stream can move. Shear stress can predict the largest substrate particle size that the channel can move (NRCS 2007).

Equation 4-5: Shear Stress (NRCS, 2007)

$$\tau = \gamma * R * S$$

Where τ is shear stress (pounds per square foot), γ is the unit weight of water (62.4 pounds-force per cubic foot), R is the hydraulic radius (feet), and S is the energy gradient or slope. The hydraulic radius, R, is the cross-sectional area divided by the wetted perimeter. To simplify the shear stress equation, the average water depth (Dbkf) is frequently used in place of hydraulic radius.

Stream power (Equation 4-6) is the relationship between shear stress and mean velocity. Stream power is used to determine the largest grain size and rate at which that sized material is transported within the channel.

Equation 4-6: Unit Stream Power (NRCS, 2007)

$$\omega = \tau * u$$

ω is the unit stream power (pound per foot per second). u is the mean velocity (feet per second).

The continuity equation (Equation 4-7) describes the uniform flow and is a result law of the conservation of mass. Given a discharge, if the area of a channel is reduced, the velocity of the water flowing through the channel will increase and vice versa.

Equation 4-7 Continuity Equation

$$Q = A * V$$

Rearranged, $V = Q/A$

Where Q is discharge (cubic feet per second), A is cross-sectional area (square feet), and V is the velocity of water (feet per second). For the same discharge, as the cross-sectional area decreases, water velocity increases and vice versa.

Lane's Balance (Equation 4-8) relates sediment quantity and size to water discharge and slope (Lane, 1954). If any of these variables change in a steady-state system, the others will adjust until the channel is back in equilibrium. For example, if the slope of a channel is decreased, according to Lane's Balance, it can be expected that the quantity and/or size of sediment being transported will decrease. A real-world example of this is the formation of alluvial fans at valley bottoms. Large material deposits are often found at that transition zone as a stream flows from a high elevation (steep slope) to the valley bottom (flatter slope). The slope is decreased, and the channel's ability to move sediment decreases; therefore, sediment is deposited where the slope decreases. This concept can also be brought back to the idea of shear stress (Equation 4-5), shear stress decreases as slope decreases, and stream power (Equation 4-6) decreases as shear stress decreases.

Equation 4-8 Lane's Balance (Lane, 1954)

$$Q_s d \propto Q_w S$$

Where Q_s is the discharge of sediment, d is the particle diameter or size of sediment, Q_w is water discharge, and S is the slope of the stream.

Figure 4-8 Sediment transport zones for a reach north of San Francisco Creek.

Sediment Sources/Sinks

For this discussion, when a stream is in a state of equilibrium it is not aggrading or degrading. Aggradation is when sediments are being deposited or building up over time. Degradation is when the channel is downcutting or sediments are transported from the bed and/or banks downstream without replacement. A stable stream reach maintains a balance, over time, of aggradation and degradation such that the sediment that is transported from the reach is replaced by sediment transported into the reach. Figure 4-8 illustrates the transport zones for an ephemeral stream reach just north of San Francisco. Within this reach the source zone, top of photo is slowly being eroded and the hillslopes are becoming less steep. The middle of the photo illustrates a transport zone, the sediments that are supplied from upstream are moved through the system to the reach below. The bottom of the photo shows an alluvial fan where the sediments are deposited before reaching San Francisco Creek. These zones shift throughout a stream depending on sediment supply.

Figure 4-9 and Figure 4-10 show examples of the unstable channels, reaches, and sediment sources observed in the Upper Culebra Watershed during the field assessment.

Figure 4-9 Top left sediment filling in behind obstruction on Willow Creek. Top right cutbank erosion from banks entering Jaroso Creek. Middle left erosion along roadside going up San Francisco Creek drainage contributing excess sediment to the stream. Middle right bank erosion on Culebra Creek in La Vega. Bottom left cutbank eating into terrace on Culebra Creek above Sanchez Diversion. Bottom right gully/headcut forming in Sangre de Cristo Ranches.

Figure 4-10 Top left Rito Seco incision. Top right channel cutting into a high terrace on Lower Culebra Creek. Middle Left mass wasting up the Vallejos drainage. Middle right El Poso is cutting into a high terrace. Bottom left El Poso cutting into a high terrace. Bottom right gully in the Vallejos drainage.

Anthropogenic is defined as *"…relating to or resulting from the influence of human beings on nature*" (Merriam-Webster n.d.). Anthropogenic activities cause most of the instabilities observed in the previous figures, and four of the main anthropogenic impacts observed in the watershed are described below.

4.1.4 Anthropogenic Impacts

The landscape is constantly changing shape due to physical and biological processes. Humans modify the environment they live in and depend on, and sometimes those modifications impact the shape, function, and processes of natural systems. This is especially true in the riverine environment. The following sections discuss the major impacts human activities have had on the Upper Culebra Watershed, including channelization, grazing, roads, and water diversions. Each of these impacts is discussed in further details in other sections of this report. Provided below are brief introductions to these ideas as they relate to geomorphology.

4.1.4.1 Channelization

When a river overtops its banks in healthy riverine systems, the water accesses its floodplain. At this point, the channel is flooding. As the water accesses its floodplain, the water's velocity and depth on the floodplain are lower than the active channel. During high water or flooding, the streams have more energy and transport larger volumes of sediments and nutrients from the contributing watershed. As the valley becomes less confined and the floodplain widens, the stream power during flood events decreases, allowing the sediments and nutrients to be deposited on the floodplain. These deposits make soils in the vicinity of the river rich and fertile. Lush riparian vegetation communities thrive along stream corridors because of the continual supply of sediments rich in nutrients and water availability. These same conditions make raising crops in and near the channel ideal for agriculture.

Rivers and streams were often moved, channelized, and straightened to increase the area available for agricultural operations. When a stream channel is straightened, the length of the stream is reduced, which increases the channel slope. When the slope of the channel increases, the channel’s ability to move sediment increases, including the ability to transport larger sediments. This increased ability will often cause the channel to start downcutting or becoming incised. Once the channel is incised, the higher flows no longer have access to the floodplain and no longer supply those beneficial sediments and nutrients to the floodplain. The water also loses its ability to irrigate the floodplain.

In the process of straightening the channel often berms were formed along the channel to keep the water within the banks so that access to the field would not be limited. This causes the depth of flow to increase, which increases the effects of the channel being straightened.

4.1.4.2 Grazing

Grazing impacts were observed across the basin during the 2021 assessment. Figure 4-11 shows examples of grazing impacts observed.

Riparian vegetation including woody shrubs and trees stabilize stream channels. Root structures of woody shrubs and trees are often more complex networks and occur at deeper levels than other vegetation; these root masses provide bank stability. Overgrazing in riparian areas, or along channel margins, negatively impacts stream health (Strand & Merrit, 1999). Overgrazing can lead to the clearing/elimination of woody vegetation along the channel banks. This clearing reduces food inputs for macroinvertebrates and can cause channel warming due to the lack of canopy cover from the sun.

Overgrazing causes banks and floodplains to be compacted, further impacting vegetation growth and water absorption. In addition to removing the riparian vegetation structure, livestock cause direct erosion to the stream bank, aka hoof shear, when the presence of woody riparian vegetation no longer slows the access to the stream. The vertical banks caused by hoof shear can be a nick point or starting point for head cuts. Waste from the grazing animals increases nutrient loading within the stream. These excess nutrients impact water quality, create algal blooms, and reduce dissolved oxygen in the water leading to eutrophication, negatively impacting aquatic life in the channel. Grazing impacts to stream health are discussed in further detail in the report's Water Quality and Grazing Assessment sections.

Figure 4-11 Top left horses in the foreground, cattle in the background Culebra Creek on La Vega note stream banks without woody riparian cover. Top right hoof shear along the stream channel. Bottom left cattle grazing next to Culebra Creek on La Vega. Bottom right cutbank on Jaroso Creek, notice fence and cattle in the background.

4.1.4.3 Roads

Road crossings over channels affect the function of the channel and their associated riparian communities. These crossings also impact debris flow (Jones J. A., Swanson, Wemple, & Snyder, 2000), sediment input and passage, and water passage. Often road crossings are undersized for the drainage that they are crossing. When the width of a channel corridor is reduced to fit into a culvert, even if sized for the expected flow, the channel function changes. Using the Continuity Equation (Equation 4-7), one can predict that with the same discharge, if you reduce the available cross-sectional area the velocity of the water must increase through the culvert. This change in area often results in water backing up at the upstream end of the culvert, causing transported sediments to “fallout” of the water column depositing upstream of the culvert. Downstream of the culvert, water moves at an increased velocity; this increases stream power (Equation 4-6), and the channel’s ability to move sediment, causing degradation in the downstream channel as sediments are removed from the downstream end of the culvert. On a landscape level, roads crossing valleys can function as dams for debris flows. Often road crossing affects the migration of aquatic organisms because of increases in velocity, large drops, and even changes in substrate.

Roads are an additional source of sediments to stream channels. Roads can function as the channel, becoming the water's preferred path for flowing. Overland flows carry the road surface material, especially dirt roads, into the stream channel, causing aggradation. Overland flow via roads can also decrease the time required to reach the stream causing increases in peak discharge downstream and subsequent decreases in baseflows.

Figure 4-12 shows road crossings observed by during the 2021 watershed assessment. Road crossings and other infrastructure are discussed in further detail in the Infrastructure Assessment section of this report. There is also a section of the report that discusses debris flow.

Figure 4-12 Top left: culvert filling with sediment below the road. Top right: three culverts convey water at the road crossing. Middle left: culvert at a road crossing, notice channel incision and cutbanks. Middle right: culvert at road crossing filling with sediment. Bottom left: culvert filling with sediment. Bottom right: water running off down the road.

4.1.4.4 Diversions

Diversion, like roads, influence the function of natural stream channels. In addition to preventing water from flowing down a channel, diversions dams often function as sediment blocks, preventing sediment from moving downstream. Water below these checks is starved of sediment and starts picking up additional sediments downstream of the check. This often causes the channel and/or canal to degrade. Diversion structures often constrict the channel's floodplain, again causing erosion. These structures can also cause barriers to the migration of aquatic species, such as fishes. Figure 4-13 shows examples of the diversions visited during the watershed assessment. It is important to note that the sediment transport principles that apply to streams also apply to ditches and canals.

Figure 4-13 Top left: sediment filling in behind check structure at San Francisco Ditch headgate, notice elevation difference between top of the structure and downstream of it. Top right: splitter box to split flows. Middle left: splitter box. Middle right: culvert and headgate. Bottom left: headgate for Culebra Cerritos, Island Ditch, and Francisco Sanchez. Bottom right: the Sanchez Dam.

4.2 Methods

To complete Task 9 – Geology/Geomorphology Assessment for the Upper Culebra Watershed Assessment, this task was broken into two major phases: the desktop analysis and field investigation phases. The following sections describe the methods employed for each of these phases of work.

4.2.1 Desktop Analysis

Using methodologies described by the Watershed Assessment of River Stability and Sediment Supply (WARSSS) (Rosgen D. , 2006), a modified Reconnaissance Level Assessment (RLA) is being performed within the project boundary. The premise of the RLA is to obtain and evaluate all the available spatial data for the project area and identify reaches that are to be evaluated by subsequent phases of the assessment.

For the RLA multiple data sources were used to assess the watershed remotely

- Aerial Imagery was used to visually identify potential problem and reference sites.
- EagleView, NAIP, Bing, and Google Earth.
- Various raster files
- Digital Elevation Models (DEM) – was used to identify/classify several physical properties of the basin (USDA, 2000-Present; United States Geological Survey, 2011).
- Hillside slopes.
- Channel catchments (or drainage areas).
- Average catchment aspect.
- Various vector files – a vector file is a point, line, and polygon data.
- Tiger Roads, supplemented by hand digitizing (U.S. Census Bureau, 2015).
- Soil Survey Geographic Database (SSURGO) and State Soil Geographic Database (STATSGO) (Schawarz & Alexander, 1995).
- TauDEM generated stream network from 10-meter DEM (Tarboton, Dash, & Sazib, October 2015).

4.2.1.1 Raster

Digital Elevation Model

TauDEM, a program developed by David Tarboton of Utah State University (Utah State University - Hydrology Research Group, 2021), was used to develop the data used for the desktop assessment of this assessment (Section 1.3.1.1). 10-meter elevation data, elevation raster files, from the USGS National Elevation Dataset (NED), a publicly available dataset, was input into TauDEM. TauDEM was used to process the elevation raster files generating outputs for evaluating the hydrology of the Upper Culebra Watershed. These outputs included slope and flow accumulation for the basin. Using TauDEM subbasins and a stream network were generated for the basin.

Hillshade visualizations can help identify instabilities, such as vertical banks, pattern inconsistencies, and places of aggradation and degradation. Hillshade visualizations of the digital elevation model were also used to identify areas of interest within the Culebra Basin. Figure 4-14 shows an example of hillshade visualization showing Rito Seco. Notice how easy it is to spot headcuts adjacent to the incised channel.

Imagery

Imagery available on Google Earth, EagleView, Historic Imagery available on Google Earth and from the USGS, and Bing were all used to evaluate the geomorphic condition of the Culebra Watershed. Imagery for each of the tributaries was visually scanned for signs of aggradation, degradation, channel incision, channel pattern, sediment sources, and the presence of riparian vegetation.

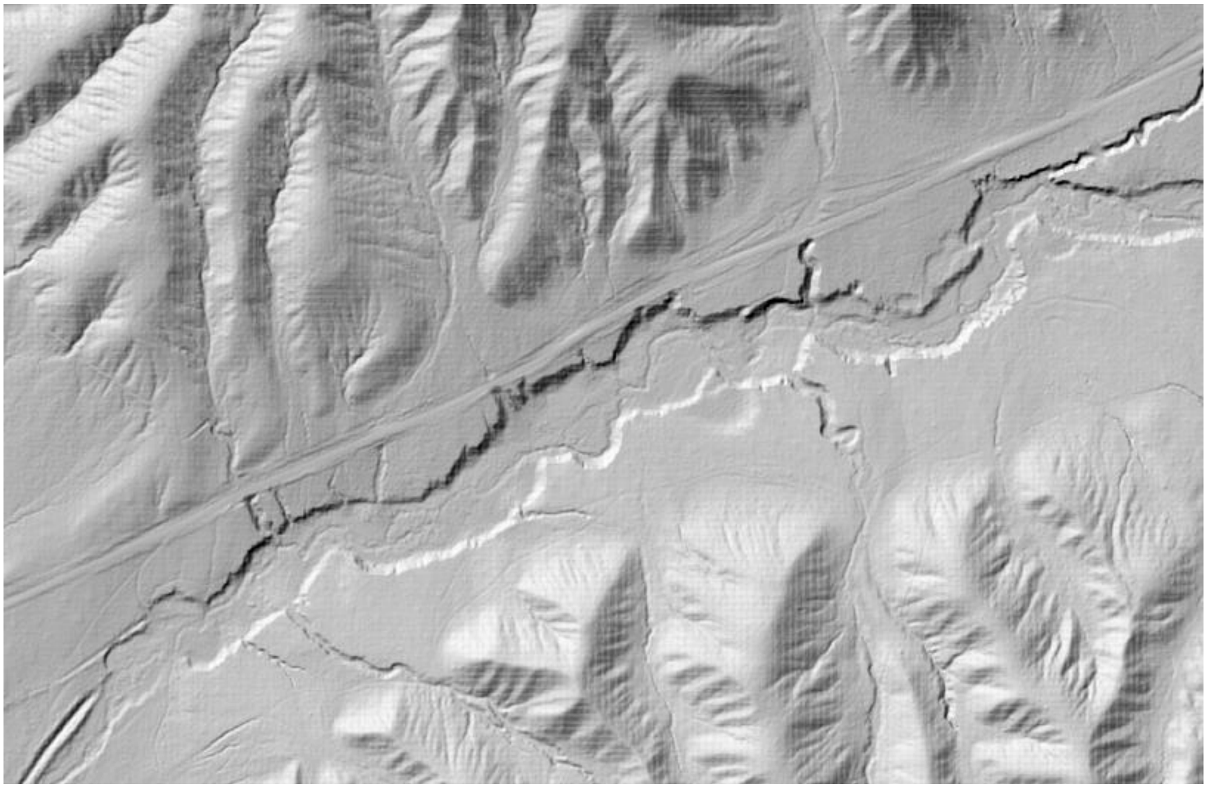


Figure 4-14 Hillshade visualization of Rito Seco. Notice headcuts feeding the channel and channel incision.

4.2.2 Field Assessment

The field assessment of the geomorphology of the Upper Culebra Watershed was completed during the summer of 2021. The field assessment included field reconnaissance, data collection for a preliminary mini-regional curve, and geomorphic assessment in coordination with the Aquatic Assessment Risk sites.

4.2.2.1 Field Reconnaissance

Field reconnaissance included traveling and observing each of the drainages. The field reconnaissance for geomorphology was paired with field reconnaissance for other tasks, such as Infrastructure, Flow Regimes, and Water Quality. General observations were made during travels through the watershed. Photo points were recorded using field tablets anywhere observations were made. More detailed geomorphic field surveys were conducted using RTK GPS or a rotary laser level.

4.2.2.2 Aquatic Assessment Risk Sites

The aquatic habitat assessment sites were selected based on hillslope erosion risk. Many of these sites were located above points of diversion and provided for representative reaches that reflect the land use, geology, and land cover within the upper watershed.

4.2.2.3 Preliminary Mini-Regional Curve

Cross-section data collected at each geomorphic site was used to general the preliminary mini-regional curve.

4.3 Results and Observations

4.3.1 Desktop Assessment, Field Verification, Preliminary Mini-Regional Curve

During the desktop assessment, 30 reaches were identified as reaches of interest (Figure 4-15 and Table 4-3). Of the 30 reaches identified, four were identified as having a low priority for a field verification visit, 14 identified as having a moderate priority for a field verification visit, and 12 a high priority for a field verification visit. High priority sites were identified based on visual indications of severe instabilities. These instabilities were often signs of aggradation/degradation, vertical banks, and issues with the channel pattern. Moderate and low priority sites showed less severe instabilities occurring within the reach. Of the 30 sites identified, 17 sites were visited. Sites were visited based on landowner access and proximity to other assessment activities. If reaches showed similar condition and were within the same general location only one of the reaches was visited.

In the following section, where appropriate, reaches were combined based on similar condition and location. The number used to identify the sites is an arbitrary unique identifier and does not refer to the condition or ranking of the site.

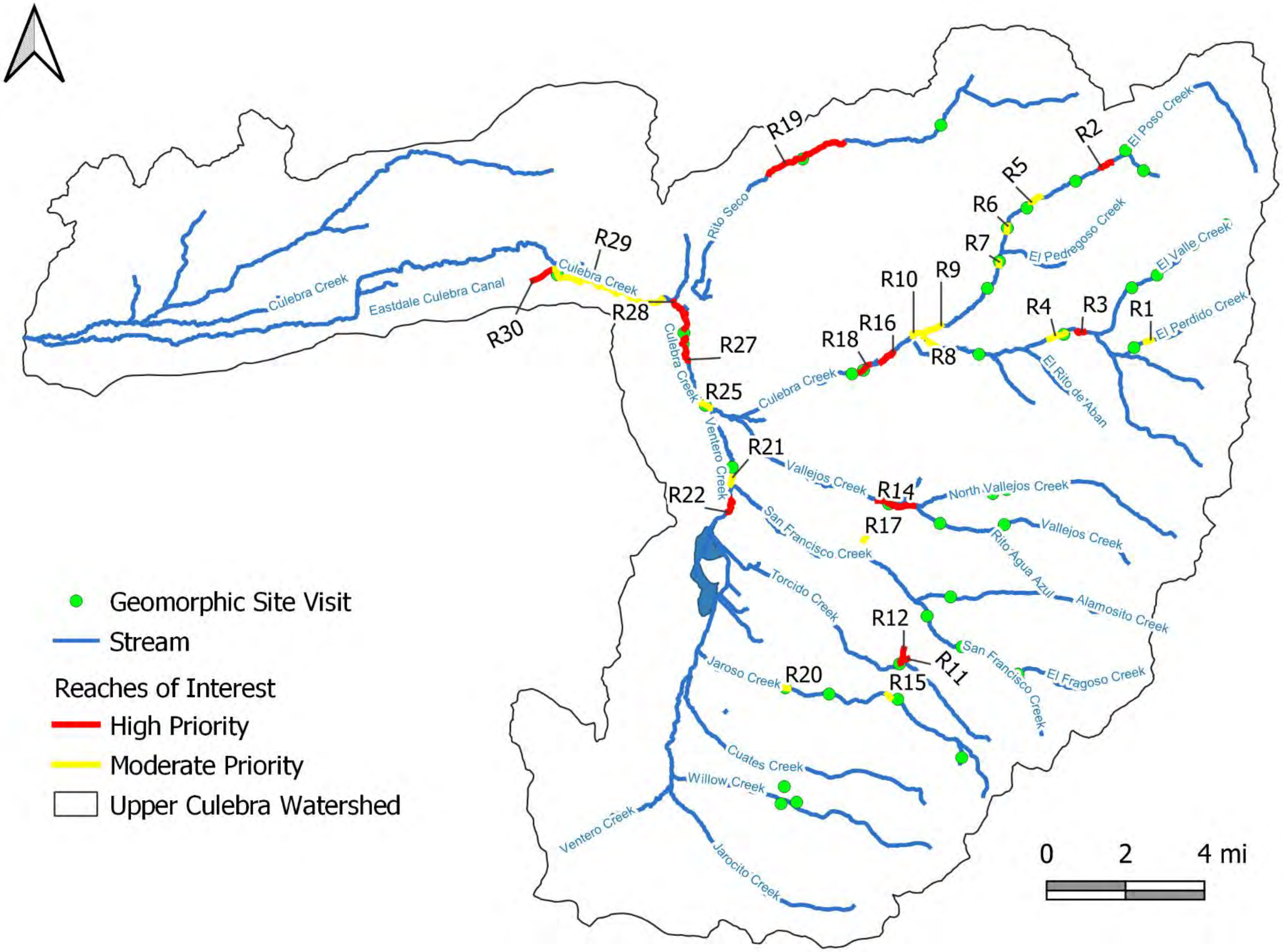


Figure 4-15 Geomorphic reaches of interest. Red has a high priority for inspection, yellow has a moderate priority for inspection.

Table 4-3 Geomorphic reaches of interest.

Number	Priority	Centroid Latitude (WGS84)	Centroid Longitude (WGS84)	Drainage	Visit
R1	Moderate	37.18016596	-105.2124174	El Perdido	Yes
R2	High	37.24468255	-105.2322766	El Poso	No
R3	High	37.18308479	-105.2438382	Culebra	No
R4	Moderate	37.1816783	-105.2545125	Culebra	Yes
R5	Moderate	37.23186431	-105.2645783	El Poso	Yes
R6	Moderate	37.2210759	-105.2775345	El Poso	Yes
R7	Moderate	37.20825255	-105.2813639	El Poso	Yes
R8	Moderate	37.17792213	-105.3107625	Culebra	No
R9	Moderate	37.18400779	-105.3118118	El Poso	No
R10	Moderate	37.18241599	-105.3184358	Culebra	No
R11	High	37.06229112	-105.3244239	Torcido	Yes
R12	High	37.06379114	-105.3251322	Torcido	Yes
R13	low	37.04752372	-105.3265634	Jaroso	Yes
R14	High	37.1197348	-105.3289073	Vallejos	Yes
R15	Moderate	37.04932401	-105.3311455	Jaroso	No
R16	High	37.17381795	-105.3323785	Culebra	Yes
R17	Moderate	37.1069669	-105.3425838	Unknown	No
R18	High	37.16959293	-105.3428474	Culebra	Yes
R19	High	37.24772659	-105.3703968	Rito Seco	Yes
R20	Moderate	37.05206559	-105.3788791	Jaroso	Yes
R21	Moderate	37.12825859	-105.4037296	Ventero	No
R22	High	37.11914752	-105.4041043	Ventero	No
R23	Low	37.21835084	-105.4145113	Unknown	No
R24	Low	37.20005971	-105.414852	Unknown	No
R25	Moderate	37.15590465	-105.4160146	Culebra	Yes
R26	Low	37.19320786	-105.4214523	Unknown	No
R27	High	37.17663419	-105.4256506	Culebra	Yes
R28	High	37.18920688	-105.4266456	Culebra	No
R29	Moderate	37.19862896	-105.4614016	Culebra	Yes
R30	High	37.2035179	-105.4903327	Culebra	Yes

4.3.1.1 Lower Culebra Creek (Reaches 25, 27, 28, 29, and 30)

Figure 4-16 Top Left Culebra Creek (30) notice use of riprap for bank stabilization. Top Right Culebra Creek (29) notice bank erosion in background. Bottom Left Culebra Creek (27) notice vertical bank in the background. Bottom Right Culebra Creek (27) notice channel is slightly entrenched with bank erosion.

A review of aerial imagery along Culebra Creek revealed five reaches of interest in the Lower Culebra Basin, Culebra (30, 29, 28, 27, and 25) (Figure 4-17). The reaches extend from Eastdale Canal upstream to near the confluence between Culebra Creek and Ventero Creek (Figure 4-16). Though broken up into smaller reaches, minor issues were identified throughout.

Overall review of Culebra Creek in the lower basin found potential issues with the channels pattern. The stream is channelized (Figure 4-18) and slightly entrenched in sections. Inspection of radius of curvature in aerial photographs throughout the stream was found to be both too small and too large to be sustainable throughout the reach. The meander bends with tighter radii are more likely to avulse over time. Meander bends that are too large are an indication of straightening which can result in accelerated bed and bank erosion, increased stream velocities, and decreased aquatic habitat.

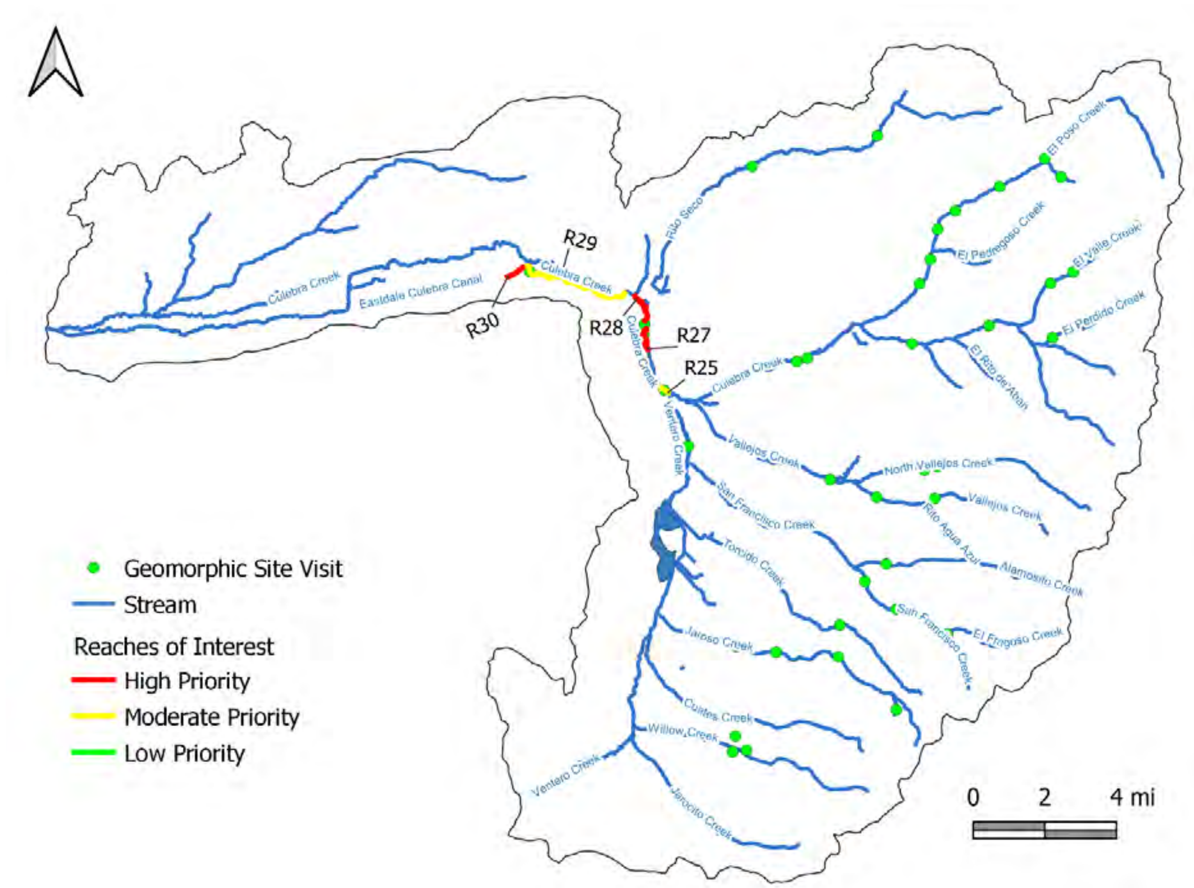


Figure 4-17 Culebra Creek reaches of interest 25, 27, 28, 29, and 30 locations.

There is evidence of aggradation and degradation throughout the reaches. The channel is forming mid-channel bars suggesting that it is overwide. These bars cause short-term instability within the reach. Like most natural river systems in this valley setting, the channel is likely to migrate within its floodplain across the valley. Degradation may be accelerated by changes in hydrology from upstream gate changes on Sanchez Reservoir which cause large fluctuations of flow over noticeably short time periods, this is discussed further in Chapter 5.

Riparian vegetation is noticeably sparse throughout the lower basin, and it is overgrazed. The riparian assessment team rated the riparian habitat poor within this reach. More information on the riparian assessment is included in Chapter 2. The channel has a good connection to its floodplain, but analysis of the flow regimes in Chapter 5 shows the hydrology is modified such that flooding rarely occurs within this reach. Though the channel is not in terrible condition, there is an opportunity to improve the channel function and habitat, thus improving the fishery and function through these reaches.

The project team visited and conducted a geomorphic assessment at Culebra Creek sites 29, 27, 25. Detailed information for each of these sites can be found in Section 4.3.2.2.

Comparing 1965 aerial imagery with current conditions shows some minor changes in channel pattern below San Luis, highlighted in Figure 4-18. Comparison of the 1965 and current aerial imagery shows the landscape to be stable and no significant increases in development (Figure 4-19).

Moving upstream toward the confluence with Ventero Creek active aggradation is observed in Culebra Creek upstream of County Road 21 (Figure 4-20). Comparing the two time periods, the riparian vegetation is sparse in 1965 and has since grown. There is a change in the County Road 23.8 bridge and some increase in number of structures within this area. A wetland and pond are present in the current aerial photographs on the southeast corner of the County Road 21 and L.7 intersection that is not present in the 1965 aerial imagery. Sediment piles and channel pattern below County Road 21 suggest that the channel is being maintained and sediments actively being removed. In 1965 the channel upstream of County Road 21 would classify as a Rosgen Type “D” having a high width to depth ratio and no entrenchment. The levees present along the channel would classify as either a B or G stream type based on entrenchment and low sinuosity. Based on valley type and slope the reference stream type for this reach is a Type “C” stream with sinuosity greater than 1.2 and good access to the floodplain.

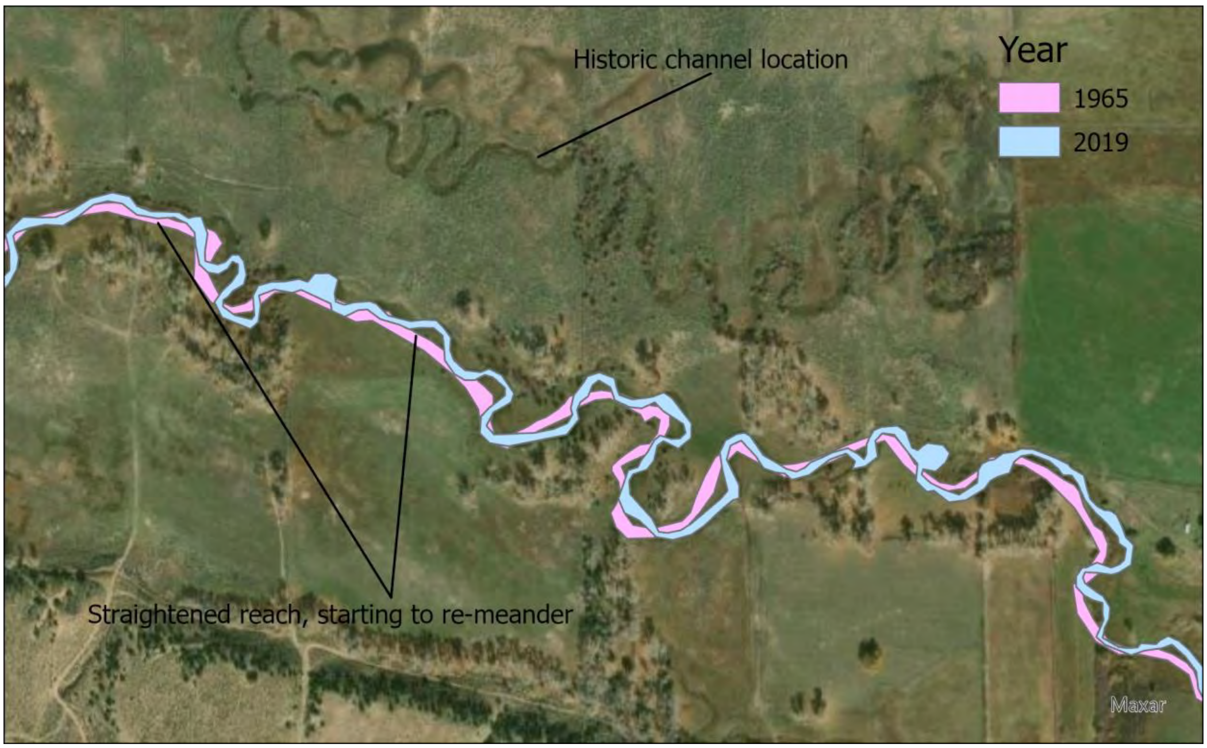


Figure 4-18 Lower Culebra Creek 1965 to present stream channel comparison.

Figure 4-19 Comparison of 1965 aerial imagery and current ESRI World Imagery.

Figure 4-20 Culebra near confluence with Ventero Creek 1965 to current aerial review.

4.3.1.2 Culebra Creek (Reaches 16, 18, and 10)

Figure 4-21 Culebra Creek (16) looking downstream towards the Sanchez Headgate.

Culebra Creek (16, 18, and 10) (Figure 4-23) are directly upstream of the Sanchez Canal Diversion, extending up Culebra Creek to its confluence with El Poso Creek.

Inspection of the aerial imagery revealed depositional areas upstream of the Sanchez Canal Diversion, and bank erosion. As is discussed further in Section 4.3.2.2, the width of Culebra Creek is reduced at the headgate (Figure 4-21). This is causing sediment to deposit or aggrade behind the structure. Bank erosion is seen upstream of the diversion, beyond the depositional area. The channel is cutting into high terraces. North of County Road L.7, the channel is not stable below the diversion. The ditch is running along a steep cut bank. Earlier work has been done in the channel north of County Road L.7. Mid-channel bars and point bars are forming behind the installed boulder structures.

Figure 4-22 Culebra Creek (18) looking upstream towards high terrace cutbank, notice toe in middle of photo becoming saturated, this will eventually slough off into the river and the bank will continue to erode.

The assessment crew walked Culebra Creek (16) up through most of Culebra Creek (18). In Culebra Creek (18), Culebra Creek actively cuts into a high terrace (Figure 4-21 and Figure 4-24). The channel has been pushed to the edge of the valley to make room for agricultural fields.

Culebra Creek (reach 10) shows the channel has been moved to the north so that the channel is directly adjacent to the historic terrace and straightened. The hill shade view of the 2011 SLV Lidar suggests that the confluence between El Poso Creek and Culebra Creek may have been moved upstream of the L.7 bridge, above the Guadalupe Sanchez Diversion structure.

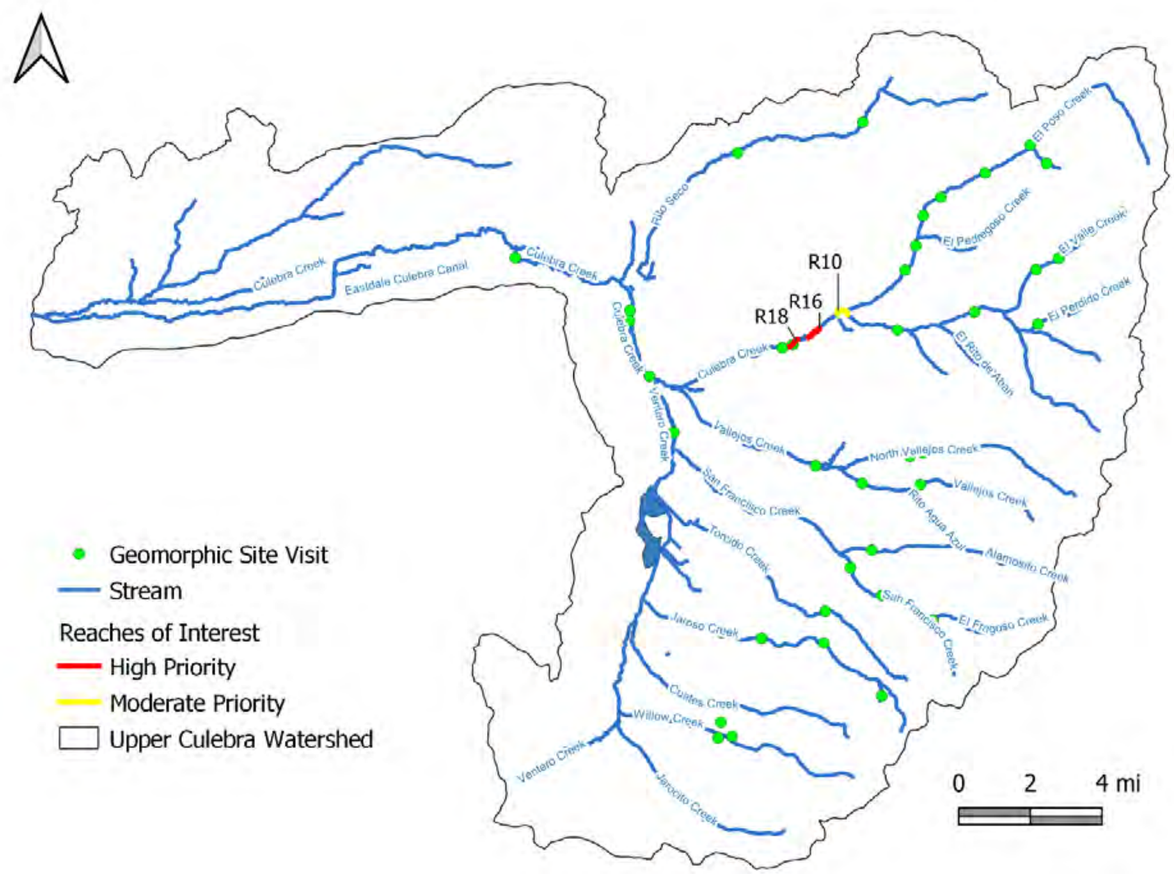


Figure 4-23 Culebra Creek, reaches of interest 10, 16, and 18, locations.

Figure 4-24 Areas where Culebra Creek is cutting into high terrace above Sanchez Canal.

Comparison of the 1965 aerial imagery and current aerial imagery shows the channel alignment is similar today as it was in 1965 although the channel today is much narrower than the channel in 1965 (Figure 4-25). This may be due to the growth of additional riparian vegetation. The line of trees to the north of the channel in the upper portion of this reach are indicators of a historic channel alignment, though most evidence of this historic channel have been removed through grading of fields for agriculture. The headgate of the Sanchez Canal shows the operations with all but a small portion of the flows being diverted through the canal and returned to the channel through floodgates. Active sediment deposition on the floodplain is greater above the County Road 23.5 bridge than below, in channel deposition is visible in the 1965 aerial photograph below the County Road 23.5 bridge. In 1965 the area around the Sanchez Canal headgate has no visible riparian vegetation, cottonwoods and other vegetation has regrown in are not continually disturbed today.

Figure 4-25 Comparison of 1965 and current aerial imagery from Sanchez Canal headgate upstream to County Road 25.5.

4.3.1.3 Culebra Creek (Reach 8)

Culebra Creek (R8) is 0.25 miles upstream of the El Poso Creek/Culebra Creek confluence. Aerial imagery showed bank erosion, lack of vegetation, and problems with the pattern of the channel through this reach.

Figure 4-26 Google Earth screen capture of Culebra Creek (8) notice tight radius of curvature in the channel pattern near middle of photo to the left of the red roofed structure and in lower left-hand side of photo.

The channel appears to have been channelized in locations. There are at least two very tight radiuses of curvatures in the reach (Figure 4-26 and Figure 4-28). These are likely to avulse (chute cut-off), causing the channel length to become shorter, increasing the slope of the channel, and potentially causing the channel to incise. The current channel at the upstream profile in Figure 4-28 is approximately four feet lower than the current channel with a narrower floodplain corridor than the historic channel (Figure 4-29). Below the road the difference between the historic channel and the current channel is approximately one foot and appears to be less confined. The channel's floodplain appears to be constricted by the bridge, and there is a low water crossing ~140 feet upstream of the bridge.

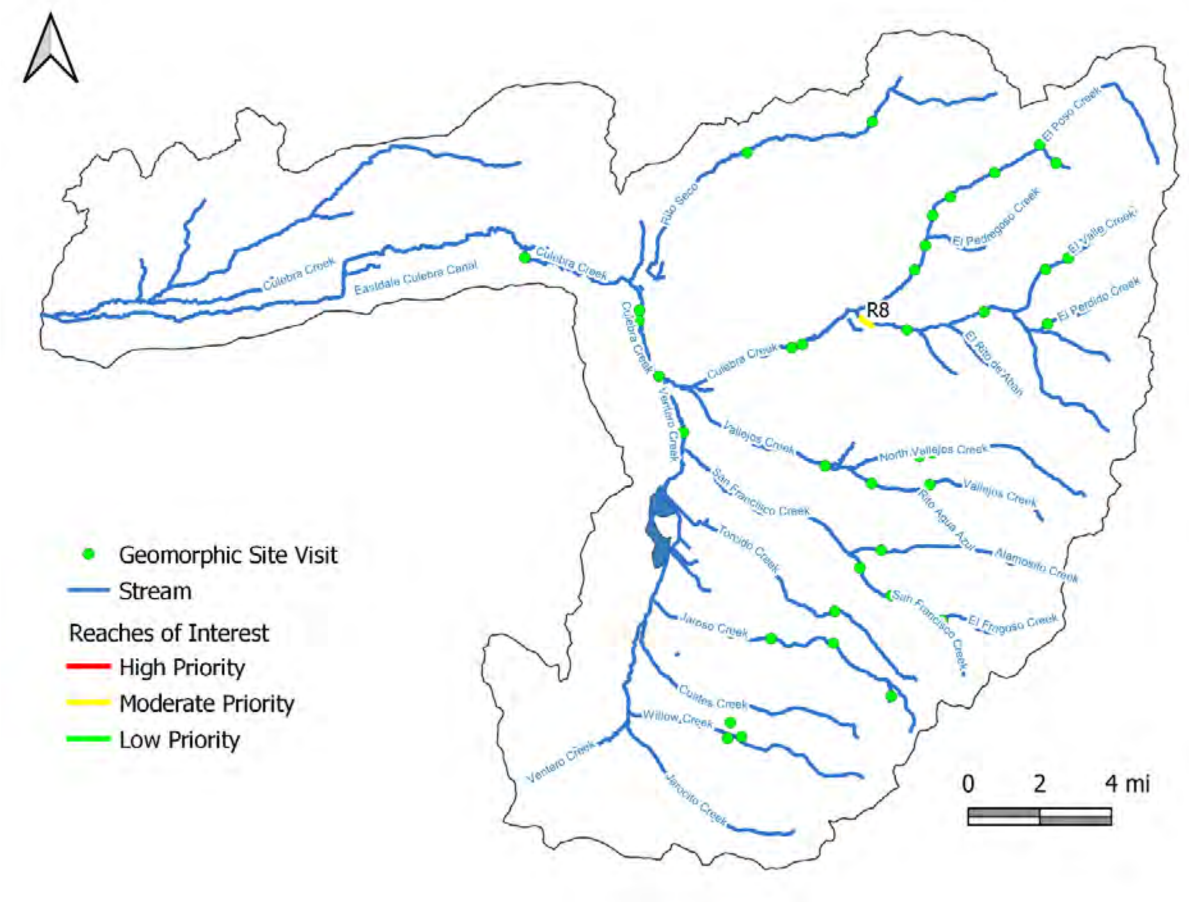


Figure 4-27 Culebra Creek, reach of Interest 8, location.

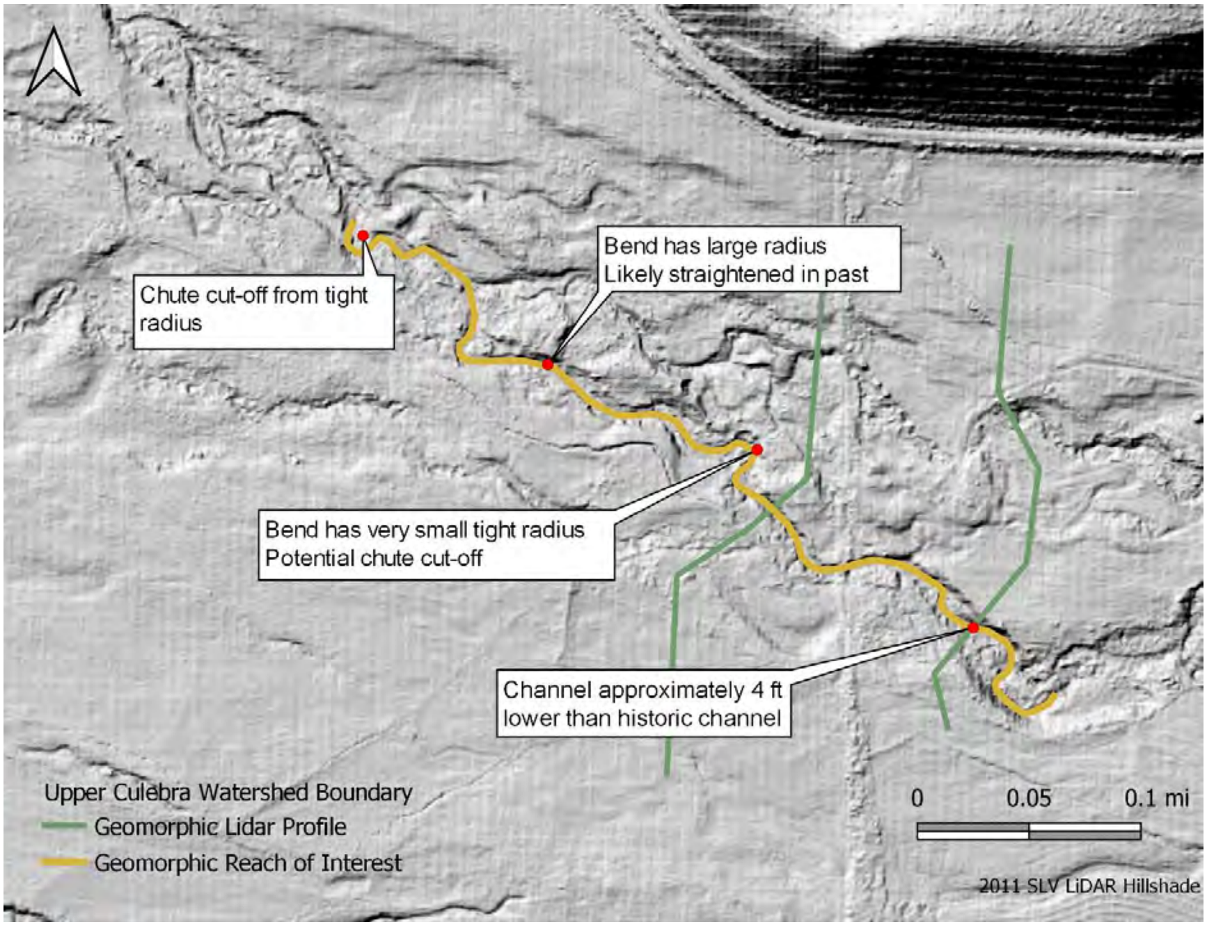


Figure 4-28 Overview of geomorphic observations in reach 8.

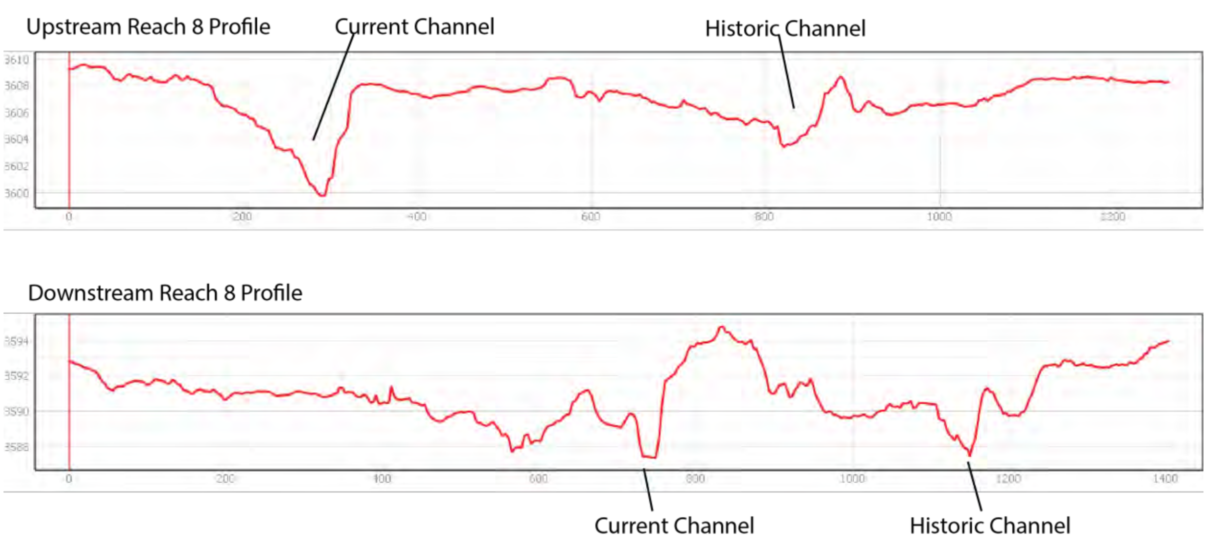


Figure 4-29 Surface cross-section profiles from 2011 SLV Lidar of Reach 8.

4.3.1.4 Culebra Creek (Reaches 3 and 4)

Figure 4-30 Culebra Creek (4). Steep section of Culebra Creek.

These reaches were identified because aerial imagery showed the presence of drops in the channel and bank erosion at Culebra Creek (reaches 3 and 4) (Figure 4-32). Riparian vegetation, especially at Culebra Creek (reach 3), is absent from these two reaches (Figure 4-30).

During this field assessment a detailed reach assessment was completed, Culebra Creek (reach 4). This visit is discussed in further detail in Section 4.3.2.2. During the visit, the assessment crew walked up stream of Culebra (reach 4) and observed drop structures in the channel, shown in Figure 4-31. The channel upstream of these drops is likely to aggrade due to the reduction in channel slope, and large pools are likely to form below the structures resulting in potential structural failure.

Figure 4-31 Rock cross-vane with large drop.

There is evidence of grazing in and around both reaches. Reach 3 is not aligned with lowest part of the valley which is north of the reach suggesting that the channel may have been moved in the past. This region is in a transition zone for the valley type as it expands. Due to this expansion of the valley and reduction in slope deposition would be expected as channel velocities decrease, especially on the floodplain as it widens.

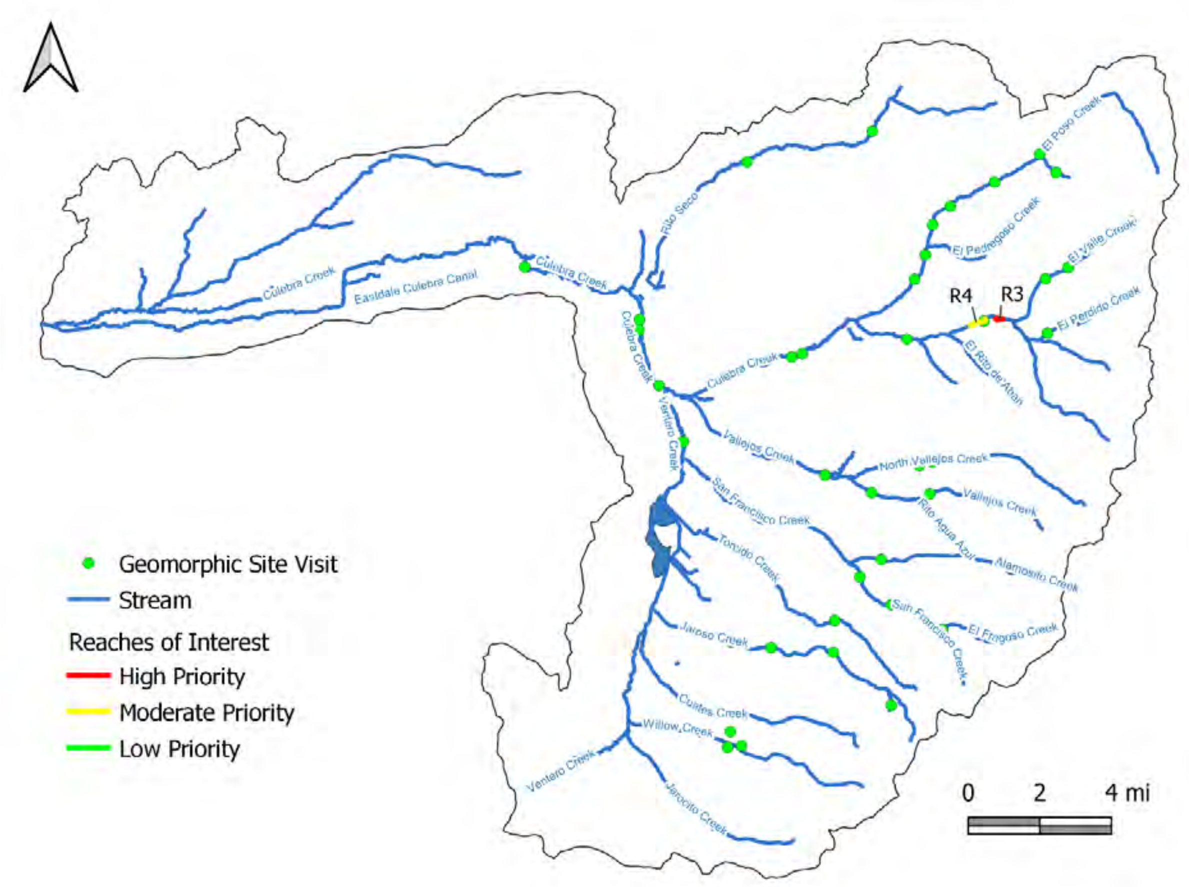


Figure 4-32 Culebra Creek, reaches of interest 3 and 4, locations.

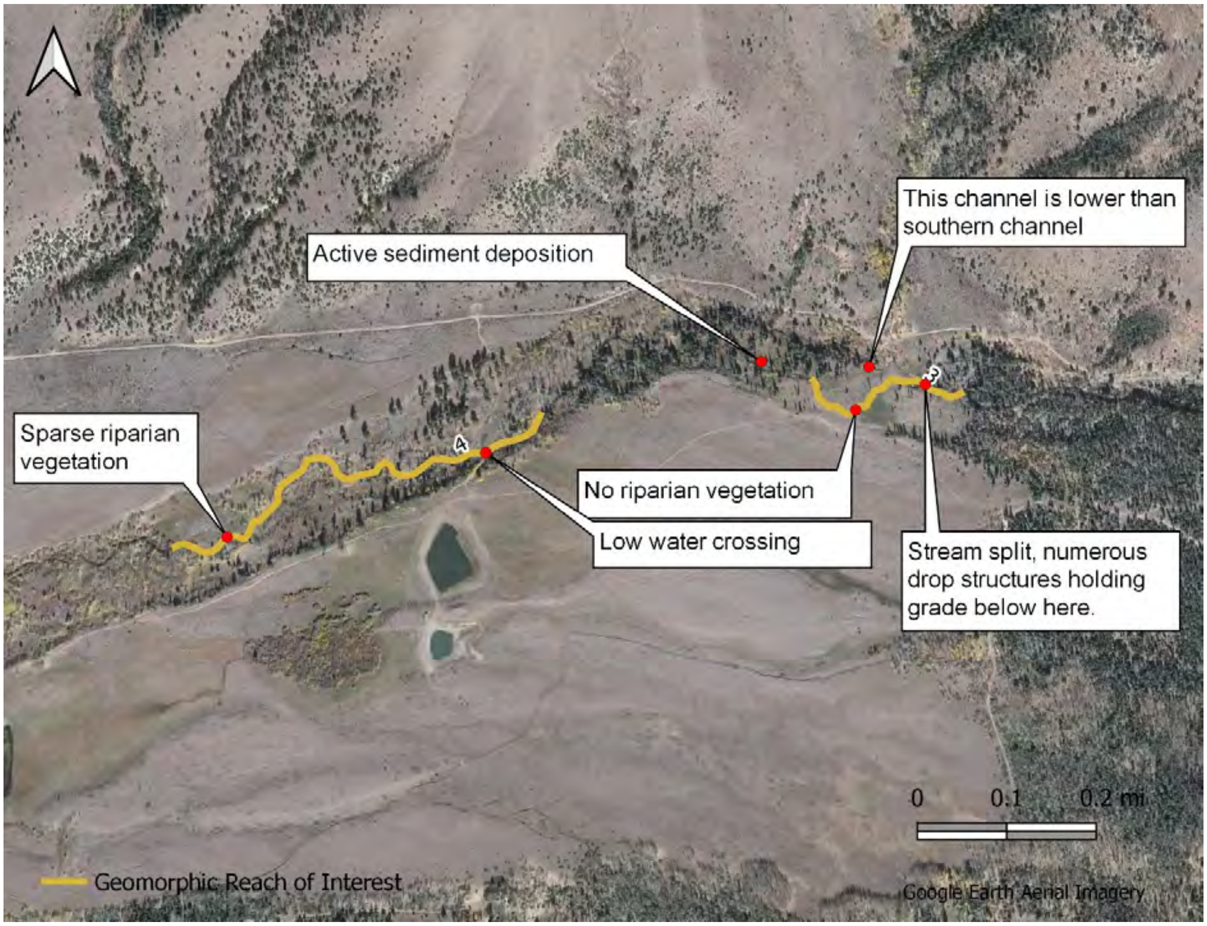


Figure 4-33 Geomorphic observations from Culebra Creek reaches 3 and 4.

4.3.1.5 Jaroso Creek (Reach 20)

A review of aerial imagery identified Jaroso Creek (reach 20) because there were areas where the channel was straightened, areas where tight bends have formed in response to this straightening, cutbanks, and lack of vegetation. The pattern is unstable with radiuses of curvatures that are both too big and too small. The channel is widening its floodplain by cutting into the high terraces, creating cutbanks (Figure 4-34). Vegetation, especially woody shrubs, is noticeably absent from this reach. This reach is where the valley transitions from confined to unconfined. The area does not have structures and preserving this state will reduce fluvial hazards within the alluvial fan, especially in reach 20 and the areas upstream.

Figure 4-34 Jaroso Creek (2) notice developing floodplain adjacent to the channel and vertical bank in the background.

Jaroso Creek (20) was visited, and detailed site assessment performed. What was observed onsite is discussed in further detail in Section 4.3.2.3.

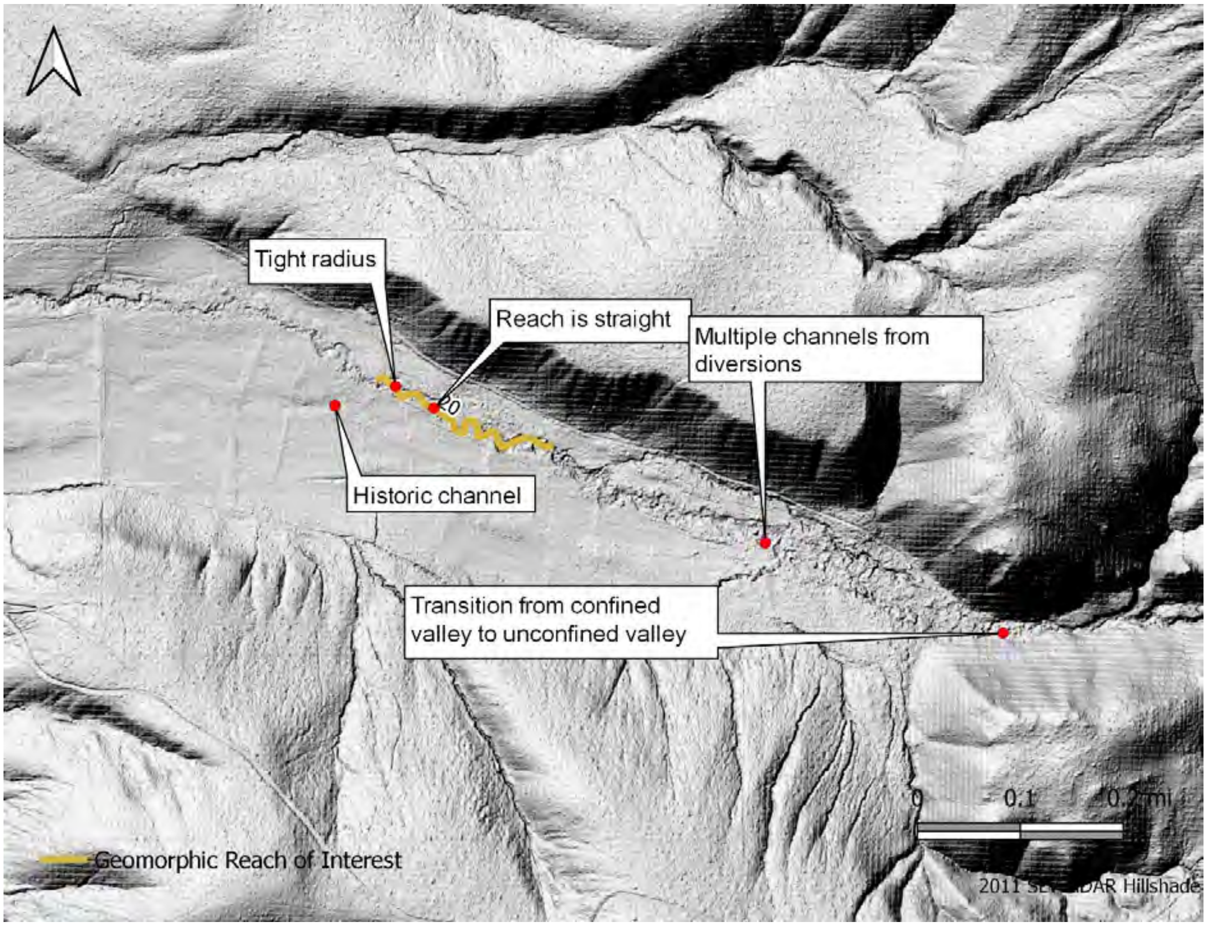


Figure 4-35 Jaroso Creek geomorphic reach 20 observations

4.3.1.6 Jaroso Creek (15 and 13)

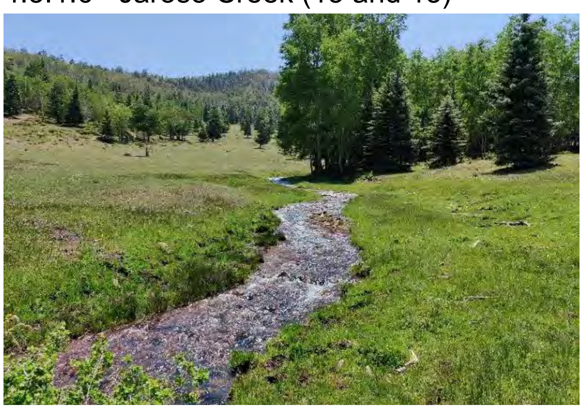


Figure 4-36 Jaroso Creek (13) notice lack of wood shrubs in riparian corridor.

The review of aerial imagery indicated issues with the channel pattern, bank erosion, and lack of vegetation at Jaroso Creek reach 15 and 13 (Figure 4-37). Immediately below the road crossing at Jaroso Creek 13 the valley becomes more confined and wooded. The valley then opens more and become less wooded through Jaroso 15. Areas with a large radius of curvature do not appear stable from the top of Jaroso Creek 13 downstream through Jaroso Creek 15. Geologic maps show these small, unconfined section occur along a concealed fault (Kirkham, Lufkin, Lindsay, & Dickens, Geologic Map of the La Valley Quadranble, Costilla County, Colorado, 2004).

Heavy grazing may be impacting the channel through these reaches (Figure 4-36) in addition to road crossings.

Two detailed site assessments were performed within these reaches: Jaroso Creek (13) and downstream of Jaroso Creek 13. A more detailed discussion about these sites can be found in Section 4.3.2.3.

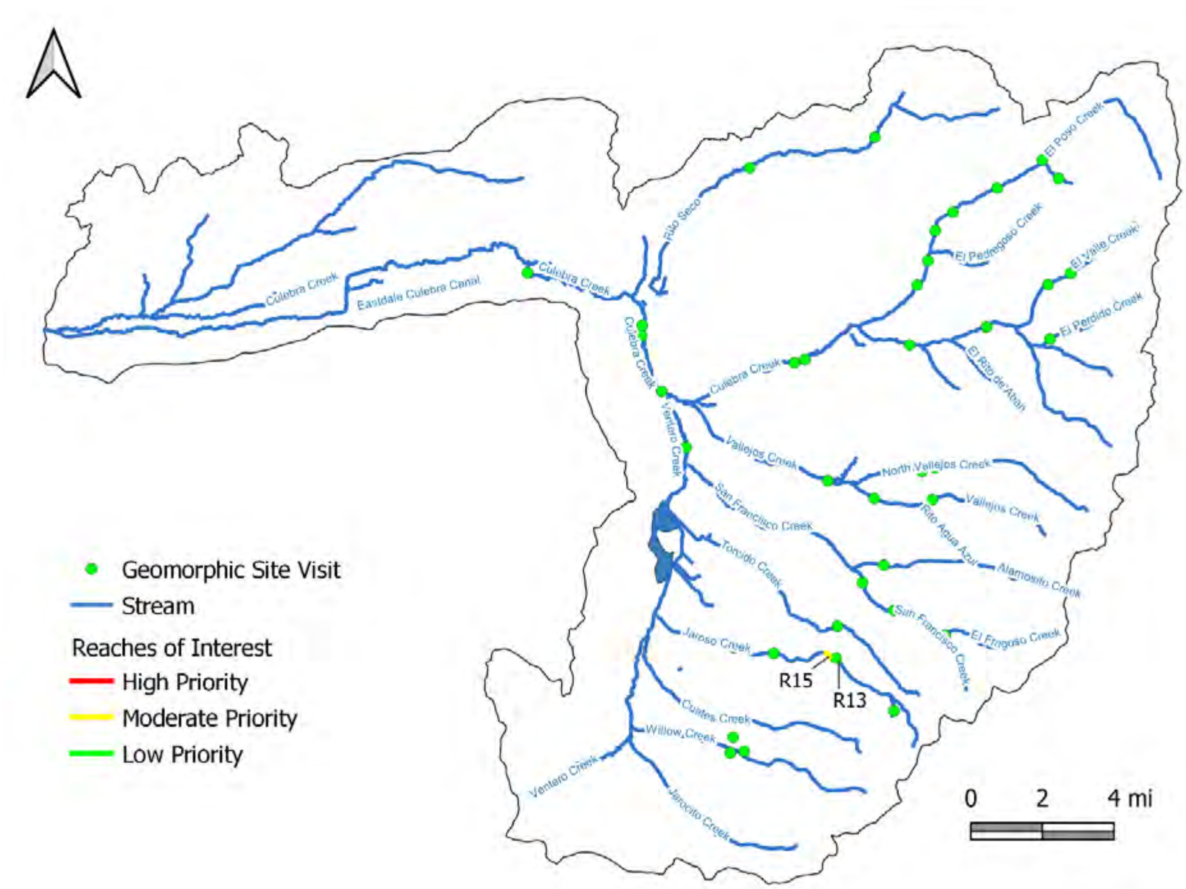


Figure 4-37 Jaroso Creek, reaches of interest 13 and 15, locations.

4.3.1.7 El Perdido Creek (Reach 1)

A review of aerial imagery showed a substantial change in the landscape through El Perdido Creek (1) (Figure 4-37). The channel travels through a large wet meadow. This reach occurs at the confluence between El Perdido Creek and a minor reach stream from the north.

Figure 4-38 El Perdido Creek (1) notice channel incising through sediments.

A visual assessment of El Perdido Creek (1) was performed. The team noted that the meadow was a relic beaver complex during the site walk. There was deposited sediment throughout the valley within the meadow. Relic channels, dams, and ponds were observed throughout the meadow in this area. The current channel was cutting down through the sediments (Figure 4-38). There may still be beaver activity present through this meadow. While this area showed bank erosion, it will stabilize and form a new meadow for grazing over time.

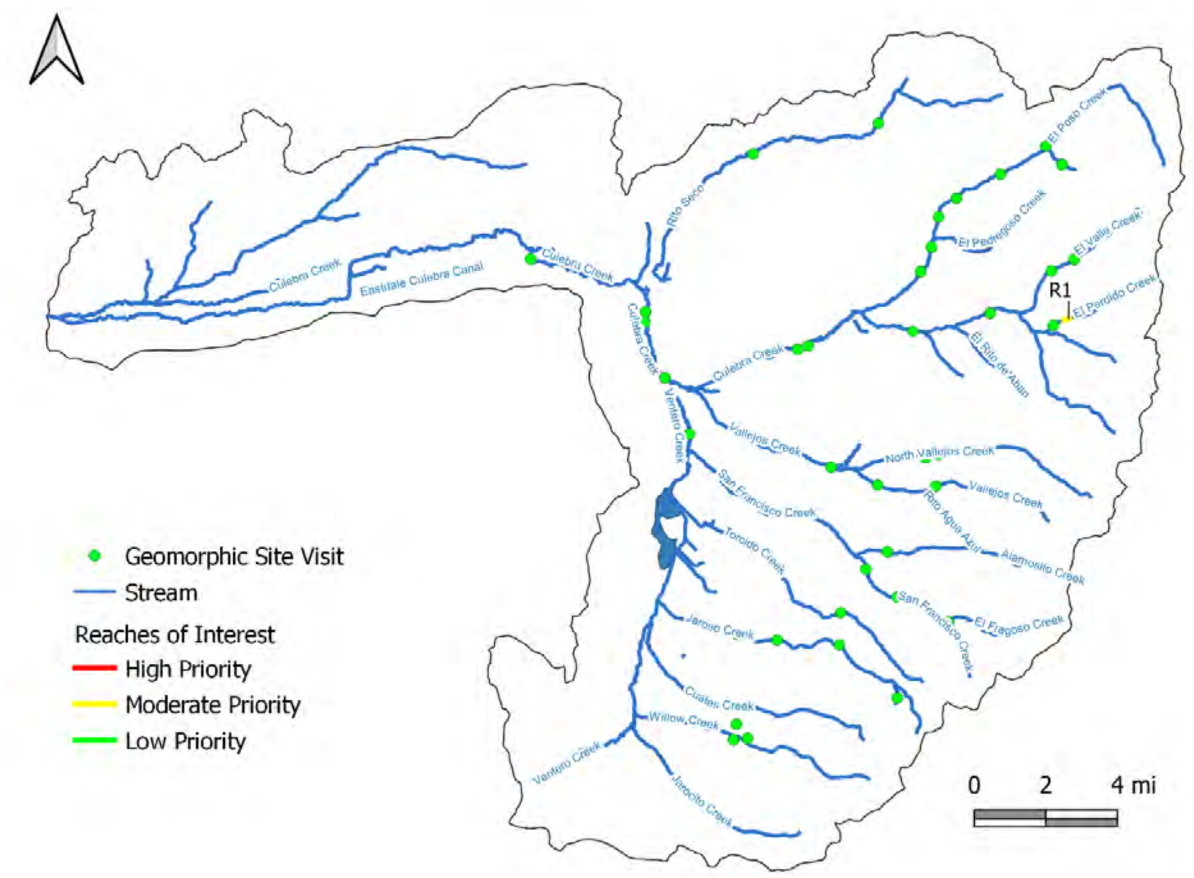


Figure 4-39 Perdido Creek, reach of interest 1.

Figure 4-40 El Perdido Creek - Geomorphic Reach 1

4.3.1.8 El Poso Creek (Reach 9)

Figure 4-41 El Poso Creek (9) notice lack of vegetation and change in floodplain across property lines. Yellow highlight is reach.

A review of aerial imagery indicated bank erosion, potential issues with channel pattern, and lack of vegetation through El Poso Creek Reach 9 (Figure 4-42). The confluence of this reach and Culebra creek has the flows of El Poso creek flowing perpendicular to the flow in Culebra Creek. As noted by boulder structures, a river restoration project has been constructed on this property. The channel through the downstream end of this reach appears to be overwide and channelized in sections. The reach measurement shows the channel thalweg to be approximately 5.5 feet below the adjacent fields.

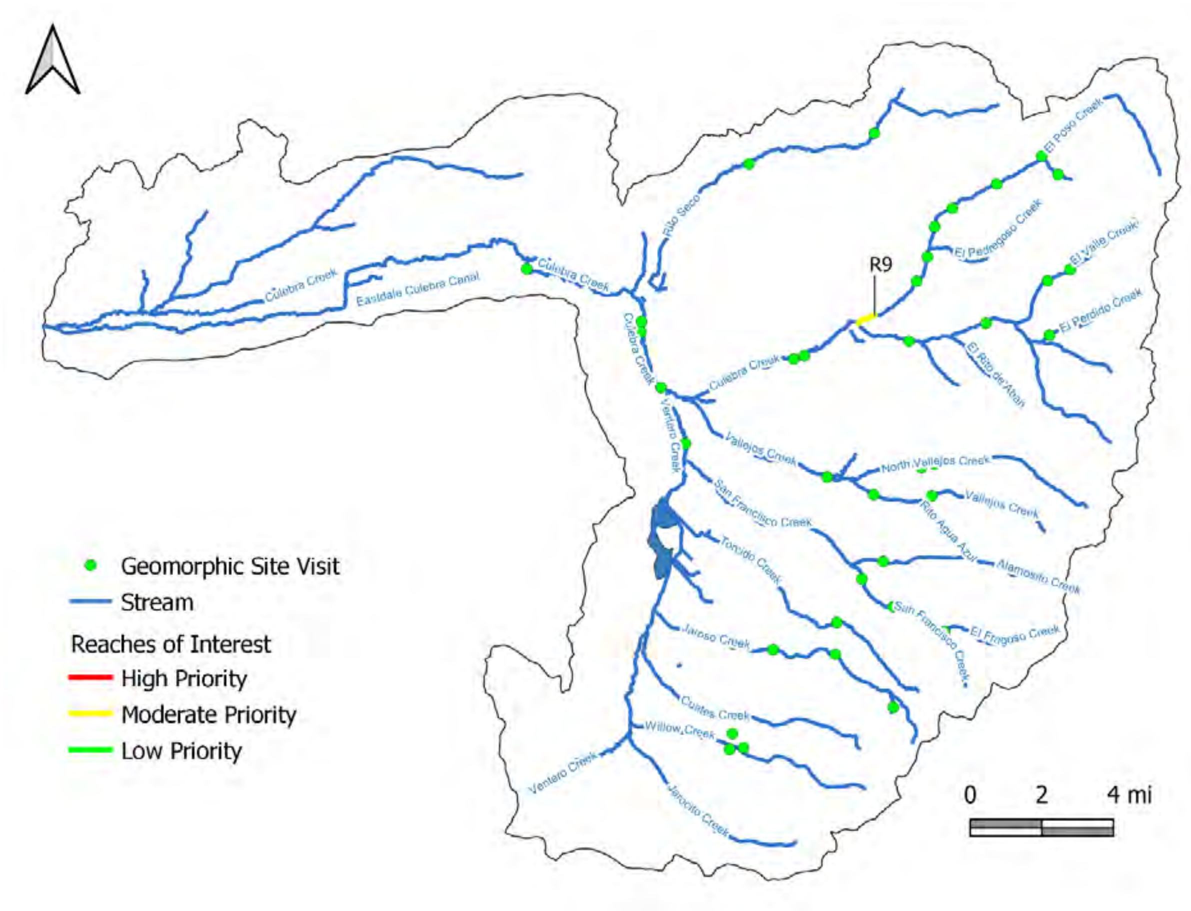


Figure 4-42 El Poso, reach of interest 9, location.

In contrast, the channel thalweg is approximately 3.5 feet below the adjacent fields in the upstream portion of the reach. Increasing the sinuosity, riparian planting, adjusting the channel to have proper dimensions in pattern, profile, and cross-section could improve the function of the channel. Reconnecting the channel with the historic floodplain could increase sub-irrigation and improve water availability later in the season.

4.3.1.9 El Poso Creek (Reach 7)

Figure 4-43 El Poso Creek (7) notice bank erosion on river left bank.

A review of aerial imagery of El Poso Creek (7) (Figure 4-44) identified cutbanks, potential issues with channel pattern, cutbanks, and an overwide low water crossing. This reach is below an actively degrading arroyo, supplying sediments to El Poso Creek. The tight radius of curvatures in the reach suggests a high likelihood of an avulsion occurring. Sections of the reach look channelized or straightened, which may be evidence of prior avulsions. The low water channel crossing is overwide and devoid of vegetation. Noticeable cutbanks are occurring within the reach and bars are forming.

The field crew visited El Poso Creek (7), Site ElPoso202107111030. A more detailed discussion about this site can be found in Section 4.3.2.5.

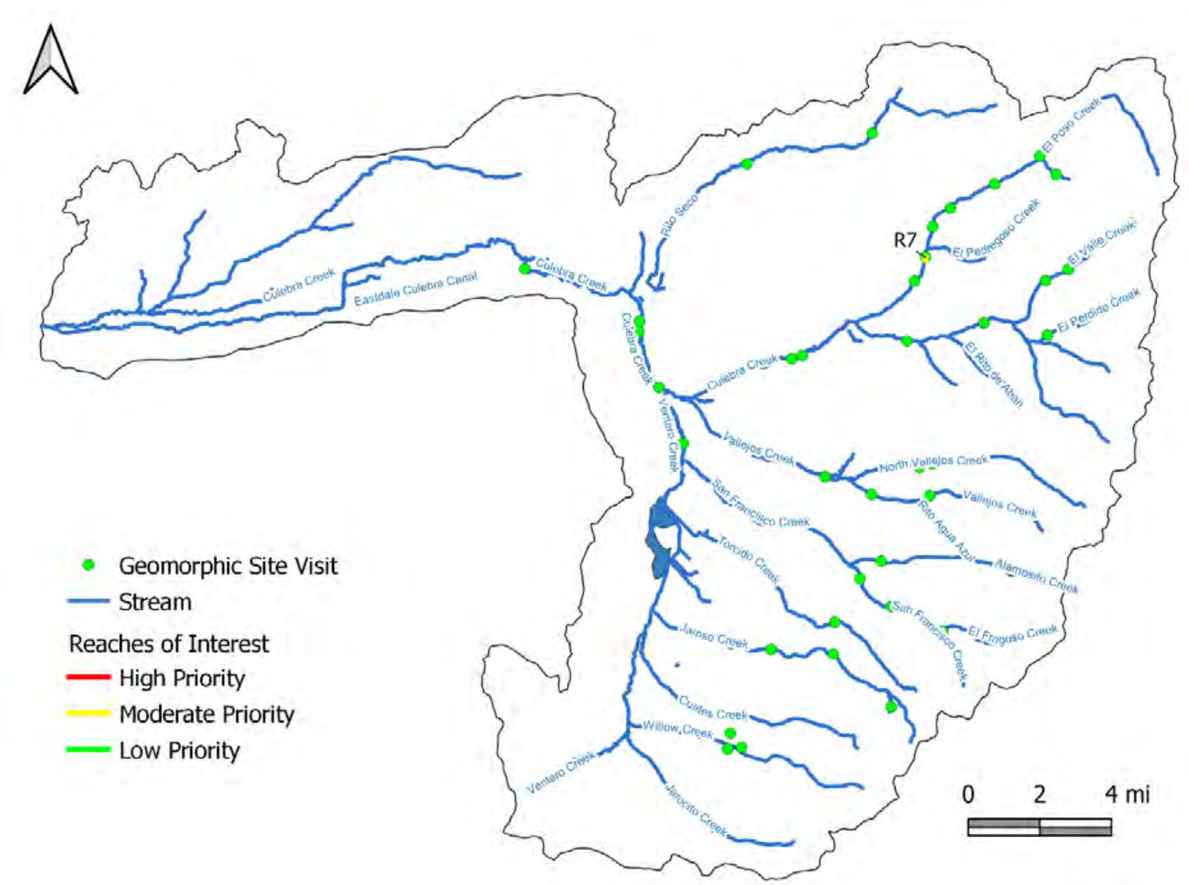


Figure 4-44 El Poso, reach of interest 7, location.

4.3.1.10 El Poso Creek (Reach 6)

Figure 4-45 El Poso Creek (6) notice vertical banks river left.

A review of aerial imagery of El Poso Creek (6) (Figure 4-46) revealed the presence of cutbanks and signs of aggradation throughout the reach. The channel through this section is over wide in places (Figure 4-45). The channel is cutting into a high terrace at the downstream end and is becoming entrenched in segments. Evidence of grazing and impacts to riparian vegetation is apparent throughout the reach.

The field crew visited El Poso Creek (6). A more detailed discussion about the site can be found in Section 4.3.2.5.

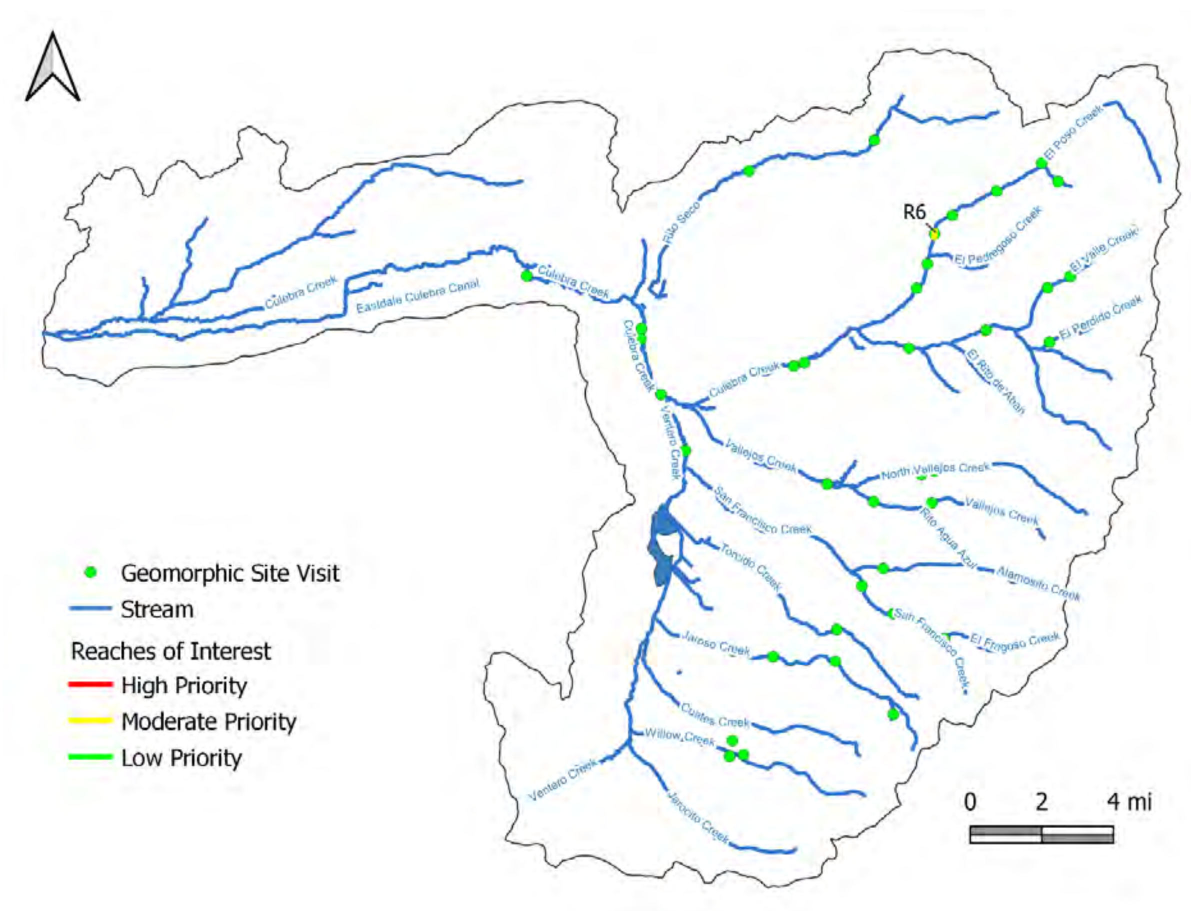


Figure 4-46 El Poso, reach of interest 6, location.

4.3.1.11 El Poso Creek (5)

Figure 4-47 El Poso Creek (5) notice bank erosion occurring on river right.

A review of aerial imagery of El Poso Creek (5) (Figure 4-48) revealed the presence of cutbanks and signs of aggradation in the reach. The reach starts just upstream of houses near the channel. In front of the houses, it looks like channel work has been completed. Channel work looks to have created big drops and large pool in and near the homes. Bank erosion was observed within the reach (Figure 4-47) and the channel is aggrading behind the big drops in the reach.

A field crew visited El Poso Creek (5) and visually assessed the reach. This reach is discussed in further detail in Section 4.3.2.5.

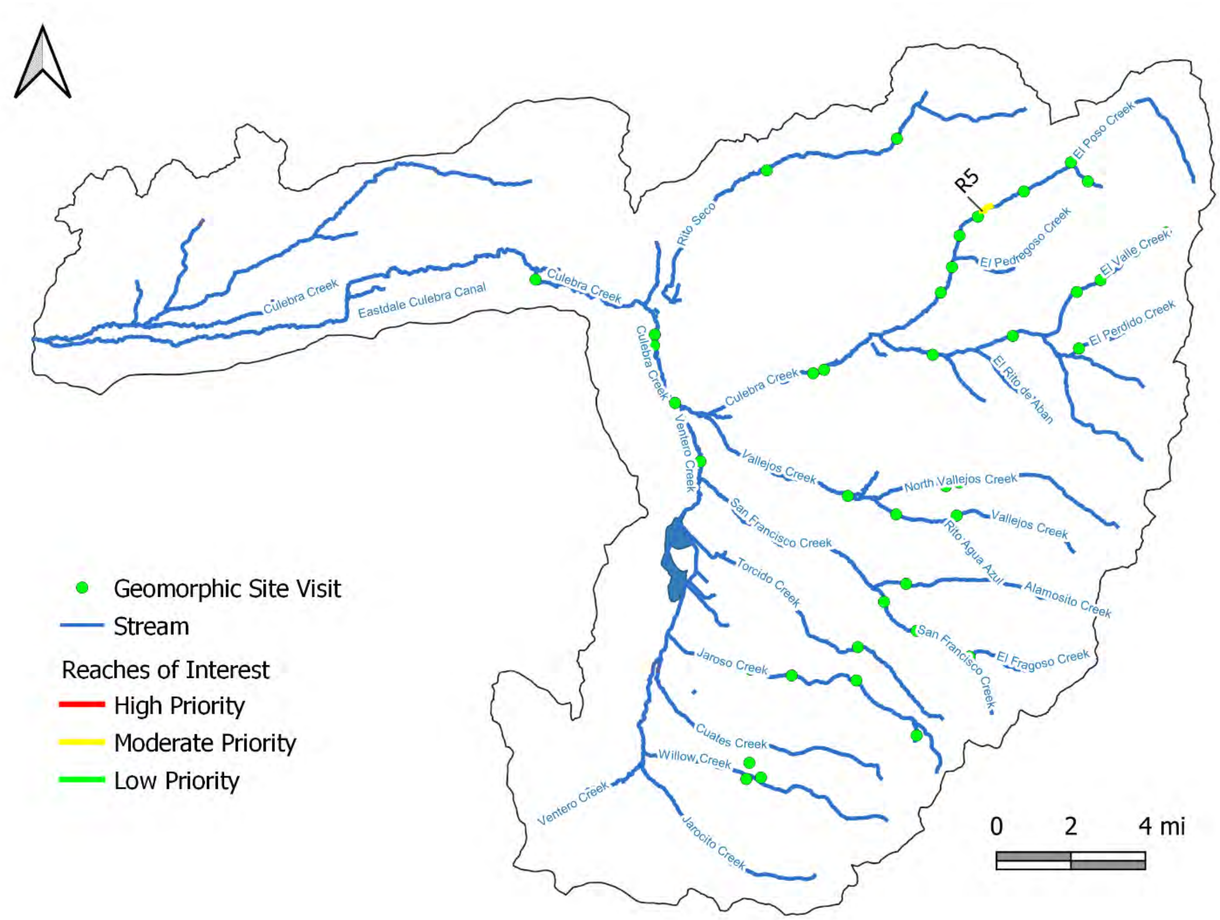


Figure 4-48 El Poso, reach of interest 5, location.

4.3.1.12 El Poso Creek (Reach 2)

A review of aerial imagery of El Poso Creek (Reach 2) (Figure 4-50) revealed the presence of vertical banks, signs of aggradation, a debris jam, and potential issues with the channels pattern through this section.

There is aggradation near the upper one-third of the reach and deposition within the valley. Deposition may be the result of a debris jam, large bever dam, or other valley constriction. There are vertical banks immediately downstream of the deposition area. Large point bars also appear to be forming on the downstream end of this reach.

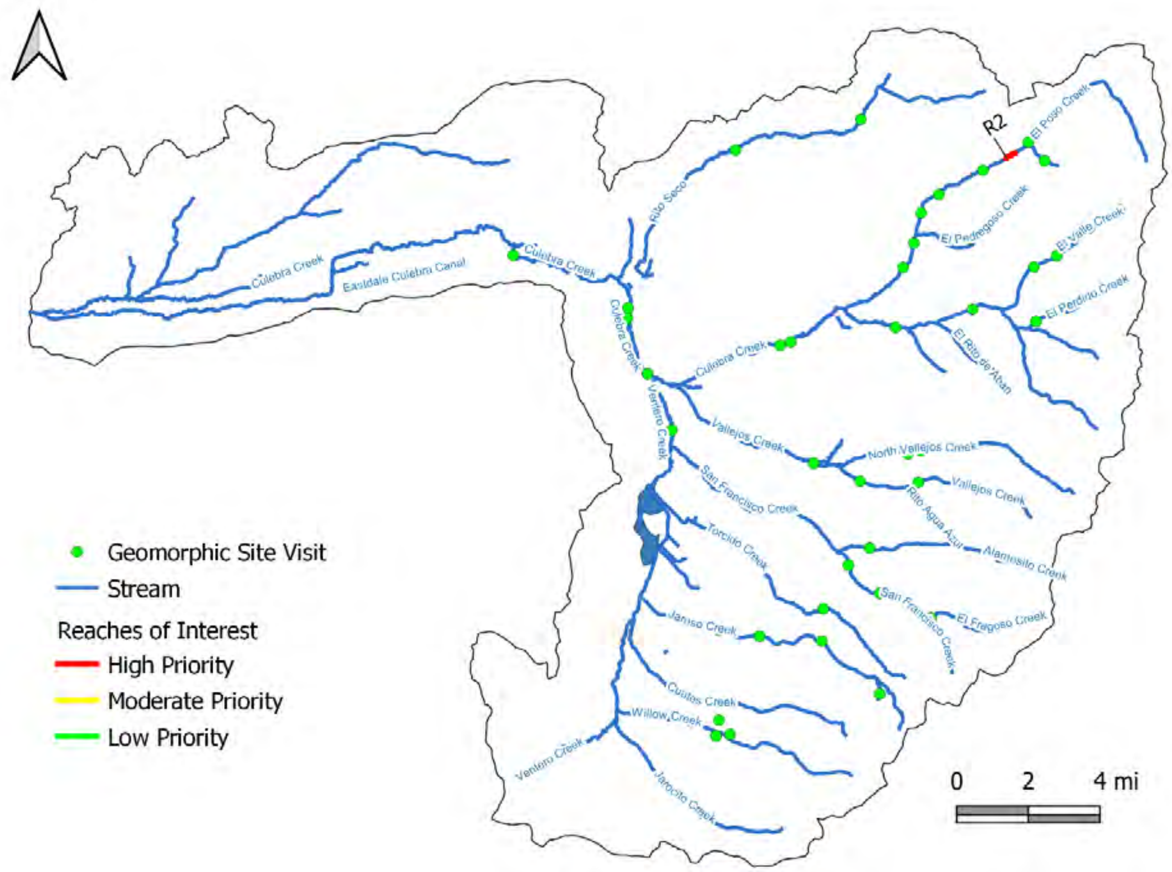


Figure 4-50 El Poso, reach of interest 2, location.

4.3.1.13 Rito Seco (Reach 19)
A review of aerial imagery of Rito Seco (reach 19)(Figure 4-52) revealed the presence of cut terraces and beaver ponds. The reach begins just upstream of the Battle Mountain mine. A significant headcut has worked up the drainage from about four miles downstream, resulting in an entrenched/incised channel.

The channel is widening its floodplain and becoming more stable at the new elevation (Figure 4-51). Riparian vegetation is filling in, and beavers have been impacting the channel.

Figure 4-51 Rito Seco (19) notice channel cutting into high terrace, left side of photo.

Drainages feeding Rito Seco through this section create gullies, as those channels adjust to the new base elevation. Rito Seco road through this reach is at risk because of the head cuts occurring within the gullies and the bank erosion cutting into the terrace along the main channel. The reach ends just upstream of a historic dike that traverses the valley.

A field crew visited this in the middle of this section. A more detailed discussion of this site visit can be found in Section 4.3.2.6.

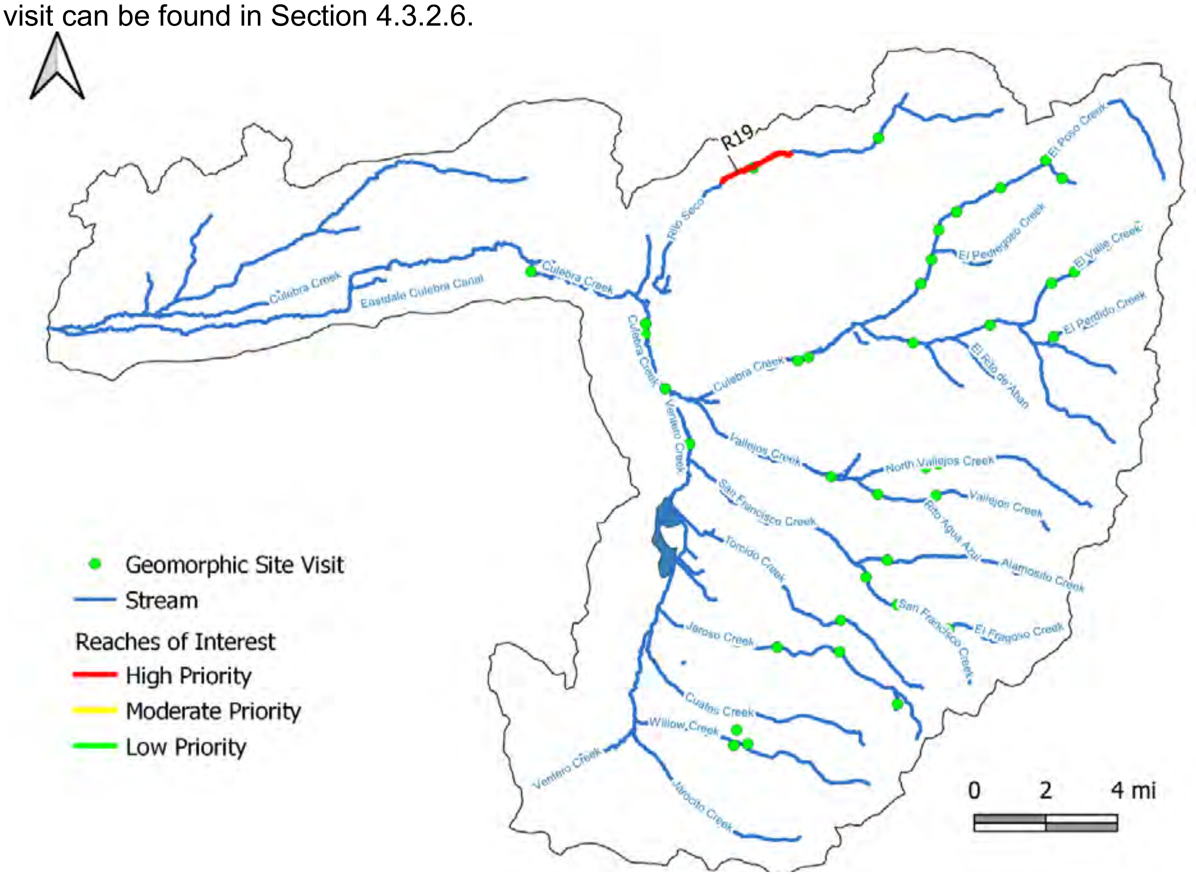


Figure 4-52 Rito Seco, reach of interest 19, location.

4.3.1.14 Torcido Creek (Reach 11 and 12)

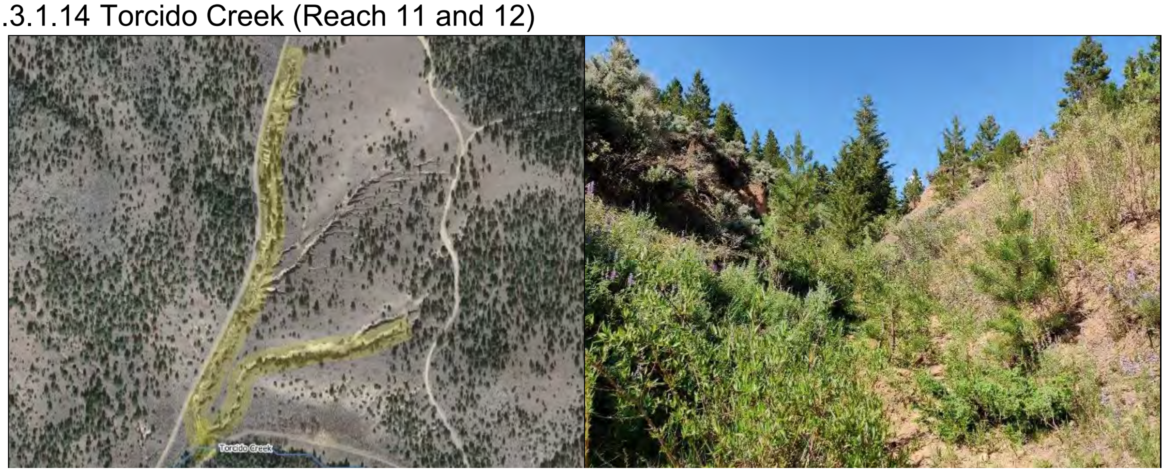


Figure 4-53 Left Torcido (11 and 12) Aerial view of headcuts forming above Torcido Creek. Right view from the ground Torcido (11 and 12) notice vegetation filling in the gully.

A review of aerial imagery identified two large headcuts/gullies forming above Torcido Creek (Figure 4-53, left). There are headcuts in the foothills near where the mountains meet the valley throughout the Culebra Basin. The headcuts appear to be stabilizing, and vegetation is starting to fill in the gullies and stabilize the banks (Figure 33, right). There was evidence of grazing and cattle trails in and around these headcuts.

A field crew visited the site. A more detailed discussion about the site can be found in Torcido Creek202106211640 Section 4.3.2.9.

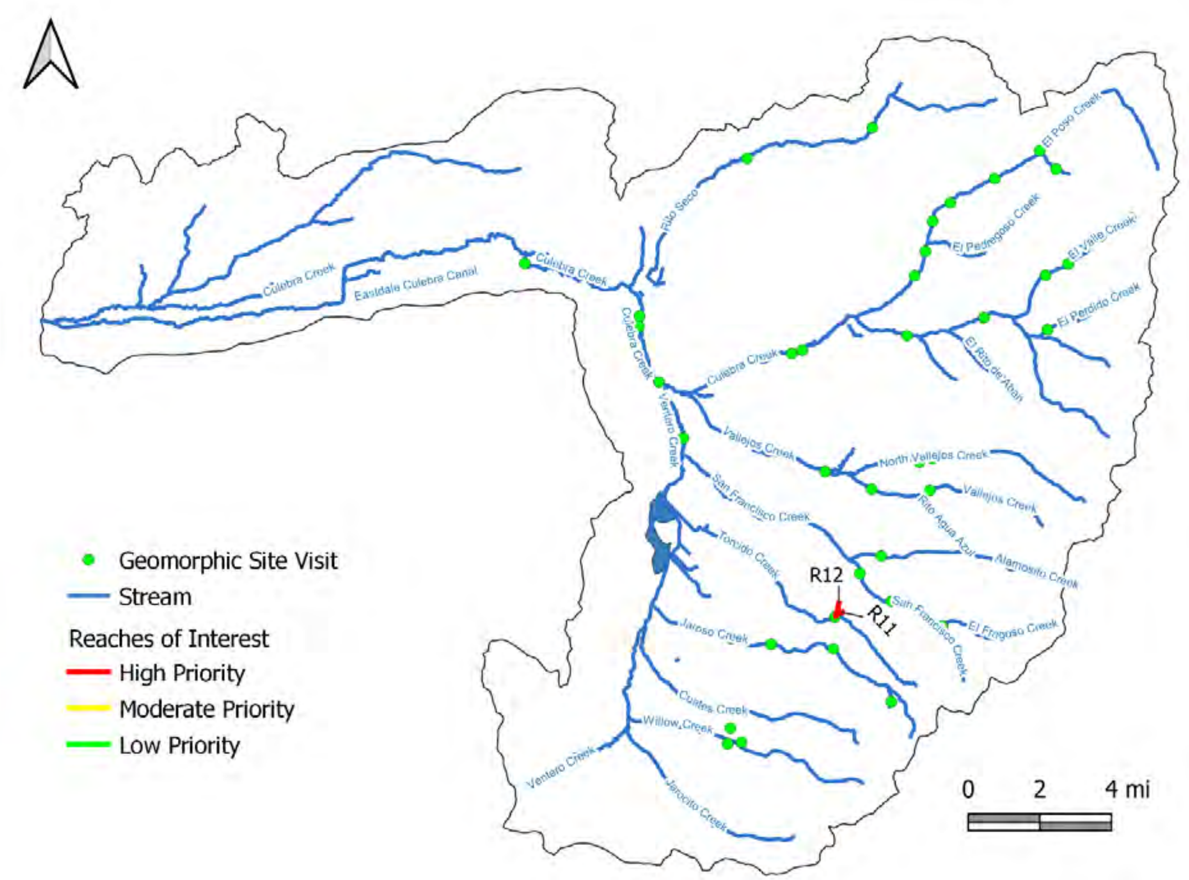


Figure 4-54 Torcido Creek, reaches of interest 11 and 12, location.

4.3.1.15 Rito Seco Historic Channels (26, 24, 23)

Figure 4-55 Top Left aerial view Return flow channel, Cerro Ditch and Rito Seco historic alluvial channel (26), notice channel pattern and signs of deposition on floodplain. Top right Unknown (26) view from the road, notice channel incision. Bottom Left aerial view of Rito Seco historic alluvial channel (24) notice channel pattern and aggradation. Bottom Right (reach 24) aggradation in channel apparent from the road.

The three Rito Seco and Cerro Ditch return flow channel (26, 24, and 23) (Figure 4-57) are locations where issues were observed in the aerial imagery. These issues pertained to ditches/canals that showed erosion. Reach 26 is a drain ditch and adjusted historic alluvial channel that showed erosion along its banks and potential issues with the channel pattern. The channel is becoming more sinuous, trending toward stability (Figure 4-55, top left and right).

Figure 4-56 Historic alluvial channel Rito Seco drainage (23) notice channel pattern and interaction with other ditches/canals/and channels.

Reach 24 showed vertical banks imagery and that the bridge influenced the channel stability (Figure 4-55, bottom left and right). There are signs of aggradation in through the reach and like reach 26 the channel is becoming more sinuous, trending towards stability.

Reach 23 is a historic alluvial channel in the Rito Seco Basin. This reach showed tight radius of curvatures and vertical banks. This area has ditches/canals/and channels coming together (Figure 4-56).

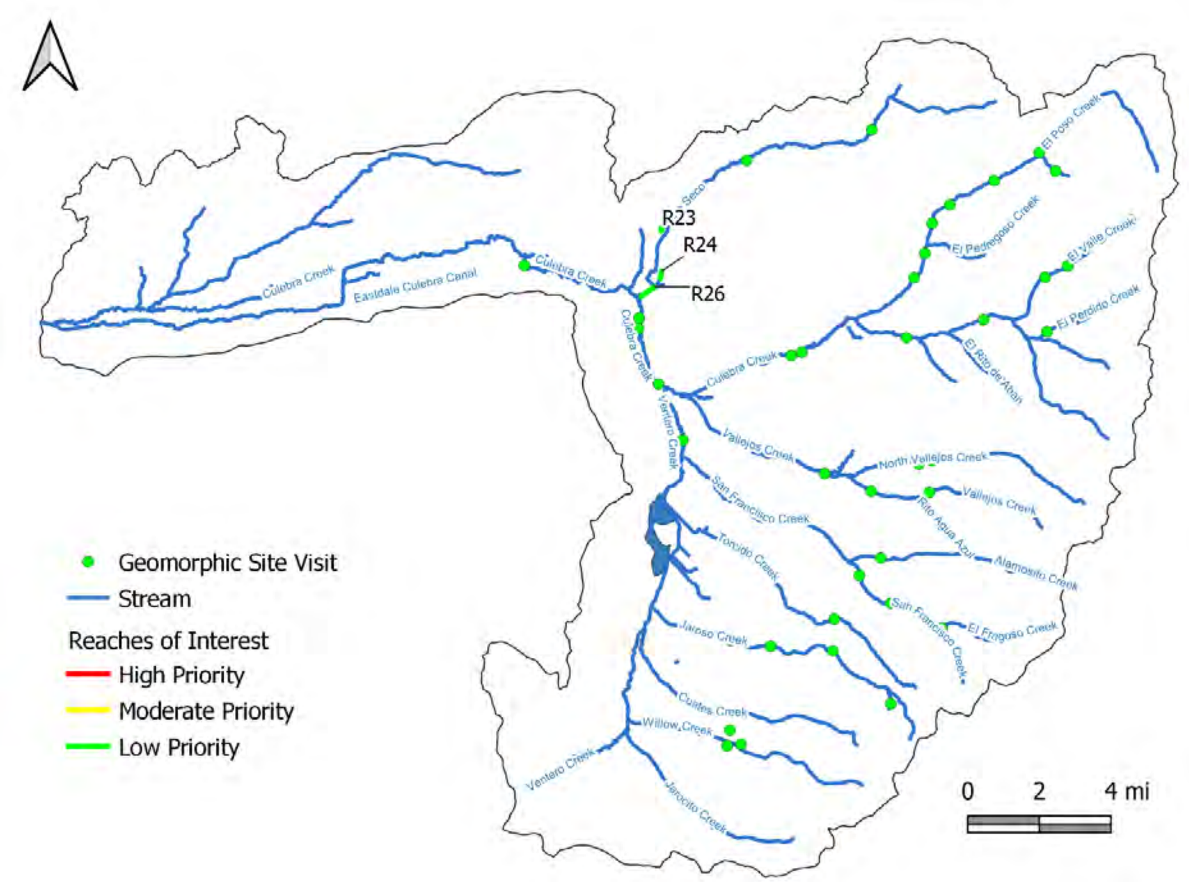


Figure 4-57 Rito Seco, reaches of interest 23, 24, and 25, locations.

4.3.1.16 Vallejos (Reach 14)

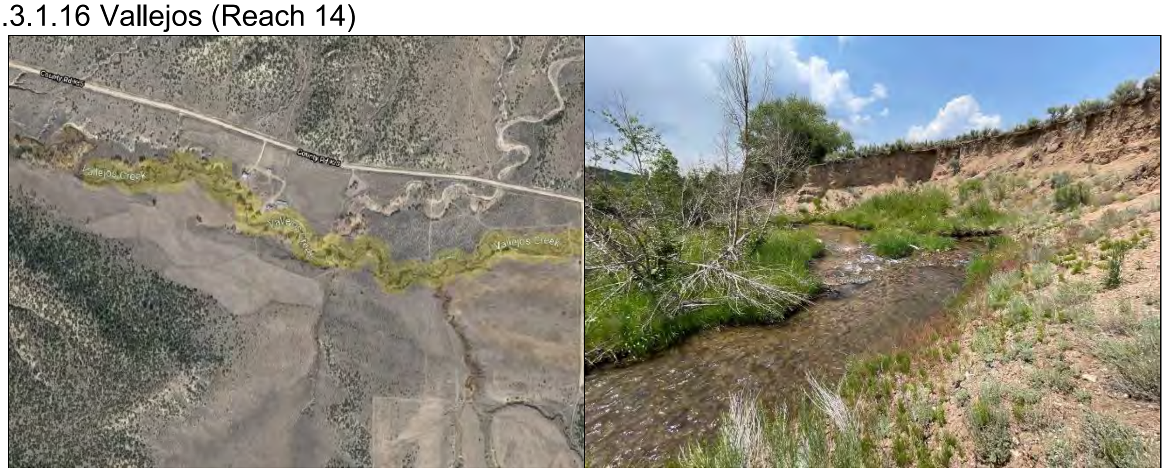


Figure 4-58 Left aerial view of Vallejos (14) notice pattern and gullies contributing to the reach. Right Vallejos (14) notice channel cutting into high terrace.

A review of aerial imagery of Vallejos (14) (Figure 4-59) identified vertical banks, and channel pattern issues from the confluence of North Vallejos Creek and Vallejos Creek downstream 1.5 miles. The channel through this reach has radiuses of curvatures that are too big and too small. Gullies feed sediments into the channel through the reach (Figure 4-58, left). The channel appears to have been pushed up again a high terrace and is incised in places (Figure 4-58, right).

A field crew visited the middle section of this reach. A more detailed discussion about this reach can be found in Section 4.3.2.11.

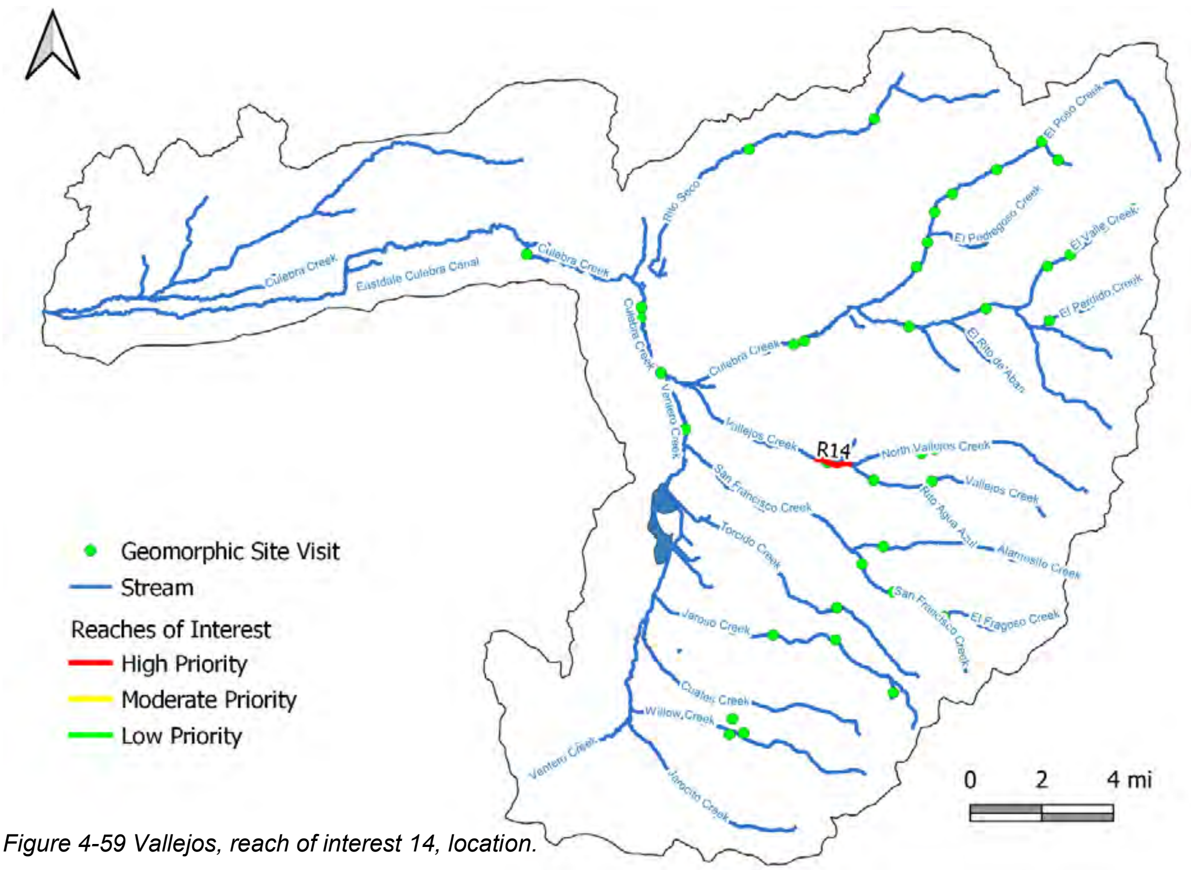


Figure 4-59 Vallejos, reach of interest 14, location.

4.3.1.17 Ventero (Reach 21 and 22)

Figure 4-60 Left aerial view of Ventero Creek (21) notice channel pattern, channel appears to have been channelized. Right aerial view of Ventero (22) notice channel pattern.

A review of aerial imagery of Ventero (21 and 22) (Figure 4-61) revealed cutbanks, signs of aggradation, signs of entrenchment, and channel pattern issues occurring within the reach (Figure 4-60).

A field crew visited Ventero Creek downstream of these reaches. This reach showed the same issues. The site visit for this location is further discussed in Section 4.3.2.12.

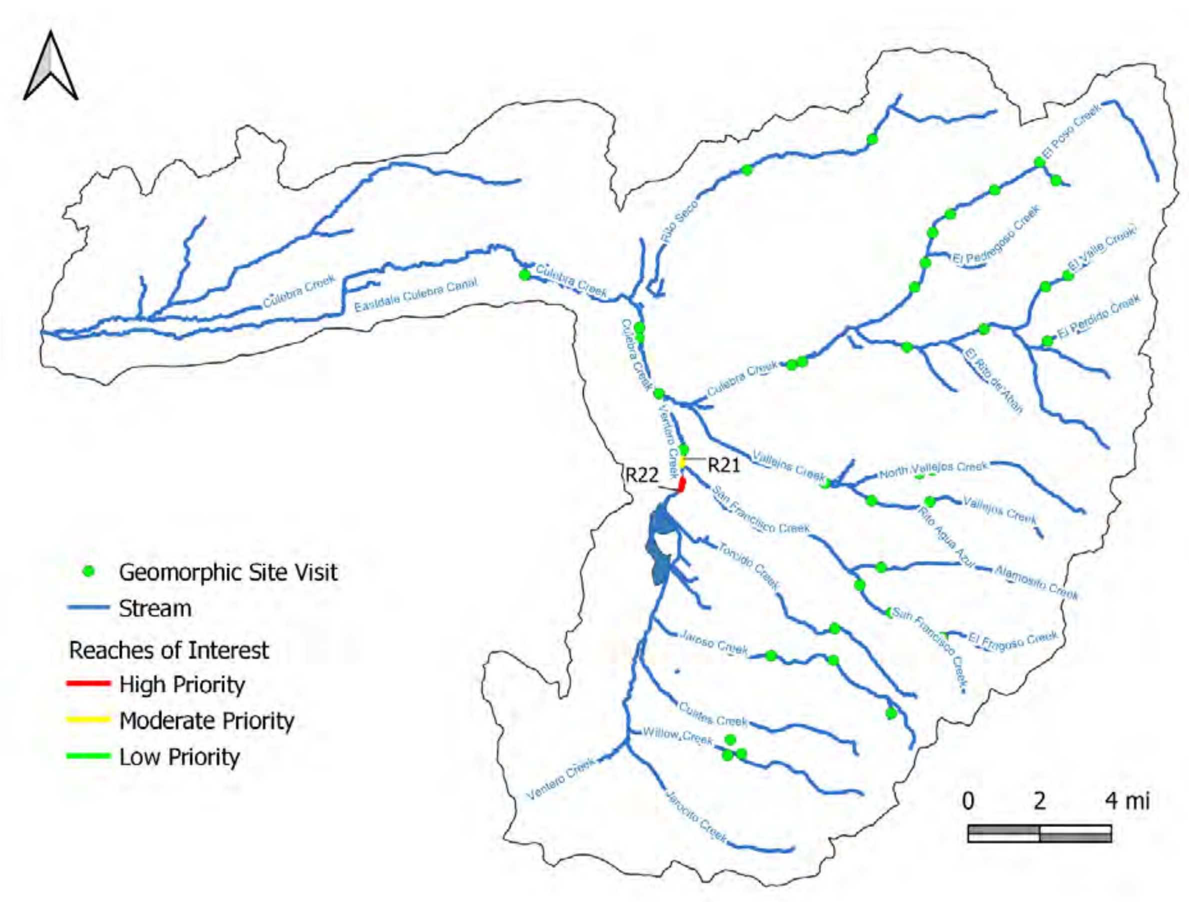


Figure 4-61 Ventero Creek, reaches of interest 21 and 22, locations.

4.3.2 Field Assessment

Geomorphic data were collected at 40 sites throughout the basin (Figure 4-62, and Table 4-4). This data can be visualized in Appendix 5.A. Twenty-three geomorphic sites were collected in coordination with the Aquatic Habitat Survey points. Often these sites correlated with the geomorphic reaches of interests identified during the desktop aerial imagery review. Additional geomorphic sites were identified during the field assessment, and others were opportunistically sampled because they were easy to access, showed reference qualities, or signs of instability.

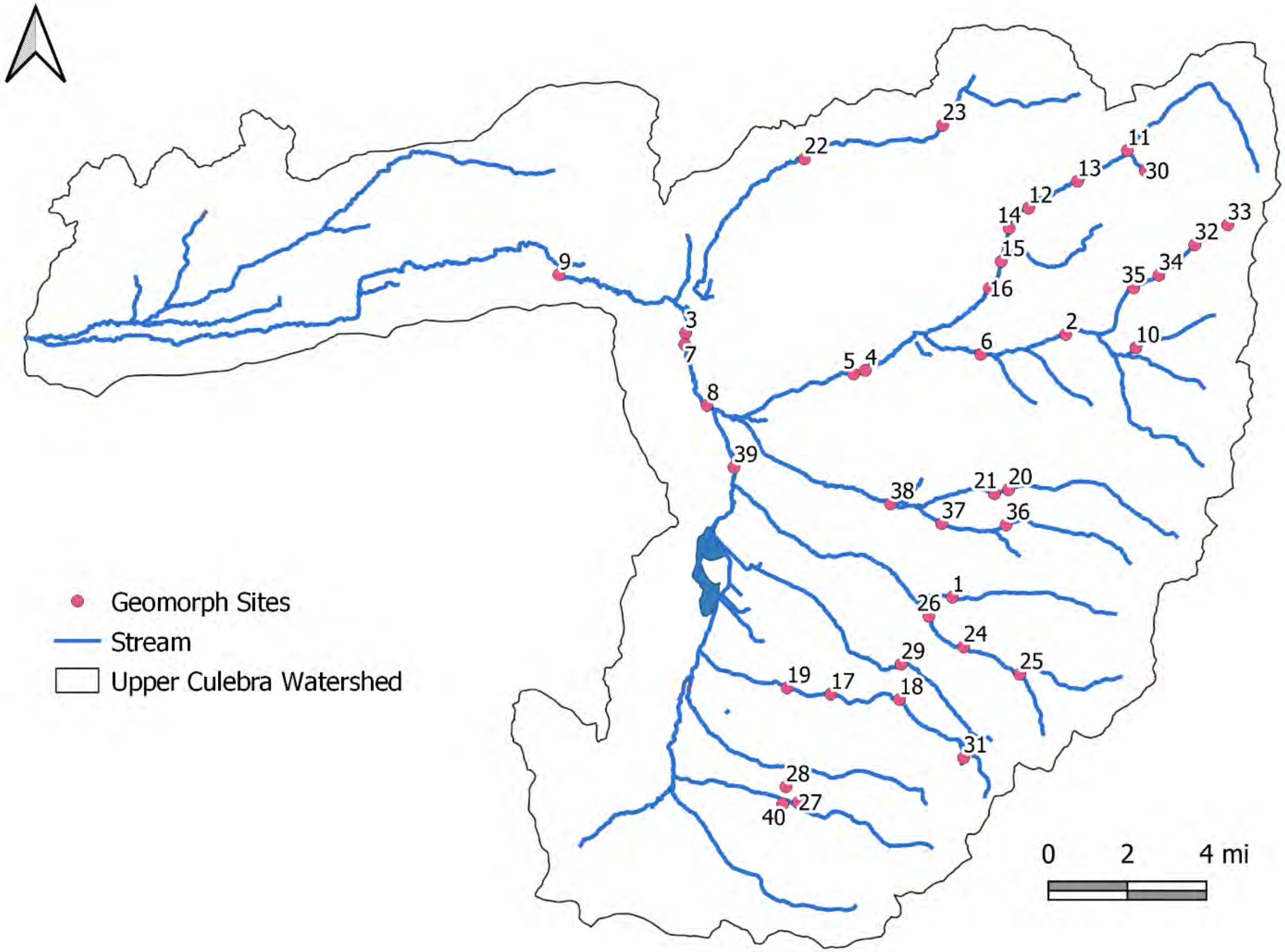


Figure 4-62 Geomorphic Site Location map

Table 4-4 Geomorphic Map Number and Reach Name key.

Map Number	Drainage	Reach Name	Link Number	Latitude (WGS84)	Longitude (WGS84)
1	Alamosito	Alamosito202107121450	981	37.08564	-105.30307
2	Culebra	Culebra202106231622	2980	37.18231	-105.25143
3	Culebra	Culebra202107061515	3860	37.18237	-105.42592
4	Culebra	Culebra202107130809	3644	37.16889	-105.34339
9	Culebra	Culebra202107130903	3652	37.16754	-105.34871
5	Culebra	Culebra202107131235	3068	37.1749	-105.29037
6	Culebra	Culebra2021071413337	3860	37.17815	-105.42626
7	Culebra	Culebra202107151340	3804	37.15576	-105.41591
8	Culebra	Culebra202107201100	3932	37.20352	-105.48420
10	El Perdido	ElPerdido202107071236	1244	37.1775	-105.21919
11	El Poso	ElPoso202107081130	379	37.25001	-105.22329
12	El Poso	ElPoso202107091115	3500	37.22875	-105.26858
13	El Poso	ElPoso202107101145	3476	37.23863	-105.24619
14	El Poso	ElPoso202107101515	3508	37.22132	-105.27752
15	El Poso	ElPoso202107111030	3524	37.20908	-105.28114
16	El Poso	ElPoso202107111312	3532	37.19915	-105.28657
17	Jaroso	Jaroso202106221008	813	37.04977	-105.3586
18	Jaroso	Jaroso202106221147	813	37.04793	-105.32712
19	Jaroso	Jaroso202106250930	1053	37.05203	-105.37871
20	Vallejos	NorthVallejos202107221020	3180	37.12517	-105.27745
21	Vallejos	NorthVallejos202107221200	3180	37.12371	-105.28387
22	Rito Seco	RitoSeco202107121234	3468	37.24651	-105.37169
23	Rito Seco	RitoSeco202107191045	315	37.25909	-105.30822
24	San Francisco	SanFrancisco202106241234	925	37.06731	-105.29784
25	San Francisco	SanFrancisco202107120920	925	37.05735	-105.27209
26	San Francisco	SanFrancisco202107121234	925	37.0786	-105.31379
27	Cuates	SCuates202106171351	--	37.00998	-105.37334
28	Cuates	SCuates202106171403	--	37.01568	-105.37899
29	Torcido	Torcido202106211640	853	37.06092	-105.32641

Table 4-4 Geomorphic Map Number and Reach Name key.--continued

Map Number	Drainage	Reach Name	Link Number	Latitude (WGS84)	Longitude (WGS84)
30	El Poso	UTEIP202107081500	2652	37.24258	-105.21501
31	Jaroso	UTJarosos202106221324	597	37.02658	-105.29768
32	El Valle	Valle202106231111	516	37.21538	-105.19224
33	El Valle	Valle202106231157	--	37.22274	-105.1771
34	El Valle	Valle202106231410	2444	37.20417	-105.20868
35	El Valle	Valle202106231452	2444	37.1995	-105.22026
36	Vallejos	Vallejos202107180915	933	37.11227	-105.27853
37	Vallejos	Vallejos202107181307	1013	37.11265	-105.30802
38	Vallejos	Vallejos202107201315	1477	37.1198	-105.33158
39	Ventero	Ventero202107150915	3732	37.13302	-105.40344
40	Willow	Willow202106160946	1173	37.00938	-105.38044

4.3.2.1 Alamosito Creek

A field crew measured one reach on Alamosito Creek. Alamosito Creek is a tributary to San Francisco Creek with a drainage area over six square miles at its confluence with San Francisco Creek.

<u>Alamosito202107121450</u>

Alamosito Creek (Alamosito202107121450) is one mile upstream of the confluence with San Francisco Creek. The creek in this location is heavily wooded (Figure 4-63). The drainage area of the reach is 5.36 square miles. At this reach, the longitudinal profile, water surface, and thalweg, along with two cross-sections were measured. The measured reach has an average slope of 7.7%. The Rosgen Stream Classification for this reach is a B4a stream type.

Figure 4-63 Alamosito Creek, heavily wooded in a mixed conifer forest.

Bank erosion was observed on banks within the reach (Figure 4-64). Large wood in and around the channel corridor affects the channel's function. Log jams were observed on-site where smaller gravels and sands back up behind the debris jams.

Figure 4-64 Alamosito Creek Bank Erosion

The channel is incised and, in places, entrenched, which is typical of a steep gradient channel. Because of the steep gradient through the reach, one would expect to see a step-pool type system. Overall, the channel is not stable, but seems to be stabilizing. The availability of wood in and near the channel’s banks at this location will benefit the reach's stability in the long term. The channel will continue to adjust. As banks erode, trees will fall into the channel causing more debris jams, which will bring the bed elevation of the channel up. This, in turn, will reduce the channel's erosive capabilities reducing shear stress and stream power during flood flows.

4.3.2.2 Culebra Creek

A field crew measured eight sites on Culebra Creek.

<u>Culebra202107201100</u>

Figure 4-65 Culebra Creek (Culebra202107201100) bank erosion

The downstream most reach on Culebra Creek that was measured as part of the geomorphic assessment is just upstream, east, of County Road 16. The drainage area of the reach is 298 square miles. The longitudinal profile of water surface and thalweg; along with four cross-sections were measured at this reach. The measured reach has an average slope of 0.3%. The Rosgen Stream Classification for this reach is a C4/5 stream type.

Figure 4-66 Culebra Creek looking upstream notice road/level on the right side of the picture and high terrace/rock outcrop on the left.

As shown in Figure 4-65, bank erosion was observed within the surveyed reach. The floodplain within this reach is constricted by levees and/or high terraces, especially at the upstream and downstream ends (Figure 4-66). The channel has been channelized, or straightened, and pushed up against the high terrace. Sinuosity in the channel seems to be increasing towards the middle of the surveyed reach. To improve the function of the reach, reducing or removing floodplain constrictions could reduce erosion potential during high flows. Increasing the sinuosity of the channel will also reduce the slope of the channel. Overall, the channel has a good floodplain connection.

Culebra202107061515

Figure 4-67 Culebra202107061515 channelized section of Culebra Creek.

Culebra Creek (Culebra202107061515) is just upstream, south, of County Road N8 near the stream gage Culebra Creek at San Luis. The drainage area of the reach is 248 square miles. Longitudinal profile of water surface and thalweg along with five cross-sections were measured at this reach. The measured reach has an average slope of 0.3%. The Rosgen Stream Classification for this reach is a C4 stream type.

The channel appears to have been straightened through the survey reach and is incising (Figure 4-67). Bank erosion and channel instability were observed on-site. Woody shrubs and overhead cover are noticeably absent from this reach.

The function of this reach could be increased by adding sinuosity to the reach, while also adding more defined lateral scour pools and habitat.

Culebra202107141337

Figure 4-68 Culebra Creek (Culebra202107141337). Notice cutbanks in background of photo.

Culebra Creek (Culebra202107141337) is just upstream of Culebra202107061515. The drainage area of the reach is 248 square miles. A longitudinal profile of water surface and thalweg along with five cross-sections were measured at this reach. The measured reach has an average slope of 0.3%. The Rosgen Stream Classification for this reach is a C4 stream type.

The channel is more sinuous than in the measured reach immediately downstream. There is still evidence of bank erosion through the reach (Figure 4-68). The bank erosion through this reach and the reach downstream is likely caused by channelization or straightening of the channel. Heavy grazing is likely impacting these reaches. Woody vegetation along the banks of Culebra Creek is noticeably barren of woody vegetation and overhead cover. The valley bottom was noticeably wet, like a floating sod mat. Irrigation return flows are contributing to this.

Culebra202107151340

Figure 4-69 Culebra Creek (Culebra202107151340) notice tall vegetation along banks.

Culebra Creek (Culebra202107151340) is about a half-mile downstream of the Culebra Creek and Ventero Creek confluence. The drainage area of the reach is 243 square miles. A longitudinal profile of water surface and thalweg along with three cross-sections were measured at this reach. The measured reach has an average slope of 0.3%. The Rosgen Stream Classification for this reach is a C4/5 stream type.

The channel has good floodplain access. Imagery in the area shows aggradation within the reach. Compared to the two downstream reaches, this reach does not appear to be as heavily grazed at the time of the survey (Figure 4-69).

To improve the function of Culebra Creek through this reach consider increasing the sinuosity of the channel, reducing slope. Use lateral scour pools to create habitat and energy dissipation.

Culebra202107130903

Figure 4-70 Culebra Creek (Culebra202107130903) stable cross-section.

Culebra Creek (Culebra202107130903) is just upstream of Road 23.5. The drainage area of the reach is 79.8 square miles. A single cross-section was measured at this reach. The Rosgen Stream Classification for this reach is a C3 stream type.

The measured, stable cross-section is downstream, 0.3 miles from the Sanchez Diversion (Figure 4-70). The channel had a good floodplain connection and did not appear to be overwide. The thalweg was deep, and there was a little overhead cover on the banks.

Culebra202107130809

Figure 4-71 Headgate across Culebra Creek for the Sanchez Canal.

Culebra Creek (Culebra202107130809) is immediately upstream of the Sanchez Diversion. The drainage area of the reach is 79.8 square miles. The longitudinal profile of water surface and thalweg along with three cross-sections were measured at this reach. The measured reach has an average slope of 1.45%. The Rosgen Stream Classification for this reach is a C3 stream type.

The headgate at this site (Figure 4-71) is causing geomorphic issues in and around the channel including restricting Bankfull width, floodplain width, and increasing channel velocity. The headgate reduces the width of Culebra Creek and its floodplain down to four feet. The width reduction backs up the water causing sedimentation upstream of the headgate. By backing up the water, the velocity of water in the channel reduces above the headgate reducing the channel's stream power, thus reducing its capacity to transport sediments. As suggested by the continuity equation, water velocities through the headgate increase.

Figure 4-72 Culebra Creek above Sanchez Diversion.

In Figure 4-72, sediments were observed piled up along the banks of the Culebra immediately upstream of the headgate. Piling sediments along the banks, as they are throughout this reach reduces the floodplain width. By narrowing the floodplain, flow depths on the floodplain increase during flood events. This increase in depth increases the applied shear stress on the floodplain. Thus, increasing the channel's capacity to move sediments and cause erosion during high flow events.

Figure 4-734-74 Culebra Creek 1.5 miles upstream of Sanchez Diversion. Potential source of sediment at the diversion.

It is common for a stream to move sediments from the upstream extents downstream. When a stream system is in pseudo equilibrium or a balanced state, the channel within a specific reach will neither aggrade nor degrade.

1.5 miles upstream of the surveyed reach, a large cutbank was observed. This vertical bank contributes to the sediments being deposited above the headgate (Figure 4-734-74). Gullies upstream of this site are also likely contributing sediments to Culebra Creek.

Reducing sediment sources, expanding the floodplain, and increasing the width of the channel through the headgate could improve the geomorphic function of the Culebra Creek through this section. Water velocities through the current configuration of the headgate should be evaluated as a potential barrier to the upstream migration of aquatic life through the reach.

<u>Culebra202107131235</u>

Figure 4-75 Culebra Creek (Culebra202107131235) with heavy canopy cover and riparian vegetation.

Culebra Creek (Culebra202107131235) is 1.4 miles downstream of County Road M.5. The drainage area of the reach is 31.3 square miles. The longitudinal profile of water surface and thalweg along with two cross-sections were measured at this reach. The measured reach has an average slope of 2.3%. The Rosgen Stream Classification for this reach is a C3b (‘C3’ little ‘b’) stream type.

The measured reach in this section of Culebra Creek has dense riparian vegetation throughout the reach (Figure 4-75). The channel substrate, cobble with an intermixing of sand, was embedded.

While the reach is in good condition, it is possible to improve the channel function, including geomorphic pools and floodplain reconnection in locations. Reconnecting the channel to the floodplain in locations may provide the opportunity to reduce water velocities through the reach, providing habitat.

<u>Culebra202106231622</u>

Figure 4-76 Culebra Creek (Culebra202106231622). Steep section of the creek.

Culebra Creek (Culebra202106231622) is 1 mile downstream of El Valle and Carneros Creek Confluence. El Valle and Carneros Creek come together to form Culebra Creek. The drainage area of the reach is 22.5 square miles. The longitudinal profile of water surface along with a cross-section were measured at this reach. The measured reach has an average slope of 4.3%. The Rosgen Stream Classification for this reach is a B4a (‘B4’ little ‘a’) stream type.

The channel is overwide through this reach (Figure 4-76). The width-to-depth ratio is 35. Often with overwide reaches, there is a likelihood of aggradation occurring within the stream. It did not appear that the reach was aggrading due to the high energy grade, or slope through this reach. There are a series of drop structures upstream of this reach.

4.3.2.3 Jaroso Creek

A field crew measured four sites on Jaroso Creek. Jaroso Creek is a tributary to Ventero Creek with a drainage area of 8.82 square miles at its mouth. Aerial imagery suggests that Jaroso Creek does not typically flow to Ventero Creek.

<u>Jaroso202106250930</u>

Figure 4-77 Jaroso Creek (Jaroso202106250930). Notice channel next to high terrace but building a new floodplain.

Figure 4-78 Jaroso Creek (Jaroso202106250930) bank erosion.

Jaroso Creek (Jaroso202106250930) is 1 mile upstream of County Road 21. The drainage area of the reach is 8.53 square miles. A longitudinal profile of water surface and thalweg, and three cross-sections were measured at this reach. The measured reach has an average slope of 1.3%. The Rosgen Stream Classification for this reach is a C5 stream type.

Bank erosion was observed within the reach (Figure 4-78). The reach has become entrenched but is trending towards stability by building a floodplain at a lower elevation.

The channel could continue stabilizing itself at the new base level. The gully that it is in may continue to widen out until the belt width is sufficient for the channel and gradient of the stream. There is an opportunity to da a Priority 1 restoration project, putting the channel back up on the higher terrace through this reach. Doing so may raise groundwater levels through the valley, improve sub-irrigation for crops and create a more stable stream channel, with opportunity for aquatic and riparian habitat improvements.

Jaroso202106221008

Figure 4-79 Jaroso Creek (Jaroso202106221008) notice wood in stream and healthy riparian community.

Jaroso Creek (Jaroso202106221008) is 1.2 miles upstream of Jaroso202106250930. The drainage area of the reach is 5.39 square miles. A longitudinal profile of water surface and thalweg and one cross-section were measured at this reach. The measured reach has an average slope of 3.4%. The Rosgen Stream Classification for this reach is a C4b ('C4' little 'b') stream type.

Figure 4-79 shows Jaroso Creek through the measured reach. There is wood incorporated into the banks and a healthy riparian community. This provides stability to the reach. In and around the reach there is evidence of grazing, which has caused impacts to bank stability, but the reach seems to be in a stable state.

Jaroso202106221147

Figure 4-80 Jaroso Creek (Jaroso202106221147) notice bank erosion, caused by hoof shear, and overwide channel.

Jaroso Creek (Jaroso202106221147) is 2 miles upstream of Jaroso202106221008. The drainage area of the reach is 4.03 square miles. A longitudinal profile of water surface and thalweg and three cross-sections were measured at this reach. The measured reach has an average slope of 2.9%. The Rosgen Stream Classification for this reach is a C4b ('C4' little 'b') stream type.

This reach runs through a high meadow. There is a noticeable lack of vegetation, especially woody plants, along the banks. Due to hoof shear, bank erosion was observed in the measured reach (Figure 4-80), and the channel is overwide. An overwide channel is likely to aggrade, causing channel instability. There are sections of the reach that become steep and are beginning to incise. Likely, this reach is heavily impacted by grazing. Downstream of the culvert near the bottom of the reach, the channel becomes more confined, and more wood is present in the channel. The channel is steeper in this section and still appears stable adjacent to the roads.

The function of the reach could be improved with grazing management and plantings. There is river restoration potential through the reach as well, narrowing the channel, creating pools, and incorporating wood and fish habitat features.

UTJaroso202106221324

Figure 4-81 UT Jaroso (UTJaroso202106221342) step pool system.

UT Jaroso (UTJaroso202106221324) is 0.6 miles upstream of the channel's confluence with Jaroso Creek, three miles upstream of Jaroso202106221147. The drainage area of the reach is 0.63 square miles. A longitudinal profile of water surface and a cross-section was measured at this reach. The measured reach has an average slope of 14.5%. The Rosgen Stream Classification for this reach is an A4a+ ('A4' little 'a' plus) stream type.

UT Jaroso, through this reach, is a step-pool system. Notice all the wood steps or drops in Figure 4-81. The channel appears to be in a pseudo-stable state in this reach. The channel stability is heavily dependent on wood and the channel substrate.

4.3.2.4 El Perdido Creek

A field crew measured one site on El Perdido Creek. El Perdido Creek is a tributary to Bernardino Creek, which contributes to Carneros Creek, a tributary to Culebra Creek. The drainage area of El Perdido Creek is 0.87 square miles at its mouth, one mile upstream of the Bernardino Creek Confluence with Carneros Creek.

ElPerdido202107071236

Figure 4-82 El Perdido Creek (ElPerdido202107071236) heavily wooded, steep, confined channel.

El Perdido Creek (ElPerdido202107071236) is about 0.3 miles upstream of the Bernardino/El Perdido confluence. The drainage area of the reach is 0.87 square miles. A longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 16.4%. The Rosgen Stream Classification for this reach is a A4a+ ('A4' little 'a' plus) stream type.

The channel through the measured reach is very steep and heavily wooded (Figure 4-82). The reach is a stable step-pool/cascade system, steps being composed of both wood and boulders. The reach seems to be in a pseudo-stable condition. No evidence of grazing was observed in this section.

4.3.2.5 El Poso Creek

A field crew measured seven sites on El Poso Creek. El Poso Creek is a tributary to Culebra Creek with a drainage area of 34.0 square miles at its mouth. The confluence of El Poso Creek with Culebra Creek is approximately 300 feet downstream of the County Road L.7 Culebra Creek crossing.

<u>ElPoso202107111312</u>

Figure 4-83 El Poso Creek (El Poso202107111312) notice woody vegetation on banks.

El Poso Creek (ElPoso202107111312) is 2 miles upstream of the El Poso Creek Culebra Creek Confluence. The drainage area of the reach is 29.8 square miles. A longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 2.0%. The Rosgen Stream Classification for this reach is a C3 stream type.

The channel through the measured reach seems to be stable with good floodplain access. The banks are covered in woody vegetation providing stabilization and cover. The channel within the reach could benefit from more pools.

<u>ElPoso202107111030</u>

Figure 4-84 El Poso Creek (ElPoso202107111030) wood vegetation on river right bank, erosion on river left.

El Poso Creek (ElPoso202107111030) is one mile upstream of ElPoso202107111312. The drainage area of the reach is 28.5 square miles. A longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 2.4%. The Rosgen Stream Classification for this reach is a B3 stream type.

Bank erosion and channel instability were observed through this measured reach. There is evidence of hoof shear along the banks, cutbanks, and mid-channel bars are forming. Woody vegetation along the banks through the reach contributes to stability, but the channel is likely to continue to destabilize. The formation of mid-channel bars in the channel suggests that the channel is overwide. The is entrenched. Grazing management could improve the channel through this reach, and there is potential to improve the reach with restoration.

ElPoso202107101515

Figure 4-85 El Poso Creek (El Poso202107101515). Notice channel cutting into high terrace.

El Poso Creek (ElPoso202107101515) is one mile upstream of ElPoso202107111030. The drainage area of the reach is 22.7 square miles. A longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 2.2%. The Rosgen Stream Classification for this reach is a B3 stream type.

Through this reach, the channel has good riparian vegetation, including woody plants. There is evidence of grazing in and near the channel, and the channel is overwide. The channel is cutting into a high terrace, as shown in Figure 4-85. The channel through this reach could benefit from grazing management, planting, and stream restoration.

ElPoso202107091115

Figure 4-86 El Poso Creek (ElPoso202107091115) notice riparian vegetation along banks.

Figure 4-87 El Poso Creek upstream of ElPoso202107091115, notice drop structures and boulder bank protection.

El Poso Creek (ElPoso202107091115) is 0.75 miles upstream of ElPoso202107101515. The drainage area of the reach is 18.0 square miles. A longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 2.9%. The Rosgen Stream Classification for this reach is a B3.

The stream is stable through the measure reach. The banks are supported by vegetation. There are willows and alders in the riparian corridor. There is bedrock control in the reach. Large wood and deep pools are found in the reach.

Upstream of this reach, a quarter of a mile, a field crew observed stream work completed in the channel below houses. The stream work incorporated big drops into the channel. Below these drops were deep pools, and above the drops, it looked like aggradation occurred due to the reduced slope.

ElPoso202107101145

El Poso Creek (ElPoso202107101145) is 1.6 miles upstream of ElPoso202107091115. This site is located just upstream of the El Poso Creek waterfall. The drainage area of the reach is 15.6 square miles. A longitudinal profile of water surface and thalweg and a cross-section were measured at this reach. The measured reach has an average slope of 2.7%. The Rosgen Stream Classification for this reach is a B3 stream type.

Figure 4-88 El Poso Creek (ElPoso202107101145) notice wood vegetation along banks and bright channel bottom.

Channel instability was observed through the measured reach. Instabilities included bank erosion and sediment deposition on the floodplain, namely cobbles. There was evidence of wood debris jams occurring in the reach. The reach experienced a flooding event in recent history.

ElPoso202107081130

El Poso Creek (ElPoso202107081130) is 1.7 miles upstream of ElPoso202107101145). The drainage area of the reach is 6.99 square miles. A longitudinal profile of water surface and thalweg and one cross-section were measured at this reach. The measured reach has an average slope of 5.0%. The Rosgen Stream Classification for this reach is a B3a ('B3' little 'a') stream type.

Figure 4-89 El Poso Creek (ElPoso202107081130) notice bedrock outcrop on river left and dense vegetation along banks.

The measured reach has a dense woody riparian community along its banks (Figure 4-89). The reach is stable with good riparian vegetation and substrate controls. The channel is bedrock controlled, both laterally and vertically.

UTElPoso202107081500

Figure 4-90 UT El Poso (El Poso2021070815) aka Conova Creek steep reach with healthy riparian corridor.

UT El Poso Creek (UTElPoso2021070815), also known as Canova Creek, is 0.7 miles upstream of its confluence with El Poso Creek. The confluence is 0.2 miles downstream of ElPoso202107081130. The drainage area of the reach is 4.44 square miles. A longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 7.2%. The Rosgen Stream Classification for this reach is a B3a ('B3' little 'a') stream type. The riparian corridor looks intact and healthy (Figure 4-90). Bank erosion was observed through the measured reach. Even though there is observed bank erosion in the measured site, the reach seems stable. No current recommendations for improvements.

4.3.2.6 Rito Seco

Rito Seco is a tributary to Culebra Creek. At its confluence with Culebra Creek, just below San Luis, the drainage area of Rito Seco is 29.4 square miles. A field crew measured two sites on Rito Seco.

RitoSeco202107121234

Figure 4-91 Rito Seco (RitoSeco202107121234) notice bank erosion in the foreground.

Rito Seco (RitoSeco202107121234) is 2.5 miles downstream, west southwest, of the intersection of Juarez Road and Forbes Road. The drainage area of the reach is 22.4 square miles. A longitudinal profile of water surface and thalweg and three cross-sections were measured at this reach. The measured reach has an average slope of 0.7%. The Rosgen Stream Classification for this reach is a C5 stream type.

Bank erosion was noticed in the measured reach (Figure 4-91). This channel has incised to a lower base elevation. The surrounding landscape indicates that Rito Seco was historically a heavy contributor of sediments. The channel appears to be stabilizing at a lower elevation. In areas through the measured reach, the channel was well connected with the floodplain, yet it looks as if the channel is incising in other areas. Figure 4-91 shows the channel downcutting through what looks like historic sediments, deposited behind an old beaver dam. There is evidence of beavers both upstream and downstream of the measured reach. If left alone, the channel will continue to stabilize. Gullies are forming with drainages connected to the channel. The channels being formed by these headcuts will continue to move up-basin until pseudo stable slopes are obtained by the forming channel.

RitoSeco202107191045

Rito Seco (RitoSeco202107191045) is 1.6 miles upstream, northeast, of the intersection of Juarez Road and Forbes Road. The drainage area of the reach is 8.75 square miles. A longitudinal profile of water surface and thalweg and a cross-section were measured at this reach. The measured reach has an average slope of 6.6%. The Rosgen Stream Classification for this reach is a B4a ('B3' little 'a') stream type.

Figure 4-92 Rito Seco (RitoSeco202107191045) steep channel with great alder/willow riparian

Rito Seco, through the measured reach, is steep and seems stable. The wood vegetation and the substrate provide stability through the reach. As shown in Figure 4-92, wood is plentiful on-site, providing both stability and habitat.

4.3.2.7 San Francisco Creek

San Francisco Creek is a tributary to Ventero Creek, which confluences with Culebra Creek downstream of Sanchez Reservoir, 3.5 miles upstream of San Luis. San Francisco has a drainage area of 25.1 square miles at its confluence with Ventero Creek. A field crew measured three sites on San Francisco Creek.

SanFrancisco202107121234

San Francisco (SanFrancisco202107121234) is 0.5 miles upstream of the San Francisco Creek/Alamosito Creek Confluence. The drainage area of the reach is 12.5 square miles. A longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 3.4%. The Rosgen Stream Classification for this reach is a B4 stream type.

Figure 4-93 San Francisco Creek (SanFrancisco202107121234) notice canopy cover and healthy riparian vegetation.

Overall, the measured reach was stable (Figure 4-93). Sediment deposition was observed on the floodplain upstream of the culvert, towards the middle of this reach. A high concentration of fine particles was observed in the channel substrate, suggesting that the channel is aggrading. Grazing impacts the channel, with hoof shear and bare earth observed in and around the channel. Vegetation through the reach provides stability to the channel.

SanFrancisco202106241234

San Francisco Creek (SanFrancisco202106241234) is 1.3 miles upstream of the SanFrancisco202107121234. The drainage area of the reach is 11.3 square miles. A longitudinal profile of water surface and a cross-section were measured at this reach. The measured reach has an average slope of 4.5%. The Rosgen Stream Classification for this reach is a B4a ('B4' little 'a') stream type.

Figure 4-94 San Francisco Creek (SanFrancisco202106241234) notice lack of vegetation, especially woodies and overwide channel.

Channel work has been performed in and around this reach. There is boulder bank protection and drop structures added. The vegetation through this reach does not seem to be at its full potential, and there is an apparent lack of woody shrubs (Figure 4-94). The channel may be overwide through this section. There is evidence of overgrazing in the vicinity of the stream. The road and grazing impact the channel's function in this reach. The channel also appears to be straightened in places.

Increasing the length of the channel by adding sinuosity will reduce the bankfull slope and improve the reach function along with vegetation planting and grazing management. The addition of more pools would also add energy dissipation and habitat benefits.

SanFrancisco202107120920

Figure 4-95 San Francisco Creek (SanFrancisco202107120920) lot of wood in steep channel with small floodplain.

San Francisco Creek (SanFrancisco202107120920) is 1.7 miles upstream of SanFrancisco202106241234 at the San Francisco Creek/El Fragoso Creek confluence. The drainage area of the reach is 8.88 square miles below the confluence. A longitudinal profile of water surface and thalweg and four cross-sections were measured at this reach. The measured reach has an average slope of 6.4%. The Rosgen Stream Classification for this reach is a B3a ('B3' little 'a') stream type.

The surveyed reach begins below the confluence of San Francisco Creek and El Fragoso Creek and continues up El Fragoso Creek. There is a small floodplain forming along the banks of the channel (Figure 4-95). Impacts from grazing were observed in and along the banks of the channel. The presence of wood, in the channel and along the banks and the larger substrate size help stabilize the channel. Consider grazing management to improve the function of the channel.

4.3.2.8 South Cuates Creek

South Cuates Creek is a tributary to Cuates Creek, a tributary to Ventero Creek that confluences with Culebra Creek downstream of Sanchez Reservoir, 3.5 miles upstream of

San Luis. The drainage of South Cuates Creek is one square mile at its confluence with Cuates Creek. A field crew measured two sites on South Cuates Creek.

<u>SCuates202106171403</u>

Figure 4-96 South Cuates Creek (SCuates202106171403) channel against high terrace. Floodplain has cobble deposition.

South Cuates Creek (SCuates202106171403) is one mile upstream of the Confluence of Cuates Creek and South Cuates Creek. The drainage area of the reach is 0.15 square miles. A longitudinal profile of water surface and thalweg and three cross-sections were measured at this reach. The measured reach has an average slope of 3.9%. The Rosgen Stream Classification for this reach is a B3 stream type.

A review of aerial imagery suggests that this reach intermittently flows. The confluence between South Cuates Creek and Cuates Creek is not obvious; a braided network of channels connects the two streams. The channel through the measured reach appears to be stable. It looks as though the channel has cut down through a high terrace and is establishing itself at a lower base level. There is a defined floodplain in the valley bottom. Cobbles were observed and are being actively deposited on the floodplain.

<u>SCuates202106171351</u>

Figure 4-97 South Cuates Creek (SCuates202106171351) is a stable reach with strong riparian community.

South Cuates Creek (SCuates202106171351) is 0.5 miles upstream of SCuates202106171403. The drainage area of the reach is 0.08 square miles. A longitudinal profile of water surface and a cross-section were measured at this reach. The measured reach has an average slope of 6.7%. The Rosgen Stream Classification for this reach is a B3a ('B3' little 'a') stream type.

South Cuates Creek is stable through the measured reach. The channel starts to widen and look less stable below the fence line/road crossing. The riparian vegetation community is dense with woody shrubs and trees (Figure 4-97).

4.3.2.9 Torcido Creek

A field crew measured one site on Torcido Creek. Torcido Creek is a tributary to Ventero Creek, its confluence at Sanchez Reservoir. The drainage area of Torcido Creek is 5.53 square miles at its mouth.

<u>Torcido202106211640</u>

Figure 4-98 Gully above Torcido Creek, notice established vegetation suggesting gully is stabilizing.

Figure 4-99 Torcido Creek (Torcido202106211640) notice hoof shear along banks.

Torcido Creek (Torcido202106211640) is 2.8 miles upstream of the Road E5 crossing. The drainage area of the reach is 3.39 square miles. A longitudinal profile of water surface and thalweg and a cross-section were measured at this reach. The measured reach has an average slope of 2.7%. The Rosgen Stream Classification for this reach is a B4 stream type.

A review of aerial imagery along the Torcido drainage gullies have formed where trees are not prevalent on the landscape. Two gullies have formed immediately upstream, north northeast, of the measured reach (Figure 4-98). The gullies have supplied sediment to the measured reach. The gullies appear to be stabilizing, and it did not appear that the channel below was actively receiving sediments and aggrading

There is evidence of grazing in and along the creek in this reach (Figure 4-99), and it is overwide. Woody vegetation is absent on river right, left side of photo in Figure 4-98. Grazing management and riparian planting could help improve the function of the channel in this area.

4.3.2.10 El Valle Creek

The confluence of El Valle Creek and Carneros Creek create Culebra Creek. The drainage area of El Valle Creek is 6.12 square miles at this confluence. A field crew measured four sites on El Valle Creek.

Valle202106231452

Figure 4-100 El Valle Creek (Valle202106231452) notice healthy riparian vegetation, including woody shrubs, along the banks.

El Valle Creek (Valle202106231452) is 1.7 miles upstream of the confluence of Carneros Creek. The drainage area of the reach is 5.24 square miles. A longitudinal profile of water surface and thalweg and a cross-section were measured at this reach. The measured reach has an average slope of 5.5%. The Rosgen Stream Classification for this reach is a F4 stream type.

Typically, F-type channels are not stable. The channel is overwide through the measured reach with fine sediment deposition. Inspection of aerial imagery suggests disturbances upstream of the site. It looks like a potential relic beaver dam blew out. The vegetation in and around this site is healthy and will continue to fill in, narrowing the channel. Managing grazing through this reach will help ensure that the vegetation can continue to work towards stabilizing the channel. There may be a restoration opportunity upstream of this reach.

Valle202106231410

Figure 4-101 El Valle (Valle202106231410) notice riparian community along channel margins.

El Valle Creek (Valle202106231410) is 0.8 miles upstream of Valle202106231452. The drainage area of the reach is 4.47 square miles. A longitudinal profile of water surface and thalweg and a cross-section were measured at this reach. The measured reach has an average slope of 5.1%. The Rosgen Stream Classification for this reach is a B3a ('B3' little 'a') stream type.

There was evidence of recent and historic beaver activity in and around the measured reach. The riparian community around the reach is in good condition. The channel is stable.

Valle202106231111

Figure 4-102 El Valle Creek (Valle202106231111). Channel is nearing tree line elevation. Notice the boulder scree field next to the channel.

El Valle Creek (Valle202106231111) is just upstream of the final crossing of Whiskey Pass Road. The drainage area of the reach is 0.53 square miles. A longitudinal profile of water surface and thalweg and three cross-sections were measured at this reach. The measured reach has an average slope of 7.8%. The Rosgen Stream Classification for this reach is a B3a ('B3' little 'a') stream type.

There is evidence of grazing within the measured reach. The banks and channel are stable. The channel corridor has good riparian vegetation (Figure 4-102). Runoff flow down the roads in the vicinity of the site, a potential cause for sediments in the channel. Alluvial fans and rocks slides are likely to impact the channel through this reach. Notice the steep boulder scree slopes in Figure 4-102.

Valle202106231157

Figure 4-103 El Valle Creek (Valle202106231157) channel near tree line. Photo showing braided section below alluvial fan.

El Valle Creek (Valle202106231157) is one mile upstream of Valle202106231111. The drainage area of the reach is 0.25 square miles. A longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 11.5%. The Rosgen Stream Classification for this reach is a A3a+ ('A3' little 'a' plus) stream type.

The measured reach is steep and at a high altitude. The reach is just below an alluvial fan. Within the fan the reach is classified as a D3 stream type. The reach is relatively stable due to the larger substrate sizes. There are woody shrubs along the bank margins and evidence of grazing throughout the reach (Figure 4-103). The banks show signs of hoof shear, and there is erosion on the floodplain where the banks have been trampled. To improve the reach function, grazing management for the area should be considered.

4.3.2.11 Vallejos Creek

Vallejos Creek is a tributary to Culebra Creek, and its confluence is northwest of the village of San Pablo. At the confluence of Vallejos Creek and Culebra Creek the drainage area of Vallejos Creek is 29.2 square miles. A field crew measured five sites on Vallejos and North Vallejos Creek.

Vallejos202107201315

Figure 4-104 Vallejos Creek (Vallejos202107201315). Notice undercut bank on river left, left side of photo. In the background notice bank erosion/instability.

Vallejos Creek (Vallejos202107201315) is 3 miles upstream of the County Road 22.3 crossing. The drainage area of the reach is 26.5 square miles. A longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 1.8%. The Rosgen Stream Classification for this reach is a C4 stream type.

There were signs of instability through the reach. Vertical banks were observed in the measured reach. The channel is incising. It appears that the channel may have been channelized and straightened in the past and is trying to widen its floodplain. Undercut banks observed in measured reach can be great aquatic habitat (Figure 4-104). Grazing management and river restoration could improve the function of this reach. There may be opportunity to connect the river with its floodplain and improve fish/aquatic habitat.

Vallejos202107181307

Figure 4-105 Vallejos Creek (Vallejos202107181307) notice sandy deposition on bank and woody shrub riparian vegetation.

Vallejos Creek (Vallejos202107181307) is 1.9 miles upstream of Vallejos202107201315. This reach is upstream of the confluence with north Vallejos Creek. The drainage area of the reach is 8.15 square miles. A longitudinal profile of water surface and thalweg and a cross-section were measured at this reach. The measured reach has an average slope of 2.6%. The Rosgen Stream Classification for this reach is a C4b (‘C4’ little ‘b’) stream type.

The channel seems to be unstable through the measured reach (Figure 4-105). The channel is cutting into a high terrace on the downstream end. There was evidence of heavy grazing in areas in and around the reach channel corridor. The reach is heavily vegetated with alder, willow, and pinon (Figure 4-105). The bottom of the channel was noticeably slick. Grazing management and a river restoration project could improve the function of Vallejos Creek through this reach.

Vallejos202107180915

Figure 4-106 Vallejos Creek (Vallejos202107180915) steep channel with high concentration of woody vegetation along channel margins.

Vallejos Creek (Vallejos202107180915) is 2 miles upstream of Vallejos202107181307. The drainage area of the reach is 5.21 square miles. A longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 4.3%. The Rosgen Stream Classification for this reach is a B4a ('B4' little 'a') stream type.

The channel through the measured reach is showing signs of instability. The channel is cutting against a high terrace in the measured reach. Riparian vegetation, including woody shrubs, is prevalent through the site and aiding in stabilization (Figure 4-106). Fine sediments seem to be aggrading in the measured reach. The upstream source of those sediments was not observed. Signs of grazing were observed within the reach.

NorthVallejos202107221200

Figure 4-107 North Vallejos Creek (NorthVallejos202107221200) notice riparian corridor including woody shrubs.

North Vallejos (NorthVallejos202107221200) is 2.6 miles upstream of the Vallejos/North Vallejos confluence. The drainage area of the reach is 10.3 square miles. A longitudinal profile of water surface and thalweg and a cross-section were measured at this reach. The measured reach has an average slope of 3.4%. The Rosgen Stream Classification for this reach is a B4 stream type.

Channel through measured reach appears to be more stable than downstream NorthVallejos202107180915, though there is still evidence of grazing impacts on banks. The riparian corridor, especially the woody shrubs, provides stability to the reach (Figure 4-107).

NorthVallejos202107221020

Figure 4-108 North Vallejos Creek (NorthVallejos202107221020) channel has decent vegetation along its margins.

North Vallejos Creek (NorthVallejos202107221020) is 0.5 miles upstream of NorthVallejos202107221200. The drainage area of the reach is 9.9 square miles. The longitudinal profile of water surface and thalweg and two cross-sections were measured at this reach. The measured reach has an average slope of 3.5%. The Rosgen Stream Classification for this reach is a B4 stream type.

The channel through the measured reach is stable. There is evidence of grazing impacts, such as hoof shear along banks and collapsed banks. Riparian vegetation, especially woody shrubs, provides stability to the site (Figure 4-108). Wood in the channel also seems to be supplying beneficial habitat.

4.3.2.12 Ventero Creek

The assessment crew measured one site on Ventero Creek. Ventero Creek is a tributary to Culebra Creek about 3.8 miles downstream, north, of Sanchez Reservoir. Ventero Creek's drainage area at its confluence with Culebra Creek is 121 square miles.

Ventero202107150915

Figure 4-109 Ventero Creek (Ventero202107150915) notice grassy vegetation along banks and on floodplain. Bank erosion can is shown in the

Ventero Creek (Ventero202107150915) is two miles upstream of the Ventero/Culebra Creek Confluence. The drainage area of the reach is 120 square miles. A longitudinal profile of water surface and thalweg and four cross-sections were measured at this reach. The measured reach has an average slope of 0.33%. The Rosgen Stream Classification for this reach is a C4 stream type. Desktop radius of curvature measurements are shown in Figure 4-5 for this site.

Grazing is prevalent in and around the project reach (Figure 4-109). The upstream control of Sanchez Reservoir heavily influences the channel. Woody shrubs are absent from the stream corridor throughout the Ventero Creek and Lower Culebra Creek Valleys.

Grazing management, riparian planting, and stream restoration efforts could improve the function of the channel. This reach has severely modified hydrology due to the position below Sanchez Reservoir.

4.3.2.13 Willow Creek

At the Ventero Creek/Willow Creek Confluence the drainage area of Willow Creek is 15.3 square miles. Willow Creek is a tributary to Ventero Creek. A review of aerial imagery suggests that Willow Creek does not always flow to Ventero Creek. Multiple diversions are occurring on Willow Creek before it reaches Ventero Creek. The assessment crew measured one site on Willow Creek.

Willow202106160946

Figure 4-110 Willow Creek (Willow202106160946) notice woody shrubs on bank and sinuosity of the channel.

Willow Creek (Willow202106160946) is 3 miles upstream of the expected confluence with Ventero Creek. The drainage area of the reach is 7.14 square miles. A longitudinal profile of water surface and thalweg and three cross-sections were measured at this reach. The measured reach has an average slope of 3.7%. The Rosgen Stream Classification for this reach is a B4 stream type.

Willow Creek, through the measured reach, is stable. The coarser substrate, bedrock control and vegetation are providing stability. The riparian corridor surrounding the channel is about 25 feet wide. There is evidence of grazing along the channel, with hoof shear occurring along the banks. Wood vegetation is present along the channel margins. The channel has good floodplain access (Figure 4-110).

4.4 Preliminary Mini-Regional Curve

Throughout the Culebra Basin, 93 channel cross-sections were measured. Cross-sectional profiles were processed to calculate the bankfull channel cross-sectional area. Bankfull area is often correlated with drainage area within similar regions. The data from the measured cross-sections and drainage area are plotted in Appendix 5.A. Figure 4-111 shows the preliminary regional curve developed for the Upper Culebra Watershed. Data from additional riffle cross-sections should continue to be collected and added to continue the development of this curve. Impacts to channel cross-sectional area should consider factors, such as water use and diversions while analyzing the data used to develop the curve. Bieger et al. (2015) have also developed a regional curve for this physiographic region. The preliminary mini-regional curve proposed in this report and the Bieger curve could be valuable resources for developing stream design in the Upper Culebra Watershed.

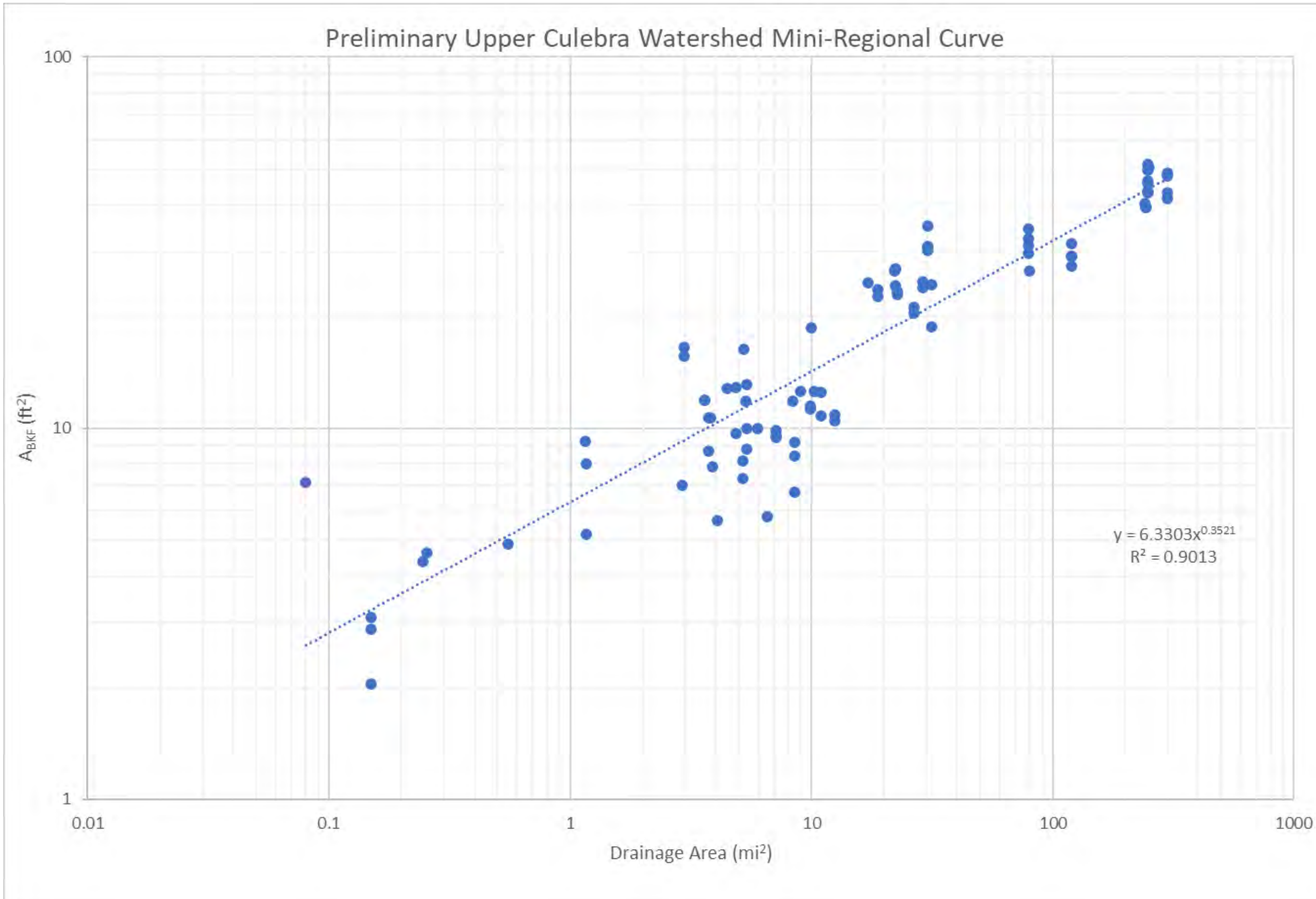


Figure 4-111 Preliminary Upper Culebra Watershed Mini-Regional Curve

4.5 Validation

Using remotely sensed data can be used to expand the measured datasets to extrapolate the data spatially. A comparison must be made between the measured values and remotely sensed values to extrapolate the datasets. One of the available comparisons is based on stream reach slope, which helps to inform information about anticipated sinuosity, sediment size and movement, and stream type. The measured geomorphic reach slope was compared with the reach slope calculated from the stream network generated from the DEM discussed in Section 1.3.1.1. On average, the stream network slope was 93% of the geomorphic reach slope. Using slope as a preliminary classifier for stream type, the stream network performed well, with 29 of 40 reaches classifying the same based on either the stream network or the measured reach slope. 9 reaches classified to the higher slope class than the measured slope class, and 2 reaches classified to the lower slope class than the measured. All miss-classified data points only differed by one slope classification. Spatial comparisons of data are shown in Figure 4-113.

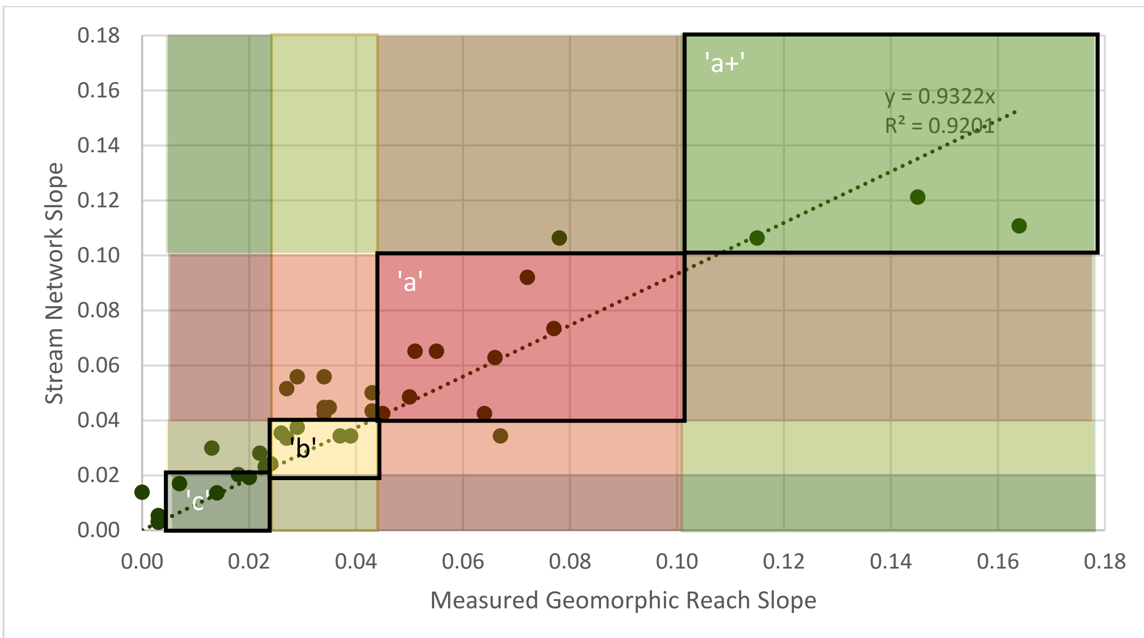


Figure 4-112 Comparison of the measured geomorphic reach slope and the stream network link slope.

Furthermore, the stream network slope would typically be greater because the stream network length is less than the stream length. This will result in the stream network sinuosity being less than the actual stream sinuosity.

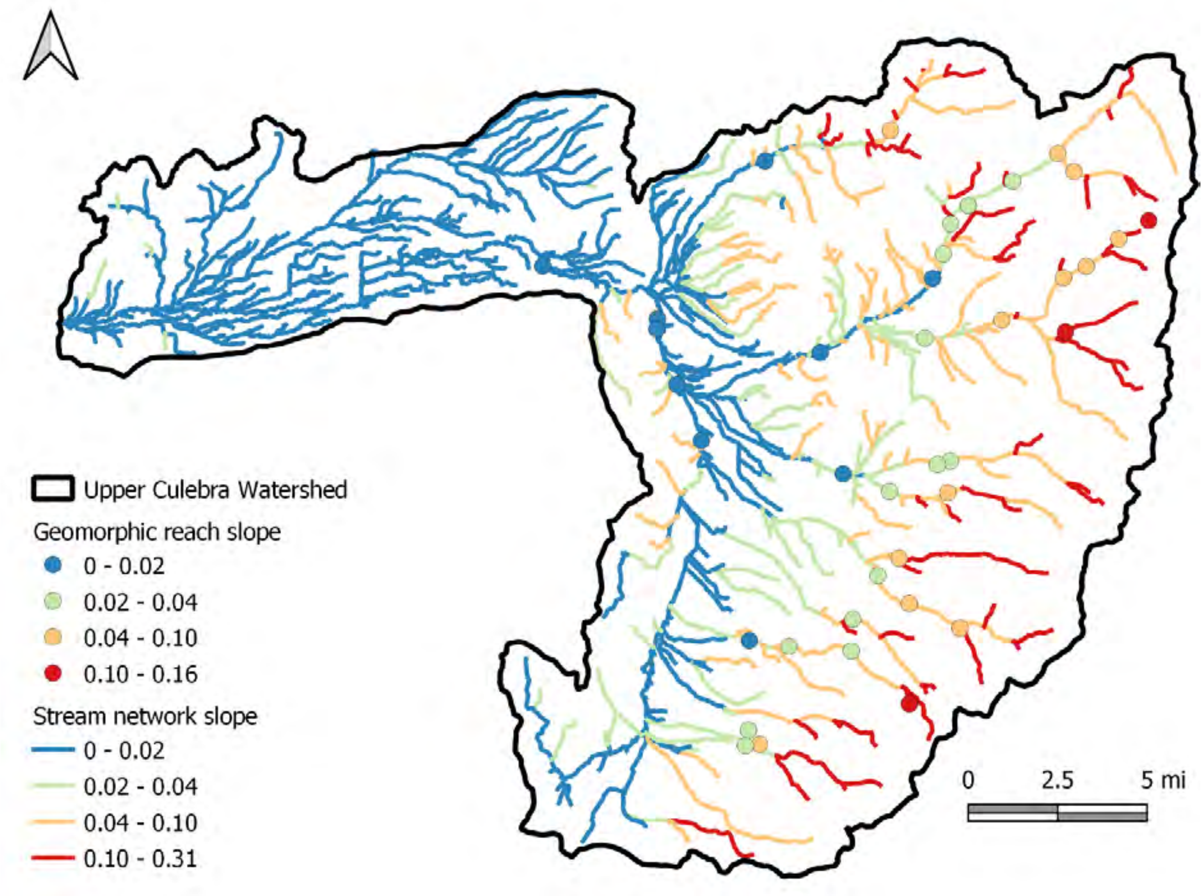


Figure 4-113 Network and geomorphic slope classification comparison.

4.6 Discussion

4.6.1 General Discussion

The assessment evaluated streams and channels throughout the Culebra Watershed. Overall, the watershed is in good condition, though there are opportunities for actions to be taken to improve the function of the channels throughout the basin.

Main objectives for improving channel function and health:

- Improve floodplain connection.
- Avoid rapid floodplain constriction and expansions.
- Improve riparian health along channel corridors.
- Avoid channelization.
- Reduce impacts of overgrazing in and around channel corridors.

4.6.2 Priority Projects

The priority projects within the Culebra Basin focus on stream reaches that appear to have been channelized in the past.

- Culebra Creek above Sanchez Canal: the constriction of the channel to a four-foot slide gate provides a significant barrier to fish and sediment passage.
- Stream restoration upstream of Sanchez Canal would reduce overall sediment contributions to Culebra Creek, improving conditions for all downstream structures.

- Diversion structure improvements would reduce flood risk, improve sediment transport, improve aquatic habitat, and improve diversion structure-function.
- El Poso Creek from Sangre de Cristo Ranches down to the confluence with Culebra Creek: The intensity of projects would vary from minor bank stabilization and grazing management to fully reconnecting the floodplain. The area downstream of Thorfinnson Rd to the confluence with Culebra Creek is upstream of the senior water rights points of diversion, so the hydrology is present.
- Confluence reach improvements to channel sinuosity, sediment transport, and Guadalupe Sanchez headgate. This reach could also be extended to include improvements to the Culebra Chama streamflow gaging station.
- Cielo Vista Ranch reach from Sangre de Cristo Ranches down to lower property boundary would benefit from grazing management, stream bank stabilization, and riparian plantings.
- Sangre de Cristo Ranches reach could be improved by adjusting the stream profile to have a lower pool-to-pool spacing, reducing aggradation and degradation. Potentially narrowing the low flow channel to increase flow depths, improve sediment transport, and reduce stream temperatures. The addition of large wood could improve the aquatic habitat.
- Vallejos Creek below the North Vallejos, Vallejos Creek confluence this reach is like Rito Seco Creek and is slowly building the large, incised terrace. During the site visit, trout were observed in the stream along the cutbanks that provide excellent habitat. Improvements in this reach will require careful consideration of sediment loading and a more detailed design approach to leverage the natural elements for preservation and combine that with the restoration of those degraded areas.
- Jaroso Creek through the “Commons” this reach is affected by channel incision. This reach is highly recommended for an example project for improving agricultural production by reconnecting the floodplain. Diversion structures within this reach would also benefit from aligning those structures to work with the creek and the alluvial fan.
- The Lower Basin Culebra Creek and Ventero Creek reaches would benefit from an appropriate restoration for the current and future hydrology. Improvements to floodplain connectivity, both lateral and longitudinally, and channel pattern will improve water quality, riparian health, and meadows within this reach.
- Culebra Creek above Ventero Creek confluence could be improved by removing and restoring the area that has been contained by non-jurisdictional levees. Improvements to this reach would improve community safety, aquatic habitat, and could improve irrigation efficiency along San Pedro Ditch. The potential uplift of this reach is very dependent on the elevations of surrounding structures.

Chapter 5. Flow Regimes Assessment

Author: Tailwater Limited

"When the well is dry, we know the worth of water." – Benjamin Franklin

5.1 Introduction

Water is the lifeblood of the Culebra Basin. All living organisms depend on water. Task 3 – Flow Regimes Assessment looks at how water flows through and is administered in the basin. The ability to assess flow regimes is related to the availability and quality of streamflow measurement records. Records of streamflow across the United States are typically maintained by state agencies, such as the Colorado Division of Water Resources (DWR); federal agencies, such as the United States Geological Survey (USGS), or the United States Bureau of Reclamation (B.O.R.); and in recent times local conservation districts. Streamflow records are maintained for several reasons, often related to water administration, water quality, and flood warnings. In addition to streamflow records, records of diversions are maintained by DWR. In some ditch/canal systems, records of deliveries to each headgate are also maintained. The quality of each of these records depends on the methods used to collect the data. Data records can be collected infrequently, such as weekly observations to more frequent, such as daily measurements, or even more frequent, such as data recorded in 15-minute increments. In addition to measurement frequency, accuracy is a critical factor in record quality – is the measurement structure operating correctly? Is it submerged? Does the structure move or change? If so, is this monitored, measured, and documented?

In Colorado, water is administered based on the principle of prior appropriations. Prior water appropriations mean that water users who hold the oldest, more senior adjudicated water rights have priority during a water shortage. Water distribution within this basin is also, at times, determined from a futile call. A futile call occurs when a junior priority water user is permitted to divert water despite the demands of more senior priority water users in the same watershed. To curtail or prohibit the junior water user from diverting would not effectively produce water for beneficial use for the senior (Colorado State University Extension, 2012). For example, if water is available for a junior user to meet their call, but because of losses in the system, the water would not be available at the senior users point of diversion, a futile call could be used to satisfy the junior user's call. Water rights are based on the point of diversion, type of diversion (use), and the time of use.

The major water users within the Culebra basin are the Sanchez Ditch and Reservoir Company, the San Pedro Ditch, the San Acacio Ditch, the San Luis People Ditch, the Cerro Ditch, the San Francisco Ditch, and the Vallejos Ditch. Except for the Sanchez Ditch and Reservoir Company, all the remaining ditches within the basin are considered acequias. An acequia is a ditch or canal used communally to distribute water. Acequias are irrigation and water-sharing systems that create a vital community bond and were historically based on the Spanish "right of thirst" doctrine (Jenson, et al., 2016 Rev.) which can be traced back to Islamic origins which states that “no living creature should be denied access to water” (NRCS). Water distribution within an acequia is based on the rules and by-laws adopted by that organization.

Although this assessment does not directly address groundwater within the basin, it is important to recognize that groundwater and surface water are connected. This connection ensures water is available to the streams during drought and supports the functions of the river corridors. This connection was legally recognized, and the state engineer was required to adopt tributary groundwater rules in regulations following the Colorado Supreme Court decision in Fellhauer v. People, 1968 (Water Education Colorado, 2021).

5.1.1 Goals and Objectives

The following three goals were identified for the Flow Regimes assessment to guide the development of the study plan in support of meeting the overall watershed assessment goals:

Goal 1 Develop understanding of existing data and records of flow with the Culebra Watershed.

Goal 2 Develop understanding of water administration based conflicts within the Culebra Watershed.

Goal 3 Identify approaches that could be implemented to improve water administration within the Culebra Watershed.

Goal 4 Evaluate hydrology within the Culebra Watershed to provide information to other tasks and future projects.

Goal 5 Identify projects that could be implemented to improve water administration, increase water related safety, reduce water related conflict, or improve overall watershed health within the Culebra Watershed.

The following objectives were identified to meet the flow regimes assessment goals.

Goals	Objectives
Goal 1 Develop understanding of existing data and records of flow with the Culebra Watershed	Objective 1.1 Summarize available streamflow and diversion data within the basin Objective 1.2 Summarizing water administration in District 24 - Acequia & prior appropriation Objective 1.3 Identify data gaps that may impact water administration, evaluation of watershed health, or hazard modeling.
Goal 2 Develop understanding of water administration-based conflicts within the Culebra Watershed.	Objective 2.1 Assess current water administration withing Culebra Watershed. Objective 2.2 Evaluate how data gaps affect water administration. Objective 2.3 Identify factors that may impact water administration resulting in conflict. Objective 2.4 Develop understanding of some of the historic factors that have resulting in present day conflict.
Goal 3 Identify approaches that could be implemented to improve water administration within the Culebra Watershed.	Objective 3.1 Identify ways to improve the flow of water through the watershed to meet multiple objectives including: irrigation, riparian health, aquatic health, and grazing conditions within the Culebra Watershed. Objective 3.2 Evaluate recommendations to identify some of the operating constraints, decrees, and other entities. Objective 3.3 Identify diversion structures that are missing either measurement structure or other infrastructure that would impact water administration within the Culebra Watershed.
Goal 4 Evaluate hydrology within the Culebra Watershed to provide information to other tasks and future projects.	Objective 4.1 Compile existing streamflow records. Objective 4.2 Research and or develop estimates of streamflow statistics where records may not exist at appropriate return interval. Objective 4.3 Research and summarize estimates of peak flow statistics Objective 4.4 Identify areas where dry-up may occur.
Goal 5 Identify projects that could be implemented to improve water administration, increase water related safety, reduce water related conflict, or improve overall watershed health within the Culebra Watershed.	Objective 5.1 Identify locations for additional streamflow gaging to improve water administration, support understanding of watershed conditions, and provide flood hazard warning. Objective 5.2 Identify projects and actions that could be implemented to reduce water related conflict.

5.2 Background

There is a lot of information regarding the history and development of surface water within the basin available. This information has been compiled and litigated over the years. One notable area of question/contention is information regarding the Hallett Decrees, described in detail in The Hallett Decrees and Acequia Water Rights (Davidson & Guarino, 2015). The Hallett Decrees and Acequia Water Rights (Davidson & Guarino, 2015) describe the blending of the various governing systems and the uncertainty occurring at the time of Colorado's original adjudications. An adjudication is defined as being a "judicial decision" (Merriam-Webster, n.d.). Some historians have noted that the individuals on the "citizens committee" may have influenced the settlement associated with the Hallett Decrees by negotiating the settlement on behalf of the parciantes (i.e., individual irrigators who own water rights which are attached to his or her land). These individuals were merchants and set to benefit from the business opportunities brought by the Freehold Company. The report continues to provide reference to Freehold and its successors' lack of attention to the details associated with Colorado Water Law, including the need to take water at the decreed location (or change decreed location in the appropriate court), the intended purpose of water use, and documentation of water use by the successors of the Freehold Company. The purpose of this brief review of the Hallet Decrees is not intended to make a judgment on the correct mode of action regarding those water rights but bring light to the importance of having the necessary elements documented and maintained to prevent future conflict and to ensure the resource continues to be available to future generations.

The flow regimes assessment that was completed as part of the Upper Culebra Watershed Assessment included an assessment of the available records. Records of available streamflow and diversions are needed to administer water distribution throughout the system, prevent the expansion of use of water within the system, and to allow for the adaptive management of water throughout the system. Streamflow is measured using a variety of tools ranging from Parshall flumes (Figure 5-1) and/or other rated structures that use stage/discharge relationships to estimate streamflow, to measurements made by more high-tech equipment such as acoustic sensors that measure water velocity and area to estimate streamflow. Historically, streamflow gages were operated based on the relationship between the water stage (level of water in-stream) and the discharge. Streamflow measurements are made over the range of stages within the stream, and a stage-discharge rating curve is developed to convert the stage to discharge. The stage-discharge rating curve is valid if the control area and velocity remain the same. However, the stage-discharge rating curve will vary when the area changes because the bed moved, or vegetation grows; these factors also affect the velocity. Routine discharge measurements verify whether the stage-discharge rating is accurate, or adjustments are needed to improve gage accuracy. Adjustments can be applied through temporary shifts or the development of new stage-discharge rating curves. Other streamflow gaging options involving velocity sensors or dilution exist but are not currently in use within Water District 24. All measurement structures require maintenance and calibration.

Figure 5-1 Parshall flume

5.3 Methods

The flow regimes assessment was completed by compiling background data, following up with a field assessment of measurement and diversion structures, and performing hydrographic modeling where data was available.

5.3.1 Compile background data

Background data for water diversions comes primarily from the Colorado Decision Support System Hydrobase Database. This database is the official digital record of diversions and structures in the State of Colorado. Records were initially compiled manually and then automated using the CDSS REST Web Service.

A list of all structures in District 24 was downloaded as a JSON file on June 10, 2021. All the structures in this file were evaluated, and records for all ditches and pipelines that were not non-existent (e.g., cuiCode != N) were retrieved June 11, 2021, and June 12, 2021, as a JSON file through the REST service (CDSS, 2021).

Structure measurements were obtained via a spreadsheet from Matt Hardesty (Personal Communication A. Taillacq, 2020), to evaluate the shifts and adjustments that may apply to the structures.

Streamflow records were obtained from the CDSS current conditions website. The locations of these gages are shown in Figure 5-2. Published streamflow records for Culebra Creek at San Luis were obtained electronically on August 30, 2021. These records are used to evaluate flood frequency and water delivery to the lower portion of the watershed. Administrative records were obtained for Ventero below Sanchez Reservoir. Records of Culebra Creek near Chama, CO, were not available from the CDSS website.

Lateral headgate San Acacio Ditch

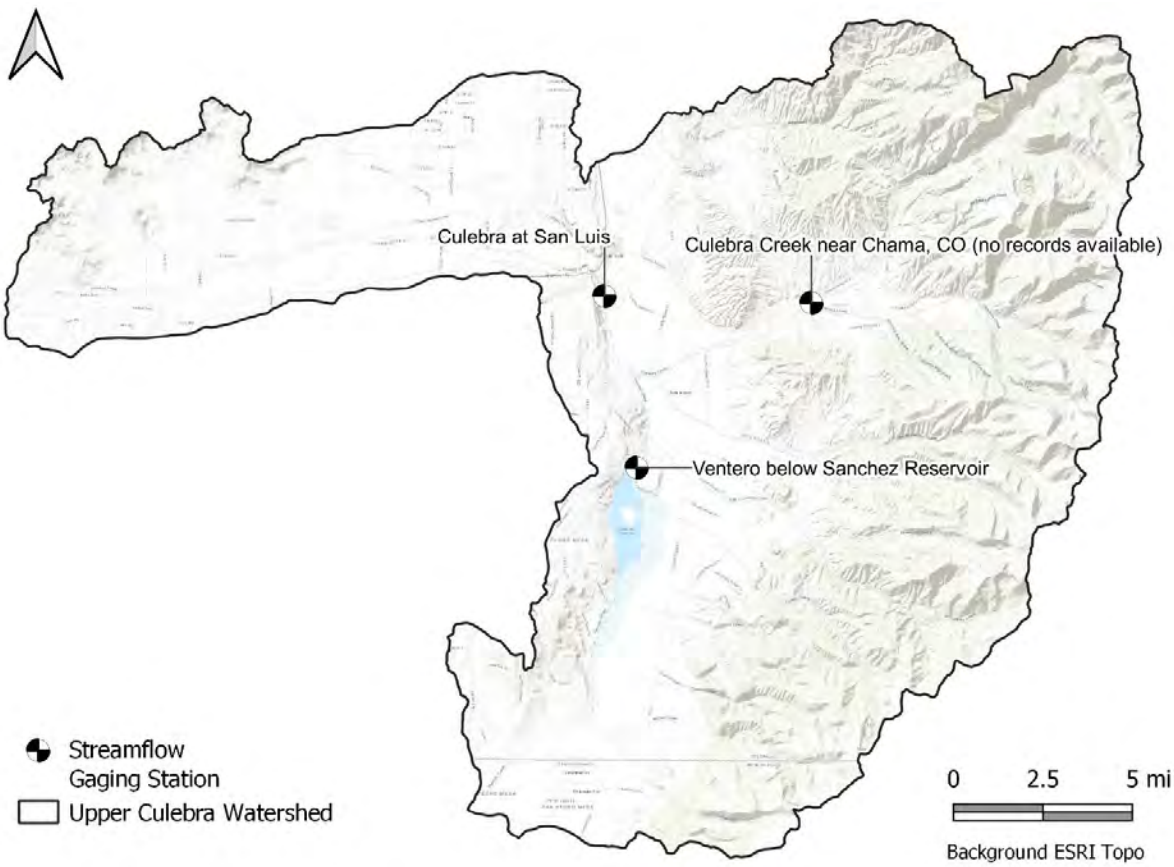


Figure 5-2 Streamflow gaging station locations.

5.3.1.1 Estimate of streamflow records for un-gaged tributaries

Most tributaries with the Culebra Basin are un-gaged, meaning that flows within the streams are not well understood. Understanding streamflow in a stream reach is essential for understanding the function of that reach. When streamflow measurements are not available, regional regressions may be used to estimate the flow through those systems. The USGS StreamStats regression equations are provided for the tributaries. These regressions are dependent on the contributing drainage area, elevation, and rainfall.

5.3.1.2 Evaluate water administration within the basin

The development of water rights within the basin began in the early 1960's securing those rights through decrees started with the first adjudication in June 1889. In this original adjudication, the courts confirmed and recorded the appropriation dates for the first structures. In the section to follow, these decrees are evaluated and briefly summarized.

From discussions with various individuals, including water users and water officials, many of the transactions related to water rights within the basin occurred through non-standard mechanisms. These non-standard mechanisms have led to significant disputes, as water availability and water uses have changed over time within the basin. This report does not discuss priority dates and decreed water quantities; instead, these discussions are more appropriate for the courts. These issues are critical, and participation in events and transactions can have impacts on the entire community.

To evaluate the current means of water administration within the basin meetings and conversations were held with water administration professionals, including the acequia representatives, the Assistant Division Engineers, and Water Commissions with DWR. Input from several conversations with community members regarding water administration were also included.

5.3.2 Field Assessment

Where possible, flow measurement and diversion structures were evaluated in the field. During this assessment, several structures were not accessible to evaluate due to a lack of property access and accurately known locations. Many of the structures were reviewed from EagleView aerial imagery.

5.3.3 Modeling

Modeling of the basin was limited to areas with sufficient data. Modeling for the region measured by the Culebra at San Luis gage and Sanchez Reservoir operations was completed for the period starting in 2012 through 2020. 2012 the first-year electronic records were available for Ventero Creek below Sanchez Reservoir. This region is the only region in the basin with sufficient records to perform such evaluation. While estimates could be made for other regions in the basin, these would be based on estimated records and could be prone to significant errors, which could be misleading.

5.4 Results

5.4.1 Streamflow Gage Assessment

An evaluation of streamflow records includes evaluating the quality of real-time records, QA/QC processes for final records, and availability of records for the intended purpose.

> *"Most people on these ditches are friends and family, but there's no love when it comes to water."* Robert Quintana in National Geographic (Oldham & Ross, November 15, 2021)

Gages that are operated for water administration need to have high-quality real-time records which is achieved through stable controls and/or frequent measurements. Timely data should be available to water administrators and those affected by the available streamflow. Availability of timely data improves water administration transparency. Streamflow often has a diurnal pattern, and while often presented as administered on an average daily basis, situations can occur such that more frequent administration is needed. With digital recording equipment, 15-minute intervals are typically used to balance the data storage required and record detail. Providing access to records, often through webpages populated from satellite, cellular, or line-of-sight telemetry, reduces time spent by water officials fielding phone calls and questions and reducing speculation. As compared to a call-in system, this type of presentation also allows for the evaluation of flow patterns that can be helpful in decision making.

Final records can be developed for gaging stations by analyzing data available, including data that occurs after the stage recording, to develop a more accurate record of actual streamflow. These records are sometimes referred to as published records. Producing a final record can typically reduce errors by allowing for time and stage-related shifting to be accounted for; this is especially true in those systems that frequently change flows. Published records typically have more detailed quality assurance processes to reduce the potential for bias within the records. Although published records can be different than real-time records, the published records provide a more accurate quantity of water for use in administrative modeling. For example, peak flow information from published records is often used for FEMA floodplain models and FIRM mapping. They can provide data for other evaluations such as habitat and culvert sizing or the development of synthetic hydrographs for adjacent basins.

Streamflow gage analysis does not provide detail for evaluating the flows within the Upper Culebra Watershed. The only continuously operated streamflow gaging station in the Culebra Basin is located upstream of San Luis on the Culebra (CULSANCO) (Figure 5-2). The control structure for this gage is a concrete Parshall flume with a concrete stilling well on the left edge of water (Figure 5-3). While this gage provides records for water administration below San Luis and water releases from Sanchez Reservoir, it does not provide the necessary data to administer water within the upper basin. Measurements at this gage are impacted by diversions and regulations upstream. Mean daily flows at CULSANCO are shown in Figure 5-5. The maximum mean daily recorded flow of 479 cfs occurred on June 6, 1942, and the minimum daily flow of 4.6 cfs was recorded on October 31, 1950. Peak instantaneous flow 654 cfs recorded July 1, 1947, from records 1927-1982 and 1991-2022 (USGS, n.d.; CWCB/DWR, 2020-2021).

Figure 5-3 Looking downstream at Culebra at San Luis gaging station. Recording equipment is housed in shelter on left bank.

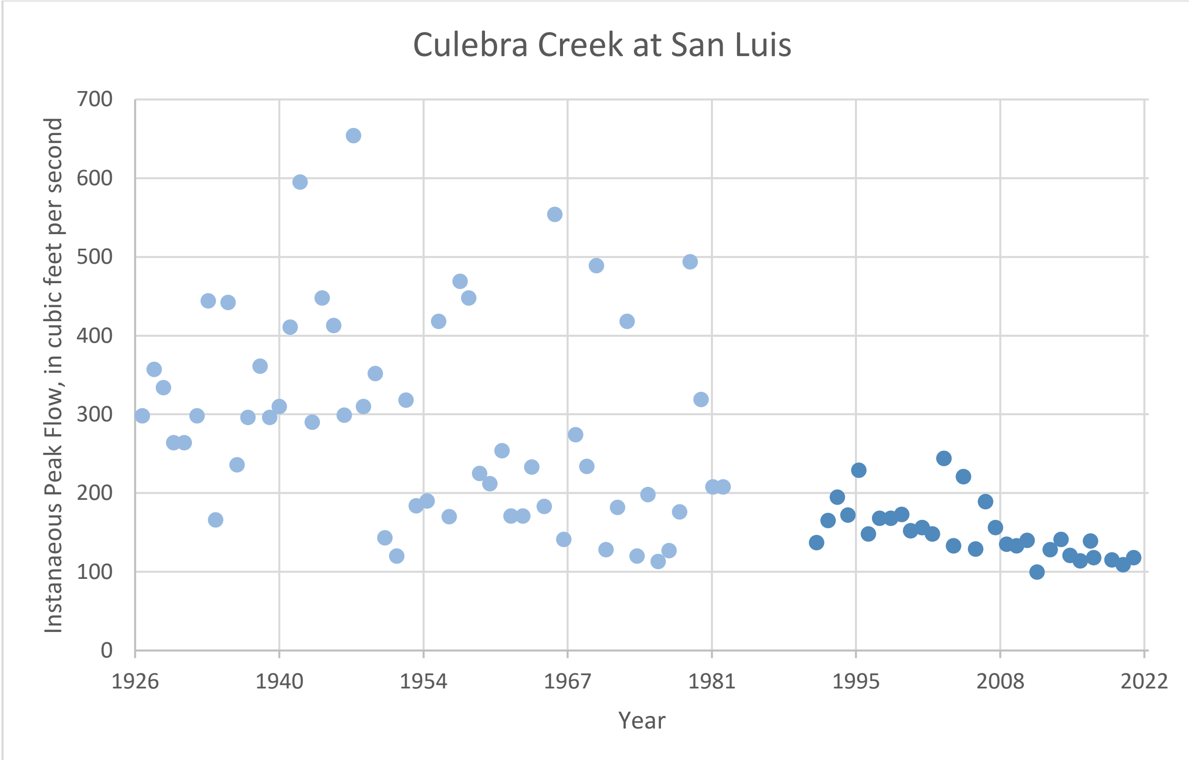


Figure 5-4 Instantaneous peak streamflow Culebra Creek at San Luis 1927-1982 and 1991-2022 (USGS, n.d.; CWCB/DWR, 2020-2021).

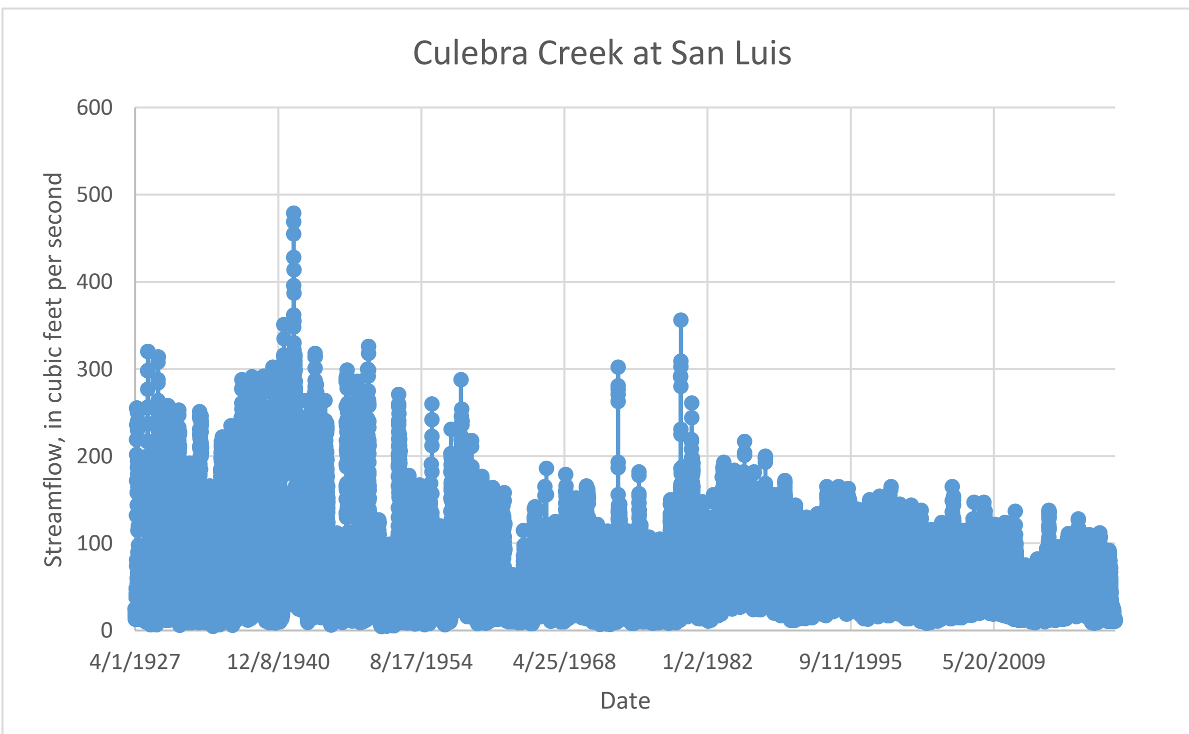


Figure 5-5 Daily streamflow record from Culebra Creek at San Luis (CULSANCO) from April 1, 1921, to December 31, 2020. Maximum daily discharge 479 cubic feet per second, minimum daily discharge 4.6 cubic feet per second.

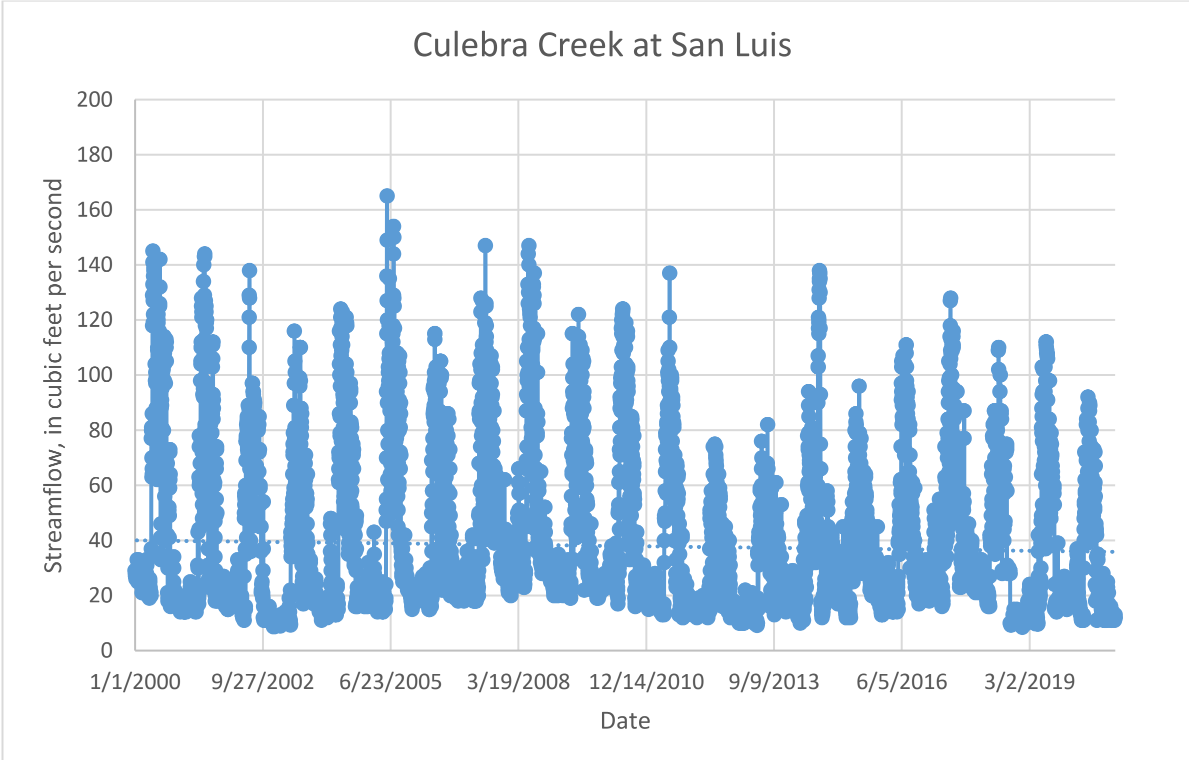


Figure 5-6 Culebra Creek at San Luis (CULSANCO) mean daily streamflow, January 1, 2000, to December 31, 2020. Maximum mean daily discharge 165 cfs and minimum mean daily discharge 8.5 cfs.

An administrative streamflow gage is located on the Culebra River near Chama, CO (CULCHACO). This administrative gage is accessed through a phone-in-system where the stage of the river is provided upon request. The site does not have telemetry and does not receive routine calibration measurements. Periodic on-demand measurements occur at the site as the water commissioner calls for them. The data record from this gage was not used in this analysis due to the high probability of error, missing data, and opportunity for misinterpretation of conditions within the basin.

Ventero Creek below Sanchez is an administrative gage measuring the flow released from Sanchez Reservoir (Figure 5-7). This record provides an opportunity to evaluate a gage that has not been periodically inspected and does not currently receive routine discharge measurements. This gage is located at a standard 10-foot Parshall flume and is currently operated with a variable shift curve (2402004AVS-18-1) applied April 26, 2018 and was last verified by a measurement dated April 25, 2018. A variable shift curve is used to define shifts that vary with stage. The variable shift curve appears to have been developed to apply a -0.05 ft shift above a stage of 0.90 ft and a 0.00 ft shift at a stage of approximately 0.56 ft to fit the measurement made April 25, 2018. The resulting variable shift curve shows a 9.03 percent difference from the standard 10-foot Parshall Flume rating at a discharge of 29.2 cfs. At this site, historical measurements above and below 30 cfs showed shifts between 0.00 ft and -0.02 ft (Table 5-1), so a -0.05 ft shift is greater than any shift historically observed. While conditions may have existed that resulted in the greater shift, it is unknown to the author if this change also affected lower discharges, if it was temporary from changes in approach conditions or algal growth, or if the measurement was an error. The use of the variable shift curve does not align with the historical measurement, and this curve needs to be further verified and potentially adjusted.

Figure 5-7 Ventero below Sanchez Reservoir gaging station.

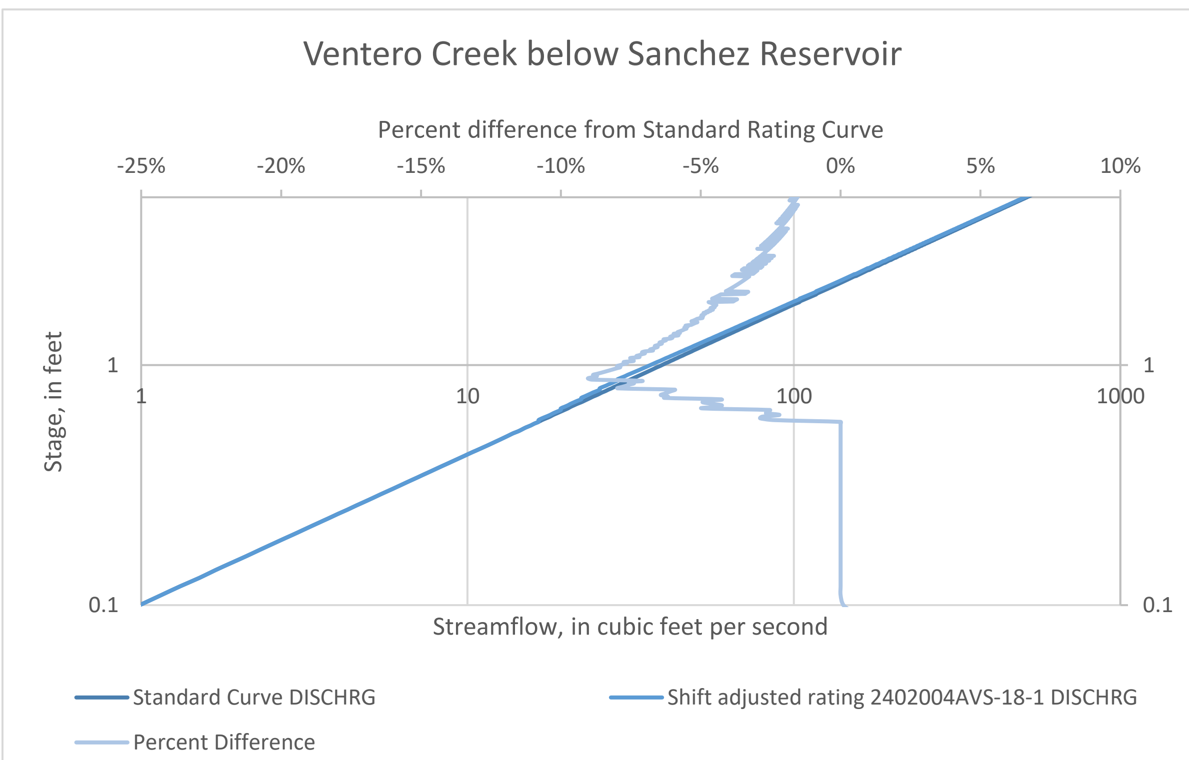


Figure 5-8 Comparison of variable shift curve for Ventero Creek below Sanchez Reservoir and standard rating curve.

Table 5-1 Measurements from Ventero Creek below Sanchez Reservoir downloaded from Colorado Decision Support System November 17, 2021. Percent difference for all measurements was not stated, and all measurements were made with the 0.6 method.

Measure Date Time	Channel Width (ft)	Section Area (sq ft.)	Mean Velocity (ft/sec)	Gage Height (ft)	Discharge (cfs)	Shift Adjustment (ft)	Measure Sections (count)
6/15/2011 10:08	12.8	26.8	4.22	1.92	113	0.01	26
8/16/2011 12:23	12.9	15.3	3.12	1.13	47.7	0	24
4/25/2012 12:40	12.0	9.58	2.73	0.77	26.2	0	25
5/31/2017 10:54	15.1	17.3	2.48	1.07	42.9	-0.02	27
5/31/2017 12:19	15.0	20.8	2.76	1.29	57.5	-0.02	26
5/31/2017 13:06	15.0	8.82	1.7	0.55	15.0	0	27
4/25/2018 13:31	14.3	13.8	2.2	0.90	30.3	-0.05	27

Table 5-1 Measurements from Ventero Creek below Sanchez Reservoir downloaded from Colorado Decision Support System November 17, 2021. Percent difference for all measurements was not stated, and all measurements were made with the 0.6 method. -- Continued

Measure Date Time	Gage Height Change (ft)	Measure Made By	Meter No	Modified
6/15/2011 10:08	0.01	ACT	Colo49	4/12/2013 10:29
8/16/2011 12:23	0	DSV	P112	4/12/2013 10:28
4/25/2012 12:40	0	LDC	P103	4/12/2013 11:05
5/31/2017 10:54	0	LAM	P3425	6/8/2017 8:29
5/31/2017 12:19	-0.02	LAM	P3425	6/8/2017 8:17
5/31/2017 13:06	0	LAM	P3425	6/8/2017 8:25
4/25/2018 13:31	0.01	LAM	F1724013	4/26/2018 8:10

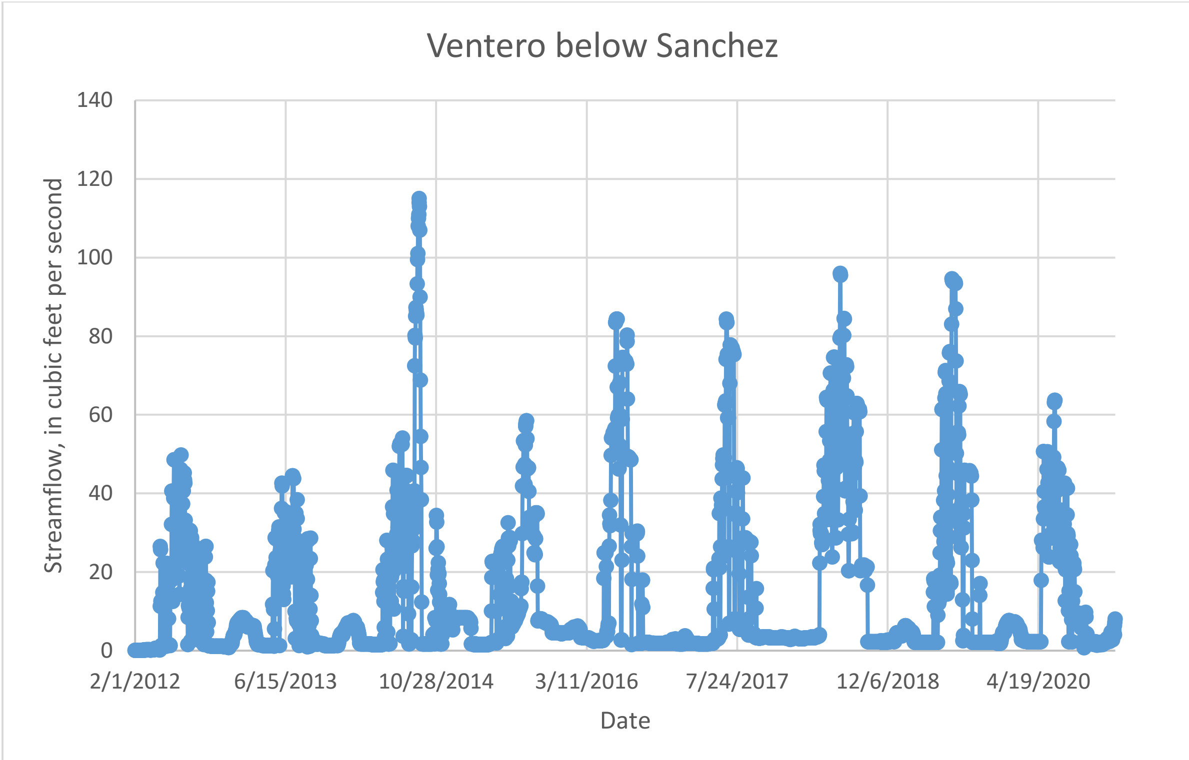


Figure 5-9 Ventero below Sanchez Reservoir February 1, 2012, to December 31, 2020. Maximum mean daily discharge 115 cfs, gage record un-reliable in the winter minimum not calculated.

Conditions in the lower basin were evaluated by using the flood frequency data from Culebra at San Luis (CULSANCO) (Table 5-2). The streamflow in Culebra Creek is impacted by upstream diversions including diversions for irrigation and for storage.

Table 5-2 Annual peak streamflow for Culebra at San Luis. Peak streamflow downloaded from Colorado Decision Support System August 19, 2021.

Water Year	Max Streamflow, Q, (cfs)	Water Year	Max Streamflow, Q, (cfs)
1991	137	2006	129
1992	165	2007	189
1993	195	2008	156
1994	172	2009	135
1995	229	2010	133
1996	148	2011	140
1997	168	2012	99.6
1998	168	2013	128
1999	173	2014	141
2000	152	2015	121
2001	156	2016	114
2002	148	2017	139
2003	244	2018	118
2004	133	2019	115
2005	221	2020	109

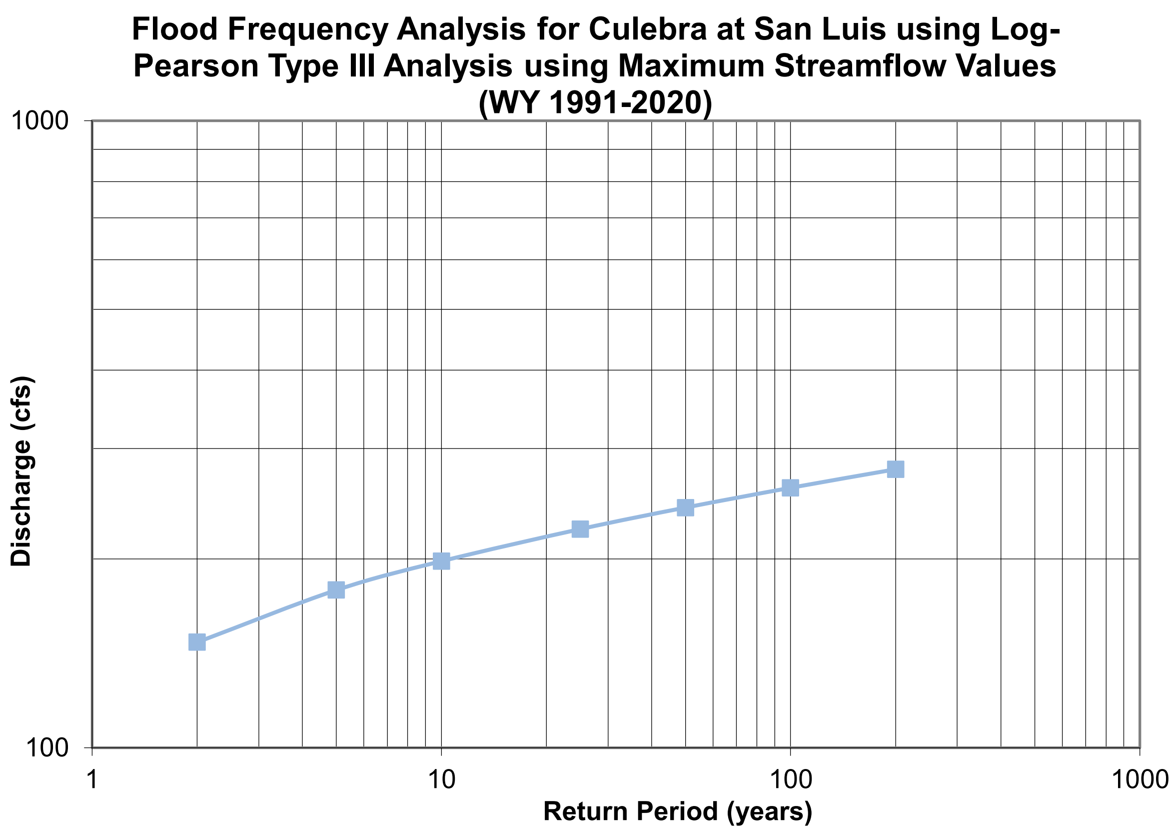


Figure 5-10 Flood frequency graph for Culebra at San Luis. Weighted skew coefficient 0.292.

Table 5-3 Flood frequency analysis for Culebra near San Luis. Weighted skew coefficient 0.292.

Return Period	Exceedance Probability	Q (CFS)
2	0.5	147
5	0.2	178
10	0.1	198
25	0.04	223
50	0.02	242
100	0.01	260
200	0.005	278

The analysis for the Culebra near San Luis gage shows the impacts from upstream diversions with the estimated 200-year return period streamflow equal to less than half of the 2-year return period streamflow (Table 5-3 and Figure 5-10).

5.4.1.1 Estimated Naturalized Streamflow

For some analysis including channel sizing and recommendations, it is often helpful to understand to what degree the hydrology has changed. To start to provide an estimate of the unmodified hydrology flood frequency analysis was also performed on the maximum daily diversions from the sum of the diversion records available within the basin (Table 5-4). Considering that all the water within the basin is used, the sum of the diversions estimates the streamflow in the lower basin, assuming the absence of all diversions. While there will be errors associated with this assumption by not accounting for errors in diversion records or additional diversions from return flows this analysis provides a starting point for evaluating streams that are formed over periods of time on geologic scales. These two different data sources were utilized to compare the current hydrology within the lower basin to an estimate of what the hydrology would be without the diversions. These analyses can be used to evaluate the floodplain connectivity within the reaches, i.e., when water starts to leave the channel, and compare historical conditions and the probable geomorphic parameters (Bankfull width and area) that would have corresponded to the historic hydrology.

To complete this daily diversion analysis, records for all structures were downloaded in a JSON file format, and all pipelines and ditch records were combined using a python script. The maximum daily diversions from 1975 to 2020 were analyzed using the same flood frequency analysis on CULSANCO. The 2-year peak discharge from this analysis was 443 cfs and the 200-yr peak discharge was 1420 cfs (Figure 5-11 and Table 5-5), three times and five times the gage analysis, respectively. This evaluation can be applied to evaluate geomorphic parameters such as Bankfull area and floodplain connection. The streamflows presented in the analysis below should be used with caution due to the errors associated with the collection of ditch diversion records but are more representative of flows in the absence of diversions and an estimate of the historic flows that formed the lower Culebra channel.

Table 5-4 Ranked annual maximum daily diversions by ditches and pipelines.

Rank	Water Year	Maximum Daily Diversion (cfs)	Rank	Water Year	Maximum Daily Diversion (cfs)
1	1979	1028	24	1991	466
2	1995	977	25	2001	465
3	2005	904	26	1978	462
4	1985	829	27	2014	412
5	1983	817	28	1982	388
6	1987	798	29	1975	379
7	1994	773	30	2004	363
8	1984	725	31	1990	341
9	1993	704	32	2009	330
10	1997	701	33	2000	305
11	2010	694	34	2020	290
12	1980	669	35	1981	289
13	2017	633	36	1989	288
14	2007	587	37	1988	282
15	1999	566	38	1996	260
16	2015	559	39	2012	246
17	2016	532	40	1976	239
18	1998	527	41	2006	217
19	1986	524	42	2013	215
20	1992	519	43	2011	194
21	2003	487	44	1977	190
22	2019	486	45	2018	149
23	2008	478	46	2002	148

Table 5-5 Flood frequency estimated from annual maximum daily diversions by ditches and pipelines.

Return Period	Exceedance Probability	Annual Maximum Daily Diversion (cfs)
2	0.5	443
5	0.2	669
10	0.1	819
25	0.04	1008
50	0.02	1147
100	0.01	1284
200	0.005	1420

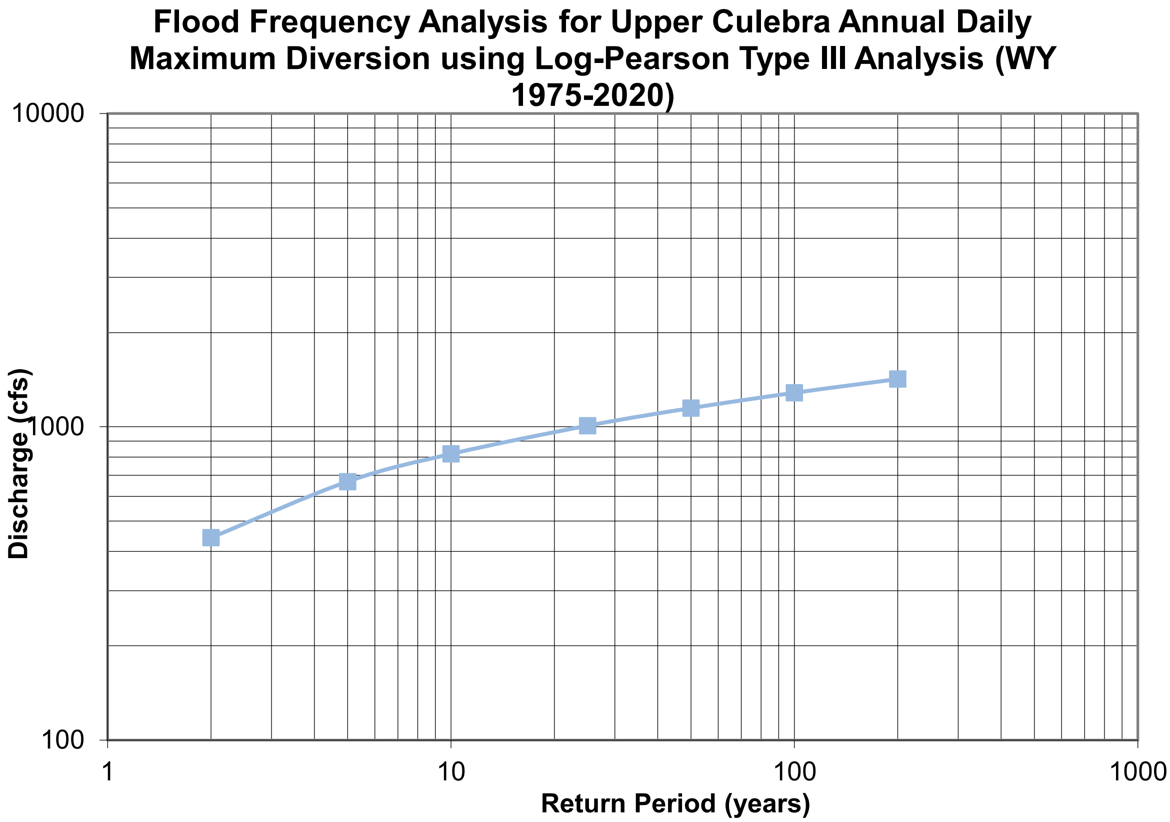


Figure 5-11 Estimated flood frequency estimated from annual maximum daily diversions by ditches and pipelines. Weighted skew coefficient -0.264.

5.4.2 Diversion Records

Evaluation of individual diversion structures from the infrastructure assessment and flow regimes assessment are combined and summarized in Chapter 6 of this report. A table summarizing the number of active diversion structures and current decreed water rights is provided in Table 5-6, accessed March 31, 2020.

Table 5-6 Water Division 24 diversion structure water sources and number of structures diverting from each source, 80 total structures. Accessed March 31, 2021.

		Direct, in cubic feet per second			Storage, in acre-feet		
Water Source	Number of Active Diversion Structures	Total Net Absolute Rights	Total Net Conditional	Net Alternate Point/ Exchange	Total Net Absolute Rights	Total Net Conditional	Net Alternate Point/ Exchange
CUATES CREEK	7	13.5000	0	4	5.25	0	0
CULEBRA CREEK	34	719.2283	0	0	103,190	0	0
EL POSO CREEK	4	3.8800	0	0		--	
EL RITO DE ABAN	1	6.0000	0	0		--	
JAROSO CREEK	4	4.9400	0	7.88		--	
PUERTESITO CREEK	1	1.0000	0	0		--	
RITO SECO	6	34.1100	0	0	133.25	0	0
SAN FRANCISCO CREEK	10	33.0250	0	0		--	
TORCIDO CREEK	1	15.8700	0	0		--	
VALLEJOS CREEK	8	35.1400	0	0		--	
VENTERO CREEK	4	3.2500	1.5	0		--	
Total	80	869.9433	1.5	11.88	103,328.50	0	0

The Colorado Division of Water Resources maintains the diversion records for the state of Colorado. Water in the Culebra Basin is listed as being diverted from the 12 creeks, as shown in Table 5-6. All streams are tributaries to Culebra Creek except Costilla Creek, which receives water from Culebra Creek through diversions but is not within the Upper Culebra Watershed. A meeting with Tom Stewart, current District 24 water commissioner, was conducted on August 19, 2021, to discuss the conditions within the basin. Representatives from the assessment team also visited many of the diversion structures as part of the infrastructure assessment to evaluate the conditions of the structures.

No records for acequia headgates were identified for this assessment. The methods for water distribution within the basin varied from a set number of hours per share rotation method with all shares being served once per month to systems that were operated on a demanding schedule based on users calling for water.

Water storage within the Culebra Basin is primarily in Sanchez Reservoir, and Salazar Reservoir No 1, Salazar Reservoir No. 2, and Cuates Creek Pond. There are four additional "storage" facilities within the Battle Mountain Mine property that are part of the Battle Mountain Gold Augmentation Plan and related to historical ore processing and reclamation. Numerous other small ponds and water impoundment areas were noted during the field assessment.

Records for all ditches and pipelines were combined to evaluate overall diversions within the basin and any noticeable trends. The total daily diversions are shown in Figure 5-12. These records were combined to determine the annual total diversions shown in Figure 5-13. A trend line analysis of this data from 1950 to 2020 would indicate an overall increase in water available within the basin. However, closer inspection of individual diversion structures reveals many diversion structures don't have records of diversion in the 1970s. Plotting the trend of the records from 1975-2020 shows a declining trend in annual diversions. This analysis only evaluates irrigation season diversions and does not account for non-irrigation season diversions that were frequently not recorded because there was no active call.

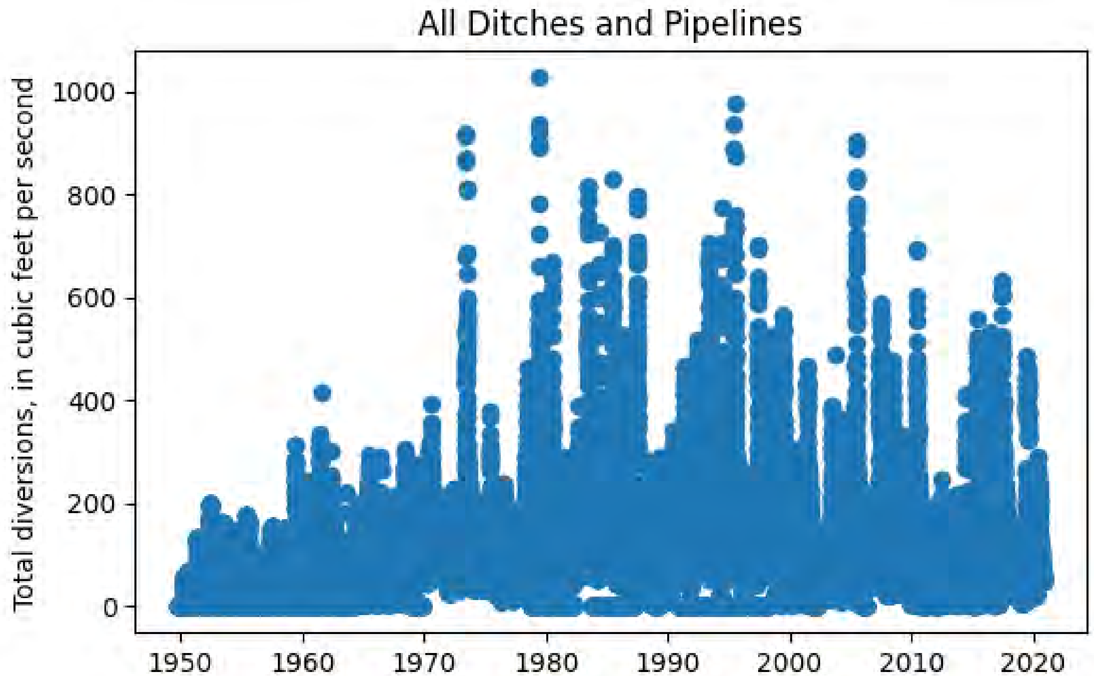


Figure 5-12 Daily sum of all recorded diversions by ditches and pipelines in district 24. The maximum daily diversion within the system is, 1,028 cfs for the period 1950 to 2020.

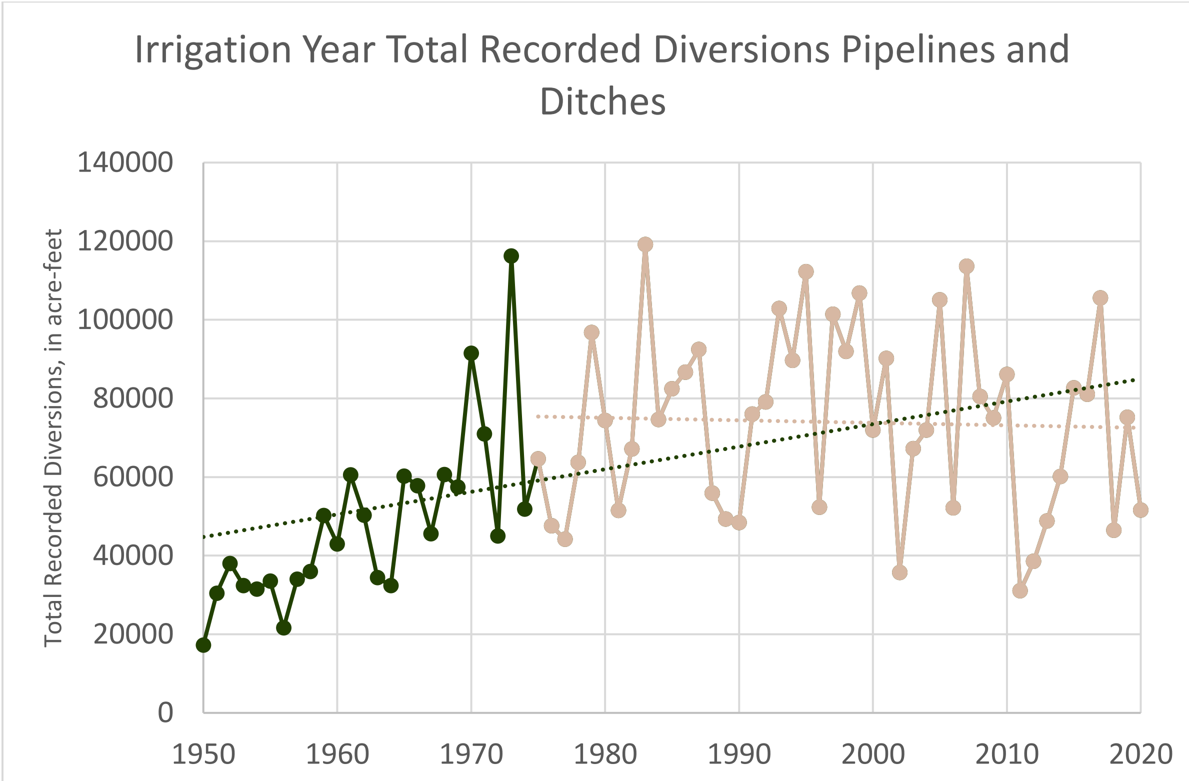


Figure 5-13 Irrigation year total recorded annual diversions in pipelines and ditches with daily records (CDSS, 2021).

Available ditch measurement records were requested and supplied by the Colorado Division of Water Resources in April 2020 (Hardesty, 2020). The data provided is summarized in Appendix 6.A. When measurements are made at a measurement structure that has an existing stage-discharge rating curve/table (i.e., flume standard curve or one developed for the station) the measurement structure is "calibrated" by determining the shift. The shift is the difference between stage from the rating table that equals the measured discharge and the actual stage. With this shift, a person needing to know how much water passes the structure can read the staff gage, apply the shift, then read the discharge from the rating table. Shifts at Parshall flumes typically result from the flume being unlevel; either side to side or front to back; the flume being submerged; algae or debris within the inlet or actual flume. Shifts can also result from flumes that do not have vertical sidewalls, such as the old San Francisco Ditch flume. Ideally, a measurement structure would be verified that the structure is level and clean before diversions being made for the season and if any conditions are noted that might affect the structure, a calibration measurement should be made. If through subsequent calibration measurements, a consistent trend in shifts is not identified, additional actions by the water user(s) may be necessary to stabilize the structure so that it is ratable. A ratable structure has a single discharge for a given stage.

The record of calibration and verification measurements includes 72 measurements at 22 structures from 2012 to 2019. It is noted that this record only includes measurements that were recorded electronically in DWR databases and not measurements filed directly. In 2019 only Culebra Eastdale Ditch and Jacquez Ditch were measured; Jacquez Ditch did not have a recorded stage. In 2018 only two measurements were made only within the San Pedro Ditch and Culebra Eastdale Ditch.

As part of the assessment each water source within the Upper Culebra watershed was evaluated individually, including mapping the location of diversion structures, and evaluating diversion records from each of the water sources.

5.4.2.1 Alamosito Creek

Alamosito Creek is a major tributary to San Francisco Creek above all diversion structures on San Francisco Creek. The creek has three diversion structures. None of the three ditches: Alamosito Ditch, (i.e., Alamosito Ditch Diversion A) (WDID 2400603), East Alamosito Ditch Diversion B1 (WDID 2400606), and East Alamosito Ditch Diversion B2(WDID 2400607) have any diversion records. The first Alamosito Ditch rights were appropriated on June 19, 1969 and appropriated in 2013CW3019. The remaining rights were appropriated June 20, 1991 and adjudicated in case 2014CW3029. The location of each of the Alamosito Creek structures is shown in Figure 5-14.

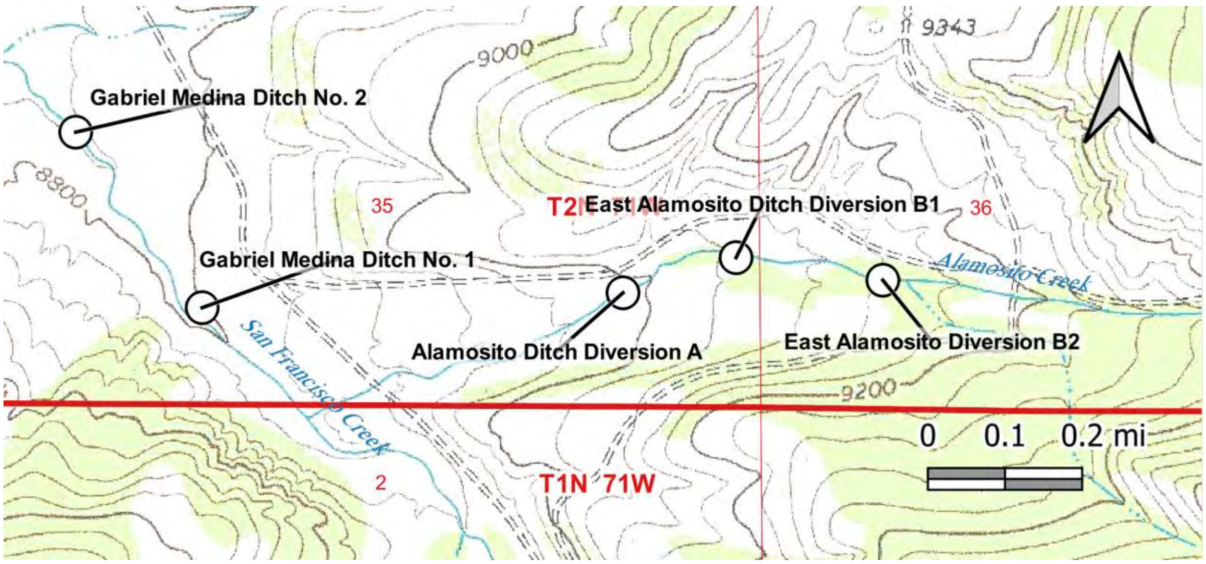


Figure 5-14 Alamosito Creek diversion structures. Background USGS 7.5 minute topo.

5.4.2.2 Cuates Creek

There are seven active ditch and pipeline diversions listed as diverting from Cuates Creek. Six of these structures included records of daily diversions. The last structure, Cuates Creek Pond Supply Pipeline, has only one annual value of volume listed in 2004. The maximum daily recorded total diversions from is 57 cfs (6/29-7/9, 1983) and the maximum daily recorded total diversion from 2000-2020 is 47 cfs (6/2-6/5, 2005). The total recorded daily diversions are plotted in Figure 5-15, and the structure locations are shown in Figure 5-16.

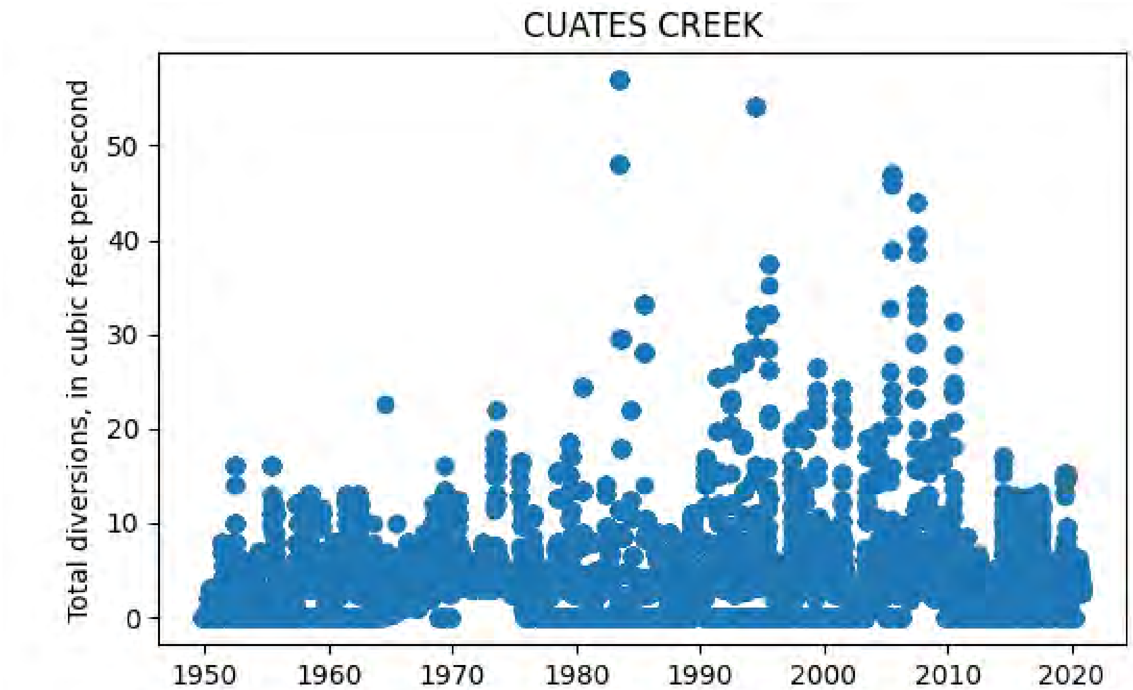


Figure 5-15 Total recorded diversions from Cuates Creek 1950-2020.

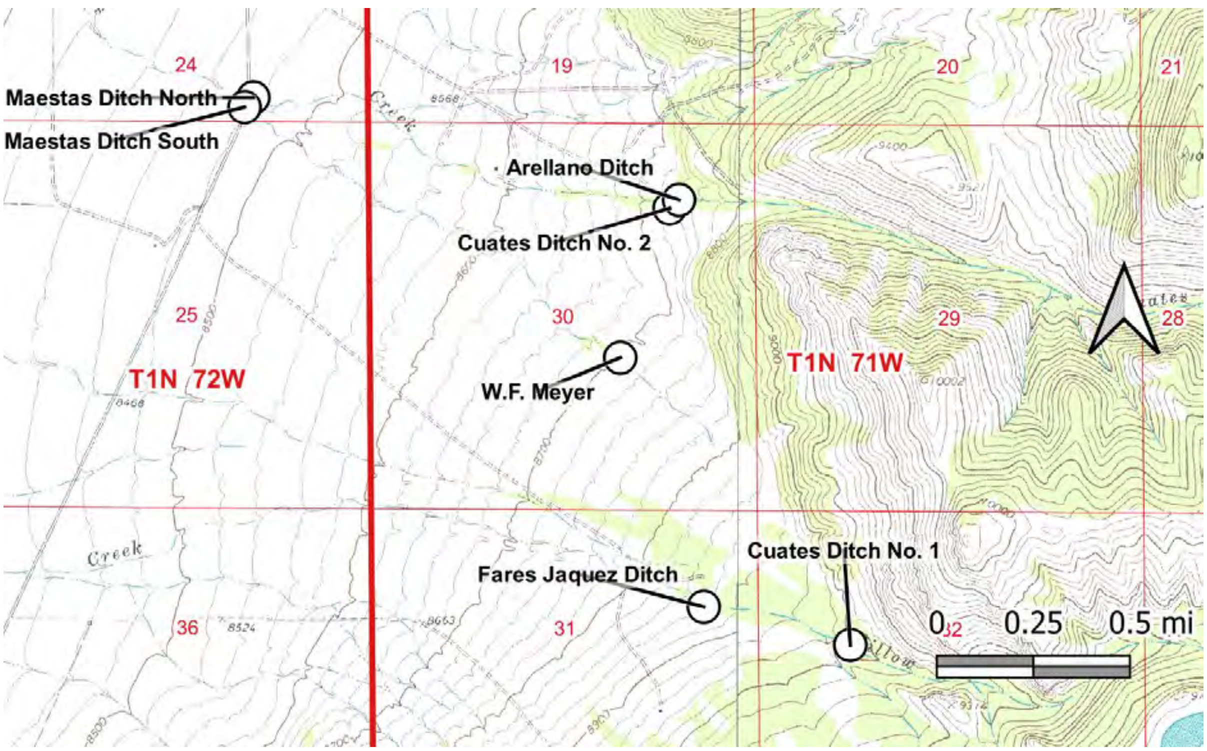


Figure 5-16 Cuates Creek diversion structures. Background USGS 7.5 minute topo.

5.4.2.3 Culebra Creek

There are currently 34 active diversion structures diverting water from Culebra Creek. There are 25 structures with records of diversion from Culebra Creek. The total maximum daily diversions recorded for these structures was 930.9 cfs, June 15, 1979, and the maximum total daily diversion from 2000 - 2020 was 781 cfs May 24, 2005. The recorded total daily diversion records for Culebra Creek are plotted in Figure 5-17. The structure location map is divided into three areas, the upper reach extends from the headwaters to the Cerro, the middle reach, which starts above the Cerro at Culebra Sanchez Canal and extends down to la Vega; and the third reach, which includes those structures below San Luis.

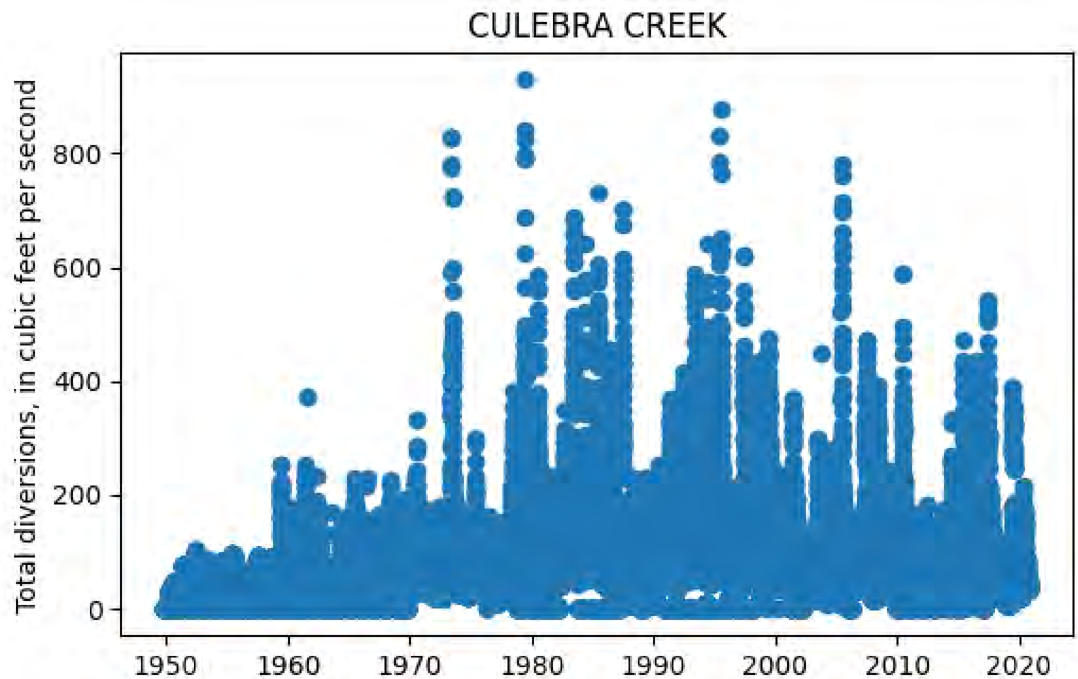


Figure 5-17 Recorded total daily diversions from Culebra Creek 1950-2020.

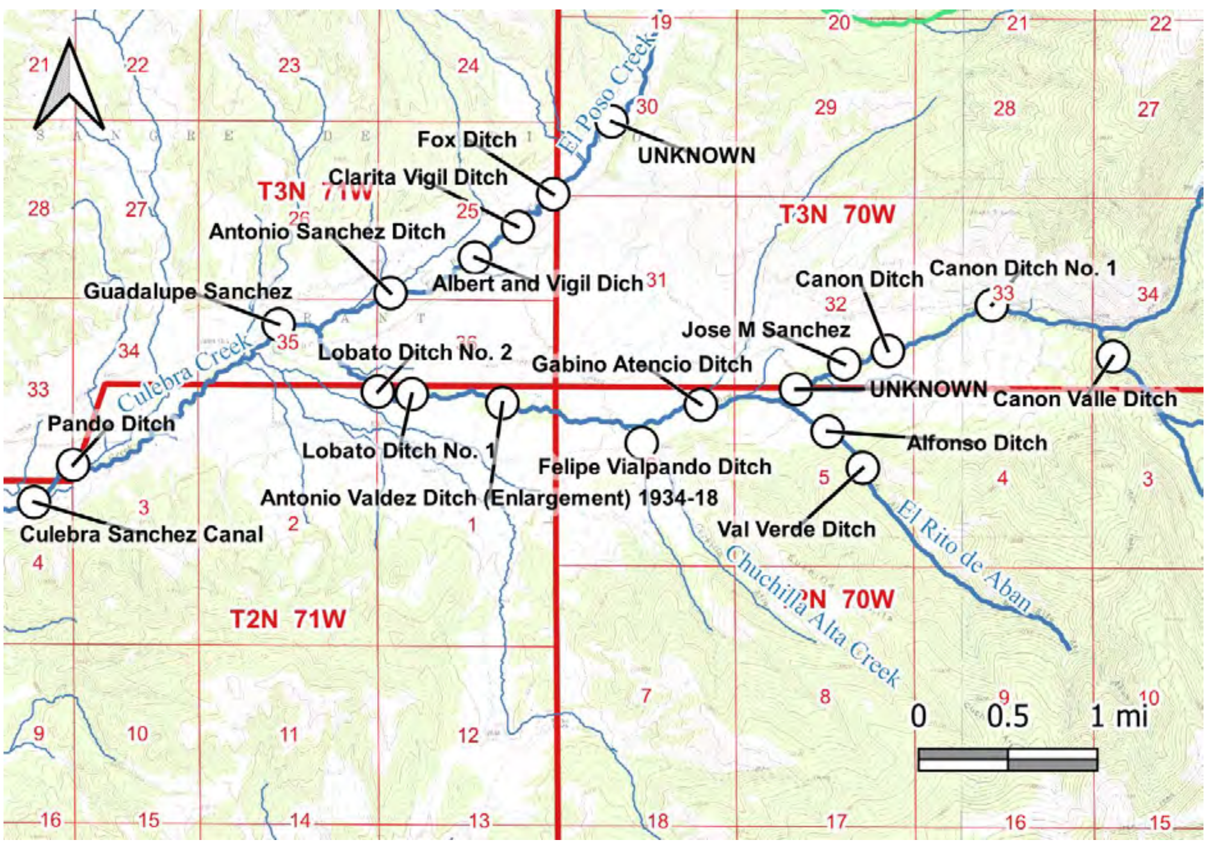


Figure 5-18 Upper Culebra Creek structures including El Poso Creek, Chuchilla Alta Creek, El Valle Creek, El Rito de Aban, and Carneros Creek. Background USGS 7.5-minute topo.

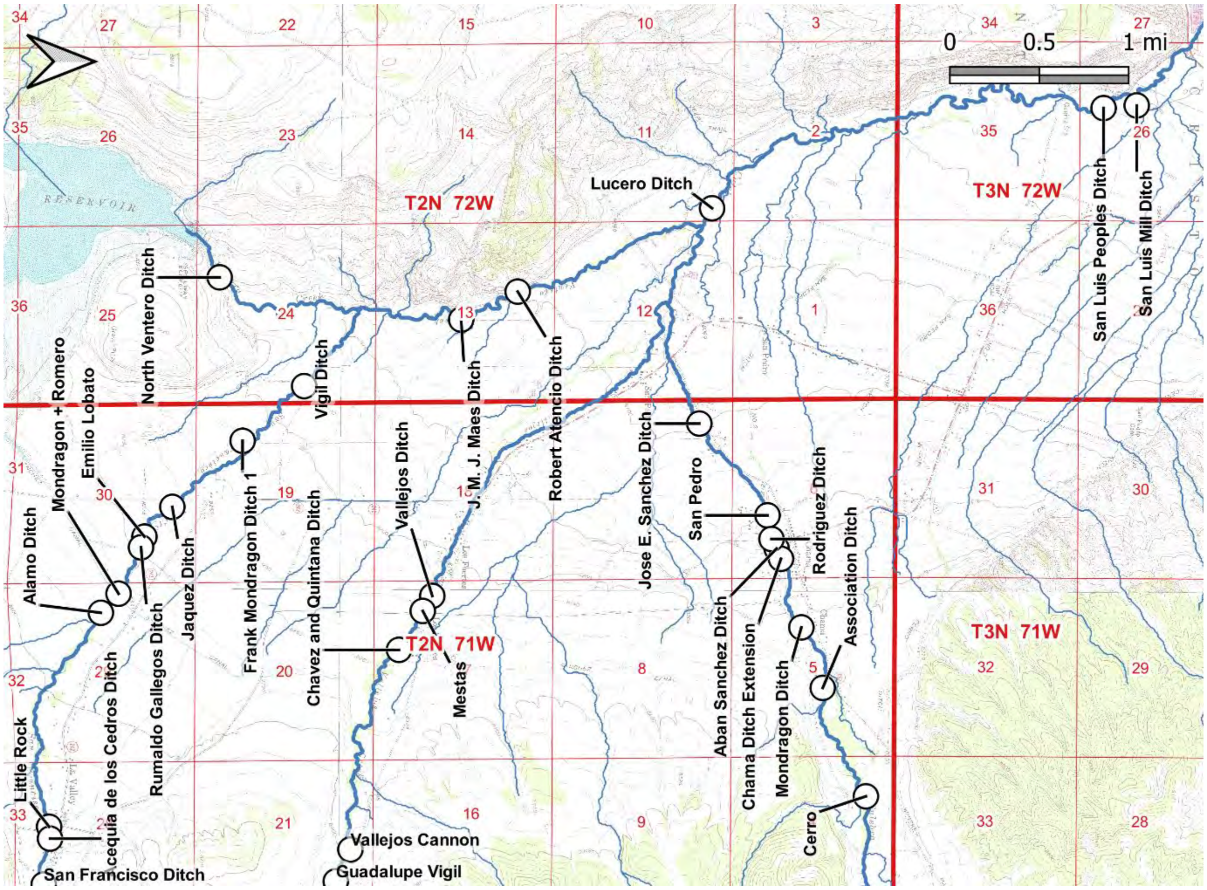


Figure 5-19 Culebra Creek, Vallejos Creek, and San Francisco Creek structures below canyons.

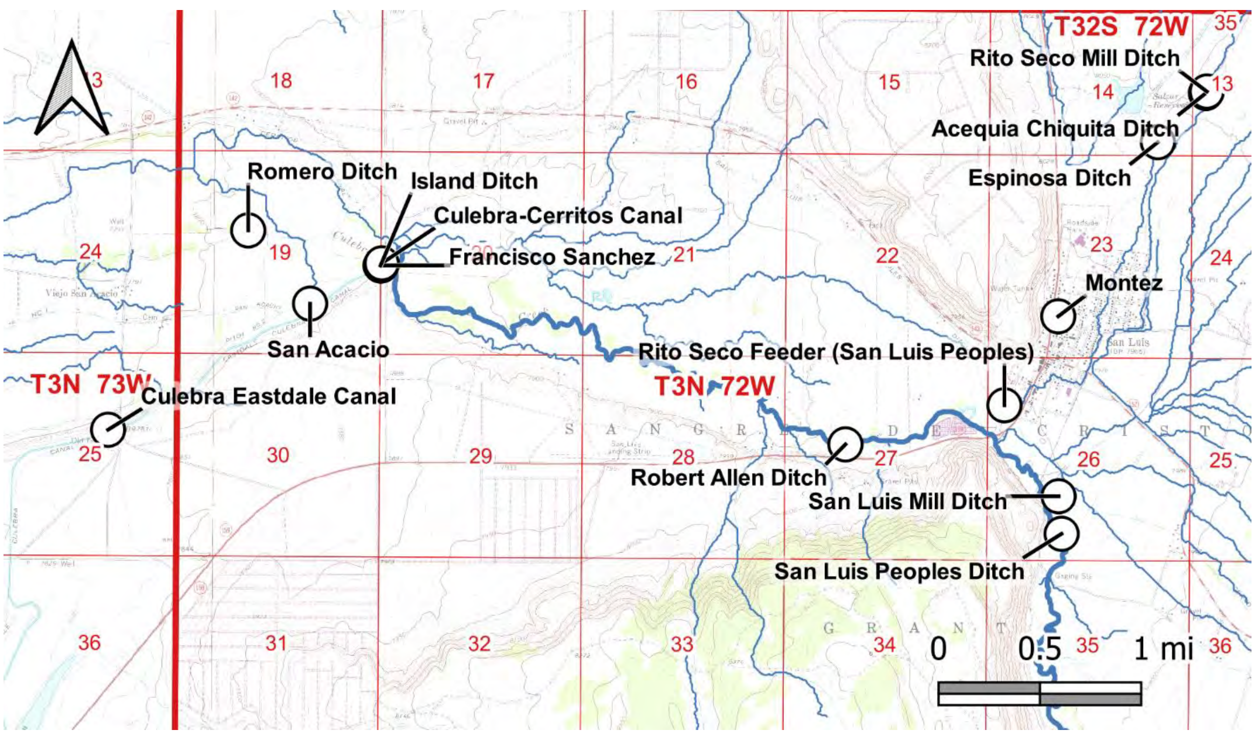


Figure 5-20 Culebra Creek structures below San Luis, Co. Background Google aerial imagery.

5.4.2.4 El Poso Creek

There are four structures listed as active, and there are four structures with records of diversion from El Poso Creek. Fox Ditch (WDID 2400625) was decreed in case 99CW0045. The maximum daily diversion for this creek is 7.12 cfs, June 21, 1993, to June 27, 1993, and the maximum daily diversion from 2000 to 2020 is 6.00 cfs, May 24, 25, and 26, 2004. The El Poso Creek structures are shown with the upper Culebra structures in Figure 5-18.

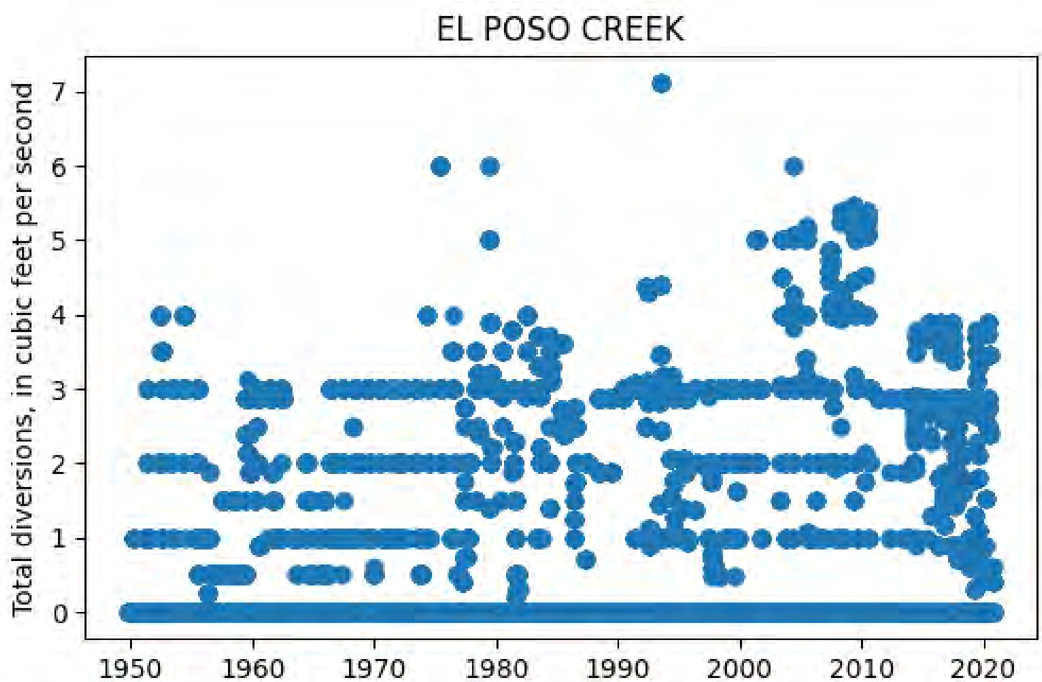


Figure 5-21 Total recorded diversions from El Poso Creek 1950-2020.

5.4.2.5 El Rito de Aban

El Rito de Aban includes one active structure with records, the Alfonso Ditch, and one historic structure, Val Verde Ditch (WDID 2400596) (Figure 5-18). The Val Verde Ditch has records in two years: 1979, which has values greater than 0, and 1989, which has only zero values. Records for the Alfonso Ditch (WDID 2400510) do not begin until 1976. The maximum recorded daily diversion is 11.5 cfs (5/22-6/5, 1979) and the maximum recorded daily diversion from 2000-2020 is 3 cfs (many days).

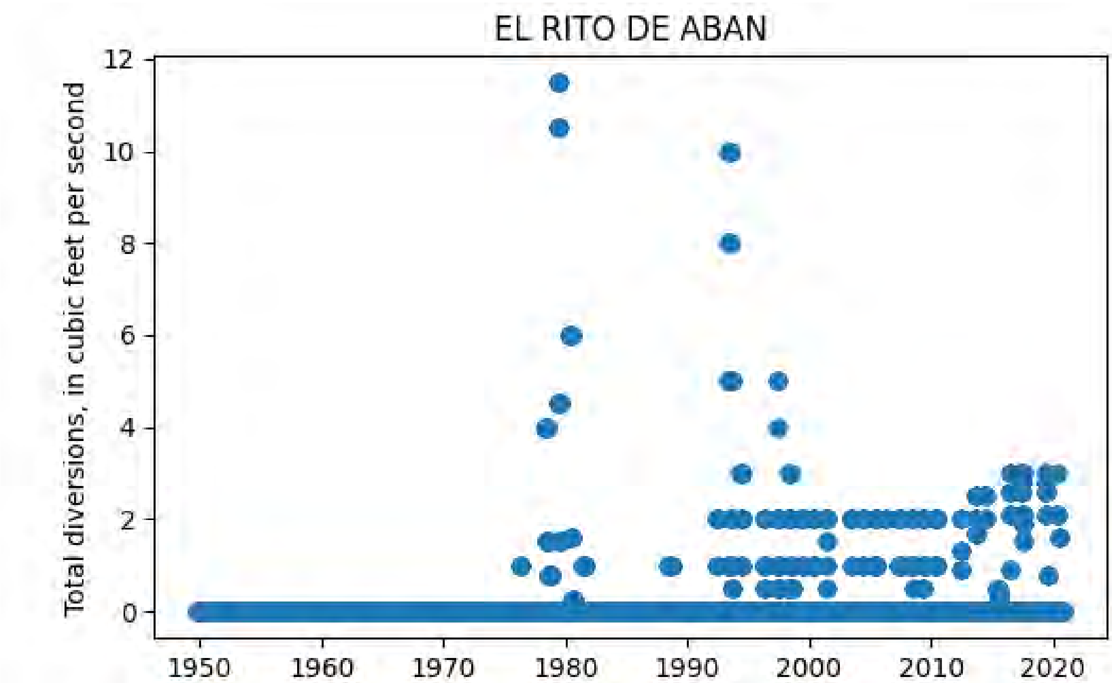


Figure 5-22 Time-series plot of total daily recorded diversions from El Rito De Aban.

5.4.2.6 Jaroso Creek

CDSS shows four active structures, but only two show diversion records. Jaroso Ranch Ditch No 1 and No2 (WDID 2400621 and 2400622) do not have records. These two ditches are shown as alternate points of diversion for the Choury Ditch. Notes indicate that records are maintained for these diversions under WDID 2400555 or 2400527 since there is a common headgate. The recorded total daily diversions are plotted in Figure 5-23. The maximum daily recorded diversion is 11.62 cfs (May 18-25, 1993), and the maximum daily diversion from 2000-2020 is 8.34 cfs (May 16-17, 2005). The locations of the diversion structures are shown in Figure 5-24.

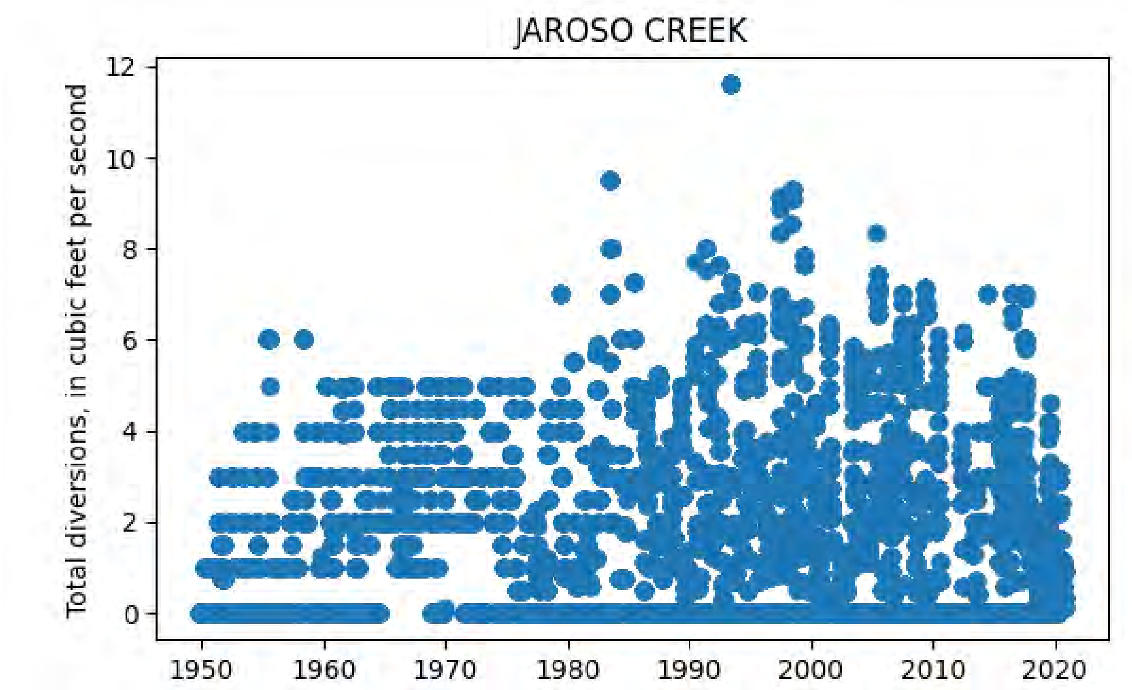


Figure 5-23 Recorded total daily diversions from Jaroso Creek 1950-2020.

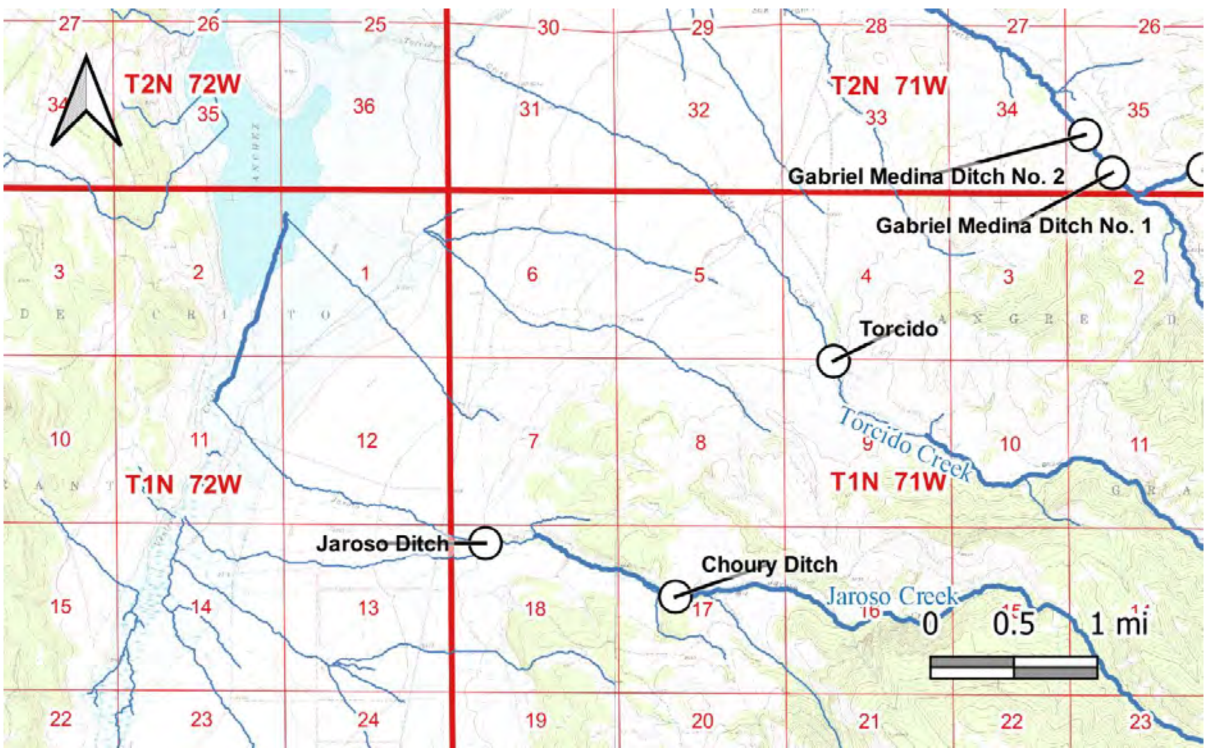


Figure 5-24 Jaroso Creek and Torcido Creek diversion structures. Background USGS 7.5-minute topo.

5.4.2.7 Puertesito Creek

The Jose Lobato Ditch (WDID 2400557) is the only structure that diverts from Puertesito Creek, these records are shown in Figure 5-25. The maximum recorded daily diversion from 1950-2020 is 10 cfs (June 8-21, 1993) and from 2000-2020 is 4 cfs (May 15-19, 2001, and May 24-27, 2005).

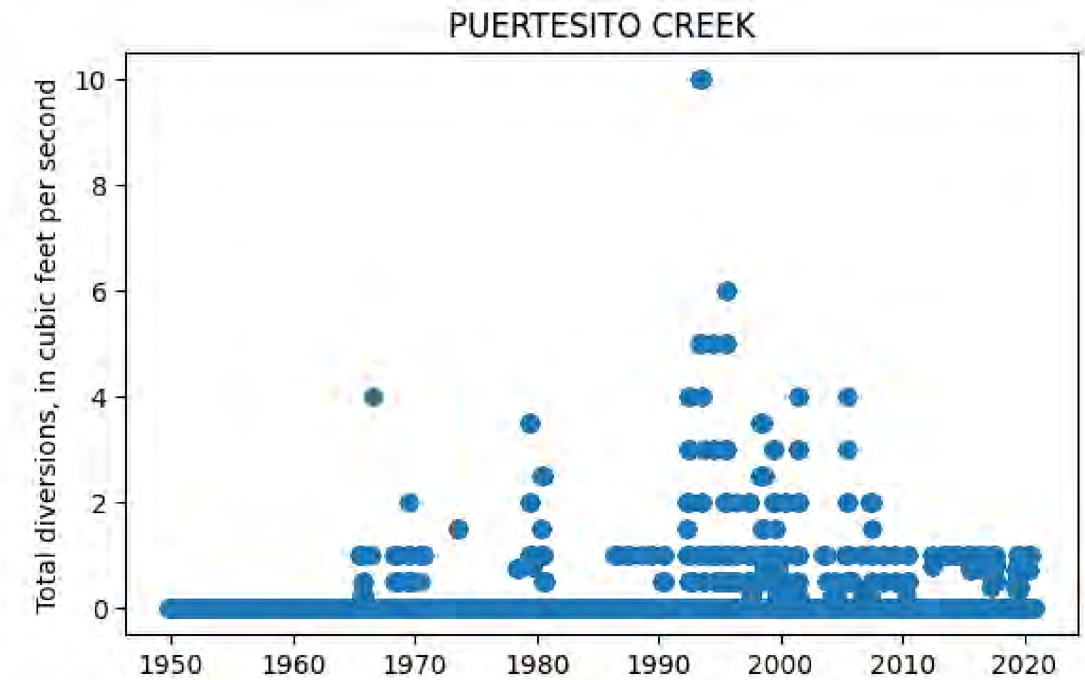


Figure 5-25 Recorded total daily diversions from Puertesito Creek.

5.4.2.8 Rito Seco

Rito Seco is the first major tributary to the Culebra, with the confluence occurring near the Highway 159 bridge just below the town of San Luis. The maximum recorded total daily diversion from 1950-2020 is 26.5 cfs (May 31, 1993) and from 2000 to 2020 is 25.04 cfs (May 16, 2019). A portion of the flows in Rito Seco are treated through the water treatment plant at Battle Mountain Mine. At times the water treatment plant is only operated 3-4 days per week per (Madrid, 2021). Water released to Rito Seco was converted from total daily release in gallons to average release in cubic feet per second and plotted in Figure 5-28. Depending how much water is in Rito Seco, the discharge from the water treatment plant may be a substantial portion of the total flow, and at other times it may be a very minimal contribution.

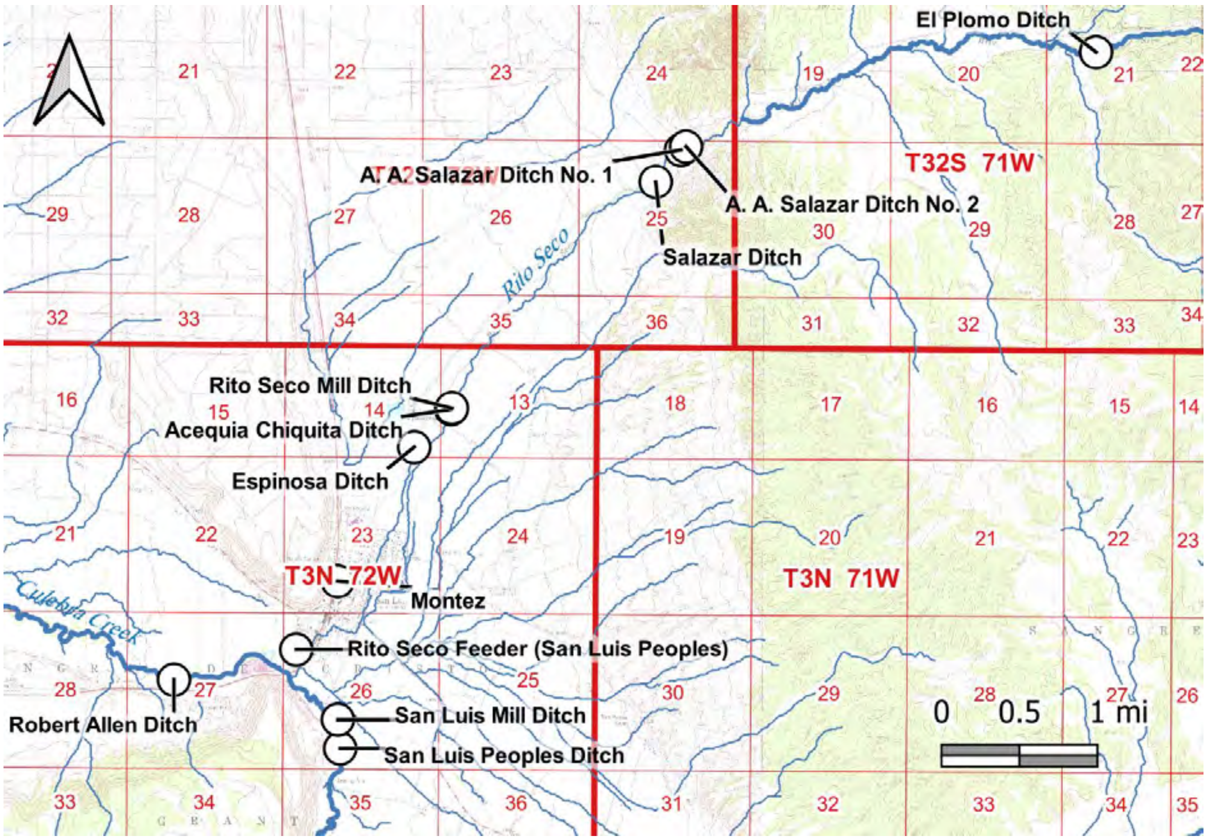


Figure 5-26 Rito Seco diversion structures. Background USGS 7.5-minute topo.

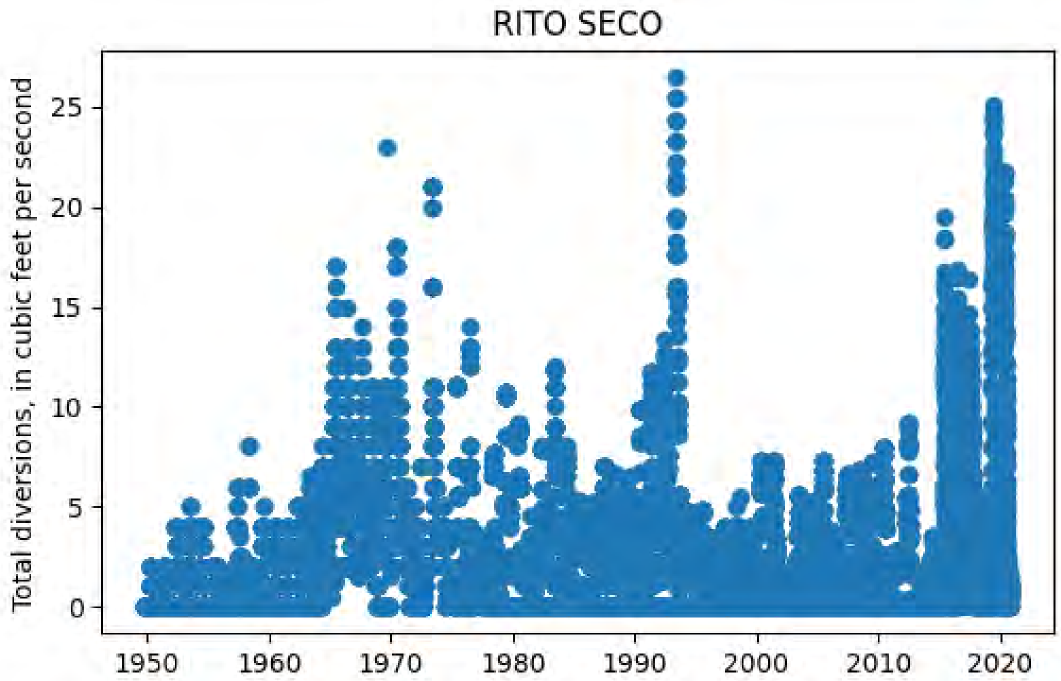


Figure 5-27 Total recorded daily diversions from Rito Seco Creek 1950-2020.

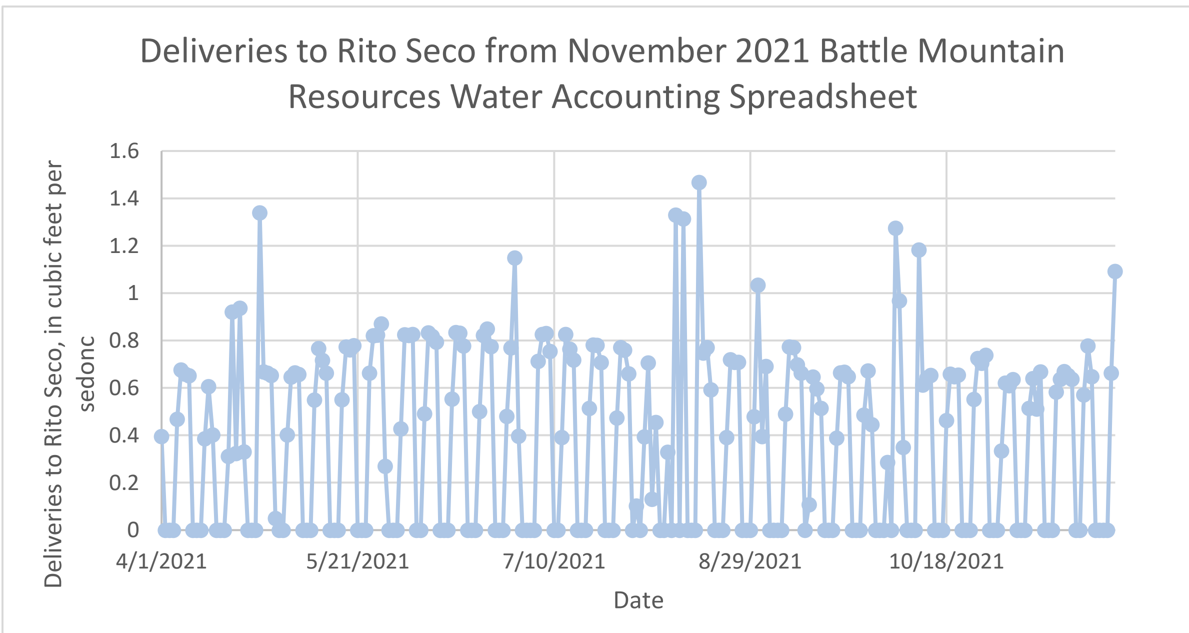


Figure 5-28 Daily Rito Seco deliveries from Battle Mountain Resources, Inc. San Luis Project water treatment plant (Madrid, 2021).

5.4.2.9 San Francisco Creek

Ten structures have records of daily diversions from San Francisco Creek. The maximum recorded total daily diversion for both the 1950-2020 and 2000-2020 period is 57.26 cfs which occurred July 30-August 2, 2003. This high volume of diversions is likely related to an error in the Jacquez Ditch diversion records on these days showing 50 cfs was diverted rather than 0.5 cfs. After adjusting for this likely error, the maximum daily recorded diversions from 1950-2020 is 34.35 cfs (June 21-June 26, 1993) and from 2000-2020 is 31.33 cfs (June 20, 2017). The recorded daily diversions are shown in Figure 5-29, and the structure locations are shown in Figure 5-30.

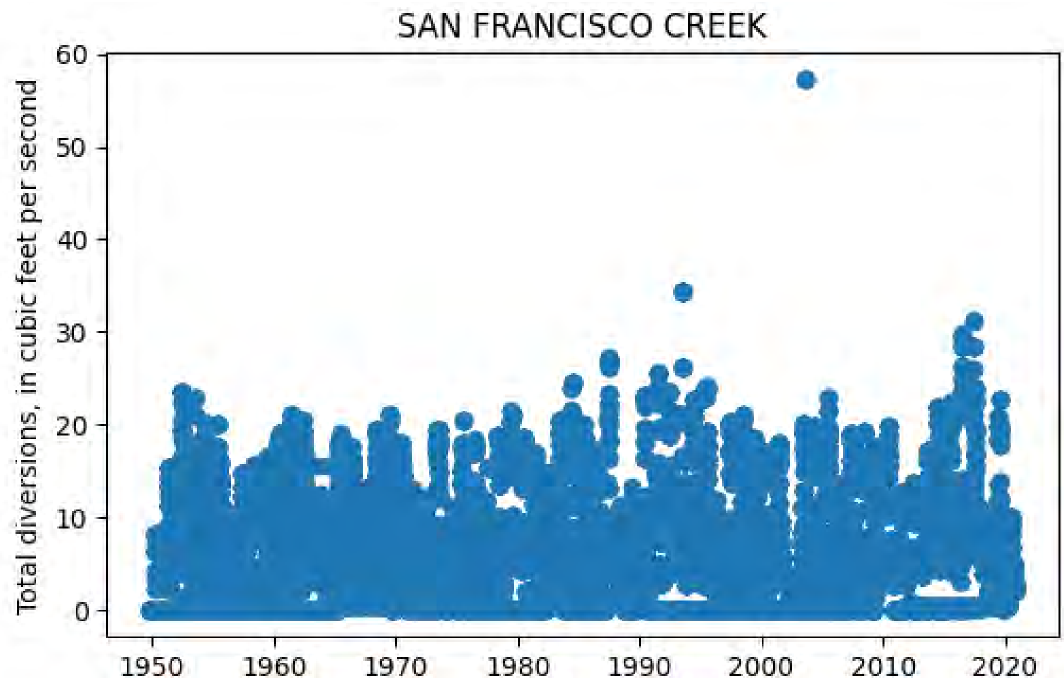


Figure 5-29 Total recorded daily diversions from San Francisco Creek 1950-2020.

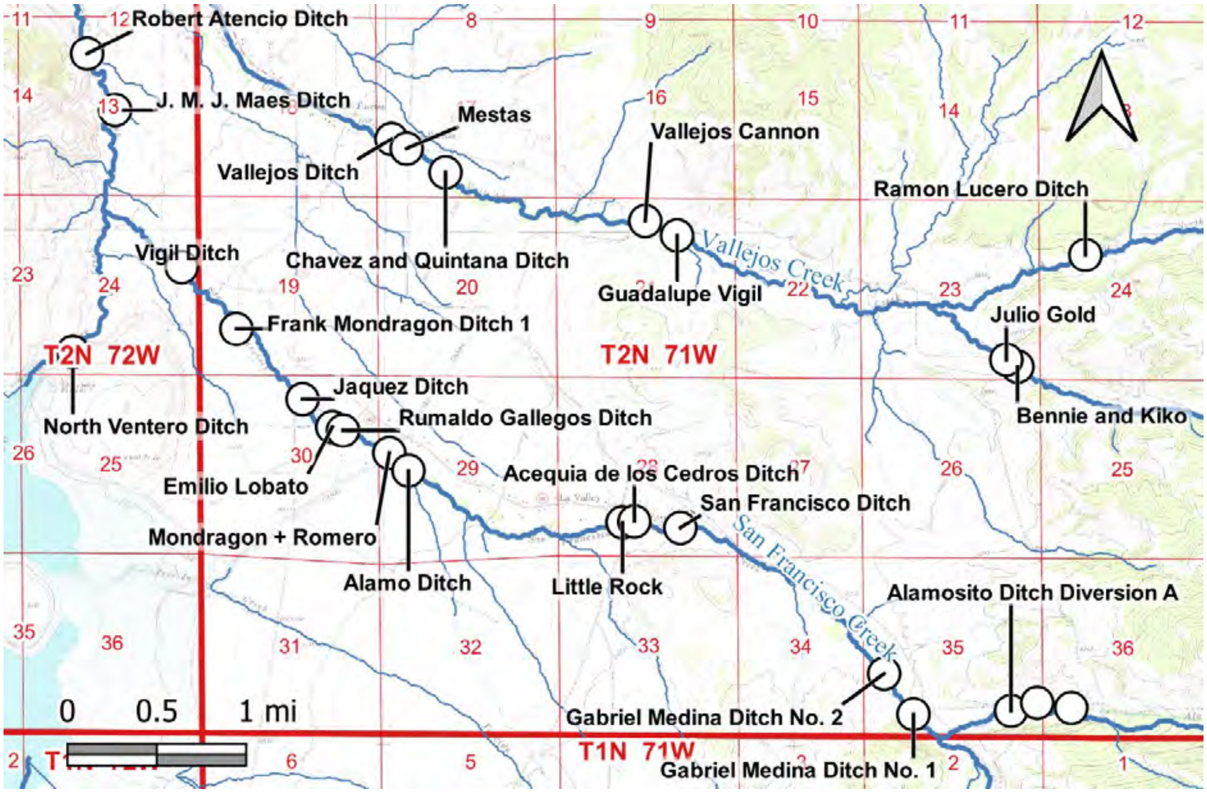


Figure 5-30 San Francisco Creek and Vallejos Creek diversion structures. Background USGS 7.5-minute topo.

5.4.2.10 Torcido Creek

There are two structures with diversion records on Torcido Creek, Torcido Ditch (WDID 2400592) and Abundo Martinez Ditch (WDID 2400609). The EP Medina Ditch (WDID 2400612) is listed as a historic structure with no records, and the Abundo Martinez ditch is also listed as a historic structure but does have records. The maximum recorded daily discharge from 1950 - 2020 is 12.5 cfs (May 26, 1964) and from 2000 - 2020 is 6.11 CFS (May 31-June 4, 2001). The 12.5 cfs is likely an error on this date where 12.5 was recorded rather than 1.25 cfs for the Torcido Ditch. The locations of the Torcido Creek structures are shown in Figure 5-24.

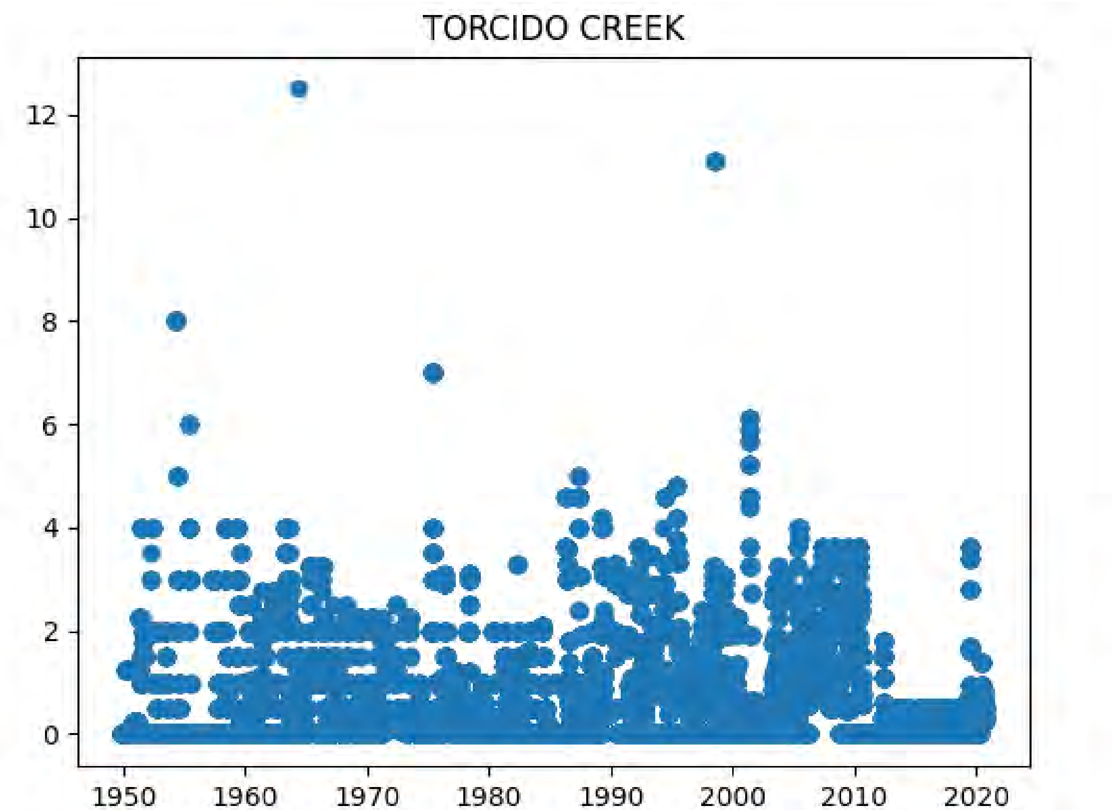


Figure 5-31 Total recorded daily diversions from Torcido Creek 1950-2020.

5.4.2.11 Vallejos Creek

There are eight structures with records on Vallejos Creek (Figure 5-33. The total recorded daily diversions are shown in Figure 5-32. The maximum total recorded daily discharge from 1950-2020 is 32.2 cfs (June 15-June 21, 1984) and from 2000-2020 is 31.85 cfs (June 10-12, 2014). The Vallejos creek structures are shown in Figure 5-30.

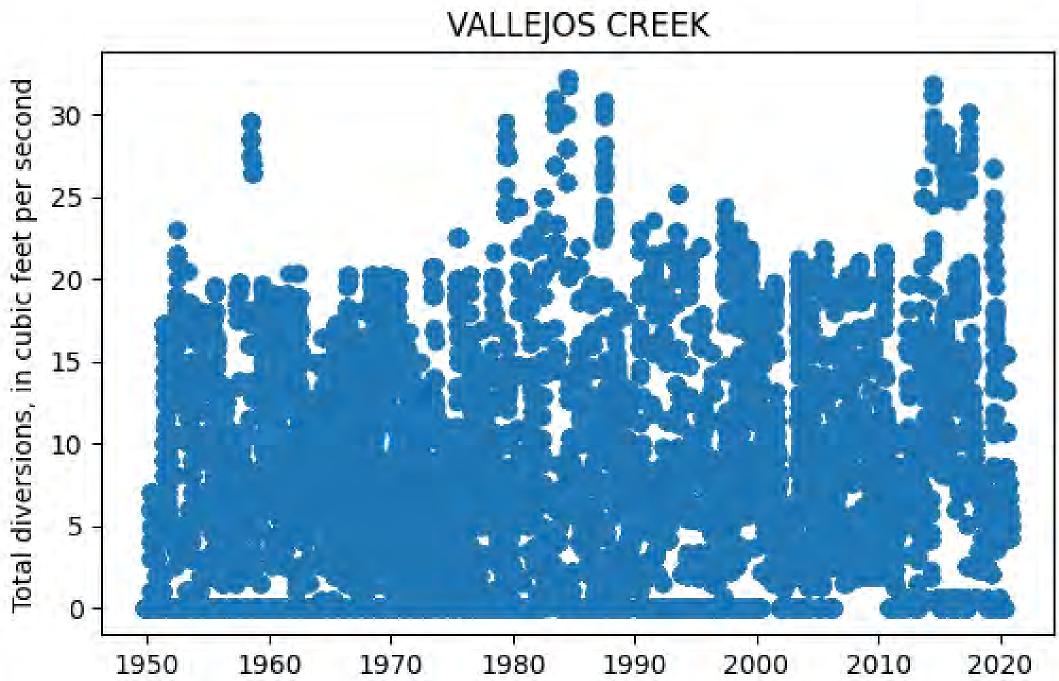


Figure 5-32 Total recorded daily diversions from Vallejos Creek.

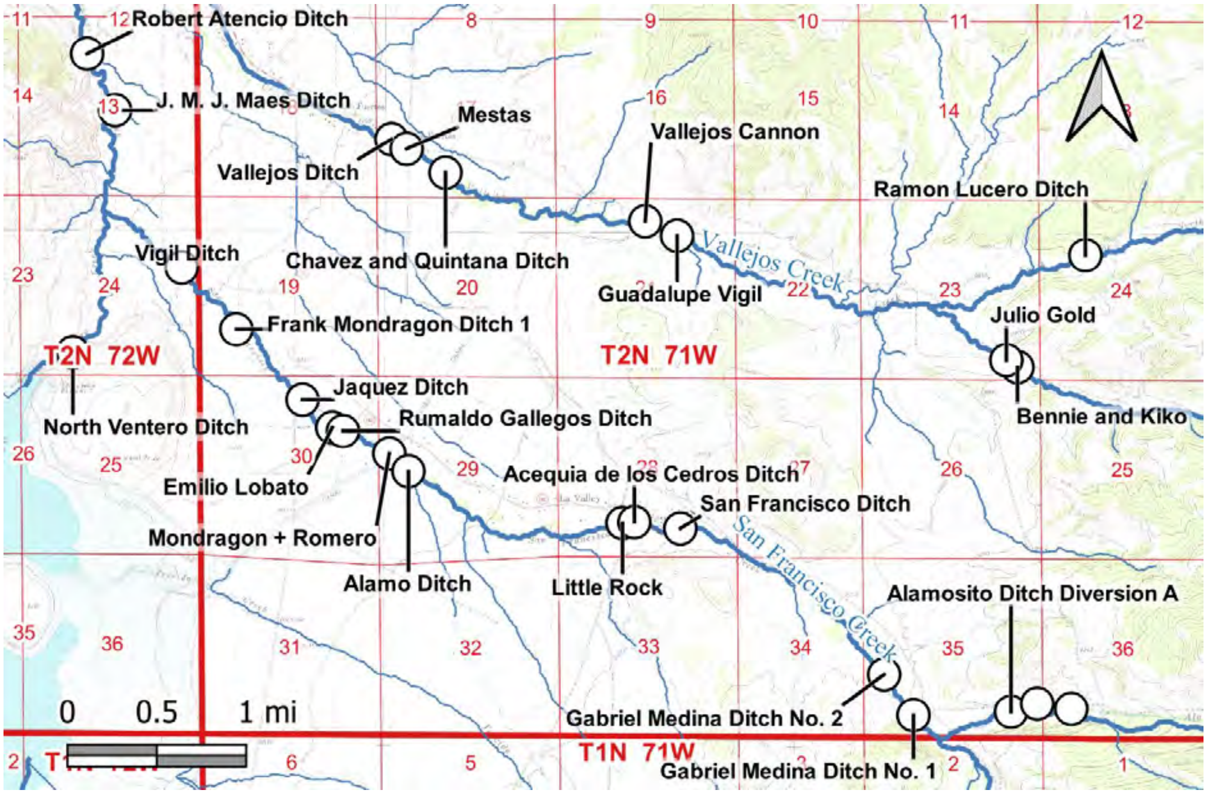


Figure 5-33 Vallejos Creek diversion structures. Background Google Earth aerial imagery.

5.4.3 Dewatered Reaches

Diversion structures that sweep, or divert all the water from the channel, can determine where aquatic habitat may be impacted due to inadequate water. Diversion structures that sweep the rivers and streams include Vallejos Ditch, San Francisco Ditch, San Acacio Ditch, Cerro Ditch. The smaller structures on Jaroso, Cuates, and Willow Creek may also dewater the reaches or naturally dewatered as the water flows over the alluvial fan. The upstream most diversion structure on these creeks may generally be considered the end of fisheries habitat. The reach on Ventero Creek below Sanchez Reservoir is at risk of dewatering due to dam operations. The dewatered areas are shown in Figure 5-34.

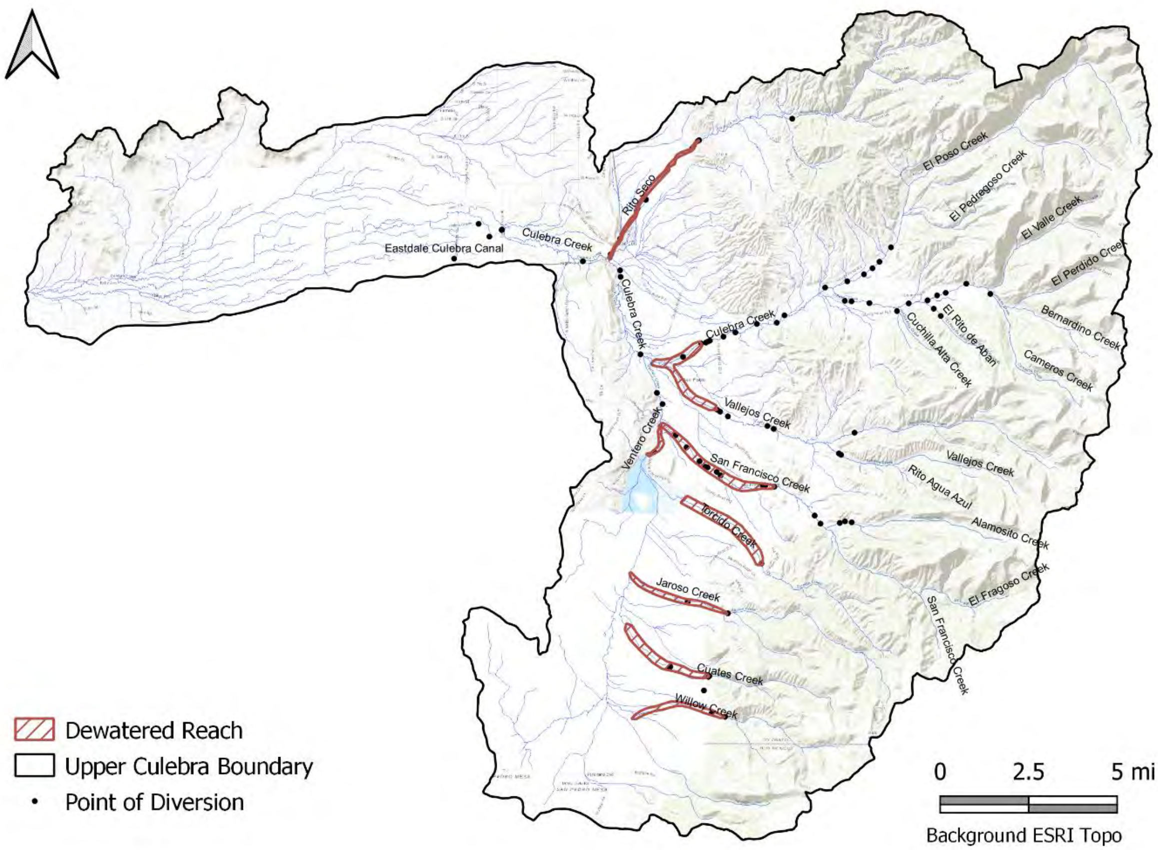


Figure 5-34 Stream reaches where dewatering occurs frequently or is at risk of occurring.

The lowest portion of the Culebra, below the headgate of the San Luis People's Ditch, is maintained because of the delivery of storage water below through this reach and the number 8 priority water right of the San Acacio Ditch.

Moving upstream from the San Luis People's ditch to the confluence with Ventero Creek, this reach benefits from the delivery of water to the number one water right and delivery of storage water.

Torcido, Jaroso, Cuates, and Willow Creeks all travel across vast alluvial fans. Water flowing through these dewatered reaches requires additional modeling and consideration to determine if the hydrology would support perennial flows, it is likely that these reaches were intermittent in recent history, but neither condition was confirmed during the review for this assessment. So while the water rights on these creeks are relatively junior, futile calls, allow the ditches to continue to divert.

San Francisco Creek is dried up by the number 14 water right on the San Francisco Ditch. Because the dry-up is caused by a junior priority water right the lower end of this reach receives summer water more often than the lower ends of Vallejos Creek or Culebra Creek. The impacted areas are expanded by the crossing at Sanchez Canal, which does not divert water during low water, but does allow for additional evaporation and lack of shade and the return flows being blocked by canal banks that could provide return flows to the lower reach.

The lower end of Vallejos Creek is dewatered by the number 5 priority senior water right. This reach receives little water resulting in a very poorly defined channel to the confluence with the Culebra.

The San Pedro ditch dries up the lower end of Culebra Creek from the headgate down to the confluence with Ventero Creek. This reach is often dried up but appears to benefit from some return flows.

5.4.4 Adjudications

Adjudications within district 24 were primarily completed within the first two adjudications started on June 14, 1889, and the second on December 14, 1905. Seventeen additional surface water adjudications have occurred within District 24, with the most recent adjudication on December 31, 2014 (Table 5-7). No adjudications for instream flow rights were identified within the Culebra watershed.

Based on Colorado law, water rights are administered based on adjudication date (court date) and then by appropriation date (when water was first put into use). Structures that have been in use since settlement that was not adjudicated will be a lower priority than a structure that has only been in use since 1900 and was adjudicated December 14, 1905. Because of this, a water user needs to stake a claim to water within the court as soon as possible and not delay.

Table 5-7 CDSS adjudication case numbers associated with surface water structures in CDSS database accessed November 4, 2021.

Adjudication Date	Associated Case Number
6/14/1889	06/14/1889
12/14/1905	12/14/1905
2/11/1935	CA0885
7/23/1951	CA1249
12/31/1971	W0197
12/31/1973	W3147
12/31/1974	W3366
12/31/1975	W3403
12/31/1977	W3760
12/31/1984	W3367

Adjudication Date	Associated Case Number
12/31/1985	85CW0039
12/31/1989	89CW0032
12/31/1991	91CW0022
12/31/1993	93CW0034
12/31/1999	99CW0055
12/31/2001	01CW0013
12/31/2002	02CW0013
12/31/2013	13CW3017,13CW3018,13CW3019
12/31/2014	14CW0.29, 14CW3005, 14CW3010

5.4.5 Estimated Streamflow

USGS developed Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado (Capesius & Stephens, 2009), including estimates for the Rio Grande Region.

Peak streamflow regression equations are provided for basins with drainage areas ranging from 2 to 517 square miles and 19 to 45 inches annual precipitation. The regression equations for the 2-yr, 10-yr, and 100-yr recurrence intervals are:

$$Q_2 = 10^{-3.00}A^{1.00}P^{2.46}$$

$$Q_{10} = 10^{-2.04}A^{0.95}P^{2.02}$$

$$Q_{100} = 10^{-0.19}A^{0.87}P^{1.17}$$

Seven Day Minimum streamflow regression equations were developed for the 2-yr, 10-yr, and 50-yr recurrence intervals. The equations developed for these are:

$${}_7Q_2 = 10^{-44.17}A^{1.03}E^{10.71}$$

$${}_7Q_{10} = 10^{-46.35}A^{1.09}E^{11.15}$$

$${}_7Q_{50} = 10^{-49.44}A^{1.13}E^{11.88}$$

Where Q is discharge, A is drainage area in square miles, P is mean annual precipitation in inches, E is mean watershed elevation. Q leading subscript indicates averaging period, and the following subscript indicates recurrence period.

The outlet of each stream listed as a water source within the Culebra watershed was evaluated to estimate the peak flow and 7-day minimum flow from the Stream Stats regression equations. The inputs to the regression equations are listed in Figure 5-10, and the streamflow statistics from the regression equations are listed in Figure 5-11.

Table 5-8 Basin outlet characteristics for stream regression equation inputs.

Stream	Drainage Area, in square miles	Mean Annual Precipitation, in inches	Mean Basin Elevation, in feet
Alamosito Creek	6.07	29.3	11,001
Cuates Creek	6.05	25.3	10,188
Culebra Creek	378	19.2	9,269
El Poso Creek	67.3	28.6	10,640
El Rito de Aban	2.30	25.2	10,243
Jaroso Creek	9.04	25.0	10,161
Puertesito Creek	4.22	19.8	9,407
Rito Seco	29.4	24.0	11,637
San Francisco Creek	25.9	25.8	10,342
Torcido Creek	6.59	24.0	10,024
Vallejos Creek	29.9	24.8	10,168

Table 5-9 Peak streamflow and 7-day average minimum streamflow calculated from Capesius and others (2009). Q-Streamflow, leading subscript is averaging period, post subscript is recurrence interval.

Stream	Peak			Minimum 7-day average		
	Q2	Q10	Q100	7Q2	7Q10	7Q50
Alamosito Creek	24.6	46.4	161	0.83	0.37	0.29
Cuates Creek	17.1	34.5	136	0.36	0.16	0.11
Culebra Creek	541	999	3575	9.37	4.92	3.99
El Poso Creek	258	435	1272	6.94	3.49	2.92
El Rito de Aban	6.5	13.7	58.2	0.14	0.06	0.04
Jaroso Creek	24.8	49.2	189	0.54	0.23	0.17
Puertesito Creek	6.5	14.9	74.3	0.11	0.04	0.03
Rito Seco	34.2	74.5	351	7.73	3.85	3.33
San Francisco Creek	76.9	143	491	1.92	0.90	0.71
Torcido Creek	16.4	33.6	137	0.33	0.14	0.10
Vallejos Creek	80.6	151	532	1.85	0.87	0.68

5.4.6 Hydrology Modeling

Sanchez Reservoir storage modifies the hydrology in Culebra Creek below the diversion structures on each of the creeks and through the remaining portion of the watershed. The first comparison is the change in storage in Sanchez Reservoir compared with the measured flows at Culebra at San Luis (Figure 5-35). When the storage in Sanchez Reservoir is increasing, flows in the lower portion of Culebra Creek are being decreased by the reservoir operations and when the storage in Sanchez Reservoir is decreasing flows in the lower portion of Culebra Creek are increased by the reservoir operations.

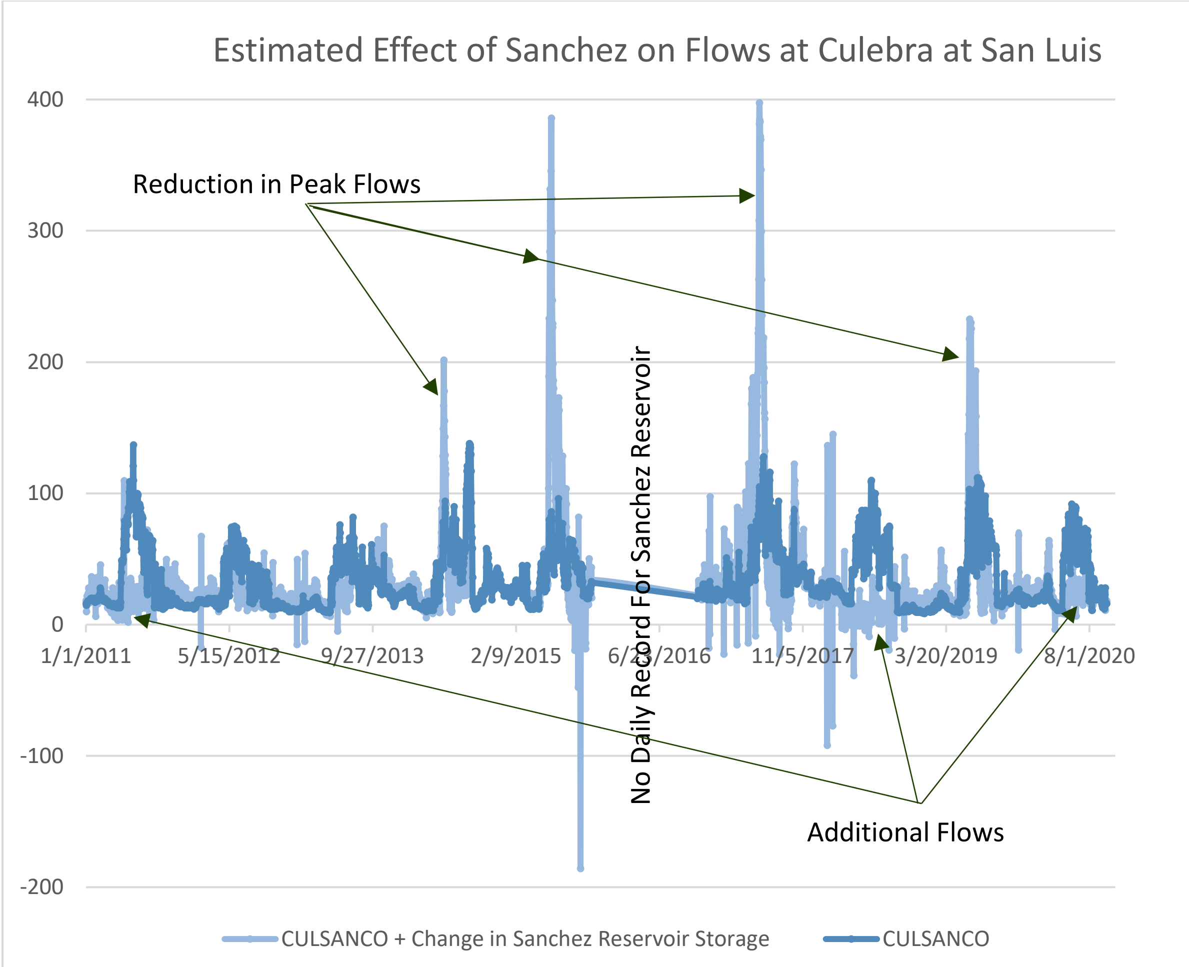


Figure 5-35 Comparison of Culebra at San Luis (CULSANCO) record with the estimated record without storage in Sanchez Reservoir (CULSANCO + Change in Sanchez Reservoir Storage). Missing data for Sanchez Reservoir December 2015-October 2016 due to construction.

The second part of the analysis was to evaluate how much of the water in lower Culebra Creek was carried through Sanchez Reservoir. The portion of the water in the Culebra at San Luis (CULSANCO) is shown in blue in Figure 5-36. At times more than 90 percent of the water measured at the Culebra at San Luis gage (CULSANCO) is from releases from Sanchez Reservoir (Figure 5-37). On average, approximately 30 percent of the water is from releases from Sanchez Reservoir, with most of the water being released during the irrigation season (Figure 5-37). In general, during high water years, Sanchez Reservoir diverts water and reduces peak flows, and during low years, the reservoir provides supplemental water to this reach.

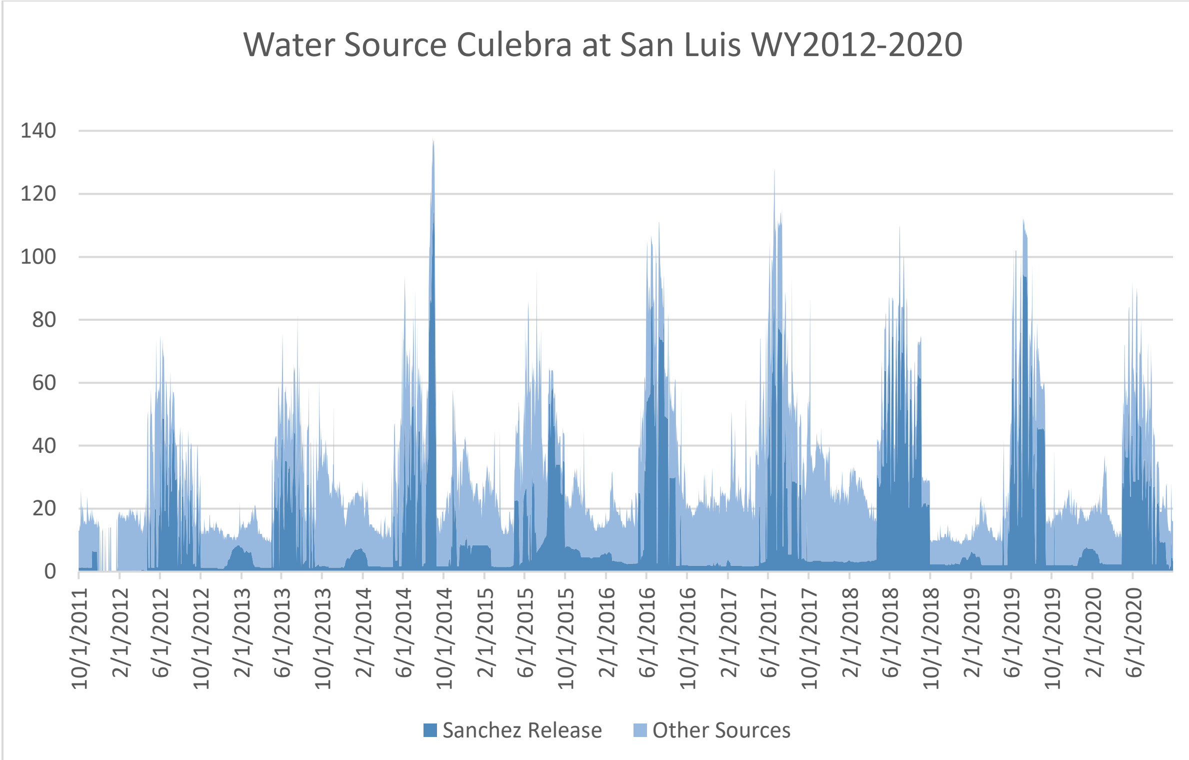


Figure 5-36 Evaluation of origin of flows measured by Culebra at San Luis Gaging Station (CULSANCO) assuming no loss of Sanchez release water. Data downloaded from Colorado Decision Support System October 13, 2021. Other sources calculated as measured flow at CULSANCO – measured release VENSANCO. Ice affected record from VENSANCO assumed to be 0 release.

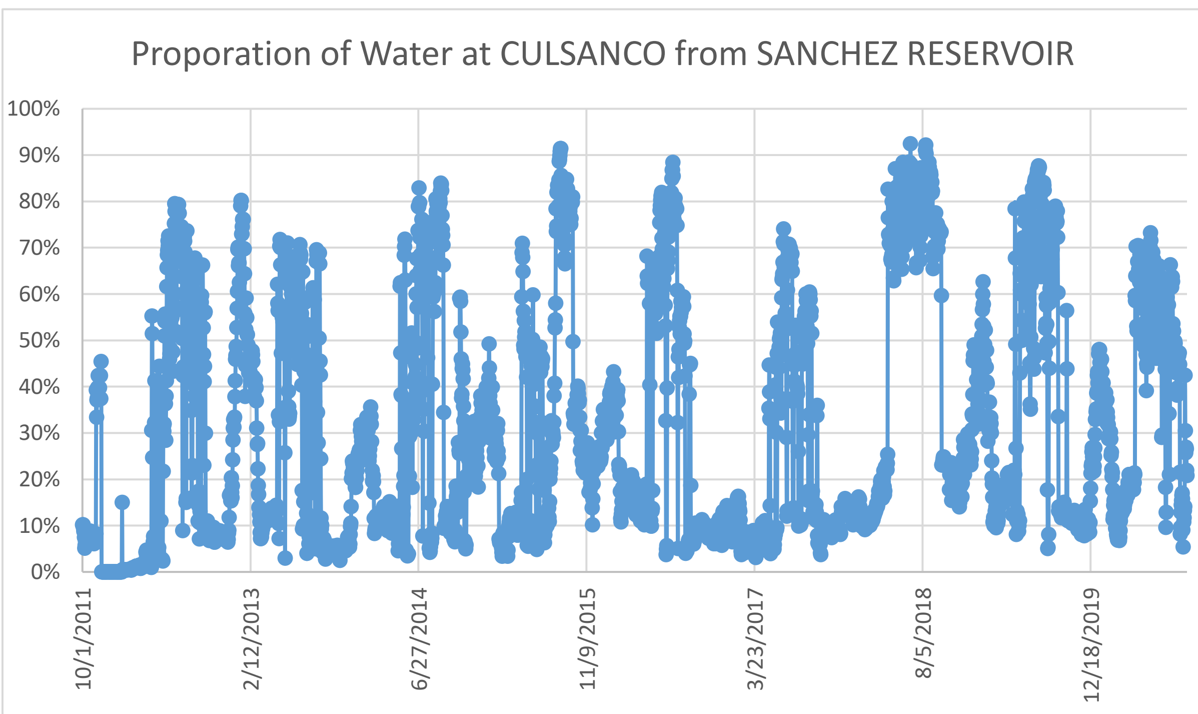


Figure 5-37 Proportion of water measured at Culebra at San Luis (CULSANCO) released from Sanchez Reservoir. Maximum 92%, minimum 0%, average 31%.

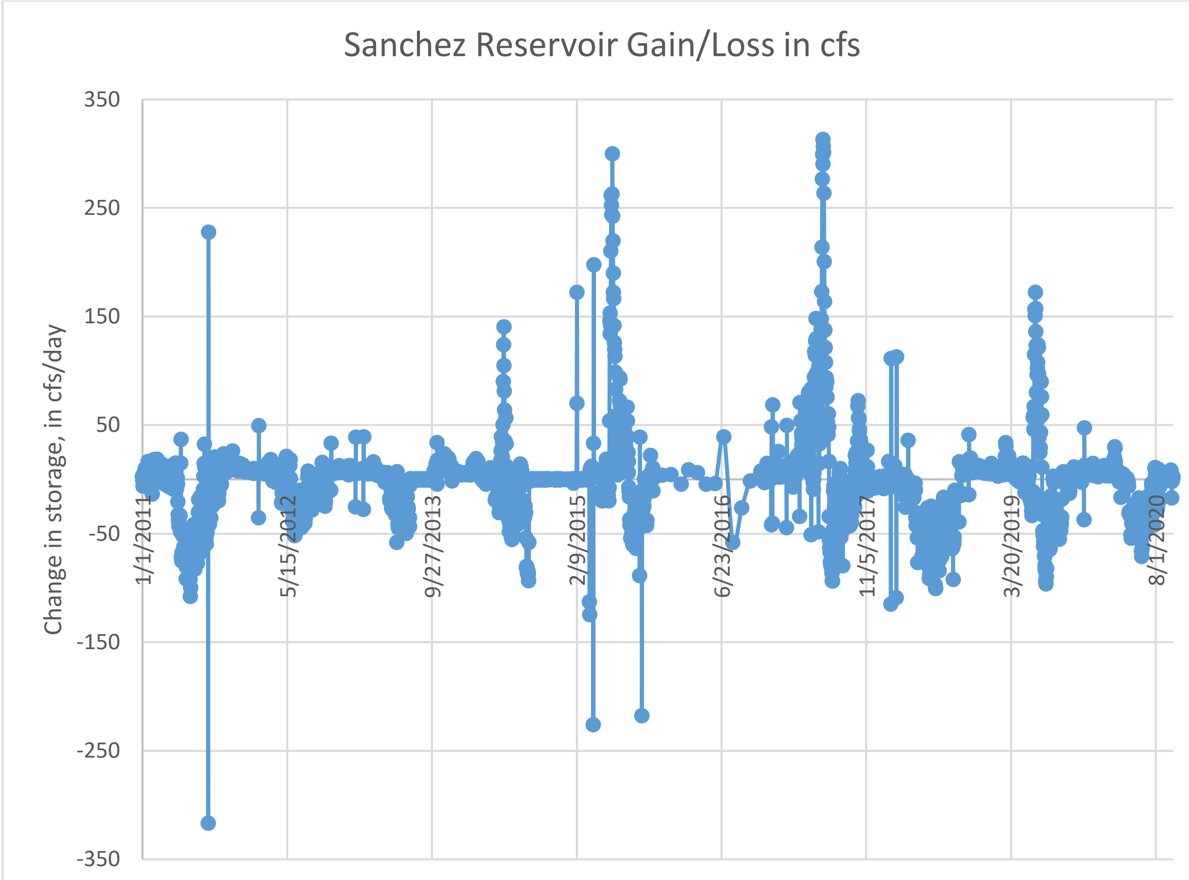


Figure 5-38 Sanchez Reservoir Gain/Loss as calculated from change in storage. Monthly record converted to daily record by assuming average value.

5.4.7 Hazard Mapping

The Colorado Hazard Mapping program has been updating flood hazard maps and revising FEMA FIRM panels in Costilla County. As part of this update, revised hydrology was developed for portions of the Culebra basin. For the Culebra basin, a HEC-HMS model with 151 subbasins was developed for Culebra Creek and Rito Creek (Rito Seco) and El Paso Creek tributary Rito Seco, San Francisco Creek, Vallejos Creek, and Ventero Creek. The information provided below represents the current best values to design structures for flooding. Compared with the information developed from the actual streamflow records and diversion records in section 5.4.1 Streamflow Gage Assessment, these values are higher than the developed flood regression curves. While these numbers may be conservative for predicting floods they are not suitable for developing new water rights within the basin. Site-specific low flow hydrology should be used for designing gate structures for diversion to ensure the adequate head is available to get water into the ditch.

Table 5-10 NOAA Atlas 14 Rainfall Depths from (Amec Foster Wheeler, 2017).

Region	Rainfall Depths (in)					
	10%	4%	2%	1%	1% Plus	0.2%
Foothills	1.72	2.10	2.41	2.74	3.58	3.59
Mountain	2.53	3.07	3.53	4.02	4.78	5.31

Table 5-11 Peak discharges calculated for Colorado Flood Hazard Mapping (Amec Foster Wheeler, 2017). Reach with Culebra at San Luis Gaging Station.

		Peak Discharges (cfs)					
Location	**Drainage Area (mi^2)**	**10%**	**4%**	**2%**	**1%**	**1% Plus**	**0.2%**
Culebra Creek Reach 1-at confluence with Rio Grande	379	1650	2900	4240	6610	13100	15700
Culebra Creek Reach 2-just downstream of CR-P 5	294	420	1220	2410	4320	10300	13100
Culebra Creek Reach 2- just upstream of confluence of Rito Creek	263	361	1050	2000	3680	9230	11400
Culebra Creek Reach 3-South of 1st street in San Luis	250	354	1030	1950	3590	8920	11100
Culebra Creek Reach 3- Northwest of the intersection of CR-19 and CR-L 5	118	217	711	1450	2500	6090	8360
Culebra Creek Reach 3- Downstream of the confluence of Culebra Creek and Vallejos Creek	87	207	645	1350	2450	5530	7350
Culebra Creek Reach 3- Intersection of CR-L7 and CR-25.5	33	225	665	1290	2270	4490	6010
El Paso- at confluence with Rito Creek	67	220	663	1300	2330	5030	6860
Rito Reach 1- at confluence with Culebra Creek	29	75	209	388	589	1400	1720
Rito Reach 2- immediately upstream of Casa Verde Real Drive	25	69	196	362	549	1290	1600
Rito Reach 2- Intersection of Rito Seco Rd. and Forbes Rd	17	62	176	323	478	1040	1340
Rito Reach 2- Intersection of Rito Seco Rd. and Wood Rd.	12	51	130	230	323	648	930
San Francisco Creek-Confluence of San Francisco and Ventero Creek	29	25	92	212	422	1130	1350
San Francisco Creek- East of CR-21	25	11	50	131	288	829	1040
San Francisco Creek-Confluence with Alamosito Creek	19	9	39	105	232	627	848
Vallejos Creek-Confluence with Culebra Creek	30	56	196	406	728	1650	2230
Ventero Creek-outlet of Sanchez Reservoir	95	107	262	466	782	1980	2240

5.5 Discussion

Our analysis of the flow regimes in the Culebra Watershed has shown that it is difficult to determine how much water is available within the system and that daily and often less frequent records of staff gage readings from flumes do not accurately capture the data necessary to administer water within the basin accurately. Water commissioner, Tom Stewart, estimated that it takes approximately five days to visit all structures during high water. During our discussion with various water rights holders, administrators, and community members, we were frequently told about water theft by upstream water users impacting the water available to senior water rights holders. During our review of the infrastructure in the basin, Chapter 9, we found many structures do not have measurement devices for administration leading to the conclusion that many of the records presented in this section of the report may be estimated. As technology advances it is becoming more cost effective to install monitoring systems to reduce administrative workload and improve administration for the community.

Lack of streamflow gaging data limits the analysis that can be done in the basin. It increases the risks associated with developing the information not being available to characterize flood hazard; it increases uncertainty in basin modeling and may result in skewed administration of water within the basin. Likewise, inaccurate streamflow information may have equally detrimental effects. Streamflow gaging programs tend to be financially viable when multiple organizations support them to meet multifaceted goals and objectives. The lack of quality measurement structures was noted throughout the basin, and those with measurement structures had minimal calibration measurements or documentation to verify structures were within error tolerances. Despite the appropriation of water going back to early in the 20th century and adjudications with similar timeframes, many diversions do not have records until the 1970s. EagleView aerial imagery, CDSS gis coverages, Sangre de Cristo Acequia Association files, and decrees were referenced to identify the location of each diversion structure in existence today.

Issues with water distribution among water users were common among the larger ditches. Issues related to return flows being diverted into lower ditches and not back to the creek or other users within the same system, and some ditches where water was not being delivered to the lower ends of the ditch. Comments were frequently made that water users often called for water not because they needed it to irrigate crops but because they were afraid of losing their water in the abandonment process.

The largest ditch, Sanchez Canal, does not currently have a measurement structure at the point of diversion(s), relying on the chart recorder located at the inlet flume at Sanchez Reservoir and the change in storage at the reservoir to regulate the flows. While this measurement and accounting method has worked historically, it is difficult to determine how much water is in the canal and how much water is diverted at the various stream crossings on the canal's path to the reservoir. The administration of water could be improved if a measurement structure were installed near the diversion points along the canal. Representatives from the ditch company were in favor of having records of diversion at the headgate to improve ditch operations.

When installing electronic measurement systems, the electronics and infrastructure are only a small portion of the overall costs. Maintenance of the structures also includes: maintaining the electronic equipment and records, developing and calibrating rating curves, and general routine maintenance, such as painting and clean-up. Additional measures may be necessary to reduce equipment vandalism, such as protection against damage by firearms. As agencies have cut costs, measurement frequency has been reduced at stable sites to approximately 1 measurement every 6 weeks or in response to events such as snowmelt, rains, or reservoir release.

Some water users have expressed financial difficulties in complying with the headgate and measurement structure provisions. NRCS is frequently called upon to aid with the cost and engineering of these structures, but funding requests must be completed across a much larger regional pool. Having local funding and an assistance pool for installing Parshall Flumes and headgates will help remove barriers to coming into compliance with State of

Colorado water measurement rules. The installation of operating measurement structures on all active ditches within the Culebra Basin will help water be administered within the established framework, and it will provide accurate record-keeping and reduce overuse and theft of water.

- Work should be done to document water sharing in the basin so that if a water transfer were to be proposed, injury to the other party could be evaluated and prevented.
- The gaging station Culebra near Chama could be improved by installing satellite telemetry after evaluating the intake pipes to reduce the occurrence of plugging and drawdown. Evaluate historical measurements for significant variations in shifts and rating changes to determine if the control structure needs to be stabilized immediately. The drop below the control structure is currently excessive and will likely be undermined eventually
- Install measurement structure(s) at diversion(s) on Culebra Sanchez
- Install streamflow measurement station on Vallejos Creek near Cielo Vista ranch boundary.
- Install streamflow gaging station on San Francisco Creek
- Install streamflow gaging stations or electronic recorders on Cuates Creek Diversions.
- Install streamflow measurement structure on Jaroso – this could be combined with a diversion structure upgrade and stream restoration project.
- Install streamflow gaging station near recreation park on Rito Seco
- Work within the basin to file for a decree confirming the location of diversions concerning modern survey systems.

5.5.1 Acequia Records and Operations

It is important for water users under a ditch system to have predictable governance in a time with uncertainty in climate and water availability. Detailed farm headgate delivery records can be time-consuming and challenging to maintain. Therefore, identifying a system among the acequia members that is communicated and understood is vital to reducing conflict within the community. The overall purpose of these recommendations is to reduce accusations and actual occurrences of water theft and promote sharing of water and economic benefit. Documentation of practices can also prevent injury to the acequia community in the event of a water transfer, especially when Catlin by-laws are included within the operating agreement.

In systems with insufficient water to irrigate the acreage under the ditch, it may be beneficial to have users lease water or combine water with other irrigators to increase the supply in sufficient quantities to produce an economically viable crop. Operations such as this should have clear agreements and rules to mitigate and handle disagreements when they occur. In addition, a transparent process for adjusting the rules based on changing times is also necessary.

While records exist for the diverting structures within the basin the infrastructure assessment, Chapter 6 of this report, found that many of the smaller structures within the basin have no measurement structure bringing into question the accuracy of the contemporary and historic diversion records. Reliance on these records should only be done so after careful evaluation of the consequences related to potential errors.

The Division of Water Resources and community members have voiced concern that there has been an expansion of use (i.e., increase in the number of irrigated acres) under many of the acequias in the Culebra Basin. Evaluation of the irrigated acreage has not been completed as part of this assessment. The 2015 Rio Grande basin implementation plan estimated that from 2000 – 2009, district 24 had an irrigated acreage of 22,000 acres with an estimated potential consumptive use of 53,000 acre-feet, estimated actual consumption of 39,000 acre-feet/year, indicating a shortage of 14,000 acre-feet (DiNatale, April 2015). In evaluating the systems, it is recommended that each acequia perform a self-evaluation of the system. A water budget is a tool that can be used to perform an analysis internally for an acequia to estimate an appropriate number of acres to be irrigated by the given water rights to promote the most efficient use of water under the acequia and throughout the basin. This provides the most value to the community regarding protecting existing water rights.

Other concerns with water administration have been raised, primarily related to the lack of data available to administer water. Water administration within the priority system is dependent on knowing how much water is available to be divided among the priorities. For most of the year, the administration of rights above the Culebra at San Luis Gage is based on water scarcity, limiting the number of structures diverting. Water records within the basin are based on spot measurements and provide a reasonable estimate as to whether a structure was diverting or not. The value shown may either be the decreed value or from a measurement structure that may/or as equally likely may not be functioning. Having some measure of how much water is available allows the commissioner to administer water fairly and efficiently. Gaging the streamflow lets the commissioner identify areas where losses may be higher or lower than usual. Thus, someone may take water out of priority or if a structure's measurement device may not be functioning correctly and they are getting too little/too much water. One person interviewed summarized this well, "He doesn't have a whole lot to work with." when speaking to the administration of water by the water commissioner. If water administration is to improve in the basin, it must increase the frequency and quality of streamflow measurement along the streams, ditches, and canals. Stream monitoring should be done with telemetered stations that are maintained with the goal of producing a published streamflow record. They should be continuously operated throughout the irrigation season. Structures that frequently call for water should be prioritized, followed by the most senior water users, and then by priority for the junior water users and the distance of travel required to monitor the structure.

The number of structure measurements within district 24 is fewer than what one should expect with annual measurements made at the structures that divert most of the water. However, it could also be contemplated as unfair to provide strict adherence to shifts at those structures with measurement devices while many structures, including the largest structure in the basin, does not have an operational measurement device at the point of diversion(s). To improve the conditions and to be able to provide an equal metric across the structures it is important that all structures meet the minimum requirements for measurement devices as required by law.

5.5.1.1 Ditch Maintenance

In numerous conversations with water users across the basin, ditch condition and the labor associated with ditch maintenance was brought up as a concern. These concerns come up in the conversation of flooding adjacent property and getting water down the ditch.

C.R.S. §37-34-101 speaks to the issue of a ditch causing flooding "The owners of any ditch for irrigation or other purposes shall carefully maintain the embankments thereof so that the waters of such ditch may not flood or damage the premises of others and shall make a tail ditch to return the water in such ditch with as little waste as possible into the stream from which it was taken." This guides the discussion to the point that if flooding occurs, it is the responsibility of the water user to fix the problem. In some of the irrigation systems, there is the issue of fewer users on the ditch than were once there. A lack of users leads to an additional burden on the remaining water users, but in the case of non-use without transfer, this will often result in additional water. If there is economic hardship associated with the maintenance of the ditch, working with neighbors and the community may improve infrastructure, such as installing ditch lining or piping, reducing the burden. The issue may also be mitigated by evaluating the reason for abandonment and if moving the point of diversion might be a beneficial and/or a cost-effective means of reducing the length of the ditch to be maintained. A third approach, if development is the primary cause of water no longer being used, evaluating the utilization of water for lawn irrigation in the place of historic use may be a way to reduce treated water demand, provide cost-effective irrigation, and revenue or assistance with ditch maintenance.

In the case of willows and other impairments to the ditch that may impede the delivery of water by the acequia, it must be realized that ditches are not without maintenance. Historically, thorough annual ditch cleanings were performed by workers from each parciante, typically at the beginning of the season, with additional spot clean-up as needed throughout the season (Crawford, 1993). Delaying even one annual cleaning can lead to a significant overgrowth in the ditch and maintenance issues. Some of the acequias within the basin were deteriorating due to mechanized cleaning removing debris and willows from the ditch with heavy equipment. This can lead to channel incision, increased sediment loading, and potentially greater ditch loss. These changes in ditch maintenance practices can take a system with farm turnouts from working for the past 50 - 80, and even sometimes 100 years to not functioning in just a few seasons.

When seeking funding for acequia structures and ditches, it is necessary to show a benefit to more than just the water users to maintain the status quo. Money is available for improving conveyance efficiency to improve irrigation systems with the added goal of reducing sediment loading on streams, improving water quality, and potentially increasing farm output to provide for the economy. More funding is typically available to those projects that can have additional community benefits, such as improvements that may benefit multiple acequias or ditches, reduction in flood risk, ability to divert less water, leaving more water in the stream, or reduction in the number of structures on a stream. The more benefits that can be identified for a project the more potential funding sources that become available. Potential funding sources include Basin Round Table, NRCS, Trout Unlimited, Division of Homeland Security and Emergency Management, U.S. Fish and Wildlife Service, and USBR WaterSMART.

5.5.1.2 Disputes

From time-to-time arguments arise among community members. Suppose the argument arises from a dispute over water delivery. In that case, quantity data can be used to help determine if there is merit in the accusation or if the dispute is a differing perception. Having local resources available to provide measurement at farm headgates, when combined with accurate records at the main headgate and critical points in the ditch, can be used as a part of a mediation process. Settling disputes outside of courtrooms can speed up the process and reduce the overall cost.

5.5.2 Abandonment List

The Division Engineer, in accordance with §37-92-401 shall prepare an abandonment list every ten years. This list includes all water rights that have been determined to be abandoned in whole or in part and have not previously been adjudicated to have been abandoned. In determining abandonment, the division engineer is to evaluate the circumstances relating to each water right that has not been fully applied to beneficial use. Failure, for ten years or more, to use the water beneficially is used as the basis of determining abandonment with the Division Engineer or State Engineer was given the ability to waive the abandonment under special circumstances C.R.S §37-92-402(11).

The abandonment list is filed with the water clerk within the Division, where objectors to the list may file a protest and submit a factual and legal basis for the protest to be considered by the water judge. Hearings for the abandonment proceedings will be conducted in accordance with all applicable rules. At the conclusion of the hearing, the water judge will enter a judgment and decree incorporating the abandonment list, with all appropriate modifications and conditions.

Using the abandonment process helps ensure water users are actively using their water for beneficial use and are not adversely affected by an increase in senior diversions that may occur if a water right has not been used for some time and then becomes activated once again. This process helps to ensure water continues to be available in as predictable a manner as possible. This process also protects against the purchase of unused senior water to gain an advantage in priority.

5.5.3 Aquatic Habitat

In the assessment of discharge in streams with Rio Grande cutthroat trout Zeigler and others (2013) found that "the majority of streams containing Rio Grande cutthroat trout had discharges less than 1.0 cfs". These streams may be at greater future risk of climate variability, reducing low summer discharges.

Within the basin's dewatered reaches, the most fundamental element of fish survival, water, is absent. Improvements to the gates on Sanchez Reservoir have resulted in lower winter flows within the lower basin due to decreased gate leakage. With the prospect of changes in administration occurring within the basin, evaluation on increasing in-stream flows through the dewatered reaches could be a way to provide improvements in the basin in the process of addressing degradation due to overuse of water.

No instream water rights were identified within the basin. Although adjudication of a new instream flow right would be junior to all the water rights in the basin this water right would be senior to any future adjudications and change cases and could allow opposition to be filed in the event that a water right was to be moved.

5.6 Summary

Water flow within the Culebra Basin was evaluated through streamflow gage records, diversion records, hydrology, and hazard mapping from the Colorado Hazard Mapping program. The data available within the basin is minimal and has resulted in mistrust between water users, administrators, and community members. The gap in available data can and should be addressed to reduce conflict within the basin and provide a basis for improving water distribution and ecosystem health within the basin.

5.7 Recommendations

- Install streamflow gages above diversions in each significant tributary. Gages should be operated at a minimum seasonally and be maintained to the equivalent standard of a published streamflow gage. Streamflow should be available to all water users via telemetry and public web interface. Standards for gaging station operation are outlined in USGS TWRI Book 3 Section A.
- Install measurement devices and lockable/adjustable headgate on all diversion structures that do not currently have either a measurement device or headgate or either are inoperable.
- Concern has been raised that NRCS funds are difficult to obtain or unavailable to assist many eligible water users with meeting this requirement. Developing a fund or mechanism to assist the Costilla County Conservancy District or Sangre de Cristo Acequia Association could facilitate water users to comply with regulatory requirements.
- This recommendation is pertinent to both the main headgate and lateral headgates of the ditch to enable the distribution of water under the agreed upon method.
- Install electronic measurement devices on structures that divert more than four weeks per year and develop a maintenance plan including maintenance funds for these devices.
- Evaluate automating critical headgates.
- Area 1: Sanchez Reservoir, San Luis People's Ditch, San Acacio, and Culebra Eastdale. Automating headgates in this reach could be used to allow gate changes on Sanchez to occur more slowly to reduce bank erosion within the upper reaches and improve fisheries habitat while reducing time spent adjusting headgates and ensure water users continue to receive their water.
- Incorporate within Acequia by-laws options for direct participation in annual cleaning or fee schedule for the acequia to hire alternative personnel. This fee should be reasonable and sufficient to cover ditch maintenance cost and be allowed to vary based on current conditions.
- Evaluate developing operational agreements and legal changes to restore year-round flowing water within the following reaches: Culebra from San Pedro to confluence with Ventero, San Francisco Creek from San Francisco Ditch to confluence, and Vallejos Creek. Restoration of flow through these reaches is further enhanced by restoration of the channels to be compatible with current hydrology which is discussed further in the geomorphology section.
- Along with the studies and modeling done for the groundwater use within the basin it would be beneficial to understand further connection of surface water and groundwater within the southern tributaries and Rito Seco to formulate a better understanding of the reference conditions for these reaches.

Chapter 6. Infrastructure Assessment

Author: Tailwater Limited

6.1 Introduction

Infrastructure assessed as part of the Upper Culebra Watershed Assessment includes diversion structures, bridges, and intake and outfall structures. This infrastructure's compatibility with the geomorphic setting can drive the long-term stability of the stream at the location, long-term maintenance requirements and costs, and overall risk. Generally, this portion of the assessment was divided into three categories: irrigation & diversions, transportation, and other (e.g., building structures, wastewater treatment plants, schools).

As part of this evaluation flooding was considered around the structures. A flood information study was completed by Wood. Environment and Infrastructure Solutions, (FEMA, 2021), this study provides a rapid hydraulic assessment of flood conditions within the basin. Llewellyn and Vaddey (December 2013) project that flooding will become more extreme with climate change and that flood control operations will be needed more often in the future, despite an overall decrease in supply.

6.1.1 Goals and Objectives

This portion of the Upper Culebra Watershed Assessment was based on the following goals and objectives to meet the overall community goal of improving conditions within the basin and the assessment specific goals of identifying priority projects, areas of degradation, and preservation areas. The infrastructure assessment goals and objectives are:

Goal 1 Assess water related infrastructure function within the Culebra Basin.

Goal 2 Protect Community Values within the Culebra Basin.

Goal 3 Identify areas to improve water quality within the Culebra Basin.

Goal 4 Identify areas to at risk of flooding due to infrastructure.

Goals	Objectives
Goal 1 Assess water related infrastructure function within the basin.	*Objective 1.1* Develop list of water related infrastructure within the basin. *Objective 1.2* Compile desktop information related to water related infrastructure within basin. *Objective 1.3* Perform visual inspection of representative sample of water related infrastructure within the basin. Inspection of accessible diversion structures and road/stream crossings. *Objective 1.4* Summarize findings of the infrastructure assessment.
Goal 2 Protect Community Values within the Culebra Basin.	*Objective 2.1* Assess community values related to the water infrastructure. *Objective 2.2*. Identify structures that do not meet those community values: fish passage, water quality, water diversion, etc. *Objective 2.3* Map current location of diversion structures within the Culebra Basin.
Goal 3 Identify areas to improve water quality within the Culebra Basin.	*Objective 3.1* Identify infrastructure that is causing geomorphic instability in the stream. *Objective 3.2* Assess land use practices within vicinity of infrastructure that may be impacted by diversion structure.
Goal 4 Identify areas to at risk of flooding due to infrastructure	*Objective 4.1* Using existing datasets to evaluate areas affected by flooding within the basin. Objective 4.2 Visually assess diversion structures for flood capacity and probable flood routing.

6.2 Diversion Structures and Ditches

Diversion and irrigation infrastructure rely on the natural stream systems to deliver water from the watershed. Both physical and legal factors impact these structures. Legal factors include those requirements outlined in laws and statutes, acequia/ditch by-laws, and local customs. Physical factors include flows available to the system, demands of water users, and sediments within the system. Diversion and irrigation infrastructure impact the function of riverine systems. These impacts include impacts on fish and organism passage/migration, water availability, and water quality. These structures can impact adjacent properties, residents, and visitors through flood risk, sediment deposition, and personal and wildlife safety changes. Historically, diversion structure construction focused primarily on water conveyance with little consideration for the ecosystem or sediment transport.

6.2.1 Methods: Diversion Structures and Ditches

Diversion structures or points of diversion are locations where water is moved from the natural stream into a ditch, canal, or pipeline, typically for the purpose of irrigation, municipal uses, commercial uses, or industrial uses. A list of criteria for a functioning diversion structure was developed to complete the assessment. A functioning diversion structure:

- The decreed water right to be diverted at all streamflows in which the water right is in priority.
- Allows for the cessation of diversion if the water right is no longer being used or is no longer in priority.
- Regulates water diverted to a maximum of the in-priority decreed amount.
- Ability to measure water diverted to prevent injury to others in the water using community including other ditches/acequias, people, fish, and wildlife.

This list is derived from the requirements described in Colorado Revised Statutes 37-84-101, -107, -112, and -113.

Beyond the basic functions of a diversion structure, a few more measures are important for a healthy stream system. These include:

- Prevention of flooding of neighboring properties and structures (C.R.S. § 37-84-101).
- Allowance for fish passage over the structure when water is present and prevention of fish entrainment within ditches.
- Channel and structure stability such that in-channel work is minimized (sediment removal and/or dam construction).

Diversion structures were evaluated using a combination of interviews and conversations, site visits, and/or review of aerial imagery. Additional documents from the Colorado Decision Support System were used to supplement findings. One of the challenges with assessing the structures was identifying the physical location of the structures to be evaluated. Each structure was assessed to determine if the structure met the requirements of a functioning structure and if the structure met the measures to promote a healthy system.

6.2.2 Results: Diversion Structure and Ditches

Diversion structures were evaluated based on the performance of the structures related to the water user's ability to divert water, the structure's ability to regulate water being taken, measurement of water, fish passage, and river stability. Across the upper Culebra basin, the diversions structures take on a wide variety of forms from the smallest push-up dams, on many of the smaller ditches, up to larger concrete structures along the Culebra and larger tributaries. During our field investigations, the assessment crew did not find fish screening structures on any of the diversion structures observed within the basin, and no mention of fish screens was made during interviews.

The diversion structure assessments are grouped based on the source stream and are listed from upstream to downstream. Structure names presented, while cross-reference against available sources, may contain errors. Photographs and locations are provided to aid in determining errors in structure naming and identifying the structure being discussed.

6.2.2.1 Rito Seco

Diversion structures within the upper portion of Rito Seco are generally managed to a greater extent than many of the other structures within the basin due to the requirements set forth for the Battle Mountain Resource plan for augmentation. The flows of Rito Seco are successively divided and moved across the Rito Seco alluvial fan above San Luis. Today water is infrequently carried in the stream channel across this alluvial fan; instead, it is conveyed and divided through a series of small ditches. A mere fraction of the channel is visible within the landscape. Four diversion structures are discussed below, including the

Espinosa Ditch, the Salazar Ditch, the Montez Ditch, and the Rito Seco Feeder. Structures within this reach, and water conveyance to the lower Rito Seco impact flow through San Luis. This conveyance increases flood risks to San Luis. To illustrate this, potential flow paths are highlighted in Figure 6-2. Changes to the flow path also affect the location of the confluence with Culebra Creek.

Without the hydrology to support a fishery, these diversions are a low priority for fish passage. Flood risks around these structures are high due to adjacent development, but these risks are generally not significantly increased by any diversion structures.

Figure 6-1 EagleView aerial imagery dated July 12, 2019, showing the historic channel of Rito Seco, middle of the picture, and the ditch carrying the water, lower left.

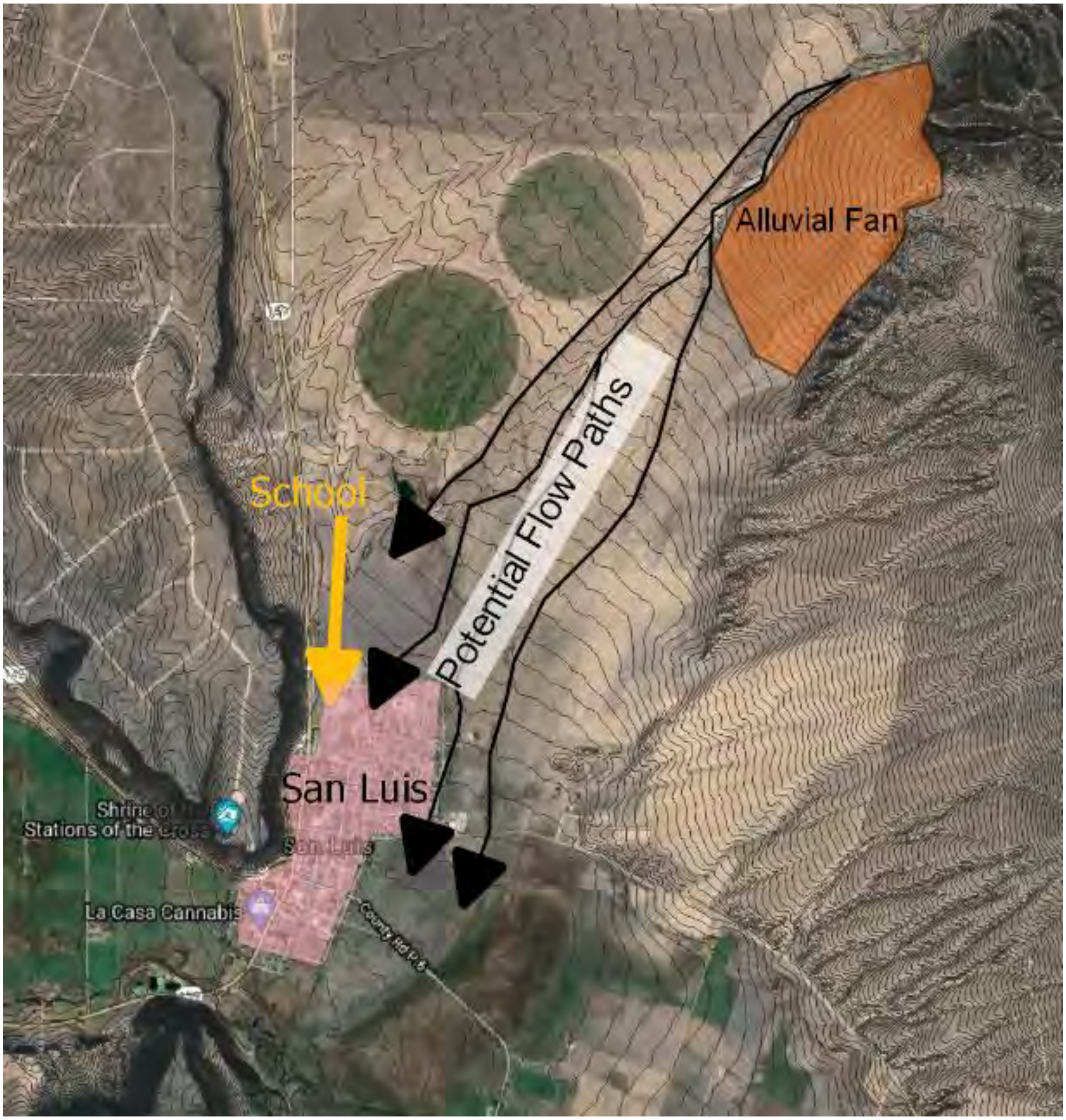


Figure 6-2 Rito Seco flows through an active alluvial fan. The potential flow paths are illustrated to highlight impacts downstream that should be considered when developing stream related infrastructure.

<u>Espinosa Ditch</u>

The Espinosa Ditch structure appears to cause significant changes in the flow pattern along Rito Seco. The June 3, 2019, EagleView Aerial imagery shows water backed up around this structure near the road (Figure 6-3). The width of the wetted area in this reach is approximately 100-feet with signs of tracking and sediment deposition. The stream in this reach is likely to rebuild a floodplain at an elevation lower than the historic floodplain; this is a baseline shift.

Figure 6-3 Espinosa Ditch, EagleView aerial imagery dated June 3, 2019.

<u>Salazar Ditch</u>

Diversions for the Salazar Ditch are measured through two flumes, the North and South Parshall flumes (Figure 6-4). The Salazar Ditch diverts upstream near the upper end of one of the historic dikes on the left edge of Rito Seco (Figure 5). These structures were reported to be maintained in good condition and are included in the Battle Mountain Gold Augmentation Plan.

Figure 6-4 North (upper right) and South (lower left) Parshall flumes for Salazar Ditch.

Figure 6-5 Salazar Ditch point of diversion.

<u>Montez Ditch</u>

The assessment crew visited Montez Ditch headgate on July 29th, 2021. The headgate was in fair condition with gate leakage (Figure 6-6). No measurement structure on this ditch was found. Water users have reported issues maintaining the ditch, which flows through the town, as the number of users has decreased over time. Portions of this ditch are piped through town. Water users stated that this ditch was historically used to water orchards and gardens through town. Riparian vegetation along this reach consists primarily of grasses. The stream channel is straight through this reach.

Figure 6-6 Montez Ditch headgate, metal splitter box with no observed measurement structure.

<u>Rito Seco Feeder</u>

The Rito Seco Feeder is one of the few structures that includes electronic recording along with the 1.5-ft Parshall flume (Figure 6-7). This structure is located along a straightened portion of Rito Seco creek.

Figure 6-7 Measurement device for Rito Seco Feeder at the Post Office upstream of 9th street.

6.2.2.2 El Poso Creek (Pozo)

Structures along El Poso Creek are small and are used to irrigate the El Poso Creek valley below the Cielo Vista Ranch boundary. Improving structure functions along this reach could improve fisheries habitat, and fish screening structures could reduce fish entrainment in ditches. Structures in the floodplain that could be at risk of flooding and storage of vehicles and septic systems near the streams may pose a risk of water quality contamination.

Diversion structure improvements within this reach should evaluate combining headgates, where feasible, to reduce the number of structures within the system.

<u>Unknown ditch El Poso Creek</u>

This structure, with a headgate, is located on Cielo Vista Ranch; it was one of the structures where a detailed walk along the structure was performed to evaluate the condition of the ditch. During the site walk, no flume was located along the channel within the first ½ mile of the diversion dam. The ditch had significant leakage back to the creek in multiple locations. Like many ditches in the watershed, a culvert was used to carry water over the arroyo. During the site visit on July 11, 2021, water in the ditch exceeded ditch capacity, and overland flow was observed back to the creek (Figure 6-8).

The rock diversion dam appeared to be functioning, and while the stream was slightly overwide in this area and could benefit from bank stabilization and restoration of the riparian communities, the impacts from this structure were minimal.

The ditch did not have the capacity to convey the volume of water being diverted (Figure 6-10), which was leaking back to the creek at the time of the site walk. This excess leakage increases the opportunity for the water in the stream to be contaminated with excessive erosion and leaching (Figure 6-11). The excess water is spread across the landscape, unused, increasing the potential for evaporation and reducing water available to downstream water users (Figure 6-11 and Figure 6-12). The excess diversion also reduces the water within the portion of the creek downstream of the diversion beyond what is necessary for conveyance. The assessment did not evaluate whether the structure was in priority or measure the volume of water being diverted.

The ditch was conveyed over a gully in a corrugated metal pipe. In the event of flooding through the gully, it is possible that the culvert could catch debris and fail, resulting in an interruption of water delivery to the ditch. However, in a general cost-benefit scenario, the risk is likely acceptable over the cost for infrastructure improvements such as installing a siphon.

Figure 6-8 Hand built cobble diversion dam. No risk of flooding, ditch may trap fish.

Figure 6-9 Return flow structure on unknown ditch, El Poso Creek.

Figure 6-10 Water diverted into ditch was greater than ditch capacity resulting in overland flow back to creek.

Figure 6-11 Flow returns from excess diversion.

Figure 6-12 Erosion from ditch seepage.

<u>Fox Ditch</u>

The Fox Ditch Headgate structure does not appear to pose an excessive flood risk. Channel degradation was observed upstream of the diversion dam (Figure 6-13). Aerial imagery shows elevation drops below the diversion structure. These drops may inhibit fish passage (Figure 6-14). No water measurement structure was observed in aerial imagery or reported within CDSS (November 30, 2021). This was one of the structures with recorded headgate orders within the CDSS system indicating the need for a lockable headgate.

Figure 6-13 EagleView imagery of the Fox Ditch Diversion Dam. Notice sediment deposition in the upper third of the photo.

Figure 6-14 EagleView Imagery of the Fox Ditch diversion dam.

Clarita Vigil Ditch

The Clarita Vigil Ditch structure was identified in aerial imagery, shown in Figure 6-15 (approximate coordinates: 473681, 4116042 UTM Zone 13N.). The ditch has a Parshall flume measurement device. Imagery shows scour below the Parshall flume. No regulation structure was observed at headgate. The El Poso Creek stream channel shows some bank instabilities upstream. This ditch is conveyed across an arroyo in a pipe (Figure 6-16), which could be at risk of failure in the event of debris blockage or high flows in the arroyo. The pipe may be promoting sediment deposition prior to El Poso Creek.

Figure 6-15 Clarita Vigil Ditch Point of Diversion. Image from EagleView Connect Explorer – May 13, 2019

Figure 6-16 Pipe across arroyo - Clarita Vigil Ditch. Image from EagleView Connect Explorer – May 13, 2019

Albert and Vigil Ditch

The Albert and Vigil Ditch diverts from the left edge of water of El Poso Creek. The diversion dam is constructed of cobble and debris, as observed from the May 13, 2019, EagleView aerial imagery. Sediment is being actively deposited above the diversion dam with a visible drop downstream (Figure 6-17). As of December 1, 2021, no measurement structure was listed in CDSS. A metal splitter box for return flows is located approximately 600 feet below the point of diversion. Riparian vegetation is present on the left edge of water around the diversion and sparse on the right edge of water near the diversion.

Antonio Sanchez Ditch

Antonio Sanchez Ditch has a significant drop below the diversion dam structure which appears to be constructed using debris. The debris dam is causing upstream over widening and mid-channel bars within the El Poso Creek (Figure 6-18). Riparian vegetation is not present on left edge of water above the stream. The structure has gates to regulate flow. The structure is not passable by fish. A measurement structure was not identified. Bank erosion upstream of the structure contributes sediment to El Poso Creek.

Figure 6-17 Albert and Vigil Ditch Diversion dam in EagleView aerial imagery dated May 13, 2019.

Figure 6-18 Antonio Sanchez diversion structure, sediment deposition as mid-channel bars observed above the structure along with bank erosion. Structures present in floodplain. EagleView Connect Explorer – May 13, 2019

Just below the diversion structure is a confluence with an arroyo that appears to be contributing sediment to El Poso Creek. Figure 6-19 shows the farm north of the Antonio Sanchez Ditch, which is near an arroyo with a high sediment load. Infrastructure and crossing improvements and an upstream sediment trap could improve conditions on this farm and reduce sediment loading to El Poso Creek.

Figure 6-19 Sediment loading on farm. EagleView Connect Explorer – May 13, 2019

Guadalupe Sanchez Ditch

The Guadalupe Sanchez Ditch structure, located on the right bank of Culebra Creek, is the largest in this reach serving approximately 175 acres, (2020 CDSS tabulation accessed December 1, 2021). The structure does not appear to have a headgate to regulate flow. This reach has active erosion and mid-channel bars indicating instability. There is no riparian vegetation on left edge of water of El Poso Creek (Figure 6-21). No measurement structure was identified in the imagery or listed in CDSS (November 30, 2021). This portion of El Poso Creek was likely re-located. El Poso Creek appears to be channelized directly upstream of the Guadalupe Sanchez Diversion combined with the 90-degree bend in the river to meet the bridge at County Road L.7 (Figure 6-20).

Figure 6-21 Guadalupe Sanchez Ditch. EagleView Connect Explorer – May 13, 2019

Figure 6-20 Guadalupe Sanchez 2011 Lidar profile. The present-day Culebra Creek channel is approximately two feet higher than the historic channel and wider than the historic channel (approximately 32 ft vs 55 ft).

6.2.2.3 El Valle Creek – Culebra to El Poso Confluence

This reach of Culebra Creek from the Carneros Creek and El Valle confluence to the El Poso Confluence has been altered. Currently, it has numerous stabilization structures from the confluence of Carneros Creek and El Valle Creek. The riparian corridor is approximately 600 feet wide from the confluence down to County Road 25.5. In this region, irrigation of the meadows along the terraces is used to grow crops, and stock ponds are used to provide water for cattle along the southern terrace.

Canon Valle Ditch

The diversion structure on Canon Valle Ditch was not visible in aerial imagery. The ditch is piped a distance and then emerges from the ground on a terrace (Figure 6-22). Erosion is present in the ditch below the pipe. Providing outlet protection below the pipe would reduce erosion and downstream sediment deposition within the ditch. No measurement device was identified in the aerial imagery or listed in CDSS. This structure would be a viable candidate for a locking headgate, fish screening, and measurement structure to improve fisheries habitat and increase fishery range.

Figure 6-22 Canon Valle Ditch below pipeline.

Canon Ditch No. 1

Canon Ditch No. 1 has a small diversion dam made from rock (Figure 6-23). The channel appears to be slightly over widened upstream. Vegetation along left edge of water is in fair condition. This reach may have had some restoration work completed in the past, as there appears to be boulder toe (boulders placed along the bank to prevent bank erosion) visible along the banks. The stream is split in this reach to bring water over to the headgate and returned to the stream. A measurement flume was found in the ditch with some debris in the inlet (Figure 6-24 and Figure 6-25).

Figure 6-23 Canon Valley Ditch diversion structure. Ditch diverting water on right edge of water, shown at the bottom of photo in EagleView aerial imagery from May 14, 2019.

Figure 6-24 Measurement flume Canon Ditch No. 1.

Figure 6-25 Measurement flume with debris in inlet and scour downstream. Scour noted on left edge of flume.

Stream stabilization structures in this reach include structures that were installed backward. The center of the structure is downstream of the arms, rather than upstream, as would be typical of this type of structure. Installing the structure this way forces water toward the banks rather than towards the center of the channel (Figure 6-26). Also noted is the significant drop height on the structures. In most circumstances, it is recommended that the drop height is limited to a maximum of ½ foot to reduce scour depth in a cobble bed stream.

Figure 6-26 Stream stabilization structures near Canon Ditch No. 1. Note structure is placed backward, with the furthest downstream point occurring in the middle of the structure.

<u>The Canon Ditch</u>

The Canon Ditch is a historic structure, CDSS indicates this structure no longer exists. This water right was transferred to the Jose M. Sanchez Ditch in Case CA0889 (District Court Case, 1926).

<u>Jose M Sanchez Ditch</u>

The Jose M Sanchez Ditch does not have a measurement structure listed in CDSS, and the structure was not identified on available aerial imagery. The headgate is a rock dam (Figure 6-27) with multiple rock dams throughout the reach. Significant erosion was noted during the system review in portions of the ditch that could benefit from stabilization (Figure 6-28).

Figure 6-27 Jose M. Sanchez Ditch Headgate. EagleView Connect Explorer – May 13, 2019

Figure 6-28 Jose M Sanchez Ditch showing significant erosion throughout portions of the ditch.

<u>Unknown</u>

Water is diverted from Culebra Creek just upstream of County Road 25.5 (Figure 6-29). A rock diversion dam diverts water on the right bank toward the south. The ditch is possibly abandoned without reclamation.

Figure 6-29 Unknown ditch diversion on Culebra Creek upstream of County Road 25.5.

<u>Val Verde (El Rito de Aban)</u>

The Val Verde structure was not identified in aerial imagery. The structure is listed as inactive but still exists. This structure is upstream of County Road M.5 on El Rito de Aban.

<u>Alfonso Ditch (Aban Creek)</u>

The Alfonso Ditch diverts from Alban Creek. A review of aerial imagery did not identify a structure to regulate flows on this ditch (Figure 6-30). The stream below the diversion has a cattle trail crossing that contributes sediment to the stream. This structure does not appear to pose a significant risk of flooding and being on a smaller tributary should rank lower on prioritization for fish passage.

Figure 6-30 Alfonso Ditch headgate.

Gabino Atencio Ditch

The Gabino Atencio Ditch is a small ditch that does not have a structure to regulate flow. The flow volume appears to be regulated by the ditch size (Figure 6-31). A measurement structure was not identified during the review of aerial imagery. The channel appears to be in good condition, with riparian vegetation along its banks. The structure is just below the ditch return flow. The channel benefits from this water. Additional water may be diverted from return flow just below the point of diversion.

Figure 6-31 Gabion Atencio Ditch Headgate. EagleView Connect Explorer – May 13, 2019

Felipe Vialpando Ditch

Felipe Vialpando Ditch diversion structure is a small rock structure below a low water crossing (Figure 6-32). Water is taken on the left side of the creek. Riparian vegetation is in fair condition, with no riparian vegetation on left edge of water upstream of diversion. During the review of aerial photography, no measurement structure or regulation structure was identified. The map shows a structure just below the historical Cuchilla Alta Creek channel. In aerial imagery, high-density livestock is shown on the floodplain (Figure 6-33).

Figure 6-32 Felipe Vialpando Ditch. EagleView Connect Explorer – May 13, 2019

Figure 6-33 High density livestock near headgate. Google Earth Imagery – October 18, 2016.

Antonio Valdez

The Antonio Valdez point of diversion was not found within various channels. This structure does not appear like it is currently in use. Numerous wetland areas have backwater and dense riparian habitat (Figure 33).

Figure 6-34 Aerial imagery of estimated location of the Antonio Valdez Ditch.

Lobato Ditch No. 1

Lobato Ditch No. 1 diverts water from the right side of the creek at a structure that appears to be constructed from rock (Figure 6-35). No headgate or measurement structure was identified in the review of aerial imagery. No measurement structure for this ditch was listed in CDSS.

Figure 6-35 Lobato Ditch No. 1 headgate.

This structure and Lobato Ditch No. 2 map and filing statement show that the structures have moved because the creek was moved. The map and filing statement for the ditch shows the creek well below the section corners of sections 1 and 2 (Figure 6-36), while the creek is now shown intersecting the section corner (Figure 6-37). When the map was filed, Lobato Ditch No. 1 was downstream of Lobato Ditch No. 2, which has now been reversed. One residential structure is approximately 1,200 feet below the structure and potentially at risk of flooding; this risk is not increased by the presence of this diversion structure.

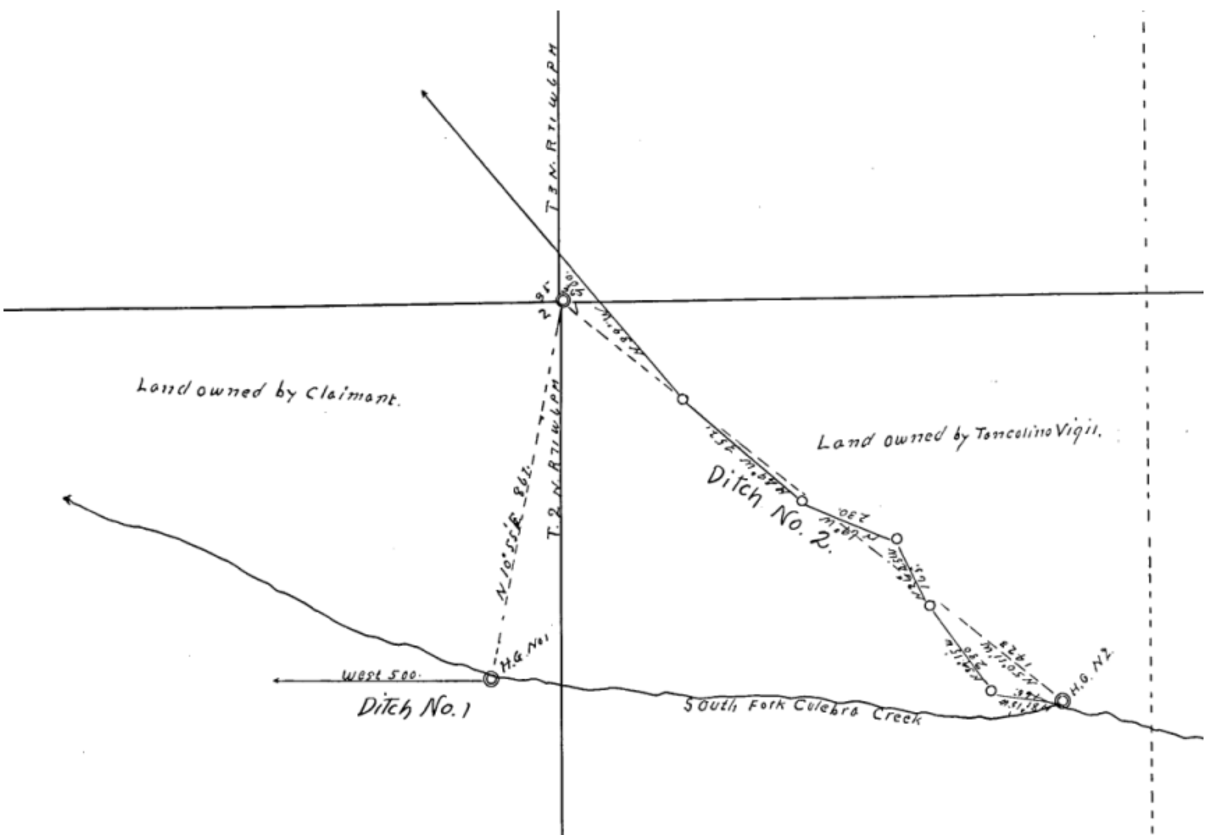


Figure 6-36 Map from Lobato Ditch No. 1 and Lobato Ditch No. 2 map and filing statement.

Figure 6-37 Map showing current configuration of Culebra Creek near the Lobato Ditch No. 1 and Lobato Ditch No. 2 diversions.

<u>Lobato Ditch No. 2</u>

Lobato Ditch No. 2 diverts water from the left side of Culebra Creek (Figure 6-38). A discussion of some of the history of this reach is provided under the Lobato Ditch No. 1 structure. The Lobato Ditch No. 2 structure does not have gates to regulate flow into the ditch. The aerial photograph near the headgate observed return flows from over diversion in multiple locations. Just below the headgate is a high-intensity livestock area. A measurement structure was not identified during the review of aerial imagery. There is minimal riparian vegetation along the ditch. The width of riparian vegetation is approximately 60 feet. The width of the riparian vegetation upstream was approximately 600 feet. There is an abundance of fine sediments in the upstream low water crossing. The low water crossing seems to be frequently used despite the presence of a bridge near the crossing. The structures are likely within the floodplain, flood risk potentially increased by a private bridge over a creek.

Figure 6-38 Lobato Ditch No. 2 Headgate. EagleView Connect Explorer – May 13, 2019

<u>El Puertesito</u>

Jose Lobato Ditch

This ditch diverts from Puertesito Creek. No measurement structures were listed in CDSS or identified during a review of aerial imagery.

6.2.2.4 Culebra Creek – Confluence with El Poso Creek to Confluence with Ventero Creek

<u>The Pando Ditch</u>

The Pando ditch headgate shows bank erosion along the left edge of water (Figure 6-39). Many structures adjacent to the stream may be at risk of flooding. The risk of flooding does not appear to be increased by diversion structure. No measurement flume was identified during the review of aerial photographs, and none were listed in CDSS (December 1, 2021). The flow is primarily regulated by a rock diversion structure and return flow gate (Figure 6-40 and Figure 6-41). There is evidence of high-density livestock adjacent to the stream (Figure 6-42).

Figure 6-39 Pando Ditch headgate. EagleView Imagery May 13, 2019.

Figure 6-40 Pando Ditch headgate.

Figure 6-41 The Pando Ditch return flows.

Figure 6-42 High density livestock adjacent to stream, right edge of water. Flow going from bottom to top of photo.

Sanchez Canal

The Sanchez Canal is the largest diversion structure within the Culebra Basin. According to the map and filing statement Appendix "A" dated November 12th, 1920, construction on Culebra-Sanchez Canal began November 2nd, 1909, and was completed by December 1912. This canal has three headgates and intercepts one stream within the Culebra basin, Headgate 1, Culebra River; Headgate 2, Ballejos Creek (Vallejos Creek); Headgate 3, San Francisco Creek, and intercepts Torcido Creek (Figure 6-44). This structure is junior to many of the water rights within the Culebra basin. During our interview, Ditch company representative indicated that the main headgate functions to divert water and that sediment removal and channel maintenance were not typically a large issue with the structure. Concerns were raised with the function of the gates at the main headgate (Figure 6-44), the San Francisco Creek diversion (Figure 6-55),) and the Vallejos Creek diversions (Figure 6-54). Water diverted through this canal is measured at a concrete flume located at the inlet to Sanchez Reservoir (Figure 6-57).

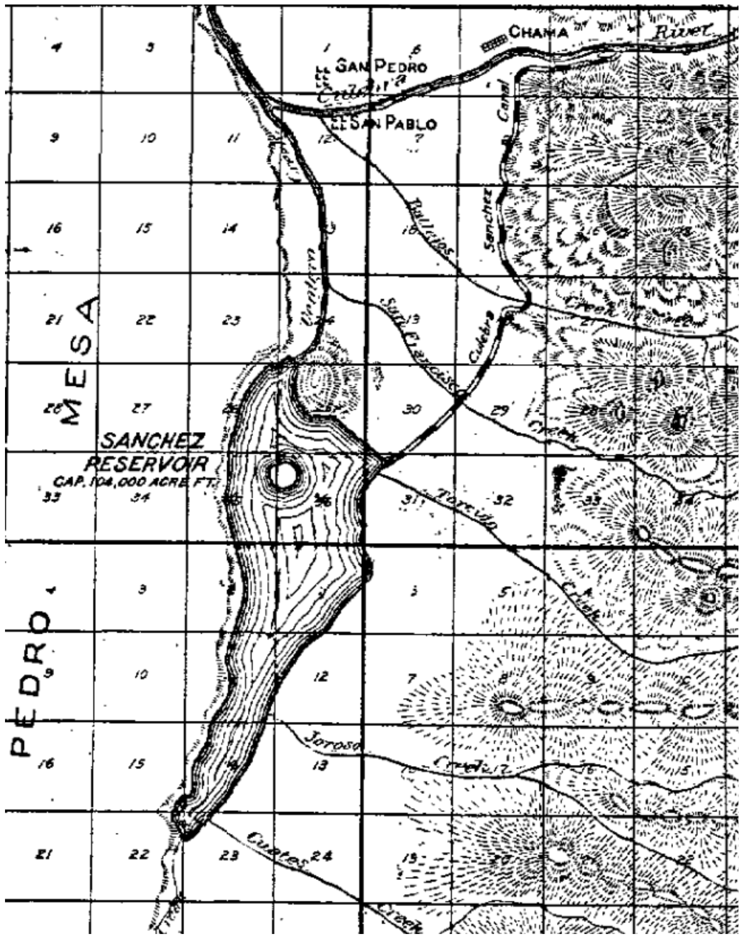


Figure 6-43 Map of Culebra Sanchez Canal from map and filing statement dated November 12th, 1920 (Sanchez Reservoir Amended and Culebra-Sanchez Canal., 1920).

Assessment team representatives visited the diversion structure on July 21, 2021, to evaluate the main structure. During this visit, large piles of sediment were observed along the banks (Figure 6-48) and shown in aerial imagery in Figure 6-45. The diversion structure gates were placed to regulate flow into the creek rather than into the canal (Figure 6-44). Flood gates were deteriorating and do not function to direct flood flows back to the creek (Figure 6-47). Downstream of the structure, sediment piles were noted confining the stream (Figure 6-49), and trash was dumped along the left edge of the stream (Figure 6-50).

This structure poses flood risks to adjacent properties and potentially to properties down the Sanchez Canal. This structure does not provide quality fish passage and may be a barrier to fish migration. Riparian vegetation along the corridor is disturbed by sediment removal from the reach, which also impacts adjacent landowners. Sediment piles increase channel incision, this may increase flood stage and result in unpredictable flow patterns in the event of a flood. The channel above the diversion structure is overwide, increasing stream temperatures and reducing available fish habitat within the reach.

Figure 6-44 Sanchez Canal headgate, headgate seeping into canal. Culebra Creek regulated to flow through four-foot slide gate.

Figure 6-45 Sanchez canal headgate.

Figure 6-46 Sanchez Canal near County Road M.5

Figure 6-47 Flood gates on Sanchez Canal near Culebra Creek headgate. Concrete apron once had places to insert boards to stop flow down ditch.

Figure 6-48 Sediment piles from Sanchez Canal.

Figure 6-49 Levee or sediment pile along Culebra Creek downstream of Sanchez Canal.

Figure 6-50 Trash dumping near headgate of Sanchez Canal.

Many areas were noted along the canal where sediments were deposited into the canal (Figure 6-51). These sediments will be transported to Sanchez Reservoir during higher flow events. Excess rainwater was noted within the canal after the rains on July 21, 2021 (Figure 6-52).

Figure 6-51 Canal intercepts sediments and water from hillslopes along the ditch.

Figure 6-52 Sanchez Canal intercepts rainwater near County Road K.5 on July 22, 2021.

Similar to the main headgate, Sanchez Canal regulates flows in the creeks at Vallejos Creek (Figure 6-53 and Figure 6-54) and San Francisco Creek rather than regulating flows into the canal (Figure 6-55, Figure 6-56, and Figure 6-57). The Vallejos Creek headgates were recently replaced and are in better condition than the other two diversions. Figure 6-54 shows large piles of sediment along the banks near Vallejos Creek, where sediment was removed from the creek. On Sanchez Canal above San Francisco Creek, drains were noted going directly into the canal along with trash. Some of the trash included an older television set that likely includes mercury-containing components, which may impact water quality.

Figure 6-53 Sanchez Canal Vallejos Creek. From EagleView Aerial Imagery dated June 4, 2019

Figure 6-54 Sanchez canal at Vallejos Creek. From EagleView aerial imagery dated May 13, 2019.

Figure 6-55 Sanchez Canal at San Francisco Creek crossing. From EagleView aerial Imagery dated June 4, 2019

Figure 6-56 San Francisco Creek below Sanchez Canal August 19, 2021.

Figure 6-57 Pipe conveying San Francisco Creek through Sanchez Canal.

In addition to the issues with the headgates, reports were made that there were issues conveying water across the Sanchez Canal. During the assessment, some of the pipes across the canal were observed (Figure 6-58). in addition, the EagleView aerial imagery shows water being backed up above the canal through the Vallejos and San Francisco Creek floodplains (Figure 6-59 and Figure 6-60).

Figure 6-58 Pipes transporting ditch return flows across Sanchez Canal.

Figure 6-59 Backwater from canal embankment right edge of floodplain Vallejos Creek.

Figure 6-60 Canal causing backwater right floodplain San Francisco Creek drainage.

While Sanchez Canal represents exceptional construction and engineering for the period in which it was constructed, improvements could be made to the system to improve operations, reduce conflict, reduce flood and water quality risks, and improve the ecology of the streams that this canal intersects. This structure is impacted by fine sediment erosion upstream of the structure that deposits within the diversion structures from each stream.

<u>Cerro Ditch</u>

On the Cerro Ditch, historic channel cleaning and bank stabilization appear in the aerial photo on the right edge of water upstream of diversion. The measurement structure for this canal is a 4-ft Parshall flume, and the canal is lined below the headgate. The channel is overwide upstream of the diversion dam, increasing stream temperatures, increasing sediment deposition, bank erosion, and decreasing fish habitat. Sediment deposition upstream of the dam is shown in aerial photography (Figure 59). This diversion dam is likely a fish barrier at some, if not all, stages. The new concrete splitter box appears to be functioning and has improved safety, including catwalk for access (Figure 6-63). This structure is Priority 11, and as such, must pass water downstream to the senior San Pedro Ditch and is not a sweeping point on Culebra Creek. This structure does not appear to cause significant flood risks because there is no development in the floodplain. This is an area to continue to protect from development. Portions of this ditch have been lined; some issues were noted along the ditch with access to headgates due to dense willows that are difficult to remove using typical methods.

Figure 6-61 Cerro Ditch headgate.

Figure 6-62 New concrete splitter box on Cerro Ditch.

Figure 6-63 Cerro Ditch farm headgate.

Figure 6-64 Upstream of culvert above Cerro Ditch farm headgate shown in Figure 6-63

<u>The Association Ditch</u>

The Association Ditch is the first ditch in this reach that diverts water on the left bank to lands to the south of Culebra Creek. This small ditch has been impacted by development within the floodplain. The diversion structure was not identified during the review of the aerial imagery. The area is covered in dense riparian vegetation. The structure is located downstream of an alluvial fan that may have pushed Culebra Creek to the north. The reach this diversion is in is highly developed. No measurement structure was visible in the review of aerial imagery, nor is any listed in CDSS (December 1, 2021).

The Mondragon Ditch

Figure 6-65 Mondragon Ditch headgate. Ditch shown in lower center of picture.

The Mondragon Ditch diverts in an area with multiple residential structures. This reach has good tree cover, but the riparian vegetation becomes sparser in areas. In the EagleView aerial imagery dated June 4, 2019, it appears that some irrigation is occurring directly below the headgate near residential structures, although this may be due to excessive diversions. Because this structure diverts on the same side of the creek and irrigates lands that the Cerro Ditch could also serve, any adjustments to this structure should consider moving the point of diversion up to the Cerro Ditch diversion, thus reducing the number of structures impacting the creek. No assessment of the diversion dam or measurement structure was made.

Chama Ditch Extension

No diversions were recorded for this structure from 2011 to 2020. Water was not available in 2011 and 2012 but was available for the remaining seven years. This structure was not assessed.

The Aban Sanchez Ditch

This structure is not visible in aerial photography. No measurement structure was listed in CDSS.

Rodriguez Ditch

The point of diversion for the Rodriguez Ditch is upstream of County Road 23.8. With a 2001 priority date, this relatively junior water right receives water most years and appears to be functioning. No information was available on the headgate or measurement structure.

Figure 6-66 Water backed up behind County Road 23.8 bridge near Rodriguez Ditch headgate

<u>San Pedro Ditch</u>

The San Pedro Ditch is the first structure on Culebra Creek that sweeps the stream. This structure is considered functioning with respect to the requirements for diversion structures and the ability to divert water (Figure 6-67). The structure has been channelized by constructing levees on both banks, removing access to the floodplain, and increasing shear stresses (Figure 6-68). Structures upstream have reduced the transportation of sediment and water, therefore, aggradation upstream of the structure is not a concern. The San Pedro 4-ft Parshall flume could be upgraded to include a data logger. The Parshall flume appears to have a significant drop below the structure, increasing downstream erosion. The Culebra Creek channel is severely degraded below the structure due to levees and historic channelization. The San Pedro Ditch diversion dam results in a backwater, which could increase flood risk when combined with the development of this structure. This structure likely impedes fish passage when the structure is not diverting.


Figure 6-67 San Pedro Ditch headgate and measurement flume.

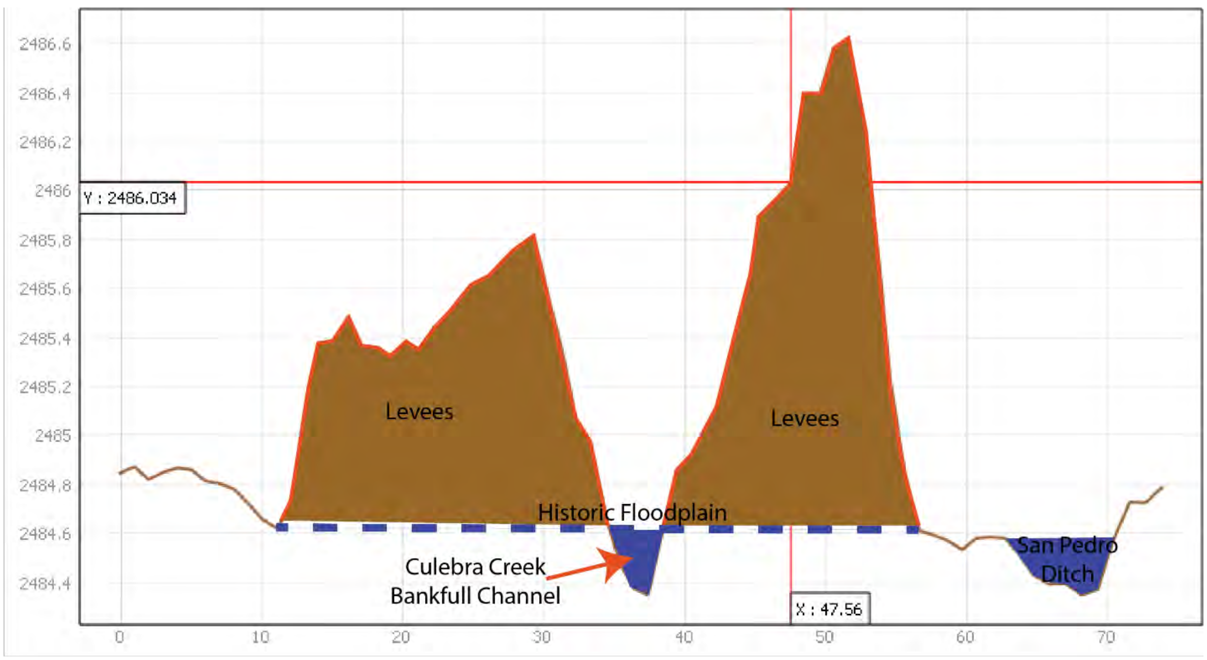


Figure 6-68 Cross-section profile of San Pedro Ditch near the San Pedro Diversion Dam. Note the height of the levees constructed around the creek increasing channel incision. Note units on both axes are in meters.

<u>The Jose E. Sanchez Ditch</u>

The Jose E. Sanchez Ditch structure was not located, and no measurement structure was listed in CDSS (December 2, 2021). Information provided by others suggests that this structure needs repair.

6.2.2.5 Culebra Creek – Confluence with Ventero Creek to Culebra Eastdale Canal

Culebra Creek, between the Ventero Creek Culebra Creek Confluence and the Eastdale Canal includes the most senior priority water rights and is the conveyance channel for water released from Sanchez Reservoir. Excess diversions in this reach will affect upstream water users' ability to divert water legally. Larger structures in this reach are a priority for electronic diversion records to improve direct flow and water storage administration in the reach.

Lucero Ditch

The Lucero Ditch is the first diversion below the confluence with Ventero Creek, diverting water on the left bank. The Diversion dam appears to be a small cross vane structure. No headgate or measurement structure was identified during the available aerial photographs review. The structure was located by following the ditch upstream. No issues with this structure were noted during interviews. The structure does not appear to be a fish barrier. It appears to pass sediment and is not likely to increase flood risk.

Figure 6-69 Lucero Ditch point of diversion. Image from EagleView dated June 2, 2019.

Sam Lucero Ditch

This structure was not located and was not evaluated.

San Luis People's Ditch

This diversion structure is new and was moved approximately 1,200 feet upstream of the historic diversion dam (Figure 6-70). The new structure does not have any overhead structure, which reduces the risk during flooding. A sediment sluice is present at the headgate. The structure reduces fish passage with an approximately 5-foot drop off the structure. A downstream historic diversion structure was abandoned in place, leaving the concrete structure and floodplain grading in place (Figure 6-71). The structure has a measurement flume without a logging device. There is no riparian vegetation around the structure, and some upland vegetation encroachment along banks. Any improvements to this structure should evaluate flooding around the structure to ensure San Luis People's ditch is not a conduit to increase flooding on San Luis residents. San Luis People's ditch intercepts return flows from the Cerro Ditch (Figure) that are downstream of the measurement flume. Approximately half of this ditch was recently relined with concrete, and in general, the turnouts were reported to be in good condition. The Mayordomo reported that there are issues with seepage that if corrected could improve down-ditch operations, especially for those water users at the end of the ditch.

Figure 6-71 Old diversion dam. EagleView aerial imagery June 2, 2019.

Figure 6-70 San Luis People Ditch Diversion Dam. EagleView aerial imagery June 2, 2019.

Figure Cerro Ditch return flow into San Luis People's Ditch.

Robert Allen Ditch

The Robert Allen Ditch diverts water from the left bank of Culebra Creek (Figure 6-72) in a portion of the creek that appears to have been straightened. No information regarding the measurement flume was available or listed in CDSS.

Figure 6-72 Robert Allen diversion structure.

Culebra Cerritos, Island Ditch, and Francisco Sanchez

These three ditches use a common diversion dam to divert water from Culebra Creek (Figure 6-73). The diversion dam was recently rebuilt to improve operations at these three structures. The diversion dam backs up water such that houses are infrequently flooded during winter (Figure 6-74).

Figure 6-73 Culebra Cerritos, Island Ditch, and Francisco Sanchez Headgates.

Figure 6-74 Culebra Cerritos, Island Ditch, and Francisco Sanchez diversion dam.

Francisco Sanchez

The Francisco Sanchez is the eastern ditch diverted from the diversion headworks. Water users reported that the canal brings sediment down the ditch. The Francisco Sanchez flume was submerged during the site visit (Figure 6-75).

Figure 6-75 Francisco Sanchez measurement flume, submerged - inoperable.

Culebra Cerritos Canal and Island Ditch

Flows into this ditch are measured by a 6-foot Parshall flume (Figure 6-76). The structure was found to have significant growth in the entrance of the flume along with a standing wave. The staff plate was also located in the wrong position along the flume wall. Sedimentation is present along the banks of the canal.

Figure 6-76 Culebra Cerritos Canal and Island Ditch 6-ft measurement flume.

San Acacio Ditch

The San Acacio Ditch diversion dam was recently rebuilt (Figure 6-77). This new dam raises the water surface and diverts water more reliably than the previous dam. No changes to the gate structure were made when the dam was rebuilt, and the gates are all difficult to operate and icing in winter makes getting cattle water difficult (Figure 77). There remain issues diverting water when flows are low.

The measurement flume has a good drop through the structure, enabling streamflow measurement, but erosion protection is not present, increasing the risk of washout. Similarly, significant erosion is present below the splitter structure for North and South San Acacio Ditches (Figure 6-79 and Figure 6-80). Many farm headgate structures date back to the 1920s (Figure 6-81), erosion throughout the ditch was observed (Figure 6-80). The downcutting is causing farm deliveries to be less dependable than they once were.

Figure 6-77 San Acacio diversion dam, with trash.

Figure 6-78 San Acacio headgates.

Figure 6-79 Large scour pool between splitter structure for North and South San Acacio Ditches.

Figure 6-80 Erosion along San Acacio ditch.

Figure 6-81 Farm headgate from San Acacio Ditch. Estimates indicate that many of these structures may date back to the 1920s.

Figure 6-82 Bank erosion along San Acacio ditch.

Culebra Eastdale Ditch

Culebra Eastdale Canal marks the downstream most diversion structure on the Culebra. This structure diverts water from storage and is used directly for irrigation and storage. This structure diverts water during the non-irrigation season. This structure receives all excess flows that were not delivered upstream, making this point in the stream critical in water administration. The structure does include a stilling well and a recording device for the development of records (Figure 6-83). Flooding was not determined to be of significant concern. Sediment deposition in the ditch is preferable to deposition in Stabilization Reservoir. The fish passage may be an issue with this structure, and the reach could provide better habitat for aquatic species.

Figure 6-83 Measurement structure for Culebra Eastdale Canal.

6.2.2.6 Vallejos Creek and North Vallejos Creek

Ramon Lucero Ditch

The Ramon Lucero Ditch has a structure that diverts at approximately a right angle from the North Vallejos Creek channel. A Parshall flume and headgates were observed in the aerial photograph (Figure 6-84). No issues were identified with the headgate or diversion structure through interviews. The addition of a fish screen on this structure would prevent fish entrainment in the ditch. The culvert upstream of the diversion may pose a barrier to fish passage which should be evaluated before work on this structure (Figure 6-85).

Figure 6-84 Ramon Lucero Ditch headgate. EagleView imagery May 13, 2019.

Figure 6-85 Reach upstream of Ramon Lucero Ditch diversion. Stream is a multithread channel that is likely a response to excess sediment from upstream sources. Image from EagleView aerial imagery dated May 13, 2019.

Bennie & Kiko

The Bennie and Kiko Ditch diverts water from Vallejos Creek via a 2-foot slide gate (Figure 6-86). During the site visit, the gate was found to be leaking slightly but otherwise in good condition. The 1-foot Parshall flume was full of debris. The debris could be cleaned out to restore the function (Figure 6-87). Erosion was observed in the ditch in its steeper sections. The channel is slightly overwide at the diversion structure, with a mid-channel bar being used to direct flows to headgate. The ditch is conveyed over the arroyo; clearance is approximately 20 ft to the bottom of the gully. The ditch intercepts sediments as it traverses the valley's edge.

Figure 6-86 Bennie & Kiko headgate. Appears to be functioning with some gate leakage.

Figure 6-87 Bennie & Kiko 1 ft Parshall Flume with significant debris in structure including grass and rocks.

<u>Julio Gold</u>

The Julio Gold diverts water from the left bank of the Vallejos just below the headgate of the Bennie & Kiko. The headgate is in thick riparian vegetation and is not visible from historic aerial imagery. During interviews, this structure was reported as having issues with headgates or measurement structures. Downstream degradation was noted on the ditch (Figure 6-88). This degradation will increase sediments to the stream and potentially headcut, reducing head available for irrigation.

Figure 6-88 Julio Gold incised ditch.

Guadalupe Vigil

The Guadalupe Vigil diverts from Vallejos Creek. This ditch has a headgate structure, and the riparian corridor appears to be in good condition. It appears that there have been some past issues with sediment in the reach (Figure 6-89). The creek is slightly over widened around this structure. Some channel over widening downstream was observed. This structure may be a barrier to fish passage within this reach. Flooding risk is minimal due to no development within the floodplain upstream of the structure. Improper structure operation may pose a flood risk to downstream structures and personal property.

Figure 6-89 Guadalupe Vigil Ditch headgate. May 13, 2019

Vallejos Canon Ditch

The Vallejos Canon ditch diversion structure is located 200 feet upstream of a commercial building. No issues were identified with this structure related to headgates or measurements structures. EagleView aerial imagery from May 13, 2019, shows the headgate effectively prevents water from flowing down the ditch. Structure placement in the creek likely results in sediment and trash being directed toward the headgate, with fine sediment deposition upstream of the dam. LiDAR indicates a drop across the structure is approximately 1.5 ft, resulting in scour below the structure. Downstream of the diversion dam, culverts have been placed in Vallejos Creek for placement of the driveway may increase flooding by catching debris and may provide for less desirable fish passage. Two driveways are present across the stream, increasing the number of crossings (Figure 6-90). Based on the 2011 LiDAR, the structures were constructed along a higher terrace; however, they may be at risk because they were constructed near the edge of the terrace, which could be eroded by the channel in the event of a flood or slowly over time (fluvial hazard zone) (Figure 6-91). It appears that a portion of the cars stored on the lot are within the floodplain. Grade control structures are present between the two crossings, which likely was straightened and presently has degraded riparian habitat conditions.

Figure 6-90 Vallejos Canon Ditch headgate. EagleView May 13, 2019.

Figure 6-91 Structures along Vallejos Creek near Vallejos Canon ditch.

Conditions down ditch on the Vallejos Canon were evaluated through 2019 EagleView aerial imagery. Restrictions in flow may exist due to piping across the Sanchez Canal (Figure 6-92). It was observed that downcutting conditions of the ditch affect land irrigation opportunities and increase sediment contributed from the banks (Figure 6-93).

Figure 6-92 Vallejos Canon Ditch crossing Sanchez Canal.

Figure 6-93 Vallejos Canon Ditch - ditch is downcutting

<u>Chavez and Quintana Ditch</u>

Chavez and Quintana Ditch diverts water from Vallejos Creek on the right (Figure 6-94) and left bank (Figure 6-95). A flow regulation structure was visible in aerial photography, and no issues with the headgate or measurement device were identified during interviews. Aerial imagery shows sediment piled along the banks of the ditch, which may indicate a maintenance issue. A residential structure downstream of diversion is near the banks of Vallejos Creek and could be at risk of flooding. Configuration of the diversion dam and ditch with respect to the channel may increase down ditch flooding in the event of a flood on Vallejos Creek.

The creek flow spreads across low water livestock crossings, which may be a barrier to fish passage and increase in-stream sediments and water temperature (Figure 6-95). It appears that livestock may frequently be kept in the floodplain.

Figure 6-94Chavez and Quintana Ditch headgate on right bank.

Figure 6-95 Left bank diversion for Chavez and Quintana Ditch.

<u>Mestas Ditch</u>

The Mestas Ditch diverts water from the Vallejos just below County Road 22.3. This structure was listed as not functioning from an administrative prospected due to either lack of measurement structure or locking headgates. The structure is in an area with a dense, tall canopy that was not spotted from the bridge and is not visible in aerial photographs. The structure is affected by flows through County Road 22.3, which is likely the controlling feature upstream of the diversion. Downstream Vallejos Ditch diversion structure affects flooding in this reach. Adjacent County Road K.5 is approximately 3.6 feet above the channel bottom in the 2011 LiDAR, increasing flood risks from the diversion structure.

<u>Vallejos Ditch</u>

This diversion structure diverts to both the north and south of the creek. The north Parshall flume was clean with a good drop (Figure 6-96). The south Parshall flume had a good drop and some light debris that would affect the accuracy of water measurement (Figure 6-97). The levelness of the structures was not checked during the site visit. The headgate is a concrete structure in good condition. The structure was designed to sweep the channel and had sediment deposition in the structure above gates. Within the channel, the grass is growing below the structure. This structure has an overflow designed to allow flood flows to pass downstream. Overhead structure on the diversion may increase flood elevations around the structure.

This structure, at times, sweeps Vallejos Creek, including during wintertime for stock water. Below this structure, the creek is severely degraded with only a small defined channel and sparse riparian vegetation (Figure 6-98). Riparian vegetation starts to improve just above County Road 21, where return flows accumulate. The creek is heavily encroached by structures along this reach.

Figure 6-96 North Parshall flume was found with good drop and was clean in good condition.

Figure 6-97 Vallejos Ditch south Parshall flume some light debris.

Figure 6-98 Vallejos ditch headgate.

6.2.2.7 San Francisco Creek

<u>Alamosito Creek</u>

The three diversion structures on Alamosito Creek were recently adjudicated and included Alamosito Ditch Diversion A (Figure 6-99), East Alamosito Ditch Diversion B1 (Figure 6-100), and East Alamosito Ditch Diversion B2 (Figure 6-101). A well-developed active alluvial fan is present at the mouth of Alamosito Creek (Figure 6-102). Maintaining this feature will allow the fan to continue functioning and reduce downstream sedimentation. It is important to avoid channelizing or developing these lands to maintain this function.

None of the three Alamosito Creek diversions have any record of diversion. It appears that some irrigation has occurred along this reach and that diversions may be occurring through a few small ditches. It is important to make a record of diversions to avoid abandonment. The well-connected floodplain helps to reduce required irrigation and is important to preserve the riparian corridor and channel. Preservation of this floodplain connection continues to allow grasses to be naturally sub-irrigated. It also allows the reach to function as a sediment deposition zone protecting downstream water users. Preserving fish passage at these headgates also preserve range in the fishery by maintaining the connection to San Francisco Creek.

Figure 6-99 Alamosito Diversion Ditch A.

Figure 6-100 East Alamosito Ditch Diversion B1.

Figure 6-101 East Alamosito Diversion Ditch B2.

Figure 6-102 Channel braiding in Alamosito Creek alluvial fan. Channel braiding reduces stream energy and allows sediments to be deposited.

Gabriel Medina No. 1
The diversion structure is not visible in the aerial imagery. During interviews, this structure was listed as having issues with administrative requirements, including lockable headgate and/or measurement structure. The stream shows instability along the left edge of the water just above the diversion structure (Figure 102). Bank erosion and mid-channel bars are noted below the structure. No flooding or fish passage issues were noted.

Figure 6-103 Gabriel Medina No. 1 headgate. EagleView Aerial imagery May 13, 2019.

Gabriel Medina No. 2
The Gabriel Medina No. 2 diverts water from San Francisco Creek. During interviews, this structure was identified as having issues with administrative requirements, including a lockable headgate and/or measurement structure. No diversion dam was visible in aerial imagery, and measurement structure was not listed in CDSS or spotted in the available aerial imagery (Figure 6-104). Flooding is likely not a large risk because the area is not developed; however, vegetation encroachment on the floodplain is apparent below the structure.

Figure 6-104 EagleView Aerial imagery of Gabriel Matina No. 2.

San Francisco Ditch
This structure diverts water from both the north and south sides of San Francisco Creek (Figure 6-105). The structure can sweep the creek at times. The stream is overwide at diversion dam with a large drop on the creek that poses hazards to fish passage. The structure has fine sediment deposition, with vegetation growing in the channel in front of the south gate (Figure 6-106). In the winter, the gates on the south side do not close completely, so to prevent downstream flooding, the ditch bank is breached to push water back into the creek. A new measurement flume on the north side of the ditch does not have a staff gage, so the old flume is still in use.

Figure 6-105 San Francisco Ditch from EagleView aerial imagery.

Figure 6-106 Looking downstream at San Francisco Ditch diversion structure.

Future projects along the south San Francisco Ditch should consider consolidation with Acequia de Los Cedros and Little Rock to reduce the number of in-stream structures on San Francisco Creek.

<u>Acequia de los Cedros Ditch</u>

The Acequia de Los Cedros diverts water from the left bank downstream of a small private bridge (Figure 6-107). This structure was listed as having deficiencies meeting the locking headgate or measurement structure. There appears to be a splitter box across the stream in the EagleView aerial image dated May 13, 2019. This reach includes many structures near the stream that could be impacted by flooding. Tall riparian vegetation is present along the banks. Fish passage may be an issue at this structure, but this would not be a high priority site due to the creek being frequently dewatered and minimal flows through this reach.

Figure 6-107 Acequia de los Cedros headgate.

Future projects on this ditch's headgate should consider consolidating the headgates with San Francisco Ditch and Little Rock Ditch to reduce the number of in-stream structures.

<u>Little Rock Ditch</u>

The structure for Little Rock Ditch could not be located among the trees in aerial photographs. This structure was identified as having issues with either the headgate or measurement device. The ditch appears to be well maintained; however, livestock is kept near the stream, and all riparian vegetation except the tall trees is degraded. Structures and debris in the floodplain could be damaged by floods and could pose risks downstream if mobilized in a flood. A future upgrade to the diversion headgate should consider consolidation with Acequia de los Cedros and/or San Francisco Ditch to reduce the number of in-stream structures.

Alamo Ditch

The Alamo Ditch diverts water from the south bank of San Francisco Creek in an area with dense riparian vegetation (Figure 6-108). The width of the riparian vegetation is approximately 190 ft near the structure. The diversion dam and measurement structure were not visible in aerial imagery. A lidar profile shows San Francisco creek is against a low terrace to the south in this location. This increases flood risk to structures adjacent to the stream in the event of overbank flows that may not follow the main channel. More detailed analysis around this structure is needed to determine an elevated risk of avulsion.

Figure 6-108 Alamo Ditch headgate. Aerial imagery from EagleView June 3, 2019.

Mondragon and Romero

The Mondragon and Romero Diversion receives water from Sanchez Canal at the San Francisco Creek diversion. See the Sanchez Canal section for more information related to this structure. No issues were identified with the measurement structure. The measurement structure was not visible in aerial photographs.

Emilio Lobato Ditch

Two diversions were observed in the vicinity of the Emilio Lobato Ditch, and the upper diversion has a splitter box for diverting flows. The structure spans San Francisco Creek and may result in the channel becoming overwide and depositing sediment upstream. No issues were identified with the measurement structure or headgates through interviews. The San Francisco Creek channel is not located in the lowest part of the valley, increasing flood risk for property to the north and east. The channel was likely relocated into this historic channel to increase available head for irrigation. Because the stream is higher than the surrounding terrain, losses through this reach are potentially increased.

Figure 6-109 Multiple diversions from San Francisco Creek in the vicinity of Emilio Lobato. EagleView aerial imagery from June 3, 2019.

Figure 6-110 Emilio Lobato diversion dam.

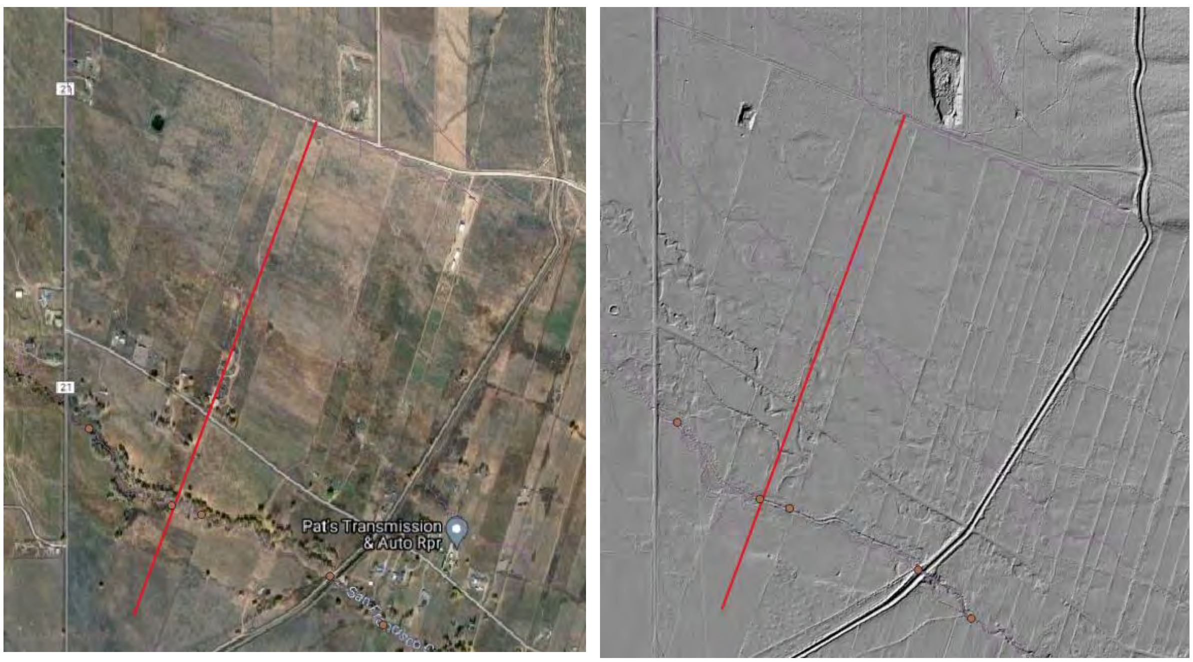


Figure 6-111 Cross section profile location with Google Satellite Hybrid Imagery, left, and SLV LiDAR Hillshade Left.

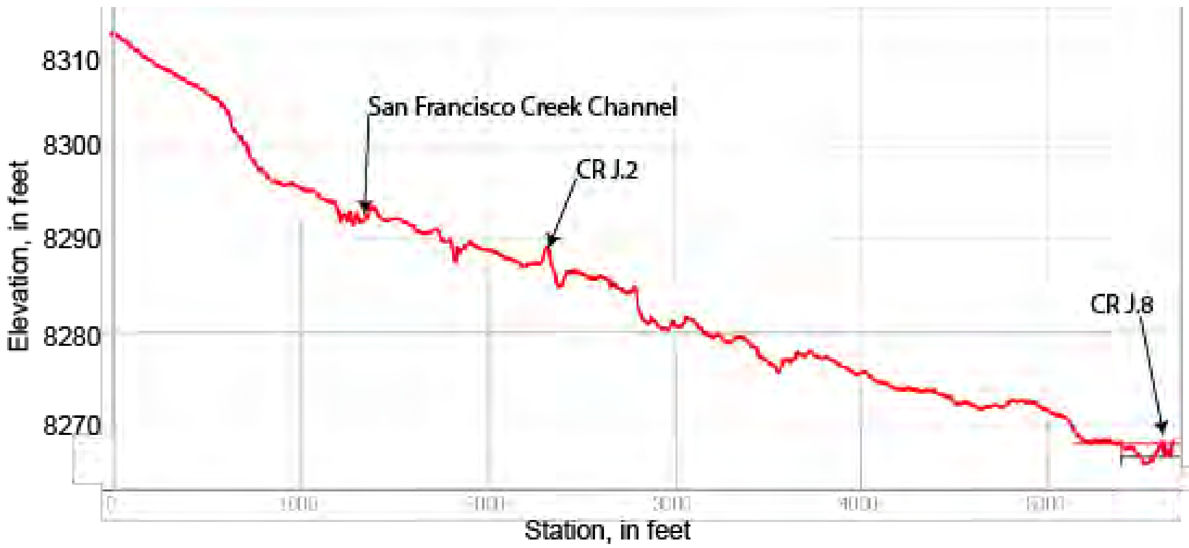


Figure 6-112 Cross-Section profile near Emilio Lobato. San Francisco Creek follows the southern terrace, flood flows in this reach are likely to flow toward the north to the lower portion of the valley.

Rumaldo Gallegos Ditch

The Rumaldo Gallego ditch was identified through interviews as having issues with either measurement structure or locking headgates. The map and filing statement show San Francisco Creek as a very straight course. The bend is shown in the map, and the filing statement projects north, while today's course has a more southern direction. This structure was not visible in aerial imagery due to dense riparian vegetation cover.

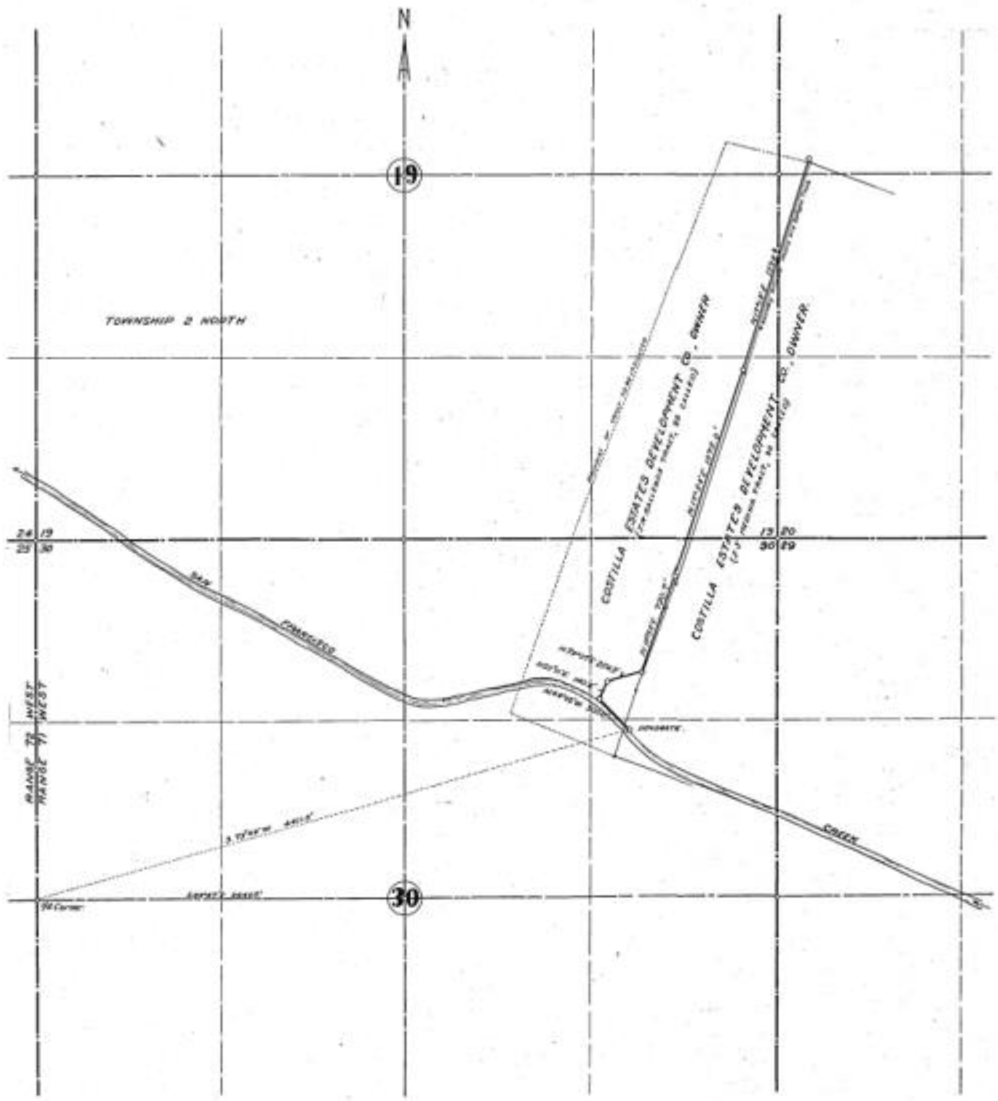


Figure 6-113 Map from Rumaldo Gallegos Ditch map and filing statement dated April 23, 1918.

<u>Jacquez Ditch</u>

Like the conditions observed at the Emilio Lobato Ditch of the San Francisco Creek near the Jacquez Ditch, it appears that the creek has moved, and it does not flow at the lowest elevation in the valley. This may increase ditch loss around this channel because the stream is raised above the water table. During flood events, flows have a high probability of being conveyed in the channels below the current conveyance channel, and the risk of avulsion is increased.

The metal diversion structure has a visible drop below the structure which is an indication that the structure was set too high for geomorphic stability and may cause backwater upstream. Backwater often results in sediment deposition and can cause the channel to become overwide, resulting in bank erosion and additional sediment deposition. The drop below the structure has some erosion on the left bank. Maintaining erosion protection below this structure will prevent scour below the structure and reduce sediment contributions. Riparian vegetation has been removed from banks increasing the risk of channel degradation.

Figure 6-114 Jacquez Ditch headgate. EagleView aerial imagery dated June 4, 2019.

Figure 6-115 Jacquez Ditch diversion structure.

Frank Mondragon Ditch 1

The Frank Mondragon Ditch 1 and the Frank Mondragon Ditch 2 were listed as seepage rights. This structure has headgates and a measurement flume visible in aerial imagery. The San Francisco Creek channel has sparse vegetation in this reach. Downstream of the diversion, tall riparian vegetation is present, but most other riparian vegetation is not present. Noticeable bank erosion is occurring upstream of the diversion structure. Since this structure receives most of the water from return flows it is one of the structures that will be more impacted by changes in upstream operations including improvements in irrigation efficiency and blocked seepage. No issues with this structure were noted in interviews.

Figure 6-116 Frank Mondragon Ditch 1 headgate and measurement structure.

Vigil Ditch

The Vigil Ditch structure is a small diversion from lower San Francisco Creek. The diversion dam and lack of riparian vegetation are causing the channel to be overwide at this section. A Parshall flume measurement device is visible in the aerial photograph. Minor ditch bank erosion was noted below the flume. The creek has good floodplain access in this reach. The diversion dam likely impedes fish passage.

Figure 6-117 Vigil ditch diversion structure. EagleView aerial imagery June 3, 2019.

6.2.2.8 Torcido Creek

The diversion structures along Torcido Creek divert water over the alluvial fan. Adjustments to the creek for diversion have likely changed the hydrology throughout the alluvial fan, reducing agricultural production.

Torcido Ditch and Abundo Martinez

The Abundo Martinez ditch has a historic structure that no longer exists. Diversions for the water along Torcido Creek for these two water rights occur at the canyon's mouth. The water diverts through numerous channels to irrigate fields over the alluvial fan. Issues were noted with this structure concerning measurement structures and locking headgates. This reach may have some slight flooding risk to ranch infrastructure but is otherwise not developed, and it does not appear to increase flood risks to adjacent lands. This area would benefit from restoration to reduce channel incision to increase water table and sub-irrigation. Restoration to this reach could improve meadow quality, wildlife habitat, and water delivery to downstream water users. This area would also be an area that could benefit from electronic recording devices to reduce water commissioner workload and improve record accuracy. Improvements could include telemetry and streamflow gaging near this location would benefit water administration.

Figure 6-118 Splitter on Torcido Creek.

Figure 6-119 Incision on Torcido Creek.

Figure 6-120 Incision along ditch.

Frank Mondragon Ditch 2

This ditch is listed as being diverted from Torcido Creek in the map and filing statement dated May 14, 1919. The diversion structure was not found in aerial imagery, but this structure was not identified as having issues.

6.2.2.9 Ventero Creek

Sanchez Reservoir

During our evaluation of the infrastructure associated with Sanchez Reservoir, safety hazard near the outlet works were observed. No cover or safety rail is present to prevent falling into the stream, and an unlocked ladder was present at the upstream left side of the outlet works. Safety railing and warning signs should be placed to prevent accidents (Figure 6-121). The outlet for Sanchez Reservoir was recently rehabilitated. Bringing the structure up to safety standards with handrails, signage, and confined space entry protection measures would reduce hazards in this area.

Figure 6-121 Outlet works of Sanchez Reservoir.

J.M. J. Maes Ditch

The J.M.J. Maes ditch diversion dam is a rock drop structure with a significant drop below the structure (Figure 6-122 and Figure 6-123). Aerial imagery from EagleView shows significant bank erosion on the right bank above the structure within a tight meander pattern. This structure likely poses issues with fish passage.

Figure 6-122 J.M. Maes Ditch diversion dam.

Figure 6-123 J.M.J Maes ditch from EagleView aerial imagery taken June 3, 2019.

North Ventero Ditch

North Ventero Ditch diverts directly below the Sanchez Reservoir outlet. This small ditch does not increase flood risk. Fish passage was not evaluated because of the proximity to Sanchez Dam. No issues with headgates or measurement structures were identified during interviews. Ventero creek is likely overwide for the hydrology within the reach, with no well-defined low flow channel as it emerges from the canyon. Diversions were noted on both banks of the channel in this location (Figure 6-124).

Figure 6-124 North Ventero Ditch diversion. Water being diverted on both north and south side of Ventero Creek. Ventero Creek flowing from left to right in photo.

6.2.2.10 Jaroso Creek

The Jaroso Creek assessment began at the mouth of the canyon. This assessment included the measurement of geomorphic cross-sections and a site walk along the channels. Ditches were observed along both the north and south sides of the valley. The floodplain was connected in the upper reaches (Figure 6-125), and although the diversion box structure did divide the water somewhat, it appeared the flow paths were comingled below this structure. The channels were walked to try to locate the measurement flume, but this was not found. A historic dam was identified within the valley (Figure 6-126).

Figure 6-125 Floodplain inundation along Jaroso Creek.

Figure 6-126 Historic dam along main Jaroso Creek channel

The Choury Ditch and Jaroso Ditch (south side)

The Choury Ditch headgate is an in-line 3 ft box (Figure 6-127). Scour was noted below the structure, and water was leaking through the closed gate. The ditch along the south side of the channel and the channel were walked, and no flume was not found, although it is listed as having a 2-foot Parshall flume. Water was observed leaking out of the ditch and returning to the channel. Portions of the ditch have been lined (Figure 6-128). An incision was noted in both the ditch (Figure 6-130) and the channel (Figure 6-131) with areas of fine sediment deposition (Figure 6-129). Farm ditches began below ditch and channel incision (Figure 6-132).

Figure 6-127 Choury Ditch diversion structure.

Figure 6-128 Choury ditch flowing on south side of valley Jaroso Creek.

Figure 6-129 Sand in channel below Choury Ditch diversion structure.

Figure 6-130 Cut bank in Choury Ditch.

Figure 6-131 Channel incision Jaroso Creek.

Figure 6-132 Farm ditches began where the ditch was no longer incised.

<u>Jaroso Ranch Ditch No. 1 and No. 2 (north side)</u>

The channel observed on the north side of Jaroso Creek was lined with willows (Figure 6-133) and had many areas that were well connected to the floodplain just below the in-line box structure. Some erosion was noted along the splitter box (Figure 6-134).

Figure 6-133 North side ditch.


Figure 6-134 Jaroso Ranch ditch splitter structure with erosion on left edge.

6.2.2.11 Cuates Creek

Diversion structures on North and South Cuates Creeks are generally considered to be in acceptable condition for the purpose of water administration except for the Arellano Ditch. Installing electronic recording devices on these structures could reduce water commissioner efforts in administering these structures and provide a complete record of diversions. Streamflow gaging on upper Cuates Creek would benefit water administration, provide valuable information for understanding the Rio Grande Cutthroat trout population and climate risks, and improve water administration.

Figure 6-135 Diversion dam on upper Cuates Creek for Arellano and Cuates Ditch No. 2.

Cuates Creek is an area that could benefit from cooperative actions along the stream to improve conditions for all water users within this sub-watershed. Actions could include improvements to riparian areas to reduce incision, increase shading, improve bank stability, and improve floodplain storage to support flows to the lower portion of the reach.

In addition to the diversion structures, splitter boxes on Cuates Creek near County Road 21 were evaluated. The flumes in this area were generally level, some did not have staff plates.

Figure 6-136 Large drop below splitter box on Cuates Creek diversions, preventing fish passage and increasing risk of structure failure.

Figure 6-137 Wood splitter box on Cuates Creek.

<u>Cuates Ditch No. 2</u>
A 1-foot Parshall flume was found with the left slightly high and front to back, was level.

<u>Arellano Ditch</u>
The Arellano Ditch diverts water through North Branch Cuates Creek by diverting water through a concrete structure. There is a headcut below the structure in right channel. A 1-foot Parshall flume had debris on the right edge of the water at the flume entrance. The flume was found to be level front to back.

<u>Cuates Creek Pond Supply Pipeline</u>
During the assessment, it was noted that many of the air release pipes for this pipeline were broken and none of these were screened. Screening the air release pipes, for a relatively low cost, could reduce future maintenance issues by preventing large debris and small animals from entering the pipeline.

Figure 6-138 Cuates Creek Pond Supply Pipeline.

<u>Maestas Ditch North and Maestas Ditch South</u>
No issues with measurement structures of headgates were identified through interviews at this location. The North flume was level with grass at the entrance during the site visit, affecting performance. The South flume was also level with some grass in the entrance. A third flume was found with no staff plate. This flume was mostly level front and back with light debris in

front. Culverts under County Road 21 are at risk of filling with debris, plugging, and potential flooding on County Road 21.

Figure 6-139 Maestas Ditch spitter boxes at County

Figure 6-140 Splitter boxes and headgates Maestas Ditch South.

6.2.2.12 Willow Creek

Fares Jaquez Ditch

The Fares Jaquez Ditch is diverted from Willow Creek (S. Cuates Creek). Willow Creek is located within the alluvial fan as Willow Creek traversed the foothills. Riparian vegetation is dense in this area, although it decreases just downstream of the structure. No issues with the structure were identified through interviews. The structure does not appear to increase the risk of flooding. Fish passage was not evaluated at this location.

Figure 6-141 Fares Jaquez Ditch headgate. EagleView aerial imager June 20, 2019.

W.F. Meyer

The W.F. Meyer had a lockable slide gate at the headgate Figure 6-142. The W.F. Meyer structure had a levee on the right edge of water downstream of the structure to prevent water from leaving the channel. A 1-foot Parshall flume was observed on site (Figure 6-143).

Figure 6-142 W.F. Meyer diversion structure from Willow Creek.

Figure 6-143 W.F. Meyer measurement flume. Downcutting noted in channel below structure.

6.2.3 Diversion Structures and Ditches Summary

Diversion structure and ditch issues include issues with meeting administrative requirements, areas of sediment deposition, dewatered areas, and conflicts between water users. These issues are summarized as headgate or administrative issues and issues with the diversion/stream interactions.

6.2.3.1 Headgates

The diversion structures and ditches were evaluated for their impacts on the watershed. Many structures do not have lockable headgates and/or measurement structures. This equipment protects all water users and ensures that water rights may be administered equitably across the basin. The review of information available from CDSS and evaluation of diversion structures showed that this requirement is most stringently enforced on those water users with more recent decrees and the larger/more senior water users. Headgate orders are the typical mechanism used by the Division of Water Resources to enforce headgate and measurement structure requirements. Smaller acequias that have not had a change in use may have received headgate orders in the past but have not implemented the required infrastructure.

Headgates are required to provide safety to the community and keep water where it should be. Headgates prevent down-ditch flooding by regulating the volume of water that enters the ditch during high water and allowing the stoppage of water in the event of ditch failure downstream. These structures block water from entering the ditch when it is not being used. This helps keep water in the stream to prevent dewatering, support the ecosystem, and prevent water quality degradation. These structures also help protect the water right by allowing the water commissioner to lock the structure and prevent out-of-priority diversions or excess diversions allowing water to pass the headgate to keep water in the system for the senior water users and the stream.

Headgates belong on the ditch and not in the stream. The purpose of headgates is to regulate flow into the ditch, not regulate the water left in the stream. While this is most notable at the intersections between the Sanchez Canal and the streams, San Francisco Creek and Vallejos Creek, it is also the case on many smaller tributaries.

Installing an accurate measurement structure can help water users avoid having their water rights listed on the abandonment list by having more accurate records of water use. More accurate records help water administration by providing a better understanding of where losses occur and identifying practices to improve the system for all water users and habitats. Installing electronic logging on a diversion structure is a mechanism that helps protect the water right by providing a complete log of water use. This is beneficial in proving injury in a future change case and can include measurable requirements in future decrees. Records of diversion will increase the value of the water by providing documentation of the rate and timing of water available for operation. This information can benefit younger generations as they take over a farm.

6.2.3.2 Diversion/Stream Interactions

Diversion structures such as the Sanchez Canal, San Pedro, Cerro, and others have large diversion dams that back-up water to increase the head available to divert water into the ditch. These structures reduce the channel slope upstream of the diversion structure. Reducing channel slope results in the water having less capacity to carry sediments, causing sediment to drop out above the diversion dam. Newer headgates sometimes have sediment sluices that allow a portion of the sediment to be diverted around the diversion dam and routed back to the stream. However, older structures, such as the Sanchez Canal at Culebra Creek, block the sediment, resulting in the ditch company being required to maintain the ditch/channel by periodically entering the stream and removing the sediments. These sediments sometimes placed along the banks, often in the riparian areas, damaging the riparian areas and blocking and constricting the floodplain.

As the water cascades off the diversion dam, the head that was used to push water down the ditch is also pushing downward on the bed of the channel below the structure. If the structure has sufficient scour protection through stepped drops, concrete aprons, and/or riprap, the channel will be protected for the life of those measures; if not, the bed is typically eroded and slowly undermines the diversion dam. Because the sediment was left upstream of the dam the water has the capacity to carry additional sediment and will pick these up from the channel causing further degradation. These large structures often inhibit fish passage.

Structures identified as having fish passage issues for some or all stages are listed in Table 6-1. These include structures that may divert all or most of the water, have large drops, or fast velocities.

Table 6-1 Structures that are potential fish barriers at some or all stages.

Fox Ditch	Antonio Sanchez	Cerro Ditch	San Pedro
Culebra Eastdale Canal	Guadalupe Vigil	San Francisco Ditch	Acquia de los Cedros
Vigil Ditch	J.M.J. Meas	Cuates Ditch No. 1	W.F. Meyer
Arellano Ditch	Sanchez Canal	Choury Ditch	San Luis People’s Ditch

6.3 Transportation

The transportation network is evaluated because of the impacts the roadways have on the stream system and the impacts the streams have on the roadways. Examples of ways the transportation system may impact the stream include sediment input, reduced available flow area, decreased concentration time, and floodplain access. The streams affect the transportation system by hill slope failure, over-road water flows, and impacts to culverts and bridges. Research has shown that forest roads are one of the largest contributors of sediments within a forest, estimating that roads can increase erosion rates and turbidity by three orders of magnitude (Grace, 2002), or 1,000 times the predevelopment erosion rate. Traffic volume has been shown to significantly increase sediment production from forest roads (Sosa-Perez & MacDonald, 2017). Within the Upper Culebra basin, approximately 1,800 miles of roads and vehicle traveled routes were evaluated at a varying resolution to prioritize those segments that are likely to be contributing the most sediment. Improperly installed, undersized, and plugged culverts are common reasons for culvert failure (Keller & Ketcheson, October 2015).

A crucial element of the evaluation of the transportation network in the Culebra basin is the interaction with the arroyos and other ephemeral and intermittent streams. Some studies have suggested that many of the arroyos in arid and semi-arid areas of the southwestern United States may have formed during the mid-nineteenth century during the increase in livestock grazing and during a period of frequent flooding (Charlton, 2008). While these streams are often overlooked in studies of watershed health, these streams contribute water and sediment to the perennial stream systems and can support vibrant ecosystems. These streams are often underappreciated and are used for dumping, roadways, gravel mining, and often overlooked in planning (Datry, Bonada, & Boulton, 2017).

The last category, other structures, which includes streamflow gages, fish barriers, and buildings and personal property located within the floodplain. Streamflow gages were evaluated for the impacts on water administration and the potential for conflict. Buildings and personal property located within the floodplain were evaluated for the potential impacts from flooding and debris flows on those buildings and properties. Buildings and personal property included in this report are used to highlight some of the risks and issues associated with structures and other infrastructure that is within the floodplain. This is not a comprehensive list of all structures within the basin. Fish barriers are reviewed for the impacts to channel stability near the structures and the structure-function to protect Rio Grande Cutthroat Trout populations. Fish barrier structures were not targeted directly for analysis but were included because they were identified at risk through the other tasks in the assessment.

6.3.1 Methods

The assessment of the transportation network included a rapid visual inspection of public road crossings and an opportunistic sampling of private road crossings to develop an overall evaluation of the general condition of road crossings within the basin. The second portion of the transportation network evaluation evaluated the risk of sediment delivery from roads to streams within the basin through a modeled approach. This evaluation was completed following methods adapted from the Rapid Resources Inventory for Sediment and Stability Consequences described by Rosgen (2009). Sediment inputs from roadways are significant because most of the sediments contributed from roadways are fine sediments, less than 2mm (Reid & Dunne, 1984). Fine sediments impact fisheries by affecting the emergence of fry (Lachance, Dube, Dostie, & Berube, 2008) by “silting in” redds, where fish lay their eggs.

The first step in assessing the transportation network was to develop a map of the areas that have been traveled by vehicles. This task took considerable time, as many of the roads within the upper Culebra Watershed are private forest roads, historic logging roads, farm access roads. The developed transportation network included damage from recreational traffic that was not included or was inaccurately mapped in available electronic datasets like TIGER/Line shapefiles (U.S. Census Bureau, 2015). The final vector file showing the road locations is provided within the electronic deliverables. The final transportation network file is shown in Figure 6-144.

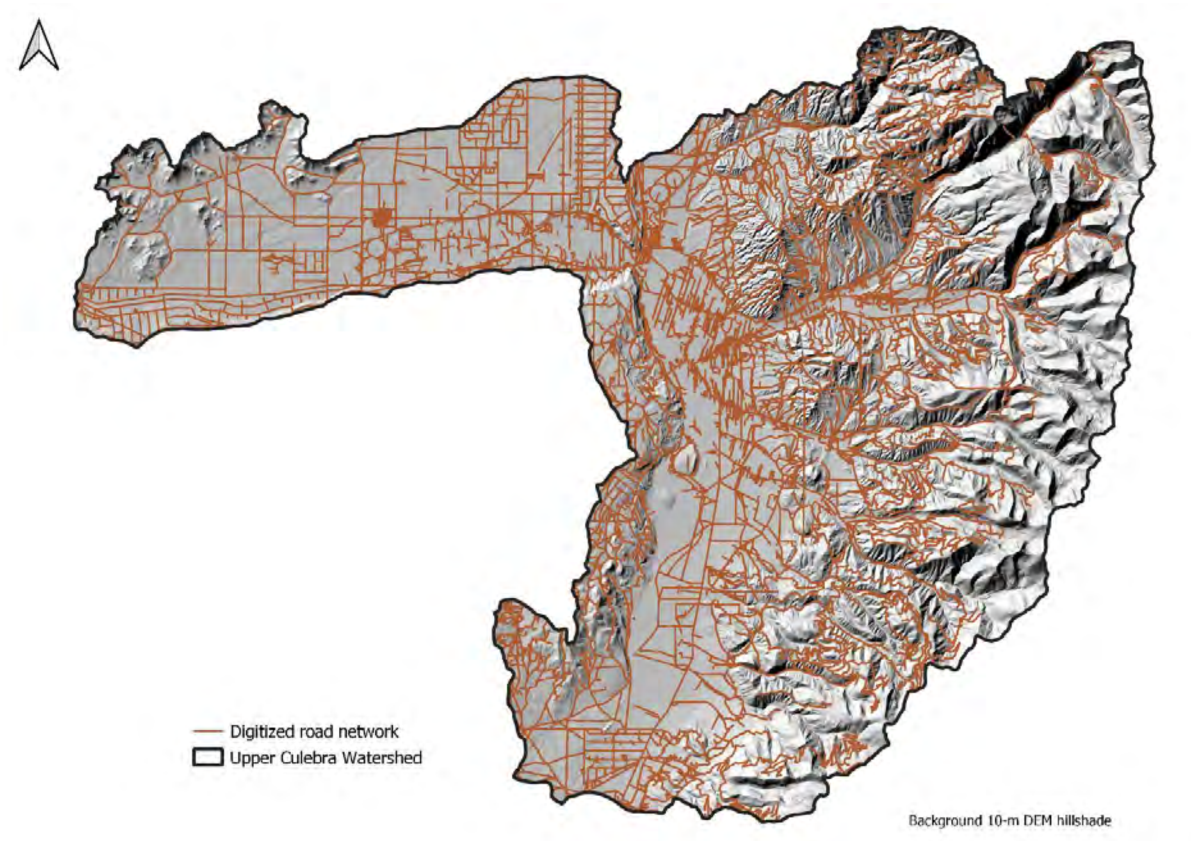


Figure 6-144 Upper Culebra watershed roadway linework.

Because the sediment contribution from roads within a watershed is related to road density, the watershed was evaluated using reach contributing areas. These additional areas contributed to a reach that does not contribute to an upstream reach. The Culebra watershed stream network has 768 links or reaches, resulting in 768 catchments shown in Figure 6-145. A more detailed view, including watershed numbers for each catchment, is provided in Section 1.3.1.2. Combining roadways by watershed allows the cumulative effects of the roadways to be weighted to identify locations where combined inputs are critical.

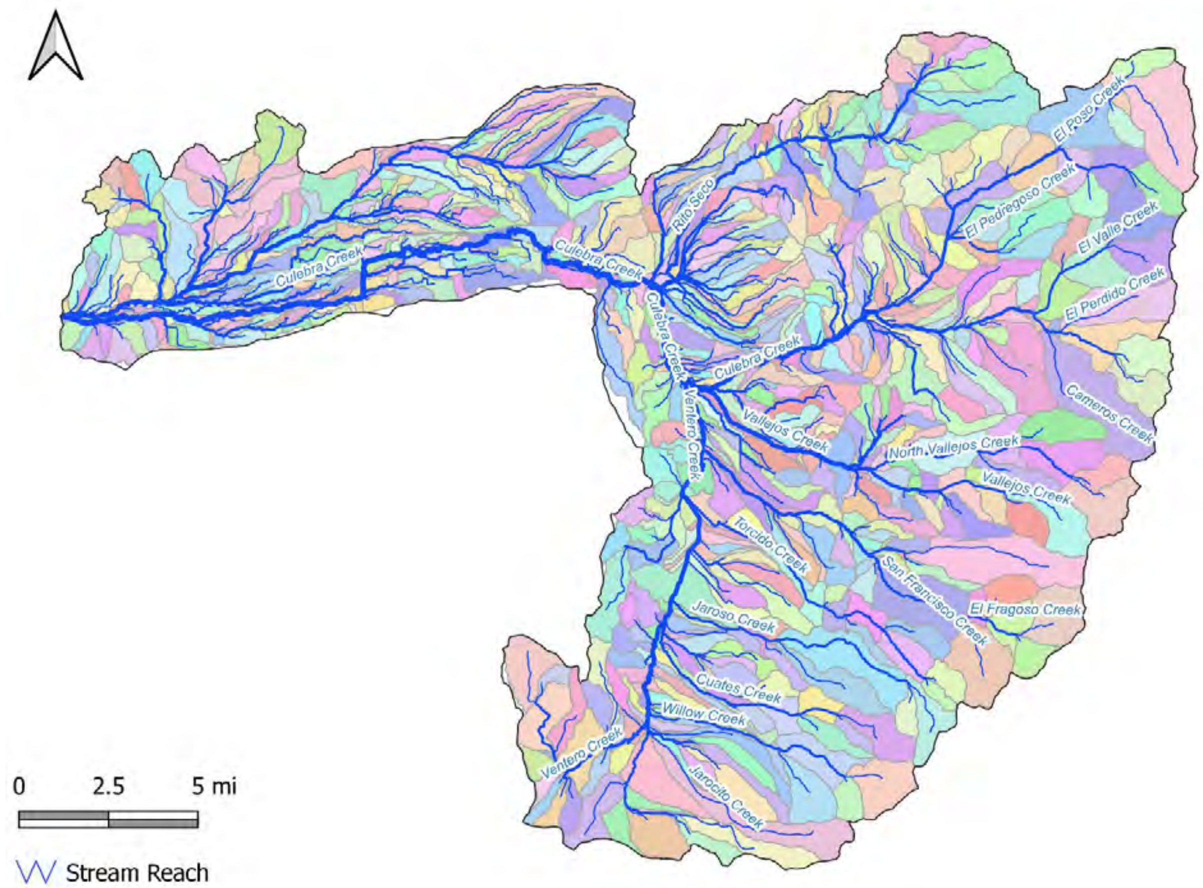


Figure 6-145 Contributing areas for each stream reach.

6.3.1.1 Visual assessment of stream crossings

The analysis of stream impacts to roadways focused on the visual assessment of conditions from field observation and available aerial imagery. Crossings on public roadways were prioritized, and additional opportunistic sampling on private property was conducted. The assessment crew evaluated the reaches to visually determine if the stream was incised at the crossing, if the structure could be a potential fish barrier, or if the structure could increase flood risk. In addition, the general condition of the structures was evaluated. Based on the visual inspection notes, these structures were ranked based on professional judgment as functioning, functioning at-risk, or not functioning. Some structures were not ranked based on uncertainty related to site conditions.

6.3.1.2 National Bridge Inventory

The National Bridge Inventory is a program by the Federal Highway Administration that combines inspection data collected by each state. The data available through this program is summarized.

6.3.1.3 Roadway sediment risk analysis

There are nearly 2,000 miles of roads within the Upper Culebra Basin. A modified version of the transportation section of the Rapid Resource Inventory for Sediment and Stability Consequences (RRISSC) (Rosgen, 2009) was developed and completed to identify regions that should be evaluated to be a priority project. This resource inventory evaluated sediment delivery based on determining factors in sediment delivery from roads to streams. These factors included the number of road crossings and road density, the position of roadways based on slope position, the distance roadway is from a stream and the slope of the road.

The watersheds were rated based on the factors described below. These calculations were adapted for this assessment to utilize GIS processing steps instead of manual processing.

Road impact index:

$$Road\ Density\ Index = \frac{\sum Road\ Length\ x\ Road\ Width}{Watershed\ Area} xNumber\ road\ crossings$$

The road impact index increases significantly as the number of road crossings increases (Jones J. A., Swanson, Wemple, & Snyder, 2000).

The road impacts are higher if the roads are lower within the slope position (closer to the stream) and more minor if the sediments travel over the hillslope to reach the stream. This is because roads that are higher on the hillslope tend to parallel the contours of the hillslope resulting in sediments having to be carried greater distances and over more vegetation prior to reaching the stream. Whereas roads lower in the hillslope tend to parallel the stream with shorter distances to the stream providing additional opportunity for direct sediment input. The roadway impacts to the network also increase as the density of roads increases (Jones J. A., Swanson, Wemple, & Snyder, 2000). A map of hillslope position was developed and used to classify road networks by hillslope position. This map can also be used to highlight valley bottoms (shown in red). The total length of the road within each slope position was calculated for each watershed. The roads were reclassified into the lower slope position (position 1 and 2), the middle position (13), and the upper slope position (4), as shown in Figure 144. The risk rating for each group was calculated. The road width was assumed for this assessment to be 20 feet because road width data are not available for the entire basin.

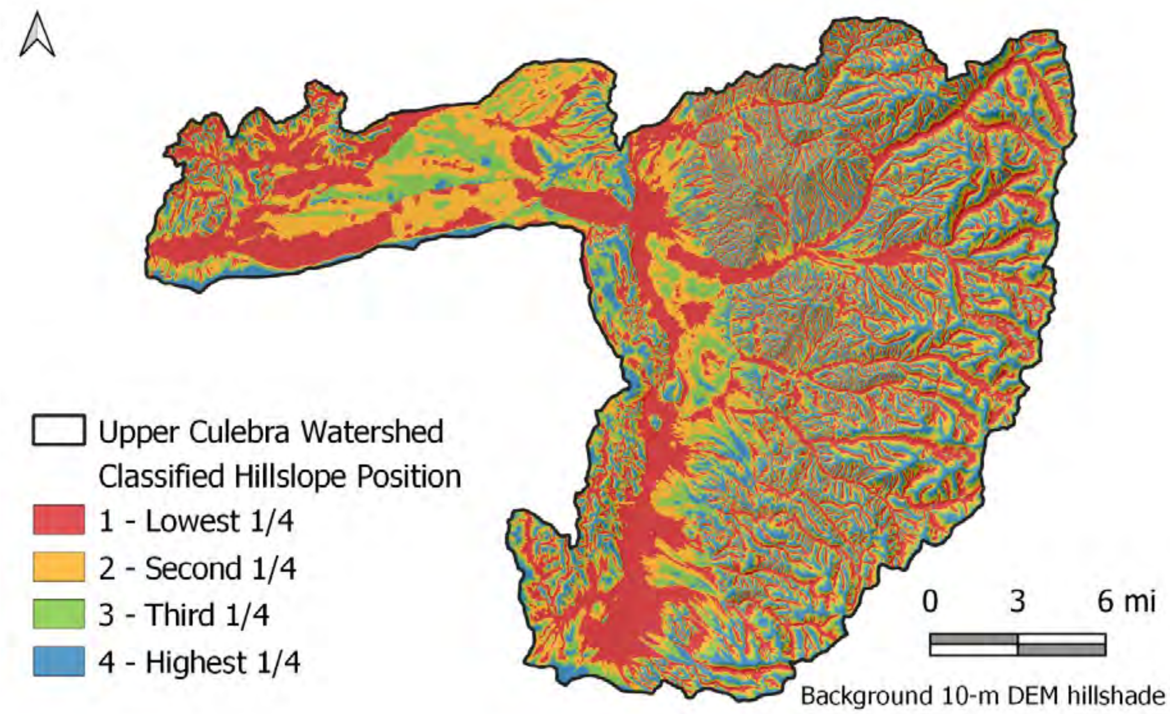


Figure 6-146 Map of classified hillslope position. 1 is lower, 2 is lower middle, 3 is upper middle, and 4 is the upper slope (SAGA-GIS, 2021).

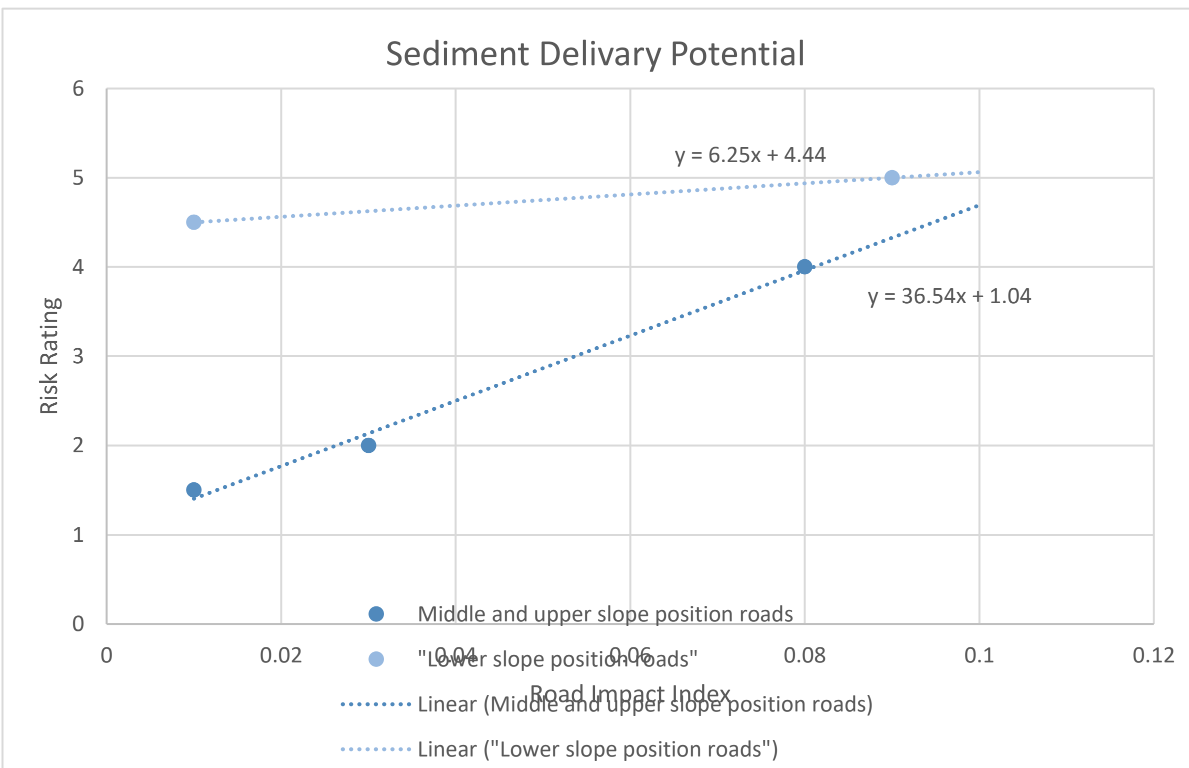


Figure 6-147 Roadway sediment delivery potential based on slope position and road impact index, adapted from Rosgen (2009)

The next component of the road impact analysis was to evaluate the sediment input risks based on the distance from the roads to the waterways. Roads that are closer to the stream pose higher risks than roads that are farther from the stream. Sediments from roads further from the stream have more opportunity for sediment deposition along their path before reaching the stream. The risk rating was assigned using the rating method shown in Figure 6-149. An example of the road classification banding based on 25 ft buffer intervals is shown in Figure 6-148.Roads closest to the streams should be prioritized for sediment reduction measures.

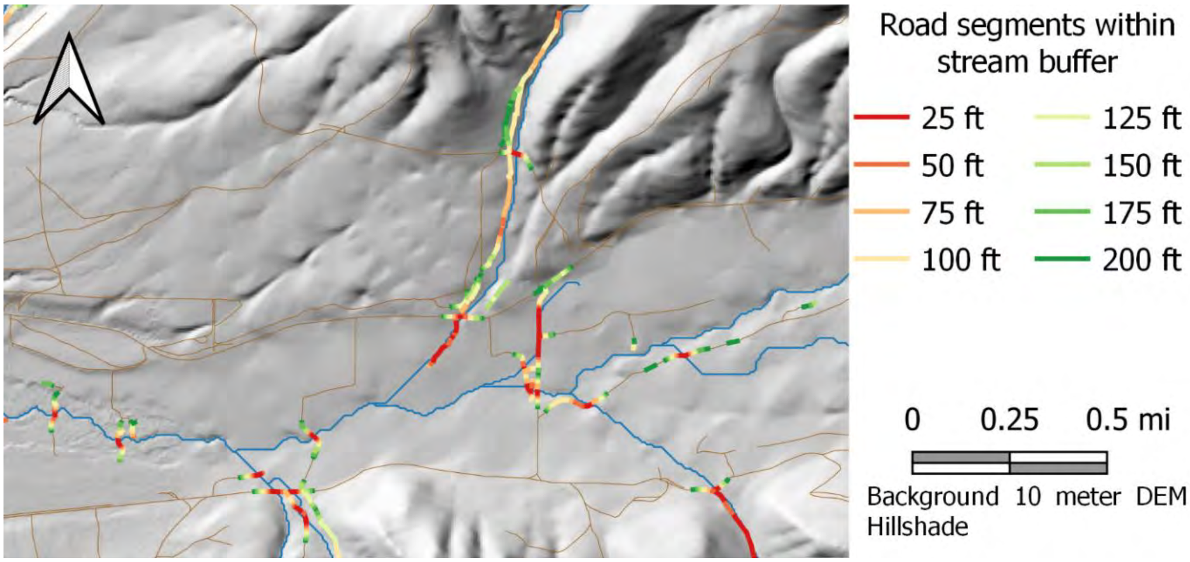


Figure 6-148 Example of road segments classified by distance from stream network.

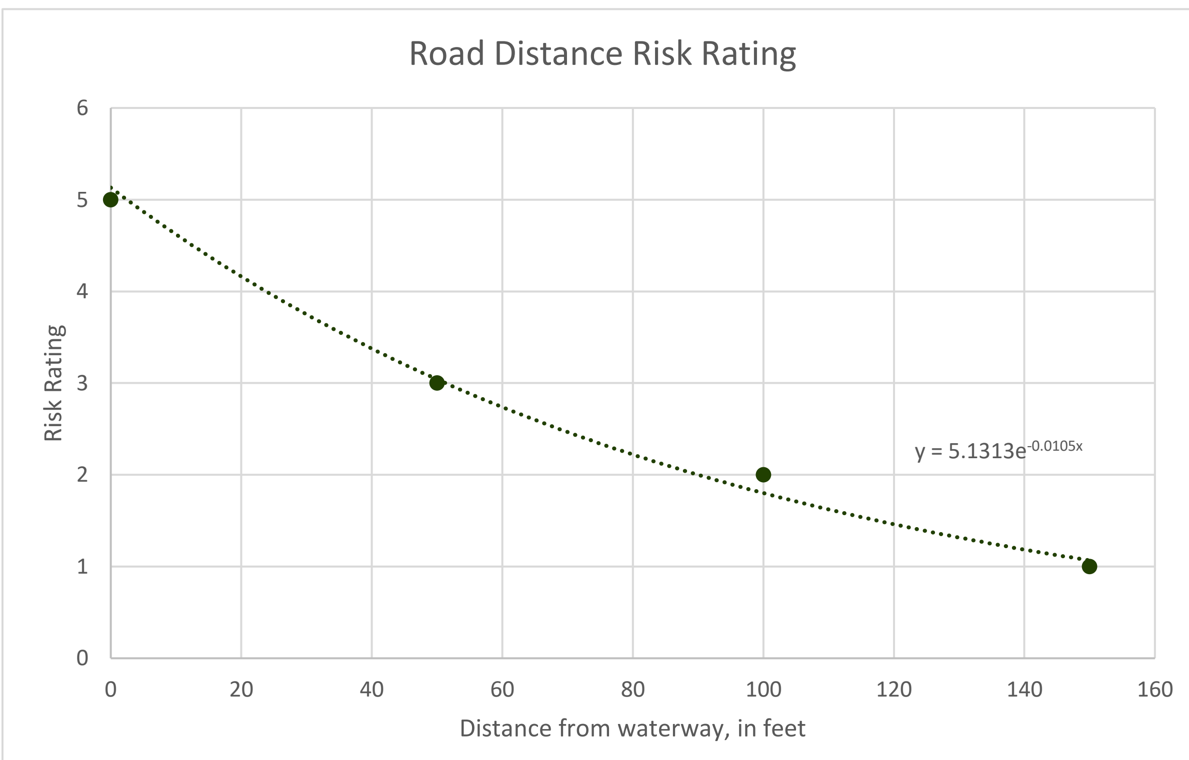


Figure 6-149 Road risk rating based on distance from stream adapted from Rosgen (2009).

Road slope is the last factor in determining roadway risk of sediment input into stream channels. Slopes were calculated using elevation from the 10-meter digital elevation model that was used to develop the stream network. An example of the road slope segments is shown in Figure 6-150. The risk of each segment was determined using the rating system shown in Figure 6-151.

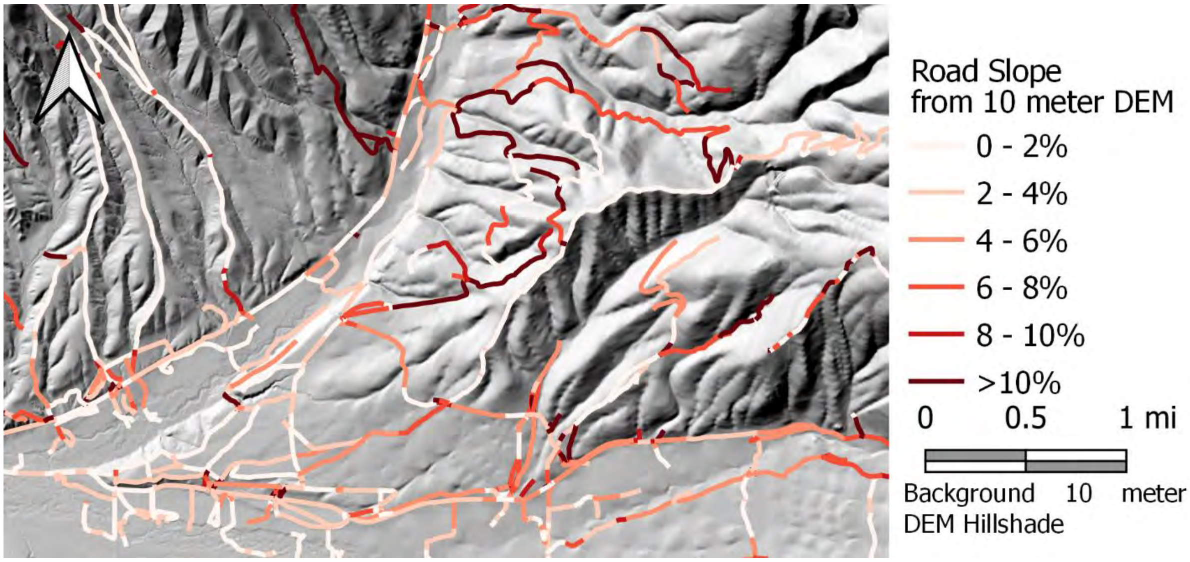


Figure 6-150 Example of road segments slope classification

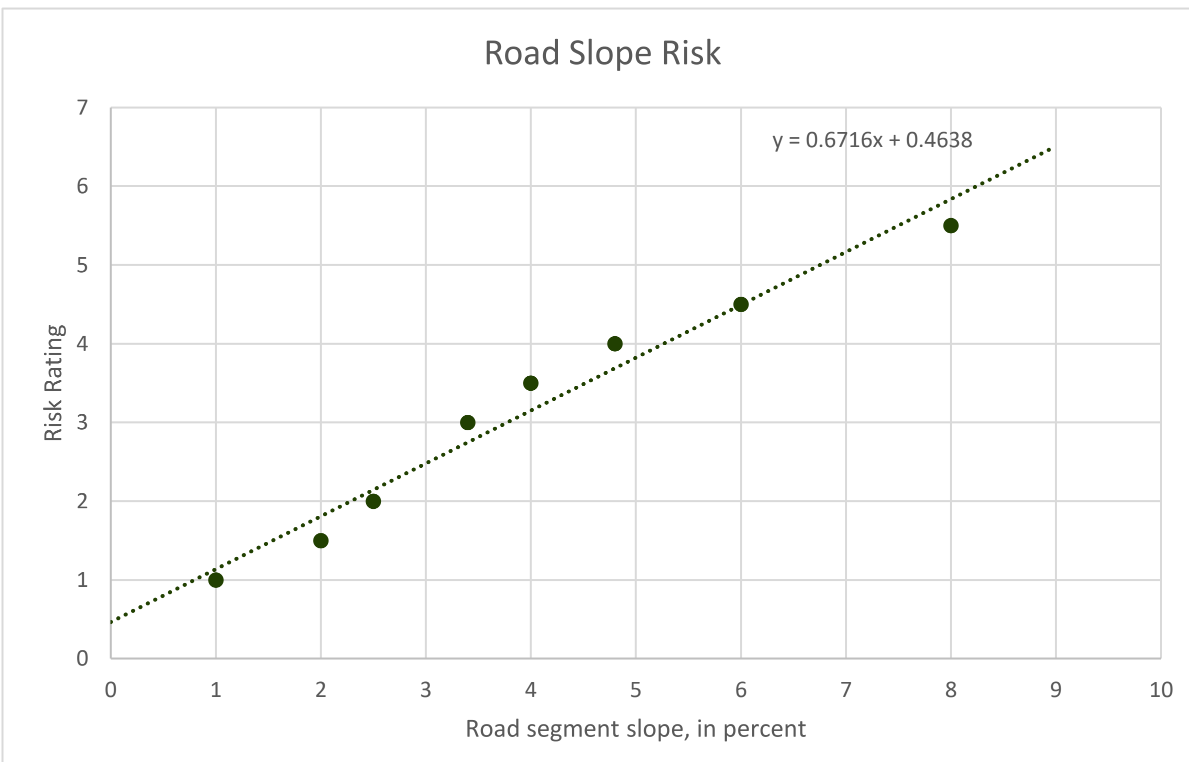


Figure 6-151 Road slope risk rating function adapted from Rosgen (2009).

For each watershed, a weighted average risk for each parameter was determined as the length weighted average risk by watershed (Equation 6-1). The road density and slope position calculation include all road segments and does not change. Utilizing this approach reduces the overall risk score for segment slope and distance by including the segments that do not fall within the classification system.

Equation 6-1 Length weighted watershed risk.

$$WatershedRisk = \sum\left[Length_{RoadSegment} * Risk_{RoadSegment}\right] / \sum Length_{RoadSegment}$$

6.3.2 Transportation Results

The transportation network provided a basis for analysis of roadways that posed high risk within the basin due to proximity to streams or hill slope properties.

6.3.2.1 Sediment Risk Analysis

Each stream reach was evaluated to determine roadway risks within the contributing drainage area. Risk ratings were generated for each reach with regards to road impacts, distance from streams, and average slope. These ratings were averaged per watershed to develop a watershed risk rating. The overall risk for each contributing area was computed by multiplying the watershed risk rating by the length of roads within the watershed. This result was used to rank the stream reaches based on risk of sediment inputs from roadways. The road impact index, road density, length of roads, and watershed area for the top 40 ranked watersheds is listed in Table 6-2. The individual risk factors and rank are listed in Table 6-3. Figure 6-152 shows those watersheds with high-risk ranking based on each factor computed and listed in Table 6-2.

The risk rating for road density and slope position is the greatest for all watersheds because this calculation includes a risk for all stream segments, whereas the risk from road distance will be reduced by those segments greater than 200 feet from the stream.

Individual segment risk ratings based on slope, distance, and combined slope and distance are shown in Figure 6-154, Figure 6-155, and Figure 6-155 respectively. Segments with the highest risk due to roadway slope are generally positioned either in the mountains to the east or along San Pedro Mesa. The segments with the great risk due to distance are generally evenly distributed throughout the basin. Combining the two risk categories highlights some areas including much of Cuates Creek, Rito Agua Azul, El Rito de Aban and the two basins to the west, and a tributary of Rito Seco for highest risk. The portions of the creek where the stream valley is most confined are also areas that are typically protected from road construction due to natural topography.

Table 6-2 Watershed road impacts summary for top 40 ranked watersheds for sediment contributions.

WSNO	Rank	Watershed area in square miles	Sum of watershed road length, in feet	Road density in foot/square mile	Road Impact Index
277	1	4.7	116064	24478	0.02
59	2	3.2	109748	33984	0.02
925	3	3.7	80131	21486	0.09
453	4	1.9	106908	54909	0.04
349	5	1.7	72368	41886	0.09
158	6	2.3	76925	33934	0.02
572	7	0.5	62681	137637	0.10
813	8	3.4	71374	21029	0.02
1724	9	2.3	66327	28816	0.02
2364	10	0.8	56354	74145	0.32
581	11	2.0	64229	31430	0.05
805	12	1.8	54725	30938	0.89
78	13	1.7	68312	40199	0.03
110	14	1.9	64427	34164	0.02
3492	15	1.1	43633	40069	0.26
132	16	1.3	56842	42410	0.03
3692	17	0.3	39159	137689	0.10
1365	18	2.4	57603	23961	0.07
86	19	3.7	54182	14745	0.03
2444	20	2.0	38374	18947	0.16
3772	21	0.7	46357	67981	0.05
533	22	2.9	52824	18199	0.04
2220	23	1.6	47789	29658	0.02
1940	24	0.5	35566	71135	0.20
413	25	0.9	40884	43448	0.03
220	26	1.0	39232	37833	0.11
685	27	1.7	36841	21585	0.08
174	28	1.7	38769	23408	0.12
1076	29	1.0	37224	35588	0.05
3628	30	0.6	36542	58821	0.17
28	31	1.4	49016	36061	0.03
150	32	1.2	49823	41554	0.03
1740	33	0.6	34755	58714	0.38
2156	34	0.6	28556	50304	0.22
1708	35	1.0	37582	38510	0.03
797	36	0.9	27895	32421	0.16
1716	37	1.2	35594	30726	0.02
30	38	2.1	45618	21386	0.05
3948	39	0.7	38892	59158	0.04
1356	40	0.4	32717	83917	0.18

Table 6-3 Risk rating for individual factors, watershed average risk factor, and average risk factor x roadway length. Ranked based on average risk factor x roadway length. Top 40 watersheds shown in table.

WSNO	Rank	Risk rating from road impact index and slope position	Average risk rating based on distance to stream	Average risk rating based on road slope	Average risk rating	Average risk rating x road length
277	1	3.21	0.22	1.87	1.77	204981
59	2	3.36	0.21	1.31	1.63	178345
925	3	4.77	0.63	1.15	2.18	174892
453	4	3.91	0.19	0.54	1.55	165548
349	5	4.81	0.35	0.69	1.95	141086
158	6	4.35	0.17	0.70	1.74	134038
572	7	4.97	0.87	0.34	2.06	129096
813	8	3.42	0.22	1.33	1.66	118187
1724	9	3.24	0.46	1.61	1.77	117380
2364	10	5.04	0.53	0.30	1.96	110324
581	11	3.56	0.03	1.35	1.65	105828
805	12	5.01	0.15	0.58	1.91	104661
78	13	3.53	0.12	0.70	1.45	98866
110	14	3.28	0.24	1.00	1.51	97212
3492	15	5.08	0.93	0.62	2.21	96366
132	16	3.62	0.10	1.34	1.69	95968
3692	17	5.56	1.12	0.58	2.42	94754
1365	18	4.29	0.01	0.55	1.62	93124
86	19	3.71	0.28	0.97	1.65	89644
2444	20	5.00	0.27	1.47	2.25	86327
3772	21	3.99	1.02	0.41	1.81	83819
533	22	3.76	0.00	0.87	1.54	81585
2220	23	3.66	0.32	1.10	1.69	80904
1940	24	5.59	0.34	0.73	2.22	78945
413	25	3.85	0.35	1.58	1.93	78879
220	26	5.24	0.20	0.50	1.98	77662
685	27	4.47	0.37	1.42	2.09	76919
174	28	5.01	0.42	0.47	1.96	76100
1076	29	3.69	1.25	0.95	1.96	73069
3628	30	5.02	0.16	0.82	2.00	73031
28	31	3.05	0.03	1.35	1.48	72409
150	32	3.88	0.08	0.40	1.45	72356
1740	33	5.29	0.20	0.74	2.07	72111
2156	34	5.50	1.18	0.89	2.52	72091
1708	35	3.23	0.30	2.00	1.85	69416
797	36	5.01	0.73	1.64	2.46	68594
1716	37	3.50	0.63	1.64	1.92	68482
30	38	3.63	0.01	0.85	1.49	68193
3948	39	4.40	0.34	0.35	1.70	66015
1356	40	5.34	0.32	0.38	2.01	65875

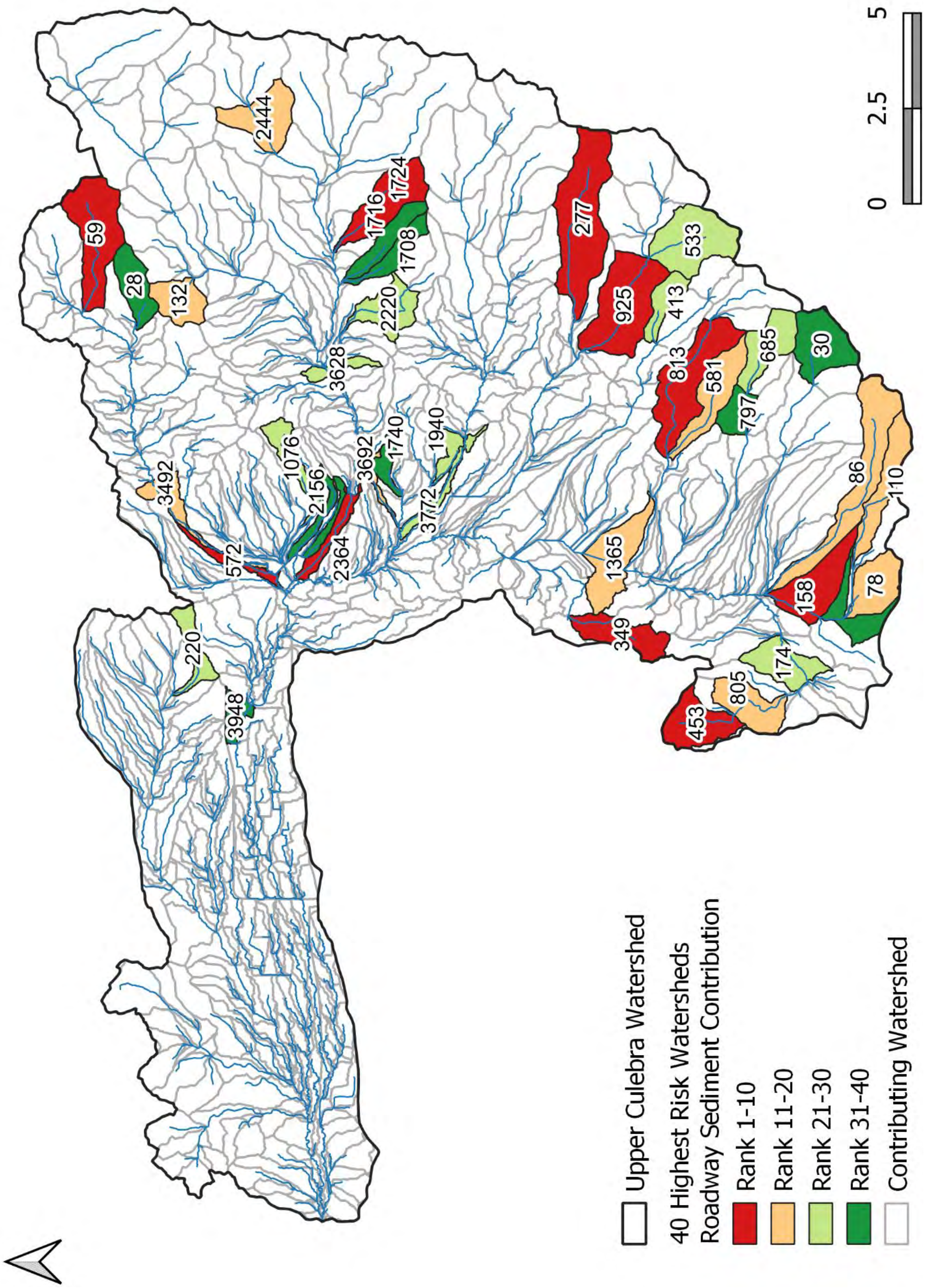


Figure 6-152 Ranked top 40 watersheds for sediment contribution to streams based on average risk factor x watershed roadway length.

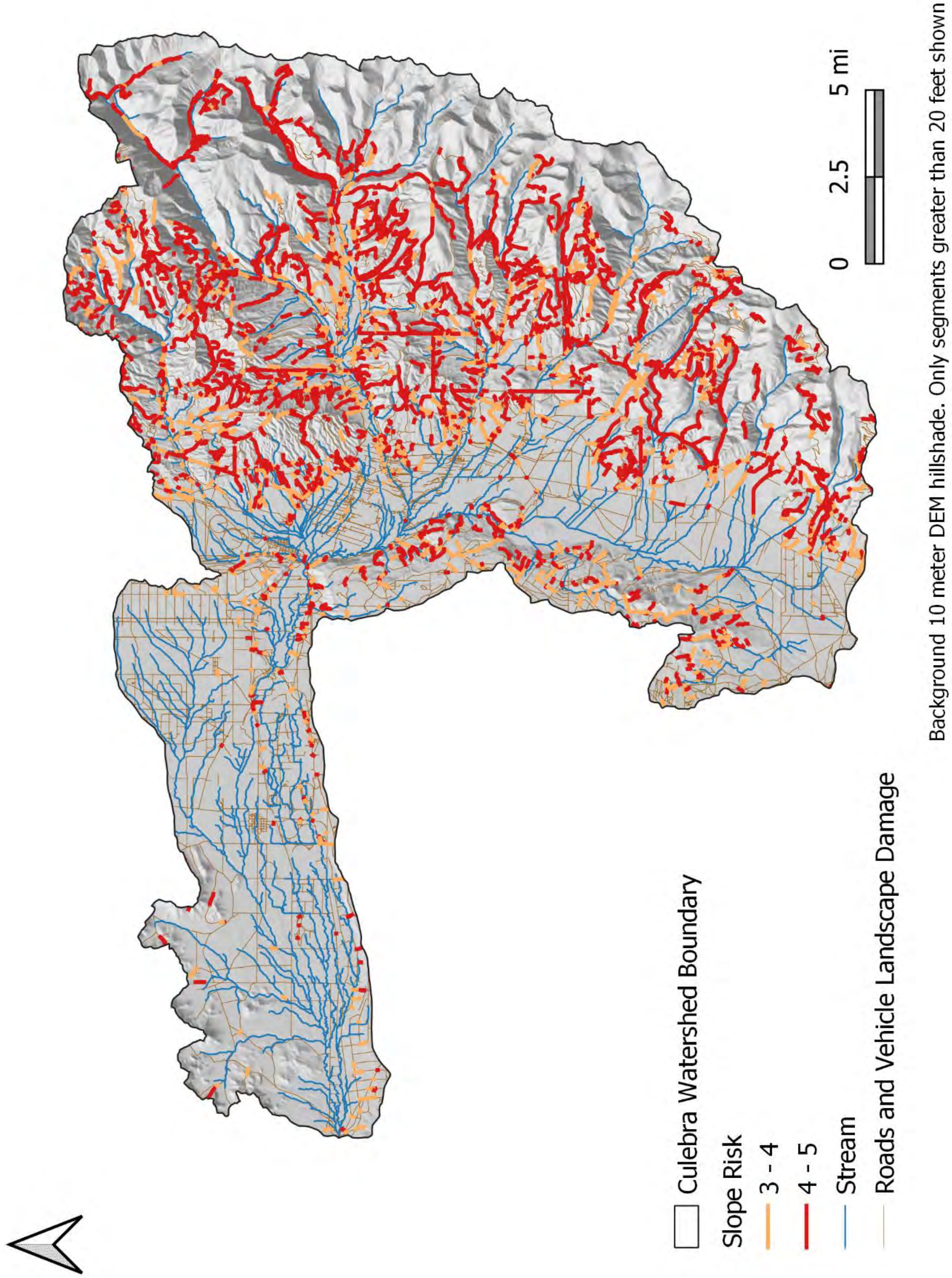


Figure 6-153 Roadway segments with slope risk rating greater than 3 and length greater than 20 feet.

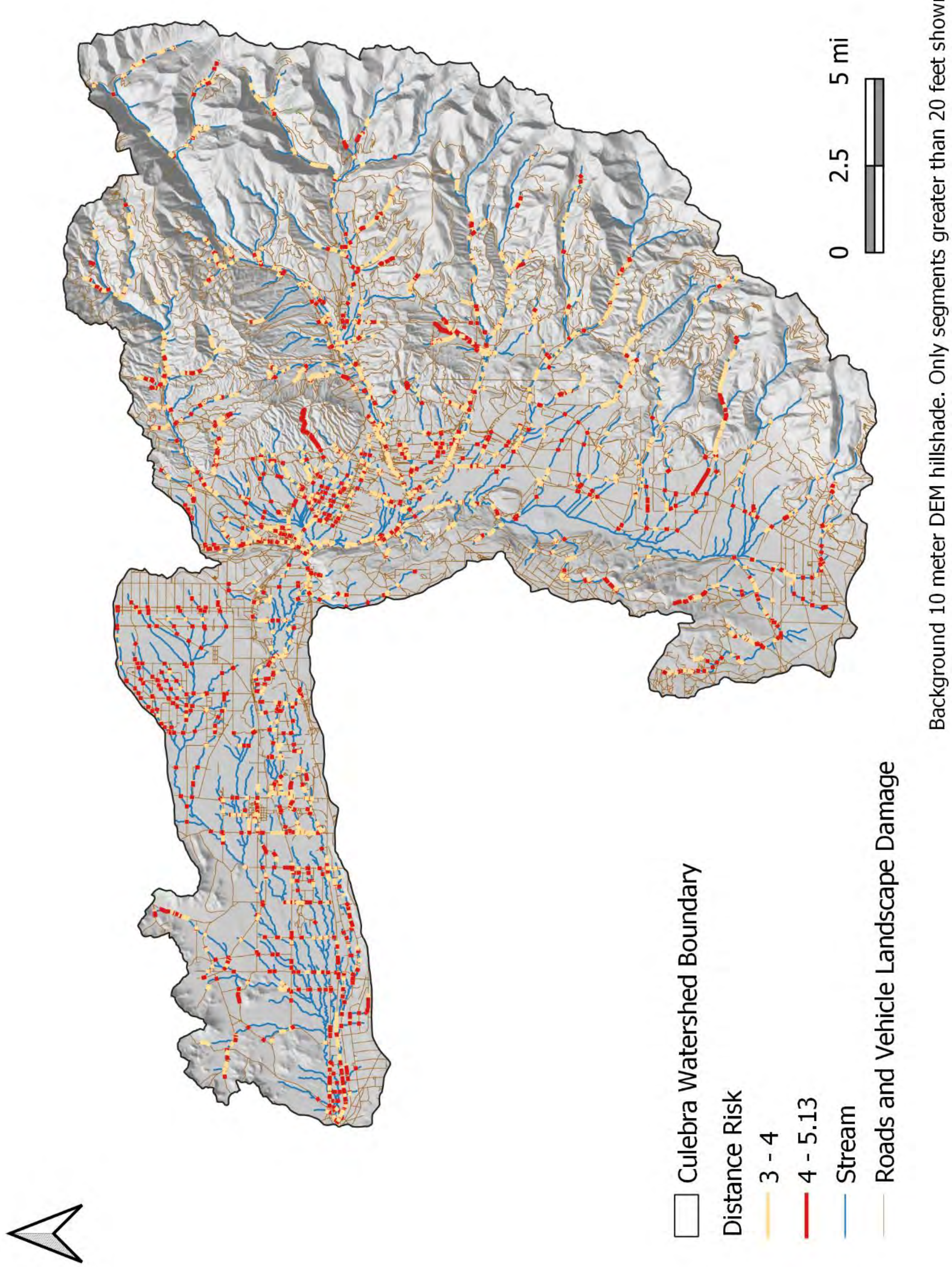


Figure 6-154 Roadway segments with distance risk rating greater than 3 and length greater than 20 feet.

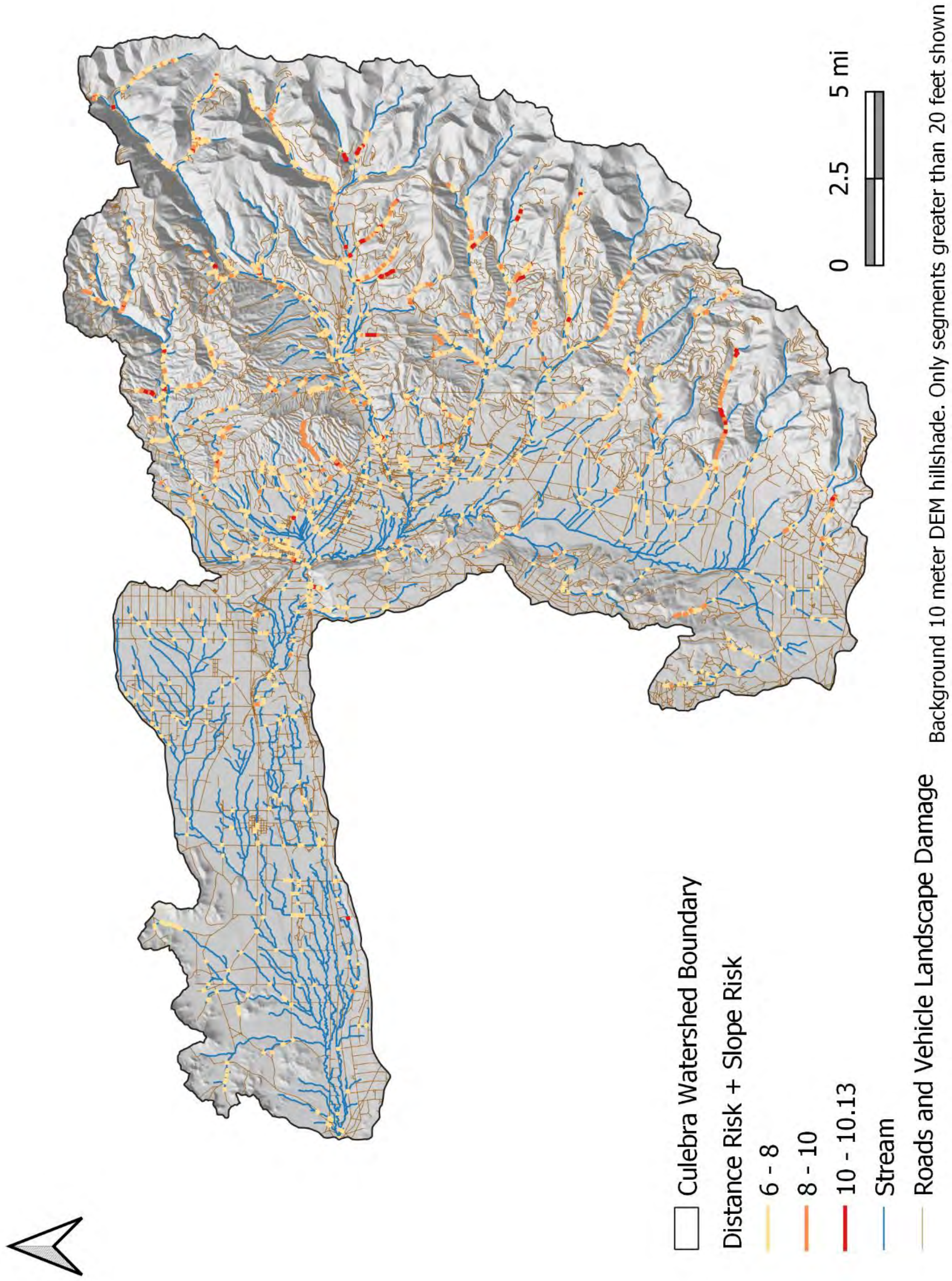


Figure 6-155 Roadway segments with combined slope and distance risk rating greater than 6 and length greater than 20 feet.

6.3.2.2 Road Maintenance

Within the foothills region of the basin, roads have been constructed across erosive soils and slopes. Significant impacts were observed because of these roads during the inventory of the road crossings. Roadway maintenance activities were reported to increase sediment loading into some of the acequias that flow adjacent to county roads. This increased sediment loading causes loss of conveyance and increased maintenance for the acequia and in some cases causes additional water to flow into roadway increasing required road maintenance.

Figure 6-156 Road grading around crossing on Rito Seco creek shows the creation of berms that prevent water from running off the road as sheet flow (37.2531, -105.3336).

Figure 6-157 County Road M.5, water concentrated from road is the probable cause of gully erosion.

Figure 6-158 Skidmore Road head cut, Note concentrated flow down road (lower left) culvert remnant (lower right).

Figure 6-159 Head cut on unnamed road west of Sanchez Canal and north of County Road K.5

Figure 6-160 Water flowing down Forbes Rd.

Figure 6-161 Arroyo crossing County Road R. Culvert was blocked upstream of the road.

Figure 6-162 Minor gully erosion observed around County Road 16.

Figure 6-163 Two plugged culverts and roadway erosion on Forbes Road.

6.3.2.3 Road-Stream Crossings

A sample of road-stream crossings was evaluated visually for fish passage, flood conveyance, and general condition. A total of 196 crossings were evaluated, including 42 bridges, 117 culverts, 29 low water crossings, five locations based on incoming and outgoing channels that should have structures, and three fluvial hazard areas (areas where channel migration affects roadway). The locations of these structures are shown in Figure 6-166. The sampled structures were primarily culvert crossings, followed by bridges and low water crossings. Efforts were focused on public roadways resulting in a higher percentage of bridge crossings.

A total of 185 of these structures were classified as functioning, functioning at-risk, and not functioning based on factors including channel condition, culvert/bridge condition, and surrounding environment (Table 6-4). Five bridges were not classified because of uncertainties in hydrology and flood risk, though these structures may increase the flood stage. Examples of not functioning structures include plugged culverts, channel head cutting, and roadway damage. Structures classified as functioning at-risk lack the capacity to pass some storm events; the downstream end of the culvert lacks scour protection without current degradation; increased risk of sediment inputs to stream, insufficient cover to distribute traffic load, fluvial hazard risks, and issues with culvert/stream alignment.

Evaluating the condition versus structure type, Table 6-4, low water crossings and bridges were most likely to be rated as functioning or functioning at-risk, with just 7% and 3% listed as not functioning. 21% of the Culverts were rated as functioning and 36% of the culverts were rated as not functioning.

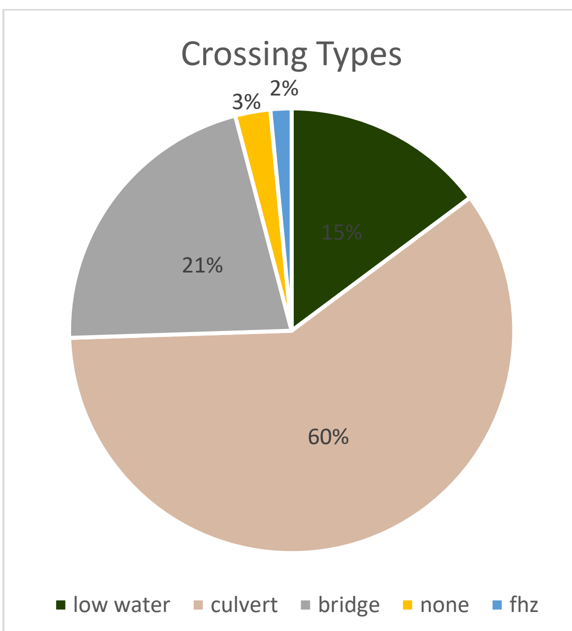


Figure 6-164 Crossing-types sampled.

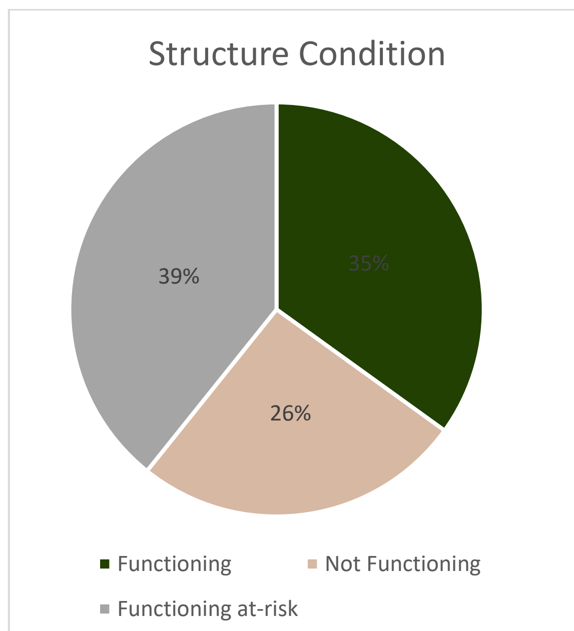


Figure 6-165 Structure condition classification.

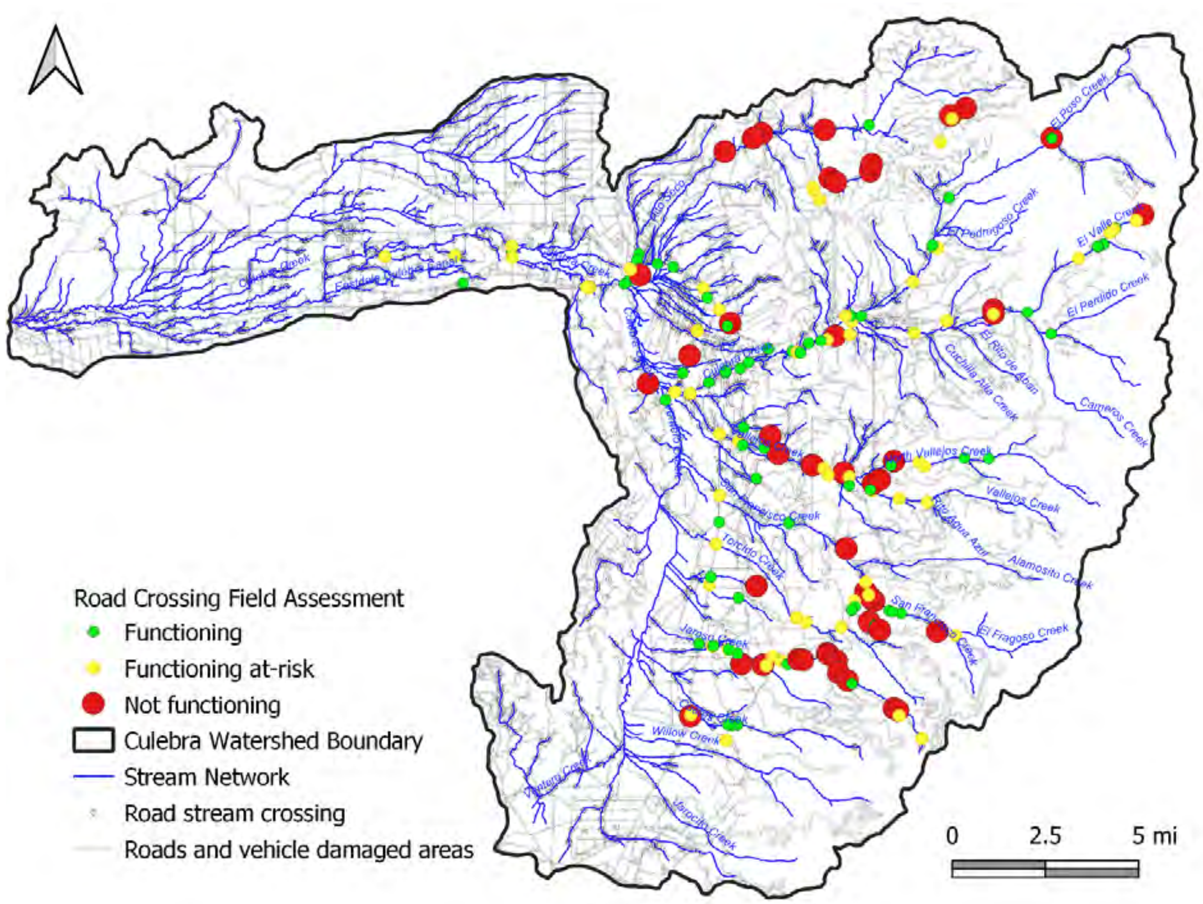


Figure 6-166 Map of structure rating and location.

Table 6-4 Summary of structure type and structure condition for sampled structures in Upper Culebra Watershed.

Crossing	Functioning	Functioning At-Risk	Not Functioning	Total
Low Water	16	9	2	27
Culvert	24	50	42	116
Bridge	25	11	1	37
None	0	3	2	5
Total	65	73	47	185

The National Bridge Inventory data was accessed through LTBP InfoBridge:Data which included the evaluation of 23 bridges within the study area. Bridge ratings ranged from Fair to Good. All inspections were made in 2017.

Table 6-5 National Bridge Inventory accessed through LTBP InfoBridge January 31, 2022.

Structure Number	Year Built	Stream	Road	Bridge Condition
CSVEN-S10-242AA	1994	SANCHEZ CANAL	COUNTY ROAD 21	Fair
CS242-S0.4-SMME	1955	CULEBRA CREEK	COUNTY ROAD 21	Fair
CS242D-0.1-152A	1984	CULEBRA CREEK	COUNTY ROAD 22.3	Fair
CS242-.8-VENRDA	1988	SANCHEZ CANAL	COUNTY ROAD J.2	Fair
CSTHOR-S0.3-MAL	2012	EL POSO CREEK	THORFINNSON ROAD	Fair
CS152E-0.1-152A	1990	CULEBRA CREEK	COUNTY ROAD 22.4	Fair
CS152-56-242AA	1997	EL POSO CREE	COUNTY ROAD L.7	Fair
CS152B-.1-152DA	1988	CULEBRA CREEK	COUNTY ROAD 23.5	Fair
CSJACQ-S08-142A	1987	EASTDALE CANAL	COUNTY ROAD 16	Fair
CS152B-17-242DA	1988	SANCHEZ CANAL	COUNTY ROAD M.5	Fair
CSSMME-0.6-242A	1988	CULEBRA CREEK	COUNTY ROAD 19	Fair
P-15-D	1936	RITO SECO CREEK	SH 142 ML	Good
CS21-S4.3-J.2	2005	JAROSA CREEK	COUNTY ROAD 21	Fair
CSNACA-S1.5142A	1990	CULEBRA EASTDALE CANAL	COUNTY ROAD 15	Fair
SAN LUIS-1A	1990	RITO SECO	6TH STREET	Fair
SAN LUIS-2A	1990	RITO SECO	ARCHIE STREET	Fair
CSL.7-5.9-21	2004	CULEBRA CREEK	COUNTY ROAD L.7	Fair
CS242C-1.1-242A	1999	SANCHEZ CANAL	COUNTY ROAD E.5	Fair
P-15-C	1936	CULEBRA CREEK	SH 159 ML	Fair
CS152-0.4-S159	2006	UNNAMED DRAINAGE	COUNTY ROAD P.6	Good
CS242B-S1-242AA	1996	SAN FRANCISCO CREEK	COUNTY ROAD E.5	Fair
CSLYC-W1.0S159A	1992	CULEBRA EASTDALE CANAL	COUNTY ROAD P	Fair
CS152A-S0.1152A	1992	CULEBRA CREEK	COUNTY ROAD M.5	Good

At the bridges, especially within the lower basin where creeks are typically dewatered, vegetation has grown within the channel, reducing the conveyance of water through the structures. An example of this is shown in Figure 6-167. In this area, it is possible that the channel was widened from the historic channel to reduce the required height of the bridge. In some locations, the road is not aligned with the creek; an example is shown in Figure 6-167 and Figure 6-168. The structure shown in Figure 6-170 may also pose as a fish passage barrier during high flows if water is confined to the metal pipe, causing a significant increase in channel velocity. Except for the new bridge across Hwy 159, existing structures are typically set to pass bankfull flows, which are typically associated with the 1 to 2-year flood recurrence and will back up water for flows greater than these. Many of the roadways have been built up within the upper valleys, eliminating the stream’s access to the floodplain. These low bridge structures are at risk of catching debris, elevating flood stage, or having water flow around the structure when the floodplains are active. A detailed hydraulic analysis would be required to determine the extent of flooding near these structures.

Bridges on private property tend to be closer to the channel bottom than those on public roads. These bridges typically are not associated with berms across the floodplain. Like the public road bridges, these lower structures may catch debris and increase the flood stage upstream of the structure, but the extent of the increased flood stage is often reduced due to flow paths available around the structure. Suppose these structures are not properly secured during a flood. In that case, the structure may be mobilized and deposited as debris downstream, resulting in additional flood risk upstream of where the bridge is deposited.

Figure 6-167 Jaroso Creek at County Road 21 bridge partially blocked by sediments and willows.

Figure 6-168 Culebra Creek County Road L.5 bridge. This bridge is not aligned with the creek. Some seepage noted on left edge.

Figure 6-169 Bridge not aligned with creek.

Figure 6-170 Culverts causing degradation in the stream and reducing fish passage on Torcido Creek.

culverts were the most evaluated type of crossing. Both perennial and non-perennial stream culvert crossings, as well as some ditch and drainage crossings were evaluated. Non-perennial stream crossings had the greatest number of issues related to culverts. These issues were typically related to sediment blocking the upstream end of the culvert or the end of pipe not having erosion protection. Many of the evaluated culverts were found on roads that follow the base of the foothills and have been damaged by road maintenance activities. Culvert crossing issues were especially notable in the Rito Seco and Vallejos drainages.

Figure 6-171 Culvert outlet causing downstream erosion due to large drop below outlet.

6.3.2.4 Forest Roads

During field observations, many occurrences of water flowing down roadways was observed (Figure 6-172-Figure 6-176). The result of this is increase run-off velocity. This increase in water velocity typically increases peak flows while decreasing base flows. The runoff from the roads increases sedimentation in the stream and may increase stream water temperatures. In areas where herbaceous plants have regrown, flows are slowed and have increased opportunity to infiltrate, thus increasing travel time and decreasing sediment loading and temperatures (Figure 6-174).

Figure 6-172 Water flowing down road along El Valle Creek.

Figure 6-173 Channel along road Jaroso Creek drainage.

Traffic volume has been found to be one of the driving factors in sediment production from forested roads along with road surfaces. While most of the roads within the mountains do not have a significant traffic volume, an increase in traffic will increase sediments. Prior to increasing traffic, sediment mitigation measures should be taken to reduce impacts from increased traffic. Many of the historic logging roads were found to have new vegetation growth (Figure 6-177 and Figure 6-178). These roads often still have concentrated flow paths that could be addressed by installing water bars or similar mitigation measures.

Figure 6-174 Grass growing along the only road in upper El Valle basin. Spring flow through the hillslope on left side of photo.

Figure 6-175 road rutting, San Francisco Creek drainage.

Figure 6-176 Road rutting Vallejos Creek drainage.

Figure 6-177 Trees growing in old logging road.

Figure 6-178 Vegetation on old logging road San Francisco Creek drainage.

Along San Francisco Creek, roads that were cut through steep hillslopes were failing. The road was not safely passable by UTV (Figure 6-179). Below this road cut, channel aggradation was observed. This reach had some channel stabilization (Figure 6-180). Low water crossings in a variety of conditions were observed. Most of the crossings were like the crossing from Rito Seco shown in Figure 6-181. This crossing occurs where the channel is slightly overwide, reducing flow depths. Fine sediment inputs may be occurring at steep banks. Sediment contribution volume depends on traffic volume. However, a few of the crossings were areas where sediment inputs were not stabilized by the cobble streambed like the crossing shown in Figure 6-182. This crossing causes the channel to be significantly overwide with a substrate as road base rather than the stream bed. Fine sediments from the roadway are likely to be tracked into the stream. Over widening reduces flow depths such that fish passage is not possible.

Figure 6-179 Hillslope failure up San Francisco Creek. Left shows north side of valley, right shows south side of valley.

Figure 6-180 Stream channel stabilization below area of extensive hillslope erosion.

Figure 6-181 Low water crossing, Rito Seco drainage causing stream to be over wide and fine sediment deposition which could be disturbed when vehicle crosses.

Figure 6-182 Low water crossing that is not stabilized by streambed.

6.3.2.5 Farm Roads

Often farm equipment travels across streams via low water crossings because bridges are not present or do not have the capacity to carry the heavy loads. Figure 6-183 is an example of a low water crossing that results in fine sediments being transported into the creek, thus causing the creek to be overwide. These factors will cause the channel to become destabilized. Sediments are tracked from the floodplain ruts into the stream as vehicles cross the channel.

Newly constructed roads that did not consider water conveyance were observed, such as the road shown in Figure 6-184. Equipment was used to make roadway while covering smaller drainages with road base and fill. Filling these drainages will result in either water running down the road, causing rutting, or a headcut forming below the road because of the change in slope, eventually threatening the road.

Figure 6-183 Example of low water crossing, this crossing is from El Poso Creek, but many such crossings are present within the basin.

Figure 6-184 Recently constructed road in Jaroso Creek drainage.

Culvert installation issues are highlighted across the arroyos. Figure 6-185 highlights the headcut occurring near a culvert that had been plugged by sediment. Water, unable to reach the drain, found a path downhill along the road embankment and not the channel. Figure 6-186 shows the downstream end of this culvert, which likely was plugged shortly after installation because the channel does not appear to be significantly degraded below the pipe, despite the lack of erosion protection below the significant drop.

Figure 6-185 Headcut up road ditch near culvert.

Figure 6-186 Downstream end of culvert that is buried upstream in Jaroso Creek drainage, headcut along road embankment shown in Figure 6-185..

6.3.3 Transportation Network Summary

The transportation network and stream networks frequently interact as water flows from the hillslopes to the streams and then through the streams. The assessment of the transportation network included an evaluation of combined sediment risk for each of the sub-watersheds in addition to the individual stream crossings. Road impact index risks, or risks associated with roadway density and number of crossings, were greatest in the lower watershed. Those watersheds with the greatest risk from average roadway distance were typically small because the average risk decreases as the number of roads away from the stream increases. The watersheds with the greatest risk from roadway slope were within the upper watershed. Once roadway length was considered, the top 40 watersheds with the greatest risk were distributed throughout the basin and mapped. The roadway risk analysis will overestimate the risks because mitigating factors including traffic volume and road surface were not considered in the development of the models.

Field sampling of road crossing structures including bridges, culverts, low-water, and fluvial hazards showed a relatively even distribution between functioning, functioning at-risk, and not functioning structures. However, when this is stratified by structure type, Culverts were found to have the most proportion listed as not-functioning. The greatest risks associated with low-water crossings occurred in areas where the channel is incised and/or has a confining geologic feature that causes the road slope to be high as the vehicle enters/leaves the channel.

Observed impacts on forest roads included flow paths down roads, decreasing travel time to streams. This forest benefits from low traffic volumes. If this traffic volume increases, sediment inputs from the roads to the stream will increase. Low water crossings in the forest are typically cobble and could be improved by installing armoring on side slopes.

Observed impacts on private lands in the lower basin include many small structures that increase flood risk and bank instability. Small private bridges and culverts are typically smaller and often found where there is significant livestock grazing, thus removing the riparian vegetation. The lower basin has increased risk because the stream flows have been reduced and dewatered in some cases.

Gully erosion around roads where new road-stream crossings are being constructed should be prevented through the proper installation of culverts, coupled with downstream energy dissipating devices. Culverts should be installed with a proper cover to prevent a collapse of the structure due to the weight of traffic. Culverts should be sized based on appropriate flow recurrence intervals. Culverts should be installed so that there is no notable slope change from the channel to the culvert, within the culvert, or from the culvert to the channel (CDOT, 2019). The installation of floodplain culverts will also improve the floodplain's function at the crossing.

A culvert inspection and maintenance program can significantly reduce the risks to public roadways and repair costs by detecting issues at culverts before excessive erosion (CDOT, 2019). Monitoring of existing degraded crossings can be used to identify areas of critical concern for maintenance prioritization.

Restoration of gullies can benefit stream health, infrastructure safety, and long-term maintenance. Restoration of gullies should include the construction of pools within the profile and pattern. The spacing of pools should be based on the slope of the channel. Brush matting and the addition of wood within the channel structure provides additional sediment trapping capacity and macroinvertebrate habitat. If check-dam or gully plugs are selected for restoration, frequent small structures with drop sizes based on scour depth without energy dissipation are preferred. Replacement of culverts at the appropriate slope with adequate road base will likely be necessary at most of the crossings. Properly grading roadways adjacent to the areas will reduce future degradation risk.

Arroyos should not be treated as roadways or recreational areas. Measures should be taken to protect perennial streams within the basin and ephemeral and intermittent streams.

6.4 Other Structures

6.4.1 Methods

Other structures include streamflow gaging stations, fish barriers, and personal property within the floodplain. The streamflow gaging stations, and fish barriers were evaluated based on the geomorphic setting, whether the structures were causing geomorphic instability, and whether the structures were functioning as intended. Gaging station operations are discussed in the flow regimes section of this report, Section 5.4.1. Buildings and personal property near the stream were evaluated. This analysis does not inventory all structures or buildings within the basin or even the floodplain. The examples are provided for reference to highlight some of the observed risks within the floodplain.

6.4.2 Results

6.4.2.1 Floodplain Structures

In addition to irrigation and transportation infrastructure, community structures that may be impacted by stream function were evaluated. This includes the Costilla County Wastewater Treatment Plant, San Luis Wastewater Treatment Plant, and Centennial School (Figure 6-187). This infrastructure was evaluated with respect to flooding utilizing the Colorado Hazard Mapping and Risk MAP Portal (CWCB, 2021).

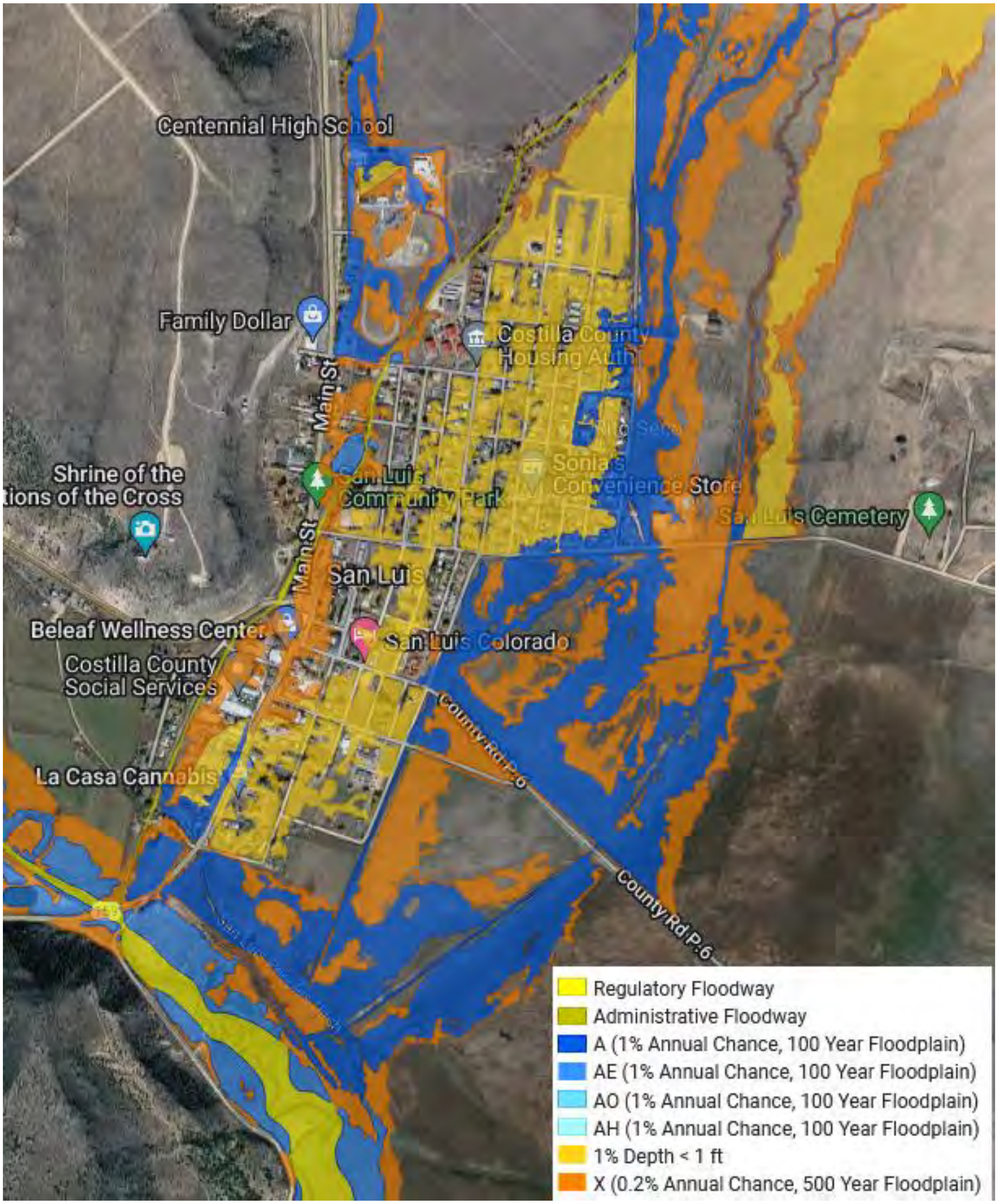


Figure 6-187 Preliminary floodplains near the Town of San Luis (CWCB, 2021).

Adjacent to the San Luis Wastewater Treatment Plant, Culebra Creek has been straightened in addition to portions of the treatment facility being located within the 1% depth grid (Figure 6-188).

Figure 6-188 San Luis Wastewater Treatment Plant Preliminary 1% Depth Grid from Colorado Hazard Mapping and Risk Portal accessed October 29, 2021.

Centennial school, including portions of the building and track, were mapped within the 1% depth grid, which is the estimated depth of the water during the 100-year flood event (Figure 6-189). While the majority of flows from Rito Seco were mapped to the east of town, a portion of the flows was mapped going through the Town of San Luis. These flows are in addition to flows from Salazar Reservoir and another upstream dam. Much of San Luis is at the lower end of the Rito Seco alluvial fan, where flow path mapping may be limited due to the potential for an avulsion.

Figure 6-189 Centennial School Preliminary 1% Depth Grid from Colorado Hazard Mapping and Risk Portal accessed October 29, 2021.

Costilla County Wastewater Treatment Plant was not included within the 1% depth grid or within the 0.2% annual chance floodplain (Area X) (Figure 6-190). However, this facility is located between Culebra Creek's active channel and the historic Culebra Creek Channel, to the north and east, below the levees on Culebra Creek, increasing the fluvial hazard risks to the Costilla County Wastewater Treatment Plant.

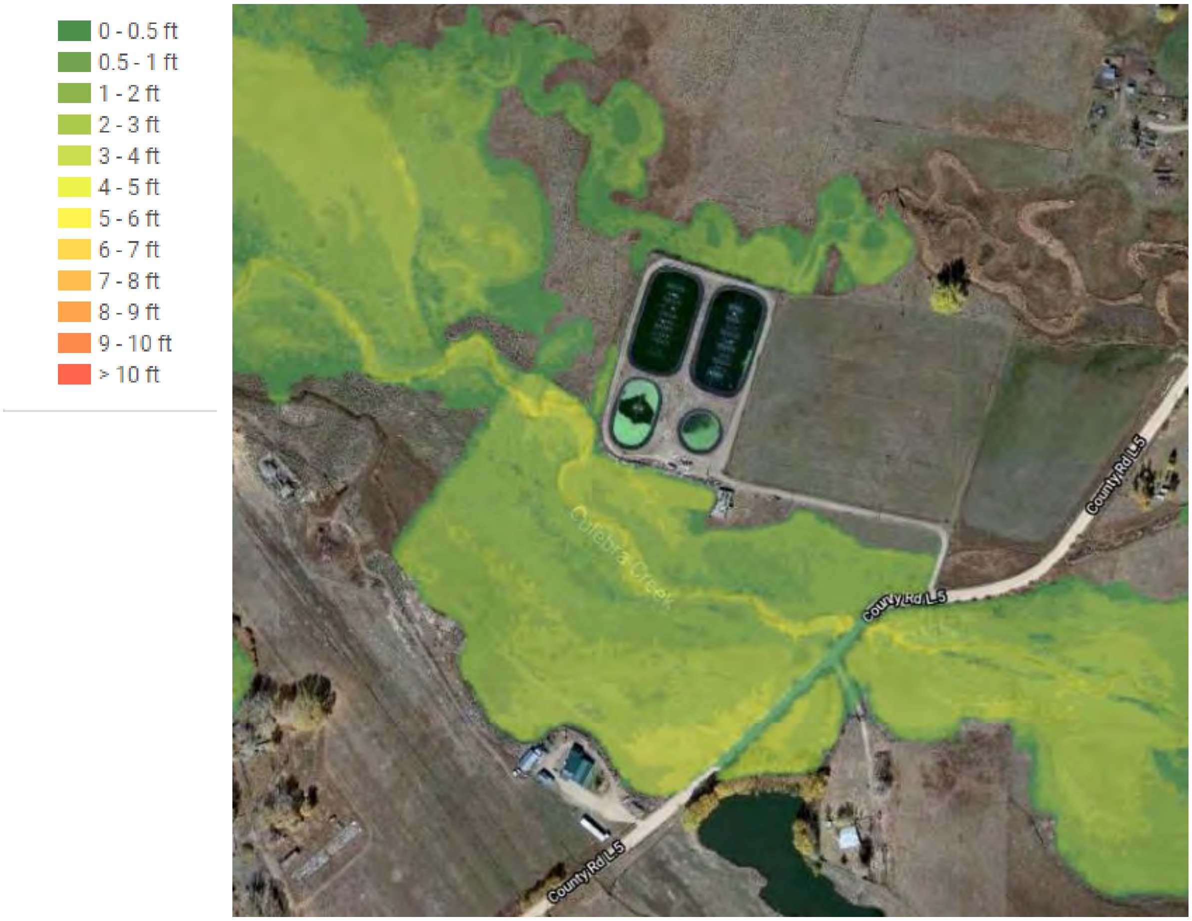


Figure 6-190 Costilla County Wastewater Treatment Plant. Preliminary 1% Depth Grid from Colorado Hazard Mapping and Risk Portal accessed October 29, 2021.

Potential erosion issues with sewer lines in Sanchez Canal (Figure 6-191) was observed. Depth of the actual sewer line is unknown, but these crossings should be monitored for erosion and if necessary additional protective measures taken to protect the sewer.

Figure 6-191 Sewer line crossing Sanchez Canal near County Road J.2 August 19, 2021.

In addition to infrastructure within the floodplain, many instances of structures and personal property within the floodplain were observed. Development within the floodplain increase flood risk and damage by reducing the floodplain capacity (Figure 6-192 and Figure 6-193), increasing the risk of water quality degradation from chemicals leaching through the ground to the waterway, and may increase flood risk downstream as debris is caught on bridges and other structures if mobilized by floodwaters.

Figure 6-192 Structures in floodplain including livestock shelter, storage, and residential structures.

Figure 6-193 Boulder toe stabilizing channel around houses along El Poso Creek (left) and channel stabilization work resulting in a large drop in a channel that is causing excessive erosion downstream and high probability of head cut upstream after toe failure in a channel (right).

Levees were constructed along Culebra Creek adjacent to County Road L.7, which blocks the view of the creek and may reduce flooding during low-frequency events. However, if not properly constructed, these levees are at risk of failure during flood events. This failure may result in increased flood risk. Levees should have routine annual and comprehensive inspections every five years (USACE, 2021). This levee is not recognized as a structure within the National Levee Database, and the documentation of levee inspections were not located.

Figure 6-194 Levees block view of Culebra Creek channel (upper left) vegetation growth reduces conveyance within levees (upper right), floodplain converted to upland vegetation communities (lower left), and small Culebra Creek channel (lower right).

6.4.2.2 Streamflow gages

<u>Culebra Creek at San Luis</u>

The streamflow gage Culebra at San Luis (CULSANCO) was evaluated and functioning at-risk. The streamflow gaging station is located at a 12-foot concrete flume that operates within the current flow regime. The roadway into the property from the east creates a dam forcing flows through the flume. The left wall of the flume was found to be spalling with exposed rebar. The gaging station has small inlets that are prone to plugging with no flush risers present to remove sediment from the stilling well. Gage is subject to confined space entry hazards which provide additional hurdles to quality streamflow records.

Figure 6-195 Left edge of water gaging station stilling well and flume wall.

Figure 6-196 Exposed rebar on left edge of water Culebra Creek at San Luis streamflow gage.

<u>Culebra Creek near Chama</u>

Culebra near Chama streamflow gage was evaluated with a site visit and discussions with representative personnel. The telemetry at this site is provided through a cellular modem that users may call to retrieve the current stage, which must be converted to discharge via a rating table. The control section for the gage is a rock weir with a large, approximately two-foot drop. The control section is at risk of failure due to downstream scour. This gage is operated for administrative purposes only and does not receive routine measurements or calibration. Colorado Division of Water Resources hydrography website indicates the user should direct questions regarding station to U.S. Geological Survey. The Division of Water Resources shows 39 measurements have been made at the station over the past 10 years (10-1-2010 to 09-30-2020), averaging 4 measurements per year. No rating curve or shift application information was available on the Colorado Decision Support System Station interface.

Figure 6-197 Culebra near Chama Streamflow gage.

Figure 6-198 Culebra River looking downstream at Culebra Chama control.

<u>Ventero below Sanchez Reservoir</u>

The Ventero below Sanchez Reservoir gage is a stilling well located at a 10-foot Parshall flume. Pipes with a swinging metal arm were found at the upstream left edge of the flume. A staff plate was located on the right edge of water across from stilling well and was unreadable. The operations of this station were evaluated as part of the flow regimes section of this report.

Figure 6-199 Looking upstream at Ventero below Sanchez Reservoir.

Figure 6-200 Ventero below Sanchez Reservoir

Figure 6-201 Device located near flume at Ventero below Sanchez Reservoir.

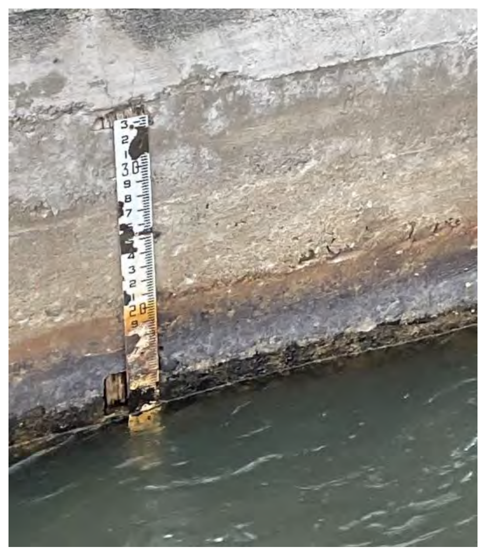


Figure 6-202 Ventero below Sanchez Outside Staff Gage.

Sanchez Canal at Sanchez Reservoir

During the field investigations, the measurement flume above Sanchez Reservoir, measuring the deliveries from Sanchez Canal, was evaluated (Figure 6-203). This structure is referred to as Sanchez Canal at Sanchez Reservoir. This structure is a 12-foot concrete Parshall flume. Interviews with the Sanchez Ditch and Reservoir Company are still monitored with a paper chart recorder with a 30-day clock. The structure was clean and free of debris (Figure 6-204). The structure showed evidence of degradation downstream that has been mitigated through riprap placement (Figure 6-206). The upstream left edge wing wall showed erosion and potential seepage (Figure 6-205).

Figure 6-203 Sanchez Canal at Sanchez Reservoir.

Figure 6-204 Flume clean and relatively free of debris. Staff plate has been vandalized.

Figure 6-205 Some scour noted on upstream left edge of flume.

Figure 6-206 Downstream riprap placed to prevent erosion.

6.4.2.3 Fish Barriers

On Jaroso Creek, one six-foot-wide fish barrier structure was found in good condition. Cuates Creek fish barrier is a boulder drop structure that appears to be functioning (Figure 6-208).

Figure 6-207 Jaroso Creek fish barrier.

Figure 6-208 Cuates Creek fish barrier structure.

The fish barrier on Willow Creek is constructed from fence posts and hog wire to create a drop (Figure 6-209). Willow Creek fish barrier showed some flow along the left edge of water during high flow 2021 (Figure 6-210). The structure is catching fine sediments and debris, which eventually results in the structure's failure. The channel downstream of the structure appears to be in good condition (Figure 6-211).

Figure 6-209 Looking upstream at Willow Creek fish barrier.

Figure 6-210 Flow along left edge of water of Willow Creek fish barrier.

Figure 6-211 Looking downstream from Willow Creek fish barrier.

6.4.3 Summary

6.4.3.1 Streamflow gages

The streamflow gaging infrastructure was found to be minimal within the Culebra Basin. Existing operating structures were found to have inadequately sized inlets and need to upgrade to meet current safety, reliability, and accessibility standards. The gage wall at the only published gage in the watershed, Culebra near San Luis, has exposed rebar and deteriorating concrete that affects the location and performance of the stilling well. The control section at Culebra near Chama is elevated above the streambed and will cause downstream scour and eventually failure within the section. The boulder control section results in the filling of the gage pool, which will affect rating curve shifts.

6.4.3.2 Floodplain Structures

Flood hazards are significant at the San Luis Wastewater Treatment Plant, Centennial School, and most of the town of San Luis. The Costilla County Wastewater Treatment Plant might be affected by flooding if a stream channel avulsion were to occur.

Many residences and businesses are within the floodplain, increasing the risks to those individuals and downstream infrastructure. The floodplain mapping outside of the regulatory areas does not appear to include refinement of structures such as Sanchez Canal and modifications around San Luis People’s ditch. This may not accurately represent true floodplain and probable flow paths. Because the structures within the floodplain are most likely to increase flood stage, refining the modeling to depict on the ground conditions more accurately would help quantify the risks within the floodplain. Structures should be ranked for replacement, as many bridges within the basin appear to be undersized, posing flood hazard risks in addition to fluvial hazard risks.

Gully formation in the ephemeral and intermittent drainages results in safety hazards along public roadways and increases sediment delivery to the stream systems. These streams often are habitat for many creatures and can be fragmented by roads, gravel mining, and dams. In general, if the gullies require guardrails, this is a good indicator that restoration should be prioritized to reduce risks to the roadway and the public.

6.4.3.3 Fish Barriers

The three constructed fish barriers that were located during the 2021 field investigations were evaluated. The structures on Cuates Creek and Jaroso Creek appear to be functioning. The structure on Willow Creek allows fish passage for some if not all flows. The structure on Willow Creek does not appear to be a structure that was constructed with the intention to prevent fish passage. This structure is an example of the issues that can arise when fencing is installed across streams without a mechanism for debris passage.

6.5 Recommendations

Below are recommendations that were identified as part of the assessment of infrastructure. The first list is general recommendations that are not specific to diversion structures, streamflow gages, and transportation. The diversion structure, streamflow gage, and transportation recommendations are provided under separate headings. The list is provided in no specific order.

- Evaluate the function of the levee along Culebra Creek. Make necessary repairs, if appropriate, or restore the reach function to reduce flood risk, improve aquatic habitat, and improve riparian habitat.
- Encourage the removal of structures and personal property from the floodplain.
- Evaluate alternative solutions to removing structures from the floodplain, such as moving the stream.
- Discourage development within the floodplain through land-use codes and zoning.
- Require stormwater management plans and implementation for all grading activities.

Rubble, broken concrete, and other non-rock material for erosion control are discouraged. Although this was historically widely used for stabilizing slopes, research has shown that this material often creates more damage than it prevents (CDOT, 2019).

6.5.1 Diversion Structures and Streamflow Gages

- Replace gaging station on Culebra River near San Luis with a functioning stilling well with operable flushing capabilities. Records at this gage are generally good, as long as the water in the stream does not frequently freeze. Ideally, this gage would be replaced with a structure that can be operated without confined space entry hazards.
- Watch control structure at Culebra near Chama, and if necessary, perform stream restoration to repair damage around gaging station. The station is subject to some filling that will result in rating curve shifting that may go unrecognized due to minimum measurement frequency. Recommend upgrading the telemetry data availability through standard user interfaces (Division of Water Resources) or a common community resource.
- Stream restoration around Guadalupe Valdez ditch headgate to reduce bank erosion and improve headgate structure.
- Prioritize installing lockable headgates and fish passage structures based on location in the basin and priority. Structures higher in the basin with more junior priority are critical for ensuring diversions can cease when a water right is no longer in priority. Fish passage at the upper structures will extend the fishery range and prevent entrapment.
- Prioritize installation of measurement structures and recording devices based on priority with senior priorities and those priorities with larger decreed flow rates having the highest priority.

- Outlet works below Sanchez should be modified to have handrails and other hazard protection mechanisms.
- Monitor upper-left edge of flume wall at the end of Sanchez Canal. Seepage may be occurring here that could eventually undermine the structure. If additional gaging is implemented upstream, it may be prudent to evaluate the removal of the structure and restoration of the reach to include sediment retention forebay to reduce sediment loading in Sanchez Reservoir.
- Evaluate having equipment and expertise available to assist acequias with ditch maintenance. This could include having qualified personnel for herbicide application and commercial mulching equipment to thin, thick vegetation.
- Combine diversion structures where possible when improving structures.
- Remove and restore stream around historic diversion structures as facilities are updated.
- Improve infrastructure around Sanchez Canal diversions on all streams to regulate flow into the ditch and maintain streamflow.
- Upgrades should pass 100-year flows,
- Allow fish passage,
- Consider sediment regimes current and future

6.5.2 Transportation

The transportation network includes private roads within the upper watershed, public roads, and private roads on smaller parcels within the lower watershed. Areas within the upper watershed may see changes due to various factors, including building, maintaining, and decommissioning roads. While it may be viewed differently, private roads within the lower watershed should generally follow similar practices as those within the upper basin.

Given that forest roads are one of the most significant contributors of sediments within a forest, managing these features is critical to maintaining a healthy watershed. Best management practices should be adopted for all roads within the basin, which include:

- Always evaluate whether a new road is necessary.
- Require stormwater management plans for all road construction activities.
- Construct roads along natural features where possible, including terraces and following natural contours.
- Minimize road/stream crossings.
- Managing run-off from roads maintaining below erosive thresholds (velocity and depth).
- Design roadway drainage systems that will include cross-drain culverts or drainage bars with spacing based on slope and contributing drainage area.
- Including rolling dips can be an alternative approach to draining roadways (Keller & Ketcheson, October 2015).
- Maintain filter strips along forest roads and detention areas.
- Manage traffic volume where possible.
- Decommission roads that are no longer needed.
- Block access to roads that have already been naturally reclaimed.
- Rip compacted roadbeds to increase infiltration, then apply mulch and seeding.
- Large-scale reclamation may be necessary if significant sediment loading is observed downstream (channel degradation).
- Promote intermingled ownership to reduce the number of roads and road-stream crossings within the watershed.
- Install tracking pads and stabilize low water crossings, prioritizing traffic volume.

- New temporary roads should include decommissioning plan and funding before approval.
- Roadway improvements such as installing water bars, pavement, and crossing upgrades should be prioritized based on traffic volume and watershed risk.

Colorado State Forest Service has put together a forest road handbook for protecting water quality within forested areas. This guide is available at: https://static.colostate.edu/client-files/csfs/pdfs/csfs-frst-rd-hndbk-www.pdf.

In addition to the forest road handbook, the US Department of Transportation has developed an extensive guide for gravel road design and maintenance that can be used as a basis for a county-wide road maintenance program (Skorseth & Selim, 2000). This document is available from the EPA at: https://www.epa.gov/sites/default/files/2015-10/documents/2003_07_24_nps_gravelroads_gravelroads.pdf. This document discusses many of the nuances of gravel road maintenance, including proper grader blade settings, pothole repair, roadbed thickness. For a robust maintenance program to be implemented and effective, maintenance workers must be retained and trained to maintain infrastructure properly.

USDA Forest Service has put together guidance for roadways in “Storm Damage Risk Reduction Guide for Low-Volume Roads” (Keller & Ketcheson, October 2015) that provides guidance appropriate for all roads within the basin that are not state highways.

6.5.2.1 Bridges and Culverts

As bridges and culverts are replaced, the structure size must be designed to adequately pass floods of an appropriate size for the road priority. Critical transportation routes should be sized to pass the 100-yr floods, and secondary routes should be sized to pass the 25-yr flood flows with risk analysis (CDOT, 2019). Consider placing vented low water type crossings in areas where a 100-year flood cannot be accommodated (Keller & Ketcheson, October 2015). Avoid abrupt expansions and contractions in the stream and floodplain.

As projects occur along roadways, consider placing additional floodplain culverts to reduce upstream flood stage and flood velocities around bridges. Many of the channels have been relocated within the floodplain, resulting in flood flows following a historic path, these paths should be considered when floodplain culverts are placed, and bridges are upgraded.

6.5.2.2 Gullies

- Prevention is the most cost-effective way of dealing with Gullies. Inspecting crossings and roads followed by addressing erosion prior to gully formation will prevent further damage (Keller & Ketcheson, October 2015).
- Restore channels that have been damaged by recreational traffic, including installation of flow spreading devices where needed and revegetation.
- Wherever possible, spread water to an appropriate depth and increase roughness to reduce velocity while avoiding concentrating flow near banks.
- High-frequency, low drop structures are preferred for restoration.
- Recruit willing landowners for arroyo restoration, especially steep arroyos.
- Prioritize restoration based on the geomorphic condition of receiving reach, flood hazards, and debris flow risk.

- Prioritize crossings based on public safety – those where degradation is encroaching on the road and those roads that are primary ingress/egress routes.
- Consider replacing culverts with bridges where significant degradation has occurred.

Chapter 7. Water Quality Assessment

Author: Tailwater Limited

7.1 Introduction

"Water is the most critical resource of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land." – Luna Leopold

> The Clean Water Act of 1977 was an addition to the Federal Water Pollution Control Act passed in 1948. The 1948 statute "*authorized the Surgeon General of the Public Health Service, in cooperation with other Federal, state and local entities, to prepare comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries and improving the sanitary condition of surface and underground waters. During the development of such plans, due regard was to be given to improvements necessary to conserve waters for public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural and industrial uses. The original statute also authorized the Federal Works Administrator to assist states, municipalities, and interstate agencies in constructing treatment plants to prevent discharges of inadequately treated sewage and other wastes into interstate waters or tributaries."* (U.S. Fish and Wildlife Service, 2020)

All living things are dependent on water. The quality of that water has an impact on the life that depend on it. Below, the assessment delves into rules and regulations regulating water quality within the country, the state, and more specifically the Culebra Basin. As part of the assessment, existing water quality data within the basin was evaluated, along with collecting and analyzing water quality samples at major tributaries to and including the Culebra River. Results from these samples provide a snapshot of the water quality within the basin.

Water quality is a term that is used to describe physical, chemical, and biological characteristics of water. Water quality is described based on the way the water is used and if it poses threats to those water users (aquatic life, consumption, irrigation). Water that is of good quality for aquatic life may be of poor quality for drinking.

Water quality is impacted by many factors including geology of the contributing basin, industrial activity, agricultural activity, and atmospheric deposition. An example of atmospheric depositions impact on water quality comes from Fisher and Oppenheimer (1991) who estimated that roughly 25 percent of the nitrogen that entered Chesapeake Bay came from atmospheric deposition. Concentration of contaminates varies largely based on geology, transport time, vegetation density, and other factors for the same land use characteristics (Hamilton, Miller, & Myers, 2004).

Within the Upper Culebra Basin water quality sampling has historically focused on two streams and areas within the basin. The first area being near the streamflow gage upstream of San Luis on the Culebra River and the second area focused on the Battle Mountain Mine on Rito Seco. One of the primary organizations responsible for the existing water quality data is Colorado River Watch, with sampling performed by teachers and students from the Centennial School District from 1992 to 2006. Sampling has also been performed by the Colorado Department of Public Health and Environment, United

States Geological Survey, Tetra Tech, and North American Lake Management Society. Past, future, and continued support for these programs ensures that data is available to monitor current conditions and trends into the future.

7.1.1 Acknowledgements

Tailwater Limited would like to extend a huge thank you to Alamosa Field Division Water Quality Lab, Bureau of Reclamation for their support with the analytical samples processing and feedback provided during the study design.

7.1.2 Background

Water quality in the Culebra basin has been sampled routinely by Colorado Department of Public Health and Environment – Water Quality Control Division, Colorado River Watch volunteers, North American Lake Management Society, USGS Colorado Water Science Center, and Tetra Tech- for the 2008 Sanchez Reservoir TMDL study.

Water within the basin is used for agricultural, recreational, and domestic purposes. Agricultural uses include irrigation and livestock water. Recreational uses include fishing, swimming, boating, and scenic. Water within the basin supports habitat for numerous aquatic and terrestrial species.

With respect to climate change, it is anticipated that the concentrations of nitrogen, phosphorus, suspended solids, and salt may increase in the future due to increases in evaporation (Llewellyn & Vaddey, December 2013).

Water from the Culebra and tributaries south of the Culebra provide water for storage in Sanchez Reservoir. Sanchez Reservoir is the largest open-water recreation area within the basin. Residents and visitors come to the State Wildlife Area predominantly to fish, but also to boat and hike. Colorado Department of Public Health and the Environment (CDPHE) samples water quality and biological samples (fish tissue) to monitor water quality in conjunction with the Clean Water Act (CWA).

7.1.2.1 Battle Mountain Gold Augmentation Plan

Within the stipulation of Case 89CW32, samples from lysimeters installed downstream of the tailing ponds were to be installed and checked every six months. If water sufficient for sampling had collected in the lysimeter, this water is to be tested for total cyanide, fluoride, cadmium, mercury, chromium, barium, silver, iron, copper, manganese, selenium, lead, zinc, arsenic, and molybdenum. The results were to be reported to Dos Hermanos and Mined Land Reclamation Board. Upon closure of the mine an amendment was made to the augmentation plan in case no. 99CW057 which included the pumping of water from one of the pits and treating this water prior to discharge into the alluvium of Rito Seco (CDPHE Discharge Permit No. CO-0045675). Surface water quality monitoring was added at three locations with this decree, including the headgate of the Salazar Ditch, in the vicinity of Rito Seco within the unnamed drainage west of the San Luis tailings facility, and third in a third drainage. Water quality samples will be analyzed for Total Sulfate, Weak-Acid Dissociable (WAD) cyanide, Total Fluoride, Dissolved Manganese, Dissolved Iron, Dissolved Copper, Dissolved Arsenic, and Dissolved Zinc.

7.1.3 Regulations

Water quality regulations are typically developed at the national and state level. These regulations are based on linkages identified between poor water quality and negative societal impacts. One such example is from Flint Michigan, where a change in water source resulted in lead exposure to approximately 99,000 residents (CDC, 2021) leading to a public health crisis (PBS Science, 2017). A second recent example is the increased prevalence of toxic algae (cyanobacteria or cyanonHABs) which can lead to skin irritation, diarrhea, liver damage, allergic reactions, etc. The increased prevalence of these blooms has been linked to increased nutrient levels (CDPHE, 2021). These algae also cause taste and odor issues with drinking water supplies and can lead to toxins in the water supply that are difficult to remove. These recent examples and historic events have led to health advisories, leading to the creation of regulations. Several such regulations are discussed below.

7.1.3.1 Regulation 31 and 36

Regulation 31 (5 Code of Colorado Regulations (CCR) 1002-31) outlines the basic standards and methodologies for surface water to meet requirements of the antidegradation rule and implementation process, Colorado Water Quality Control Act. Copies of these regulations may be found on the Colorado Department of Public Health and Environment's website at https://cdphe.colorado.gov/water-quality-control-commission-regulations.

Regulation 36 (5 CCR 1002-36) establishes the classification and numeric standards for the Rio Grande Basin, including the streams within the Upper Culebra Watershed. Regulation 36 provides the basis for classification and determination of standards for the issuance of discharge permits. Within the Upper Culebra basin Regulation 36 divides the waterbodies into four stream segments and three lake segments. These segments are shown in Figure 7-1 and described as follows:

Stream Reaches:

CORGRG28. Mainstem of Rito Seco, including all tributaries and wetlands, from the source to the road crossing at 37.218809, -105.411762.

CORGRG29. Mainstem of Rito Seco from the road crossing at 37.218809, -105.411762 to the confluence with Culebra Creek.

CORGRG30. Mainstem of Culebra Creek, including all tributaries and wetlands, from the source to the Culebra Sanchez Canal diversion, excluding the specific listings in segment 31. East Fork and West Fork of Costilla Creek, including all tributaries and wetland, within Colorado.

CORGRG31. Mainstem of Culebra Creek from the Sanchez Canal Diversion to Hwy 159. Mainstem of Ventero Creek from the Colorado/New Mexico border to the confluence with Culebra Creek. Mainstem of Costilla Creek, including all tributaries and wetlands within Colorado, excluding the listings for the East and West Forks in segment 30.

Lakes:

CORGRG35. All lakes and reservoirs tributary to the Rio Grande from the Hwy 112 bridge near Del Norte to the Colorado/New Mexico border, excluding the specific listings in segments 34, 36,37, 38, and 30.

CORGRG36. All lakes and reservoirs tributary to Ute Creek, from the source to Hwy 160. All lakes and reservoirs tributary to Sangre de Cristo Creek, from the source to Hwy 159. All lakes and reservoirs tributary to Trinchera Creek, from the source to the inlet of Mountain Home Reservoir. All lakes and reservoirs tributary to Rito Seco, from the source to Salazar Reservoir. All lakes and reservoirs tributary to Culebra Creek, from the source to Hwy 159, excluding the specific listing in segment 37. All lakes and reservoirs tributary to Costilla Creek, and within Colorado.

CORGRG37 Sanchez Reservoir.

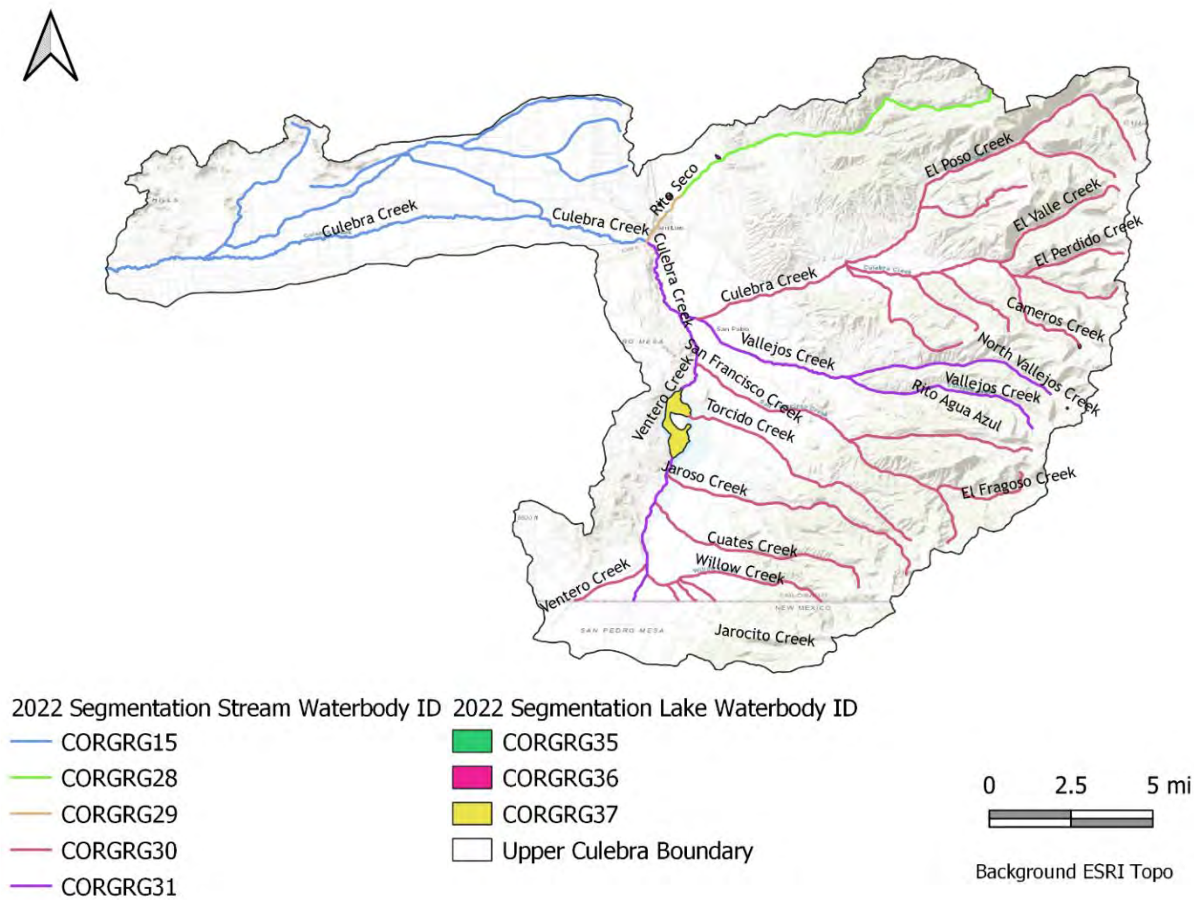


Figure 7-1 CDPHE Waterbody identifiers. An error in this file was noted during the review: the lower portion of Culebra Creek below the Sanchez Canal diversion should be listed as CORGR31. Note CORGRG15 is the Rio Grande.

Regulation 36 lists two discharge permit holders that have been operating prior to May 31, 2012: San Luis Water and Sanitation District (segment CORGRG15, permit COG589082) and Costilla County Water and Sanitation District WWTF (segment CORGRG31, permit CO0036528). These facilities fall under the delayed implementation rules for Regulation 85. Regulation 85 is discussed in further detail below.

The numeric standards applied to each segment are developed based on the classification applied to the reach. The uses are based on agricultural use, type of aquatic life present/expected, type of recreation, and if the stream could be used as a water supply. The recreation class descriptions are in the process of being updated and may be referenced using two different standards. The description of each recreation standard is provided in

Table 7-1 and shown in Figure 7-2. The aquatic life standards are listed in Table 7-2 and shown on Figure 7-3.

Table 7-1 Recreation class descriptions (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018). Recreation classes are described using two differing schemes – the first using numbers and the original using the letters E and N. Designations are transitioning to the Class numbering scheme.

Recreation Class	Alternative Recreation Class	Description
Class 1a	E	Recreation with whole body contact.
Class 1b		Body of water where analysis demonstrating that Class 2 classification is appropriate has been performed.
Class 2	N	Are those stream segments where primary contact recreation does not exist and cannot be expected to exist in the future, regardless of water quality. The reasons for this determination are usually because the stream is unsuitable for this type of recreation due to temperature or streamflow. An example would be an ephemeral or small stream that does not have sufficient depth to support Class 1 recreation.

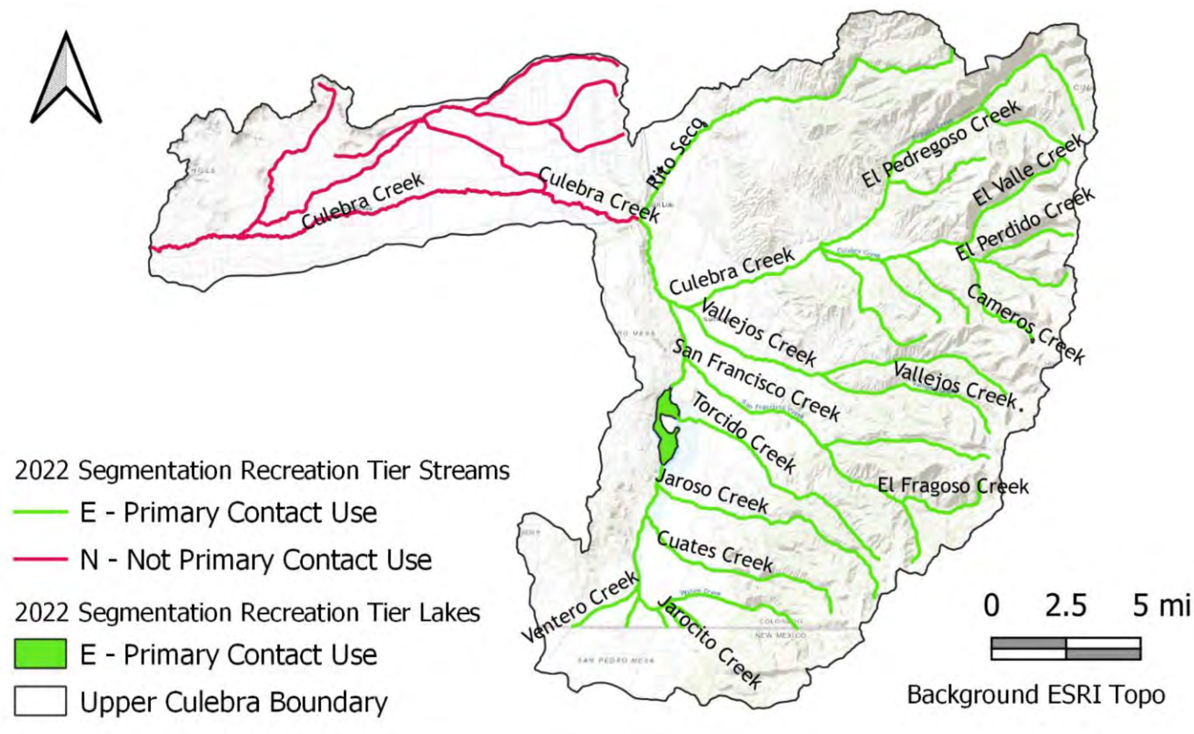


Figure 7-2 CDPHE Recreation tier.

Table 7-2 Colorado Department of Public Health and Environment Aquatic Life Standards Categories. MWAT – Maximum weekly average temperature and DM is daily maximum temperature for Culebra watershed segments. (Regulation No. 36 - Classifications and Numeric Standards for Rio Grande Basin)

Temperature Tier	Aquatic Life Classification	Fish Species Expected to be Present	Applicable Months	MWAT, in degrees Celsius	DM, in degrees Celsius
Cold Stream Tier 1 (CS-I)	Aquatic Life Cold 1	Brook trout, cutthroat trout	June-Sept. Oct. - May	17.0 9.0	21.7 13.0
Cold Stream Tier 2 (CS-II)	Aquatic Life Cold 2	Other cold-water species	April -Oct. Nov-March	18.3 9.0	24.3 13.0
Cold Lake (CL)	Aquatic Life Cold 1	Brook trout, brown trout, cutthroat trout, lake trout, rainbow trout, Arctic grayling, sockeye salmon.	April-Dec. Jan. – March	17.0 9.0	21.2 13.0
Warm Lakes (WL)	Aquatic Life Warm 2	Black crappie, bluegill, common carp, gizzard shad, golden shiner, largemouth bass, northern pike, pumpkinseed, sauger, smallmouth bass, spottail shiner, stonecat, striped bass, tiger muskellunge, walleye, wiper, white bass, white crappie, yellow perch.	April-Dec. Jan. – March	26.2 13.1	29.3 24.1

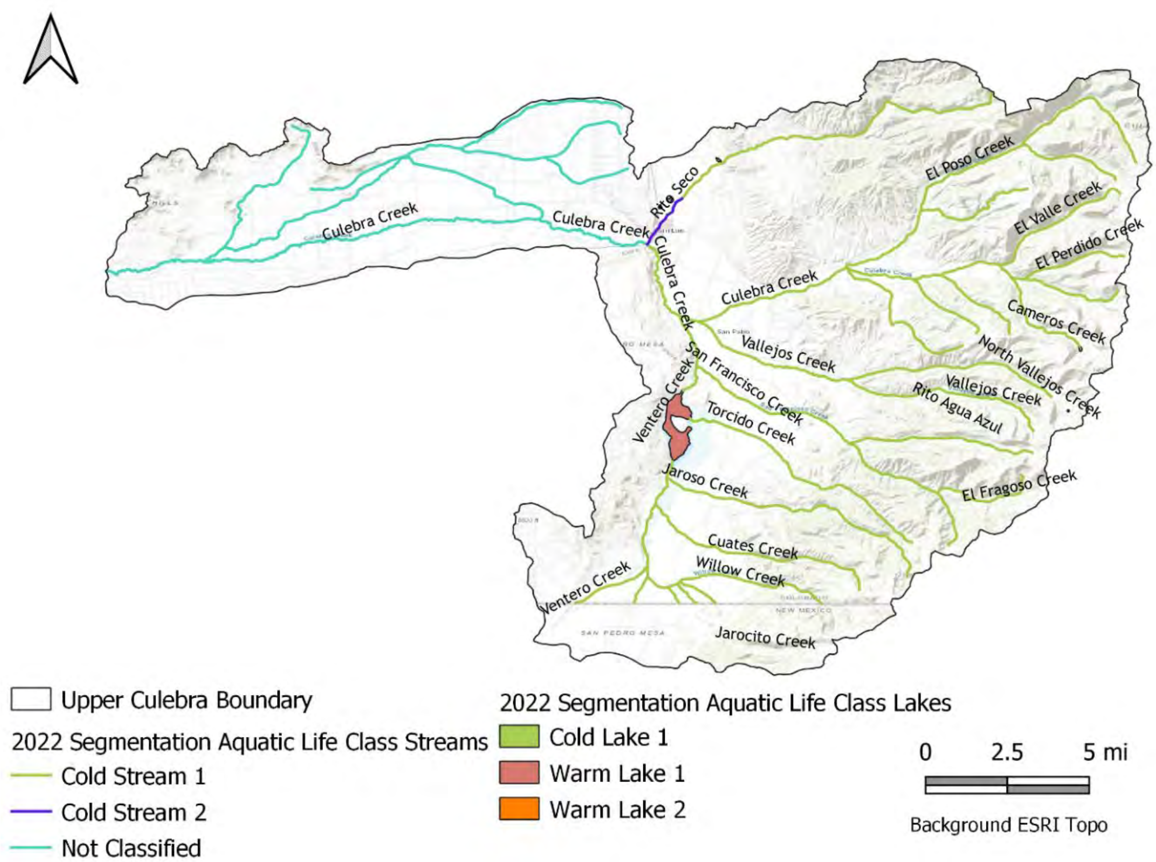


Figure 7-3 CDPHE Aquatic life class, classifications is as shown in the CDPHE gis coverage, The occurrence of Warm Lake 2 was found to be in error and should be listed as Cold Lake 1, this error was reported to CDPHE and should be revised in the next release.

7.1.3.2 Regulation 85 – Nutrients Management Control Regulation

Regulation 85 (5 CCR 1002-85) applies to both point sources and nonpoint sources of nutrients providing numeric water quality standards and discharge limits for total phosphorus and total Inorganic nitrogen as N3. “A point source is a concentrated, identifiable source of pollution, like a sewer pipe or old mine. Nonpoint source pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands and groundwater.” – www.coloradobasinroundtable.org. Regulation 85 outlines the timeline for enforcement of standards based on several factors including community size, economic status, age of wastewater treatment facility, and others.

This regulation encourages monitoring of surface water for nutrients to allow communities to determine the extent and magnitude of nutrients in their region prior to regulatory enforcement. Regulation 85.5(5) calls for cooperation to manage nonpoint source discharges by adoption of Best Management Practices (BMP), planning, and education. Regulation 85.5(5)(c) provides for actions if cooperative efforts and BMP are not implemented to reduce nutrient levels by May 31, 2022. This includes prohibitions or precautionary measures to further limit nutrient concentrations including adoption of regulations specific to agricultural and silvicultural practices.

Monitoring is outlined under Regulation 85.6 including specific monitoring for nonpoint source and unpermitted point source monitoring. Regulation 85.6(4) which encourages entities responsible for nonpoint sources and currently unregulated point sources to determine what their impacts are, prior to regulation, to collaborate on future regulation.

These regulations have been developed to avoid economic hardships on communities dependent on the water resources being impacted by point source and nonpoint source pollution. Taking preemptive action within the Upper Culebra Basin, the community may be able to avoid regulation for some unspecified amount of time. These regulations have been developed in response to observed impacts to several communities. It is recommended the community work to continue to implement a monitoring program and identify funding sources and to practice current BMPs, so that the water quality continues to meet and/or exceed the numeric standards set forth by the regulation for the protection of the community.

7.1.3.3 Regulation 93 – List of Impaired Waters and Monitoring and Evaluation List

Regulation 93 (5 CCR 1002-93) is the list of all water bodies with required total maximum daily loads (TMDL), impaired water bodies with approved TMDL’s or 4b Plans, and Colorado’s Monitoring and Evaluation List (M&E). This list is prepared for Colorado to comply with section 303(d) of the federal Clean Water Act. The M&E list identifies water bodies where there is reason to suspect water quality problems but are not subject to EPA control. The current status of the segments is shown in Figure 7-4.

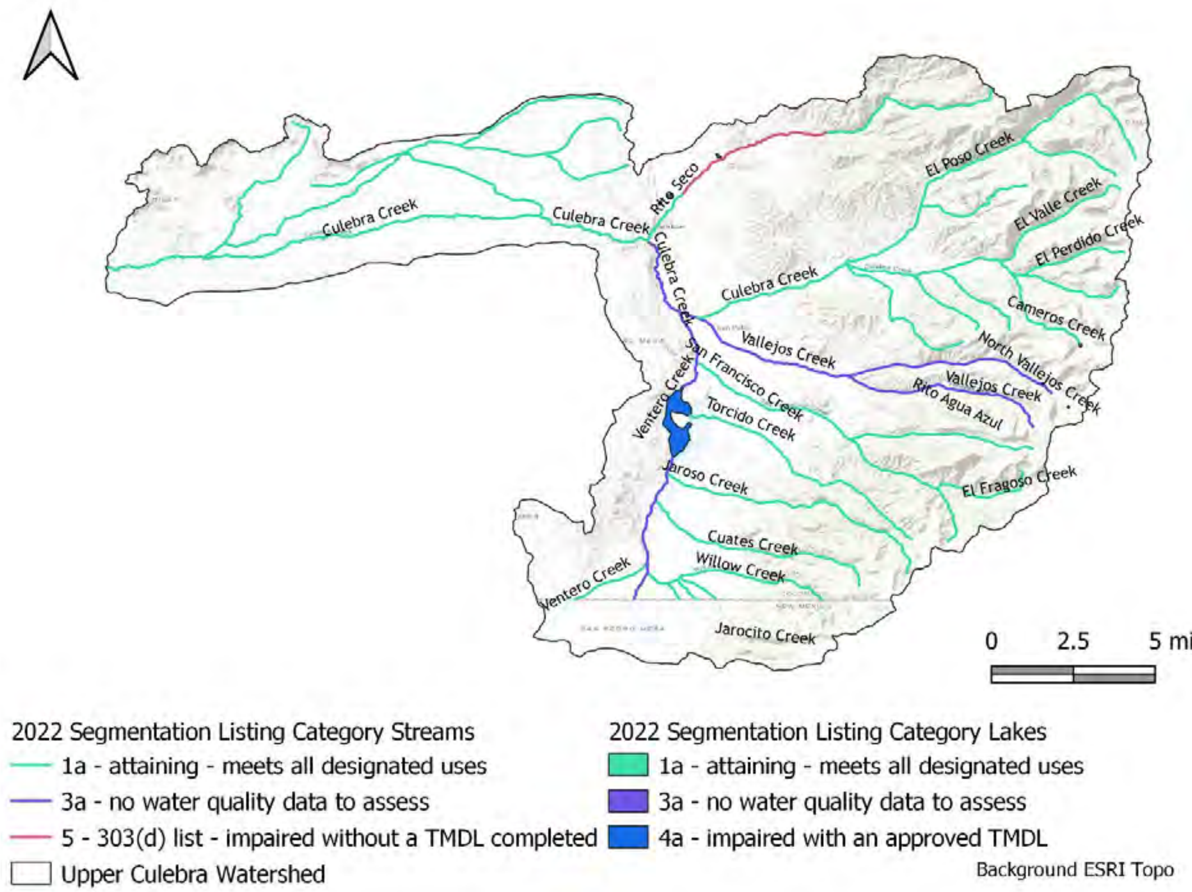


Figure 7-4 Category 1a. – Meets all designated uses, 3a. – Segment with no water quality data to assess, 4a. – Impaired with an approved TMDL, 5 – 303(d) listed – impaired without a TMDL completed.

Sanchez Reservoir was removed from the 303(d) list, aka delisted, once the TMDL was completed and is currently M&E listed for total arsenic due to not meeting water supply use standards. Rio Grande segment 28, Upper Rito Seco below Battle Mountain was added to the M&E list due to exceedance of water quality standards for copper and was retained as a high priority on the 303(d) list for E. coli (Regulation #93 - Colorado's Section 303(d) List of Impaired waters and Monitoring and Evaluation List, 2021). These segments are shown in Figure 7-5.

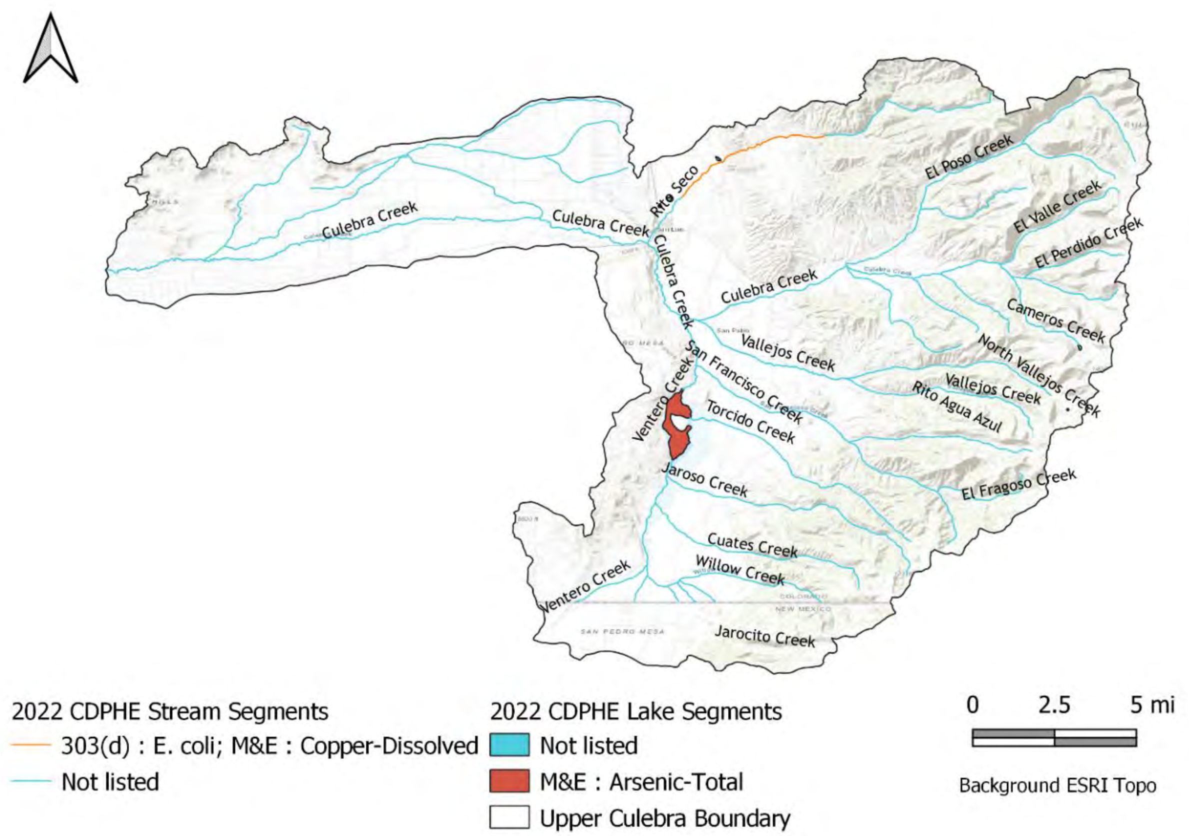


Figure 7-5 CDPHE listed segments along with analyte of concern.

7.1.4 Accuracy and Detection Limits

Water quality is measured either directly using a water quality meter, through observation (aesthetics, smell, taste, odor), or through analytical methods. Water quality data is subject to the respective detection limits of the method used to analyze the constituent, or physical property. Depending on the characteristic and range that is expected and/or desired to have data for dictates the method used for measurement.

Water quality measurements that are below the detection limit are reported as below the detection limit; this is not the same as saying that the constituent is not present. This could be a result of a limitation of the equipment being used for the measurement and/or the lack of need for more precise data.

7.1.5 Goals and Objectives

To access the water quality within the Culebra Basin, the task assessment team, in conjunction with project stake holders, identified several goals and objectives.

Goal 1 Assess current surface water quality condition within the Culebra Basin.

Goal 2 Compile existing surface water quality data within the Culebra Basin.

Goal 3 Develop projects that could be implemented to improve water quality within the Culebra Basin.

The following objectives were identified for this assessment to meet the water quality assessment goals.

Goals	Objectives
Goal 1 Assess current water quality condition within Culebra Basin.	*Objective 1.1* Develop sampling plan with locations for sampling that assess changes in land use. *Objective 1.2* Collect and analyze water samples for standard water quality parameters including nutrients, metals, and major ions. *Objective 1.3* Summarize water quality data and compare with current water quality standards.
Goal 2 Compile existing surface water quality data within the Culebra Basin.	*Objective 2.1* Identify past water quality sampling programs within the Culebra Basin. *Objective 2.2* Compile all water quality data into one comprehensive dataset. *Objective 2.3* Summarize water quality data. *Objective 2.4* Compare water quality data with current water quality standards.
Goal 3 Identify areas to improve water quality within the Culebra Basin.	*Objective 3.1* Identify locations and characteristics that water quality standards were not met. *Objective 3.2* Assess methods for improving water quality. *Objective 3.3* Identify strategies for improving understanding of water quality stressors within the basin. *Objective 3.4* Make recommendations for future sampling to address Culebra Basin water quality concerns.

7.2 Methods

The water quality assessment was performed in two parts. The first part was assessing existing water quality data available within the basin, and the second was the collection and analysis of additional water quality samples.

7.2.1 Existing Water Quality

Water quality point sample data were obtained from EPA Water Quality Portal which combines data from multiple agencies including EPA, RiverWatch, and USGS NWIS (National Water Quality Monitoring Council, 2021). Data were filtered to include only sites within the study area. The samples within the study area included surface water, ground water, wastewater, precipitation, and biological samples. Additional mercury sample points were obtained from the Tetra Tech TMDL report and included within the sample database (Tetra Tech, Inc, June 2008). These samples include mercury and methylmercury concentrations within the water, sediments, and biological samples. The water samples were included in the analysis for this report.

The water quality sample sites were grouped based on latitude and longitude to compare samples of the same type and same general location with different names. Site groups and individual site locations are shown on Figure 7-6.

Existing data sets were processed into base characteristics by performing unit conversions and adjustments to naming convention. This insured that data from across sources were made comparable so comparisons could be made. Total recoverable characteristics are considered synonymous with total values and were grouped with the total characteristics. The summary listing of the data may be found in Appendix 8.A.

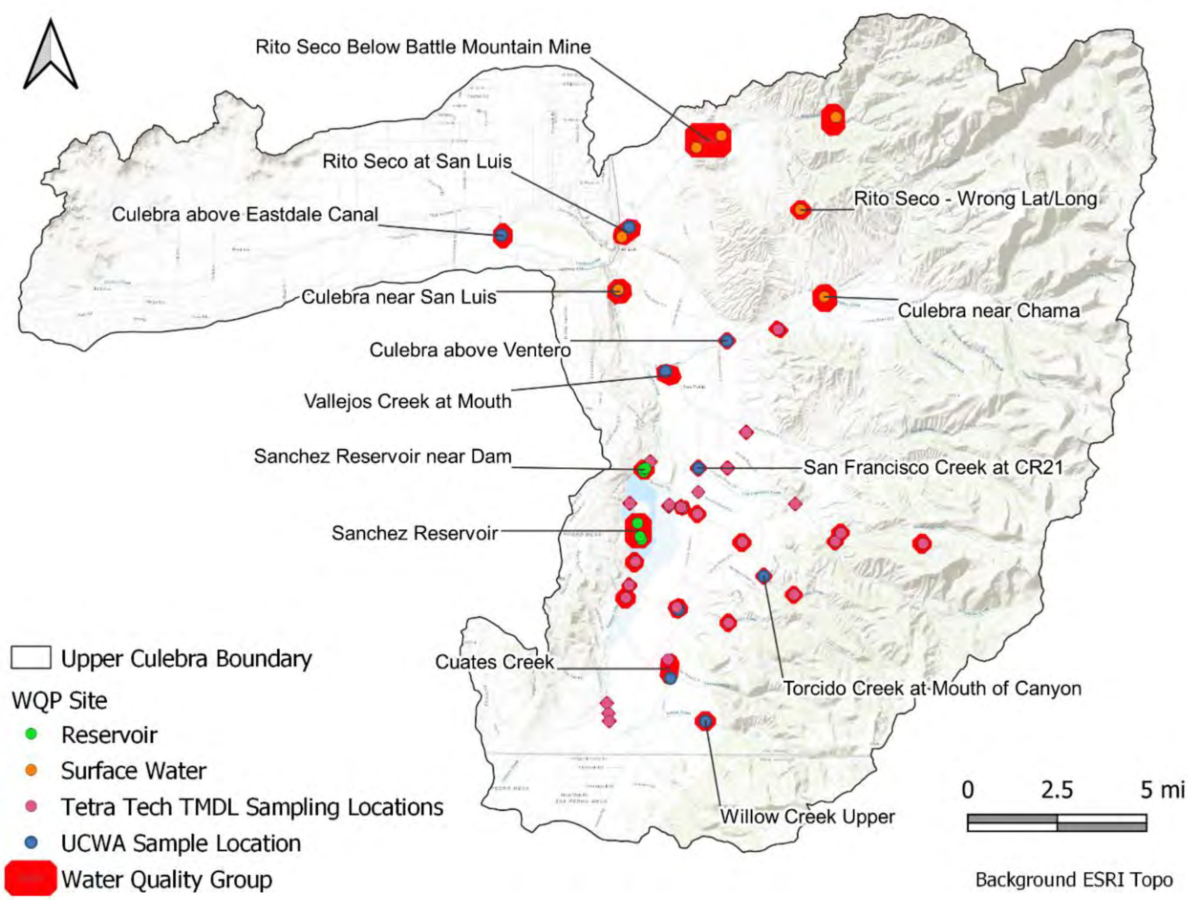


Figure 7-6 Site group names with location and type of each water quality sample type included in the assessment. Tetra Tech sampling groups labeled in Figure 7-7.

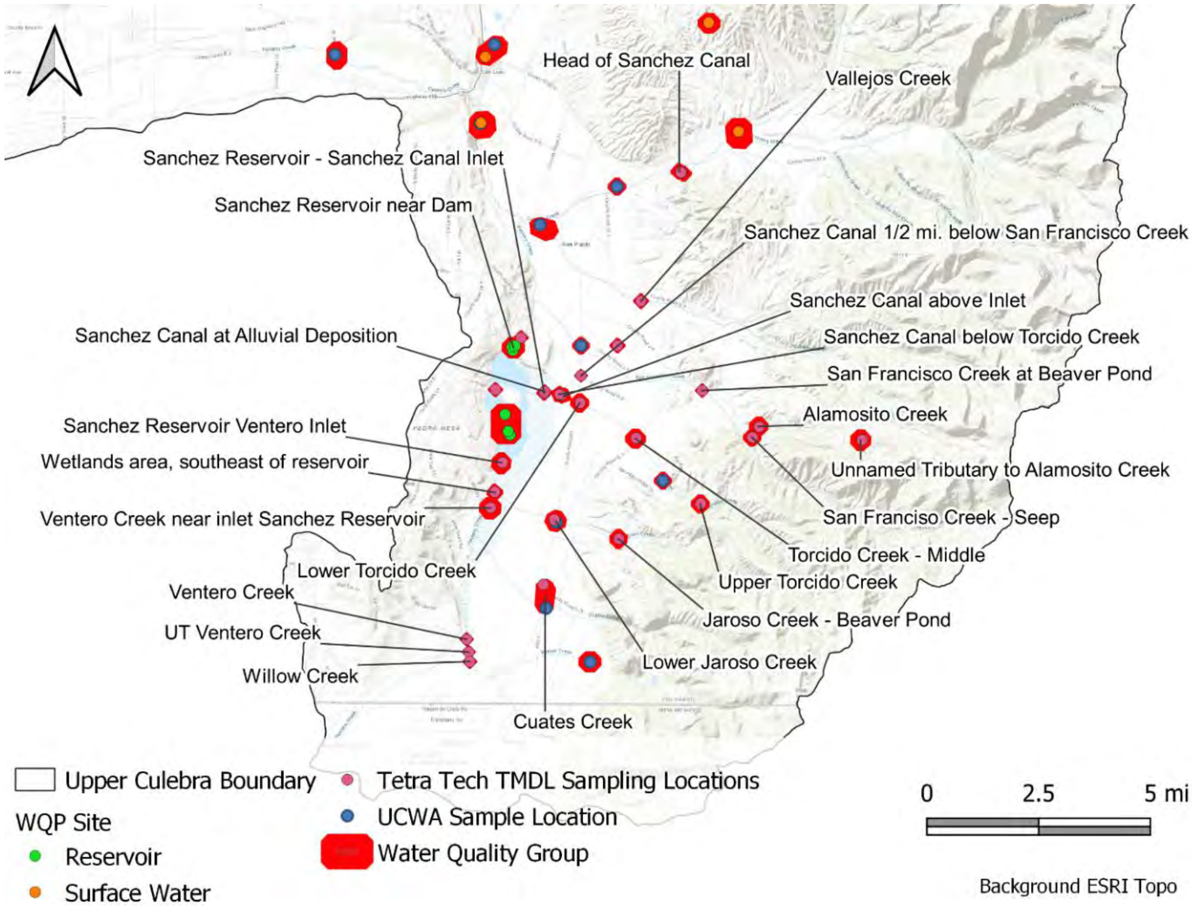


Figure 7-7 Water quality sampling groups -- Tetra Tech 2008 TMDL

Continuous temperature data was obtained from the NorWest project for the 6 sites within the study area. These sites have daily average stream temperatures for some of the tributaries that are critical habitat for the Rio Grande Cutthroat Trout including Alamosito Creek, Cuates Creek, Jaroso Creek, North Vallejos Creek, Vallejos Creek, and Torcido Creek. Sensor locations are shown on Figure 7-8. This data was collected for research into the sensitivity of habitats to environmental variation (Zeigler, Todd, & Caldwell, 2013).

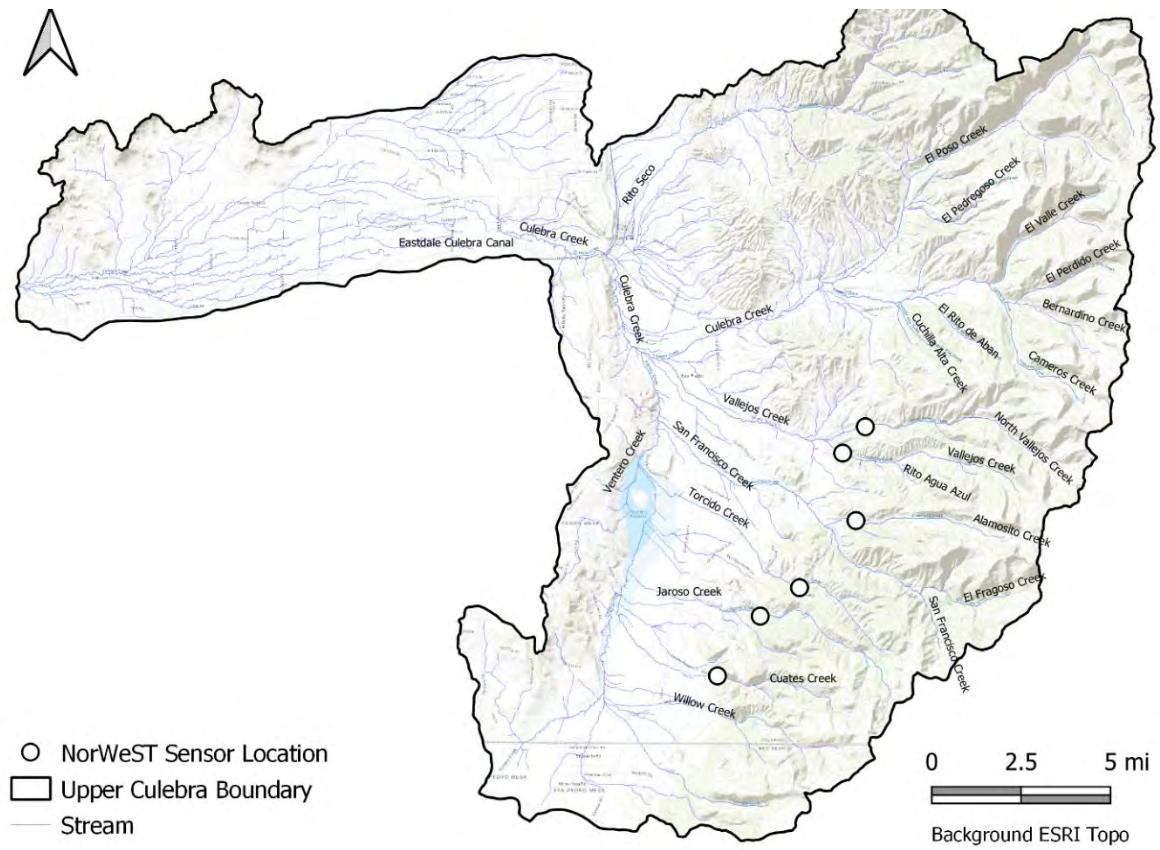


Figure 7-8 NorWeST temperature sensor locations. Sensors located on North Vallejos Creek, Vallejos Creek, Alamosito Creek, Torcido Creek, Jaroso Creek, and Cuates Creek.

7.2.2 Water Quality Sampling

The sampling plan was developed in conjunction with project stakeholders and funding. Based on an analysis of available resources, the sampling plan included grab samples at the lower end of each of the major tributaries paired with a more extensive mapping of field parameters, (pH, specific conductance, and temperature) within the basin. The approach allowed for a greater number of sites to be evaluated for potential changes in water quality. Thus, resulting in a greater spatial resolution for data that can provide a strong basis for a robust future sampling program.

Correlations with field parameters and other parameters are analyzed to identify groups of characteristics that are related to each other (i.e., resulting from similar land use or parent geology).

Land use within the basin includes undeveloped forests in the upper region transitioning through the alluvial valleys into irrigated agriculture. The overall lack of data for the tributaries within the basin leads to a need for a distributed approach to identifying water quality degradation within the basin.

The laboratory analytical sampling points include ten sites along with one replicate sample and one blank sample for Quality assurance and quality control. The sample sites were selected to be at the lower end of the tributary where water would likely be present. This allowed the sample to include the impacts from the land use activities within the tributary. The sampling sites are listed below in Table 7-3 and shown in Figure 7-9. The analytes included are listed in Table 7-4. Sampling site locations were field adjusted based on access and water presence.

Table 7-3 Sampling locations.

Stream Name	Location	Latitude	Longitude
Willow Creek	Near Dos Hermanos Ranch Gate	37.0093640767	-105.380449983
Cuates Creek	At County Road 21	37.0266886833	-105.398295887
Jaroso Creek	At County Road 21	37.0545965233	-105.39435349
Torcido Creek	At Mouth of Canyon near Valley Road	37.0681770100	-105.35125417
San Francisco Creek	At County Road 21	37.1118096633	-105.384605867
Vallejos Creek	Above Confluence with Culebra Creek.	37.1509997867	-105.401415433
Rito Seco	near Centennial School	37.2092932133	-105.420217873
Culebra Creek above Ventero	At County Road 22.4	37.1634078567	-105.37029169
Culebra Creek	at San Luis	37.1836672733	-105.42581167
Culebra Creek	Above Eastdale Canal near County Road 16	37.2057916967	-105.48492676

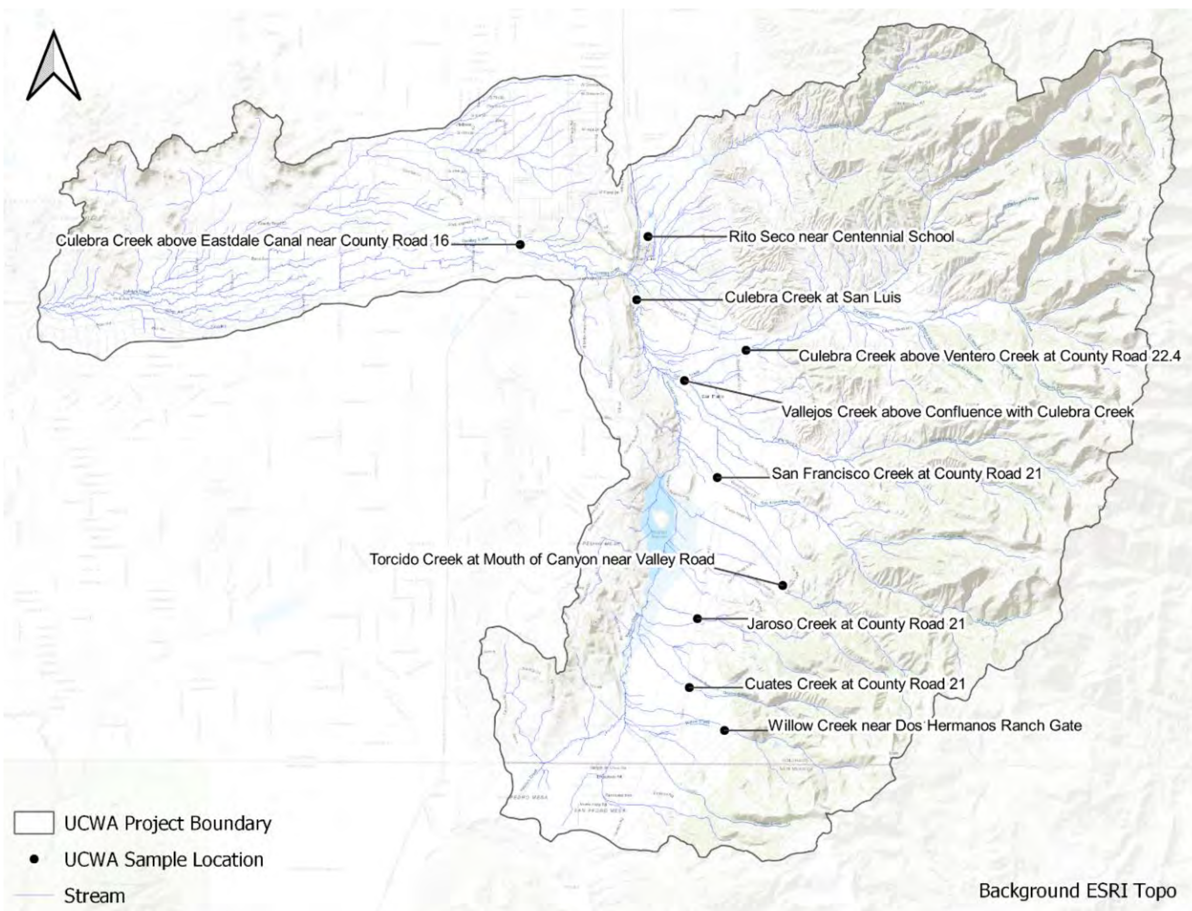


Figure 7-9 Upper Culebra Watershed Assessment sampling locations. Samples collected June 22, 2021, and analyzed at the Bureau of Reclamation water quality lab in Alamosa, CO.

Table 7-4 Water quality lab analytical characteristics.

Characteristic	Reporting Limit	Units	Characteristic	Reporting Limit	Units
Alkalinity	5	mg/l	Manganese	0.03	ug/l
Aluminum	1.2	ug/l	Molybdenum	0.04	ug/l
Ammonium	0.01	mg/l	Nickel	0.02	ug/l
Antimony	0.01	ug/l	Nitrate	0.01	mg/l
Arsenic	0.03	ug/l	Nitrite	0.01	mg/l
Arsenic - total recoverable	0.3	mg/l	Phosphate	0.04	mg/l
Barium	0.02	ug/l	Phosphorus	0.01	mg/l
Beryllium	0.05	ug/l	Potassium	0.1	mg/l
Bicarbonate	5	mg/l	Selenium	0.37	ug/l
Boron	0.01	mg/l	Silica	0.05	mg/l
Bromide	0.04	mg/l	Silver	0.08	ug/l
Cadmium	0.03	ug/l	Sodium	0.5	mg/l
Calcium	0.1	mg/l	Strontium	0.01	mg/l
Carbonate	5	mg/l	Sulfate	0.04	mg/l
Cerium	0.01	mg/l	Sulfur	0.01	mg/l
Chloride	0.02	mg/l	Thallium	0.03	ug/l
Chromium	0.57	ug/l	Thorium	0.03	ug/l
Cobalt	0.01	mg/l	Tin	0.03	ug/l
Cobalt	0.02	ug/l	Titanium	0.01	mg/l
Copper	0.5	ug/l	Total recoverable iron	5	mg/l
Dissolved Iron	0.01	mg/l	Total recoverable selenium	0.05	mg/l
Fluoride	0.02	mg/l	Uranium	0.03	ug/l
Lead	0.02	ug/l	Vanadium	0.05	ug/l
Lithium	0.01	mg/l	Zinc	0.12	ug/l
Magnesium	0.1	mg/l			

Water quality samples were taken as grab samples at ten locations within the basin during June, the period of typical peak water use and flow within the Culebra Basin. Samples were taken in one day to limit influence from seasonal and climatic variation. This period was selected to improve the likelihood of water being present at the lower end of these reaches and after the initial spring irrigation.

Additional field parameter sampling was performed along the extents of the reaches where stream was accessible from rights-of-way or where other measurements occurred. Field parameters measured using a pocket field meter included specific conductance, pH, and water temperature. During field sampling general notes about weather and hydrologic condition were noted.

Specific conductance and pH were measured to evaluate changes in the water chemistry across the basin. Changes in specific conductance and pH can typically be related to chemical composition of the water and are being used to expand the water quality analysis in the basin while minimizing the analytical costs. These parameters can be utilized to identify monitoring locations and appropriate frequencies that would likely significantly contribute to the understanding of water quality in the basin. All measurements of pH and Specific Conductance were temperature corrected to a standard reference temperature of 25 °C.

7.2.2.1 Sampling Procedure

Water samples were collected as a grab sample in each selected tributaries with a clean 1 L HDPE bottle and 500 mL HDPE bottle Water samples were collected near the centroid of flow by completely immersing the HDPE bottles into the stream about 4 inches deep. Sample bottles were rinsed three times dumping rinse water downstream prior to collection of the sample. Gloves were worn and changed before and after collecting and filtering the water samples to avoid contamination and cross contamination.

Remaining sample bottles were filled from the 1L grab bottle using the following procedure. The first aliquot was poured directly from grab bottle into the 250mL unfiltered sample bottle. The remaining water from the 1 L bottle was filtered with through a 0.45 μm filter a 250 mL HDPE bottle and 250 mL amber HDPE bottle, both labeled as filtered. Sample bottles were labeled with tributaries name, date, and time and whether the sample was filtered or unfiltered. The filtered and unfiltered water samples are separated in zip lock bags and stored in a cooler on ice until delivered same day to lab. Samples were acidified at the lab prior to storage in monitored refrigeration space.

Field notes were taken when collecting each water samples. The field notes data includes name of the water body, location, date and time of collection, name of collector, weather, natural or manmade conditions that may assist in interpreting the water quality.

<u>Sampling Equipment</u>

- 125 mL amber HDPE bottle preserved to pH < 2 with Sulfuric Acid
- 125 mL HDPE bottle preserved to pH < 2 with Nitric Acid (3mL 1+1)
- 125mL HDPE bottle filtered (0.45 micron) and preserved to pH < 2 with Nitric Acid (3 mL 1+1)
- 500 mL HDPE bottle unfiltered unpreserved
- 1 L HDPE bottle for sample collection
- Blank water – ASTM Type II, Cat#: LC267502, Lot#: K296-23, exp 10/22/2025
- Filters GeoTech #83050011, 0.45μm, 450 cm3
- Filters were pre-rinsed with approximately 250 mL of distilled water drained and rinsed with approximately 250mL of sample water prior to filling.
- Nitrile Disposable Gloves
- (x2) 250 mL HDPE bottle, one filtered one unfiltered
- (x1)250 mL amber HDPE bottle, filtered.

7.2.2.2 Analytical Methods

Water quality samples for dissolved and total recoverable metals were evaluated using EPA Method 200.8 and EPA Method 200.7. Alkalinity, carbonate, and bicarbonate samples were analyzed using Standard Method 2320. Anions were analyzed using EPA Method 300.0.

7.2.2.3 Field parameters

Field parameters include Water Temperature, Specific Conductance, and pH with field notes such as weather conditions, description of flow regime to assist in determining if variation in results may be the result of a hydrologic event.

Field parameters were collected with a Hach Pocket Pro Multi 2 meter with calibration checked prior to each grab sample and at least twice daily for distributed field parameter collection. Calibration checks were performed using NIST traceable standard solution and re-calibration was performed if meter read more than 10% different than standard value for Specific Conductance and more than 0.2 std units for pH based on the value temperature corrected to 25 deg C.

7.3 Sampling Results

7.3.1 Water Quality Samples

Water quality samples were collected on June 16, 2021, at ten sites including one replicate sample and one blank sample for quality assurance and quality control (QA/QC). This point sample analysis provides a baseline for the current routine summer conditions within the basin. Using only a single point of water quality sampling does not capture variability and routine errors that occur with sampling such as contamination or analytical errors.

Two levels of reporting are used when evaluating data, the first is for detection, and the second is for quantification. Environmental sampling and evaluation require a handling and chemical processes to be able to evaluate the chemical composition of the sample. The instruments are first able to provide whether a characteristic was found in the sample or if it was “Not detected” the second level is whether the concentration of the characteristic was above the noise typically found in the sample, or whether the value is such that noise is a greater proportion of the value, these values are below the reporting limit and are expressed as “<Reporting Limit”. The concentration at which values are not detected or <Reporting limit are based on analysis of the method used to evaluate the samples and statistical analysis of multiple known samples across many laboratories. Values that are <Reporting Limit can be thought of like measuring a hair with a ruler, we can see it is there, but the accuracy of any reported diameter would be very poor.

There were three parameters that were not detected in any sample, six parameters that were less than the reporting limit in all samples, and one parameter that only quantifiable at one site. Bromide, Thallium, and Total Recoverable Selenium were not detected in any sample. Selenium, Silver, Cadmium, Beryllium, Total Recoverable Arsenic, and Total Recoverable Iron were less than reporting limit for all samples. Carbonate included only one measurable value – Culebra Creek above Eastdale Canal.

To evaluate the quality of the water from the analytical results water quality parameters were compared with the numeric standard from Regulation 36 (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018). The only constituent of concern is pH at Culebra Creek above Eastdale Canal (Figure 7-10). Because regulatory standards do not exist for all analytical parameters standards from literature where were also compared. The only parameter that was identified as a concern was phosphate which is recommended by the EPA to be below 0.05 mg/l (Mueller & Helsel, 1996) for those waters that discharge into lakes or reservoirs. All values where phosphate was detected exceeded this limit. No other constituents of concern were identified. The highest values of phosphorus, nitrate, and nitrite occurred downstream of the larger water users where the water was comprised of more return flows.

The second portion of the analysis was to evaluate relationships that could be identified between the analytical results that could be used to potentially extrapolate the data to the upper portion of the basin. The first correlations were the regulated inorganic characteristics listed in Table 7-5. The maximum values were associated with sites most affected by irrigation return flows. No site included detection of all nutrients. A correlation matrix (Figure 7-11) was used to evaluate the correlations between the regulated inorganic compounds and the filed parameters. Alkalinity and boron showed a strong positive correlated with specific conductance. Chloride and sulfate were both positively correlated with both specific conductance and pH.

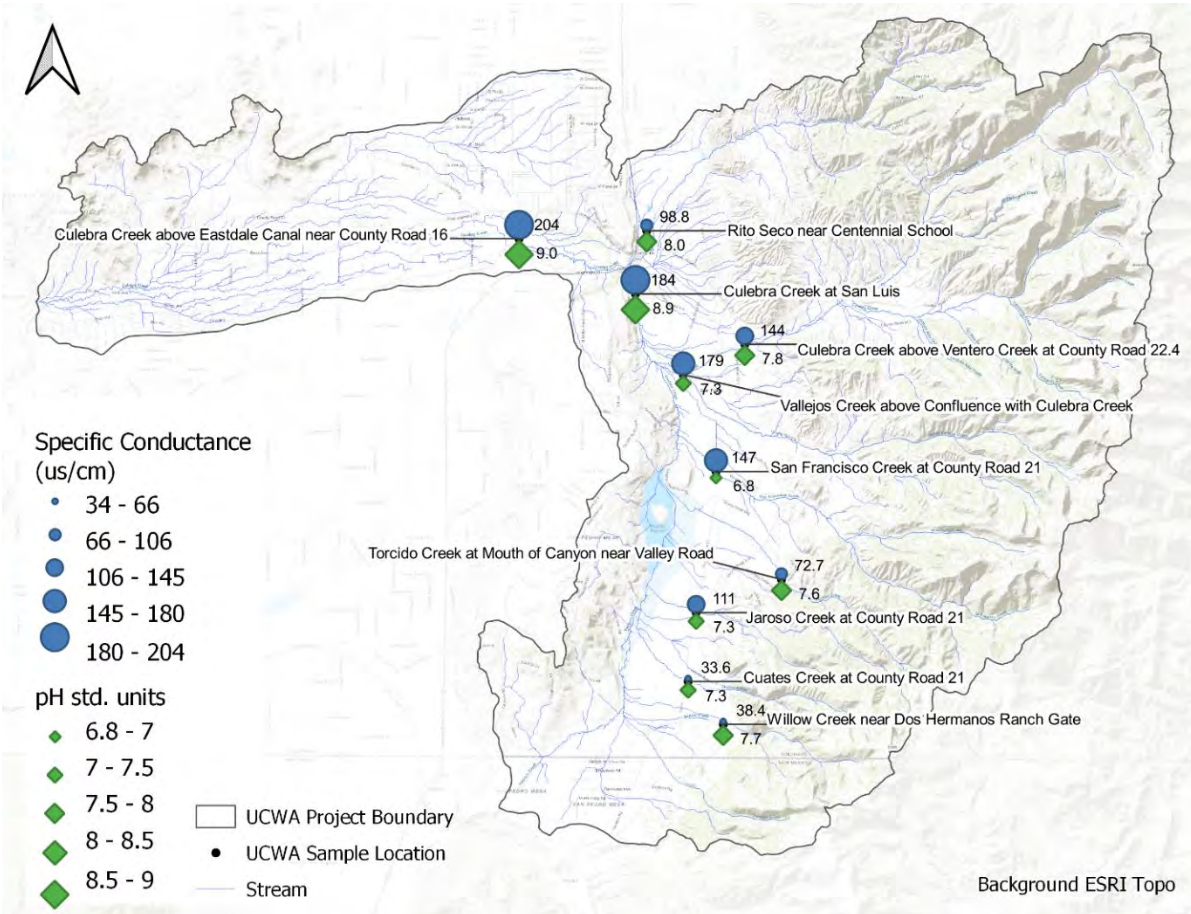


Figure 7-10 Water quality field parameters at sites where water quality samples were collected.

Table 7-5 Regulated inorganic characteristic results and field parameters.

Location code	pH Std. units	SC µs/cm	Alkalinity mg/l	Phosphorus mg/l	Nitrate mg/l	Nitrite mg/l	Phosphate mg/l
Willow Creek near Dos Hermanos Ranch Gate	7.7	38.4	21.54	<0.005	0.599	Not Detected	Not Detected
Cuates Creek at County Road 21	7.3	33.6	19.63	<0.005	0.496	Not Detected	Not Detected
Jaroso Creek at County Road 21	7.3	111	63.22	0.043	Not Detected	Not Detected	0.09
Torcido Creek at Mouth of Canyon near Valley Road	7.6	72.7	37.35	Not detected	Not Detected	Not Detected	Not Detected
San Francisco Creek at County Road 21	6.8	147	77.75	0.017	Not Detected	0.029	Not Detected
Vallejos Creek above Confluence with Culebra Creek	7.3	178	101.33	0.042	Not Detected	Not Detected	0.07
Culebra Creek above Ventero Creek at County Road 22.4	7.8	144	70.74	Not detected	0.73	Not Detected	Not Detected
Culebra Creek at San Luis	8.9	184	100.44	0.021	Not Detected	Not Detected	Not Detected
Rito Seco near Centennial School	8.0	98.8	55.57	0.031	Not Detected	Not Detected	0.06
Culebra Creek above Eastdale Canal near County Road 16	9.0	204	111.53	0.007	0.07	0.034	Not Detected

Table 7-5 – Continued -- Regulated inorganic characteristic results and field parameters

Location code	pH	SC	Alkalinity	Boron	Chloride	Sulfate
	Std. units	µs/cm	mg/l	mg/l	mg/l	mg/l
Willow Creek near Dos Hermanos Ranch Gate	7.7	38.4	21.54	<0.01	0.195	2.42
Cuates Creek at County Road 21	7.3	33.6	19.63	<0.01	0.161	2.511
Jaroso Creek at County Road 21	7.3	111	63.22	<0.01	0.801	4.121
Torcido Creek at Mouth of Canyon near Valley Road	7.6	72.7	37.35	<0.01	0.409	3.924
San Francisco Creek at County Road 21	6.8	147	77.75	<0.01	0.738	9.75
Vallejos Creek above Confluence with Culebra Creek	7.3	178	101.33	0.018	0.672	6.735
Culebra Creek above Ventero Creek at County Road 22.4	7.8	144	70.74	<0.01	0.276	13.53
Culebra Creek at San Luis	8.9	184	100.44	0.011	1.183	12.057
Rito Seco near Centennial School	8.0	98.8	55.57	<0.01	0.956	6.881
Culebra Creek above Eastdale Canal near County Road 16	9.0	204	111.53	0.011	1.167	11.633

The measured sulfate at Culebra Creek at San Luis, 12.1 mg/l exceeded the maximum measured value in the historic record, 9.0 mg/l.

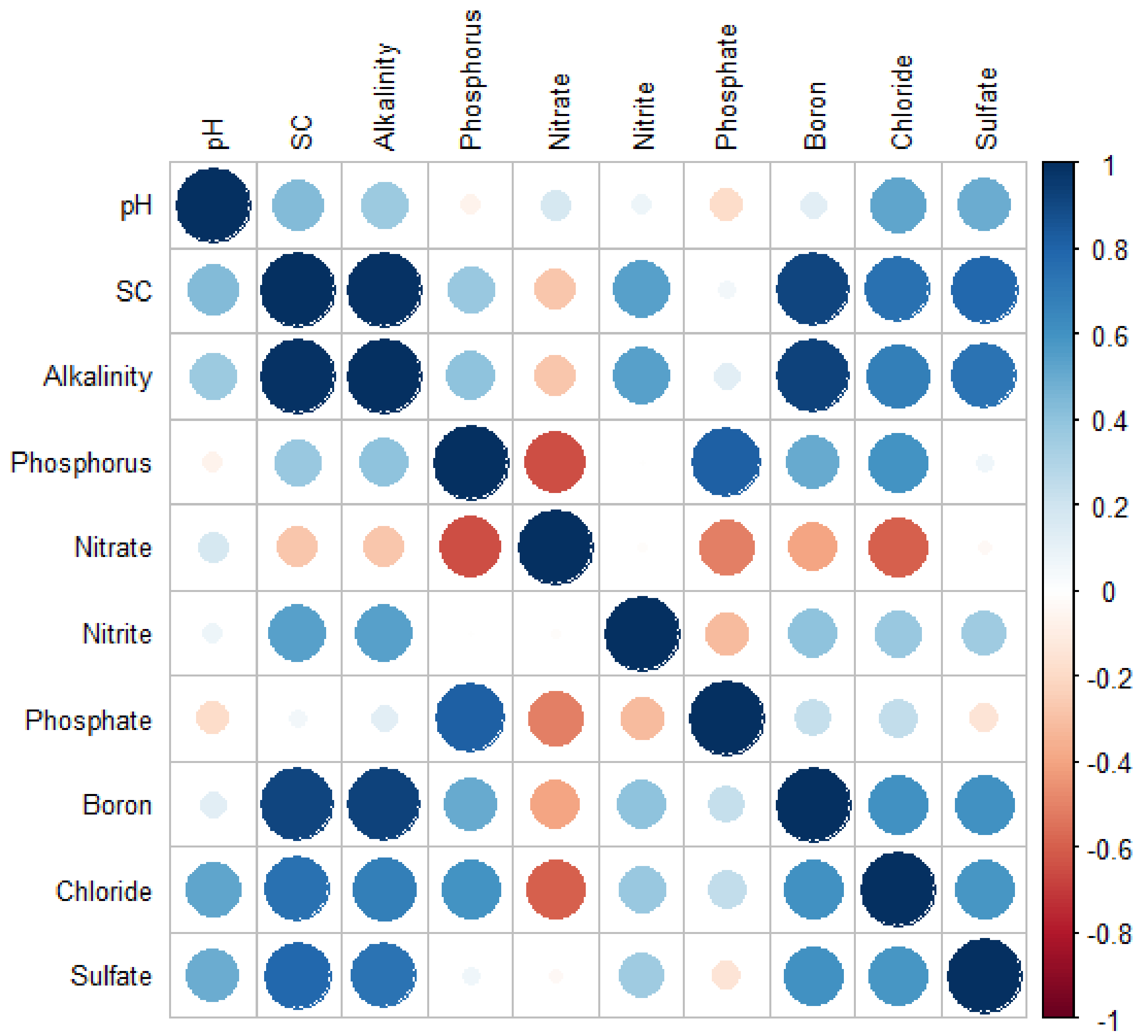


Figure 7-11 Spearman correlation between measured regulated inorganic parameters, field parameters, and alkalinity/harness parameters.

Regulated metals were analyzed. The lowest concentrations were typically associated with Willow Creek and Cuates Creek. The Culebra Creek at San Luis Creek had the highest values of arsenic, chromium, and copper. The highest levels of lead and molybdenum were observed on Rito Seco Creek at Centennial School. The highest value of uranium occurred at the lower end just above Culebra Creek above Eastdale Canal. The highest values of manganese, nickel, cadmium, and dissolved iron were observed on San Francisco Creek. Vallejos had the highest level of zinc observed. Manganese was significantly higher in the San Francisco Creek and Vallejos samples than the other tributaries.

Correlations were computed for all regulated metals with measured values above the reporting limit. Positive correlations with specific conductance were noted for all parameters except total recoverable arsenic, where most of the values were not detected. The strongest correlations included copper, nickel, uranium, cadmium, and arsenic. pH showed weak positive correlations with the presence of copper, molybdenum, and uranium. Positive correlations were found between uranium, copper, molybdenum, and arsenic, nickel, and cadmium.

Arsenic levels were notably highest in the Culebra Creek at San Luis sample and were below the detection limit for Culebra Creek above Ventero. Detectable levels of Arsenic for tributaries that can be diverted to Sanchez Reservoir were measured in the Jaroso, Torcido, San Francisco, and Vallejos Creek samples. The Rito Seco sample also had measurable levels of Arsenic.

Water quality samples show concentrations of Boron ranging from .003 mg/l to .018 mg/l which is below the recommended standards and the most sensitive crops standards (Bauder, Waskom, Sutherland, & Davis, 2014).

Table 7-6 Metals sample results.

Location code	pH	SC	Arsenic	Chromium	Copper	Lead	Molybdenum	Selenium	Silver
Units	**Std. units**	**µs/cm**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**
Willow Creek near Dos Hermanos Ranch Gate	7.7	38.4	<0.032	<0.57	<0.5	Not detected	0.821	<0.37	<0.08
Cuates Creek at County Road 21	7.3	33.6	<0.032	<0.57	<0.5	Not detected	0.769	<0.37	Not detected
Jaroso Creek at County Road 21	7.3	111	0.233	0.819	<0.5	<0.016	0.376	Not detected	Not detected
Torcido Creek at Mouth of Canyon near Valley Road	7.6	72.7	0.122	<0.57	<0.5	Not detected	0.506	Not detected	Not detected
San Francisco Creek at County Road 21	6.8	147	0.285	1.42	0.59	Not detected	1.49	<0.37	Not detected
Vallejos Creek above Confluence with Culebra Creek	7.3	179	0.136	1.41	0.611	Not detected	2.15	Not detected	Not detected
Culebra Creek above Ventero Creek at County Road 22.4	7.8	144	<0.032	1.23	0.751	<0.016	1.53	<0.37	Not detected
Culebra Creek at San Luis	8.9	184	0.522	1.74	0.856	<0.016	1.93	<0.37	Not detected
Rito Seco near Centennial School	8.0	98.8	0.227	0.711	0.68	0.049	2.93	<0.37	<0.08
Culebra Creek above Eastdale Canal near County Road 16	9.0	204	0.456	1.42	0.814	Not detected	2.1	<0.37	Not detected

Table 7-6 – continued Metals sample results.

Location code	Uranium	Zinc	Manganese	Nickel	Cadmium	Dissolved Iron	Total Recoverable Iron	Total Recoverable Arsenic
Units	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**mg/l**	**mg/l**	**mg/l**
Willow Creek near Dos Hermanos Ranch Gate	0.339	0.521	0.479	0.177	<0.026	0.007	<5	0.007
Cuates Creek at County Road 21	0.341	0.631	0.482	0.171	<0.026	<0.005	<5	0.008
Jaroso Creek at County Road 21	0.351	1.59	41.9	1.17	<0.026	0.051	<5	Not Detected
Torcido Creek at Mouth of Canyon near Valley Road	0.307	1.63	3.44	0.559	<0.026	0.012	<5	Not Detected
San Francisco Creek at County Road 21	1.36	2.84	278	1.49	<0.026	0.662	<5	0.01
Vallejos Creek above Confluence with Culebra Creek	0.542	3.05	163	1.30	<0.026	0.122	<5	Not Detected
Culebra Creek above Ventero Creek at County Road 22.4	2.18	1.04	8.91	0.945	<0.026	0.021	<5	0.004
Culebra Creek at San Luis	3.07	1.36	9.25	1.26	<0.026	0.01	<5	Not Detected
Rito Seco near Centennial School	1.78	0.94	7.06	0.674	<0.026	0.142	<5	0.001
Culebra Creek above Eastdale Canal near County Road 16	4.12	1.28	6.95	1.34	<0.026	0.01	<5	Not Detected

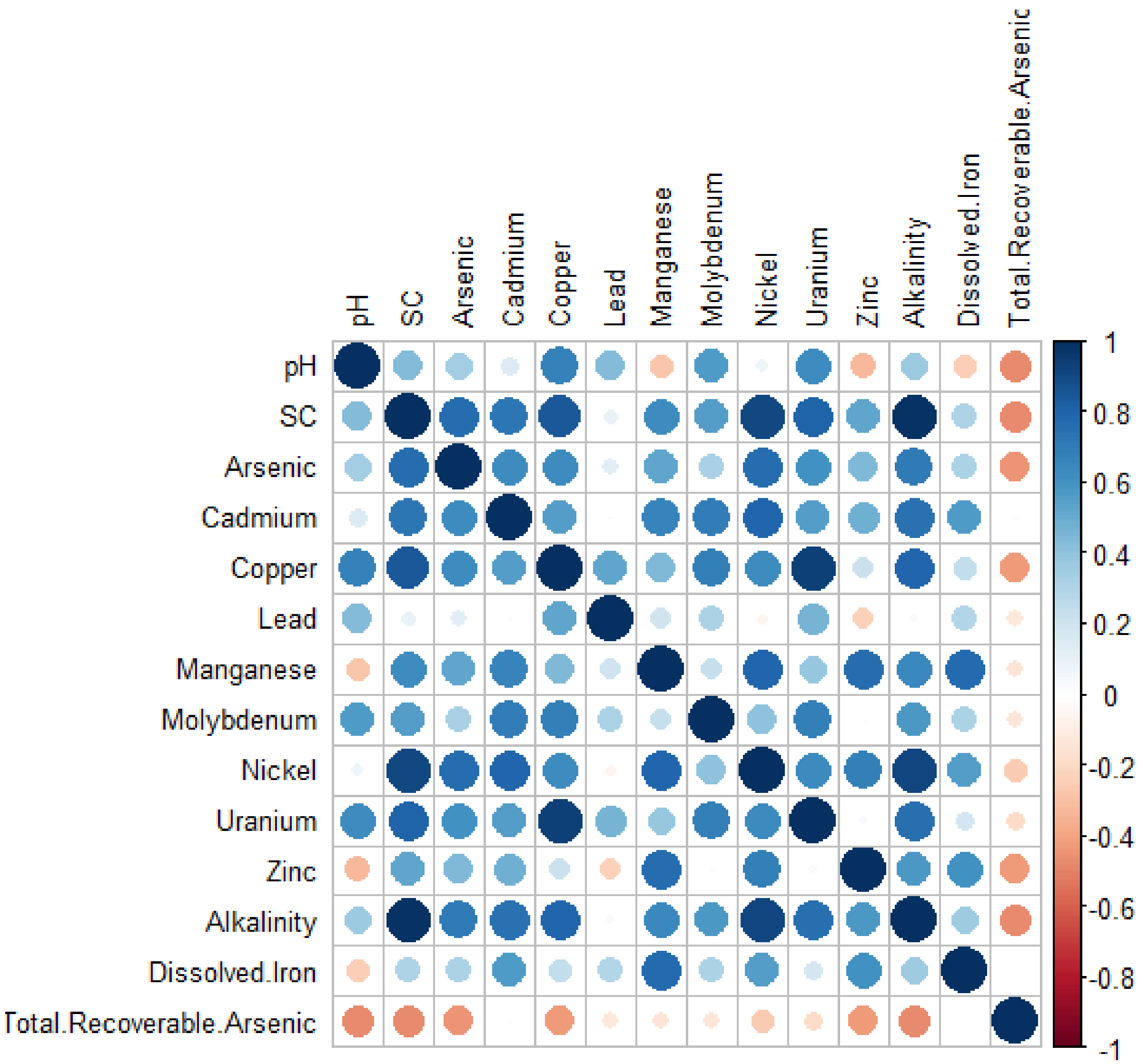


Figure 7-12 Spearman Correlation for measured regulated metals and field parameters.

Other analytical parameters were evaluated for trends. Characteristics that were highest in the smaller southern tributaries are aluminum, beryllium, thorium, tin, antimony, and potassium. Characteristics that were highest in the Culebra at San Luis or above Eastdale Canal were sodium, calcium, magnesium, strontium, and vanadium. Jaroso was highest for silica and fluoride.

Correlations were evaluated between the field parameters and the analytical results. Strong positive correlations with specific conductance were observed with calcium, magnesium, barium, and bicarbonate. Moderate positive correlations were noted with sodium, vanadium, and sulfur. Strong negative correlations with specific conductance were identified with aluminum, beryllium, and tin. Strong negative correlations with pH were silica and beryllium. Other positive correlations were identified between barium, calcium, lithium, and magnesium. Negative correlations were noted with aluminum and calcium, lithium, magnesium, bicarbonate, and sodium and sulfur and beryllium, tin, and fluoride.

Table 7-7 Nonregulated characteristics.

Location code	pH	SC	Lithium	Sodium	Calcium	Magnesium	Strontium	Silica	Aluminum	Beryllium
Units	**Std. units**	**µs/cm**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**µg/l**	**µg/l**
Willow Creek near Dos Hermanos Ranch Gate	7.7	38.4	<0.005	2.39	3.86	0.736	0.016	12.7	12.4	0.135
Cuates Creek at County Road 21	7.3	33.6	<0.005	2.31	3.64	0.685	0.015	12.2	14.6	0.108
Jaroso Creek at County Road 21	7.3	111	<0.005	3.77	15.9	2.87	0.086	20.8	3.7	0.085
Torcido Creek at Mouth of Canyon near Valley Road	7.6	72.7	<0.005	3.56	9.06	2.31	0.051	18	2.43	<0.05
San Francisco Creek at County Road 21	6.8	147	<0.005	3.85	20.1	4.93	0.109	15.7	1.88	<0.05
Vallejos Creek above Confluence with Culebra Creek	7.3	179	<0.005	5.08	24.2	5.49	0.134	17.7	<1.2	<0.05
Culebra Creek above Ventero Creek at County Road 22.4	7.8	144	<0.005	2.02	23.4	4.09	0.12	7.57	6.56	<0.05
Culebra Creek at San Luis	8.9	184	<0.005	7.38	25.4	5.45	<0.005	2.77	2.24	<0.05
Rito Seco near Centennial School	8.0	98.8	<0.005	3.98	13.2	3.30	0.108	11.7	2.76	<0.05
Culebra Creek above Eastdale Canal near County Road 16	9.0	204	<0.005	7.99	28.1	5.76	0.176	7.17	1.49	<0.05

Table 7-7 Nonregulated characteristics. -- continued

	Thorium	Tin	Barium	Cobalt	Potassium	Antimony	Vanadium	Bicarbonate	Fluoride	Sulfur
Units	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**mg/l**	**µg/l**	**µg/l**	**mg/l**	**mg/l**	**mg/l**
Willow Creek near Dos Hermanos Ranch Gate	0.267	0.103	3.0	<0.024	0.375	0.278	0.059	26.28	1.879	0.386
Cuates Creek at County Road 21	0.09	0.049	2.82	<0.024	3.87	0.108	<0.05	23.95	1.496	0.665
Jaroso Creek at County Road 21	0.064	0.028	30.9	0.22	1.6	0.073	0.983	77.13	1.895	0.824
Torcido Creek at Mouth of Canyon near Valley Road	<0.034	<0.027	20.1	0.045	0.664	0.021	0.474	45.56	1.304	0.904
San Francisco Creek at County Road 21	<0.034	Not detected	44.1	0.923	1.55	<0.013	0.674	94.86	0.705	2.62
Vallejos Creek above Confluence with Culebra Creek	<0.034	Not detected	32.1	0.153	3.78	Not detected	0.59	123.63	1.053	1.5
Culebra Creek above Ventero Creek at County Road 22.4	<0.034	Not detected	24.1	0.072	0.862	Not detected	0.592	86.3	0.502	3.80
Culebra Creek at San Luis	<0.034	Not detected	33.5	0.123	1.57	<0.013	2.74	122.54	1.443	3.34
Rito Seco near Centennial School	0.174	0.049	18.9	0.068	0.763	0.235	1.09	67.8	0.869	1.96
Culebra Creek above Eastdale Canal near County Road 16	0.074	0.013	38.1	0.133	1.57	0.139	2.36	117.41	0.845	3.28

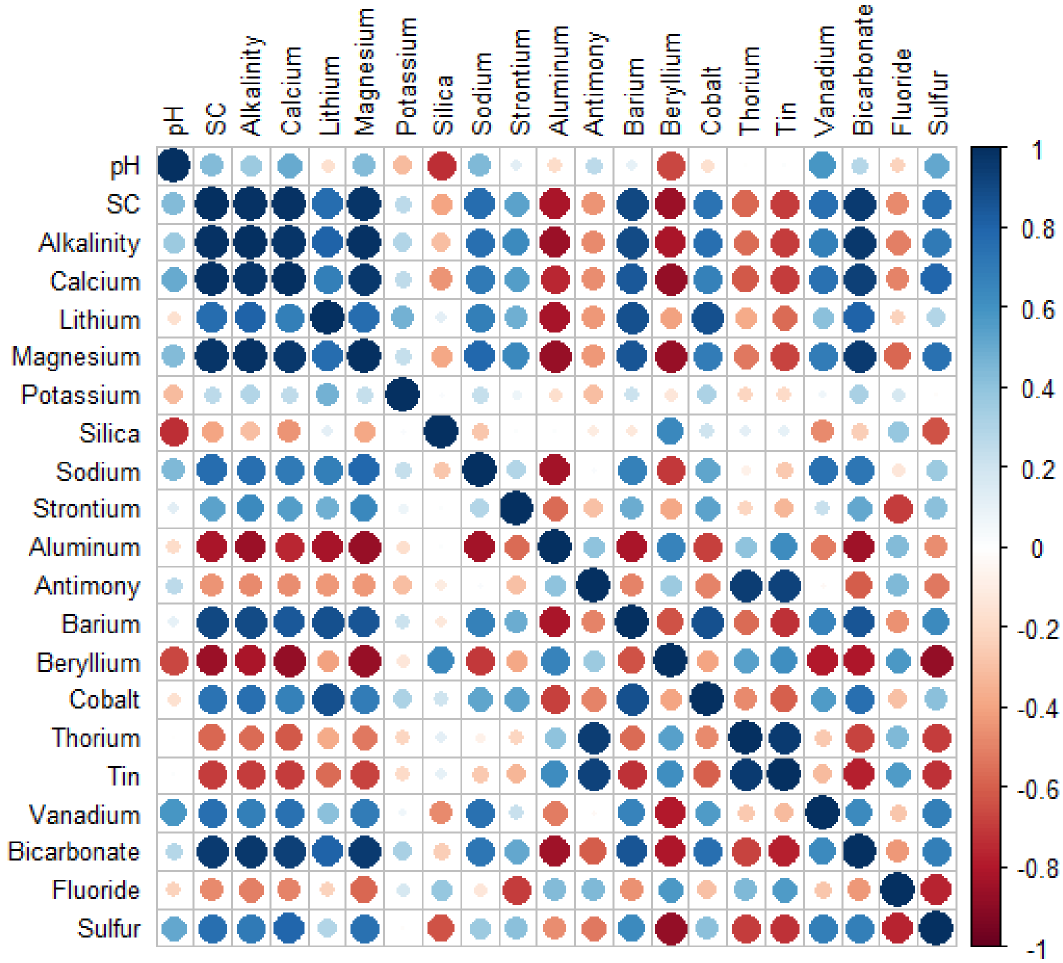


Figure 7-13 Correlation matrix for non-regulated characteristics.

The analysis of location of maximum occurrence revealed the correlation between given parameters such as manganese and nickel being highest in the San Francisco Creek samples. This relationship is likely related to the geologic formations within the basin and can be used to target watershed projects to address future water quality concerns.

7.3.1.1 Quality Assurance & Quality Control

One replicate and one blank sample were collected and analyzed along with the grab samples. The replicate sample was collected at Torcido Creek and the Blank sample was bottle at the Culebra at San Luis gage. The blank sample reported results greater than the reporting limit for zinc, fluoride, sulfate, and silica see Figure 7-14.

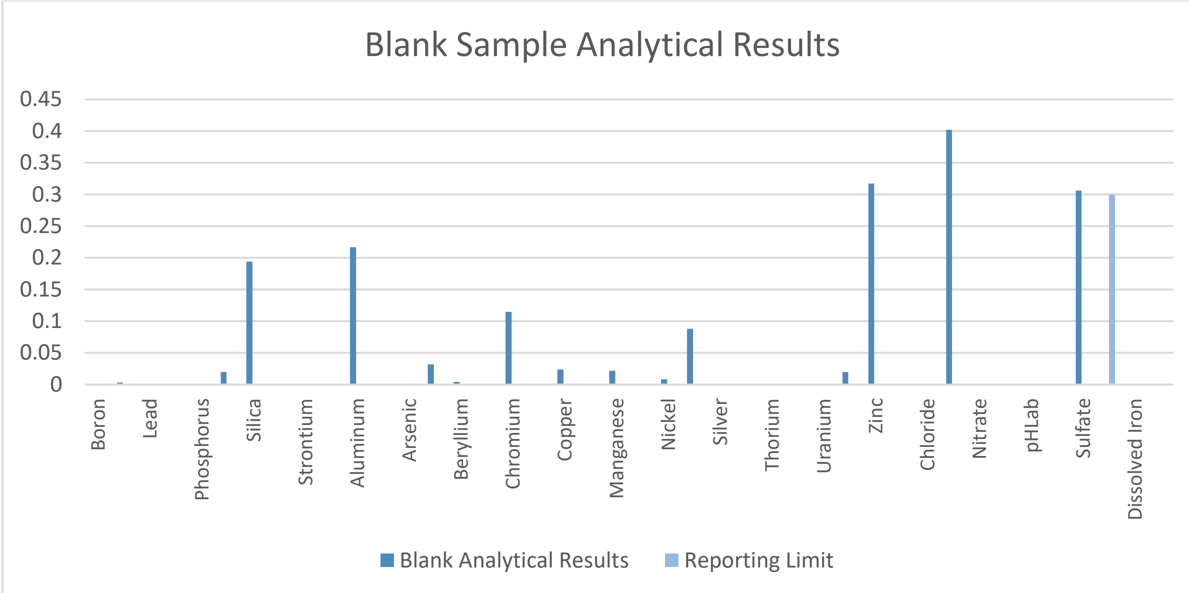


Figure 7-14 Blank sample analytical results compared with analytical reporting limits. Blank concentration exceeded reporting limit for Silica, Zinc, Fluoride, and Sulfate.

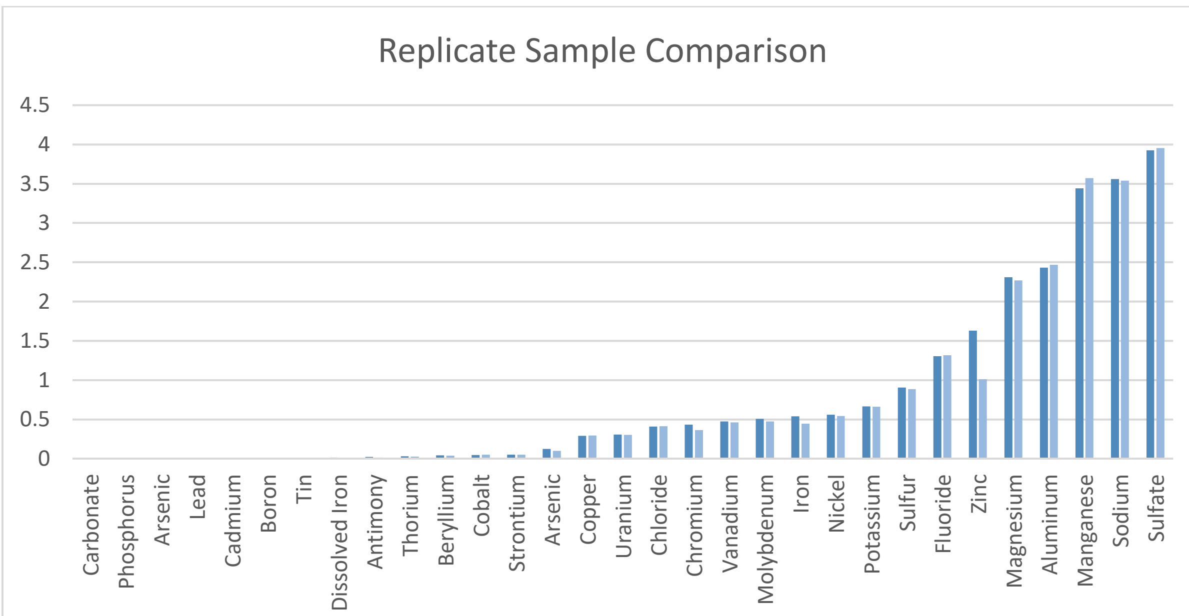


Figure 7-15 Replicate sample comparison, for results less than 5 reporting units.

The replicate sample was analyzed for difference from the sample value. Uncensored measured results, reporting limit, and difference for the sample and replicate are shown in Table 7-8. Differences greater than 10 percent for values greater than the reporting limit were dissolved iron, antimony, thorium, and zinc.

Table 7-8 Uncensored replicate sample results and comparison of reported values.

Replicate Sample Analysis – Torcido Creek June 16, 2021					
Analyte	**Reporting Units**	**Uncensored Sample Result**	**Uncensored Replicate Result**	**Reporting Limit**	**Relative Percent Difference**
Carbonate	mg/L	0	0	5	<5
Phosphorus	mg/L	Not detected	0.002	0.005	<0.005
Arsenic	mg/L	Not Detected	0.003	0.01	<0.01
Lead	mg/L	0.002	0.003	0.005	<0.005
Cadmium	ug/L	0.002	0.005	0.026	<0.026
Boron	mg/L	0.004	0.004	0.01	<0.01
Tin	ug/L	0.008	Not detected	0.027	<0.027
Dissolved Iron	mg/L	0.012	0.009	0.005	14%
Antimony	ug/L	0.021	0.015	0.013	17%
Thorium	ug/L	0.031	0.025	0.034	11%
Beryllium	ug/L	0.044	0.04	0.05	<0.05
Cobalt	ug/L	0.045	0.052	0.024	7%
Strontium	mg/L	0.051	0.051	0.005	0%
Arsenic	ug/L	0.122	0.099	0.032	10%
Copper	ug/L	0.291	0.293	0.5	<0.5
Uranium	ug/L	0.307	0.302	0.034	1%
Chloride	mg/L	0.409	0.414	0.02	1%
Chromium	ug/L	0.433	0.362	0.57	<0.57
Vanadium	ug/L	0.474	0.461	0.05	1%
Molybdenum	ug/L	0.506	0.472	0.04	3%
Iron	mg/L	0.538	0.446	5	<5
Nickel	ug/L	0.559	0.544	0.022	1%
Potassium	mg/L	0.664	0.66	0.1	0%
Sulfur	mg/L	0.904	0.883	0.01	1%
Fluoride	mg/L	1.304	1.318	0.02	1%
Zinc	ug/L	1.63	1.01	0.12	23%
Magnesium	mg/L	2.31	2.27	0.1	1%
Aluminum	ug/L	2.43	2.47	1.2	1%
Manganese	ug/L	3.44	3.57	0.032	2%
Sodium	mg/L	3.56	3.54	0.5	0%
Sulfate	mg/L	3.924	3.954	0.04	0%
Lab pH	Std. units	7.528	7.251	--	2%
Calcium	mg/L	9.06	8.96	0.1	1%
Silica	mg/L	18	17.9	0.05	0%
Barium	ug/L	20.1	19.9	0.022	1%
Alkalinity	mg/L	37.35	43.85	5	8%
Bicarbonate	mg/L	45.56	53.49	5	8%
SPCL	µS/cm	78.65	79.25	5	0%
Lead	ug/L	Not detected	Not detected	0.016	<0.016

Replicate Sample Analysis – Torcido Creek June 16, 2021					
Analyte	**Reporting Units**	**Uncensored Sample Result**	**Uncensored Replicate Result**	**Reporting Limit**	**Relative Percent Difference**
Selenium	ug/L	Not detected	Not detected	0.37	<0.37
Silver	ug/L	Not detected	Not detected	0.08	<0.08
Thallium	ug/L	Not detected	Not detected	0.03	<0.03
Bromide	mg/L	Not Detected	Not Detected	0.04	<0.04
Nitrate	mg/L	Not Detected	Not Detected	0.008	<0.008
Nitrite	mg/L	Not Detected	Not Detected	0.01	<0.01
Phosphate	mg/L	Not Detected	Not Detected	0.04	<0.04
Selenium	mg/L	Not Detected	Not Detected	0.005	<0.005

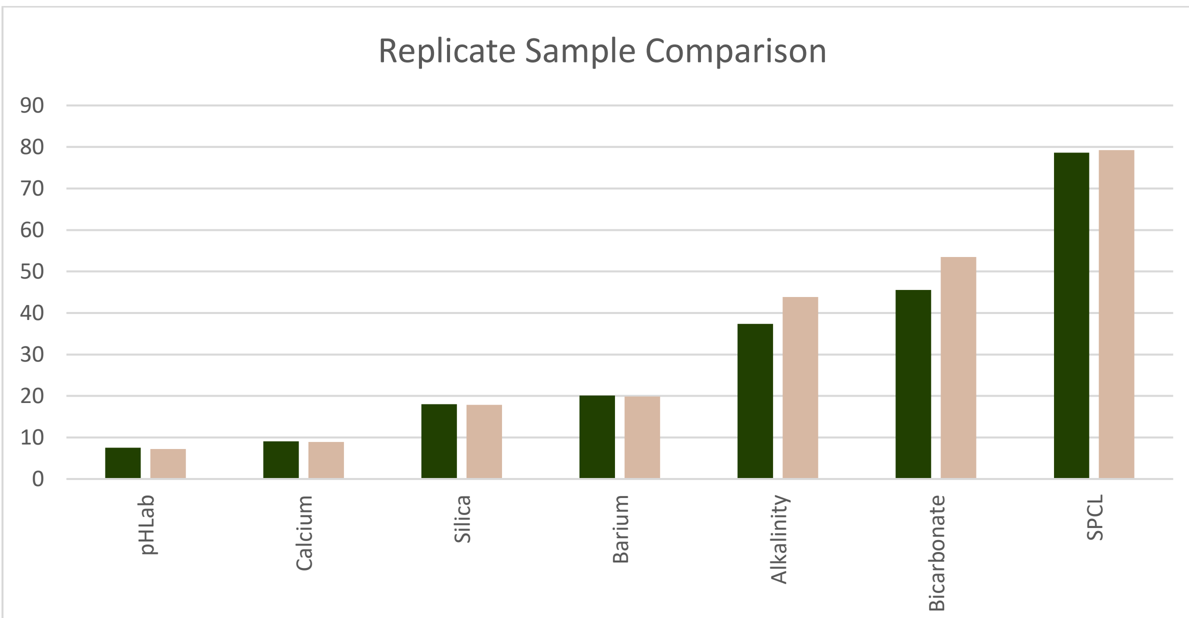


Figure 7-16 Replicate sample comparison for results values greater than 5 reporting units.

7.3.2 Field Parameter Sampling

Specific conductance and pH were measured opportunistically with other field measurements for aquatic habitat, infrastructure, and geomorphology. These measurements are shown in Figure 7-17 and Figure 7-18. The purpose of this sampling was to evaluate if changes were occurring in the watershed with changes in land use. Baseline conductivity and pH is determined by baseline geology, Nelson and others (2011)correlated changes in both sloped wetland and stream water chemistry to changes in overlying geology. The highest conductivity was measured in a sloped wetland at the top of El Valle Creek (Figure 7-20), similarly an elevated specific conductance (138 us/cm vs 40 us/cm) was observed in a wetland adjacent to Jaroso Creek (Figure 7-19).

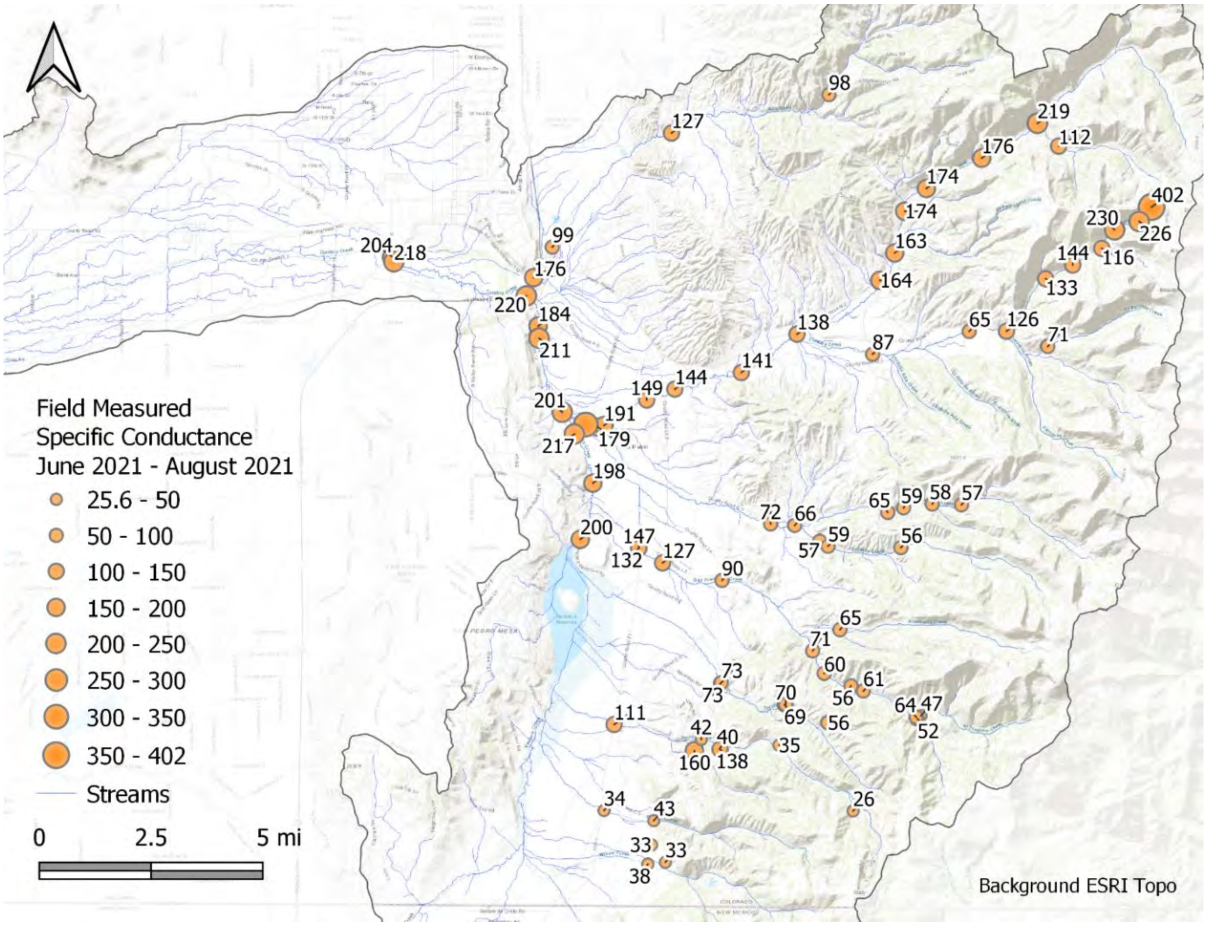


Figure 7-17 Specific conductance measurements from June 2001 to August 2021.

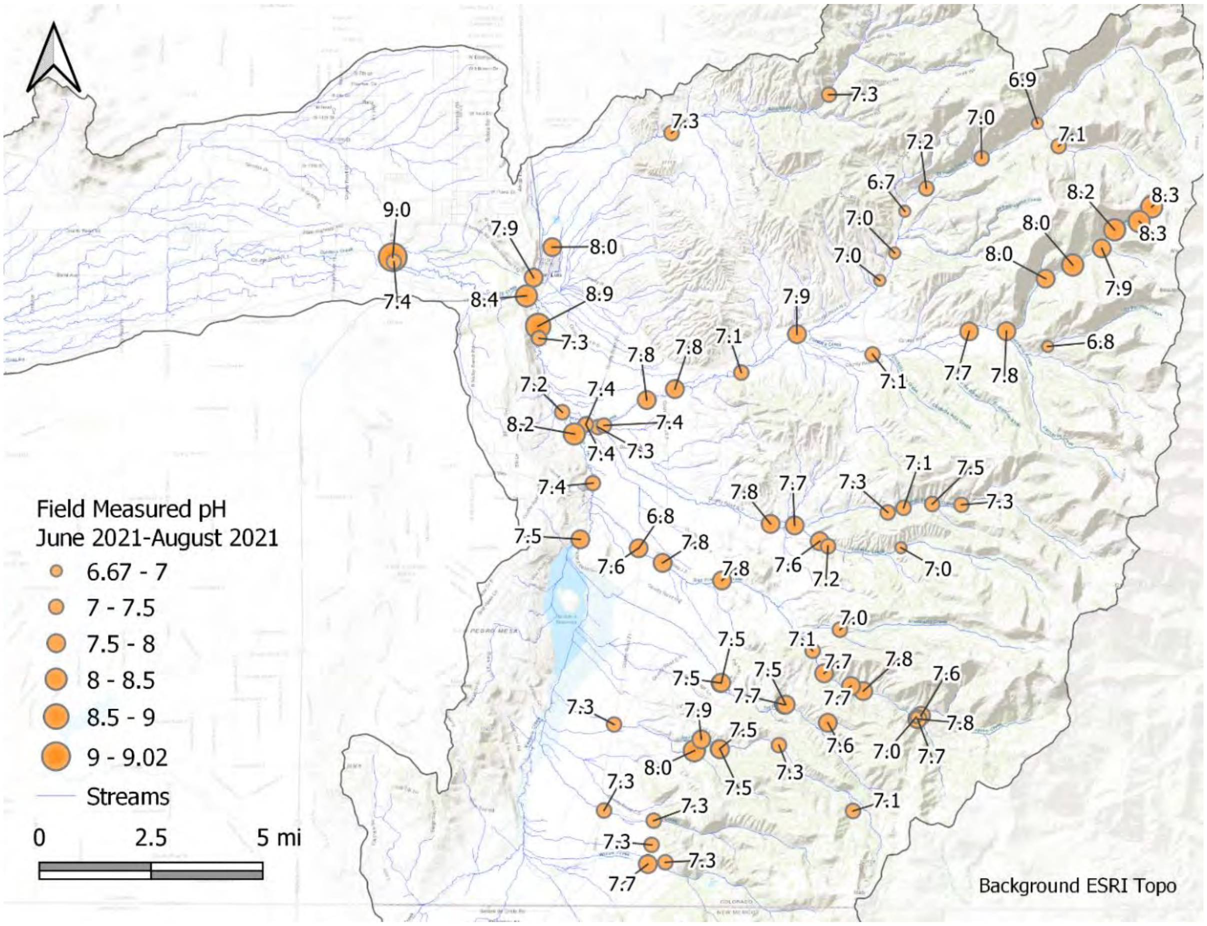


Figure 7-18 pH measurements from June 2021 to August 2021.

Figure 7-19 Sloped wetland adjacent to Jaroso Creek. Specific Conductance 138 us/cm in wetland and 40 us/cm in stream.

Figure 7-20 Sloped wetland on El Valle Creek. Specific Conductance 402 us/cm. Stream below 226 us/cm.

The pH along Culebra Creek from the confluence with Ventero Creek down to Eastdale Canal was further investigated after the initial water quality sampling due to the observed elevated pH on the Culebra above Eastdale Canal. The pH values for this region are categorized by sampling month and shown in Figure 7-21. For reference the flows from Culebra Creek at San Luis and Ventero Creek below Sanchez for this period are shown in

Figure 7-22 and Figure 7-23. During the water quality sampling effort June 16, 2021, the release from Sanchez reservoir was 47 cfs and the gage measured 74 cfs, so approximately 2/3 of the water at the gage was being released from Sanchez Reservoir. The pH was not measured out of Sanchez reservoir during the June sampling, but the pH was measured on Culebra above Ventero Creek, 7.3 vs 8.9 at the gage.

During the aquatic habitat sampling the pH was measured from Ventero Creek down through Culebra and was very consistent, 7.2 – 7.4. This sampling occurred July 14, 15, and 20. The flows measured by Culebra Creek at San Luis were 96, 101, and 92 cfs while the flows measured at the outlet of Sanchez were 79, 79, and 77 cfs. Roughly 80% of the water at the gage was coming from Sanchez Reservoir.

As a follow-up pH was measured in this region again August 18th. The pH on Culebra Creek above Ventero was 7.3 while the pH on Ventero above Culebra Creek was 8.2. The pH below Sanchez Reservoir was 7.5. The pH at the historic bridge was 8.4. During this event pH was not measured in the Culebra above Eastdale Canal. The release from Sanchez Reservoir was 50 cfs and the measured flow at the Culebra Creek at San Luis Gage was 71 cfs. Roughly 70% of the water at the gage was coming from Sanchez Reservoir.

It is apparent that the water chemistry is fluctuating through this reach of Culebra Creek and Ventero Creek. Initial observations from the August sampling would suggest that the pH is being increased within this zone and not by the flows from Sanchez Reservoir.

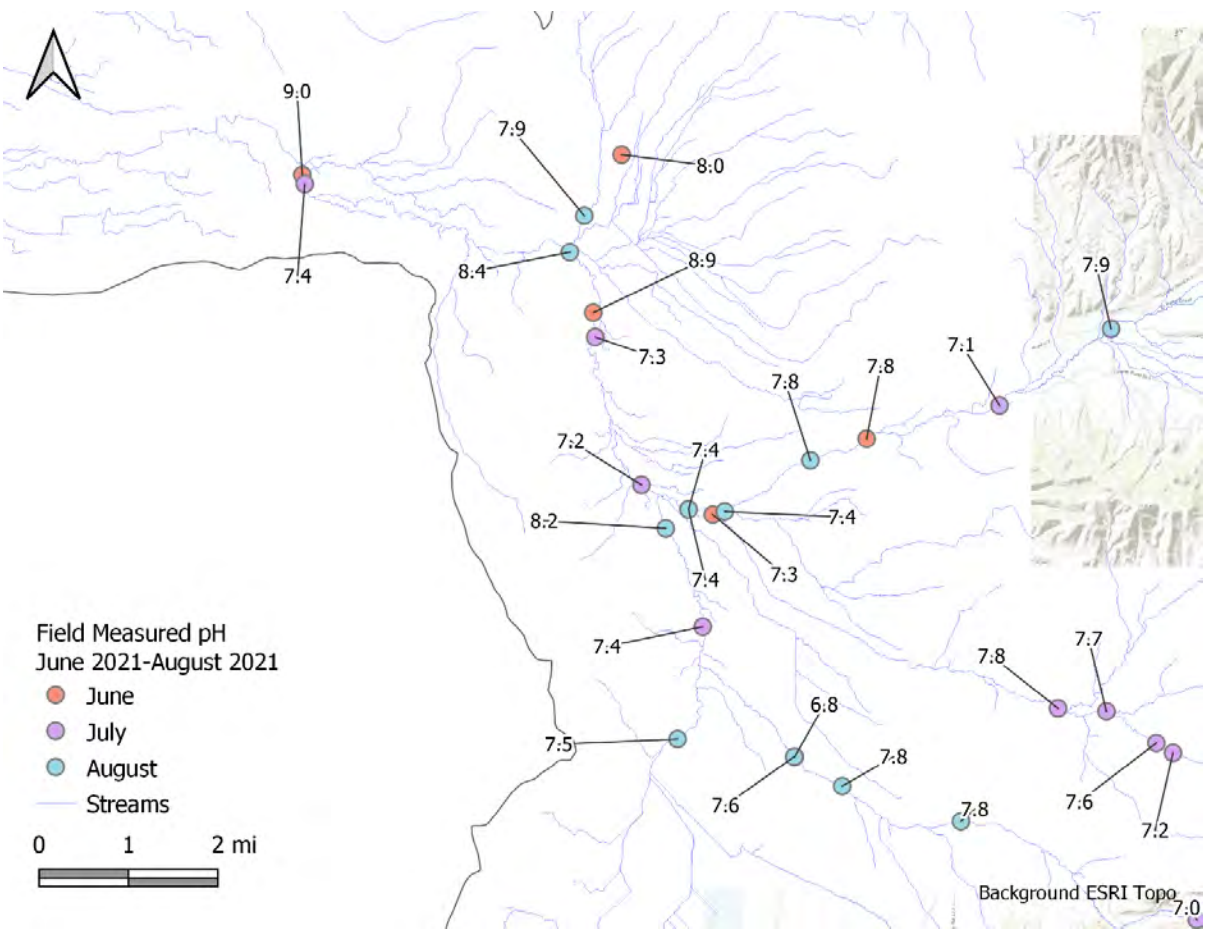


Figure 7-21 pH measurements below Sanchez Reservoir classified by sampling month.

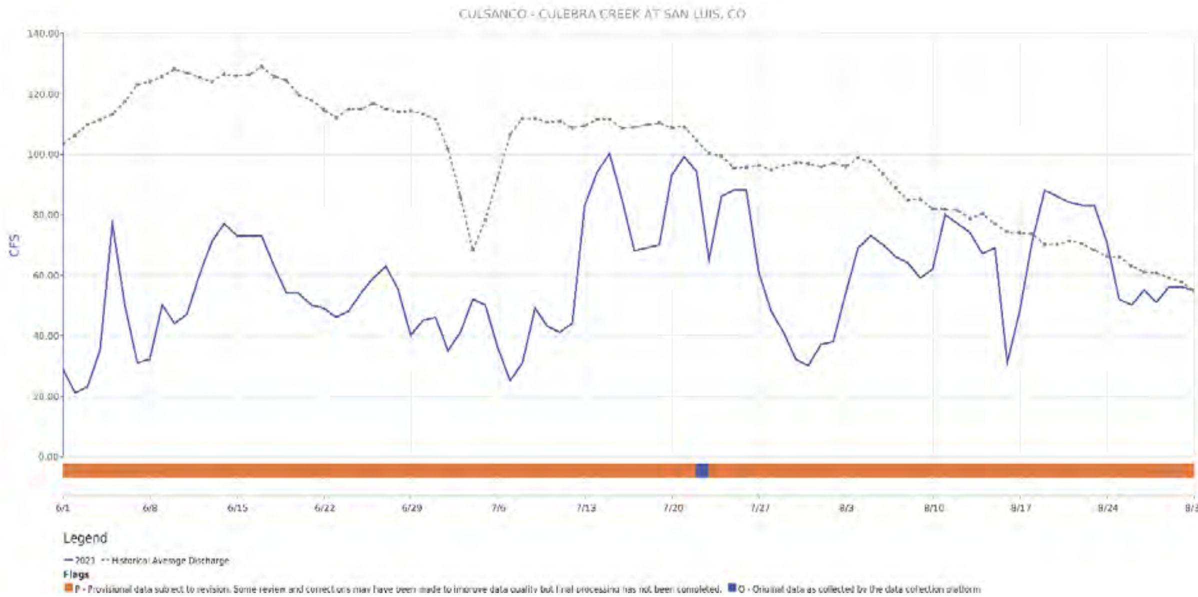


Figure 7-22 Streamflow measured at Culebra Creek at Sanchez from June 1, 2021, to August 31, 2021, accessed October 8, 2021.

Figure 7-23 Streamflow measured at Ventero Creek below Sanchez Reservoir from June 1, 2021, to August 31, 2021, accessed October 8, 2021.

7.4 Existing Data Results and Discussion

The water quality characteristics are grouped by type either includes the physical characteristic and chemical, or microbiological. characteristic. Physical characteristic includes temperature, turbidity, solids while chemical characteristics includes inorganic materials, metals, etc. Chemical characteristics are grouped based on chemical properties (speciation) that are beneficial for evaluation. The data available for the Upper Culebra Basin can be described as follows: nutrients, metals, or other. A brief description of each of the characteristics that were measured in the basin are described in this section along with existing data. Existing data is collected and stored based on the parameter names and units that were used in the analytical methods. Sometimes these naming conventions change over time resulting in separate characteristics being created in the database that refer to the same value. Where possible these characteristics were combined under a single title, the mapping for the characteristics that were adjusted are listed in Appendix 8A. Some samples were reported under two separate programs, these samples may inadvertently increase the number of samples, but the occurrence of this issue is not likely to change conclusions. Where available, the typical method detection limits are provided for reference, actual laboratory detection limits may vary based on instrument settings and processes. Where non-detects were present in the dataset average and standard deviation are not shown.

The first samples within the basin were collected by the U.S. Geological Survey in the 1967 water year. Periodic observations of water temperature were made at the gage until 1970. From 1978-1982 water temperature was collected at Culebra near San Luis. The first water quality sample on Rito Seco was collected May 1979, samples were collected two additional times at this site on November 15, 1979, and May 15, 1980. The next water quality sample wasn't collected until April 1992 – this sampling effort included Culebra near San Luis and Rito Seco above and below Battle Mountain Mine. Sampling frequency on Rito Seco decreased at the end of 2002 to semi-annually in 2003 and then annually in 2004 and 2005. while sampling of Culebra near San Luis continued until June 2006. Samples were collected on Culebra near San Luis and Rito Seco below Battle Mountain Mine September 2010, February 2011, and June 2011. The sampling effort for the Sanchez Reservoir TMDL occurred in June and August 1999. Much of the data (190 site-dates) of the 596 site-dates in the existing dataset were collected as part of the Colorado River Watch program.

Sanchez reservoir was first sampled in June, August, and September 1992 and was sampled again August and September 2005, August 2006, July and August 2010, July 2013, and July 2015. All samples for Sanchez Reservoir have occurred during the summer.

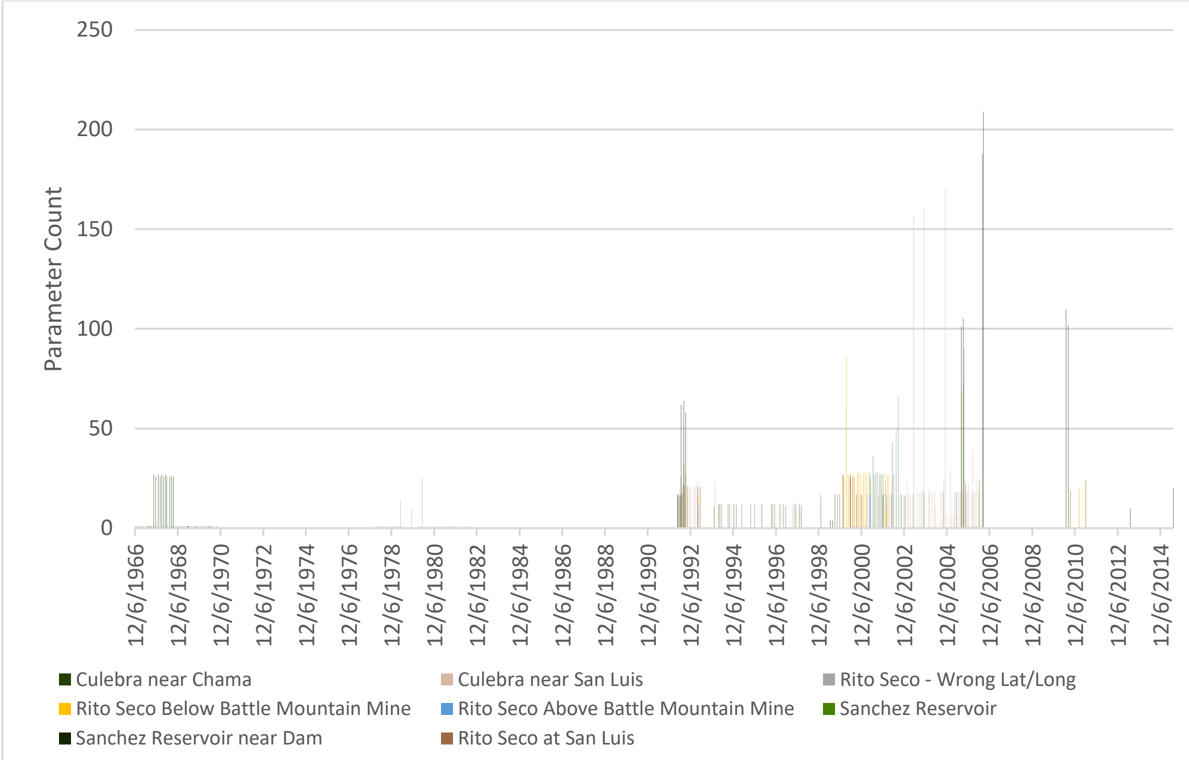


Figure 7-24 Existing water quality samples from Water Quality Portal by group.

Existing data was evaluated for trends and availability. The complete listing of existing data is provided in Appendix A. Critical characteristics were determined from the Regulation 93 listing. These parameters include dissolved copper, E. Coli, Total Mercury, and Arsenic. Graphs of the existing data for each of these parameters starting with the first sample in the 1990's to the last sample are shown in this section.

Generally, most of the data parameters include a considerable proportion of samples that were below the analytical detection limit. This high frequency of non-detect data may skew the interpretation of the data. From the samples that have detectable concentrations it is possible to determine what the maximum measured concentration additional measurements would be needed to help identify if these higher values are occurring seasonally or are correlated with events such as precipitation or anthropogenic.

7.4.1 Physical Characteristics

Physical characteristics that have been measured within the basin include water temperature, pH, specific conductance, dissolved oxygen, total alkalinity, hardness, and solids content.

7.4.1.1 Water Temperature

Water temperature in a stream is affected by many characteristics including catchment slope, aspect, and elevation, catchment precipitation patterns, land cover and stream cover, and streamflow modification from diversion. As water temperature increases chemical and biological reaction rates increase. Water temperature is a critical determining factor for survival of the aquatic life present in the stream. The state of Colorado determines temperature standards based on the aquatic life expected to be present. Within the Upper Culebra basin include Cold Stream Tier 1, Cold Stream Tier 2, and Warm Stream Tier 1

(Colorado Department of Public Health and Environment, 2020). The water quality standards based on fish species expected are listed in Table 7-9.

Table 7-9 Colorado Department of Public Health and Environment Aquatic Life Standards Categories. MWAT – Maximum weekly average temperature and DM is daily maximum temperature. (Regulation No. 36 - Classifications and Numeric Standards for Rio Grande Basin)

Temperature Tier	Fish Species Expected to be Present	Applicable Months	MWAT, in degrees Celsius	DM, in degrees Celsius
Cold Stream Tier 1 (CS-I)	Brook trout, cutthroat trout	June-Sept.	17.0	21.7
		Oct. - May	9.0	13.0
Cold Stream Tier 2 (CS-II)	Other cold-water species	April-Oct.	18.3	24.3
		Nov-March	9.0	13.0
Warm Stream Tier 1 (WS-I)	Common shiner, Johnny darter, orange throat darter, stonecat	March-Nov.	24.2	29.0
		Dec.-Feb.	12.1	24.6

Temperatures for good to excellent Rio Grande Cutthroat Trout habitat are between 8 and 16 °C during spawning and incubation periods whereas fair to poor habitat had summer temperatures consistently above 16 °C or below 8 °C (Alves J. E., Patten, Brauch, & Jones, 2008). Optimal temperature from temperature preference test suggests the optimal temperature range for adult cutthroat trout to be between 12-15 °C (Hickman & Raleaigh, Habitat suitability index models: Cutthroat trout., 1982). Roberts et al (January 30, 2015) provided some guidance for temperature preferences for Eco-physiological states for the warmest 30-days of daily mean temperatures:

Table 7-10 Temperature impacts to fisheries (Roberts & Fausch, January 30, 2015) .

Parameter	Definition	State
Mean summer stream temperatures (M30AT)	The warmest 30-day mean of the average daily water temperature, used to evaluate recruitment and growth	No recruitment: < 8.0 deg C
		Low recruitment: 8.0-9.0 deg C
		Optimal growth and recruitment: 9.1-18.0 deg C
		Declining growth: 18.1-19.9 deg C
		Low or no growth: >= 20.0 deg C

Water temperature is typically measured when water quality samples are collected or when other field parameters are measured. Water temperatures that exceeded the daily maximum temperature for Cold Stream Tier I (21.7 °C) and Cold Stream Tier II (24.3 °C) were noted within the historic data (Table 7-11).

Table 7-11 Water temperature measurements from existing water quality sample database. [min – minimum, max – maximum, avg – average, std. dev. Standard deviation]

Water Temperature in °C

	Min	Max	Avg	Std. Dev.	Count	First Date	Last Date
All Data	0	26.5	13.3	6.3	473	12/6/1966	7/13/2016
Rito Seco Below Battle Mountain Mine	0	21.4	9.7	7.6	33	1/24/2000	6/8/2011
Rito Seco Above Battle Mountain Mine	0.3	12.2	7.5	3.9	14	4/17/2001	9/27/2005
Rito Seco - Wrong Lat/Long	0.6	6.1	4.0	2.4	4	5/8/1979	5/15/1980
Rito Seco at San Luis	0.1	26.5	16.2	7.2	16	6/29/1992	6/8/2011
Culebra near San Luis	0	23.3	11.4	6.0	114	2/14/1978	6/8/2011
Culebra near Chama	0	17.0	6.0	5.0	67	12/6/1966	9/29/1970
Sanchez Reservoir near Dam	12.8	22.7	17.8	1.8	162	6/25/1992	7/14/2015
Sanchez Reservoir	14.5	20.5	16.9	1.3	47	6/25/1992	7/13/2016

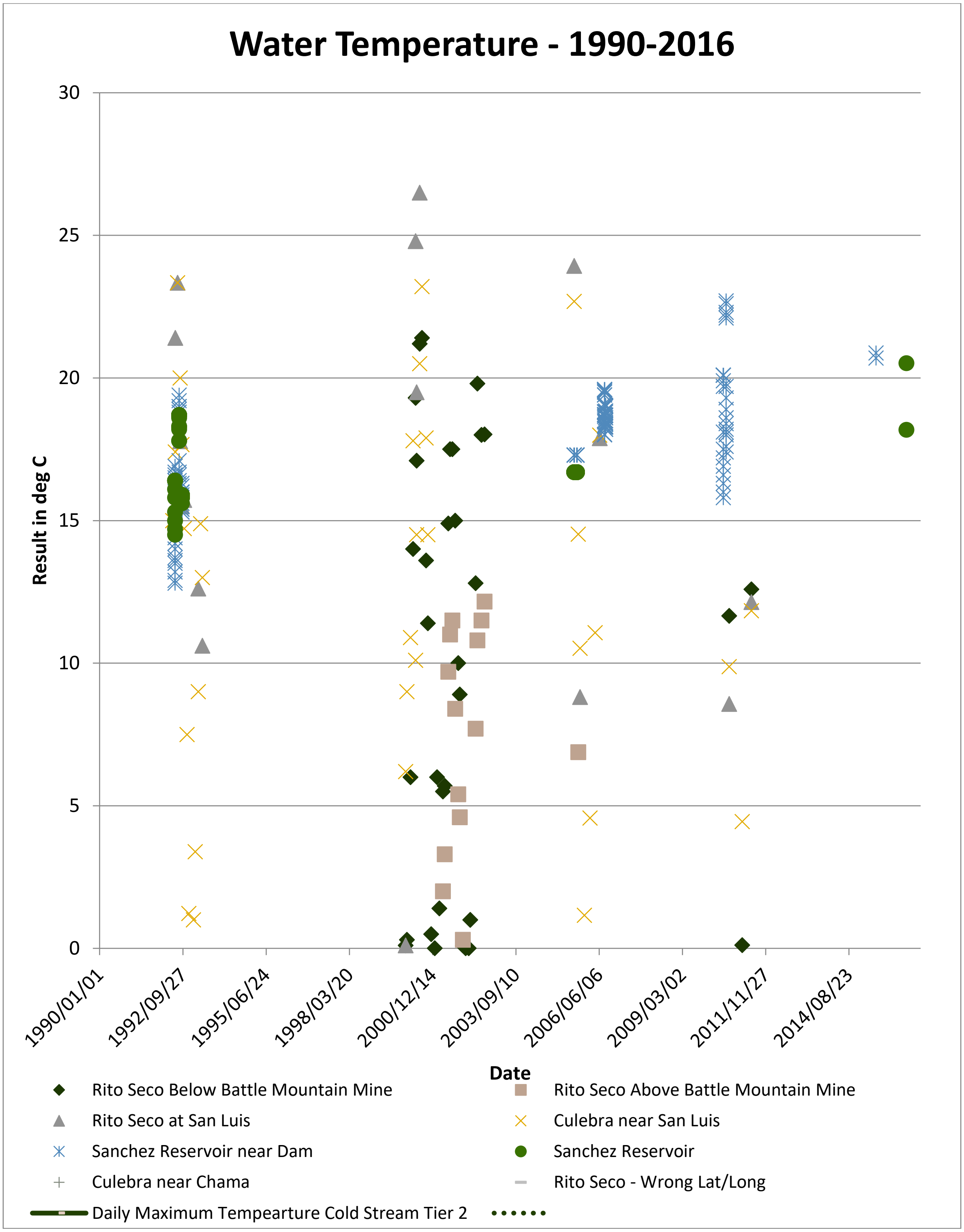


Figure 7-25 Water temperature measurements included with existing water quality sample data.

NorWeST Data

Time-series temperature data was downloaded from U.S. Forest Service Rocky Mountain Research Station NorWeST project website (https://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html). These temperature loggers were located at lower elevation portions of four creeks within the watershed. These data are compared to criteria available for Rio Grande and other similar Cutthroat Trout to determine the thermal suitability of the habitat. All sites except Vallejos Creek were below the maximum optimal temperature of 16°C and it is likely that there is a decline in growth rate among native fishes.

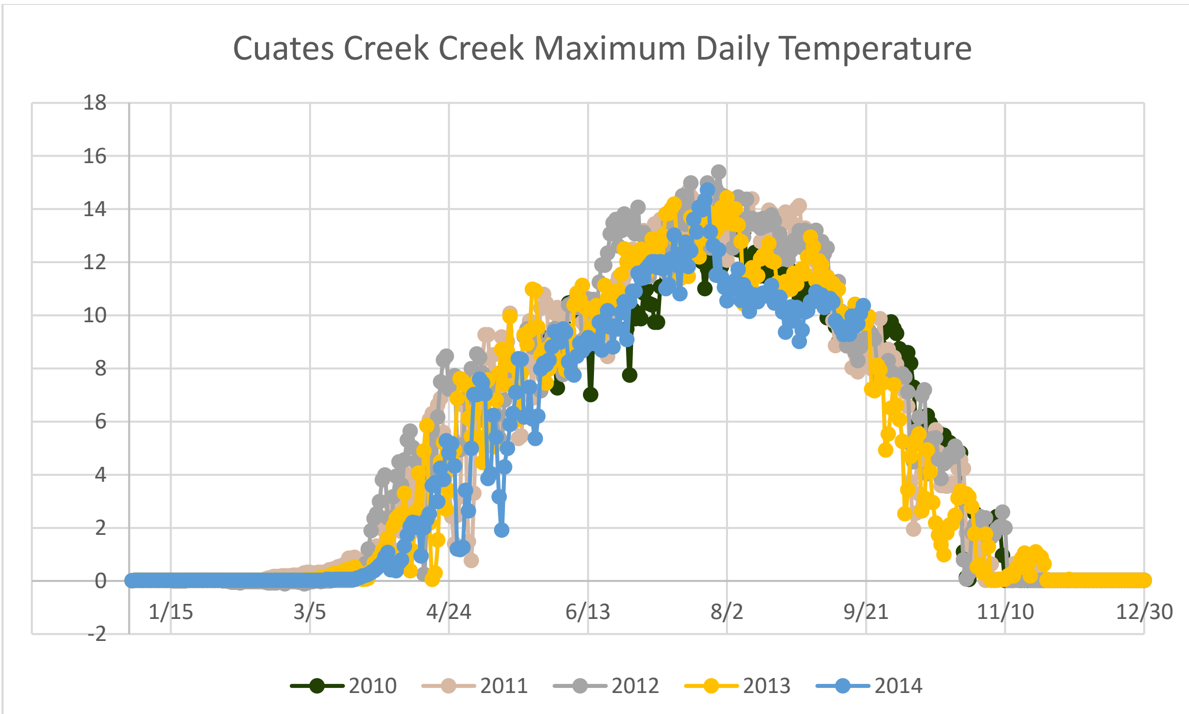


Figure 7-26 NorWeST maximum daily temperature data from Cuates Creek.

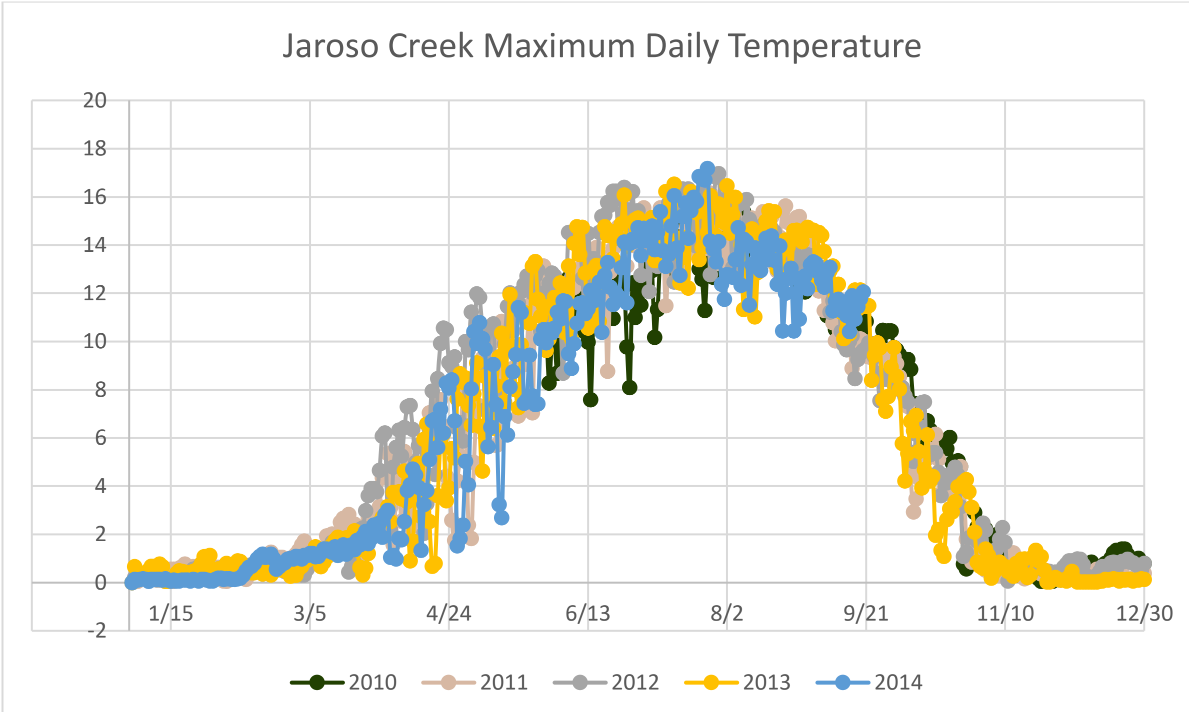


Figure 7-27 NorWeST maximum daily temperature data from Jaroso Creek.

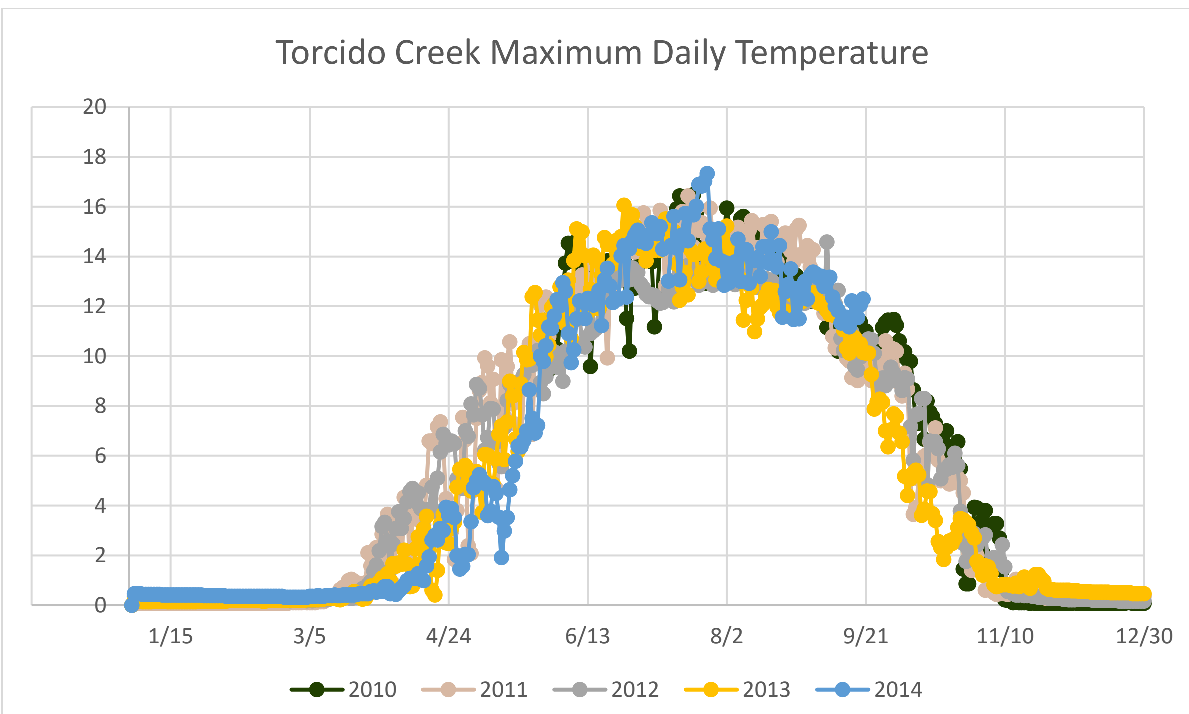


Figure 7-28 NorWeST maximum daily temperature data from Torcido Creek.

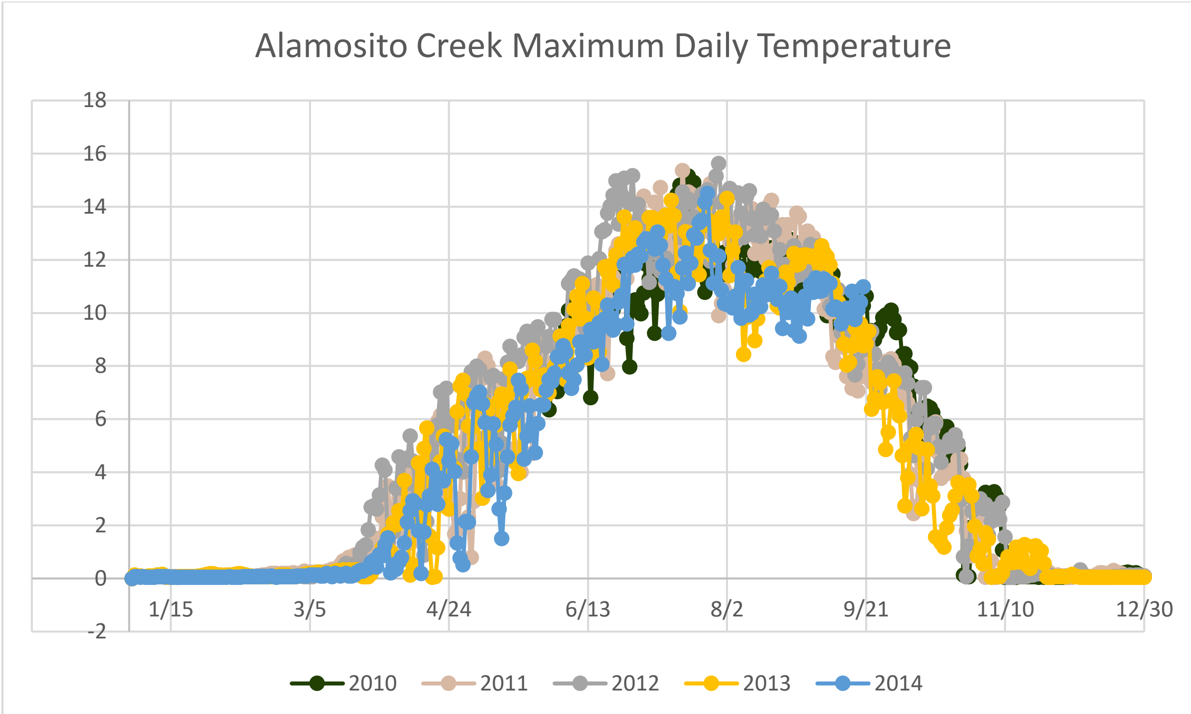


Figure 7-29 NorWeST maximum daily temperature data from Alamosito Creek.

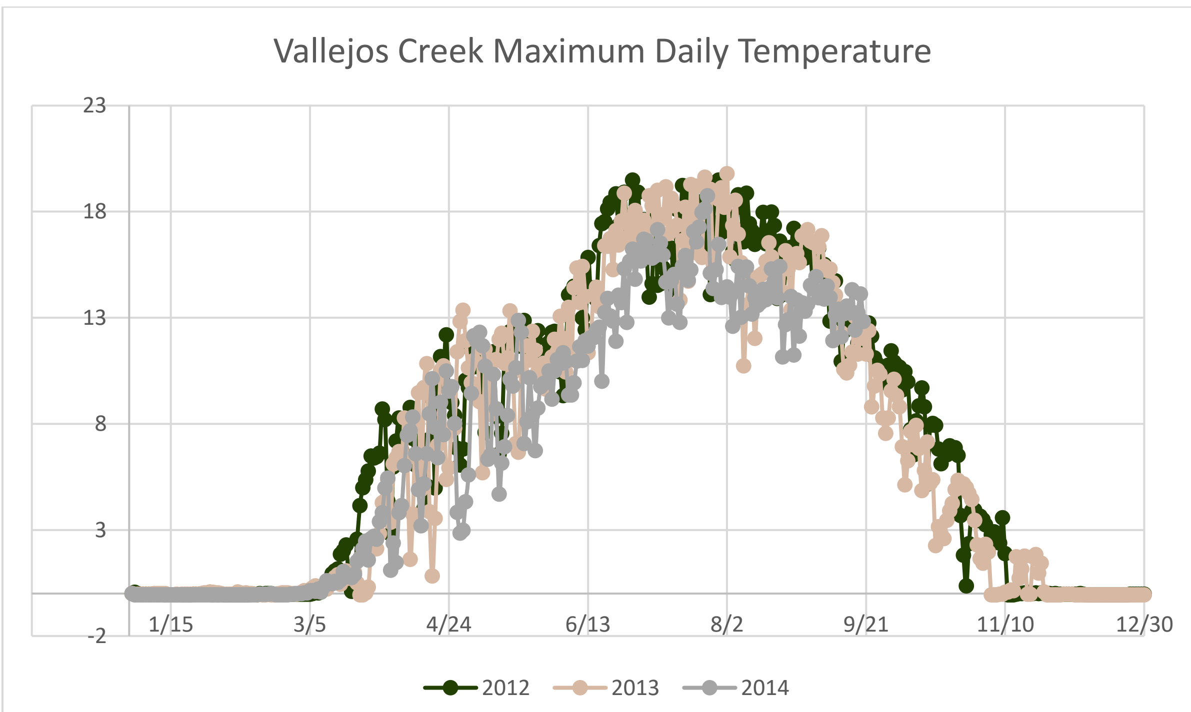


Figure 7-30NorWeST maximum daily temperature data from Vallejos Creek.

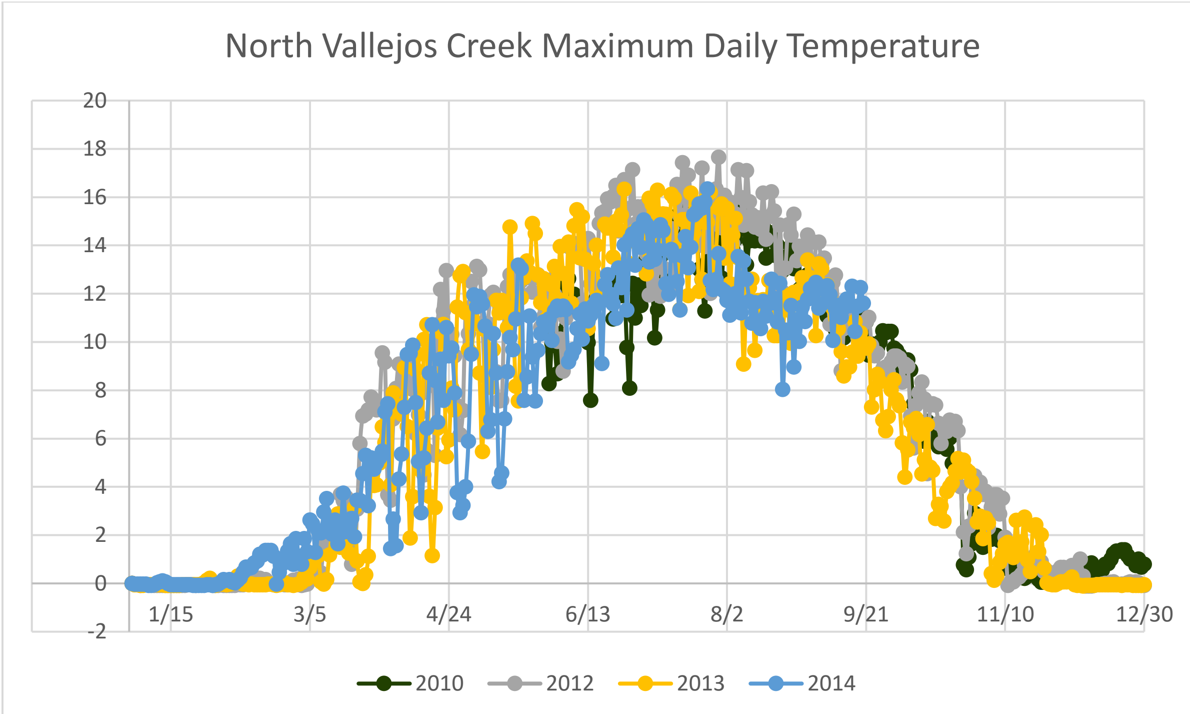


Figure 7-31 NorWeST maximum daily temperature data from North Vallejos Creek.

7.4.1.2 pH

pH measures how acidic or basic a water is. It is an important measurement concerning water quality. In general, water with a pH < 7 is considered acidic and pH > 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5. The water quality standard for the reaches in this basin is 6.5-9.0.

pH was measured with the following methods: 150.1, METER_1, HISTORIC, and NA. This characteristic does not have non-detects. Samples are available for Culebra near Chama from water year 1968 and for the Rito Seco Site with unknown Lat/Long from 1979 and 1980. The observed pH shows a range from 6.8 to 9.5. The high intensity TMDL sampling indicates a variation in reservoir pH with likely a variation with season and/or storage volume.

Several observations of pH greater than 9.0 were observed within the data including observations at Culebra near San Luis and measurements for Sanchez Reservoir (Table 7-12 and Figure 7-32).

Table 7-12 pH data from existing water quality sample database. [min – minimum, max – maximum, avg – average, std. dev. Standard deviation].

pH Total in standard units

	Min	Max	Avg	Std. Dev.	Count	First Date	Last Date
All Data	6.8	9.5	8.0	0.5	422	10/18/1967	7/13/2016
Rito Seco Below Battle Mountain Mine	7.1	8.9	7.9	0.3	77	4/24/1992	6/8/2011
Rito Seco Above Battle Mountain Mine	7.0	8.3	7.9	0.3	60	4/24/1992	9/27/2005
Rito Seco at San Luis	6.8	8.5	8.1	0.4	15	6/29/1992	6/8/2011
Rito Seco - Wrong Lat/Long	7.4	8.1	7.8	0.3	4	5/8/1979	5/15/1980
Culebra near San Luis	7.4	9.3	8.4	0.4	122	4/22/1992	6/8/2011
Culebra near Chama	7.3	7.5	7.4	0.1	11	10/18/1967	9/16/1968
Sanchez Reservoir near Dam	7.3	9.5	7.9	0.5	115	6/25/1992	7/14/2015
Sanchez Reservoir	7.6	9.2	7.9	0.5	18	6/25/1992	7/13/2016

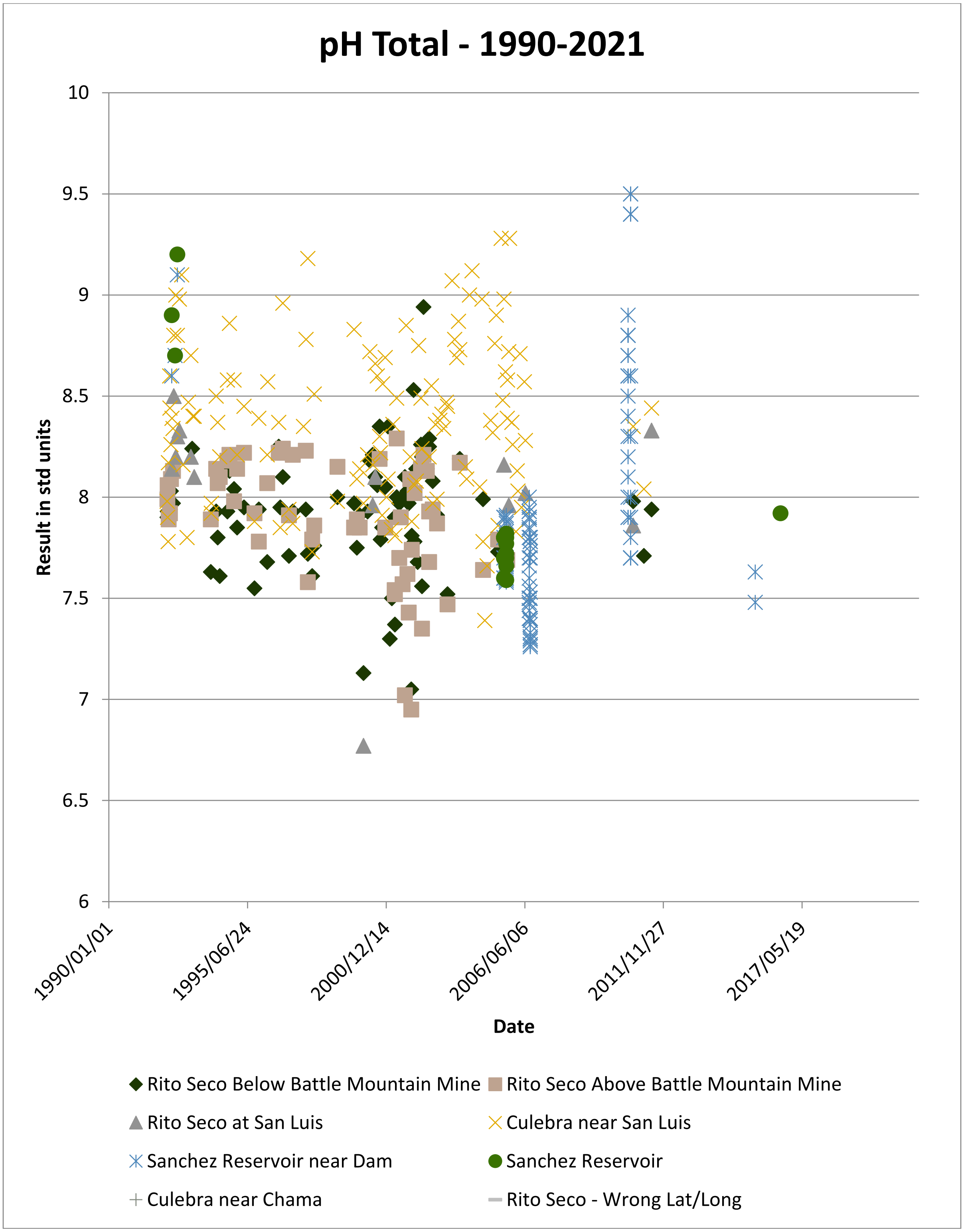


Figure 7-32 Time-series plot of pH measurements included with existing water quality data showing all data post-1990.

7.4.1.3 Specific Conductance

Specific conductance is simply the ability of water to conduct electricity and is measured in base terms siemens/cm, or how much resistance per centimeter of water is measured. This relatively simple measurement is highly related to the amount of dissolved material within the water. When calibrated to the watershed with the analytical results of water quality samples this parameter can be used to develop a time-series of the water quality and assist in developing trends in water quality that may then be linked to stressors or watershed activities. Specific conductance in surface water typically ranges from 50 to 1,500 µS/cm.

Specific conductance data has the following listed methods: USGS WHT04, USEPA 160.4, NA, METER_1, and USEPA 120.1. Specific conductance from the historic samples ranges from 87 to 470 us/cm. The average specific conductance of 224 samples was 207 us/cm.

All historic measured values of specific conductance were within the expected range.

Table 7-13 Specific conductance data from existing water quality dataset. [min – minimum, max – maximum, avg – average, std. dev. Standard deviation]

Specific Conductance in µS/cm	**Min**	**Max**	**Average**	**Std. Dev.**	**Count**	**First Date**	**Last Date**
All Data	87.4	470	204	52.4	216	10/18/1967	7/14/2015
Rito Seco Below Battle Mountain Mine	102	470	217	89.2	32	1/24/2000	6/8/2011
Rito Seco Above Battle Mountain Mine	87.4	157	124	19.1	14	4/17/2001	9/27/2005
Rito Seco at San Luis	159	378	236	70.1	9	1/24/2000	6/8/2011
Rito Seco - Wrong Lat/Long	105	200	155	45.7	4	5/8/1979	5/15/1980
Culebra near San Luis	199	348	238	35.4	20	1/24/2000	6/8/2011
Culebra near Chama	115	161	141	13.7	11	10/18/1967	9/16/1968
Sanchez Reservoir near Dam	145	243	213	24.8	113	6/25/1992	7/14/2015
Sanchez Reservoir	154	181	178	7.3	13	9/17/1992	9/13/2005

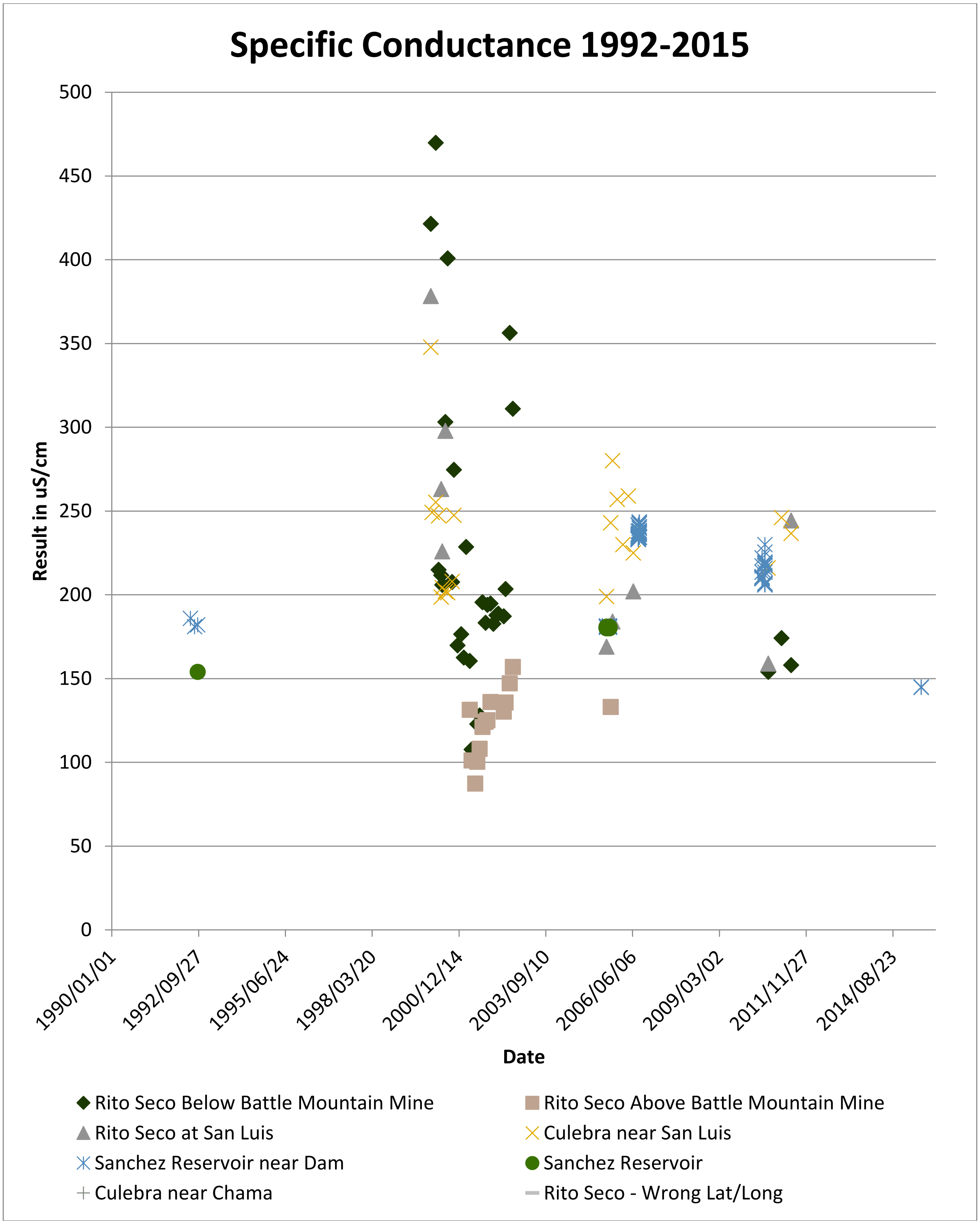


Figure 7-33 Time-series plot of specific conductance measurements found in existing water quality datasets all post-1990 data.

7.4.1.4 Dissolved Oxygen

Dissolved oxygen is a measure of how much oxygen is in the water. The amount of oxygen that can be dissolved into water is dependent on the barometric pressure and the temperature of water, the warmer the water and the lower the barometric pressure the less oxygen the water is able to dissolve.

Water is considered to hypoxic when the dissolved oxygen is below 2 mg/l. Hypoxic conditions were observed in portions of the water column during the Sanchez Reservoir profile samples. Maximum dissolved oxygen concentration is directly related to barometric pressure and indirectly related to water temperature. Hypoxic conditions are often caused by eutrophication induced by excess nutrient loading (Mueller & Helsel, 1996).

Table 7-14 Dissolved oxygen data found in existing water quality datasets. [min – minimum, max – maximum, avg – average, std. dev. Standard deviation]

Dissolved Oxygen in mg/L

	Min	Max	Average	Std. Dev.	Count	First Date	Last Date
All Data	0	15.0	7.7	3.3	470	5/8/1979	7/14/2015
Rito Seco Above Battle Mountain Mine	6.5	15.0	10.0	1.8	56	7/13/1992	9/27/2005
Rito Seco Below Battle Mountain Mine	4.0	15.0	9.4	2.1	76	7/13/1992	6/8/2011
Rito Seco at San Luis	4.6	9.7	7.4	1.3	16	6/29/1992	6/8/2011
Rito Seco - Wrong Lat/Long	9.1	9.1	9.1	--	1	5/8/1979	5/8/1979
Culebra near San Luis	5.0	14.0	10.1	2.0	118	5/28/1992	6/8/2011
Sanchez Reservoir near Dam	0	11.8	4.6	2.7	160	6/25/1992	7/14/2015
Sanchez Reservoir	2.4	7.4	6.5	1.1	43	6/25/1992	9/13/2005

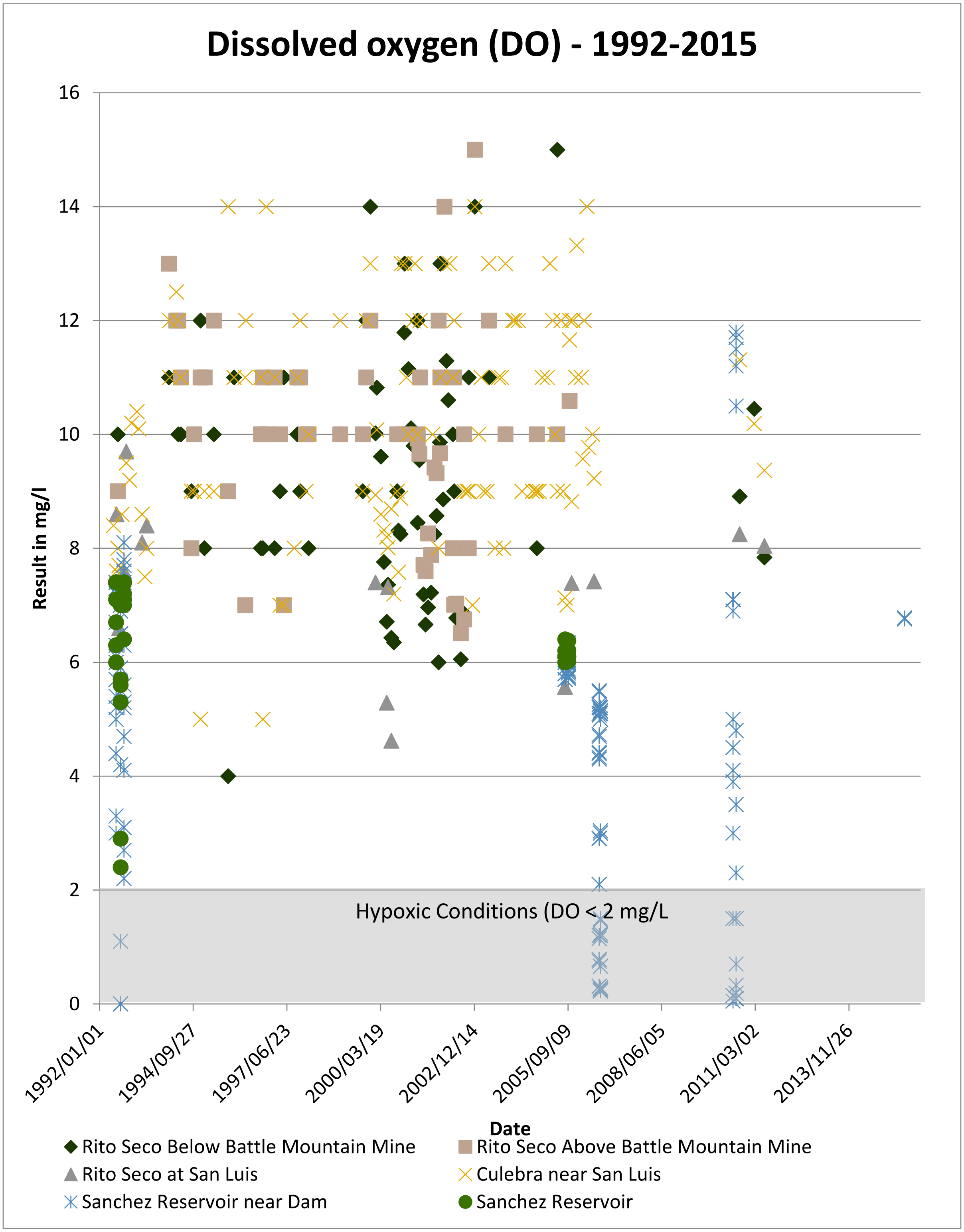


Figure 7-34 Dissolved oxygen measurements from 1992-2015 found in existing water quality datasets, includes all post-1990 data.

7.4.1.5 Total Alkalinity

Alkalinity measures the capacity of the water to neutralize acid. This is one of the best measurements for determining the sensitivity of a body of water to acidic inputs such as acid precipitation, certain plant activities, and industrial wastewater (United States Environmental Protection Agency, 2021). The alkalinity is typically determined by the overlying geology. Many of the standards for water quality included in Regulation 31 and applied regionally in Regulation 36 are dependent on hardness because the toxicity of metals is reduced with increased hardness, in application of these standards Alkalinity is sometimes substituted for hardness because alkalinity is a simpler measurement (Regulation No. 31 - The basic standards and methodologies for surface water, 2017).

Data naming conventions were standardized to combine historic data for comparison. See Appendix 8.A for the conversions that were applied to summarize the data.

Generally, it is observed that the alkalinity of Rito Seco above Battle Mountain Mine is less than below Battle Mountain Mine which is less than Culebra near San Luis (Figure 7-35). Also noted was the standard deviation for Rito Seco above Battle Mountain Mine was less than either Culebra near San Luis or Rito Seco below Battle Mountain Mine (Table 7-15).

Table 7-15 Total alkalinity data found in existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation]

Total Alkalinity in mg/L CaCO3

Site Group	Min	Max	Avg	Std. Dev.	Count	First Date	Last Date
All Data	27.0	180	85.8	28.3	323	10/18/1967	7/14/2015
Rito Seco Below Battle Mountain Mine	40	156	75.6	22.1	81	4/24/1992	6/8/2011
Rito Seco Above Battle Mountain Mine	27	72	53.2	10.1	61	4/24/1992	9/27/2005
Rito Seco at San Luis	44	180	81.9	35.0	15	6/29/1992	6/8/2011
Rito Seco - Wrong Lat/Long	40	78	55.0	17.8	4	5/8/1979	5/15/1980
Culebra near San Luis	68	156	110	16.0	125	4/22/1992	6/8/2011
Culebra near Chama	49	75	63.5	7.45	11	10/18/1967	9/16/1968
Sanchez Reservoir near Dam	64	120	97.9	14.8	21	8/13/1992	7/14/2015
Sanchez Reservoir	80	84	81.2	1.64	5	9/17/1992	9/13/2005

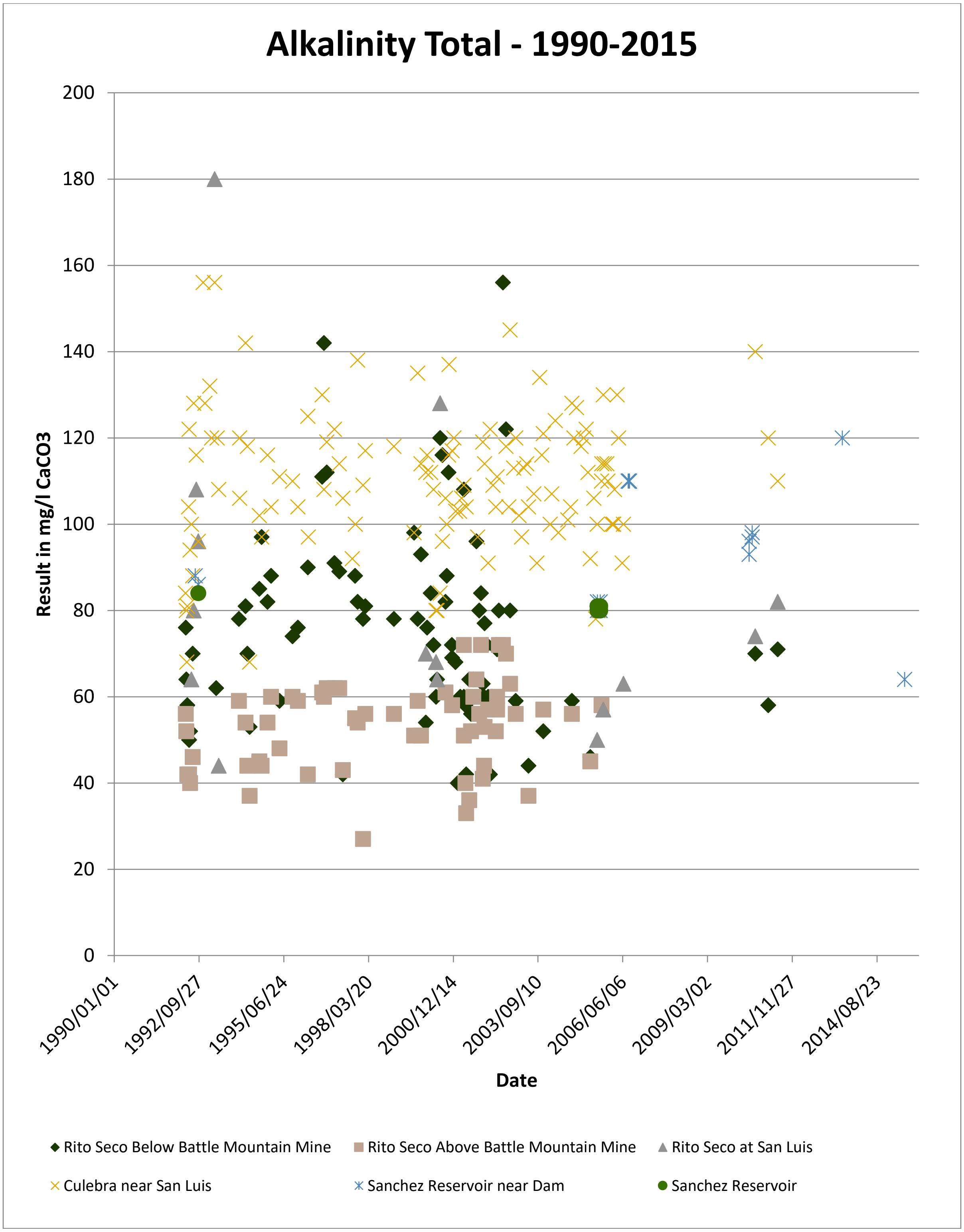


Figure 7-35 Time-series plot of total alkalinity including all post-1990 data.

7.4.1.6 Solids Content

The total solids content of water is defined as the residue remaining after evaporation of the water and drying the residue to a constant weight at 103 °C to 105 °C. The organic fraction (or volatile solids content) is related to the loss of weight of the residue remaining after evaporation of the water and after ignition of the residue at a temperature of 500 °C. The volatile solids will oxidize at this temperature and will be driven off as gas. The inorganic (or fixed solids) remains as inert ash. Solids are classified as settleable solids, suspended solids, and filterable solids. Settleable solids (silt and heavy organic solids) are the one that settle under the influence of gravity. Suspended solids and filterable solids are classified based on particle size and the retention of suspended solids on standard glass-fiber filters.

Table 7-16 Total dissolved solids data form existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Total Dissolved Solids in mg/L

Site Group	Min	Max	Average	Standard Deviation	Count	First Date	Last Date
All Data	41	240	119	41.4	107	10/18/1967	9/13/2005
Rito Seco Above Battle Mountain Mine	57	120	82.3	15.4	15	4/17/2001	8/28/2002
Rito Seco Below Battle Mountain Mine	64	240	127	45.8	29	1/24/2000	8/28/2002
Rito Seco at San Luis	89	230	162	49.1	11	6/29/1992	7/11/2000
Culebra near San Luis	110	190	144	19.6	22	5/28/1992	10/18/2000
Culebra near Chama	41	101	83.7	12.8	22	10/18/1967	9/16/1968
Sanchez Reservoir near Dam[1]	130	130	130	0	4	8/11/2005	9/13/2005
Sanchez Reservoir1	130	130	130	0	4	8/11/2005	9/13/2005

[1]Each site has two samples on each of the two days sampled, but samples are not marked as replicates.

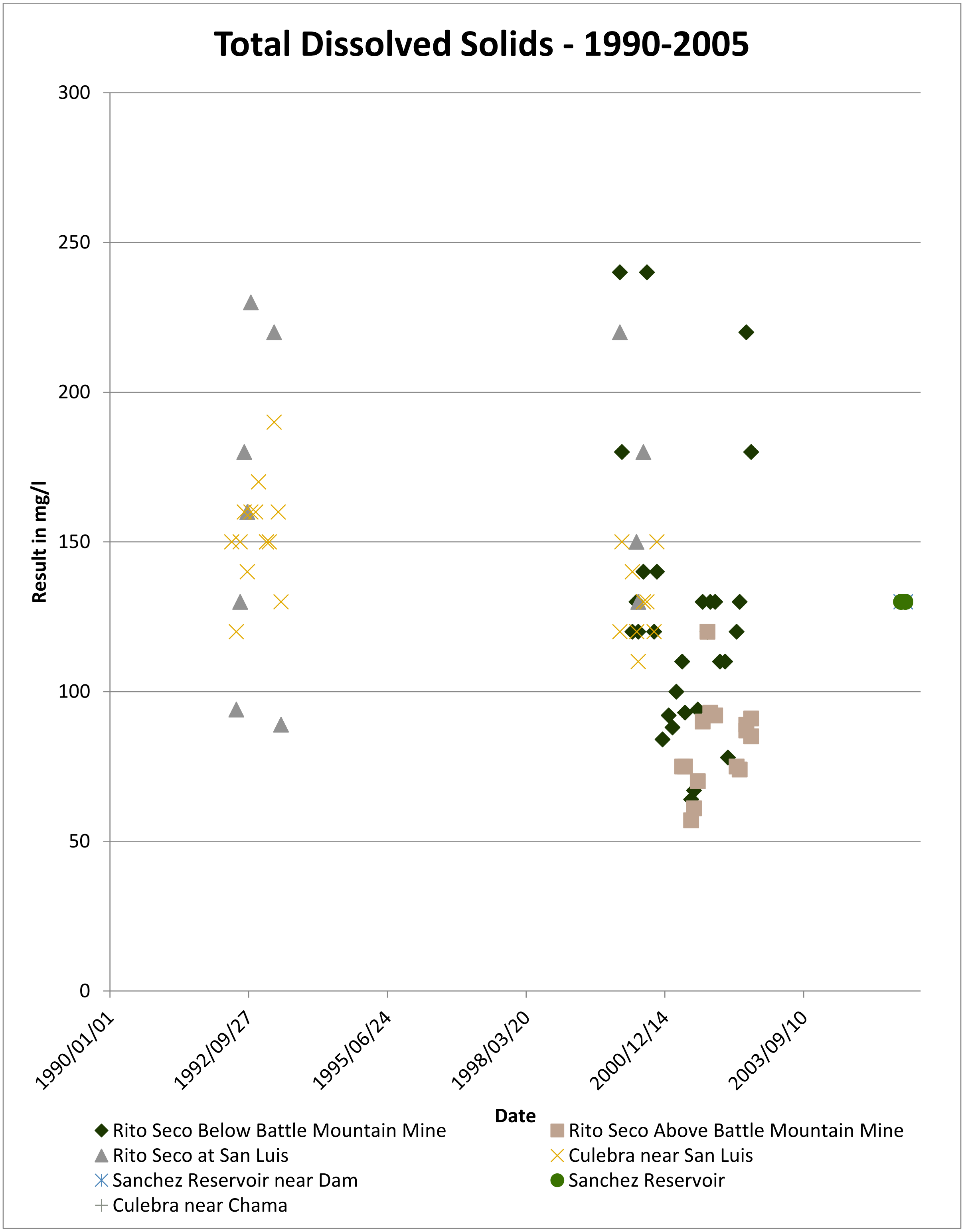


Figure 7-36 Time series plot of total dissolved solids data from 1990-2005 in existing water quality datasets.

Table 7-17 Summary of existing total suspended solids data from existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Total Suspended Solids Non-filterable in mg/L

Site	Min	Max	Average	Std. Dev.	Count above DL	ND Count	First Date	Last Date
All Data	ND	560	35.5	87.2	44	37	5/28/1992	9/13/2005
Rito Seco Above Battle Mountain Mine	ND	12	10.7	1.2	3	12	4/17/2001	8/28/2002
Rito Seco Below Battle Mountain Mine	ND	150	33.1	36.0	14	15	1/24/2000	8/28/2002
Rito Seco at San Luis	ND	560	98.9	193.6	8	3	6/29/1992	7/11/2000
Culebra near San Luis	ND	77	14.5	17.7	19	3	5/28/1992	10/18/2000
Sanchez Reservoir near Dam	ND		--	--	0	2	9/13/2005	9/13/2005
Sanchez Reservoir	ND		--	--	0	2	9/13/2005	9/13/2005

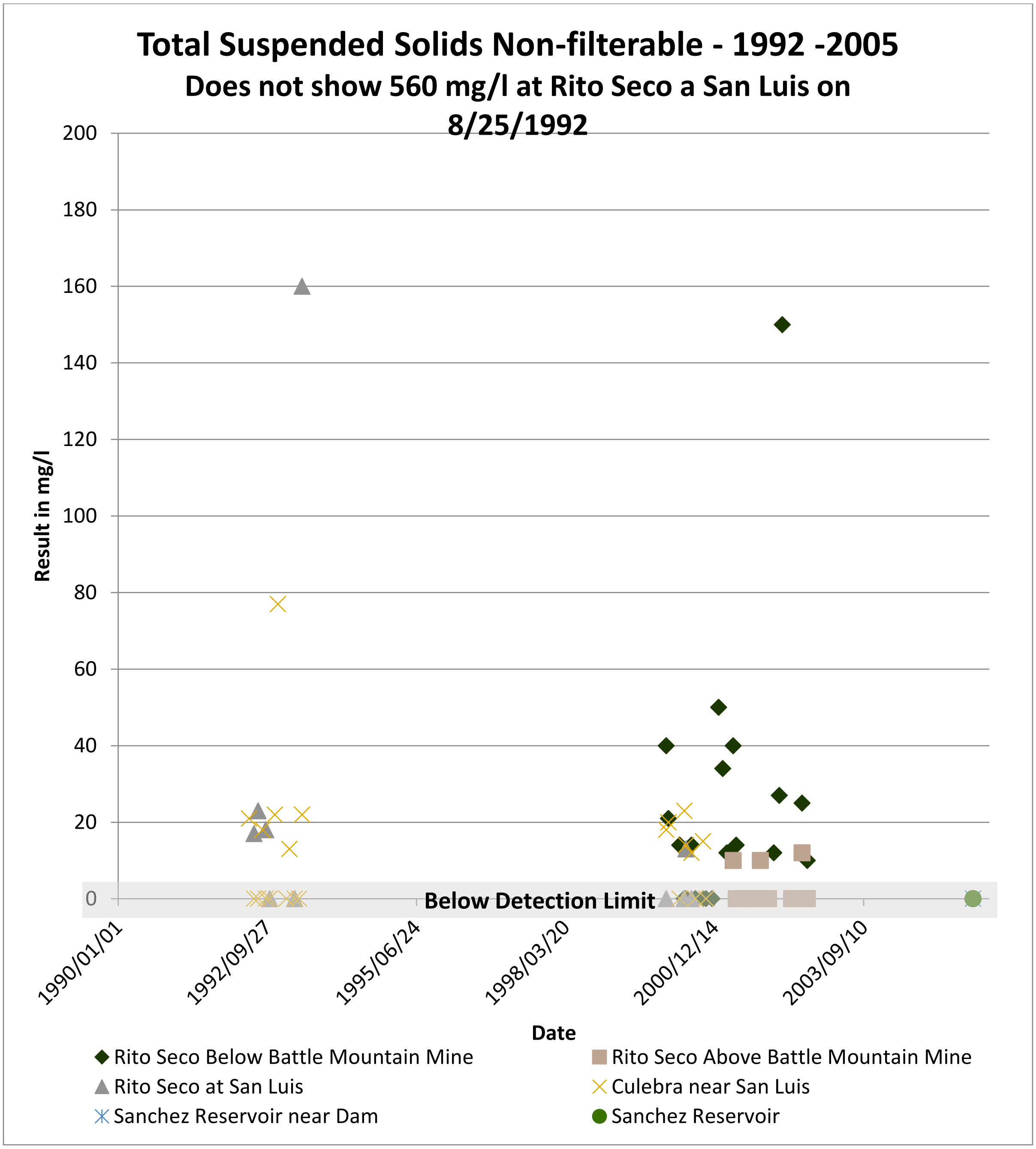


Figure 7-37 Time-series plot of total suspended solids data from existing water quality datasets 1992-2005.

Total suspended solids data was collected in January and May in 2001, 2002, and 2003 as part of the Colorado River Watch program. The total suspended solids for the three January samples averaged 8 mg/l while the may samples averaged 47 mg/l including data from 2001 and 2003 and 0 for the non-detect in 2002.

Table 7-18 Summary of total suspended solids data from existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Total Suspended Solids in mg/L

Site	Min	Max	Avg	Std. Dev.	Count above DL	ND Count	First Date	Last Date
All Data	ND	120	--	--	10	11	1/10/2001	8/10/2010
Rito Seco Below Battle Mountain Mine	43	120	81.5	54.4	2	0	5/15/2001	1/30/2002
Culebra near San Luis	ND	79	--	--	6	1	1/10/2001	10/13/2004
Sanchez Reservoir near Dam	ND	19	--	--	2	8	8/11/2005	8/10/2010
Sanchez Reservoir	ND					2	8/11/2005	8/11/2005

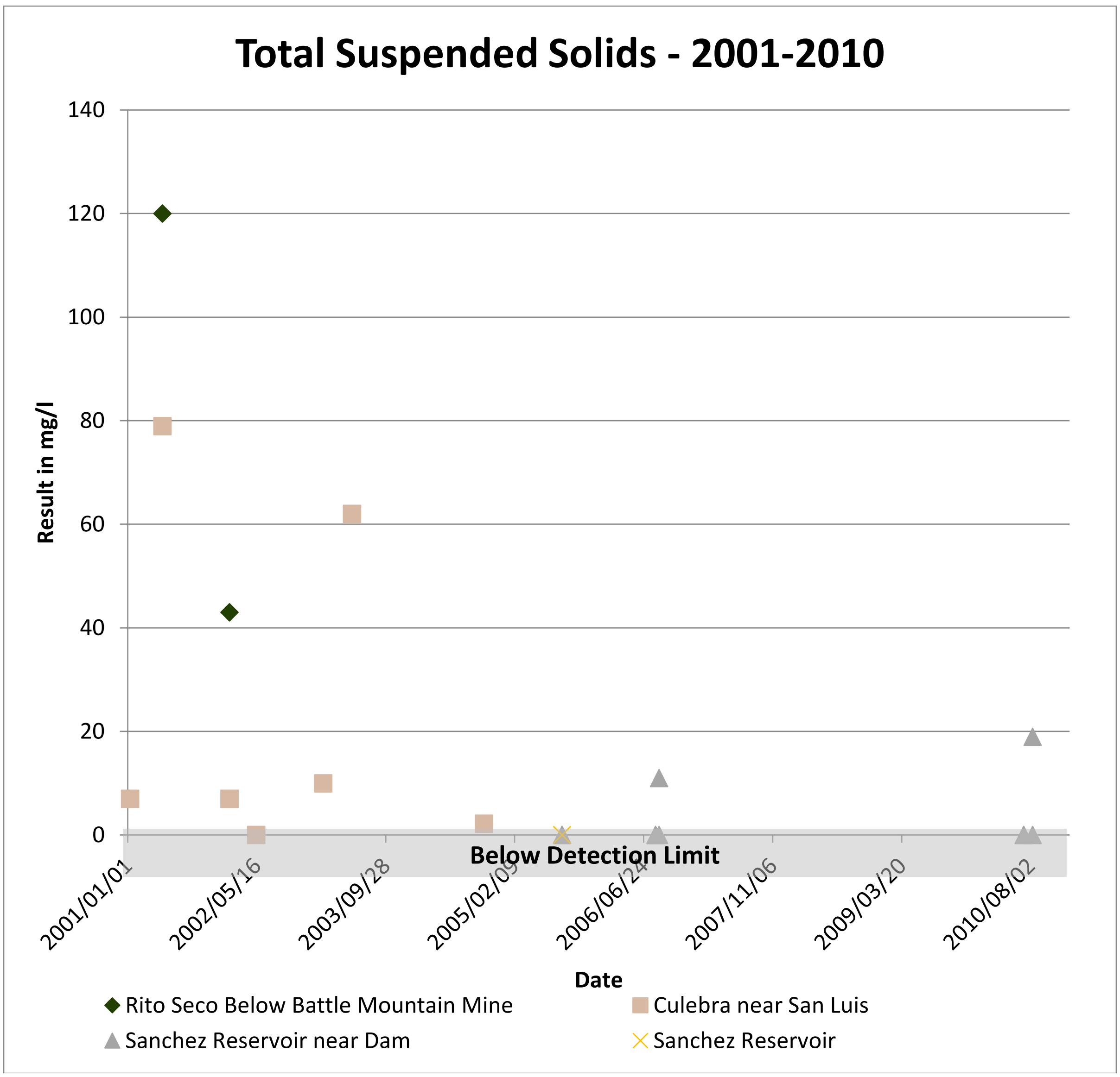


Figure 7-38 Time-series plot of total suspended solids data in existing water quality datasets from 2001-2010. Includes all data post-1990.

7.4.1.7 Hardness

The 1968 water year sampling event at Culebra near Chama had a range of non-carbonate total hardness from 3 to 8 mg/l $CaCO_3$, and Calcium-Magnesium total hardness from 56 to 78 mg/l $CaCO_3$. Calcium-Magnesium Total Hardness values ranged from 37 to 194 and averaged around 88 mg/l. Hardness is an important parameter because the toxicity of certain metals is directly related to the hardness of the water.

The hardness values generally follow the trend of alkalinity with Culebra near San Luis generally higher than Rito Seco below Battle Mountain Mine which is higher than Rito Seco above Battle Mountain Mine. However, these data show more variation in the trends for Rito Seco.

Table 7-19 Summary of hardness data from existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation]

Hardness, Ca, Mg, Total mg/l							
Site Group	**Min**	**Max**	**Avg**	**Std. Dev.**	**Count**	**First Date**	**Last Date**
All Data	37	194	88.4	28.6	308	5/8/1979	7/14/2015
Rito Seco Below Battle Mountain Mine	43	194	79.1	27.8	75	4/24/1992	6/8/2011
Rito Seco Above Battle Mountain Mine	37	101	58.4	11.2	63	4/24/1992	9/27/2005
Rito Seco at San Luis	52	170	88.9	34.7	16	6/29/1992	6/8/2011
Rito Seco - Wrong Lat/Long	50	83	65.8	13.7	4	5/8/1979	5/15/1980
Culebra near San Luis	69	157	110	17.8	124	4/22/1992	6/8/2011
Sanchez Reservoir near Dam	70.6	104	87.1	9.5	21	8/13/1992	7/14/2015
Sanchez Reservoir	75	80	77.6	2.4	5	9/17/1992	9/13/2005

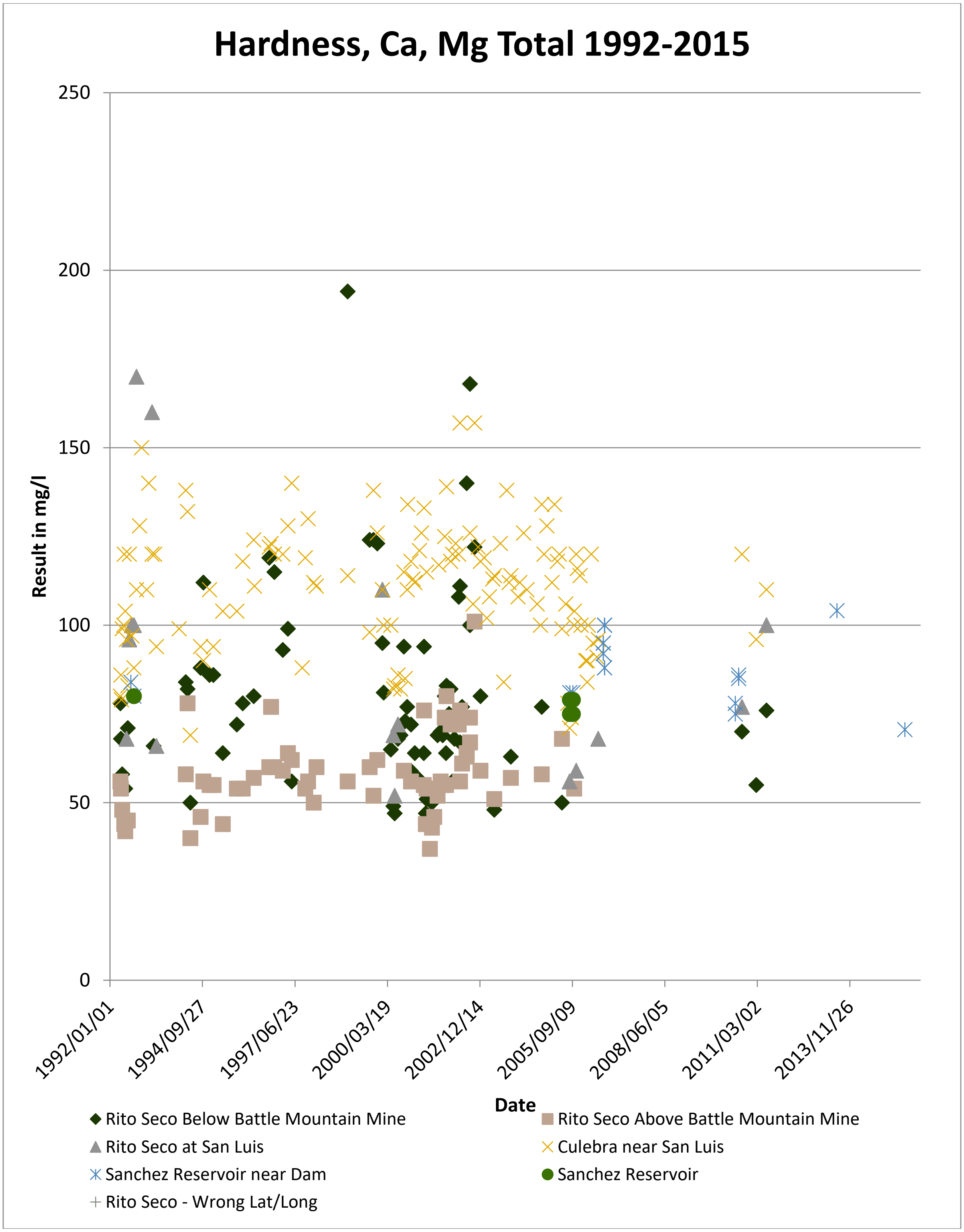


Figure 7-39 Time-series plot of total hardness data from existing water quality datasets 1992-2015.

7.4.2 Chemical Characteristics

The chemical characteristic of natural water reflects how rocks and soils are in contact with water. Agriculture, urban runoff, municipal and industrial treated wastewater impact the water quality. Microbial and chemical transformations also affect the chemical characteristics.

7.4.2.1 Nutrients

Nutrients are essential for plant and animal growth and nourishment. Nutrients are naturally present in water resulting from dissolution of natural materials. However, an excess of a certain nutrients in water can result in adverse health and ecological effects (Mueller & Helsel, 1996). High concentration of nutrients in streams and lakes has been found to be related to land use practices. Nutrients consists of the various forms of nitrogen and phosphorus.

Excess nutrients can cause eutrophication which can result in fish kills, noxious tastes and odors, clogged pipelines, and restricted recreation. (Mueller & Helsel, 1996). Eutrophication occurs when excess nutrients increase the growth of algae which then results in lowered oxygen in the water also known as Hypoxic Conditions. In some wetlands and lakes eutrophication is part of the natural progression of these bodies, but land use changes are often the cause of these conditions.

Regulation 85 was developed specifically targeting nutrients including nitrogen, phosphorus, and chlorophyll.

<u>Nitrogen</u>

Nitrogen is necessary for plant and animal growth but in higher concentrations can lead to adverse health and ecological affects (U.S. Geological Survey). Nitrogen pollution comes from fertilizers and from precipitation including acid rain. Excess nitrogen from precipitation results from automobile and industrial emissions. Farming and land use practices that increase the rate at which water drains may lead to increased nitrogen concentrations.

Nitrogen comes from livestock, sewage, fertilizers, and industrial and automobile emissions. In Regulation #36 there are acute standards for nitrate and nitrite, these standards are aimed at point-source contributors with the primary target within the Upper Culebra basin being the wastewater treatment plants. Regulation 85 includes standards for total inorganic nitrogen, and interim regulation 31.17 provide limits for total nitrogen. Total inorganic nitrogen is sometimes measured directly or calculated as the sum of Kjeldahl nitrogen plus nitrate-nitrite.

The nitrogen species include nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen (ammonia + organic nitrogen), and total nitrogen (Kjeldahl nitrogen + nitrite + nitrate). The nitrogen parameters shown below are those with associated water quality regulations. Nitrogen is often reported using a variety of combinations of the various forms due to the methods used for measurement and the application of the data such as adjustment to wastewater treatment processes.

Ammonia

Ammonia has historically been regulated as either total ammonia (ammonia + ammonium) or un-ionized ammonia (NH_3). Only the un-ionized form of ammonia is toxic, however the type of ammonia present changes with pH and temperature (United States Environmental Protection Agency, 2021). Ammonium ($NH4+$) is considered non-toxic. All reaches within the Upper Culebra Watershed have table value standards for ammonia (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018). Ammonia standards are set assuming salmonids are present in cold water segments and that early life stages are present in warm water segments from April 1 through August 31.

The standard for Total Ammonia is related to the temperature and pH of the water. Acute is a one-day value whereas chronic is a 30-day average.

Cold Water:

$acute = \frac{0.275}{1+10^{7.204-pH}} + \frac{39.0}{1+10^{pH-7.204}}$, in mg/l as N

$chronic = \left\{\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right\} * MIN(2.85, 1.45 * 10^{0.028(28-T)})$, in mg/l as N

Warm Water:

$acute = \frac{0.411}{1+10^{7.204-pH}} + \frac{58.4}{1+10^{pH-7.204}}$, in mg/l as N

$chronic(Apr1 - Aug31) = \left\{\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right\} * MIN(2.85, 1.45 * 10^{0.028(28-T)})$, in mg/l as N

$chronic\ (Sep1 - Mar31) = \left\{\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right\} * 1.45 * 10^{0.028*(25-MAX(T,7))})$, in mg/l as N

All sample values were below the acute total ammonia water quality standard (Table 7-20). Sanchez Reservoir had observations of Total Ammonia that exceeded the chronic warm water standard within a portion of the sampled water column (samples >0.15 mg/l).

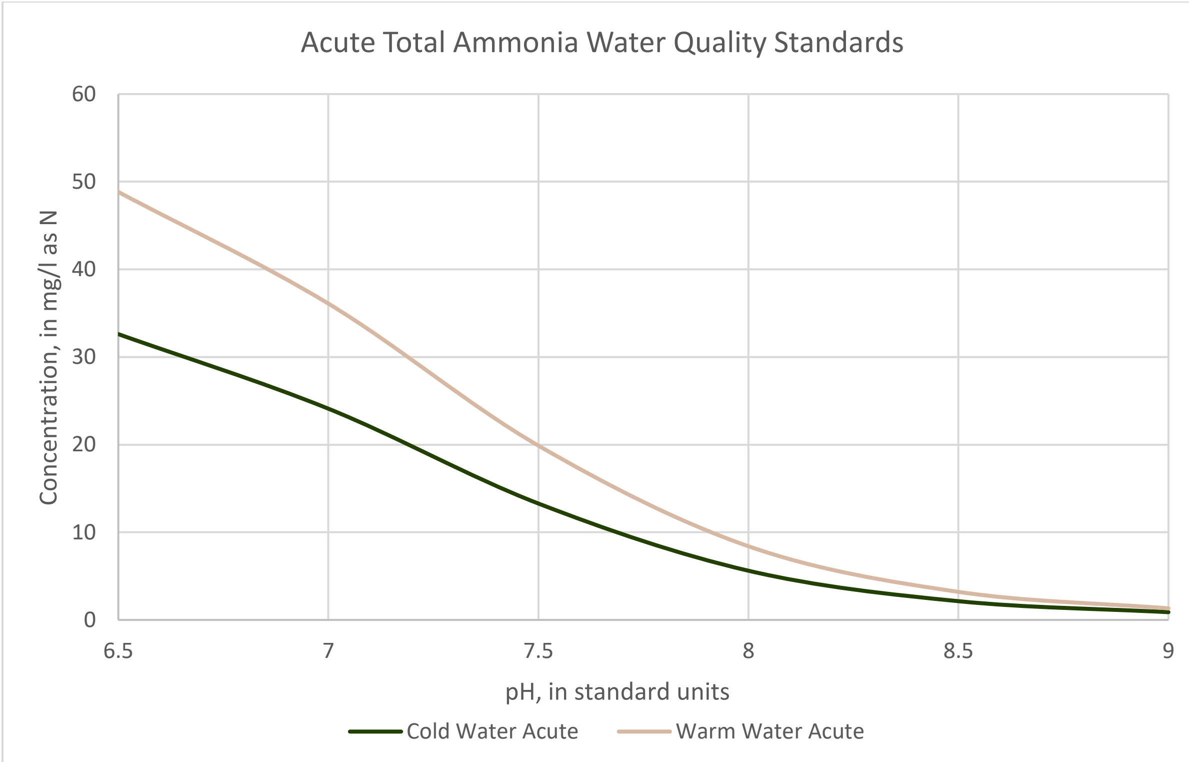


Figure 7-40 Acute total ammonia water quality standards for cold and warm water.

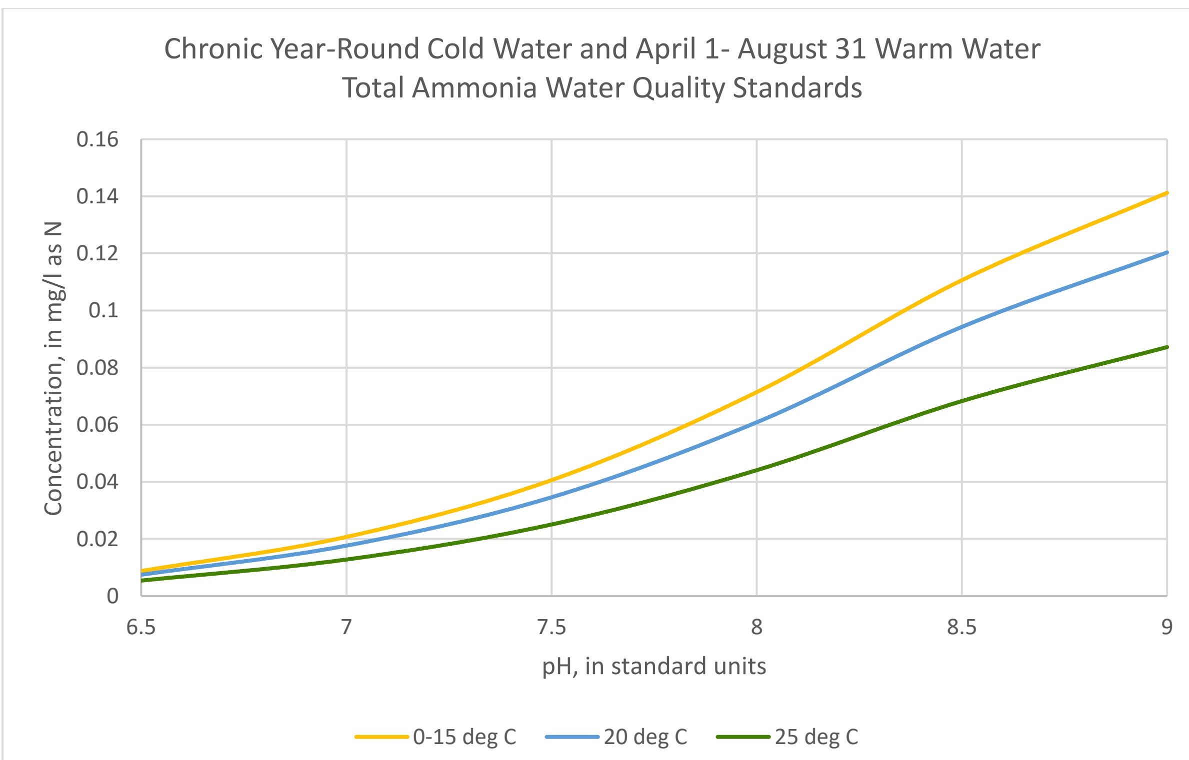


Figure 7-41 Chronic year-round cold water total ammonia standards and April 1-August 31 warm water total ammonia water quality standards.

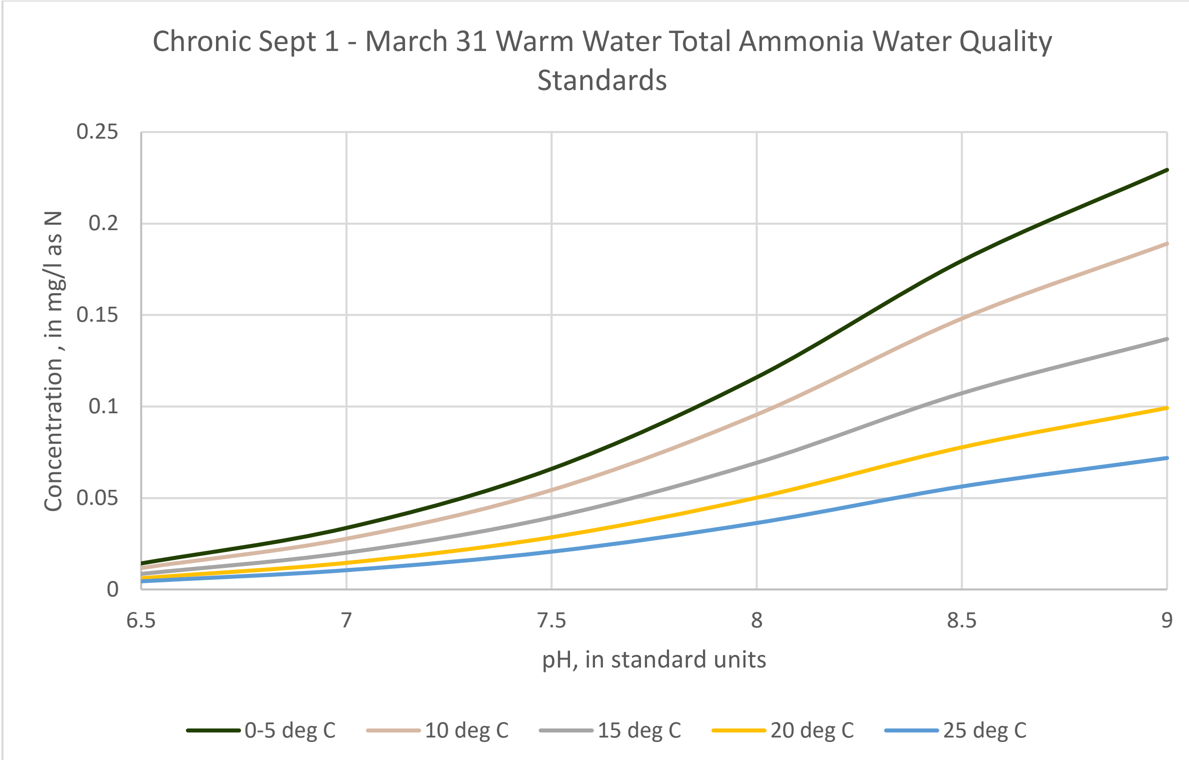


Figure 7-42 Chronic September 1 - March 31 warm water total ammonia water quality standards.

Table 7-20 Summary of total ammonia data in existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Total Ammonia, in mg/l

Site	Min	Max	Avg	Std. Dev.	Count above DL	ND Count	First Date	Last Date
All Data	ND	0.33	--	--	60	47	1/24/2000	6/8/2011
Rito Seco Above Battle Mountain Mine	ND	0.09	--	--	6	10	4/17/2001	9/27/2005
Rito Seco Below Battle Mountain Mine	ND	0.05	--	--	9	25	1/24/2000	6/8/2011
Rito Seco at San Luis	ND	0.04	--	--	4	5	1/24/2000	6/8/2011
Culebra near San Luis	ND	0.14	--	--	12	15	1/24/2000	6/8/2011
Sanchez Reservoir near Dam	ND	0.33	--	--	16	1	8/11/2005	8/10/2010
Sanchez Reservoir	0.13	0.14	0.14	0.006	4	0	8/11/2005	9/13/2005

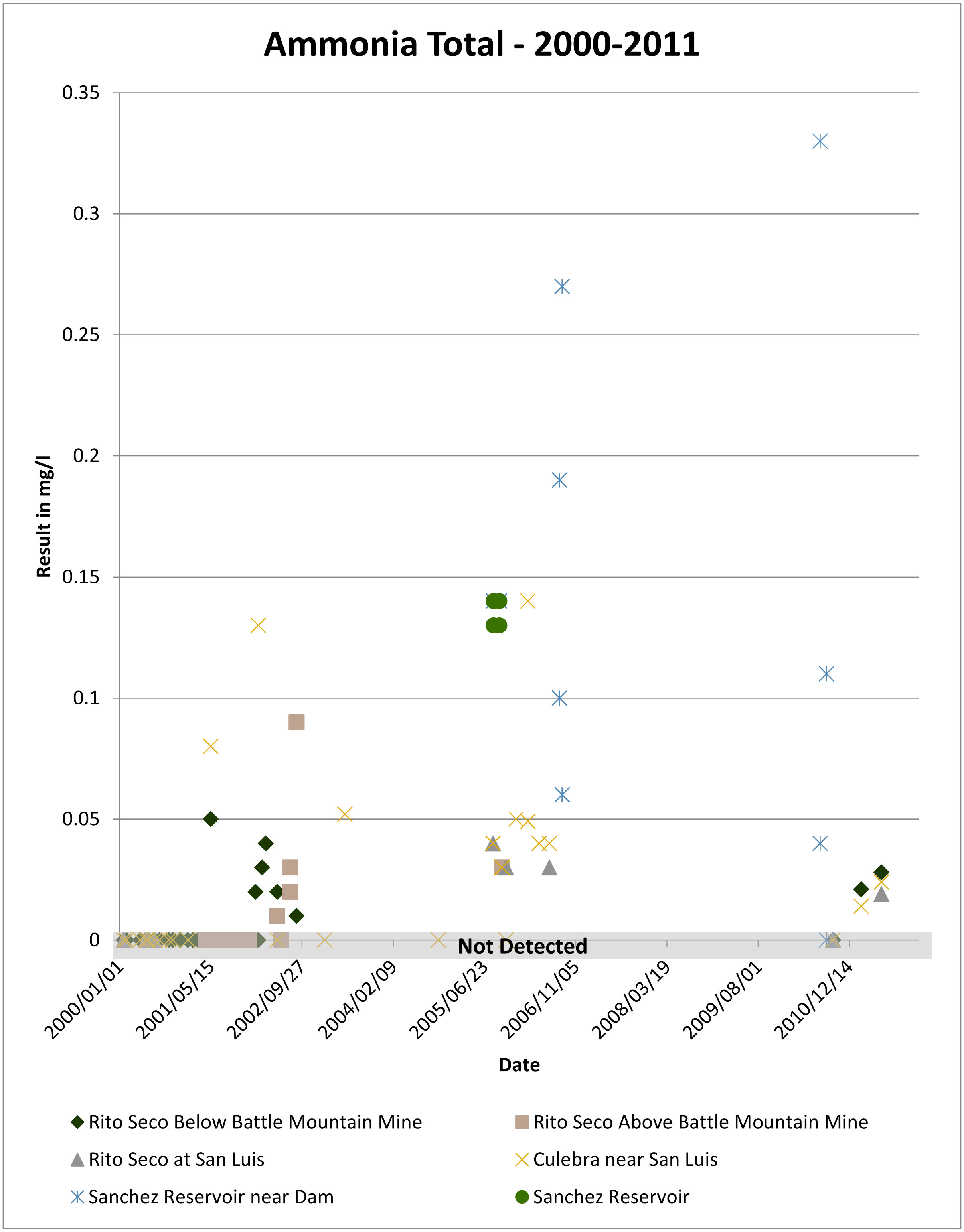


Figure 7-43 Time series plot of total ammonia data from existing water quality datasets 2000-2011.

Nitrate

The acute standard for Nitrate is 10 mg/l as N for all segments within the Upper Culebra Basin this is based on the water supply classifications for all reaches. One site, Culebra near Chama, had sample values for dissolved nitrate as NO3 from the 1968 water year, the measured values ranged from 0.1 to 0.9 mg/l as NO3 (0.023 to 0.203 mg/l as N). Total nitrate as N was measured twice at Sanchez Reservoir in August 2006, measured values ranged from 0.03 to 0.25 mg/l as N.

To convert from Nitrate as NO3 to Nitrate as N multiply by 0.2259.

Table 7-21 Summary data for total nitrate from existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Total Nitrate, in mg/l as N

Site	Min	Max	Avg	Std. Dev.	Count above DL	ND Count	First Date	Last Date
Sanchez Reservoir near Dam	ND	0.25	--	--	5	3	8/9/2006	8/10/2010

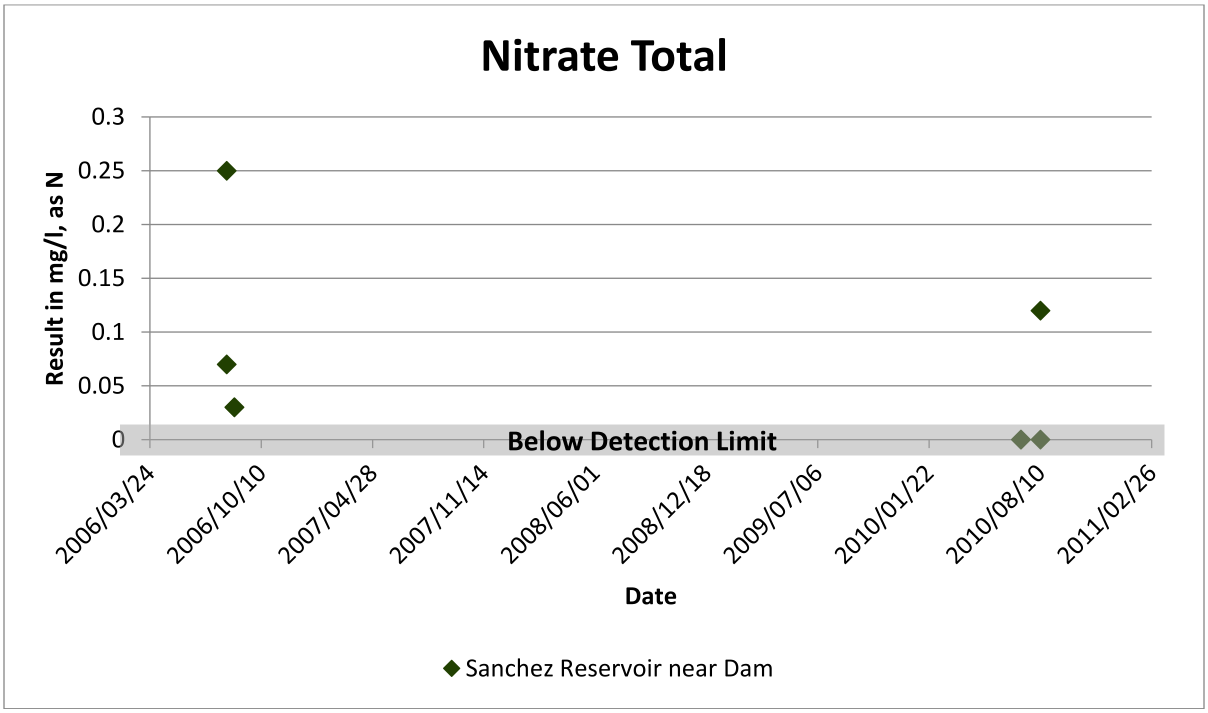


Figure 7-44 Time series plot of total nitrate data from existing water quality datasets.

Nitrite

The acute standard for Nitrite is 0.05 mg/l for all segments within the Upper Culebra Basin this is based on the water supply classification for all reaches.

Table 7-22 Summary of total nitrate data from existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Total Nitrite, in mg/l as N

Site	Min	Max	Avg	Std. Dev.	Count above DL	ND Count	First Date	Last Date
Sanchez Reservoir near Dam	ND	0.01	--	--	9	4	8/9/2006	8/10/2010

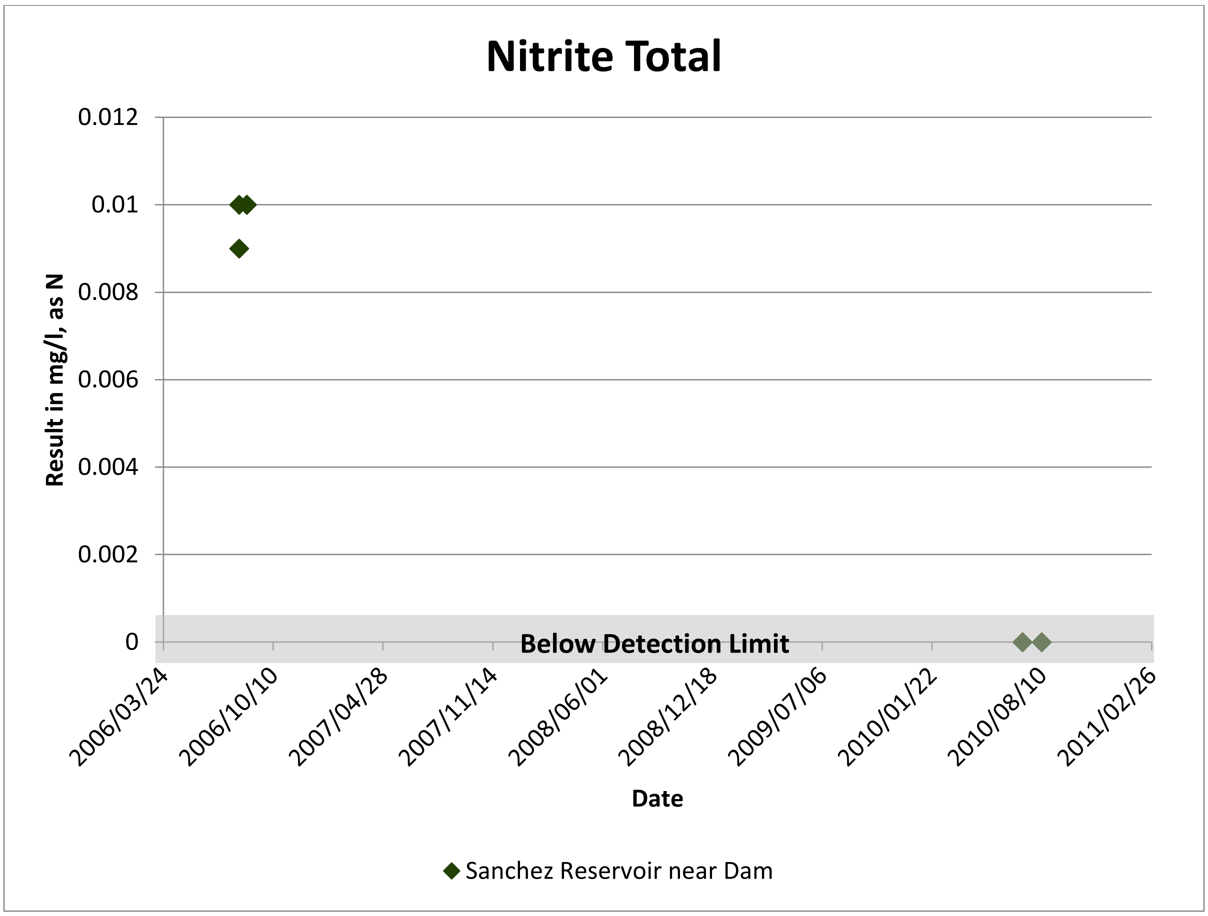


Figure 7-45 Time-series plot of total nitrite data in existing water quality datasets.

Phosphorus

Phosphorus is necessary for plant growth; however, when there is too much phosphorus in the water this can lead to eutrophication of rivers and lakes. Phosphorus pollution comes from agricultural fertilizers, manure, and organic wastes in sewage and industrial effluent. Phosphates are the only significant form of phosphorus found in natural waters (Mueller & Helsel, 1996).

Regulation 36 sets a chronic standard for Phosphorus at 0.11 mg/L in the streams except those segments below the San Luis Water and Sanitation District and Costilla County Water and Sanitation District. Regulation 36 sets the chronic Phosphorus standard at 0.083 mg/l for Sanchez Reservoir. Minimal data was found in the existing datasets for total phosphorus (Table 7-23).

Table 7-23 Summary of total phosphorus measurements in existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Total Phosphorus, in mg/l as P

Site	Min	Max	Avg	Std. Dev.	Count above DL	ND Count	First Date	Last Date
All Data	ND	0.18	--	--	6	3	1/10/2001	10/13/2004
Rito Seco Below Battle Mountain Mine	0.06	0.12	0.09	0.04	2	0	5/15/2001	1/30/2002
Culebra near San Luis	ND	0.18	--	--	4	3	1/10/2001	10/13/2004

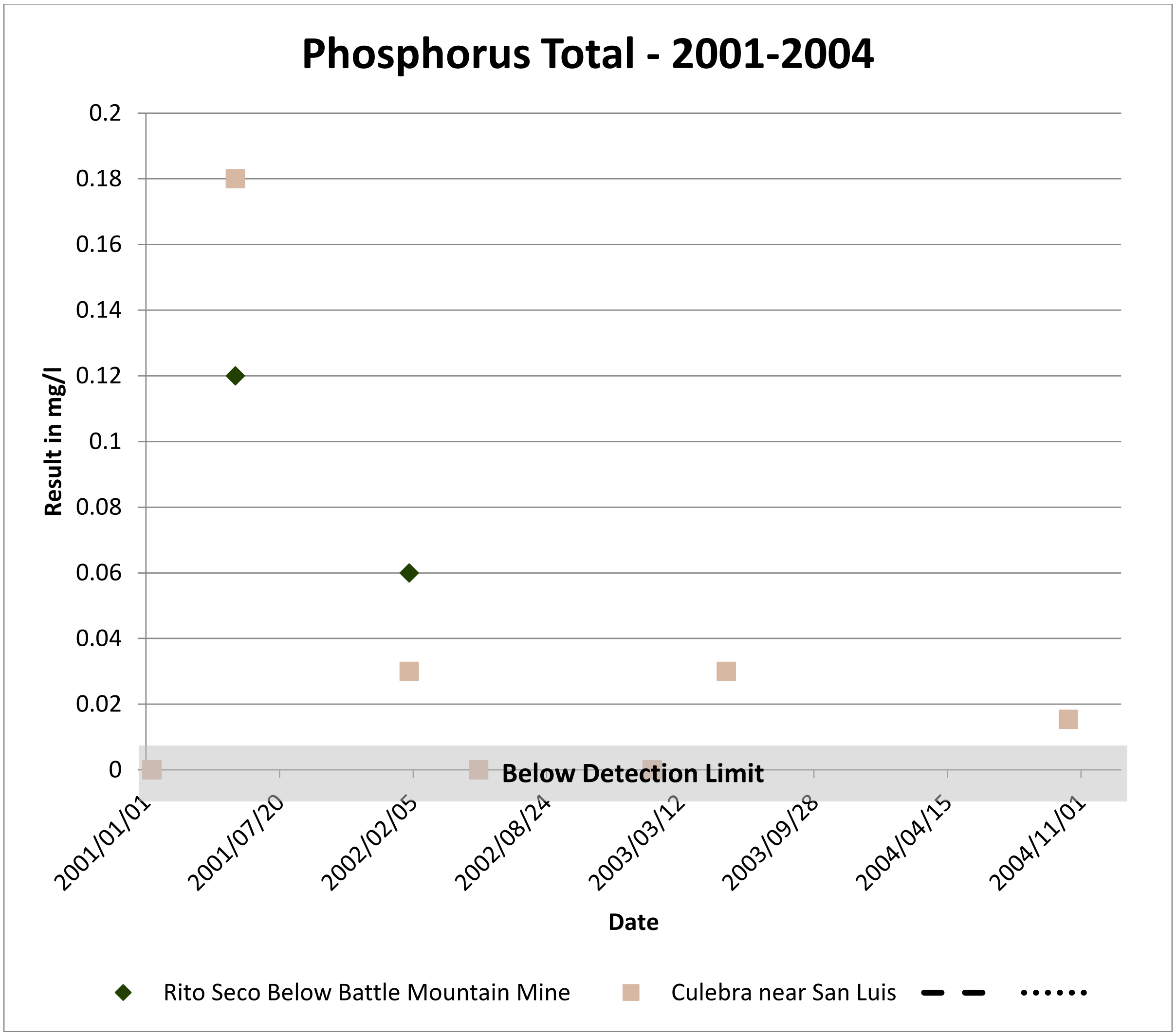


Figure 7-46 Time-series plot of total phosphorus data in existing water quality datasets.

Phosphate

In 1992, the EPA recommended that total phosphates should not exceed 0.05 mg/L (as phosphorus) in streams that flow into lakes or reservoirs and 0.1 mg/L in streams that do not discharge into lakes or reservoirs (Mueller & Helsel, 1996). Several measurements of total phosphate showed exceedances of EPA recommended limits including Rito Seco at San Luis, Culebra near San Luis, and Sanchez Reservoir.

Table 7-24 Summary table of total phosphate data from existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Total Phosphate, in mg/l as P

Site	Min	Max	Average	Standard Deviation	Count	Not Detected Count	First Date	Last Date
All Data	Not Detected	0.52	--	0.07	116	7	5/28/1992	6/8/2011
Rito Seco Below Battle Mountain Mine	0.02	0.1	0.05	0.02	32	0	1/24/2000	6/8/2011
Rito Seco Above Battle Mountain Mine	Not Detected	0.05	--	0.01	9	1	4/17/2001	9/27/2005
Rito Seco at San Luis	Not Detected	0.52	--	0.13	15	1	6/29/1992	6/8/2011
Culebra near San Luis	Not Detected	0.15	--	0.03	30	3	5/28/1992	6/8/2011
Sanchez Reservoir near Dam	0.019	0.4	0.12	0.12	9	0	6/25/1992	8/23/2006
Sanchez Reservoir	Not Detected	0.07	--	0.02	4	1	6/25/1992	9/13/2005

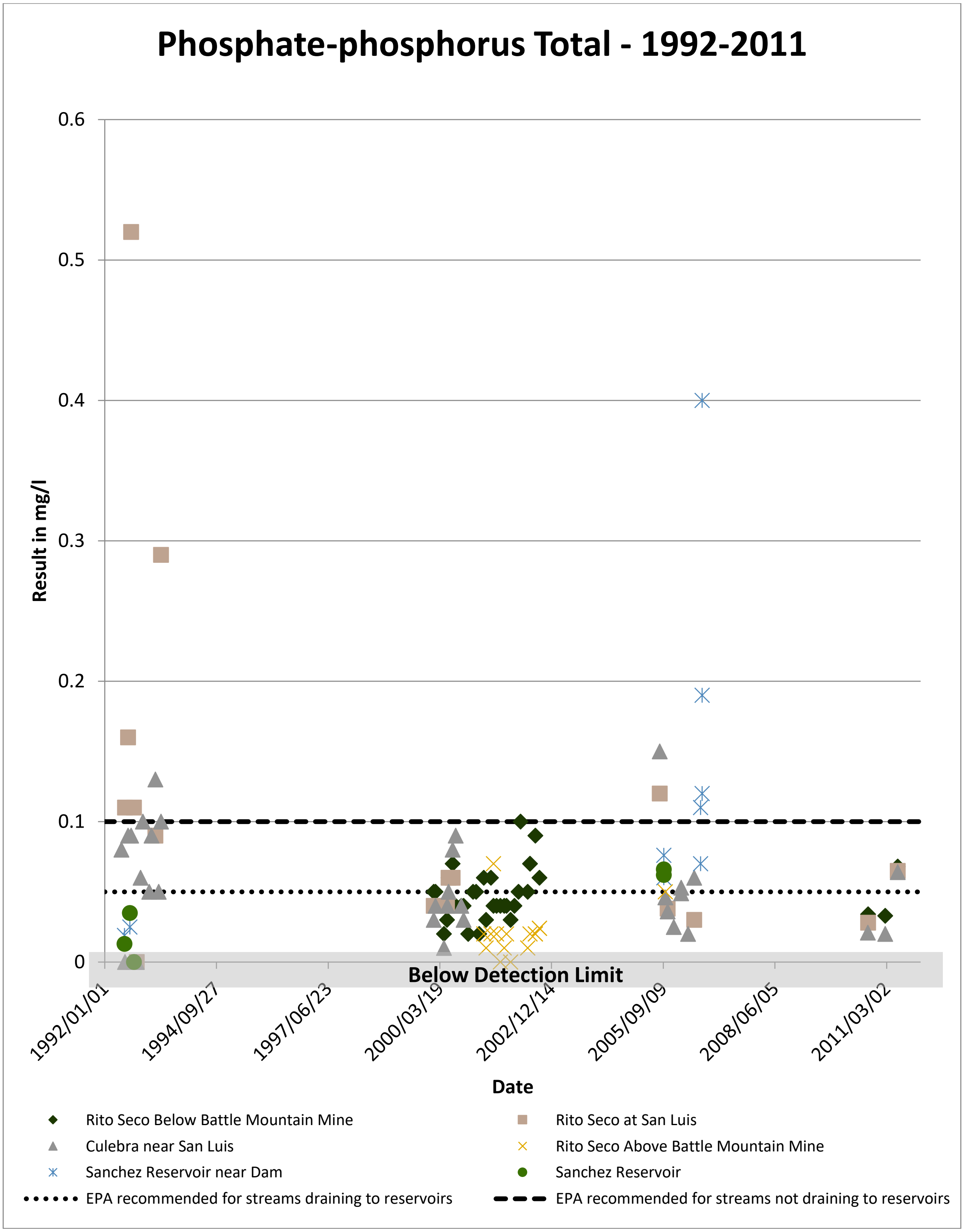


Figure 7-47 Time-series plot of total phosphate data in existing water quality datasets 1992-2011.

7.4.2.2 Metals

Detection limits provided are the typical detection limits associated with the specified method. There may be variations to the methods that will affect sensitivity of the results.

Arsenic

The primary source of Arsenic is typically natural and not anthropogenic or geothermal (Welch & Stollenwork, 2003). The acute dissolved arsenic water quality standard is 340 ug/l for all segments within the Upper Culebra Watershed. All segments have a total chronic standard of 0.02 ug/l with a modification for water supply standards on segment 29 with a modified limit of 10 ug/l (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018). The more stringent total chronic standard is based on exposure from direct consumption of the water and consumption of fish flesh, which accumulates the pollutant. These standards are based on revisions adopted August 2005 which went into effect for segments with Aquatic Life Class 1 that also are used as a Domestic Water Supply and those segments with Aquatic Life class 2 with Domestic Water Supply where fish are of catchable size and normally consumed (Regulation No. 36 - Classification and Numeric Standards for Rio Grande Basin). This revision was in response to EPA's classification of arsenic as a Class A carcinogen (Regulation No. 31 - The basic standards and methodologies for surface water, 2017). Because of the difficulties associated with wastewater treatment permittees meeting the regulation modified limits were adopted, where existing permit holders may not meet the standard due to baseline standards this temporary modification is set to expire December 31, 2021.

Sanchez reservoir was listed on the M&E list for dissolved arsenic. Although higher concentrations of dissolved arsenic have been reported for Culebra near San Luis, this segment has a modified dissolved arsenic standard due to the existing Wastewater Treatment Plant discharge permits.

Of 85 measurements for total arsenic on Rito Seco above Battle Mountain Mine (21), Rito Seco below Battle Mountain Mine (19), Culebra near San Luis (48), and Sanchez Reservoir near Dam (3) only one value above the reporting limit was reported at Sanchez Reservoir with 1.5 ug/l. Samples were analyzed with either EPA Method 200.8(W) or 200.15, the typical reporting limits shown in Table 7-25. None of the samples were analyzed with a detection limit low enough to determine status with regards to the total chronic standard (0.2 ug/l). Dissolved arsenic was analyzed with the same methods as total arsenic with the addition of some samples analyzed using EPA method 200.7 with a typical reporting limit of 8 ug/l.

Table 7-25 Arsenic Typical Detection Limits

Arsenic Typical Detection Limits	
Method	**Detection Limit**
200.15	3 ug/l
200.7	8 ug/l
200.8	Total Recoverable 0.4 ug/l direct 0.1 ug/l

Table 7-26 Summary of dissolved arsenic data from existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Dissolved Arsenic, in ug/l

Site	Min	Max	Average	Standard Deviation	Count	Not Detected Count	First Date	Last Date
All Data	ND	17	--	--	98	62	4/16/1993	8/10/2010
Rito Seco Below Battle Mountain Mine	ND	ND	--	--	0	29	1/24/2000	8/28/2002
Rito Seco Above Battle Mountain Mine	ND	ND	--	--	0	17	4/16/1993	5/18/2005
Rito Seco at San Luis	ND	ND	--	--	0	7	1/24/2000	6/14/2006
Culebra near San Luis	ND	17	--	--	7	22	1/24/2000	6/14/2006
Sanchez Reservoir near Dam	1	3	1.94	0.81	17	0	8/11/2005	8/10/2010
Sanchez Reservoir	1	1	1	0	4	0	8/11/2005	9/13/2005

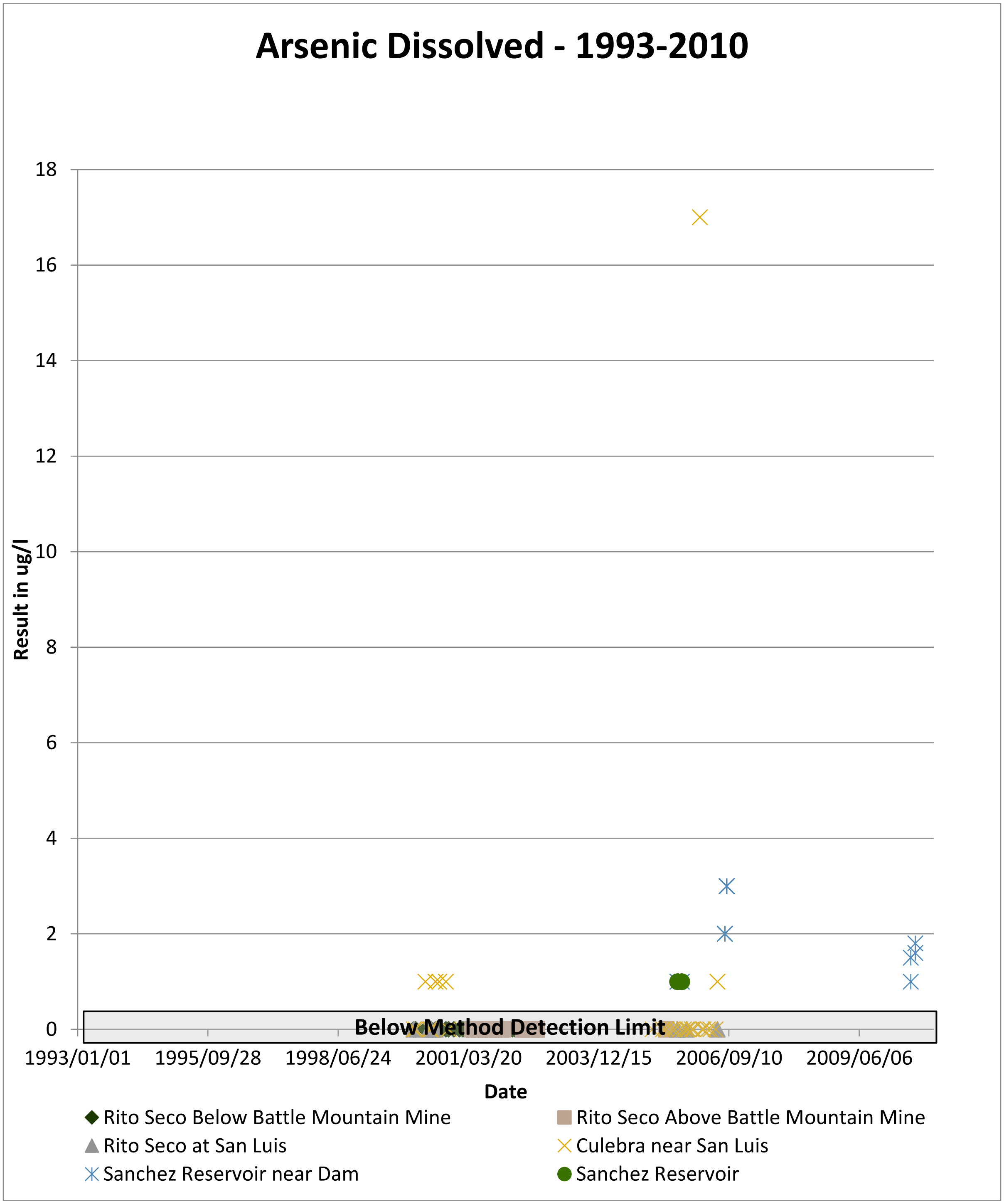


Figure 7-48 time-series plot of dissolved arsenic data in existing water quality datasets 1993-2010.

Cadmium

Cadmium samples were processed using method 200.15, 200.8(w), and historic samples with un-specified analytical method, the typical method detection limits are shown in Table 7-27.

Table 7-27 Typical method detection limits for Cadmium.

Cadmium (Cd) Typical Detection Limits	
Method	**Detection Limit**
200.15	0.2-0.4 ug/l
200.7	1 ug/l
200.8	0.03 ug/l

Cadmium Dissolved – TVS Chronic and Acute

$$Acute(warm) = (1.136672 - (\ln(hardness) * 0.041838))e^{0.9789*\ln(hardness)-3.443}$$

$$Acute(cold) = (1.136672 - (\ln(hardness) * 0.041838))e^{0.9789*\ln(hardness)-3.866}$$

$$Chronic = \left(1.101672 - (\ln(hardness) * 0.041838)\right) * e^{0.7977*\ln(hardness)-3.909}$$

Cadmium Total acute 5.0 ug/l

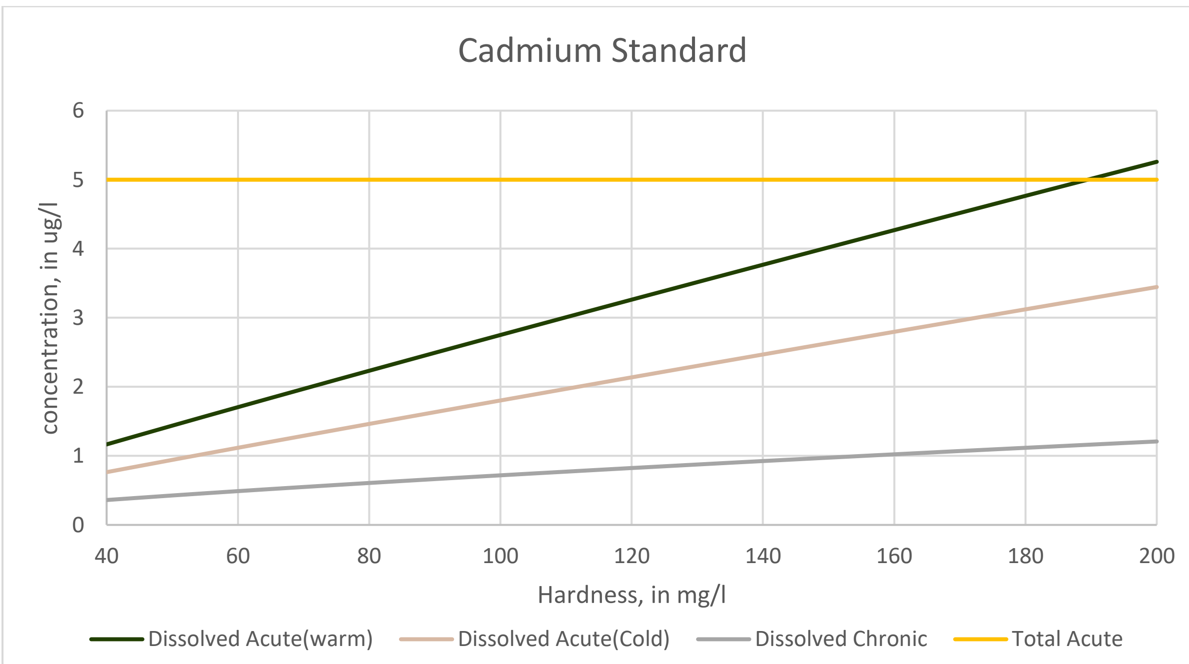


Figure 7-49 Hardness based water quality standards for cadmium.

All measurements of total cadmium were less than the recommended acute standard of 5 ug/l (Table 7-28 and Figure 7-50). The highest observed value of total cadmium occurred at Culebra near San Luis on January 31, 2005. This value was approximately 6 times that of the other samples at this site that were above the detection limit.

Table 7-28 Summary of total cadmium data in existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Total Cadmium, in ug/l

Site	Min	Max	Average	Standard Deviation	Coun t	Not Detected Count	First Date	Last Date
All Data	not detected	1.31			352	6	5/8/1979	5/31/2006
Rito Seco Below Battle Mountain Mine	not detected	0.6			4	44	4/24/1992	10/13/2004
Rito Seco Above Battle Mountain Mine	not detected	0.32			2	47	4/24/1992	10/13/2004
Culebra near San Luis	not detected	1.31			10	71	4/22/1992	5/31/2006
Rito Seco - Wrong Lat/Long	0.0003	0.001	0.0006	0.0004	4	0	5/8/1979	5/15/1980

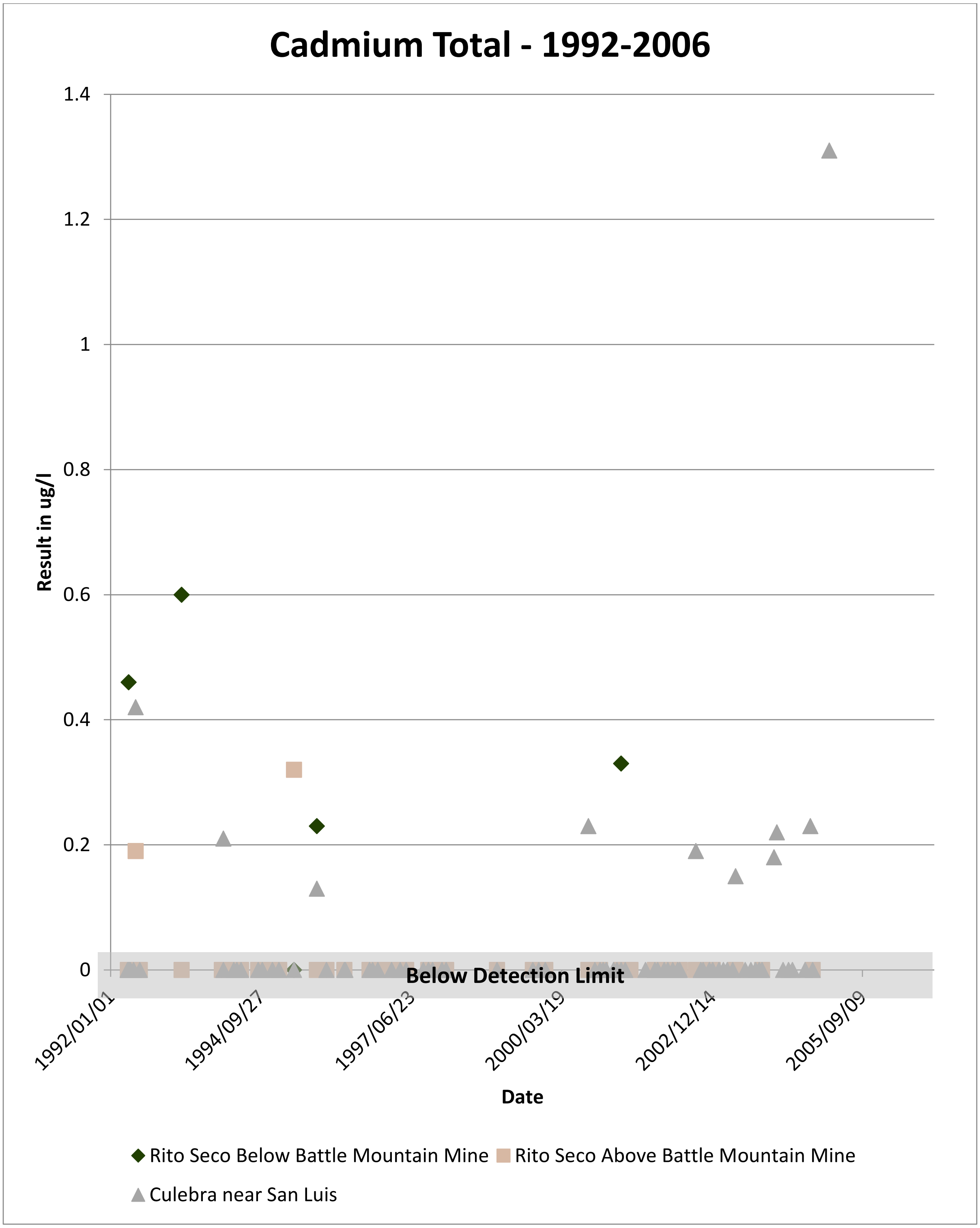


Figure 7-50 Time-series plot of total cadmium data in existing water quality datasets.

Dissolved cadmium was measured above the detection limit in samples from Rito Seco and Culebra near San Luis prior to April 16, 1993 and then again at Culebra near San Luis in January 2006. The observed trend appears to be related to the analytical method, values that were above the detection limit were analyzed with method 200.15, there were no samples with detectable values that were analyzed with EPA method 200.8.

Table 7-29 Summary of dissolved cadmium data in existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Dissolved Cadmium, in ug/l

Site	Min	Max	Average	Standard Deviation	Count above DL	Not Detected Count	First Date	Last Date
All Data	not detected	0.92	0.18	0.19	139	93	4/22/1992	6/8/2011
Rito Seco Above Battle Mountain Mine	not detected	0.26	0.26		1	23	4/24/1992	9/27/2005
Rito Seco Below Battle Mountain Mine	not detected	0.16	0.16	0	2	33	4/29/1992	6/8/2011
Rito Seco at San Luis	not detected	0.92	0.57	0.29	4	12	6/29/1992	6/8/2011
Culebra near San Luis	not detected	0.51	0.32	0.14	6	46	4/22/1992	6/8/2011
Sanchez Reservoir near Dam	not detected	not detected	--	--	0	23	6/25/1992	8/10/2010
Sanchez Reservoir	not detected	not detected	--	--	0	4	8/11/2005	9/13/2005

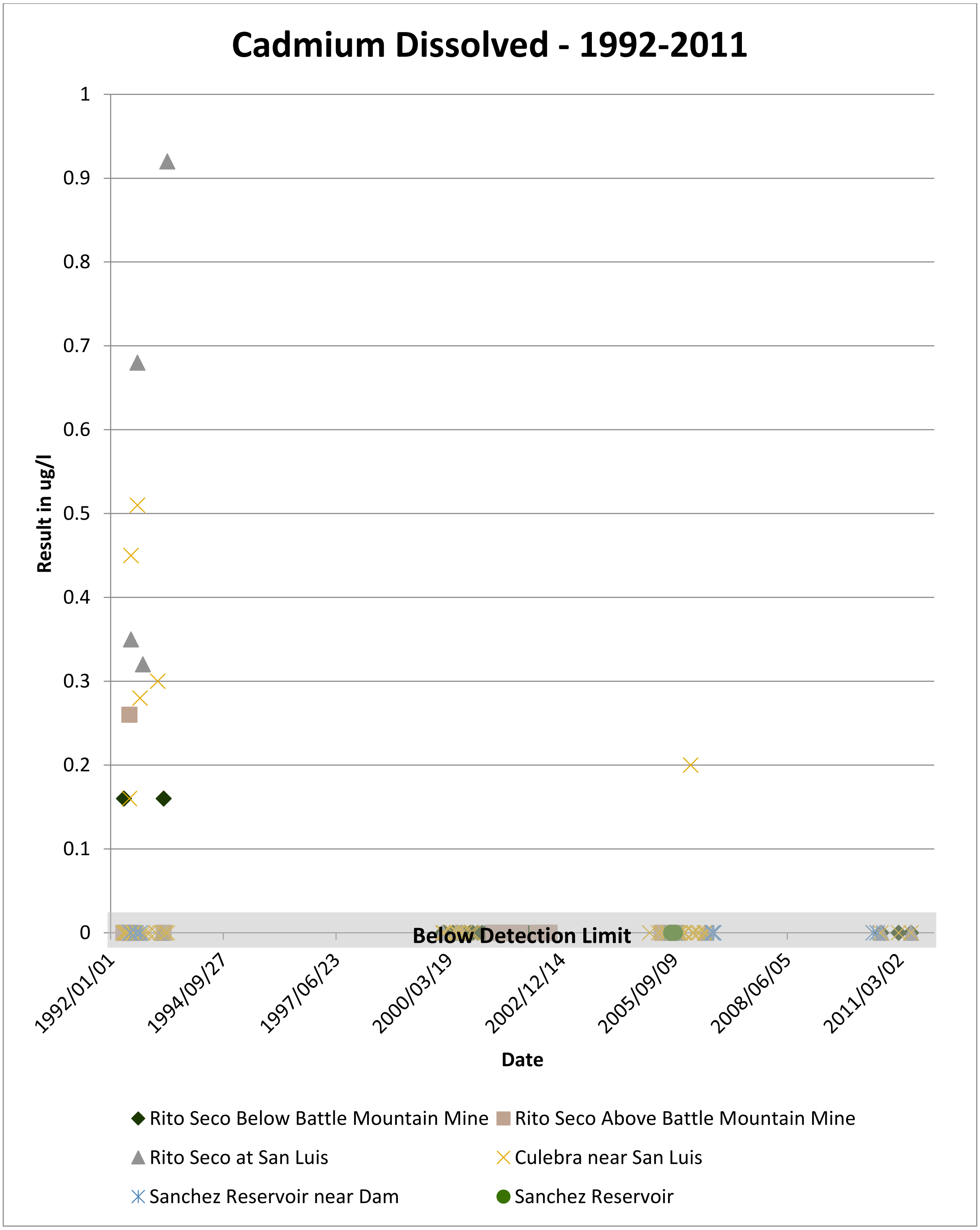

Cadmium Dissolved - 1992-2011
Result in ug/l
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Below Detection Limit
1992/01/01
1994/09/27
1997/06/23
2000/03/19
2002/12/14
2005/09/09
2008/06/05
2011/03/02
Date
Rito Seco Below Battle Mountain Mine
Rito Seco Above Battle Mountain Mine
Rito Seco at San Luis
Culebra near San Luis
Sanchez Reservoir near Dam
Sanchez Reservoir

Figure 7-51 Time-series plot of dissolved cadmium data in existing water quality datasets 1992-2011.

<u>Chromium</u>

No historical chromium data was found. Chromium standards are developed based on the form of chromium present. These standards are as follows:

Chromium III – Chronic TVS: $Chronic = e^{0.819[\ln(hardness)]+0.5340}$
Chromium III Total – acute 50 ug/l
Chromium VI – acute = 16 ug/l
Chromium VI – chronic = 11 ug/l

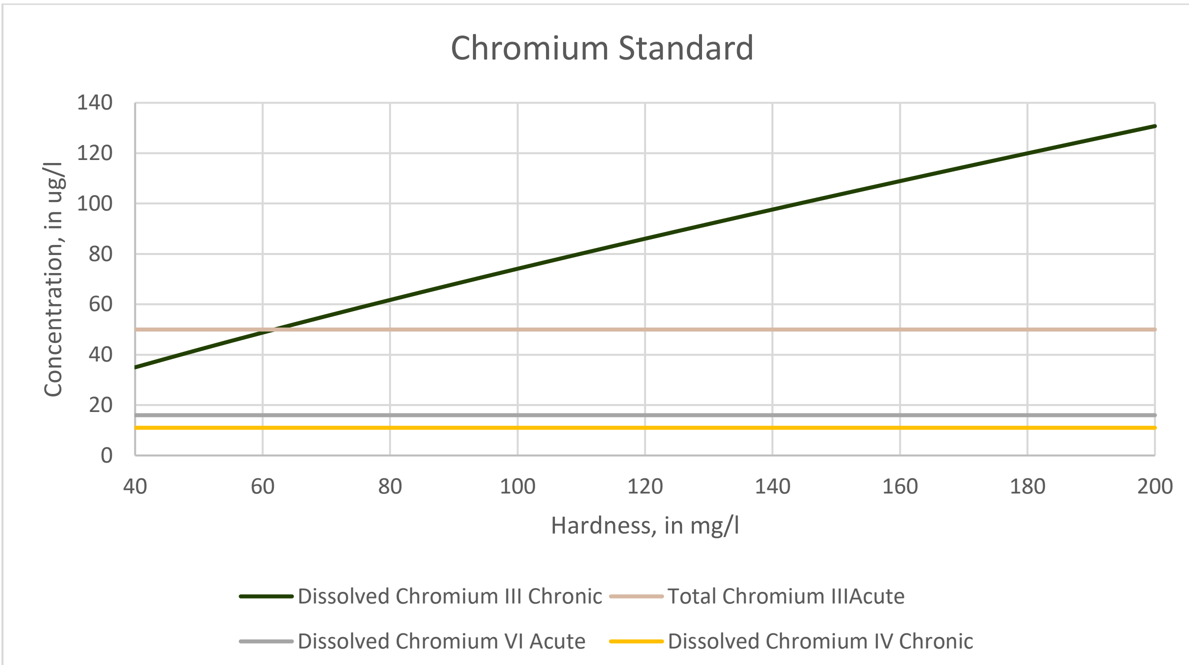


Figure 7-52 Hardness based chromium water quality standards.

Copper

Rito Seco, segment CORGR28 (Figure 7-1), is on the M&E list for dissolved copper. It is also on the Section 303(d) list for E. Coli. The dissolved copper listing was based on a single sample taken on June 8, 2011; where the measured dissolved copper level was 41 ug/l. Prior to this sample copper had not been measured above the detection limit in any sample since April 16, 1993. Rito Seco above Battle Mountain Mine was last sampled September 27, 2005. It is undetermined if the dissolved copper was also higher above the mine on June 8, 2011, because this site was not sampled on that date. Dissolved copper levels were historically similar in earlier samples where both sites were sampled, and all results were less than 2 ug/l. Existing dissolved copper results are listed in Table 7-31. Total copper samples included higher concentrations in the historic datasets, but total copper was not analyzed with the June 8, 2011, dissolved copper measurement.

Total copper samples were analyzed with method 200.15 except one sample from Rito Seco below Battle Mountain Mine and one from Rito Seco above Battle Mountain Mine on June 20, 2001, which was analyzed using method 200.8(W). Dissolved coper samples were analyzed with methods 200.15, 200.7(W), and 200.8(W). The typical method detection limits are listed in Table 7-30.

Table 7-30 Copper typical detection limits for analytical methods listed in the dataset.

Copper (Cu) Typical Detection Limits	
Method	**Detection Limit**
200.15	0.7-2 ug/l
200.7	3 ug/l
200.8	Total recoverable 0.02 ug/l, direct 0.01 ug/l

Dissolved acute and chronic TVS

$$Acute = e^{0.9422[\ln(hardness)]-1.7408}$$
$$Chronic = e^{0.8545[\ln(hardness)]-1.7428}$$

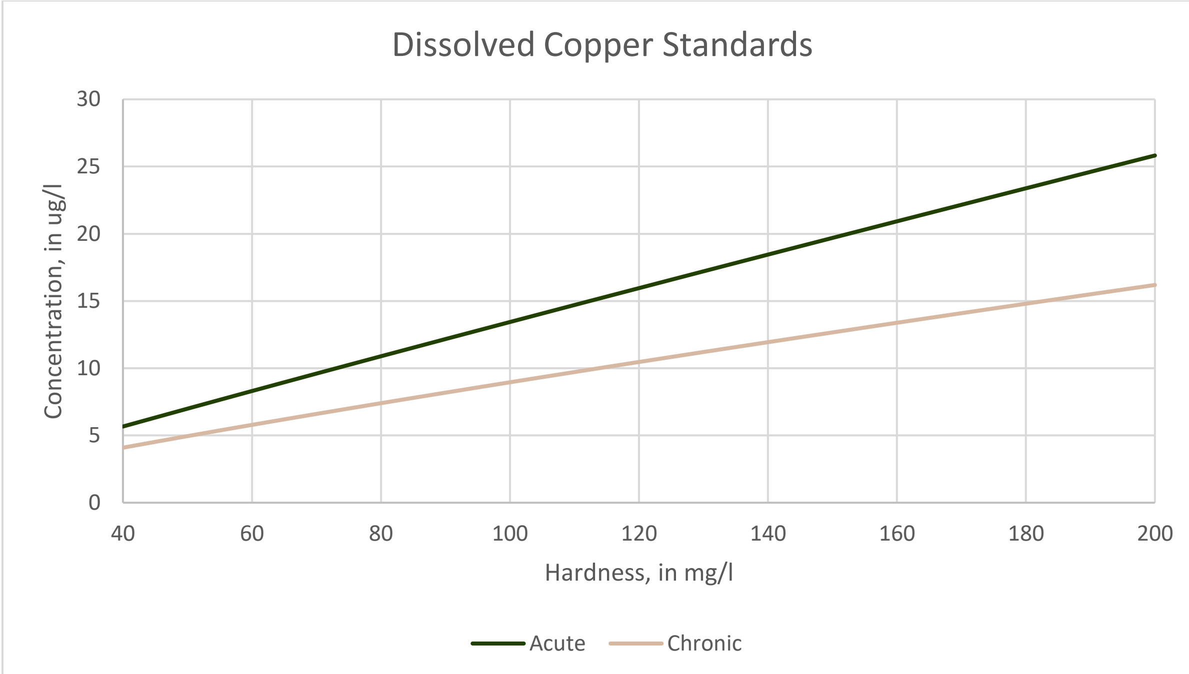


Figure 7-53 Hardness based dissolved copper standards.

Table 7-31 Summary of dissolved copper data in existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected, DL – detection limit]

Dissolved Copper, in ug/l

Site	Min	Max	Avg	Std. Dev.	Count above DL	Not Detected Count	First Date	Last Date
All Data	ND	41	--	--	131	99	4/22/1992	6/8/2011
Rito Seco Below Battle Mountain Mine	ND	41	--	--	7	32	4/24/1992	6/8/2011
Rito Seco Above Battle Mountain Mine	ND	3	--	--	5	19	4/24/1992	9/27/2005
Rito Seco at San Luis	ND	7	--	--	2	14	6/29/1992	6/8/2011
Culebra near San Luis	ND	2.2	--	--	2	51	4/22/1992	6/8/2011
Sanchez Reservoir near Dam	ND	ND	--	--	0	19	6/25/1992	8/23/2006
Sanchez Reservoir	ND	ND	--	--	0	4	8/11/2005	9/13/2005

Table 7-32 Rito Seco below Battle Mountain Mine and Rito Seco above Battle Mountain Mine existing dissolved copper data.

Sample Date	Rito Below Battle Mountain Mine Concentration in ug/l	Rito Seco Above Battle Mountain Mine Concentration in ug/l	Analytical Method
1992/04/24	1.7	*Non-detect	200.15
1992/04/29	1.9	1.2	200.15
1992/05/12	*Non-detect	*Non-detect	200.15
1992/06/02	1.8	1.5	200.15
1992/06/15	1.3	1.8	200.15
1992/07/13	1.1	1.1	200.15

Sample Date	Rito Below Battle Mountain Mine Concentration in ug/l	Rito Seco Above Battle Mountain Mine Concentration in ug/l	Analytical Method
1993/04/16	1.1	*Non-detect	200.15
2000/01/24	*Non-detect	Not Sampled	200.7(W)
2000/02/08	*Non-detect	Not Sampled	200.7(W)
2000/04/24	*Non-detect	Not Sampled	200.7(W)
2000/05/23	*Non-detect	Not Sampled	200.8(W)
2000/06/05	*Non-detect	Not Sampled	200.8(W)
2000/07/11	*Non-detect	Not Sampled	200.8(W)
2000/08/07	*Non-detect	Not Sampled	200.8(W)
2000/09/27	*Non-detect	Not Sampled	200.8(W)
2000/10/18	*Non-detect	Not Sampled	200.8(W)
2000/11/27	*Non-detect	Not Sampled	200.8(W)
2001/01/09	*Non-detect	Not Sampled	200.8(W)
2001/02/06	*Non-detect	Not Sampled	200.8(W)
2001/03/06	*Non-detect	Not Sampled	200.7(W)
2001/04/17	*Non-detect	*Non-detect	200.7(W)
2001/05/07	*Non-detect	*Non-detect	200.7(W)
2001/06/20	*Non-detect	*Non-detect	200.8(W)
2001/07/12	*Non-detect	*Non-detect	200.8(W)
2001/08/08	*Non-detect	*Non-detect	200.8(W)
2001/09/11	*Non-detect	*Non-detect	200.8(W)
2001/10/16	*Non-detect	*Non-detect	200.8(W)
2001/11/06	*Non-detect	*Non-detect	200.8(W)
2001/12/11	*Non-detect	*Non-detect	200.8(W)
2002/01/15	*Non-detect	Not Sampled	200.8(W)
2002/02/20	*Non-detect	Not Sampled	200.8(W)
2002/03/12	*Non-detect	Not Sampled	200.8(W)
2002/05/14	*Non-detect	*Non-detect	200.8(W)
2002/06/05	*Non-detect	*Non-detect	200.8(W)
2002/07/23	*Non-detect	*Non-detect	200.8(W)
2002/08/28	*Non-detect	*Non-detect	200.8(W)
2005/05/18	Not Sampled	*Non-detect	200.15
2005/09/27	Not Sampled	*Non-detect	200.8(W)
2010/09/16	*Non-detect	Not Sampled	200.7(W)
2011/02/17	*Non-detect	Not Sampled	200.7(W)
2011/06/08	41	Not Sampled	200.7(W)

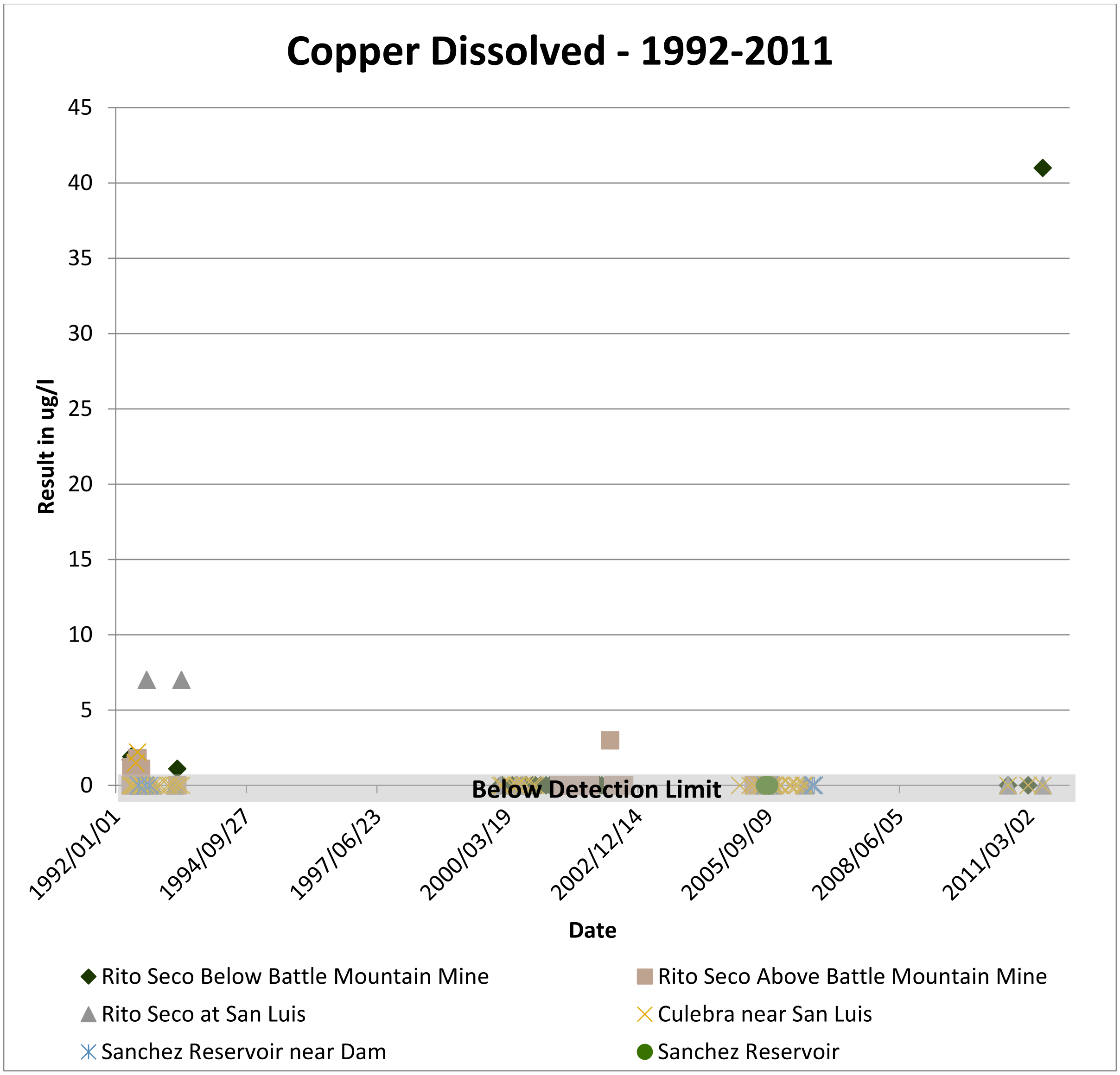


Figure 7-54 Time series plot of dissolved copper data in existing water quality datasets 1992-2011.

Table 7-33 Summary of total copper data from existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. dev. – standard deviation, ND – not detected]

Total Copper, in ug/l

Site	Min	Max	Avg	Std. Dev.	Count	ND Count	First Date	Last Date
All Data	ND	25.3	--	--	348	6	5/8/1979	5/31/2006
Rito Seco Below Battle Mountain Mine	ND	25.3	--	--	33	14	4/24/1992	10/13/2004
Rito Seco Above Battle Mountain Mine	ND	22.5	--	--	19	30	4/24/1992	10/13/2004
Culebra near San Luis	ND	23.1	--	--	39	41	4/22/1992	5/31/2006
Rito Seco - Wrong Lat/Long	0.005	0.008	0.006	0.002	4	0	5/8/1979	5/15/1980

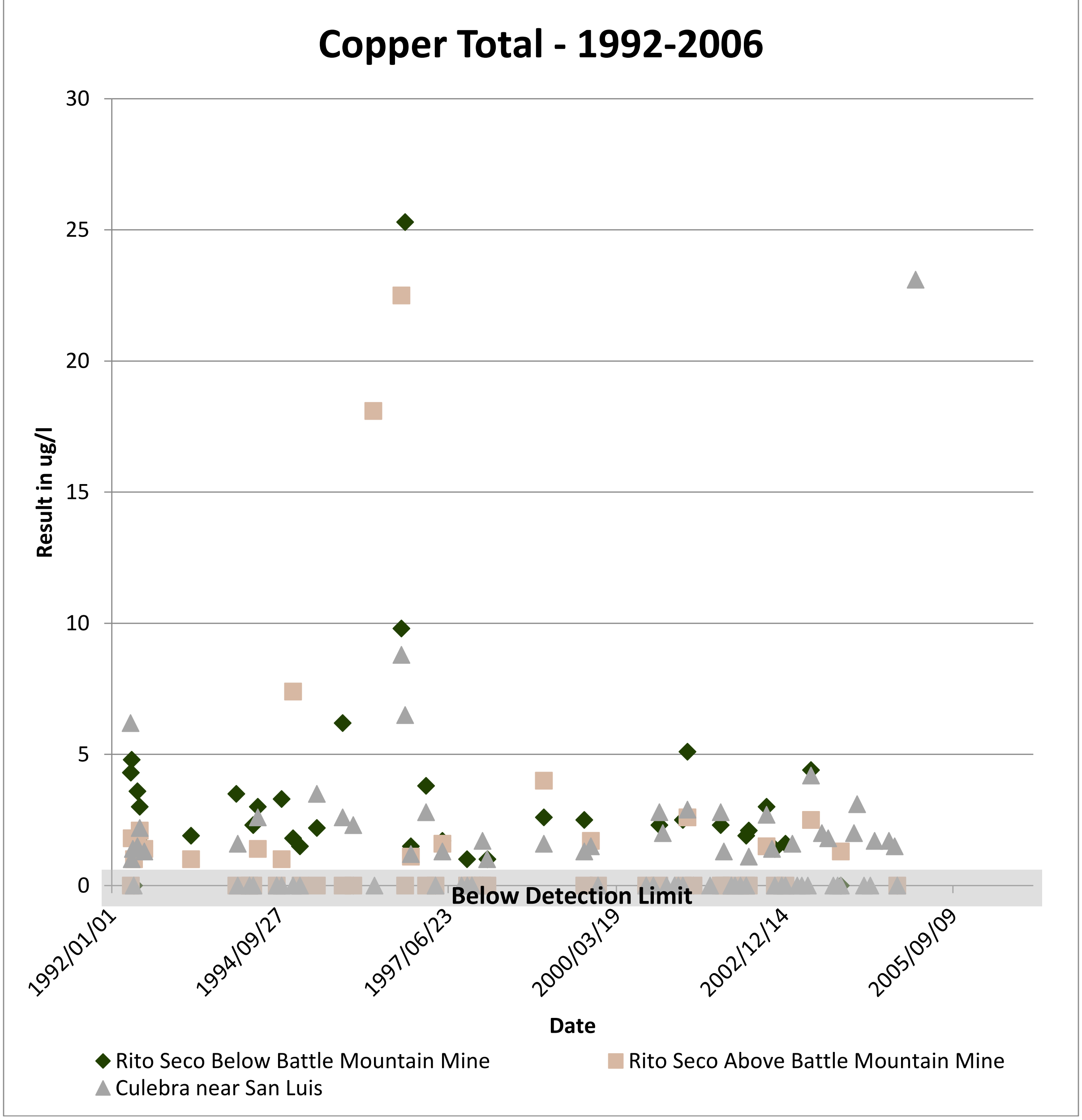


Figure 7-55 Time-series plot of total copper data in existing water quality datasets 1992-2006.

Iron

Total and dissolved iron samples were analyzed by method 200.7(W) and 200.15, the method detection limits are listed in Table 7-34. Iron has a chronic water quality standard for dissolved iron based on secondary drinking water standards is set at the less restrictive of either the existing quality as of January 1, 2000, or 300 µg/l. and a chronic standard for total iron of 1000 µg/l. The chronic water quality standard was exceeded in some of samples from Rito Seco above Battle Mountain Mine (Table 7-35 and Figure 7-56). The standards for total iron were exceeded in samples from Rito Seco above Battle Mountain Mine, Rito Seco below Battle Mountain Mine, and Culebra near San Luis (Table 7-33 and Figure 7-57). Total iron should be monitored based on historic exceedance of water quality standards.

Table 7-34 Iron typical method detection limits.

Iron (Fe) Typical Detection Limits

Method	Detection Limit
200.15	2-10 ug/l
200.7	30 ug/l

Table 7-35 Summary of dissolved iron data from existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, std. dev. – standard deviation, ND – not detected]

Dissolved Iron, in ug/l

Site	Min	Max	Avg	Std. dev.	Count	ND Count	First Date	Last Date
All Data	ND	340	--	--	210	1	4/22/1992	6/8/2011
Rito Seco Below Battle Mountain Mine	ND	290	--	--	34	5	4/24/1992	6/8/2011
Rito Seco Above Battle Mountain Mine	ND	340	--	--	20	4	4/24/1992	9/27/2005
Rito Seco at San Luis	61	200	135	51.4	9	0	1/24/2000	6/8/2011
Culebra near San Luis	ND	170	--	--	33	7	4/22/1992	6/8/2011
Sanchez Reservoir near Dam	ND	140	--	--	15	2	8/11/2005	8/10/2010
Sanchez Reservoir	61	61	61	0	4	0	8/11/2005	9/13/2005

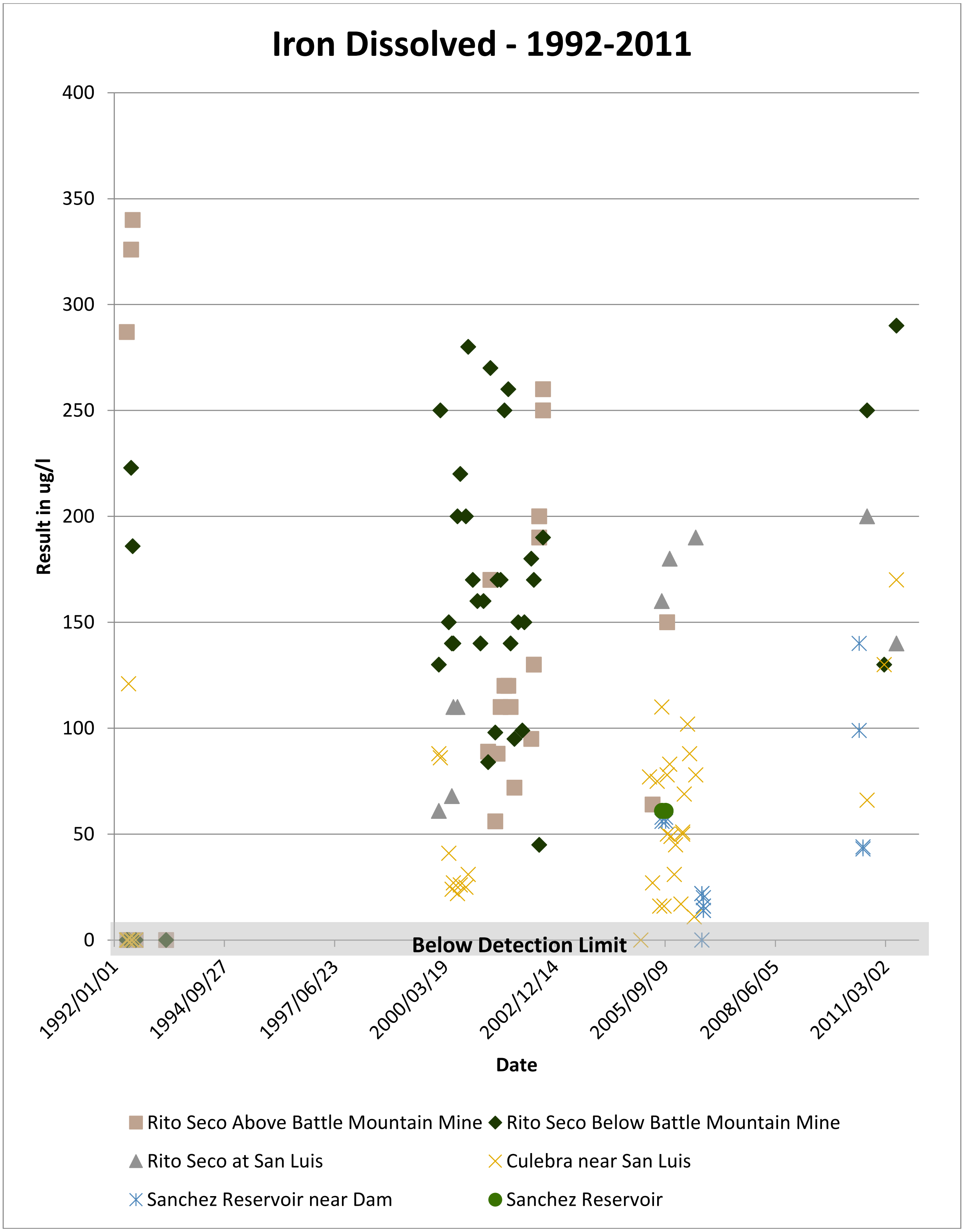


Figure 7-56 Time-series plot of dissolved iron data from existing water quality datasets.

Table 7-36 Summary of total iron data from existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, Std. Dev. – standard deviation, ND – not detected]

Total Iron, in ug/l

Site	Min	Max	Ave	Std. Dev.	Count	ND Count	First Date	Last Date
All Data	ND	20000	--	--	521	4	11/15/1979	6/8/2011
Rito Seco Below Battle Mountain Mine	280	4100	1034	666	79	0	4/24/1992	6/8/2011
Rito Seco Above Battle Mountain Mine	ND	1300	--	--	56	7	4/24/1992	9/27/2005
Rito Seco at San Luis	49	20000	2038	5020	16	0	6/29/1992	6/8/2011
Rito Seco - Wrong Lat/Long	0.17	470	157	271	3	0	11/15/1979	5/15/1980
Culebra near San Luis	ND	2900	--	--	109	5	4/22/1992	6/8/2011
Sanchez Reservoir near Dam	19	550	254	146	23	0	6/25/1992	8/10/2010
Sanchez Reservoir	120	210	165	52	4	0	8/11/2005	9/13/2005

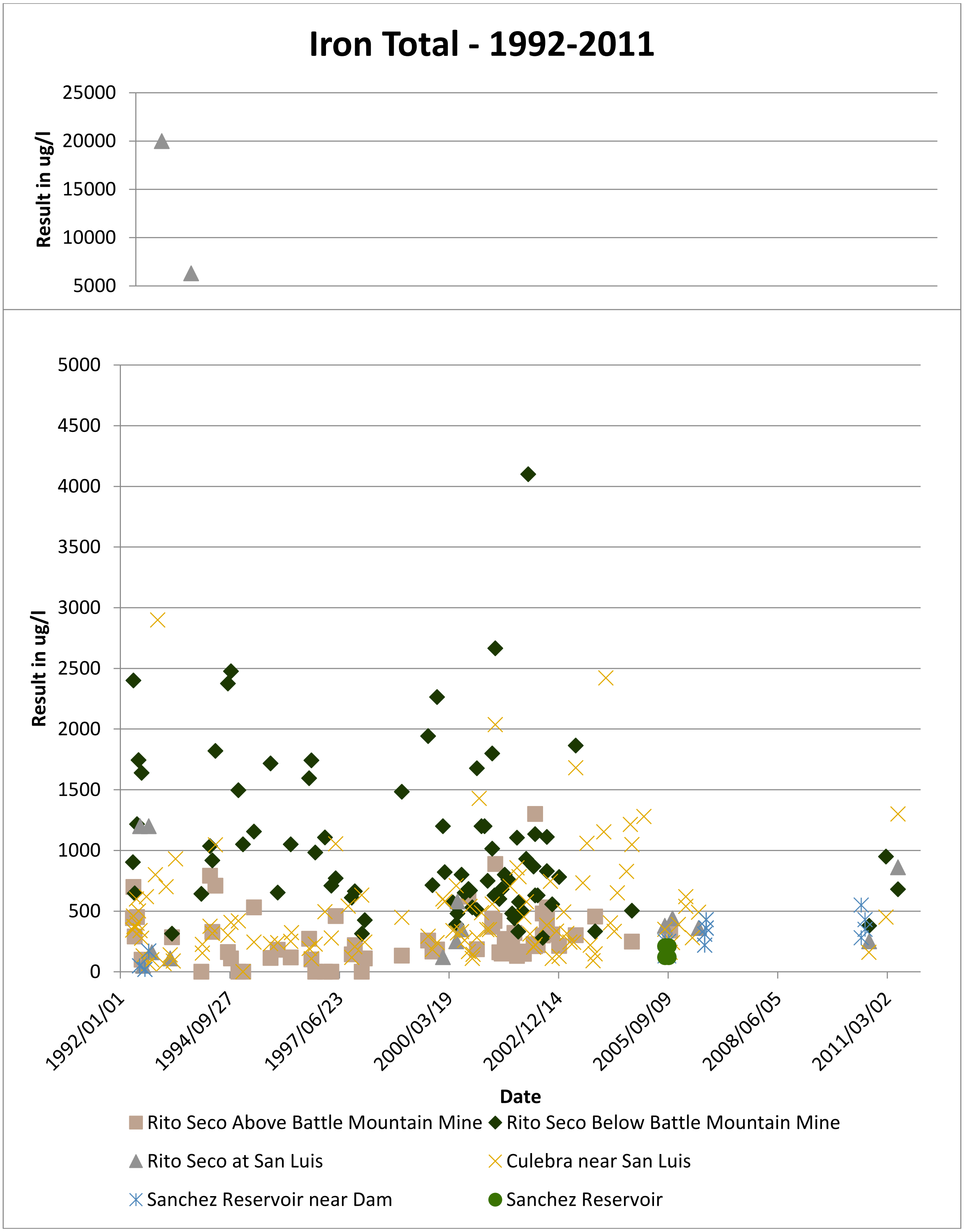


Figure 7-57 Time-series plot of total iron data from existing water quality datasets.

Lead

Lead enters drinking water primarily through corrosion of plumbing fixtures, including pipes, solder, and fittings, with minimal contribution from natural sources (WHO, 2016) since the restriction of lead use in fuels. Ingestion of lead can lead to behavioral and cognitive deficits, reproductive toxicity, and cancer with the most severe health effects observed in infants and small children (WHO, 2016). Within the existing datasets samples measured dissolved lead above the level of detection and 7 of 182 samples had measured concentrations of total lead above the detection limit.

Table 7-37 Typical method detection limits for lead.

Lead Detection Limits (Pb)	
Method	**Detection Limit**
200.15	2-4 ug/l
200.7	10 ug/l
200.8	Total recoverable 0.05 ug/l direct 0.02 ug/l

Dissolved acute and chronic TVS

$$Acute = (1.46203 - [\ln(hardness) * (0.145712)]) * e^{1.273[\ln(hardness)]-1.46}$$

$$Chronic = (1.46203 - [\ln(hardness) * (0.145712)]) * e^{1.273[\ln(hardness)]-4.705}$$

Total acute 50 ug/l

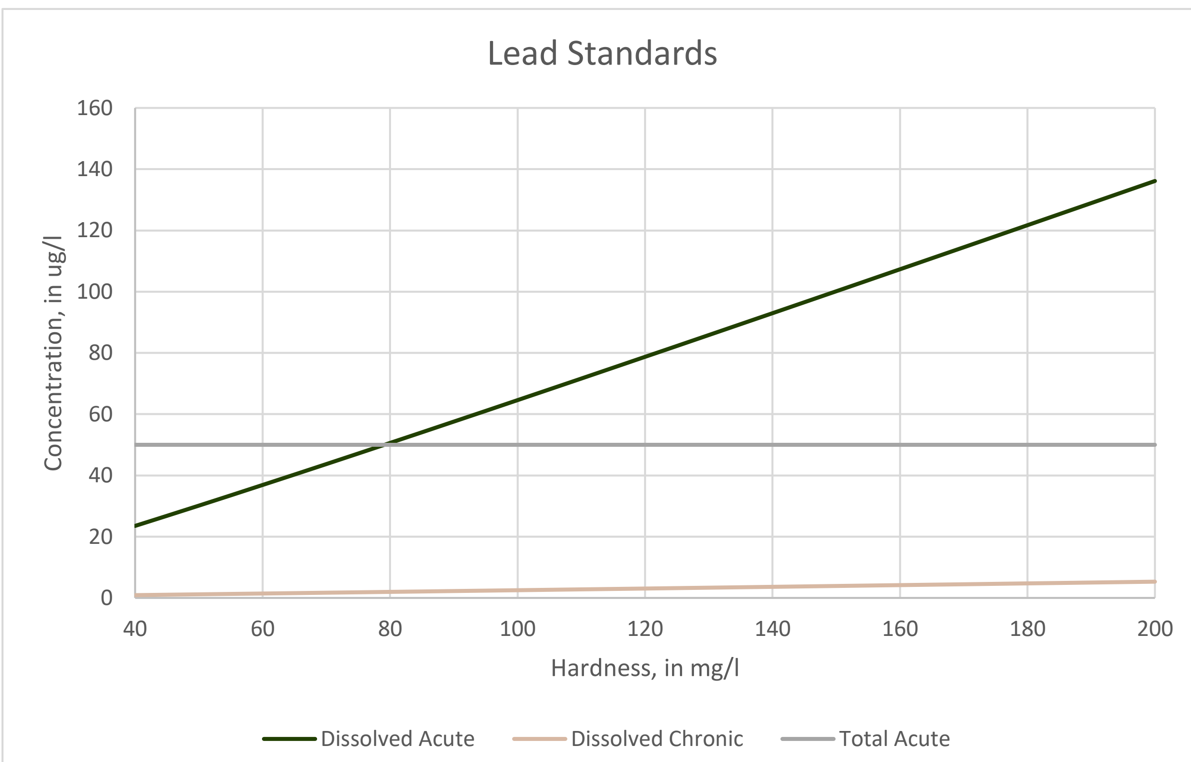


Figure 7-58 Hardness based lead water quality standards.

Table 7-38 Summary of dissolved lead data in existing water quality datasets. [max – maximum, min – minimum, ND – not detected]

Dissolved Lead, in ug/l

Site	Min	Max	ND Count	First Date	Last Date
All Data	ND	ND	159	4/22/1992	6/8/2011
Rito Seco Below Battle Mountain Mine	ND	ND	39	4/24/1992	6/8/2011
Rito Seco Above Battle Mountain Mine	ND	ND	24	4/24/1992	9/27/2005
Rito Seco at San Luis	ND	ND	16	6/29/1992	6/8/2011
Culebra near San Luis	ND	ND	53	4/22/1992	6/8/2011
Sanchez Reservoir near Dam	ND	ND	23	6/25/1992	8/10/2010
Sanchez Reservoir	ND	ND	4	8/11/2005	9/13/2005

Table 7-39 Summary of total lead data in existing water quality datasets. [DL – detection limit, min – minimum, max – maximum, avg -average, std. dev. – standard deviation]

Total Lead, in ug/l

Site	Min	Max	Ave	Std. dev.	Count Above DL	ND Count	First Date	Last Date
All Data	ND	3.6	--	--	7	175	5/8/1979	5/31/2006
Rito Seco Below Battle Mountain Mine	ND	3.6	--	--	2	46	4/24/1992	10/13/2004
Rito Seco Above Battle Mountain Mine	ND	ND	--	--	0	49	4/24/1992	10/13/2004
Culebra near San Luis	ND	2.2	--	--	1	80	4/22/1992	5/31/2006
Rito Seco - Wrong Lat/Long	0.009	0.01	0.010	0.001	4	0	5/8/1979	5/15/1980

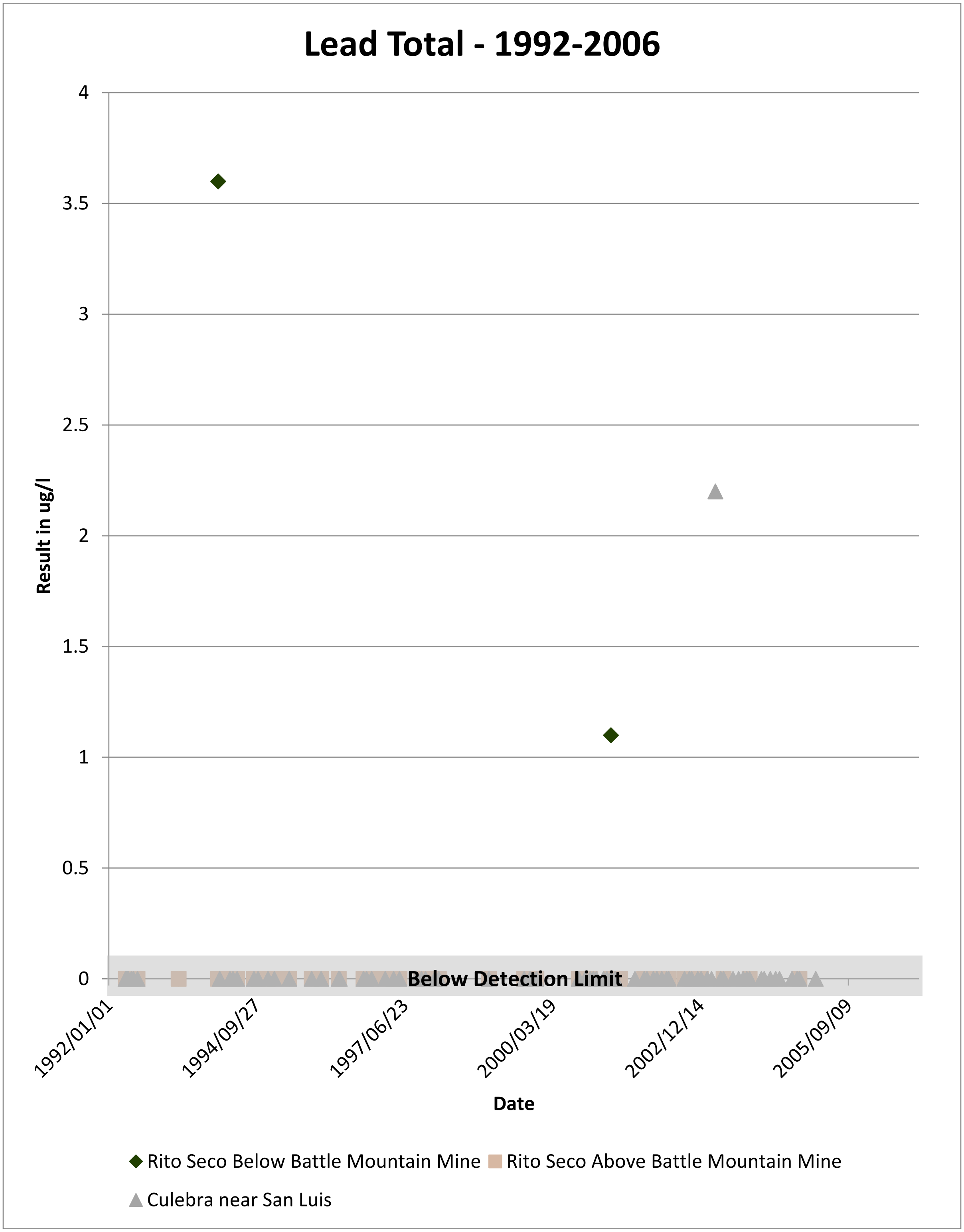


Figure 7-59 Time-series plot of total lead data from existing water quality datasets 1992-2006.

Manganese

Manganese is naturally occurring and can be found in soil, air, and water. Manganese is an essential nutrient but can be hazardous in high concentrations (United States Environmental Protection Agency, 2004). Manganese compounds have been associated with ferroalloy production facilities, coke ovens, and power plants. The manganese detection limits are provided in Table 7-40, approximately 89 percent of the samples were above the detection limit.

Table 7-40 Typical method detection limits for Manganese.

Manganese Detection Limits (Mn)	
Method	**Detection Limit**
200.15	0.08-.09 ug/l
200.7	0.1 ug/l
200.8	Total recoverable 0.02 ug/l, direct 0.04 ug/l

The numeric standards for manganese are (Regulation No. 36 - Classification and Numeric Standards for Rio Grande Basin, p. 6):

$$Acute = e^{0.3331[\ln(hardness)]+6.4676}$$

$$Chronic = e^{0.3331[\ln(hardness)]+5.8743}$$

Secondary drinking water standard (dissolved) = 50µg/l

These values are plotted against hardness in Figure 7-60, the secondary drinking water standards are much lower than the numeric standards for manganese. Although many of the samples exceeded the secondary drinking water standard, all samples were less than both the Acute and Chronic water quality standards (Table 7-41).

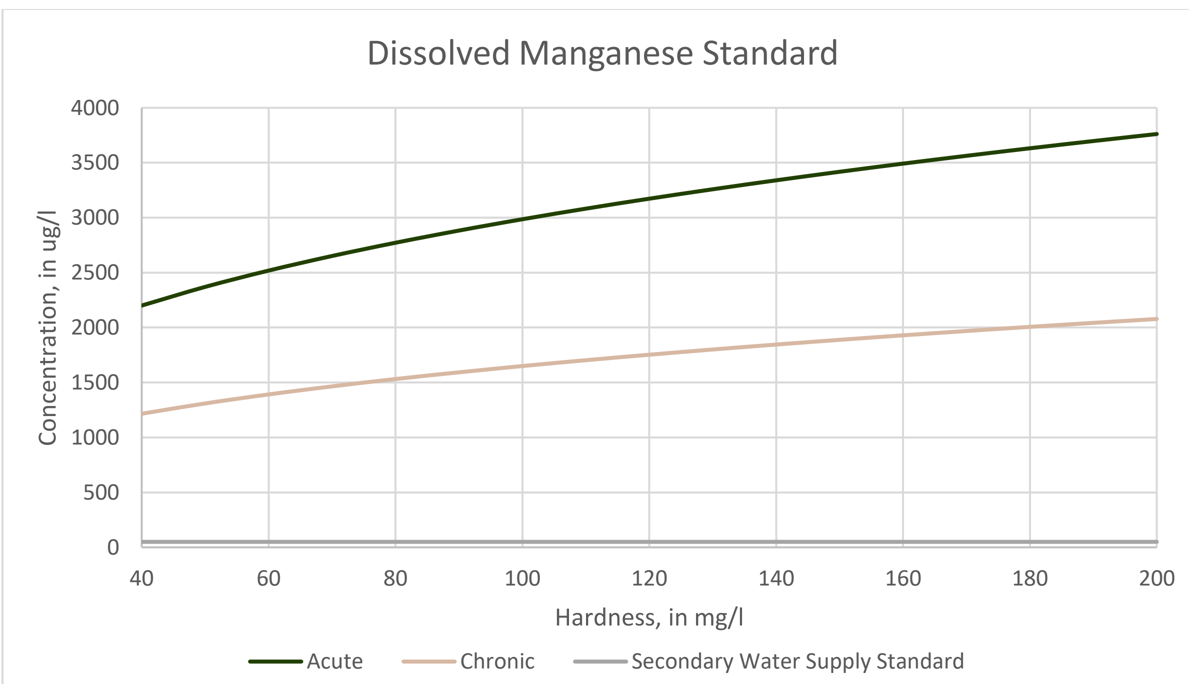


Figure 7-60 Dissolved manganese water quality standards (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018).

Table 7-41 Dissolved manganese existing data summary. [DL – detection limit, ND – not detected, Min – minimum, Max – maximum, Avg – average, std. dev. Standard deviation]

Dissolved Manganese, in ug/l

Site	Min	Max	Ave	Std. dev.	Count above DL	ND Count	First Date	Last Date
All Data	ND	500	--	--	143	15	4/22/1992	6/8/2011
Rito Seco Below Battle Mountain Mine	ND	210	--	--	38	1	4/24/1992	6/8/2011
Rito Seco Above Battle Mountain Mine	ND	47	--	--	17	7	4/24/1992	9/27/2005
Rito Seco at San Luis	ND	130	--	--	13	3	6/29/1992	6/8/2011
Culebra near San Luis	ND	97	--	--	50	2	4/22/1992	6/8/2011
Sanchez Reservoir near Dam	ND	500	--	--	21	2	6/25/1992	8/10/2010
Sanchez Reservoir	16	16	16	0	4	0	8/11/2005	9/13/2005

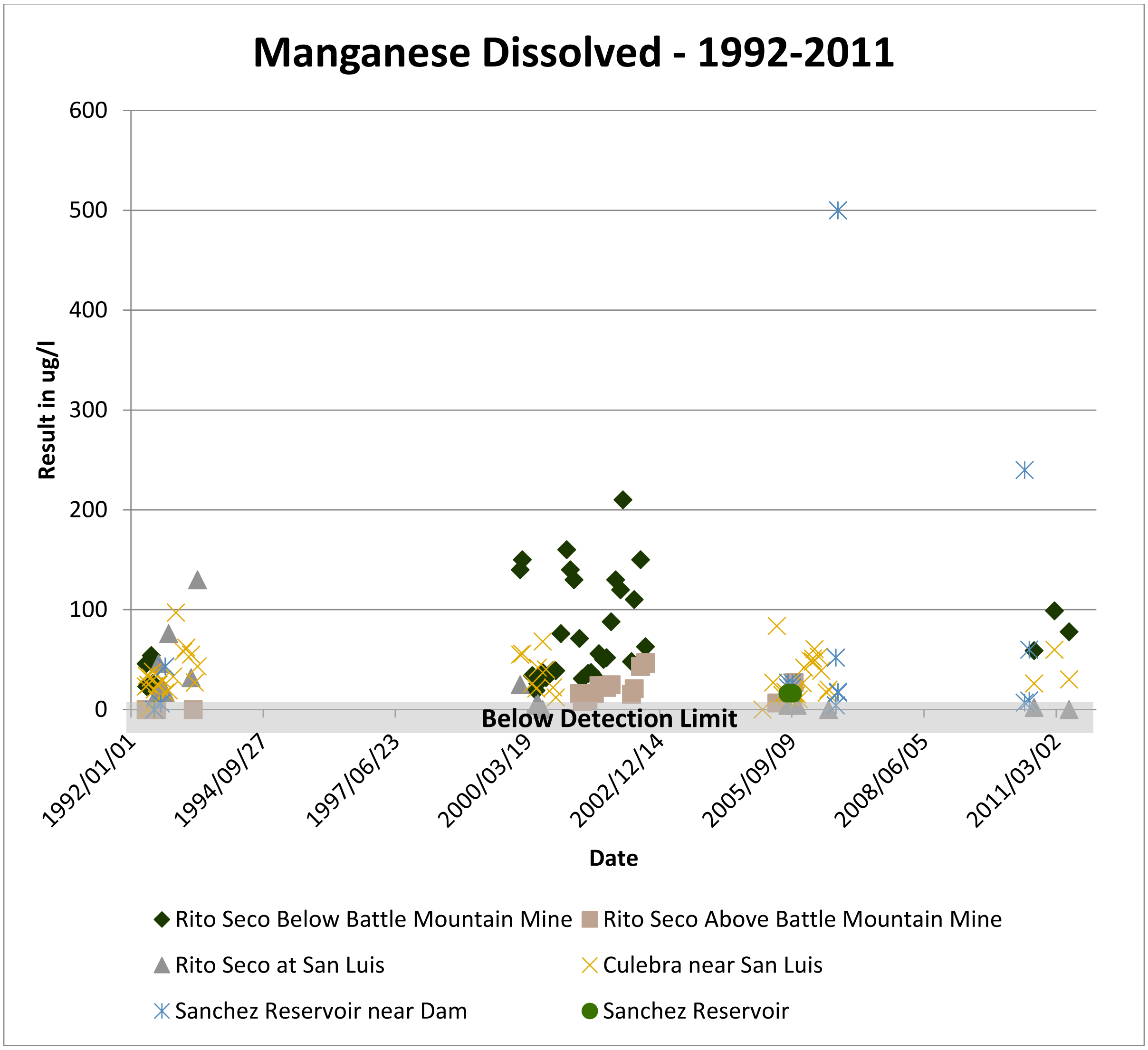


Figure 7-61 Time-series plot of existing dissolved manganese data from 1992-2011.

Table 7-42 Existing total manganese data summary. [DL – detection limit, Min – minimum, Max – maximum, avg – average, std. dev. – standard deviation]

Total Manganese, in ug/l

Site	Min	Max	Ave	Std. dev	Count above DL	Not Detected Count	First Date	Last Date
All Data	0.05	759	--	--	158	20	5/8/1979	1/31/2005
Rito Seco Below Battle Mountain Mine	15	463	140	91.9	48	0	4/24/1992	10/13/2004
Rito Seco Above Battle Mountain Mine	ND	93	--	--	30	19	4/24/1992	10/13/2004
Culebra near San Luis	ND	759	--	--	76	1	4/22/1992	1/31/2005

Rito Seco - Wrong Lat/Long	0.05	0.5	0.29	0.24	4	0	5/8/1979	5/15/1980

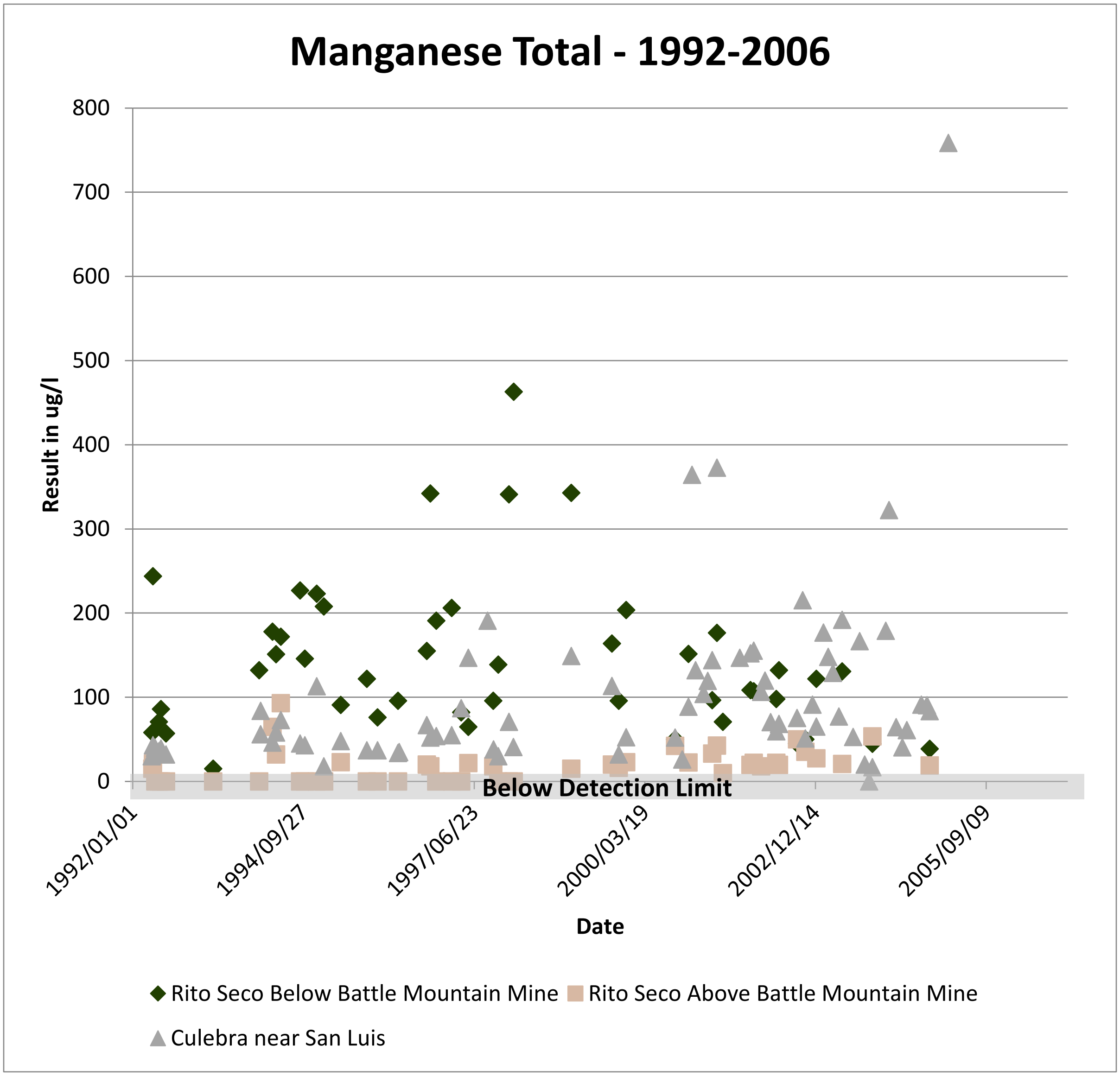


Figure 7-62 Time series plot of existing total manganese data from 1992-2006.

<u>Mercury</u>
Mercury is a characteristic that requires ultra-clean processing to enable the measurement of sample concentration, and as such, requires specially cleaned equipment and laboratory analysis specializing in low level mercury detection. As a result many of the water quality samples that were processed alongside the standard suite of metals characteristics are below the method detection limit because these samples were processed alongside the standard suite of metals characteristics. Sample collected by Tetra Tech for the June 2008 Sanchez Mercury TMDL study were collected and analyzed using ultra-clean sampling and analysis providing results that are within the detection limit of the selected method.

The recommended water quality standard for chronic concentration of total mercury is 0.01 ug/l.

Table 7-43 Mercury typical method detection limits.

Mercury (Hg) Typical Detection Limits

Method	**Detection Limit**
200.15	2-3 ug/l
200.7	7 ug/l
200.8	No suitable
Ultra-clean	0.2 ng/l (0.002 ug/l)

Sanchez reservoir was Section 303(d) listed in 2008, with a high priority for development of a TMDL because the mercury concentration in fillets, of 20 inch or greater walleye, exceeded the target average concentration on 0.3 mg/kg methylmercury (Tetra Tech, Inc, June 2008). Even though the level of mercury in the water is low enough to require ultra-clean sampling (Table 7-44) and analysis the concentrations are sufficiently high enough to lead to bioaccumulation in fish. Fish tissue mercury levels lead to the Section 303(d) listing of Sanchez Reservoir resulting in a Total Maximum Daily Load study (Tetra Tech, Inc, June 2008).

The TMDL study was completed to identify sources of mercury and determine actions likely to improve conditions in Sanchez Reservoir. This study found that the major contributor of mercury to the reservoir was likely from atmospheric deposition with some potential contribution from improper disposal of waste including fluorescent light bulbs, household detergents and cleaners, batteries, mercury switches in appliances and automobiles. Atmospheric deposition can enter a body of water directly by deposition within the reservoir, dissolved in the water that is diverted to the reservoir, and with the sediments carried by the water. Sediment reduction was recommended to reduce mercury loading on the reservoir. Tetra Tech determined that an annual loading of mercury to attain this standard would be 154 grams/year and the current loading was 495 grams/year of which approximately 389 grams/year was derived from nonpoint sources within the watershed primarily from atmospheric deposition (Tetra Tech, Inc, June 2008).

During the development of the TMDL elevated mercury concentrations were detected at the inlet to Sanchez Reservoir during the August 1999 sampling event and total mercury concentration was lower in August than in June in 13 of the samples, and greater in August than in June in 6 of the samples (Figure 7-63).

Table 7-44 Existing dissolved mercury data. DL-detection limit, ND – not detected, std. dev. – standard deviation. Note concentrations reported in ug/l to be consistent with TMDL report (Tetra Tech, Inc, June 2008) and water quality standards reporting.

Dissolved Mercury, in µg/l

Site	Min	Max	Average	Std. dev	Count above DL	ND Count	First Date	Last Date
All Data	--	0.00398	--	--	46	70	5/28/1992	8/28/2002
Rito Seco Below Battle Mountain Mine	--	--	--	--	0	23	5/23/2000	8/28/2002
Rito Seco Above Battle Mountain Mine	--	--	--	--	0	13	6/20/2001	8/28/2002
Rito Seco at San Luis	--	--	--	--	0	10	6/29/1992	7/11/2000
Culebra near San Luis	--	--	--	--	0	19	5/28/1992	10/18/2000
Sanchez Reservoir near Dam	--	--	--	--	0	4	6/25/1992	9/17/1992
Sanchez Reservoir	--	--	--	--	0	1	8/13/1992	8/13/1992
Sanchez Canal above Inlet	0.00175	0.00074	0.00125	0.00071	2	0	6/3/1999	8/2/1999
Ventero Creek - Outlet Sanchez Reservoir	0.00080	0.00065	0.00073	0.00011	2	0	6/3/1999	8/3/1999
Sanchez Reservoir between Island and West Side	0.00076	0.00026	0.00051	0.00020	4	0	6/17/1999	8/5/1999
Sanchez Reservoir - Sanchez Canal Inlet	0.00094	0.00054	0.00074	0.00017	4	0	6/17/1999	8/6/1999
Sanchez Reservoir Ventero Inlet	0.00075	0.00051	0.00063	0.00010	4	0	6/6/1999	8/6/1999
Unnamed Tributary to Alamosito Creek	0.00132	0.00132	0.00132	--	1	0	8/2/1999	8/2/1999
Torcido Creek - Middle	0.00058	0.00058	0.00058	--	1	0	8/3/1999	8/3/1999
Ventero Creek near inlet Sanchez Reservoir	0.00131	0.00104	0.00118	0.00019	2	0	6/6/1999	8/6/1999
Vallejos Creek	0.00208	0.00062	0.00135	0.00103	2	0	6/4/1999	8/2/1999
Sanchez Canal - Middle above San Francisco Creek	0.00143	0.00064	0.00104	0.00056	2	0	6/3/1999	8/2/1999
San Francisco Creek at Beaver Pond	0.00273	0.00082	0.00178	0.00135	2	0	6/4/1999	8/2/1999
Alamosito Creek	0.00388	0.00104	0.00246	0.00201	2	0	6/4/1999	8/2/1999
San Francisco Creek - Seep	0.00054	0.00049	0.00052	0.00004	2	0	6/4/1999	8/2/1999
Upper Torcido Creek	0.00398	0.00126	0.00262	0.00192	2	0	6/4/1999	8/3/1999
Lower Torcido Creek	0.00272	0.00272	0.00272	--	1	0	6/5/1999	6/5/1999
Lower Jaroso Creek	0.00135	0.00135	0.00135	--	1	0	8/4/1999	8/4/1999
Jaroso Creek - Beaver Pond	0.00243	0.00152	0.00198	0.00064	2	0	6/4/1999	8/4/1999

Site	Min	Max	Average	Std. dev	Count above DL	ND Count	First Date	Last Date
Cuates Creek	0.00337	0.00109	0.00223	0.00161	2	0	6/4/1999	8/4/1999
UT Ventero Creek	0.00233	0.00105	0.00169	0.00091	2	0	6/5/1999	8/4/1999
Willow Creek	0.00323	0.00292	0.00308	0.00022	2	0	6/5/1999	8/4/1999
Culebra Creek at Sanchez Canal	0.00127	0.0008	0.00104	0.00033	2	0	6/3/1999	8/2/1999
Ventero Creek Pond	0.00212	0.00165	0.00189	0.00033	2	0	6/5/1999	8/4/1999

Table 7-45 Summary of existing total mercury data. DL-detection limit, ND – not detected

Total Mercury, in µg/l

Site	Min	Max	Average	Standard Deviation	Count above DL	ND Count	First Date	Last Date
All Data	0.0004	0.0107	--	--	46	15	8/13/1992	3/20/2002
Rito Seco Below Battle Mountain Mine	ND	ND	--	--	0	6	1/24/2000	5/7/2001
Rito Seco Above Battle Mountain Mine	ND	ND	--	--	0	2	4/17/2001	5/7/2001
Rito Seco at San Luis	ND	ND	--	--	0	1	1/24/2000	1/24/2000
Culebra near San Luis	ND	ND	--	--	0	3	1/24/2000	4/24/2000
Sanchez Reservoir near Dam	ND	ND	--	--	0	2	8/13/1992	9/17/1992
Sanchez Reservoir	ND	ND	--	--	0	1	8/13/1992	8/13/1992
Snow	0.00390	0.00390	0.00390	--	1	0	3/20/2002	3/20/2002
Sanchez Canal above Inlet	0.00329	0.00141	0.00235	0.00133	2	0	6/3/1999	8/2/1999
Ventero Creek - Outlet Sanchez Reservoir	0.00103	0.00100	0.00102	0.00002	2	0	6/3/1999	8/3/1999
Sanchez Reservoir between Island and West Side	0.00156	0.00064	0.00095	0.00041	4	0	6/17/1999	8/5/1999
Sanchez Reservoir - Sanchez Canal Inlet	0.00839	0.00074	0.00283	0.00372	4	0	6/17/1999	8/6/1999
Sanchez Reservoir Ventero Inlet	0.00075	0.00062	0.00069	0.00005	4	0	6/6/1999	8/6/1999
Unnamed Tributary to Alamosito Creek	0.00458	0.00458	0.00458	--	1	0	8/2/1999	8/2/1999
Torcido Creek - Middle	0.00062	0.00062	0.00062	--	1	0	8/3/1999	8/3/1999

Site	Min	Max	Average	Standard Deviation	Count above DL	ND Count	First Date	Last Date
Ventero Creek near inlet Sanchez Reservoir	0.00158	0.00108	0.00133	0.00035	2	0	6/6/1999	8/6/1999
Vallejos Creek	0.00324	0.00086	0.00205	0.00168	2	0	6/4/1999	8/2/1999
Sanchez Canal - Middle above San Francisco Creek	0.00243	0.00112	0.00178	0.00093	2	0	6/3/1999	8/2/1999
San Francisco Creek at Beaver Pond	0.00703	0.00161	0.00432	0.00383	2	0	6/4/1999	8/2/1999
Alamosito Creek	0.01070	0.00148	0.00609	0.00652	2	0	6/4/1999	8/2/1999
San Francisco Creek - Seep	0.00074	0.00040	0.00057	0.00024	2	0	6/4/1999	8/2/1999
Upper Torcido Creek	0.00624	0.00248	0.00436	0.00266	2	0	6/4/1999	8/3/1999
Lower Torcido Creek	0.00348	0.00348	0.00348	--	1	0	6/5/1999	6/5/1999
Lower Jaroso Creek	0.00351	0.00351	0.00351	--	1	0	8/4/1999	8/4/1999
Jaroso Creek - Beaver Pond	0.00760	0.00304	0.00532	0.00322	2	0	6/4/1999	8/4/1999
Cuates Creek	0.00341	0.00132	0.00237	0.00148	2	0	6/4/1999	8/4/1999
UT Ventero Creek	0.00282	0.00118	0.00200	0.00116	2	0	6/5/1999	8/4/1999
Willow Creek	0.00665	0.00435	0.00550	0.00163	2	0	6/5/1999	8/4/1999
Culebra Creek at Sanchez Canal	0.00180	0.00157	0.00169	0.00016	2	0	6/3/1999	8/2/1999

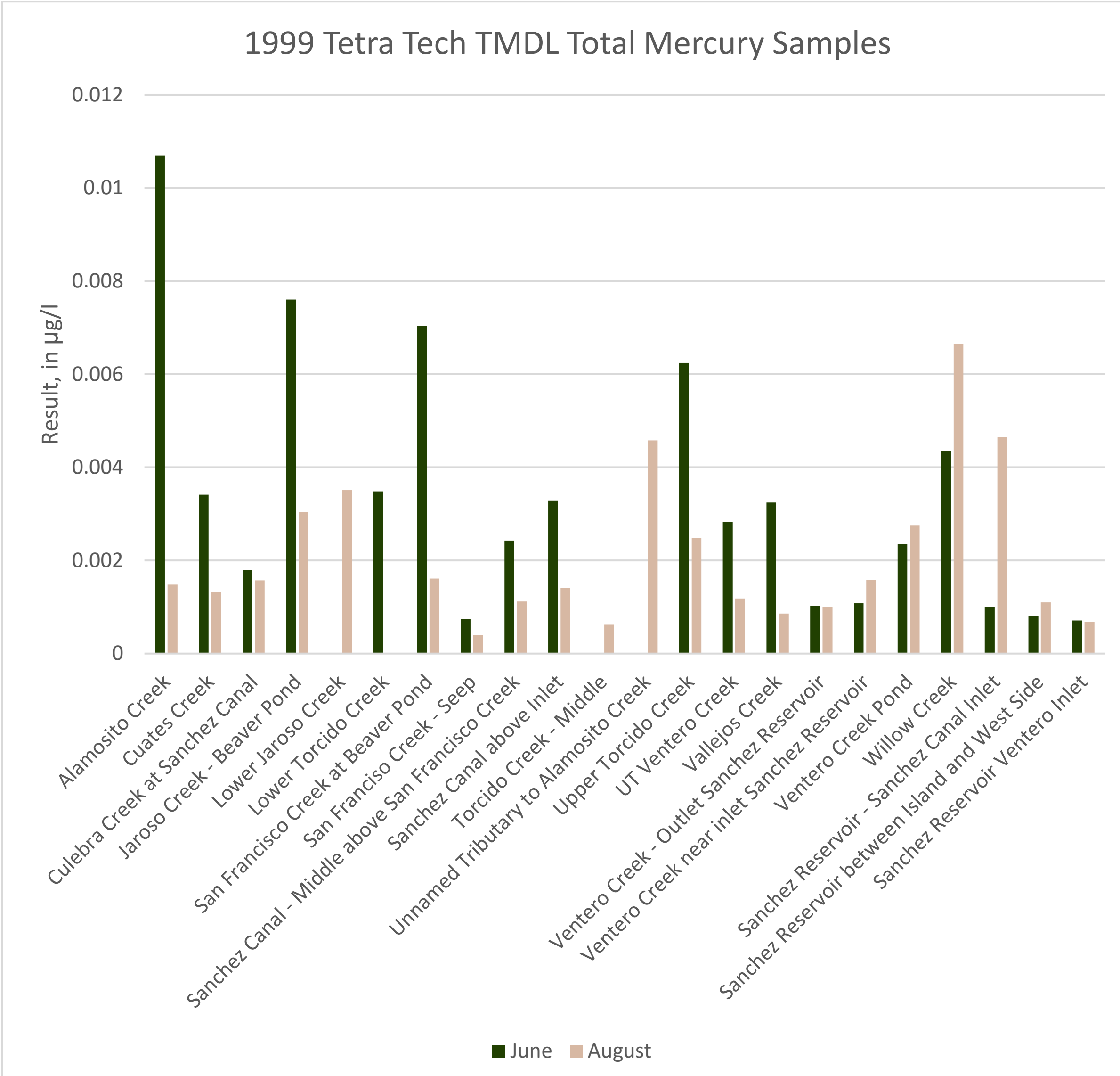


Figure 7-63 Tetra Tech 1999 Total Mercury sample results for stream and wetland sites (Tetra Tech, Inc, June 2008).

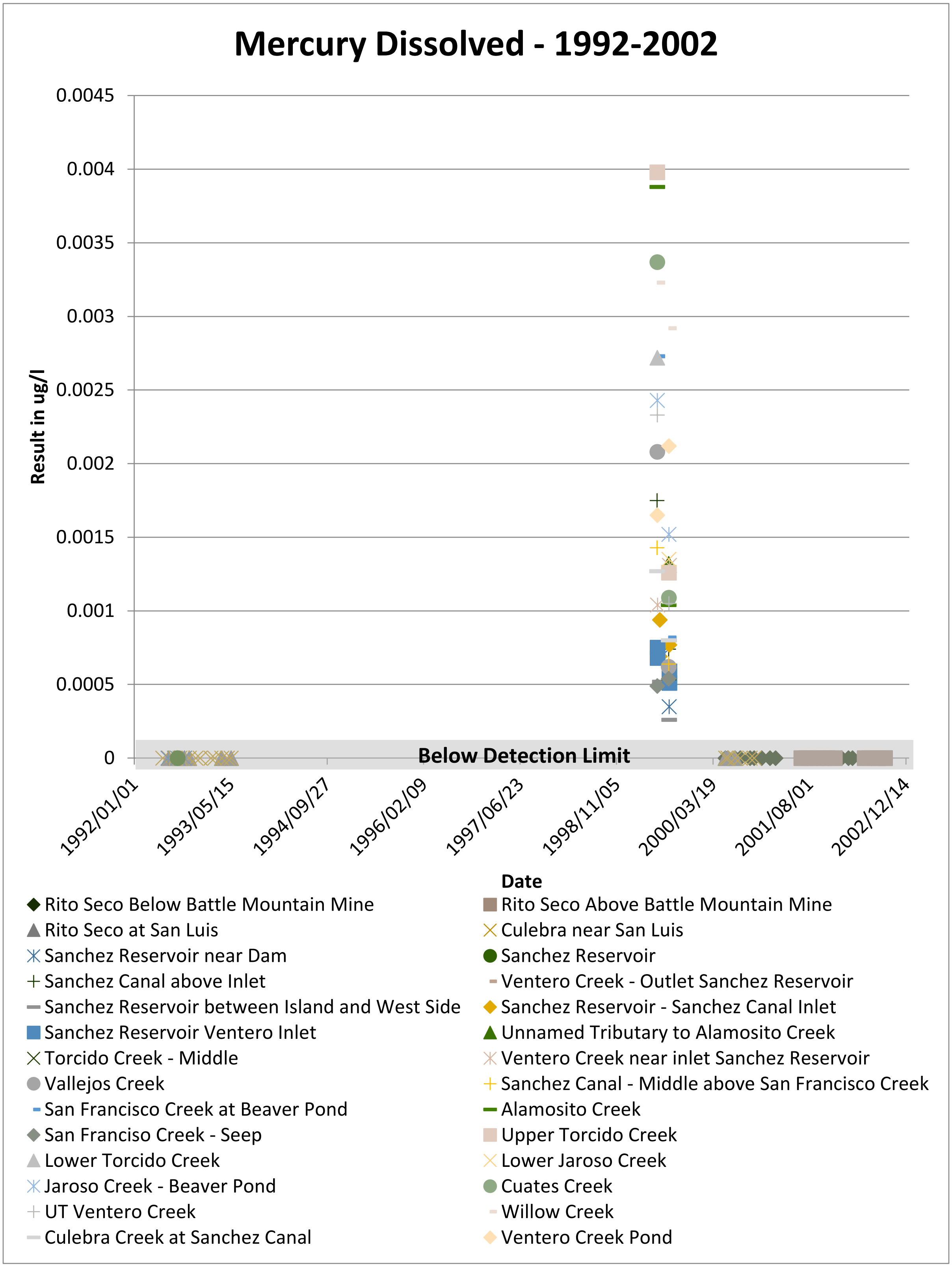


Figure 7-64 Time series plot of dissolved mercury data in existing water quality datasets 1992-2002.

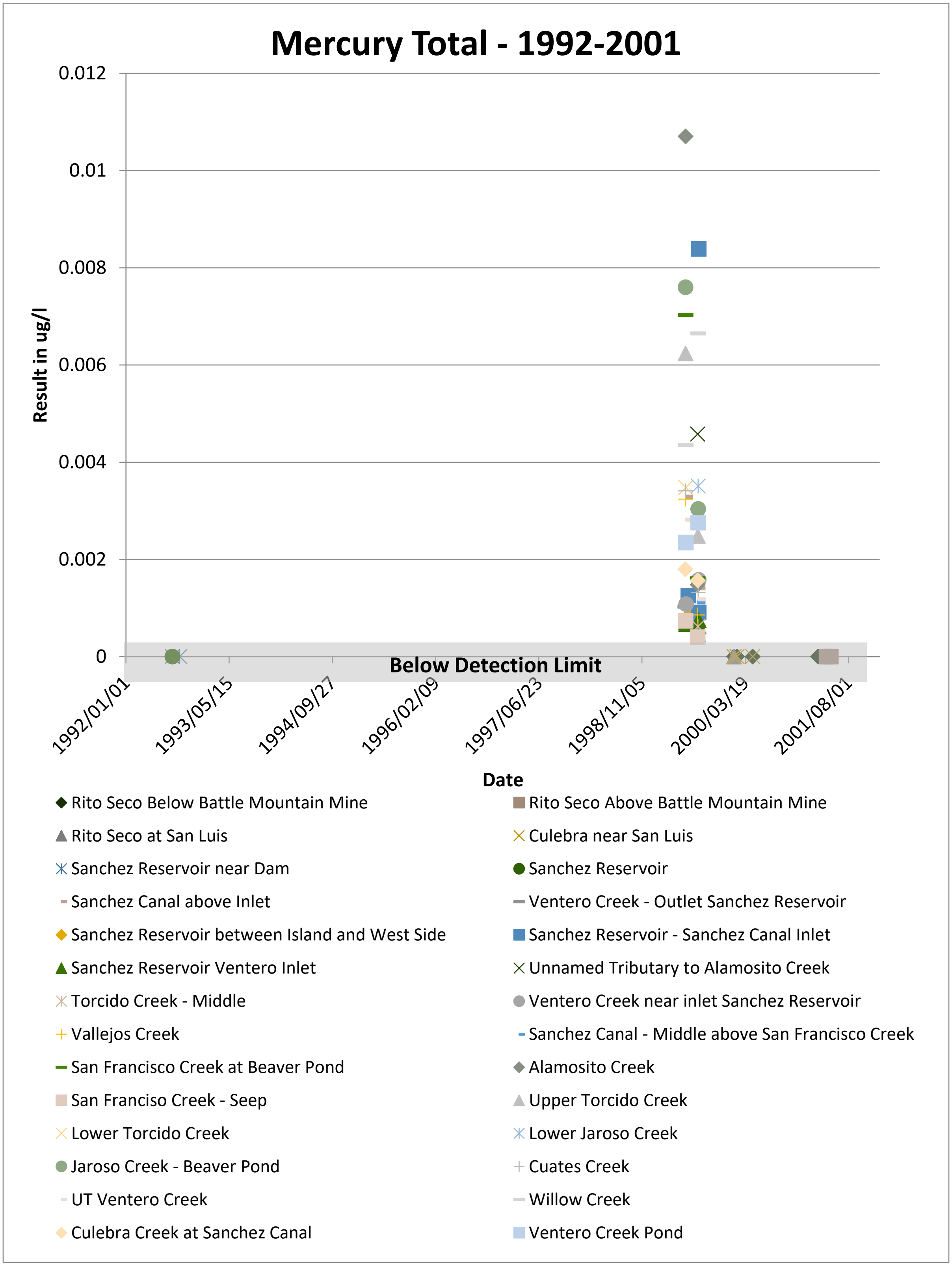


Figure 7-65 Time-series plot of dissolved mercury data from existing water quality datasets.

Molybdenum

Molybdenum has a total molybdenum chronic standard of 150 ug/l (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018). No existing samples for molybdenum were found.

Nickel

Nickel has dissolved acute and chronic standards and total chronic standards which are (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018):

$$Dissolved\ Acute = e^{0.846*[\ln(hardness)]+2.253}$$

$$Dissolved\ Chronic = e^{0.846*[\ln(hardness)]+0.0554}$$

$$Total\ Chronic = 100ug/l$$

These standards are plotted over the range of typical hardness values observed in the Culebra basin in Figure 7-66, No existing water quality data was found for Nickel in the existing water quality data sets to compare with numeric standards. Typical detection limits for nickel are provided in Table 7-46.

Table 7-46 Typical method detection limits for nickel.

Nickel (Ni) Typical Detection Limits

Method	Detection Limit
200.15	0.7-0.8 ug/l
200.7	5 ug/l
200.8	Total recoverable 0.06 ug/l, direct 0.03 ug/l

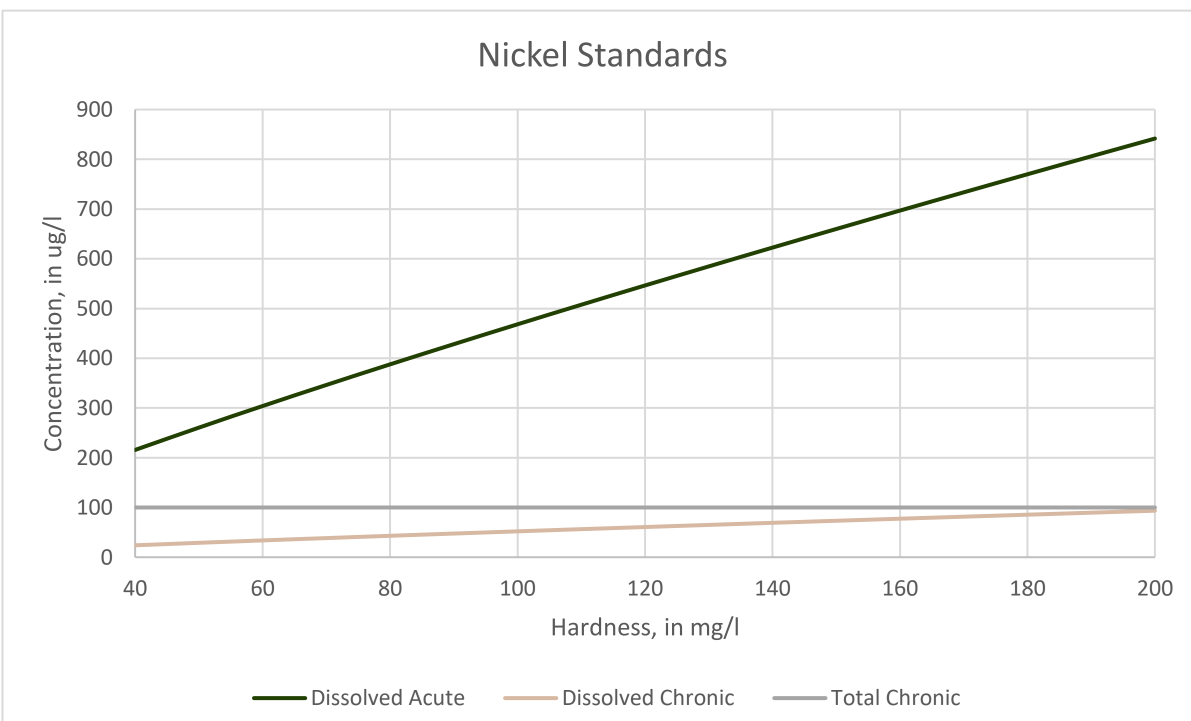


Figure 7-66 Hardness based nickel standards.

Selenium

Selenium naturally occurs in rocks and soils including around 40 known selenium containing minerals (USEPA, 2021). Selenium concentrations for anthropogenic sources typically result from either mining or irrigation of selenium rich soils, both activities increase soil erosion (USEPA, 2021). Selenium, like mercury, bioaccumulates within the food web resulting in elevated concentrations of selenium in fish tissue. Acute = 18.7 ug/l and chronic = 4.6 ug/l, Regulation 36 states "selenium is a bioaccumulative metal and subject to a range of toxicity values depending upon numerous site-specific variables." These standards do not reflect EPA's current revised standards (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018).

All values of dissolved selenium above the detection limit occurred between June and December 2005 and were analyzed with either method 200.8(W) or 200.15 and were collected by two different sampling groups. Total selenium is routinely above the detection limit with the dissolved chronic limit exceeded at Culebra near San Luis. Selenium reduction can be achieved through reduced erosion upstream.

Table 7-47 Typical method detection limits for selenium.

Selenium (Se) Typical Detection Limits	
Method	**Detection Limit**
200.15	3-5 ug/l
200.7	20 ug/l
200.8	Total recoverable 2.1 ug/l, direct 0.5 ug/l

Table 7-48 Summary of dissolved selenium data in existing water quality datasets. [DL- detection limit, ND – not detected, min – minimum, max – maximum, avg - average]

Dissolved Selenium, in ug/l								
Site	**Min**	**Max**	**Avg**	**Standard Deviation**	**Count above dl**	**ND Count**	**First Date**	**Last Date**
All Data	ND	4.4	--	--	7	124	6/25/1992	6/8/2011
Rito Seco Below Battle Mountain Mine	ND	ND	--	--	0	32	1/24/2000	6/8/2011
Rito Seco Above Battle Mountain Mine	ND	3.8	--	--	1	16	4/17/2001	9/27/2005
Rito Seco at San Luis	ND	1.3	--	--	1	12	6/29/1992	6/8/2011
Culebra near San Luis	ND	4.4	--	--	5	37	6/29/1992	6/8/2011
Sanchez Reservoir near Dam	ND	ND	--	--	0	23	6/25/1992	8/10/2010
Sanchez Reservoir	ND	ND	--	--	0	4	8/11/2005	9/13/2005

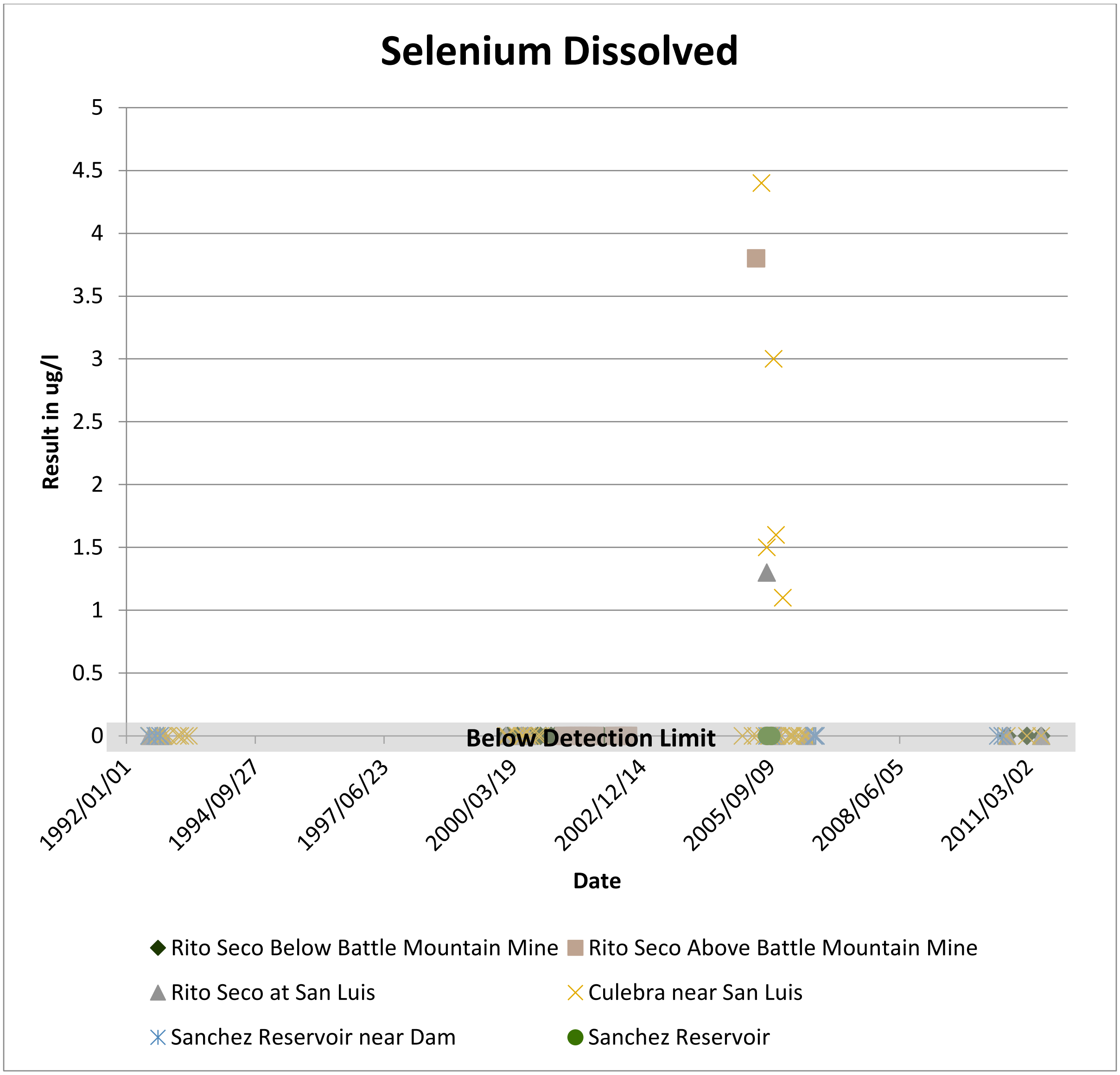


Figure 7-67 Time-series plot of dissolved selenium data in existing water quality datasets 1992-2011.

Table 7-49 Summary of total selenium data in existing water quality datasets. [DL – detection limit, ND – not detected, min – minimum, max – maximum, avg-average]

Total Selenium, in ug/l

Site	Min	Max	Avg	Standard Deviation	Count above DL	ND Count	First Date	Last Date
All Data	ND	6.2	--	--	19	63	1/13/1999	1/31/2005
Rito Seco Below Battle Mountain Mine	ND	3.1	--	--	5	13	9/9/1999	10/13/2004
Rito Seco Above Battle Mountain Mine	ND	2.7	--	--	3	17	1/13/1999	10/13/2004
Culebra near San Luis	ND	6.2	--	--	11	33	9/9/1999	1/31/2005

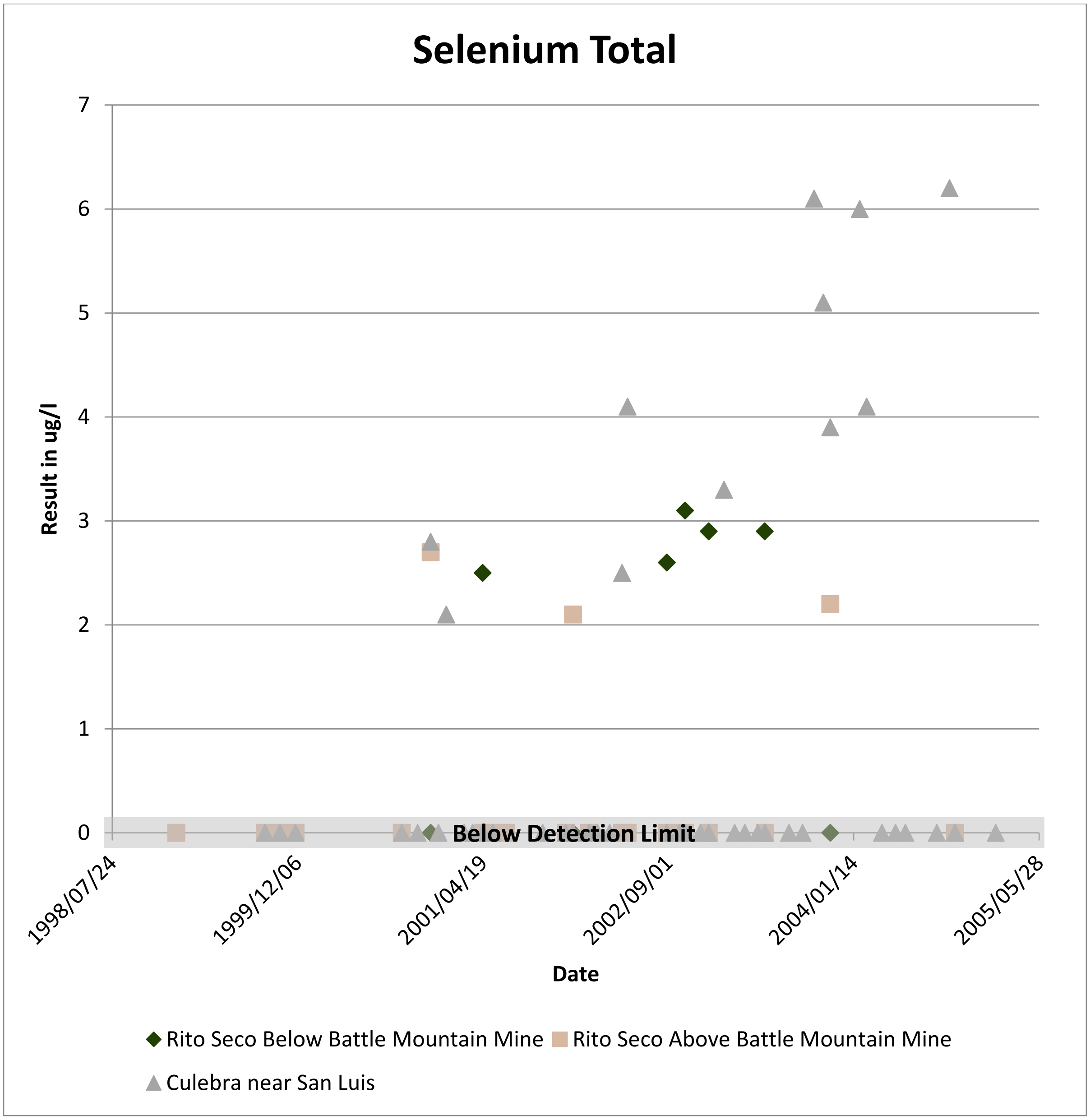


Figure 7-68 Time-series plot of total selenium data from existing water quality datasets.

<u>Silver</u>

Silver is a naturally occurring in soils and is typically found as insoluble silver chloride or silver sulfide (WHO, 1996). Water quality standards for dissolved silver including acute, chronic, and chronic-trout streams are listed in Regulation 36 and are:

Chronic and acute TVS and chronic trout standard

$$Acute = {}^{1}/_{2}\, e^{1.72[\ln(hardness)]-6.52}$$

$$Chronic = e^{1.72[\ln(hardness)]-9.06}$$

$$Chronic\ (trout) = e^{1.72[\ln(hardness)]-10.51}$$

These standard are plotted over the range of typical hardness values within the Culebra watershed in Figure 7-69. Only method 200.8 has a detection limit low enough to measure concentrations related to the chronic trout water quality standard.

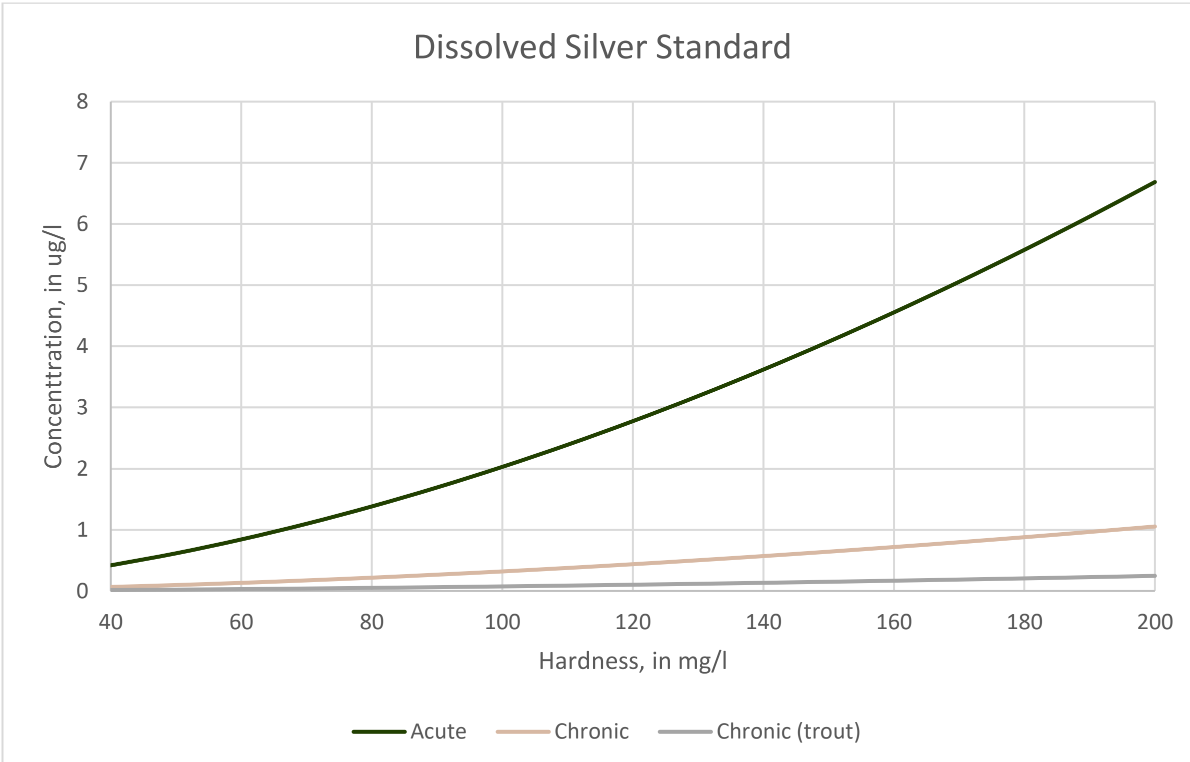


Figure 7-69 Plot of dissolved silver standard versus hardness.

Table 7-50 Typical method detection limits for silver.

Silver (Ag) Typical Detection Limits	
Method	**Detection Limit**
200.15	0.6 ug/l
200.7	2 ug/l
200.8	0.005 ug/l

Of the 124 results for dissolved silver were found within the existing water quality datasets, no detections of silver were measured (Table 7-51). The typical detection limits for silver are listed in

Table 7-50.

Table 7-51 Summary of dissolved silver data in existing water quality datasets. [Min – minimum, Max – maximum, ND – not detected]

Dissolved Silver, in ug/l						
Site	**Min**	**Max**	**Samples above Detection Limit**	**ND Count**	**First Date**	**Last Date**
All Data	ND	ND	0	124	5/28/1992	6/8/2011
Rito Seco Below Battle Mountain Mine	ND	ND	0	32	1/24/2000	6/8/2011
Rito Seco Above Battle Mountain Mine	ND	ND	0	16	4/17/2001	9/27/2005
Rito Seco at San Luis	ND	ND	0	16	6/29/1992	6/8/2011
Culebra near San Luis	ND	ND	0	33	5/28/1992	6/8/2011
Sanchez Reservoir near Dam	ND	ND	0	23	6/25/1992	8/10/2010
Sanchez Reservoir	ND	ND	0	4	8/11/2005	9/13/2005

Uranium

Uranium is found in granites and other mineral deposits and is released into the environment through the combustion of coal and other fuels and use of uranium containing phosphate fertilizers (WHO, 2005). Uranium levels in surface water shall be maintained at the lowest practicable level. Uranium levels in waters assigned a water supply classification cannot exceed 16.8-30 ug/l or naturally occurring concentrations, whichever is greater (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018).

$$Acute = e^{1.1021*\ln(hardness)+2.7088}$$

$$Chronic = e^{1.1021*\ln(hardness)+2.2382}$$

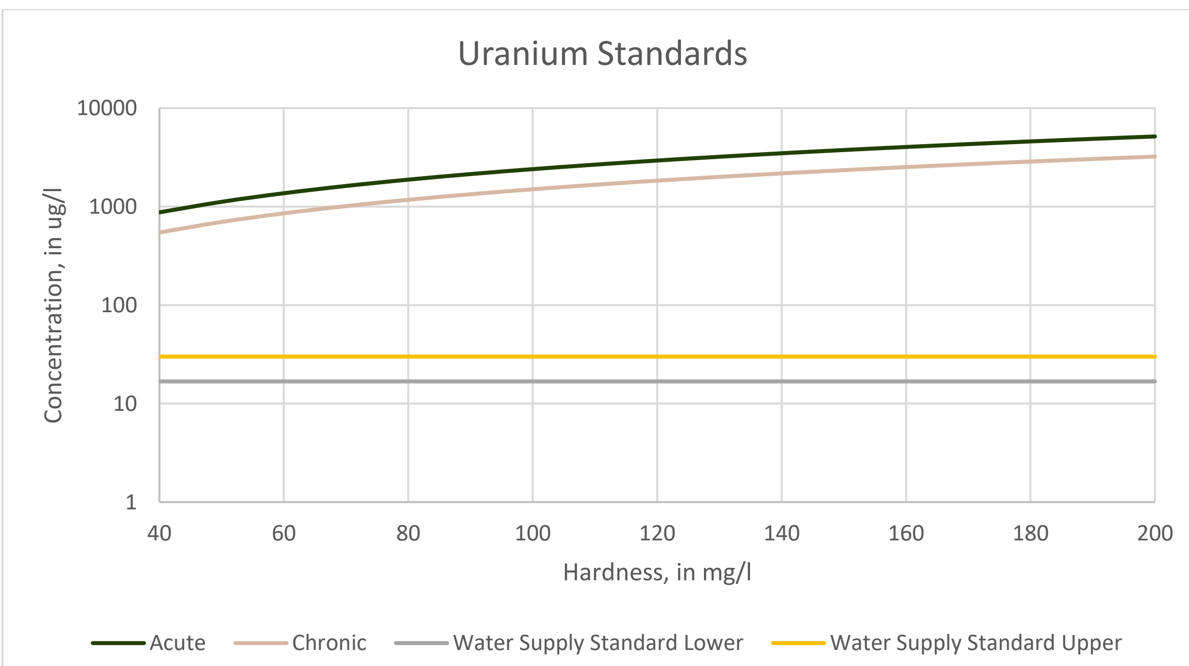


Figure 7-70 Graph of hardness-based uranium standards.

Uranium measurements within the existing datasets did not include any non-detect measurements, likely from the relatively low detection limit for uranium Table 7-52 compared with the environmental concentrations. The 12 samples for uranium included concentrations between 2 and 4 ug/l and did not show a large variation for any individual location (Table 7-53 and Figure 7-71). Samples from Sanchez Reservoir were also analyzed for uranium-238 which were the same concentration as the dissolved uranium sample concentrations and is consistent with the findings that naturally occurring uranium typically occurs as the uranium-238 isotope (WHO, 2005).

Table 7-52 Typical method detection limits for uranium.

Uranium (U) Typical Detection Limits	
Method	**Detection Limit**
200.8	0.01 ug/l

Table 7-53 Summary of dissolved uranium data in existing water quality datasets. [Min – minimum, Max – maximum, Avg – average, ND – Not Detected]

Dissolved Uranium, in ug/l

Site	Min	Max	Ave	Standard Deviation	Count	ND Count	First Date	Last Date
All Data	2	4	3	0.43	12	0	9/13/2005	8/23/2006
Rito Seco at San Luis	2	2	2	--	1	0	6/14/2006	6/14/2006
Culebra near San Luis	3	4	3.5	0.71	2	0	4/19/2006	6/14/2006
Sanchez Reservoir near Dam	3	3	3	0	7	0	9/13/2005	8/23/2006
Sanchez Reservoir	3	3	3	0	2	0	9/13/2005	9/13/2005

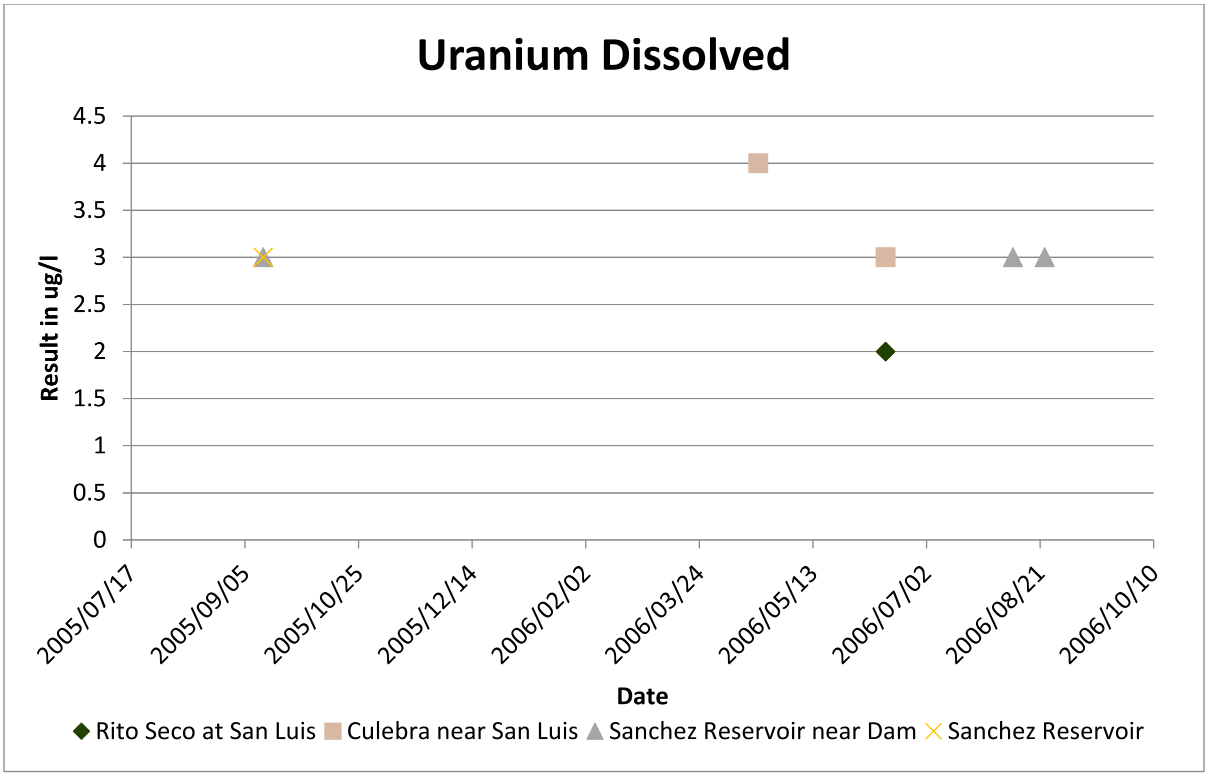
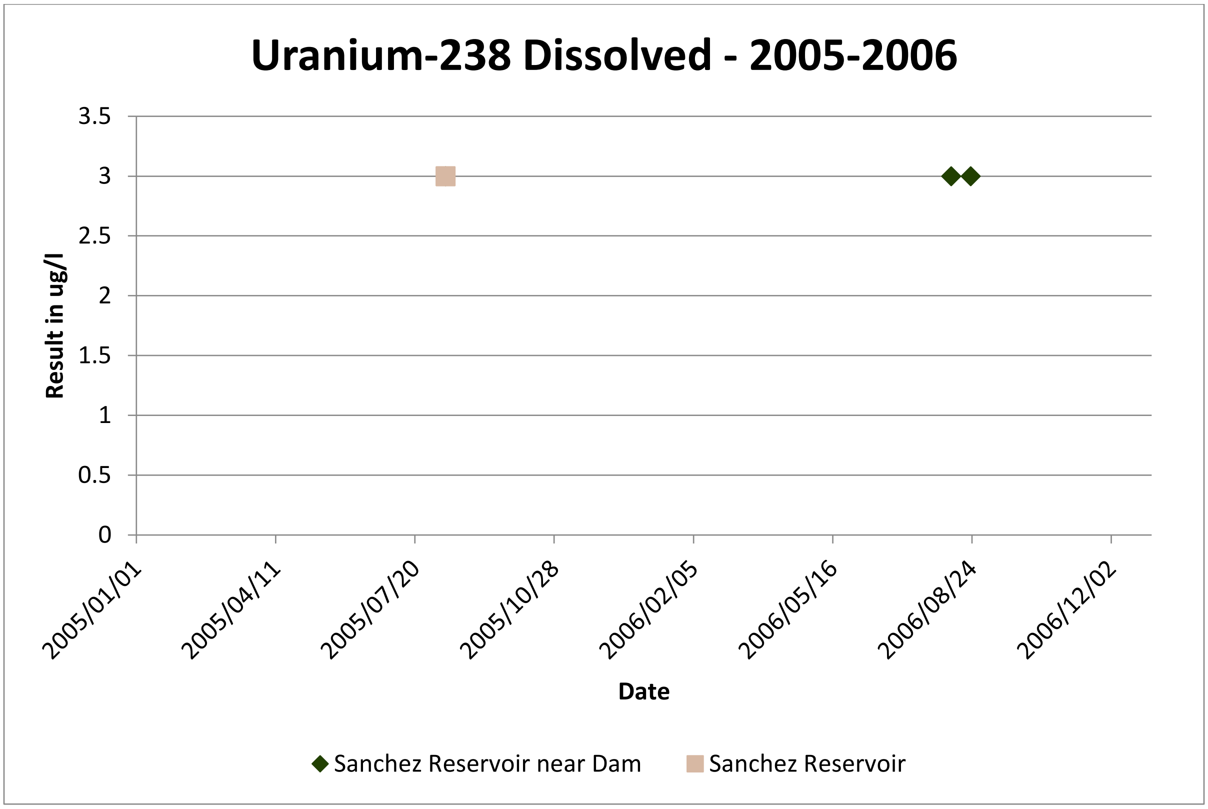


Figure 7-71 Time-series plot of dissolved uranium data from existing water quality datasets.

Table 7-54 Summary of Dissolved Uranium 238 data in existing water quality datasets. [ND – not detected, Min – minimum, Max – maximum, Avg – average]

Dissolved Uranium-238, in ug/l

Site	Min	Max	Avg	Standard Deviation	Count	ND Count	First Date	Last Date
All Data	3	3	3	0	8	0	8/11/2005	8/23/2006
Sanchez Reservoir near Dam	3	3	3	0	6	0	8/11/2005	8/23/2006
Sanchez Reservoir	3	3	3	0	2	0	8/11/2005	8/11/2005



Uranium-238 Dissolved - 2005-2006
Result in ug/l
3.5
3
2.5
2
1.5
1
0.5
0
2005/01/01
2005/04/11
2005/07/20
2005/10/28
2006/02/05
2006/05/16
2006/08/24
2006/12/02
Date
Sanchez Reservoir near Dam
Sanchez Reservoir

Zinc

Zinc standards are aimed primarily at protecting aquatic life (USEPA, 1980). The effects of zinc on the aquatic environment are greatly affected by the pH of the water and is typically sorbed by clay and organic materials at pH greater than 7. This sorption decreases as salinity increases. Brinkman and Johnston evaluated mayfly sensitivity to zinc and found that survival and moulting rates decreased with increasing exposure to zinc (2008) . In this study the lethal concentration for zinc was significantly higher for copper and cadmium.

$$Acute = 0.978e^{0.9094*\ln(hardness)+0.9095}$$

$$Chronic = 0.986 * e^{0.9094*\ln(hardness)+0.6253}$$

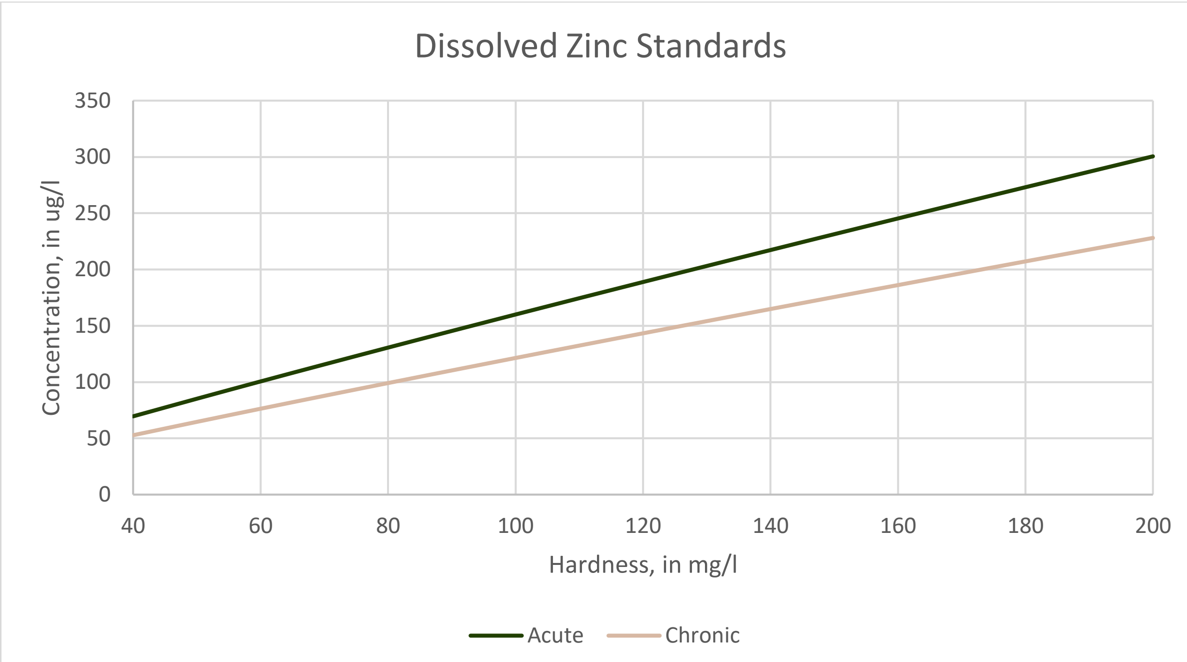


Figure 7-72 Plot of hardness based dissolved zinc water quality standards.

Table 7-55 Typical method detection limits for zinc.

Zinc (Zn) Typical Detection Limits	
Method	**Detection Limit**
200.15	0.5-0.7 ug/l
200.7	2 ug/l
200.8	Total recoverable 0.1 ug/l, direct 0.2 ug/l

Table 7-56 Summary of dissolved zinc data in existing water quality datasets. [Min – minimum, Max – Maximum, Avg – Average, ND—not detected, DL – detection limit].

Dissolved Zinc, in ug/l

Site	**Min**	**Max**	**Avg**	**Standard Deviation**	**Count above DL**	**ND Count**	**First Date**	**Last Date**
All Data	ND	81	--	--	46	102	4/22/1992	6/8/2011
Rito Seco Below Battle Mountain Mine	ND	18	--	--	13	22	4/24/1992	6/8/2011

Rito Seco Above Battle Mountain Mine	ND	19	--	--	4	16	4/29/1992	9/27/2005
Rito Seco at San Luis	ND	37	--	--	6	10	6/29/1992	6/8/2011
Culebra near San Luis	ND	81	--	--	18	32	4/22/1992	6/8/2011
Sanchez Reservoir near Dam	ND	25	--	--	5	18	6/25/1992	8/10/2010
Sanchez Reservoir	ND	ND	--	--	0	4	8/11/2005	9/13/2005

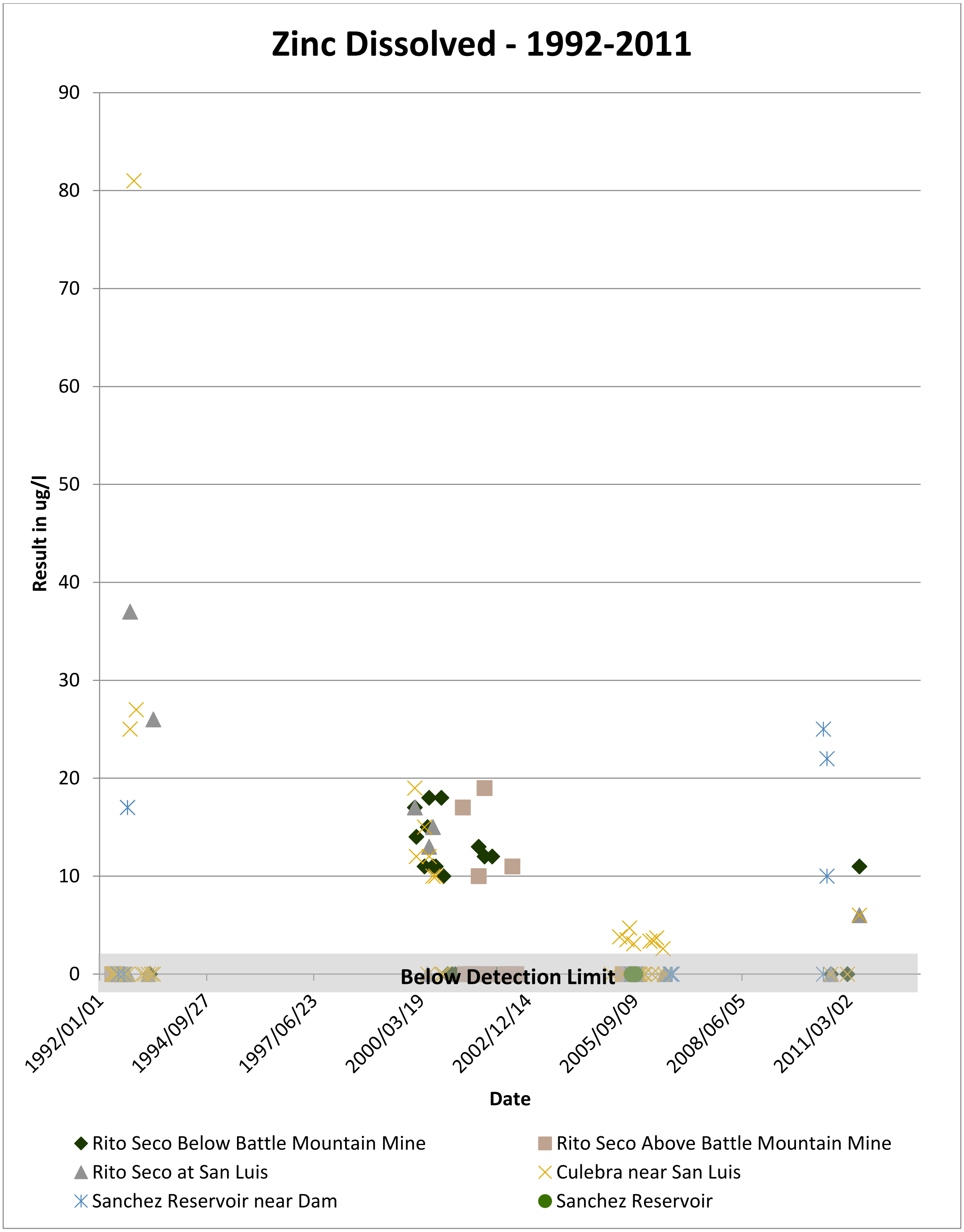


Figure 7-73 Time series plot of dissolved zinc data in existing water quality datasets 1992-2011.

Table 7-57 Summary of total zinc data in existing water quality datasets. [min – minimum, max – maximum, avg – average, ND – not detected]

Total Zinc, in ug/l

Site	Min	Max	Avg	Standard Deviation	Count	ND Count	First Date	Last Date
All Data	ND	338.8	--	--	65	111	5/8/1979	1/31/2005
Rito Seco Below Battle Mountain Mine	ND	52	--	--	21	27	4/24/1992	10/13/2004
Rito Seco Above Battle Mountain Mine	ND	134	--	--	14	35	4/24/1992	10/13/2004
Culebra near San Luis	ND	338.8	--	--	27	49	4/22/1992	1/31/2005
Rito Seco - Wrong Lat/Long	0.02	0.02	0.02	0	3	0	5/8/1979	5/15/1980

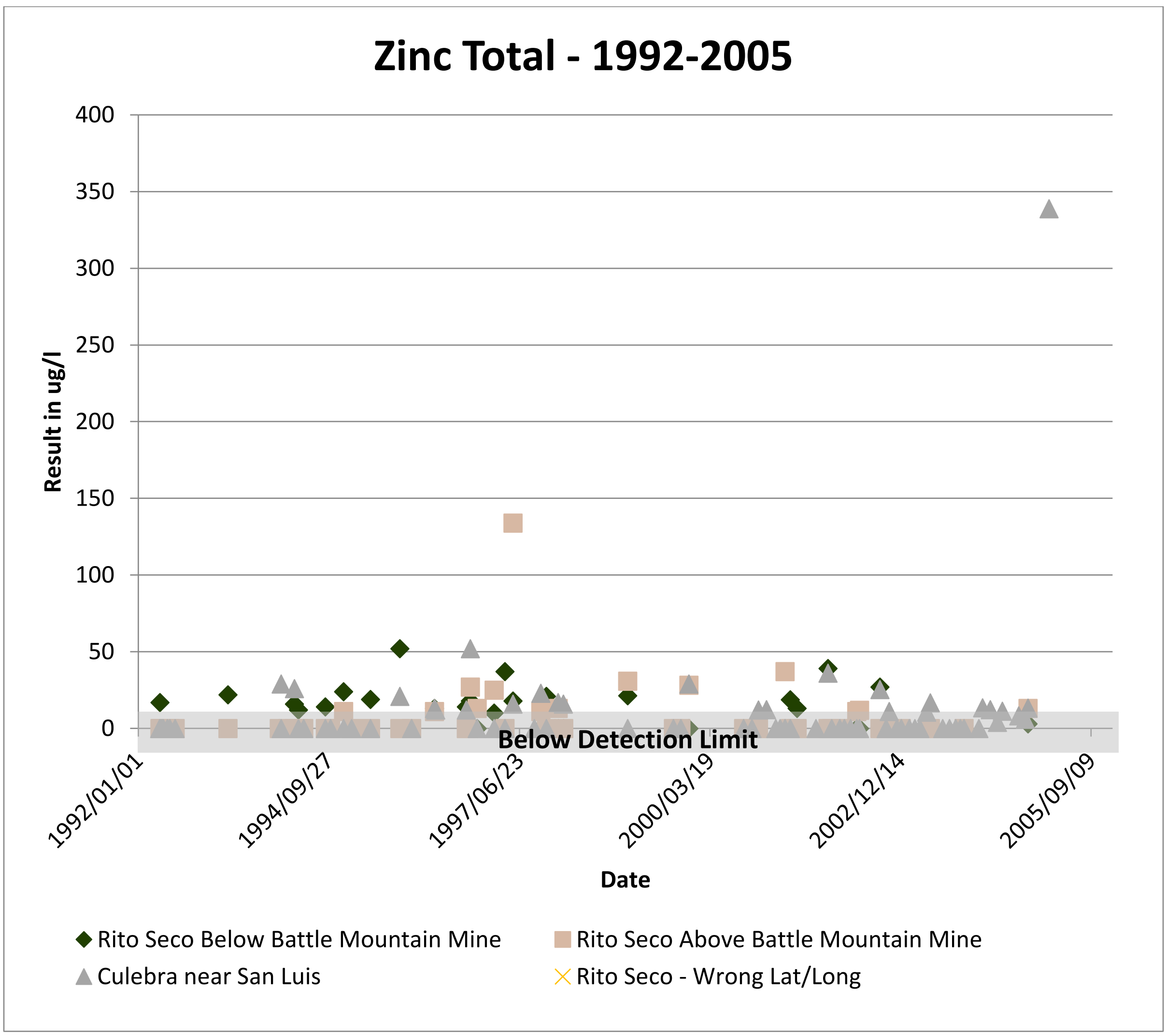


Figure 7-74 Time-series plot of total zinc data from existing water quality datasets.

7.4.2.3 Other

Boron

Boron is essential in low concentrations but is toxic at higher concentrations. Crops that are sensitive to boron include barley, wheat, and dry beans. Crops that are boron tolerant include corn, oats, and alfalfa (Bauder, Waskom, Sutherland, & Davis, 2014).Boron has a listed chronic standard of 0.75 mg/l (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018). Boron has not historically been sampled. Chloride

Chloride

Chloride has a listed chronic standard of 250 mg/l. Culebra near Chama included historic samples for dissolved chloride for the 1968 water year ranging from 0.8 – 1.5 mg/l. For irrigation water optimal chloride concentration is less than 70 mg/l (Bauder, Waskom, Sutherland, & Davis, 2014).

Table 7-58 Summary of total chloride data in existing water quality datasets. [DL – detection limit, ND – not detected, min – minimum, max - maximum]

Total Chloride, in mg/l

Site	Min	Max	Average	Standard Deviation	Count above DL	ND Count	First Date	Last Date
All Data	ND	15	--	--	9	15	1/10/2001	7/14/2015
Rito Seco Below Battle Mountain Mine	2	7	4.5	3.5	2	0	5/15/2001	1/30/2002
Culebra near San Luis	ND	15	--	--	5	2	1/10/2001	10/13/2004
Sanchez Reservoir near Dam	ND	2.5	--	--	2	13	8/9/2006	7/14/2015

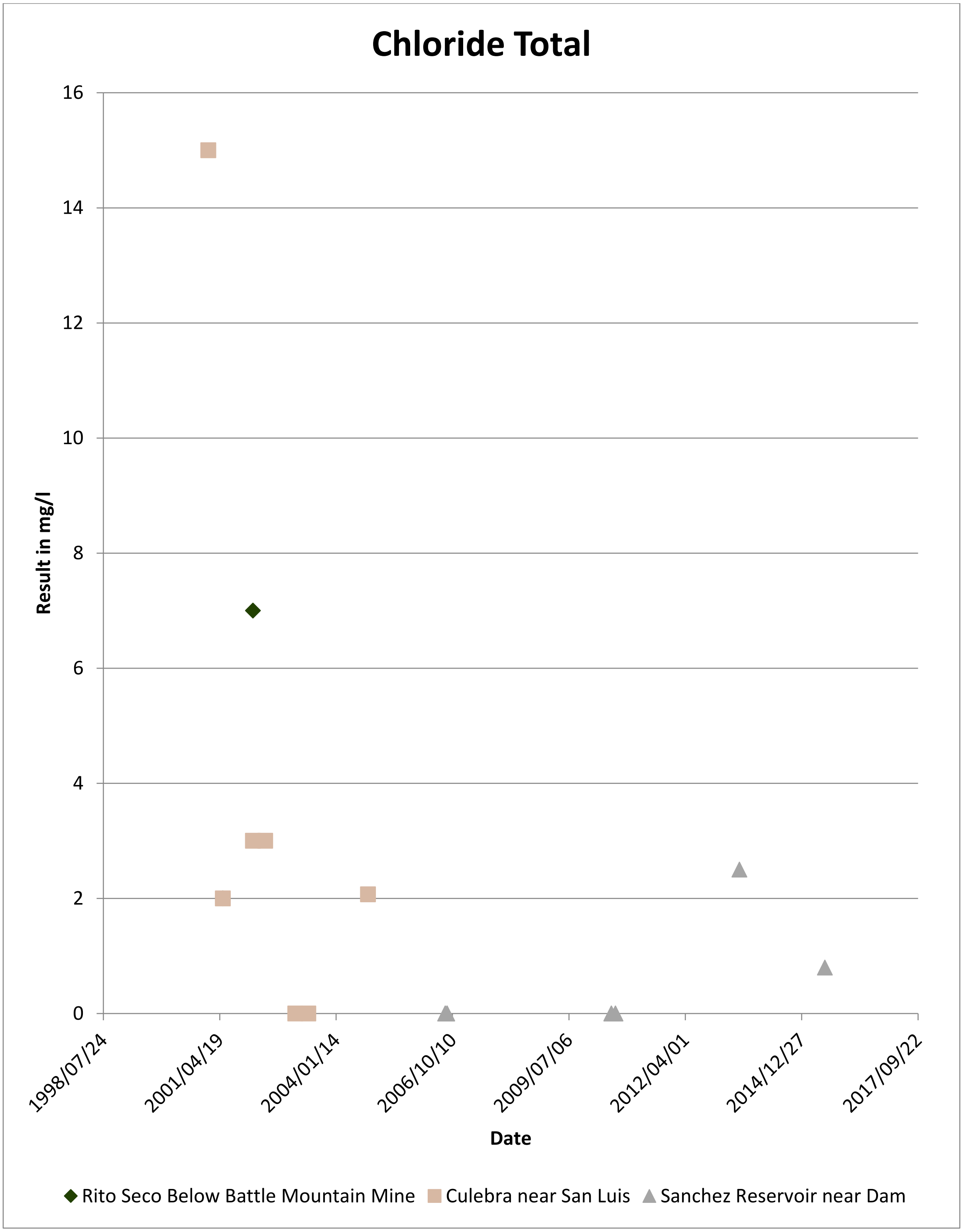


Figure 7-75 Time series plot of total chloride data in existing water quality datasets.

Chlorine

Regulation 36 has acute standard of 0.019 mg/l and chronic standard of 0.011 mg/l for chlorine. Existing datasets do not contain results for chlorine.

Cyanide

Cyanide is often used in industrial processes including mining. The type of cyanide compound found in natural waters is determined by pH and temperature. Cyanide toxicity is dependent on the type of cyanide compound present and the hardness of the water. Cyanide has a water quality standard of 0.005 mg/l for the segments within the Upper Culebra Watershed (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018).

All dissolved cyanide samples from Rito Seco at San Luis from June 29, 1992, to May 18, 1993, were below the analytical method detection limit. Two samples for the Rito Seco site at the unknown latitude and longitude from May 8, 1979, and May 15, 1980, both showed a total cyanide concentration of 0.005 mg/l, which is likely the method detection limit used at that time.

All measurements of cyanide amenable to chlorination (HCN & CN) from Rito Seco Above Battle Mountain Mine (14 samples), Rito Seco Below Battle Mountain Mine (24 samples), and Rito Seco at San Luis (2 samples) from April 2001 to October 2005 were below the detection limit.

Sulfate

Sulfate is a naturally occurring substance found in rocks, soils, and minerals. Sulfate in fresh water supplies typically ranges from 3 to 30 mg/l but can be >1000 mg/l in some locations depending on geology. No known hazards to public health are associated with sulfate. High consumption of sulfate has been linked to increased reports of diarrhea generally associate with concentrations greater than 500 mg/l. (USEPA, February 2003).

Table 7-59 Sulfate typical detection limits.

Sulfate Typical Detection Limits	
Method	Detection Limit
375.4	1 mg/l
300 (A)	2.85 mg/l

Water quality standards for sulfate are based on actual use as a water supply. Waters that are used as a water supply have a standard for dissolved sulfate of 250 mg/l for aesthetic purposes (taste and odor). Sulfate may contribute to salinity in many irrigation waters. Data from existing water quality showed measured values of total sulfate between the expected range (Table 7-60 and Figure 7-76), Rito Seco below Battle Mountain Mine and Rito Seco at San Luis had measured concentrations more than 6 times that of any other site. Sulfate is one of the required monthly sample parameters for the Battle Mountain Gold monthly augmentation plan accounting decrees Case No. 99CW57 and 89CW032.

Existing data for Culebra near Chama from the 1968 water year showed the range of dissolved sulfate to be from 7.5 to 11 mg/l.

Table 7-60 Summary of total sulfate data from existing water quality datasets. [DL-detection limit, ND – Not Detected]

Sulfate, in mg/l

Site	Min	Max	Average	Standard Deviation	Count above DL	ND Count	First Date	Last Date
All Data	--	77	--	--	91	7	5/28/1992	8/23/2006
Rito Seco Above Battle Mountain Mine	--	7	--	--	13	3	4/17/2001	9/27/2005
Rito Seco Below Battle Mountain Mine	--	62	--	--	27	2	1/24/2000	8/28/2002
Rito Seco at San Luis	6.5	77	21.3	20	14	0	6/29/1992	6/14/2006
Culebra near San Luis	--	9	--	--	28	2	5/28/1992	6/14/2006
Sanchez Reservoir near Dam	6	9	8	1.3	7	0	9/13/2005	8/23/2006
Sanchez Reservoir	6	6	6	0	2	0	9/13/2005	9/13/2005

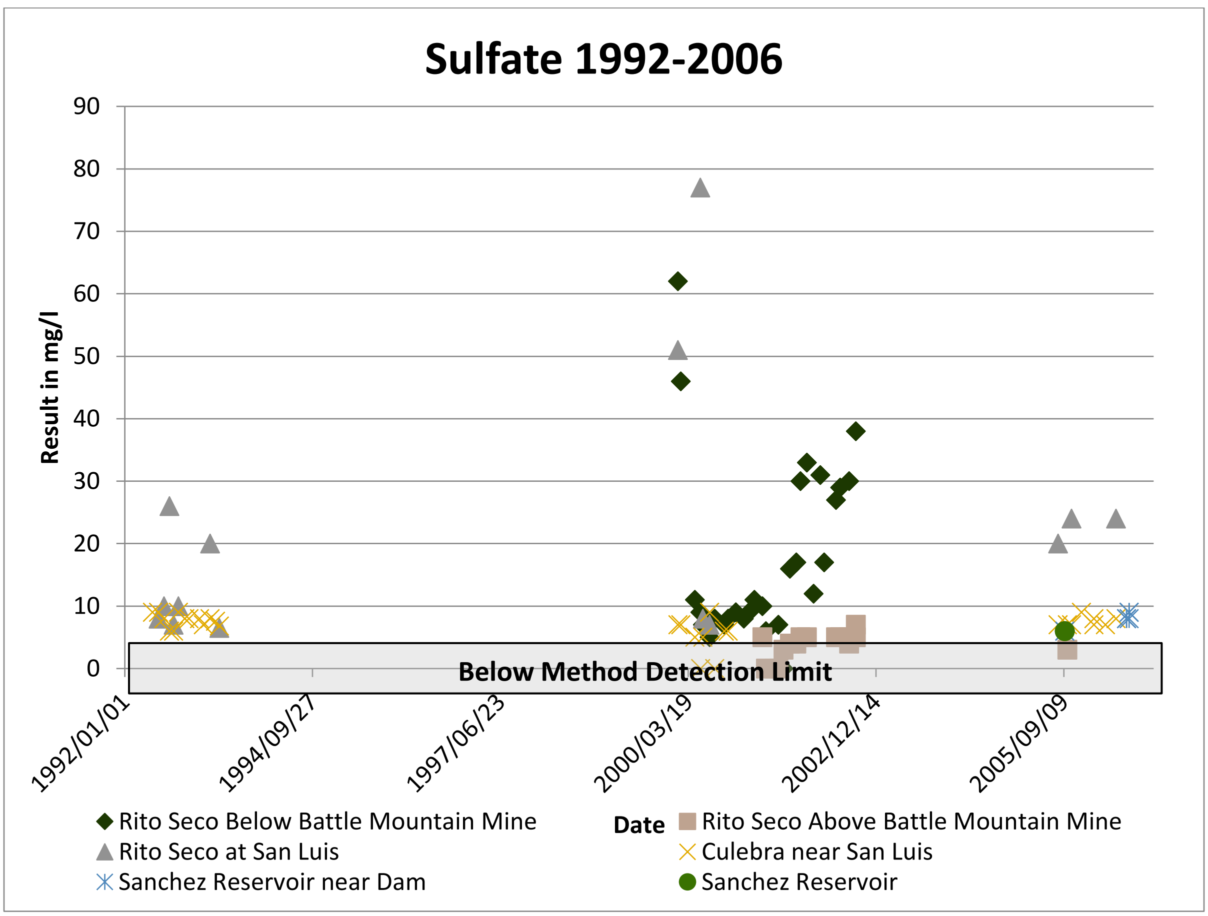


Figure 7-76 Time-series plot of total sulfate data from existing water quality datasets.

Sulfide

The water quality standard for sulfide is 0.002 mg/l (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018) for all segments within the Upper Culebra Watershed. One total sulfide sample was found in the existing database for Sanchez Reservoir dated August 13, 1992, which was below the detection limit.

Fluoride

Fluoride occurs natural in water and is sometimes added to drinking water to reduce tooth decay. EPA has a secondary maximum contaminate level for fluoride in drinking water of 2 mg/l (EPA, 1993) this was based on protection against dental fluorosis, which was considered a cosmetic effect and not an adverse health effect.

No existing fluoride data was found for any surface water sites.

7.4.2.4 Other Organics

Methylmercury

Dissolved and total methylmercury concentrations were analyzed as part of the Sanchez Reservoir TMDL study (Tetra Tech, Inc, June 2008). These samples were collected using ultra-clean sampling and processing protocols to enable analysis of concentrations of Methylmercury at a level appropriate for the waters. While the concentrations are on the order of magnitude such that reporting in ng/l is appropriate, the data was reported in ug/l to be consistent with water quality standards for total mercury.

Table 7-61 Summary of dissolved methylmercury data from existing water quality datasets. Note units reported in ug/l to be consistent with TMDL report. ND – not detected, # - sample count

Dissolved Methylmercury, in ug/l

Site	Min	Max	Average	Standard Deviation	#	ND Count	First Date	Last Date
All Data	0.000001	0.000221	--	--	25	3	6/3/1999	8/6/1999
Sanchez Canal above Inlet	0.000001	0.000001	0.000001	--	1	0	6/3/1999	6/3/1999
Ventero Creek - Outlet Sanchez Reservoir	0.000024	0.000024	0.000024	--	1	0	6/3/1999	6/3/1999
Sanchez Reservoir between Island and West Side	0.000013	0.000038	0.000027	0.000010	4	0	6/17/1999	8/5/1999
Sanchez Reservoir - Sanchez Canal Inlet	0.000016	0.000062	--	--	3	1	6/17/1999	8/6/1999
Sanchez Reservoir Ventero Inlet	0.000008	0.000017	--	--	2	2	6/6/1999	8/6/1999
Ventero Creek near inlet Sanchez Reservoir	0.000148	0.000148	0.000148	--	1	0	6/6/1999	6/6/1999
Vallejos Creek	0.000030	0.000030	0.00003	--	1	0	6/4/1999	6/4/1999
Sanchez Canal - Middle above San Francisco Creek	0.000013	0.000013	0.000013	--	1	0	6/3/1999	6/3/1999
San Francisco Creek at Beaver Pond	0.000010	0.000010	0.000010	--	1	0	6/4/1999	6/4/1999
Alamosito Creek	0.000033	0.000033	0.000033	--	1	0	6/4/1999	6/4/1999
San Francisco Creek - Seep	0.000011	0.000011	0.000011	--	1	0	6/4/1999	6/4/1999
Upper Torcido Creek	0.000041	0.000041	0.000041	--	1	0	6/4/1999	6/4/1999
Lower Torcido Creek	0.000221	0.000221	0.000221	--	1	0	6/5/1999	6/5/1999
Jaroso Creek - Beaver Pond	0.000032	0.000032	0.000032	--	1	0	6/4/1999	6/4/1999
Cuates Creek	0.000089	0.000089	0.000089	--	1	0	6/4/1999	6/4/1999
UT Ventero Creek	0.000206	0.000206	0.000206	--	1	0	6/5/1999	6/5/1999
Willow Creek	0.000158	0.000158	0.000158	--	1	0	6/5/1999	6/5/1999
Culebra Creek at Sanchez Canal	0.000003	0.000003	0.000003	--	1	0	6/3/1999	6/3/1999
Ventero Creek Pond	0.000112	0.000112	0.000112	--	1	0	6/5/1999	6/5/1999

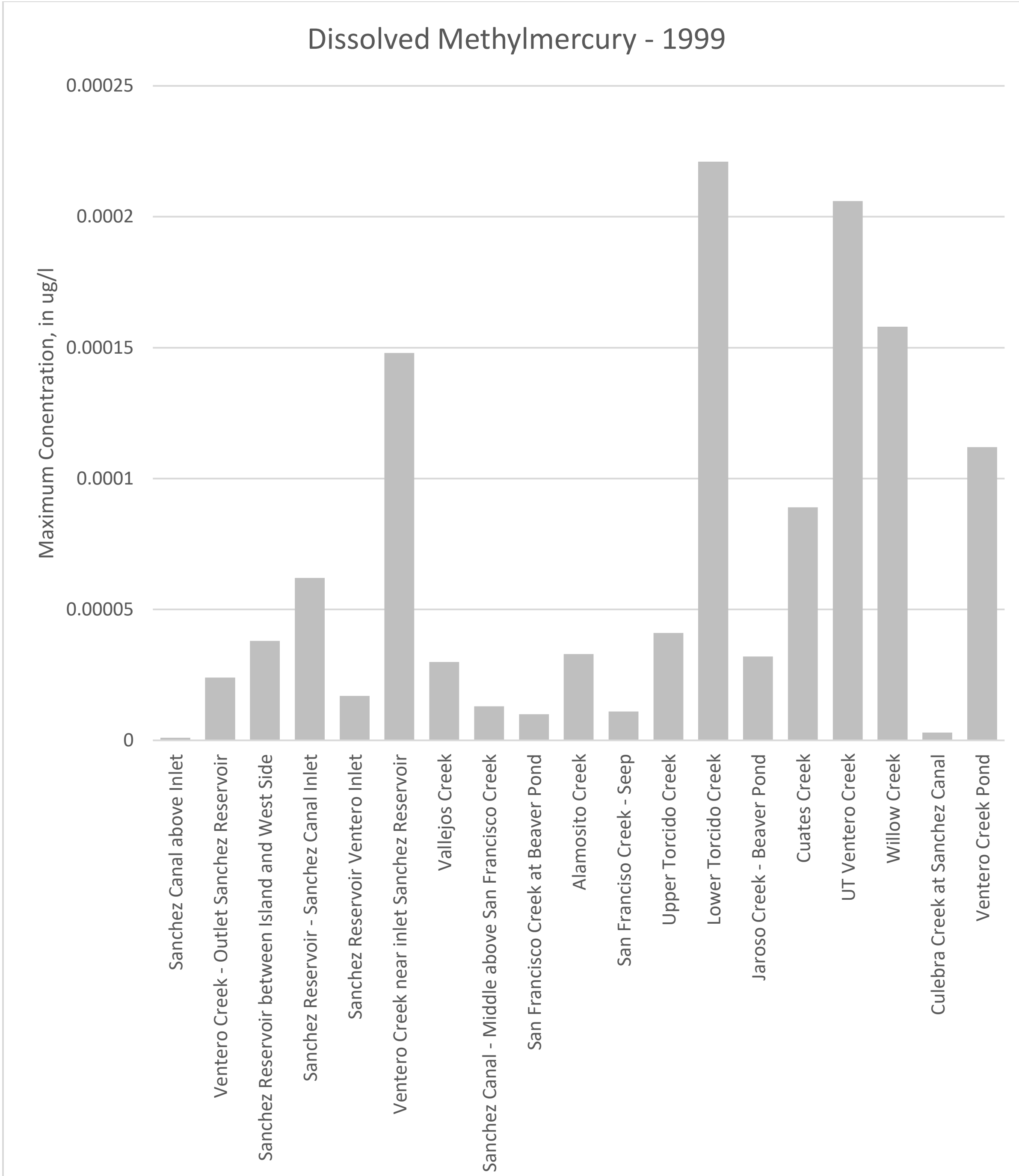


Figure 7-77 Maximum Dissolved methylmercury data by site from 1999 TMDL sampling event.

Table 7-62 Summary of total methylmercury data from existing water quality datasets. ND – not detected, #-count

Total Methylmercury, in ug/l

Site	Min	Max	Average	Standard Deviation	#	ND Count	First Date	Last Date
All Data	0.000001	0.000439	0.000119	0.0000865	46	0	6/3/1999	8/6/1999
Sanchez Canal above Inlet	0.000084	0.000108	0.000096	0.0000170	2	0	6/3/1999	8/2/1999
Ventero Creek - Outlet Sanchez Reservoir	0.000093	0.000439	0.000266	0.0002447	2	0	6/3/1999	8/3/1999
Sanchez Reservoir between Island and West Side	0.000026	0.000092	0.000055	0.0000288	4	0	6/17/1999	8/5/1999
Sanchez Reservoir - Sanchez Canal Inlet	0.000042	0.000106	0.000085	0.0000289	4	0	6/17/1999	8/6/1999
Sanchez Reservoir Ventero Inlet	0.000001	0.000101	0.000062	0.0000443	4	0	6/6/1999	8/6/1999
Unnamed Tributary to Alamosito Creek	0.000065	0.000065	0.000065	--	1	0	8/2/1999	8/2/1999
Torcido Creek - Middle	0.000052	0.000052	0.000052	--	1	0	8/3/1999	8/3/1999
Ventero Creek near inlet Sanchez Reservoir	0.000107	0.00014	0.000124	0.0000233	2	0	6/6/1999	8/6/1999
Vallejos Creek	0.000066	0.000075	0.000071	0.0000064	2	0	6/4/1999	8/2/1999
Sanchez Canal - Middle above San Francisco Creek	0.000052	0.000072	0.000062	0.0000141	2	0	6/3/1999	8/2/1999
San Francisco Creek at Beaver Pond	0.000105	0.000161	0.000133	0.0000396	2	0	6/4/1999	8/2/1999
Alamosito Creek	0.000084	0.000208	0.000146	0.0000877	2	0	6/4/1999	8/2/1999
San Franciso Creek - Seep	0.000034	0.000086	0.000060	0.0000368	2	0	6/4/1999	8/2/1999
Upper Torcido Creek	0.000068	0.000085	0.000077	0.0000120	2	0	6/4/1999	8/3/1999
Lower Torcido Creek	0.000232	0.000232	0.000232	--	1	0	6/5/1999	6/5/1999
Lower Jaroso Creek	0.000138	0.000138	0.000138	--	1	0	8/4/1999	8/4/1999
Jaroso Creek - Beaver Pond	0.000169	0.000174	0.000172	0.0000035	2	0	6/4/1999	8/4/1999
Cuates Creek	0.000109	0.000225	0.000167	0.0000820	2	0	6/4/1999	8/4/1999
UT Ventero Creek	0.000186	0.000301	0.000244	0.0000813	2	0	6/5/1999	8/4/1999
Willow Creek	0.000206	0.000334	0.000270	0.0000905	2	0	6/5/1999	8/4/1999
Culebra Creek at Sanchez Canal	0.000014	0.000048	0.000031	0.0000240	2	0	6/3/1999	8/2/1999
Ventero Creek Pond	0.000173	0.000185	0.000179	0.0000085	2	0	6/5/1999	8/4/1999

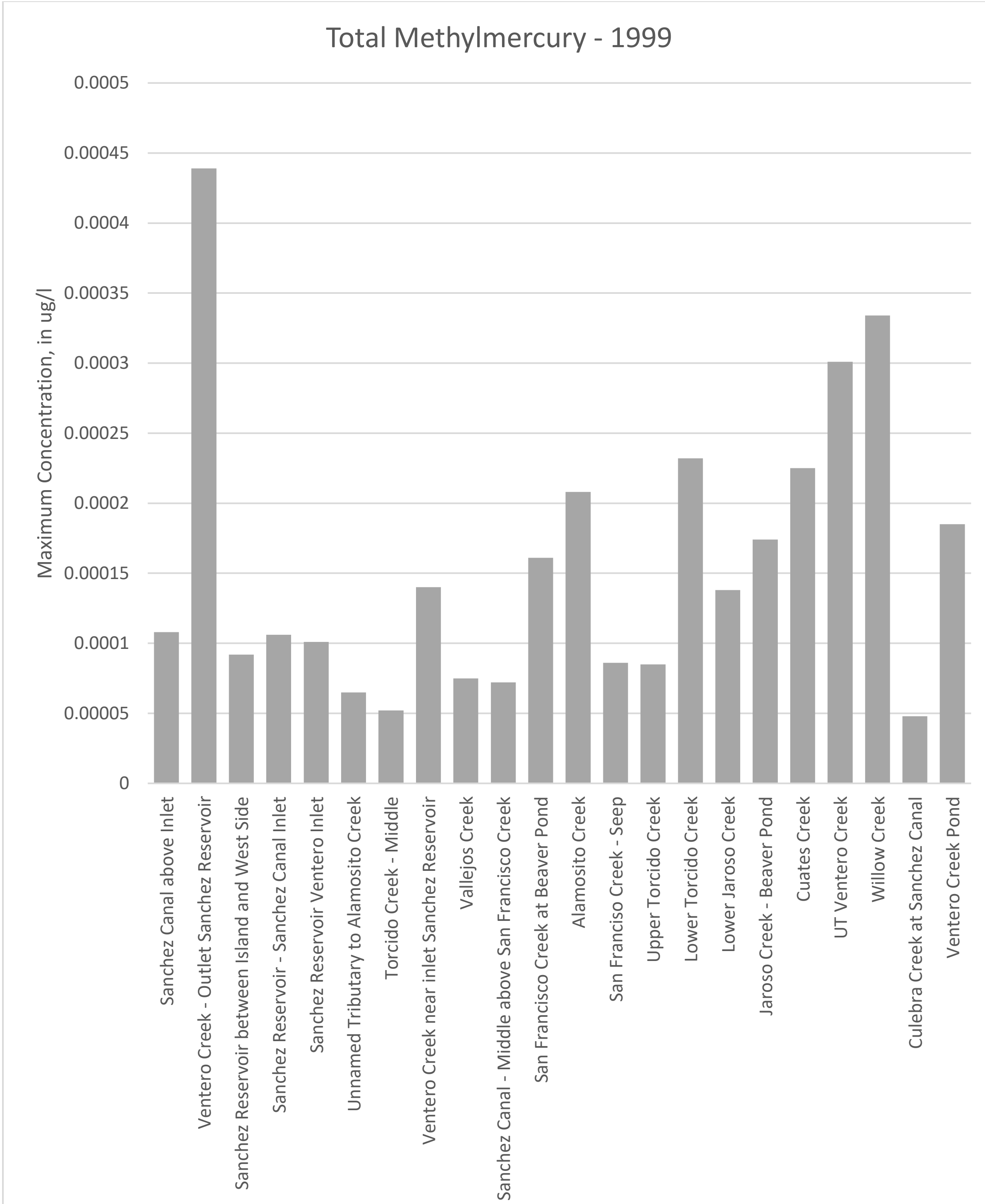


Figure 7-78 Plot of maximum total methylmercury data from 1999 TMDL study by site.

7.4.3 Microbiological Characteristics

7.4.3.1 Escherichia Coli (e-coli)

E. coli is becoming the standard for biological indicators or fecal coliform. This parameter is measured as count/100mL. All segments within the Upper Culebra Watershed have a water quality standard of 126 #/ml. The value is supposed to be calculated based on the two-month geometric mean of the sample data.

Rito Seco, CORGR28 (Figure 7-1), was Section 303(d) listed for Escherichia coli (E. Coli). E. coli is found in the intestinal tract and feces of warm-blooded animals. The existing e. coli data was plotted and is shown in Figure 7-79. The most recent E. coli sampling on Rito Seco was collected at San Luis on June 14, 2006, with a count of 44/100ml. Trends in E. coli counts above and below Battle Mountain Mine indicate an increase in E. Coli throughout this reach in 2002. No other data was available for this stream. 2002 was an extreme drought year which may have had impacts on the water quality measurements. Potential sources of E. coli include cattle, wildlife, and human waste, both directly and indirectly through septic systems which are improperly functioning.

Table 7-63 Existing E. coli data for Rito Seco.

Sample Date	Characteristic	Rito Seco above Battle Mountain Mine	Rito Seco below Battle Mountain Mine	Rito Seco at San Luis	units
2002/03/12	Escherichia coli	Not Sampled	16.1	Not Sampled	#/100ml
2002/06/05	Escherichia coli	143.9	344.8	Not Sampled	#/100ml
2002/07/23	Escherichia coli	6.3	1299.7	Not Sampled	#/100ml
2002/08/28	Escherichia coli	8.5	248.9	Not Sampled	#/100ml
2005/10/19	Escherichia coli	Not Sampled	Not Sampled	15	#/100ml
2006/06/14	Escherichia coli	Not Sampled	Not Sampled	44	#/100ml

Recreation class 1a has a E. coli standard of 126 #/100 ml and class 1b has a standard of 325 #/100ml.

Table 7-64 Summary of Escherichia Coli data from existing water quality datasets.

Escherichia Coli (E. Coli) in#/ mg/L

Group	Min	Max	Average	Standard Deviation	Count	Not Detected Count	First Date	Last Date
All Data	0	1300	96.8	270	24	2	3/12/2002	8/23/2006
Rito Seco Above Battle Mountain Mine	2	144	33.0	62.1	5	0	6/5/2002	8/28/2002
Rito Seco Below Battle Mountain Mine	16.1	1300	477	565	4	0	3/12/2002	8/28/2002
Rito Seco at San Luis	15	44	29.5	20.5	2	0	10/19/2005	6/14/2006
Culebra near San Luis	0	90	24.8	35.9	7	0	8/9/2005	6/14/2006
Sanchez Reservoir near Dam	Not Detected	7.4	3.0	2.6	5	1	8/11/2005	8/23/2006
Sanchez Reservoir	Not Detected	0.5	--	--	1	1	8/11/2005	9/13/2005

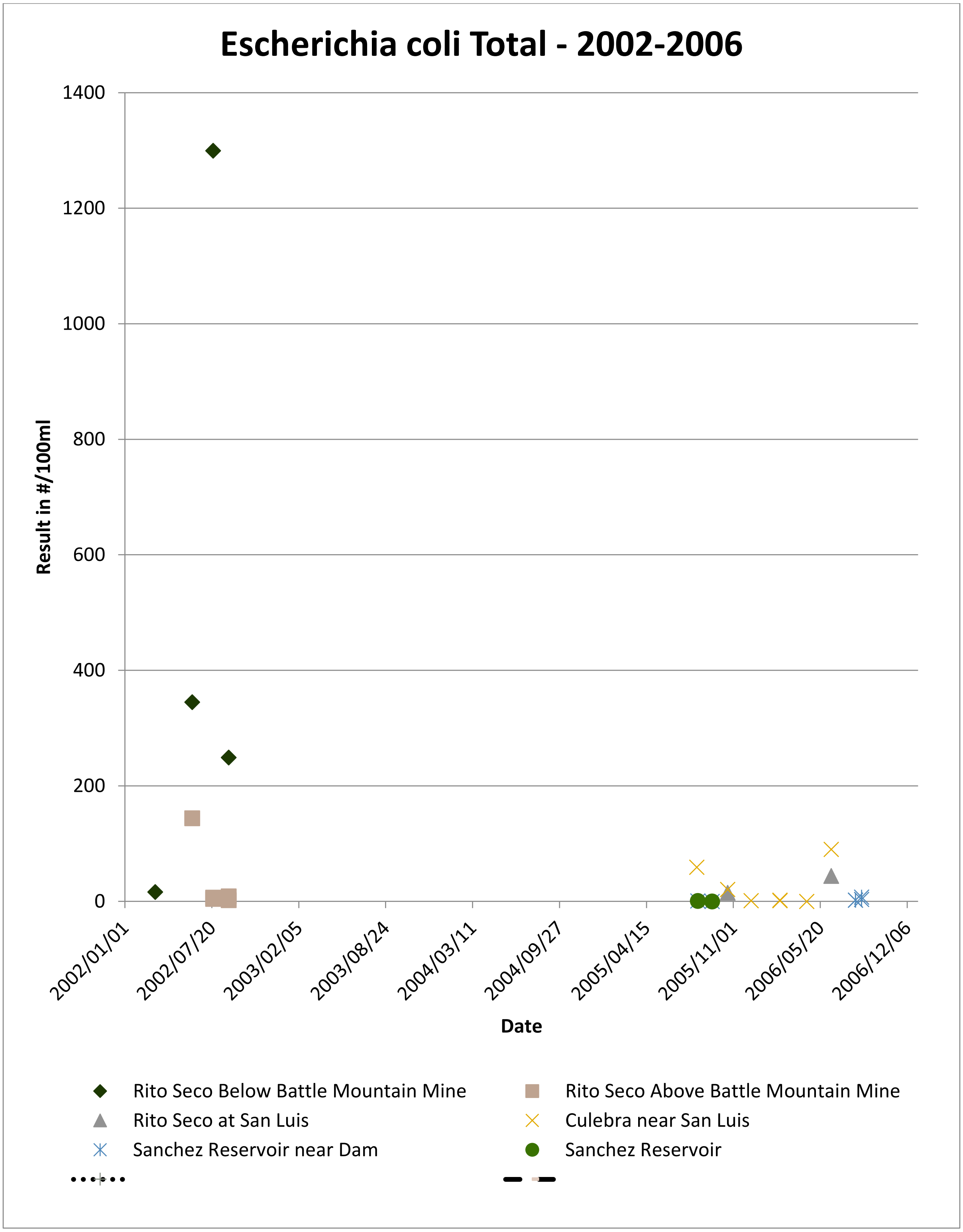


Figure 7-79 Time-series plot of Escherichia coli from existing water quality datasets.

7.4.3.2 Fecal Coliform

Fecal coliform is an indicator organism and does not always indicate a source of pathogens. The source of the fecal coliform can help determine urgency of health hazard. If fecal coliform in high due to agricultural run-off the health hazard may be reduced as compared to human sewage. Utilizing Fecal coliform criteria is being removed in favor of using E. coli standards within the numeric standards.

Recreation – Class 1a generally has a standard of 200 fecal coliform per 100 ml, Class 1b has a standard of 325 #/100ml, and Class 2 generally has a standard of 2000 fecal coliform per 100 ml. (Regulation No. 36 Classification and Numeric Standards for Rio Grande Basin, 2018).

Table 7-65 Summary of fecal coliform data from existing water quality datasets.

Fecal Coliform in #/mg/L

Site Group	Min	Max	Average	Standard Deviation	Count	Not Detected Count	First Date	Last Date
All Data	Not Detected	920	59.6	142	51	9	6/25/1992	2/20/2002
Rito Seco Above Battle Mountain Mine	Not Detected	10	4.3	4.3	4	5	4/17/2001	12/11/2001
Rito Seco Below Battle Mountain Mine	Not Detected	113	23.3	32.8	23	1	1/24/2000	2/20/2002
Rito Seco at San Luis	Not Detected	920	254	284	8	1	7/27/1992	7/11/2000
Culebra near San Luis	Not Detected	240	29.7	60.9	15	1	8/25/1992	10/18/2000
Sanchez Reservoir near Dam	Not Detected	7	7	--	1	1	6/25/1992	8/13/1992

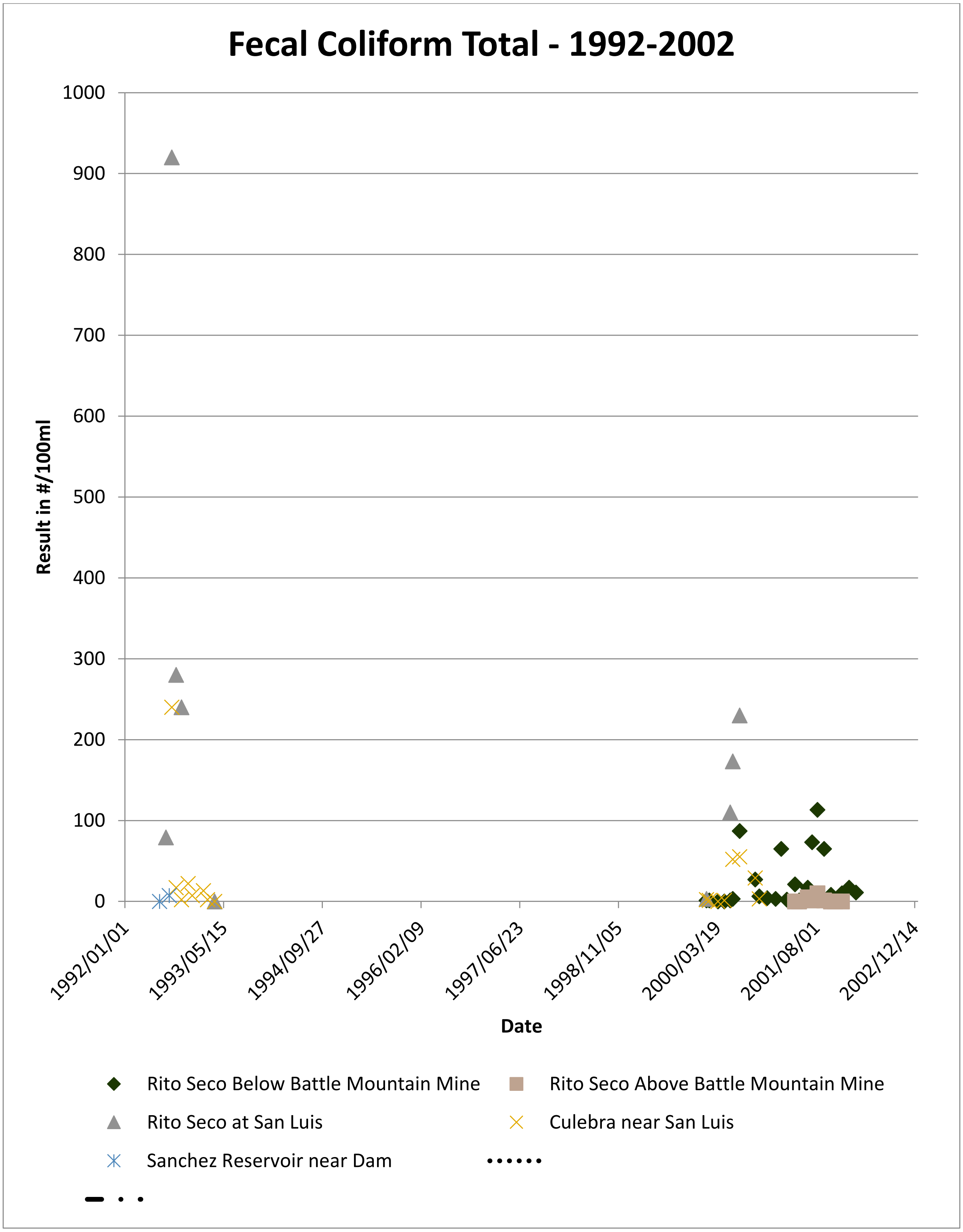


Figure 7-80 Time-series data for fecal coliform from existing water quality datasets.

7.5 Discussion

The analysis of water quality within the Upper Culebra basin showed that the water quality within the basin is generally good. There are detectable levels of some metals and other characteristics that are likely related to the local geology. Historic water quality sampling frequency is poor within the basin and a routine sampling program could improve understanding of the water quality characteristics including seasonal and event-based variation.

Visually evaluating the existing data for trends did not reveal any that were striking. The high quantity of samples below the method detection limit decreases the confidence in which trends could be evaluated.

Noticeable changes in water chemistry were noted in the reach of Ventero Creek and Culebra Creek below Sanchez Reservoir. Understanding of this system could be improved by additional sampling or continuous monitoring within this reach.

The TMDL for Sanchez Reservoir removed this body of water from the Section 303(d) list for biological mercury levels. The water quality measurements for mercury concentration in the water of Sanchez Reservoir are not of concern. Sanchez Reservoir is currently listed on the Monitoring and Evaluation list for arsenic.

Using field parameters to assess changes in the water quality allowed greater spatial distribution of sampling without the additional expense associated with collection of water quality samples, many of which were below the detection limits.

7.5.1 303(d) listing

Having portions of a basin listed on the monitoring and evaluation list or Section 303(d) listed is a flag to indicate that the water in the stream does not meet the designated uses for that stream. However, it is important to evaluate what the source for that characteristic is and what can be done to improve water quality in the stream. If the contaminate is coming from a point-source discharge, then this is a concern that will likely result in more rapid action.

If the source of contamination is from the natural geology or atmospheric deposition action may be more difficult and require cooperative approaches to reducing the contaminate. The approach to reduction from these sources is often stream stabilization and reduction in sediment sources to a stream. Typical sources of sediments are land erosion, stream beds and banks, and roads.

A stream that is not listed on the 303(d) list may have degraded water quality, but insufficient data is available to make this determination. A reach being placed on the 303(d) list brings heightened awareness to the reach.

7.5.2 Water quality concerns from unplanned release

There are community concerns related to the operations occurring within the Battle Mountain mine site and the impacts on the town of San Luis. The existing sample data did not reveal any parameters outside of health standards. However, if water quality were temporarily degraded due to an accidental spill or release of untreated water the event would not be tracked unless it coincided with the routine sampling.

In addition to the concerns related to accidental releases, there are times that water from the water treatment plant is a substantial portion of the flows in Rito Seco Creek. This has the potential to provide a variation in water chemistry, which could disrupt aquatic health in addition to the changing flows.

Additional information related to the water chemistry changes from above and below the disturbed area within the Rito Seco drainage and continuous water quality monitoring downstream of the site could be used to improve the understanding of the water chemistry and could be used to inform decisions in the future. The water treatment plant was operated 3-4 days a week in November 2021, (Madrid, 2021) which is resulting in wide fluctuation of flows within Rito Seco Creek, and during low flows likely a varying water chemistry. Having additional information available could help to determine if site operations are meeting the goals of project or if adjustments to operations should be made to achieve the goal of having clean safe water.

7.5.3 Mercury in Reservoirs

In a national study of fish tissue samples which included samples from 76,559 lakes 48.8% of the lakes had fish tissue mercury concentrations that exceeded 0.3 mg/kg (USEPA, September 2009). Wolff, Johnson, and Lepak (2016) have shown that a shift in the food web within a reservoir, and the subsequent shift in predator diets, can be used to reduce mercury concentrations within the sport fish population. This gives rise to the possibility of utilizing fisheries management to help manage mercury in consumed fish.

Coordination was made with Colorado Department of Public Health and Environment and Colorado Parks and Wildlife to obtain biological samples during the summer of 2020. Fisheries evaluation of the reservoir in 2020 revealed that the species composition of the reservoir is still recovering from the reservoir draining and gate replacement that was completed in 2014. The reservoir is on the priority list to be sampled once the species composition has recovered.

7.5.4 Municipal Solid Waste

During the field assessments many arroyos and areas were observed to have significant volumes of residential waste dumped into them. In many locations carcasses were observed along with household waste. A detailed assessment of dump area contents was not performed but residential wastes may include electronics; petroleum products; paint (lead based and non-lead based); Mercury containing items such as Fluorescent and Ballast light bulbs, some thermostats, and thermometers; batteries; etc. Distance to the nearest landfill is the San Luis Valley Regional Landfill which is 59 miles from San Luis with and estimated travel time of 69 minutes.

Figure 7-81 Dumping in arroyos and open lands.

Transfer station operates with limited hours and may be difficult for some residents to access. Improve and keep updated online information including location of transfer station, load requirements, and fee schedule.

7.5.5 Septic Systems

While portions of the basin have wastewater that is treated through municipal wastewater treatment plants other areas in the basin rely on Septic Systems to treat household wastewater. As streams have been degraded and streamflows been reduced from drought it becomes more likely for septic systems to be placed in areas that will rapidly contribute to streamflow, increasing risk of degrading stream water quality.

7.6 Recommendations

Monitoring water quality over long periods throughout the seasons enables trends to be detected early, which often leads to less expensive solutions. Developing regulatory framework provides steps toward preventing degradation. Providing education related to water quality for residents increases understanding and improves success of other programs.

7.6.1 Sampling

- Install continuous water quality monitoring at Rito Seco Creek.
- Perform sampling at least three times per year at Culebra at San Luis Gage. Sampling prior to run-off, during peak flow, and base flow.
- Perform annual sampling of water quality near, or at the locations sampled for this assessment.
- Install continuous water quality monitoring at Culebra at San Luis gaging station or increase field parameter sampling at the gaging station.
- If variations are noted in continuous water quality monitoring data that are not captured within the routine sampling it is recommended to setup an "Alert" system and perform event-based sampling.
- Monitor water quality downstream of any large land disturbing activities such as construction sites, below roads, and logging activities. This could be included as a permitting requirement.
- Track development in basin and increase monitoring frequency at sites experiencing increases in land use changes.
- Sanchez reservoir has indications of nutrient pollution including high ammonia values, high phosphate values, and low dissolved oxygen in portions of the water column. Additional routine nutrient sampling is recommended to better identify sources of nutrient loading and trends.

Recommended Parameters

Nitrate+Nitrite
Total Nitrogen
Total Inorganic Nitrogen
Total Phosphorus
Sulfate
Chloride
Carbonate
Bicarbonate
Calcium
Magnesium
Sodium
Potassium
Aluminum
Iron (Total and Dissolved)
Copper
Nickel
Silver
Zinc
Lead
Arsenic
Selenium
Cadmium
Manganese
Molybdenum
Ammonia
Boron
Alkalinity
pH
Electrical Conductivity
Volatile Organic Compounds
E.coli

7.6.2 Regulatory

- Implement storm water management regulations requiring best management practices for construction including installation of silt fencing and revegetation of exposed slopes.
- Encourage buffer strips and other nutrient and sediment reducing practices on farms within the basin.
- Discourage storage of vehicles and hazardous chemicals within the floodplain including gas and propane tanks and fertilizers.
- Develop manual for roadway construction including design requirements for stream/roadway crossings. Develop design review process that includes review by a qualified professional.
- Prosecute illegal dumping including fines and community service. Increase fines for illegal commercial dumping.
- Prosecute vandalism to reduce long-term maintenance and life cycle costs.

7.6.3 Projects

- Implement projects to reduce sediment loading on the streams including areas with cut banks and degradation.
- Improve road crossings to reduce gully erosion.
- Stabilize gullies around roads.
- Clean up existing dump sites.

- Improve access to waste disposal by developing local waste disposal facility that could serve Costilla and Conejos counties.
- Provide more opportunities for sustainable waste disposal including composting, recycling, and hazardous waste disposal.
- Reduce ditch loss return flows through high loss reaches.
- Restore floodplain connection to reduce bank erosion and sediment transport in unconfined valleys.
- Improve riparian habitat to reduce bank erosion and attenuate overland sediment flows.

7.6.4 Education

- Teach basin residents about proper trash disposal. Provide resources to make it possible. Research has shown that reducing the perception of the acceptability of dumping is effective in reducing illegal dumping (APSOS, 2020).
- Improve and maintain online information related to transfer station hours, cost, and requirements.
- Provide training to county staff on roadway maintenance.
- Provide training for farmers on nutrient and sediment reduction practices.
- Replace signage discussing Mercury in fish at Sanchez Reservoir and develop outreach program to educate residents on Mercury consumption.

Figure 7-82 Roadside "dump" potentially contributing to the quality of water in the Culebra Basin.

7.7 Summary

Sampling of streams within the basin historically occurred on Culebra Creek and Rito Seco, but has not occurred since 2011, Sanchez Reservoir water quality was last sampled in 2015. The first samples within the basin were collected by the U.S. Geological Survey in the 1967 water year at Culebra near Chama.

Samples collected as part of this assessment indicate water quality within the Upper Culebra watershed is generally very good. The water quality does appear to have some impacts within the lower basin and there are some regulatory concerns related to copper, E. Coli, and arsenic within the basin. These concern areas are based on very limited sampling and data that could be improved by increasing sample frequency.

Chapter 8. Rangeland Assessment – To be completed 2022

Chapter 9. Wildlife Assessment – To be completed 2022

Chapter 10. Forest Health Assessment

Author: SWCA Environmental Consultants

10.1 Introduction

This forest health assessment report focuses on the existing forest health conditions in the Upper Culebra Watershed (UCW), located in the southern Sangre de Cristo Mountains of southcentral Colorado in Costilla County, with the southernmost portion of the watershed continuing into Taos County, New Mexico (Figure 10-1). The UCW covers 242,409 acres. Streams and rivers in the mountains deliver water to the valleys around the villages of the Culebra Basin, which receives an average of less than 8 inches of precipitation per year. Agriculture is the primary economic driver in the region.

This UCW forest health assessment primarily encompasses three privately managed ranches: the Trinchera, Cielo Vista, and Dos Hermanos ranches. These ranches fall within the Costilla County Conservancy District (CCCD). CCCD recognizes the value of natural resources (primarily water) within the district and promotes enhancement and efficiencies of water use in a manner that benefits the community (Costilla County Conservancy District (CCCD), 2019). The three private ranches occupy an area of 96,233 acres or approximately 40% of the UCW. Forest management and health on these ranches directly impacts the health of the watershed and water resources.

Over the last 10 years, the spruce beetle has been one of Colorado's most widespread and damaging forest insects (Colorado State Forest Service (CSFS), 2017). One of the most severe spruce beetle outbreaks in the state is in the Sangre de Cristo Mountains (CSFS 2017). In addition, in the UCW western spruce budworm has also impacted forests comprised of Engelmann spruce. Outbreaks of both of these insects has resulted in widespread forest mortality within the region. Current efforts to improve forest health and resiliency include sustainable timber operations, some of which focus on salvaging beetle killed trees.

Tree mortality caused by beetle infestations in combination with fire suppression tactics and reduced logging activity is contributing to high fuel loads in the area. High fuel loads and conditions of prolonged drought are cause for concern for forest health and public safety within the UCW (Costilla County Mitigation Advisory Committee, 2015). These phenomena are thought to contribute in part to the size and intensity of the wildfires in the area. Since the early 2000s, nearly 300 square miles have burned in the Valley (Pohl, 2018). These wildfires have been the cause of mandatory evacuation orders and have destroyed homes. Over 200 homes were burned in the 2018 Spring Creek Fire and impacted 108,045 acres of forested woodland just north of the UCW (Arkansas River Watershed Collaborative, 2021; Colorado Encyclopedia, 2021).

Severe, extensive wildfires can cause major disruptions to water quality and supply. During active wildfire events, ash and other contaminants settle on water sources. Furthermore, vegetation is burned which destabilizes ground soil. Therefore, precipitation following a burn can flush large quantities of ash, sediment, and other contaminants into waterways and downstream reservoirs. Soil becomes prone to erosion and flooding, potentially causing debris flows and impacting drinking water, irrigation sources, and important resources for recreation (U.S. Environmental Protection Agency, 2020). Forest health and management is critical to protect water sources and mitigate these post-fire impacts.

10.1.1 Purpose and Need

For several years stakeholders in the watershed have recognized the environmental challenges facing the UCW and the need to implement projects to address forest health, however documentation of conditions in the upper watershed have been limited to date. The primary intent of this UCW forest health assessment is to quantify current existing conditions of the 242,409-acre area that includes the Trinchera, Cielo Vista, and Dos Hermanos ranches. Using existing conditions, this report provides mitigation measures and recommendations to landowners which are aimed to promote forest health, reduce fuel loads, reduce catastrophic wildfire risk, implement sustainable forestry practices, and promote forest resiliency to future disturbances by restoring the Culebra forest structure.

10.1.1.1 Forest Health Initiatives and Forest Resiliency

The overall objective of this assessment is to understand current conditions and promote sustainable forest health initiatives in part to protect the watershed. Overstocked stands are those that are crowded with too many trees. Overstocked stands of pine, mixed conifer, and aspen in conjunction with prolonged drought have degraded the forest health within the UCW analysis area. When individual trees are crowded, resources such as sunlight and water become scarce, and the trees can become weak, which allows them to be more susceptible to insect attacks (Powell, 2008). Drought can exacerbate these conditions, further weakening trees and perpetuating insect damage and disease. These conditions, currently present in the analysis area, are contributing to insect and disease outbreaks in the watershed’s forests. Working to combat overstocked conditions will not only help mitigate the impacts of insect and disease outbreaks in the UCW, but also will help build forest resiliency to other disturbances, including wildfire.

<u>Fuels Reduction and Merchantable Timber Sales</u>

Generally, the stands that are within the UCW are overstocked with even-aged overstory trees. A diversity of tree ages is important to forest health because it increases resiliency to disturbance. For example, a windstorm is more likely to damage older trees and certain insects prefer younger trees. If tree age is diverse, disturbances are less likely to impact entire regions or stands (Climate Action Tool, 2021).

Beetle infestations and other pest impacts on forests often kill large portions of individual tree stands when there is limited tree age diversity. As trees die, forests become less capable of carbon sequestration, contributing to a decline in watershed health, and production of harvestable timber.

To address overstocking and even-aged stands, mechanical treatments could be used. There is a history of timber sales throughout the analysis area, and evidence of previous timber harvest operations is present on each ranch. Additionally, mechanical treatments would also reduce hazardous fuels and provide job opportunities for the local community.

<u>Conjunction with Healthy Forests Restoration Act</u>

This analysis effort is consistent with the guidelines set forth in the Healthy Forests Restoration Act of 2003 (HFRA). The HFRA was passed to enhance the federal government’s ability to conduct hazardous fuels reduction projects that aim to protect communities and watersheds from disastrous wildfire events. The Act is defined by six main purposes. The analysis in this document specifically addresses HFRA purposes 3 and 6, which are: (3) “to enhance efforts to protect watersheds and address threats to forest and rangeland health, including catastrophic wildfire across the landscape” and (6) “to protect, restore and enhance forest ecosystem components - (B) to improve biological diversity and (C) to enhance productivity and carbon sequestration.”

10.2 Analysis Area

As described in Section 1, the UCW is in Costilla County, Colorado (with a small portion located in Taos County, New Mexico), in the southern Sangre de Cristo Mountains (see Figure 10-1Figure 1-3). The largest community in the watershed is San Luis, Colorado, which in 2019 had a population of 790 (United States Census Bureau [USCB], 2020) and is the oldest town in the state. The region is home to extensive Hispanic and religious history.

The watershed is 242,409 acres in total and has an elevation range spanning from 7,462 to 14,050 feet above sea level. The UCW is home to several high-elevation peaks such as the only privately owned 14,000-foot mountain: Culebra Peak. Great Sand Dunes National Park is approximately 50 miles north of the analysis area. Recreational activities are a major focus of the area which is home to many mountain biking and hiking trails, as well as opportunities for backcountry skiing. The Rio Grande River is a major water source throughout the Valley and provides opportunities for rafting, fishing, and other related activities (Colorado Tourism Office, 2021).

The UCW analysis area is composed of moderately steep forested mountain slopes, exposed high alpine ridges and basins, flat structural benches, open grassland meadows, shrublands, and riparian areas. As aforementioned, the majority of the land in the analysis area is owned by three private ranches: Trinchera, Cielo Vista, and Dos Hermanos. Streams and rivers in the analysis area deliver water to the San Luis Valley, which is primarily dominated by agricultural activity.

Much of the agricultural activity in the Valley is dependent on the acequia water system. Brought to Colorado by the original settlers of the San Luis Valley, these irrigation ditches also represent a way of life and a form of government. Water is managed communally, where all farmers cut back during drought years to ensure at least some distribution to all (Meluso, 2021).

Each ranch has had a varied approach to forest health and management to date. The sections below describe this in more detail.

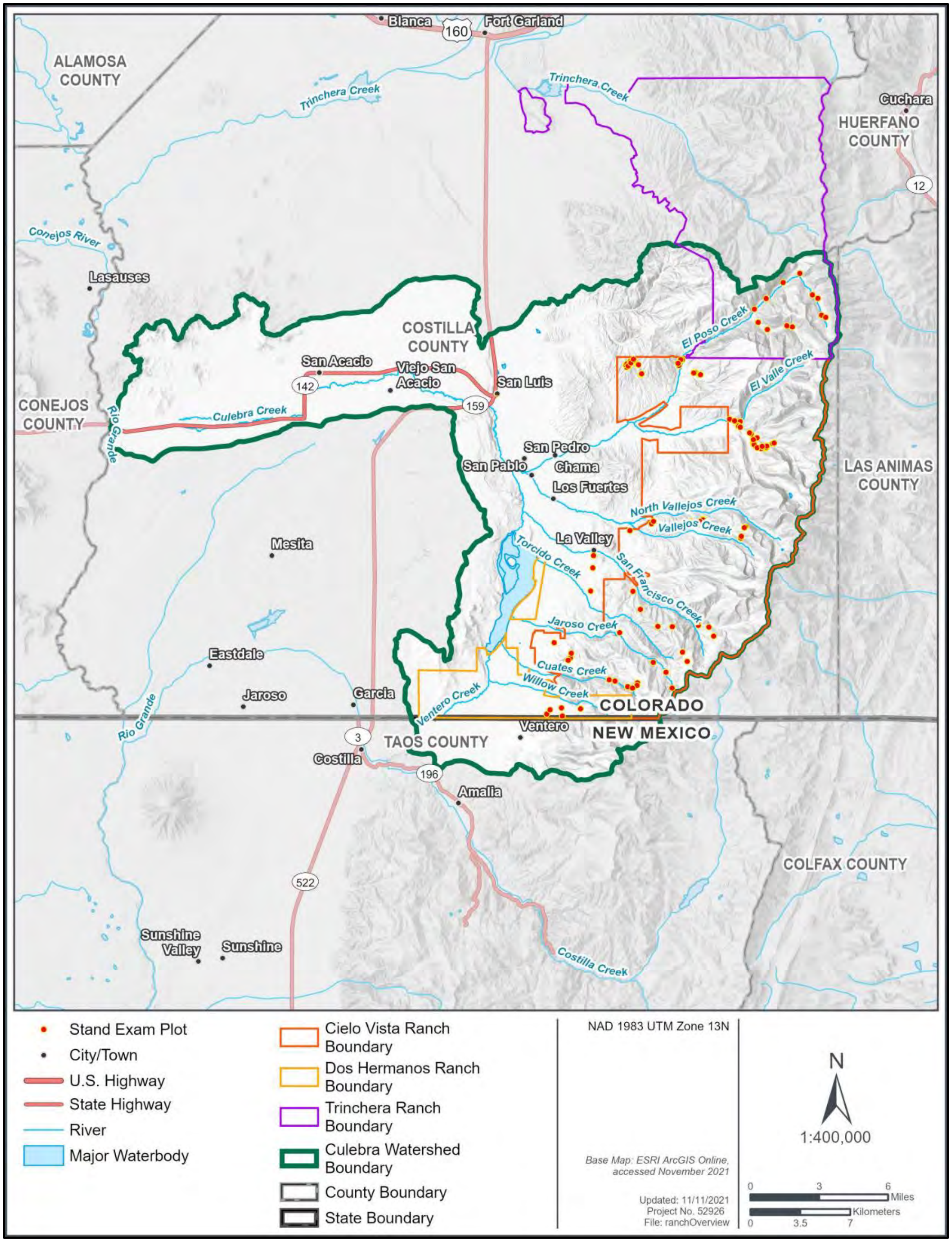


Figure 10-1 The Upper Culebra Watershed analysis area.

10.2.1 Trinchera Ranch

Trinchera Ranch is the northernmost ranch in the project area and totals approximately 14,219 acres or 15% of the UCW analysis area (Figure 2). A large portion of the ranch is outside of the analysis area to the north; the ranch totals 172,000 acres and is protected by multiple conservation easements. Many structures are present on the ranch, including a lodge available for events, weddings, and travelers (Trinchera Ranch, 2020). Trinchera Ranch is a destination for activities such as fly fishing, hunting, hiking, mountain biking, rock climbing, mountaineering, and wildlife viewing.

El Poso Creek is the main drainage in the portion of Trinchera Ranch that was surveyed during field sampling. This creek is fed from snowmelt, naturally occurring springs, and ephemeral drainages from the Canova and Jarioso Canyons. El Poso Creek and Jarioso and Canova Canyons can be accessed through ranch-maintained dirt access roads (J. Fischer, personal communication, June 2021).

Over the years, the Trinchera Ranch owners have been actively managing mountain pine beetle infestations, overstocking, defensible space around structures, and hazardous fuel loads on their property by harvesting merchantable timber and creating forest products at the on-site lumber mill. Currently the ranch removes 2.5 million board feet of timber per year but is planning to increase this capacity and thereby increase profitability of this work (J. Fischer, personal communication, June 2021).

Additionally, the ranch practices mastication of sagebrush communities along roadways at lower elevations to maintain fuel breaks. At higher elevations, the ranch uses various commercial timber sales and other fuels reduction projects. Additionally, throughout the ranch, slash piles (accumulations of limbs, leaves, and miscellaneous fuel) are used around budding aspen groves to deter potentially damaging ungulates like Rocky Mountain elk (*Cervus canadensis nelsoni*) and mule deer (*Odocoileus hemionus*). Aspen are an important species to conserve as they serve as a natural fire break, retain soil moisture, and are biodiversity hotspots for plants, insects, birds, and mammals (J. Fischer, personal communication, June 2021).

10.2.2 Cielo Vista Ranch

Cielo Vista Ranch is midway between Trinchera Ranch and Dos Hermanos Ranch within the UCW (see Figure 10-2). Cielo Vista accounts for 70,402 acres or 73% of the UCW analysis area. The ranch in total is over 80,000 acres. The ranch has a small number of historic structures, along with a few camping areas for hikers. A number of roads are throughout the ranch, in addition to the older logging roads that are not regularly maintained (C. DeLeon, personal communication, June 2021).

Although there are no existing land management plans for the ranch, about 33% of Cielo Vista Ranch is protected by a conservation agreement with the Rocky Mountain Elk Foundation (RMEF) (Mirr Ranch Group, 2021). RMEF works with partners to protect elk range, migration corridors, and birthing areas. This is accomplished through various land management practices such as forest thinning, prescribed burning, and noxious weed treatments (Rocky Mountain Elk Foundation [RMEF], 2021).

Cielo Vista Ranch is home to Culebra Peak, one of the few privately owned 14,000-foot mountain in Colorado. Prospective users can pay an entry fee to hike the peak. In addition to being a hiking destination, the ranch is also used for hunting and fishing. As Cielo Vista Ranch is a working ranch, the grasslands found throughout the ranch are used for cattle grazing (C. DeLeon, personal communication, June 2021). Grazing and firewood procurement on the ranch land through historic land grants is common.

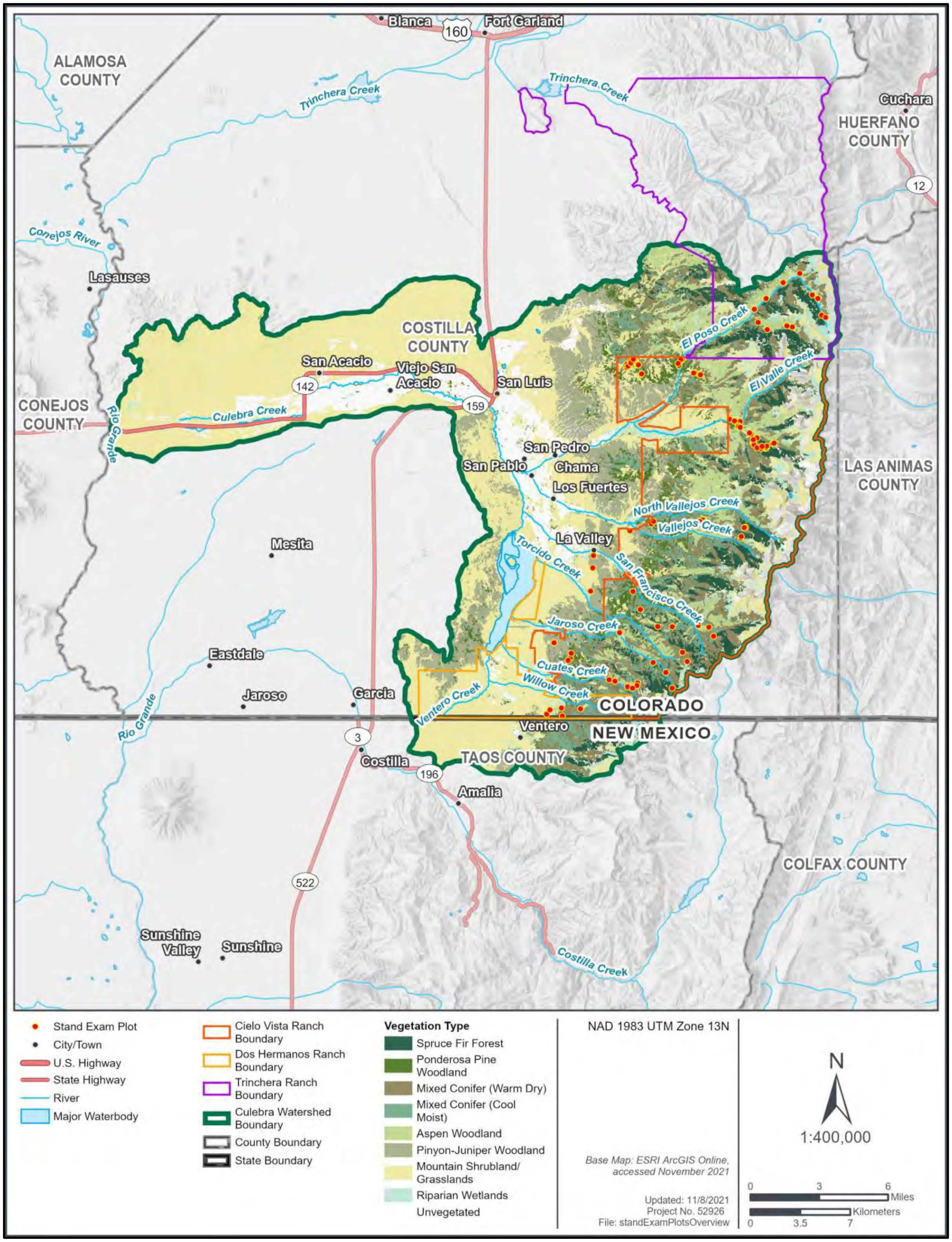


Figure 10-2 Sampling point locations for the forest health field assessments throughout the UCW analysis area.

Historically, land grants were issued in this area by the Mexican government in the 1800s to encourage settlement to ward off impending intrusion by an expanding United States. The Sangre de Cristo Land Grant is the second largest of its kind in the state and has also been one of the most contentious. Despite many years of conflict with private landowners in control of the property under this land grant, the Supreme Court ruled in favor of local descendants in 2002 for their access for grazing and timber purposes. An appeal was filed by the Cielo Vista Ranch owner, but the Supreme Court ruling was upheld by the Colorado Court of Appeals in 2018 (Simmonds, 2020).

El Poso Creek flows across the northwestern corner of the ranch. The stream complex of Bernardino Creek, El Perdido Creek, Carneros Creek, and El Valle Creek flow together to form Culebra Creek. Farther south are North Vallejos Creek and Vallejos Creek. The San Francisco Creek, Torcido Creek, Jaroso Creek, and Cuates Creek are the southernmost waterways on the ranch. These drainages and the slopes above them were sampled during the field effort.

10.2.3 Dos Hermanos

Dos Hermanos Ranch is at the southern end of the UCW analysis area and amounts to 11,612 acres or 12% of the analysis area (see Figure 10-2). The majority of the ranch is composed of low-elevation grasslands at the center of the UCW. These grasslands are predominantly used for agriculture and grazing. During this project, forest health analysis was conducted on the eastern portion of the ranch within the Willow Creek drainage. Multiple seasonal and year-round homes are located in the eastern portion of the ranch.

Mastication has been employed at lower elevations with the piñon-juniper and sagebrush communities to reduce the risk of wildfire. Mastication has been funded by the Colorado Parks and Wildlife Habitat Protection Partnership for wildlife enhancement historically.

10.3 Existing Forest Conditions

In this section, existing forest conditions within the UCW are described. Furthermore, each ranch is broken down into their respective forest conditions for a more detailed analysis. Methodology is presented to give a background on how data was collected and analyzed.

10.3.1 Methodology

10.3.1.1 Existing Data

Spatial datasets that were used in the desktop assessment and to determine sampling locations for this task include 1/3 Arc Second resolution Digital Elevation Models (U.S. Geological Survey, 2021) to derive slope and land cover; Southwest Regional Gap Analysis Project (Southwest Regional Gap Analysis Project (SWReGAP), 2021) data to derive vegetation types; TIGER/Line Shapefiles (U.S. Census Bureau, 2015) to compile a roads dataset; and aerial imagery (EagleView, 2021-22) to manually delineate roads, described in Section 1.3.7.

Other existing datasets were also used to assess forest health during the desktop analysis. Information on areas of insect infestations, disease conditions, and human-caused stressors affecting forest health was assessed using the National Insect and Disease Risk Map database (U.S. Forest Service [USFS], 2021a). Basal area and stand density were assessed using the Individual Tree Species Parameter database (U.S. Forest Service [USFS], 2021b). Status and trends in tree health, growth, and mortality was assessed using data from the Forest Inventory and Analysis Program (U.S. Forest Service [USFS], 2021c). Other factors affecting forest health (including drinking water risk, forest asset risk, riparian asset risk, and wildfire risk) were assessed using data from the Colorado Forest Atlas (Colorado State Forest Service [CSFS], 2021a).

10.3.1.2 Selection of Survey Plots

Geographical information system (GIS) specialists used the aforementioned spatial datasets to select survey plots or sampling locations that were stratified by forest cover type and adjusted for distance to the nearest roads (for efficiency) and slopes under 40% (for field crew safety).

The field surveys were conducted by two crews of staff biologists on June 15 through 24, 2021. Following the USFS common stand exam protocols (U.S. Forest Service, 2020), the biologists recorded the site condition, vegetation composition, tree age and height, basal area and diameter, canopy structure and cover, insect and disease factors, dead and downed fuel loading, and seedling regeneration and snag (standing dead tree) density at each sampling location.

The GIS specialists and biologists ensured all recorded data aligned with existing protocols set forth by the UCW stakeholders. This was achieved through pre-field meetings as well as other conversations amongst stakeholders and project team members to ensure congruency. The body of data for the UCW is limited and therefore newly acquired data can contribute to a baseline record of existing conditions.

10.3.1.3 Field Sampling Plan and Data Collection

Plot-level Data Collection

Data were recorded using a tablet equipped with a global positioning system (GPS), Esri ArcGIS Collector, and Survey 123 software programs. Proper stand exam protocol involves using either a fixed or variable radius plot depending on the vegetation type being sampled.

In fixed-radius plot sampling, instead of measuring all the trees in an area, only trees occurring within a pre-determined circular area from the plot center are assessed. A variable radius plot uses specialized timber cruising (the process of measuring forest stands) instruments to determine what trees to collect information on (U.S. Forest Service (USFS), 1965). Using these methods, the basal area or a determination of how much wood is present within the area can be decerned along with other attributes.

For pinyon juniper woodlands with the analysis area (i.e., a mixture of *Pinus* spp. and *Juniperus* spp.), a fixed radius plot of 0.05 acre (26.3 feet) was used to define plot boundaries while variable radius sampling was used in all other vegetation types. When using the variable radius method to define plot boundaries, a basal area factor (BAF) was chosen to ensure that at least four to eight trees are included in each plot.

For every plot, a series of location descriptions was recorded (refer to the *UCW Assessment Project Task 5 Technical Memorandum* (SWCA Environmental Consultants [SWCA], 2021)] for more specific information).

Tree Data Collection

Once general plot location data were recorded, field biologists proceeded to collect data following either the fixed or variable radius plot method depending on vegetation cover type. At each sampling location, tree data were recorded. Following standard forestry practices, tree numbering commenced from 0 degrees north and continued clockwise until the plot was complete. Refer to the *UCW Assessment Project Task 5 Technical Memorandum* (SWCA 2021) for more specific information concerning tree data collection fields. All trees larger than 5 inches in diameter at breast height (DBH) or diameter root collar (DRC) were measured for tree height, age, crown base height, crown class, and tree damage.

Tree age is determined by "coring" the tree with a specialized forester tool. A small cross section of the tree's wood is removed and the annual growth rings are counted. Figure 10-3 below shows the woody material removed from a tree where annual growth rings are counted.

Figure 10-3 Core sample of a Douglas fir.

Tree regeneration was measured in each plot around a 0.01-acre (11.8-foot) radius. All seedlings and saplings within this radius were recorded by species. Diameter and height were recorded for all saplings. A percentage of this radius dominated by regeneration was estimated. For seedlings and saplings, live and dead tallies by species were recorded.

Fuels were measured on one 70-foot Brown's transect per sampling location, which was oriented on a random azimuth from plot center (Brown J. K., 1974).

10.3.2 Forest Structure

Conditions within the project area are characterized at three spatial scales:

- Landscape scale (1,000–10,000 or more acres)
- Mid-scale (aka stand scale) (10–1,000 acres)
- Fine scale (less than 10 acres)

The landscape scale usually has variable elevations, slopes, aspects, soil types, plant associations, disturbance processes, and land uses. The fine scale is an area in which the tree species, age, structure, and spatial distribution are expressed in addition to the same characteristics for other species such as grasses, forbs, and shrubs. Overall, mid- and fine scales provide additional details necessary for guiding site-specific projects and activities. Discussion of desired conditions at the landscape scale can help shape an understanding of the big picture across the Culebra Watershed.

Vegetation and forest health are discussed in this report at the stand scale, while certain effects (such as insect, disease, and drought) are discussed on a landscape scale. Understanding current conditions at the stand scale can help to clarify potential drivers behind these conditions (drought, overstocking, etc.) and will better inform mitigation strategies that can be applied at the stand scale but ideally will improve conditions at both the mid- and landscape scales. Figure 10-4 further illustrates these three spatial scales used to describe desired conditions for each vegetation type in the Culebra Watershed (Reynolds, et al., 2013).

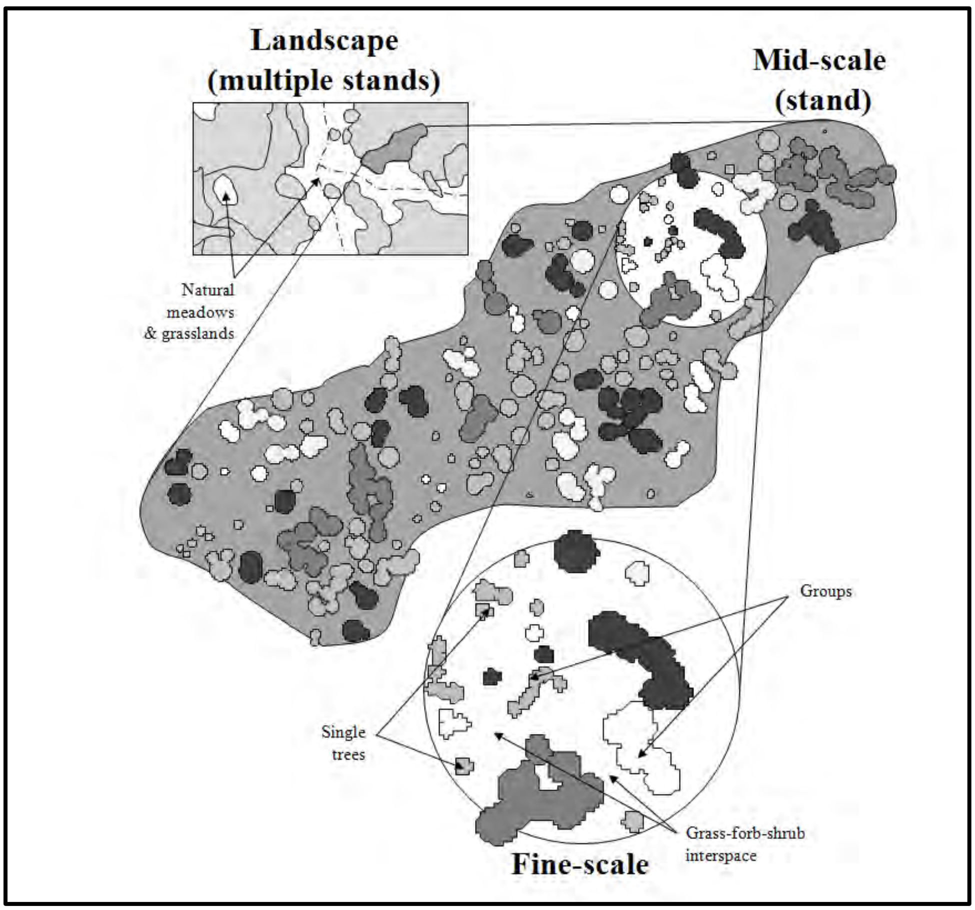


Figure 10-4 Illustration of the three spatial scales (source: Reynolds et al. 2013).

The primary vegetation cover types in the UCW analysis area are pinyon-juniper woodland, ponderosa pine stands, mixed conifer, aspen with conifer, aspen woodland, mountain shrubland and grasslands, riparian woodlands/wetlands, and spruce-fir forests (Table 10-1; Figure 10-6). For an explanation of these cover types, please see Sections 3.2.1 through 3.2.8. These cover types make up approximately 93% of the analysis area. Land cover types such as open water, Rocky Mountain bedrock and scree, and residential areas and agriculture land constitute 7% of the analysis area and were excluded from analysis in this report as they are not forested.

These primary vegetation types generally match with previous estimates for vegetation cover in the region. Valdez's (1992) research on building materials utilized by early Hispanic settlers within the Culebra River Watershed displayed a correlation relationship between basic vegetation ecology and elevation across the Sangre de Cristo Mountains. Alluvial deposits at lower elevations were rich with clay and rocks with shrub growth as the predominant vegetative cover. Valdez described deciduous species such as cottonwoods (*Populus* sp.) and willows (*Salix* sp.) occurring along stream banks -stretching to the upper elevations; with Pinon Pine (*Pinus edulis*), and juniper (*Juniperus* sp.) occurring on the upland sites. He describes ponderosa pine (*Pinus ponderosa*) occurring at mid-elevations. Finally, in order of increasing altitude, he lists the occurrences of following high-elevation species: lodgepole pine (*Pinus contorta*), aspen (*Populus tremuloides*), douglas-fir (*Pseudotsuga menziesii*), limber/bristle cone pine (*Pinus flexilis* and *Pinus aristata*), and, finally, spruce/fir (*Abies concolor*, *Abies lasiocarpa*, and, *Picea engelmanii*) (Figure 10-5).

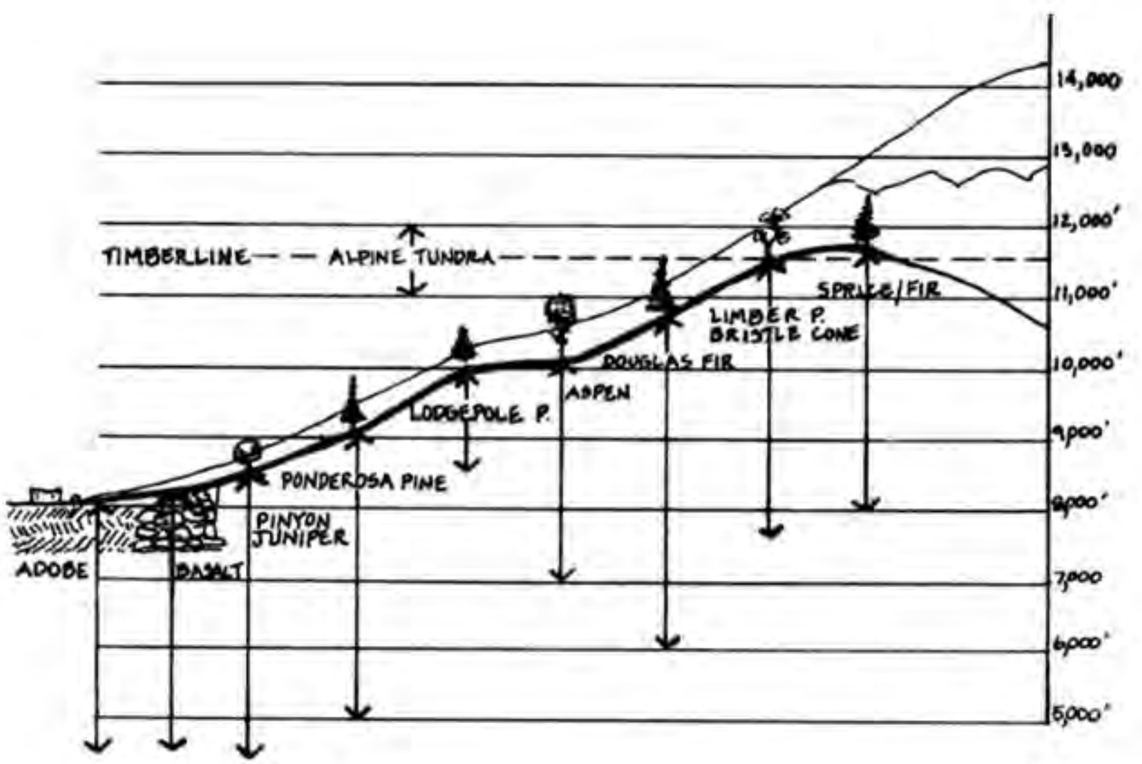


Figure 10-5 Elevation zones of basic vegetation types in Sangre de Cristo Mountains (taken from Valdez 1992).

The following sections contain background information on current cover types as well as general trends observed in the field.

Table 10-1 Dominant Vegetation Types within the Culebra Watershed Analysis Area.

Cover Type	Total Acres within the UCW Analysis Area	Percentage within UCW Analysis Area
Aspen with Mixed Conifer	3,962.67	4.2
Aspen Woodland	13,065.09	13.5
Mixed Conifer (Cool-Moist)	7,799.00	8.1
Mixed Conifer (Warm-Dry)	16,488.03	17.1

Mountain Shrublands and Mountain Grasslands	21,707.80	22.6
Pinyon-Juniper Woodland	6,129.70	6.4
Ponderosa Pine Woodland	4,494.10	4.7
Riparian Woodland and Wetlands	5,703.10	5.9
Spruce-Fir Forest	9,445.90	9.8
Not Analyzed (Non-Forested)	7,437.60	7.7
Total	**96,233.00**	**100.0**

Note: Totals may not be exact due to rounding.

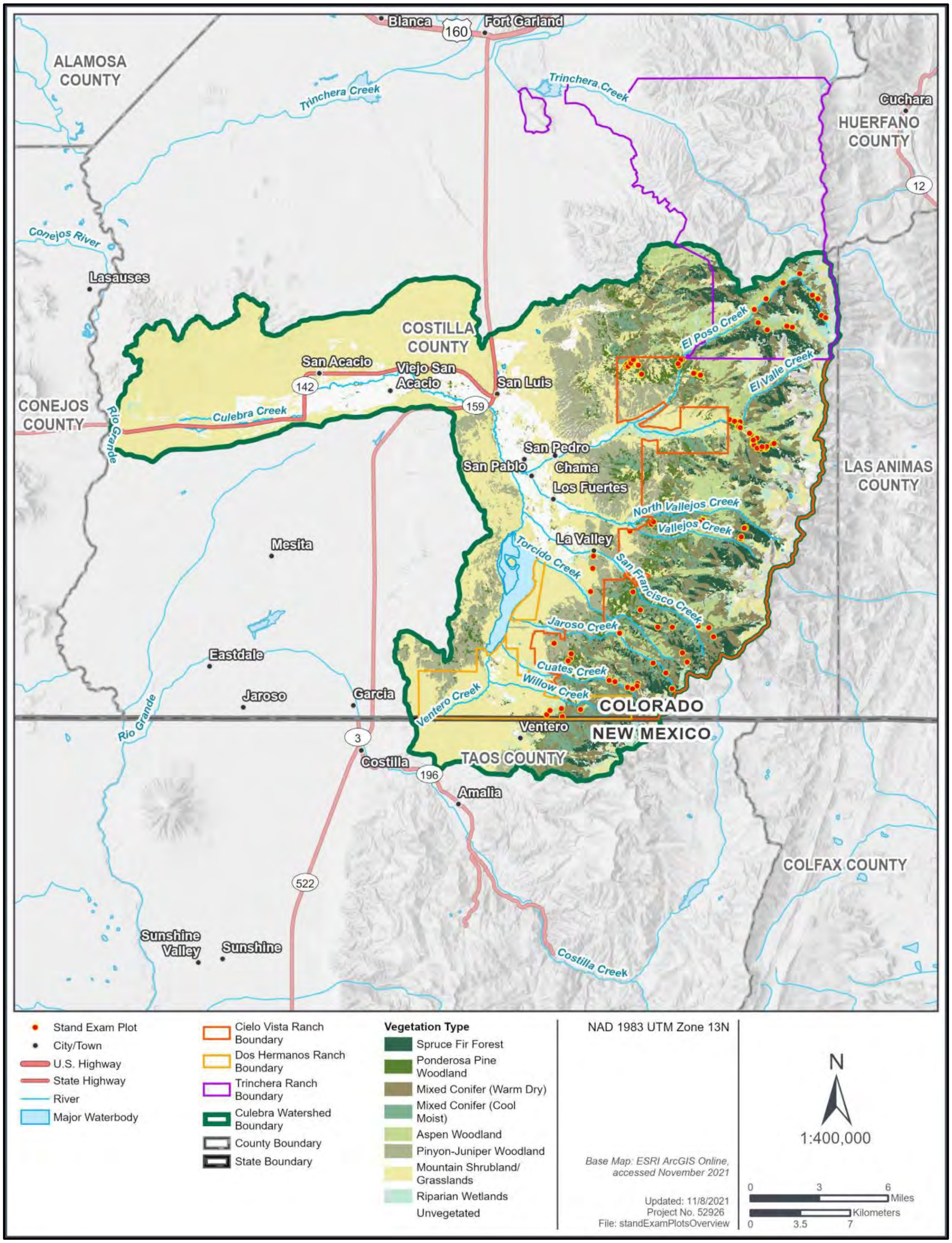


Figure 10-6. Vegetation types within the Culebra Watershed analysis area.

10.3.2.1 Mountain Shrublands and Mountain Grasslands

Together, mountain shrublands and grasslands occupy approximately 21,707.8 acres, or 22.6% of the analysis area (Figure 10-7). These areas range in size depending on the location. While most of the larger grasslands in the analysis area can be found in the western portion at lower elevations, some smaller patches are also interspersed at higher elevations within warm-dry mixed conifer (see 10.3.2.2) stands, and aspen with mixed conifer (see 10.3.2.2) stands.

Occasionally, shade-intolerant trees are found encroaching into these mountain grasslands, such as ponderosa pine and dry-site aspen. Most of the mountain grasslands within the analysis area function as primary range for permitted livestock. Grazing is discussed in more detail in Chapter 8.

Mountain shrublands can be found along the major drainages within the Culebra Watershed. These areas are dominated by Gambel oak (*Quercus gambelii*) and mixed grasses. Gambel oak is also prevalent in warm-dry mixed conifer and ponderosa pine (10.3.2.8) stands.

Throughout the UCW, mountain shrublands and grasslands are primarily used for grazing and agriculture.

Figure 10-7 View of the mountain grasslands and mountain shrublands cover type.

10.3.2.2 Mixed Conifer

The mixed conifer cover type is scattered throughout the analysis area and occupies approximately 24,287.03 acres which represents 25.2% of the analysis area. The mixed conifer cover type can be divided into two sub-types of forests: warm-dry and cool-moist. These two sub-types are both present within the analysis area.

Mixed conifer stands in the analysis area have subalpine fir (*Abies lasiocarpa*), Douglas fir (*Pseudotsuga menziezii*), Engelmann spruce (*Picea engelmannii*), and aspen (*Populus tremuloides*) in the overstory. The midstory and understory are dominated by subalpine fir, Douglas fir, Engelmann spruce, and occasional patches of aspen. There are typically few midstory pine and understory pine seedlings or saplings because of the shade-intolerant nature of this species. Kinnikinnick (*Arctostaphylos uva-ursi*) and mountain mahogany (*Cercocarpus montanus*) are the dominant understory shrubs throughout most of the mixed conifer cover type in the analysis area. Herbaceous understory vegetation is primarily a mixture of grasses and forbs.

As tree density and canopy cover increase, all tree species in mixed conifer forests are increasingly under higher levels of competitive stress as they vie for available moisture, nutrients, and growing space. This stress causes individuals to be less healthy and vigorous, leading to susceptibility to insect and disease attacks. The 2020 aerial CSFS surveys revealed light to heavy defoliation by western spruce budworm (*Choristoneura freemani*) and spruce beetle (*Dendroctonus rufipennis*) damage in the mixed conifer in the analysis area as a whole (CSFS 2021b).

The most common insect affecting Douglas-fir in the analysis area is Douglas-fir beetle (*Dendroctonus pseudotsugae*). The Douglas-fir beetle is known for selectively attacking larger, older, and more dominant trees of their host species before succeeding beetle generations spread to smaller, younger trees (Fettig, et al., 2007).

Other common insects and diseases affecting Douglas-fir in the analysis area include western spruce budworm and dwarf mistletoe (*Arceuthobium* spp.). Western spruce budworm has been known to cause varying levels of defoliation in the lower crowns of Douglas-fir, and sometimes extensive/severe defoliation throughout the crowns of sapling- and pole-sized trees of this species (Colorado State Forest Service (CSFS), 2016). Western spruce budworm and dwarf mistletoe rarely kill their hosts, but they will weaken trees and increase their susceptibility to other mortality factors (Colorado State Forest Service (CSFS), 2021c).

The most common insect affecting Engelmann spruce in the analysis area is spruce beetle. Mortality of Engelmann spruce has dramatically increased in recent years especially in southern Colorado (Colorado State Forest Service (CSFS), 2021d).

<u>Warm-Dry</u>

Approximately 16,488.03 acres, or 17.1% of the mixed conifer in the analysis area, is classified as the warm-dry type (Figure 10-8). These stands are primarily made up of ponderosa pine and Douglas-fir. Warm-dry mixed conifer is generally higher in elevation than pure ponderosa pine stands. The majority of these stands occur in the western portion of the analysis area and on south-, west-, and northwest-facing slopes.

Figure 10-8 View of the warm-dry mixed conifer cover type.

<u>Cool-Moist</u>

Cool-moist mixed conifer comprises approximately 7,799 acres or 8.1% of the analysis area and is characterized by the presence of white fir (*Abies concolor*), Douglas-fir, small amounts of blue spruce (*Picea pungens*) and, at higher elevations, Engelmann spruce and subalpine fir (Figure 10-9). Cool-moist mixed conifer in the analysis area is found intermixed with warm-dry mixed conifer, aspen, and spruce-fir forests.

The majority of these stands occur typically on east- and north-facing slopes at higher elevations. The majority of regeneration found in these stands is white fir, Douglas-fir, and aspen in forest openings. Currently, ponderosa pine exists only on the margins of the cool-moist mixed conifer, scattered in drier areas like ridges or rocky, exposed slopes.

Like both the ponderosa pine and warm-dry mixed conifer cover types, past timber harvest, fire suppression, and insects and disease have shaped the current conditions of the cool-moist mixed conifer in the analysis area.

A variety of insects and diseases are affecting the tree species found in cool-moist mixed conifer in the analysis area. The most common insects affecting both Engelmann spruce and blue spruce in the analysis area are the aforementioned spruce beetle and the western spruce budworm. Western spruce budworm has been causing varying levels of defoliation in spruce and subalpine fir in the analysis area as that described earlier for Douglas-fir and white fir. Western spruce budworm will weaken its host tree and increase its susceptibility to other mortality factors.

Figure 10-9 View of the cool-moist mixed conifer cover type.

10.3.2.3 Aspen

In addition to occurring as individual stems within the other forested cover types, aspen stands can be intermixed with conifer species or completely dominate the canopy in some areas in the analysis area. Aspen is susceptible to many diseases, affecting foliage, stems, and roots. Due to this susceptibility, aspen trees are relatively short-lived, with overstories generally ranging from 110 to 120 years old in Colorado (U.S. Forest Service [USFS], 1990).

However, the relationship between aspen and conifer species can be thought of as cyclical; aspen establish after disturbance and within one aspen generation, shade-tolerant conifers can replace aspen and dominate the canopy (Kulakowski, Veblen, & Drinkwater, 2004) until wildfire occurs again (Kaye, Binkley, & Stohlgren, 2005) and aspen regenerate. It is possible for aspen stands to be self-replacing (Kulakowski, Veblen, & Drinkwater, 2004; Kurzel, Veblen, & Kulakowski, 2007; Smith, O'Loughlin, Buck, & St.Clair, 2011), potentially never converting to a conifer-dominated canopy. It is thought that aspen stands are threatened by conifer encroachment if aspen cover makes up less than 40% of the canopy (Kaye, Binkley, & Stohlgren, 2005).

<u>Aspen with Mixed Conifer</u>

Aspen with mixed conifer stands occupy approximately 3,926.67 acres, or 4.2% of the analysis area. Currently in the analysis area within this cover type, conifers make up a high percentage of the understory and midstory. Mature conifers are sometimes even present in the overstory of these aspen stands.

Figure 10-10 View of the aspen with mixed conifer cover type.

Aspen Woodlands

Approximately 13,065.09 acres, or 13.5% of the analysis area is categorized as pure aspen woodlands without competition from any other vegetation type. Figure 10-10 and Figure 10-11 provide an example of each aspen vegetation type.

The pure aspen stands in the UCW are predominantly affected by insects, disease, and ungulates. Field crews consistently observed ungulate damage within even-age aspen stands in the analysis area. In addition, defoliation due to the western tent caterpillar (*Malacosoma californicum*), *Cytospora* cankers, and *Ceratocystis* cankers is prevalent within the analysis area.

Figure 10-11 View of the aspen woodland cover type.

10.3.2.4 Spruce-Fir Forest

Spruce-fir stands comprise approximately 9,445.9 acres, or 9.8% of the analysis area and are dominated by Engelmann spruce and subalpine fir with occurrences of aspen and blue spruce (Figure 10-12). These stands are found on higher elevations and are surrounded by aspen and cool-moist mixed conifer stands. The majority of regeneration found in these stands is dominated by Engelmann spruce and subalpine fir.

A variety of insects and diseases are affecting the tree species found in spruce-fir stands in the analysis area. The most common insects and diseases affecting both Engelmann spruce and subalpine fir in these stands are spruce beetle and western spruce budworm.

Figure 10-12 View of the spruce-fir forest cover type.

10.3.2.5 Not Analyzed (Non-Forested)

Within the UCW, areas like agriculture fields, houses, travel rights-of-way, exposed scree fields, and open water were not considered for the forest health analysis. These areas total approximately 7,437.6 acres or 7.7% of the analysis area.

10.3.2.6 Piñon-Juniper Woodland

The piñon-juniper (PJ) (*Pinus edulis* and *Juniperus communis*) cover type occupies approximately 6,130 acres which represents 6.4% of the analysis area (Figure 10-13). Most of the PJ stands are located centrally in the analysis area at lower elevations along the foothills of the Sangre de Cristo Mountains range.

Structure within these woodlands varies depending on topography and site conditions. Soils classified as coarse-textured, or rock outcrops in areas of otherwise finer textured deep soils are preferred sites for this cover type. Most of the PJ stands are dominated by large juniper trees interspersed with a mixture of younger juniper and piñon trees. The dominant shrubs within these stands include big sagebrush (*Artemisia tridentata*) and mountain mahogany. Herbaceous understory vegetation consists of deciduous scrub, mixed forbs, and a variety of grasses. The herbaceous understory in these stands is generally sparse and bare soil is common. Transition zones exist where piñon-juniper intermix with ponderosa pine throughout the analysis area at higher elevations zones.

Piñon-juniper woodlands are mostly affected by the pinyon Ips (*Ips confuses*) and dwarf mistletoe. However, during the 2021 field mobilization, no evidence of pinyon Ips or dwarf mistletoe was observed affecting piñon-juniper stands within the UCW analysis area.

Figure 10-13 View of the piñon-juniper cover type.

10.3.2.7 Riparian Woodland and Wetlands

Riparian woodland and wetlands are scattered throughout the analysis area and occupy approximately 5,703.1 acres, or 5.9% of the analysis area (Figure 10-14). These areas are associated with perennial and intermittent streams, ponds, wet meadows, springs, and seeps. These areas are predominantly found in drainages and lowland areas. The riparian areas throughout the UCW primarily support a mixture of Engelmann spruce and aspen trees with Douglas fir and subalpine fir also occurring in some locations. Herbaceous vegetation in these communities generally consists of mixed grasses and forbs. Riparian vegetation is discussed in more detail in Chapter 2.

Figure 10-14 View of the riparian woodland and wetlands cover type.

10.3.2.8 Ponderosa Pine Woodland

The ponderosa pine (*Pinus ponderosa*) forest type occupies approximately 4,494 acres, or 4.7%, of the analysis area (Figure 10-15). Ponderosa pine was also observed in isolated pockets within other cover types throughout the analysis area. This forest occurs generally in higher elevations than piñon-juniper woodlands and is present on all three ranches.

Understory shrub species commonly found in ponderosa pine stands in the analysis area are Gambel oak (*Quercus gambelii*), serviceberry (*Amelanchier alnifolia*), mountain mahogany, common juniper (*Juniperus communis*), big sagebrush, and a variety of grasses and forbs. Ponderosa pine trees have been observed as a mixed cohort of several small pine stands scattered across the analysis area located on drier sites such as ridgetops, or in open areas on the margins of meadows and mountain shrublands. The current stand structure and species composition of ponderosa pine in the analysis area has been influenced by past timber harvest, insect and disease activity, and, to a lesser extent, livestock grazing.

In the analysis area, two main insects were found to affect the ponderosa pine: the mountain pine beetle (*Dendroctonus ponderosae*) and the western pine beetle (*Dendroctonus brevicomis*) (U.S. Forest Service [USFS], 2021a). Field crews observed insect damage in small amounts and in various locations across ponderosa pine stands within the UCW. Pine beetles generally prefer larger trees over smaller trees due to the thick bark, which provides greater protection from periods of extreme cold. Larger trees, particularly older trees, are also often less vigorous, which makes them less resistant to pink beetle activity.

Figure 10-15 View of the ponderosa pine cover type.

10.3.3 Forest Composition within the Analysis Area

10.3.3.1 Trinchera Ranch

The Trinchera Ranch occupies at total of 14,219 acres of the UCW and is the northernmost ranch within the analysis area. This property exhibits all vegetations types noted in Section 10.3.2. Table 10-2 and Figure 10-16 present the primary vegetation cover types that occur within the Trinchera Ranch boundary.

Table 10-2 Vegetation Cover Type and Their Approximate Acreage within Trinchera Ranch

Cover Type	Approximate Acres within Ranch Boundary	Approximate Percentage within Ranch Boundary
Aspen with Mixed Conifer	625.39	4
Aspen Woodland	2,291.01	16
Mixed Conifer (Cool-Moist)	327.87	2
Mixed Conifer (Warm-Dry)	2,696.68	19
Mountain Shrublands and Mountain Grasslands	2,040.25	14
Pinyon-Juniper Woodland	2.92	<1
Ponderosa Pine Woodland	8.57	<1
Riparian Woodland and Wetlands	2,138.32	15
Spruce-Fir Forest	2,805.43	20
Not Analyzed	1,282.06	9
Total	**14,218.5**	**100**

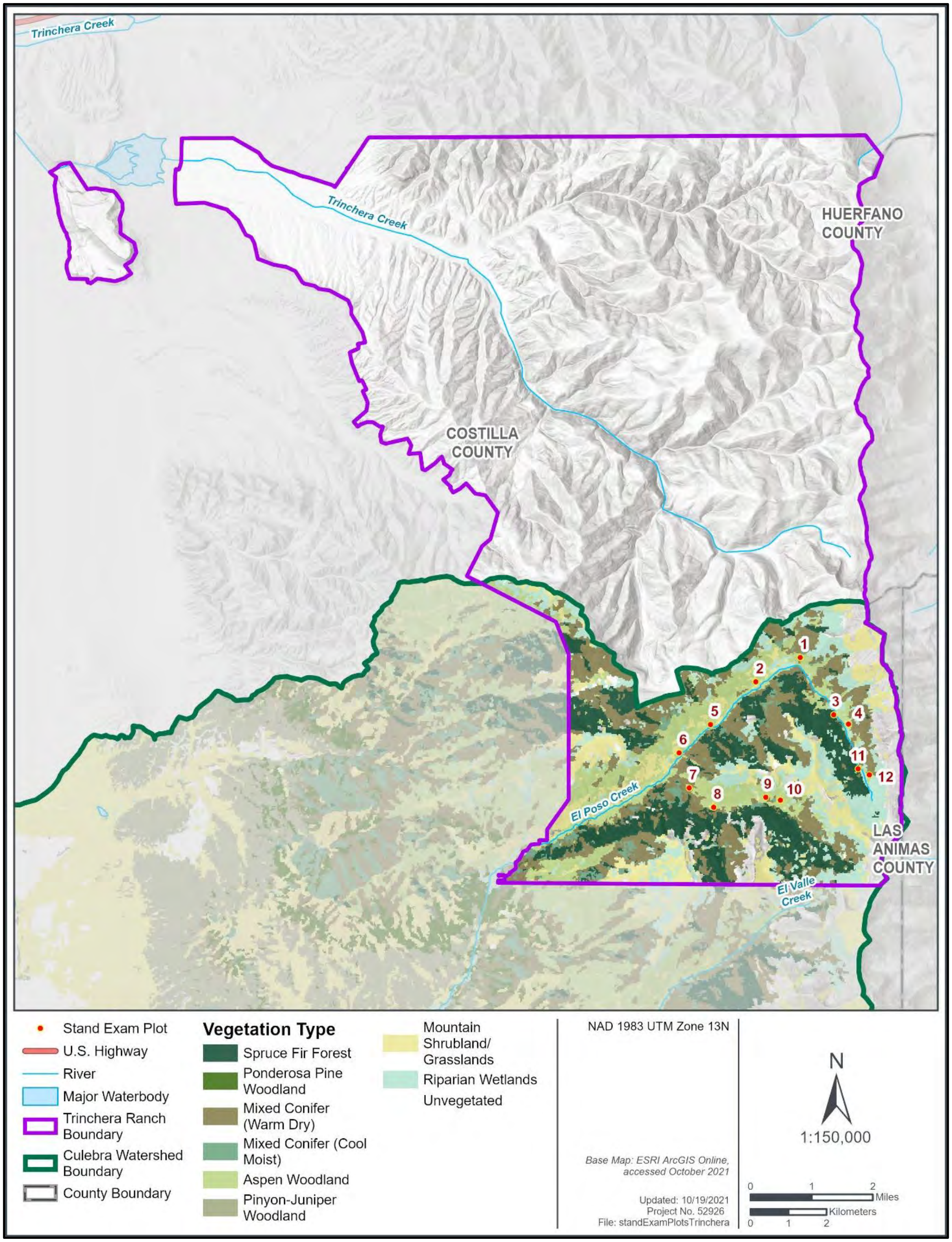


Figure 10-16 Vegetation cover type within Trinchera Ranch.

The CSFS has been actively monitoring insect and disease outbreaks that are affecting the forests of Colorado since 2005 by way of their annual aerial detection forest health survey, in conjunction with cooperating agency programs such as the U.S. Department of

Agriculture National Insect and Disease Risk and Hazard Mapping Program (CSFS 2021b; USFS 2021a). During the 2020 detection flight over Trinchera Ranch, the CSFS detected three main defoliators: the spruce beetle, western spruce budworm, and unknown aspen defoliator.

Table 10-3 Insect and Disease Type and Approximate Acreage within Trinchera Ranch provides approximate acreage that is affected in the Trinchera Ranch boundary, while Figure 10-17 presents the areas where tree damage was observed during the 2020 aerial detection flight.

Table 10-3 Insect and Disease Type and Approximate Acreage within Trinchera Ranch

Insect and Disease Type	Approximate Acres within Ranch Boundary	Approximate Percentage within Ranch Boundary	Damage Type	Severity
Spruce beetle	164.2	1	Mortality	Light to Moderate 4%–30%
Western spruce budworm	88.9	<1	Defoliation	Very Severe >50%
Aspen defoliation (unknown)	75.0	<1	Defoliation	Very Severe >50%
Total	**328.1**	**2**		

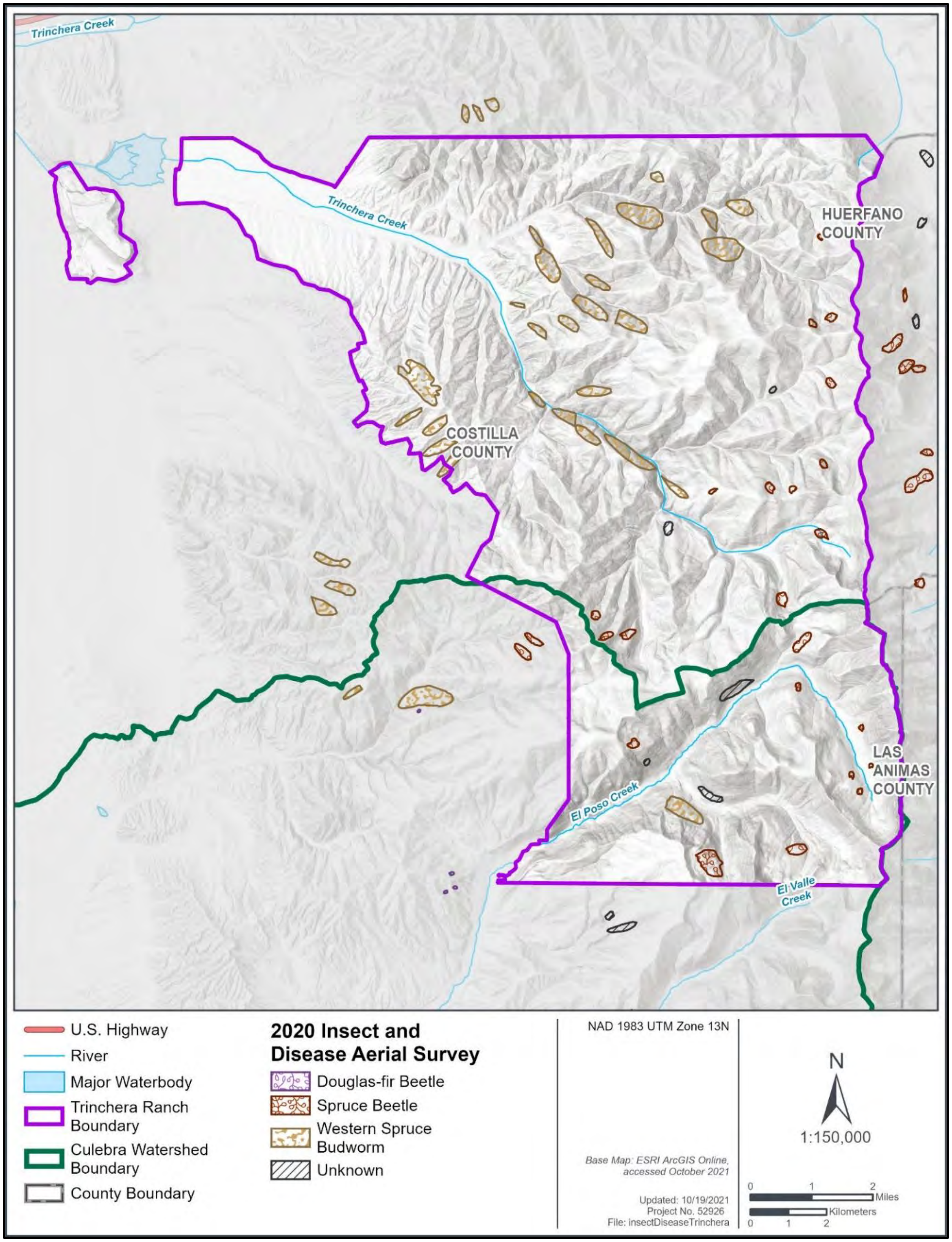


Figure 10-17 Insect and disease observations within Trinchera Ranch.

10.3.3.2 Cielo Vista Ranch

The Cielo Vista Ranch occupies 70,402 acres of the UCW and is the largest ranch within the analysis area. This property exhibits all vegetations types noted in Section 10.3.1.1. Table 10-4 and Figure 10-18, Figure 10-19, and Figure 10-20 present the primary vegetation cover types that occur within the Cielo Vista Ranch boundary.

Table 10-4 Vegetation Cover Type and Approximate Acreage within Cielo Vista Ranch.

Cover Type	Approximate Acres within Ranch Boundary	Approximate Percentage within Ranch Boundary
Aspen with Mixed Conifer	3,212.72	5
Aspen Woodland	10,550.35	15
Mixed Conifer (Cool-Moist)	7,000.80	10
Mixed Conifer (Warm-Dry)	12,827.52	18
Mountain Shrublands and Mountain Grasslands	11,498.49	16
Pinyon-Juniper Woodland	5,382.95	8
Ponderosa Pine Woodland	4,367.22	6
Riparian Woodland and Wetlands	3,368.16	5
Spruce-Fir Forest	6,568.09	9
Not Analyzed	5,625.70	8
Total	**70,402.0**	**100**

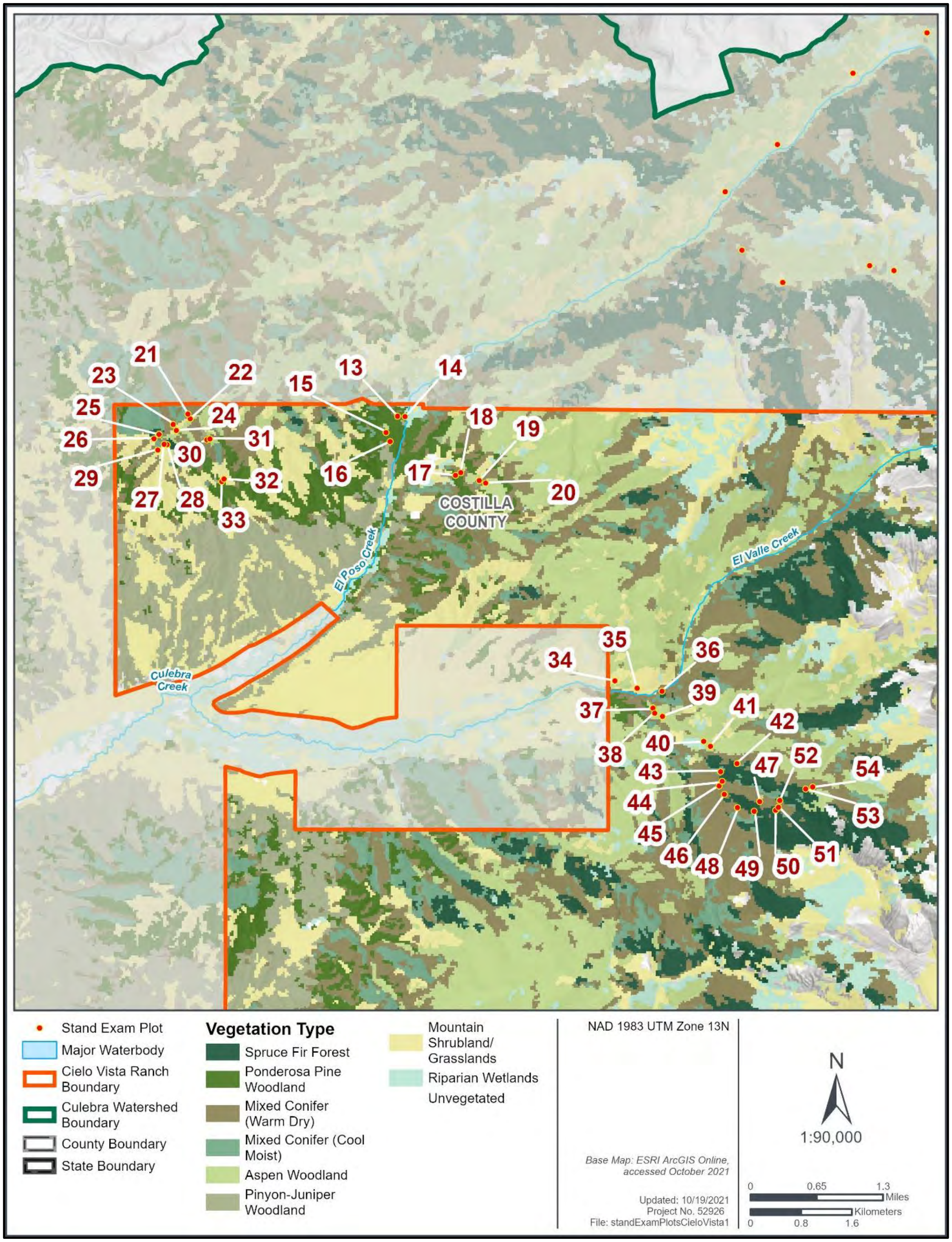


Figure 10-18 Vegetation cover type within Cielo Vista Ranch (Map 1 of 3).

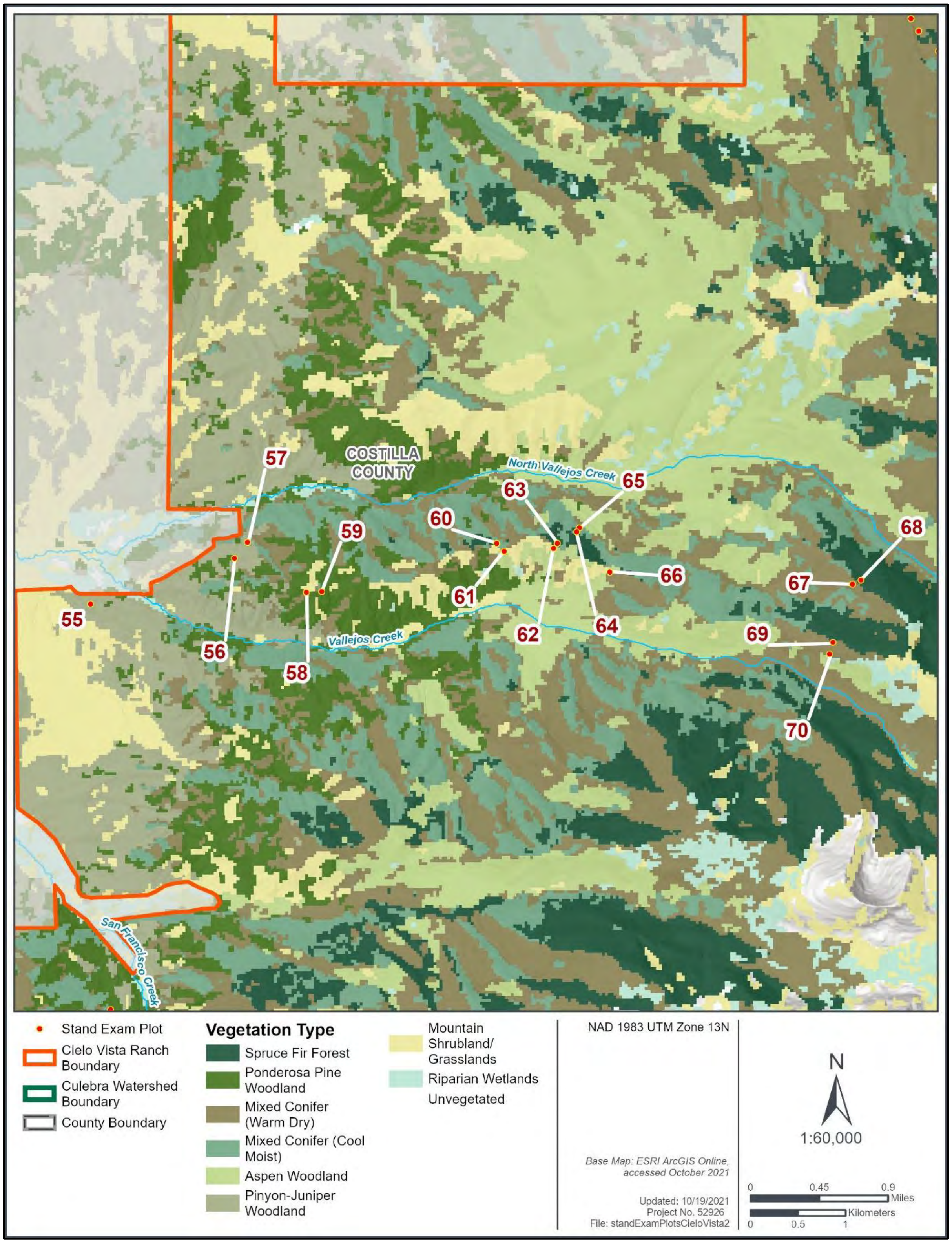


Figure 10-19 Vegetation cover type within Cielo Vista Ranch (Map 2 of 3).

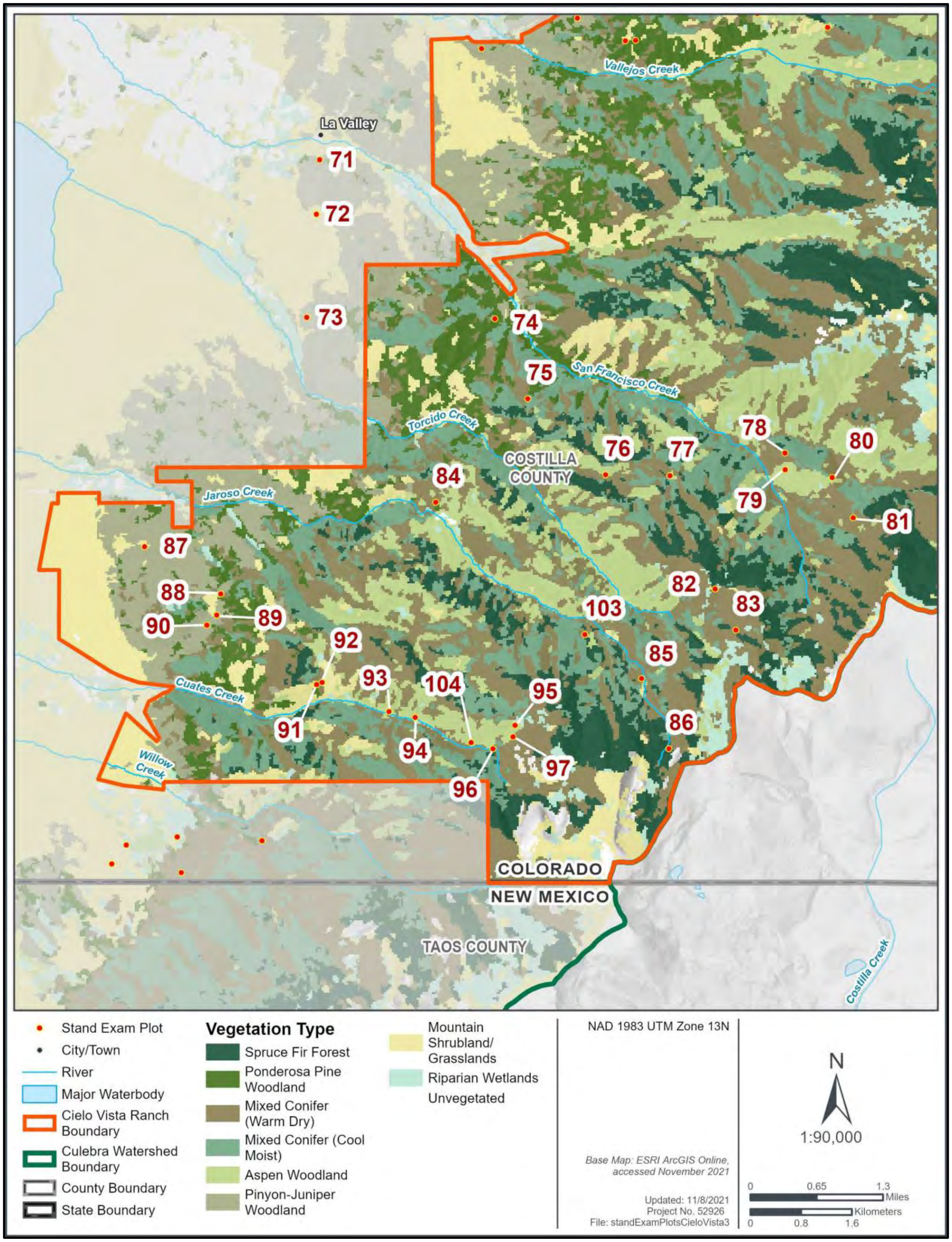


Figure 10-20 Vegetation cover type within Cielo Vista Ranch (Map 3 of 3).

The CSFS has been actively monitoring insect and disease outbreaks that are affecting the forests of Colorado since 2005 by way of their annual aerial detection forest health survey, in conjunction with cooperating agency programs such as the U.S. Department of Agriculture National Insect and Disease Risk and Hazard Mapping Program (CSFS 2021b;

USFS 2021a). During the 2020 detection flight over the Cielo Vista Ranch, the CSFS detected four main insect agents and one unknown defoliator: the spruce beetle, western spruce budworm, Douglas fir beetle, mountain pine beetle, and unknown aspen defoliator.

Table 10-5 provides approximate acreage that is affected in the Cielo Vista Ranch boundary, while Figure 10-21 presents the areas where tree damage was observed during the 2020 aerial detection flight.

Table 10-5 Insect and Disease Type and Approximate Acreage within Cielo Vista Ranch.

Insect and Disease Type	Approximate Acres within Ranch Boundary	Approximate Percentage within Ranch Boundary	Damage Type	Severity
Spruce beetle	188.6	<1	Mortality	Light to Moderate 4%–30%
Western spruce budworm	719.4	1	Defoliation >75%	Severe 30%–50%
Douglas fir beetle	2.6	<1	Mortality	Light 4%–10%
Mountain pine beetle	3.1	<1	Mortality	Light 4%–10%
Aspen defoliation (unknown)	379.4	<1	Defoliation >75%	Light to Very Severe 4%–>50%
Total	**1,293.2**	**2**		

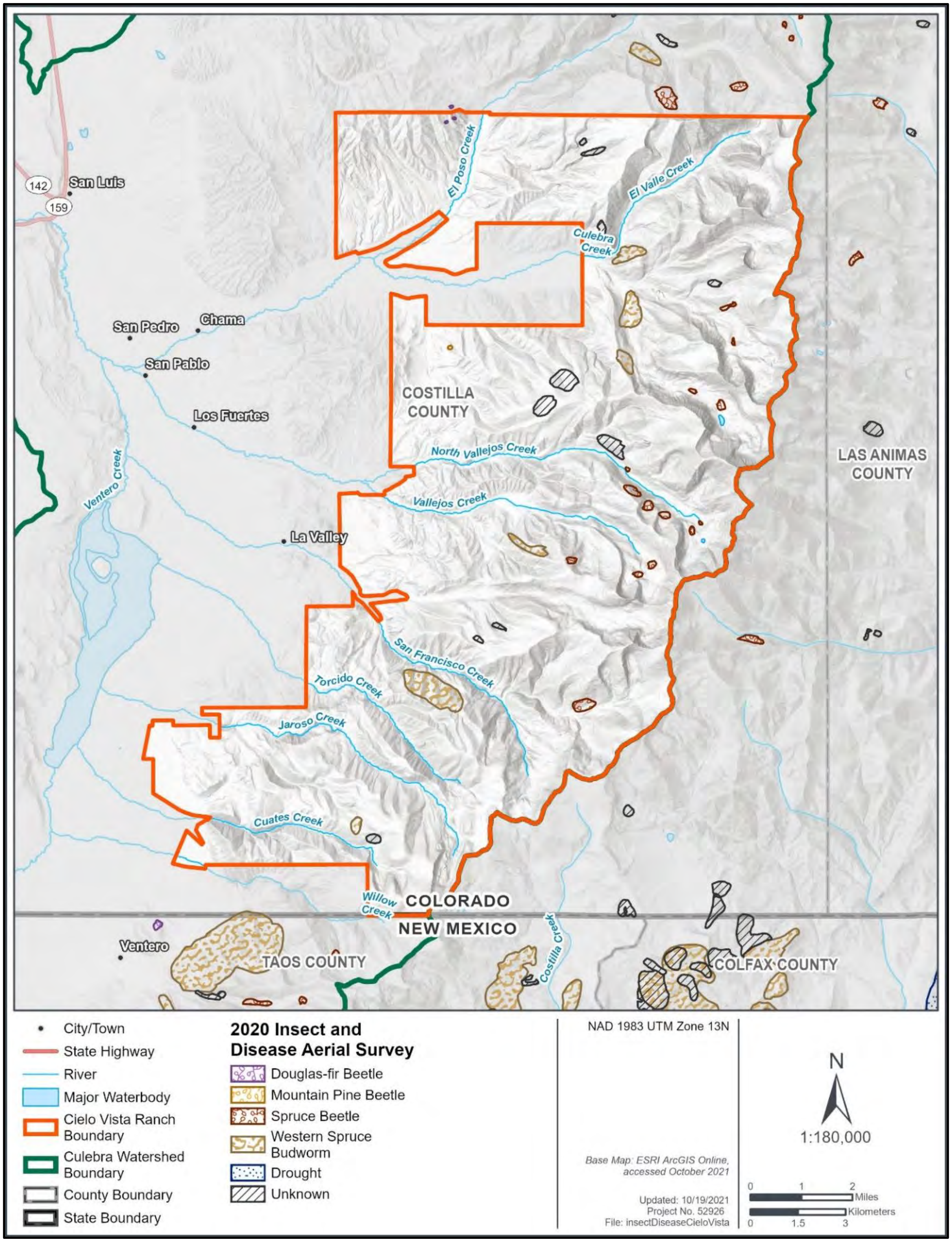


Figure 10-21 Insect and disease observations within Cielo Vista Ranch.

10.3.3.3 Dos Hermanos Ranch

The Dos Hermanos Ranch occupies 11,612.4 acres of the UCW and is the smallest ranch within the analysis area. This property exhibits all vegetations types noted in Section 3.1.1. Table 10-6 and Figure 10-22 present the primary vegetation cover types that occur within the Dos Hermanos Ranch boundary.

Table 10-6 Vegetation Cover Type and Approximate Acreage within Dos Hermanos Ranch.

Cover Type	Approximate Acres within Ranch Boundary	Approximate Percentage within Ranch Boundary
Aspen with Mixed Conifer	223.72	2
Aspen Woodland	124.55	1
Mixed Conifer (Cool-Moist)	470.34	4
Mixed Conifer (Warm-Dry)	963.8	8
Mountain Shrublands and Mountain Grasslands	8,169.07	70
Pinyon-Juniper Woodland	743.79	6
Ponderosa Pine Woodland	118.29	1
Riparian Woodland and Wetlands	196.60	2
Spruce-Fir Forest	72.35	1
Not Analyzed	529.90	5
Total	**11,612.4**	**100**

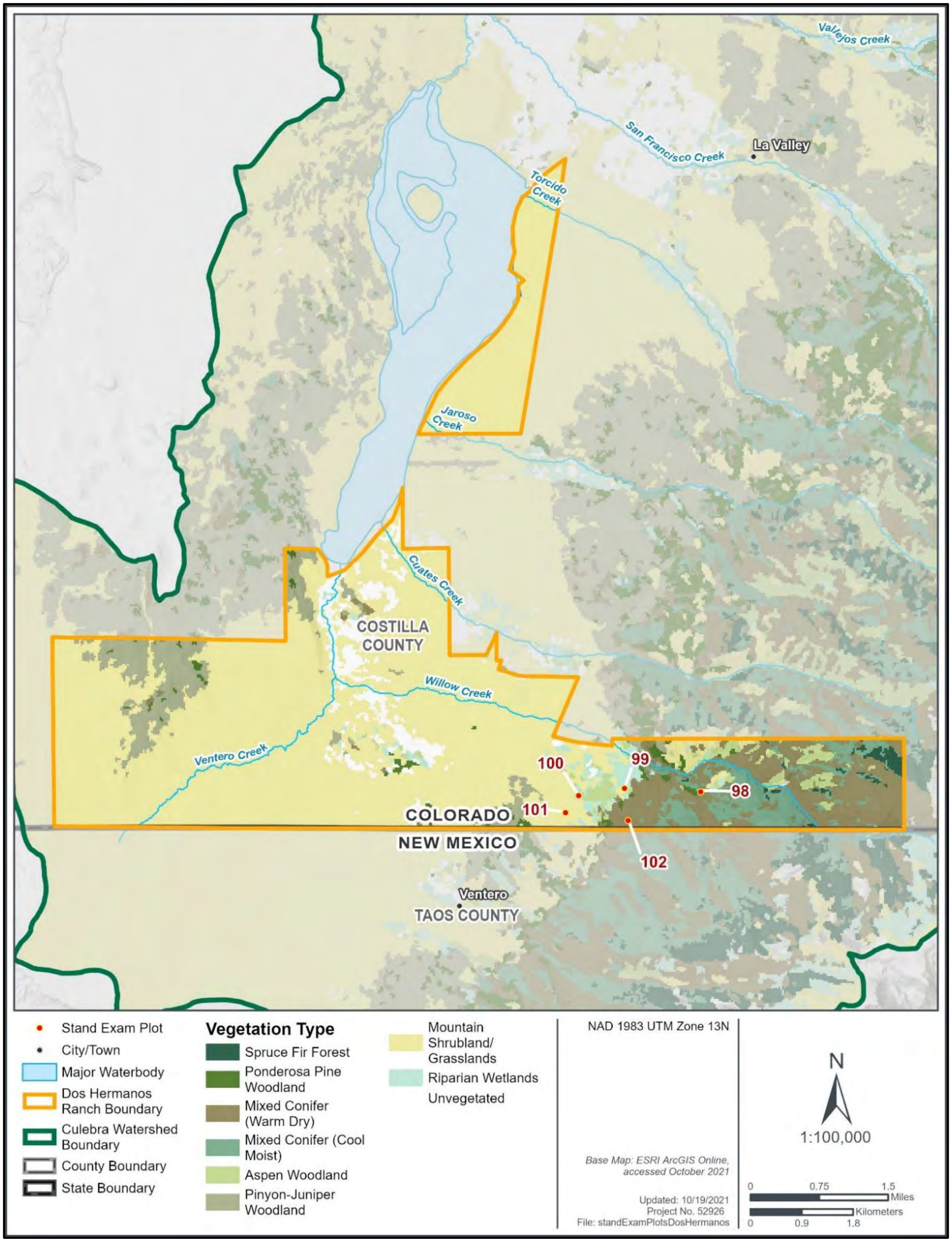


Figure 10-22 Vegetation cover type within Dos Hermanos Ranch.

The CSFS has been actively monitoring insect and disease outbreaks that are affecting the forests of Colorado since 2005 by way of their annual aerial detection forest health survey, in conjunction with cooperating agency programs such as the U.S. Department of Agriculture National Insect and Disease Risk and Hazard Mapping Program (CSFS 2021b;

USFS 2021a). During the 2020 detection flight over the Dos Hermonos Ranch, CSFS detected one main insect agent: the western spruce budworm.

Table 10-7 provides approximate acreage that is affected in the Dos Hermanos Ranch boundary, while Figure 10-23 presents the areas where tree damage was observed during the 2020 aerial detection flight.

Table 10-7 Insect and Disease Type and Their Approximate Acreage within Dos Hermanos Ranch.

Insect and Disease Type	Approximate Acres within Ranch Boundary	Approximate Percentage within Ranch Boundary	Damage Type	Severity
Western spruce budworm	17.6	1	Defoliation >75%	Very Severe >50%
Total	**17.6**	**1**		

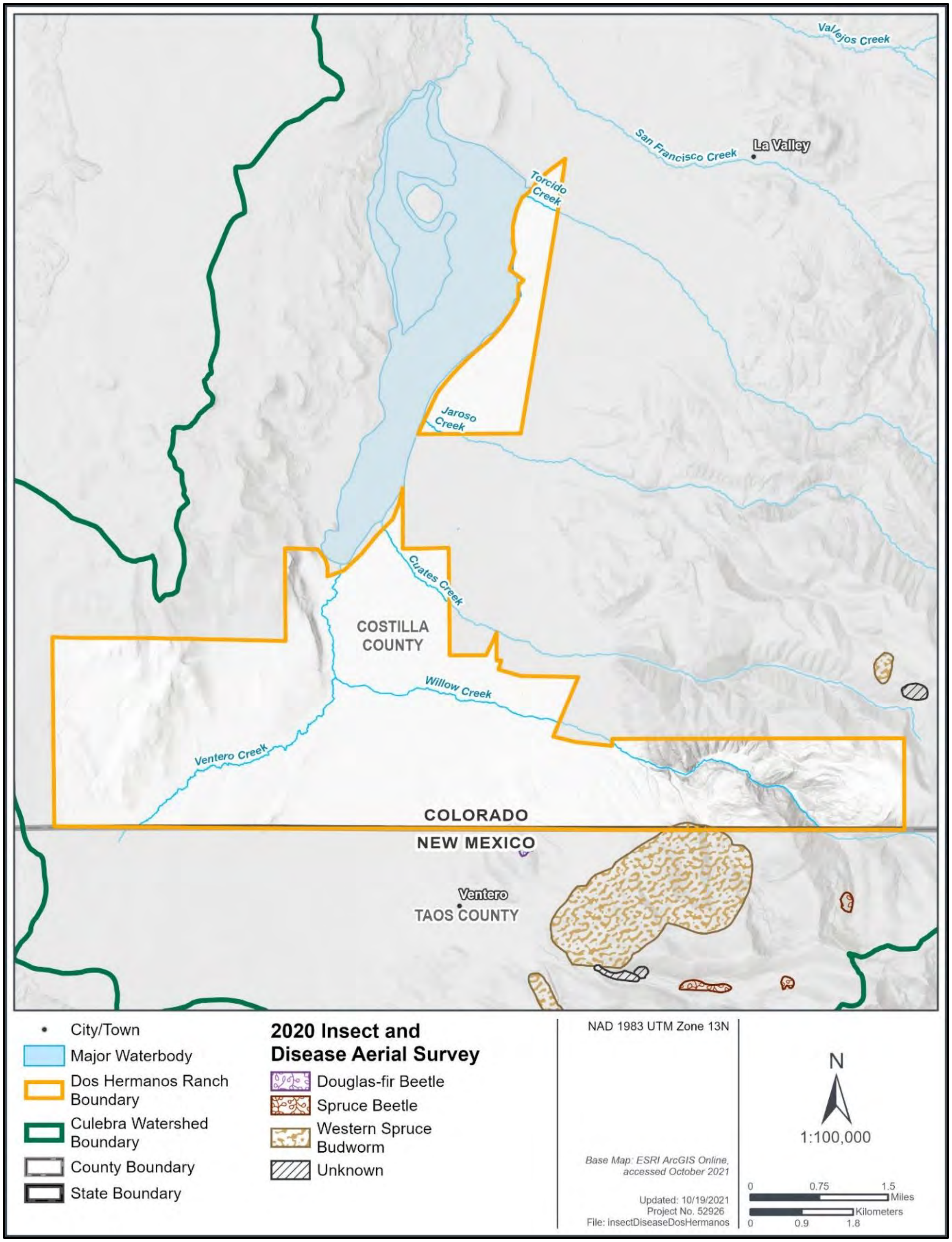


Figure 10-23 Insect and disease observations within Dos Hermanos Ranch.

10.4 Wildland Fire Environment

As part of the overall UCW forest health assessment, a safety and emergency management assessment was completed (Chapter 11). The purpose of the assessment was to identify and quantify the risks of wildfires (and other hazards) in the watershed by gathering information on where fires are likely to occur, the intensity at which they might occur, and determine impacts to the highly valued resources and assets (HVRAs) within the community.

10.5 Desired Conditions

10.5.1 Forest Health

Long-term management objectives in the UCW include rangeland management, wood fiber production, providing wildlife winter range habitat, and potentially local recreational opportunities. Silvicultural prescriptions can promote forest health by reducing stocking levels and creating resilient multi-cohort stands. In turn, improving overall forest health moves the stands toward achieving long-term management objectives including improved forest and rangeland grazing opportunities and sustained forest products from the UCW.

The CSFS developed a comprehensive Forest Action Plan (Colorado State Forest Service [CSFS], 2021a) to improve and sustain forests within Colorado. The Forest Action Plan identifies several strategies for improving forest condition in Colorado, as summarized below (Table 10-8).

Table 10-8 Goals and Strategies for Improving Forest Condition in Colorado (Adapted from CSFS 2021).

Goals	Strategy	Approach
Keep Forests as Forests	Maintain and, where practical, increase forest cover. Promote forest retention and creation.	Enhance economic incentives, such as the Colorado Forest Agriculture incentive and Forest Legacy Program. Promote silvicultural practices that support forest regeneration. Encourage natural regeneration through forest management.
	Reduce the impacts of biological stressors. Manage for more resilient forests that can better survive disturbances and changing climate.	Use silvicultural practices that identify and promote biological and structural diversity, including thinning and regeneration techniques. Actively manage forests to improve resilience to insects and disease.
	Plan for post-disturbance recovery and transition	Preserve forest systems that will maintain resilience to future disturbance. Monitor and manage for potential transitions in forest systems. Promote post-fire recovery through various means including planting and soil stabilization.

Goals	Strategy	Approach
Improve Forest Productivity	Maintain and enhance species and structural diversity and complexity. Diversify species and structure to provide myriad ecosystem services.	Maintain and enhance existing and new forest productivity by managing for diversity in tree age and size classes and stocking/density. Retain dead trees, both standing and fallen, to maintain carbon storage stocks and provide high-quality habitat cover and food for wildlife.
	Diversify species and structure to provide myriad ecosystem services.	Retain dead trees, both standing and fallen, to maintain carbon storage stocks and provide high-quality habitat cover and food for wildlife. Support a wood products industry to harvest stored carbon and promote regeneration for future carbon storage and sequestration.
	Promote the ability of forest systems to resist and rebound from disturbances.	Manage fire-dependent forest systems to maintain and promote resistance to fire mortality. Seed and replant post-disturbance to renew the forest system's carbon storage and sequestration capacity, especially in young stages of relatively rapid growth.
Promote Adaptive Management	Reduce impacts of biological stressors. Manage for appropriate diversity and complexity in species, age, and size.	Manage for resistant and resilient forest composition, age, structure, and function. Consider reforestation with a mixture of species better suited to expected future climate conditions.
	Facilitate forest community adjustments through species retention and transitions. Promote continued ecosystem function by managing species and structure.	Identify productive sites and best adapted species. Monitor natural regeneration response to changing environmental conditions.
	Maintain and create refugia (areas of relative stability to climate change). Identify desired forested landscape compositions that are resilient.	Monitor for forest response to treatments and harvesting, natural disturbance, and climate change.

10.5.2 Wildfire Resilience

The long-term management objective in the UCW related to fire is to create landscapes across the watershed that are resilient to disturbance, including intense, uncharacteristically severe wildfire. Reaching these desired conditions involves building fire-adapted communities with residents who are able to live with fire and reintroducing fire to vegetation communities that are fire-dependent. These desired conditions are supported at the state and federal levels through the Colorado Forest Action Plan, which implements federal fire policy developed as part of the National Cohesive Wildland Fire Management Strategy (Cohesive Strategy). The Cohesive Strategy focuses on three goals: 1) restore and maintain resilient landscapes; 2) create fire-adapted communities; and 3) maintain safe and effective fire response. The Forest Action Plan identifies several strategies for meeting the Cohesive Strategy goals in Colorado, as discussed in Chapter 10.

10.6 Special-Status Species

The Valley has an extensive system of wetlands and riparian habitats that support over a dozen threatened and endangered species along with dozens of species of birds. The ranches and land throughout the Valley provide the critical wildlife habitat necessary to support these species. This land is critical habitat for all life stages such as migrating, nesting, and wintering. The wetlands and waters throughout the watershed are also important areas for the life cycles of native fish such as the Rio Grande cutthroat trout (*Oncorhynchus clarkia virginalis*). River and stream modification has threatened these populations and caused a reduction in individuals. Furthermore, these streams support the migration of other species such as elk, deer, and moose. As such, the special-status species discussed below rely on the Valley's plethora of resources and habitat availability for various stages of their lives. These species should be considered when making decisions on forest management practices. In some cases, state or federal guidelines may need to be followed if a project poses a potential impact to certain species (DiNatale Water Consultants, 2015).

The special-status species evaluated in this report consist of 1) federally protected (endangered and threatened) species (U.S. Fish and Wildlife Service (USFWS), 2021); 2) additional species listed by the USFWS as candidate and proposed species (USFWS 2021); 3) and state-listed endangered and threatened species (CNHP, 2020). Table 10-9 describes the special-status species with the potential to occur in Costilla County, Colorado, their habitat, and potential for occurrence in the proposed project area. The potential for occurrence of a species was identified using the following categories.

- *Known to occur*—the species was documented in the proposed project area either during or prior to the biological survey by a reliable observer.
- *May occur*—the proposed project area is within the species' currently known range, and vegetative communities, soils, water quality conditions, etc., resemble those known to be used by the species.
- *Unlikely to occur*—the proposed project area is within the species' currently known range, but vegetative communities, soils, water quality conditions, etc., do not resemble those known to be used by the species, or the proposed project area is clearly outside the species' currently known range.

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Table 10-9 Special-Status Species for Costilla County, Colorado

Common Name (Species Name)	Status*	Potential for Occurrence in Project Area
Invertebrates		
Monarch butterfly (*Danaus plexippus plexippus*)	FC	May occur within the analysis area due to the presence of suitable habitat. Analysis area is within the species' expected range.
Fish		
Greenback cutthroat trout (*Oncorhynchus clarkia stomias*)	FT	May occur within the analysis area due to the presence of suitable habitat. Analysis area is within the species' expected range.
Rio Grande cutthroat trout (*Oncorhynchus clarkia virginalis*)	FC, SC	May occur within the analysis area due to the presence of suitable habitat. Analysis area is within the species' expected range.
Rio Grande chub (*Gila pandora*)	SC	May occur within the analysis area due to the presence of suitable habitat. Analysis area is within the species' expected range.
Rio Grande sucker (*Catostomus plebeius*)	SE	May occur within the analysis area due to the presence of suitable habitat. Analysis area is within the species' expected range.
Birds		
Mexican spotted owl (*Strix occidentalis lucida*)	FT	May occur within the analysis area due to mountainous habitat and deep canyons preferred by the species.
Southwestern willow flycatcher (*Empidonax traillii extimus*)	FE, SE	May occur within the analysis area due to the presence of riparian habitat or associated vegetation species.
Yellow-billed cuckoo (*Coccyzus americanus)*	FT, SC	May occur within the analysis area due to the presence of riparian habitat or associated vegetation species.
Western snowy plover (*Charadrius nivosus nivosus*)	SC	Unlikely to occur in the analysis area due to the lack of suitable habitat.
Long-billed curlew (*Numenius americanus*)	SC	May occur within the analysis area due to the presence of riparian habitat or associated vegetation species.
Gunnison sage-grouse (*Centrocercus minimus*)	SC	Unlikely to occur in the analysis area. Analysis area is outside of species' expected range.
Mountain plover (*Charadrius montanus*)	SC	Unlikely to occur in the analysis area. Analysis area is outside of species' expected range and lacks suitable habitat.
Ferruginous hawk (*Buteo regalis*)	SC	May occur within the analysis area due to the presence of multiple suitable habitat types.
Bald eagle (*Haliaeetus leucocephalus*)	BGEPA, SC	May occur within the analysis area due to the presence of multiple suitable habitat types.
Golden eagle (*Aquila chrysaetos*)	BGEPA	May occur within the analysis area due to the presence of multiple suitable habitat types.
American peregrine falcon (*Falco peregrinus anatum*)	SC	May occur within the analysis area due to the presence of multiple suitable habitat types.
Burrowing owl (*Athene cunicularia*)	ST	May occur within the analysis area due to the presence of prairie dog colonies.
Greater sandhill crane (*Antigone canadensis tabida*)	SC	May occur within the analysis area because the San Luis Valley is a known stopover site for the species.

Common Name (Species Name)	Status*	Potential for Occurrence in Project Area
Mammals		
Canada lynx (*Lynx canadensis*)	FT, SE	May occur within the analysis area due to the presence of suitable habitat.
New Mexico meadow jumping mouse (*Zapus hudsonius luteus*)	FE	May occur within the analysis area due to the presence of suitable habitat. Analysis area is within species' expected range.
Back-footed ferret (*Mustela nigripes*)	SE	Unlikely to occur in the analysis area. Analysis area is outside of species' expected range.
Wolverine (*Gulo gulo*)	SE	Unlikely to occur in the analysis area. Analysis area is outside of species' expected range.
Swift fox (*Vulpes velox*)	SC	Unlikely to occur in the analysis. Analysis area is outside of species' expected range.
Townsend's big-eared bat subspecies (*Corynorhinus townsendii pallescens*)	SC	May occur within the analysis area due to the presence of suitable habitat. Analysis area is within the species' expected range.

Source: USFWS

* Federal (USFWS) status: FE = Endangered, FT = Threatened, FC = Candidate; BGEPA = Bald and Golden Eagle Protection Act

Colorado State status: SC = State Special Concern SE = State Endangered, ST = State Threatened.

Other species of concern to consider in forest management plans are Brewer's sparrow (*Spizella breweri*), brown-capped rosy-finch (*Leucosticte australis*), northern harrier (*Circus cyaneus*), American pika (*Ochotona princeps*), snowshoe hare (*Lepus americanus*), and southern red-backed vole (*Myodes gapperi*). These species either have range or breeding range within the watershed or surrounding area.

Six additional USFWS Birds of Conservation Concern have the potential to occur in the analysis area (Table 10-10). These species are migratory birds and are protected under the Migratory Bird Treaty Act. However, these species are only likely to occur during their respective breeding seasons.

Table 10-10 Migratory Bird Species for Costilla County, Colorado

Common Name (Species Name)	Breeding Season
Cassin's finch (*Carpodacus cassinii*)	May 15 to July 15
Evening grosbeak (*Coccothraustes vespertinus*)	May 15 to August 10
Lewis's woodpecker (*Melanerpes lewis*)	April 20 to September 30
Olive-sided flycatcher (*Contopus cooperi*)	May 20 to August 31
Pinyon jay (*Gymnorhinus cyanocephalus*)	February 15 to July 15
Virginia's warbler (*Vermivora virginiae*)	May 1 to July 31

Source: USFWS (2021).

10.7 Forest Inventory Results

10.7.1 Trinchera Ranch

Trinchera Ranch occupies 14,218.5 acres of the UCW analysis area and encompasses all vegetation type as described in section 3.2.1 above. However, only 12 stand exam plots were within Trinchera Ranch due to the types and amount of vegetation cover in the ranch boundaries within the analysis area.

At these plots, four tree species were measured and recorded: Bristlecone pine, Engelmann spruce, quaking aspen, and subalpine fir. Table 10-11 provides average stand information for each of the four species.

Table 10-11 Average Results per Plot recorded within the Trinchera Ranch Boundary.

Tree Species Sampled	Number of Individuals Sampled	Average DBH/DRC (inches)	Average Tree Height (feet)	Damage Indicators
Bristle Cone Pine	1	18.0 DBH	48.9	None
Engelmann Spruce	30	15.1 DBH	46.8	Physical Damage Insect
Quaking Aspen	22	9.5 DBH	43.4	Physical Damage Disease
Subalpine fir	5	9.6 DBH	42.3	Physical Damage

10.7.1.1 Rocky Mountain Bristle Cone Pine (Pinus aristata)

Out of the 58 of individuals recorded on the Trinchera Ranch, only one bristle cone pine tree was recorded in Plot 20. This species was observed as co-dominant with Englemann spruce and quaking aspen. This tree is slow growing. Generally, individuals of this species with DBH values between 16 and 20 inches are between 200 and 250 years old. The oldest Rocky Mountain Bristle Cone Pine documented in Colorado has 2,435 countable annual rings when it was inventoried in 1992 (U. S. Department of Agriculture [USDA], 2021). This species occupying the lower montane vegetation community rarely live past 300 years and can be found between elevations of 7,000 feet to 13,000 feet amsl. Table 10-12 provides detailed information on the Rocky Mountain Bristle Cone Pine sampled on Trinchera Ranch during the 2021 SWCA field survey.

Table 10-12 Sample information of the Rocky Mountain Bristle Cone within Trinchera Ranch

Number of Individuals Sampled	DBH (inches)	Tree Height (feet)	Crown Base Height (feet)	Crown Ratio (%)
1	18	48.9	3.0	60.0

Rocky Mountain Bristle Cone Pine was inventoried at Plot 20 at approximately 10,955 feet amsl. These trees are considered mature and are reaching their maximum growth height at an average of 40 feet tall (USDA 2021). The crown base height of these trees averaged 3.0 feet above ground level with an average of 60.0% crown to tree ratio. No seedling or sapling of this species was observed at Plot 20.

<u>Damage Indicators</u>

During the 2021 field survey no apparent tree damage indicator was observed with this individual.

10.7.1.2 Engelmann Spruce (Picea engelmannii)

Engelmann Spruce was observed in nine out of 12 plots and was the most recorded species on Trinchera Ranch. Engelmann spruce are often seen with subalpine fir associations and were observed as dominant, co-dominant, and intermediate trees with bristle cone pine, quaking aspen and subalpine fir. This species occupies high elevation between 9,000 to 11,00 feet amsl in the Southern Rocky Mountains. Mature Engelmann spruce trees average 15 to 30 inches DBH but it is not uncommon to find individuals that exceed 40 inches. Overall, the average lifespan of this species is 350-450 years (USDA 2021). Table 10-13 provides detailed information on the Engelmann spruce sampled on Trinchera Ranch during the 2021 SWCA field survey.

Table 10-13 Sample Information of the Engelmann Spruce within Trinchera Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
30	3.9–44.7	17.7–77.7	5.9	58.7

Engelmann spruce was inventoried at 10 plots with an elevation range between 10,120 feet and 11,500 feet amsl. These trees are considered mature. Eleven Engelmann spruce trees were cored to determine their age. The oldest Engelmann spruce cored was 167 years old and had a 25.6 inch DBH at a height of 77.7 feet, while the youngest Engelmann spruce cored was 41 years old and had a 3.9 inch DBH and a height of 17.7 feet. Tree height and DBH is not consistent with relative age for this species and solely dependent on available resources. The crown base height of these trees averaged 5.9 feet above ground level with an average of 58.7% crown to tree ratio. An assortment of seedling and saplings were observed in 10 out of 11 plots with even distribution between age groups.

<u>Damage Indicators</u>

During the 2021 field survey of Trinchera Ranch, Engelman spruce exhibited an assortment of biotic and abiotic damage. Biotic factors include insect infestation, fungal diseases, and elk browsing. Abiotic factors included but are not limited to lightning strikes, landslides, nearby falling tree damage and wind events that cause damage to the tree.

Plots 2, 3, 8, and 11 exhibited signs of western spruce beetle damage however, there was no active infestation or recent tree mortality observed during the 2021 field survey. The only other damage recorded was physical abiotic damage. Falling trees in dense forests are quite common and the amount of damage sustained by other trees is negligible in these locations.

10.7.1.3 Quaking Aspen (Populus tremuloides)

Quaking aspen was observed in seven plots. They were observed as co-dominant with Engelmann spruce and subalpine firs. Aspen trees are fast growers and depending on site conditions, can achieve large DBHs in a relatively short amount of time when compared with other species. This species occurs on a wide variety of sites in Colorado. Aspen can be found between elevations of 6,500 feet to 11,500 feet amsl. Table 10-14 provides detailed information on the Quaking Aspen sampled on Trinchera Ranch during the 2021 SWCA field survey.

Table 10-14 Sample Information of the Quaking Aspen within Trinchera Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
22	4.2–14.3	30.3–55.9	31.3	28.0

The quaking aspen was inventoried at seven plots with an elevation range between 9,983 feet and 10,970 feet amsl. These trees age classifications range from seedling to mature trees. It was observed that the majority of aspen stands were of a single age class and competition for resources are high. The results are consistent with an average 28.0% crown to trunk ratio and a high average crown base height of 31.3 feet above ground level.

Damage Indicators

During the 2021 field survey, it was noted that a high number of aspen trees exhibited disease and animal damage. Evidence of elk rubbing on aspen trunks was consistent throughout dense aspen stands. A series of cankers on the bole of the tree were also noted.

During the 2020 Colorado State Forest Service annual aerial detection forest health survey, an unknown defoliator was observed effecting aspen stands on Trinchera Ranch. This was confirmed during the 2021 SWCA field survey. Please refer to section 10.9.1.1 for Trinchera Ranch Recommendations.

10.7.1.4 Subalpine Fir (*Abies lasiocarpa*)

Subalpine firs are the most widely distributed fir in North America occurring mainly in mountainous areas. Subalpine firs can occur in Douglas fir forests, spruce-fir forests, and lodgepole pine forests and is usually found with associations of Engelmann spruce. This species was observed in plots 3, 8, 9, and 10 as young trees. Mature subalpine firs are within 18 to 24 inches DBH and are usually 60 to 100 feet tall (USDA 2021). These specific individuals that were observed within Trinchera Ranch were dominant and co-dominant with Engelmann spruce within its stand. This species occupies high elevation between 8,000 to 12,000 feet amsl in the Southern Rocky Mountains and is an ecologically important species for large game like mule deer, elk, and bighorn sheep (USDA 2021). Table 10-15 provides detailed information on the subalpine fir sampled on Trinchera Ranch during the 2021 SWCA field survey.

Table 10-15 Sample Information of the Subalpine Fir within Trinchera Ranch

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
5	8.0–12.0	37.2–49.0	2.8	76.0

Subalpine fir was inventoried at four plots with an elevation range between 10,110 and 11,430 feet amsl.

Four trees were cored and were determined to have an average age of 59 years old while the oldest tree sampled was 84 years old. Subalpine firs have a lifespan of 250 years (USDA 2021). The crown base height of these trees averaged 2.8 feet above ground level with an average of 76.0% crown to tree ratio, which is common for this species. Seedlings and saplings were observed in two plots surveyed within Trinchera Ranch.

Damage Indicators
During the 2021 field survey abiotic damage was observed with recorded individuals. Abiotic factors included but are not limited to lightning strikes, landslides, nearby falling tree damage and wind events that cause damage to the tree.

10.7.1.5 Basal Area
Basal Area is the common term used to describe the average amount of an area occupied by tree stems. It is defined as the total cross-sectional area of all stems in a stand measured at breast height (4.5 feet) and expressed as per unit of land area (USFS 1965, MDWFP 2021). This helps land managers understand the density of their forest and if there are any management concerns.

Each management area is different and has varying management goals. The term Timber Targets is coined by the US Forest Service to describe basal area management goals for timber managed areas. Below are some examples of timber targets of southern Colorado USFS districts (Nauman, 2021).

Species	Post Management Basal Area Target
Ponderosa Pine	40-60
Mixed Conifer	50-70
Aspen	50-70
Pinon-Juniper	N/A

Any areas that are over 100 for basal area are identified for mitigation. If these timber targets are achieved, it is expected that the area treated would need minimal maintenance and monitoring for years to come.

provides information concerning species recorded, live/dead ratio, total basal area within that plot, and the vegetation community the plot falls within.

Table 10-16 Basal Area of Plots within Trinchera Ranch

Plot Number	Species Recorded	Live/Dead	Basal Area	Vegetation Community
1	Bristle Cone Pine Engelmann Spruce Quaking Aspen	5/2	100	Aspen Forest and Woodland
2	Engelmann Spruce Quaking Aspen	4/0	80	Mountain Shrublands/ Grasslands
3	Engelmann Spruce	2/0	40	Spruce-Fir Forest
4	Engelmann Spruce	6/0	120	Mountain Shrublands/ Grasslands
5	Quaking Aspen	5/2	100	Aspen Forest and Woodland
6	Quaking Aspen	5/1	100	Aspen Forest and Woodland
7	Engelmann Spruce	4/0	80	Aspen with Mixed Conifer
8	Engelmann Spruce Quaking Aspen Subalpine Fir	4/0	80	Aspen Forest and Woodland
9	Engelmann Spruce Quaking Aspen Subalpine Fir	7/0	140	Aspen Forest and Woodland
10	Engelmann Spruce Quaking Aspen Subalpine Fir	5/0	100	Aspen Forest and Woodland
11	Engelmann Spruce	5/1	100	Spruce-Fir Forest
12	Engelmann Spruce	6/0	120	Spruce-Fir Forest

10.7.1.6 Summary

Trinchera Ranch has taken a proactive approach with their forest management practices. Historically, when areas identified as having an insect infestation or disease outbreak, mitigation and best management practices were utilized. SWCA has not observed any active insect infestation within the boundaries of the UCW and Trinchera Ranch. However, aspen defoliation and mortality was observed on the property. Please refer to section 9.1.1 for Trinchera Ranch Recommendations.

The tree stocking levels for Trinchera Ranch are within an acceptable level but are due for more management. Increasing tree spacing for all species above would reduce the spread of pathogens and insects that could threaten the vitality of Trinchera's Forest. In combination with reduction of ladder fuels, the removal of fuel would reduce the chance for widespread catastrophic fire damage.

Please refer to section 11.8 and 11.9 for Mitigation Measure Definitions and Recommendations.

10.7.2 Cielo Vista Ranch

Cielo Vista Ranch occupies 70,402.0 acres of the UCW analysis area and encompasses all vegetation types as described in section 3.2.1 above. 86 stand exam plots were selected due to the percentage of vegetation cover-type occupying Cielo Vista Ranch.

When common stand exams were conducted, nine tree species were measured and recorded: blue spruce, Douglas fir, Engelmann spruce, lodgepole pine, two-needle pinyon pine, ponderosa pine, Rocky Mountain juniper, quaking aspen, and subalpine fir. Table 10-17 provides average stand information for each of the nine species.

Table 10-17 Average Results per Plot recorded within the Trinchera Ranch Boundary

Tree Species Sampled	Number of Individuals Sampled	Average DBH/DRC (inches)	Average Tree Height (feet)	Damage Indicators
Blue Spruce	3	13.5 DBH	50.3	None
Douglas fir	73	11.5 DBH	39.5	Physical Damage Disease
Engelmann Spruce	97	10.6 DBH	48.2	Insect Disease
Lodgepole Pine	7	8.7 DBH	80.9	Insect
Ponderosa Pine	74	15.7 DBH	41.8	Physical Damage
Quaking Aspen	94	9.0 DBH	40.2	Physical Damage Disease
Rocky Mountain Juniper	8	11.7 DRC	14.3	None
Subalpine fir	15	8.2 DBH	43.7	None
Two-needle Pinyon Pine	18	9.3 DRC	12.6	Physical Damage

10.7.2.1 Blue Spruce (*Picea pungens*)

Blue spruce was recorded in one plot within Cielo Vista Ranch but was observed throughout the area. They were observed as dominant, and co-dominant, with Engelmann spruce and subalpine fir. This species generally occupies moderate elevations between 6,700 to 8,500 feet amsl in the Southern Rocky Mountains. Table 10-18 provides detailed information on the blue spruce sampled on Cielo Vista during the 2021 SWCA field survey.

Table 10-18 Sample Information of the Blue Spruce within Cielo Vista Ranch

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
3	9.8–16.7	43.0–55.0	9.3	43.3

Blue spruce was inventoried at one plot with an elevation of 11,500 amsl. These trees are considered young. One blue spruce tree was cored to determine its age, which was 143 years old with a 16.7 inch DBH at a height of 53.0 feet tall. Blue spruce are often associated with Engelmann spruce and subalpine fir. Tree height and DBH is not consistent with relative age for this species. The crown base height of these trees averaged 9.3 feet above ground level with an average of 43.3% crown to tree ratio.

<u>Damage Indicators</u>

During the 2021 field survey no apparent tree damage indicator was observed with these recorded individuals.

10.7.2.2 Rocky Mountain Douglas Fir (*Pseudotsuga menziesii var. glauca*)
Rocky Mountain Douglas fir was the third most recorded species on Cielo Vista Ranch. They were observed as dominant, co-dominant, and intermediate trees with Engelmann spruce, ponderosa pine, subalpine fir and aspen. This species occupies high elevation between 8,000 to 9,500 feet amsl in the Southern Rocky Mountains and growth typically slows dramatically between 90 and 140 years of age (USDA 2021). Table 10-19 provides detailed information on the Rocky Mountain Douglas Fir sampled on Cielo Vista Ranch during the 2021 SWCA field survey.

Table 10-19 Sample Information for the Rocky Mountain Douglas Fir within Cielo Vista Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
73	4.5–24.1	18.0–70.0	11.9	48.5

Rocky Mountain Douglas Fir was inventoried at multiple plots at approximately 8,700 to 11,200 feet amsl. These trees are considered young to mature. Twenty-seven Douglas firs were cored to determine their age. The oldest Douglas fir cored was 162 years old, with a 22.9 inch DBH at a height of 64.5 feet, while the youngest Douglas fir cored was 50 years old with a DBH of 7.0 inches and a height of 34.0 feet. Douglas fir trees can live in a variety of subalpine conditions. Tree height and DBH is not consistent with relative age for this species. The crown base height of these trees averaged 11.9 feet above ground level with an average of 48.5% crown to tree ratio which is common for this species.

Damage Indicators
Previous insect infestation, physical damage and disease were observed in Cielo Vista Ranch for Douglas fir. Dense forests lead to higher levels of physical damage from falling dead trees. These wounds sustained from physical impacts can lead to fungal and other pathogens infecting these trees.

10.7.2.3 Engelmann Spruce (*Picea engelmannii*)
The Engelmann Spruce was the most recorded species on Cielo Vista Ranch. They were observed as dominant, co-dominant, and intermediate trees with lodgepole pine, quaking aspen and subalpine fir. This species occupies high elevation between 9,000 feet to 11,00 feet amsl in the Southern Rocky Mountains. Mature Engelmann spruce trees average 15-30 inches DBH but it is not uncommon to find individuals that exceed 40 inches with an average lifespan of 350-450 years old (USDA 2021). Table 10-20 provides detailed information on the Engelmann spruce sampled on Cielo Vista Ranch during the 2021 SWCA field survey.

Table 10-20 Sample Information of the Engelmann Spruce within Cielo Vista Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
97	4.4–27.1	19.6–81.0	13.3	47.4

Engelmann spruce was inventoried at 27 plots with an elevation range between 9,800 feet and 11,300 feet amsl. These trees are considered young to mature. Twenty-seven Engelmann spruce trees were cored to determine their age. The oldest Engelmann spruce cored was 185 years old and had a 17.9 inch DBH at a height of 79.0 feet, while the youngest Engelmann spruce cored was 41 years old and had a 9.3 inch DBH and a height of 41.0 feet. Engelmann are often seen with subalpine fir associations. Tree height and DBH is not consistent with relative age for this species. The crown base height of these trees averaged 13.3 feet above ground level with an average of 47.4% crown to tree ratio. An assortment of seedling and saplings were observed throughout the 27 plots.

Damage Indicators

During the 2021 field survey of Cielo Vista Ranch, Engelman spruce exhibited an assortment of biotic and abiotic damage. Biotic factors include insect infestation, fungal diseases, and elk browsing. Abiotic factors include but not limited to lightning strikes, landslides, nearby falling tree damage and wind events that cause damage to the tree.

There were multiple plots that exhibited signs of western spruce beetle and other insect damage. In the vicinity of North Vallejos Creek and Vallejos Creek, active insect infestation was observed. Please refer to Section 10.8 Mitigation Measures and Recommendations for further analysis and actions.

10.7.2.4 Lodgepole Pine (*Pinus contorta var. latifolia*)

Lodgepole pine was observed in 5 plots. They were observed as dominant within stands of the same species. Lodgepole pine occurs as even-age single storied stands that grow rapidly as young trees and slow growers as they mature. This species occurs on a wide variety of sites in Colorado. Lodgepole pine can be found between elevations of 1,500 and 11,500 feet amsl. Table 10-21 provides detailed information on the lodgepole pine sampled on Cielo Vista Ranch during the 2021 SWCA field survey.

Table 10-21 Sample Information of the Lodgepole Pine within Cielo Vista Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
7	6.0–11.6	32.0–63.2	50.9	46.0

Lodgepole pine was inventoried at 5 plots with an elevation range between 9,100 feet and 10,200 feet amsl. These trees age classification is determined to be young. These lodgepole pines were of a single age class. The results are consistent with an average 46.0% crown to trunk ratio and a high average crown base height of 50.9 feet above ground level.

Damage Indicators

The lodgepole pine that was observed on Cielo Vista Ranch exhibited signs of previous insect infestation. Although, no active infestation was observed. Other damage indicators were from physical damage from falling trees within the area.

10.7.2.5 Two-needle Pinyon Pine (*Pinus edulis*)

Pinyon pine was observed in seven plots. This pinyon in conjunction with Utah Juniper (*Juniperus osteosperma*) and Rocky Mountain Juniper (*Juniperus scopulorm*) create what is called the pinyon-juniper woodland. Depending on resources, this tree grows as a shrub in open and high desert savannas throughout the Southern Rocky Mountains. Two-needle pinyon pine can be found between elevations of 5,200 to 9,000 feet amsl. Table 10-22 provides detailed information on the two-needle pinyon pine sampled on Cielo Vista Ranch during the 2021 SWCA field survey.

Table 10-22 Sample Information of the Two-needle Pinyon Pine within Cielo Vista Ranch

Number of Individuals Sampled	Minimum/Maximum DRC (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
18	4.4–11.7	9.3–14.1	0.7	93.4

Pinyon pine was inventoried at seven plots with an elevation range between 8,600 and 9,200 feet amsl. These trees age classification are determined to be mature. The average crown to trunk ratio is 93.4% and an expected 0.7 feet crown base height. The distribution of pinyon within Cielo Vista is excellent with minimal patches of crowding and even spacing.

Damage Indicators

Overall, the pinyon that were observed on Cielo Vista Ranch was in excellent health. Throughout the west, dwarf mistletoe is the common parasite that is leading to the overall degradation of pinyon-juniper woodlands. During the 2021 field mobilization, no signs of insect or disease were observed for this species. Some individuals exhibited physical damage from an unknown agent. This is no cause for concern.

10.7.2.6 Ponderosa Pine (*Pinus ponderosa*)

Ponderosa pine was observed in 22 plots. This species, at lower elevations, is found to be within a transition zone of pinyon-juniper woodland and Douglas Fir forests (USDA 2021). In the most optimal conditions, spacing between individuals are large while canopy cover is low. This species is long lived where individuals can attain ages of 700 years or more. Generally, ponderosa pine can be found between elevations of 6,300 and 9,500 feet amsl. Table 10-23 provides detailed information on the ponderosa pine sampled on Cielo Vista Ranch during the 2021 SWCA field survey.

Table 10-23 Sample Information of the Ponderosa Pine within Cielo Vista Ranch.

Number of Individuals Sampled	Minimum/Maximum DRC (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
74	7.0–34.2	22.8–64.4	9.3	46.0

Ponderosa pine was inventoried at 22 plots with an elevation range between 9,200 and 10,200 feet amsl. These trees age classification is determined to be young to mature. The average crown to trunk ratio is 46.0% and an expected 9.3 feet crown base height. In comparison to some of the oldest ponderosa pine trees in Colorado, these trees are young. Wood utilization and potential harvestability of this species is high. These trees have only exhibited physical damage from lightning strikes and had no apparent signs of insect infestation of disease. 19 trees were cored to determine age with the youngest at 37 years old while the oldest was 120 years old.

Damage Indicators

Trees of this species were observed to be in excellent condition. The spacing found between these individuals was excellent and this warm-dry mixed conifer forest was in great health.

10.7.2.7 Quaking Aspen (*Populus tremuloides*)

Quaking aspen was observed in 36 plots. They were observed as dominant, co-dominant with Engelmann spruce, Douglas fir, lodgepole pine and subalpine firs. Aspen trees are fast growers and depending on site conditions, can achieve large DBHs in a relatively short amount of time. This species occurs on a wide variety of sites in Colorado. Aspen can be found between elevations of 6,500 to 11,500 feet amsl. Table 10-24 provides detailed information on the Quaking Aspen sampled on Cielo Vista Ranch during the 2021 SWCA field survey.

Table 10-24 Sample Information of the Quaking Aspen within Trinchera Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
94	4.0–20.9	15.5–82.0	27.7	18.0

The quaking aspen was inventoried at 36 plots with an elevation range between 9,000 and 11,000 feet amsl. These trees age classifications range from seedling to mature trees. During the 2021 field survey, it was noted that one third of all aspen trees inventoried exhibited disease and animal damage. Evidence of elk rubbing on aspen trunks was consistent throughout dense aspen stands. Additionally, it was observed that the majority of aspen stands were of a single age class and competition for resources are high. The results are consistent with an average 18.0% crown to trunk ratio and a high average crown base height of 27.7 feet above ground level.

<u>Damage Indicator</u>

During the 2020 Colorado State Forest Service annual aerial detection forest health survey, it was noted that an unknown defoliator was observed effecting aspen stands on Cielo Vista Ranch. This was confirmed during the 2021 SWCA field survey. Please refer to section 10.8 for specific mitigation measures.

10.7.2.8 Rocky Mountain Juniper (*Juniperus scopulorum*)

Pinyon pine was observed in seven plots. This juniper tree in conjunction with the two-needle pinyon pine create what is called the pinyon-juniper woodland. Depending on resources, this tree grows as a shrub in open and high desert savannas throughout the Southern Rocky Mountains and can exhibit several different morphologies. Rocky Mountain Juniper can be found between elevations 4,000 feet to 8,500 feet amsl. Table 10-25 provides detailed information on Rocky Mountain Juniper sampled on Cielo Vista Ranch during the 2021 SWCA field survey.

Table 10-25 Sample Information of the Rocky Mountain Juniper within Cielo Vista Ranch.

Number of Individuals Sampled	Minimum/Maximum DRC (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
8	6.8–18.6	7.4–25.9	0.1	95.4

Juniper was inventoried at seven plots with an elevation range between 7,800 and 8,200 feet amsl. These trees age classification is determined to be mature. The average crown to trunk ratio is 95.4% and an expected 0.1 feet crown base height. The distribution of juniper within Cielo Vista is excellent with minimal patches of crowding and even spacing.

<u>Damage Indicators</u>

Overall, the juniper trees that were observed on Cielo Vista Ranch were in excellent health. Throughout the west, dwarf mistletoe is the most common parasite that is leading to the overall degradation of pinyon-juniper woodlands. During the 2021 field mobilization, no signs of insect or disease were observed for this species. Some individuals exhibited physical damage from an unknown agent.

10.7.2.9 Subalpine Fir (*Abies lasiocarpa*)

Subalpine firs are the most widely distributed fir in North America occurring mainly in mountainous areas. Subalpine firs can occur in Douglas fir forests, spruce-fir forests, and lodgepole pine forests and is usually associated with Engelmann spruce. This species was observed in seven plots as young to mature trees. Mature subalpine firs are within 18 to 24 inches DBH and are usually 60 to 100 feet tall (USDA 2021). These specific individuals that were observed within Cielo Vista were dominant and co-dominant with Engelmann spruce within its stand. This species occupies high elevation between 8,000 to 12,000 amsl in the Southern Rocky Mountains and is an ecologically important species for large game like mule deer, elk, and bighorn sheep (USDA 2021). Table 10-26 provides detailed information on the subalpine fir sampled on Cielo Vista Ranch during the 2021 SWCA field survey.

Table 10-26 Sample Information of the Subalpine Fir within Cielo Vista Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
15	3.5–12.7	24.1–74.0	8.4	57.6

Subalpine fir was inventoried at nine plots with an elevation range between 9,900 and 10,800 feet amsl.

Seven trees were cored and were determined to have an average age of 79 years old while the oldest tree sampled was 135 years old. Subalpine firs have a lifespan of 250 years (USDA 2021). The crown base height of these trees averaged 8.4 feet above ground level with an average of 57.6% crown to tree ratio, which is common for this species.

Damage Indicators

During the 2021 field survey no apparent tree damage indicator was observed with these recorded individuals.

10.7.2.10 Basal Area

Basal Area is the common term used to describe the average amount of an area occupied by tree stems. It is defined as the total cross-sectional area of all stems in a stand measured at breast height (4.5 feet) and expressed as per unit of land area (U.S. Forest Service (USFS), 1965; Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP)). This helps land managers understand the density of their forest and if there are any management concerns.

Each management area is different and has varying management goals. The term Timber Targets is coined by the US Forest Service to describe basal area management goals for timber managed areas. Below are some examples of timber targets of southern Colorado USFS districts (Nauman 2021).

Species	Post Management Basal Area Target
Ponderosa Pine	40-60
Mixed Conifer	50-70
Aspen	50-70
Pinon-Juniper	N/A

Any areas that are over 100 for basal area are identified for mitigation. If these timber targets are achieved, it is expected that the area treated would need minimal maintenance and monitoring for years to come.

Table 10-27 provides information concerning species recorded, live/dead ratio, total basal area within that plot, and the vegetation community the plot falls within.

Table 10-27 Basal Area of Selected Plots within Cielo Vista Ranch.

Plot Number	Species Recorded	Live/Dead	Basal Area	Vegetation Community
13	Douglas Fir	1/0	20	Aspen Woodland
14	Engelmann Spruce Ponderosa Pine	5/0	100	Ponderosa Pine Woodland
15	Douglas Fir Ponderosa Pine	4/0	80	Ponderosa Pine Woodland
16	Ponderosa Pine	4/0	80	Ponderosa Pine Woodland
17	Douglas Fir Ponderosa Pine	4/0	80	Mixed Conifer (Warm-Dry)
18	Douglas Fir Quaking Aspen	4/1	80	Mixed Conifer (Warm-Dry)
19	Douglas Fir Quaking Aspen	5/0	100	Mixed Conifer (Warm-Dry)
20	Douglas Fir Quaking Aspen	6/0	120	Aspen Woodland
21	Douglas Fir	6/0	120	Mixed Conifer (Cool-Moist)
22	Ponderosa Pine	4/0	80	Aspen Woodland
23	Douglas Fir Rock Mountain Juniper	3/0	60	Mixed Conifer (Cool-Moist)
24	Ponderosa Pine	3/1	60	Mountain Shrubland Mountain Grassland
25	Douglas Fir Engelmann Spruce Quaking Aspen	6/1	120	Aspen Woodland
26	Douglas Fir	5/0	100	Mixed Conifer (Cool-Moist)
27	Douglas Fir Quaking Aspen	4/0	80	Mixed Conifer (Cool-Moist)
28	Douglas Fir Ponderosa Pine	3/0	60	Spruce-Fir Forest
29	Ponderosa Pine	4/0	80	Mountain Shrubland Mountain Grassland
30	Douglas Fir Ponderosa Pine Rocky Mountain Juniper	4/0	80	Mountain Shrubland Mountain Grassland
31	Ponderosa Pine	3/0	60	Mixed Conifer (Cool-Moist)
32	Ponderosa Pine	4/0	80	Ponderosa Pine Woodland

Plot Number	Species Recorded	Live/Dead	Basal Area	Vegetation Community
33	Pinyon Pine	3/0	60	Pinyon-Juniper Woodland
34	Ponderosa Pine	2/0	40	Mountain Shrubland Mountain Grassland
35	Ponderosa Pine Quaking Aspen	2/1	40	Mountain Shrubland Mountain Grassland
36	Douglas Fir Engelmann Spruce	3/0	60	Mixed Conifer (Warm-Dry)
37	Douglas Fir	4/0	80	Aspen Woodland
38	Douglas Fir	1/0	20	Aspen Woodland
39	Quaking Aspen	5/0	100	Aspen Woodland
40	Quaking Aspen	3/1	60	Aspen Woodland
41	Quaking Aspen	5/1	100	Aspen Forest and Woodland
42	Lodgepole Pine	2/1	40	Spruce-Fir Forest
43	Douglas Fir Engelmann Spruce	4/0	80	Mixed Conifer (Cool-Moist)
44	Lodgepole Pine Quaking Aspen	7/1	140	Mixed Conifer (Warm-Dry)
45	Engelmann Spruce Lodgepole Pine	4/0	80	Mixed Conifer (Warm-Dry)
46	Douglas Fir Ponderosa Pine	4/0	80	Ponderosa Pine Woodland
47	Engelmann Spruce Quaking Aspen Subalpine Fir	6/2	120	Mixed Conifer (Warm-Dry)
48	Douglas Fir Engelmann Spruce Quaking Aspen Subalpine Fir	7/3	140	Mixed Conifer (Warm-Dry)
49	Engelmann Spruce Lodgepole Pine Subalpine Fir	3/0	60	Spruce-Fir Forest
50	Lodgepole Pine Quaking Aspen	4/0	80	Spruce-Fir Forest
51	Engelmann Spruce Quaking Aspen	6/1	120	Mixed Conifer (Warm-Dry)
52	Engelmann Spruce Quaking Aspen Subalpine Fir	6/6	120	Mixed Conifer (Cool-Moist)
53	Quaking Aspen Subalpine Fir	3/3	60	Spruce-Fir Forest

Plot Number	Species Recorded	Live/Dead	Basal Area	Vegetation Community
54	Engelmann Spruce Subalpine Fir	6/0	120	Mixed Conifer (Warm-Dry)
55	Ponderosa Pine Rocky Mountain Juniper	5/0	100	Pinyon-Juniper Woodland
56	Ponderosa Pine	4/0	80	Ponderosa Pine Woodland
57	Douglas Fir Ponderosa Pine	3/0	60	Pinyon-Juniper Woodland
58	Douglas Fir Ponderosa Pine	4/0	80	Ponderosa Pine Woodland
59	Ponderosa Pine	6/0	120	Ponderosa Pine Woodland
60	Douglas Fir	3/0	60	Mixed Conifer (Cool-Moist)
61	Ponderosa Pine Quaking Aspen	3/1	60	Aspen Woodland
62	Douglas Fir Quaking Aspen	3/1	60	Aspen Woodland
63	Douglas Fir	2/0	40	Spruce-Fir Woodland
64	Lodgepole Pine	2/1	40	Spruce-Fir Forest
65	Douglas Fir	4/1	80	Mixed Conifer (Cool-Moist)
66	Douglas Fir Quaking Aspen	4/3	80	Mixed Conifer (Warm-Dry)
67	Engelmann Spruce Quaking Aspen	4/0	80	Mixed Conifer (Warm-Dry)
68	Engelmann Spruce	4/1	80	Spruce-Fir Forest
69	Engelmann Spruce	5/1	100	Mixed Conifer (Warm-Dry)
70	Engelmann Spruce Quaking Aspen	4/0	80	Mixed Conifer (Warm-Dry)
71	Pinyon Pine	3/0	60	Pinyon-Juniper Woodland
72	Pinyon Pine	3/0	60	Mountain Shrubland Mountain Grassland
73	Pinyon Pine Rocky Mountain Juniper	8/0	160	Pinyon-Juniper Woodland
74	Ponderosa Pine	7/1	140	Mixed Conifer (Cool-Moist)
75	Douglas Fir Quaking Aspen	7/1	140	Mixed Conifer (Warm-Dry)

Plot Number	Species Recorded	Live/Dead	Basal Area	Vegetation Community
76	Engelmann Spruce Subalpine Fir	6/0	120	Mixed Conifer (Warm-Dry)
77	Engelmann Spruce Quaking Aspen Subalpine Fir	9/1	180	Aspen Forest and Woodland
78	Engelmann Spruce Quaking Aspen	4/1	80	Mixed Conifer (Warm-Dry)
79	Quaking Aspen	6/0	120	Aspen Woodland
80	Quaking Aspen	6/0	120	Mixed Conifer (Warm-Dry)
81	Engelmann Spruce	7/1	140	Mixed Conifer (Warm-Dry)
82	Engelmann Spruce	6/0	120	Mixed Conifer (Warm-Dry)
83	Blue Spruce	3/0	60	Mixed Conifer (Warm-Dry)
84	Douglas Fir Quaking Aspen	11/1	220	Mixed Conifer (Warm-Dry)
85	Engelmann Spruce	7/0	140	Mixed Conifer (Warm-Dry)
86	Engelmann Spruce	6/1	120	Spruce-Fir Forest
87	Pinyon Pine	3/0	60	Mountain Shrubland Mountain Grassland
88	Ponderosa Pine	2/0	40	Pinyon-Juniper Woodland
89	Ponderosa Pine	2/0	40	Pinyon-Juniper Woodland
90	Ponderosa Pine	2/0	40	Pinyon-Juniper Woodland
91	Douglas Fir	4/0	80	Mountain Shrubland Mountain Grassland
92	Douglas Fir	3/0	60	Mixed Conifer (Warm-Dry)
93	Douglas Fir Quaking Aspen	6/0	120	Aspen Woodland
94	Douglas Fir Quaking Aspen	7/0	140	Aspen Woodland
95	Engelmann Spruce Quaking Aspen	5/0	100	Aspen Woodland
96	Engelmann Spruce	2/0	40	Mixed Conifer (Warm-Dry)
97	Engelmann Spruce	14/1	280	Aspen Woodland

Plot Number	Species Recorded	Live/Dead	Basal Area	Vegetation Community
103	Engelmann Spruce Quaking Aspen Subalpine Fir	7/0	140	Mixed Conifer (Warm-Dry)
104	Engelmann Spruce Quaking Aspen	8/0	160	Aspen Woodland

10.7.2.11 Summary

Cielo Vista is the largest ranch within the UCW analysis area. There have been previous management activities within its forest but in order to enhance forest health, there is a need for additional forest management and mitigation. Generally, stands within the ranch boundary are overstocked allowing for disease and the potential spread of insect infestations. Cielo Vista has a defined road network, but it is overgrown and unmaintained. If land managers are considering opening up the forest to commercial activities, these road networks would need to be upgraded. Upgrades to roads would also serve a purpose of improving access for fire response, in the event of a large wildfire on the property and creating a fuel break network across the ranch.

Throughout the UCW analysis area there are signs of defoliators and tree mortality. Given its size, Cielo Vista encompasses the highest areas where tree mortality and defoliators were detected during the 2020 Colorado State Forest Service annual aerial detection forest health survey. It was determined that the spruce beetle, western spruce budworm, Douglas fir Beetle, Mountain Pine Beetle, and unknown aspen defoliators were observed within the ranch boundary.

Please refer to section 10.8 and 10.9 for Mitigation Measure Definitions and Recommendations.

10.7.3 Dos Hermanos

Dos Hermanos Ranch occupies 11,612.4 acres of the UCW analysis area and encompasses all vegetation type as described in section 3.2.1 above. However, only five stand exam plots were selected due to the percentage of vegetation cover-type occupying the Dos Hermanos Ranch.

When common stand exams were conducted, five types of tree species were measured and recorded: Bristlecone pine, Douglas fir, Gambel oak, quaking aspen, and Rocky Mountain juniper. Table 10-28 provides average stand information for each of the five species.

Table 10-28 Average Results of Plot recorded within the Dos Hermanos Ranch Boundary.

Tree Species Sampled	Number of Individuals Sampled	Average DBH/DRC (inches)	Average Tree Height (feet)	Damage Indicators
Bristle Cone Pine	2	10.4 DBH	35.0	None
Douglas Fir	10	15.4 DBH	56.1	None
Gambel Oak	4	6.3 DBH	23.1	None
Rocky Mountain Juniper	1	8.8 DRC	7.1	None
Quaking Aspen	6	10.6 DBH	38.1	Ungulate

10.7.3.1 Rocky Mountain Bristle Cone Pine (*Pinus aristata*)

Out of the 23 of species surveyed on the Dos Hermanos Ranch only two bristle cone pine trees fell within plot 12 radius. They were observed as co-dominant with Douglas fir, Englemann spruce and at times with isolated pockets of Aspen. This tree is slow growing. Generally, trees with DBH values between 16 and 20 inches have been aged between 200 and 250 years old while the oldest Rocky Mountain Bristle Cone Pine documented in Colorado has 2,435 countable annual rings in 1992 (USDA 2021). This species occupying the lower montane vegetation community rarely live past 300 years and can be found between elevations of 7,000 to 13,000 feet amsl. Table 10-29 provides detailed information on the Rocky Mountain Bristle Cone Pine sampled on Dos Hermanos Ranch during the 2021 SWCA field survey.

Table 10-29 Sample Information of the Rocky Mountain Bristle Cone Pine within Dos Hermanos Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
2	9.7–11.1	32.8–37.1	7.0	52.5

Rocky Mountain Bristle Cone Pine was inventoried at Plot 98 at approximately 9,755 feet amsl. These trees are considered mature and are reaching their maximum growth height at an average of 40 feet tall (USDA 2021). The crown base height of these trees averaged 7.0 feet above ground level with an average of 52.5% crown to tree ratio. No seedling or sapling of this species was observed at Plot 12.

10.7.3.2 Rocky Mountain Douglas Fir (*Pseudotsuga menziesii var. glauca*)

Rocky Mountain Douglas fir was observed in Plots 98 and 102 and was the most recorded species on Dos Hermanos Ranch. They were observed as dominant, co-dominant, and intermediate trees with bristle cone pine and aspen. This species occupies high elevation between 8,000 to 9,500 feet amsl in the Southern Rocky Mountains and growth typically slows dramatically between 90 and 140 years of age (USDA 2021). Table 10-30 provides detailed information on the Rocky Mountain Douglas Fir sampled on Dos Hermanos Ranch during the 2021 SWCA field survey.

Table 10-30 Sample Information of the Rocky Mountain Douglas Fir within Dos Hermanos Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
10	7.0–22.8	28.8–85.6	21.7	34.8

Rocky Mountain Douglas Fir was inventoried at Plot 98 and 102 at approximately 9,755 and 9,350 feet amsl, respectively. These trees are considered young to mature. Two Douglas firs were cored to determine their age. The oldest Douglas fir cored was 85 years had a 22.8-inch DBH at a height of 55.9 feet, while the youngest Douglas fir cored was 56 years with a DBH of 17.3 inches and a height of 65.2 feet. Douglas fir trees can live in a variety of subalpine conditions. Tree height and DBH is not consistent with relative age for this species. The crown base height of these trees averaged 21.7 feet above ground level with an average of 34.8% crown to tree ratio which is common for this species. No seedling or sapling of this species was observed at Plot 12 or 5.

10.7.3.3 Gambel Oak (*Quercus gambelii*)

Gambel oak is often seen as an understory shrub in ponderosa pine forests and within transition zones in low elevations. It is commonly seen as small DBH bushes but when it is allowed to mature, it can grow into short stature groves. Gambel oak was observed in Plot 24 in its mature grove stage. It was observed as dominant within its stand. This species occupies moderate elevation between 4,000 to 8,500 feet amsl in the Southern Rocky Mountains and is an ecologically important species for providing food and shelter for many wildlife species (USDA 2021). Table 10-31 provides detailed information on the Gambel oak sampled on Dos Hermanos Ranch during the 2021 SWCA field survey.

Table 10-31 Sample Information of the Gamble Oak within Dos Hermanos Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
4	5.6–6.7	21.7–24.0	13.5	9.3

Gamble oak was inventoried at Plot 99 at approximately 9,145 feet amsl. These trees are considered to be mature. No Gambel oak was cored on Dos Hermanos Ranch due to damage concerns and potential mortality to the individual. On average, an individual measuring at 7.0 inches DBH is approximately 65 to 70 years old. Gambel oak have a general lifespan of 90 year but it is not uncommon for this species to reach 120 years old (USDA 2021). Gamble oak favor ponderosa pine forests and are very competitive for resources. The crown base height of these trees averaged 13.5 feet above ground level with an average of 9.3% crown to tree ratio, which is common for this species. No seedling or sapling of this species was observed at Plot 24 but large swaths of Gambel oak are present in lower elevations of Dos Hermanos Ranch.

10.7.3.4 Rocky Mountain Juniper (*Juniperus scopulorum*)

Rocky Mountain Juniper was observed in one plot. This juniper tree in conjunction with the two-needle pinyon pine create what is called the pinyon-juniper woodland. Depending on resources, this tree grows as a shrub in open in high desert savannas throughout the Southern Rocky Mountains and can exhibit several different morphologies. Rocky Mountain Juniper can be found between elevations 4,000 to 8,500 feet amsl. Table 10-32 provides detailed information on Rocky Mountain Juniper sampled on Cielo Vista Ranch during the 2021 SWCA field survey.

Table 10-32 Sample Information of the Rocky Mountain Juniper within Dos Hermanos Ranch.

Number of Individuals Sampled	DRC (inches)	Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
1	8.8	7.1	0.0	100.0

This species was inventoried at one plot at approximately 9,000 feet amsl. This individual was cored and it was determined to be approximately 23 years old. The crown base height of this tree is 0 feet above ground level with an average of 100% crown to tree ratio, which is common for this species. No seedling or sapling of this species was observed at Plot 23, but distribution of this species is widespread throughout lower elevations of Dos Hermanos Ranch.

10.7.3.5 Quaking Aspen (*Populus tremuloides*)

Quaking aspen was observed in two plots. They were observed as co-dominant with Douglas fir. Aspen trees are fast growers and depending on site conditions, can achieve large DBHs in a relatively short amount of time. This species occurs on a wide variety of sites in Colorado. Aspen can be found between elevations of 6,500 and 11,500 feet amsl. Table 10-33 provides detailed information on the Quaking Aspen sampled on Dos Hermanos Ranch during the 2021 SWCA field survey.

Table 10-33 Sample Information of the Quaking Aspen within Dos Hermanos Ranch.

Number of Individuals Sampled	Minimum/Maximum DBH (inches)	Minimum/Maximum Tree Height (feet)	Average Crown Base Height (feet)	Average Crown Ratio (%)
6	6.7–19.4	19.9–62.1	31.6	8.5

The Quaking Aspen was inventoried at approximately 9,000 feet amsl. Overall, these trees are considered mature. During the 2021 field survey, it was noted that a high number of aspen trees exhibited disease and animal damage. Evidence of elk rubbing on aspen trunks was consistent throughout dense aspen stands. Additionally, it was observed that the majority of aspen stands were of a single age class and competition for resources are high. The results are consistent with an average 8.5% crown to trunk ratio and a high average crown base height of 31.6 feet above ground level.

10.7.3.6 Basal Area

Basal Area is the common term used to describe the average amount of an area occupied by tree stems. It is defined as the total cross-sectional area of all stems in a stand measured at breast height (4.5 feet) and expressed as per unit of land area (USFS 1965, MDWFP 2021). This helps land managers understand the density of their forest and if there are any management concerns.

Each management area is different and has varying management goals. The term Timber Targets is coined by the US Forest Service to describe basal area management goals for timber managed areas. Below are some examples of timber targets of southern Colorado USFS districts (Nauman, 2021).

Species	Post Management Basal Area Target
Ponderosa Pine	40-60
Mixed Conifer	50-70
Aspen	50-70
Pinon-Juniper	N/A

Any areas that are over 100 for basal area are identified for mitigation. If these timber targets are achieved, it is expected that the area treated would need minimal maintenance and monitoring for years to come.

Table 10-34 provides information concerning species recorded, live/dead ratio, total basal area within that plot, and the vegetation community the plot falls within.

Table 10-34 Basal Area of Selected Plots within Dos Hermanos Ranch.

Plot Number	Species Recorded	Live/Dead	Basal Area	Vegetation Community
98	Bristle Cone Pine Douglas Fir	6/2	120	Mixed Conifer (Warm Dry)
99	Gambel Oak	4/0	80	Mountain Shrublands Mountain Grasslands
100	Douglas Fir Quaking Aspen	5/0	100	Riparian Woodlands Riparian Wetlands
101	Rocky Mountain Juniper	1/0	20	Mountain Shrublands Mountain Grasslands
102	Douglas Fir Quaking Aspen	7/1	140	Mixed Conifer (Warm Dry)

10.7.3.7 Summary

Dos Hermanos Ranch is the smallest ranch that is within the UCW. The property encompasses an even amount of open high desert shrubland/grassland to warm-dry mixed conifer forests in higher elevations. Property owners have been using modern mastication techniques to reduce fuel loading in the surrounding forest and ladder fuels have been greatly reduced. In higher elevations, the basal area of Douglas Fir and Quaking Aspen increases with limited road access to the area. These areas have limited dead and down fuel types and contract thinning can be implemented.

During the 2020 Colorado State Forest Service annual aerial detection forest health survey, it was noted that an infestation of Western Spruce Beetle was encroaching on the ranch boundary from the south across the New Mexico State border. There was no observed beetle infestation during the 2021 field survey. However, areas identified by the aerial survey must be prioritized and investigated further.

Please refer to section 10.8 and 10.9 below for Mitigation Measure Definitions and Recommendations.

10.8 Mitigation Measures

This section outlines proposed mitigation measures that could be applied to address forest health concerns across the upper watershed. Recommendations are broken down by landownership.

10.8.1 Treatment Descriptions

Proposed mitigation measures for forest health could include a combination of prescriptions designed to move even aged stands toward uneven or a multi-cohort structure. This structure is generally advisable for promoting forest resilience to disturbance and enhancing overall stand vigor and production in all forest types. In stands that have an older age size class and structure an ITS (Individual Tree selection) with a Restoration emphasis prescription should be used. In stands that lack a large tree component, a Commercial Thin prescription should be used to reduce stocking density. In other stands that lack a younger age class a, Group Selection prescription should be utilized.

In the stands most heavily infested with bark beetles and disease, prescriptions focus on removing the infected species. A more aggressive approach to harvest needs to be taken on these stands as this is the source of future beetle populations. If stocking levels are insufficient to regenerate these stands, tree planting may be needed on sites with sufficient soil to grow trees. Mastication of infested trees would be a secondary option if contractors /market are not available. Dead trees will be left for snags at 15 inches DBH or greater distributed at 4 per acre if available.

10.8.1.1 Timing

The annual Normal Operating Season (NOS) for commercial timber sales would be between May and November. Winter months Dec-Feb are permitted providing soil conditions are frozen.

10.8.1.2 Prescriptions

Timber Stand Improvement (TSI): timber stand improvement includes activities or treatments that improve the composition, structure, condition, health and growth or even aged or uneven aged stands. Activities include mechanical or chemical treatments to remove undesirable trees, removal of dying or dead trees, thinning, pruning and post-harvest treatments.

Individual Tree Selection (ITS): this prescription would require individual tree marking or designation by description. Trees would be marked for cut or leave with a marking guide. Typically, this guide would describe a minimum basal area (45–60 square feet) and the best formed trees of all age and size class would be left, with some spacing requirements. Additionally, if management treatment allows, 30% of 16 inches and over DBH trees would remain within the area to promote larger fire resistant, seed producing overstory trees.

Commercial Thin (CT) this prescription would be used in an even-aged stand to thin trees out, leaving the best trees at a spacing or basal area requirement. In trees a spacing of 20 feet with a tolerance of +/- 5 feet to allow for the best tree and different size class to be retained. This prescription works well with a mastication contract and does not require a stand to be marked.

Group Selection (GS) this prescription would require small groups of 0.1 to 0.5 acre to be cut due to bark beetle or disease, leaving quality seed trees around the cut to reforest. These groups will not exceed a radius of 1 ½ tree length from quality leave trees. The matrix in between cuts can be thinned to a spacing guideline similar to the commercial thin. Typically, small pockets are created in the stand to initiate regeneration and 10-20% of the stand would be opened up.

Fuel Breaks and Hazardous Fuel Reduction: Areas requiring hazardous fuel treatments based on projected fire behavior, are delineated in Figure 11-23 and described in Section 11.3.6. Many of the same vegetation management protocols are employed in reducing hazardous fuels.

10.8.1.3 Sanitation Salvage

Sanitation/ Salvage (SS): In timbered stands with merchantable size trees/volume and heavy infestation of bark beetle or rampant disease, Sanitation/Salvage could be utilized. This prescription would cut and remove the bark beetle infested trees, salvage a portion of the recent dead trees and thin the matrix in between the areas of infestation. In heavy infested beetle hit stands the prescription would be to remove all currently beetle infested trees and thin the matrix out, red needled and dead trees are available for harvest if the purchaser selects to remove them. Dead snags greater than 15 inches DBH should be left at 4 trees/acre to promote wildlife habitat trees.

10.8.1.4 Mastication/Biomass/TSI

Mastication. Stands with a high percentage of small diameter trees (>40 tpa, <12 inches DBH) should be identified. These would likely be masticated to control stocking density, reduce ladder fuels and prepare these stands for a broadcast burn. Typically, the mastication with hydro-axe can remove trees from 5 to 12 inches in diameter and those larger trees would need to be thinned with a second entry of a timber sale in the future. Smaller diameter trees (<12 inches DBH) should be thinned to promote best formed, healthy trees and allow growing space and nutrients to optimize growth. Also suppressed, diseased and over-stocked trees 12 inches DBH and smaller should be targeted for cutting.

Biomass. If timber-sale units are non-economically viable due to lumber market, then they could become biomass units or treated with mastication. The same prescriptive parameters would exist, and the result would be very similar. In units offered for biomass, slash may be chipped and hauled off site for utilization. If the treatment is followed with prescribed fire, the burn would then be cooler and easier to implement.

Hand Thin/TSI. Areas where an abundance of small diameter trees (<12 inches DBH) exist, could be selected for a timber stand improvement prescription. These units are particularly well suited for public access and firewood. Spacing guidelines for those trees in the sapling to 12-inch DBH size class will be 15 to 25 feet with an average of 20 feet. Residual stocking levels should average 70 square feet/acre to 90 square feet/acre of basal area, with all those trees greater than 12 inches DBH left until another entry. Thinned bole wood of 4 to12-inch DBH should be offered for personal and commercial firewood where appropriate. Slash from the felled trees should be piled in openings and away (10 feet or greater) from residual trees and pile burned or could be used as biomass

10.8.1.5 Reforestation

Reforestation. In portions of any selected treatment, there could be open pockets where disease and insect infestation trees would have been. The overall density of this area would be low, which could leave areas open to potentially undesirable succession plants to establish. Any areas that have been determined to have any disease or insect infestations should be targeted for harvest and or mastication. Once the areas have been cleared, a suggestion of 150 seedlings should be planted per acre to restock the area.

10.8.1.6 Prescribed Burning

There are a few areas where prescribed burning would greatly increase the resiliency of the stand. Areas that have been masticated or previously harvested are ideal candidates for this prescription. The removal and reintroduction of nutrients to the soil substrate would only benefit the area as a whole. Prescribed fire could also be used to train local fire department personnel and efforts could be made to engage multi-agency crews to support these efforts and further build collaboration between response agencies.

10.8.1.7 Access Roads

Overall, the Trinchera and Dos Hermanos Ranches have the most improved access roads within the UCW analysis area. If commercial logging becomes a viable revenue stream, little upgrades and improvements to their respective road systems would be needed.

Historically, Cielo Vista Ranch allowed for large scale timber harvests. The road base still exists throughout the ranch boundary. However, there are large diameter trees, brush, and other obstacles that are encroaching on the road base, making travel difficult and commercial operations limited. If managers of Cielo Vista Ranch decided to prioritize merchantable timber, the road system would need to be upgraded and maintained.

10.8.2 Best Management Practices

Best management practices (BMPs) would be incorporated into project design and implementation. The following features are design elements that further detail management actions, mitigate environmental consequences, and establish priorities for implementation.

10.8.2.1 Timber Harvesting, Mastication, Felling Operations

- Restrict hydro-mowing and heavy equipment activities during periods of spring snowmelt and periods of heavy rain when soils are too wet. Soils are too wet when vehicle ruts exceed 4 inches depth for 10 feet or more.
- Intermittent streams would be buffered 100 feet both sides of the stream channel from operation of heavy equipment (consult Hydrologist as needed).
- Springs/wetlands/stock ponds would be buffered 100 feet from mechanized equipment.
- Temporary roads used or created by the timber sale contractor must be scarified, ripped, re-seeded, covered with debris, and effectively blocked after treatment.
- No tree over 16 inches DBH would be cut. Trees this size and larger would be retained as “seed” trees and left within the area.
- Dead standing trees would be considered wildlife trees and left within the area.
- Mitigation treatments would avoid and protect stream channels, wetlands, floodplains and flood-prone areas with buffers.
- All timber operations will adhere to state and federal laws.

10.8.2.2 Prescribed Fire Treatments

- Prescribed burning would require preparation of a written Burn Plan and a Smoke Management permit that complies with State Air Quality Management District standards, notification of county (Costilla) prior to burning and monitoring of smoke production.
- Install water bars on fire line where slopes are greater than 20%.

- Limit fire-line construction thru stream crossings to the minimum number necessary to treat a unit. Cross streams perpendicular to the direction of flow and do not cross stream if banks exceed 30% slope.

10.9 Recommendations

This section includes selected recommendations for promoting forest health, resiliency and increasing forest wood products production while allowing for more grazing opportunities throughout the UCW analysis area. Recommendations are broken out by ranch ownership.

10.9.1 Trinchera Ranch

Recommendations for Trinchera Ranch are provided below in Table 10-35 and Figure 10-24. Basal area targets for various forest types are described in the Section 10.7.1.

Table 10-35 Recommendations of Plots within Trinchera Ranch.

Plot Number	Proposed Mitigation Strategy	Existing Basal Area	Notes
1	Timber Stand Improvement	100	There is an abundance of small diameter trees within this area with signs of ungulate damage and aspen disease. This unit can be used for firewood collection.
2	Timber Stand Improvement	80	There is an abundance of small diameter trees within this area with signs of ungulate damage and aspen disease. This unit can be used for firewood collection.
3	Individual Tree Selection	40	Individual trees can be selected for thinning by prescription. Material collected can be utilized for firewood or commercially sold.
4	Individual Tree Selection	120	Individual trees can be selected for thinning by prescription. Material collected can be utilized for firewood or commercially sold.
5	Timber Stand Improvement	100	There is an abundance of small diameter trees within this area with signs of ungulate damage and aspen disease. This unit can be used for firewood collection.
6	Mastication/ Biomass	100	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
7	Mastication/ Biomass	80	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
8	Mastication/ Biomass	80	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
9	Commercial Thinning	140	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
10	Commercial Thinning	100	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
11	Individual Tree Selection	100	Individual trees can be selected for thinning by prescription. Material collected can be utilized for firewood or commercially sold.
12	Individual Tree Selection	120	Individual trees can be selected for thinning by prescription. Material collected can be utilized for firewood or commercially sold.
El Valle Creek Basin	Reforestation	-	This area has been previously logged. Potential reforestation could improve the overall health of the area.

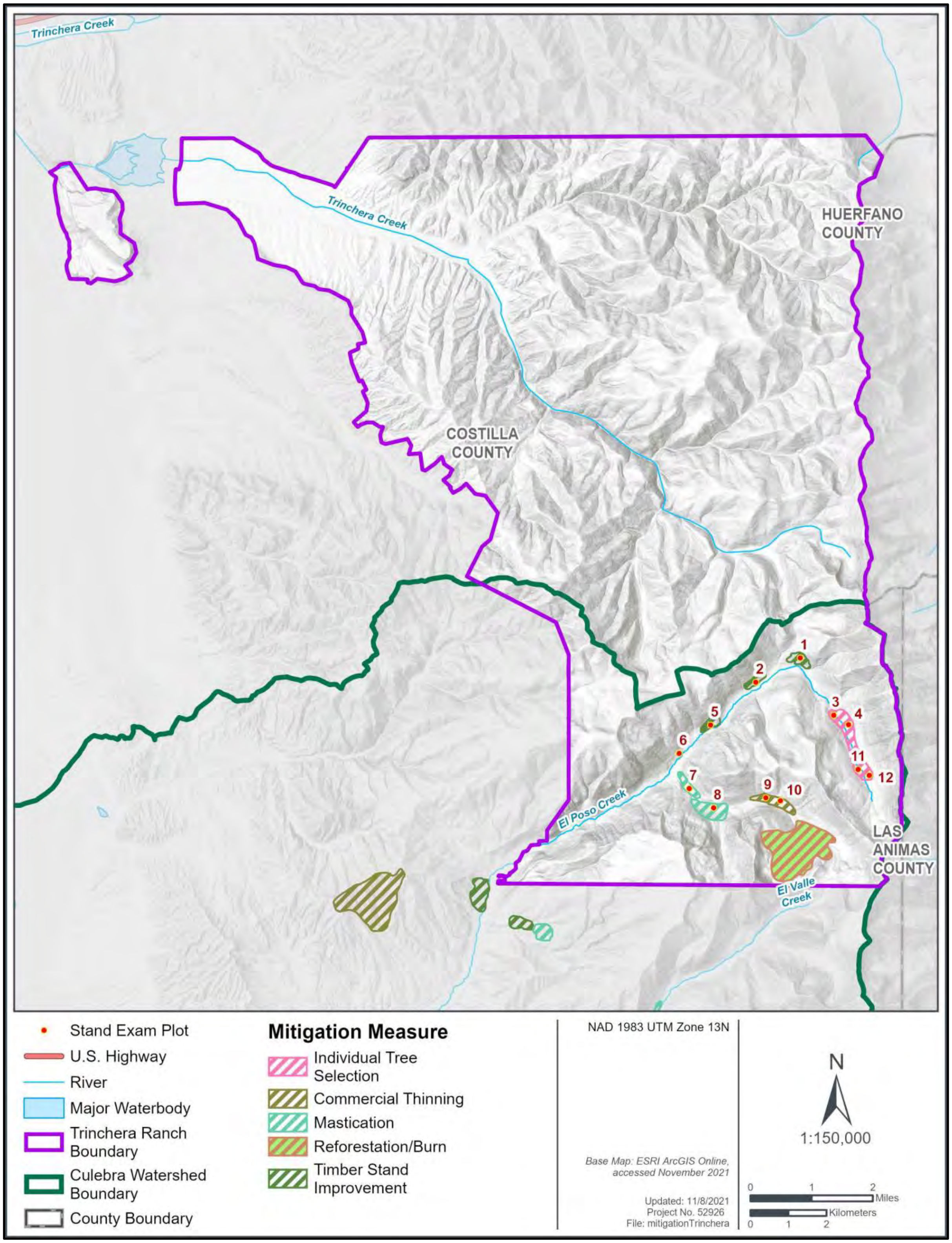


Figure 10-24 Mitigation Measures Map of Trinchera Ranch.

SWCA recommends five different forest health approaches for Trinchera Ranch. Table 10-36 below categorize each treatment and how each management strategy coincides with Colorado Forest Service goals and strategies for improving Colorado forests.

Table 10-36 Forest Management Approaches for Trinchera Ranch.

Number of Plots	Proposed Mitigation Strategy	Technique for Improving Forest Health	Priority
3	Timber Stand Improvement	-Reduce impacts from biological stressors by reducing competition. -Maintain and enhance existing and new forest productivity by managing for diversity in tree class, tree age and stand stocking.	1
3	Mastication/ Biomass	-Manage fire-dependent forest systems to maintain and promote resistance to fire mortality.	2
4	Individual Tree Selection	-The use of silvicultural practices that identify and promote biological and structural diversity, including thinning and regeneration techniques. -Enhance economic incentives of the local community.	4
2	Commercial Thinning	-Enhance economic incentives of the local community.	3
1	Reforestation	-Promote recovery through various means including planting and soil stabilization.	5

Trinchera Ranch has been actively managed. The overall forest health of the area is in good condition. There are some areas where ladder fuels should be reduced through mastication and debris either used as biomass energy fuel or broadcast burned. Commercial thinning and individual tree selection techniques could be utilized to increase wood product production within the area. Since the lumber mill operated by the ranch is a community mill, sourcing material for the production of wood products could create a bottleneck effect. As more areas at the ranch or across the watershed are identified for material procurement, production at the mill could be increased. The lumber mill should be utilized as a tool for forest health maintenance to the greatest extent possible since it not only benefits the ranch but is also an important piece of the local economy. In conjunction with timber harvesting and forest product production, reforestation of areas that have had previous timber sales should be reseeded to promote natural soil stabilization and carbon sink for the area.

The Trinchera Ranch should continue to monitor the area for any disease and beetle outbreaks in all vegetation types. During the 2021 field survey it was noted that a majority of aspen trees exhibited open wounds and disease. Trinchera Ranch should also take a proactive approach in mitigating these aspen stands.

10.9.2 Cielo Vista Ranch

Recommendations for Cielo Vista Ranch are provided below in Table 10-37 and Figure 10-25, Figure 10-26, and Figure 10-27. Basal area targets for various forest types are described in the Section 10.7.1.2.

Table 10-37 Recommendations of Plots within Cielo Vista Ranch.

Plot Number	Proposed Mitigation Strategy	Existing Basal Area	Notes
13	Timber Stand Improvement	20	There is an abundance of small diameter trees. This unit can be used for firewood collection.
14	Timber Stand Improvement	100	There is an abundance of small diameter trees. This unit can be used for firewood collection.
15	Timber Stand Improvement	80	There is an abundance of small diameter trees. This unit can be used for firewood collection.
16	Timber Stand Improvement	80	There is an abundance of small diameter trees. This unit can be used for firewood collection.
17	Timber Stand Improvement	80	There is an abundance of small diameter trees. This unit can be used for firewood collection.
18	Timber Stand Improvement	80	There is an abundance of small diameter trees. This unit can be used for firewood collection.
19	Timber Stand Improvement	100	There is an abundance of small diameter trees. This unit can be used for firewood collection.
20	Mastication/ Biomass	120	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
21	Commercial Thinning	120	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
22	Commercial Thinning	80	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
23	Commercial Thinning	60	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
24	Commercial Thinning	60	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
25	Commercial Thinning	120	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
26	Commercial Thinning	100	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
27	Commercial Thinning	80	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
28	Commercial Thinning	60	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
29	Commercial Thinning	80	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
30	Commercial Thinning	80	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
31	Commercial Thinning	60	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.

Plot Number	Proposed Mitigation Strategy	Existing Basal Area	Notes
32	Commercial Thinning	80	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
33	Commercial Thinning	60	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
34	N/A	40	No mitigation needed.
35	Mastication/ Biomass	40	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions
36	Mastication/ Biomass	60	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions
37	Commercial Thinning	80	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
38	Commercial Thinning	20	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
39	Commercial Thinning	100	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
40	N/A	60	No mitigation needed.
41	N/A	100	No mitigation needed.
42	Prescribed Burning	40	This area would benefit from a low intensity prescribed burn. The area has an abundance of dead and down woody material that can be burned.
43	N/A	80	No mitigation needed.
44	Mastication/ Biomass	140	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
45	Mastication/ Biomass	80	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
46	Mastication/ Biomass	80	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
47	Mastication/ Biomass	120	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
48	Mastication/ Biomass	140	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
49	Mastication/ Biomass	60	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.

Plot Number	Proposed Mitigation Strategy	Existing Basal Area	Notes
50	Mastication/ Biomass	80	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
51	Mastication/ Biomass	120	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
52	Mastication/ Biomass	120	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
53	Mastication/ Biomass	60	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
54	Mastication/ Biomass	120	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
55	N/A	100	No mitigation needed.
56	Sanitation and Salvage	80	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.
57	Sanitation and Salvage	60	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.
58	Sanitation and Salvage	80	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.
59	Sanitation and Salvage	120	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.
60	Sanitation and Salvage	60	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.

Plot Number	Proposed Mitigation Strategy	Existing Basal Area	Notes
61	Sanitation and Salvage	60	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.
62	Sanitation and Salvage	60	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.
63	Sanitation and Salvage	40	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.
64	Sanitation and Salvage	40	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.
65	Sanitation and Salvage	80	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.
66	Sanitation and Salvage	80	Recent observations of this area have exhibited signs of an active beetle infestation that have been targeting ponderosa pine and mixed conifer. More investigation and delineation of infested trees are needed. Trees that have an active infestation would need to be cut down and not piled. Sufficient space would be created from infested trees and non-infested trees to contain the beetle outbreak.
67	Commercial Thinning	80	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
68	Commercial Thinning	80	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
69	Commercial Thinning	100	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
70	Commercial Thinning	80	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
71	N/A	60	No mitigation needed.
72	N/A	60	No mitigation needed.

Plot Number	Proposed Mitigation Strategy	Existing Basal Area	Notes
73	N/A	160	No mitigation needed.
74	Mastication/ Biomass	140	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
75	Mastication/ Biomass	140	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
76	Commercial Thinning	120	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
77	Commercial Thinning	180	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
78	Group Selection	80	Within this area, aspen trees are all the same cohort and show signs of disease and damage. The aspens would be the target of the prescription. Patches of aspen would be removed to promote regeneration.
79	Group Selection	120	Within this area, aspen trees are all the same cohort and show signs of disease and damage. The aspens would be the target of the prescription. Patches of aspen would be removed to promote regeneration.
80	Group Selection	120	Within this area, aspen trees are all the same cohort and show signs of disease and damage. The aspens would be the target of the prescription. Patches of aspen would be removed to promote regeneration.
81	Timber Stand Improvement	140	There is an abundance of small diameter trees. This unit can be used for firewood collection.
82	Commercial Thinning	120	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
83	Commercial Thinning	60	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
84	Commercial Thinning	220	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
85	Mastication/ Biomass	140	There is an abundance of saplings within this are adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
86	Timber Stand Improvement	120	There is an abundance of small diameter trees. This unit can be used for firewood collection.
87	N/A	60	No mitigation needed.
88	N/A	40	No mitigation needed.
89	N/A	40	No mitigation needed.
90	N/A	40	No mitigation needed.
91	N/A	80	No mitigation needed.
92	N/A	60	No mitigation needed.
93a	Individual Tree Selection	120	Harvestable aspen and mixed conifer trees would be selectively marked and removed from the area then sold at market.

Plot Number	Proposed Mitigation Strategy	Existing Basal Area	Notes
103	Mastication/ Biomass	140	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
94	Individual Tree Selection	140	Harvestable aspen and mixed conifer trees would be selectively marked and removed from the area then sold at market.
95	Individual Tree Selection	100	Harvestable aspen and mixed conifer trees would be selectively marked and removed from the area then sold at market.
104	Timber Stand Improvement	160	There is an abundance of small diameter trees. This unit can be used for firewood collection.
96	Individual Tree Selection	40	Harvestable aspen and mixed conifer trees would be selectively marked and removed from the area then sold at market.
97	Timber Stand Improvement	280	There is an abundance of small diameter trees. This unit can be used for firewood collection.

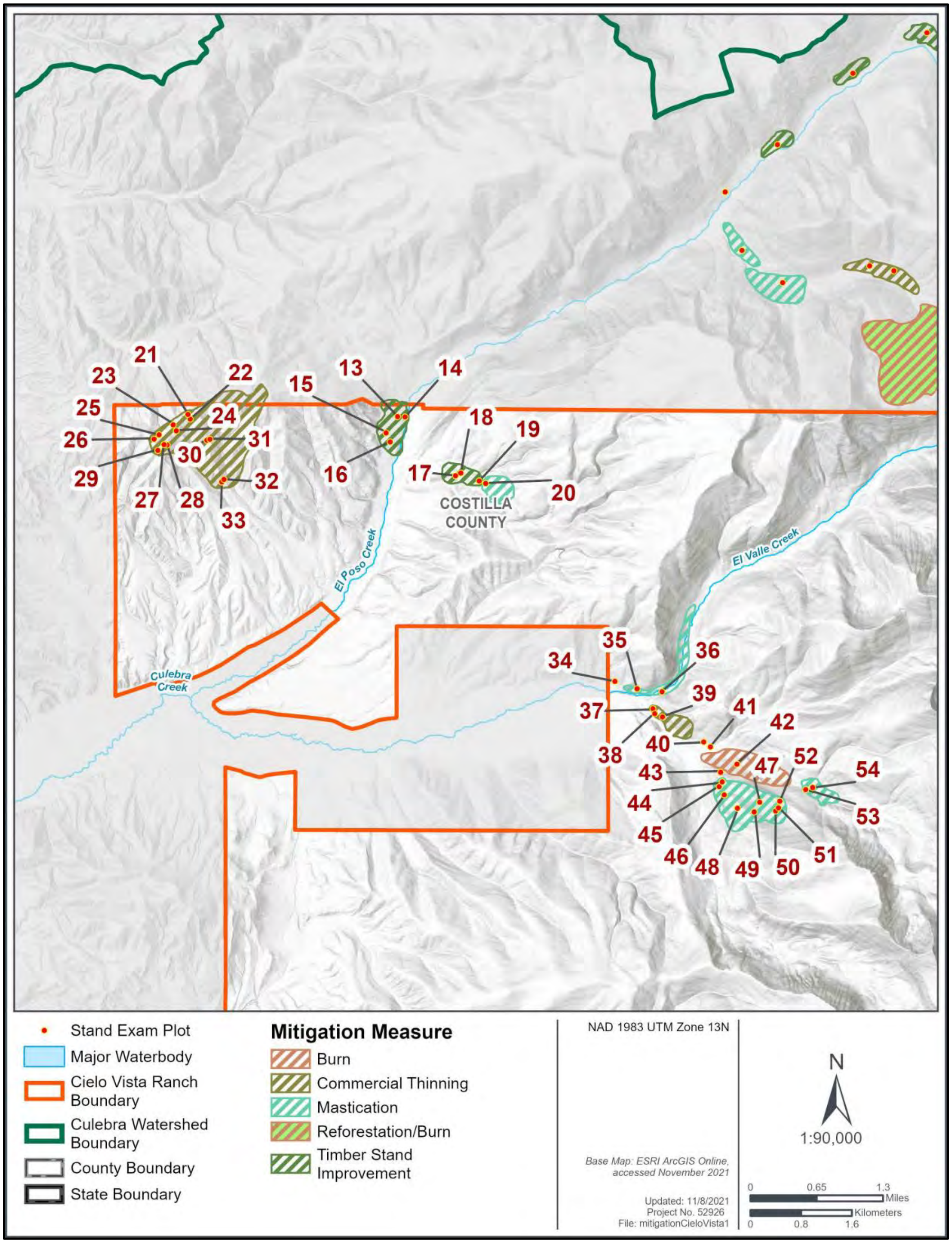


Figure 10-25 Mitigation Measures Map of Cielo Vista Ranch (Map 1 of 3).

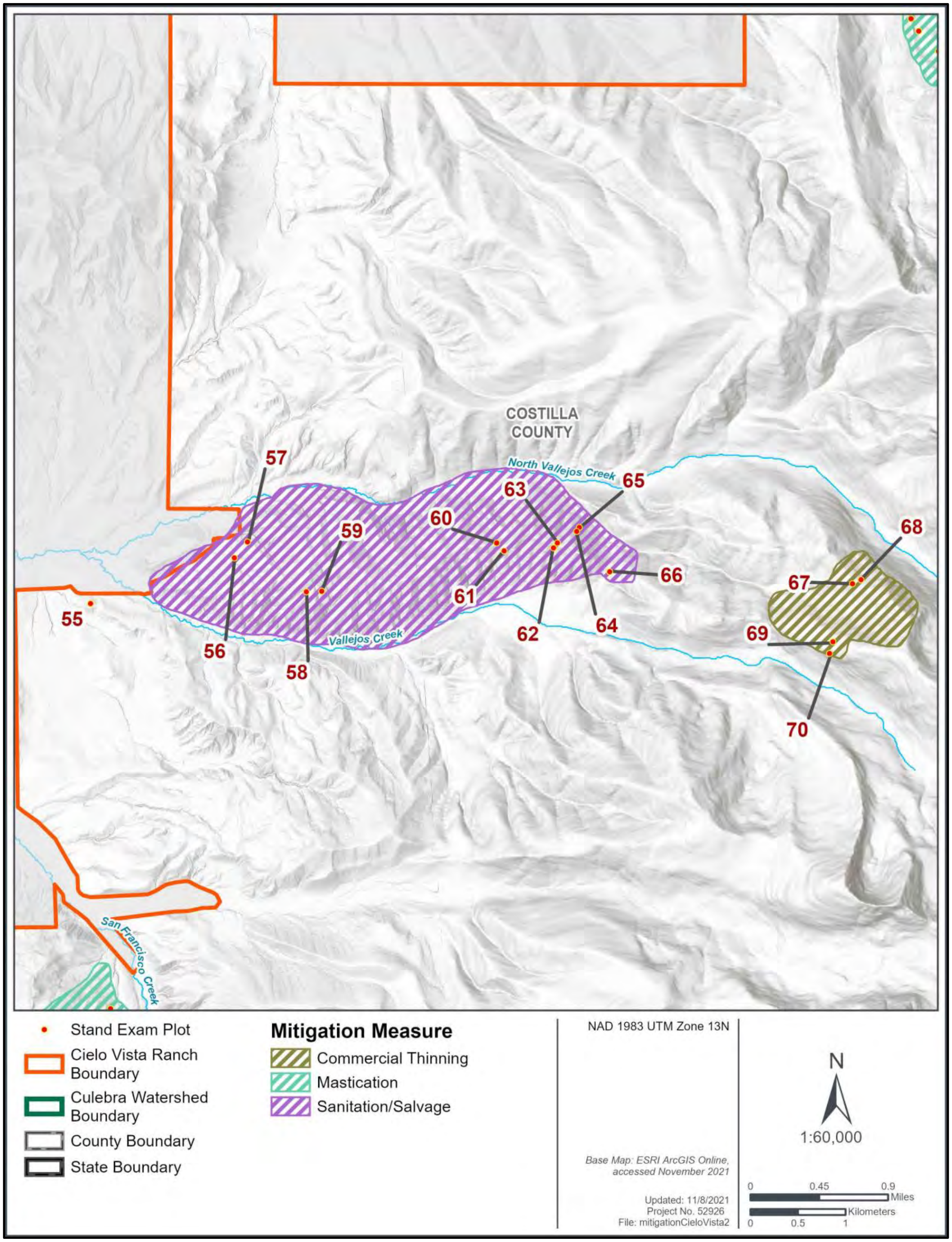


Figure 10-26 Mitigations Measures Map of Cielo Vista Ranch (Map 2 of 3).

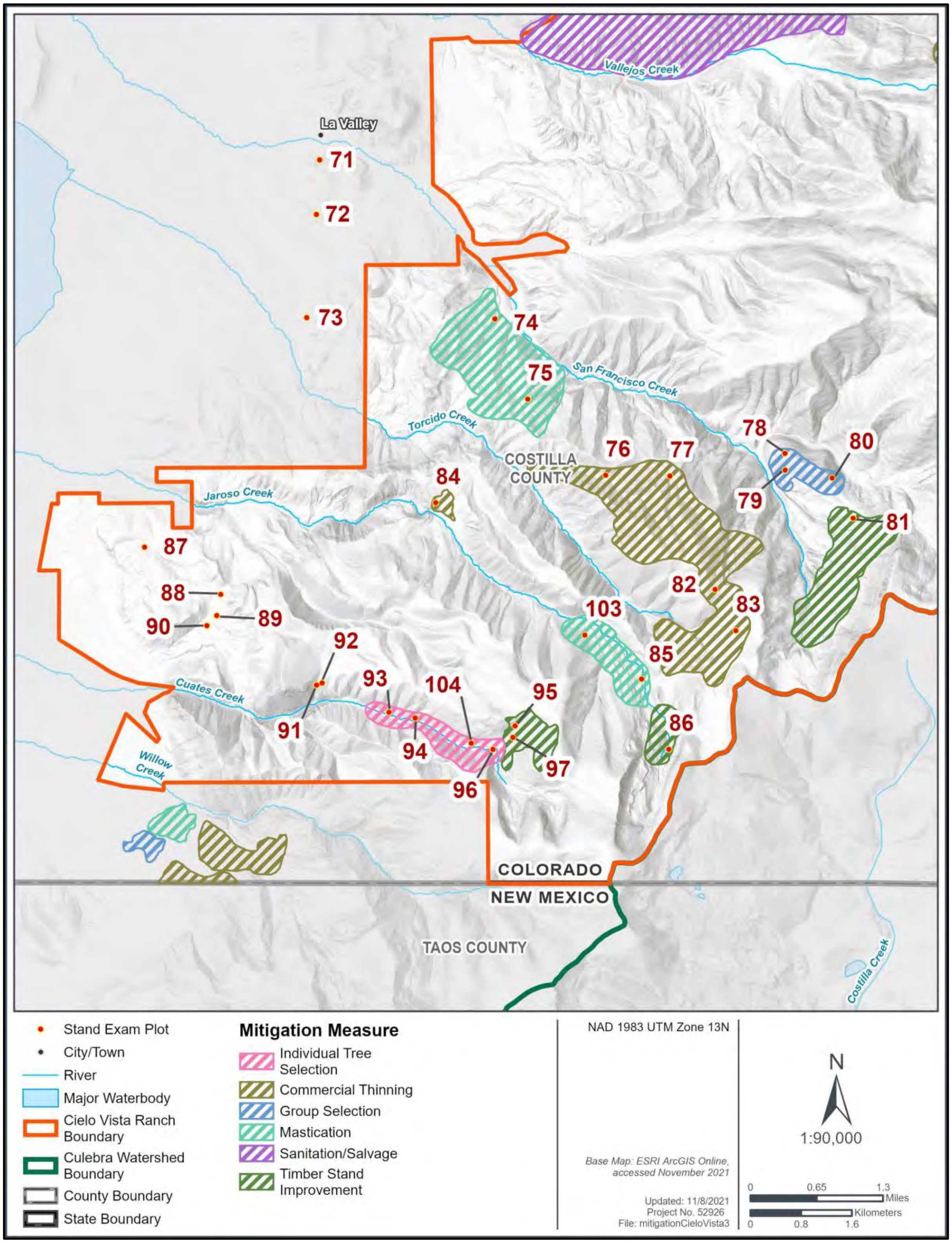


Figure 10-27 Mitigation Measures Map of Cielo Vista Ranch (Map 3 of 3).

SWCA recommends seven different forest health approaches for Cielo Vista. Table 10-38 below categorize each treatment and how each management strategy coincides with Colorado Forest Service goals and strategies for improving Colorado forests.

Table 10-38 Forest Management Approaches for Cielo Vista Ranch.

Number of Plots	Proposed Mitigation Strategy	Technique for Improving Forest Health	Priority
11	Timber Stand Improvement	-Reduce impacts from biological stressors by reducing competition. -Maintain and enhance existing and new forest productivity by managing for diversity in tree class, tree age and stand stocking.	5
17	Mastication/ Biomass	-Manage fire-dependent forest systems to maintain and promote resistance to fire mortality.	3
4	Individual Tree Selection	-The use of silvicultural practices that identify and promote biological and structural diversity, including thinning and regeneration techniques. -Enhance economic incentives of the local community.	6
25	Commercial Thinning	-Enhance economic incentives of the local community.	2
3	Group Selection	-Actively manage forests to improve resilience to insects and disease.	4
1	Prescribed Burn	-Manage fire-dependent forest systems to maintain and promote resistance to fire mortality.	7
11	Sanitation/ Salvage	-Actively manage forests to improve resilience to insects and disease.	1

Cielo Vista Ranch stands to greatly benefit from future forest products through actively managing their land for improved forest health. By far, Cielo Vista ranch is the largest ranch within the UCW analysis area and has varying forest conditions throughout its boundary. The largest basal area recorded during the 2021 field survey was recorded within the boundary of the ranch. Commercial thinning is the largest proposed mitigation strategy with the highest potential economic yield. By selecting commercial thinning units, contractors would be able to sell harvested wood products at market. Generating economic yield is also the case with individual tree selection and timber stand improvement mitigation strategies.

The Cielo Vista Ranch should continue to monitor the area for any disease and beetle outbreaks in all vegetation types. During the 2021 field survey it was noted that a potential beetle outbreak is occurring within the ranch boundary. Eleven plots fall within the sanitation and salvage mitigation strategy. This area should be prioritized for mitigation due to the fact that it could degrade surrounding tree stands of the area.

It was also noted that aspen trees exhibit some sort of defoliators and disease. Areas where aspen trees are degrading should be identified and monitored annually. If it is determined that the disease is spreading, identified stands should fall under a sanitation and salvage treatment or a group selection treatment.

10.9.3 Dos Hermanos Ranch

Recommendations for Dos Hermanos Ranch are provided below in Table 10-39 and Figure 10-28. Basal area targets for various forest types are described in the Section 7.1.3.

Table 10-39 Recommendations of Plots within Dos Hermanos Ranch.

Plot Number	Proposed Mitigation Strategy	Existing Basal Area	Notes
98	Commercial Thinning	120	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.
99	Mastication/ Biomass	80	There is an abundance of saplings within this area adding to high levels of ladder fuels. Using heavy equipment to reduce the low-lying fuel load would decrease dangerous wildfire risk and improve grazing conditions.
100	Group Selection	100	In this specific plot, aspen trees are observed to be of an even age class and exhibit disease. If implemented all deformed aspen trees would be removed from the area.
101	N/A	20	No prescription needed within this area.
102	Commercial Thinning	140	This tree stand is of even age and would benefit from a commercial thinning contract to sell wood products at market.

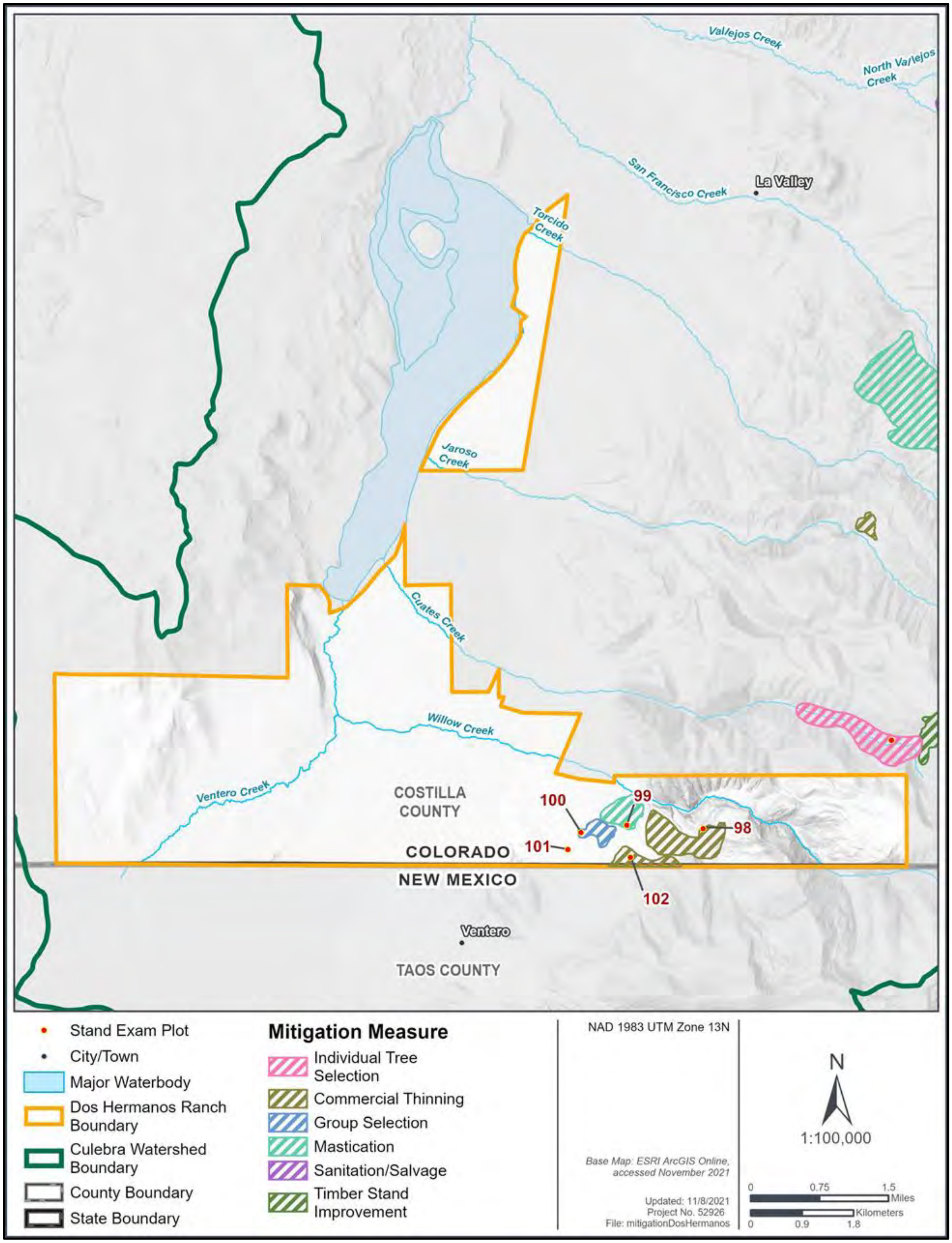


Figure 10-28 Mitigation Measures Map of Dos Hermanos Ranch.

SWCA recommends three different forest health approaches for Dos Hermanos. Table 10-40 below categorize each treatment and how each management strategy coincides with Colorado Forest Service goals and strategies for improving Colorado forests.

Table 10-40 Forest Management Approaches for Dos Hermanos Ranch.

Number of Plots	Proposed Mitigation Strategy	Technique for Improving Forest Health	Priority
1	Mastication/ Biomass	-Manage fire-dependent forest systems to maintain and promote resistance to fire mortality.	1
2	Commercial Thinning	-Enhance economic incentives of the local community.	3
1	Group Selection	-Actively manage forests to improve resilience to insects and disease.	2

The overall forest health of the Dos Hermanos Ranch area is in good condition. There are some areas where ladder fuels should be reduced through mastication and debris either used as biomass energy fuel or broadcast burned. Commercial thinning could be utilized to increase wood product production within the area; however, units would need to be large enough to be economically feasible.

Dos Hermanos Ranch should continue to monitor the area for any disease and beetle outbreaks in all vegetation types. During the 2021 field survey it was noted that large pockets of aspen trees exhibited open wounds and disease. This area is identified for a group selection strategy and should be removed. Ongoing mastication operations, that the ranch is conducting should also continue.

10.9.4 Alpine Meadows and Firewood Collection Sites

As part of this assessment 11 alpine meadows were identified within the analysis area that could serve as multiple use platforms (Figure 10-29).

10.9.4.1 Meadow staging areas and safety zones

If a wildfire event were to occur within the UCW, these meadows could be used as initial and extended attack helicopter staging areas. If these areas are maintained in compliance with U.S. Interagency Fire Command standards, it can be used for wildland suppression tactics if a wildfire were to occur with the UCW.

10.9.4.2 Meadow Grazing Enhancements

The contractor proposes that these alpine meadows could be enlarged to accommodate increased grazing production by promoting and providing access for timber cutting units along meadow fringes. Not only could the public gather much-needed firewood from these marked units, but these actions could further improve and enhance grassland meadows for use as staging areas. Additionally, areas that are opened to increased grassland are also able to host larger grazing populations within the ranches, including grazing for domestic livestock and wildlife. These firewood collection sites would follow processes set forth by timber stand improvement protocols and would have a defined prescription for the area. Enforcement and monitoring of meadow conditions would be needed, in order to ensure deleterious impacts are not occurring to native species and habitat. Please refer to Figure 10-29 below for locations of proposed enhanced alpine meadows.

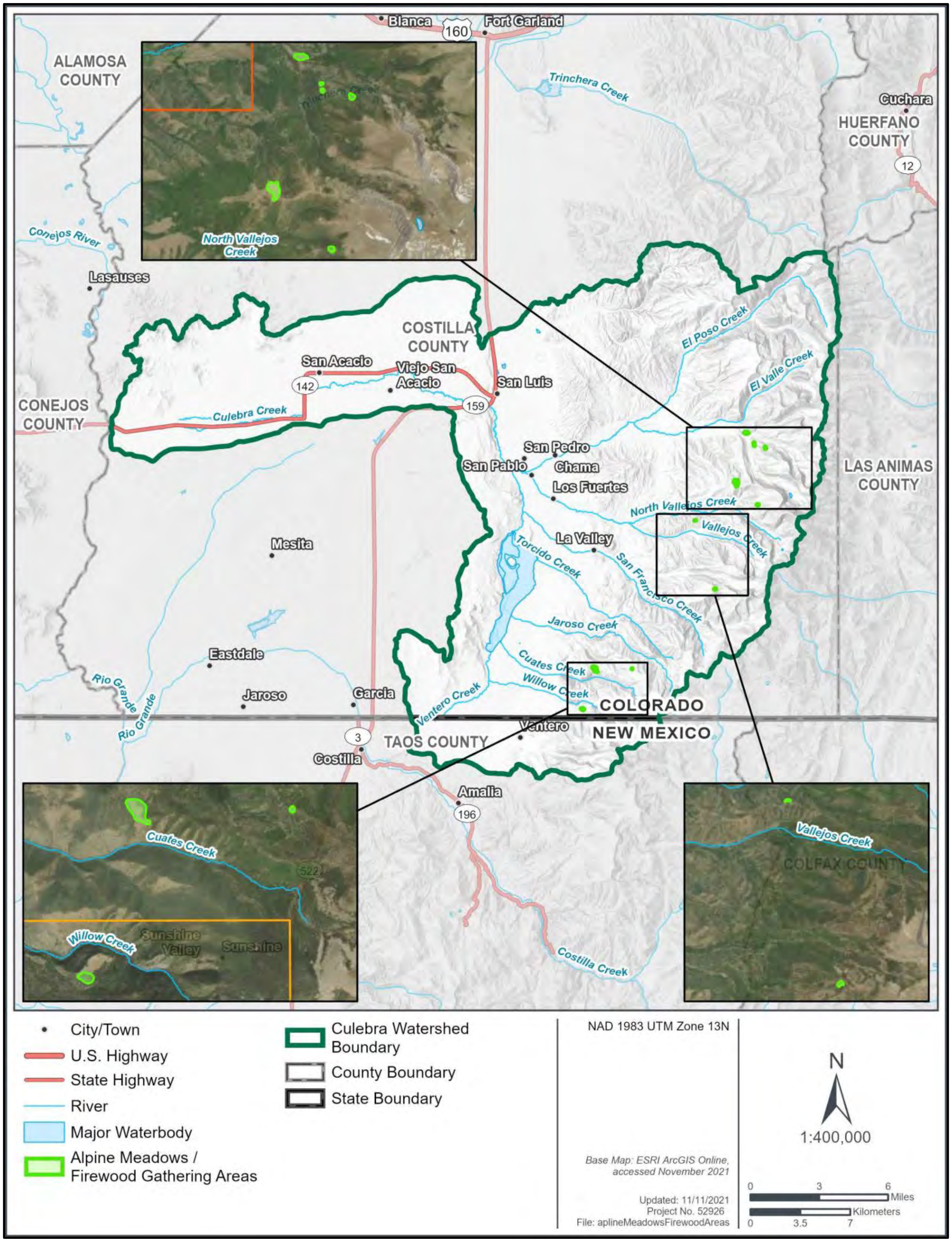


Figure 10-29 Locations for potential meadow expansion and enhancements.

10.9.5 Community Collaboration

In order to build better collaboration between the ranch management and the local community, there is a need to support and promote a mechanism for public outreach education and involvement related to sustainable forest management. Examples of potential mechanisms include field tours, webinars, educational tours, and published articles. These events should be focused on topics such as forest health, required management to improve forest resilience, the impacts of unhealthy forests, and the benefits to the community of performing treatments and using best management practices.

10.10 Expected Cumulative Effects

10.10.1 Forest Structure and Resiliency

Each ranch has their own mitigation strategy, but with the reduction of ladder fuels, overstocked stands, and removal of diseased and insect infested trees would create a positive outcome and would result in more balanced, healthy self-sustaining ecosystem in the UCW analysis area. Residual stands would be healthier due to the removal of forked, crooked and diseased trees. Diameter growth would increase along with health and vigor. Stand structure across the project area would move from even-aged to uneven-aged, multi-cohort structure with openings created for recruitment of seedlings, making it more resilient to disease and fire.

Commercial thinning and mastication would allow the reintroduction of prescribed fire. Prescribed fire would allow for nutrients to be reintroduced to existing soil substrates. This would allow for an increase of native grasses forbs to flourish within the analysis area. With an increase in sunlight and decrease in canopy cover, native grasses and forbs would increase and result in improved forage and grazing areas. Treated stands would be more fire resilient, and mortality due to crown fire would become less of a threat.

10.10.2 Fire and Fuels

Thinned stands would experience less intense surface fire behavior during a wildfire thus limiting crown fire risk. These stands would be more resilient to disturbance and more sustainable for the long term. With the reduction of fuels, the analysis area would increase its options for fire suppression, improvement to firefighter safety, provide strategic fuel breaks while improving defensible space within the area. In general, treated areas would have reduced fire activity, less crown fire events, and reduced overall fire effects.

10.10.3 Wildlife

The proactive treatments within the UCW analysis area would only improve wildlife habitat. It is expected that foraging habitat will increase for native wildlife species and could potentially increase grazing areas for cattle. Impacts from proposed management activities are unlikely to negatively affect native wildlife populations. Treatment areas are located across a large geographical span and may cause a temporary disturbance within the area. Wildlife are able to move into adjacent suitable habitat without being impacted by proposed treatments.

10.11 Funding Resources

The following section outlines potential funding sources that could be used to apply the treatment recommendations proposed in this report.

10.11.1 Federal Funding Information

Source: Emergency Forest Restoration Program (EFRP)

Agency: USDA Farm Service Agency (FSA)

Website: https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/emergency-forest-restoration/index

Description: The Emergency Forest Restoration Program (EFRP) helps the owners of non-industrial private forests restore forest health damaged by natural disasters. The EFRP does this by authorizing payments to owners of private forests to restore disaster damaged forests. The local FSA County Committee implements EFRP for all disasters with the exceptions of drought and insect infestations. Eligible practices may include debris removal, such as down or damaged trees; site preparation, planting materials, and labor to replant forest stand; restoration of forestland roads, fire lanes, fuel breaks, or erosion-control structures; fencing, tree shelters; wildlife enhancement.

To be eligible for EFRP, the land must have existing tree cover; and be owned by any nonindustrial private individual, group, association, corporation, or other private legal entity.

Source: Urban and Community Forestry Program, 2021 National Urban and Community Forestry Challenge Cost Share Grant Program

Agency: USFS

Website: https://www.fs.usda.gov/managing-land/urban-forests/ucf

Description: USFS funding will provide for Urban and Community Forestry Programs that work with local communities to establish climate-resilient tree species to promote long-term forest health. The other initiative behind this program is to promote and carry out disaster risk mitigation activities, with priority given to environmental justice communities. For more information, contact a USFS Regional Program Manager.

Source: Environmental Quality Incentives Program (EQIP)

Agency: National Resources Conservation Service (NRCS)

Website: https://www.nrcs.usda.gov/wps/portal/nrcs/main/co/programs/financial/eqip/

Description: The Environmental Quality Incentives Program (EQIP) is a voluntary program authorized under the Agricultural Act of 2014 (2014 Farm Bill) that helps producers install measures to protect soil, water, plant, wildlife, and other natural resources while ensuring sustainable production on their farms, ranches, and working forest lands.

Source: Emergency Conservation Program (ECP)

Agency: USDA Farm Service Agency (FSA)

Website: https://www.fsa.usda.gov/programs-and-services/conservation-programs/emergency-conservation/index

Description: The Emergency Conservation Program (ECP) helps farmers and ranchers to repair damage to farmlands caused by natural disasters and to help put in place methods for water conservation during severe drought. The ECP does this by giving ranchers and farmers funding and

assistance to repair the damaged farmland or to install methods for water conservation. The grant could be used for restoring conservation structures (waterways, diversion ditches, buried irrigation mainlines, and permanently installed ditching system).

Source: Emergency Watershed Protection (EWP) Program

Agency: NRCS

Website: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewpp/

Description: The program offers technical and financial assistance to help local communities relieve imminent threats to life and property caused by floods, fires, windstorms, and other natural disasters that impair a watershed.

Eligible sponsors include cities, counties, towns, conservation districts, or any federally recognized Native American tribe or tribal organization. Interested public and private landowners can apply for EWP Program recovery assistance through one of those sponsors.

EWP Program covers the following activities:

Debris removal from stream channels, road culverts, and bridges

Reshape and protect eroded streambanks

Correct damaged drainage facilities

Establish vegetative cover on critically eroded lands

Repair levees and structures

Repair conservation practices

Source: Hazard Mitigation Grant Program (HMGP) – Post Fire

Agency: FEMA

Website: https://www.fema.gov/grants/mitigation/post-fire

Description: The HMGP Post Fire grant program provides assistance to communities for the purpose of implementing hazard mitigation measures following a wildfire. Mitigation measures may include:

- Soil stabilization
- Flood diversion
- Reforestation

Source: Tribal Environmental General Assistance Program (GAP)

Agency: U.S. Environmental Protection Agency (EPA)

Website: https://www.epa.gov/tribal-pacific-sw/epa-region-9-tribal-environmental-gap-funding

Description: Funding under this program is used to aid Native American tribes in establishing and implementing their own reservation-specific environmental protection programs. To find out more about this funding opportunity please contact Tribal Branch Manager, Jeremy Bauer, at bauer.jeremy@epa.gov.

Source: Conservation Innovation Grants (CIG)

Agency: NRCS

Website: https://www.nrcs.usda.gov/wps/portal/nrcs/site/ca/home/

Description: CIG State Component. CIG is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, Environmental Quality Incentives Program (EQIP) funds are used to award competitive grants to non-federal governmental or nongovernmental organizations, tribes, or individuals. CIG enables the NRCS to work with other public and private entities to accelerate technology transfer and adoption of promising technologies and approaches to address some of the nation's most pressing natural resource concerns. CIG will benefit agricultural producers by providing more options for environmental enhancement and compliance with federal, State, and local regulations. The NRCS administers the CIG program. The CIG requires a 50/50 match between the agency and the applicant. The CIG has two funding components: national and State. Funding sources are available for water resources, soil resources, atmospheric resources, and grazing land and forest health.

Source: Catalog of Federal Funding Sources; Land Resources

Agency: Multiple

Website: https://ofmpub.epa.gov/apex/wfc/f?p=165:512:6483383318137:::512::

Description: The Land Finance Clearing House is a catalogue of federal funding sources for all things land related.

Examples of the types of grants found at this site are:

- Forest and Woodlands Resource Management Grant: https://sam.gov/fal/a798ad78cac749639b48270db3e86fdc/view?index=cfda&page=2&organization_id=100011100
- Environmental Education Grant: https://www.epa.gov/education/grants
- Public Assistance Grant Program: https://www.fema.gov/assistance/public
- Hazard Mitigation Grant: https://www.fema.gov/grants/mitigation/hazard-mitigation

Source: Catalog of Federal Funding Sources; Water Resources

Agency: Multiple

Website: https://ofmpub.epa.gov/apex/wfc/f?p=165:12:6483383318137:::12::

Description: The Water Finance Clearing House is a catalogue of federal funding sources for all things water related.

Examples of the types of grants found at this site are:

- Water Conservation Field Services Program: https://www.usbr.gov/waterconservation/
- California Community Development Block Grant: https://www.hcd.ca.gov/grants-funding/active-funding/cdbg.shtml
- California Clean Water State Revolving Fund Program (CWSRF): https://www.waterboards.ca.gov/water_issues/programs/grants_loans/srf/index.html

Source: GSA-Federal Excess Personal Property

Agency: USFS

Website: https://gsaxcess.gov/

Description: The Federal Excess Personal Property (FEPP) program refers to USFS-owned property that is on loan to State Foresters for the purpose of wildland and rural firefighting. Most of the property originally belonged to the Department of Defense (DoD). Once acquired by the USFS, it is loaned to State Cooperators for firefighting purposes. The property is then loaned to the State Forester, who may then place it with local departments to improve local fire programs. State Foresters and the USFS have mutually participated in the FEPP program since 1956.

10.11.2 State Funding Information

Source: Colorado State Forest Service Grant & Funding Assistance

Agency: Colorado State Forest Service

Website: https://csfs.colostate.edu/funding-assistance/

Description: The Colorado State Forest Service Grants & Funding Program offers some forest-related grants with differing scopes and funding details. Some of the programs include:

- Forest Restoration & Wildfire Risk Mitigation Grant Program: https://csfs.colostate.edu/funding-assistance/
- Colorado Forest Legacy Program: https://csfs.colostate.edu/forest-legacy-program/
- Colorado Wood Utilization & Marketing Program: https://csfs.colostate.edu/cowood/
- Forest Stewardship Program: https://csfs.colostate.edu/forest-stewardship-program/
- Tree Farm Program: https://csfs.colostate.edu/tree-farm/

Source: Colorado Water Conservation Board Grant Programs

Agency: Colorado Water Conservation Board, Department of Natural Resources

Website: https://cwcb.colorado.gov/funding/grants

Description: The Colorado Water Conservation Board offers numerous loans and grants to water providers and other entities statewide for water related projects, including a watershed restoration grant.

- Colorado Watershed Restoration Grants: https://cwcb.colorado.gov/colorado-watershed-restoration-grants

10.11.3 Private Funding Information

Source: The Urban Land Institute (ULI)

Website: http://www.uli.org

Description: ULI is a 501(c)(3) nonprofit research and education organization supported by its members. The institute has more than 22,000 members worldwide, representing the entire spectrum of land use and real estate development disciplines, working in private enterprise and public service. The mission of the ULI is to provide responsible leadership in the use of land to enhance the total environment. ULI and the ULI Foundation have instituted Community Action Grants that could be used for Firewise Communities activities. Applicants must be ULI members or part of a ULI District Council. Contact actiongrants@uli.org or review the web page to find your District Council and the application information.

Source: Environmental Systems Research Institute (ESRI)

Website: http://www.esri.com/grants

Description: ESRI is a privately held firm and the world's largest research and development organization dedicated to geographic information systems. ESRI provides free software, hardware, and training bundles under ESRI-sponsored Grants that include such activities as conservation, education, and sustainable development, and posts related non-ESRI grant opportunities under such categories as agriculture, education, environment, fire, public safety, and more. You can register on the website to receive updates on grant opportunities.

Source: National Forest Foundation; Innovative Finance for National Forests Grant Program

Website: https://www.nationalforests.org/grant-programs/innovative-finance-for-national-forests-grant-program

Description: The Innovative Finance for National Forests Grant Program aims to bring in non-USFS funds to increase forest resilience. There are three main topics for funding: Wildfire Resilience and Recovery, Sustainable Recreation Access and Infrastructure, and Watershed Health. In addition, three types of projects are funded. Pilot Programs with on-the-ground implementation, Scaling Projects to deliver backlogs of unfunded work, and Research and Development to provide to new forest information.

Source: StEPP Foundation

Website: https://steppfoundation.org/

Description: StEPP is a 501(c)(3) organization dedicated to helping organizations realize their vision of a clean and safe environment by matching projects with funders nationwide. The StEPP Foundation provides project oversight to enhance the success of projects, increasing the number of energy efficiency, clean energy, and pollution prevention projects implemented at the local, State, and national levels for the benefit of the public. The website includes an online project submittal system and a Request for Proposals page.

Source: Matching Awards Program

Agency: National Forest Foundation (NFF)

Website: https://www.nationalforests.org/grant-programs/map

Description: The NFF is soliciting proposals for its Matching Awards Program (MAP) to provide funds for direct on-the-ground projects benefitting America's National Forests and Grasslands. By pairing federal funds provided through a cooperative agreement with the USFS with non-federal dollars raised by award recipients, MAP measurably multiplies the resources available to implement stewardship projects that benefit the National Forest System.

Source: Patagonia Environmental Grants and Support

Agency: Patagonia

Website: https://www.patagonia.com/how-we-fund/

Description: Patagonia supports innovative work that addresses the root causes of the environmental crisis and seeks to protect both the environment and affected communities. Patagonia focuses on places where they have built connections through outdoor recreation and through their network of retail stores, nationally and internationally.

Source: Leonardo DiCaprio Foundation Grants

Agency: Leonardo DiCaprio Foundation

Website: https://www.rewild.org/

Description: The foundation supports projects around the world that build climate resiliency, protect vulnerable wildlife, and restore balance to threatened ecosystems and communities.

Source: U.S. Endowment for Forestry and Communities

Agency: EPA, NRCS, USFS, U.S. Department of Defense, U.S. Economic Development Agency

Website: https://www.usendowment.org/

Description: As the nation's largest public charity dedicated to keeping our working forests working and ensuring their bounty for current and future generations, the Endowment deploys the creativity and power of markets to advance their mission: The

Endowment works collaboratively with partners in the public and private sectors to advance systemic, transformative and sustainable change for the health and vitality of the nation's working forests and forest-reliant communities.

10.11.4 Other Funding Information

The following resources may also provide helpful information for funding opportunities:

- Western Forestry Leadership Coalition: https://www.thewflc.org/
- USDA Information Center: https://www.nal.usda.gov/main/information-centers
- Sustainable Forestry Initiative: https://www.forests.org/conservation-grant-rfp-process/

Chapter 11. Safety and Emergency Management Assessment

Author: SWCA Environmental Consultants

11.1 Introduction

The Upper Culebra Watershed (UCW) is an area of deep history and cultural values that can trace its roots back to the earliest Hispanic settlers. The area has traditionally been used for activities such as agricultural production, hunting, and timber harvest. As these industries are an important piece of the economy for the watershed, it is imperative to ensure that the communities within the watershed are prepared for and resilient to potential natural hazards.

Previous hazard identification and assessment has been conducted by Costilla County for the purposes of the 2015 *Costilla County, Colorado Multi-Jurisdictional Multi-Hazard Mitigation Plan* (HMP) (Costilla County Mitigation Advisory Committee, 2015). The plan identified and ranked hazard potential in the county and included hazards such as wildfire, drought, flooding, and severe storms. Table 11-1 below summarizes and ranks these hazards based on their probability to occur and potential impacts.

As wildfire has been deemed to have a significant likelihood of occurrence within the county, this document will have the primary focus of addressing this natural hazard and offering mitigation strategies to better protect watershed livelihoods and values. Other notable hazards, such as flooding, severe storms, and droughts will be analyzed for risk and addressed. Mitigation strategies for these hazards are provided later in the document.

Local historical natural hazard data for this area is limited (CCMAC 2015).

11.1.1 Purpose

There are two main goals that the *Upper Culebra Watershed Safety and Emergency Management Report* will address. The first goal is to quantify existing conditions and key assets within the watershed. This is accomplished through an analysis of the current fire, flood, and other natural hazard environments, as well as defining what values are at risk. Community hazard assessments and a review of historical natural hazard occurrences have been conducted and summarized as part of this goal.

The second goal is to provide mitigation strategies tailored to existing conditions within the watershed. Strategies provided will be designed to improve key assets and ensure that communities within the watershed are prepared in case of disaster. Ultimately, these strategies are intended to bolster community resilience throughout the watershed and help residents be better prepared for potential hazards.

11.1.2 Landownership

The majority of land within the watershed is privately owned. In fact, over 99% of the 242,409-acre watershed is composed of private land. Just over 1,000 acres are owned by Costilla County and roughly 5 acres fall under federal ownership. Much of the land in the valley has been subdivided into 35-acre parcels or is being used for agricultural production. The major landowners within the watershed are the three ranches on the eastern portion: Trinchera Ranch, Cielo Vista Ranch, and Dos Hermanos Ranch.

Trinchera Ranch is the northernmost ranch within the analysis area and accounts for 14,219 acres of the UCW. The ranch is actively managed for fire using a variety of techniques such as creating fire breaks through sagebrush mastication and forest thinning in the higher elevations. Cielo Vista Ranch lies at the central-eastern portion of the watershed. This is the largest ranch represented in the watershed and accounts for 70,402 acres. The ranch extends from the low-elevation grasslands to high-elevation alpine. The ranch is used for grazing and firewood collection by local residents through historic land grants.
Dos Hermanos Ranch is the southernmost ranch within the watershed and accounts for 11,612 acres. The majority of the ranch lies at the lower elevations and is composed of grasslands and sagebrush shrublands.

11.1.3 Values at Risk

There are multiple values within the analysis area that are at risk from natural hazards. The most important value at risk is infrastructure that is critical to community function and emergency management, including roads, the airport, the dam, communication towers, and the fire station (Figure 11-2).

In addition to critical infrastructure (Figure 11-2), values at risk can also include natural, social, and cultural resources.

Figure 11-1 Natural values at risk

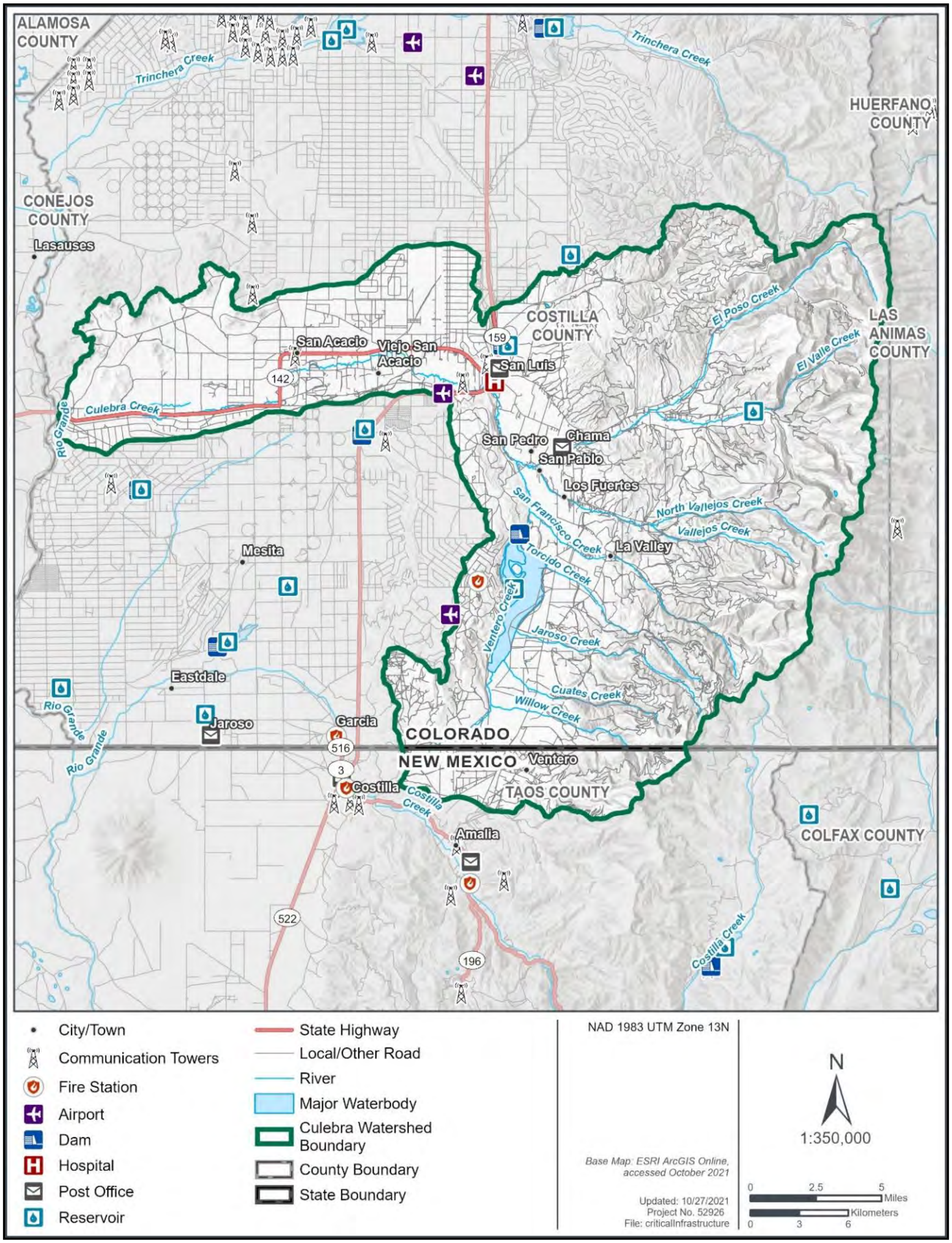


Figure 11-2 Critical infrastructure

11.1.3.1 Natural Community Values at Risk

The analysis area has a variety of natural resources of particular concern, such as wildlife habitats, timber resources, and grazing lands (Figure 11-1). Examples of natural values include the following:

- *Timber resources*
- *Grazing areas*
- *Hunting areas*
- *Agricultural land*
- *Viewsheds*
- *Wildlife habitat and game species*
- *Watersheds and water quality*

11.1.3.2 Socioeconomic Community Values at Risk

Social values include population, recreation, infrastructure, agriculture, and the built environment. Examples include the following:

- *Recreation*
- *Schools*
- *Hospital*
- *Businesses*
- *Acequia infrastructure*

11.1.3.3 Cultural Community Values at Risk

Many historical landmarks are scattered throughout the watershed. Examples of items of cultural significance in the area are:

- *Historic properties and churches*
- *Agricultural infrastructure*
- *Sites of cultural significance*

11.2 Safety and Emergency Management Overview

This safety and emergency management report was developed to build upon existing emergency management documents that are already in place in Costilla County. These include the *Costilla County, Colorado Multi-Jurisdictional Multi-Hazard Mitigation Plan* (CCMAC 2015), the Costilla County Emergency Operations Plan (CCEOP) (Costilla County Department of Emergency Management [CCDEM], 2021) and the *Costilla County Community Wildfire Protection Plan* (CWPP) (Land Stewardship Associates, LLC, 2008). This report is aligned with these documents (updating baseline information as needed) and is not intended to replace or supersede them.

Emergency management direction for Costilla County is guided by federal, state, and local directives. Federal authority is provided by the Robert T. Stafford Disaster Relief and Emergency Assistance Act (42 United States Code 5121–5207), April 2013; the National Response Framework, January 2008; Directives from the Department of Homeland Security; and authorities under the Federal Emergency Management Agency (FEMA). State authorities are provided by a series of statutes, including the 2012 Colorado Disaster Emergency Act (Colorado Revised Statutes, Title 24, Article 33.5, Part 701). Local authority is provided by the Costilla County Resolution passed May 5, 1985, and the adoption of the 2021 CCEOP. For more details on emergency management authority within the county, please see the CCEOP, Section III, page 3.

> "*No matter how much work is put into reducing risks and hazards, emergencies and disasters cannot be eliminated. Therefore, it is important to have a robust preparedness program. The mitigation stage of the emergency management program limits the effects of a disaster and the preparedness stage readies those involved. This includes adequate planning, establishment of authorities and financial documents, warning programs, resource management and logistics, training programs, intergovernmental relationships, crisis communications and public education, and exercises*"
>
> (Colorado Office of Emergency Management, Department of Public Safety 2016:16).

To implement directives for emergency management, FEMA and the U.S. Environmental Protection Agency (EPA) provide emergency managers with guidelines, tools, and methodologies to use while preparing their organizations to respond to and recover from emergencies and disasters. The CCEOP provides emergency response direction to all local, volunteer, and private-sector emergency responders in the county (CCDEM 2021). The CCEOP aligns with the National Response Framework by incorporating the National Incident Management System (NIMS) and Incident Command System (ICS).

The following provides a description of pertinent tools and frameworks used by Costilla County in implementing emergency management throughout the county.

11.2.1 National Incident Management System

The NIMS was developed and is administrated by Homeland Security Presidential Directive 5 (HSPD-5) Management of Domestic Incidents. NIMS was first issued by the U.S. Department of Homeland Security on March 1, 2004. It serves as a nationwide uniform template across all levels of government, nongovernmental organizations, and the private sector, enabling these entities to collaborate in the prevention, protection, response, recovery, and mitigation of incidents, despite their origin, size, locality, or complexity. HSPD-5 requires that all federal bodies incorporate NIMS into their individual incident management programs. It also requires that federal bodies use NIMS to support measures taken to aid governments at the state, tribal, and local levels.

11.2.2 Incident Command System

The ICS provides a standard and workable procedure for effective cross-jurisdictional incident management coordination and collaboration. The ICS is used by both nongovernmental organizations and the private sector, as well as by all branches of government: federal, state, tribal, and local. It is composed of five primary functional areas: command, operations, planning, logistics, and finance/
administration. An additional area, investigations, is implemented on a case-by-case basis.

11.2.3 Emergency Operations Center

The Emergency Operations Center (EOC) addresses responsibilities that fall outside of the command structure (i.e., emergency first responders, incident commander, incident management team, etc.), and necessitates more direct management action from the EOC and the emergency manager. Responsibilities an EOC might assume include evacuations, donation management systems, and shelters and assistance centers. In the event of an incident, EOCs are the primary point of coordination and serve as physical locations where information and resource organization take place. While the physical size, staffing, and supply capabilities of an EOC will greatly depend on the jurisdiction size, available resources, and anticipated workload of incident management efforts, the operational structure of the EOC should always satisfy the needs and capacity of the incident and available resources, and adhere to the local laws, regulations, and policies.

Emergency management at the county is divided into four phases: prevention, preparedness, response, and recovery (Figure 11-3).

Figure 11-3 Phases of emergency management

Each stage of the emergency management cycle can be defined in the following way:

- **Prevention**: Activities designed to avert a potential incident and minimize the losses from disaster
- **Preparedness**: Development of plans and procedures including mitigation measures
- **Response**: Actions taken during the disaster to preserve life, property, the environment, and the social economic and political structure
- **Recovery:** Activities that help to restore critical community infrastructure and functions and manage reconstruction

The cycle is the same for each type of emergency and tiers to NIMS and ICS to facilitate operations and coordination across local, state, and federal agencies. This report focuses primarily on the prevention and preparedness piece of the emergency management cycle. However, an understanding of response and recovery is important in identifying areas requiring focus for mitigation.

11.2.3.1 Emergency Operations

Costilla County falls under the South East District, San Luis Valley (SLV) Region of the Division of Fire Prevention and Control (DFPC). Costilla County departments and SLV agencies will have a lead or support role during an incident within Costilla County. The emergency operations roles and responsibilities are described in the CCEOP.

<u>County</u>

The Costilla County Board of Commissioners has delegated responsibility for fire management and coordination of county emergency operations to the Costilla County Office of Emergency Management. The emergency management director is responsible for the organization and operation of the CCEOP when activated for an emergency and provides coordination with all other county departments. According to the CCEOP, the majority of incidents are handled at the local level; the county should not expect state response assets to arrive for at least 72 hours (CCDEM 2021).

<u>Regional</u>

Costilla County is one of six counties that fall within the San Luis Valley Region. There are a number of regional organizations that provide support to the CCDEM during a larger event, including a SLV Regional Emergency Preparedness and Response Program, the SLV Emergency Command Center Committee, and SLV Regional Homeland Security. The roles and responsibilities of these regional entities are described in the CCEOP.

<u>State</u>

Each DFPC district has a supervisory district chief and regional battalion chiefs. District and battalion chiefs assist local agencies with preparedness, planning, training, coordination, and response. They serve as subject matter experts, provide technical assistance to local agencies during wildfire incidents, and fill incident command positions when requested. On large, extended attack fires, district and battalion chiefs conduct assessments to determine if local resources have been exceeded and whether there is eligibility for transition to state responsibility. If approved, the DFPC assumes cost and management responsibility for the fire but will have ongoing involvement from local and county partners (Colorado Division of Fire Prevention and Control (DFPC), 2021).

Federal

The federal government is responsible for responding to national emergencies and providing assistance to states when an emergency or disaster is beyond their capability to handle. The federal government will assume a support role to assist the state and Costilla County.

The priorities for emergency management, as described in the CCEOP (CCDEM 2021) are as follows:

1. Save lives and protect the health and safety of the public, responders, and recovery workers
2. Ensure security for personnel and property
3. Protect and restore critical infrastructure
4. When appropriate, conduct a law enforcement investigation to resolve the incident, apprehend the perpetrators, and collect and preserve evidence for prosecution
5. Protect property and mitigate damages and impacts to individuals, communities, and the environment
6. Facilitate recovery of individuals, families, businesses, local government, and the environment

11.3 Hazards in Costilla County

The 2015 HMP for Costilla County identifies 10 potential natural hazards that may threaten the county (see Table 11-1) (CCMAC 2015). The 2021 CCEOP states that Costilla County continues to be vulnerable to a multitude of hazards (CCDEM 2021). The most significant hazards facing the area are wildfire, drought and severe winter storms. The county is also under moderate threat of severe thunderstorms/hailstorms and flooding. Information on these hazards are presented below and described in more detail in the HMP.

Figure 11-4 shows occurrences of natural disasters within and around the UCW. This figure covers some of the hazards identified in Table 11-1 with the exception of wildfire. Past wildfire occurrences can be found in Figure 11-5. As is evident in the Natural Disasters and Hazards map, hazard events are common across the county and within the watershed. Hail, floods, tornados, and drought are some of the more recent hazard occurrences in the UCW. While not discussed further in this report, the risk of avalanche or landslide is another hazard illustrated in Figure 11-4 that has a moderate to high likelihood in the higher elevations of the UCW.

Table 11-1 Costilla County Hazard Identification Results

Hazard Type	Hazard Level
Wildfire	*Significant*
Drought	*Significant*
Severe winter storms	*Significant*
Severe thunderstorms/hailstorms	*Moderate*
Flooding	*Moderate*
Earthquake	*Limited*
Tornado	*Limited*
Water supply contamination	*Limited*
Landslide	*Limited*
Dam failure	*Limited*

Source: CCMAC (2015)

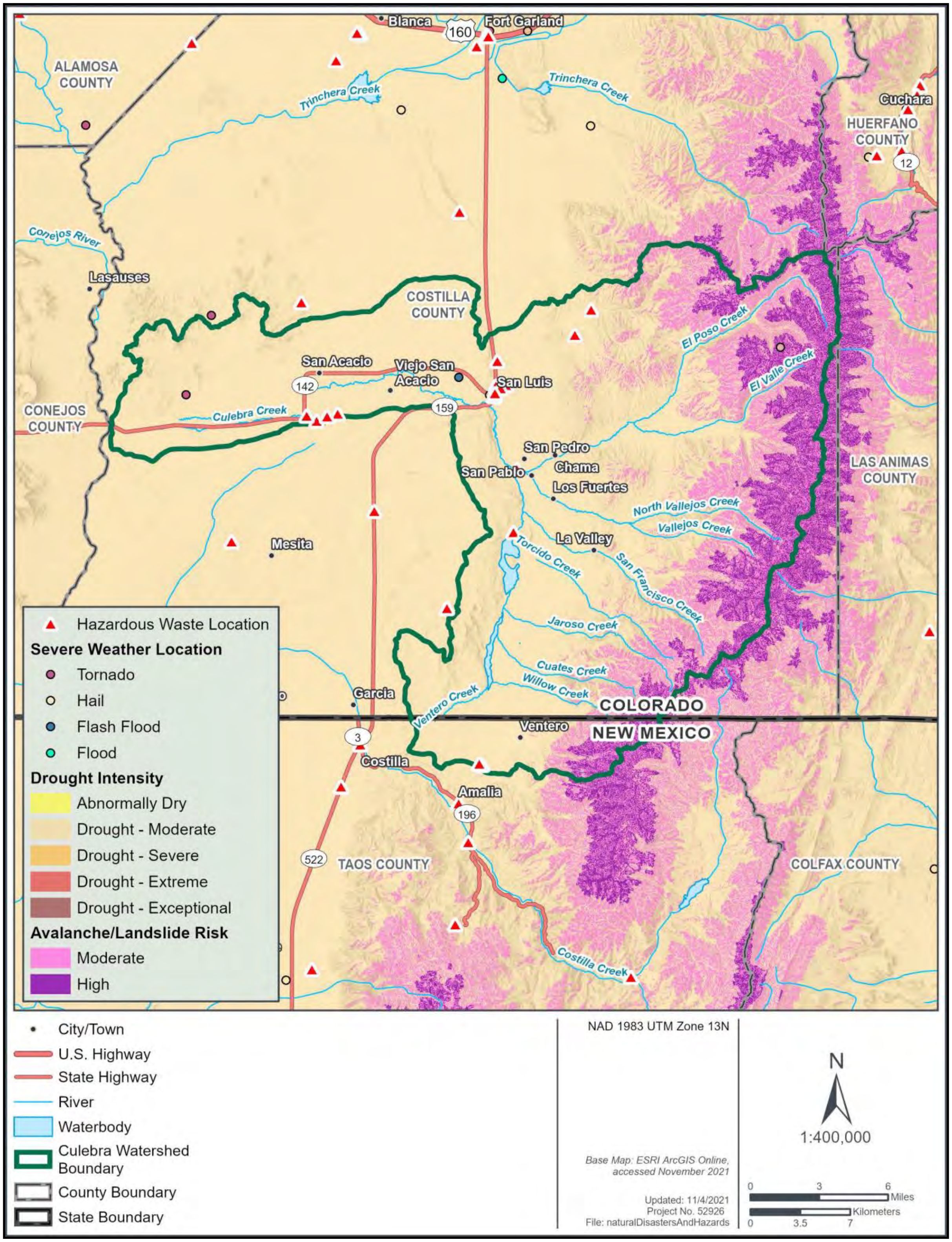


Figure 11-4 Natural disasters and hazards map.

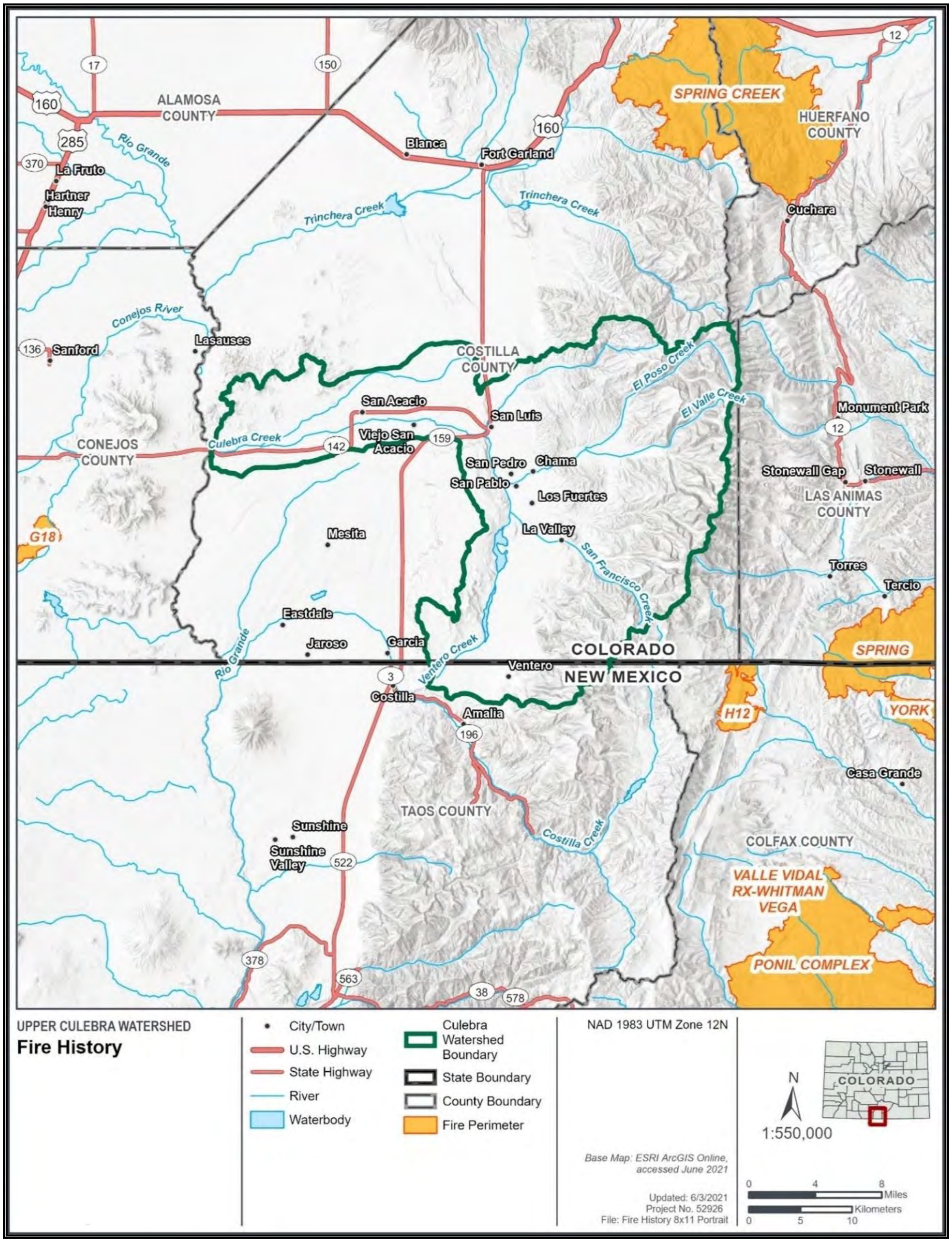


Figure 11-5 Fire history in the Upper Culebra Watershed.

11.3.1 Wildfire

One of the most likely and dangerous threats to the watershed is wildfire. While the UCW has yet to experience a major fire within its borders, disastrous fires have occurred within Costilla County and in counties surrounding the watershed (see Figure 11-5). Increased prevalence of drought combined with high fuel concentrations, poor vehicle access, and a majority of residents living within the wildland urban interface (WUI) make the risk of wildfire even more dangerous. Throughout the watershed, the fire hazard varies depending on factors such as location, elevation, fuel load, and more. The lower elevations within the watershed tend to have an overall hazard rating of moderate with the rating increasing to high as elevation and forest cover increase. Many residents around the watershed live in areas that are considered at high risk for wildfire. As the population in the area increases, so will the potential for fire. According to the 2015 HMP, 21% of fires reported in the county have been caused by people in their cars (CCMAC 2015).

11.3.2 Drought

As agriculture is the dominant industry in the watershed, drought is a major consideration in safety and emergency management. A major drought could have huge social, economic, and environmental implications and could increase the likelihood and intensity of wildfires. Persistent droughts have been an issue for the watershed in the past and are highly likely to occur in the future. As shown in Figure 11-4 below, the watershed as a whole is in a state of moderate drought. A drought can affect both surface water and groundwater availability. Although residents in the western portion of the watershed rely on groundwater, eastern portions are dependent on available surface water. Water restrictions have been imposed in Costilla County in the past due to a decrease in overall water availability. With limited water available, farmers and ranchers will see reduced crop and cattle efficiencies, businesses dependent on water will struggle, and firefighters will have less resources to fight wildfires. Droughts can also create conditions in which flash floods are more likely to occur. When persistent drought is coupled with a period of intensive rainfall, flash floods can arise and cause loss of life and property. Lastly, drought can have a negative effect on water quality and natural resources. Adverse conditions for local flora and fauna can lead to increased mortality and disease (CCMAC 2015).

11.3.3 Severe Winter Storms

Severe winter storms are a common occurrence in Colorado and the UCW. In the past, presidential disaster declarations have been made for severe winter storms in the state. Winter storms can disrupt lives for periods of a few hours to several days depending on the severity. A number of impacts can be expected based on the severity of the storm. Not only can the ability to heat one's residence be affected, but also the capacity for utility infrastructure to withstand extremely low temperatures and heavy snow can be drastically hindered. Damage to power and communication lines can cause blackouts, which can further exacerbate the situation for some residents. Water pipes can freeze and burst, leading to property damage. Furthermore, steep slopes around the watershed, coupled with snow and ice, can completely halt transportation or leave residents stranded in areas away from their homes. All of these factors can ultimately take a massive toll on overall human health and well-being within the watershed if adequate planning and response are not implemented (CCMAC 2015).

11.3.4 Severe Thunderstorms and Hailstorms

The summer months in the UCW also have the potential to bring severe storm events. Severe thunderstorms and hailstorms are both common weather events in this area as shown in Figure 11-4. Although generally occurring between the months of April and October, these types of storms can happen on occasion during the winter, as well. Lightning that accompanies severe thunderstorms can be a hazard for multiple reasons. Lightning strikes can directly lead to death and to wildfire. Colorado ranks 11th in deaths from lightning across the United States. Lightning is unpredictable and can cause damage to personal property, as well.

Hail is another potential danger related to severe storms. Hail is prevalent throughout Colorado during storms and has caused severe damage in many parts of the state, including the UCW (CCMAC 2015).

11.3.5 Flooding

The steep slopes and numerous drainages in the watershed make flooding a major potential hazard for the area. Historically, flooding has occurred between May and September. The county has sustained flood damage from Sangre de Cristo Creek (CCDEM 2021). Across the county, the majority of flooding occurs as flash floods although, as shown in Figure 11-4, other flood events have occurred, as well.

Rapid runoff from tributaries in higher elevations can sharply increase water levels in streambeds, leading to flash floods. Primary effects of flooding include loss of life and property, generally due to the sudden nature of these events and the lack of preparation time for residents. There are also some secondary effects from flooding. Damage to infrastructure such as roadways can limit the ability of emergency services personnel to respond to related situations. Other secondary effects such as water quality and service or wastewater treatment can also be hindered (CCMAC 2015).

11.3.6 Wildland Fire Environment

Because wildfire is the primary risk to the watershed and communities, as identified in the HMP (CCMAC 2015), a more detailed assessment of the fire environment is provided below. This assessment relates to both forest health and safety and emergency management.

The purpose of the assessment was to identify and quantify the risks of wildfires (and other hazards) in the watershed by gathering information on where fires are likely to occur, the intensity at which they might occur, and determine impacts to the highly valued resources and assets (HVRAs) within the community.

11.3.6.1 Fire Regime

Fires are characterized by their intensity, the frequency with which they occur, the season in which they occur, their spatial pattern or extent, and their type. Combined, these attributes describe the fire regime. Fire regimes in the western United States have changed dramatically within the past several decades.

Historically, frequent, low-intensity surface fires would have burned through some lower elevation ponderosa pine and warm-dry mixed conifer dominated forest types (below 8,500 feet), creating a mosaic of different stages of vegetative structure across the landscape. For the most part, these fires helped to preserve an open vegetative community structure by consuming fuels on the ground surface, maintaining open meadows and clearing the forest understory of encroaching vegetation. However, large areas of the county have not burned in more than 100 years. This departure from historical, low-intensity fire regimes has caused recent wildland fires to burn much more intensely and unpredictably in adjacent counties, resulting in far more significant mortality of canopy trees and more damaging post-fire impacts.

Many of the higher elevation (8,500 feet amsl and above) spruce-fir and mid-elevation mixed-conifer forests would have naturally experienced infrequent stand replacing fires as part of their natural regeneration cycle (Margolis, Swetnam, & Allen, 2007), so for these forest types, high levels of canopy mortality are expected. Large stand-replacing fires in these high elevation forests have been linked to periods of drought in forest across the region (Kipfmueller & Baker, 2000; Sibold & Veblen, 2006). As drought and climate change have hit these forests over the last few decades, the scale of these infrequent, stand-replacing fires has changed significantly with fires growing to a size that was not observed historically (Westerling, Hidalgo, Cayan, & Swetnam, 2006).

Stands of quaking aspen in the analysis area possibly represent a legacy of stand-replacing fires that historically occurred in upper montane forests, opening up areas for succession by aspen that are now undergoing succession back to conifers. However, literature suggests that aspen stands in the San Luis Valley may also be linked to the mining boom of the mid- to late 1800s and could have been the result of human-ignited fires for land clearing (Agee & Cuenin, 1924; U.S. Forest Service [USFS], 1999).

Human influences on fire regimes have been greatest at low-elevation sites. An additional factor contributing to the natural disturbance regime in forest cover types in the region are outbreaks of bark beetle, which have killed significant numbers of spruce (Picea spp.), fir (Abies spp.), and pine (Pinus spp.) trees throughout the analysis area.

11.3.6.2 Vegetative Fuels

Fuels include snags and coarse woody debris, as well as smaller diameter woody debris, needles, leaves, grasses, and other flammable materials on the forest floor. Fuels also include ladder fuels, which are shrub or tree species that create vertical connectivity from the forest floor to the dominant canopy layer (Figure 11-6). The presence of ladder fuels in frequent-fire forests that make up a portion of the UCW greatly increases the risk of canopy fires occurring, increasing fire severity and often leading to fire spread over larger areas.

The western portion of the watershed is predominantly composed of grassland fuels, transitioning into shrubsteppe- or shrubland-dominated fuels to the east. Forested communities exist primarily in the higher elevations of the Sangre de Cristo Mountains in the eastern portion of the watershed. Grassland communities are primarily characterized by shortgrass prairie, which is relatively sparse and usually occurs on flat to rolling topography at lower elevations. Grasslands may occur as pure herbaceous stands, as a shrubsteppe community, or as a juniper savanna (Figure 11-7).

Figure 11-6 Ladder fuels in the project area.

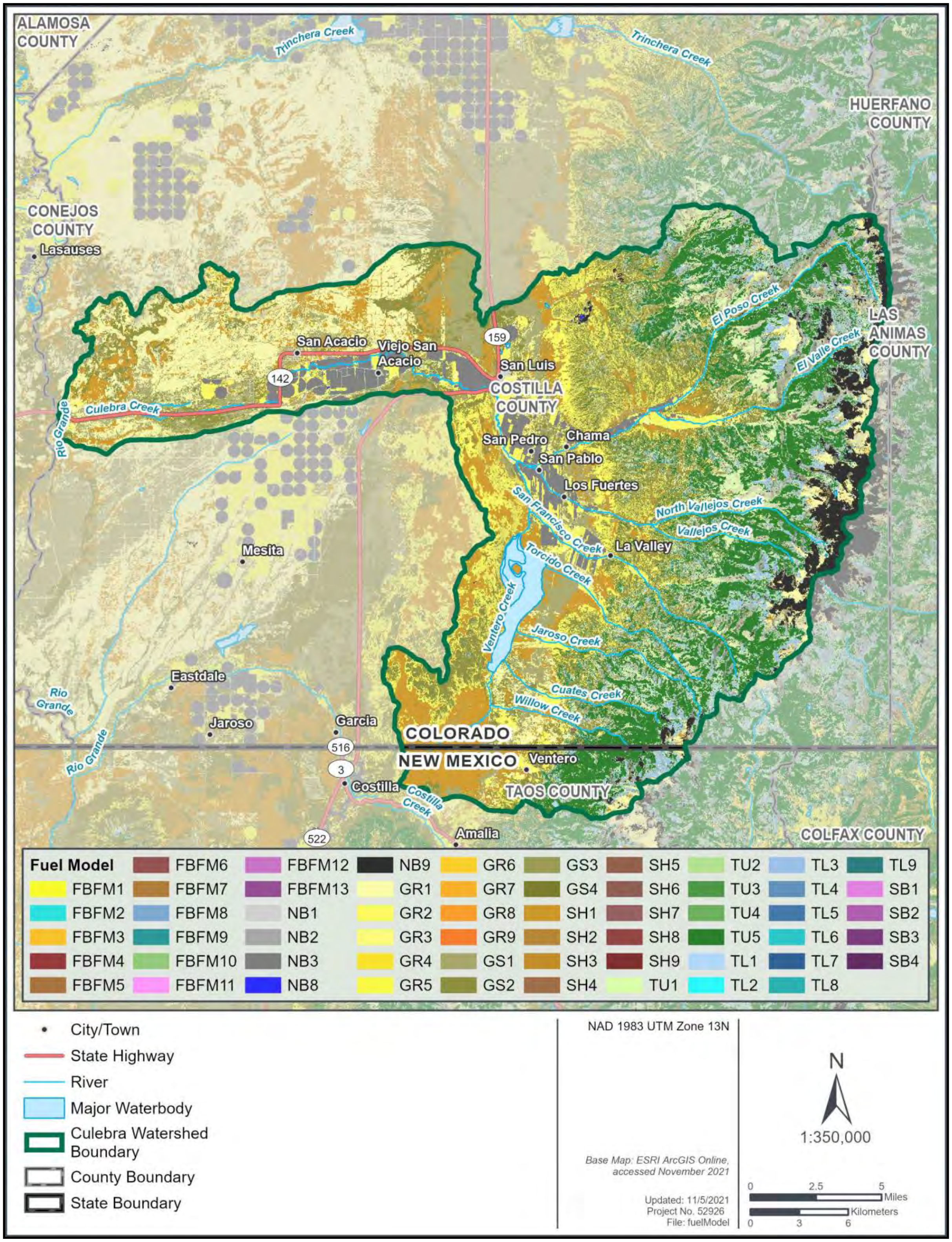


Figure 11-7 Fuels model map.

Grasslands

The second most common vegetative community in the analysis area is the grassland/shrubland community. This is also the community in which most of the housing and agricultural production are located. Grassland fires have the potential to move quickly under dry, windy, and steep conditions and can easily spread at a surprisingly rapid rate, often reaching over 300 feet per minute. Many authors have suggested that the mean historic fire-return intervals (FRIs) for grasslands throughout the seventeenth to early nineteenth centuries are thought to have been every 5 to 10 years (Leopold A. , 1924; Swetnam, Baisan, Caprio, Touchan, & Brown, 1992). Fire-suppression policies may have contributed to declining fire frequency in this cover type, but other interacting factors may have contributed, as well. About the time of the Civil War, intensive livestock grazing is thought to have been responsible for a decline in grassland fires (Touchan, Allen, & Swetnam, 1996; West, 1984). Heavy grazing reduced the fuels available to propagate fire spread and also reduced competition with herbaceous plants, tipping the balance in favor of the woody species. Woodland encroachment, increased tree density, and altered fire behavior characterize many former grasslands of the Southwest. Once woody plants become dominant, their long lifespans and their ability to extract both shallow and deep soil moisture can maintain a woodland condition indefinitely (Burgess, 1995). Frequent fire plays a significant role in grassland nutrient cycling and successional processes, and long-term exclusion may produce irreversible changes in ecosystem structure and function (McPherson, 1995).

Piñon-Juniper Woodlands

Although piñon-juniper woodlands comprise just over 6% of the analysis area, this community is an important consideration for fire management due to its proximity to population centers in the watershed. These woodlands are some of the most poorly understood ecosystems in terms of fire regimes, but recent research suggests that fire may have been a less-common and less-important disturbance agent in piñon-juniper woodlands compared with adjacent ponderosa pine and grassland ecosystems. In a recent review of piñon-juniper disturbance regimes, Romme et al. (2007) subdivided the piñon-juniper cover type into three subtypes: areas of potential woodland expansion and contraction, piñon-juniper savannas, and persistent woodlands. These categories are helpful in separating the broad piñon-juniper cover type into distinct communities, which are subject to different climatic, topographic, and disturbance conditions.

Areas of potential expansion and contraction are those zones wherein the boundaries of the piñon-juniper ecotones have shifted. As mentioned previously, many grasslands in the Southwest have been colonized by trees as a result of a complex interplay of environmental factors. The issue of woodland encroachment into grasslands goes hand in hand with the assessment of historical conditions of the woodlands. These shifting boundaries have been widely documented (e.g., Gottfried (2004)), but the historical condition of the ecosystem may be relative to the time scale of evaluation. Betancourt (1987) has suggested that the changing distribution patterns seen in the last century may be part of larger trends that have occurred over millennia and not the result of land use changes. Overall, it is believed that greater landscape heterogeneity existed previously in many of these areas that are now uniformly covered with relatively young trees (Romme, et al., 2007).

Piñon-juniper savannas are found on lower elevation sites with deep soils where most precipitation comes during the summer monsoon season. Juniper savanna consists of widely scattered trees in a grass matrix (Dick-Peddie, 1993). Similar to grasslands, the range of savannas has decreased as tree density has increased, but the mechanisms for tree expansion are complex as is the subject of current research. Significant scientific debate currently exists over the natural FRI for savannas, but most experts agree that fire was more frequent in savannas than in persistent woodlands.

Persistent woodlands, characteristic of rugged upland sites with shallow, coarse soils, tend to have older and denser trees. Herbaceous vegetation within this community is typically sparse, even in the absence of heavy livestock grazing. Research from persistent woodlands provides strong evidence to support the theory that the natural fire regime of piñon-juniper woodlands was dominated by infrequent but high-severity fires and that FRIs may have been on the order of 400 years (Baker & Shinneman, 2004; Romme, et al., 2007). These findings are in stark contrast to previous estimates of piñon-juniper FRIs of 30 to 40 years (Schmidt, Menakis, Hardy, Hann, & Bunnell, 2002). The short FRI estimates are mostly inferred from FRIs of adjacent ponderosa pine ecosystems due to the scarcity of fire-scarred trees in these ecosystems.

In contrast to ponderosa pine, piñon pines, and junipers produce relatively small volumes of litter. Understory fuels, either living or dead, must be sufficiently contiguous to carry a low-intensity surface fire. In the absence of fine surface fuels, fires that spread beyond individual trees are most likely wind-driven and spread from crown to crown (Romme, et al., 2007). Fire extent is greatest in higher-density woodlands and is limited by both fuels and topography in sparse, low-productivity stands on rocky terrain. Most scientists agree that fire has been more common in savannas and areas of expansion and contraction than in persistent woodlands, but debate remains on the exact range of fire frequency. Overall, frequent, low-intensity surface fires are not the predominant fire regime in piñon-juniper woodlands. Therefore, fire exclusion may not have altered forest structure as dramatically in this forest type. The degree of departure from historical conditions and the causes of any observed changes remain uncertain; therefore, restoration treatments in woodlands should be approached with caution (Romme, et al., 2007).

Ponderosa Pine Forests

In general, studies in southwest ponderosa pine found that pre–1900 FRI ranged from 4 to 25 years and that fire frequencies and areas burned were the greatest in mid-elevation ponderosa pine forests (Fulé, Henlein, Covington, & Moore, 2003; Grissino-Mayer, Romme, Floyd, & Hanna, 2004; Swetnam & Dietrich, Fire history of ponderosa pine forests in the Gila Wilderness, New Mexico, 1985; Veblen, Kitzberger, & Donnegan, 2000). Ponderosa pine stands, which exist in the higher, steeper elevations within the watershed, are fire-adapted ecosystems that are maintained by frequent, low-intensity fires. Throughout the Southwest, extensive fire history studies have documented historical fire frequencies in ponderosa pine using tree-ring data (Allen, et al., 2002; Richardson, 1998). Large variation in the spatial and temporal scales of fires in ponderosa pine was common and was usually based on forcing factors, such as seasonality, regional climate, elevation, aspect, and other site conditions (Brown & Shepperd, 2001). The effects of fire exclusion on forest structure are thought to be more profound in forests that previously sustained frequent, low-intensity surface fires (Westerling, Hidalgo, Cayan, & Swetnam, 2006), and it is likely that fire exclusion was a primary cause of departure from historical conditions in ponderosa pine forests. Historically, frequent fire would have consumed fuels on the ground surface and culled young trees to maintain an uneven age distribution and mosaic pattern throughout the forest (Allen, et al., 2002). Frequent fire disturbance maintained an open, park-like forest structure with canopy openings and an abundant herbaceous and shrubby understory (Biswell, 1973; Cooper C.

F., 1960; Covington & Moore, 1994; Weaver, 1947). In contrast to this historical structure, modern ponderosa stands are often overly dense with an understory of younger trees, increasing the likelihood for a fire to be lifted into the canopy. In areas where canopy spacing is less than 20 feet, there is increased crown fire hazard and potential for long-range spotting, especially in the presence of wind and steep slopes.

Mixed-Conifer/Spruce-Fir Forests

These forest types combined constitute the largest portion of the UCW analysis area by covering over 39%. Often forest patches affected by low- and high-severity fire are closely juxtaposed in a transition zone made up of a forest type known as mixed conifer (Fulé, Henlein, Covington, & Moore, 2003). Fire histories in mixed conifer forests vary with forest composition, landscape characteristics, and human intervention, but tend to exhibit mixed severity fire regimes with both low-intensity surface fires and patchy crown fires (Touchan, Allen, & Swetnam, 1996). Mixed-severity fire regimes are the most complex fire regimes in the western United States (Agee J. K., 1998) because of their extreme variability (Agee J. K., 2005). A mixed-severity fire regime exists where the typical fire, or combination of fires over time, results in a complex mix of patches of different severity, including unburned, low-severity, moderate-severity, and high-severity patches (Agee J. K., 2005).

Ponderosa pine was once co-dominant in many mixed-conifer forests with relatively open stand structures, but fire suppression has allowed the development of dense sapling understories, with regeneration dominated by the more fire-sensitive Douglas-fir, white fir, and Engelman spruce. Forest stand inventory data from the southwest show an 81% increase in the area of mixed-conifer forests between 1962 and 1986 (Johnson, 1994). Herbaceous understories have been reduced by denser canopies and needle litter, and nutrient cycles have been disrupted. Heavy surface fuels and a vertically continuous ladder of dead branches have developed, resulting in increased risks of crown fires (Touchan, Allen, & Swetnam, 1996).

Spruce-fir forests that occur at higher elevations in the analysis area exhibit high densities (782–1382 trees/acre), high basal areas (28–39 square meters per hectare [m^2/ha]), continuous canopy cover (52%–61%), and increased woody debris (28–39 m^2/ha). These forest characteristics naturally support high-intensity and severe stand replacing fires (Fulé, Henlein, Covington, & Moore, 2003) and an infrequent fire regime. Approximately 80% or more of the aboveground vegetation is either consumed or dies as a result of such fire.

Riparian Communities

In some nearby ecosystems, a more frequent fire regime has occurred as a result of changes in vegetation composition and structure. Fire-adapted invasive species, such as saltcedar (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*), have invaded many Southwestern riparian corridors, increasing both fuel volume and continuity. While not currently observed in the UCW, changes in vegetation structure should be monitored over the coming years. These species sprout readily after fire. Although native cottonwoods and willows will also regenerate after fire, they typically have limited survival of resprouting individuals. Native riparian vegetation is not adapted to fire to the extent and severity it is currently experiencing in some regions. Once saltcedar has been established at a location, it increases the likelihood that the riparian area will burn and, as a result, alter the natural disturbance regime further. These altered fire regimes, rather than the natural hydrologic system, are now influencing the composition and structure of riparian ecosystems (Ellis, 2001), as well as causing a threat to communities situated in or adjacent to the riparian zone.

11.3.6.3 Fire History

Recent documented fire history in the analysis area is limited (see Figure 11-5), although plans and literature for the area describe frequent fires having occurred in the region for centuries (CCMAC 2015). Adjacent lands, however, have experienced frequent, large fires in recent history, demonstrating the potential fire occurrence that the UCW could be susceptible to (Colorado State Forest Service [CSFS] 2020). Historical records of fires are evident through dendrochronology and observed bole char to stumps and snags, illustrating that fires have occurred in the region historically (CCMAC 2015). During the 1900s, fire suppression actions limited fire spread across the region and the west, explaining a paucity in the fire record.

Of the few fires that have occurred in the last two decades, several are notable. The Mato Vega Fire burned 13,000 acres and resulted in the evacuation of the Forbes Wagon Creek Ranches and Paradise Acres. The Million Fire in 2002 burned over 11,000 acres in adjacent Rio Grande County and destroyed 33% of the structures in the Willow Park subdivision. The Sand Dunes Fire of 2000 burned over 8,5000 acres in one burn period and destroyed one structure in Great Sand Dunes National Park and Preserve (Land Stewardship Associates, LLC, 2008).

The most significant fire in the past decade was the Spring Creek Fire in June 2018 (Figure 11-8). The fire burned 108,045 acres near La Veta Pass on the eastern edge of the San Luis Valley. The fire burned 141 structures and cost more than $32 million to fight. The fire was ignited through arson. Prior to the fire, the area had been experiencing extreme drought that fueled the fire’s spread across Costilla and Huerfano Counties (Colorado Encyclopedia, 2021). The fire burned on 85,942 acres of state and private lands, 12,226 acres managed by the Bureau of Land Management and 9,837 acres managed by the U.S. Forest Service on the San Carlos Ranger District of the Pike-San Isabel National Forests (Arkansas River Watershed Collaborative, 2021). The Cucharas and Indian Creek watersheds, which serve the communities of La Veta and Walsenburg, were heavily burned and impaired by the fire and experience ongoing sediment transport, debris flows. and flooding (Arkansas River Watershed Collaborative 2021). Post-fire effects are expected to last at least 10 years, illustrating the significant impacts that fires such as Spring Creek could pose to the UCW and downstream communities in the San Luis Valley.

Figure 11-8 The Spring Creek fire. Photo courtesy of the Colorado Department of Transportation.

11.3.6.4 Wildland Urban Interface

A WUI is composed of both interface and intermix communities and is defined as areas where human habitation and development meet or intermix with wildland fuels (U.S. Department of the Interior [USDI] and U.S. Department of Agriculture [USDA], 2001, pp. 752-753). Interface areas include housing developments that meet or are in the vicinity of continuous vegetation. Intermix areas are those areas where structures are scattered throughout a wildland area where the cover of continuous vegetation and fuels is often greater than cover by human habitation.

The WUI creates an environment in which fire can move readily between structural and vegetative fuels, increasing the potential for wildland fire ignitions and the corresponding potential loss of life and property. Human encroachment upon wildland ecosystems within recent decades is increasing the extent of the WUI throughout the country as a whole, which is having a significant influence on wildland fire management practices. Combined with the collective effects of aggressive suppression policies, resource management practices, land use patterns, climate change, and insect and disease infestations, the expansion of the WUI into areas with high fire risk has created an urgent need to modify fire management practices and policies and to understand and manage fire risk effectively in the WUI (Pyne, 2001; Stephens & Ruth, 2005). Mitigation techniques for fuels and fire management can be strategically planned and implemented in WUI areas; for example, with the development of defensible space around homes and structures.

The HMP (CCMAC 2015) identifies WUI communities throughout the UCW, such as Mountain Lake Ranch, San Acacio, San Pedro Mesa, and Vallejos Creek. The Colorado Forest Atlas (2021) also delineates WUI areas based on housing density data (the Where People Live dataset) and 2016 LandScan USA population count data, which is obtained from the U.S. Department of Homeland Security HSIP data. Populated areas not surrounded by wildland fuels are removed from the delineated WUI (Figure 11-9).

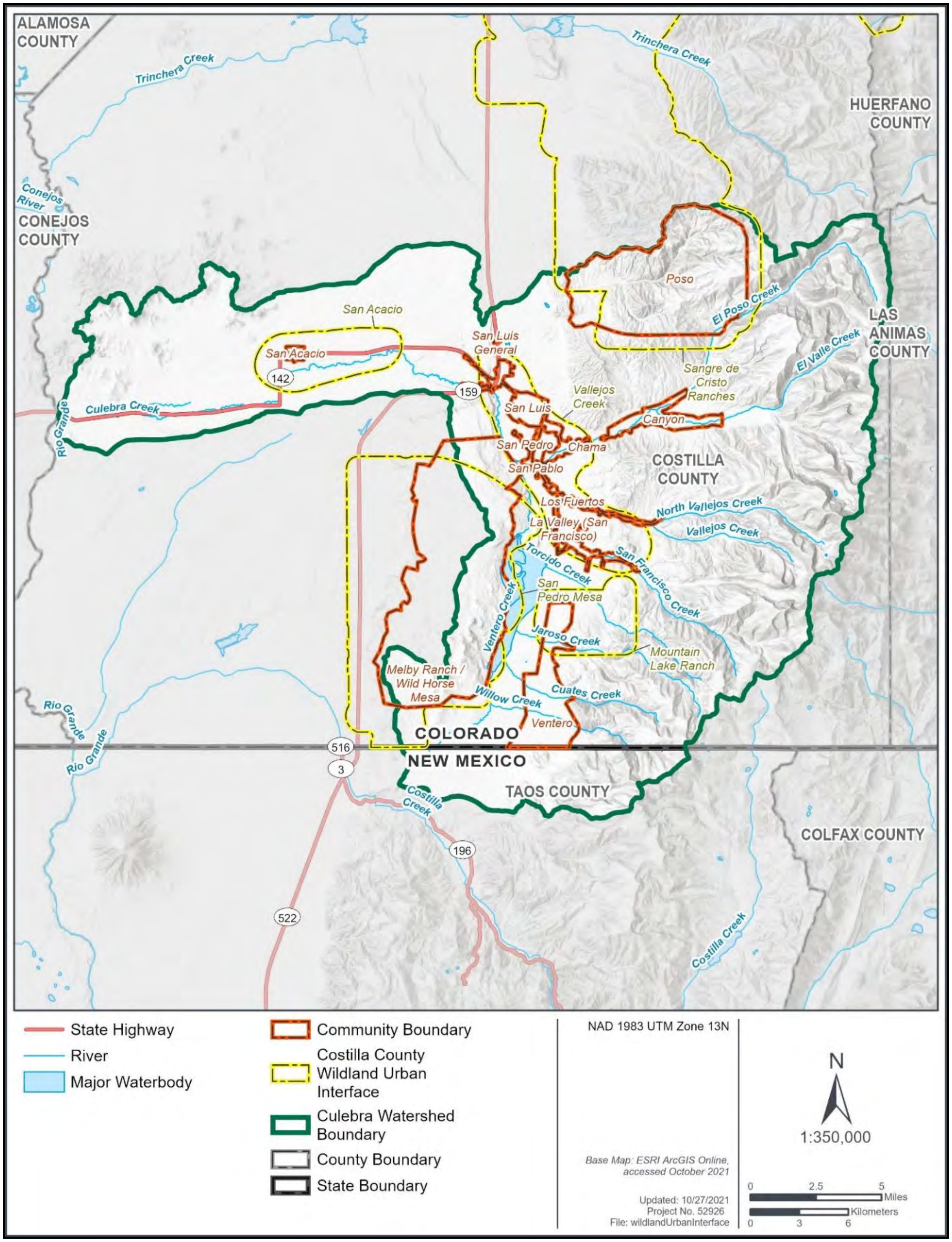


Figure 11-9 Wildland urban interface in the Upper Culebra Watershed.

11.3.6.5 Values at Risk

Background research and discussions with stakeholders has helped in the development of a list of community values at risk (CVARs) from wildland fire. These data are also supplemented with HVRA data, which is a dataset that is being gathered nationwide and available through the Interagency Fuel Treatment Decision Support System. In addition to critical infrastructure, CVARs can include natural, social, and cultural resources (Figure 11-10). A key value at risk that is high priority for protection, is drinking water supply (Figure 11-11).

It is important to note that although an identification of CVARs can inform treatment recommendations, a number of factors must be considered to fully prioritize areas for treatment; these factors include appropriateness of treatment, landownership constraints, locations of ongoing projects, available resources, and other physical, social, or ecological barriers to treatment.

The scope of this assessment does not allow determination of the absolute natural, socioeconomic, and cultural values that could be impacted by wildfire in the analysis area. In terms of socioeconomic values, the impact due to wildfire would cross many scales and sectors of the economy and call upon resources locally, regionally, and nationally.

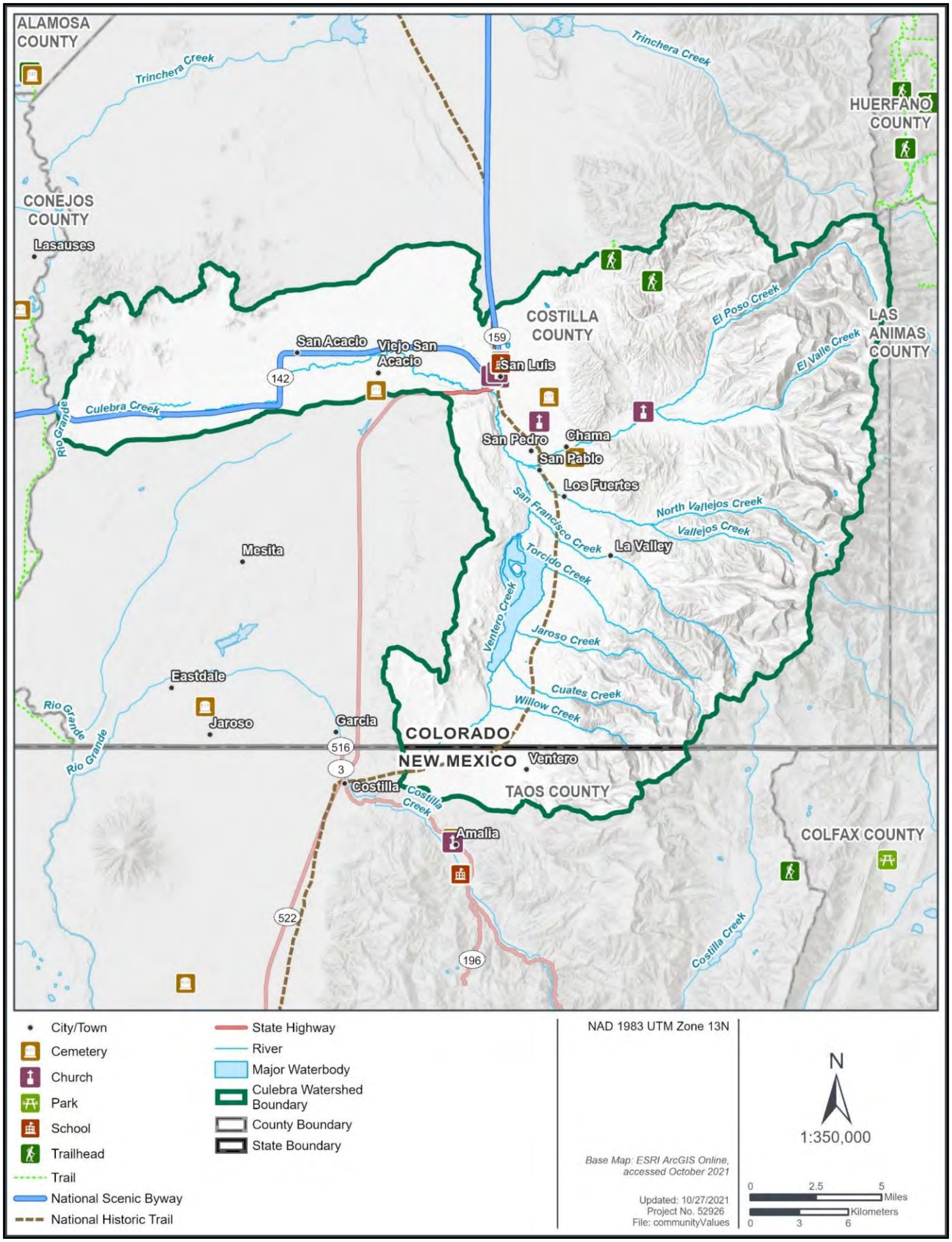


Figure 11-10 Values at risk in the Upper Culebra Watershed.

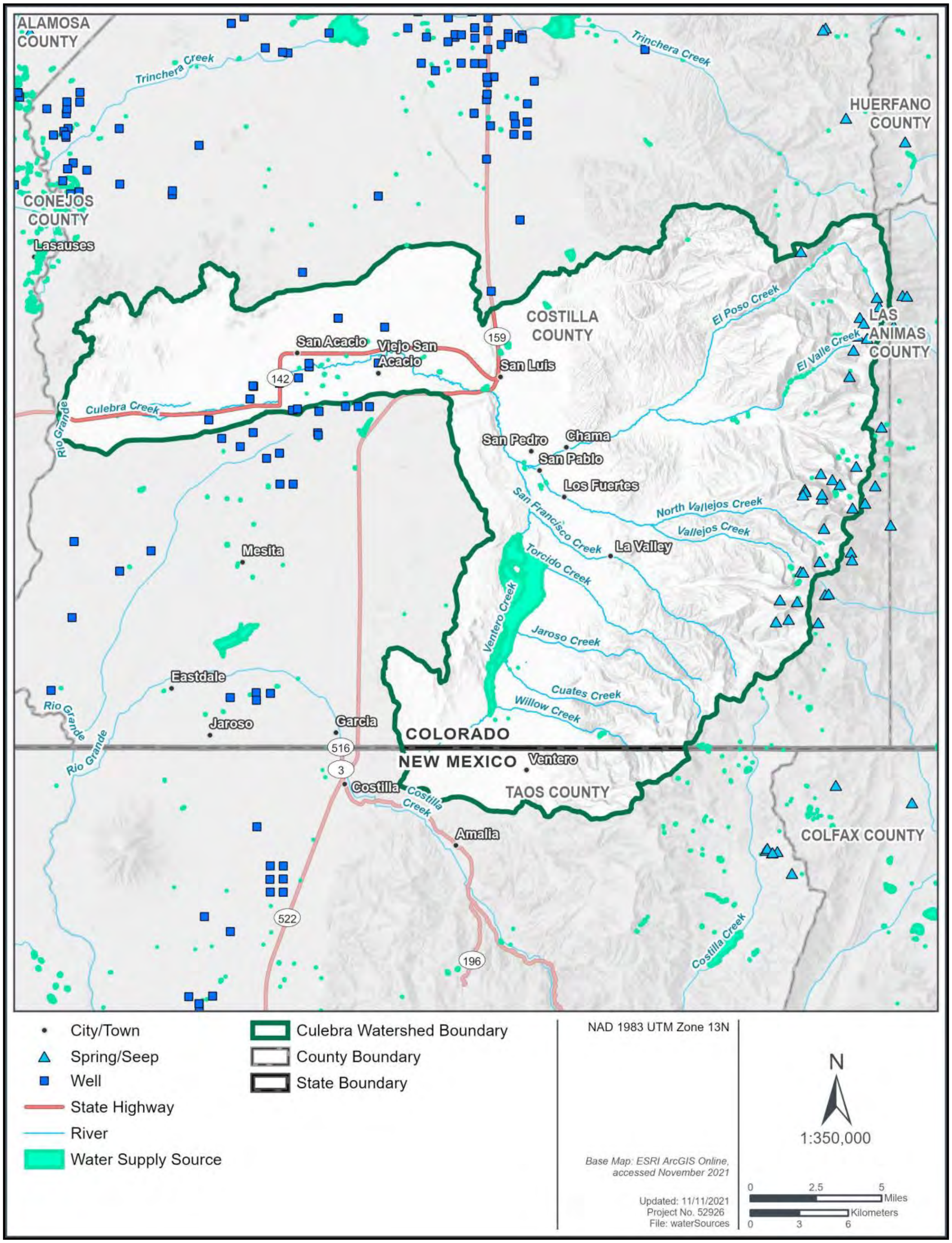


Figure 11-11 Drinking water supply areas.

11.3.6.6 Fire Risk and Hazard

Although many definitions exist for hazard and risk, for the purpose of this document these definitions follow those used by the firefighting community:

- Hazard is a fuel complex defined by kind, arrangement, volume, condition, and location that forms a special threat of ignition and resistance to control.
- Risk is defined as the chance of a fire starting as determined by the presence and activity of causative agents (National Wildfire Coordinating Group, 1998).

Wildfire risk analysis is about seeking answers to several important questions (Scott, Thompson, & Calkin, 2013):

- When, where, and how are large fires are likely to occur?
- Which assets (e.g., life, structures, infrastructure, and ecology) have the most significant exposure to wildfire hazards?
- What are the likely effects of fire within and adjacent to the community at different intensity levels?
- Where might fires cause harm/damage, and where might they lead to benefits?
- How is wildfire risk distributed across the interface/intraface?
- Which areas are most likely to experience loss?
    - How much loss?
    - To which HVRAs?

According to several sources, the fundamental components for quantifying wildfire risk—likelihood, intensity, and susceptibility to effects (Miller & Ager, 2012; Scott J. H., An analytical framework for quantifying wildland fire risk and fuel treatment benefit, 2006; Thompson & Calkin, 2011)—can be visualized as a wildfire risk triangle (Figure 11-12).

Figure 11-12 Wildfire risk triangle.

Figure 12. Wildfire risk triangle.

In this assessment, *likelihood* is being assessed by fire history, weather history, and topography as a function of the placement of assets relative to the wildland fuels. *Intensity* is being measured by fireline intensity, rate of spread, and flame length for current and worst-case wildland fuel configurations. Finally, *susceptibility* encompasses building construction, infrastructure, access, available water capabilities, and fire response resources (Figure 11-13).

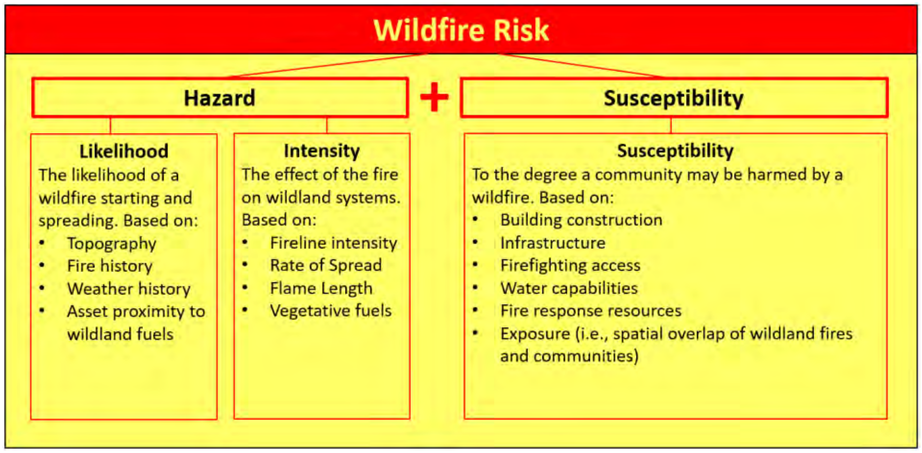


Figure 11-13 Components of wildfire hazard and risk.

11.3.6.7 Fire Behavior

The wildland fire environment consists of three factors that influence the spread of wildfire: fuels, topography, and weather. Understanding how these factors interact to produce a range of fire behavior is fundamental to determining treatment strategies and priorities in the WUI.

In the wildland environment, vegetation is synonymous with fuels. When sufficient fuels for continued combustion are present, the level of risk for those residing in the WUI is heightened. Fire spreads in three ways:

1. Surface fire spread: the flaming front remains on the ground surface (in grasses, shrubs, small trees, etc.) and resistance to control is comparatively low
2. Crown fire: The surface fire "ladders" up into the upper levels of the forest canopy and spreads through the tops (or crowns) independent of or along with the surface fire; when sustained, it is often beyond the capabilities of suppression resources
3. Spotting: Embers are lifted and carried with the wind ahead of the main fire and ignite in receptive fuels; if embers are plentiful and/or long range (>0.5 mile), resistance to control can be very high.

Crown fire and spotting activity has been a concern for fire managers in the region, particularly under extreme weather conditions such as those observed during the Spring Creek Fire. In areas where homes are situated close to shrubs and trees, potential spotting from woody fuels to adjacent fuels should always be acknowledged.

Treating fuels in the WUI can lessen the risk of intense or extreme fire behavior (Martinson & Omi, 2013; Safford, Schmidt, & Carlson, Effetcs of fuel treatments on fire severity in an area of wildland-urban interface, Angora Fire, Lake Tahoe Basin, California, 2009). Studies and observations of fires burning in areas where fuel treatments have occurred have shown that the fire either remains on or drops to the surface, thus avoiding destructive crown fire, as long as activity fuels are treated or removed (Graham, McCaffrey, & Jain, 2004; Pollet & Omi, 2002; Prichard, Peterson, & Jacobson, 2010; Safford, Stevens, Merriam, Meyer, & Latimer, 2012; Waltz, et al., 2014). Fuel mitigation efforts therefore should be focused specifically where these critical conditions could develop in or near communities at risk (CARs).

For this plan, an assessment of fire behavior has been carried out using well-established fire behavior models: FARSITE, FlamMap, BehavePlus, and FireFamily Plus, which are housed within the Interagency Fuel Treatment Decision Support System, as well as Esri ArcGIS

Desktop Spatial Analyst tools. Fire behavior varies with fuel, terrain, and weather conditions. To demonstrate the projected fire behavior that could occur in the analysis area under 97th percentile weather conditions (similar to those that occurred during the Spring Creek fire), the following fire behavior parameters were modeled: rate of spread (Figure 11-15), flame length (Figure 11-16), and fireline intensity (Figure 11-7), and crown fire potential (Figure 11-18).

Data used in the Composite Risk/Hazard Assessment is largely obtained from LANDFIRE. Information on the modeling is included in Appendix 12.A.

Figure 11-14 Fire signage in the project area.

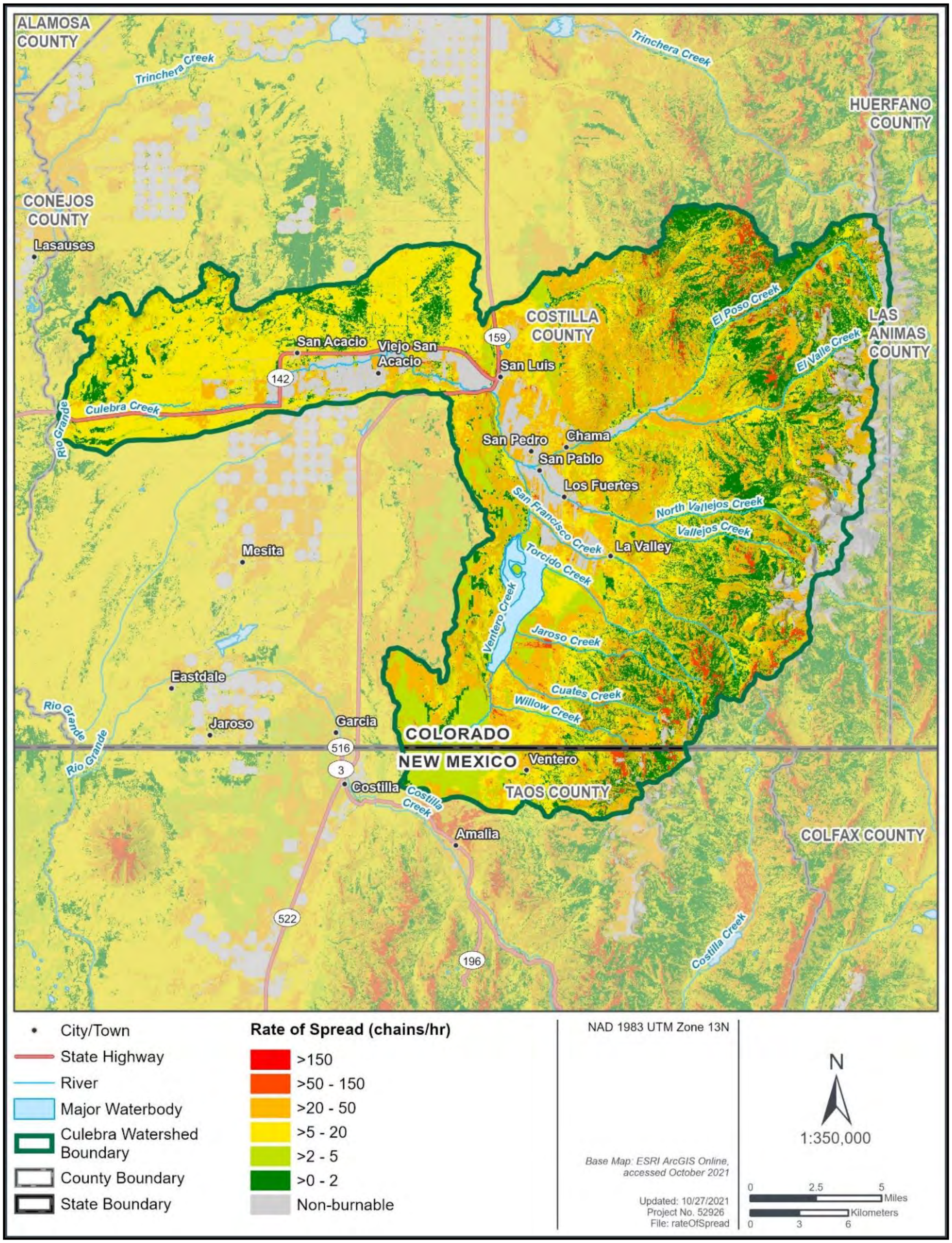


Figure 11-15 Modeled rate of spread under existing fuel and weather conditions.

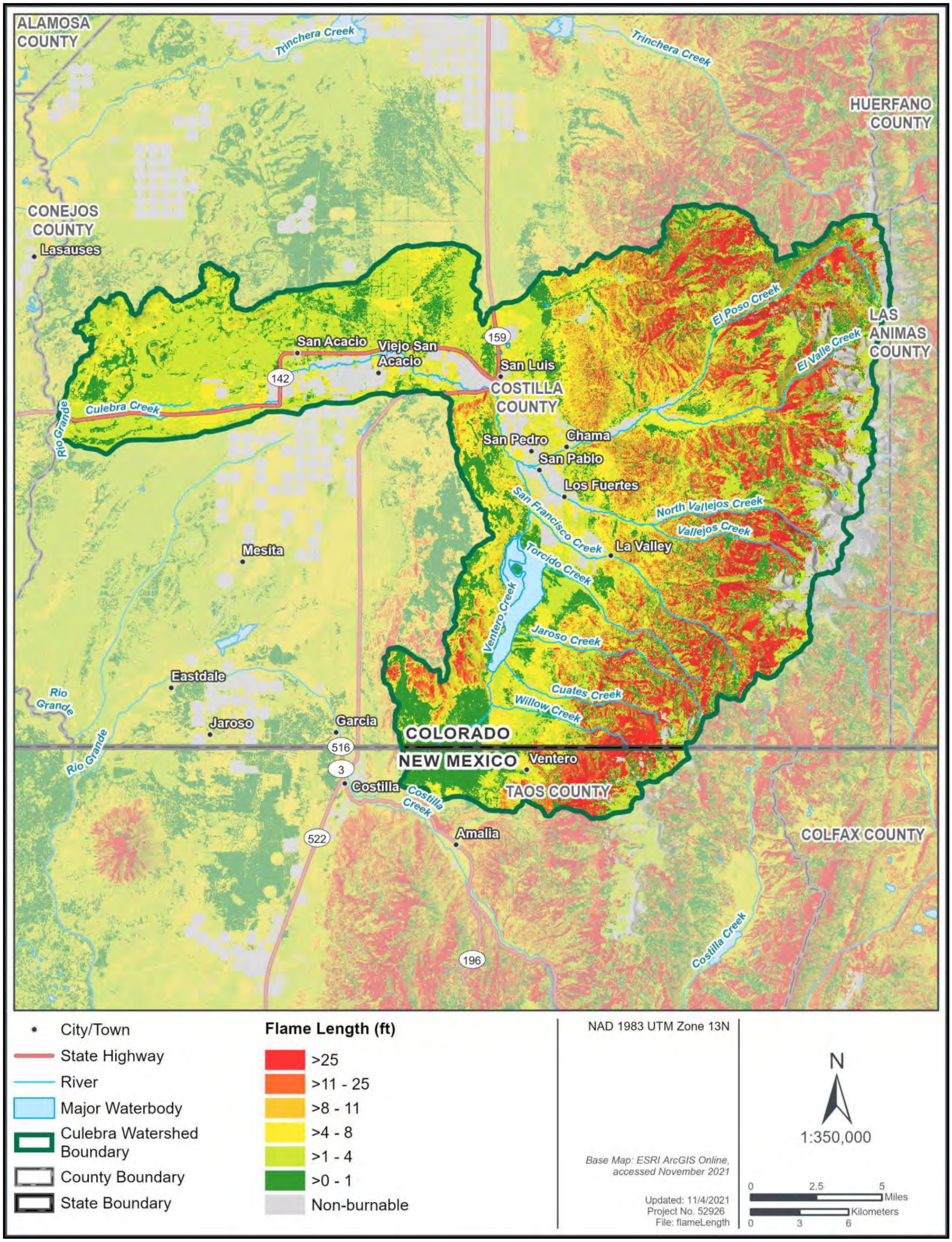


Figure 11-16 Modeled flame length under existing fuel and weather conditions.

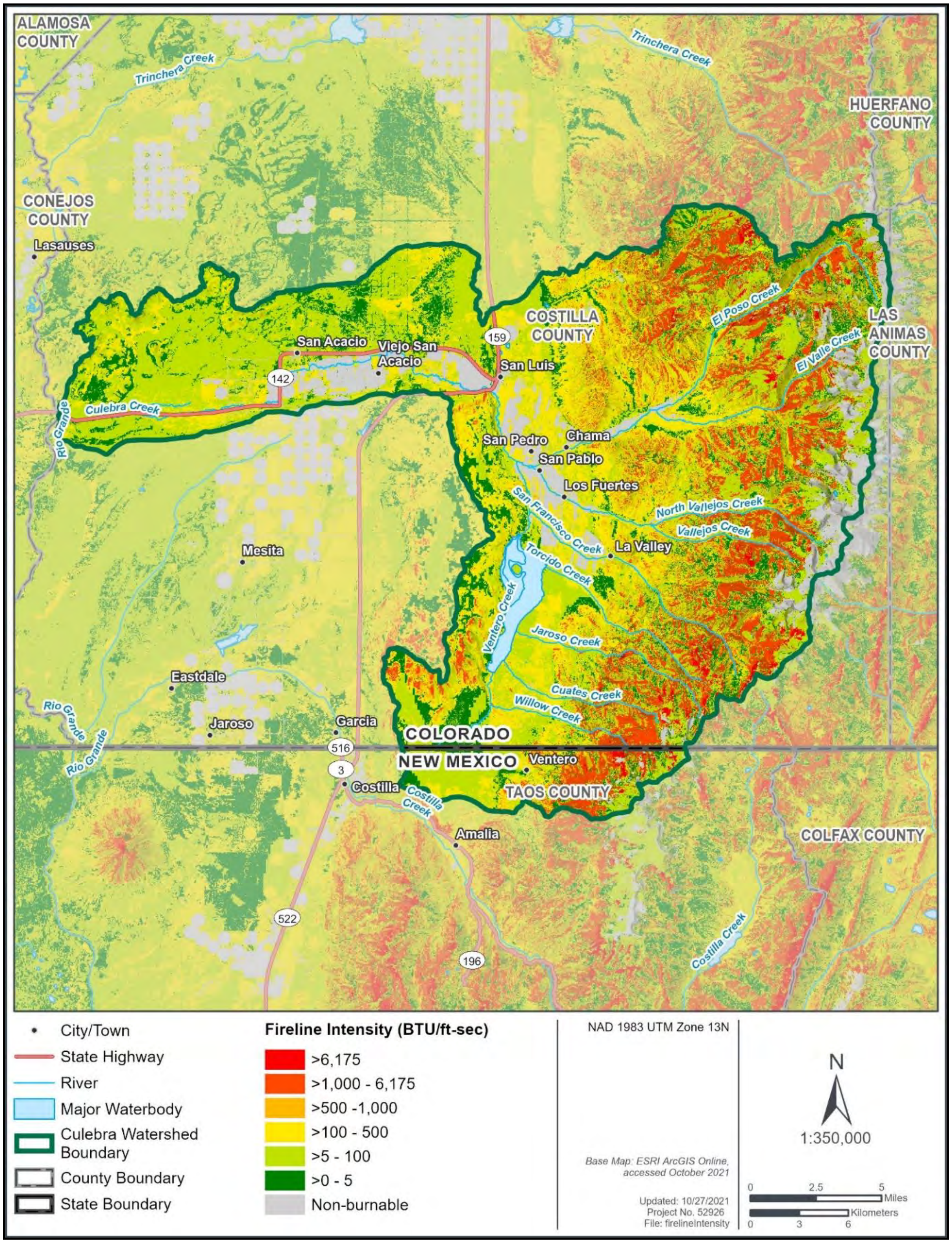


Figure 11-17 Modeled fireline intensity under existing fuel and weather conditions.

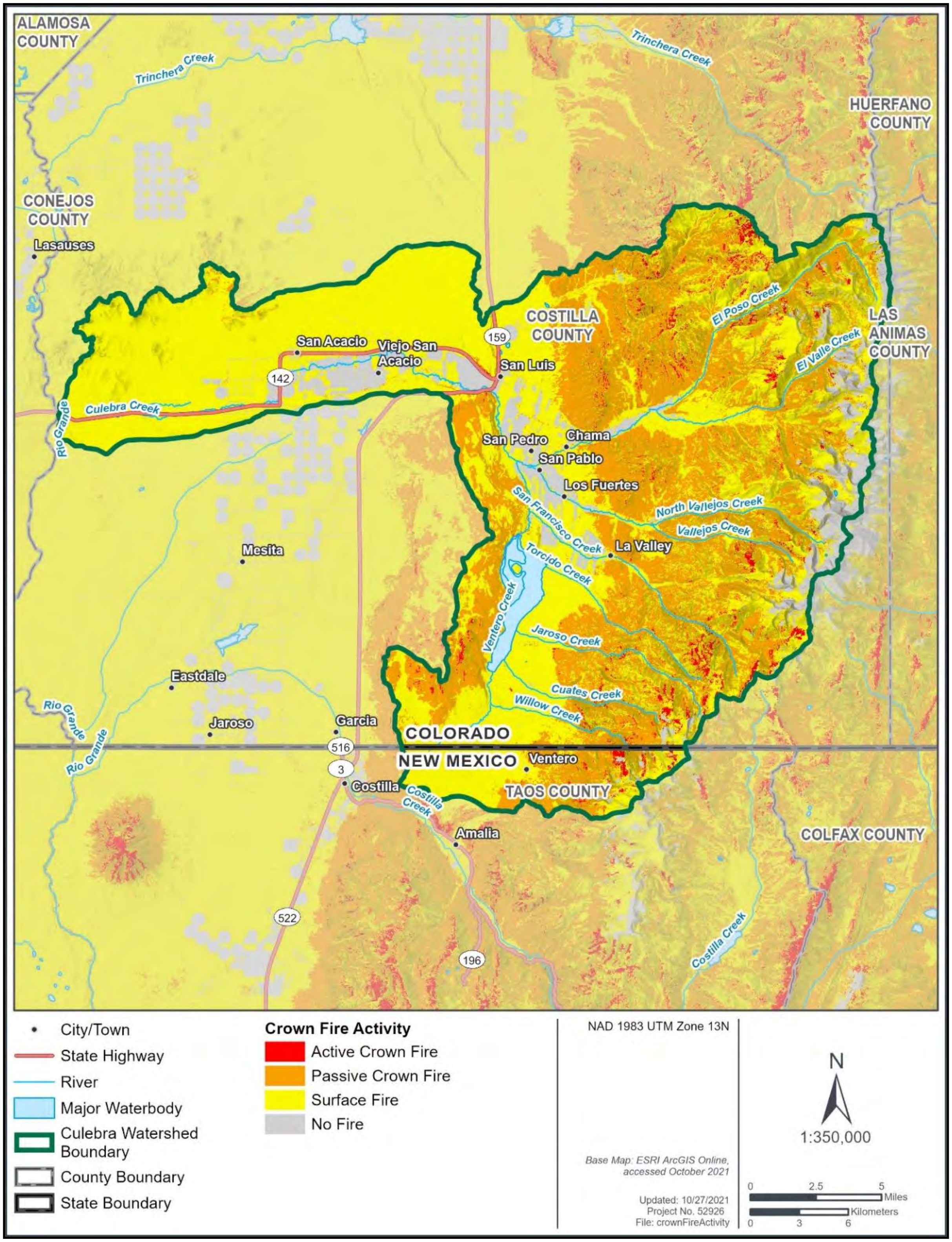


Figure 11-18 Modeled crown fire potential under existing fuel and weather conditions.

Rate of Spread

Figure 11-15 illustrates the rate of spread classifications for the analysis area. The rates of spread in the analysis area range from 0 chains/hour up to >150 chains/hour (one chain is approximately 66 feet and is a common measure in wildland firefighting). Low rates of spread are associated with timber-dominated areas or riparian areas, while moderate and high rates of spread are associated with grass and shrub fuels. Agricultural areas are modeled with a low rate of spread; however, these fuel types may also pose a severe hazard during certain times of the year (prior to harvest or following harvest when residual materials remain). Some areas of the WUI exhibit very steep slopes that can contribute to increased rates of spread and intense fire behavior (see Figure 11-19).

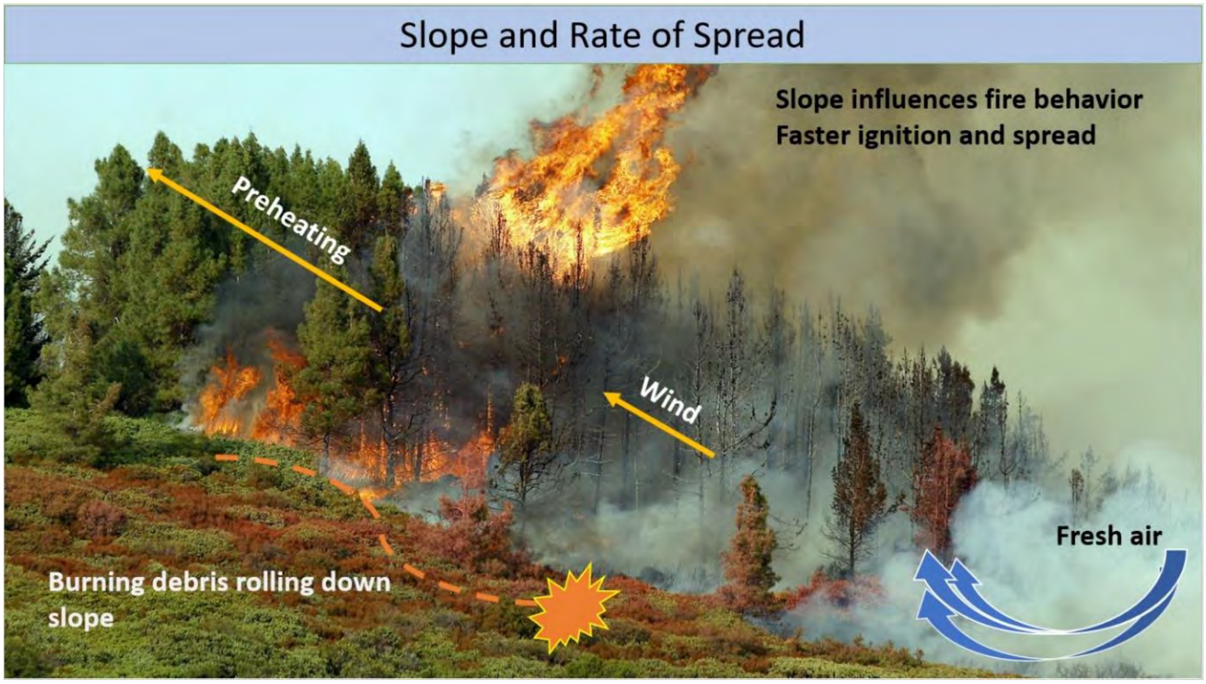


Figure 11-19 Impacts of topography on fire spread rates.

<u>Flame Length</u>

Figure 16 illustrates the flame length classifications for the analysis area. Flame lengths are determined by fuels, weather, and topography. Flame length is a particularly important component when assessing risk because it relates to potential crown fire (particularly important in timber areas) and suppression tactics. Direct attack by hand lines is usually limited to flame lengths less than 4 feet. In excess of 4 feet, indirect suppression is the dominant tactic. Suppression using engines and heavy equipment will move from direct to indirect with flame lengths in excess of 8 feet.

Flame lengths across the analysis area range from 0 to more than 25 feet. The highest flame lengths are associated with the timber fuels found in the upper watershed.

<u>Fireline Intensity</u>

Figure 11-17 illustrates the predicted fireline intensity throughout the analysis area. Fireline intensity describes the rate of energy released by the flaming front and is measured in British thermal units per foot, per second (Btu/ft/sec). This is a good measure of intensity and is used for planning suppression activities. The expected fireline intensity throughout the analysis area is similar in pattern to predicted flame length, as fireline intensity is a function of flame length. The pattern for fireline intensity is similar to flame length in that intensities range from low (less than 100 Btu/ft/sec) through moderate (100–1000 Btu/ft/sec) high and extreme intensity (greater than 1,000 Btu/ft/sec), which tend to be associated with areas dominated by tall shrub and timber fuel loads.

Crown Fire Potential

Figure 11-18 illustrates the range of projected crown fire activity from surface fire (in grass-dominated areas) to passive and active crown fire (in timber-dominated fuels).

11.3.6.8 Composite Hazard Assessment Model

The data layers described above contribute to the risk and hazard in the analysis area, as illustrated in Figure 11-20. To determine the overall risk and hazard across the UCW, an overlay model was used that combined all the previously described datasets. The Composite Risk/Hazard Assessment modeling approach uses a Weighted Sum Model, which "stacks" geographically aligned datasets and evaluates an output value derived from each cell value of the overlaid dataset in combination with the weighted assessment. In a Weighted Sum Model, the weighted values of each pixel from each parameter dataset are added together so that the resulting dataset contains pixels with summed values of all the parameters. This method ensures that the model resolution is maintained in the results and thus provides finer detail and range of values for denoting fire risk. Table 11-2 lists the individual datasets and the relative weights assigned within the modeling framework. Figure 11-20 illustrates the final composite risk/hazard assessment.

Table 11-2 Weights Assigned to Each Layer of the Composite Risk/Hazard Assessment Model.

Parameter	% Weight in the Model
Crown fire activity	10
Fireline intensity	20
Flame length	20
Rate of spread	10
Fire occurrence density	5
HVRAs	15
WUI	20

Based on Figure 11-20, the areas of greatest risk are located in the areas of timber fuels at mid- to high elevations. Riparian areas and lowland irrigated agricultural lands are classified as low risk due to the limited fire behavior expected in those fuel types. Grass and shrublands are classified as moderate risk, due in large part to the potential for rapid rates of spread in those fuels, in combination with the presence of values at risk in those woodland and transitional areas of the watershed. Due to the limited forest fuels at the highest elevations, and the distance from values at risk, the eastern portion of the watershed is classified as low risk.

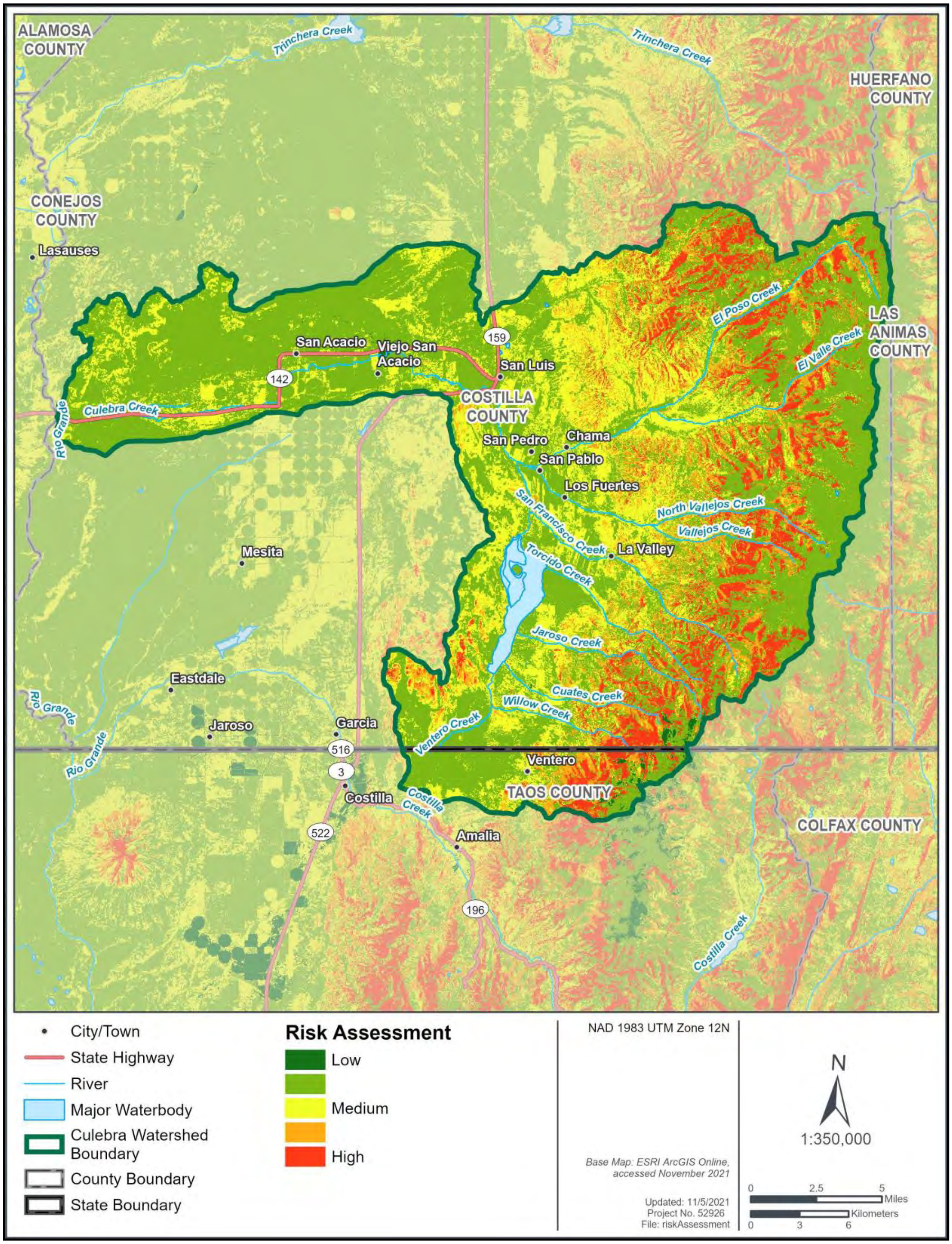


Figure 11-20 Composite risk/hazard assessment.

11.3.6.9 Influence of Climate Change

The long periods of drought that have been observed throughout the region, in combination with altered forest management practices and fire exclusion policies over the last century, have resulted in frequent landscape-level, high-severity fires that are beyond the range of natural variability within lower to mid-elevation ponderosa pine and mixed confider forests (Allen, et al., 2002; Covington & Moore, 1994). In the past few years, fires have grown to record sizes and are burning earlier, longer, hotter, and more intensely than they have in the past (Loehman, Flatley, Holsinger, & Thode, 2018; Westerling, Hidalgo, Cayan, & Swetnam, 2006; Westerling, Increasing western US forest wildfire activity: sensitivity to changes in timing of spring, 2016). According to the National Interagency Fire Center (NIFC), occurrence of catastrophic wildfires has greatly increased over the past 20 years. Westerling et al. (2006) claim that a study of large (>1,000 acres) wildfires throughout the western United States between 1970 and 2003 saw a pronounced increase in frequency of fire since the mid-1980s (1987–2003 fires were four times more frequent than the 1970–1986 average). The length of the fire season was also observed to increase by 78 days when comparing 1970–1986 to 1987–2003. An update to Westerling et al's. 2006 work found that the frequency of large wildfires has continued to increase with each decade since 1970 (Westerling 2016). Within just the past 10 years, a record number of acreages have burned, and numbers are continually getting larger (National Interagency Fire Center (NIFC), 2021). In 2019, 50,477 fires were reported nationwide, burning 4.7 million acres (NIFC 2021). With increased fires comes increased suppression costs; over the past decade, 2018 saw the highest suppression costs, with federal fires hitting $3,143,256,000 (NIFC 2021).

Periodic drought and intense rainfall patterns projected throughout the Southwest contribute to significantly diminished stream flow and drier surface conditions (Seager, et al., 2008), shifting the regional climate further toward aridity. These changes in relative humidity are blamed for many of the wildfire conditions observed today, as increased drying has led to an increase in days with high fire danger (Abatzoglou & Williams, 2016; Prein, Holland, Rasmussen, Clark, & Tye, 2016). In the forests of southern Colorado and northern New Mexico, total area burned and percent burned at high severity have continued to increase over the past three decades (Mueller, et al., 2020). Since ca. 2000, there has been a notable increase in annual area burned at high severity and a greater percent of fires are burning at high severity (Mueller, et al., 2020).

Drought conditions coupled with warmer temperatures, also called global-change-type droughts, increase water stress on vegetation (Breshears, et al., 2005) and decrease forest resilience to wildfire and other disturbance events. Advanced computer models are now making national-scale simulations of ecosystems, providing predictions of how fire regimes will change in the twenty-first century (Neilson, Lenihan, Drapek, & Bachelet, 2004). Western grasslands are predicted to undergo increased woody expansion of piñon-juniper associated with increased precipitation during typical wet seasons. Summer months are predicted to be hotter and longer contributing to increased fire risk (Neilson, Lenihan, Drapek, & Bachelet, 2004). The periodic drought and intense rainfall patterns that Gutzler (2013) and others (Alexander, et al., 2006; Gutzler & Robbins, 2011; Hurd & Coonrod, 2008) project for the region are expected to result in significantly diminished stream flow and drier surface conditions (Seager, et al., 2008), shifting the climate in the region further toward aridity. Under these greater climatic extremes, fire behavior is expected to become more erratic, with larger flame lengths, increased torching and crowning, and more rapid runs and blowups associated with extremely dry conditions (Brown, Hall, & Westerling, 2004). Extreme hot-arid climatic conditions can push forest ecosystems over a tipping point, or threshold, at which even small changes could reorganize ecosystem processes (Loehman, Flatley, Holsinger, & Thode, 2018). Dry forests already at the edge of their climatic tolerance are most likely to convert to non-forest systems (Millar & Stephenson, 2015; Stevens-Rumann, et al., 2018). In Loehman et al.'s (2018) study, shrubland ecosystems were identified as a stable alternative to forest systems. These findings are in agreement with observed shifts from ponderosa pine forests to pinyon-juniper woodlands as a result of global-change style drought conditions. These predicted and observed shifts will radically affect land management goals and strategies on landscapes in southern Colorado and New Mexico. Current strategies cannot prevent this ecosystem reorganization (Loehman, Flatley, Holsinger, & Thode, 2018). Rather, novel approaches must be used to manage for desired ecosystem conditions.

Although fire suppression is still aggressively practiced, fire management techniques are continually adapting and improving, especially in light of changing climate. Management of fire for resource objectives is an option for land managers. Due to scattered human developments (homes, ranches, and farms) and values (residential and commercial structures, historic and natural values) throughout the WUI, suppression in WUI areas will always have to be a priority. However, combining prescribed fire and managing wildland fire for resource objectives with effective fuels management and restoration techniques have been proven to help re-establish natural fire regimes and reduce the potential for catastrophic wildfires on public lands associated with heightened risk due to a warming climate. The use of prescribed fire on private land is a decision to be made by the landowner, and it is acknowledged that, given the prevailing drought, such a management technique may not always be feasible in the watershed.

11.3.6.10 Future Desired Conditions for Wildfire

Long-term management objectives related to fire are to create resilient landscapes across the watershed that are resilient to disturbance, including intense, uncharacteristically severe wildfire. Reaching these desired conditions involves building fire-adapted communities with residents who are able to live with fire and reintroducing fire to vegetation communities that are fire dependent. These desired conditions are supported at the state and federal level through the *Colorado Forest Action Plan* (CSFS 2020), which implements federal fire policy developed as part of the National Cohesive Wildland Fire Management Strategy (Cohesive Strategy; (Forests and Rangelands, 2014)). The Cohesive Strategy focuses on three goals: 1) restore and maintain resilient landscapes; 2) create fire-adapted communities; and 3) safe and effective fire response. The *Colorado Forest Action Plan* identifies several strategies for meeting the Cohesive Strategy goals in Colorado, as summarized below (Table 11-3). In order to align with state and federal direction for wildfire prevention and management, this report tiers some of the mitigation measures outlined in Section 11.6, with several of these statewide strategy goals. Since these strategies have been prioritized by the state and supported by land management agencies, whenever possible, stakeholders implementing projects for wildfire prevention in the watershed should align projects with these strategies to increase options for project funding.

Table 11-3 Goals and Strategies for Living with Fire in Colorado (Colorado Forest Action Plan, 2020)

Goal	Strategy	Approach
Promote community fire adaptation	Facilitate social community adjustments through a deeper understanding of living with wildfire	-Collaborate with land management agencies, fire protection districts, place-based collaboratives, and insurance organizations to promote fire-adapted concepts that lead to reduction of risk to communities. -Use existing programs and networks. -Realign community expectations before, during and after a wildfire. -Ensure that wildfire risk reduction information is current and incorporates the latest science. -Work with communities to improve the understanding of living in a fire-dependent environment. -Take advantage of current events.
	Enhance community wildfire risk reduction planning	-Support the development, revisions, and implementation of CWPPs. Integrate CWPPs with HMPs. -Maintain and enhance the Colorado Wildfire Risk Assessment to provide a consistent statewide risk assessment for risk-reduction planning efforts. -Promote place-based efforts for wildfire risk reduction activities. -Reduce structural ignitability; establish and enhance evacuation routes. -Enhance land use planning through adoption of building codes that address home ignition zone concepts. -Integrate post-fire recovery, smoke impacts, evacuation, and at-risk population considerations into CWPPs.
	Increase pace and scale of wildfire risk reduction efforts	-Coordinate fuels treatments at a scale and strategic value that will significantly reduce wildfire risk. -Support local funding solutions for wildfire risk reduction work. -Collaborate with local, state, and federal land management agencies, communities, and private landowners to link fuel treatment to increase effectiveness on a landscape scale.
Reduce the risk of uncharacteristic wildfire	Reduce the risk of long-term impacts of severe disturbances	-Alter forest structure or composition to reduce risk or severity of wildfire. -Collaborate with local, state, and federal land management agencies, communities, and private landowners to link fuel treatment to increase effectiveness on a landscape scale. -Promptly revegetate sites after disturbance with appropriate plant materials.
	Maintain and enhance species and structural diversity	-Promote diverse forest age classes where ecologically appropriate. -Maintain and restore diversity of native species. -Use fire as a tool, including prescribed fire and managed wildfire.
	Facilitate community adjustments pre- and post-disturbance through species transitions	-Favor or restore native species that are expected to be adapted to future conditions. -Guide changes in species composition at early stages of stand development. -Disfavor species that are distinctly maladapted. -Manage for species and genotypes with wide moisture and temperature tolerances.
Promote the role of fire in ecological processes	Sustain fundamental ecological functions	-Reduce impacts to soil and nutrient cycling. -Reduce competition for moisture, nutrients, and light. -Restore or maintain fire in fire-dependent ecosystems by using it as a tool to achieve species and structural diversity.
	Improve the understanding of the	- Increase diversity of partners engaged in the Colorado Prescribed Fire Council.

Goal	Strategy	Approach
	role fire plays in Colorado's ecosystems, including the need for using prescribed and managed wildfire as tools	- Increase outreach and education around fire's natural role in Colorado's ecosystems and the trade-offs of using prescribed fire versus wildfire smoke impacts.
	Increase the use of prescribed and managed wildfire	- Foster relationships among researchers, managers, practitioners, and emergency responders to facilitate knowledge transfer and resource sharing. - Integrate potential prescribed fire projects in planning efforts (e.g., forest management plans, CWPPs). - Identify areas to manage fire to reduce fuels and restore ecosystems. Coordinate with appropriate entities and integrate information into response plans and management actions.

Note: Adapted from Colorado State Forest Service (2020)

11.3.7 Flood Environment

Nationally, flooding accounts for roughly 75% of all natural disasters. Comparably, it is also one of the most destructive hazards that can occur within the entirety of Costilla County (CCMAC 2015). The terrain and drainages surrounding the watershed are the main factors contributing to the likelihood of flooding in the area. The watershed has mountainous terrain to the east consisting of steep slopes and prominent valleys that flow down to the low-lying farm and grasslands to the west.

11.3.7.1 Main Waterways in the Upper Culebra Watershed

There are two major drainages within the boundaries of the UCW. Due to the presence of these two drainages within town limits, the Town of San Luis has the highest potential for flood losses in all of Costilla County (CCMAC 2015). The first major drainage in the watershed is Culebra Creek, which flows out of the Sangre de Cristo Mountains, past the Town of San Luis to the south, and into the Rio Grande River to the west of the watershed. Because the creek's headwaters are located in the steep terrain of the mountain range, the potential for floods to occur following a significant rainfall event or spring snowmelt is high. Another major drainage in the watershed is Rito Seco Creek, which, like Culebra Creek, flows out of the mountainous terrain to the east and into the grasslands. Rito Seco Creek flows through San Luis to the west and connects to Culebra Creek near the intersection of Highway 159 and County Road 19. There are numerous other drainages and acequias throughout the watershed that could contribute to flood conditions in other areas in the event of significant rainfall or snowmelt.

Other natural hazards can increase the likelihood of flood conditions within the watershed. Severe thunderstorms can produce high levels of rain in short periods of time that can lead to flooding. Heavy snowfall followed by warmer weather can lead to rapid snowmelt and flooding. Lastly, drought can also create conditions in which flood chances are higher when followed by a period of severe rainfall (CCMAC 2015).

11.3.7.2 Critical Infrastructure at Risk

The majority of the Town of San Luis lies in a floodplain, and the sections that are most susceptible to flood damage are those lying adjacent to Rito Seco Creek. Although development in the floodplain of Culebra Creek and Rito Seco Creek is minimal, it is estimated that $24,471,923 in residential and commercial improvements are at risk within the town. The HMP details the critical facilities within the Town of San Luis that have been developed in floodplain areas. These facilities are shown in Table 11-4 below (CCMAC 2015).

Table 11-4 Critical Facilities in Floodplain Areas within the Town of San Luis.

Jurisdiction	Type of Facility	Facility Name
Costilla County	Rescue	Costilla County Sheriff's Office
Costilla County	Rescue	San Luis Fire Station
Costilla County	Rescue	Costilla County EMS
Costilla County	Government	Administrative Building
Costilla County	Government	Elected Officials Building
Costilla County	Government	Department of Social Services
Costilla County	Government	Department of Public Health
Costilla County	Government	Costilla County Courts
Costilla County	Government	Costilla County Library
Town of San Luis	Government	San Luis Town Hall
Town of San Luis	School	San Luis Headstart

Source: CCMAC (2015)

11.3.7.3 Costilla County Resilience

Flood data for Costilla County was gathered and is available to view through the Colorado Hazard Mapping and Risk MAP Portal (coloradohazardmapping.com). In April 2021, the Costilla County Resilience meeting was held to discuss recently approved floodplain mapping and risk, as well as mitigation strategies. Mitigation strategies identified in this meeting were ideas such as capital improvement projects, zoning changes, mitigation plans, and acquisition projects.

Three main objectives were achieved in the MAP process: 1) identify flood hazards (Mapping), 2) assess risk (Assessment), and 3) create community mitigation plans and actions (Planning). This process focused on two waterways within the UCW: Rito Seco Creek and Culebra Creek. Results for the floodplain mapping effort show that much of the Town of San Luis lies in flood-prone areas. Additionally, most other communities around the watershed are shown to have buildings and infrastructure within the boundaries of mapped floodplain.

11.4 Methods and Results

11.4.1 Stakeholder Meetings

An assessment of ranch emergency management capabilities and concerns was completed by convening ranch representatives during a meeting on June 17, 2021. Emergency management protocols and capabilities for emergency response vary between the private ranches within the analysis area. The following sections are a summary of current capacities and protocols.

11.4.1.1 Trinchera Ranch

Internal capacity:

- Internal emergency management points of contact identified.
- Ongoing coordination and communication with the county, but no official pre-season coordination.
- Established relationships with local fire department and coordinate access for emergencies.

- Established relationships with regional and state emergency management (DFPC).
- Established procedures for responding to smoke reports.
- Established procedures for fire bans (campfires and agricultural burning).
- Have staff trained and certified in wildland fire response.
- Have limited wildland fire suppression apparatus and equipment staged on the ranch.

Emergency management concerns:

- Slow emergency response times by local resources due to distance to fire stations.
- Data gaps for small fires throughout the watershed.
- Lightning ignitions due to high elevation.
- Restrictions on camping placed to reduce potential human ignitions but not well enforced by sheriff's department.
- Economically, communities would be impacted heavily by another natural disaster.
- Ranch sign-in is required, but not always good radio communication to know where people are located for potential evacuation.
- Limited notification systems beyond reverse 911.
- Beetle infestation and tree mortality is increasing wildfire hazard throughout portions of the ranch.
- WUI areas adjacent to ranch are a concern for values at risk, evacuation, and ignitions.

11.4.1.2 Cielo Vista Ranch

Internal capacity:

- Do not have emergency management or fire plan on the ranch.
- Currently respond to most wildfires on the ranch with ranch staff.
- Have established relationships with local fire department and have coordinated access for emergencies (for example, fire departments all have keys to property).
- Do not have wildland fire–trained and certified staff.
- Do not have wildland fire–specific apparatus or equipment on the ranch.

Emergency management concerns:

- Roads not well maintained, and many roads would not accommodate emergency vehicles.
- Fire departments and county do not have appropriate equipment to access some areas of the ranch.
- Existing mapping not accurate for representation of navigable roads.
- Limited water supply for suppression.
- Concerned about availability and response of federal resources due to lack of structures and other built values at risk.

- Concerned about fire response times due to scale of property. Initial attack may be slow; fire would not be contained at a small size.
- Ranch depends on community for alerting fire responders to smoke.
- Concerned about unauthorized camping, campfires, and fireworks. July 4–related ignitions have occurred. Fire departments have not been able to stage resources.
- There are cameras on the gates of Cielo Vista, it is possible to monitor who is on the ranch, but if there was a need for evacuation, no way to know where people are located.

Limited notification systems beyond reverse 911.

Control of people during an incident is a concern; people can block roadways and prevent movement of emergency responders.

Need livestock evacuation planning to move or shelter cattle in event of emergency.

- Need improved signage for exits to help fire responders navigate.

11.4.1.3 Dos Hermanos Ranch

<u>Internal capacity:</u>

- Do not have an emergency management or fire plan.
- Have considered use of prescribed fire but have not acted yet.

Do not have wildland fire trained and certified staff.

Do not have wildland fire–specific apparatus or equipment on the ranch.

- Currently respond to most wildfires on the ranch with ranch staff. Limited fire history, have been able to catch some high-elevation fires before they grow in size.

Closest fire stations include departments in New Mexico. Limited coordination with New Mexico departments.

Have good relationships with local fire department and have coordinated access for emergencies (for example, fire departments all have keys to property).

<u>Emergency management concerns:</u>

- Roads to access higher elevations limited and not well maintained, and many would not accommodate emergency vehicles.
- Fire departments and county do not have appropriate equipment to access some areas of ranch.
- Existing mapping is not an accurate representation of navigable roads.
- Water supply for suppression limited.
- Concerned about availability and response of federal resources due to lack of structures and other built values at risk.
- Concerned about fire response times due to the scale of property. Initial attack may be slow, and fire would not be contained at a small size.
- Depend on the community for alerting fire responders to smoke.

11.4.2 Community Hazard Assessments

The assessments were conducted in June 2021 using the National Fire Protection Association (NFPA) Wildland Fire Risk and Hazard Severity Form 1144 (Appendix B). This form is based on the NFPA Standard for Reducing Structure Ignition Hazards from Wildland Fire 2013 Edition (National Fire Protection Association, 2021). The NFPA standard focuses on individual structure hazards and requires a spatial approach to assessing and mitigating wildfire hazards around existing structures. It also includes ignition-resistant requirements for new construction and is used by planners and developers in areas that are threatened by wildfire and is commonly applied in the development of Firewise Communities (for more information, see www.firewise.org).

Each area was rated based on conditions within the community and immediately surrounding structures, including access, adjacent vegetation (fuels), defensible space, adjacent topography, roof and building characteristics, available fire protection, and placement of utilities. Where a range of conditions was less easily parsed out, a range of values was assigned on a single assessment form. Each score was given a corresponding adjective rating of low, moderate, or high. The purpose of the community WUI assessment and subsequent hazard ratings is to identify fire hazard and risks and prioritize areas requiring mitigation and more detailed planning. These assessments should not be seen as tactical pre-suppression or triage plans. The community assessment helps to drive the recommendations for mitigation of structural ignitability, community preparedness, and public education. The assessment also helps to prioritize areas for fuels treatment based on the hazard rating.

The Communities At Risk hazard ratings from the community assessment and the GIS hazard/risk assessment are provided in Table 11-5. This table also includes a summary of the positive and negative attributes of a community as they relate to wildfire risk. Full NFPA assessment results are provided in Appendix B.

11.4.2.1 Assessment Summary

Across the watershed, common hazard themes were identified during the community hazard assessments. Overall, building and roofing materials were the most common negative factor affecting ratings from community to community. Building and roofing materials across communities range from highly combustible, wood shingles to mixed and fire resistive materials. The vast majority of deck and fencing materials are rated as combustible with some of these structures being located close to slopes. Around structures in these communities, defensible space is limited and considered difficult to maintain. These defensible spaces tend to be overgrown with vegetation such as grasses, weeds, and shrubs. The infrastructure throughout the watershed is deficient, as well. Nearly all communities within the watershed are lacking a suitable water source. Ten out of the 11 communities identified did not have a local water source. Furthermore, all communities in the watershed have utilities, such as gas and electricity, placed aboveground. Lastly, although most communities have wide, surfaced roads with low to moderate grades, some roads in and around communities are unsurfaced with steep grades and washboard conditions (Figure 11-21 Example of poor road grade and surface conditions that would slow evacuation and ingress by emergency vehicles.) that would make access difficult in the event of an emergency.

Figure 11-21 Example of poor road grade and surface conditions that would slow evacuation and ingress by emergency vehicles.

Table 11-5 Summary of NFPA 1144 Assessments of Wildfire Hazard for Communities Identified Throughout the Analysis Area.

Community Polygon	**Fire Department**	**CAR Rating (based on NFPA 1144)**	**Positive**	**Negative**
Poso	Costilla County Fire Protection District – San Luis Station 1	230 Extreme	• Ingress/egress: two or more roads in and out • Road width: moderately wide roads with good access • Fire access: good access with turnaround • Street signs: visible and somewhat reflective, poor condition • Previous fire occurrence: low • Separation of adjacent structures: good, large plots • Weather: potential for severe weather is low	• Road conditions: unsurfaced roads with moderate grade, rough condition • Vegetation: timber with grass and shrub understory • Defensible space: limited clearance around homes • Building construction: mixed; combustible • Deck and fencing: combustible materials, close to slope • Water source: none • Utility placement: both gas and electric are aboveground • Topography: steep slopes near structures, some homes mid-slope • Roofing materials: mixed materials but mostly wood • Organized response: fire department in neighboring community, over 5 miles

Community Polygon	Fire Department	CAR Rating (based on NFPA 1144)	Positive	Negative
Melby Ranch/ Wild Horse Mesa	Costilla County Fire Protection District – San Luis Station 1	200 Extreme	• Fire access: good access with turnaround • Street signs: visible and somewhat reflective • Previous fire occurrence: low • Separation of adjacent structures: good, large plots • Weather: potential for severe weather is low	• Ingress/egress: one major route in and out • Road width: narrow roads • Road conditions: unsurfaced roads with steep grades, washboard conditions, confusing orientations • Vegetation: thick shrubs • Defensible space: limited clearance around homes • Building construction: mixed; fire resistive • Deck and fencing: combustible materials, close to slope • Water source: none • Utility placement: both gas and electric are aboveground • Topography: steep slopes near structures, some homes mid-slope • Roofing materials: mixed materials • Organized response: fire department in neighboring community, over 5 miles

Community Polygon	Fire Department	CAR Rating (based on NFPA 1144)	Positive	Negative
Canyon	Costilla County Fire Protection District – San Luis Station 1	152 Extreme	• Road width: moderately wide roads • Street signs: visible and somewhat reflective • Slope: low slope and minimal topography • Previous fire occurrence: low • Separation of adjacent structures: good, large plots • Weather: potential for severe weather is low • Topography: closer to mountains but still in valley	• Ingress/egress: one major route in and out • Road conditions: unsurfaced roads with low grade • Fire access: minimal access with no turnaround • Vegetation type: mostly grass • Defensible space: limited clearance around homes; many structures close together • Building construction: fire resistive; mixture of building types and roofing materials • Deck and fencing: combustible materials • Water source: none • Utility placement: gas and electric both above ground • Organized response: fire department in neighboring community, over 5 miles

Community Polygon	Fire Department	CAR Rating (based on NFPA 1144)	Positive	Negative
Ventero	Costilla County Fire Protection District – San Luis Station 1	138 Extreme	• Ingress/egress: two or more roads in and out • Road width: moderately wide roads with good access • Road conditions: surfaced roads with moderate grade • Fire access: good access with turnaround • Street signs: visible and somewhat reflective • Topography: moderate slop near structures • Previous fire occurrence: low • Separation of adjacent structures: good, large plots • Weather: potential for severe weather is low	• Vegetation type: mostly grass • Defensible space: limited clearance around homes • Building construction: mixed; fire resistive • Deck and fencing: combustible materials • Water source: none • Utility placement: gas and electric are aboveground • Roofing materials: mixed materials • Organized response: fire department in neighboring community, over 5 miles

Community Polygon	Fire Department	CAR Rating (based on NFPA 1144)	Positive	Negative
Chama	Costilla County Fire Protection District – San Luis Station 1	136 Extreme	• Ingress/egress: two or more roads in and out • Road width: moderately wide roads • Fire access: good access with turnaround • Street signs: visible and somewhat reflective • Slope: low slope • Defensible space: larger lots, structures are farther apart than in other neighborhoods • Previous fire occurrence: low • Separation of adjacent structures: good, large plots • Weather: potential for severe weather is low • Organized response: fire department close to community	• Road conditions: unsurfaced roads with low grade • Building construction: mixed; fire resistive • Deck and fencing: combustible materials • Water source: none • Utility placement: gas and electric are aboveground • Roofing materials: mixture of materials • Vegetation: grass and grass shrubs

Community Polygon	Fire Department	CAR Rating (based on NFPA 1144)	Positive	Negative
San Acacio	Costilla County Fire Protection District – San Luis Station 1	130 Extreme	• Ingress/egress: two or more roads in and out • Road width: wide roads with good access • Road conditions: surfaced main road with low grade, unsurfaced community roads • Fire access: good access with turnaround • Street signs: visible and somewhat reflective • Slope: low slope and minimal topography • Defensible space: larger lots with open vegetation • Previous fire occurrence: low • Separation of adjacent structures: good, large plots • Weather: potential for severe weather is low • Organized response: fire department close to community	• Vegetation type: mostly grass, lots of weeds • Building construction: highly combustible; wood common in community • Deck and fencing: combustible materials • Roofing materials: highly combustible, dilapidated wooden materials • Water source: none • Utility placement: gas and electric are above ground • Organized response: fire department in neighboring community, over 5 miles

Community Polygon	Fire Department	CAR Rating (based on NFPA 1144)	Positive	Negative
La Valley	Costilla County Fire Protection District – San Luis Station 1	128 Extreme	• Ingress/egress: two or more roads in and out • Road width: moderately wide roads • Fire access: good access with turnaround • Street signs: visible and somewhat reflective • Slope: low slope and minimal topography • Previous fire occurrence: low • Separation of adjacent structures: good, large plots • Weather: potential for severe weather is low • Organized response: fire department close to community	• Road conditions: unsurfaced roads with low grade • Vegetation type: mostly grass, lots of weeds • Defensible space: limited clearance around homes • Building construction: mixed, fire resistive • Deck and fencing: combustible materials • Water source: none • Utility placement: gas and electric are aboveground • Organized response: fire department in neighboring community, over 5 miles • Roofing materials: mixture of materials

Community Polygon	Fire Department	CAR Rating (based on NFPA 1144)	Positive	Negative
Los Fuertes	Costilla County Fire Protection District – San Luis Station 1	124 Extreme	• Ingress/egress: two or more roads in and out • Road width: moderately wide roads with good access • Road conditions: surfaced roads with low grade • Fire access: good access with turnaround • Street signs: visible and somewhat reflective • Slope: low slope • Previous fire occurrence: low • Separation of adjacent structures: good, large plots • Weather: potential for severe weather is low	• Defensible space: limited clearance around homes • Vegetation type: mostly grass • Building construction: mixed; fire resistive • Deck and fencing: combustible materials • Water source: none • Utility placement: gas and electric are aboveground • Roofing materials: mixed materials • Costilla County Fire Protection District – San Luis Station 1

Community Polygon	Fire Department	CAR Rating (based on NFPA 1144)	Positive	Negative
San Luis	Costilla County Fire Protection District – San Luis Station 1	96 High	• Ingress/egress: two or more roads in and out • Road width: wide roads with good access • Road conditions: surfaced roads with low grade • Fire access: good access with turnaround • Street signs: visible and reflective • Slope: mostly flat with some topography in vicinity • Organized response: fire department close to community • Previous fire occurrence: low • Separation of adjacent structures: good, large plots; agricultural land provides good separation between homes • Weather: potential for severe weather is low • Vegetation: agricultural and sparse vegetation	• Defensible space: limited, harder to maintain defensible space • Building construction: fire resistive; mixture of building types and roofing materials • Deck and fencing: combustible materials • Water source: water tank • Utility placement: gas and electric are aboveground

Community Polygon	Fire Department	CAR Rating (based on NFPA 1144)	Positive	Negative
San Pablo	Costilla County Fire Protection District – San Luis Station 1	96 High	• Ingress/egress: two or more roads in and out • Road width: wide roads with good access • Road conditions: surfaced roads with low grade • Fire access: good access with turnaround • Street signs: visible and somewhat reflective • Slope: low slope and minimal topography • Defensible space: larger lots with open vegetation • Previous fire occurrence: low • Separation of adjacent structures: good, large plots; agricultural land provides good separation between homes • Weather: potential for severe weather is low • Organized response: fire department close to community • Vegetation: agricultural	• Building construction: fire resistive; mixture of building types and roofing materials • Deck and fencing: combustible materials • Water source: none • Utility placement: gas and electric both above ground

Community Polygon	Fire Department	CAR Rating (based on NFPA 1144)	Positive	Negative
San Pedro	Costilla County Fire Protection District – San Luis Station 1	96 High	• Ingress/egress: two or more roads in and out • Road width: wide roads with good access • Road conditions: surfaced roads with low grade • Fire access: good access with turnaround • Street signs: visible and somewhat reflective • Slope: low slope and minimal topography • Defensible space: larger lots with open vegetation • Previous fire occurrence: low • Separation of adjacent structures: good, large plots; agricultural land provides good separation between homes • Weather: potential for severe weather is low • Organized response: fire department close to community • Vegetation: agricultural	• Building construction: fire resistive; mixture of building types and roofing materials • Deck and fencing: combustible materials • Water source: none • Utility placement: gas and electric aboveground

11.5 Mitigation Strategies

Based on the analysis described above, this section outlines various mitigation strategies that may be applied across the watershed to address the natural hazards that threaten communities and values at risk. Mitigation actions shown in italics are taken from the 2015 HMP.

11.5.1 General Emergency Management Strategies

11.5.1.1 Organization and Preparedness

There is a vast amount of data available in the county to support emergency management and hazard mitigation. This data has been gathered through various historical assessments and desktop analysis of the UCW, including this assessment. However, much of this data is in a format that is inaccessible to emergency management staff and agencies. The following strategies are suggested to enhance the use of this information to inform planning:

1. The county should develop an online web mapping application that could house the various data layers and associated meta data that have been collected historically and as part of this assessment. This platform should be made available to all stakeholders in land management and emergency management to support spatial planning for all hazards.
2. Digitize critical data layers to support planning and response. A significant portion of the data gathered in the watershed is not in a spatial format. Funding should be sought to digitize critical data layers. For safety and emergency management, the following datasets should be included:
    a. Hydrant locations
    b. Other water locations: draft sites, dry hydrant locations, etc.
    c. Water protection areas
    d. Road conditions, including data on surface type to inform maintenance needs

11.5.1.2 Stakeholder Communications

Enhancements in communication between the stakeholders (especially ranch owners) and emergency management personnel will increase community preparedness and resilience to all natural hazards.

1. It is recommended that the ranch managers and the county Department of Emergency Management seek a medium through which communications can be made for seasonal preparations or in the event of an emergency (for example, pre-season in-person planning meetings between relevant stakeholders throughout the watershed). These in-person meetings could facilitate collaboration and the sharing of knowledge or plans that would give other relevant stakeholders a better understanding of what other stakeholders have in mind or their plans for that year. These meetings would also provide opportunities for prioritizing and leveraging funding across property boundaries when seeking grant funding for project implementation that could be applied watershed-wide.
2. Following these pre-season meetings, other reliable forms of communication should be considered for regular and emergency communication. Internet-based resources, telephones, and radio resources could be used interchangeably and as the situation dictates. Using a single radio frequency for communications between ranches and emergency management could improve communications.

11.5.1.3 Public Education and Outreach

The 2015 HMP recognizes the need to enhance community outreach related to hazards and emergency management. Building upon strategies identified in the HMP, additional actions for improving public education and outreach regarding natural hazards and mitigation could include the following:

1) Enhancing public notifications. The ideal warning system would ensure that all potential victims are alerted to an incipient disaster as quickly as possible, irrespective of the time or their location. Present systems may

alert people unnecessarily and others may not reach those who are asleep or out of range of electronic media, which is common in the watershed. Options might include:

a) Public and private partnerships to develop and install technologies that are accessible to and reach the most residents in the community

b) Using special tone alerts such as those provided by National Oceanic and Atmospheric Administration (NOAA) weather radios that activate receivers only in the area of the natural hazard

c) Using systems that trigger alerts (for example, installing precipitation gages upstream of flood areas to trigger early flood warnings directly to residents at risk)

d) The following public notification measures have been employed by Huerfano County and would be suitable for Costilla County:

    i) CodeRED (OnSolve), an emergency notification service that notifies residents through phone calls, text messages, emails, and social media (OnSolve, 2021)

    ii) FEMA's Integrated Public Alert and Warning System (IPAWS). IPAWS is FEMA'S national system for local alerting that provides emergency information to the public through various means, including mobile phone notifications, radio and television alerts, internet notifications, and alerts through NOAA's weather radio (Federal Emergency Management Agency [FEMA], 2021)

    iii) Specific Area Message Encoding (SAME) weather radios. SAME weather radios allow listeners to receive emergency alerts specific to their county of residence. Weather information and hazardous weather events are broadcasted 24 hours a day, 7 days a week (National Oceanic and Atmospheric Administration, 2021a)

    iv) SKYWARN from the National Weather Service. SKYWARN is a program that trains local citizens to become severe weather spotters. The volunteers assist in keeping their local communities safe by providing timely and accurate reports of severe weather to the National Weather Service (National Oceanic and Atmospheric Administration, 2021b).

3. Use multimedia methods for engaging the public. Different residents respond to different forms of communications, so developing a tool set of outreach materials and methods is critical to reaching the broadest section of the community. For example, use a range of social media, news media, radio, mailings, and fliers posted in public places; conduct focus group meetings for churches, community groups, schools etc.; and conduct in-person and virtual workshops and recorded information webinars.

4. Increase use of community volunteer groups, including SLV Red Cross, the Community Emergency Response Team, and search and rescue organizations to provide outreach to the community on emergency management, preparedness, and mitigation measures. These groups are made up of members of the community, and educational messaging coming directly from trusted friends and neighbors could increase acceptance and mobilize mitigation actions.

5. Revise the Costilla County CWPP with a heightened focus on community engagement by using online platforms for developing and sharing plan content and encouraging interaction with plan deliverables (i.e., hubs and story maps). Work with the county Department of Emergency Management to integrate the development of the CWPP with the update of the county HMP to create one comprehensive planning document.

11.5.1.4 Continuity of Operations

- Use and implement the Costilla County Continuity of Government Plan (annex to the CCEOP).

- Utilities (e.g.., electric, gas, telecommunications) are vulnerable to failure during an emergency, but they are also critical to response and recovery. Involve utilities in emergency planning by integrating their natural hazards planning in county and watershed emergency planning efforts and inviting representatives to partake in planning efforts such as HMPs, EOPs and CWPPs.

- Improve telecommunications during incidents: Establish pre-event agreements between the county and telecommunications to facilitate emergency assistance and restoration of service during and following an event. For example, establish agreements for provision of satellite communications links in an emergency.

11.5.2 Fire Mitigation Strategies

Wildfire is the single most likely and potentially most dangerous natural hazard that can be expected within the watershed. Costilla County has a history of wildfire occurrence with one of the most devastating fires in recent state history, the Spring Creek fire, having occurred nearby. Most of the communities within the watershed were rated as high or extreme during the community hazard assessments. Due to this, wildfire mitigation has been prioritized for the purposes of this document. The following mitigation strategies tier to strategies in the *Colorado Forest Action Plan* (CSFS 2020; in bold text below and in Table 11-6) and align with mitigation measures identified in the county HMP:

1) Collaborate with land management agencies, fire protection districts, place-based collaboratives, and insurance organizations to promote fire-adapted concepts that lead to reduction of risk to communities.
    a) As emphasized in other sections, collaboration and communication are key in emergency management. No one agency or organization should be left to handle an emergency situation on their own. It is recommended that collaborative channels be created between relevant organizations within the watershed for the promotion of fire adaptation practices that will ultimately reduce the risk of wildfire to communities.
    b) During the pre-fire season, fire responders should convene to discuss the outlook for the fire season, identify potential resource shortages, and make plans for any areas that might create operational hazards for fire crews.
    c) Consider use of mock incidents to address concerns for slow response times to some areas of private land where road access and maintenance may impede travel by emergency vehicles.
    d) Work with local insurance agents/brokers to identify measures that homeowners can take to mitigate hazards and risks on their property and assess feasibility of instituting an incentive program for reduced premiums for residents who carry out mitigation actions.
    e) Identify all agencies responsible for notifying community members of wildfire hazards and coordinate the implementation of evacuation plans among those agencies (as described in the HMP- Action # 6 [CCMAC 2015]).
    f) Initiate wildfire pre-hazard awareness program which can use GIS mapping of risk of natural hazards (as described in the HMP- Action # 7 [CCMAC 2015]).
2) Facilitate social community adjustments through a deeper understanding of living with wildfire.

Community education, another key and common theme throughout this report, is again recommended here in the wildfire section. Although the communities within the watershed are familiar with fire and wildfire outcomes, education will play an important role in facilitating some of the other strategies recommended here.

    a) Work with community members on situational awareness related to wildfire risk and hazard. Use products from this assessment and others (i.e., the Colorado Forest Atlas) to demonstrate the wildfire risk posed to communities in the watershed and encourage greater preparedness for wildfire.
    b) Initiate an education campaign:

i) Hold an annual wildfire preparedness event prior to fire season, providing educational resources, interaction with the fire department, green waste disposal options (stage chippers at the event), Smokey Bear themes, Firewise resources, and provide opportunities for residents to ask questions of experts in fire prevention.

ii) Partner with local businesses to provide resources to residents. For example, connecting residents with contractors who can provide defensible space services. Offer an incentive to residents to carry out actions on their home (e.g., raffle for free defensible treatment or installation of vent covers to harden home against embers).

iii) Distribution of information using various approaches (e.g., fliers, social media, news media, focus groups, community groups, etc.)

iv) Provide online resource (hub or story map) for a one-stop-shop for wildfire education and resources, tailored to the community.

v) Provide templates for a family preparedness plan to cater to all hazards.

c) Work with community members on fire prevention measures, specifically safety and fire prevention related to use of fireworks in forested areas (Table 11-6). This is a concern for the stakeholders in the upper watershed and something that could be addressed with an education campaign.

3) Support the development, revisions, and implementation of CWPPs. Integrate CWPPs with HMPs.

a) Costilla County adopted its CWPP in 2008. It is recommended that this plan be reviewed and revised as appropriate since the plan is now over 13 years old. It is also recommended that this and future CWPPs be integrated into any relevant HMPs to support cohesive planning.

b) Use the NFPA 1144 assessment results (see Appendix 12-B) and fire behavior risk and hazard analysis to create the risk assessment section of the revised CWPP. Use hazard ratings and findings from these assessments to develop community-specific recommendations to reduce risk (e.g., delineate fuel treatments along roads identified to have high fuel hazards and slow response times; focus public education efforts on communities shown to have construction-related hazards; or identify locations to stage water resources for communities that have limited water for suppression).

c) Consider the development of an online CWPP in order to make the document more accessible to the community and increase engagement opportunities.

d) Pursue funding to support development of the CWPP.

Table 11-6 Action Items for Homeowners to Reduce Structural Ignitability.

Low- or no-cost investment (<$50)	Regularly check fire extinguishers and have a 100-foot hose available to wet perimeter.
	Maintain defensible space for 30 feet around home. Work with neighbors to provide adequate fuels mitigation in the event of overlapping property boundaries.
	Make every effort to keep lawn mowed and green during fire season.
	Screen vents with non-combustible meshing; mesh opening should not exceed nominal ¼-inch size.
	Ensure that house numbers are easily viewed from the street.
	Keep wooden fence perimeters free of dry leaves and combustible materials. If possible, noncombustible material should link the house and the fence.
	Keep gutters free of vegetative litter. Gutters can act as collecting points for fire brands and ashes.
	Store combustible materials (e.g., firewood, propane tanks, grills) away from the house; if available, store in a shed.
	Clear out materials from under decks and/or stacked against the structure. Stack firewood at least 30 feet from the home, if possible.
	Reduce your workload by considering local weather patterns. Because prevailing winds in the area are often from the west-southwest, consider mitigating hazards on the west corner of your property first, then work around to cover the entire area.
	Seal up any gaps in roofing material and enclose gaps that could allow fire brands to enter under the roof tiles or shingles.
	Remove flammable materials from around propane tanks.
Minimal investment (<$250)	When landscaping in the home ignition zone (HIZ) (approximately 30 feet around the property), select noncombustible plants, lawn furniture, and landscaping material. Combustible plant material such as junipers and ornamental conifers should be pruned and kept away from siding. If possible, trees should be planted in islands and no closer than 10 feet to the house. Tree crowns should have a spacing of at least 18 feet when within the HIZ. Vegetation at the greatest distance from the structure and closest to wildland fuels should be carefully trimmed and pruned to reduce ladder fuels, and density should be reduced with approximately 6-foot spacing between tree crowns.
	Box in eaves, attic ventilation, and crawl spaces with non-combustible material.
	Work on mitigating hazards on adjoining structures. Sheds, garages, barns, etc., can act as ignition points to your home.
	Enclose open space underneath permanently located manufactured homes using non-combustible skirting.
	Clear and thin vegetation along driveways and access roads so they can act as a safe evacuation route and allow emergency responders to access the home.
	Purchase or use a NOAA weather alert radio to hear fire weather announcements.

Moderate to high investment (>$250)	Construct a noncombustible wall or barrier between your property and wildland fuels. This could be particularly effective at mitigating the effect of radiant heat and fire spread where 30 feet of defensible space is not available around the structure.
	Construct or retrofit overhanging projections with heavy timber that is less combustible.
	Replace exterior windows and skylights with tempered glass or multilayered glazed panels.
	Invest in updating your roof to noncombustible construction. Look for materials that have been treated and given a fire-resistant roof classification of Class A. Wood materials are highly combustible unless they have gone through a pressure-impregnation fire-retardant process.
	Construct a gravel turnaround in your driveway to improve access and mobilization of fire responders.
	Treat construction materials with fire-retardant chemicals.
	Install a roof irrigation system.
	Replace wood or vinyl siding with nonflammable materials.
	Relocate propane tanks underground.

4) Reduce structural ignitability; establish and enhance evacuation routes.

Community hazard assessments showed that most homes across the watershed are at high risk of ignition in the event of a fire. Furthermore, many roads across the watershed are unsurfaced and have generally unfavorable conditions for emergency management. It is recommended that improvements be made to structures and roadways across the watershed to create more fire-adapted communities.

a) Use a roads analysis to determine priority roads requiring mitigation measures. Focus efforts on primary arteries to facilitate evacuation and address areas where steep grade, narrow road width, poor surfacing, and roadside vegetation might impede ingress and egress.

b) Work with the community on understanding emergency response to avoid situations where responders are impeded due to the presence of residents observing the scene.

c) Increase the community/jurisdiction's wildfire mitigation and prevention activities and participation in the Firewise and associate programs (as described in the HMP-Action # 10 [CCMAC 2015]).

d) As part of the education campaign described in Item 2 above, provide specific actions that homeowners can take to reduce potential structural ignitability. The tables below outline actions that can be taken by homeowners, categorized by approximate cost.

5) Coordinate fuels treatments at a scale and strategic value that will significantly reduce wildfire risk.

a) As is evident on Trinchera Ranch, fuels treatments can range in scale and type, and can even be developed into marketable products. It is recommended that similar fuels treatments be considered and implemented across the entirety of the watershed in a more coordinated manner. See forest health recommendations in Section 10.9. Focus should be placed on areas of concern identified based on fire behavior analysis and suppression difficulty data gathered via the Colorado Forest Atlas. These areas are delineated in Figure 11-23 below.

   b) Investigate the Colorado State Forest Service's assistance programs, publicize these programs and use existing wildfire maps to prioritize analysis areas in the county. Educate local residents in priority areas to reduce wildfire hazards (as described in the HMP- Action # 9 [CCMAC 2015]). Figure 11-23 delineates areas of concern based on hazardous fuels. These locations should be prioritized as landowners implement thinning treatments. Various techniques may be applied, as described in Chapter 10, section 10.8.

6) Use fire as a tool, including prescribed fire and managed wildfire.
   a) As discussed previously, community education will be an important aspect in making this recommendation successful. Given that this ecosystem is fire dependent, prescribed fire can be a great tool in fostering healthy forests and grasslands that are less prone to the larger, more intense fires seen in recent years. Figure 11-23 identifies areas where prescribed fire may be used as a tool for improving forest health and for reducing hazardous fuels.
   b) Prescribed fire, for instance, is often a contentious topic but also a greatly beneficial practice. Community support for this practice is crucial, and community education is the key to creating support.

7) Reduce the risk of long-term impacts of severe disturbances.
   a) Develop a watershed protection plan that includes measures to alleviate potential post-fire impacts, including debris flows, erosion, sedimentation and contamination of water bodies. Use debris flow modeling developed in Chapter 12 to identify priority areas for treatment to mitigate post-fire effects. Overlay data for known watershed protection areas (values at risk) that provide community water supply (Figure 11-11). Layer debris flow modeling and values at risk with areas modeled to experience extreme fire behavior to prioritize areas of concern in the upper watershed and inform treatment actions.

Figure 11-22 Fire station in the project area.

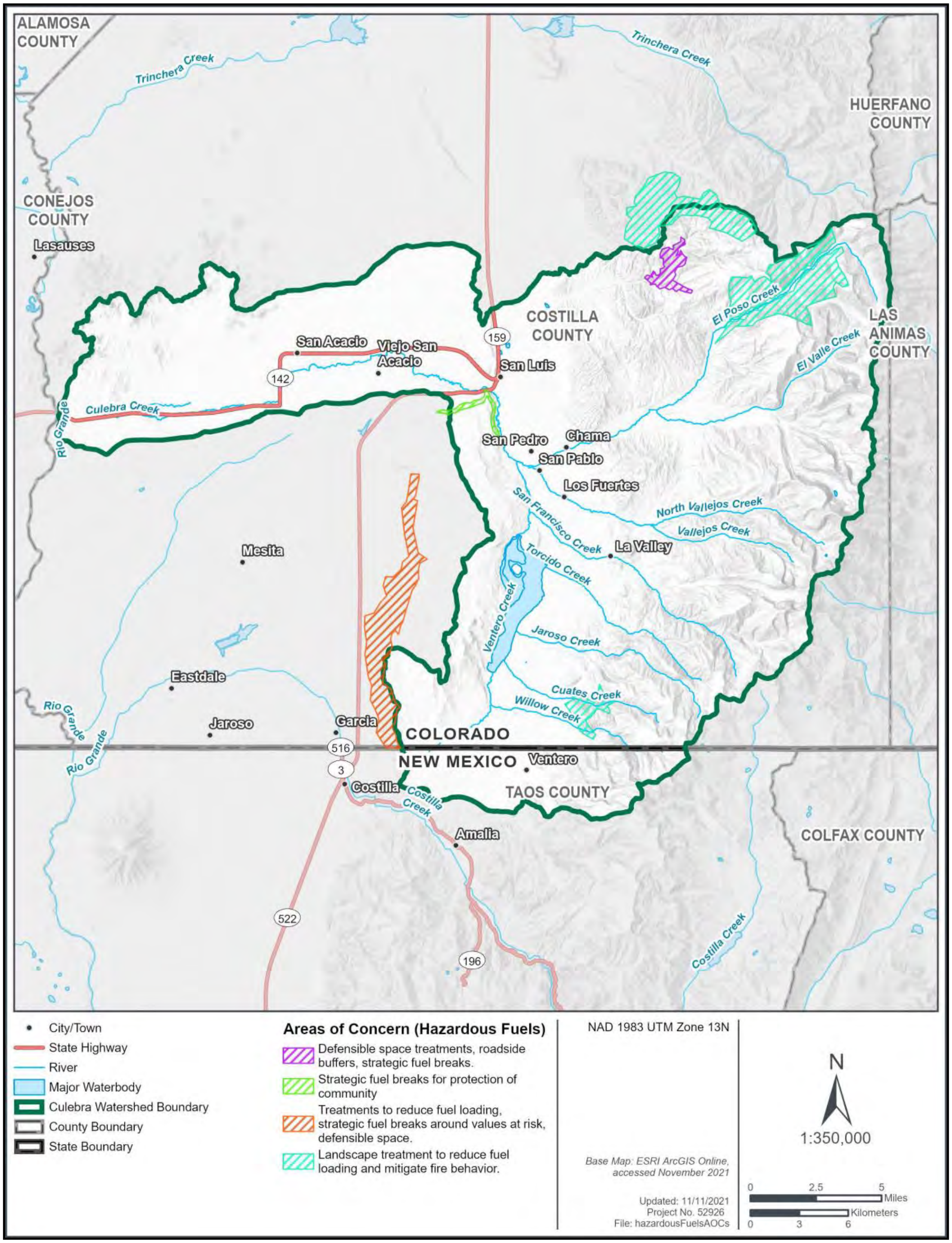


Figure 11-23 Areas of concern (hazardous fuels).

11.5.3 Flood Mitigation Strategies

Flood mitigation strategies recommended in this section are aligned with local HMPs and EOPs adopted by Costilla County. In addition to aligning with these local plans, these strategies are also aligned with FEMA-recommended mitigation strategies. Based on an analysis of flood hazards within the watershed, the following mitigation strategies are either currently in use or recommended to protect communities from potential floods while creating *resiliency* in the event a flood disaster occurs.

11.5.3.1 Current Flood Mitigation Strategies

Costilla County has implemented regulations as part of their comprehensive plan and land use code that govern the development of new subdivisions on areas designated as floodplain overlay districts. These districts are zoned areas containing floodplain hazards and any land adjacent to a water course that could be inundated by a 100-year flood. The purpose of these districts is to minimize flood losses and regulate the development within designated floodplain areas. The subdivision of land that has the potential for flood hazard is prohibited unless measures are taken to overcome those hazards. Regulations require that developers obtain a special use permit from the county. Additionally, developers must install appropriate drainage facilities and design water and sewer systems in a way that minimizes the impact of flood damage.

Prior hazard assessments conducted by Costilla County are summarized and planned for in the county HMP. The HMP is aligned with the county's comprehensive plan and seeks to curb development in flood-prone areas. Costilla County's HMP includes two goals that strive to protect county communities from flood hazards. Goal 3 of the HMP is to "Increase the communities' floodplain management activities and participation in the National Flood Insurance Program (NFIP)." Goal 8 of the HMP is to "Limit floodplain development to maintain public safety and protect the integrity of Riparian Corridors" (CCMAC 2015).

11.5.3.2 Recommended Flood Mitigation Strategies

To complement the strategies currently employed by the county, the following strategies are also recommended:

1) Develop a community warning system and response plan
   a) As with other natural hazards covered in this document, a community warning system is recommended as one of the first steps in preparing the communities within the watershed for potential hazards. A community warning system would allow residents time to make preparations before an impending flood. To supplement a warning system, it is also recommended that a flood response plan be devised to support local and vulnerable populations in the event of a flood (FEMA 2013).
   b) *Pursue opportunities for funding and technical assistance to develop watershed flood hazard reduction plans (as described in the HMP – Action #11 [CCMAC 2015]).*
   c) *Review the Costilla County jurisdictions' floodplain ordinances that are outdated. Revise each year to ensure ongoing compliance with NFIP standards (as described in the HMP – Action #13 [CCMAC 2015]).*
   d) *Review the Town of San Luis' floodplain ordinances that are outdated. Revise each year to ensure ongoing compliance with NFIP standards (as described in the HMP for San Luis – Action #2 [CCMAC 2015]).*
2) Create natural areas that serve multiple purposes

a) Natural areas can be designed to serve several purposes, such as stormwater detention and mitigation. Proper siting and construction would allow for runoff to be detained in a natural area rather than resulting in residential or commercial flooding. In addition to this functional benefit, wildlife and residents can also benefit from the creation of a natural area or open space. Wildlife can use the resulting wetlands or open space for forage and habitat. Watershed residents could use the area for recreation.

3) Tax adjustments for development
   a) To supplement the floodplain ordinances and development limitations goals adopted by Costilla County, tax adjustments to discourage development within flood-prone areas is recommended. While the ordinances rely on improvements being made if a developer chooses to develop in a floodplain, these improvements will not guarantee that residential flooding will not occur. Tax adjustments that discourage any development in floodplain areas, however, could completely prevent development in these areas and, ultimately, the flooding of residential properties.
4) Improvements to streams with flood potential

This final series of recommendations could be the most direct flood mitigation strategies. A series of improvements could be made to the streams themselves that would strategically alter streamflow during a high-precipitation or snowmelt event.

a) The first recommendation would be to plant vegetative cover along stream banks to not only reduce erosion but also to absorb some of the heavier streamflow that can occur during a storm or snowmelt event (FEMA 2013). Furthermore, this vegetation would also serve as habitat for a variety of species. Native riparian vegetation found around the watershed could be employed for this purpose.
b) The next recommendation is to make channel alterations to streams to improve and control flow. Altering a stream channel changes the way in which the water flows through the channel and can provide a more specific type of mitigation (FEMA 2013).
c) The final recommendation is to create small reservoirs on streams that are mostly likely to flood or could cause the most damage in the event of a flood. This recommendation would also provide a mitigation strategy to be used in the event of drought as described above. Creating a dam and reservoir system would allow another form of direct control over flow in a period of high precipitation or snowmelt. As a stream begins to increase flow, the dam could be employed to slow the flow of water and, thus, increasing the level of the associated reservoir (FEMA 2013). Water from the reservoir could then be employed during periods of drought to assist with agricultural production. It is also recommended that best practices be used when considering this recommendation so that vulnerable species are not negatively affected by the creation of a dam and reservoir. Available water rights and change of place and use would be necessary to implement such a plan.
d) Identify specific locations where Road and Bridge maintenance equipment can be used to reduce localized flooding problems by improving and maintaining storm water infrastructure throughout the area (as described in the HMP – Action #12 [CCMAC 2015]).

11.6 General Disaster Mitigation Strategies

11.6.1 Introduction

The natural hazards discussed in this section are taken from the Costilla County HMP (CCMAC 2015). Although wildfire hazard and flood hazard are discussed in separate sections, drought hazard, severe winter storm hazard, and severe thunderstorms and hailstorms will be covered in this section. These hazards are rated from moderate to significant according to the Costilla County HMP. This document seeks to assess these hazards at the watershed level and make recommendations in a manner that could overlap between potential hazards. Ideally, some mitigation strategies will not only work for one hazard but could also be useful for others. Priority for these mitigation strategies is given to the protection of local residences and the critical infrastructure required to ensure safety across the watershed.

11.6.2 Drought

The Costilla County HMP hazard assessment identifies the risk of drought across the county as significant. This rating comes from the considerable presence of agricultural activity in the area that is the base of the local economy. Drought, however, can come in three forms. Meteorological drought is a diversion from the usual precipitation levels for an area. Hydrologic drought is a deficit in water levels of lakes, reservoirs, streams, or rivers. Lastly, agricultural drought is a soil moisture insufficiency that adversely affects plant and crop life. An overall drought event that leads to a decrease in health, well-being, quality of life, or economic efficiency can lead to a socioeconomic drought (CCMAC 2015).

Drought conditions change from year to year and are difficult to predict. Planning for drought events is an important aspect of mitigating their effects. The following strategies are recommended for drought mitigation in the watershed:

1) Monitor drought and local water supply.
    a) Seeing a drought coming before it happens is the first line of defense in drought preparation. Through drought monitoring, the public can make necessary adjustments to ensure that impacts are minimized. Additionally, ensuring that the local water supply is adequate and free of damage can save water supply in the long term (FEMA 2013).
2) Educate the public on drought and what they can do to lighten the burden on the watershed.
    a) Drought education is another vital aspect of drought preparation. Educate the public on water-saving techniques. Water conservation should be required during a drought to lessen the impacts on the watershed as a whole. Simple steps such as installing low-flow shower heads, adjusting sprinklers, or turning off water when it is not needed are recommended. Ensure that farmers are implementing soil and water conservation techniques. It also important to ensure that overgrazing is not occurring within the watershed, especially during a drought (Federal Emergency Management Agency [FEMA], 2013).
3) Work collaboratively with water rights holders to voluntarily augment water supply through mechanisms to transfer to areas of shortage during droughts (Colorado Water Conservation Board Department of Natural Resources [CWCB], 2010).
4) Create one to two micro-reservoirs in the area to be used in the event of drought.
    a) This could be accomplished through the formation of a compact between landowners and water rights holders. Additionally, it is advised that a stakeholder task force be created to make decisions on when to use the stored water. For distribution of resources, it is recommended to build one reservoir off Rito Seco Creek and one reservoir off Culebra Creek. Cielo Vista Ranch, being the largest landowner in the UCW, could potentially have the reservoirs as projects on the ranch. Development of this type of storage would be contingent upon available water rights and appropriate change of use.

5) Contact Natural Resources Conservation Service regarding opportunities for technical assistance and financial assistance for drought preparedness and response (as described in the HMP – Action #1 [CCMAC 2015]).
6) Initiate appropriate drought preparation actions as specified in the Costilla County Drought Preparedness Action Guide (as described in the HMP – Action #2 [CCMAC 2015]).

11.6.3 Severe Winter Storms

Severe winter storms can affect the watershed in many ways. Transportation is one of the hardest-hit sectors during a winter storm. Road conditions can dramatically worsen, leading to road closures, public transportation shutdowns, and impacts to local businesses if the event persists. Utility infrastructure such as power or water lines can also be heavily impacted by winter storms. These impacts can cause frozen water lines and ruptures or electric power line snaps. These utility failures can lead to flooding and power outages or heat loss.

To ensure the effects of a severe winter storm are minimized, the following recommendations are suggested:

1) Create a plan to contact and assist vulnerable populations.
    a) As there are many dispersed and elderly residents within the watershed, outreach to notify and assist these populations during a severe winter storm is recommended. A recommendation for assisting these populations is to create storm shelter/heating centers where these residents can come if a storm causes a loss of heat at their residence (CCMAC 2015).
2) Protect critical infrastructure
    a) Water and power infrastructure are at a higher vulnerability during severe snow storms. In the event of an approaching storm, prepare critical water infrastructure by conducting inspections to check for leaks and ensure that the infrastructure is functioning properly. To better protect power infrastructure, it is recommended that overhead power lines be buried. Not only will this protect these lines in the case of wildfire, but it will also ensure that lines are not loaded with ice, which can lead to line snaps and power outages (FEMA 2013).
3) Mitigate effects to transportation infrastructure and services
    a) Before the storm arrives at the watershed, ensure that road clearing services are prepared to keep roads free of snow and debris. To aid in keeping roads clear of snow, it is recommended that “living snow fences” be planted along areas with the tendency for snow drifts or along sections of critical roadway (FEMA 2013).
4) Coordinate among all agencies to ensure rapid and comprehensive dissemination the necessary information and of response operations (as described in the HMP – Action #3 [CCMAC 2015]).

11.6.4 Severe Thunderstorms and Hailstorms

Severe thunderstorms have the ability to bring hail, heavy rain, high wind, and lightning. These occurrences can lead to a loss of critical infrastructure, flooding, and structural damage. Mitigation for severe thunderstorms and hailstorms can be conducted in conjunction with mitigation for some of the other natural hazards mentioned elsewhere in this document.

1) Create a community notification system and response plan

   a) Community outreach in the event of an impending storm could be a great benefit to those with inadequate accommodation. Since severe thunderstorms and hailstorms can lead to secondary natural hazards, residents must be notified and prepared. A notification system can give residents the time they need to make adjustments to their housing and prepare for potential damage.
2) Protect critical infrastructure
   a) To better protect power infrastructure, it is recommended that overhead power lines be buried. Just as in the case of wildfire or a severe winter storm, burying overhead power lines can also protect them against high winds and hail (FEMA 2013).
3) Adopt building codes for wind and hail and retrofit existing residences
   a) As development increases around the watershed, it is important to adopt and enforce building codes that shield new development from damage from wind and hail. These codes could function in tandem with existing county ordinances on development in floodplain areas. For existing housing within the watershed, improvements to windows and roofing, or reinforcing garage doors, can be helpful in reducing potential damage (FEMA 2013).
4) Create a community storm shelter
   a) A storm shelter that also functions as a heating center could provide necessary assistance to vulnerable populations in the event of an oncoming severe storm. During an emergency, the Costilla County Human Services Department is responsible for providing sheltering services (CCDEM 2021), in conjunction with the Red Cross. Such a shelter could be located at the school in San Luis and could be officially delineated as an emergency shelter in the EOP. Alternative shelters should also be delineated to provide contingencies.

11.7 Conclusion

The Upper Culebra Watershed is an area with a rich history and an array of values worth protecting. It is also an area with great potential for damage due to a number of natural hazards discussed throughout this report. While some hazards can be short-lived and only lead to minor damage, other hazards have the potential to drastically alter the landscape and associated values found throughout the watershed. This document was designed to review these values and the conditions in which they are currently in with the ultimate goal of providing specialized mitigation strategies that will improve upon current conditions. While the strategies discussed above are by no means exhaustive, they were designed to align with existing plans and policies found in Costilla County, State of Colorado, and federal safety and emergency management guidebooks or plans. In doing so, the authors of this report seek to foster an environment of collaboration for planning managers at all levels.

Chapter 12. Post-Wildfire Debris Flow Potential

Author: Tailwater Limited

12.1 Introduction

Post-fire debris flows are some of the most dangerous post-fire hazards in the United States (U.S. Geological Survey, n.d.). As wildfire size and intensity have increased across the western United States, the risks associated with debris flow are increasing. Wildfires increase debris flow risk by removing vegetation and ground cover that absorbs precipitation, alters the soil's absorption capacity, and decreases surface roughness (National Weather Service, August 2015). Post wildfire debris flows become a risk when these hazards intersect with development and other related infrastructure (Cannon & DeGraff, 2009). This effort of pre-wildfire planning is to reduce the risk of post-fire debris flow damage and loss by identifying areas of potential post-fire debris flows and assets at risk within these areas. Direct risks associated with debris-flows include infrastructure loss, habitat loss, and access loss in some areas. Additionally, indirect risks arise due to the large quantities of sediments transported by these debris' flows, resulting in an increased risk of future flooding.

12.1.1 Goals and Objectives

The purpose of this exercise is to identify areas at-risk of debris-flow, at-risk infrastructure, and areas where land management decisions may reduce future risk of debris flow from encroachment.

Goal 1. Identify areas within the Culebra Basin at risk of post-fire debris flow.

Goals	Objectives
Goal 1 Identify areas within the Culebra Basin at risk of post-fire debris flow.	*Objective 1.1* Identify a post-wildfire debris flow model that can be run with available datasets. *Objective 1.2* Map third-order watershed debris flow risk. Objective 1.3 Provide digital mapping for finer scale evaluation.

12.2 Methods

12.2.1 Identify areas with a high probability of post-wildfire of debris-flows

Post-fire debris flow mechanisms are extremely complex, and thus a probabilistic approach is relied on to determine debris flow risk. The risk of a post-fire debris flow has been related to physical factors such as soil type, burn intensity, topography, and rainfall intensity. Debris flow modeling quickly becomes highly complex, and as such, regression models provide the most cost-effective approach to modeling these complex problems. Cannon and others (2010) have compiled data from numerous fires across the western United States and evaluated critical parameters associated with basins that experienced and those basins that did not experience post-fire debris flows. This pre-wildfire evaluation of post-fire debris-flow risk is estimated based on a set of regression equations developed by Cannon and others (2010, p. model A). Elliot and others have outlined the methods used in this study (2012).

This approach was selected due to the simplified model inputs related to burn severity which is not available in the planning stage (pre-wildfire). For pre-fire risk, tree and shrub cover was used in place of the percentage of area burned at moderate to high severity. The estimates of debris flow are point estimates.

Debris flow probability was calculated using the following equation from Cannon and others (Cannon, et al., Predicting the probability and volume of postwildfire debris flows in the intermountain western United States, 2010):

$$P = e^x/(1 + e^x)$$

Where,

P is the probability of debris-flow occurrence in fractional form, and

$$x = -0.7 + 0.03(\%SG30) - 1.6(R) + 0.06(\%AB) + 0.07(I) + 0.2(\%C) - 0.4(LL),$$

where,

- $\%SG30$ is the percentage of the watershed area with slopes equal to or greater than 30 percent;
- R is the watershed ruggedness, calculated as the change in watershed elevation divided by the square root of the watershed area;
- $\%AB$ is the percentage of watershed area burned at moderate to high severity;
- I is the average storm intensity (in millimeters per hour);
- $\%C$ is the clay content of the soil (in percent);
- And LL is the liquid limit of the soil (percentage of soil moisture by weight), which is the water content at which a soil changes from a plastic to a liquid state (in percent).

A description of each of the data inputs required to evaluate the regression equation are described below.

- $\%SG30$ – Percentage of the watershed with slopes equal to or greater than 30 percent was calculated from a slope raster generated from the USGS 10m DEM, then converted to a binary 10m raster with 1 equal to a slope greater than or equal to 30 percent and 0 for areas with a slope less than 30 percent. A map showing the processed slope raster is shown in Appendix A – Model Inputs, Figure 12-40.
- R – Watershed Ruggedness is calculated as maximum elevation from the watershed, as calculated from the TauDEM D8FlowPathExtreemUp algorithm, minus the watershed outlet elevation divided by the drainage area calculated from TauDEM (Tarboton, Dash, & Sazib, October 2015). A map showing the watershed ruggedness by reach outlet is shown in Appendix A – Model Inputs, Figure 12-40.
- $\%AB$ – Percentage of watershed area burned at moderate to high severity utilized the surrogate parameter- the percentage of watershed area covered in shrubs or trees as determined from the National Land Cover Dataset ((U. S. Geological Survey, 2019)). A map showing the tree and shrub cover extracted from the NLCD is shown in Appendix A – Model Inputs. The Tree and Shrub layer includes the 41, 42, 4, and 52, vegetation classes. This approach is similar to the approach taken by Elliot and others (2012). A map showing tree and shrub areas is shown in Appendix A – Model Inputs, Figure 12-40.

- I – Average storm intensity was developed by taking the watershed area-weighted precipitation values from the NOAA Atlas 14 coverage for the 2-, 5-, 10-,25-,50-, and 100-year 60-minute rainfall coverage. Data was converted from thousandths of inches to millimeters and re-sampled and aligned to the 10m DEM for this application (Office of Water Prediction(OWP), 2017). A map showing each return interval storm extracted from the NOAA 14 Atlas is shown in Appendix A – Model Inputs, Figure 12-39.
- $\%C$ – Percent Clay was extracted from the STATSGO dataset and converted to a 10-meter raster (Schawarz & Alexander, 1995). A map of the percent clay raster derived from the STATSGO dataset is shown in Appendix A – Model Inputs, Figure 12-40.
- LL – Liquid Limit was extracted from the STATSGO dataset and converted to a 10-meter raster for the analysis (Schawarz & Alexander, 1995). A map of the liquid limit as derived from the STATSGO dataset is shown in Appendix A – Model Inputs, Figure 12-40.

Watershed area-weighted raster datasets for %SG30, % A.B., I, %C, and L.L. were calculated for each 10-meter pixel within the study reach. These rasters provide an average value for contributing drainage area for each of the parameters.

Results from the model were masked to include only areas greater than 0.01 km^2 up to 103 km^2.

12.2.2 Reduce future risk of debris flow hazards

High debris flow hazard areas are delineated and evaluated to determine the resources at risk, including identifiable structures, public and critical transportation networks, and water resources infrastructure, including diversions and water/wastewater treatment plants. Infrastructure within the watershed was classified as part of the Infrastructure Assessment task.

Debris flow sediments occur within the stream corridor between the transport zone and the deposition zone (Figure 4-8). To Identify and delineate the probable debris flow areas, a Flow-R model of the basin was developed. This model utilizes empirical modeling techniques to identify areas that are susceptible to debris flow runout. The Modified Holmgren method was selected due to minimal, available, input requirements, robustness, and performance when modeling depositional features such as alluvial fans. Input parameters were selected to be generally conservative and could be further refined based on regional calibrations.

A slope of 15 degrees with tree or shrub coverage was used as a conservative estimate of source areas. The slope was determined from data from Horton and others (2008), Heinimann (1998), and Rickenmann and Zimmermann (1993), as presented in Horton and others (2013). This assumption has naturally overestimated the potential source areas where contributing drainage areas are small. For planning, no limit was placed on the upslope contributing drainage area, and no adjustments were made for surface curvature, which could be used to reduce potential source areas.

Source Raster = (Tree or Shrub > 0)x(Slope > 15°)

Within the direction algorithm, the flow direction exponent of 4 was selected based on suggestions from Claessens and others (2005), and DH of 0 was selected because the 10m resolution DEM was used and is considered sufficiently smooth for regional-scale modeling

(Horton, Jaboyedoff, Rudaz, & Zimmermann, 2013). The persistence algorithm selected was weighted, and the weighted parameter was set to default.

The friction model is used to determine the distance the debris flow may travel, which is based on the debris flow travel angle in the simplified friction-limited model; the travel angle was set to 11 degrees as recommended for coarse- and medium-grained debris flows (Horton, Jaboyedoff, Rudaz, & Zimmermann, 2013). A maximum debris flow velocity of 15 m/s was implemented to reduce excessive runout in overly steep catchments. The travel angle and maximum velocity parameters were selected to be conservative estimates and increase the area modeled as susceptible to debris flows.

12.3 Results

The debris flow probability models were developed for each drainage area using raster calculation and are available for the entire watershed within the appropriate drainage area range. The debris flow probabilities were qualitatively ranked to provide a relative comparison of the results within the basin. These results are summarized in Table 12-1. The results for third-order outlets by HUC 12 are summarized in Table 12-2 and illustrated within this report (Figure 12-1 through Figure 12-4). For specific locations, such as specific road crossings, the raster should be utilized. The results are correlated with the stream network that is generated from the 10-meter dem, and as such, professional judgment may be necessary for determining risks below flat areas and alluvial fans. The results do not account for upstream landscape factors that may reduce debris flow risk.

Table 12-1 Model output to debris flow risk.

Probability	Debris Flow Risk
0 – 0.25	Not mapped
0.50 – 0.75	Low debris flow risk
0.50 – 0.75	Moderate debris flow risk
0.75 – 1.0	High debris flow risk areas

Relative debris flow volumes for each third-order watershed are presented in the figures and divided into quartiles for the model results. These values are shown to give a relative ranking for the assessment of probability versus volume.

12.3.1 Cerritos Canal

Cerritos Canal is in the lower watershed and is generally associated with lower slopes. The risk of debris flows from high-frequency storm events is generally low, with the risk being highest from the San Luis Hills. The debris flow volume is highest near the lower end of Cerritos Canal but is also associated with a lower debris flow probability (CE-5 and CE-7). The location and modeled debris flow probabilities for all outlets within this HUC 12 are listed in Table 12-2. Outlets with debris flow probability greater than 0.25 are shown along with relative debris flow volumes for the 1-, 2-, 5-, and 10-yr storms in Figure 12-1, Figure 12-2, Figure 12-3, and Figure 12-4.

Table 12-2 Post-wildfire debris flow probabilities for third-order watershed outlets within the Cerritos Canal HUC12.

Label	Outlet point location		Debris flow probability			
	Latitude	Longitude	1-yr	2-yr	5-yr	10-yr
Cerritos Canal						
CE-1	4115533	440094	0.01	0.02	0.03	0.04
CE-2	4119453	447474	0.03	0.03	0.05	0.07
CE-3	4119343	448224	0.03	0.03	0.05	0.07
CE-4	4119323	448304	0.03	0.03	0.05	0.07
CE-5	4119463	447464	0.14	0.17	0.25	0.33
CE-6	4121293	449314	0.14	0.17	0.25	0.33
CE-7	4120303	448374	0.14	0.17	0.25	0.33
CE-8	4121703	449674	0.14	0.18	0.26	0.34
CE-9	4121933	450084	0.17	0.21	0.29	0.38
CE-10	4122313	452674	0.19	0.23	0.33	0.42
CE-11	4122113	453114	0.20	0.25	0.35	0.45
CE-12	4122053	454084	0.22	0.27	0.37	0.47
CE-13	4122043	454184	0.23	0.28	0.38	0.48
CE-14	4116193	441014	0.23	0.28	0.37	0.46
CE-15	4121963	454694	0.23	0.28	0.38	0.48
CE-16	4121683	456044	0.23	0.28	0.39	0.49
CE-17	4121893	455034	0.23	0.28	0.39	0.49
CE-18	4119673	442264	0.27	0.32	0.42	0.51
CE-19	4119623	442214	0.30	0.35	0.46	0.55
CE-20	4117143	441484	0.33	0.39	0.49	0.58

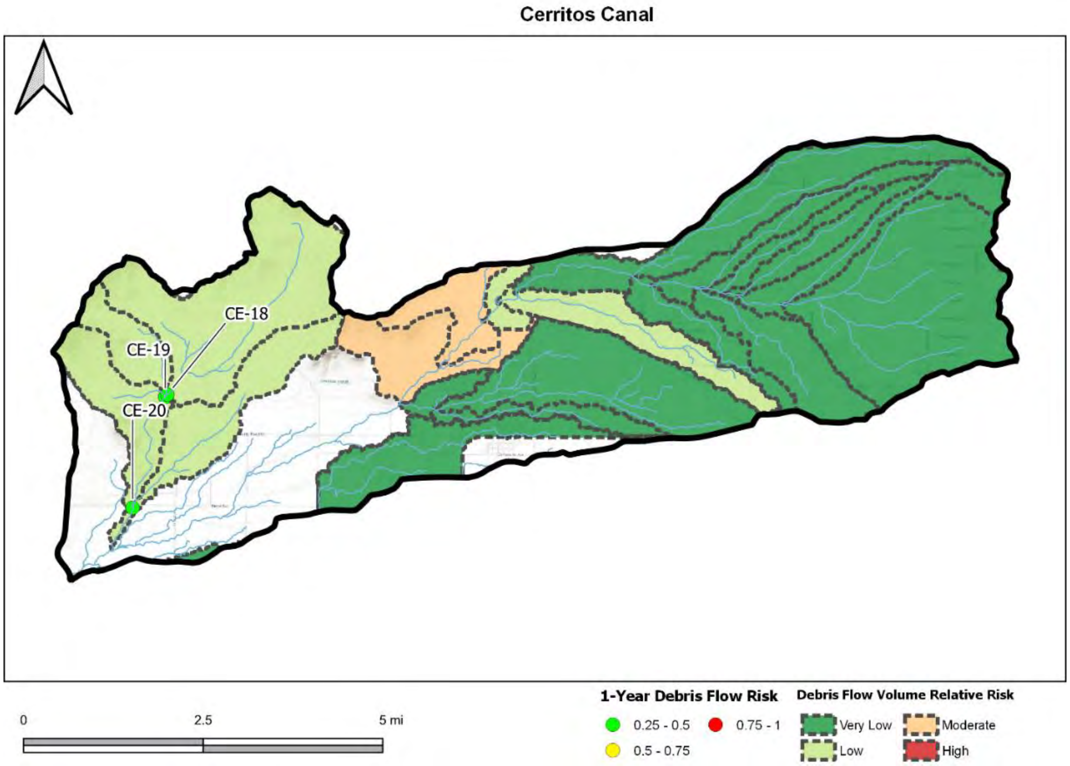


Figure 12-1 Cerritos Canal third-order watershed outlet 1-year post-wildfire debris flow risk. Background ESRI Topo.

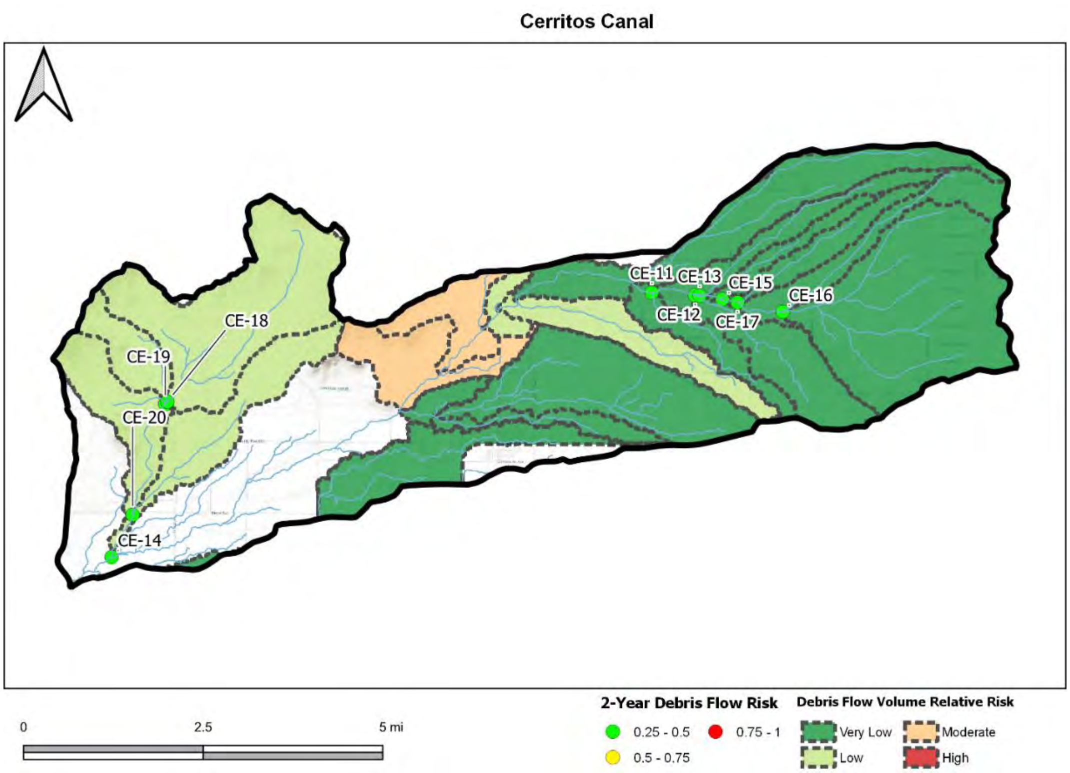


Figure 12-2 Cerritos Canal third-order watershed outlet 2-year post-wildfire debris flow risk. Background ESRI Topo

Cerritos Canal

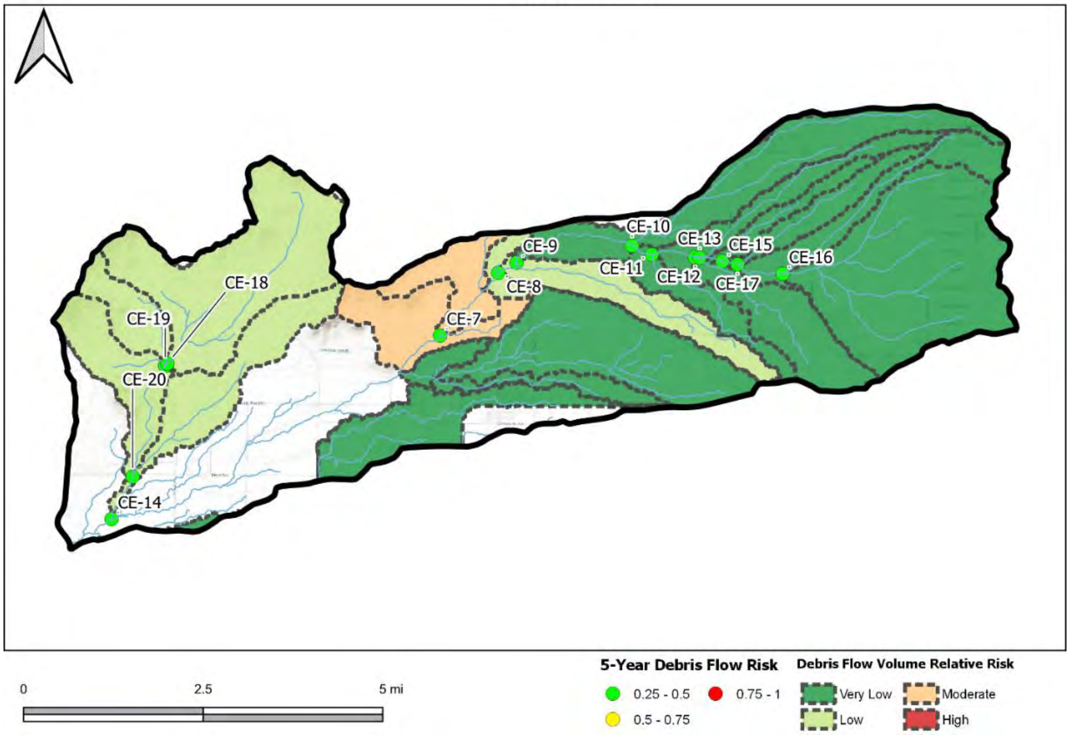


Figure 12-3 Cerritos Canal third-order watershed outlet 5-year post-wildfire debris flow risk. Background ESRI Topo

Cerritos Canal

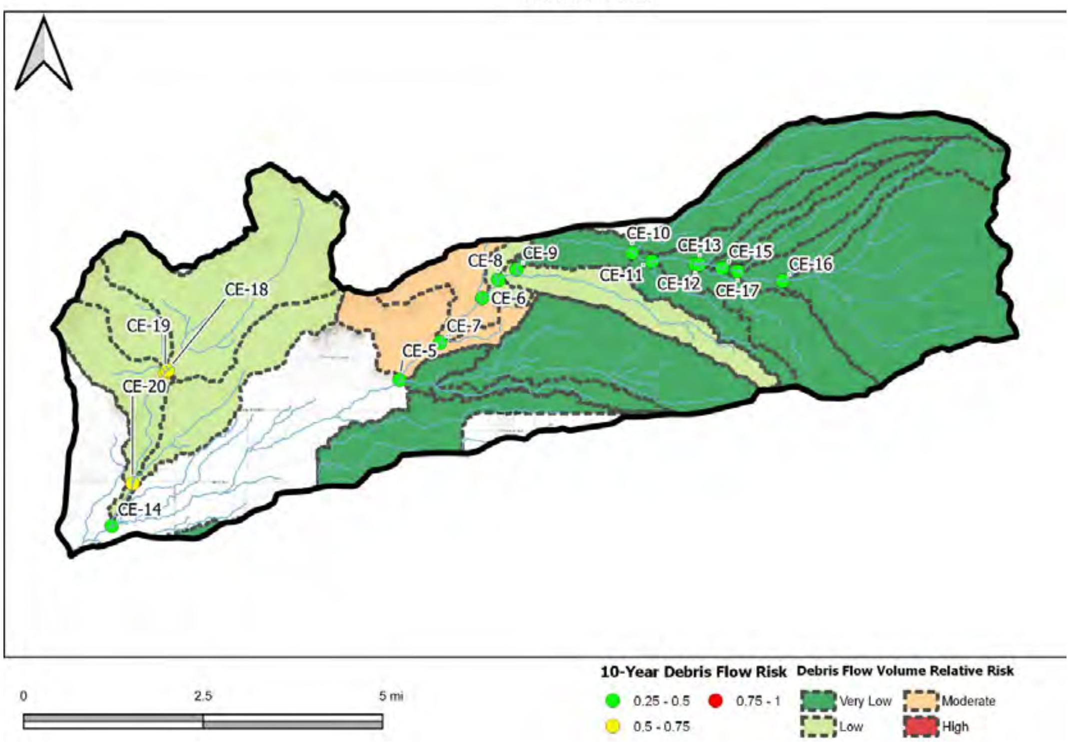


Figure 12-4 Cerritos Canal third-order watershed outlet 10-year post-wildfire debris flow risk. Background ESRI Topo

12.3.2 El Poso Creek

El Poso Creek has a moderate risk of debris flows during the high-frequency storms (1-yr and 2-yr) and a high risk of debris flow for the lower frequency storms (5-yr and 10-yr). The estimated debris flow volume increases as the position in the watershed is lower. The location and modeled debris flow probabilities for all outlets within this HUC 12 are listed in Table 12-3, and outlets with debris flow probability are shown along with relative debris flow volumes for the 1-, 2-, 5-, and 10-yr storms in Figure 12-5, Figure 12-6, Figure 12-7, and Figure 12-8.

Critical infrastructure within this area includes the following road crossings: low volume County Road N2, County Rd L.7, and road crossing in Sangre de Cristo Ranches, including Jaquez Road, Nickolson Road. Within Sangre de Cristo Ranches, approximately 6 properties with structures along El Poso Creek may be at risk of debris flows, and in lower El Poso Creek, structures adjacent to the stream may be at risk. The broad valley in lower El Poso creek may reduce the impacts to those lower structures. Avoiding development within the area between EP-6 and EP-7 and ensuring good floodplain connectivity and riparian habitat are strategies that can be utilized to minimize downstream impacts.

Table 12-3 Post-wildfire debris flow probabilities for third-order watershed outlets within the El Poso Creek HUC12.

	Outlet point location		**Debris flow probability**			
Label	**Latitude**	**Longitude**	**1-yr**	**2-yr**	**5-yr**	**10-yr**
El Poso Creek						
EP-1	4115123	471964	0.32	0.39	0.51	0.61
EP-2	4115303	472244	0.61	0.67	0.77	0.83
EP-3	4115493	472684	0.61	0.68	0.77	0.84
EP-4	4115733	473264	0.62	0.68	0.78	0.84
EP-5	4116643	474364	0.62	0.68	0.77	0.84
EP-6	4116653	474374	0.61	0.68	0.77	0.84
EP-7	4117463	474904	0.61	0.67	0.77	0.83
EP-8	4118483	475144	0.58	0.65	0.75	0.82
EP-9	4118553	475164	0.55	0.62	0.72	0.80
EP-10	4119803	475434	0.48	0.55	0.66	0.74
EP-11	4115133	471964	0.60	0.67	0.76	0.83
EP-12	4121253	477864	0.45	0.52	0.64	0.72
EP-13	4114783	472244	0.34	0.40	0.52	0.62

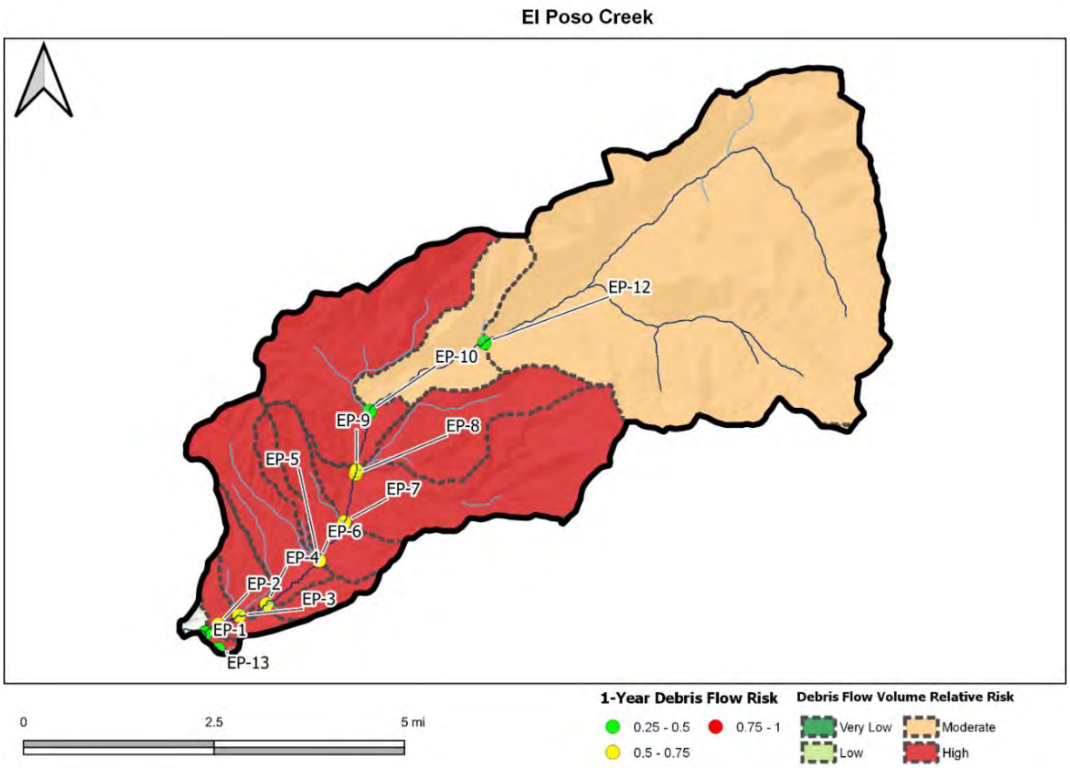


Figure 12-5 El Poso Creek third-order watershed outlet 1-year post-wildfire debris flow risk. Background ESRI Topo

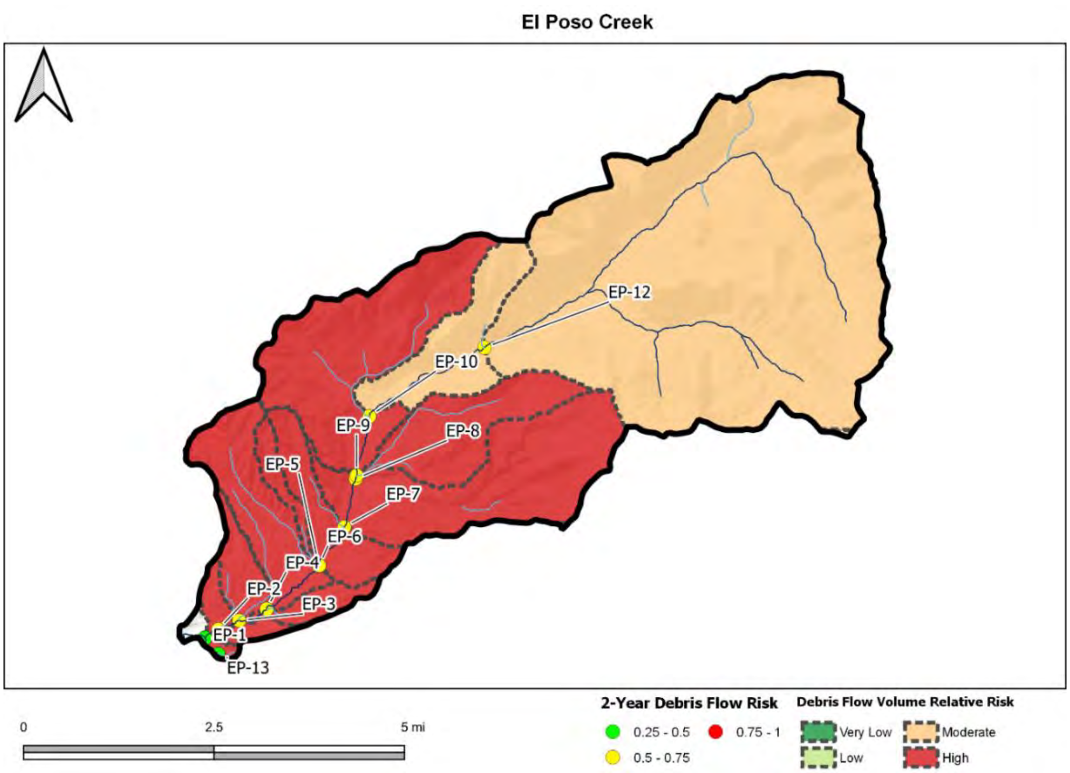


Figure 12-6 El Poso Creek third-order watershed outlet 2-year post-wildfire debris flow risk. Background ESRI Topo

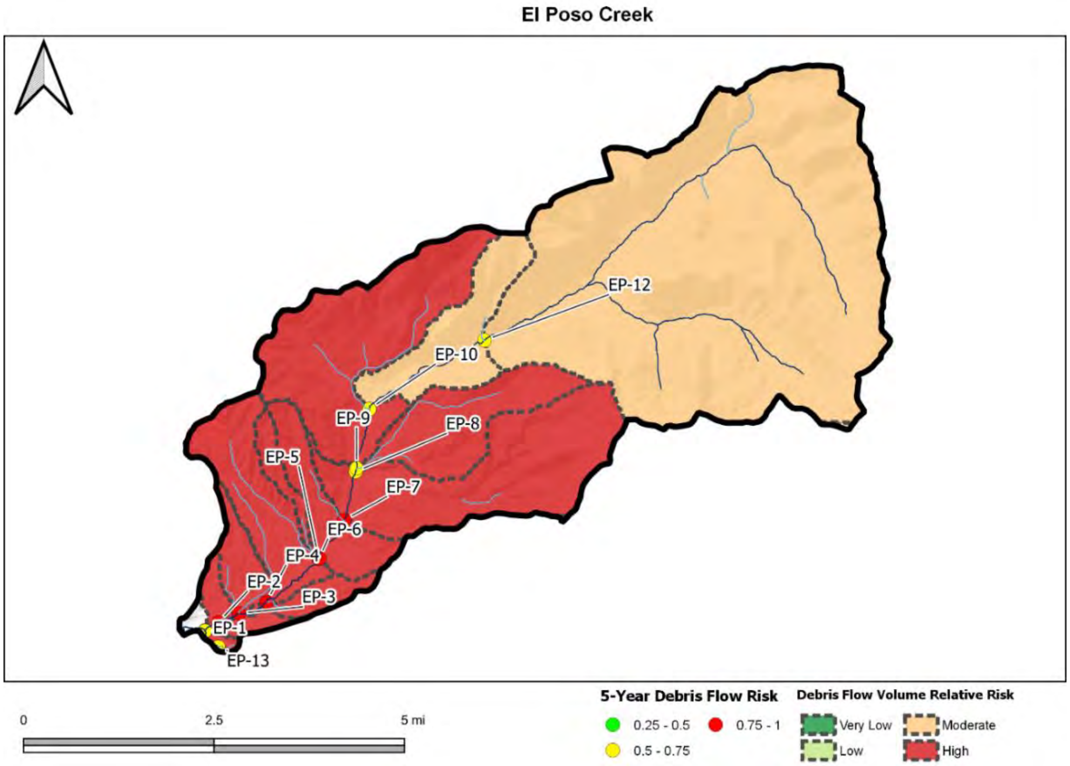


Figure 12-7 El Poso Creek third-order watershed outlet 5-year post-wildfire debris flow risk. Background ESRI Topo

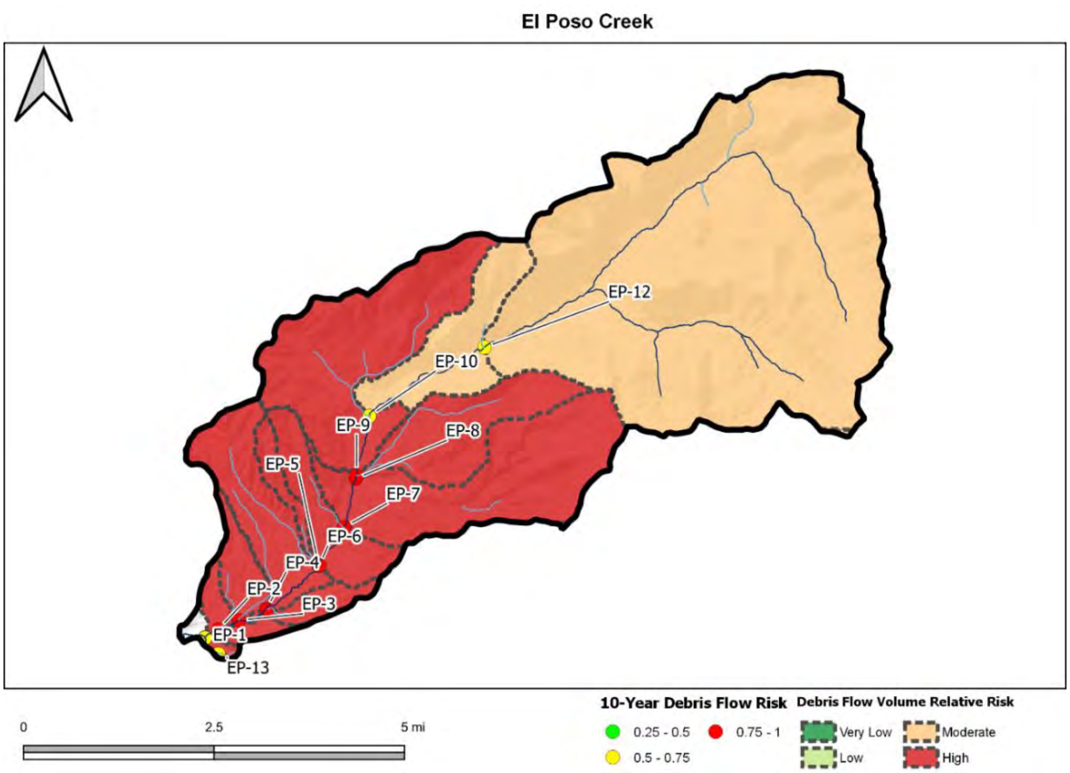


Figure 12-8 El Poso Creek third-order watershed outlet 10-year post-wildfire debris flow risk. Background ESRI Topo

12.3.3 El Puertesito-Culebra Creek

Within the El Puertosito-Culebra Creek HUC-12, debris flow probabilities range from low to high, and debris flow volumes are generally low or very low. PU-6, on Culebra Creek at the end of Barber Rd, has a high risk for debris flow for all storms with a frequency greater than 2-yr and a moderate risk for the 1-yr storm events. PU-5, the drainage that crosses County Road P7 just west of the San Luis Cemetery, also has a moderate risk of debris flow for 1-yr to 5-yr storms and high debris flow risk for the 10-yr storms. The location and debris flow probabilities for all third-order watershed outlets are listed in Table 12-4. All outlets with debris flow probability greater than 0.25 for each storm recurrence interval are shown in Figure 12-9, Figure 12-10, Figure 12-11, and Figure 12-12.

The alluvial fans at the base of the hills provide some buffering capacity for debris flows from this region. Maintaining vegetation in the swales and monitoring for gully formation within these reaches will provide buffering for debris to this region. Ditches that traverse the foothills in this region are at risk of debris flow, including Sanchez Canal and Cerro Ditch Number 1. Suppose debris flows make it to the channelized section of Culebra Creek downstream of Chama. In that case, the risk of fluvial hazards is high due to a high stream power resulting from the lack of floodplain connectivity and low sinuosity, and an increase in channel slope and depth.

Table 12-4 Post-wildfire debris flow probabilities for third-order watershed outlets within the El Puertesito-Culebra Creek HUC12.

	Outlet point location		Debris flow probability			
Label	**Latitude**	**Longitude**	**1-yr**	**2-yr**	**5-yr**	**10-yr**
El Puertesito-Culebra Creek						
PU-1	4116243	462234	0.01	0.01	0.01	0.02
PU-2	4111763	464594	0.18	0.22	0.30	0.39
PU-3	4116603	463014	0.40	0.46	0.58	0.69
PU-4	4116603	463004	0.47	0.54	0.65	0.74
PU-5	4116663	463024	0.54	0.61	0.71	0.79
PU-6	4113923	469814	0.71	0.76	0.84	0.89

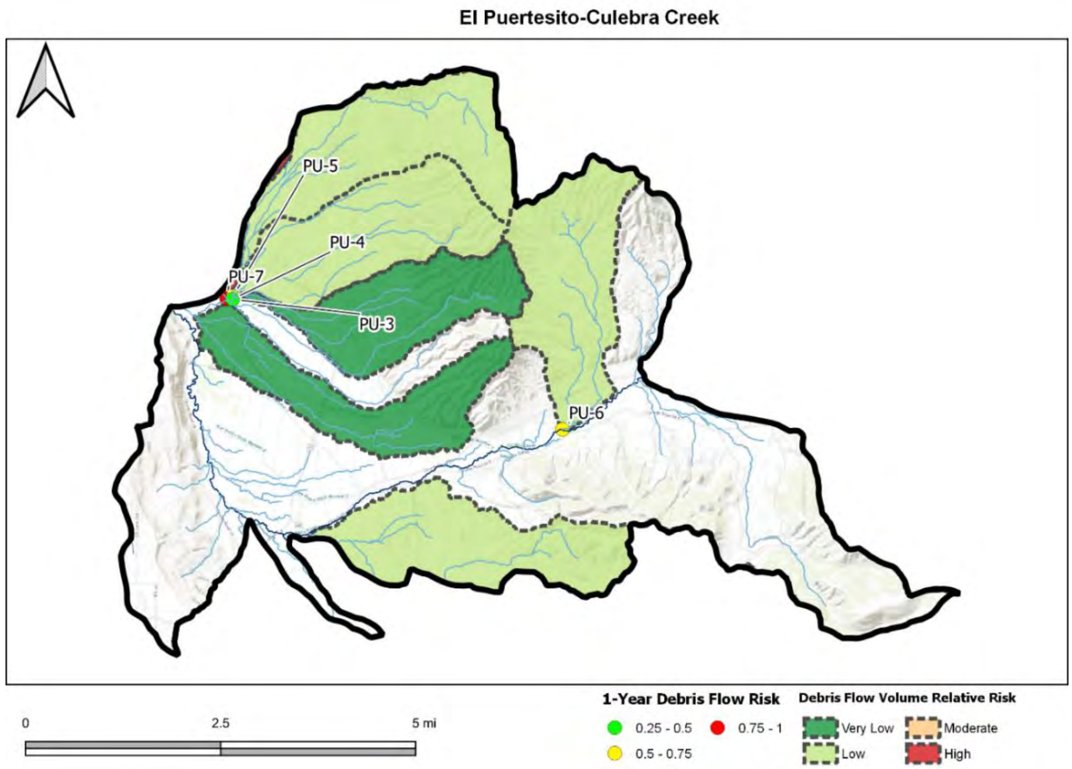


Figure 12-9 El Puertesito-Culebra Creek third-order watershed outlet 1-year post-wildfire debris flow risk. Background ESRI Topo

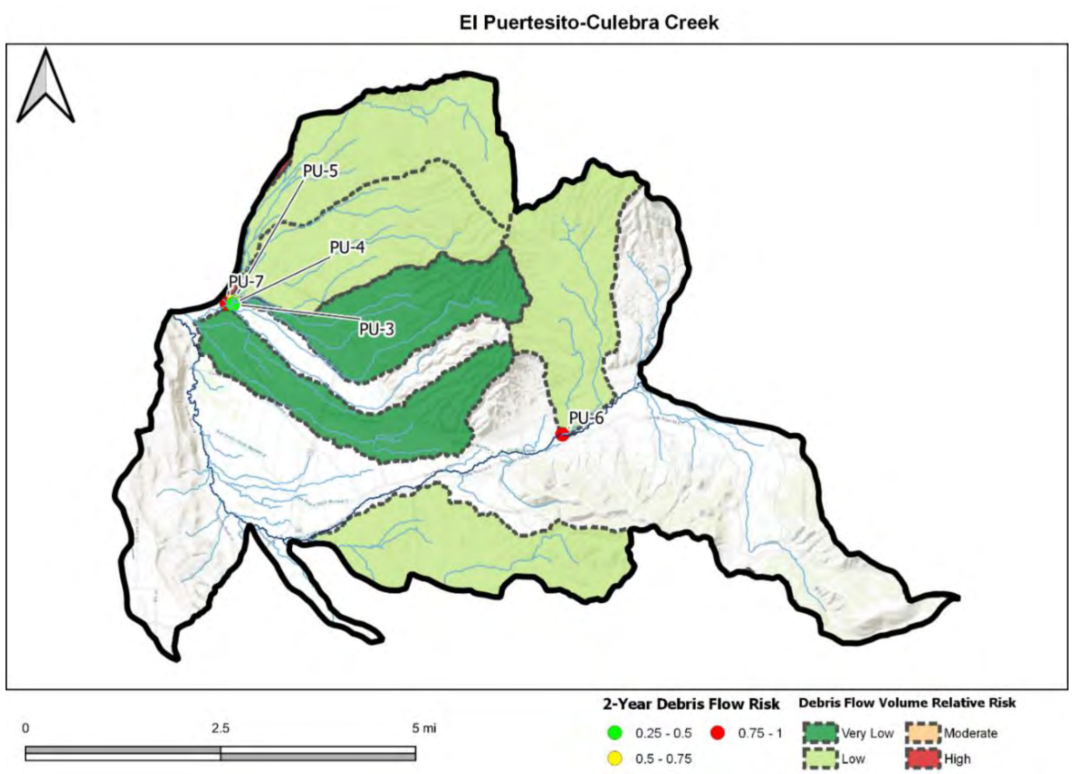


Figure 12-10 El Puertesito-Culebra Creek third-order watershed outlet 2-year post-wildfire debris flow risk. Background ESRI Topo

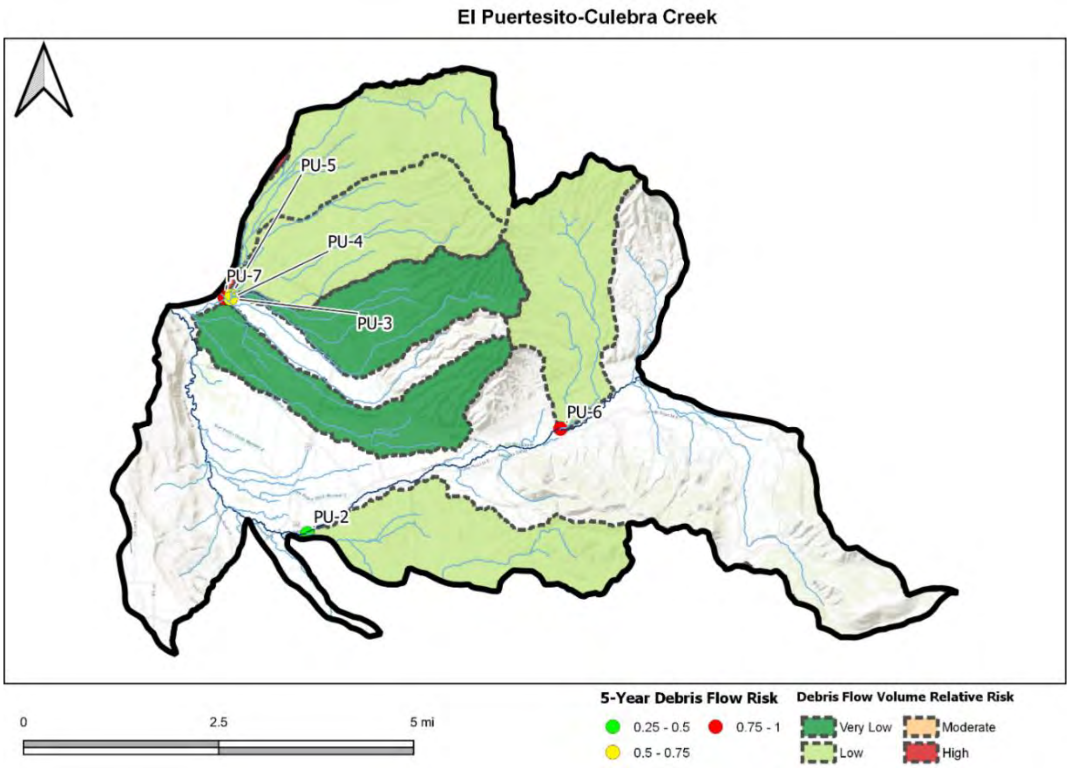


Figure 12-11 El Puertesito-Culebra Creek third-order watershed outlet 5-year post-wildfire debris flow risk. Background ESRI Topo

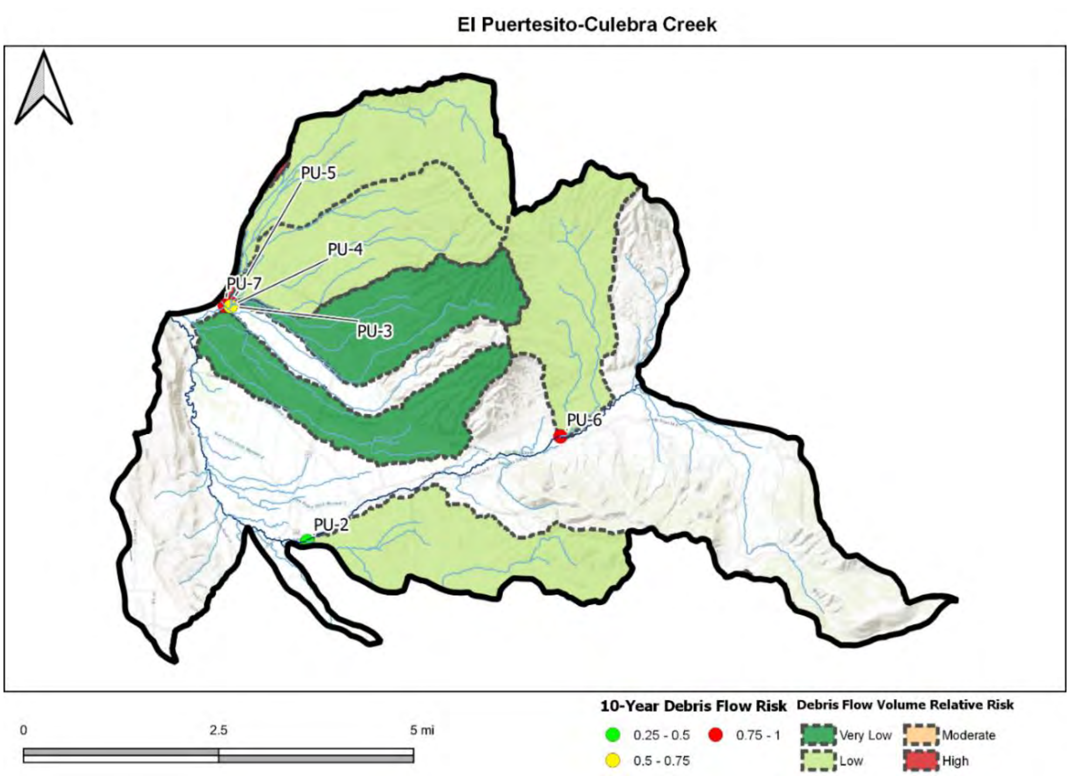


Figure 12-12 El Puertesito-Culebra Creek third-order watershed outlet 10-year post-wildfire debris flow risk. Background ESRI Topo

12.3.4 Headwaters Culebra Creek

The third-order watershed outlets within the Headwaters of Culebra Creek all have low debris flow probability risk for the high-frequency storms (1-yr and 2-yr). The debris flow probability increases to moderate for CH-1 and CH-2 for the 5-yr storm events and C-3, C-4, and C5 for the 10-yr storm events. The probability for debris flows generally increases as the position in the watershed decreases. A few structures adjacent to Culebra Creek may be at risk of debris flows. The debris flow volumes are moderate to high when compared to other watersheds in the basin. Third-order watershed outlet locations and debris flow probabilities for Headwaters Culebra Creek are listed in Table 12-5, and outlets with debris flow probability greater than 0.25 are shown for the 1-yr, 2-yr, 5-yr, and 10-yr recurrence intervals in Figure 12-13, Figure 12-14, Figure 12-15, and Figure 12-16 respectively.

Table 12-5 Post-wildfire debris flow probabilities for third-order watershed outlets within the Headwaters Culebra Creek HUC12.

Label	Outlet point location		Debris flow probability			
	Latitude	**Longitude**	**1-yr**	**2-yr**	**5-yr**	10-yr
Headwaters Culebra Creek						
CH-1	4114523	473554	0.34	0.41	0.53	0.63
CH-2	4114273	474734	0.34	0.40	0.52	0.62
CH-3	4114453	475304	0.29	0.36	0.47	0.58
CH-4	4114533	475754	0.29	0.35	0.47	0.57
CH-5	4114513	476114	0.24	0.30	0.41	0.51
CH-6	4114713	476494	0.22	0.28	0.38	0.48
CH-7	4115273	478324	0.21	0.26	0.37	0.47

Headwaters Culebra Creek

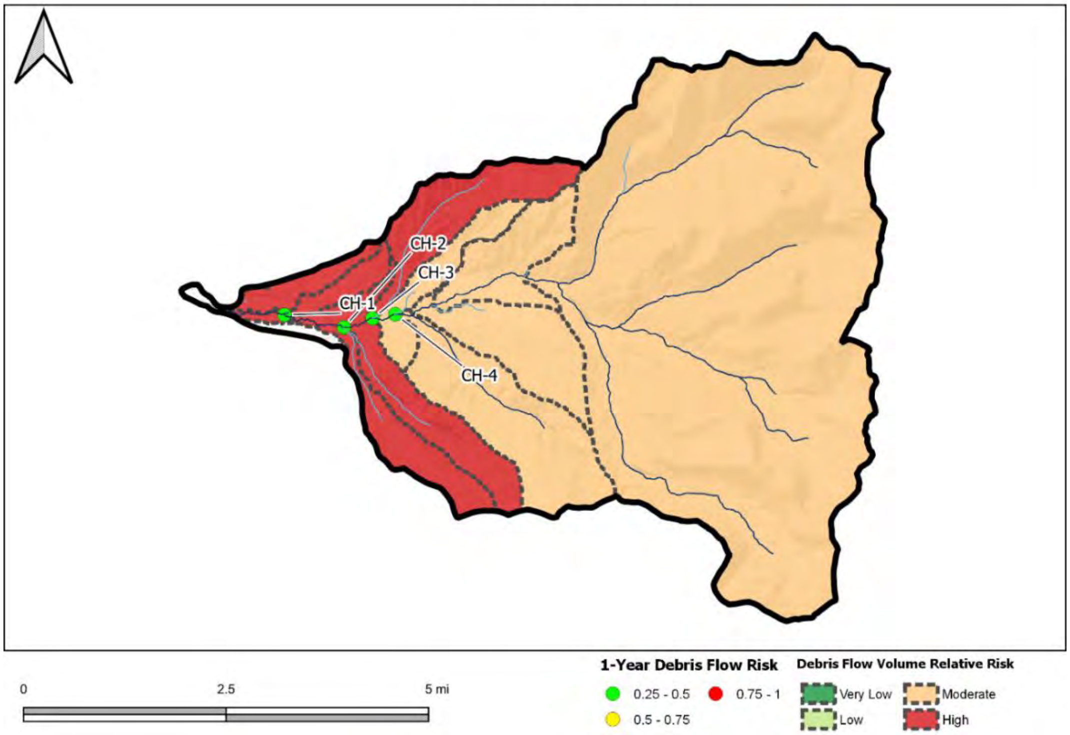


Figure 12-13 Headwaters Culebra Creek third-order watershed outlet 1-year post-wildfire debris flow risk. Background ESRI Topo

Headwaters Culebra Creek

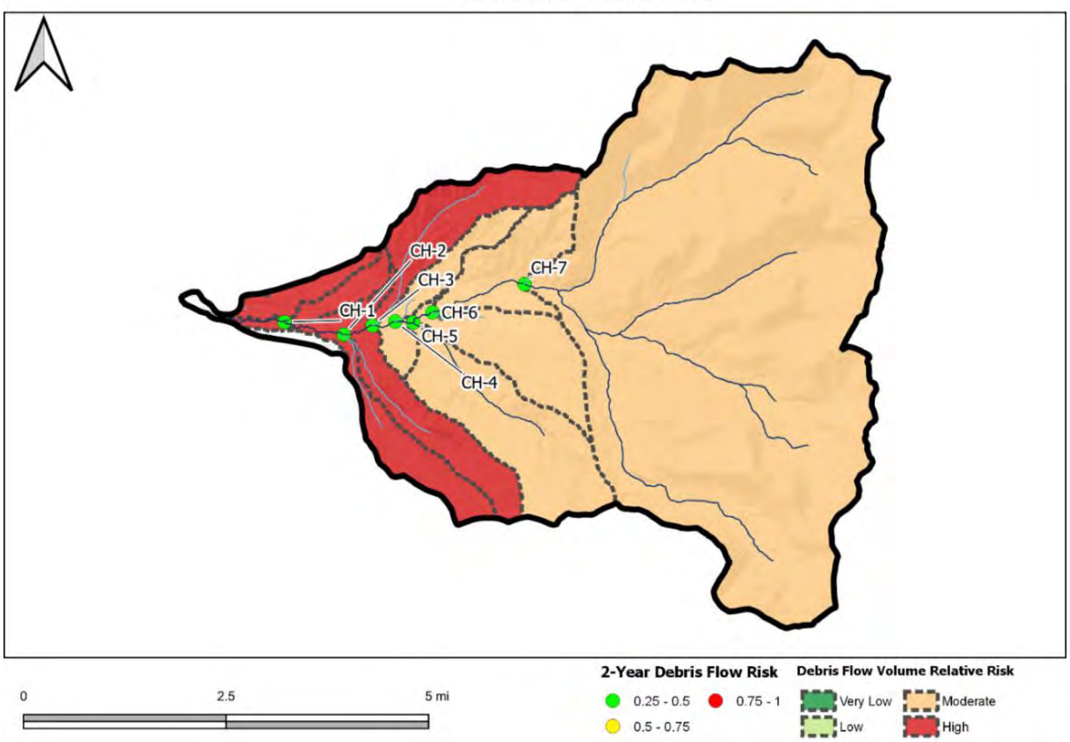


Figure 12-14 Headwaters Culebra Creek third-order watershed outlet 2-year post-wildfire debris flow risk. Background ESRI Topo

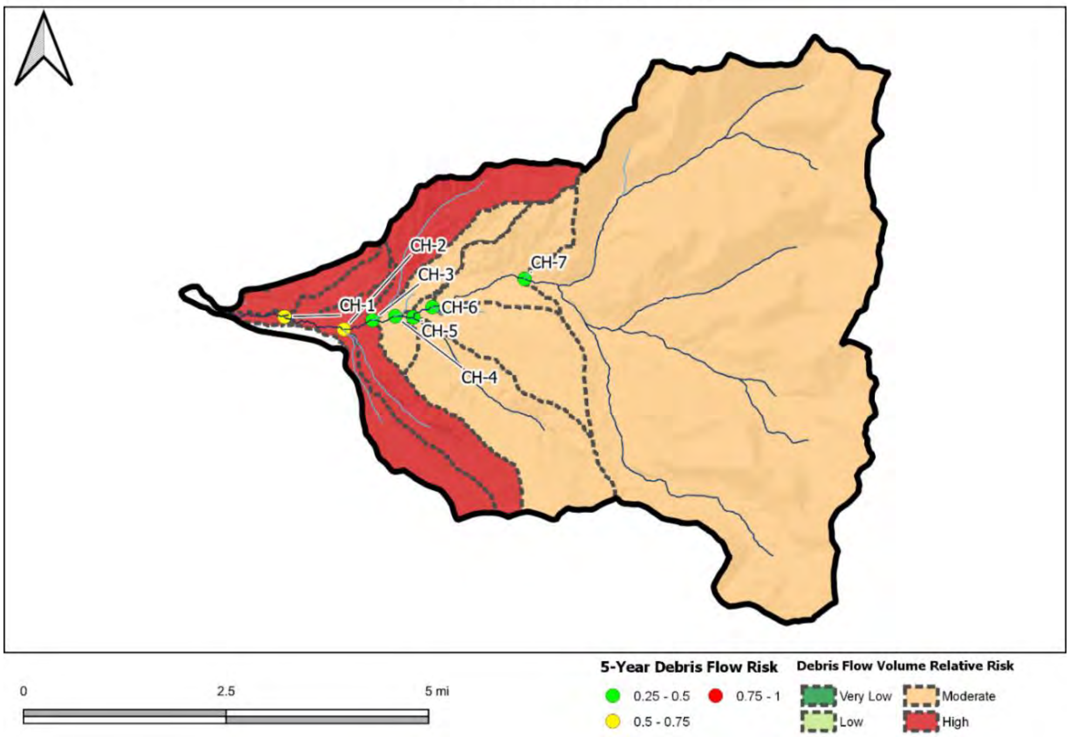


Figure 12-15 Headwaters Culebra Creek third-order watershed outlet 5-year post-wildfire debris flow risk. Background ESRI Topo

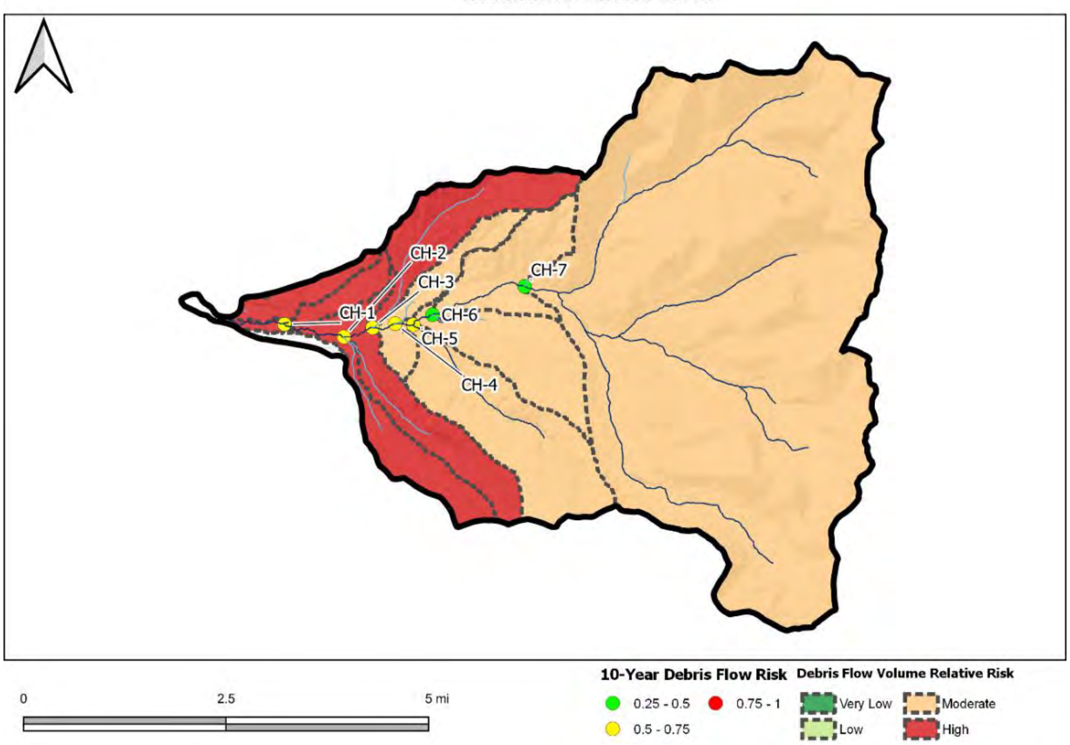


Figure 12-16 Headwaters Culebra Creek third-order watershed outlet 2-year post-wildfire debris flow risk. Background ESRI Topo

12.3.5 Headwaters Ventero Creek

The headwaters of Ventero Creek is generally at low risk for debris flows with the higher frequency storms. Moderate debris flow risks were modeled for the 1-yr storm at VE-9 and the 2-yr storm at VE-2 and VE-4. All third-order outlets showed moderate debris flow risks for the 5-yr storms, and this increased to high debris flow risk at VE-2 and VE-9. VE-9 is associated with the confluence of Cuates Creek with Ventero Creek, and VE-1 is associated with Willow Creek. Third-order watershed outlet locations and debris flow probabilities for Headwaters Ventero Creek are listed in Table 12-6, and outlets with debris flow probability greater than 0.25 are shown for the 1-yr, 2-yr, 5-yr, and 10-yr recurrence intervals in Figure 12-17, Figure 12-18, Figure 12-19, and Figure 12-20 respectively. Structures at the base of the foothills are at risk of debris flows. Maintaining floodplain connection on the alluvial fans will provide buffering from debris flow downstream. Irrigation infrastructure and fish barriers could be damaged by debris flows within this basin.

Table 12-6 Post-wildfire debris flow probabilities for third-order watershed outlets within the Headwaters Ventero Creek HUC12.

	Outlet point location		**Debris flow probability**			
Label	**Latitude**	**Longitude**	**1-yr**	**2-yr**	**5-yr**	**10-yr**
Headwaters Ventero Creek						
VE-1	4096743	461674	0.40	0.46	0.56	0.66
VE-2	4096743	461694	0.50	0.58	0.70	0.78
VE-3	4096473	461454	0.40	0.45	0.56	0.65
VE-4	4096533	461664	0.45	0.53	0.65	0.74
VE-5	4095883	460834	0.41	0.47	0.57	0.67
VE-6	4095633	460074	0.38	0.43	0.54	0.63
VE-7	4095623	459944	0.38	0.44	0.55	0.64
VE-9	4101113	462434	0.56	0.62	0.72	0.80

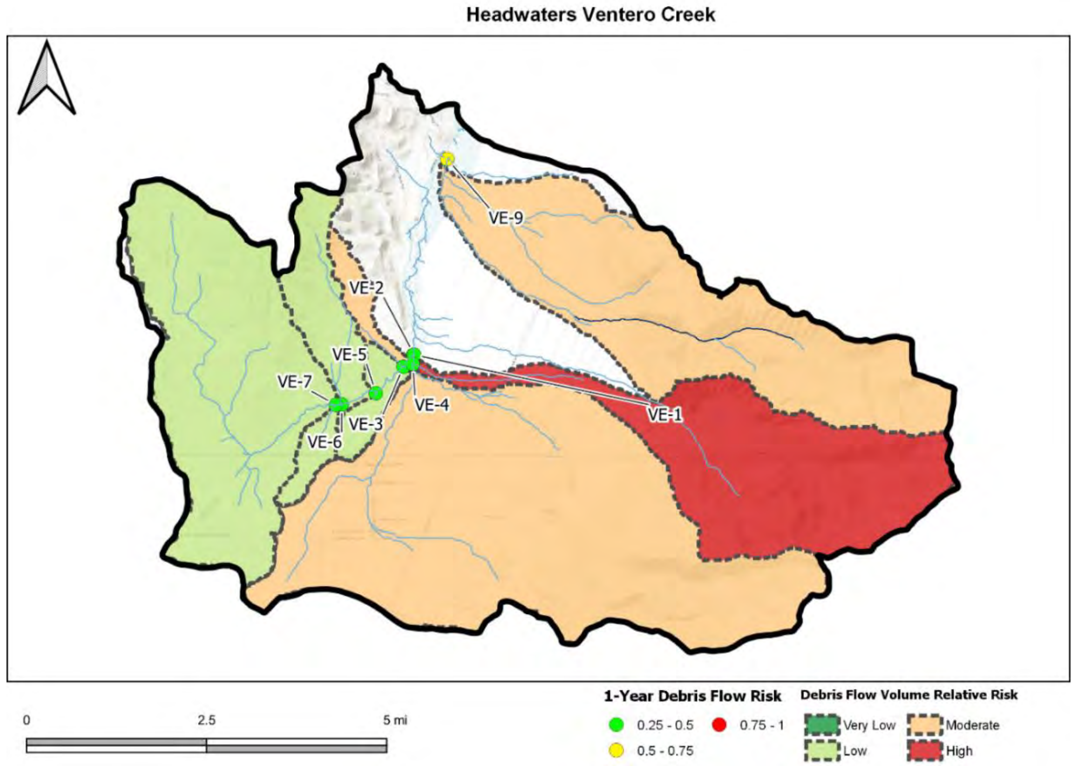


Figure 12-17 Headwaters Ventero Creek third-order watershed outlet 1-year post-wildfire debris flow risk. Background ESRI Topo

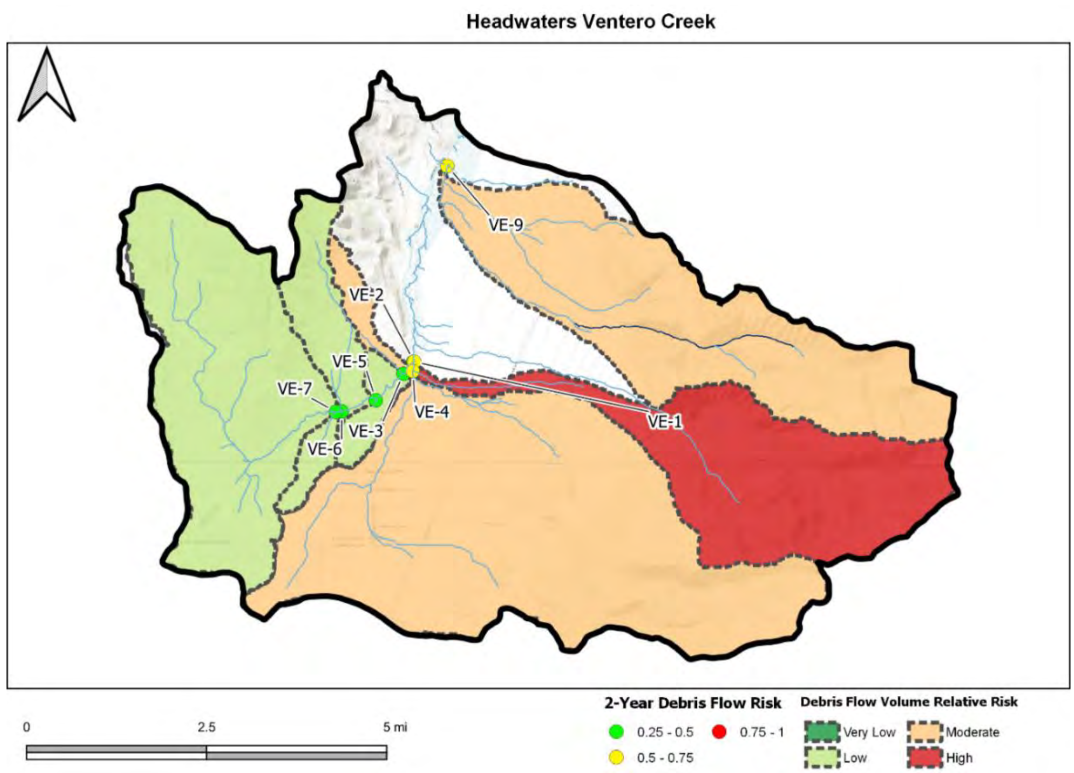


Figure 12-18 Headwaters Ventero Creek third-order watershed outlet 2-year post-wildfire debris flow risk. Background ESRI Topo

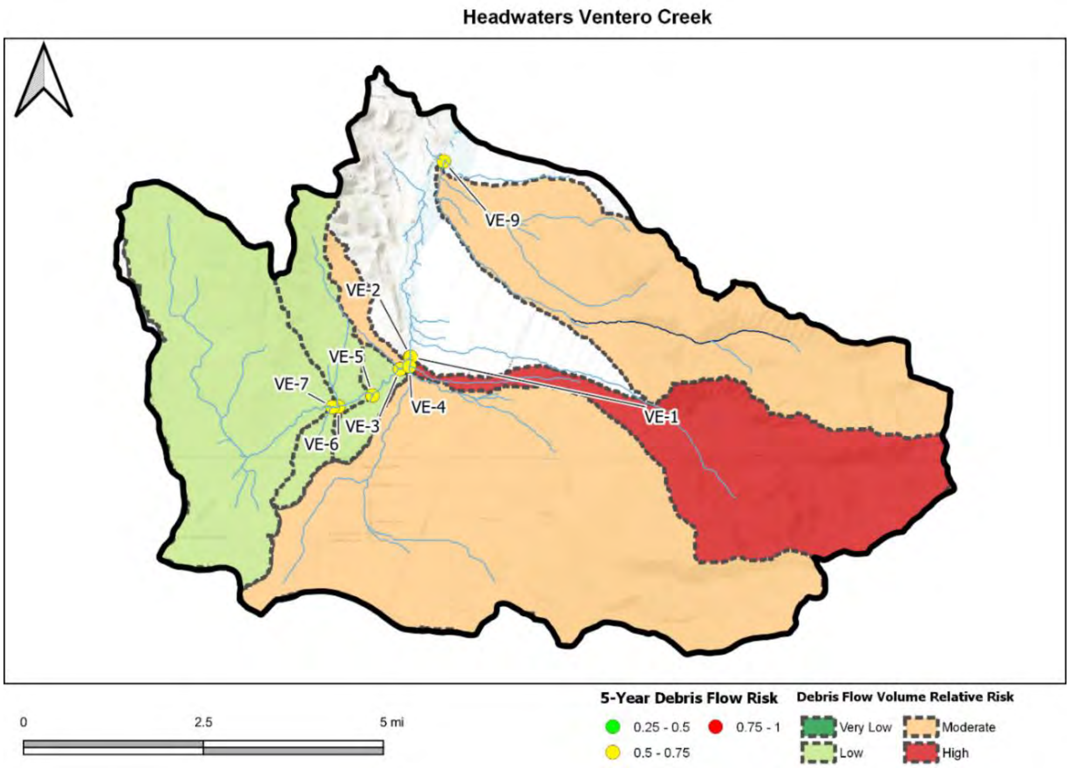


Figure 12-19 Headwaters Ventero Creek third-order watershed outlet 5-year post-wildfire debris flow risk. Background ESRI Topo

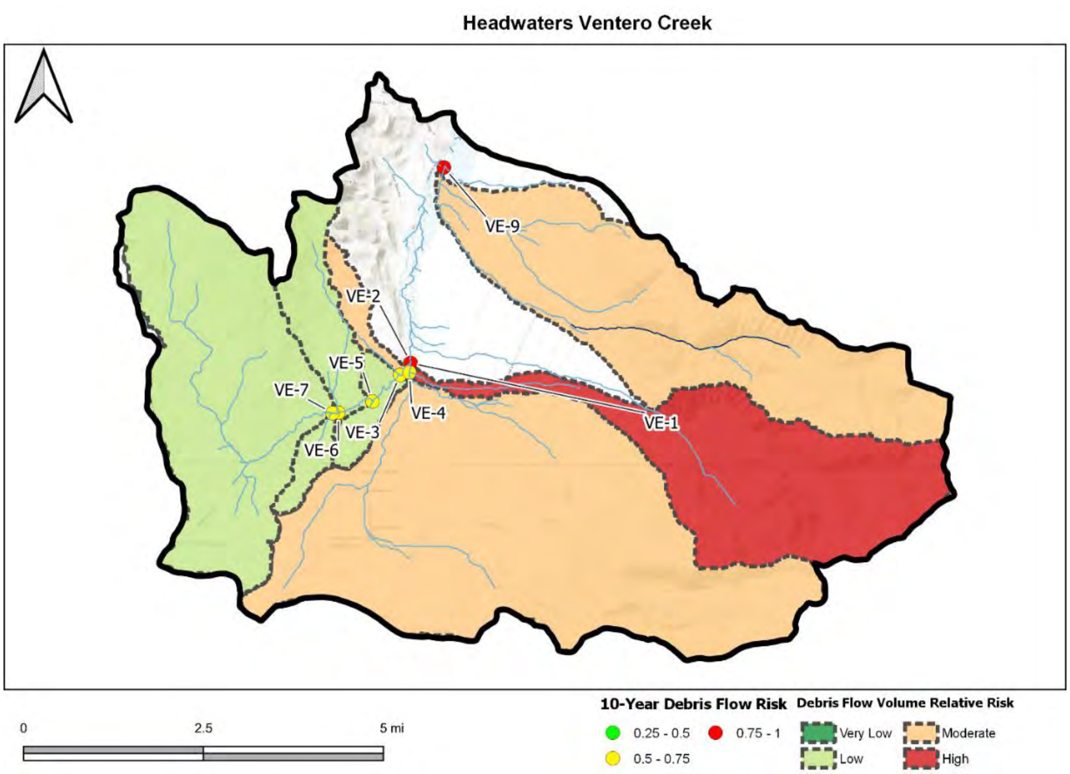


Figure 12-20 Headwaters Ventero Creek third-order watershed outlet 10-year post-wildfire debris flow risk. Background ESRI Topo.

12.3.6 Outlet Culebra Creek

CO-1 is the watershed that drains San Luis Hills. CO-1 has a low debris flow risk for the high-frequency storms, 1-yr and 2-yr, and moderate debris flow risk for the 5-yr and 10-yr storms. The other third-order outlets have less than a 0.25 probability for debris flows. Third-order watershed outlet locations and debris flow probabilities for Outlet Culebra Creek are listed in Table 12-7, and outlets with debris flow probability greater than 0.25 are shown for the 1-yr, 2-yr, 5-yr, and 10-yr recurrence intervals in Figure 12-17, Figure 12-18, Figure 12-19, and Figure 12-20 respectively.

Table 12-7 Post-wildfire debris flow probabilities for third-order watershed outlets within the Outlet Culebra Creek HUC12.

Label	Outlet point location		Debris flow probability			
	Latitude	Longitude	1-yr	2-yr	5-yr	10-yr
Outlet Culebra Creek						
CO-1	4115603	439584	0.35	0.41	0.51	0.60
CO-2	4115603	443024	0.01	0.01	0.02	0.03
CO-3	4115623	442244	0.01	0.01	0.02	0.03
CO-4	4118043	457084	0.01	0.02	0.03	0.04
CO-5	4115723	443364	0.01	0.02	0.03	0.04
CO-6	4118003	456994	0.01	0.02	0.03	0.04
CO-7	4116333	445644	0.02	0.02	0.03	0.04
CO-8	4116513	461684	0.09	0.11	0.17	0.24
CO-9	4116683	448884	0.00	0.00	0.00	0.00

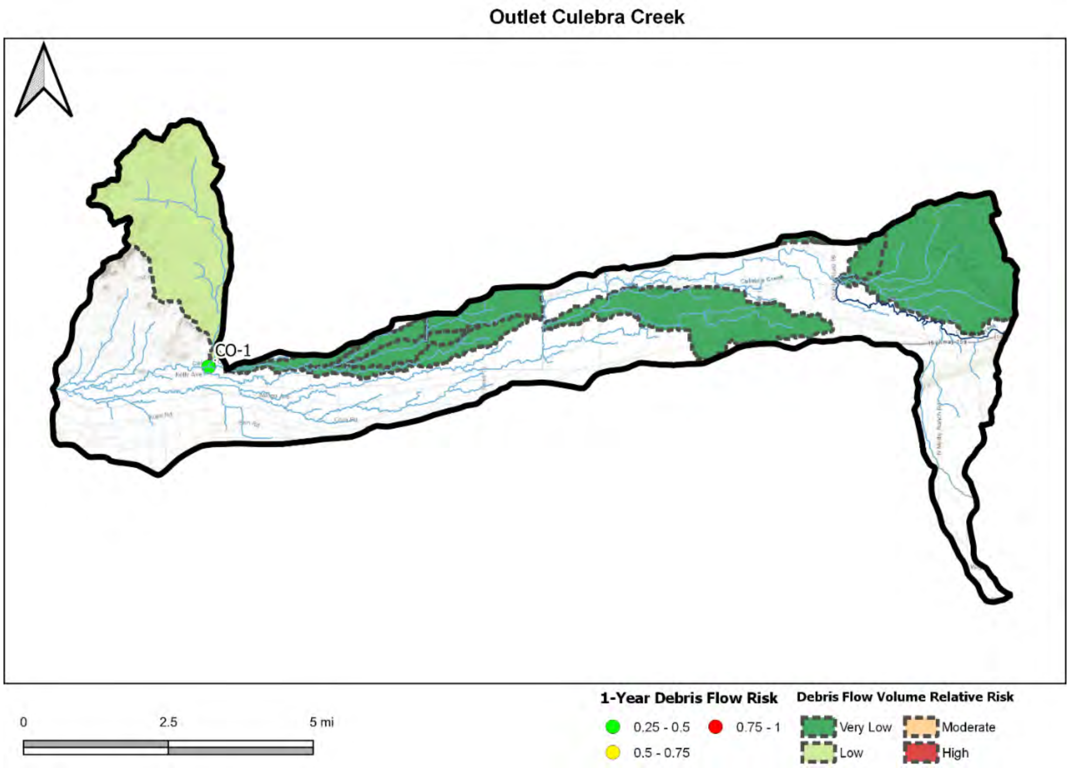


Figure 12-21 Outlet Culebra Creek third-order watershed outlet 1-year post-wildfire debris flow risk. Background ESRI Topo

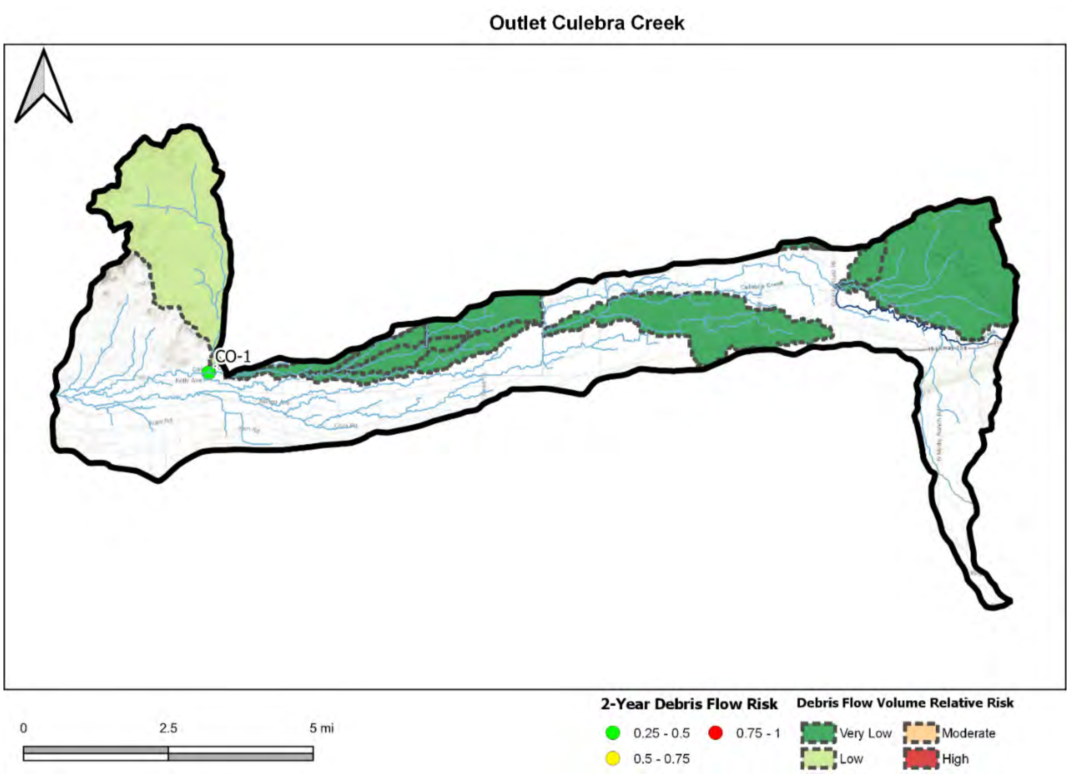


Figure 12-22 Outlet Culebra Creek third-order watershed outlet 2-year post-wildfire debris flow risk. Background ESRI Topo

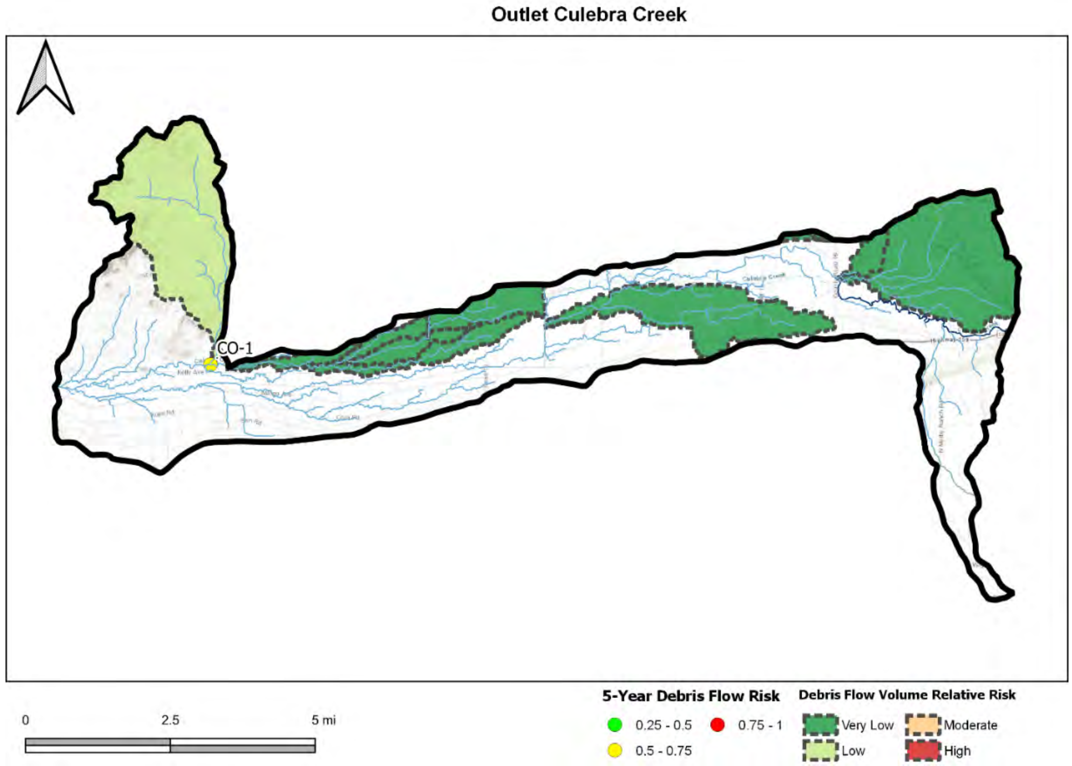


Figure 12-23 Outlet Culebra Creek third-order watershed outlet 5-year post-wildfire debris flow risk. Background ESRI Topo

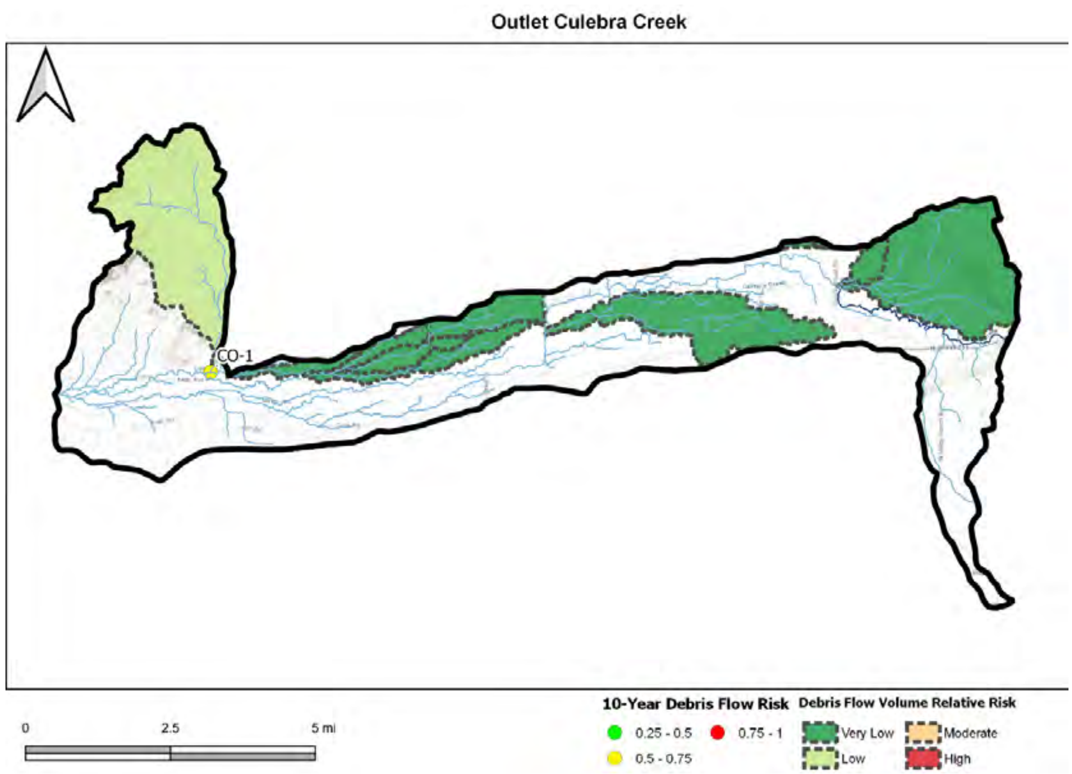


Figure 12-24 Outlet Culebra Creek third-order watershed outlet 10-year post-wildfire debris flow risk. Background ESRI Topo

12.3.7 Rito Seco

The Rito Seco drainage has a high risk of post-fire debris flows for all storm events except for RS-14 and RS-16, which drain those areas north of San Luis, including the crop circles and west to the watershed boundary. Third-order watershed outlet locations and debris flow probabilities for Rito Seco are listed in Table 12-8, and outlets with debris flow probability greater than 0.25 are shown for the 1-yr, 2-yr, 5-yr, and 10-yr recurrence intervals Figure 12-25, Figure 12-26, Figure 12-27, and Figure 12-28respectively. Debris flow volumes increase with the drainage area highest as the canyon's channel and the stream floodplain access is restored near the historic dam. Maintaining floodplain access and limiting development on the alluvial fan will promote this reach, continuing to be a depositional reach. This area is significant for protecting the assets in San Luis from debris flow. A detailed analysis of floodplain function from the historic dam to the town of San Luis for determining restoration and management strategies and subsequent implementation should be evaluated to reduce debris flow and flooding risks to San Luis. Road crossing within Sangre de Cristo Ranches and the trails within the open space park are also at risk of debris flows

Table 12-8 Post-wildfire debris flow probabilities for third-order watershed outlets within the Rito Seco HUC12.

Label	Outlet point location		Debris flow probability			
	Latitude	Longitude	1-yr	2-yr	5-yr	10-yr
Rito Seco						
RS-1	4117293	462834	0.82	0.86	0.91	0.94
RS-2	4122163	466474	0.83	0.87	0.91	0.94
RS-3	4122273	466964	0.83	0.87	0.92	0.95
RS-4	4122653	467614	0.84	0.88	0.92	0.95
RS-5	4122753	467754	0.84	0.88	0.92	0.95
RS-6	4122923	468194	0.84	0.88	0.92	0.95
RS-7	4122893	468474	0.85	0.88	0.92	0.95
RS-8	4122943	469534	0.85	0.89	0.93	0.95
RS-9	4122893	469814	0.86	0.89	0.93	0.96
RS-10	4123023	471674	0.87	0.90	0.94	0.96
RS-11	4123013	471694	0.86	0.90	0.94	0.96
RS-12	4123033	471934	0.86	0.90	0.94	0.96
RS-13	4123123	472054	0.86	0.89	0.93	0.96
RS-14	4116693	461934	0.12	0.15	0.22	0.30
RS-15	4125503	473864	0.89	0.91	0.95	0.97
RS-16	4118603	462354	0.22	0.27	0.37	0.48
RS-17	4124253	472964	0.87	0.90	0.94	0.96
RS-18	4116613	462894	0.81	0.85	0.90	0.93

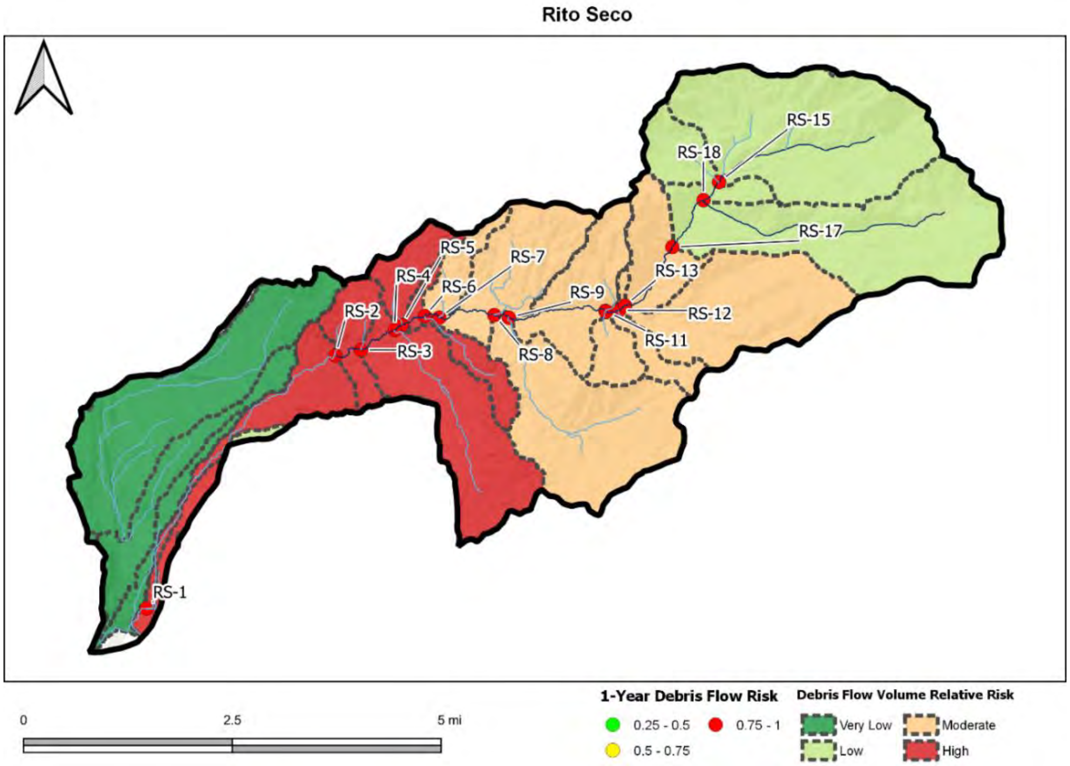


Figure 12-25 Rito Seco third-order watershed outlet 1-year post-wildfire debris flow risk. Background ESRI Topo

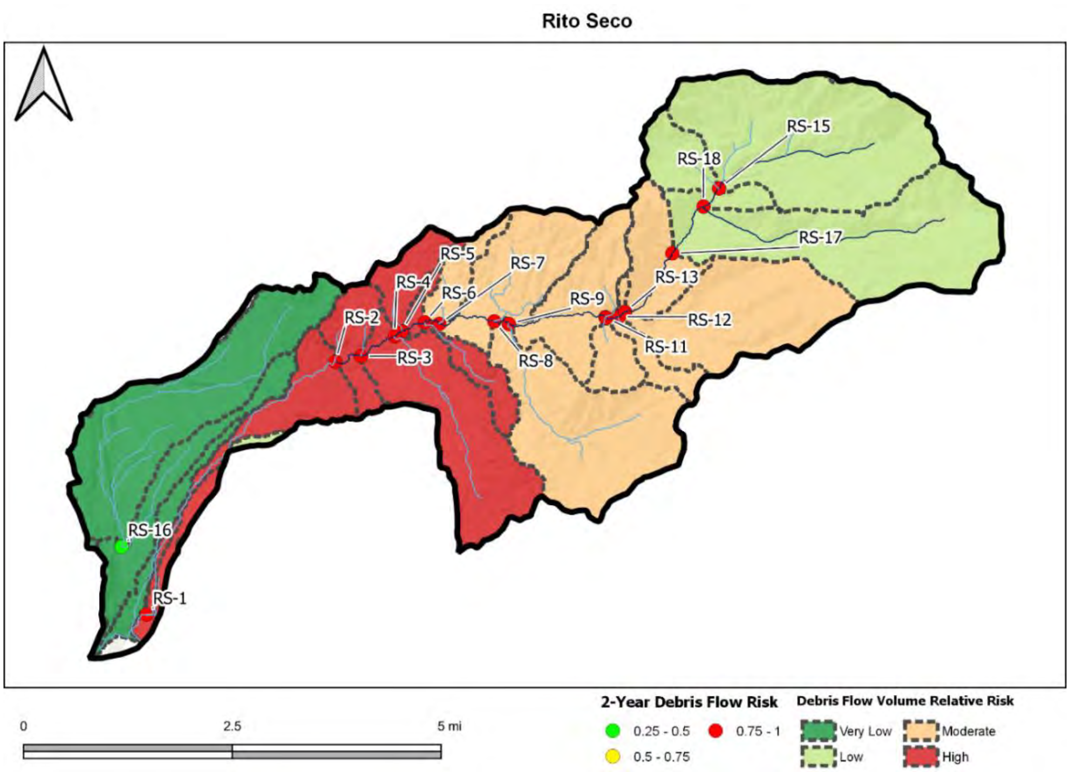


Figure 12-26 Rito Seco third-order watershed outlet 2-year post-wildfire debris flow risk. Background ESRI Topo

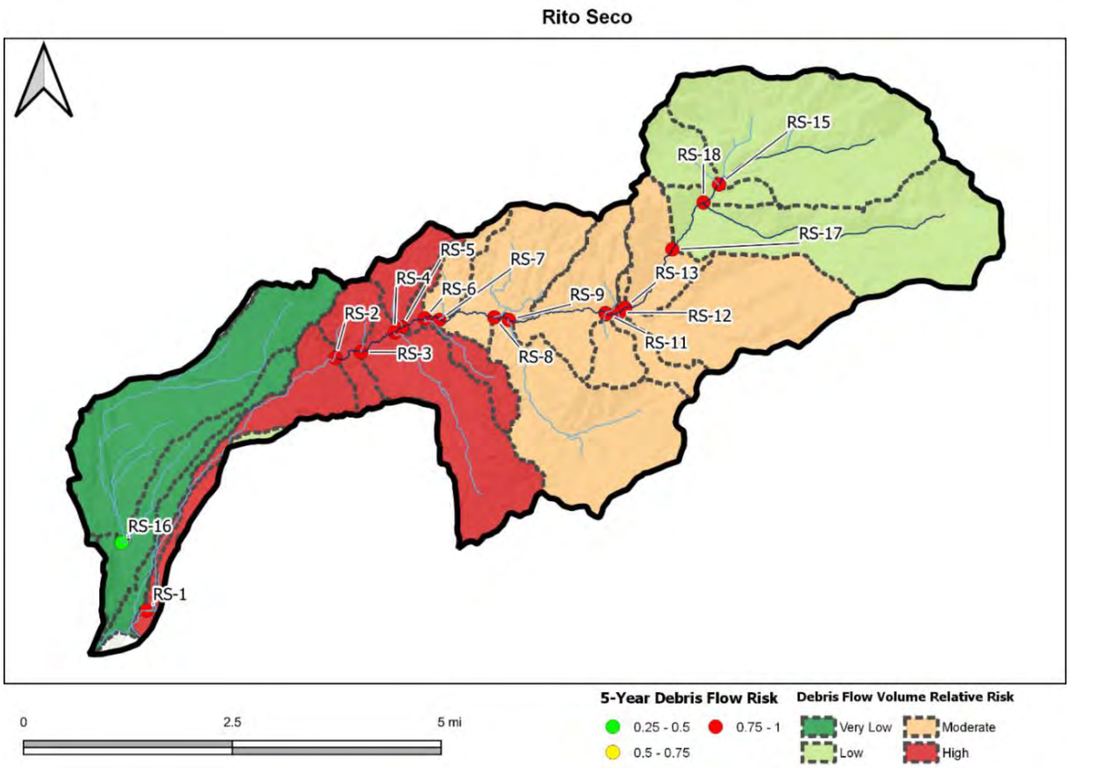


Figure 12-27 Rito Seco third-order watershed outlet 5-year post-wildfire debris flow risk. Background ESRI Topo

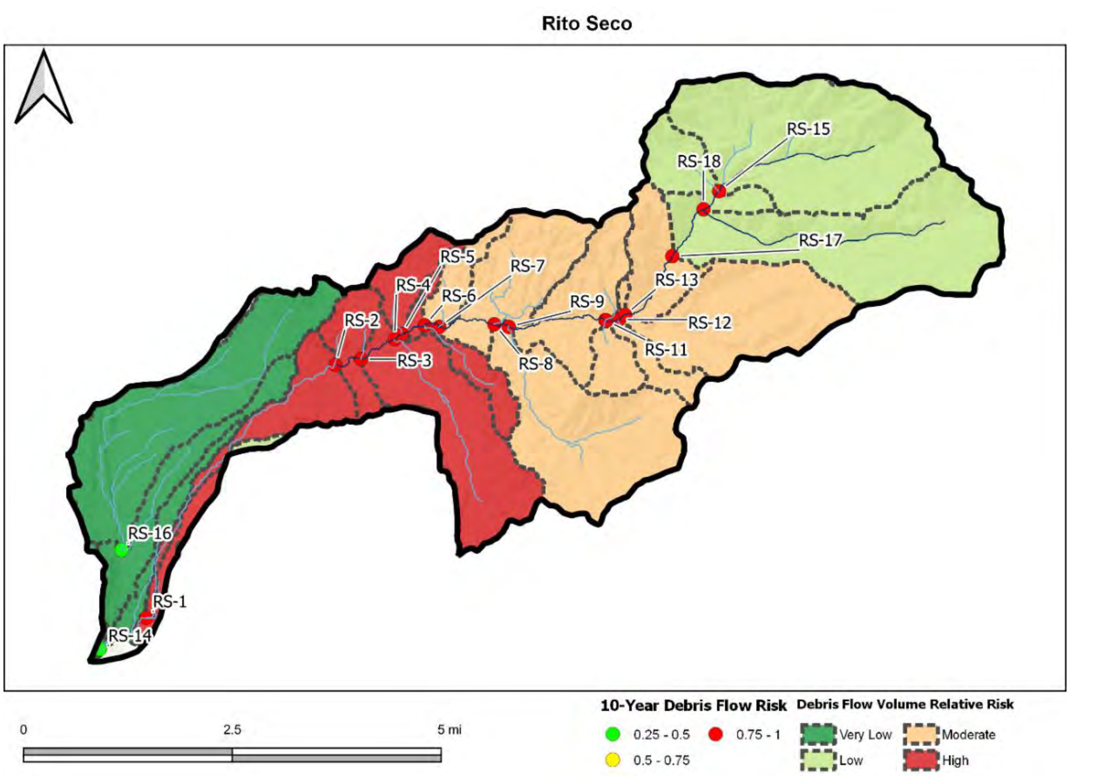


Figure 12-28 Rito Seco third-order watershed outlet 10-year post-wildfire debris flow risk. Background ESRI Topo

12.3.8 San Fransisco Creek – Ventero Creek

Generally, the debris flow risks are moderate for the 1-yr and 2-yr storms and high for the 5-yr and 10-yr storms. Third-order watershed outlet locations and debris flow probabilities for

San Francisco Creek - Ventero Creek are listed in Table 12-9, and outlets with debris flow probability greater than 0.25 are shown for the 1-yr, 2-yr, 5-yr, and 10-yr recurrence intervals in Figure 12-29, Figure 12-30, Figure 12-31, and Figure 12-32 respectively. The San Francisco Creek crossing at Sanchez Canal will reduce the risk of debris flows below the canal. Numerous structures adjacent to San Francisco Creek in San Francisco may be at risk of debris flows. Floodplain access near the confluence of Alamosito Creek and San Francisco Creek provides a depositional zone from main-stem debris flows.

Table 12-9 Post-wildfire debris flow probabilities for third-order watershed outlets within the San Francisco Creek-Ventero Creek HUC12.

	Outlet point location		Debris flow probability			
Label	**Latitude**	**Longitude**	**1-yr**	**2-yr**	**5-yr**	**10-yr**
San Francisco Creek-Ventero Creek						
SF-1	4108993	464114	0.51	0.58	0.69	0.78
SF-2	4106603	466924	0.58	0.65	0.75	0.83
SF-3	4106233	467404	0.60	0.66	0.77	0.84
SF-4	4106133	467554	0.60	0.67	0.77	0.84
SF-5	4106063	468244	0.60	0.67	0.77	0.84
SF-6	4105263	470804	0.59	0.66	0.77	0.84
SF-7	4105663	470284	0.60	0.67	0.77	0.84

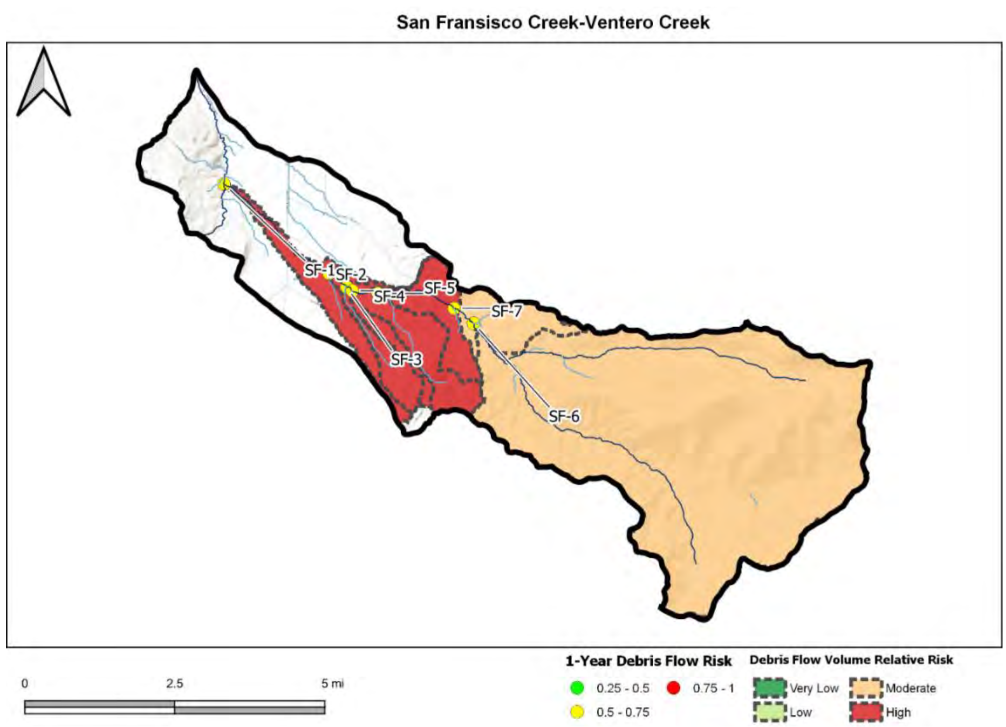


Figure 12-29 San Fransisco Creek-Ventero Creek third-order watershed outlet 1-year post-wildfire debris flow risk. Background ESRI Topo

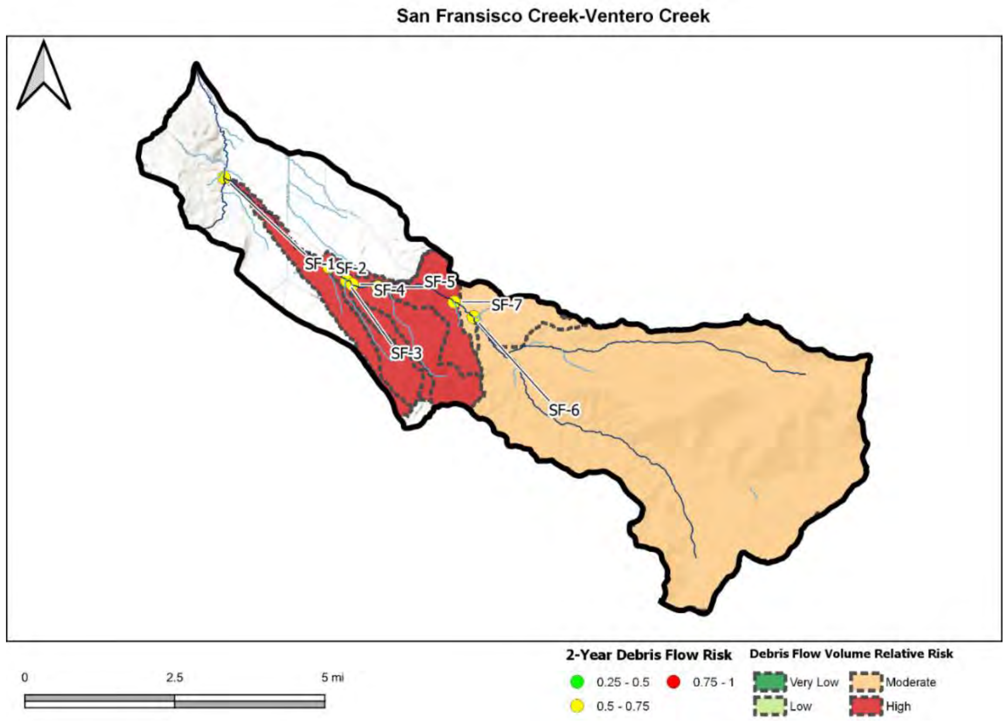


Figure 12-30 San Fransisco Creek-Ventero Creek third-order watershed outlet 2-year post-wildfire debris flow risk. Background ESRI Topo

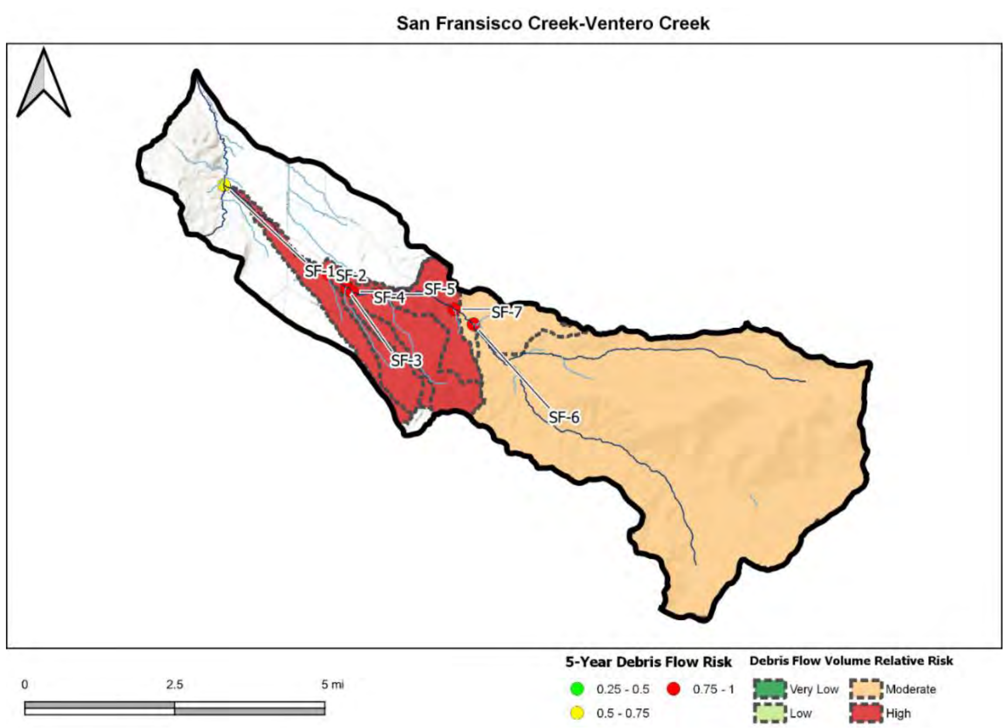


Figure 12-31 San Fransisco Creek-Ventero Creek third-order watershed outlet 5-year post-wildfire debris flow risk. Background ESRI Topo

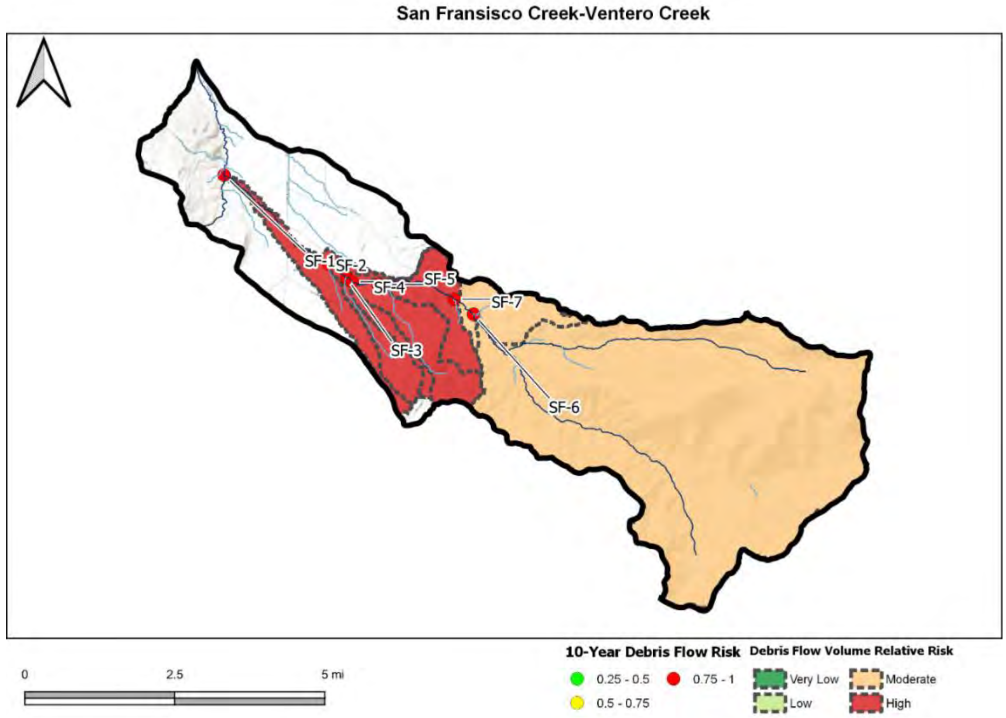


Figure 12-32 San Fransisco Creek-Ventero Creek third-order watershed outlet 10-year post-wildfire debris flow risk. Background ESRI Topo

12.3.9 Vallejos Creek

Debris flow risks are moderate and high for all third-order outlets within the Vallejos Creek HUC12. Third-order watershed outlet locations and debris flow probabilities for Vallejos are listed in Table 12-10, and outlets with debris flow probability greater than 0.25 are shown for the 1-yr, 2-yr, 5-yr, and 10-yr recurrence intervals in Figure 12-33, Figure 12-34, Figure 12-35, and Figure 12-36 respectively. One tributary of concern due to upland vegetation disturbance is the tributary near point VA-3. This tributary does have an in-line stock pond which may provide some sediment storage before the confluence with Vallejos Creek but may also be at risk of avulsion. Lack of upland vegetation within this reach will reduce the risk of wildfire but will likely increase the risk of debris flows as the existing head cuts migrate upstream in the landscape.

Table 12-10 Post-wildfire debris flow probabilities for third-order watershed outlets within the Vallejos Creek HUC12.

Label	Outlet point location		Debris flow probability			
	Latitude	Longitude	1-yr	2-yr	5-yr	10-yr
Vallejos Creek						
VA-1	4108143	470734	0.81	0.85	0.90	0.93
VA-2	4108143	470744	0.57	0.63	0.74	0.82
VA-3	4108073	471034	0.56	0.63	0.74	0.82
VA-4	4108113	471554	0.72	0.77	0.85	0.90
VA-5	4107193	473254	0.70	0.76	0.84	0.89
VA-6	4107163	473904	0.68	0.74	0.83	0.88
VA-7	4108473	471214	0.82	0.86	0.90	0.93
VA-8	4109213	471814	0.84	0.87	0.92	0.94

Vallejos Creek

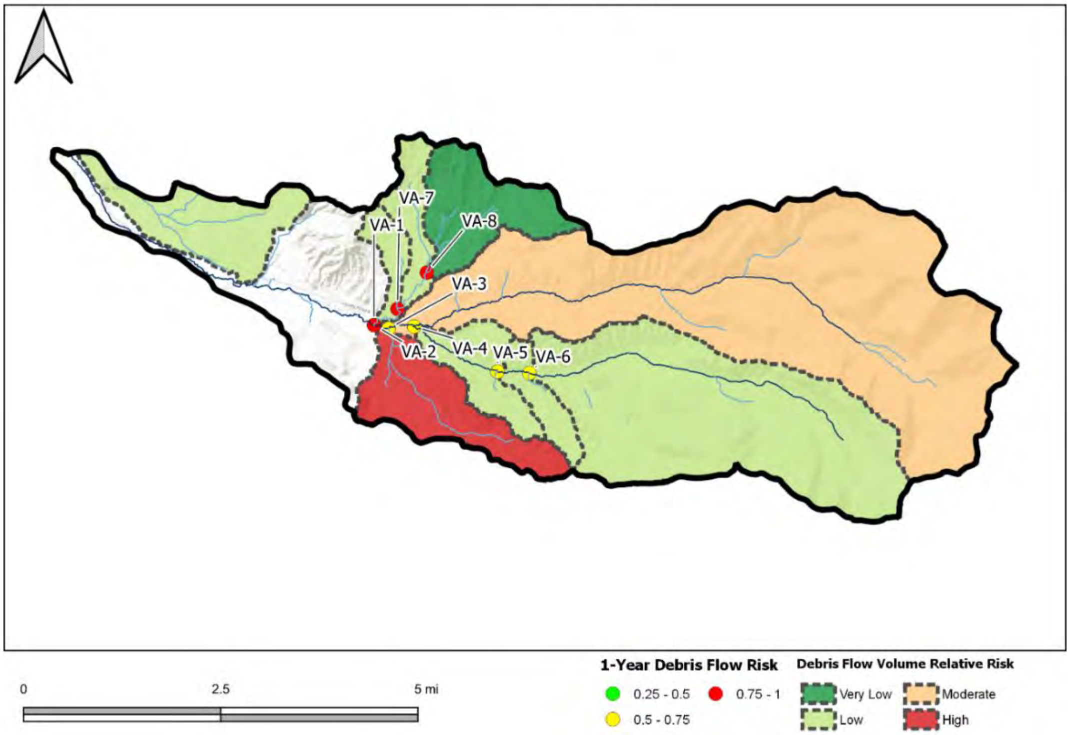


Figure 12-33 Vallejos Creek third-order watershed outlet 1-year post-wildfire debris flow risk. Background ESRI Topo

Vallejos Creek

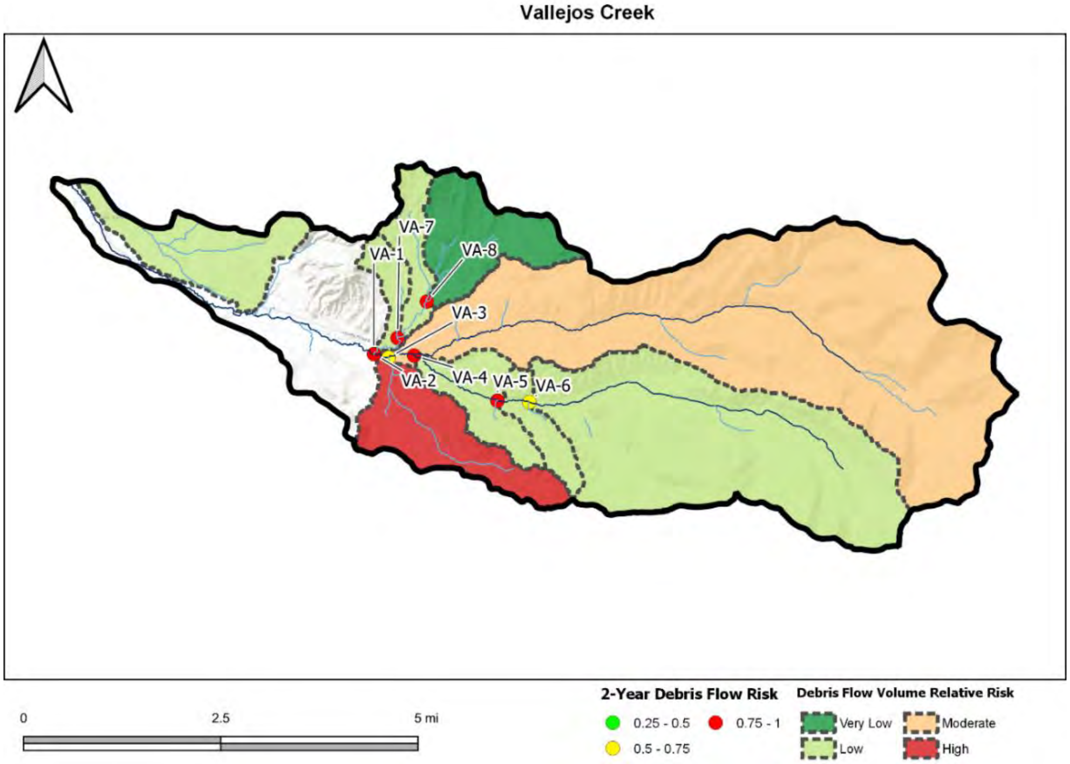


Figure 12-34 Vallejos Creek third-order watershed outlet 2-year post-wildfire debris flow risk. Background ESRI Topo

Vallejos Creek

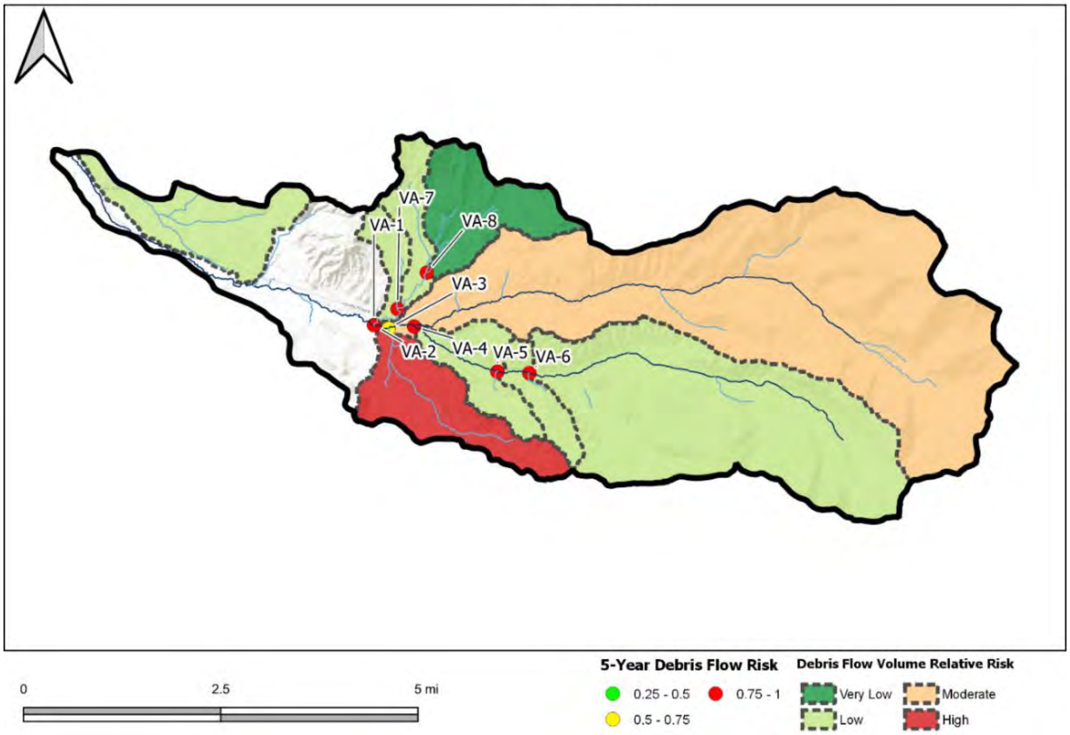


Figure 12-35 Vallejos Creek third-order watershed outlet 5-year post-wildfire debris flow risk. Background ESRI Topo

Vallejos Creek

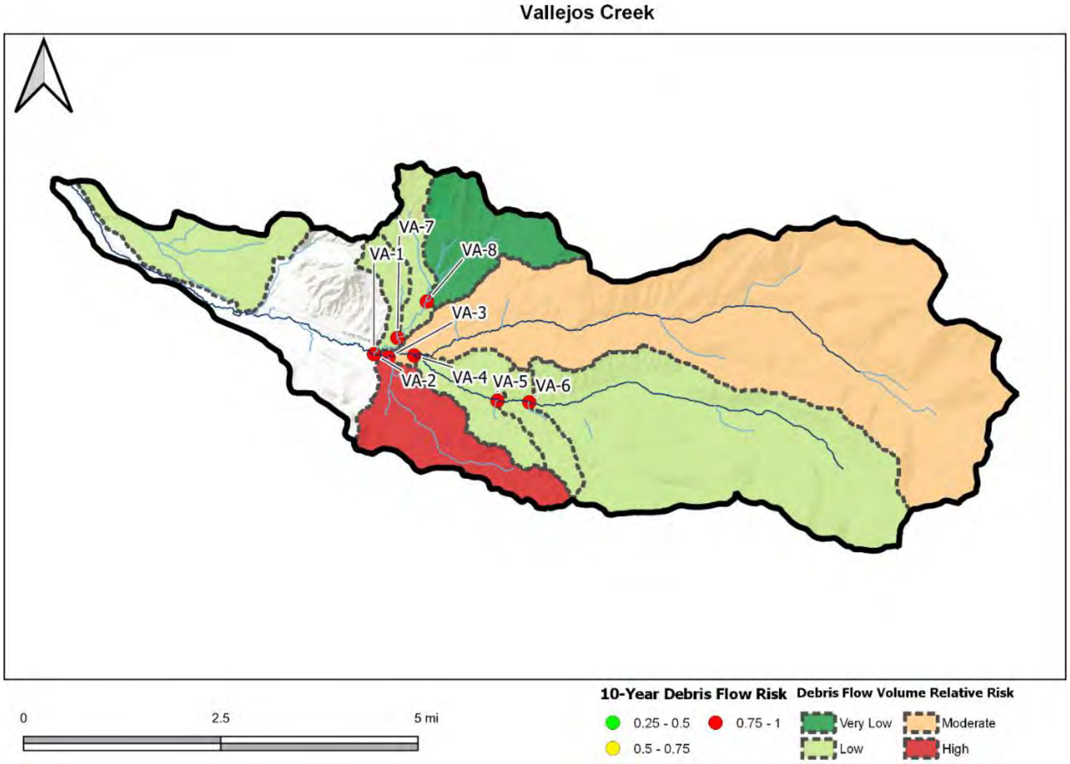


Figure 12-36 Vallejos Creek third-order watershed outlet 10-year post-wildfire debris flow risk. Background ESRI Topo

12.3.10 Infrastructure

Modeled debris flow risks were compared with the public transportation network and irrigation infrastructure with more than three water users to identify moderate to high debris flow risk areas. Areas with moderate to high debris flow risk are shown in Figure 12-37 and are available electronically. The irrigation structures are listed in Table 12-11. Professional judgment based on visual interpretation of landscape and risk factors were used to define risk areas. The ESRI Topo background overlay dataset provides road names, including Highway 142 and 159, numerous county roads, and many roads within Sangre de Cristo Ranches and Wild Horse Mesa. The roads are listed in Table 12-12.

During the review, in addition to transportation and irrigation infrastructure, the San Luis WWTP and Rito Seco Park were identified as areas with moderate to high potential for post-wildfire debris flows. Another area of concern is the access road to the Sanchez Reservoir outlet.

Table 12-11 Irrigation infrastructure with moderate to high risk of post-wildfire debris flows.

Structure	
Cerro Ditch	San Francisco Ditch
Sanchez Canal	Culebra Eastdale Canal

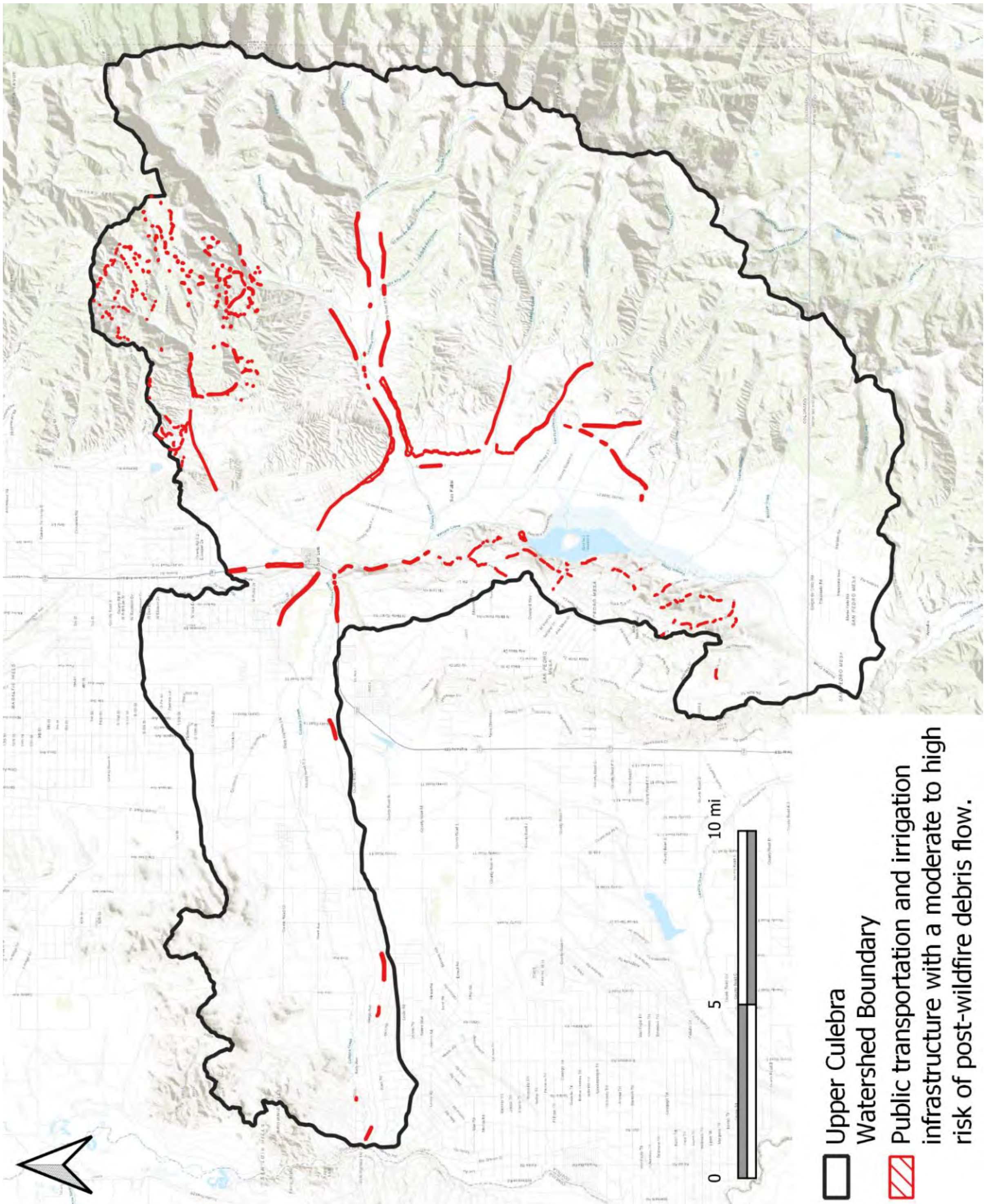


Figure 12-37 Public transportation and irrigation infrastructure with a moderate to high risk of post-wildfire debris flow. Background ESRI topo.

Table 12-12 Road with moderate to high post-wildfire debris flow risk.

Ackerman Road	County Road E.5	Hwy 159	Schluetter Road
Alden Road	County Road H	Jaquez Road	Sedback Road
Alexandra Road	County Road J.2	Juarez Road	Shioshitard Road
Appleman Road	County Road J.8	Kelly Avenue	Skidmore Road
Balleroy Road	County Road K.5	Kerrigan Road	Sleger Road
Balton Road	County Road K.8	Lake Sanchez Dr	Slegers Road
Barbara Road	County Road L.7	Lakeview Dr	Starkbeather Road
Batenburg Road	County Road M.5	Lundy Road	Suegers Road
Belleroy Road	County Road N.2	Lyet Road	Tagge Road
Big Buck Tr	County Road P7	Malcolm Road	Thornfinnson Road
Bronfman Road	County Road R	Malcom Road	Triumph Road
Bronfmann Road	Dana Road	Mountain View Trail	Westby Ct
Buck Horn Trail	Donna Road	Mule Deer Road	Whiney Road
Bucktail Dr	Doyle Road	Nicholson Road	White Tail Cir
Bull Elk Trail	Dunn Road	Park Road	White Tail Road
Cooper Road	Forbes Road	Philip Road	Whitney Road
Cora	Goldsmith Road	Phillips Road	Wild Horse Dr
County Road 18	Goldstein Road	Rito Seco Road	Wood Road
County Road 18.9	Hidalgo Road	Ryland Road	
County Road 19	Hoadley Road	Saada Road	
County Road 22.3	Hwy 142	SC52	

12.3.11 Preservation Areas

Flow-R was used to identify areas susceptible to debris flow runout. These areas are likely to be affected by debris flows if a wildfire were to occur. The debris flow runout model should be evaluated in conjunction with the debris flow probability model to provide an overall assessment of debris flow risk. The runout areas are shown in Figure 12-38.

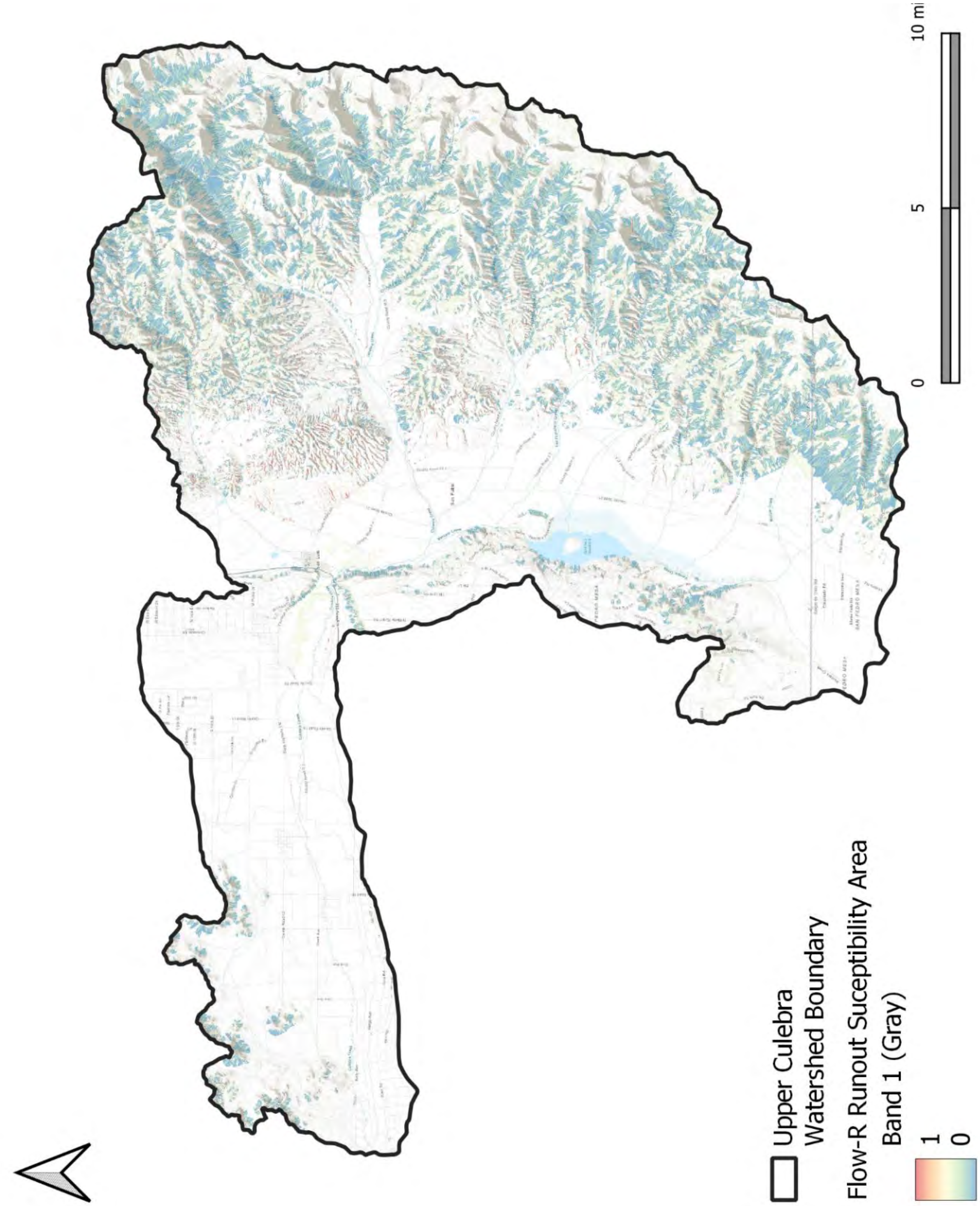


Figure 12-38 Upper Culebra watershed Flow-R runout susceptibility area. Background ESRI Topo.

12.4 Limitations

This assessment estimates the probability of post-wildfire debris flow based on a predictive model developed from burned areas throughout the western United States. These estimates are based on forecasted burn severity parameters from remotely sensed data sets. The intent of these estimates is for planning purposes to provide a basis for planning decisions.

The debris flow runout model is a predictive model developed from the research of debris flows from a variety of sources. The intent of this modeling is to provide areas of debris-flow risk for planning purposes at a regional scale.

This work was developed based on the available information at the planning stage and may warrant revision as new science and data are developed.

12.5 Recommendations

Utilizing the results from the modeling presented in this report can be used to inform land use decisions. In addition, the results can be used to assist in determining locations of forest treatment areas. The downstream risk can be reduced by providing depositional zones at the mouth of the arroyos.

12.6 Summary and Conclusion

The debris flow models generally indicate a high risk of post-wildfire debris flows within the Rito Seco, Vallejos Creek, and San Francisco Creek basins. Good floodplain access and limiting development where the valley confinement and channel slopes decrease along perennial streams will naturally mitigate debris flows in these regions. Debris flows along with the alluvial fans, especially within the southern tributaries, resulting in the streams moving as debris is deposited. Channelization of streams will increase runout distances from debris flows and may result in debris flows traveling farther downstream.

12.7 Model Inputs

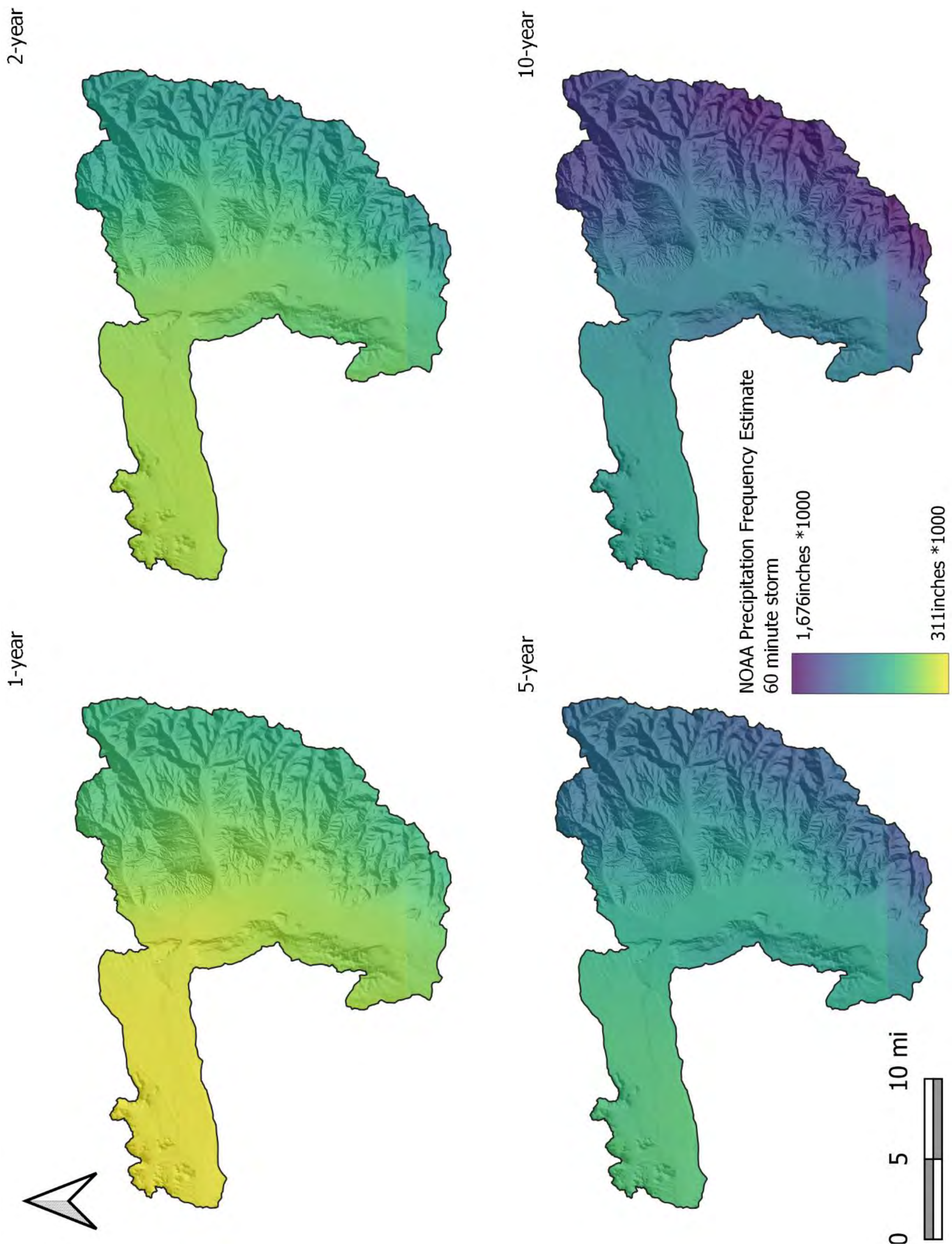


Figure 12-39 NOAA Atlas 14 precipitation frequency estimates for 60-minute storm events in inches X 1000. Grids from Midwest and Southwest regions merged to complete study area (NOAA, 2017).

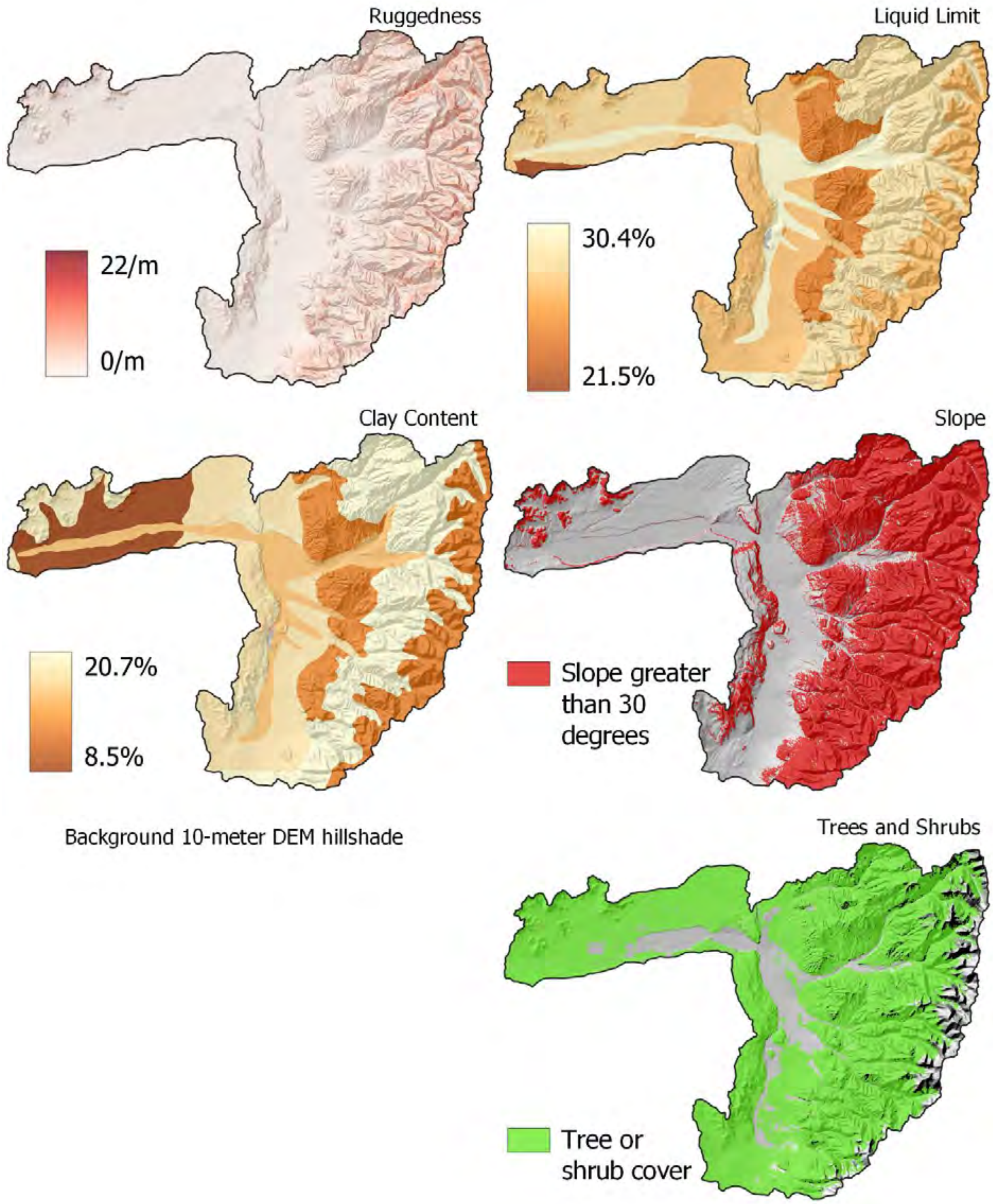


Figure 12-40 Topographic and soil parameter inputs into debris flow probability model. Ruggedness calculated from 10-meter dem processed with Tau DEM (Tarboton, Dash, & Sazib, October 2015), liquid limit and clay content extracted from STATSGO dataset (Schawarz & Alexander, 1995), slope calculated from 10-meter dem using QGIS, tree and shrub cover extracted from National Land Cover Dataset (U. S. Geological Survey, 2019).

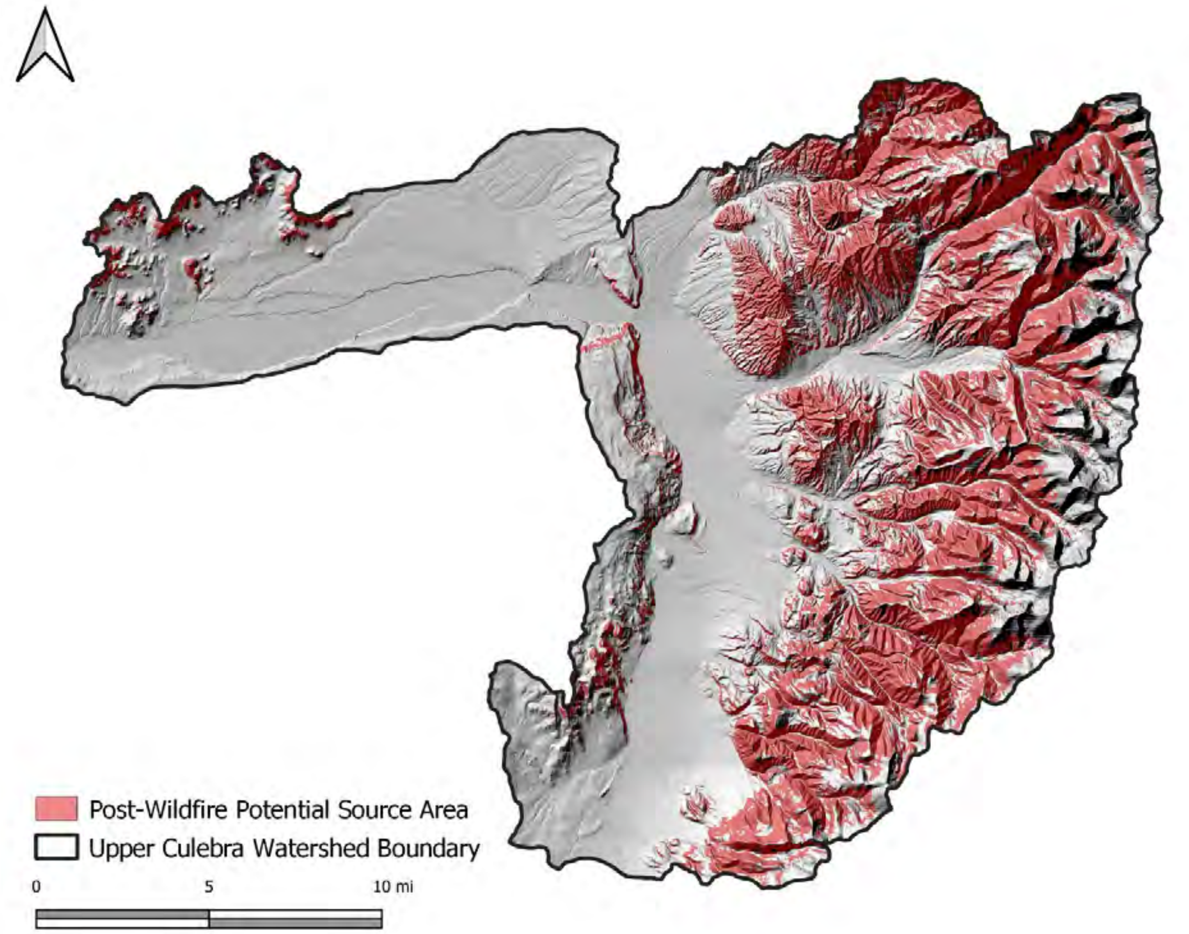


Figure 12-41 Post-wildfire debris flow source areas defined by slope greater than 15 degrees with tree or shrub cover.

Chapter 13. Recreation

Author: Tailwater Limited

13.1 Recreational Areas

Access to public recreation areas is limited within the Culebra Basin. Much work to develop recreational opportunities has been undertaken including construction of trails within the Rito Seco open-space and the proposed trail near Carpenter Ranch. Recreation is an important revenue source contributing approximately $62 billion dollars to the state of Colorado in 2017 and accounts for 5000,000 jobs (CPW, 2019). Recreational opportunities attract individuals to work within the communities. Developing access to undeveloped areas fosters an appreciation for the environment and a greater understanding of the watershed.

During the assessment evaluation of the watershed a few ideas for recreational access were developed. These areas and suggestions were developed based on high compatibility with current and future land use, current areas of conflict that were identified through interviews, and discussion about historic practices. These ideas are provided as example areas, other areas may potentially provide similar value to the community.

13.1.1 Fishing & Picinic Area Salazar Meadow

Salazar Meadow was identified as a location that could provide an area for picnic and fishing access. The historic cabins along the creek could be utilized in providing historical reference and educational opportunities. While this is a relatively small area this could provide legal access to fishing for residents and visitors. Site planning could be used to facilitate livestock fencing and watering.

13.1.2 Fishing access Vega

This reach of stream is the closest reach of Culebra to the Town of San Luis. Currently livestock grazing is causing degradation in riparian habitat. Allowing fishing access could provide an opportunity for angling while helping to offset costs associated with installation of riparian fencing and is often compatible with livestock grazing.

13.1.3 El Poso Waterfall

This area was identified as an area where frequent trespass occurs. This beautiful waterfall attracts many visitors. The trail into the waterfall is a narrow single track that is well defined due to the relatively high volume of hikers that visit this area. This area was identified as an area that may provide scenic recreation access while reducing liability on current property owner and providing mechanism for removal of litter, and restoration.

13.1.4 Hunting Opportunities

Hunting access is very limited within the area. Developing cooperative agreements for providing affordable hunting opportunities within the area especially the local youth.

Colorado Parks and Wildlife Ranching for Wildlife Program provides some access for hunting to Colorado residents through the Colorado Parks and Wildlife draw process within designated ranch properties throughout Colorado including Trinchera Ranch.

Colorado Parks and Wildlife Landowner Preference Program (LPP) also provides eligible landowners preference for hunting licenses. To qualify for this program the landowner much own a minimum of 160 contiguous acres of private agricultural land inhabited by the species being applied for with a history of game damage or a huntable population and be within a Game Management Unit (GMU) for which all rifle licenses are totally limited for the species being applied for (CPW, 2022).

13.1.5 Camping Opportunities

Camping in the mountains was shared as one of the fond memories by many residents growing up in the area. Developing cooperative opportunities through a youth outdoor program could provide a mechanism for providing experiences in the Culebra to celebrate the communities culture and stewardship.

13.1.6 Parks and Open Space

The Costilla County Trails, Recreation, and Open Space plan (2012) identified Rito Seco through San Luis as an opportunity to improve in-town recreational opportunity. This stream corridor was identified as being degraded because of flood risks, riparian structure was rated fair to poor (2), diversion structures did not meet minimum requirements, reach was historically straightened.

Costilla County and Colorado Open Lands with support from Great Outdoors Colorado and National Park Service Rivers Trails Conservation Assistance Program (RTCA) worked together to acquire lands around Batenburg Meadows. This area was historically used for a youth hunting and fishing camp and is used by residents and visitors for outdoor recreation. The Batenburg Meadows greenbelt expansion worked to acquire parcels from 2016 to 2019 to expand the Sangre de Cristo Ranches greenbelt to support local recreational access.

13.1.7 Community Gardens

The Culebra Basin is home to many heritage crops that highlight the region through culinary experiences. Water rights from Rito Seco could be evaluated to provide water and educational opportunity for the community and visitors to continue to cultivate and promote the heritage. This opportunity could have multiple benefits such as aiding ditch maintenance through town. Produce from the community garden could be utilized to provide local access to fresh produce especially to those residents that do not have access to land for personal gardens.

13.2 Discussion

13.2.1.1 Electronic donation option at sites that accept donations

Where cash donations have historically been collected it is difficult to donate if the visitor does not carry cash. Providing QR codes and electronic donation options could increase revenue by allowing those who do not carry cash to donate.

13.2.1.2 Vandalism prevention and repair

Unfortunately, vandalism can quickly turn a community asset into a liability. Preventing and preparing for vandalism will improve visitor’s impressions of the community and promote visitors to linger longer eating in restaurants, shopping, and staying in hotels.

13.2.1.3 Funding sources

Great Outdoors Colorado

Great Outdoors Colorado provides funding on a Triannual cycle and an annual cycle. Triannual grants include land acquisition, community impact, planning & capacity, and stewardship impact grants. Annual grants include RESTORE Colorado, Centennial Program Visioning, Conservation Service Corps, and Fellowship program grants.

- Directors Innovation Fund – Used on Colorado Parks and Wildlife projects including state wildlife areas and the RiverWatch program
- Local Government – Trail construction, community parks and playgrounds, environmental education centers, learning gardens, interpretive signage, picnic areas, and storytelling
- Open Space – Purchase of open space property or easements.
- Planning – Master plan for parks, recreation, and trails.
- Restoration- Large-scale habitat restoration and stewardship projects across priority habitats.
- Youth Corps – Example projects that were funded in 2020: community garden and education, trail clean-up and repair, removal of invasive plants, and planting.

13.2.1.4 Trespass and poaching

To foster relationships necessary to develop these ideas and other potential opportunities one of the first steps is to ensure that the development of legal recreational opportunities will reduce illegal activities that occur on the property owned by current landowners. Because these activities require either leasing or purchasing property landowner agreeance is necessary to facilitate moving any of these ideas forward.

Chapter 14. Historical Land Use

Authors: RedFISH Environmental and Tailwater Limited

14.1 Introduction

This chapter of the report summarizes the findings from a community survey and interviews with community members. A public survey was distributed during the Sangre de Cristo Acequia Association's (SdCAA) Annual Congreso in August 2021. A link to the electronic survey form was also made available at the Costilla County Conservancy website (www.costillaccd.org) and through social media. Interviews were conducted in October 2021 with individuals who knew the history of the Culebra Watershed. Both the survey and interview were developed with input from individuals from the project team and stakeholders. This report provides a summary of information collected through surveys and interviews. The survey and interview data in this chapter was reformatted from the original memo prepared by RedFISH Environmental (de la Hoz E. , 2021).

14.1.1 Goals and Objectives

Goal 1 Document community concerns within the basin.

Goal 2 Document probable causes and trends in degradation.

14.2 Survey Summary

The survey requested input on historic and current land use practices, changes in water use, participation in soil and water conservation programs; changes in water quality; landowner plans for the future; types of open space areas community members use and are interested in seeing conserved or protected, improved or developed; use of forest resources; perception of watershed condition; and management actions community members are interested in seeing implemented. Of the total 13 survey responses received, eight were completed by farm or ranch owners. A blank copy of the survey may be found in Appendix 15.A.

All responses were from community members that live within the Culebra Basin, and most were originally from the area; 62% were farm/ranch operators and most do not currently own livestock. Those that currently own livestock have less than 20 animals. Historically, some of these farmers/ranchers owned a greater number of animals (50+) primarily cattle and sheep. Changes in observed livestock numbers among farmers/ranchers ranged from 2 to 17 years. Most respondents (75%) indicated mixed production as their livestock management practice and 25% indicated changes in practices used were driven by the sale of livestock and limited water resources that have led to reducing livestock numbers. Although the number of animals has been reduced, 50% of farmers/ranchers indicated the size of their operations has increased or and 38% indicated the size of their operations has remained the same.

Most landowners (75%) have been involved in soil or water conservation programs and learned about those programs through the Natural Resources Conservation Service (NRCS) and community members. Participation in those programs was driven, in part, by the need for financial assistance to implement practices and an interest in improving the ecology of the land and sustainability. Over 60% of respondents indicated they have not tested soils or do not have a nutrient management plan, and 50% indicated they had observed soil erosion on their property. Practices used to prevent soil loss included the use of land leveling, cover crops, and irrigation water management. Half of the landowners indicated irrigation practices have changed, primarily through the increased use of gated pipe to increase the efficiency of water use. All respondents indicated they use water for irrigation and domestic use; 88% also use water for livestock. In addition to the use of gated pipe, half of the farmers/ranchers noted having implemented changes in water use practices. Changes included increased use of ground water due to drought conditions, use of solar power for livestock wells, and installation of French drain systems to manage groundwater seepage. Of the 8 farmers/ranchers that completed the survey, five indicated they have plans for implementing soil and water quality management projects in the future. Projects described included using cover crops, improving water diversion points, establishing raised beds for vegetables and herbs, and implementing center pivot irrigation on one section of the property. Practices used that could have an effect on soil and water quality included the use of gated pipe and structures to manage water conveyance, cover crops, tree planting, in-ground watering for livestock, riparian fencing, not allowing cattle to overgraze, and picking up trash (at a significant cost).

75% of landowners have been involved in soil or water conservation programs

Farmers/ranchers that implemented soil and water conservation practices have observed reductions in soil erosion, increased foraging for animals, improvements in habitat for bees and wildlife, improvements in water distribution, increased pasture area, and increased crop yields. Other benefits listed included visual and enhanced quality of life for livestock and pets. Difficulties in implementing practices included the monetary cost and need to purchase equipment. All farmers/ranchers expressed a willingness to implement recommendations to improve the soil and water quality of the area.

Farmers/ranchers expressed concern over water quality. Sediment in the ditches and the main creek is one concern. One landowner worried about the potential effect of roundup use by the Sanchez Reservoir and Sanchez Ditch Company on his wells and animals, as well as the effect of discrepancies in the decreed and actual water use on the availability of water for irrigation. When asked if water quality has changed over time, one landowner noted that flows though his property are better and water quality has likely improved. However, others noted more land development leads to more trash in streams and reductions in water.

Regarding the administration of water resources, four of six landowners/ranchers feel management at the state level is not effective, most feel management at the division and district (water commissioner) level is effective, and four of seven feel management by the mayordomo is not effective. Effective water resource management is important since most landowners note a key factor that will determine their continued residence in the Culebra Basin is water availability. Landowners associated water management as a determining factor to continue farming and ranching. Although most farmers and ranchers indicated most of their income comes from non-farm sources, all expressed their desire to continue working on their land, indefinitely, and expect their operation to be active in 20 years.

In terms of use of open/public space, most respondents use areas for recreation, fishing, and wood-gathering. Acequias are used by 11 of 13 landowners and most participate in annual spring limpieza (ditch cleaning). Most also have access to Cielo Vista Ranch (La Sierra) and use forest resources. Primary use of forest in the watershed included water, recreation, timber, and visual (scenic features, aesthetic resource). Wood is used for firewood (2 to 30+ cords per year) and construction of outbuildings and fences. Recreation uses include camping and walking. One of 13 landowners noted grazing and faith (as spiritual connection with natural resources) as the primary use of forest resources in the watershed.

The survey gave opportunities to landowners to share their perspectives on watershed health, voice concerns, and share ideas to improve watershed condition. We asked landowners to evaluate the health of riparian and aquatic habitats, water quality, soils, forests, and rangeland. Fair condition was the most common response for all watershed components. Although two of 13 landowners strongly disagree with seeing changes in the watershed in the future, most (69%) are willing to see or make changes (in the mountains, on public lands, and/or their own property), and the types of management actions/recommendations they would like to see included the following:

- Enforcement of county watershed protection
- Update infrastructure throughout the watershed
- Improve maintenance of roads
- Proper grazing on the mountain and La Vega.
- Restricting non-resident access to logging and off-road vehicle use.
- Restricting the sale of hunting and fishing licenses to non-residents. More input from heirs on the care of the watershed, the forest, and wildlife.

75% of landowners felt the community can work together to improve the overall condition of the watershed.

Most landowners (75%) felt the community can work together to improve the overall condition of the watershed. Those who did not think that is possible noted that it has never happened before, and that people lack interest in conducting the work.

14.3 Interview Summary

The purpose of the interviews was to gather additional land use and land-use history information. General topics included input on farm/ranch management, economic activity in the Culebra Basin, perceived changes in the watershed, changes in land use activity and potential drivers of those changes, and perspective on current and future challenges faced by the community. The following is a summary of interview responses.

14.3.1 Main economic activities in the Culebra Basin

Jobs in the Culebra Basin are limited. Not everyone works and there is a significant number of retired seniors. The largest employers are the county government and the school district. Outside of the county government, perhaps the largest economic driver is the Trinchera Sawmill. Some people are self-employed and there are a few family-owned businesses on Main Street in San Luis. Many people commute to work elsewhere (e.g., Alamosa, Monte

Vista). The declining forest health condition following the drought in the early 2000s has led the Trinchera Sawmill to shift from production of marketable timber to a salvage operation (harvesting mostly firewood). In more recent years, social assistance has become a significant economic driver; a substantial percentage of the population rely on welfare and various social programs.

Many residents in the basin have small farms and ranches and work on agriculture. They have sheep and/or cattle, and they raise hay either for their own cattle or to sell. However, agriculture is not a driver for the local economy. People farm because they have the land, but they have other jobs to support themselves. Agriculture only provides supplemental income for most landowners. Only large landowners generate enough income to live off the farm/ranch.

"There's really not much money in farming. Pretty much just maintenance of what you have to hang onto it. A great life, but to make a living on it, you know, you gotta have, in most cases, that big job."

Agriculture is considered an important part of the local culture.

"I always say [farming and ranching] it's in my blood. It's part of our life and it's hard to let it go. Because we don't make a ton of money on that, you know, it helps."

People that have lived in the area, often their entire lives and for multiple generations, have a deep connection with the environment because they worked the land with their parents and grandparents.

People forced to leave rural areas for work has impacted the economic activity in the area. Due to the lack of jobs, people encourage kids to go to college and when they graduate, they tend to move somewhere else. Most do not come back which, in part, explains the small size of the community. Some people that established careers in other locations have moved back to the basin after retirement with their pension or social security. Overall, out-migration and reliance on social programs has further reduced economic activity in the basin.

Historically, there was more economic activity in the area. There were banks, drug stores, grocery stores, a theater, multiple barber shops, five or six restaurants, and other businesses in San Luis and surrounding villages; a few decades ago, there were more liquor stores. Now, there are no banks, a few businesses on Main Street, and more cannabis dispensaries. The gold mine employed a lot of people for about 10 years, and when the mine closed [mid-1990s], some people went to work for the mining company elsewhere; some eventually returned to San Luis area. In the following years, economic activity began to slow down further. Lack of jobs and the increase in social assistance in more recent years contributed to the lack of business interest in the area. Other factors noted that led to change in population included the decrease in family size, out-migration after World War II, limited access and use of Taylor Ranch in the1960s, and more recently the COVID pandemic; many people left the area after receiving social assistance through COVID economic initiatives.

The effects of out-migration and limited economic activity are widespread. For example, there were 11 school districts in Costilla County in the 50s and 60s. Following a reorganization by the State of Colorado, the number of districts was reduced to two (Sierra Grande and Centennial). There were about 2000 kids in Centennial School District in the 1950s and now there are about 200 students. The small size of the community precludes establishment of some basic services such as waste management. There is a waste service, but many people cannot afford it.

Industries that have been proposed for the San Luis area include a prison, a pig farm operation, and a wood pulp mill--industries that residents do not want.

14.3.2 Effects of land use change on the environment and community

“Communal use of these mountain lands, I feel like it's a lifeblood of the …. villages and they provide meat for hunting, fishing, herbs for medicinal purposes, wood for fuel, timber for building homes, pasture for cattle and sheep, and most importantly water, which is the essence of life for our community.”

For the community, perhaps the most significant change in land use is reduced access to Cielo Vista Ranch, also known as La Sierra by the local community. Historically, people in the community had access to collect firewood, hunt, fish, hike, ride horses, and camp. Access for wood and grazing continues to be part of the community legacy, but restrictions placed on the other uses, considered part of an ancestral right, is negative for the community. Many people sold their sheep when former owner Jack Taylor closed the mountain in 1960 and then the newer generations began losing a connection to the mountain. Public land and open space are extremely limited in Costilla County and access to the mountain was very important for the local residents. Wood-gathering was common, and pinion was very popular for firewood. A decrease in pinion has been observed along with a decrease in small game. Pheasants and rabbits were more common historically.

Historically, people grew crops and livestock for their livelihood. For some, farming and ranching was the main source of income. In the 1930s during the Great Depression, people in the San Luis area continued to raise their own food and farmed for their own subsistence.

“When the Depression hit, a lot of people didn’t even know it hit in this area.”

However, while the Great Depression did not have as drastic an impact on the San Luis area as it did in other farming communities and in urban areas, the economic situation in the basin did not improve much following the Great Depression.

From the 1940s and 1950s to the 1970s, a lot of the crops traditionally grown for personal subsistence started being grown for profit. Farmers stopped raising cauliflower, cabbage, zucchini, beans, potatoes, and other crops, and turned mostly to hay for their cattle. Around that time, more of the younger generation started leaving the area and moved to cities. The vara strip system of dividing the land is regarded as a fair system that allows for subsistence, but it does not allow for more industrialized systems of irrigation and production (e.g., center pivots) and that is why few people live off the farm and part of the reason agriculture is not an economic driver and why economic activity in the area is limited.

Coupled with low economic activity in the Culebra Basin, travel, and interaction with people from other parts of the country led young men returning from WWII to move out of the area as they often felt they could do better economically in other places. Since then, there has been a progressive loss of connection to the land, and it is difficult to find people to work on farms or ranches. In recent years, the reliance on welfare and social services has exacerbated that problem. Many properties are not being utilized (farmed, irrigated) and some landowners recognize that overgrazing, not leaving crop residue, and not maintaining moisture on soils is detrimental and leaves fields prone to wind erosion, particularly under drought conditions, which in turn, can affect adjacent properties. However, within the last couple of years, more properties are being planted, or at least leased, and it appears that some landowners are trying to get properties back into production. It is possible that this change is due to people now having grazing rights at Cielo Vista Ranch. Having more animals and more farmland irrigated can be considered beneficial for adjacent properties and can help reduce pressure in communal grazing areas (La Vega).

Grazing pressure at La Vega and areas adjacent to stream channels has had significant impacts. In the 1970s, landowners started letting their meadows grow for hay production and cattle. Most people were overgrazing their land. and did not have the acreage needed to support the number of cattle they owned. Consequently, many properties are now in a similar condition to La Vega where a substantial amount of grazing damage has been observed. In the 1970s and 1980s, grazing practices started to change the condition of La Vega and those practices are seen as people taking advantage of free access to grazing in that area. A few decades ago, La Vega was used as a playground. Kids went tubing, swimming, and fishing. Fish were plentiful. Since the 1980s, many of the small drainages where people fished have filled in. It is recognized that some people take advantage of free grazing but do not contribute to any kind of management or planning. Most people do not have cross fencing along streams that run through their property because of the cost. In addition, to overgrazing at La Vega, it is also recognized that this use has impacted vegetation and streams at Cielo Vista Ranch.

Environmentally, the most drastic change observed in the past twenty years is perhaps long-term drought. A drought in 2002 and surrounding years affected farmers and ranchers, and some were forced to sell their livestock, including people with junior and senior water rights. Drought had an impact throughout the watershed. The driest year was 2002 but the drying cycle began in the mid-1990s. There were no major insects or disease issues in the forests in the early 2000s. Effects of drought started to show in the forest conditions around 2004 when spruce beetle and bug worm infestations grew and small, natural water springs began drying up.

Although drought conditions affected landowners in the area, few people were aware of the declining forest conditions. People in the community did not see the issues in the forest as a problem of their own until the Spring Fire occurred [2018]. Following that fire, people from the community participated in tours of the burn area and debris flows that highlighted the connectivity between uplands and the valley, and the potential effects of wildfire on the local community.

The Spring Fire was a catalyst to bring people to the table to address watershed issues as a stakeholder process. At Trinchera Ranch, the emphasis of current forest management is scientific-based harvest restrictions, salvage logging and reduced fuel loads, and increased efforts to maintain mixed conifer stands at lower elevations to minimize the risk of losing those areas to fire, insects, and disease. Prior to this, the emphasis of forest management was on production.

Landowners and ranch managers recognize that grazing management is necessary to improve and maintain environmental conditions. The lack of coordination among users results in overgrazing certain areas.

Previous efforts to establish a grazing management plan for La Vega and La Sierra have not been successful. A grazing association was initially established as a subgroup within the Land Rights Council and subsequently established their own 501C3 entity so they could apply for grants. Workshops through the Land Rights Council and the grazing association were aimed at the development of a grazing management plan with input from different organizations in the community including farmers and ranchers. Some cross fencing and electric fencing were started but not maintained. Maintaining pastures in that area is beneficial. Factors that have precluded the completion of a grazing management plan included disagreement over the consultant recommended by the Land Rights Council, the cost of developing the plan, lack of incentive to implement the plan, and the time commitment to participate in plan development and implementation. Another factor that may prevent agreement on a grazing plan is that for some people limiting their ability to take cattle to Cielo Vista Ranch could result in the need to lease property elsewhere. There is no incentive to manage grazing (prevent overgrazing) and organized, voluntary action is unlikely.

While there are very few livestock owners that actively move their cattle based on the condition of pastures at Cielo Vista, most leave their animals unattended. Members of the community have the right to graze at Cielo Vista, and that right is based on the number of animals an individual can sustain at his/her own property; however, some individuals take more animals to graze at Cielo Vista Ranch than they should according to the acreage they own. The effects of grazing pressure are observed in meadows where there is limited vegetation cover.

Limited vegetation cover along some areas of stream corridors has been associated with an increased algae cover of stream substates. In addition to the effects of grazing on stream banks, the observed increase in algae may be related to the removal of trees along the river. Further, many stream sections in the lower part of the basin are now rented for fly fishing and those areas have been cleared.

In the early 2000s, after Jack Taylor's ownership of Cielo Vista Ranch, the new management removed native vegetation to plant grasses in the Salazar Meadow and low areas of South Vallejos and Jaroso Creeks. Those areas that were covered in grass at that time are now degraded due to grazing pressure.

Opening additional areas for grazing is needed to allow for rotations and rest. Although there are areas at Cielo Vista Ranch (e.g., Salazar Meadow) that could be irrigated to grow grasses, this requires a substantial amount of work and there are not coordinated efforts by users themselves to maximize the use of those areas. Developing and implementing a grazing management plan is considered by both community members and Cielo Vista

Ranch management as an action that could both help improve environmental condition and have a beneficial economic effect on the community.

Filing a notice of intent is required before people can exercise their right to put livestock at Cielo Vista Ranch. The form includes the number of animals that will be taken to the ranch, but the accuracy of those records is not certain, and it may not reflect the actual number of animals taken to the ranch since calves are often not counted (i.e., cow-calf pair numbers are not documented), and there is no requirement to record the dates and time frames that the animals are grazing on the ranch.

At La Vega, although overgrazing still occurs, the overall administration of grazing rights and coordination of them has improved over time. Before, people from outside the area would bring cattle and leave them in that area (poachers). Some locals could leave their cattle in La Vega and would only check periodically; that is not the case anymore and now there is some organization and oversight.

In the late 1990s, the community was concerned with logging activity in Cielo Vista Ranch. Many roads were built for logging. Farmers observed a drastic increase in sediments on the acequias and headgates. Locals and people from environmental organizations that protested logging activity were arrested; it was a very contentious time. More sediment on the acequias resulted in more work or more cleanup cost for landowners. Reduced flows also had an effect on crop production. Since then, many of the roads that were built for logging have been closed and that has helped to some extent, but sedimentation is still a problem. Part of that problem is the poor location of roads and little or no maintenance. New development has also led to construction of new roads in other areas such as El Poso. There are also roads that may be used by people to access the land for wood-gathering and grazing.

Overgrazing and subsequent sedimentation has been considered a problem at Cielo Vista Ranch, but community members do not consider the impact of grazing to be larger than the impact of previous logging. Also in the 1990s, the community was concerned with environmental disturbance and contamination of water caused by mining on the Rito Seco drainage. The observed increase of sediment has also been associated with county road maintenance. Roads are not as well maintained as they used to be and are now narrower with wider bar ditches that carry a considerable amount of sediment during rainstorms. In some cases, sediment can fill up acequias entirely, and heavy equipment is required for the clean-up at a significant cost. Some of the sediment also ends up on the fields. Maintaining headgates is also expensive. A lot of the canal infrastructure dates from the 1950s and 1960s. Leaking headgates affect people upstream because they have reduced access to their water rights. The perception of increased sedimentation in the basin was not shared by everyone we interviewed. For some, the landscape has not changed drastically in the basin and areas of erosion are not significant.

Concurrent with the effects of drought on forest health, other environmental changes noted by community members include the declining wildlife abundance. Pheasants, rabbits, and small game were more common in the 1950s and 1960s. Bears were abundant in the early 2000s and now sightings of them are rare. In addition, the number of beaver dams in the watershed has declined. There were more beaver dams in the 1970s and it was noted that some time in the 1950s or 1960s the county may have straightened out some creeks and removed abandoned dams to deliver water more quickly to the reservoir, thus impacting the streams.

14.3.3 Challenges for the Community

There are mixed feelings from the community regarding in-migration and out-migration. On one hand, retaining local people in the community is difficult due to the lack of jobs, on the other hand, there is an influx of new people into the community that do not have a similar background to long-time residents. Some of that influx is from a generation that grew up in the city, whose parents or grandparents are from San Luis. Those individuals have some connection to San Luis but do not share the same deep connection to the land or the culture. An important part of the loss of culture is the loss of Spanish language.

The lack of economic activity, recreation, and entertainment opportunities have contributed to the out-migration from the area particularly by the younger generation. There is interest in promoting small businesses in the downtown area of San Luis, but there is concern about people with financial resources from outside the community coming in and changing the community. There is interest though in promoting small business owned by local residents. Many people in the community do not want to see they type of change that has occurred in other communities (e.g., Taos). However, some recognize that some change is good.

Restoring the buildings along Main Street and creating new businesses is often brought up by community members as ways to improve the economic situation and retain population and cultural heritage. One factor preventing small business development and growth is a lack of financial resources at both individual and institutional levels. There are no lending institutions in Costilla County and there is limited access to credit. The banking institutions are in Alamosa County. Loan applications by basin residents are often rejected and that is perceived by some as institutional racism. That is something that happens in Costilla and Conejos Counties. "*As Hispanos they don't treat us well. Costilla and Conejos is [a] Hispano area.*"

Besides providing access to water, acequias are a cultural resource and the infrastructure has been degraded. In some areas of San Luis, people do not know where the ditches are located, and some have sold their water rights (to the gold mine). The influx of new people interested in the growth of marijuana has been contentious because they also take water from acequias or from wells; this issue has been brought up in acequia meetings. The community also faces a significant drug problem. As more people move to mountain areas such as El Poso, lack of planning and lack of practices to reduce disturbances to the ground will impact the watershed.

On a basin-wide scale, it is recognized that there is a significant wildfire hazard. The challenge is taking care of La Sierra and minimizing the risk of fire. Because there is not a lot of infrastructure on the mountains, there is concern that the state would not be able to control a fire when one occurs. Coordination between community members, Trinchera Ranch, and Cielo Vista Ranch is also noted as a challenge for the management of the mountain area and one that needs to be overcome " *so that he [Cielo Vista Ranch owner] doesn't destroy it, so that we [local residents with access] don't destroy it*."

Although the risk of fire is recognized, the magnitude of the fire risk is possibly not understood well by many in the community. A trend of increasing fire size has been observed in the past 20 years. The fire at the sand dunes (Great San Dunes National Park, 2010) was around 2000 acres, the Mato Vega Fire in 2006 was around 14k acres, the West Fork Complex Fire in 2013 was over 106k acres, then the Spring Fire in 2018 encompassed 180k acres in two counties. Managing fire risk and the potential impacts of fire on the forest and the community below the mountain is complex. People in the community now have an idea of the potential impacts but likely do not a full understanding of the long-term effects of fire on the landscape and how it can affect irrigators.

The community does not agree with forestry management given the observed increased sedimentation in irrigation systems. Forest managers recognize that one of the main issues with timber operations is erosion caused by roads and they have also observed that sedimentation in upland areas can affect fish and stream habitat. However, it was noted that the amount of sediment in upper areas is unlikely to affect water users downstream. A previous study identified roads as sources of sediment affecting waterways and irrigation ditches. Better road maintenance was brought up as an action needed to help reduce sedimentation.

Fire mitigation treatments are important around roads because that is the most accessible point for a fire to start and move to other areas. If the community recognizes that forest management is needed to reduce the potential impacts of fire and measures to reduce fuel loads can take place, the next limitation and challenge is the limited work force and infrastructure to access areas that need to be treated.

The limitation on workforce is not a local issue but one that has been observed in the region. Many people in the community and the region moved away when the COVID pandemic started, and they received financial assistance. Many people left their jobs and now live on social welfare. Often there are multiple generations in the same family living on welfare. This coupled with increasing drug use in the area poses a challenge for increased economic activity in the basin.

Other challenges faced by the community include waste management, sources of drinking water, and the effects of global warming. Waste management is a growing concern in the basin because residents have limited options for garbage disposal and trash is observed in yards, on roads, and in creeks. Drinking water could become a problem if there is contamination by the mine tailings holding facility in Rito Seco. The amount of water in Sanchez Reservoir is significantly less than what it used to be and that highlights the reduction in snowpack and water runoff in the area. Global warming is of concern as snow melts faster and it is harder to retain the water on the mountain. Less water retention on the mountain leads to a shorter irrigation season and decreased crop production.

14.3.4 Stakeholder recommendations for environmental and community improvement

- Complete and implement a grazing management plan.
- Opening and planting grasses in additional areas coupled with grazing management can help reduce pressure on La Vega and Cielo Vista Ranch. The grazing areas need to rest.
- Re-establishing grass in areas opened after Taylor’s management at Cielo Vista Ranch can help reduce grazing pressure in other areas.

- Since most farmers/ranchers have access to the water, develop water taps along the creeks to reduce the impact of cattle on stream banks.

Improve maintenance of pastures and meadows to improve riparian areas.

Improve canal infrastructure including headgates.

- Restore ditches and acequias though San Luis and promote the re-establishment of orchards.

Work with landowners and local government to manage sediments.

Consider building sediment traps.

Improve road maintenance throughout the basin to reduce erosion and sedimentation.

- Increased water storage during wet years.

A fire could have significant impacts on the environment and community and management is needed to reduce risk and protect forests in the basin.

- Improve waste management.
- Increase accountability over access to Cielo Vista Ranch, particularly access by people that do not come from the area.

Diversify and improve economic activity. Promote more businesses on Main Street (galleries, restaurants).

Develop more locations and cultural and recreational activities to help to retain the younger population and attract tourism.

14.4 Historical Information

Included in this section is a compilation of some of the historical data that was evaluated to provide additional background for the assessment.

Figure 14-1 Cattle on the Commons, San Luis from History Colorado Collection. (Adams, 1963-1974)

One of the major focuses of the watershed assessment is on water and how water moves through the basin, from raindrop to stream and back out to the fields. Our journey takes a trip back in time and summarizes some of the events that are known to have impacted the way water is used and flows through this watershed. This section describes some of the pitches that were used to market the Culebra Basin to settlers, the changes in trade over time, how the lands were/are divided, water administration, both local and state, documented events relating to forestry and timber harvest, and the advancement of technology. There are numerous documents describing history within the region, this discussion is aimed to highlight some of the events that are tied to the current conditions of the natural resources within the Culebra Watershed.

While these lands have supported the population of indigenous peoples throughout time (Cooper J. K., 2001) and Hispano settlers as early as the 1820's (Water Education Colorado, 2004), this evaluation begins sometime between 1850 and 1860, "when the Chicano villages of the Culebra were settled by" … "pobladores (village colonists) invited by the heirs of the Sangre de Cristo Land Grant" (Peña, 1999). These settlers utilized gravity irrigation systems known as Acequias, nearly all of which are still in use today. The Sangre de Cristo Land Grant was a Mexican land grant issued in January 1844 (Colorado Encyclopedia, 2022). The Sangre de Cristo Land Grant is vast and was described using natural metes and bounds, using features such as the Rio Grande and the Mountains (Blackmore, 1869, p. Sangre de Cristo Grant).

In 1848, with the signing of the Treaty of Guadalupe Hidalgo, a large tract of land, including the Culebra Basin, became part of the United States. This basin was transferred from New Mexico to Colorado Territory in 1861 (Water Education Colorado, 2004). Colorado became a state in 1876.

14.4.1 Marketing

The region was actively being marketed to settlers from many regions, trying to attract them to Colorado. The United States Freehold Land and Emigration Company in Colorado Territory, formed in 1870 (Davidson & Guarino, 2015) was competing for their share of the market, selling parcels to people that had come to settle the region. The United States Freehold Land and Emigration Company in Colorado Territory was sold to Freehold, a group of Dutch investors, who had great plans for roads and homes to be constructed for prospective immigrants (Davidson & Guarino, 2015).

Blackmore's report (1869) to Governor William Gilpin provides insight into how the region was being marketed for settlement. Contained within is an excerpt from Joseph S. Wilson's report of the General Land Office:

"The descending terraces present a fauna and a flora increasing in richness and variety; cereals, flax, vegetables, and fruits flourish upon the plain; sheep and cattle attain superior development upon the hills of luxuriant grass. The products of the dairy, the orchard, and the garden give promise of the value yet to be realized by a systematic industry."

In the section on Southern Colorado contained in the Extracts from the Report of the Denver Board of Trade on Colorado includes a description of farming practices. "*Irrigation is an essential part of farming, and the labour (sic) is mostly performed by Mexicans. Very few farms are fenced, the necessity being obviated by the laws requiring stock to be herded during the growing season."* The aridness of the lands is highlighted with farming and limited to those areas where water can be brought from the streams by acequias. Going further into livestock the conditions are described as: "*Stock of all kinds graze and fatten the year round, with no other care or expense than herding, and as the range for grazing is unlimited, stock-growing will always be as it is now, the most profitable business for agriculturalists."*

The agricultural system was described in the Auriferous Regions of North America, The Parks of Colorado – The New Magnets of Auriferous Attraction as follows: "*In pastoral* *agriculture there is seen the spontaneous production by nature of peat, dairy food, hides, wool and kindred elements, sustained as fish in the see. It is here we find an immense self-sustaining element of food for the human family*."

These accounts of the region enticed new settlers with the promise of abundant harvests, livestock growth, and profitable farms. These sales were being made to people despite the area having already been extensively settled by many families with deeds issued by Beaubien.

14.4.2 Trade

With the addition of more people and access to greater markets by the expansion of the railroad, there was increased desire to increase agricultural yields. Marketing was used to promote an abundance of production to increase wealth through trade. While great lengths were taken to promote the large quantities of crops and livestock that could be supported on the lands in the section on The Agriculture of Colorado from Bowels's "Summer Vacation in the Parks and Mountains of Colorado" it is acknowledge that yields will decline: "*Exhaustion of the virgin freshness of the soil will tend to decrease these [crop productions] in the future; but against that we may safely put improved cultivation and greater care in harvesting."* (Blackmore, 1869). This expansion of trade has been tied to overgrazing within the watershed (Hicks & Peña, 2003).

Exports from the region were a key focus of many efforts. This includes the development of wagon roads and trails. The San Luis Valley Historian Article: *A Rebuttal Concerning Roads, Trails, Traces and Wagons* (Cooper J. K., 2001) provides a description of some of the history behind these efforts. Today, travel to the north and east of the region is conducted along US Hwy 160 over La Veta Pass, this was ultimately the route that was chosen. Other routes used included Mosca Pass and various routes near La Veta Pass.

One foot trail from the region was Whisky Pass. This foot trail crossed the Sangre de Cristo Mountains at El Valle Creek and connected to Whisky Creek to the east (Scott G. R., 2002). This road was reported as one of the few roads within la Sierra prior to 1960 (Hicks & Peña, 2003). Still visible on the landscape today are remnants of a tunnel that was abandoned prior to its completion.

14.4.3 Parcels and Commons

Lands within this basin are divided based on a long-lot system. These strips of land, or vara strips, connected each property to a variety of biotic zones from riparian to uplands (Peña, 1999). Using this system, the people have access to many of the natural resources necessary for survival including a place to grow irrigated crops, pastures for livestock, and a place for a homestead. As settlers from different regions came to the area there was a clash between the vara strips and the U.S. survey patterns as agriculture and grazing threatened the biological diversity (Crowther, 2003).

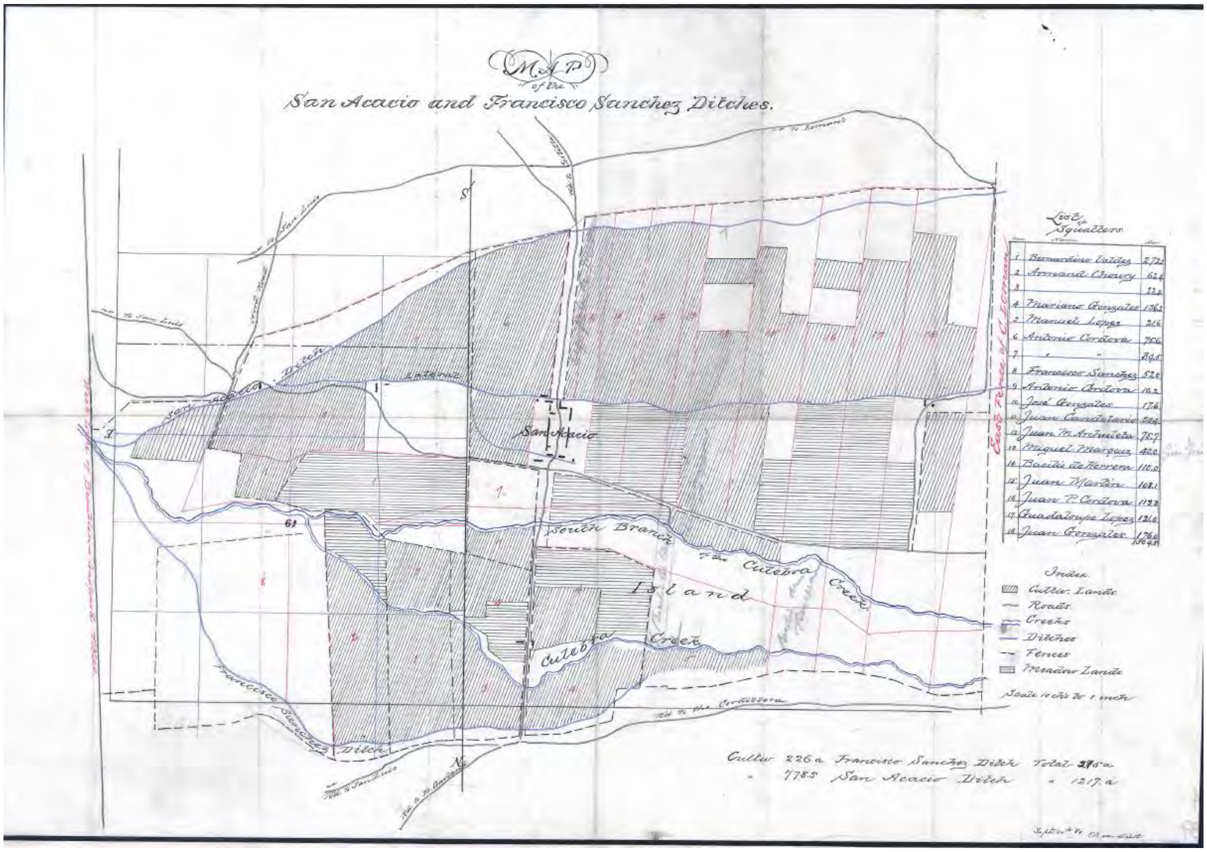
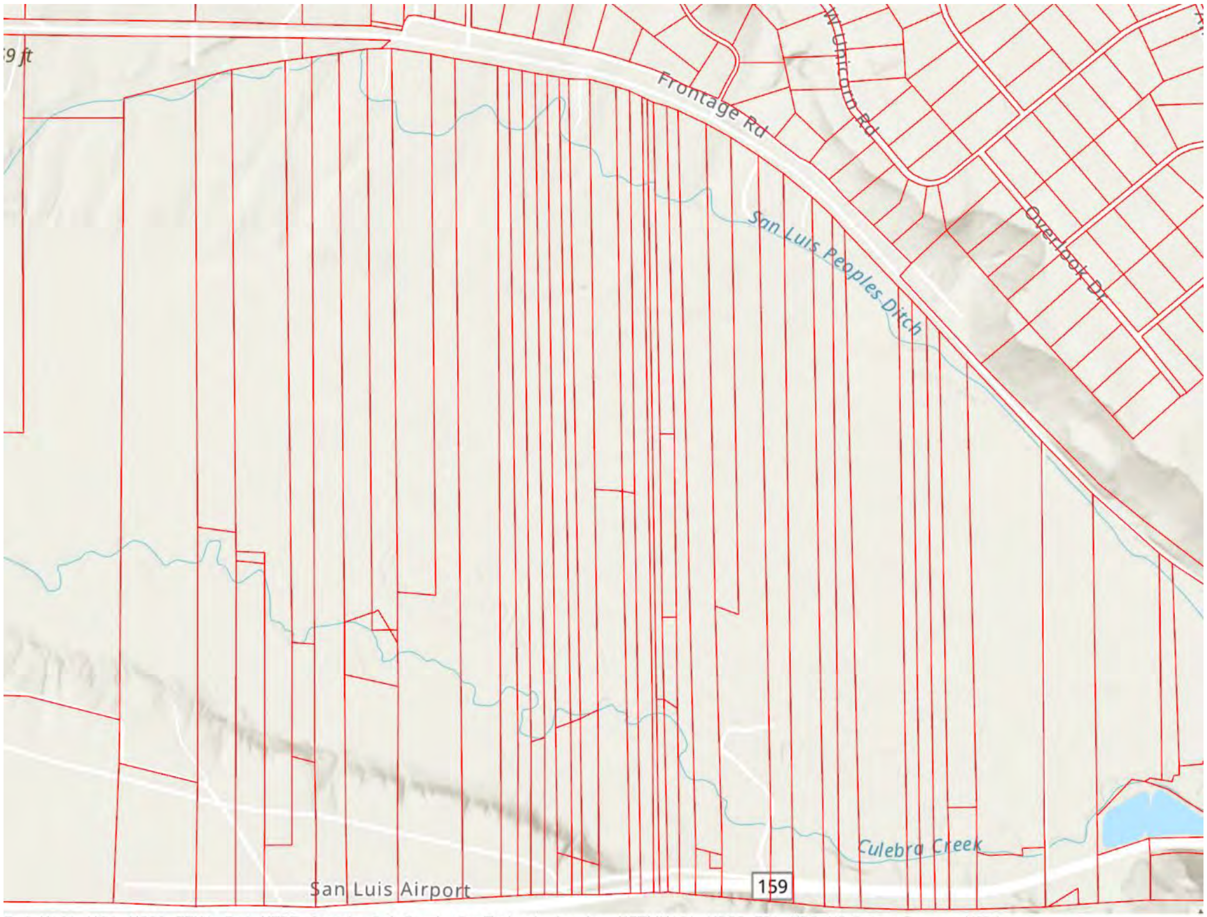


Figure 14-2 Map of the San Acacio and Francisco Sanchez Ditch that was marked up to show lot lines for Vara strips within this area. Map dated September 1884.

The long-lot system of land division provides access to the natural resources needed for settlement. Over time parcels, which were once large enough to support the inhabitant, are subdivided and may no longer have sufficient resources to support additional inhabitants. An example of parcel division under the San Luis People's ditch is shown in Figure 14-3. The lot sizes vary significantly, and some of the parcels have been disconnected from the stream.



Esri, NASA, NGA, USGS, FEMA, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA
Parcel lines Costilla County

Figure 14-3 2018 parcel lines along Culebra Creek serviced by San Luis People's Ditch.

Commons were established in the Beaubien Document, the rights which have been the subject of numerous court hearings (Lobato v. Taylor, 2002). Within the region commons were allocated including La Vega and La Sierra (including parts of what is known as Cielo Vista Ranch and privately owned parcels today).

The usage of La Vega as described by-laws from 1916 was to allow "*each head of a family of San Luis, San Pedro, San Pablo and those settlers of the Valleojs and Gregorio Creek [San Francisco Creek] are entitled to pasture four head of livestock, either cattle, horses, mules or asses but no sheep, goats or hogs are to be permitted on the premises."*

The Beaubien document granted rights stating, *"all the inhabitants will have enjoyment of benefits of pastures, water, firewood and timber, always taking care that one does not injure another."* (Lobato v. Taylor, 2002). Despite the grant of these rights, the ranch remained privately held, unlike most land grant communities. In 1960, a portion of La Sierra was purchased by Jack Taylor who proceeded to deny local landowners access and fenced the property (Lobato v. Taylor, 2002). Commercial logging on La Sierra has been the subject of lawsuits, including a 1997 lawsuit by Jaroso Creek Ranch for exceeding timber harvest limits, and 1999 lawsuit by Western Properties Investors to halt excessive logging (Affidavid of Ranch Manager, 2004). With the Colorado Supreme Court ruling in Lobato v. Taylor (2002) access to the ranch for livestock grazing and firewood gathering were restored.

Figure 14-4 Slash piles from previous logging activities, photo July 9, 2019 Eagleview Pictometry.

14.4.4 Water Administration

In 1879, three years after Colorado became a state and 27 years after the official year of appropriation of the San Luis People's ditch, Colorado adopted the doctrine of prior appropriations (Water Education Colorado, 2004). The doctrine of prior appropriations is different than the acequia traditions which where rooted in the traditions of the community. The doctrine of prior appropriations uses a first in time and first in right approach based on appropriation and adjudication to administer water rights. Whereas acequia traditions promote sharing within the community, ensuring the basic needs of all are met prior to irrigating livestock feed or crops for trade. While the practices in the basin did not immediately change, over time, administration within a priority system became more common (Water Education Colorado, 2004).

The first adjudication within Water District 24, the water district that the Culebra Basin sits within as recognized by the State of Colorado, was completed when the final decree was issued on June 14, 1889. This decree was contested by the Freehold Company who claimed ownership of some of the rights within this adjudication, despite only being named in the decree under the Montez Ditch. In a ruling on July 17, 1900, Judge Moses Hallett of the United States Circuit Court for the District of Colorado settled an appeal of the original adjudication by Freehold adjusting the water decreed held by the parciantes and transferring a portion of that water to Freehold (Davidson & Guarino, 2015). These water rights eventually were listed on the Division Engineer's 1984 Abandonment List. Opposition to the abandonment was filed and these water rights were removed from that year's abandonment list. At this time these rights remain on the tabulation but could be brought back to the abandonment list leading to potentially lengthy and costly court battles (Davidson & Guarino, 2015).

Water right flow rates shown within the first decrees were based on calculations of the duty of water for the lands being irrigated by a ditch and the physical capacity of the structures. The actual amount of water was then limited both by the decree rate and the physical limitations of the actual irrigated acreage. Additionally limiting the water right, is defining the point of diversion which cannot be moved without a change of water rights to protect other water users from injury. Because often the calculated duty of water in the early decrees provided more water than was necessary for irrigation, many farmers devised ways to irrigate more lands, in water court today this is known as "expansion of use".

14.4.5 Forestry

The forests were used to provide firewood, timber for structures and fences, and other uses within the basin. After 1898, a year with a notable number of forest fires, State Engineer Field expressed concern for these fires in his report to the Governor of Colorado in 1899. In speaking of forest fires, he states:

"I can not (sic) leave these recommendations without calling attention to the forest fires which during the last year, have been more than ever destructive and numerous, and I would urge that some law be passed to prevent, if possible, these conflagrations, even to the extent of discouraging hunters and campers from entering the timber reserve or thickly wooded portions of our mountains when there has been a long spell of dry weather. I would then urge that some effective measure be adopted for fighting the fires when first discovered. The entire irrigation section is dependent on the preservation of our forests, which, I believe, can never be replaced, no matter what the necessity and regardless of expense; for, with the forest, the soil alike disappears, is washed off by rains and rapidly melting snows, land slides (sic), lend their aid, and we have a prospect bare, rocky ranges without trees, grass or soil. I would recommend that instead of building reservoirs to hold our flood waters that the forests, those great natural reservoirs be preserved, to the end that our floods not be increased and, as a consequence, or summer flow decreased."

While this statement illustrates the recognized connection between forests and water yield for irrigation, it was not until the forest had become overgrown that it was recognized that fire and disturbance are necessary to maintain a healthy ecosystem and maximize water yield. Fire suppression over the past century has been linked to increased fire intensity today.

14.4.6 Imagery

It is often said that a picture is worth a thousand words. The available photographs can provide some limited clues to the landscape.

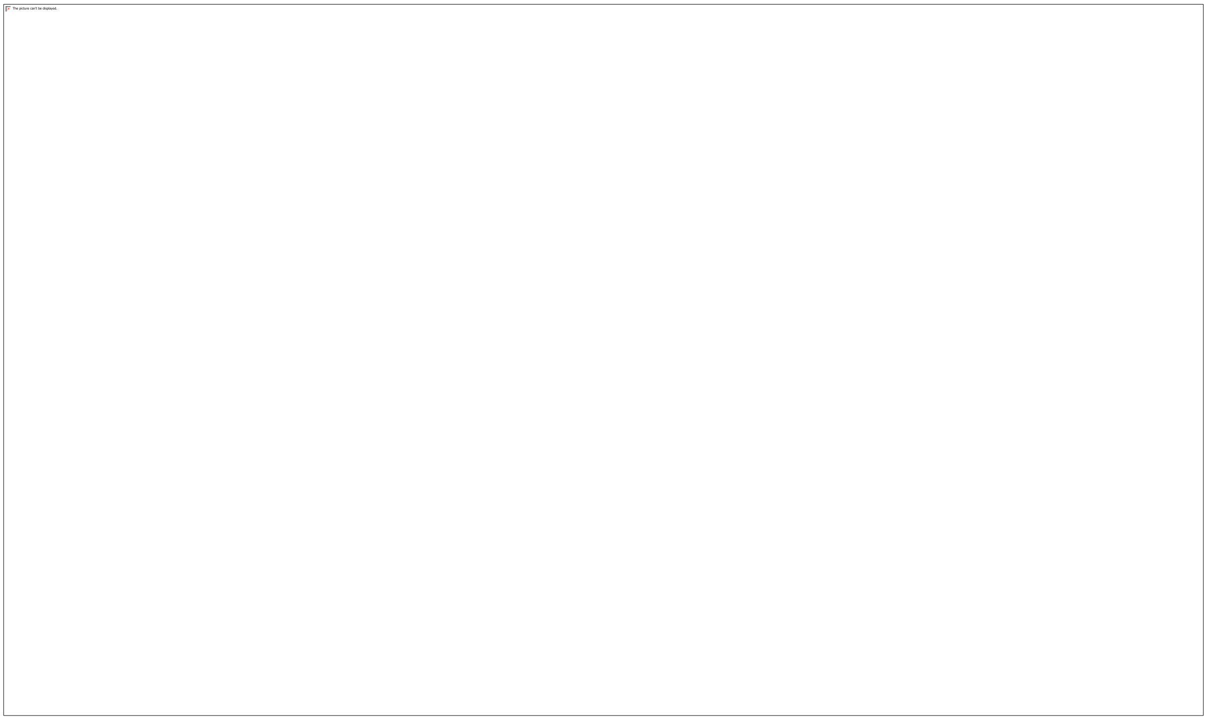


Figure 14-5 Photo of Culebra Creek from July 11, 1896. This photo was taken near the home of "Francisco A. Valdes". This photo appears to have been taken somewhere near the headgate of the Guadalupe Sanchez Ditch, just upstream of the present-day Culebra Chama streamflow gage (Calabra [sic] Creek, San Luis Valley, 1896). Photo from the Colorado State University Irrigation Photograph Collection.

In a photograph from 1896, which was taken somewhere near the present-day headgate of the Guadalupe Sanchez Ditch (Calabra [sic] Creek, San Luis Valley, 1896) vertical banks and banks with minimal riparian vegetation provide indication that channels were being affected by the activities within the basin even as early as 1896.

Aerial imagery is a key dataset for evaluating how the pattern of many streams have adjusted over time. The 1954 and 1965 aerial imagery both highlight areas around the stream channels that appear to have recent sediment deposition without riparian vegetation. The 1965 aerial imagery, Figure 14-6, shows efforts being made upstream of County Road 21 to maintain a single thread channel within Culebra Creek. The sediment deposition occurring in the 1950's and 1960's was not found to be present today.

Figure 14-6 Aerial imagery comparison of 1965 aerial imagery to 2017 NAIP aerial imagery.

14.4.7 Technology

When we look back and think about technology one of the greatest advances that changed the way water is used within the basin was electricity. Electricity has influenced the interactions with water bringing additional access to groundwater through the use of electric pumps which did not need to be frequently refueled. Through the Rural Electrification Act of 1936, the San Luis Valley Rural Electric Cooperative was formed and is the second oldest in Colorado (San Luis Valley REC, 2022; San Luis Valley Historical Society, 1994). The “C” section of the REC system was organized by T.C. McPherson who represented San Acacio's Costilla Estates Development and saw the advantage of power in the area. Lines were built and power was obtained from Public Service lines at a point west of Blanca extending south to the New Mexico state line in 1939 (San Luis Valley Historical Society, 1994). While adoption of pumps and sprinklers has been limited within the upper basin, electricity brought wells for drinking water and other domestic uses.

14.5 Conclusion

Understanding land use change is important for the management of natural resources where environmental impacts from land use have occurred. Surveys and interviews with stakeholders were conducted to help identify factors that have influenced environmental condition. These conclusions were originally presented in de la Hoz (2021).

In the Culebra Basin, anthropogenic activities including logging, road construction, and grazing, underlined by climate and various socio-economic and institutional factors have resulted in land use change. Information from surveys and interviews suggest that previous logging and road construction associated with this activity coupled with grazing at Cielo Vista Ranch, La Vega, and in private properties have contributed to erosion and increase sedimentation in streams and irrigation systems. That in turn, has affected farmers and ranchers in the community.

Drought conditions are perceived to be a key factor affecting land use change in the past twenty years. Before that, it was logging. Although currently there is no large-scale commercial logging at Cielo Vista Ranch and some work has been done to reclaim roads and reduce soil erosion from roads in that area, erosion and sedimentation are still of concern for the local community. There may be less livestock in the basin now than in the 1990s, but overgrazing is another important factor affecting streams and irrigation systems. Both community members and ranch managers recognize that the lack of coordination among livestock owners that have access to Cielo Vista and La Vega, and the absence of a grazing management plan contribute significantly to erosion and sedimentation.

For most landowners surveyed, namely farmers and ranchers, agriculture is part of their cultural heritage and reducing sedimentation is critical for restoring acequias, maintaining their livelihoods, and providing supplemental income. Since storing water in soil decreases the negative impacts of droughts, efforts to help increase water retention capability both in the mountains and in agricultural areas can be beneficial for the community and the health of the basin.

In recent years, there has been increased awareness by the local population of the environmental changes that have occurred in the basin, particularly after observing the effects of previous fires in the area. Wildfires that have occurred in, or in the vicinity of the Culebra Basin, have provided examples that communicate the risk of wildfire and its potential effects on the landscape and the community. However, there seems to be a discrepancy between recognizing potential compounding effects of logging, wildfire, erosion, overgrazing, and taking steps for coordinated action to improve the condition in the basin. That discrepancy is generally recognized and there is consensus among many stakeholders that a grazing management plan needs to be implemented. A plan to reduce erosion from roads and maintain acequias is also needed.

Most landowners and ranch managers believe the community can find opportunities to work together to help improve the environmental condition and resiliency in the basin, but previous efforts have not succeeded. Slow economic activity in the area, limited financial resources, and the lack of incentives to promote and implement soil and water conservation management practices are factors that influence individual and community participation. In general, the local population has a strong connection to the land and there are farmers and ranchers that have implemented practices aimed at soil and water conservation. While a coordinated effort to address issues identified at a watershed scale have not taken place, reaching consensus over watershed scale management efforts is only possible with increasing public, landowner participation.

There are varying perspectives on the effect of drought in the basin. At higher elevations, the drought has been associated with declining forest health condition, increased susceptibility of trees to pests and disease, increased risk of wildfire, and declining wildlife abundance. At lower elevations, farmers and ranchers see the effect of reduced flows, reduced crops, and reduced livestock production. The increased awareness of the community on the basin-wide effects of drought, and the increased risk of wildfire, has led to increased participation, but more is needed to address concerns at the watershed scale.

Limited access to Cielo Vista Ranch is considered by the community as a significant change in land use, one that has contributed to the loss of connection between the community and the watershed and the loss of cultural heritage. However, that change likely has not translated to change in the environmental conditions in the basin. Access to grazing and wood collection are maintained as a right for the local community, and it is generally recognized that overgrazing is a problem that persists throughout the basin with exceptions in localized areas.

In addition to the depressed economic activity in the area, the risk of wildfire is a challenge faced by the community, and one that has the potential to significantly impact the condition of the watershed. Continued outreach efforts to raise awareness in the community of ongoing efforts to reduce the potential effects of wildfire are needed. Also, there is a need to raise awareness of land management practices that could be implemented by landowners to help with soil and water conservation. Understanding that financial capability is a limiting factor, incentives are needed to promote practice, adoption, and implementation.

Chapter 15. Hillslope Erosion Potential

Author: Redfish Environmental

The model to predict soil erosion by water, assess critical areas in the watershed, and identify aquatic habitat survey sites was based on (Renard, Foster, Weesies, McCool, & Yoder, 1997) and (Laflen & Flanagan, 2013). Below is a summary of the factors used and how they were calculated.

Additional details on the factors used, model development and output are described in de la Hoz (2020), Appendix 2C.

15.1 LS-factor

The S-factor measures the effect of slope steepness, and the L-factor defines the impact of slope length. The combined LS-factor describes the effect of topography on soil erosion (Laflen & Flanagan, 2013) (Panagos et al. 2015). The grid-cell size is very important for the S-factor, since the slope varies due to smoothing as the cell size increases; thus, the 10-meter DEM was selected for this analysis.

Equation 15-1 S-factor equation

$$S - factor = \frac{0.43 + 0.30 * s + 0.043 * s^2}{6.613}$$

where s is the percentage of slope gradient

Equation 15-2 L-factor equation (feet).

$$L - factor = \frac{\lambda}{72.6^m}$$

Where 72.6 is used for feet (or 22.12 for meters) and m is the slope length exponent:

m = 0.5 if the percentage of slope gradient is higher 5
m = 0.4 if the percentage of slope gradient is between 3 and 5
m = 0.3 if the percentage of slope gradient is between 1 and 3
m = 0.2 if the percentage of slope gradient is less 1

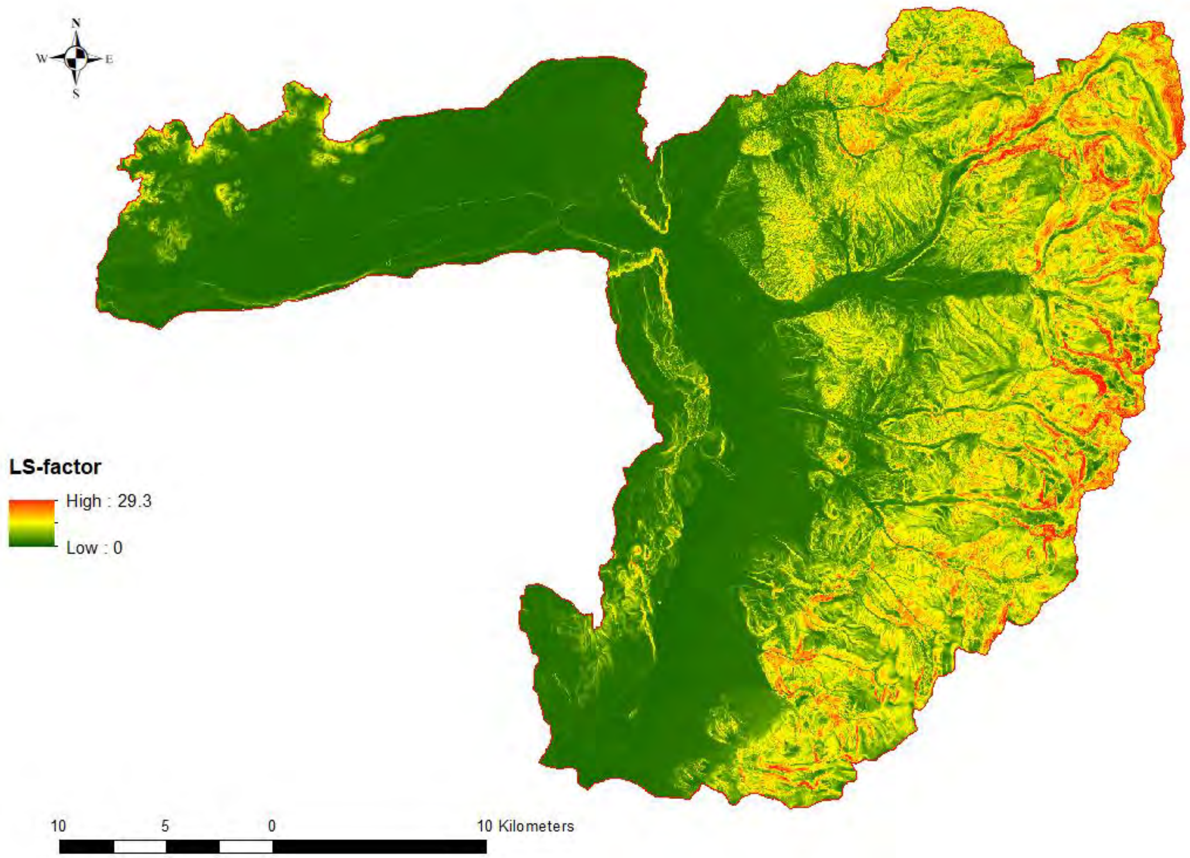


Figure 15-1 Culebra watershed LS-factor.

15.2 K-factor Erodibility

KFFACT of the soil map is the soil erodibility factors and quantifies the susceptibility of soil particles to detachment and movement by water. This factor is used in the Universal Soil Loss Equation to calculate soil loss by water. Erodibility factor is a value between 0 and 1.

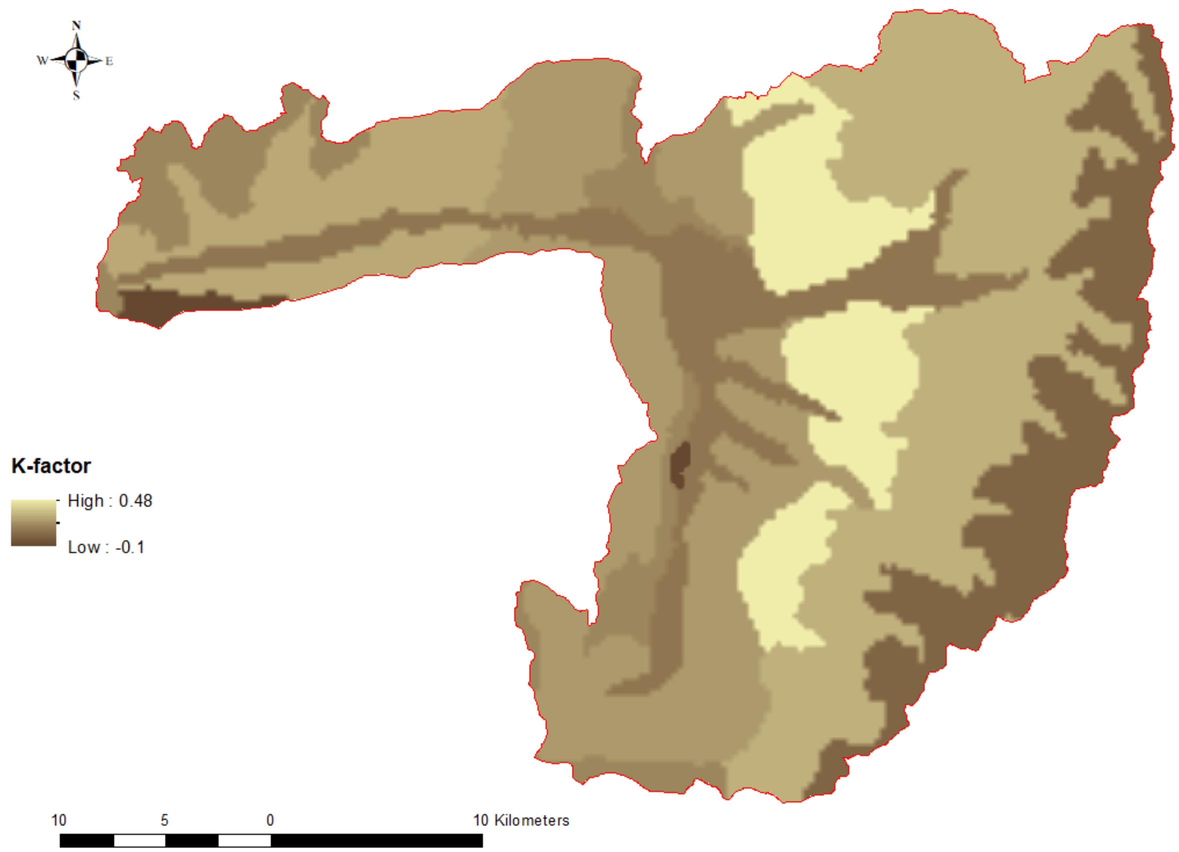


Figure 15-2 Culebra Watershed -K-factor (Schawarz & Alexander, 1995)

15.3 R -factor Rain

Annual average precipitation of 30 years in mm.

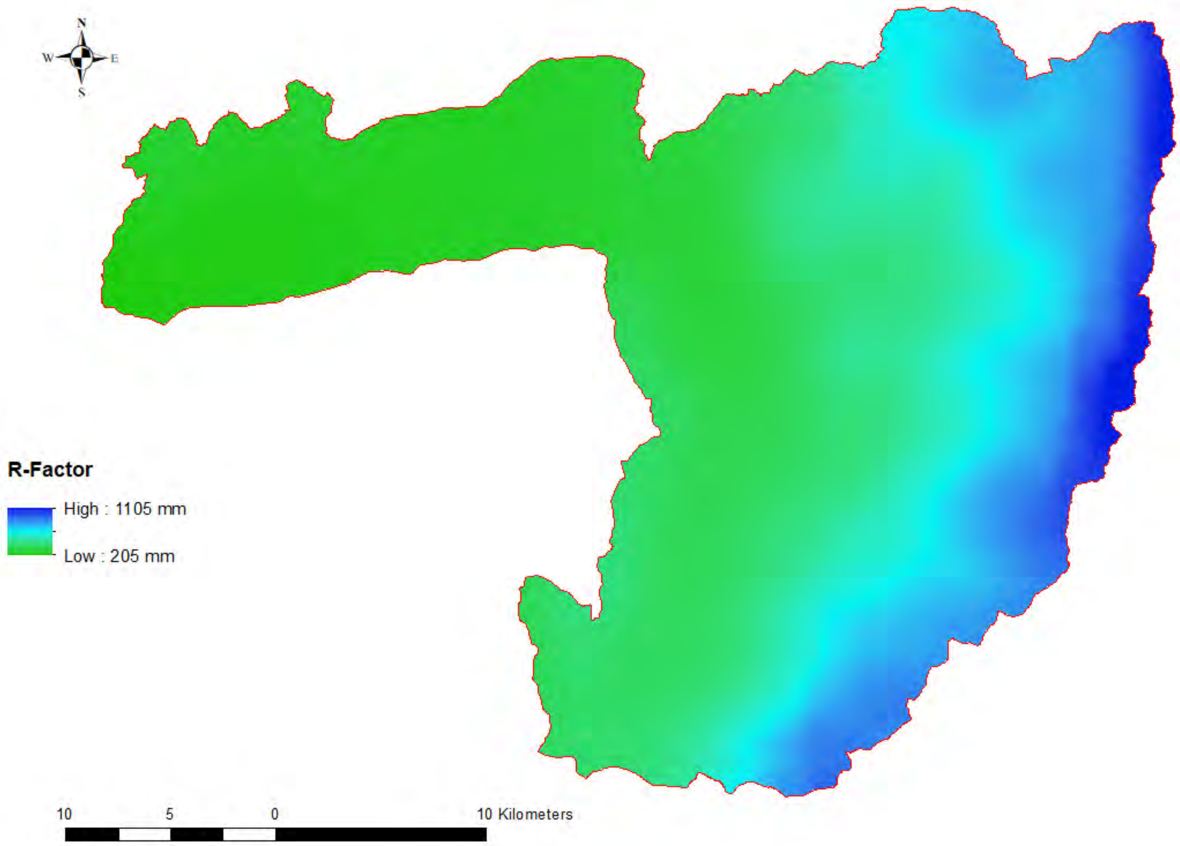


Figure 15-3 Upper Culebra Creek Watershed - R-Factor

15.4 C- factor Land cover

The C-factor is a crop management value that represents the ratio of soil erosion from a specific cover type compared to the erosion that would occur on a clean-tilled fallow under identical slope and rainfall. The C-factor integrates several variables that influence erosion including vegetative cover, plant litter, soil surface, and land management. Original ULSE C-factors were experimentally determined for agricultural crops and have since been modified to include rangeland and forested land cover types. For this assessment, the C-factor was estimated for various land cover types using the National Land Cover Database and C-factor interpretations applied during previous USLE modeling projects (e.g., Montana DEQ and EPA Region 8, 2014) (Table 15-1 C-factor values for USLE model.).

Table 15-1 C-factor values for USLE model.

NLCD Land	Value in the model
Unclassified	NA
Open Water	NA
Perennial Snow/Ice	NA
Developed, Open Space	0.003
Developed, Low Intensity	0.001
Developed, Medium Intensity	0.001
Developed, High Intensity	0.001
Barren Land	0.001
Deciduous Forest	0.003
Evergreen Forest	0.003
Mixed Forest	0.003
Shrub/Scrub	0.008
Herbaceous	0.013
Hay/Pasture	0.013
Cultivated Crops	0.013
Woody Wetlands	0.03
Emergent Herbaceous Wetlands	0.003

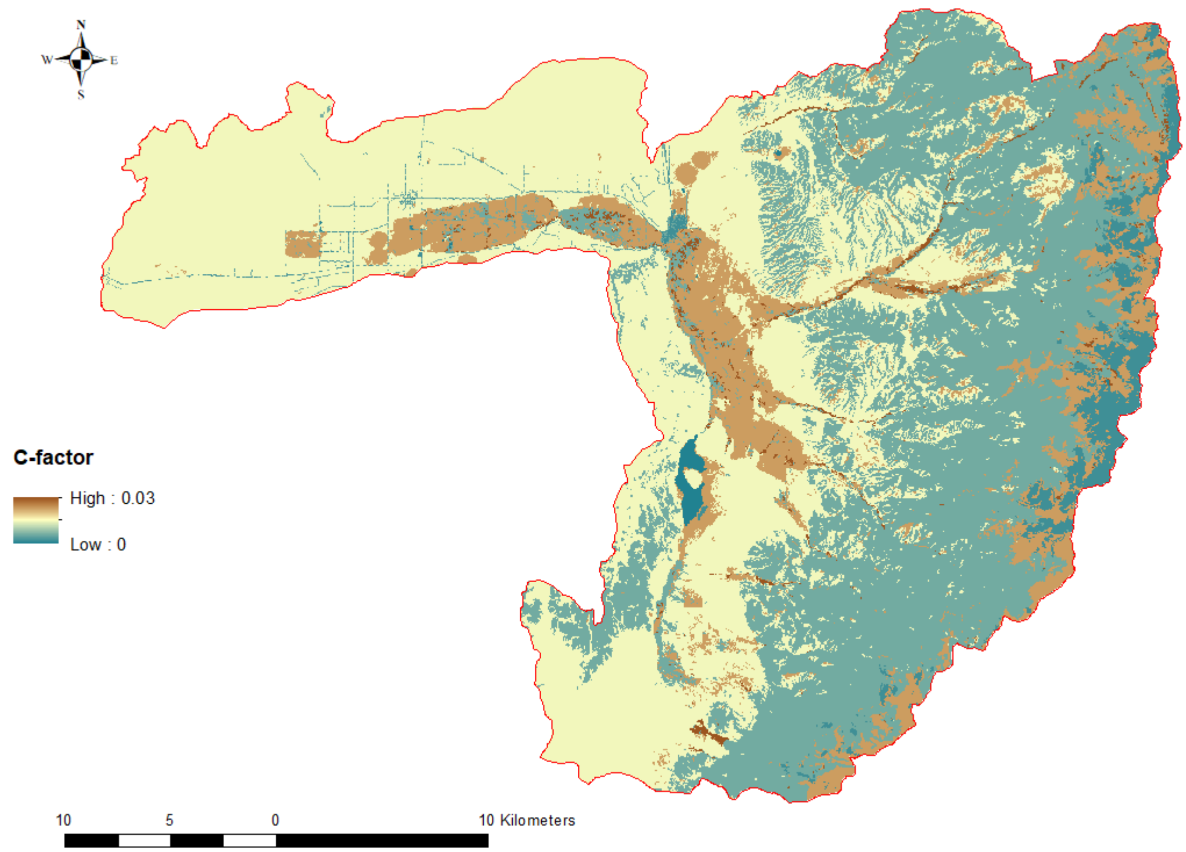


Figure 15-4 Upper Culebra Creek Watershed - C Factor

15.5 P-factor practice factor

P-factor factor was not included in the model since this project still does not have field data to estimate this factor of the USLE equation. The P-factor, or conservation practice factor, is a function of the land management practice. It incorporates the use of erosion control practices such as strip cropping, terracing, and contouring, and is applicable only to agricultural lands.

15.6 Results

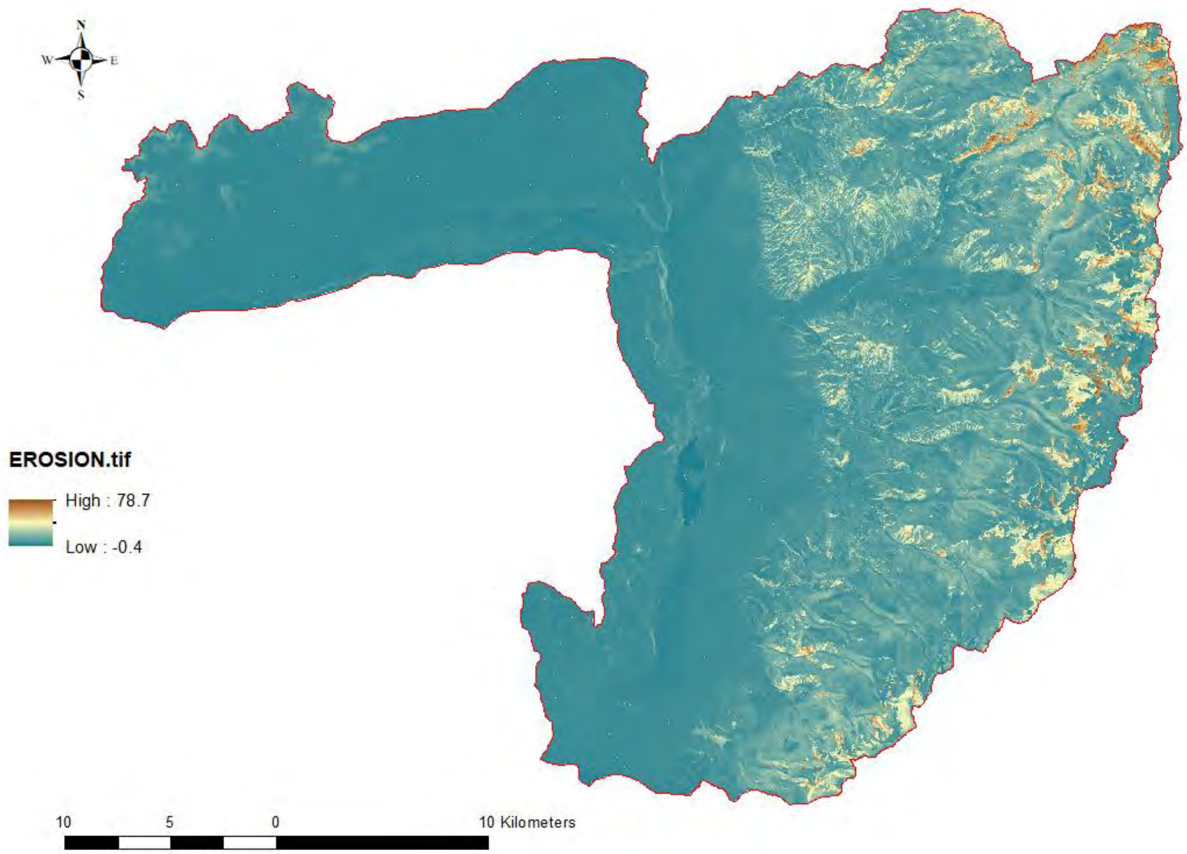


Figure 15-5 Upper Culebra Creek Watershed model of soil erosion potential for assessment of critical areas. Areas with higher erosion potential denote critical areas.

Chapter 16. Priority Projects and Degradation

Author: Tailwater Limited

16.1 Introduction

The primary purpose of the Upper Culebra Watershed Assessment was to develop a plan and identify projects within the Culebra Basin that would increase resiliency and sustainability while decreasing the continued degradation of natural resources within the basin. The assessment evaluated the watershed health by investigating the following indicators across the watershed: riparian habitat, aquatic habitat, geomorphology, flow regimes, infrastructure, water quality, rangeland health, forest health, and safety and emergency management. The assessment also evaluated historical land use and community connections within the basin.

Several projects and areas were identified through the assessment and are discussed within the respective technical chapters within this report. The projects listed in this section are highlighted because of the potential for overall positive benefit for the community. The following goals were utilized to assess positive benefits for the community:

- Improving community safety and reducing overall community risk from natural hazards,
- Improving water quality,
- Reduce conflict or improve conflict resolution related to natural resources,
- Fill in data gaps that that were identified from the technical sections of this report,
- Increase water yield or water availability, and
- Improve aquatic habitat.

****Rangeland to be included once complete – this will cover more of the riparian areas in the upper basin*****

Projects developed around diversion structures have a central goal of maintaining the ability of water users to fulfill the decreed water right associated with their structures. No recommendation(s) in this section, or this report, is intended to infringe upon these decreed rights.

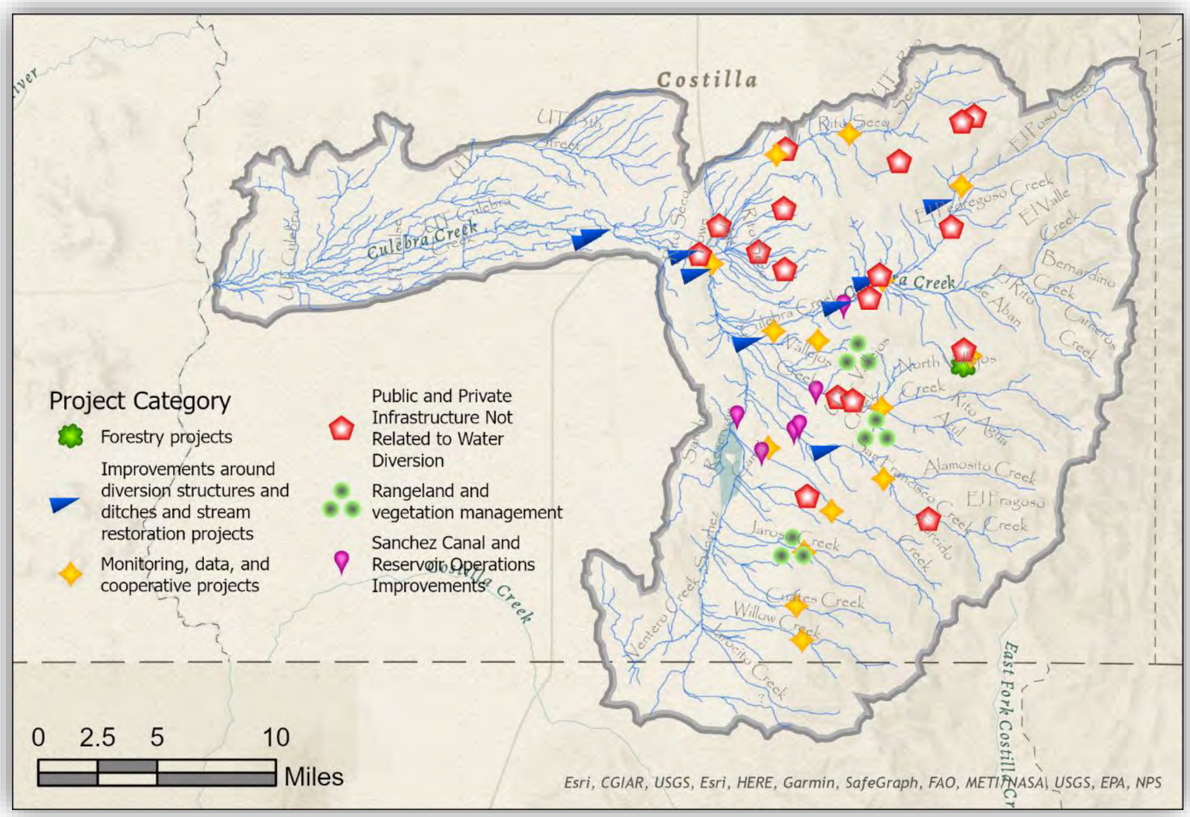


Figure 16-1 Upper Culebra Watershed Assessment priority projects.

16.2 Forestry Management and Wildfire Mitigation

Wildfire is the single most likely, and potentially most dangerous natural hazard that can be expected to occur within the Culebra Watershed. As has been seen in recent years and throughout history, wildfires are common in Colorado. There is at least some potential for a catastrophic fire within the Culebra Basin. While fires are common to this landscape, today's fire is likely to be catastrophic because the forest is overgrown due to fire management practices over the past 100 or more years. A potential fire is prone to burning hotter and more intensely than landscapes that have adapted to fires. A catastrophic fire will degrade water quality and increase sediment loading in the basin. The potential for debris flow will also increase, impacting infrastructure, roads, housing, etc. Most of the communities within the watershed were rated as having a high or extreme risk of wildfire impacts during the community hazard assessments. Strategies for community fire mitigation are detailed further in Section 11.5.3.2.

Fire mitigation and wildfire risk reduction impacts the entire Culebra watershed and adjacent communities. Mitigating severe wildfire risks also reduces the future risk of post-fire debris flows, degradation of water quality and water supply, and post-fire flooding. Strategies for wildfire mitigation include improving defensible space around structures, maintaining critical roads for ingress and egress, and collaborating to implement forest health improvements, including the use of prescribed fire and slash removal. Landscape-scale forest management is necessary to reduce fire hazards, increase forest resiliency to disease and drought, and reduce conflict within the basin.

Forests are adapted to function with disturbances, including fire. Since the early 20th century, the suppression of fire has resulted in significant changes in forest composition. These changes have resulted in meadow encroachment, reducing available forage for wildlife and livestock. Decreases in forest diversity, including species and age class, increase the risk of insects and disease. An increase in canopy cover reduces water yields. Logging and forest management techniques have improved since the 1960s, and forest management could substantially improve the watershed in ecosystem health and economics by utilizing the best available techniques.

In addition to reducing wildfire risk, good forest management that minimizes the risk of scour has been shown to increase water yield from a watershed providing additional benefits to all water users within the basin. Forest management also provides disturbance of the forests to reduce shrub and tree encroachment on meadows increasing grasses and herbaceous plants, which provide forage for wildlife and livestock.

Concerns	Strategies
• Fire risk • Safe ingress and egress • Insects and disease • Increased fuels loading • Structural hazards including minimal defensible space and high combustibility • Decreased water yield • Reduced meadows for wildlife and grazing. • Increased insurance costs • Decreased wildlife habitat and forage • Increased risk of post-fire hazards	• Revisit and revise Community Wildfire Protection Plan • Develop an adaptive management plan, including the forest management recommendations from Chapter 11, in conjunction with stakeholders. • Promote developing Firewise communities and educate residents about living with wildfire. See Chapter 12 for detailed recommendations. • Development of subdivision/community-scale fuels reduction programs. • Improvements in routes for safe ingress and egress.

16.3 Water Administration

Water administration improvements were identified as an area that would provide community-wide positive impacts. Positive impacts from improvements in water administration extend beyond water users and include improvements in monitoring and warning to improve safety and understanding of the watershed. Water administration, including water rights and water quality, requires measurements to administer the resource effectively. Monitoring streamflow, diversion volume, and water quality in an accessible and transparent manner improves decision-making. Transparent decision-making improves community trust, makes-decision-making a process rather than an event, and considers multiple viewpoints. The need for measurement structures at headgates are recognized by Colorado Revised Statutes §37-84-112, 113, and 114.

16.3.1 Streamflow and Diversion Measurement

Effective water administration can only occur if the availability and use of that water are known. During this assessment, it was abundantly clear that the available information was inadequate for supporting water administration. Improvements to water administration will require projects to be supported and implemented by private and public entities. These projects include monitoring flows on diversion structures, streams, and down-ditch structures within the acequia and ditch systems.

Water measurement rules and regulations are implemented to provide fair and transparent water administration for all water users. Financial and technical assistance for compliance with these rules and regulations may be available from NRCS through Farm Bill programs and the USBR WaterSMART program. It is essential to comply with these rules to ensure fair and transparent administration of water for all users rather than implementing rules for a select few individuals and/or entities. Issuance of headgate orders to comply with rules and regulations is a tool that can be leveraged to enforce this requirement. However, voluntary compliance is preferred and will benefit all water users within the basin.

> All diversion structures need to have the ability to measure the rate of water diverted and regulate flow into the ditch based on priority and down-ditch conditions (flooding, farm operations, etc.).

Streamflow measurement is also necessary for equitable distribution of water within the prior appropriations system. This includes the administration of acequia water-sharing agreements. Streamflow gages can also be used to improve community safety by providing flood warnings while monitoring climate change and drought conditions. Continual, real-time streamflow monitoring requires equipment and maintenance. Streamflow can be monitored by various entities, including the Division of Water Resources, Conservancy Districts, United States Geological Survey, or private consultants. Gages that improve water administration efficiency are most likely to be supported and potentially operated by the Colorado Division of Water Resources.

Nine potential locations for streamflow monitoring were identified from this assessment. These locations are listed in Table 16-1 with comments specific to the gage or group of gages.

Concerns	Strategies	Opportunities
• Unfair or difficult water administration • Conflict over water administration decisions. • Lack of transparent data-driven decision-making. • Inadequate data for understanding, modeling, and future decision-making. • No flood warning systems • Vandalism to existing equipment • High level of non-compliance with headgate and measurement rules at diversion structures. • Significant time and resources are spent driving to maintain diversion records.	• Monitor streamflow on all major tributaries (see Table 16-1) • Provide data used for administration in real-time • Maintain streamflow gages to standards adequate to meet all objectives, including modeling and decision-making. • Utilize equipment shelters and locations to reduce the occurrence and damaged by vandalism. • Work with water rights holders and acequias to install measurement structures. • Install telemetry on distant structures and major water users. • Install lockable headgates prioritizing upstream acequias and those with headgates that frequently leak out-of-priority.	• Install new streamflow gages near upstream diversion structures where possible to reduce instrumentation cost and travel time to gages.

Table 16-1 Recommended streamflow monitoring location and comments.

Location	Comments
Culebra Creek at Chama	Adjust gage operation to include more frequent measurements, telemetry, and evaluate safety and stability upgrades to existing infrastructure.
Rito Seco	New streamflow gage for improved flood warning and water administration efficiency.
San Francisco Creek, Vallejos Creek, and El Poso Creek	New streamflow gage for improved flood warning and water administration efficiency.
Willow Creek, Cuates Creek, Torcido Creek, and Jaroso Creek	New streamflow gage potentially including upgrades to upstream diversion structures to provide electronic monitoring of these structures. These structures are targeted at improving water administration efficiency.

Funding for stream gaging within the basin will be more accessible if community progress toward meeting water measurement rules is made and the community supports the need for streamflow monitoring and administration efficiency. Additional streamflow monitoring can reduce the cost of water administration by reducing the number of miles and hours spent traveling to check and obtain records of streamflow and diversions.

Vandalism to monitoring equipment has been a problem, and new gage shelters and antennas require special consideration for the potential of vandalism. Precautions and measures to prevent vandalism will increase the overall cost of building, running, and maintaining this equipment. When vandalism occurs, this results in funds and time spent on repair, increasing the likelihood of site abandonment. Individuals that cause this vandalism likely do not understand that rather than "sticking it to" the State or Government they are really "sticking it to" their neighbors and themselves.

16.3.2 Acequia Measurement and Record-Keeping

Many of the acequias have a conflict between the landowners, reporting that water distribution practices were unfair to users. Improved record-keeping and data availability to the acequia community can improve conflict resolution and water administration transparency. Measurements and record-keeping include maintaining measurement structures at critical down-ditch diversion points.

Water sharing is an important element of the community's heritage. This heritage has been celebrated and recognized by state laws. It is essential to ensure that all water users and administrators understand the rules and practices in this system. During times of water sharing, the Mayordomos, water users, and water commissioners all need to be informed of the water sharing agreements so the water can be distributed. If this agreement is communicated and documented, there is less room for interpretation and misunderstanding. Developing a standardized communication protocol and notification system could improve efficiency and transparency within this system.

Documentation of water sharing, including location and timing of water use, protects the user's water rights against abandonment and increases the value of water rights. Water sharing also promotes the efficient use of water within the basin, benefiting the community.

Concerns	Strategies
• Unfair or perceived unfair water distribution • Poor communication about water sharing. • Inadequate documentation to protect water rights. • Reduced community property value due to inadequate records to support historic use.	• Clear and documented rules and strategies for water distribution under each acequia. • Measurement of water at critical structures and headgates. • Maintain records of how water was divided each year. • Community system for initiating and communicating water sharing between acequias.

16.3.3 Water Quality Monitoring

Water quality monitoring and data assessment for trends can provide early indicators of disruption within the basin that may warrant action. Water quality changes can often be one of the first indicators that impacts occur within a basin. Developing a balanced monitoring approach is necessary to have the information available for an informed decision, present and future, while efficiently managing costs and other resources. More information related to water quality sampling is provided in Section 7.6.1.

The top two water quality concerns in Rito Seco were related to Battle Mountain Mine impacts and biological mercury concentrations in Sanchez Reservoir during the assessment. Battle Mountain Mine was identified based on reporting requirements set forth by DRMS and Sanchez Reservoir through synoptic sampling due to listed uses of water, including recreation. These conditions would likely go undetected without these programs, posing health concerns.

The collected samples and reported water quality values are not available to the community. They do not have any associated trends or statistics presented to aid in understanding the sample results. Having the data available to the public with a short explanation of the targets can improve community understanding and confidence in the implemented processes.

Concerns	Strategies
• Limited recent water quality samples within the basin. • Concern over contamination of public water supply. • Data is inaccessible to the community. • Unknown degraded water quality conditions. • Inadequate data available to determine annual and seasonal trends.	• Continuous water quality monitoring and routine sampling on Rito Seco below Battle Mountain Mine and periodic paired sampling above Battle Mountain Mine, • Tri-annual sampling on Culebra Creek near the San Luis gaging station, • Annual sampling on the remaining tributaries, and • Making data from sampling, SWSP's, and discharge monitoring reported to agencies accessible to the community.

16.3.3.1 Rito Seco water quality monitoring and data accessibility

One of the concerns identified as part of the assessment was water contamination from leaks from the tailing's ponds in the Rito Seco drainage. There is community concern for uncontrolled releases from the tailing's ponds or other activities due to operations on the Battle Mountain Resources property. Continuous water quality monitoring would provide frequent observations that can alert the community in the event of such releases. This equipment would also evaluate seasonal or flow-related changes in water quality. Continuous water quality monitoring should include pH, specific conductance, and temperature at a minimum. Routine water quality samples are used to provide a more detailed assessment of the characteristics affecting water quality.

Contamination clean-up is often very costly. The types and levels of treatment may change over time, based on site conditions, understanding of contaminants, and advancements in clean-up technology. Contamination of the water supply for the town of San Luis would be devastating. Water quality sampling is currently being performed and reported as part of the industrial discharge permit for Battle Mountain Mine to the Colorado Department of Public Health and Environment. The Battle Mountain Gold Augmentation Plan accounting is reported to the Division Engineer's Office and other parties associated with the Battle Mountain Gold Augmentation Plan water rights change case (99CW057). This information can be difficult to obtain and could be made more accessible by providing links to and/or copies of the information on local websites and community offices. Providing data plots and tabulation of basic statistics can provide a rapid review for changes within the water quality characteristics that are not available from the standard reports.

16.3.3.2 Culebra Creek water quality monitoring

Monitoring water quality on Culebra Creek at San Luis gaging station will assess water quality trends within the basin and indicate potential impacts on water quality. Sampling water quality 3-4 times a year representing different hydrologic conditions would evaluate the conditions and allow for year-to-year trend assessment. Due to the significant storage of cars and equipment within the floodplain upstream and large volumes of trash within arroyos, it is recommended to include sampling for volatile organic compounds (V.O.C.s). If funding and resources are available continuous water quality monitoring would improve the evaluation of temporal changes in water quality, including changes related to the operations of Sanchez Reservoir.

16.3.3.3 Tributary and reservoir water quality monitoring

To supplement frequent water quality sampling, additional annual sampling, like the sampling completed for this assessment, can be correlated to the Culebra Creek samples to identify chemical signatures and extrapolate the more frequent sampling to the tributaries within the basin. This would enhance the sampling regiment on Culebra Creek to provide more tributary-specific data.

16.3.4 Cooperative Water Management

Cooperative water management is a way for water supply gaps to be addressed while mitigating impacts on other water users within the basin. Sometimes the impacts are addressed by providing water supply with alternative timing or by allowing water diversion at an alternative location to keep stream reaches wet. At other times the gaps may be addressed by providing efficiency improvements that allow water to be left in a stream while not impacting water available at the farm headgate. Cooperative water agreements could also be applied to support the adjudication of instream flow rights in the Culebra Basin to protect the basin from future development.

16.3.4.1 Instream Flow Rights

Currently, there are no adjudicated instream flow rights within the basin. Adjudicating instream flow rights to preserve flows in the upper basin will allow these rights to be senior to any change of use or future water appropriations. This will require future changes of water appropriations to evaluate impacts on existing rights and preserve flows within the upper basin before moving or changing the use of a water right. Instream flow rights are junior to all existing water rights at the time of adjudication and would not be allowed to cause injury to any existing water rights.

16.3.4.2 Dewater Reaches

Cooperative water-sharing agreements could be utilized to provide additional water throughout the late summer to dewatered reaches. As additional data becomes available, modeling should be completed to identify additional infrastructure that could facilitate water management within the Culebra watershed, such as upstream water storage for flow augmentation, water for fire suppression, and potentially minor flood control.

16.4 Public and Private Infrastructure Not Related to Water Diversion

The projects listed in this section cover sizable portions of the Culebra Watershed and primarily focus on administrative and operational changes within the community, including government and public-private partnerships.

16.4.1 Public roads maintenance and monitoring improvements

During the evaluation of roadways and road/stream crossings, numerous issues with gravel road maintenance were observed. Issues included removal of the culvert cover by road grading activities and road surface gravels graded to road edges causing concentrated flows resulting in gully formation.

Figure 16-2 Damaged culvert in Rito Seco Road.

Improvements to road maintenance will improve basin conditions for all residents and visitors. In addition to improving watershed health, these improvements can improve parcel access for safe ingress and egress, reduce the overall cost of road maintenance in the basin, and reduce vehicle damage. Improvements to roadway maintenance will benefit those acequias with ditches near roadways that are often filled with gravel.

Figure 16-3 No culvert found in drainage, guardrail along roadway downstream due to gully formation (headcut).

Proper roadway maintenance reduces the volume of gravel material needed to maintain the road because the material stays on the road rather than being pushed from from the roadway. When gravel is pushed from the road with maintenance equipment, it is no longer providing the cover intended over underground infrastructure, such as culverts and utilities, and is at greater risk of being transported into the adjacent streams and acequias, blocking the flow of water. In places, it may be beneficial to replace the gravel with pavement if traffic volume and/or maintenance frequency warrants. In high sediment arroyos replacing culverts with bridges can be a preferred alternative.

Developing a training program for county employees and an employee retention process to maintain institutional knowledge will improve roadway safety and reduce sediment transport to streams. Coupling this with a monitoring program for road/stream crossings, including culverts and bridges, will help identify and address these issues before they become more significant and more costly to fix.

Tracking can provide better documentation of actual spending on road issues and provide a basis for adjusting actions to reduce long-term expenses. Monitoring programs that track the location of issues and actions taken to address those issues inform future decision-making.

This information is often used to facilitate spending decisions and applications to other funding sources.

Concerns	Strategies
• Increased long-term maintenance cost • Sediment loading into the stream system • Public safety • Road maintenance causing increased ditch maintenance • Damage to roadway infrastructure. • Increased ingress/egress time	• Improve maintenance staff training and retention, • Develop a monitoring program for county roads with a maintenance priority list, • Develop standard details for road crossing and flow energy dissipation requirements, and • Track locations needing frequent maintenance for larger upgrades. • It may be preferable to replace culverts with bridges for reduced maintenance and increased sediment passage.

16.4.2 Private road decommissioning

Many private roads with direct impacts on watershed health were identified within the Culebra Basin. These impacts include destruction of vegetation, changes in slope, and concentration of flows. Many of these headwater streams should be vegetated swales with no defined channel. This landscape damage has converted these swales into concentrated flow paths with actively eroding channels.

Projects involving private roads will require public-private partnerships. Working with landowners to restore areas that have been damaged and prevent future damage will reduce downstream impacts. Restoration includes stabilizing and replanting existing channels and blocking access from public roads to drainages by installing gates, fencing, and other administrative and physical controls. Working with landowners who request assistance to prevent trespass travel and prevent new unplanned roadways is recommended.

Figure 16-4 Road concentrating flows resulting in headcutting below road 37.141870, -105.318386, Eagleview aerial imagery dated May 13, 2019

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Concerns	Strategies
• Damage to headwater streams resulting in increased erosion. • Decrease in upland vegetation productivity. • Decreases in water yield. • Changes in run-off timing. • Decreases in available wildlife and livestock forage.	• Develop a fund for assisting landowners in the prevention of damage within arroyos, including signage and barricade construction • Provide education related to the need for preserving arroyos • Work with landowners to restore arroyos and prevent future damage, including adding roughness and spreading flow • Facilitate connections with native seed providers for restoration projects • Assist with trespass issues • Develop mechanisms to provide technical assistance to landowners

16.4.3 Rito Seco flood mitigation

The Town of San Luis was constructed along the lower portion of Rito Seco, resulting in much of the town being within the modeled 100-year flood inundation area, see Figure

6-187 (FEMA, 2021). In the event of a flood, areas such as Centennial School and the Costilla County shop are likely to be flooded. The flow through this area is known to split in multiple locations, increasing the uncertainty associated with the current revised mapping.

A restoration and flood mitigation project in this area would improve the safety of the residents of San Luis, reduce risk to community infrastructure, and could be further utilized to improve community connections with water. Improving the Rito Seco channel could improve the reliability of water delivery to water rights within the lower basin. This project is extensive with the potential for significant future cost savings by reducing properties in flood-prone areas, including critical infrastructure and historic structures. The project can also be developed into a significant community asset that promotes community values, including a healthy community and celebrating cultural heritage.

Concerns	Strategies	Opportunities
• Flooding in the town of San Luis • Water conveyance through Rito Seco • Riparian vegetation degradation • Increased risk to San Luis residents and community infrastructure	• Develop a defined floodway that provides the conveyance of the 100-year flow with a width wide enough to be stabilized by native vegetation. • Provide a diversion channel that allows the sweep of flows for in-town gardens, aesthetics, and irrigation water rights. • Develop a native planting plan with zoned planting appropriate for hydrology. Evaluate the inclusion of food shrubs such as chokecherries, rose hips, and gooseberry into the corridor. • Ensure conveyance capacity is available for channels along roadways to prevent backwater. • Evaluate improvements to Salazar Reservoir for flood regulation.	• Walking/recreational access – could be developed within the 100-year floodplain outside of the 10-year flood inundation zone. • Educational signage • Art celebrating heritage. • Managed rotational grazing • Incorporation of water quality wetlands to mitigate impacts from Battle Mountain Mine.

16.4.4 Rito Seco Fluvial Hazard Reduction

Rito Seco Road is a primary ingress/egress route to portions of the Sangre de Cristo Ranches Subdivision. This road has areas where guardrails have been installed to prevent vehicles from dropping off the shear banks of Rito Seco and tributaries. The assessment identified damaged culverts and culverts without adequate downstream scour protection.

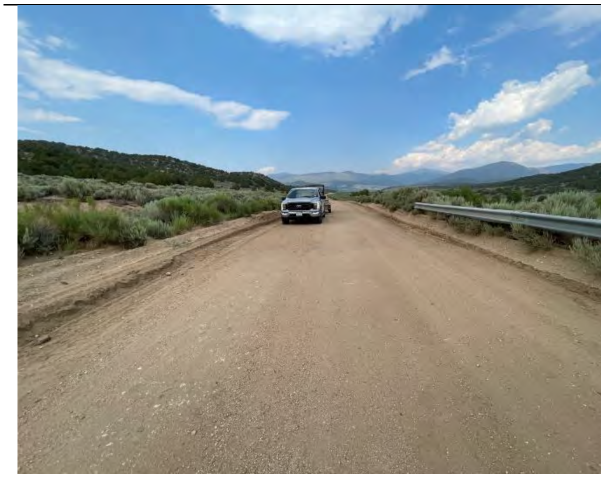



Figure 16-5 Guard rail on Rito Seco Road, location of the photo shown on the right.

Concerns	Strategies
• Increased long-term maintenance cost due to poorly installed crossings. • Increased sediment loading due to concentrated flows from the roadway. • Ingress/egress compromised along the primary access route for portions of Sangre de Cristo Ranches.	• Improvements to arroyo/road crossings, including proper culvert sizing, cover, and scour protection. • Improvements to grading to reduce concentrated flow points. • Potential hillslope stabilization along Rito Seco terrace banks and gullies that are near roadway. • Stabilize shear banks near roadways through grading or installation of retaining structures.

16.4.5 Vallejos Creek Fluvial Hazard Reduction

County Road K.5 is impacted by three gullies resulting in guardrail installation along the road to address user safety. In locations, gullies have formed where run-off from County Road K.5 is concentrated. This road is critical for emergency crew access and serves as a vital evacuation route in an emergency, such as a fire. Stabilization of gullies and prevention of new gully formation is needed to improve community safety. It may be possible to use lower cost stabilization techniques such as brush matting or hay-bale structures within the ephemeral drainages. These structures are used to promote the vegetation growth and sediment deposition necessary for stabilizing the gullies. For these measures to be successful, erosion control below replaced/constructed culverts or future bridges is necessary.

Concerns	Strategies
• Potential roadway failure resulting in increased ingress egress access time. • Sediment loading to Vallejos Creek impacts stream stability and increases loading to downstream water users, including Vallejos Ditch and Sanchez Reservoir. • Potential access blockage in the event of a fire. • Additional roadway hazards due to embankment (i.e., road-grade fill) failure and insufficient cover for roadway culverts. • Increased roadway maintenance expense.	• Replace undersized culverts. An engineer should evaluate the recommended flow conveyance of these culverts and sediment transport. • Install scour basins below culverts. • Gully stabilization • Roadway improvements to ensure sufficient cover over new road crossing elements. • Roadway improvements to reduce contributing roadway area from concentrating flows along County Road to prevent the formation of additional gullies. • Improvements in county maintenance and monitoring to prevent future issues with culvert cover. • Evaluate baseline shifts in streams and introduce mitigation measures to prevent future degradation. • Trash clean-up.

Figure 16-6 Vallejos tributary gully erosion and trash dumping along County Road K.5. Note culvert in lower left of photo extending well above the channel invert.

Figure 16-7 Roadway safety hazard due to embankment failure and insufficient culvert cover along County Road K.5.

16.4.6 Solid waste management

Figure 16-8 Example of trash dumping in arroyo. Trash includes numerous plastic bottles, aluminum cans, paper plates, and packaging.

Waste disposal is an issue that every community must deal with. During our conversations with residents, it was noted that trash disposal was inaccessible to some community residents. The lack of access to trash disposal results in illegal dumping within many of the arroyos and throughout the county. Solid waste management is a costly but necessary service that is needed for maintaining a safe and healthy community. A first step to addressing this issue is to understand the types and volumes of waste generated regionally to develop a solid waste management program that meets the community's needs. Additional landfills are often not the most effective or sustainable long-term solution to waste management. A complete solid waste assessment should include an evaluation of the volume and types of trash produced, estimates of costs, and potential buyers for recycled and/or composted materials. A complete evaluation would include multiple alternatives, including developing a new regional solid waste facility, expanded regional transfer services, and alternative waste stream solutions.

Solid waste disposal is a growing concern for many communities and developing more sustainable strategies for solid waste management is necessary for maintaining a healthy community. The strategies provided below could be utilized to help reduce the solid waste disposal issues within the basin. These recommendations cover a wide variety of costs and permitting requirements.

Concerns	Strategies
• Improper solid waste disposal. • Contamination of local water supply. • Economic impacts to the basin. • Inaccessibility of solid waste disposal resources. • Barriers to proper solid waste disposal including costs and availability.	• Improve communication about trash disposal hours and cost at the transfer station(s). • Expand the hours and days on which the transfer station is open. • Increase recycling programs. • Discourage trash production within the community by encouraging reusable shopping bags and refillable containers for drinking water. • Utilize community events, schools, and other social gatherings to help promote residents to reduce, reuse, and recycle. • Evaluate developing a local composting facility, including potential compostable material sources and markets for compost products. • Evaluate increasing and or developing carcass disposal options. Alternatives could include incineration or composting of those carcasses. At least providing information related to haulers and associated costs. • Evaluate the development of a regional landfill in either Costilla or Conejos County to reduce the distance to the landfill. Development of a landfill is expensive and will require many partners, potentially including areas of Northern New Mexico and portions of Alamosa County. • Increase enforcement of laws against illegal dumping. • Develop community assistance fund for those residents with financial barriers to proper trash disposal.

16.4.7 General Permits and Regulations

Governance and presentation of the watershed regulations determine how the regulations and required compliance is understood. Permits and regulations are mechanisms used to minimize impacts to the community from individual activities. Clear, consistent, and cohesive permitting provides a streamlined process for businesses, residents, and the regulating agency. For example, the Costilla County permitting website can be confusing and difficult to navigate, making it challenging to determine required permits, forms, and requirements.

Generally, the land-use code and permitting appear to be headed in the right direction. Updating the permitting applications and formatting could help county staff during the review process. Forms and documents should be evaluated for relevancy and adjusted to remove the information not used in the current and future decision-making process. Work with staff to identify common issues with permit applications. It is important to avoid rules that target specific landowners or entities, rather institute rules that hold everyone to an equitable standard.

Evaluation of the effectiveness of the land use code and implementation was not completed as part of this assessment. Based on discussion with community members, it is recommended that the regulations be reviewed, and adjustments made where needed, including additional fees for expert reviews, such as consulting a structural engineer prior to issuing a building permit for more complicated structures. Understanding the purpose of the land use codes can facilitate the review process and guide the necessary data for a particular permit.

Concerns	Strategies
• Confusion amongst community and staff about required permits and necessary information, • Difficulty in enforcing permitting requirements, • Potential for inequity in permit enforcement, and • Lack of compliance with regulations	• Improve website and forms to provide a more streamlined approach to obtaining proper permit forms. • Requirements based on mapped areas should be available via a web map for both staff and public review. • Update watershed protection overlay information available on the permitting website. The information is incomplete and difficult to understand and could result in arbitrary decisions. • Simplify and make available all maps necessary for watershed protection overlay decisions. The watershed protection overlay consists of at least 20 maps, which were not easily found on the permitting website. • Require single-family dwellings within the Floodplain Overlay to be subject to Special Use Review. • Reference the State of Colorado Construction Stormwater Discharge permit requirements and regulations.

16.5 Sanchez Canal and Reservoir Operations Improvements

Sanchez Canal is the largest ditch within the upper basin. The canal delivers water for direct irrigation and storage for Sanchez Reservoir, which is released for irrigation to the lower basin. Multiple projects along Sanchez Canal and Reservoir were identified as projects within the basin that can positively impact a large proportion of the community (Table 16-2, Figure 16-9).

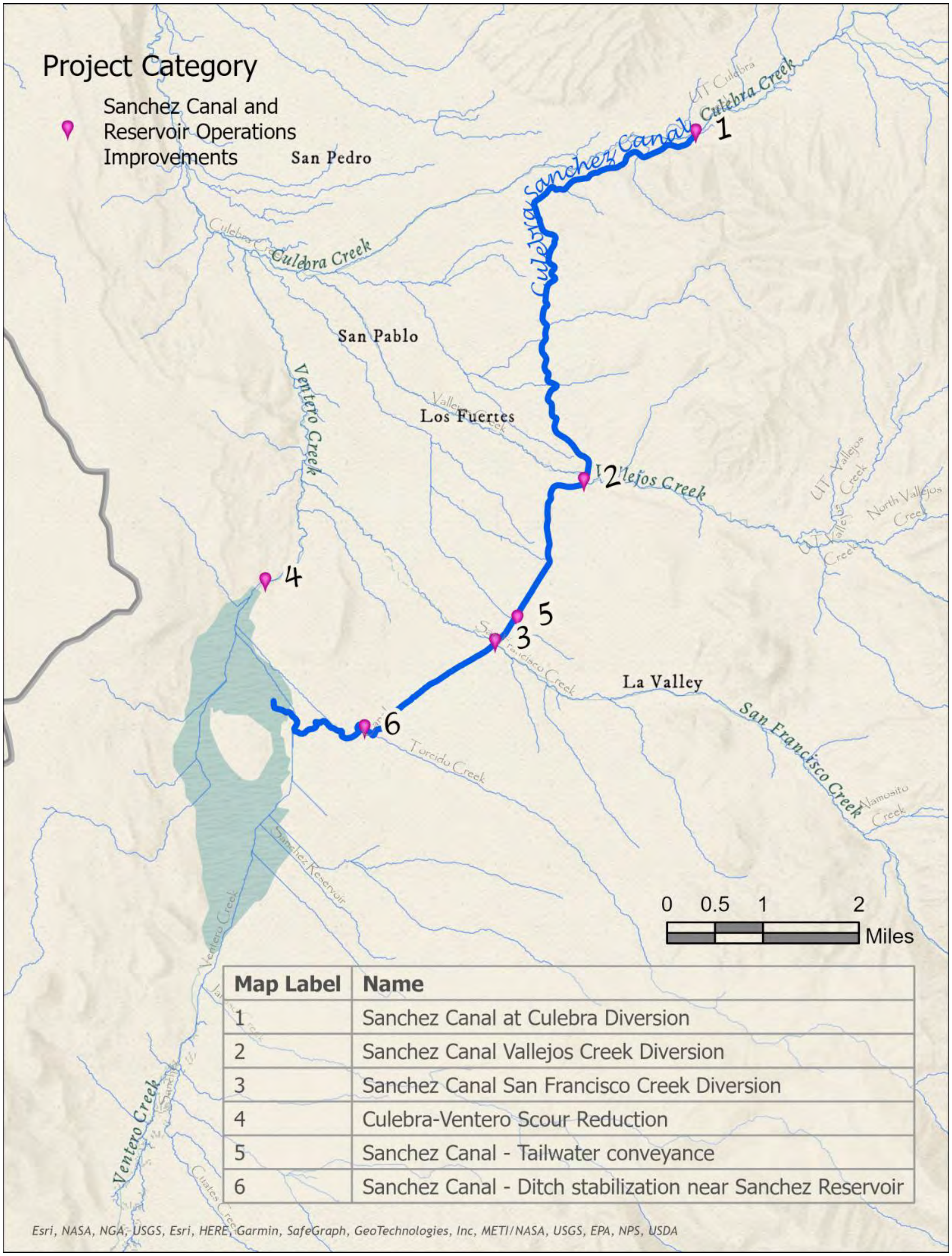
Table 16-2 Sanchez Canal and Reservoir projects

Project
Sanchez Canal-Culebra Headgate Improvements
Culebra-Ventero Scour Reduction
Sanchez Canal- San Francisco and Vallejos Creek Headgate Improvements
Sanchez Canal - Tailwater conveyance
Sanchez Canal – Ditch stabilization near Sanchez Reservoir

Sanchez Canal and Sanchez Reservoir provide critical benefits to the community by reducing flood flow into the lower reaches, supplementing flows during dry times in the lower basin, and providing water storage and supply during prolonged drought periods. Sanchez Reservoir is also a State Wildlife Area providing recreational access to residents and visitors of the basin.

Much of this watershed system infrastructure has not been upgraded in many decades. Original structure designs and diversion methods within the system were not designed with fish, flooding, or water administration. Many of the recommended changes represent a change in the standards of practice for diversion structures over the past 30 to 50 years.

Sanchez Canal conveys water and sediment to Sanchez Reservoir. Decreasing sediment inputs to Sanchez Reservoir will likely reduce mercury loading into the reservoir. The Total Maximum Daily Load (T.M.D.L.) study for Sanchez Reservoir identified sediment inputs as the primary source of Mercury loading for the reservoir (Tetra Tech, Inc, June 2008).



Map Label	Name
1	Sanchez Canal at Culebra Diversion
2	Sanchez Canal Vallejos Creek Diversion
3	Sanchez Canal San Francisco Creek Diversion
4	Culebra-Ventero Scour Reduction
5	Sanchez Canal - Tailwater conveyance
6	Sanchez Canal - Ditch stabilization near Sanchez Reservoir

Figure 16-9 Sanchez Canal Project Locations

16.5.1 Sanchez Canal-Culebra Headgate Improvements

The Sanchez Canal – Culebra headgate improvements were identified as a priority project based on field observations and individual interviews. The existing structure was reported as functioning to divert the decreed water rights. However, the assessment revealed some concerns related to this structure that impact the community, including increasing flood risk, decreasing aquatic habitat, inhibiting fish passage, and lacking measurement structure for diversion. In addition to improvements at the diversion dam, improvements in bank stability upstream of diversion and floodplain access upstream of the diversion will reduce sediment inputs into the reach and sedimentation risk to this structure and downstream water users. Execution of this project will directly impact residents of the Culebra basin by reducing flood risk to all areas below the Sanchez Canal, improving water administration, providing better accounting for basin water, and decreasing stream temperature.

Concerns	Strategies
• Lack of flow regulation could result in down-ditch flooding. • Sediment deposition upstream of the diversion dam. • Aquatic habitat degradation. • Riparian vegetation disturbance. • No monitoring equipment for water administration at headgate. • Fish passage concerns due to high velocities. • Sediment piles on banks, functioning like levees, increase flood elevation in the vicinity of the structure. • Upstream bank erosion. • The widened section upstream of the dam may increase stream temperature and evaporation. • In-channel maintenance due to sediment deposition. • Fine sediment passage to Sanchez Reservoir – increased mercury loading	• Rebuilding the existing diversion dam to improve conditions for fish and sediment passage. • Adjust channel bankfull area and width to depth ratio to improve sediment transport through the reach and increase holding pools. • Re-establishing riparian vegetation to support bank stability for a more resilient structure and decreased bank erosion. • Consider modifying the current diversion with fail-safe measures for flood management. • Remove overhead gates from Culebra Creek to reduce the risk of catching debris and increasing water elevations upstream. • Install measurement structure with electronic recording and telemetry within the canal. • Install sediment sluice. • Remove sediment piles from banks and restore stream floodplain access. • Clean up trash and debris

Figure 16-10 Slide gate regulating flows in Culebra Creek at Sanchez Canal Diversion Dam.

Figure 16-11 Flood gate diversion dam.

Figure 16-12 Culebra Creek above Sanchez Canal headgate. Note significant cottonwood cover along banks.

Figure 16-13 Bank erosion and overwide reach reducing flow depths, approximately 800 feet upstream of diversion dam, looking upstream. This is just below the Pando Ditch Diversion.

16.5.2 Culebra-Ventero Scour Reduction

Ventero Creek and Culebra Creek have accelerated bank erosion below the Sanchez Reservoir. Bank erosion in this area is accelerated by numerous factors, including rapid gate changes on Sanchez Reservoir, inaccurate flow measurements, degraded riparian vegetation, and historic channel modifications. Rapid gate changes cause rapid increases in flows along this reach, which does not have sufficient stabilizing structure without riparian cover. Performing gate changes more gradually would decrease the erosion rate within this reach. Installation of automated headgates on San Luis People's Ditch, Culebra Cerritos/Island/Francisco Sanchez, and San Acacio Ditch would maintain flows to these structures without frequent manual adjustments.

In addition to the gate changes, the flow regimes assessment identified a potential issue with the measurement of releases from Sanchez Reservoir that may negatively impact water administration in the basin. Accurate accounting of releases from Sanchez Reservoir is necessary for determining losses and calls within the basin. Water released from Sanchez Reservoir is delivered to the lower basin ditches. Having the measurements of these structures available via telemetry would allow for better accounting of losses within the reach and allow for more informed decisions.

Numerous banks are actively eroding from the Sanchez Reservoir along Ventero Creek through the confluence with Culebra Creek down to San Luis's. The hydrology of this reach is significantly altered with depletion of flows from upstream diversion during much of the year and increases in flows during late summer as water is released from Sanchez Reservoir. The riparian vegetation is severely degraded and nonexistent through much of this reach, resulting in decreased bank stability and aquatic habitat and increases in water temperature. Improvements to the reach by increasing riparian cover and decreasing channel width will improve flow conveyance below bankfull, the typical condition releases are operated under, and slow flows greater than bankfull.

Reduction of bank erosion will reduce sediment input which is likely to reduce ditch maintenance and extend the life of the stabilization ponds. Improved floodplain connection will likely raise groundwater levels for adjacent fields improving natural sub-irrigation and decreasing the need for surface irrigation.

Concerns	Strategies
• Decreased channel stability from changes in hydrology and historic channelization. • Accelerated bank erosion from frequent, abrupt flow changes. • Bank erosion from degraded riparian habitat. • Decreases in aquatic habitat and water quality due to fine sediment inputs. • Decrease in aquatic habitat suitability due to frequent changes in flow. • Inaccurate accounting of storage water • Potential for communication break-down resulting in conflict between water users. •	• Cooperative planning to reduce the magnitude of Sanchez Reservoir gate changes and performing gate changes over more extended periods. • Improvements to ditch administration below Sanchez Reservoir to facilitate delivery of storage and direct flow water. • Improvements to stream reach to adjust channel pattern and profile to decrease bank erosion and improve aquatic habitat • Increase riparian cover to decrease evaporative losses and increase bank stability. • Increase floodplain connection to increase channel stability and resiliency to flood events. • Installation of automated headgates at all structures within this reach to allow for gate changes over longer periods without the need for manual adjustments.

16.5.3 Sanchez Canal- San Francisco and Vallejos Creek Headgate Improvements

Sanchez Canal intercepts San Francisco Creek and Vallejos Creek. Water is returned to the creeks, unmeasured, through gates with low flows passed through a pipe. Ponded water in the canal is heated and increases evaporation.

No measurement structure is present to determine the volume of water available or diverted from each stream. Sediment deposition is accelerated in this location. Like the structure on Culebra Creek, these structures do not have a method for stopping the flow of water down the canal. In the event of embankment failure or other emergencies down ditch, it is impossible to stop the flow of water into the canal without heavy equipment.

Concerns	Strategies
• Increased flood risk due to degraded and inoperable gates (San Francisco Creek) • No separation of natural channel and diversion. • No measurement device for water administration. • Structure not able to pass fish at all flows. • Structure intercepts water when Sanchez Canal is out of priority resulting in warming of water and evaporation. • Sediment deposition requiring in-channel maintenance • Fine sediment passage to Sanchez Reservoir increases mercury loading.	• Evaluate the feasibility of routing the canal separately from the creek by either siphon or pipeline. • Design with fish in mind. • Install gates to allow the flow of water to the canal to be stopped. • Riparian planting. • Install measurement structure for water administration to record diversions. • Adjust structure to allow for better sediment passage. • Design to allow for changes in future operation. • Design for safe flooding, including conveyance water within stream channel in the event of flooding.

16.5.4 Sanchez Canal - Tailwater conveyance

Sanchez Canal intercepts tailwater from irrigated lands along Vallejos Creek and San Francisco Creek, diminishing the water available to lands below the canal through return flows. Often these return flows are intercepted when insufficient water supplies are carried in the Culebra Sanchez Canal, resulting in ponding in the canal bottom and increases in evaporative losses.

The impacts from tailwater interception are not as far-reaching as the other projects along Sanchez Canal and reservoir. Projects that address this issue will result in reduced conflict within the basin. This issue likely may be addressed through cooperation and the completion of smaller projects.

Concerns	Strategies
• Impacts to senior water users' ability to utilize tailwater. • Increased evaporation due to ponding.	• Improvement of tailwater conveyance across Sanchez Canal by improvements in piping across canal.

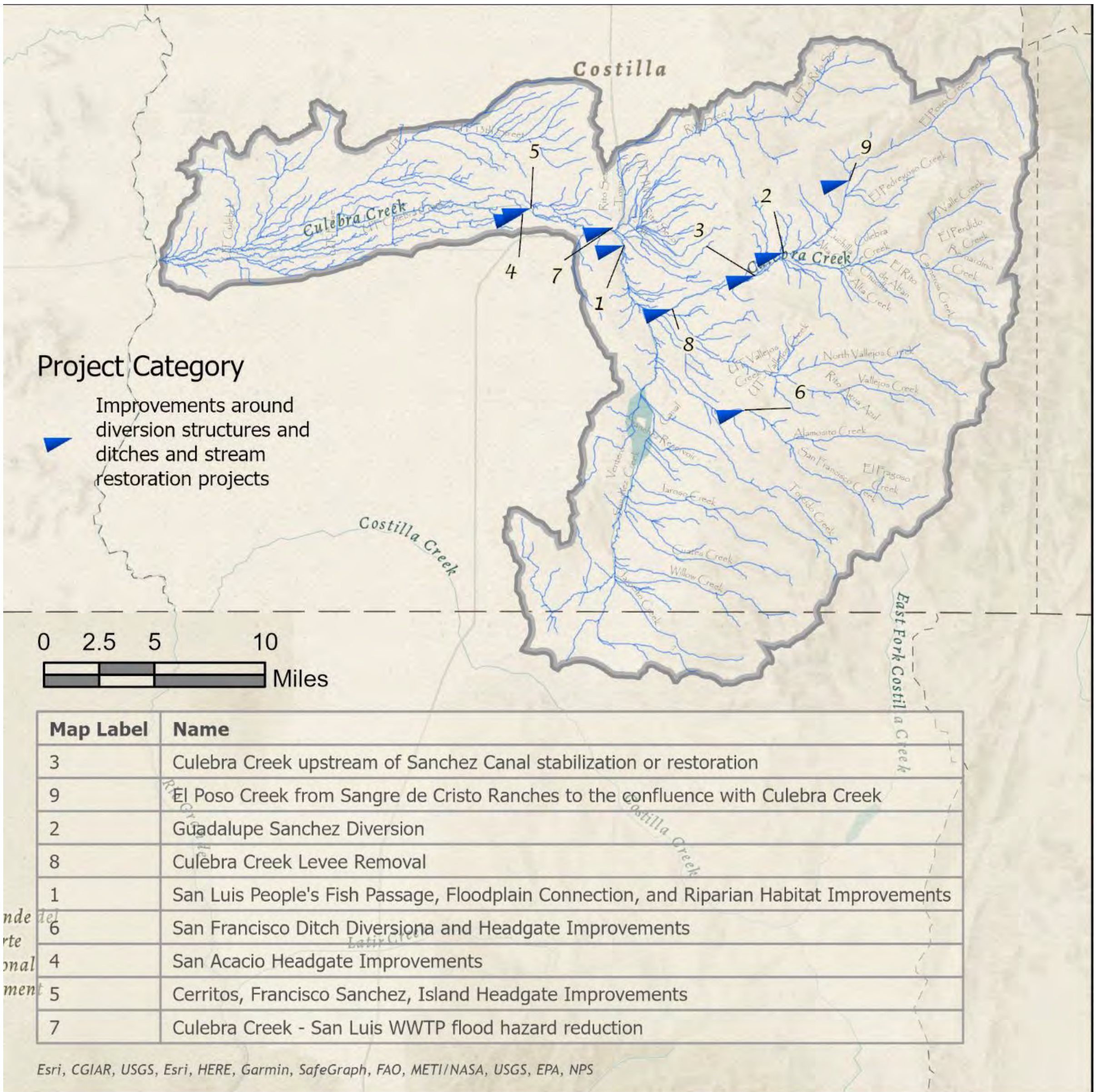
16.5.5 Sanchez Canal – Ditch stabilization near Sanchez Reservoir

Stabilizing Sanchez Canal where the canal intersects Torcido Creek would reduce sediment input into Sanchez Reservoir. This reach has significant erosion from the channel pattern and profile being impacted by the increase in flows. Sediment transported into the reservoir decreases water quality including being a source of mercury and other natural and artificial pollutants. The excess sediment fills the reservoir decreasing the available storage. Improvements to this reach should consider installation of forebay sediment trap and stabilization of the canal.

Concerns	Strategies
• Excess erosion in channel resulting in increased sediment delivery to Sanchez Reservoir • Decreased available storage volume in Sanchez Reservoir.	• Install forebay sediment trap. • Stabilize Torcido Creek/Canal to reduce erosion.

16.6 Improvements around diversion structures and ditches and stream restoration projects

Improvements around diversion structures and stream restoration projects were identified based on the positive impacts these projects can have on the Culebra basin. These projects were prioritized based on flood risks at or around the structures, fine sediment inputs to the streams, risks to community infrastructure, and impacts on calls for water. Projects were also prioritized based on the impacts on aquatic habitat and proximity to less impacted reaches. The approximate project locations are shown on Figure 16-14



Map Label	Name
3	Culebra Creek upstream of Sanchez Canal stabilization or restoration
9	El Poso Creek from Sangre de Cristo Ranches to the confluence with Culebra Creek
2	Guadalupe Sanchez Diversion
8	Culebra Creek Levee Removal
1	San Luis People's Fish Passage, Floodplain Connection, and Riparian Habitat Improvements
6	San Francisco Ditch Diversiona and Headgate Improvements
4	San Acacio Headgate Improvements
5	Cerritos, Francisco Sanchez, Island Headgate Improvements
7	Culebra Creek - San Luis WWTP flood hazard reduction

Figure 16-14 Location of improvements around diversion structures and ditches and stream restoration projects.

16.6.1 San Luis People's Fish Passage, Floodplain Connection, and Riparian Habitat Improvements

The San Luis People's Ditch is the oldest adjudicated, continuously operated structure with the Number 1 water right in the State of Colorado. The San Luis People's Ditch diversion dam was replaced in 2010 (Rio Grande Basin Round Table, 2021), and the current Mayordomo reported that the structure functioned well for diverting water. This structure is measured with a Parshall flume. The structure diverts the most senior water right within Colorado and is always prioritized. Senior water diversions impact the call for all water users within the basin and are entitled to the longest diverting season. Improvements to diversion monitoring and record-keeping, including improved reporting efficiency, can save water commissioner time and miles and improve water administration within the basin.

The San Luis People's Ditch diversion is within a reach that receives adequate flow to support various aquatic life, including native and sport fishes. Historically, community members remember this reach as a place for excellent recreational fishing. However, community members suggest it is no longer as productive as it once was. The San Luis People's Ditch diversion structure is located within La Vega and impacts these lands. Improvements to this structure provide community benefits, including an improved fishery, decreased erosion, and improved ecosystem health for various wildlife. Floodplain connectivity and adjustments for changes in hydrology can also improve adjacent wet meadow health and livestock carrying capacity.

Figure 16-15 San Luis People's Ditch old diversion dam.

The diversion dam drops five feet, making it a barrier to fish passage. The historic diversion dam also restricts flow to a narrow concrete chute, with a notable drop through the structure. Removing the downstream old diversion dam would restore floodplain function and reduce flooding risk around the structure. The stream pattern within this reach is impacted by historical channelization. Restoration of the reach could address tight radiuses and decrease fine sediment inputs into the stream, making the channel more stable. Improvements to this reach could also improve wetland function and increase basin resilience to nutrient inputs.

Concerns	Strategies
• Floodplain contraction around the diversion dam. • Fish passage around historic and current diversion dam. • Degraded aquatic and riparian habitat.	• Removal or reworking of the old diversion dam to allow for fish passage. • Restoration of stream reaches to restore floodplain connectivity and remove the cross-floodplain restrictions.

- Modified hydrology and oversized channels resulting in poor floodplain connectivity
- Increased erosional rates below diversion dam.
- Records of diversion based on infrequent observations.

- Restoration of stream reaches to improve floodplain connectivity and stability by restoring channel pattern, dimension, and profile.
- Improve fish passage at the new San Luis People's diversion dam.
- Increase willow and woody plant material.
- Grazing management to prevent future degradation of installed woody plantings.

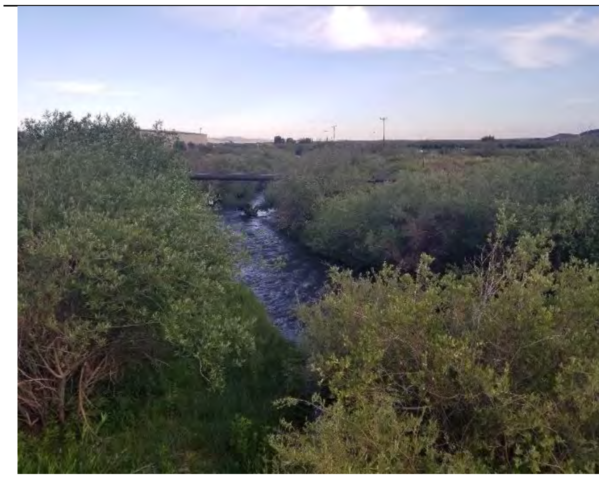


Figure 16-16 Dense riparian vegetation downstream of Hwy 159 near San Luis WWTP where cattle are excluded.

Figure 16-17 Culebra Creek near San Luis gaging station absent woody riparian vegetation.

16.6.2 Guadalupe Sanchez Diversion Improvements and Channel Restoration

Guadalupe Sanchez Ditch was identified as a project that could positively impact the Culebra watershed by decreasing the volume of sediment eroded around the structure, improving water administration, and improving aquatic habitat. Being the first major diversion within this reach, improvements at this structure would provide aquatic habitat and fish migration improvements to approximately 1.75 miles of Culebra Creek.

The diversion structure is on the right edge of water upstream of County Road L.7. At this location, El Poso Creek (Culebra Creek) and its floodplain make more than a 90-degree change in direction to align with the County Road L.7 bridge. This diversion structure did not have headgates to regulate flow or a measurement structure that could be identified from the aerial imagery.

Aerial imagery shows a decrease in riparian vegetation, especially upstream of the diversion structure. This imagery also shows rock structures within the stream above the headgate. Restoration of the riparian cover would increase shading and stabilize banks. Increasing sinuosity and lateral scour pools would provide additional habitat and stream power management.

LiDAR data sets indicate the stream was likely channelized and moved from the historic location, likely sometime before the ditch was adjudicated in 1889. Within this reach, the valley width is confined by high terraces and is further reduced by County Road 25.2. Because of this confinement, this reach is at risk of fluvial hazards.

Concerns	Strategies	Opportunities
• Excessive erosion along right edge of water near headgate. • No measurement structures • No diversion headgates • Impaired riparian vegetation. • Fluvial hazards • Aquatic habitat degradation • Decreased floodplain connection and floodplain access. • Fish entrainment	• Move headgate and diversion upstream to achieve the necessary head for diversion. • Install lockable headgate and measurement structure on ditch diversion. • Adjust channel pattern and profile to reduce fine sediment inputs, • Improve riparian vegetation along banks. • Install fish screening structure. • Improve channel alignment with the bridge. • Install floodplain culverts. • Restore floodplain access along the reach.	• Upgrade the streamflow gage and address stability concerns with the control. • Adjust the alignment of County Road 25.5 to allow more floodplain width. • Adjust pattern around El Poso Creek and Culebra Creek confluence to improve stability.

- Improvements to diversion reliability.
- Increase woody debris in reach.
- Adjust channel pattern and profile to a reference condition.

Figure 16-18 1965 aerial imagery of Culebra Creek and El Poso Creek near Guadalupe Sanchez diversion.

Figure 16-19 Current aerial imagery of Culebra Creek and El Poso Creek near Guadalupe Sanchez Ditch diversion.

16.6.3 Culebra Creek Upstream of Sanchez Canal Channel Improvements

This reach impacts the diversion structures below this area on Culebra Creek because of the sediment loading from the steep, actively eroding banks (Figure 1-20). Upstream reductions in sediment input will reduce sediment deposition above the downstream diversion structures and within the downstream canals. Reduction in fine sediment inputs reduces the deposition of these fine sediments on riffles, improving the quality of riffle habitat for spawning and early life stages of aquatic organisms. Other positive impacts from a project in this reach could include improvement of floodplain connectivity, which typically results in decreased irrigation requirements for adjacent meadows and increased in-stream cover. These improvements decrease consumptive use of water within the reach, increasing water availability to other water users. The reduction of fluvial hazards within this reach reduces risks to community members living adjacent to the stream and increases community safety.

Figure 16-21 Culebra Creek bank erosion left edge of water approximately 1 mile upstream of Sanchez Canal headgate.

Figure 16-20 Bank erosion along left edge of water, Culebra Creek.

Upstream of the Sanchez Canal Culebra Diversion Structure, Culebra Creek migrates south into steep embankments. This migration is resulting in significant bank erosion (Figure 16-21). The reach begins approximately a half-mile upstream of the Sanchez Canal diversion structure and extends approximately three-quarters of a mile upstream. Moving the channel away from the high terrace through this reach would reduce sediment inputs into Culebra Creek and reduce sediment deposition at Sanchez Canal and other downstream diversion structures.

Figure 16-22 Residence in floodplain.

Additional concerns were noted within this reach, including flood hazards and water diversion maintenance operations. Noted flood hazards included a residence along the right edge of the water (Figure 16-22). Work in this reach could be utilized to improve community safety. A small push-up dam moves water through a pond along the left edge of the water in this reach. Frequent in-stream maintenance of push-up dams often decreases stream stability and can result in the reach becoming a fish barrier at low flows due to low depths.

The riparian corridor along Culebra Creek includes numerous large trees throughout this reach. Where possible, these trees should be preserved. Trees that are impacted by a project could be used as structures in the channel, increasing woody debris. Incorporating more wood in channels has improved macroinvertebrate and fish populations.

Concerns	Strategies
• Degradation of water quality due to sediment inputs. • Increased maintenance from sediment deposition. • Degradation of aquatic habitat due to sediment deposition. • Decreased floodplain connection • Structures within the floodplain.	• Channel stabilization by moving the stream away from the high terrace. • Evaluate minimizing structures within the floodplain by either moving structures or the stream. • Bank stabilization • Decrease width-to-depth ratio. • Increase the number/depth of pools to improve stream-energy dissipation and improve aquatic habitat. • Decrease or eliminate in-channel maintenance activities. • Improve floodplain connection.

16.6.4 San Acacio and Cerritos, Francisco Sanchez, and Island- Headgate Improvements

The San Acacio ditch and the Cerritos, Francisco Sanchez, and Island ditch headgate were prioritized because of wintertime flooding, which impacts adjacent property owners. Calls for water from these structures impact many of the upstream water rights. The San Acacio ditch receives water delivered from Sanchez Reservoir, and the Cerritos, Franciso Sanchez, and Island ditch headgate must pass storage water. Like many structures in the basin, these structures provide winter water for livestock. Updated headgates and measurement structures would improve water diversion efficiency and reduce flooding risk from leaking and/or inoperable gates, which is especially problematic during winter when ice causes water to back up and flow along varied paths resulting in flooding.

The ditches along this system have incised in places. Addressing ditch incision could improve irrigation efficiency and should be evaluated along with headgate reconfiguration. Having accurate measurements of water diversions on these structures directly affects how much water is needed in the lower basin, affecting the availability of water within the upper basin for those structures with more junior priorities.

Concerns	Strategies
• Wintertime flooding due to backwater from ice. • Measurement structures are inadequate for water administration. • Inoperable gates decrease the availability of in-priority water. • Difficulties diverting during low flows. • Degradation of concrete around structures.	• Installation of new diversion headgates, including sediment sluice. • Installation of automatic headgates to improve water administration and decrease conflict. • Installation of a measurement structure with electronic recording to improve water administration. • Installation of fish screening structures.

16.6.5 San Francisco Ditch Diversion and Headgate Improvements

Figure 16-23 San Francisco Ditch diversion dam. Single screw gate on left edge of water provides sediment passage when ditch is not in priority.

The San Francisco Ditch headgate was identified as a structure that could improve water delivery to many water users with physical improvement. The acequia annually closes the headgate by breaching the diversion ditch to prevent down-ditch wintertime flooding. The southern supply ditch has difficulty delivering water to all users. This structure is the most senior priority ditch on San Francisco Creek and sweeps the creek at times, but in times of severe drought is often called out by downstream senior water rights on Culebra Creek. This diversion supplies ditches on both the north and south side of San Francisco Creek. Physical issues along the south ditch result in difficulties delivering pro-rata water to users along with this structure.

This structure is critical in addressing and restoring dewatered reaches. Improvements to water administration and records at this structure are needed to better understand if operational changes could be utilized to restore water to the lower reaches of San Francisco Creek. This structure impairs fish passage with a significant drop and a single screw gate on the north side to pass sediment around the structure. Improvements to fish passage at this structure would reconnect this reach with the 1.8-mile reach from San Francisco Ditch down to the Culebra-Sanchez Canal diversion on San Francisco Creek.

Concerns	Strategies
• Wintertime flooding due to backwater from ice. • Measurement structures are inadequate for water administration. • Sediment deposition upstream of the structure increases required instream maintenance for the south ditch. • Stream is overwide decreasing channel stability and increasing water temperatures and evaporation during low water. • A significant drop below the structure increases channel degradation downstream of the structure. • The structure is a barrier to fish passage. • Down ditch flooding. • During this assessment, the new flume on the north ditch did not have a staff plate. • Southside water users do not have conveyance to receive a pro-rata share of water.	• Install new diversion dam(s) that enables sediment and fish passage. • Reduction of the drop below the structure to reduce risk of erosion around toe of the dam. • Installation of a measurement structure with electronic recording to improve water administration. • Installation of fish screening structures. • Assessment of ditches to ensure water delivery to decreed lands. • Improve understanding of operations to determine potential aquatic habitat improvements.

16.6.6 Culebra Creek - San Luis WWTP flood hazard reduction

The reach of Culebra Creek near the San Luis WWTP was identified as a priority project that reduces risk to critical community infrastructure. Improvements in this reach could potentially enhance the function of the San Luis WWTP by providing additional passive treatment to reduce nutrient loading to Culebra Creek and stabilization reservoir. The flood hazards near the San Luis WWTP could be reduced by moving the stream channel away from the sewer pond embankments, increasing floodplain connection, and decreasing stream power. This is a priority project because it impacts all San Luis WWTP service area residents. This hazard increases the risk to all downstream water users, including those outside the basin.

Concerns	Strategies
• Flood hazard risks around San Luis WWTP • Channel incision causing fluvial hazard risk to San Luis WWTP	• Adjustment to the channel adjacent to the wastewater treatment facility. • Evaluate secondary wetland treatment for wastewater treatment facility discharge. • Adjustments to San Luis People's Ditch Rito Seco Diversion. • Floodplain culvert installation across Highway 159 to decrease floodplain contraction and expansion. • Improvements to floodplain connection to reduce stream power and increase adjacent sub-irrigation.

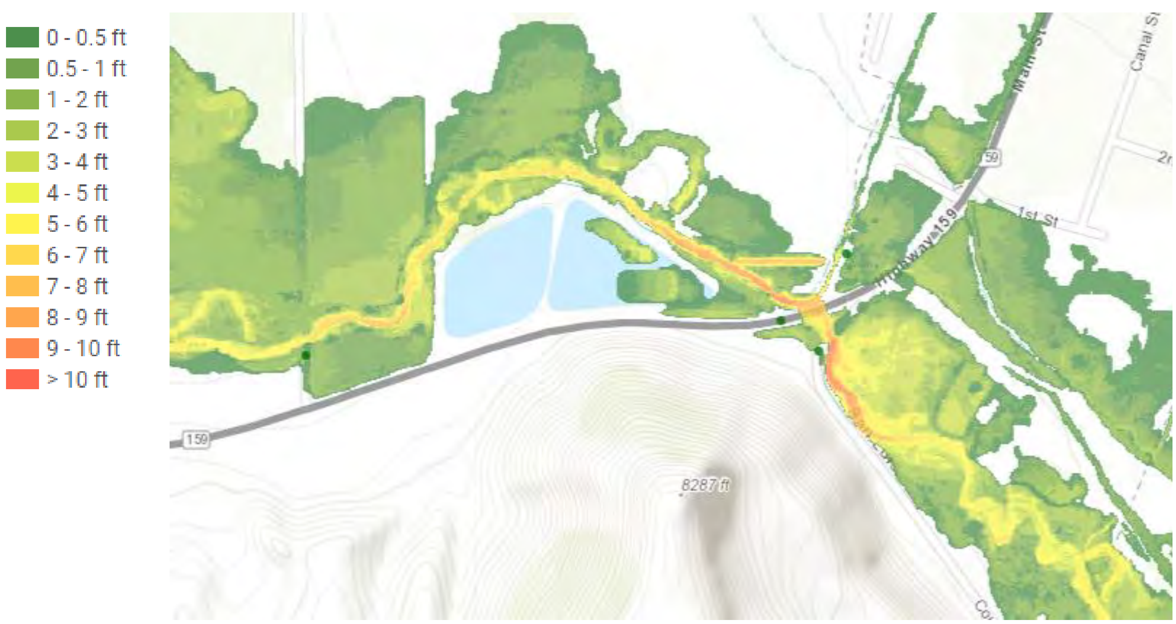


Figure 16-24 San Luis Wastewater Treatment Plant Preliminary 1% Depth Grid from Colorado Hazard Mapping and Risk Portal accessed October 29, 2021. (Also figure 7-186).

16.6.7 Levee removal/rehabilitation Culebra Creek

Figure 16-25 County Road 21 Culebra Creek Bridge.

Removal of the levees along Culebra Creek was identified because it provides positive improvements to community connection with the stream, aquatic habitat, and the hydrologic connections in this reach. The sediments used to create these berms appear to have been the result of channel maintenance due to significate sediment deposition likely caused by roadway crossings at County Road 21 and L.5. A project in this reach provides positive improvements by reducing flood hazards to numerous residences and increasing awareness along this reach. This reach begins downstream of County Road 23.8 and extends down to County Road L.5. These embankments were likely not engineered or constructed to hold back flood flows and have a high probability of unpredictable failure if water levels rise. In the event of failure, flows may leave the floodway and cause increased flood depths and/or increased flow velocities outside of the main channel.

Work within this reach has the potential to increase community safety by increasing the available width of the floodplain, improving flows through the reach to downstream water users, and developing a community asset along this stream corridor. There is potential to evaluate open-space access along the stream corridor in this reach to improve community connection to water.

Concerns	Strategies
• Flood hazard. • Poor aquatic habitat. • Poor floodplain connection. • Visual impairment decreases the quality of community assets. • Limited community connection	• Detailed flood modeling for the area. • Removal of levees and regrading of the stream channel. • Replanting of riparian vegetation. • Improve community appeal for stream by removal of visual barriers. • Improve floodplain connection by either restoring to the current floodplain or building a floodplain at a lower elevation. • Improve flood conveyance to minimize floodway extents and remove structures and residences from the floodplain. • Improve parcel mapping and property owner identification.

Figure 16-26 Berms along Culebra Creek upstream of County Road 21.

Figure 16-27 Culebra Creek inside berms upstream of County Road 21.

16.6.8 El Poso Creek from Sangre de Cristo Ranches to the confluence with Culebra Creek.

This reach was selected because of the opportunity to provide uplift and connection within the ecosystem. Improvements to this reach improve aquatic habitat through the management and smaller-scale projects. This reach benefits from forest management and has a high potential for native fisheries restoration. Projects within this reach benefit downstream water users by slowing peak flows, reducing sediment loading, buffering against post-fire flooding and debris flows, and improving water quality. Being upstream of senior water rights, the hydrology supports excellent aquatic habitat.

Portions of this reach are in relatively good condition, and portions of this reach would benefit from active restoration. Segment management along the riparian corridor throughout the reach will improve stream condition and available forage.

Figure 16-28 Bank erosion El Poso Creek.

Figure 16-29 Ruts in road from water running down road instead of in channel.

Concerns	Strategies
• Floodplain connection. • Riparian degradation. • Excess diversions. • Road maintenance is adjacent to streams. • Low water crossing stability.	• Grazing management. • Floodplain reconnection. • Targeted banks stabilization. • Improvements in the low water crossing. • Installation of fish screens and measurement devices. • Road maintenance and closure adjacent to streams.

16.7 Rangeland and vegetation management

Fencing the entirety of the riparian area from livestock is cost-prohibitive and complete exclusion, except during establishment, is often undesirable. Grazing management is often preferred and can be utilized to minimize livestock damage to riparian vegetation. The rangeland assessment is targeted to provide recommendations for Cielo Vista Ranch (La Sierra), Carpenter Ranch, and La Vega. However, having guides or recommendations for the basin may assist landowners in managing other private rangelands.

****GRAZING ASSESSMENT TO BE COMPLETED SUMMER 2022****

Weeds were noted in the watershed during the assessment. Management of invasive species is imperative to maintaining native forage and reducing the risk to economic crops and livestock. Weed management with chemical herbicides requires special handling and specific timing to reduce the risk of pollution and increase effectiveness. Grazing and mechanical suppression may provide more effective weed management than herbicides in places. Providing continued support for county weed management and documentation of the extent and types of weeds will guide the most appropriate measures for effective weed management.

16.7.1 Jaroso Creek Meadow

This project was included in the list of priority projects because this location has significant potential for being a demonstration project for floodplain reconnection. Improvements in this reach will likely have significant positive impacts on wildlife and water use efficiency. Elements of this project also work to improve water administration efficiency and understanding related to native Rio Grande cutthroat populations and the response to climate change.

Figure 16-30 Incised ditch at upstream end of Jaroso meadow.

This alluvial fan and meadow are affected by channel incision, resulting in decreased agricultural production. Restoring this area and upgrading/updating irrigation infrastructure would restore this reach to work with the channel morphology.

Figure 16-31 Jaroso meadow, note channel has formed small floodplain within the original floodplain after incision.

This reach has significant potential to demonstrate how stream restoration can improve agricultural productivity. Reconnecting a channel with historic floodplains has increased groundwater elevations, improving sub-irrigation. Restoration of this reach could help combat the encroachment of trees and shrubs on the meadows increasing meadow hay production and available forage for native ungulates.

Concerns	Strategies
• Degradation of meadow carrying capacity • Excess erosion • Poor floodplain connection • Poor water administration • Meadow encroachment • Degraded riparian habitat	• Detailed mapping of existing resources. • Restore stream and ditch reaches to work with the landscape. • Restore floodplain connectivity. • Improve water management • Improvements in water administration • Improvements in monitoring within this reach to monitor conditions in the contributing watershed.

16.7.2 Upland revegetation - Vallejos Creek south of confluence with North Vallejos Creek

The area south of the confluence of North Vallejos Creek and Vallejos Creek is severely degraded. This degradation is likely attributed to excessive grazing, and this area would benefit from active restoration including revegetation and gully stabilization. The soil erosion model indicated high erosion rates despite the low slope due to the lack of vegetative cover.

Figure 16-33 Area of upland vegetation disturbance in 1965 aerial imagery.

Figure 16-32 Damage upland vegetation south of the confluence of North Vallejos Creek and Vallejos Creek.

Concerns	Strategies
• Degraded vegetation • Decrease in water yield • Increase in run-off time • Excess hillslope erosion • Decreased carrying capacity • Loss of wildlife habitat	• Grazing management • Targeted revegetation • Weed management • Stabilization of gullies

16.7.3 Riparian Vegetation

Many areas within the Culebra basin were found to have poor functioning riparian vegetation. Riparian vegetation supports stream channel stability, decreases surface erosion, and provides shade for stream channels which have been shown to decrease stream temperatures and provide cover for a variety of wildlife.

Riparian vegetation provides woody debris, which has been shown to increase macroinvertebrate density and increase aquatic habitat. Where riparian vegetation is in fair to poor condition, stream channels are often incised and have increased bank erosion. Management actions and projects that improve riparian function and diversity will decrease fine sediment loading to downstream reaches. In areas with severe degradation, additional active restoration may provide additional benefits. Managed livestock grazing on established riparian vegetation can be used to improve diversity and riparian health so long as care is taken to avoid overgrazing in these areas. Maps of Riparian Habitat quality are provided in Chapter 3.

Concerns	Strategies
• Decreased wildlife habitat • Decreased bank stability • Increased sediment loading • Increased steam temperatures • Decreased flood attenuation	• Grazing management within reach and upstream. • Bank stabilization includes the addition of large woody debris. • Channel stabilization, where needed, to address channel incision. • Invasive weed management. • Replanting.

16.8 Discussion

The list of projects developed from this assessment marks a place to begin to take actions that can be used to improve the overall health of the Culebra Watershed. While this list marks the culmination of the assessment, it in no way marks the end; instead, it marks a beginning. I would like to challenge all readers of this report to act by participating in and supporting support programs and people working toward making the Culebra Watershed a sustainable healthy place to live, work, and play. Have patience, great things take time to grow and require iteration. Don't give up! If implementation of a project isn't quite right, adjust and move forward – don't dwell on the past learn from it.

Nearly every project is possible with enough community support. Funding and technical resources are available from a wide array of entities which are ever changing. Having a solid community that supports projects and is making progress toward improving conditions for themselves naturally attracts the attention of funders. And funders can be confident their money will be utilized to the fullest extent possible.

16.8.1 Grant Resources

Many grants and other financial resources exist to facilitate implementation of the projects outlined within this section and the report. These resources are available from many public and private entities and are directed toward each funders specific objectives.

16.8.2 Local Resources

Local resources and talents can often be leveraged to facilitate project completion and success. If at any time you have thoughts such as, "well if we did this, then I could do that…" or "I have something similar lying around", do not hesitate to bring those ideas to the table. It is possible that these ideas and/or talents were not known or were not connected to the proposed project. Many grant sources require matching funds to be used, these talents can be utilized as match toward grants. Local resources come in many different forms including trade related talents, organization and facilitation, materials, or equipment.

16.8.3 Project List

Within a basin and assessment of this size the number of projects can produce a list that is overwhelming and must be condensed using some measures. If there are projects that should be considered, please bring those up. Again, there are sometimes factors that were not considered in the prioritization that might enable a project to be feasible and/or increase the project priority.

16.8.4 Monitoring Program Support

Continue to support aquatic habitat monitoring programs including those completed by Colorado Parks and Wildlife and U.S. Geological Survey.

Chapter 17. Afterword

The Culebra watershed is the home to some amazing cultural and ecological places. The Beaubien document granted rights to maintain access to areas including La Vega and La Sierra for the benefit of all inhabitants that were necessary sustain life in the Culebra basin. Since this area was settled in the mid-19th century our world has seen significant changes in the way we survive. During this period we have observed the advent of the automobile, electricity, computers, and more. With all these changes our interactions with the environment have changed and will continue to change.

For the benefit on all inhabitants implies the ability for individuals to use a resource, or commons, so long as their use does not negatively impact the rights of others. Prior to many of the technological advancements use of these resources was naturally limited by available time, tools, and markets. With changes in how the resources are used changes in how these resources are allocated and managed are necessary. The following information discusses some of studies that have described management in these situations and suggestions for developing strategies for sustainable management and use.

The term “commons” as defined by Wikipedia is, “the commons is the cultural and natural resources accessible to all members of a society, including natural materials such as air, water, and a habitable Earth. These resources are held in common, not owned privately. Commons can also be understood as natural resources that groups of people (communities, user groups) manage for individual and collective benefit. Characteristically, this involves a variety of informal norms and values (social practice) employed for a governance mechanism. Commons can also be defined as a social practice of governing a resource not by state or market but by a community of users that self-governs the resource through institutions that it creates (Ostrom, 2015).

A common-pool resource is defined “a resource made available to all by consumption and to which access can be limited only at high cost (Ostrom, 2015). Examples of common pool resources within the Culebra Basin include La Sierra, La Vega, and water resources. Degradation of CPR’s has been widely documented globally. Documentation for this degradation includes case studies describing commons in fisheries, grazing, groundwater, pollution, among other shared resources.

Hardin, in his 1968 Science Article “Tragedy of the Commons” provides insight into the degradation of common-pool resources (Hardin, 1968). While technological advances can assist in monitoring and understanding the resources available, the solution does not lie in technical advances, but in morality. “Freedom in a commons brings ruin to all” – Hardin 1968.

To overcome issues related to degradation of CPR’s, evaluation of case studies where success in achieving sustainability is looked upon for ideas for moving forward. These ideas are the central study of Ostrom, in her book Governing the Commons (2015). In this book, seven principals are outlined that are critical to long-enduring CPRs. These seven principals as outlined by Ostrom (2015) are provided below for reference:

1. Clearly defined boundaries

   Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself.

   Discussion: Identifying these boundaries creates a layer of accountability for users of the CPR. This is the groundwork for understanding how a CPR is beginning and how to best manage that CPR.

2. Congruence between appropriation and provision rules and local conditions.

   Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labor, material, and/or money.

   Discussion: A collaborative effort to put in place rules for how a CPR is used. Doing so makes sure that everyone is playing by the same rule book, establishing a standard of practice for everyone participating in the CPR.

3. Collective-choice arrangements

   Most individuals affected by operational rules can participate in modifying the operational rules.

   Discussion: Having the governing body of the CPR be made up of a collective group of people that are impacted using the CPR will help ensure its long-term survival. As in most situation, it is important to remain flexible to changing technologies, practices, ideas. Being able to be more agile in determining the direction of a CPR may make it more sustainable over time. This is especially important with some of the uncertainties associated with global climate change.

4. Monitoring

   Monitors, who actively audit CPR conditions and appropriator behavior, are accountable to the appropriators or are the appropriators.

   Discussion: Holding users accountable for their actions, along with understanding how a particular CPR is impacted by management actions is important for the sustainability of the CPR. While the point namely focuses on individual accountability, understanding the impacts of management activities is also important.

5. Graduated sanctions

   Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offence) by other appropriators, by officials accountable to these appropriators, or by both.

   Discussion: If there is no penalty for breaking the rules then the rules are more likely to be broken. Acute, or one time, infractions to the rules of the CPR may not have obvious impacts to that CPR, but as they occur more frequently and become more chronic situation, these infractions maybe detrimental to the CPR.

6. Conflict-resolution mechanisms

   Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.

   Discussion: Avoiding high-cost court cases should be everyone's goal. They tend to be a waste of everyone's time and money. Having the ability to settle disputes related to the CPRs through arbitration and discussion will typically result in more sustainable solutions. As with some of the other discussions above, it is important for the governing of CPR to remain agile and able to adapt to changing conditions and situation. This is more possible with a mechanism built into the governance to resolve conflicts. It is better to have these things figure out before problems arise.

7. Minimal recognition of rights to organize

   The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.

   Discussion: While this bullet point may seem more related to situations outside of this country, places with more authoritative governments, it is still important here. For example, if a group has decided to *self-govern the acequia system, it would be important for the State of Colorado to be in concurrence with the new managing body.*

In developing recommendations involving CPRs within the Culebra Watershed the data and these seven guiding principles are referenced to provide recommendations for adjusting the path forward with an aim towards long-enduring CPR's.

Chapter 18. References

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